Water Quality Report

South Platte River, Barr Lake, and Milton Reservoir

2024

Water Quality Division

James Dorsch
Senior Water Quality Manager

Steve Lundt
Senior Water Quality Scientist

Jordan Parman
Senior Water Quality Scientist

Michelle Neilson
Water Quality Scientist

Abbie Culbertson
Water Quality Scientist

Ashley Bruhn
Water Quality Scientist

Table of Contents

List of Acronyms

AY	annual year
Barr	Barr Lake
BOD	biochemical oxygen demand
BMW	Barr Lake and Milton Reservoir Watershed
BP	Beebe Pipeline
CBOD	carbonaceous biochemical oxygen demand
CDPHE	Colorado Department of Public Health and Environment
chl-*a*	chlorophyll *a*
cfu/100 ml	colony forming units per one hundred milliliters (references concentrations of *E. coli*)
cfs	cubic feet per second
COS	soluble organic carbon
CPW	Colorado Parks and Wildlife
DO	dissolved oxygen
E. coli	*Escherichia coli*
ELSP	early life stages present
ELSA	early life stages absent
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Trichoptera
FC	First Creek
FRICO	Farmers Reservoir and Irrigation Company
m	meters
MDL	method detection limit
Metro	Metro Water Recovery
mg/L	milligrams per liter (aka parts per million)
Milton	Milton Reservoir
MMI	Multi-metric index

NO_5	combined nitrate (NO_3) and nitrite (NO_2) analysis results
NTP	Northern Treatment Plant
PAR	Project Action Request
RWHTF	Robert W. Hite Treatment Facility of Metro Water Recovery
QA/QC	quality assurance/quality control
SC	Second Creek
SD	Secchi depth
SDI	Shannon Diversity Index
SPCURE	South Platte Coalition for Urban River Evaluation
SRP	soluble reactive phosphorus
SPR	South Platte Renew (Littleton & Englewood WWTP)
SM	Standard Methods for the Examination of Water and Wastewater
TC	Third Creek
TDP	total dissolved phosphorus
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen (organic N and ammonia (NH3 and NH4))
TMDL	total maximum daily load
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSI	trophic state index score
µg/L	micrograms per liter (aka parts per billion)
WWTP	wastewater treatment plant
WY	water year
USGS	United States Geological Survey

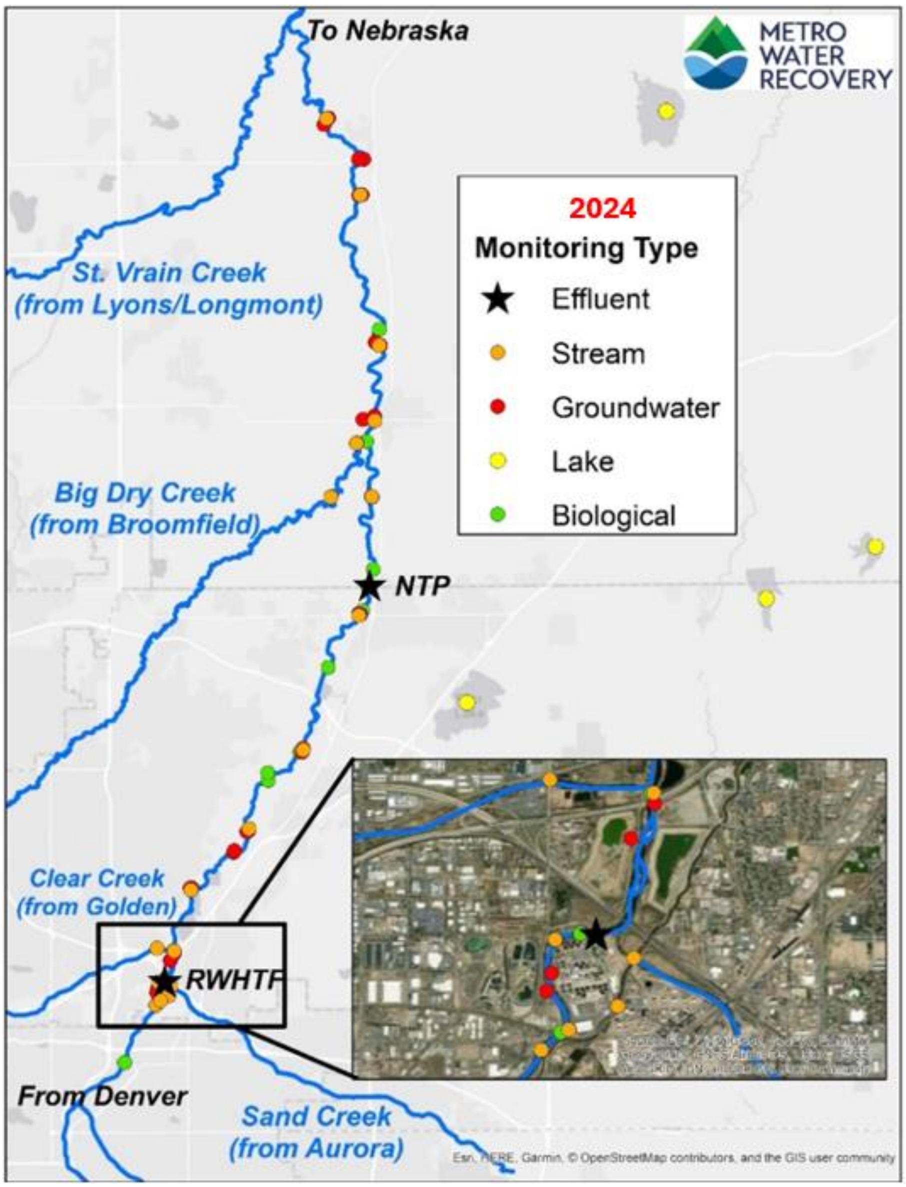
List of Tables

List of Figures

Executive Summary – 2024 Water Quality Report

Metro's Monitoring

Metro Water Recovery (Metro) has been monitoring the South Platte River from Denver to Platteville for over 50 years. This monitoring has included river habitat, fish, macroinvertebrates, reservoirs, pre & post restoration improvements, stormwater, groundwater, and special studies. Metro is a respected leader in water recovery and data collection. We provide reliable data to support regulatory policies and plant upgrades to protect the region's health and environment. Not only does Metro "*get your water*", but we also follow it down the river.



South Platte River

The South Platte River through Denver is one of the most monitored rivers in the state. Segment 15 is 26 miles long from the Burlington Ditch diversion to Big Dry Creek. Segment 1a continues another 17 miles to the confluence with the St. Vrain River. The South Platte River is a changing river that is heavily used for recreation, fishing, drinking water, and agricultural irrigation. Major influences on the river include stormwater, industrial/municipal wastewater point sources, altered flow regimes, urban and agricultural pressures, and a changing riparian habitat. In 2024, water quality monitoring occurred at 22 permanent sampling locations from upstream of the Robert W. Hite Treatment Facility (RWHTF) to the town of Platteville, CO. Over 50 water quality parameters were tested twice per month. Biological monitoring of fish and macroinvertebrate populations occurred at 11 locations.

Nutrients – In-stream total phosphorus (TP) and total nitrogen (TN) concentrations downstream of the RWHTF outfalls continue to decrease showing that treatment plant upgrades are working. Metro's enhanced biological nutrient removal is having a noticeable impact on the waterways and reservoirs downstream. For example, the average annual TN in Segment 15 of the South Platte River below the RWHTF outfalls was 3.8 mg/L in 2024, compared to 8.8 mg/L in 2013 prior to treatment upgrades. The average annual TP in Segment 15 was 0.27 mg/L in 2024, an 82% decrease from 1.5 mg/L in 2013.

Fish & Bugs – Of the 19 fish species documented in 2024, 10 were native to the South Platte River. The six most common fish species observed in 2024 are native to the South Platte River (fathead minnow, white sucker, sand shiner, longnose dace, longnose sucker and creek chub). Before-and-after habitat improvement surveys continue to show major increases in fish diversity and abundance at the four habitat projects downstream of RWHTF. The 2024 macroinvertebrate data demonstrate that following dramatic reductions in ammonia concentrations in 2014, the community has continued to shift from being dominated by pollution-tolerant taxa (aquatic worms, midge larva, etc..) to a more balanced population of both tolerant and sensitive taxa, including caddisfly and mayfly larvae. In addition, overall macroinvertebrate diversity, as measured by the Shannon Diversity Index has increased significantly following treatment plant upgrades at the Robert W. Hite Treatment Facility.

Barr Lake & Milton Reservoir

Barr Lake (Barr) and Milton Reservoir (Milton) are off channel reservoirs downstream of the Denver metropolitan area that have historically received large nutrient loads, mainly from point sources (about 90%) such as storm water and wastewater. Cultural eutrophication is occurring in both reservoirs. Approximately 2.4 million people live upstream causing overloading of nutrients that perpetually causes algal blooms, cyanobacteria scums and toxins, extreme oxygen swings, high pH, and other aesthetic issues. Metro participates in the Barr Lake and Milton Reservoir Watershed (BMW) Association to assist with implementing a phased pH/DO TMDL to break the eutrophication cycle. Metro monitors Barr and Milton 20 times a year and participates in special studies as part of a watershed effort. Metro's reservoir sites are index sites that Colorado Department of Public Health and Environment (CDPHE) uses for standards assessments for Regulation 38.

Nutrients – Barr and Milton had large reductions in nitrogen (20-50%) and phosphorus (65 – 70%) for 2023. Reasons for these reductions include wastewater and stormwater treatment upgrades, no pumping of treated effluent to Barr (no pumping since 02/10/2012), and dilution from above normal precipitation. When compared to 2003 – 2009 averages, the 2023 TP summer average for Barr was 62% less and 74% less for Milton. For the water year (November 1 – October 31), Barr received 68,600 acre-feet of water which brought in 23,200 kg of phosphorus. The annual load goal is 5,779 kg/yr. Internal loading did occur between May and July for both reservoirs, caused by low oxygen during thermal stratification. Neither reservoir exceeded the ammonia or pH standard. Dissolved oxygen was exceeded in Milton twice.

Reservoir Management – Volume and timing of inflows can have a major impact on water quality. The available water from snowpack melt and precipitation determine how the reservoirs are managed. 2023 was an above normal precipitation year with a total of 21.9 inches in Brighton, with 12.8 inches coming between May and July. Milton received 43,200 acre-feet of water, and Barr received 68,600 acre-feet. Full pool at Barr occurred for an extra 60 days causing thermal stratification and anoxic conditions at the sediment interface. Anoxic conditions allowed for internal loading of phosphorus for 112+ days. The oxygen consumption rate was 5,100 Kg of oxygen/day.

Special Studies – The TMDL implementation plan includes projects that focus on all sources of phosphorus. Metro began full-scale biological phosphorus removal at the RWHTF facility in January 2021. South Platte Renew official started tertiary chemical treatment for phosphorus in the beginning of the 2023 water year. They conducted ferric and aluminum sulfate treatment four times (12/1/22-12/28/22, 1/4/23-3/14/23, 3/29/23-5/3/23, and 8/2/23-8/29/23). TP reductions in the S. Platte River were noticeable at the Burlington Head Gate. The City and County of Denver received their new MS4 permit in 2021 that now requires more phosphorus monitoring. BMW sampled six storm events in 2023 to better understand phosphorus loads to Barr. Weekly composite samples were also collected to calculate loads. The average weekly phosphorus load to Barr was 446 kg/week for the 2023 water year (WY). The Burlington Ditch inputs from First Creek, Second Creek, Third Creek, and Beebe Pipeline were monitored 20 times in 2023. Phosphorus loads into Barr from all four ditch inputs was approximately 2,500 Kg. This amount is equivalent to internal loading or storm water estimates. This nonpoint phosphorus load is also important due to the size, timing, and proximity to Barr.

Looking Ahead to 2025

Water quality staff will continue to conduct field surveys to determine the effects of Metro's discharge on the South Platte River, Barr Lake, and Milton Reservoir. In particular, the group hopes to address the following goals and projects in 2025:

- Document potential aquatic life responses to TP concentrations related to start-up of full biological phosphorus controls at the Hite facility.
- Conduct fish surveys at Phase V Habitat Improvement Site at 160th Avenue to document post-construction conditions.
- Continue to document temperature profile of South Platte River downstream of RWHTF and NTP outfalls and assess how proposed temperature reduction strategies will impact attainment or exceedance of standards.
- Continue in-stream periphyton sampling program to assess algal abundance and chlorophyll-a concentrations in the South Platte River.
- Operate the stormwater monitoring station on the South Platte River to catch the first flush of water during a storm event and assess the nutrient load in that stormwater.
- Continue monitoring inputs into Burlington Ditch before Barr Lake inlet.
- Calculate in more detail internal loading in both reservoirs.
- Carp removal in Barr Lake using box net method.

Introduction

Historical Perspective

The Water Quality Division at Metro is charged with monitoring and evaluating the water quality conditions of waters influenced by Metro's discharges. Water quality sampling has taken place since the opening of the Metro's Robert W. Hite Treatment Facility (RWHTF) in 1966. In a U.S. Environmental Protection Agency (EPA) study conducted in 1971, the river was found to be polluted with sludge beds, low dissolved oxygen (DO), and heavy metals contamination but improved in comparison to previous conditions of the river. In 1978, the EPA concluded that even if the RWHTF discharged pure water, in-stream water quality would not be adequate to support the State of Colorado designated uses of secondary contact and warm water fisheries. By the mid-1980s, water quality had substantially improved, but still exceeded standards for fecal coliform bacteria, un-ionized ammonia, cadmium, copper, and zinc (CDM).

In 1992, Upper South Platte Segment 15, the receiving water for the discharge from the RWHTF, was included on the State's list of impaired waters (303(d) list) for DO and "other" constituents, which were clarified later to be cadmium and un-ionized ammonia (CDPHE 2010). Segment 15 remained on the 303(d) list for cadmium until 2006 when the cadmium Total Maximum Daily Load (TMDL) was completed. Water quality improved throughout the 1990s after Metro completed capital improvements that resulted in partial nitrification/denitrification in the North Complex and the construction of the dechlorination basin. Metro completed a number of studies in the 1990s and early 2000's which revealed that habitat quality was more limiting to fish populations than water quality (CDM 2006). In 1997, Metro entered into a Memorandum of Understanding with the Colorado Department of Public Health and Environment (CDPHE), Colorado Division of Parks and Wildlife (CPW), and the EPA that allowed for site-specific DO standards coupled with in-river improvements to improve dissolved oxygen and habitat conditions (CDM 2006). Metro added several re-aeration structures and is currently constructing additional habitat improvements at multiple locations throughout Segment 15.

Monitoring of the South Platte River has evolved over time, yet many of the same constituents have been continuously monitored for the past 45 years. Current monitoring efforts are guided by the South Platte Coalition for Urban River Evaluation (SPCURE), which is a collaborative organization designed to create a coordinated monitoring program that saves time and resources by eliminating duplication within the greater Denver metropolitan area. Many partners in SPCURE conduct similar water quality monitoring on the same days of the month to provide a comprehensive longitudinal dataset which can include grab samples, continuous temperature monitoring, and macroinvertebrate sampling. Currently, Metro is the only SPCURE member with resources on an annual basis to conduct fisheries and macroinvertebrate surveys because of the strength of its water quality program.

In July 2002, Metro began monitoring and evaluating the conditions at Barr Lake and Milton Reservoir in conjunction with BMW. The watershed association was established to address high pH issues due to nutrient loading in Middle South Platte Segment 4, which includes both reservoirs. A phased pH and DO TMDL was approved in 2013, and BMW Association continues to move forward with implementation. An autosampler was installed in spring of 2019 to help monitor and estimate loads to the Burlington Ditch. Sampling of inlets to the Burlington Ditch started in 2022 to look at nutrient sources to the ditch before the inlet to Barr Lake.

Starting in 2003, Metro began quarterly monitoring of water quality at 20 well sites located adjacent to the South Platte River. This groundwater data is collected to help calibrate the South Platte Water Quality Model and to determine any possible water quality effects on the South Platte River.

General Description of the Study Area

The South Platte River begins high in the Rocky Mountains and flows through the Front Range out onto the eastern plains of Colorado. The watershed covers over 850 square miles and encompasses six Colorado counties: Adams, Arapahoe, Denver, Douglas, Jefferson, and Weld. The watershed generally flows south to north, paralleling the foothills of the Front Range of the Rocky Mountains. Over 500 miles of streams and 550 miles of man-made canals, ditches, and pipelines flow through the watershed, which have direct impacts on water quality.

The watershed is highly influenced by human activity including residential, industrial, agricultural, and recreational activities. The South Platte River changes dramatically as it flows from its headwaters out onto the eastern plains of Colorado, both naturally and because of human-induced influences.

Segment 15 – Upper South Platte River

Segment 15 of the South Platte River begins at a point immediately below the Burlington Ditch diversion structure, which is located just below 50th Avenue and Franklin Street in Denver. The segment ends immediately below the South Platte River confluence with Big Dry Creek near Fort Lupton (Figure 1). The segment is approximately 26 miles long and receives major stream tributary inflows from Sand Creek and Clear Creek. Several municipal dischargers are present on this segment, including the RWHTF, NTP, South Adams County Water and Sanitation District, and the City of Brighton's Wastewater Treatment Plant. Industrial dischargers are also present on the segment, including the Xcel Energy Cherokee Generating Station, Suncor oil refinery on Sand Creek, and numerous sand and gravel mining operations.

The segment is highly regulated for water rights, with several ditch companies withdrawing water at various times during the year. At the head of the segment, the Burlington diversion draws water to fill a series of reservoirs, including Barr Lake. The Fulton Ditch, Brantner Ditch, Brighton Ditch, and Lupton Bottoms all divert water out of Segment 15 below the RWHTF discharge. These diversions have the capacity and appropriation rights to divert the entire flow of the South Platte River during dry to average years. During low flow periods (late summer, autumn, and winter), the natural flows upstream of Metro's discharge are minimal.

Land use around Segment 15 was historically agriculture but is becoming increasingly urbanized. Urban land use close to the river is only predicted to increase in coming years, which can affect the river through increased stormwater and nonpoint source pollution.

Segment 1a – Middle South Platte River

Segment 1a of the South Platte River extends from a point immediately below Big Dry Creek to a point immediately below the confluence with the St. Vrain near Platteville, Colorado (Figure 1). The segment is approximately 17 miles long and is influenced by no major tributaries other than Big Dry Creek and Little Dry Creek. Only minor discharges are present on the segment, including the Fort Lupton Wastewater Treatment Plant and the Platteville Treatment Plant.

Like Segment 15, Segment 1a flow is highly managed by water rights with six major ditch diversions along the segment: Platteville Ditch, Platte Valley Canal (a.k.a. Evans Ditch), Meadow Island Ditches 1 and 2, Farmers Independent Ditch, and Western Mutual Ditch. The river is a gaining stream in Segments 15 and 1a, meaning that groundwater flows into the river, often keeping it from drying up completely. Sampling by Metro continues through Segment 1a to document water quality.

Land use around Segment 1a remains largely agricultural with a few small urban centers along the river, including Ft. Lupton and Platteville. Livestock and agriculture occur very close to the river, potentially contributing to nonpoint source pollution.

Segment 4 – Middle South Platte – Barr and Milton Reservoir

Located northeast of the Denver metropolitan area, Barr Lake (Barr) and Milton Reservoir (Milton) are warm-water plains reservoirs filled through surface water diversions from the South Platte River at the Burlington Ditch and Evans #2 headgates. Each reservoir holds a maximum storage capacity of approximately 30,000 acre-feet. In the early 1890s, the Farmer's Reservoir and Irrigation Company (FRICO) purchased and enhanced the two reservoirs to regulate and store water for agricultural use. Their uses now include aquatic life, recreation, and domestic water supply.

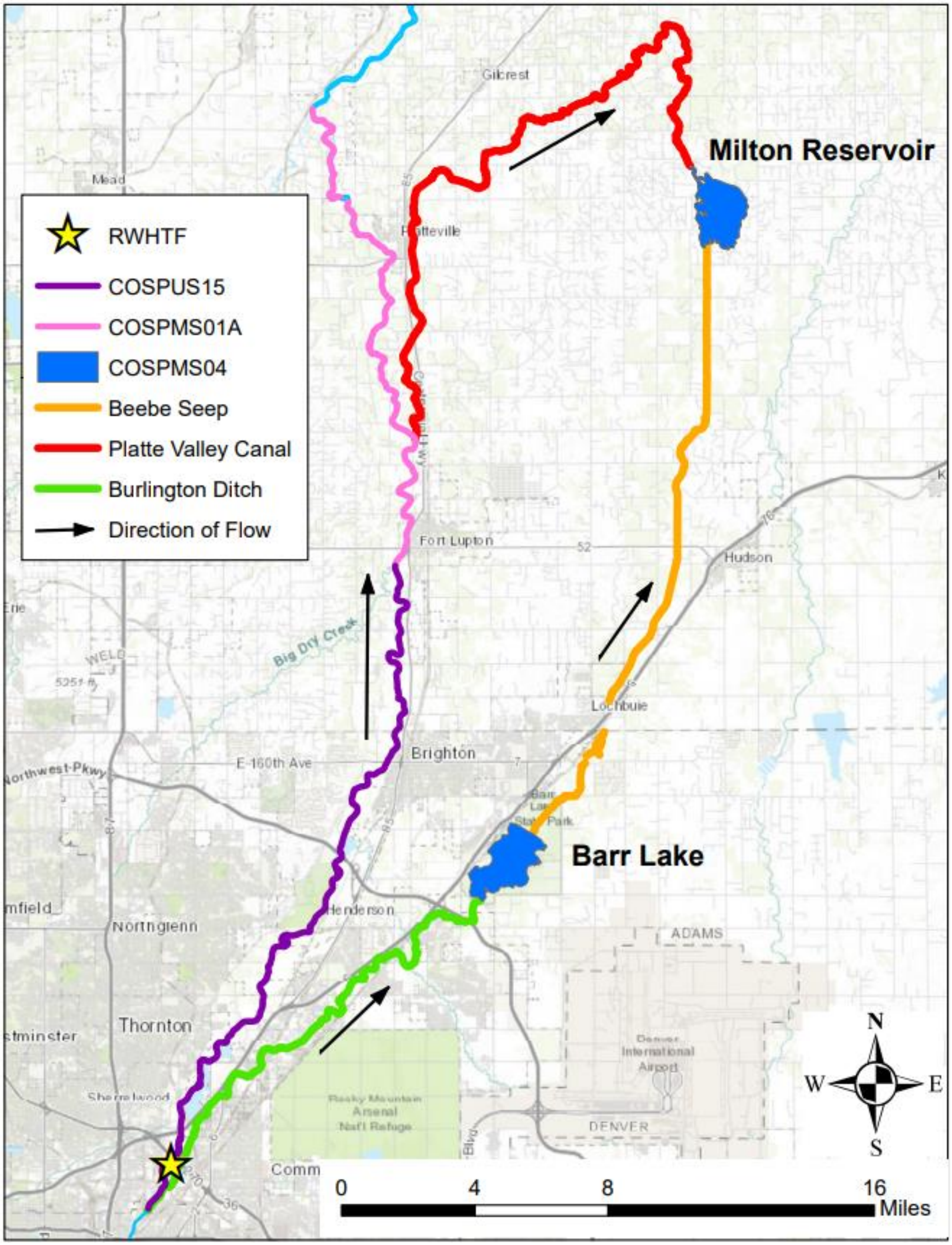


Figure 1. Map of Segments 15 and 1a of the South Platte River and irrigation canals

Monitoring Programs

Monitoring the condition of the aquatic environment requires sampling of physical habitat, water chemistry, biological condition, and flow. As conditions change, sampling techniques may be added or modified to gain additional insight or provide statistical rigor. Sampling may also be modified in response to changes in regulatory requirements or scientific advancement. The data collected during sampling events are not only used by Metro staff but are also submitted to state and national data collection centers. Data collected by Metro are used in a variety of settings from classrooms to state and national resource management agencies. Therefore, it is imperative that all data are collected and managed according to all standardized protocols. Maintaining high standards of data integrity over time requires that Metro personnel are adequately trained in acceptable field methods, sample handling, and data acquisition. The "Water Quality Division Procedural Manual" details all the relevant field sampling protocols for Metro's various monitoring programs. This procedural manual is reviewed and updated annually and provides more detail than presented in this general water quality report.

The Water Quality Division's monitoring programs consist of bi-weekly sampling of the South Platte River (in accordance with SPCURE monitoring agreements), bi-weekly sampling of Barr and Milton (monthly during the winter), quarterly monitoring of 20 groundwater wells co-located with the stream sampling sites, annual biological (fish and macroinvertebrates) sampling, and annual physical habitat evaluations. In addition to these regular monitoring programs, the Water Quality Division also conducts special studies, including sampling the South Platte River every other month to the Nebraska border and occasional sampling of ditches to determine the water quality of inflows to the reservoirs. Metro also conducts 30-hour studies to document diurnal variations in water quality to support the South Platte River Water Quality Model.

As part of these regular and special water quality studies, in situ field data (DO, temperature, turbidity, pH, specific conductance) are collected. Since 2007, the Water Quality Division has used In-Situ Multi-parameter AT600 probes to collect these field data. Before and after each use, the probes are calibrated and end-calibrated to ensure that measurements taken will be within an acceptable range (In-Situ Technical Note: *Aqua TROLL 500 and Aqua TROLL 600 Sensor Summary,* 2017). Depending on the objectives of the monitoring program, water samples are also collected and delivered to Metro's laboratory for further analysis. The following section briefly outlines the sampling protocols and associated water quality data for the regular monitoring programs.

Streams Program

Bi-Weekly Streams Sampling

The South Platte River, RWHTF and NTP Final Effluents, Sand Creek, Clear Creek, and Big Dry Creek are monitored regularly for several water quality parameters as part of the streams monitoring program. A total of 20 sites are sampled (Table 1).

Site	Description	Latitude	Longitude
SP-62	South Platte River at 62nd Avenue	39.807	-104.958
SP-64	South Platte River at 64th Avenue	39.812	-104.959
NFE	Robert W. Hite Treatment Facility North Final Effluent (PC)	39.813	-104.954
SFE	Robert W. Hite Treatment Facility South Final Effluent (PC)	39.813	-104.954
SC	Sand Creek on Burlington Ditch Flume	39.810	-104.951
BD-64	Burlington Ditch at 64th Avenue	39.805	-104.952
SP-CC	South Platte River 100 yards upstream confluence with Clear Creek	39.827	-104.949
CC	Clear Creek at York Street	39.828	-104.959
SP-88	South Platte River at 88th Avenue	39.856	-104.938
SP-104	South Platte River at 104th Avenue	39.885	-104.902
SP-124	South Platte River at 124th Avenue	39.923	-104.867
SP-160	South Platte River at 160th Avenue	39.987	-104.832
NTP-SPR	Northern Treatment Plant Effluent leaving Pond #3	40.001	-104.825
SP-RD8	South Platte River at County Road 8	40.044	-104.824
BDC	Big Dry Creek at mouth USGS Gage Station 067720990	40.069	-104.833
BDC-8	Big Dry Creek at Road 8	40.044	-104.849
SP-FTL	South Platte River at Colorado Highway 52 in Fort Lupton	40.080	-104.821
SP-RD18	South Platte River At Weld County Road 18	40.116	-104.818
SP-RD28	South Platte River at Weld County Road 28	40.188	-104.829
SP-RD32.5	South Platte River at Weld County Road 32.5	40.225	-104.850

Table 1. Sampling locations for bi-weekly streams sampling.

Sampling occurs on every 1st and 3rd Wednesday of the month throughout the year in accordance with the SPCURE monitoring program. In addition to the field data recorded from the In-Situ multi-parameter probe, samples are analyzed for metals and nutrients (Table 2).

Field Parameters	Metals	Nutrients and Other Parameters
Temperature, Dissolved Oxygen, Conductivity, pH, Turbidity	*Total Fraction*: Ag, As, Be, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Se, Sb, Zn *Dissolved Fraction:* Ag, Ca, Cd, Cr, Cu, Fe, K, Na, Mg, Mn, Ni, Pb, Se, Zn	Total Phosphorus, Orthophosphate, Ammonia, Nitrite, Nitrate and Nitrite (NO_5), TKN, Total Dissolved and Suspended Solids, Alkalinity, Hardness, Chloride, Sulfate, *E. coli*, BOD, CBOD, TOC, COS

Table 2. Parameters for bi-weekly streams sampling.

Longitudinal Nutrient Study

The Water Quality Division also conducts nutrient water quality sampling monthly downstream of the regular stream monitoring segments 15 and 1a of the South Platte River. This special study area begins at Weld County Road 8 and continues downstream along the Lower South Platte River, terminating near the Nebraska border at Julesburg (Figure 2). There are a total of nine sampling locations (Table 3).

Site	Description	Latitude	Longitude
SP-RD8	South Platte River at County Road 8	40.044	-104.824
Milliken	South Platte River at Hwy 60 near Milliken	40.320	-104.811
Kersey	South Platte River at Hwy 37 at Kersey	40.412	-104.563
Goodrich	South Platte River at Hwy 39 at Goodrich	40.342	-104.060
Fort Morgan	South Platte River at Hwy 52 at Fort Morgan	40.268	-103.801
Hillrose	South Platte River at County Road 33 at Hillrose	40.359	-103.503
Iliff	South Platte River at County Road 55 at Iliff	40.748	-103.056
Crook	South Platte River at Highway 55 at Crook	40.842	-102.805
Julesburg	South Platte River at Hwy 385 at Julesburg	40.973	-102.251

Table 3. Sampling locations for the longitudinal nutrient study.

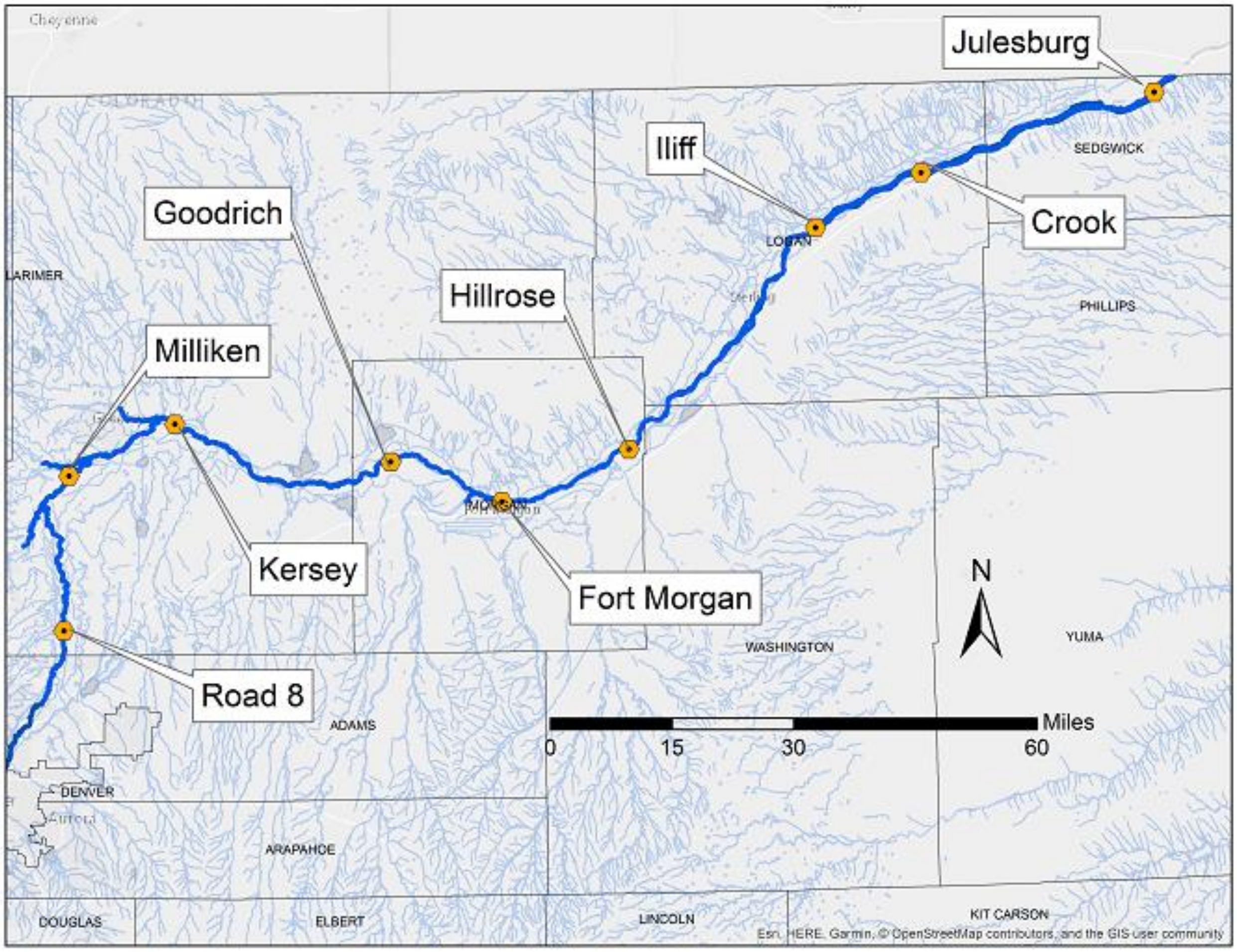


Figure 2. Map of longitudinal nutrient study locations.

In addition to the field data recorded from the In-Situ multi-parameter probe, samples are analyzed for nutrients and alkalinity (Table 4).

Field Parameters	**Metals**	**Nutrients and Other Parameters**
Temperature, Dissolved Oxygen, Conductivity, pH, Turbidity	None	Total Phosphorus, Ammonia, Nitrate (NO_5), TKN, Alkalinity, Total Nitrogen

Table 4. Parameters for the longitudinal nutrient study.

Biological Sampling

Fish Sampling

Fish diversity and abundance estimates are common ways to evaluate in-stream aquatic life. Electrofishing is currently one of the most reliable methods for sampling fish species and populations in streams. Unfortunately, low capture efficiencies are still inherent in the method, especially when working with small plains native species. Unlike game fish samples, sampling efficiently enough to create population estimates of plains species is challenging. Instead, sampling is targeted at obtaining a representative species composition at each site, different life stages of those species, and the relationships between life stages. Although the sampling procedures described here are not quantitative in a population sense, consistent sampling techniques are vital to obtaining valuable, relevant, and comparable information. Water Quality Division fisheries data are used by Metro staff, as well as the CPW to evaluate freshwater fish populations. Fish sampling is completed along a 100-meter stream reach at 14 different sites (Table 5). The locations are typically close in proximity to the bi-weekly stream sampling locations. After one thorough pass covering the entire 100-meter stream reach, the species, length, and weight of the individual fish are recorded. Length and weight data are only recorded for the first 100 individuals for each species; counts are made for the remaining individuals of the specific species.

Site	Description	Latitude	Longitude
SPR-1	South Platte River at 31st Ave	39.769	-104.982
SPR-1.8	South Platte River at 58th Ave at Metro South Bridge	39.800	-104.961
SPR-2	South Platte River at 64th, Denver, Adams County	39.812	-104.956
SPR-3.5	South Platte River upstream of Confluence with Clear Creek	39.827	-104.948
SPR-3.8	South Platte River 1/2 mile downstream 88th Avenue	39.859	-104.927
SPR-4	SPR at 88th Avenue (Phase IV Habitat Improvement Site)	39.862	-104.928
SPR-5	South Platte River 1 mile upstream of 120th Ave	39.908	-104.889
SPR-5.5	South Platte River at Habitat Site Phase 2	39.912	-104.890
SPR-6	South Platte River 1/2 mile upstream of 124th Ave	39.919	-104.871
SPR-6.5	South Platte River at 144th	39.962	-104.852
SPR-7	South Platte River at 160th Ave, Brighton	39.989	-104.830
SPR-8	South Platte River at 168th (Upstream of the NTP)	40.002	-104.825
SPR-8.5	South Platte River at Cty Rd 4 (Downstream of NTP)	40.012	-104.822
SPR-9	South Platte River 1 mile upstream of Big Dry Creek	40.060	-104.826
SPR-10	South Platte River 1/4 mile downstream of County Road 18	40.107	-104.823

Table 5. Sampling locations for biological assessment.

Benthic Macroinvertebrate Sampling

The objectives of benthic macroinvertebrate sampling are to assess invertebrate diversity within the river channel and overall aquatic life health. Kick net samples are taken in riffles using methods described in Appendix B of Water Quality Control Commission (Commission) Policy 10-1 (CDPHE 2010). Dip net samples are also taken to evaluate invertebrate populations on targeted habitat such as snags and vegetation. Benthic invertebrate sampling is completed in locations within the same 100-meter stream reaches sampled during electrofishing. If suitable locations for sampling are not available because of stream conditions, benthic invertebrates may be sampled in locations immediately adjacent to the 100-meter fish sampling reach.

For both the kick and dip net samples, the contents of the nets (benthic macroinvertebrates) are picked out with tweezers and placed into collection jars filled with a 90% solution of ethanol for preservation. The macroinvertebrates are counted and identified by a consultant, and the results are sent back to Metro for data analysis.

Habitat Sampling

The objective of stream habitat assessment is to qualitatively assess physical conditions that indicate the quantity and quality of aquatic habitat within the stream reach. This assessment, in addition to being important to determining site characteristics that may be important to aquatic species population dynamics (e.g., distribution, diversity, and population), enables comparison of stream reaches across years, between sites, and can be used to choose sites with similar habitats for a “before-after/control-impact” analysis of the habitat improvements constructed by Metro.

The Water Quality Division also completes a Rapid Bio-Assessment form for the stream bed, channel, banks, and adjacent land areas for the sample stream reach. Each of ten assessment items (including epifaunal substrate, pool substrate characterization, pool variability, sediment deposition, and channel flow status) are ranked numerically along a scale that defines conditions as “optimal,” “suboptimal,” “marginal,” or “poor.”

Currently, no analysis is performed on the habitat data; they are collected to assist in the interpretation of fisheries and macroinvertebrate data. Understanding habitat conditions can assist in determining the cause(s) for species distribution patterns.

Reservoir Program

Metro conducts regular reservoir monitoring to provide reliable information to stakeholder groups to assist with making management decisions for each reservoir. The goal is to define and identify water quality problems, understand the causes, use the collected data to build a model to help predict water quality changes, and to begin addressing the problems with rehabilitation that fits both the reservoir’s capabilities and the needs of the users.

Barr and Milton are sampled bi-weekly from March–November and once a month from December–February. In addition, Horse Creek Reservoir and Prospect Reservoir are monitored once a month from May to September. For each reservoir, sampling is conducted from a boat near the dam, in the deepest area of the reservoir (Table 6). At each site, epilimnetic samples are collected at a depth of one meter, and hypolimnetic samples are collected one meter above the sediment. The hypolimnetic sample is eliminated when water depth is less than three meters deep.

Biological data includes zooplankton and phytoplankton samples. Water clarity, another indirect measurement of algae growth, is measured using a Secchi disk.

Site	Description	Latitude	Longitude
BL03B	Barr Lake Dam, Hypolimnion	39.961	-104.751
BL03P	Barr Lake Dam, Epilimnion	39.961	-104.751
HCR02B	Horse Creek Reservoir, Dam, Hypolimnion	40.007	-104.583
HCR02P	Horse Creek Reservoir, DAM, Epilimnion	40.007	-104.583
MR03B	Milton Reservoir, Dam Location, Hypolimnion	40.238	-104.638
MR03P	Milton Reservoir, Dam Location, Epilimnion	40.238	-104.638
PR01B	Prospect Reservoir, Dam, Hypolimnion	40.018	-104.510
PR01P	Prospect Reservoir, Dam, Epilimnion	40.018	-104.510

Table 6. Sampling locations for reservoirs.

At each site, a multiparameter sonde is used to collect field parameters (turbidity, pH, DO percent and concentration, conductivity, and temperature) at each 0.5-meter interval along the water column, starting at the surface and progressing to the bottom sediment. In addition to the profile data, the water samples are lab-analyzed for a variety of parameters (Table 7).

Field Parameters	Metals	Nutrients and Other Parameters
Temperature, Dissolved Oxygen Percent Saturation and concentration, Conductivity, pH, Turbidity, Secchi Depth	*Total Fraction*: Ag, As, Be, Ca, Cd, Cr, Cu, Fe, K, Mo, Mg, Mn, Na, Ni, Pb, Se, Sb, S, Zn *Dissolved Fraction:* Ag, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, S, Se, Pb, Zn	Total Phosphorus, Orthophosphate, Ammonia, Nitrite, Nitrate (NO_5), TKN, Total Suspended Solids, Alkalinity, TOC, COS, Phytoplankton, Zooplankton, Chlorophyll*a*

Table 7. Parameters for reservoirs.

Groundwater Program

To better understand how shallow groundwater affects and interacts with the South Platte River in Segments 15 and 1a, the Water Quality Division initiated a groundwater monitoring program in 2002. The groundwater data are used to help recalibrate the South Platte River Water Quality Model which occurs approximately every five years. Monitoring is conducted four times a year in February, May, August, and November. The 20 groundwater wells are co-located with the bi-weekly stream sites (Table 8). Some of the sampling wells belong to the U.S. Geological Survey (USGS) and are part of its long-term groundwater monitoring program. The other wells were constructed by Metro on private property with landowner permission.

Site	Description	Latitude	Longitude
GW-104W	104th Avenue, Southwest Corner	39.8839	-104.9029
GW-124W	124th Avenue, Northwest Corner	39.9236	-104.8675
GW-160E	160th Avenue, Northeast Corner	39.9875	-104.8313
GW-160W	160th Avenue, Northwest Corner	39.9879	-104.8322
GW-CR32.5E	County Road 32.5, Northeast Corner	40.2252	-104.8489
GW-CR32.5W	County Road 32.5, Northwest Corner	40.222	-104.8517
GW-52E	Highway 52, Northeast Corner	40.0808	-104.8288
GW-64W	64th Avenue, West	39.807	-104.9594
GW-66E	Highway 66, Southeast Corner	40.2053	-104.8272
GW-66W	Highway 66, Southwest Corner	40.2053	-104.8304
GW-76E	Highway 76, East Side Platte	39.8259	-104.9485
GW-88E	88th Avenue, Northeast Corner	39.857	-104.9373
GW-88W	88th Avenue, Northwest Corner	39.857	-104.9383
GW-BDCW	Big Dry Creek, West	40.0695	-104.8327
GW-CR18E	County Road 18, Southeast Corner	40.1162	-104.8176
GW-CR18W	County Road 18, Northwest Corner	40.1177	-104.8207
GW-CR28E	County Road 28, Southeast Corner	40.1883	-104.8284
GW-CR28W	County Road 28, Southwest Corner	40.1879	-104.8302
GW-MRE	McKay Road, East Side	39.874	-104.9112
GW-MRW	McKay Road, West Side	39.8748	-104.9106

Table 8. Sampling locations for groundwater.

After recording the depth to groundwater, the wells are purged for 10 minutes at 4 liters/minute. After recording field parameters with the multi-parameter probe, a peristaltic pump is used to collect the water samples for analysis (Table 9).

Field Parameters	Metals	Nutrients and Other Parameters
Temperature, Dissolved Oxygen concentration, Conductivity, pH, Turbidity	*Total Fraction*: Ag, As, Be, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Zn	Total Phosphorus, Total Dissolved Phosphorus, Orthophosphate, Ammonia, Nitrite, Nitrate and Nitrate (NO_5), TKN, Alkalinity, TOC

Table 9. Parameters for groundwater.

A summary of the aggregated groundwater is provided in this report as Appendix 3. If you would like to see more specific groundwater data, the information is available upon request.

All Sampling Sites

The Water Quality Division does a thorough evaluation and monitoring of downstream water quality conditions. This comprehensive monitoring of the South Platte River, tributaries, groundwater, ditch diversions, and major reservoirs allows for a complete understanding of downstream conditions. Because of Metro's proactive efforts to understand the biological and chemical conditions, the South Platte River and BMW are the most monitored watersheds in Colorado (Figure 3).

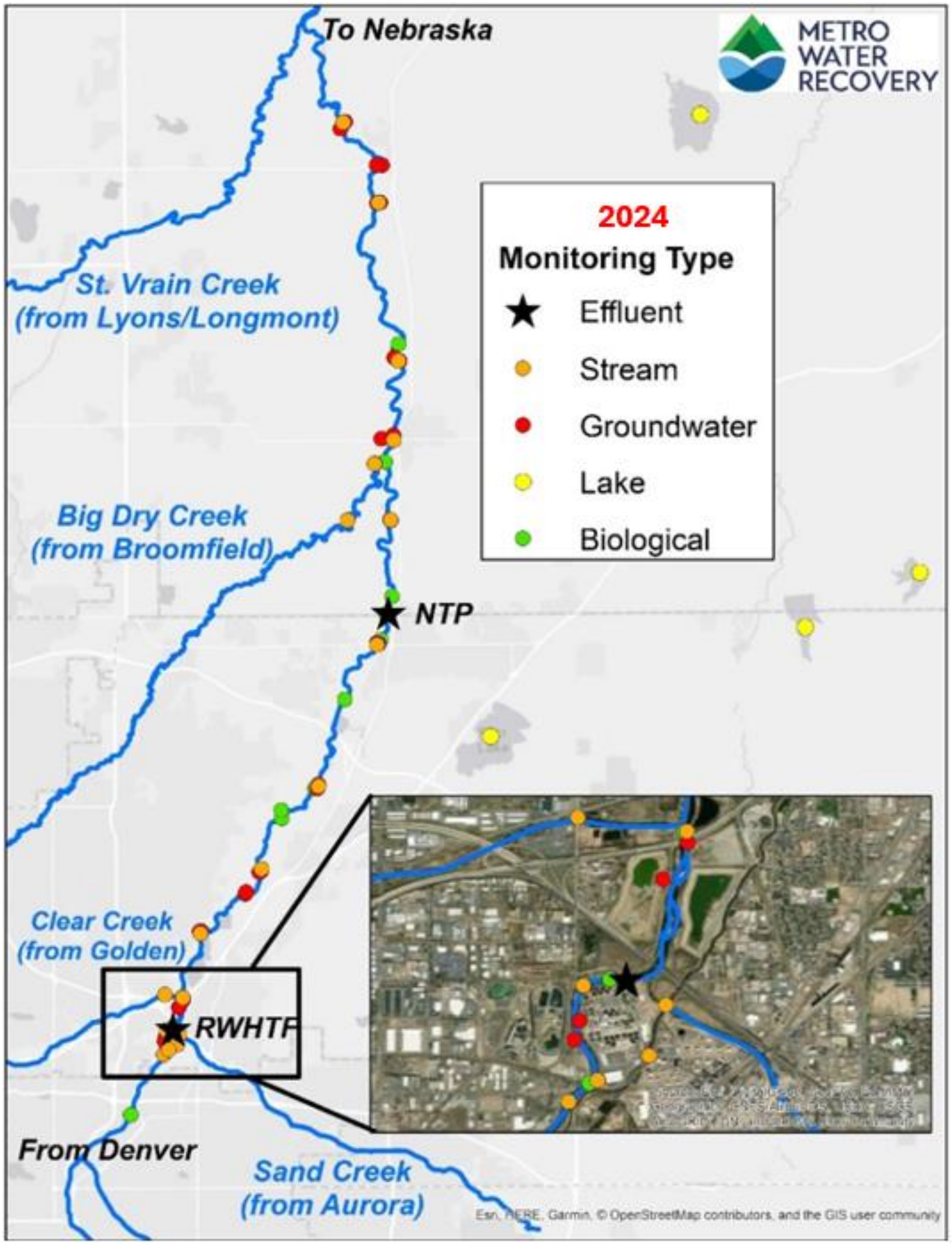


Figure 3. Location map of all Metro water quality sampling sites.

Data Analysis Methods

Method Detection Limits (MDL)

The method detection limit (MDL) is defined as the lowest concentration of a parameter of interest that can be reported with a 99% confidence that reliably measures the presence of the given constituent in the water sample. The MDL is based on the specific method and instrumentation used in the analysis. Therefore, as instrumentation changes over time, the MDL is likely to change as well. Current and historic MDLs for Metro analyses can be found in Appendix 2.

Concentrations lower than the MDL are reported as 0 as part of Metro's QA/QC protocols. There are various ways to handle data when the results are lower than the MDL, including labeling them as "Non-Detects" or less-thans (ex. <0.10 μg/L). A few of the analysis parameters were commonly at or below the MDL concentration including:

- Total and Dissolved Metals – most notably antimony, arsenic, beryllium, chromium, lead, and silver
- CBOD – especially in the downstream sampling sites in Segment 1a

The values are retained as part of Metro QA/QC protocols in part because the MDL will likely decline over time due to improvements in laboratory instrumentation and analytical methods.

Analysis

Time Series Plots

Time series plots of water quality parameters vs. time provide some of the most basic, but important relationships in water quality data analysis. These graphs can be used to demonstrate seasonal patterns, long-term trends, evidence of outliers, and random variability within the dataset. They also provide a visual representation of collection frequency and data gaps. In some of these time series graphs, connecting lines are used to highlight trends or seasonal patterns. It is important to note that these lines are only used as a visual aid for interpretation. They do not suggest that data points can necessarily be interpolated or extrapolated between and after recorded observations. Also, unless otherwise noted with statistical tests of significance, these lines do not imply a significant relationship.

Box and Whisker Plots

Box-and-whisker plots are included in this report because they provide a great deal of information about the distribution of the data in a simple visual representation. These plots can be used as a simple visual test of significance of change between groups by looking to see if the two groups generally overlap or not. The box in the box-and-whisker plot represents the middle 50% of the data (bottom = 25th percentile, horizontal line inside box = 50th percentile, top = 75th percentile) and the whiskers extend to above the box to the 90th percentile and below to the 10th percentile. The circles outside of these whiskers indicate the extreme values in the group.

Basic Summary Statistics

These simple statistics provide important quantitative measure of central tendency and data variability. In this report, the following summary statistics may be included:

- Number of Values
- Minimum and Maximum values
- 85^{th} Percentile
- Median and Mean Values
- Standard Deviation

Quality Assurance/Quality Control

Duplicate and blank samples are necessary for QA/QC of samples that are collected. Duplicates and blanks are completed once for each sampling effort. For example, a single field blank is prepared for all groundwater samples (single sampling effort), in contrast to one field blank for each *day* of groundwater sampling. Duplicates and blanks are preserved following the procedures outlined for normal sample collection. Additionally, a trip blank is used to test washing procedures and subsequent water quality analyses.

Data Analysis

Streams Program

Water Quality

Metro has been actively engaged in assessing the South Platte River for decades. Sampling of the river has varied over the years, adapting to serve the needs of Metro using a large scientifically-derived dataset. Metro staff currently sample 12 sites along the river, along with multiple tributaries. Not only are the data evaluated by Metro staff, but they also provide the foundation for the South Platte River Water Quality Model. The model provides unique site-specific information that supports water quality assessment and discharge permit evaluation activities. Few rivers in the United States have similar water management challenges, e.g., a natural system that fluctuates dramatically and a gaining stream with extremely high levels of nutrient metabolism. Having substantial volumes of site-specific data allows the development of an accurate understanding of the water quality and biotic integrity of the South Platte River.

In terms of water quantity, 2024 was an average year. The flows from January to April were low, typical of late-winter conditions along the South Platte River (Figure 4). There was a large rainstorm on April 27^{th} that led to an extreme scour event (4/27/24 average flow at Henderson gage = 3470 cfs). There were other rainstorms throughout the summer that sustained relatively high flows through the summer. The flows declined to baseflow conditions in the early fall, with only minor storms that led to brief, but small increases in daily average flow. Beginning in November, the Burlington Ditch was turned off in order to drain Barr Lake for maintenance needs. This resulted in higher than normal flows in Segment 15 during the month of November. Figure 5 demonstrates the typical streamflow patterns in Segment 15 and 1a. During the low-flow period between September and April, flows upstream of the RWHTF are very low and the river downstream is effluent-dominated. The river gains flow between 124th Avenue and Weld County Road 18 due to groundwater seepage, tributary flow (Big Dry Creek) and permitted discharges (Brighton WWTP, NTP, Fort Lupton WWTP). Measurable precipitation events, as measured at the Hite facility weather station, are noted by the black triangles. As expected, these storms correspond to brief increases in flow in the form of stormwater runoff. For the five-year flow record between 2019 and 2023, 50% of the time the river immediately downstream of the RWHTF outfalls is comprised of over 94% treated effluent. The river was less effluent dominated when looking at 2024 data only. For the majority of the year, the river was over 57% effluent (Figure 6).

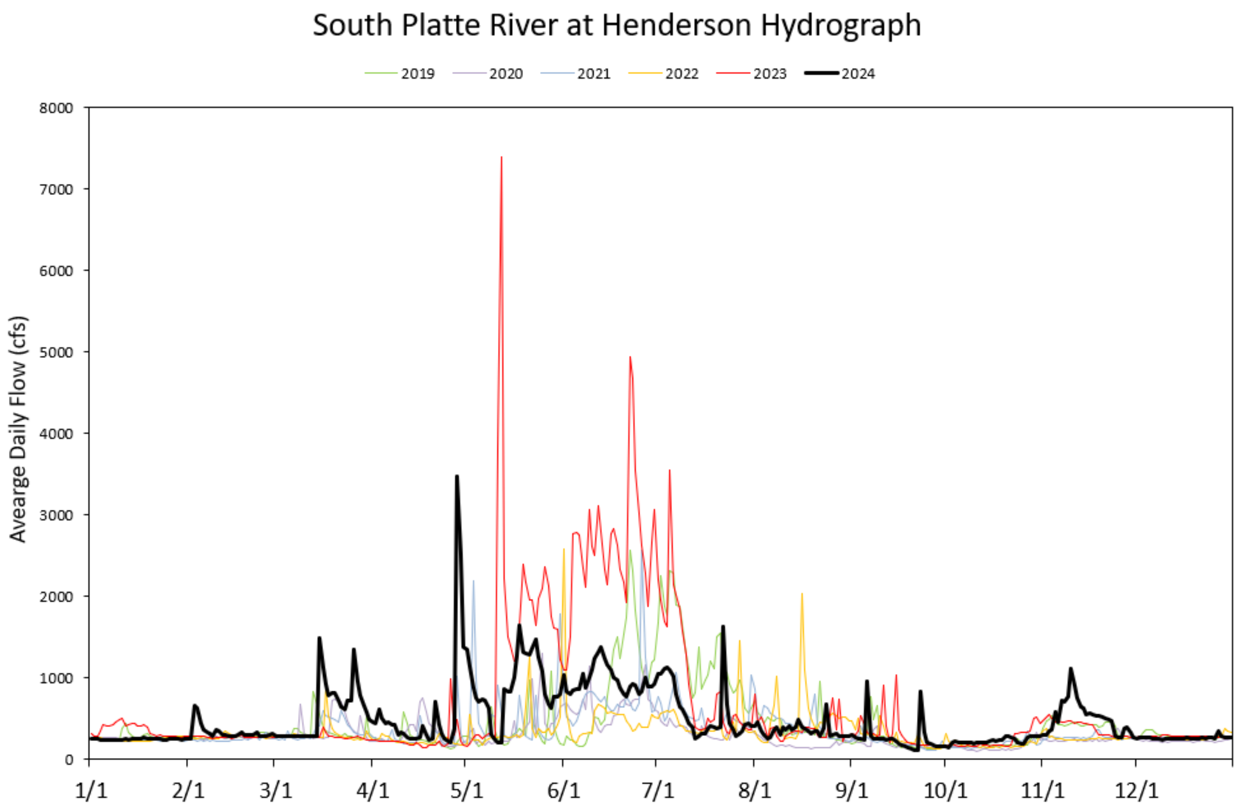


Figure 4. 2024 hydrograph at Henderson gage (SP-124).

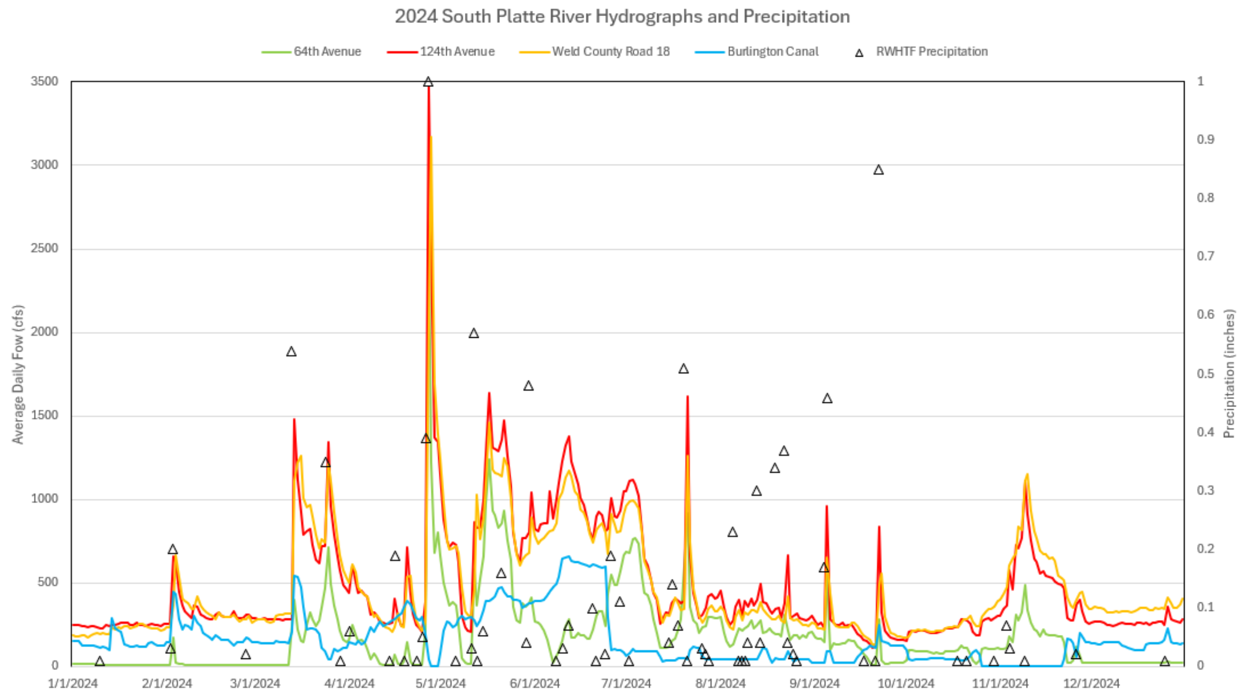


Figure 5. 2024 hydrographs at three locations along Segment 15 and 1a.

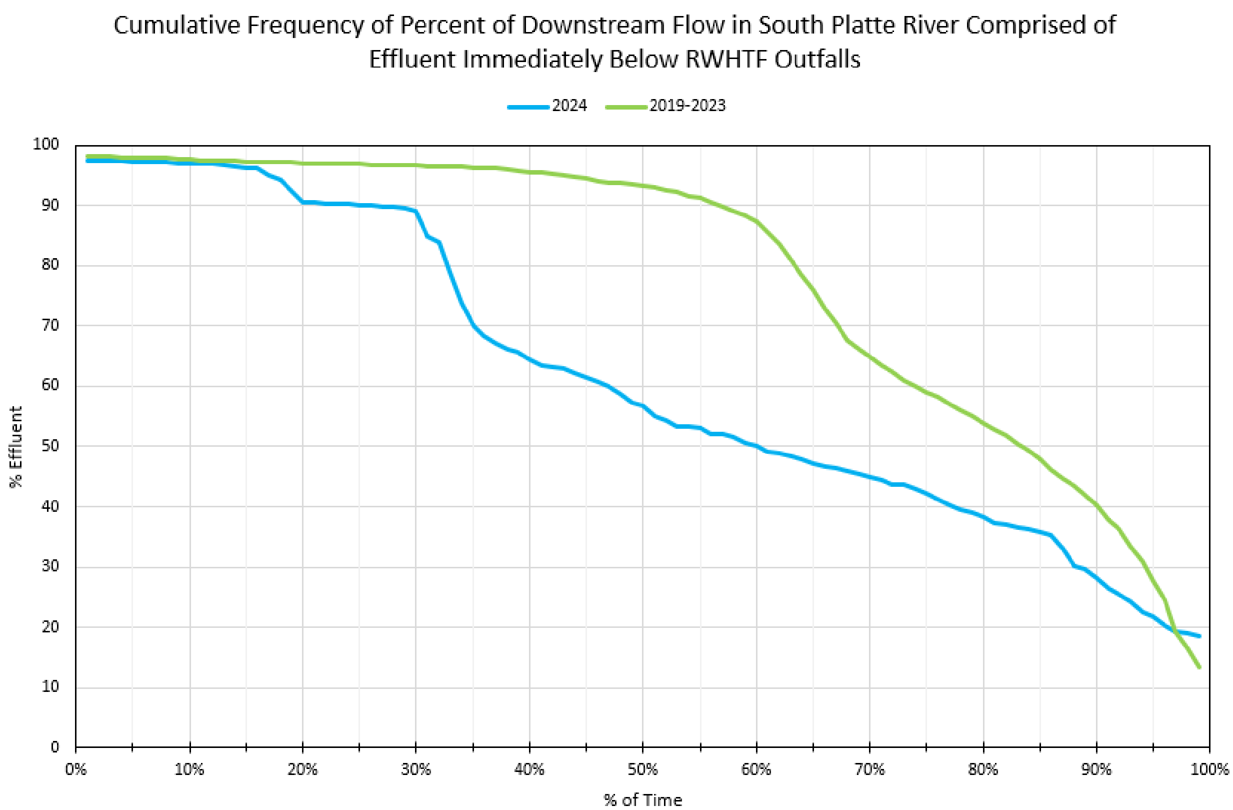


Figure 6. Cumulative frequency plot of percent effluent downstream of RWHTF outfalls.

General Chemistry

Stream sampling occurs twice a month in accordance with the sampling procedures of SPCURE. Each sampling event includes sample analysis for approximately 50 constituents at 20 locations along the river and its tributaries. The results in Table 10 and Table 11 summarize the conditions in Segments 15 and 1a respectively. All 2023 data from all the sites in a given Segment are presented together to produce a comprehensive picture of conditions. The summary results give minimum, average, medians , 85th percentiles, and maximum of the data collected. The 85th percentile is commonly used to assess the attainment of water quality standards, such as metals. It is not commonly used for other constituents but can provide insight on the distribution of the data. Further analysis of key constituents is included below.

Tributary data are not presented for this report. Data on the tributaries are typically only used to increase knowledge about water quality in the South Platte River.

Parameter	*Fraction*	*Unit*	*Count*	*Minimum*	*Average*	*Median*	*85th Percentile*	*Maximum*
Alkalinity	Total	mg/L	189	69	138	141	155	237
Aluminum	Bioavailable	ug/L	109	14	67.9	44	119	232
Aluminum	Dissolved	ug/L	189	1.5	15.2	13.6	22.9	43.7
Aluminum	Total	ug/L	188	26	326	212	577	1730
Ammonia-nitrogen	Total	mg/L	189	0.01	0.49	0.3	0.91	3.23
Antimony	Total	ug/L	188	0	0.48	0.5	0.6	1.1
Arsenic	Total	ug/L	188	0.5	1.07	1.1	1.3	2
Beryllium	Total	ug/L	188	0	0.01	0	0.05	0.26
BOD		mg/L	177	0	5.32	4	9.6	22
Bromide	Total	mg/L	189	0.00	0.32	0.27	0.42	0.82
Cadmium	Total	ug/L	188	0	0.91	0.3	0.6	31
Cadmium	Dissolved	ug/L	189	0	0.81	0.2	0.51	29.1
Calcium	Total	mg/L	189	29.6	72.9	72.7	87.9	126
Calcium	Dissolved	mg/L	189	31.2	71.8	71.7	84.3	122
CBOD		mg/L	185	0	1.82	2	3	8
Chloride	Total	mg/L	189	47.8	146	142	185	292
Chromium	Total	ug/L	188	0	0.73	0.6	1.10	2.8
Chromium	Dissolved	ug/L	189	0	0.36	0.4	0.6	1
Conductivity	Total	umho/cm	189	495	1146	1176	1333	1913
Copper	Total	ug/L	188	1.6	3.71	3.3	5	11.1
Copper	Dissolved	ug/L	189	0.9	2.01	1.9	2.6	4.9
Dissolved Oxygen		mg/L	189	5.7	8.26	8.3	9.38	11.5
Escherichia coli		EC/100ml	189	19	640	249	1550	2420
Fluoride	Total	mg/L	189	0.00	0.80	0.81	0.89	0.992

Hardness, carbonate		mg/L	189	106	258	258	310	465
Inorganic Nitrogen (Nitrate and Nitrite)	Total	mg/L	117	0.57	2.36	2.3	3.36	5.83
Iron	Total	mg/L	189	0.11	0.45	0.38	0.66	1.95
Iron	Dissolved	mg/L	189	0.02	0.17	0.11	0.22	2.8
Kjeldahl Nitrogen	Total	mg/L	188	0.02	1.38	1.2	2.4	5.1
Lead	Total	ug/L	188	0	1.28	0.9	2.30	7.6
Lead	Dissolved	ug/L	189	0	0.17	0	0.3	10
Magnesium	Total	mg/L	189	7.77	18.5	18.7	21.9	43.8
Magnesium	Dissolved	mg/L	189	8.21	17.6	17.7	20.4	33.7
Manganese	Total	ug/L	188	38.9	159	147	206	561
Manganese	Dissolved	ug/L	189	7.5	105	89.2	164	542
Molybdenum	Total	ug/L	188	2.5	5.49	5.1	7.00	10.5
Nickel	Total	ug/L	188	1.1	2.14	2.1	2.6	3.6
Nickel	Dissolved	ug/L	189	0.7	1.89	1.9	2.3	5.1
Nitrogen	Total	mg/L	189	0.68	3.78	3.6	5.48	9.55
Organic Carbon	Dissolved	mg/L	189	3	7.05	7	9	14
Orthophosphate	Dissolved	mg/L	189	0.03	0.15	0.13	0.25	0.36
pH			189	6.95	7.80	7.8	8.02	8.27
Phosphorus	Total	mg/L	189	0.06	0.27	0.26	0.4	0.51
Phosphorus	Dissolved	mg/L	189	0.03	0.19	0.18	0.3	0.44
Potassium	Total	mg/L	189	3	10.5	10.5	14.7	19
Potassium	Dissolved	mg/L	189	2.9	10.2	10.4	14.3	18.3
Selenium	Total	ug/L	188	0.4	1.55	1.5	2	4.7
Selenium	Dissolved	ug/L	189	0	1.60	1.6	2.1	4.7
Silver	Total	ug/L	188	0	0.08	0	0	11.7
Silver	Dissolved	ug/L	189	0	0.01	0	0	1.55
Sodium	Total	mg/L	189	34.3	117	118	149	198
Sodium	Dissolved	mg/L	189	33.3	114	114	143	206
Sulfate	Total	mg/L	189	45.4	139	147	165	312
Temperature, water		deg C	189	1.9	13.8	13.5	20.1	23.6
Total Dissolved Solids	Total	mg/L	189	206	609	640	730	950
Total Suspended Solids	Total	mg/L	189	2	17.5	14	27	68
Turbidity		NTU	185	0	8.99	5.7	18.4	71.8

Zinc	Total	ug/L	188	0	23.8	23.1	33.5	78.7
Zinc	Dissolved	ug/L	189	3.7	19.9	18.2	30.8	38

Table 10. 2024 summary statistics for Segment 15 of the South Platte River (all sites are combined in this analysis).

Parameter	*Fraction*	*Unit*	*Count*	*Minimum*	*Average*	*Median*	*85th Percentile*	*Maximum*
Alkalinity	Total	mg/L	95	82	143	147	159	179
Aluminum	Bioavailable	ug/L	56	33	99.6	98.5	154	292
Aluminum	Dissolved	ug/L	95	3.5	15.7	12.4	19.9	196
Aluminum	Total	ug/L	94	11	694	550	1162	2920
Ammonia-nitrogen	Total	mg/L	95	0.01	0.17	0.07	0.24	2.48
Antimony	Total	ug/L	95	0	0.53	0.5	0.69	1.2
Arsenic	Total	ug/L	95	0.8	1.41	1.4	1.7	2.7
Beryllium	Total	ug/L	95	0	0.03	0	0.07	0.66
BOD		mg/L	83	1	4.20	4	6	12
Bromide	Total	mg/L	95	0.16	0.34	0.28	0.36	0.925
Cadmium	Total	ug/L	95	0.1	0.29	0.3	0.4	0.9
Cadmium	Dissolved	ug/L	95	0	0.15	0.12	0.28	0.36
Calcium	Total	mg/L	95	38.3	74.5	78	85.7	96.1
Calcium	Dissolved	mg/L	95	38.4	74.2	78.1	83.6	92.6
CBOD		mg/L	90	0	1.11	1	2	2
Chloride	Total	mg/L	95	69.9	151	150	185	252
Chromium	Total	ug/L	95	0.2	0.99	0.8	1.4	4
Chromium	Dissolved	ug/L	95	0	0.19	0.3	0.4	0.8
Conductivity	Total	umho/cm	95	716	1226	1256	1397	1717
Copper	Total	ug/L	95	2.7	5.51	5	7.65	16.4
Copper	Dissolved	ug/L	95	1.7	2.43	2.4	2.9	4
Dissolved Oxygen		mg/L	95	6.6	8.90	8.9	9.9	11.7
Escherichia coli		EC/100ml	95	8	230	117	261	2420
Fluoride	Total	mg/L	95	0.00	0.83	0.83	0.92	1.04
Hardness, carbonate		mg/L	95	137	270	284	312	359
Inorganic Nitrogen (Nitrate and Nitrite)	Total	mg/L	71	1	2.46	2.34	3.39	5.34
Iron	Total	mg/L	95	0.06	0.83	0.72	1.09	3.95
Iron	Dissolved	mg/L	95	0	0.16	0.09	0.25	1.05
Kjeldahl Nitrogen	Total	mg/L	95	0.02	1.05	1.1	1.78	2.5
Lead	Total	ug/L	95	0.3	2.94	2.6	4.67	14.3
Lead	Dissolved	ug/L	95	0	0.33	0.2	0.3	16.3

Magnesium	Total	mg/L	95	10	20.3	21.1	23.9	28.9
Magnesium	Dissolved	mg/L	95	10.5	19.6	20.5	22.1	24.9
Manganese	Total	ug/L	95	89	159	140	186	811
Manganese	Dissolved	ug/L	95	5.7	49.9	36.2	95.3	162
Molybdenum	Total	ug/L	95	3	5.65	5.6	7.2	9.7
Nickel	Total	ug/L	95	1.8	2.72	2.7	3.1	5.5
Nickel	Dissolved	ug/L	95	1.3	2.19	2.3	2.6	2.9
Nitrogen	Total	mg/L	95	1.43	3.44	3.3	4.7	7.1
Organic Carbon	Dissolved	mg/L	95	4	6.31	6	8	9
Orthophosphate	Dissolved	mg/L	95	0.09	0.18	0.18	0.24	0.31
pH			95	7.84	8.04	8.04	8.16	8.39
Phosphorus	Total	mg/L	95	0.11	0.28	0.27	0.36	0.46
Phosphorus	Dissolved	mg/L	95	0.09	0.21	0.21	0.28	0.56
Potassium	Total	mg/L	95	5.6	11.1	11.2	13.8	16.1
Potassium	Dissolved	mg/L	95	5.3	10.8	11	13.4	15.5
Selenium	Total	ug/L	95	0.5	1.53	1.6	2	2.4
Selenium	Dissolved	ug/L	95	0	1.56	1.6	2	2.6
Silver	Total	ug/L	95	0	0.03	0	0.08	0.33
Silver	Dissolved	ug/L	95	0	0.00	0	0	0.08
Sodium	Total	mg/L	95	54.6	127	132	148	203
Sodium	Dissolved	mg/L	95	54	126	130	149	208
Sulfate	Total	mg/L	95	72.3	165	173	192	210
Temperature, water		deg C	95	0.6	13.2	13.3	20.1	23.2
Total Dissolved Solids	Total	mg/L	95	316	655	698	754	878
Total Suspended Solids	Total	mg/L	95	5	33.3	29	47.9	132
Turbidity		NTU	91	0	15.6	12.5	28	63.1
Zinc	Total	ug/L	95	9.5	29.0	30	36.9	79.1
Zinc	Dissolved	ug/L	95	8.1	18.9	18.1	26.3	36.3

Table 11. 2024 summary statistics for Segment 1a of the South Platte River (all sites are combined in this analysis).

Nutrients

Nutrient loading has been identified as one of America's most widespread, costly, and challenging environmental problems. Both nitrogen and phosphorus have natural cycles in which they support the growth of plants and animals and neither component is toxic to aquatic life, except for nitrogen as ammonia. Excess nitrogen and phosphorus can cause algal growth, which can have important impacts on DO, pH, and discourage recreational users. Nutrients have become a primary focus for the water quality community in recent years and are regulated in a number of ways. Because total nitrogen (TN) and total phosphorus (TP) are not toxic, typical endpoints for environmental assessment are not available.

In 2012, the Colorado Water Quality Commission (Commission) adopted interim numeric values for TP, TN, and chlorophyll-*a* (Chl-*a*) to be implemented in streams and rivers over the next ten years. In addition, the Commission adopted a control regulation, Regulation 85, to provide a path forward for nutrient reductions at regulated point sources around the state. Metro is striving to provide the most timely and useful data possible to ensure that nutrient regulations are appropriate over time.

Total Phosphorus

Average TP concentrations ranged from 0.16 mg/L at SP-62 to 0.32 mg/L at SP-160 (Figure 7). Prior to 2021, there was a much stronger longitudinal pattern as the effect of the Metro's RWHTF outfalls could be seen in higher TP concentrations at SP-CC and SP-88.

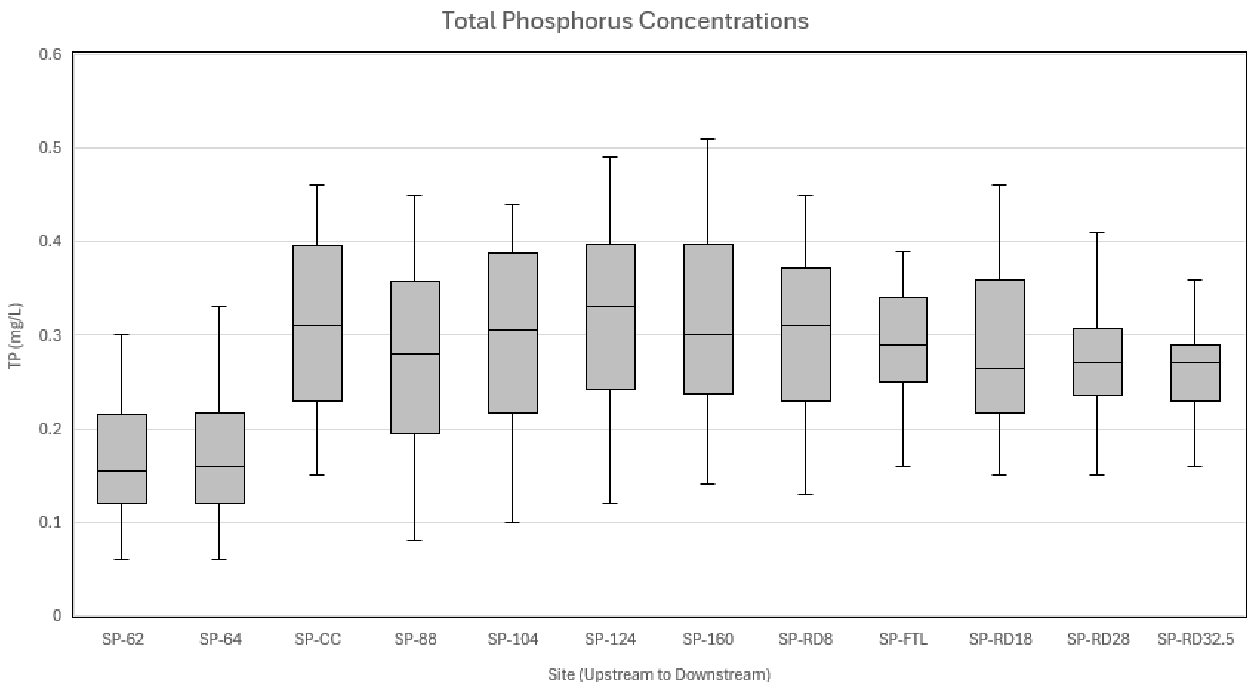


Figure 7. 2024 concentrations of TP from 62nd Avenue to Weld County Road 32.5.

Metro began full-scale biological phosphorus removal at the RWHTF facility in January 2021. Past pilot testing in 2015 has shown that there are significant corresponding reductions in in-stream TP concentrations downstream when effluent concentrations of phosphorus are lowered. In the RWHTF South Final Effluent, the average TP concentrations was 0.5 mg/L in 2024 (Figure 8), much lower than the 2017-2020 average TP concentrations of 2.1 mg/L. The total phosphorus concentrations in the RWHTF North Final Effluent and NTP Effluent leaving Pond #3 remained low in 2024, generally below 0.5 mg/L. The bar graphs of average annual TP concentrations at downstream river sites reflect the overall reductions of in-stream TP concentrations since 2015 (Figure 9). The Water Quality Division staff will continue to document changes in river conditions as biological nutrient removal is implemented throughout the RWHTF in coming years.

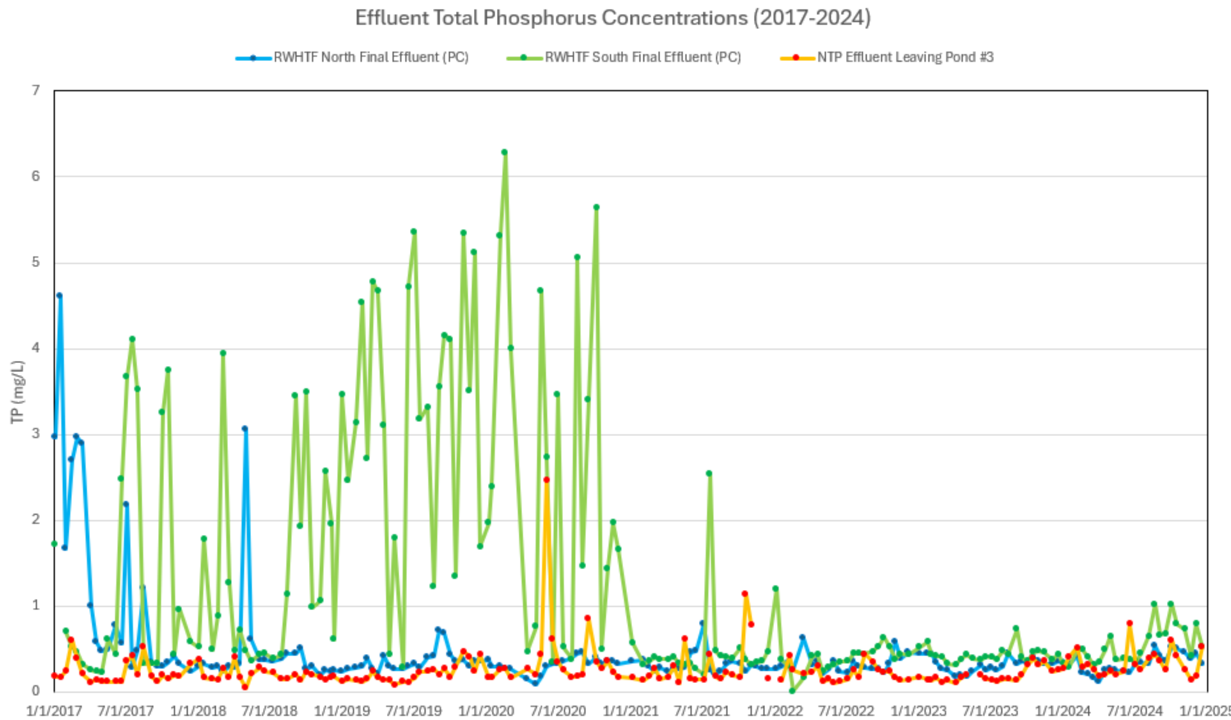


Figure 8. 2017-2024 time series of total phosphorus (TP) concentrations in the final effluent.

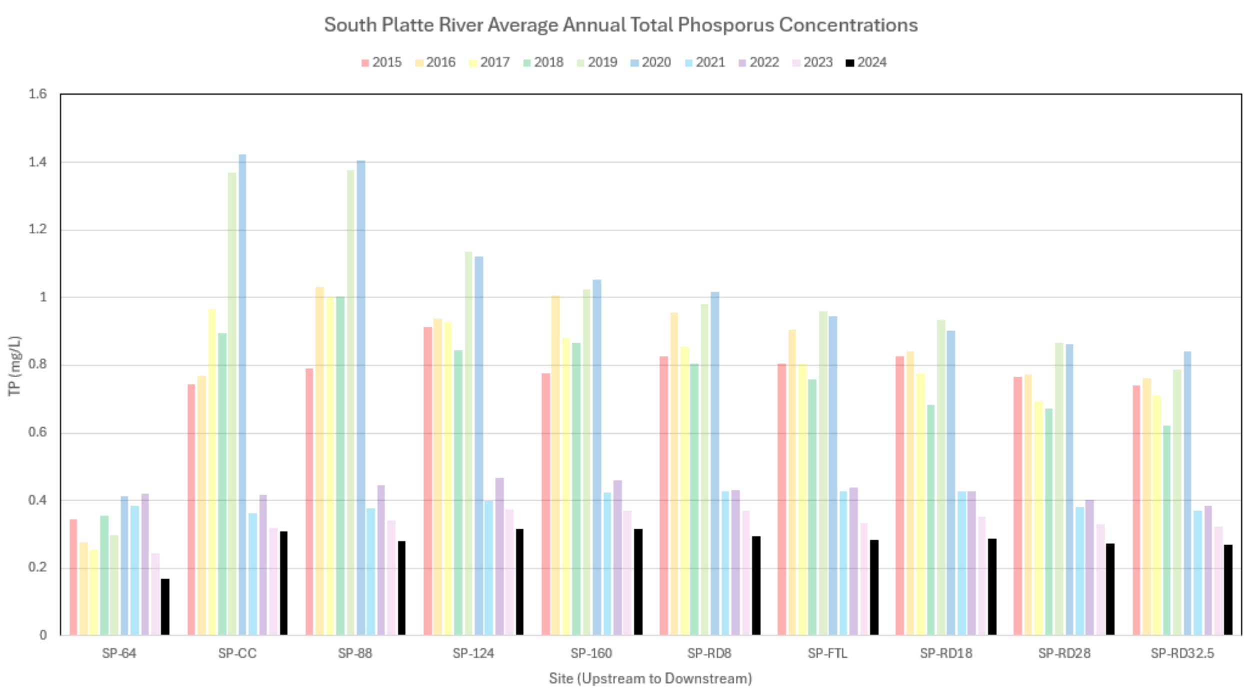


Figure 9. Bar graph of annual average total phosphorus concentrations from 2015-2024.

Total Nitrogen

The highest total nitrogen values were seen during the winter months, with the highest value of 9.6 mg/L occurring at SP-104 (Figure 10). The lowest values were seen during the May, June, and July sampling events, when flows were high with spring runoff. 2024 was the tenth complete year in which the South Complex secondary improvements were fully operational, resulting in drastically lower ammonia concentrations in the South Final Effluent. This resulted in a corresponding decrease in TN concentrations in all the stream sites. Figure 11 shows annual average TN concentrations for 2015-2024. There have been significant TN reductions at all sites since 2015. However, as seen in the box plot in Figure 10, the high variability in TN concentrations remains, indicating a variety of TN sources.

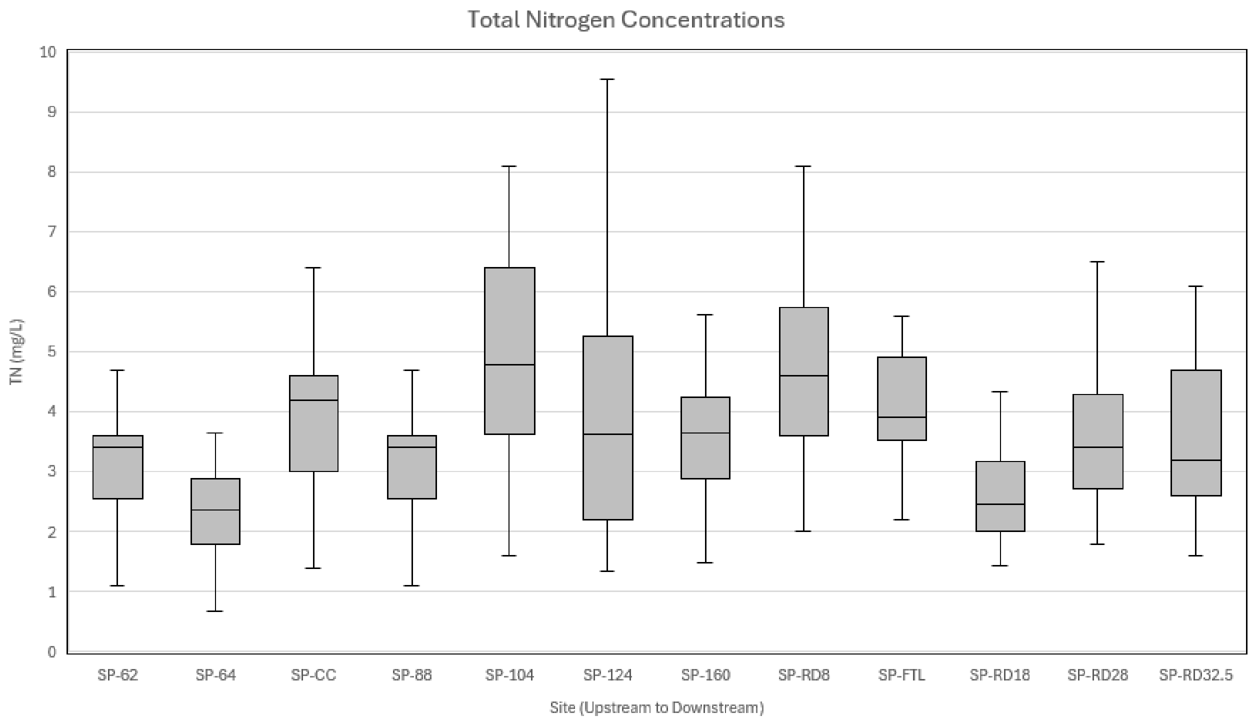


Figure 10. 2024 concentrations of TN from 62nd Avenue to Weld County Road 32.5.

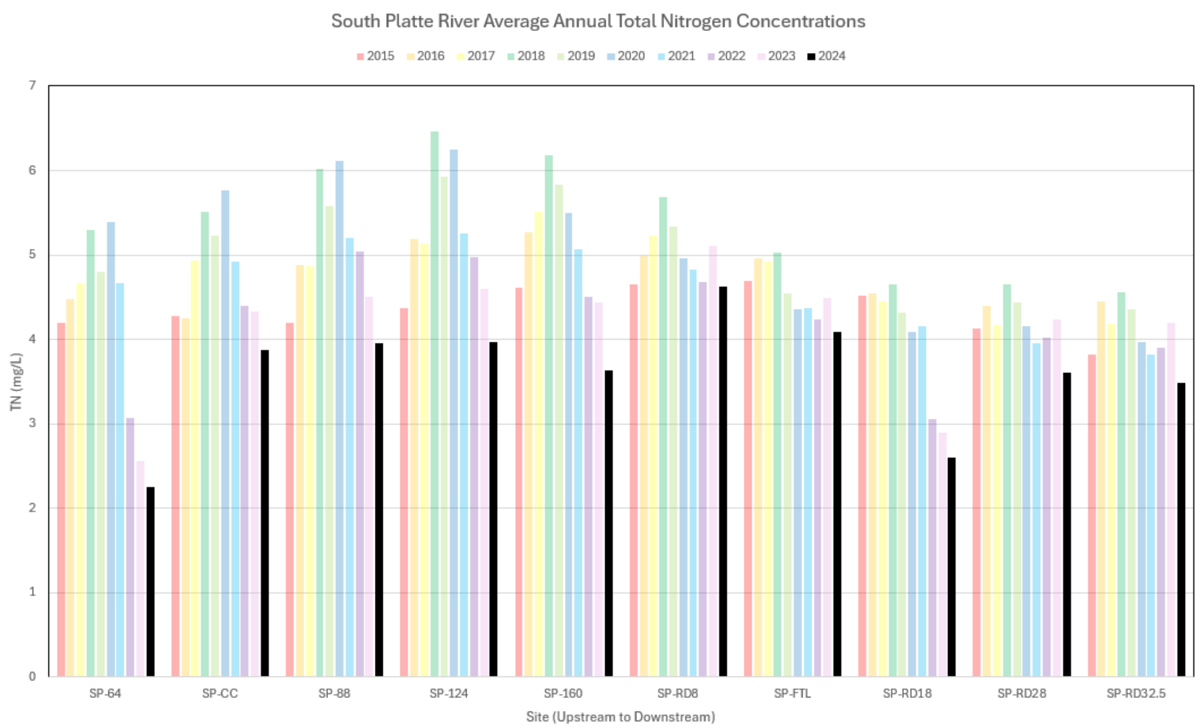


Figure 11. Bar graph of annual average TN concentrations from 2015-2024.

Ammonia

Ammonia is the only component of TN that can be toxic to fish, but the level of toxicity is dependent on both temperature and pH. Average ammonia concentrations ranged from below 0.1 mg/L at SP-64 to 0.9 mg/L at SP-104 (Figure 12). Ammonia concentrations in 2024 remained reduced due to the start-up of the South Complex secondary improvements in the fall of 2014, constructed to meet the 1999 Ammonia criteria established by the EPA. The improvements can be seen in in-stream ammonia concentrations (Figure 13). For example, the 2013 average ammonia concentration at SP-CC (~1 mile downstream of RWHTF outfalls) was 4.91 mg/L, compared to the 2024 average ammonia concentration of 0.45 mg/L. There are similar drastic reductions at all the downstream monitoring sites. These results are encouraging in terms of regulatory compliance of instream ammonia standards, as well as expected benefits to aquatic life.

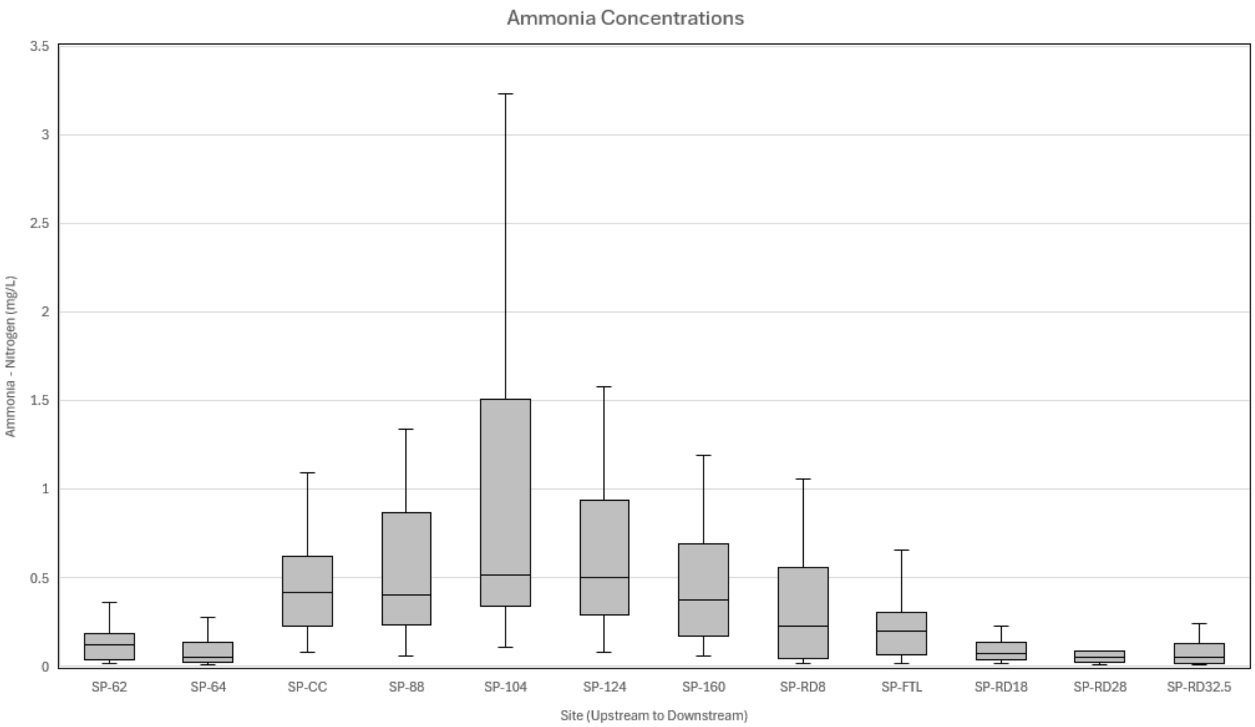


Figure 12. 2024 concentrations of ammonia from 62nd Avenue to Weld County Road 32.5.

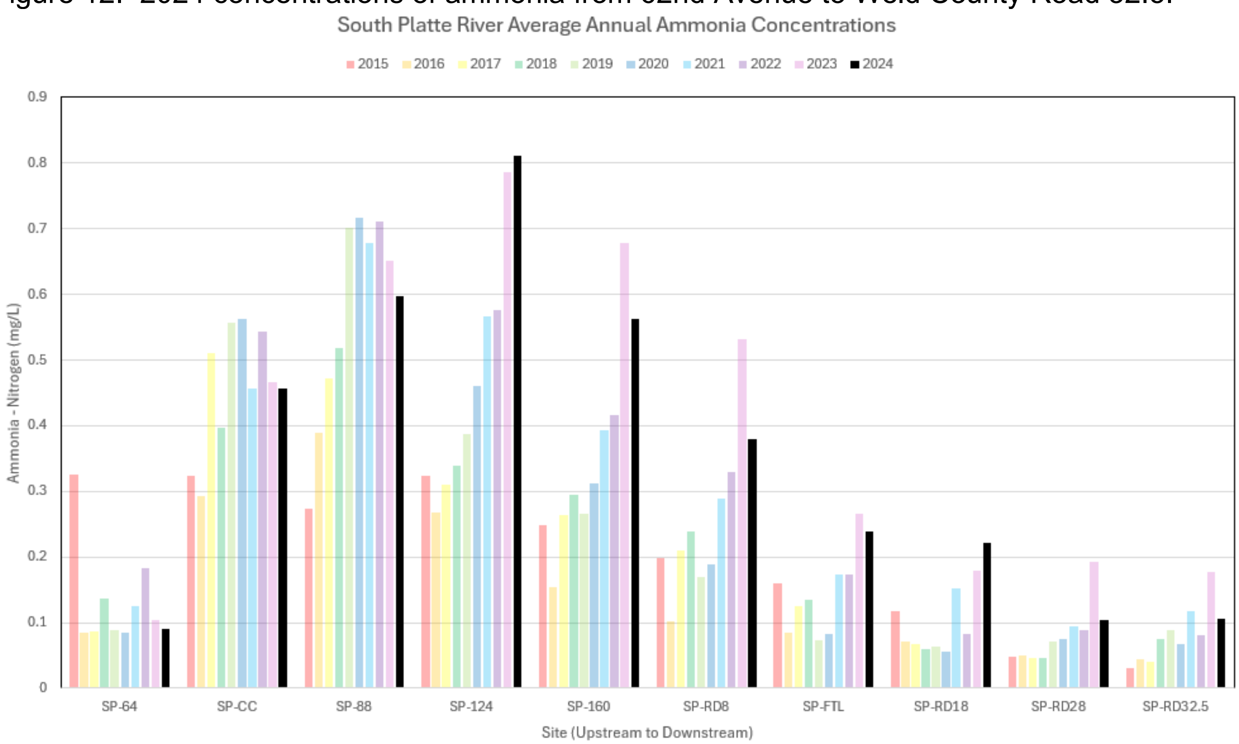


Figure 13. Bar graph of annual average ammonia-N concentration from 2015-2024.

Dissolved Oxygen

Along with temperature, nutrient concentrations can affect dissolved oxygen concentrations. On average, 2024 monthly DO concentrations in Segment 15 remain between 7.0 and 9.5 mg/L.

There is a pronounced seasonal pattern, with summertime and early-fall values tending to be lower as compared to the higher DO concentrations in the winter months. This seasonal pattern is expected because the solubility of oxygen decreases as temperature increases; therefore, cold water holds more DO than warm water. The pattern is similar in Segment 1a, with average monthly DO concentrations ranging from 7.0 to 11.4 mg/L (Figures 14 and 15). Summer concentrations also show less variability in the lower segment. The 2024 results suggest that the South Complex secondary improvements may have indirectly benefited DO levels, as the lower ammonia concentrations in the river result in less nitrification and consumption of dissolved oxygen. In 2025, Metro will monitor continuous DO concentrations between the RWHTF outfalls and Weld County Road 28 to better characterize the diel patterns and help put the values observed during biweekly sampling into context.

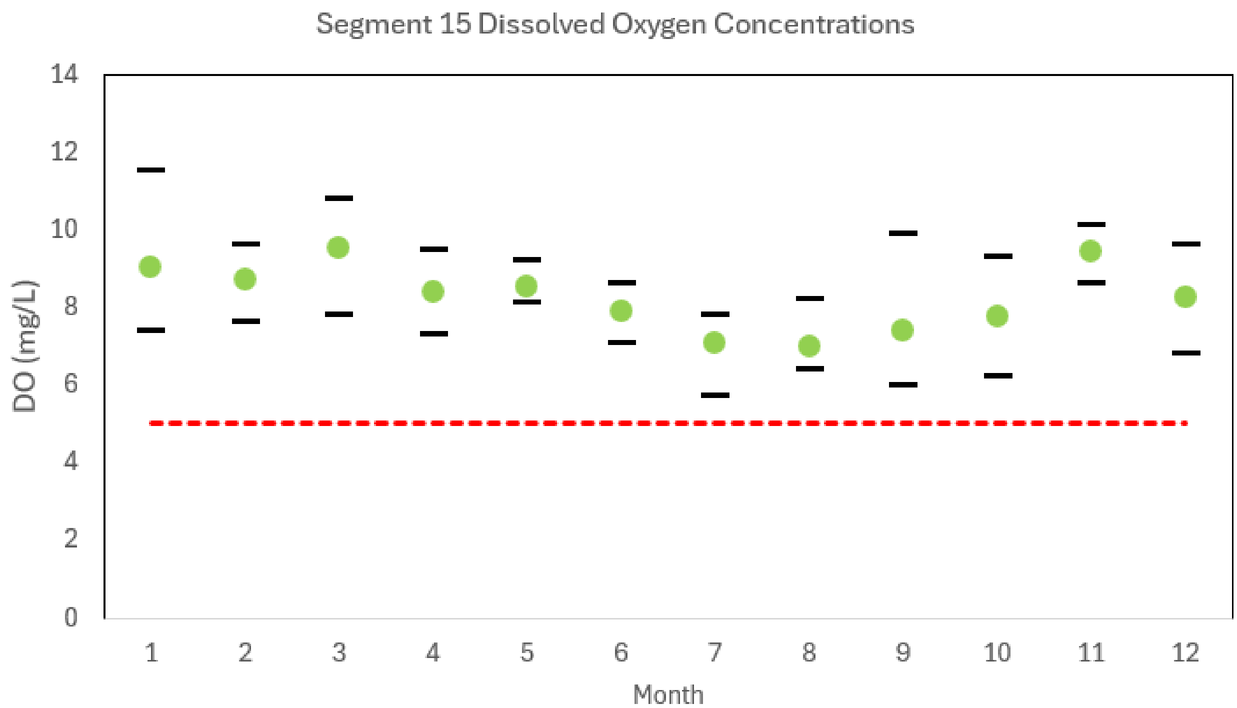


Figure 14. Concentrations of DO in Segment 15 by month (green circles indicate average values and black lines indicate high and low values).

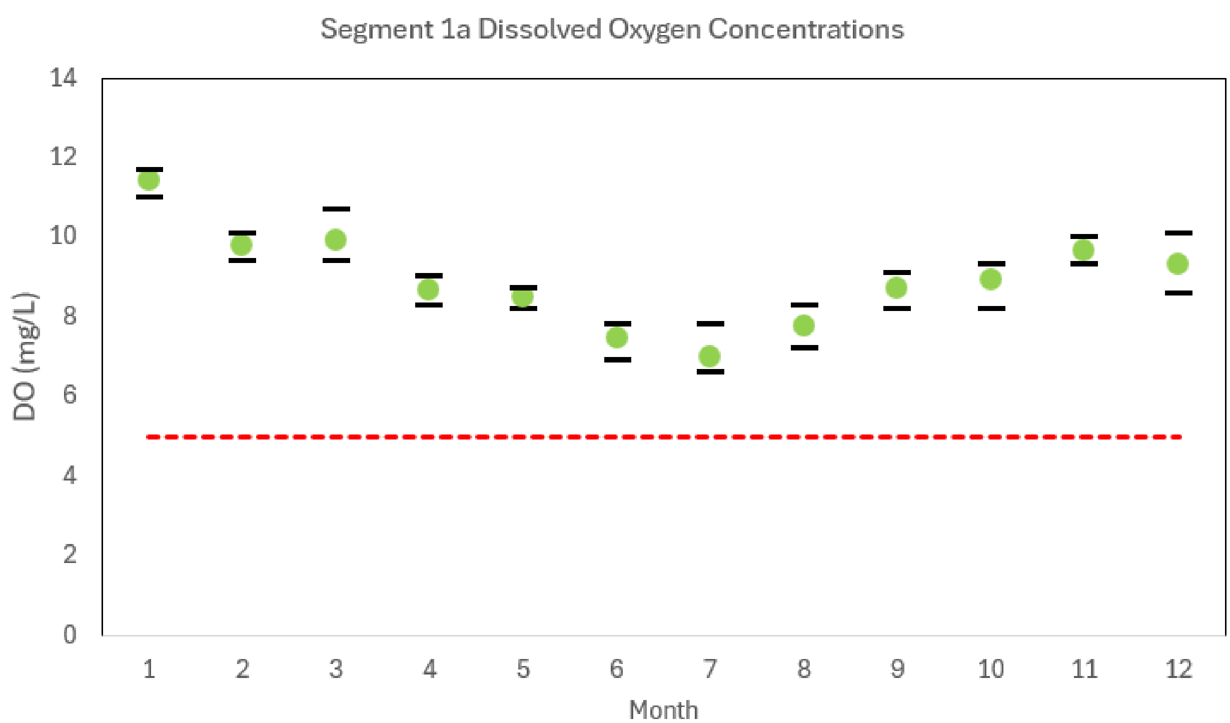


Figure 15. Concentrations of DO in Segment 1a by month (green circles indicate average values and black lines indicate high and low values).

pH

pH concentrations can also be affected by nutrient cycling. The average values in Segments 15 and 1a for 2024 were 7.8 and 8.0 respectively. Sites close to Metro's outfalls can have lower pH values, which are a closer reflection of the conditions in the effluent.

Total Dissolved Solids

Total dissolved solids (TDS) are solids in water that can pass through a filter and can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions and other ions. Sometimes, TDS is also referred to as salinity. TDS can enter the stream from irrigation return flows and storm events, washing in pollutants such as fertilizers and deicing compounds. The effluent from wastewater treatment plants also adds dissolved solids to streams, although most of the suspended solids are removed as part of the treatment process. There is also a natural component of salinity, as some rocks naturally release ions easily when water flows over or around them. The EPA has set a secondary drinking water standard of 500 mg/L for TDS. Aquatic organisms are not adversely affected until TDS gets over 1000 mg/L. Between 1000 – 5000 mg/L, there may be reductions in crop yield. The highest values in Segment 15 occur at 64th Avenue, where the average TDS was 637 mg/L in 2024 (Figure 16). The concentrations generally range between 500 – 800 mg/L at the other sites throughout Segments 15 and 1a, with slight increases in salinity moving downstream into Segment 1a.

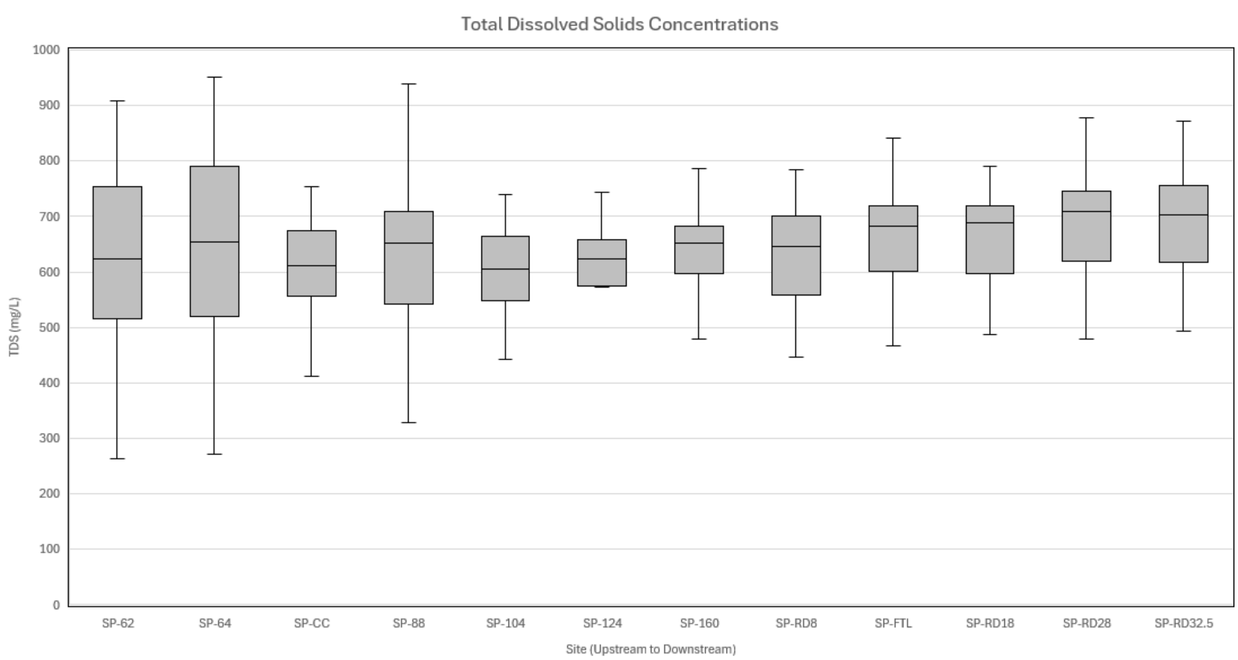


Figure 16. 2024 TDS concentrations from 62nd Avenue to Weld County Road 32.5.

E. coli

Segment 15 was placed on the State's 303(d) list of water-quality impaired water bodies for non-attainment of the *Escherichia coli* (*E. coli*) water quality standard in 2002. This impairment affects the beneficial use of existing recreation (Recreation E) and was therefore a priority for the completion of a TMDL due to the non-attainment of a human health-based standard. Metro staff, in conjunction with partners in SPCURE, submitted a final draft TMDL to CDPHE to address *E. coli* in Segment 15. The TMDL was open to public comment during November 2015 and approved by the EPA in February 2016. The evaluation of *E. coli* levels uses two-month geometric mean calculations. Data from 2024 shows similar patterns to data from previous years, with more exceedances occurring during summer months when flows are very low. In 2024, all sites sampled along the South Platte River in Segments 15 and 1a show geometric mean calculations higher than the standard of 126 cfu/100 ml (Table 12). The discharges from the Metro's RWHTF are consistently well below the standard and increasing point source treatment is not considered an effective solution to address high *E. coli* values in natural systems. Sources in Segments 15 and 1a include runoff from storm events, agricultural facilities, and wildlife contributions.

	Segment 15	Segment 1a
Jan/Feb	**230**	59
Mar/Apr	123	52
May/Jun	**180**	109
Jul/Aug	**1236**	**387**
Sep/Oct	**401**	**135**
Nov/Dec	**292**	105

Table 12. Geometric means of all *E. coli* data by Segment (bolded red text indicates values exceeding the river standard of 126 cfu/100 mL).

Metals

Arsenic

Arsenic is a naturally occurring element that can be toxic. It is commonly used to strengthen metals and used to help produce pesticides but is also naturally occurring in soils. Total arsenic in the South Platte River ranged from 0.5 to 2.7 μg/L during 2024 (Figure 17). Arsenic was lowest at SP-CC, SP-88 and SP-104, which are the closest downstream sites to the RWHTF discharge. The values typically increase as the river moves downstream, which may be driven by groundwater inflows (groundwater data indicates that groundwater is naturally high in arsenic). The arsenic standard is a hybrid standard based on the water supply use designation. All sites show concentrations higher than the first human-health risk-based number in the hybrid standard (0.02 μg/L), but all are well below the maximum contaminant level goal standard (10 μg/L).

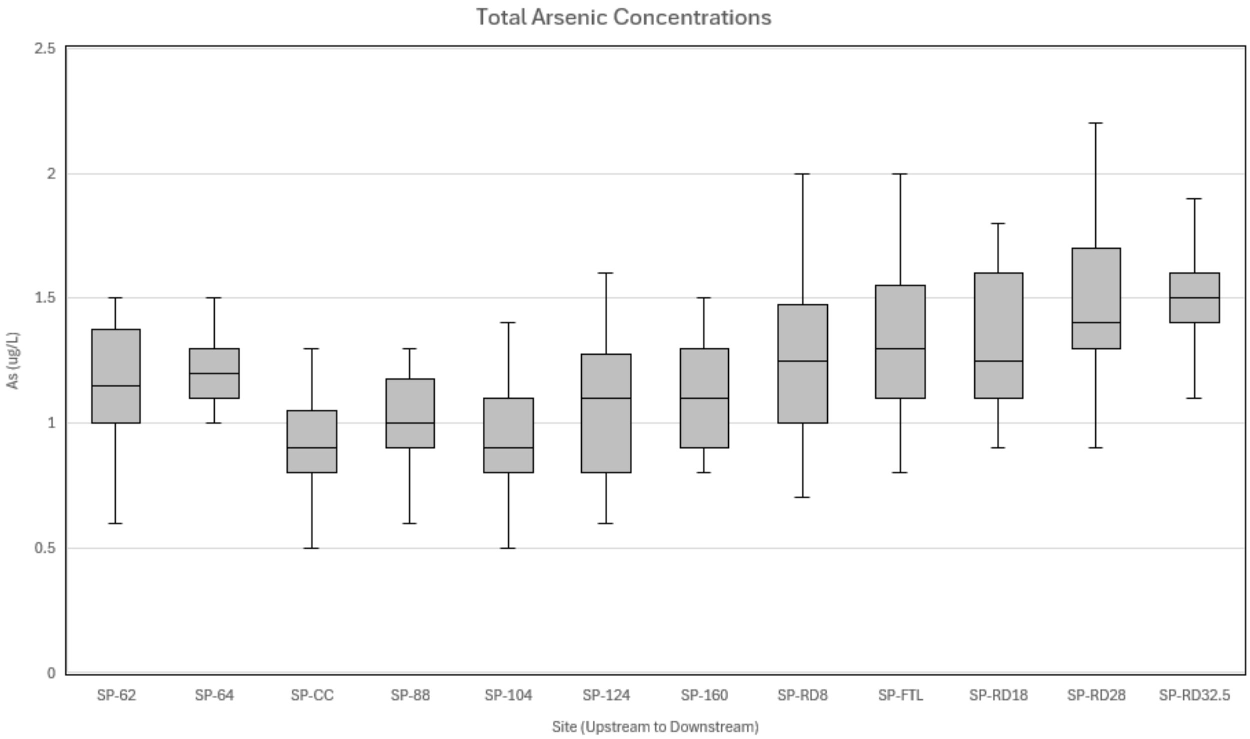


Figure 17. 2024 concentrations of total arsenic from 62nd Avenue to Weld County Road 32.5.

Cadmium

Cadmium is a metal of concern in Segment 15, as aquatic life use-based water quality standards for this constituent are not attained in the portion of the South Platte River between the Burlington Ditch headgate and Clear Creek. Currently, water quality goals exist for dissolved cadmium from SP-64 to SP-88 based on a TMDL implemented in 2011 (CDPHE 2011). According to the TMDL, surface water and groundwater data in the area indicate that contaminated groundwater plumes originating under or near the former Globeville ASARCO Facility (https://cdphe.colorado.gov/asarco-globe) are the primary sources of cadmium loading. The upstream (SP-64) dissolved cadmium concentrations remain elevated (2024 average = 5.0 ug/L). The RWHTF effluent dilutes the upstream water and all downstream sites met the chronic aquatic life criteria (85th percentile = 1.45 ug/L) (Figure 18). 2024 data from the river monitoring sites at 62nd Avenue indicate that the elevated cadmium concentrations are isolated at 64th Avenue. The 2024 average 62nd Avenue dissolved cadmium concentration was 0.06 ug/L, indicating clearly that the groundwater plume enters the South Platte River somewhere in the 0.4-mile reach between 62nd Avenue and 64th Avenue.

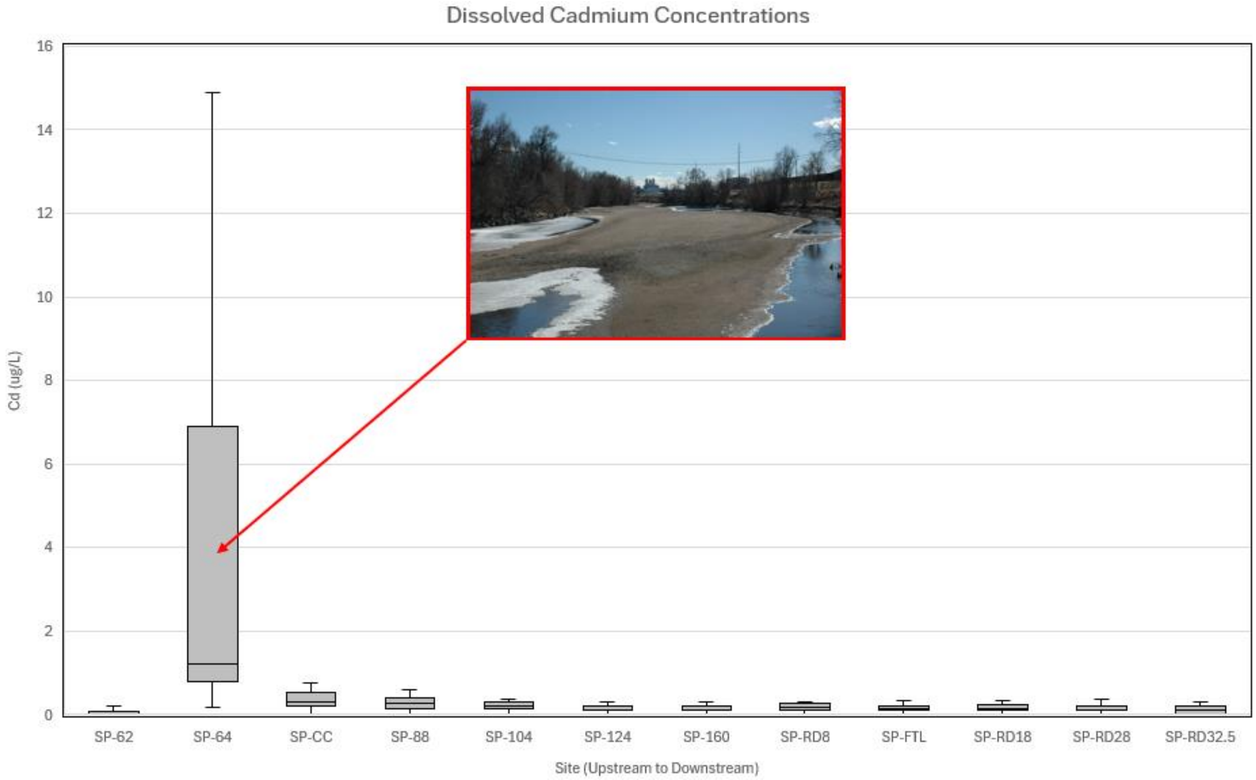


Figure 18. 2024 concentrations of dissolved cadmium from 62nd Avenue to Weld County Road 32.5.

Iron

Iron is a common element often used to make steel and other common products, and is also naturally occurring in soils. Iron is not toxic to humans and is a vital contributor to respiration. Iron is regulated in the South Platte River to protect fish populations and water supplies. Past years' data indicated that total recoverable iron concentrations were approaching the chronic aquatic life standard of 1 mg/L (50th percentile). In 2024, the total recoverable iron concentrations were lower than in previous years, with the highest median concentration at SP-RD32.5 (0.92 mg/L). Total recoverable iron concentrations become higher and slightly more variable in Segment 1a. Median values are relatively higher from SP-FTL to SP-32.5 at the downstream end of Segment 1a. While not presented here, these high total iron values in Segment 1a can also be attributed to high concentrations in Big Dry Creek which enters the South Platte River between SP-RD8 and SP-FTL.

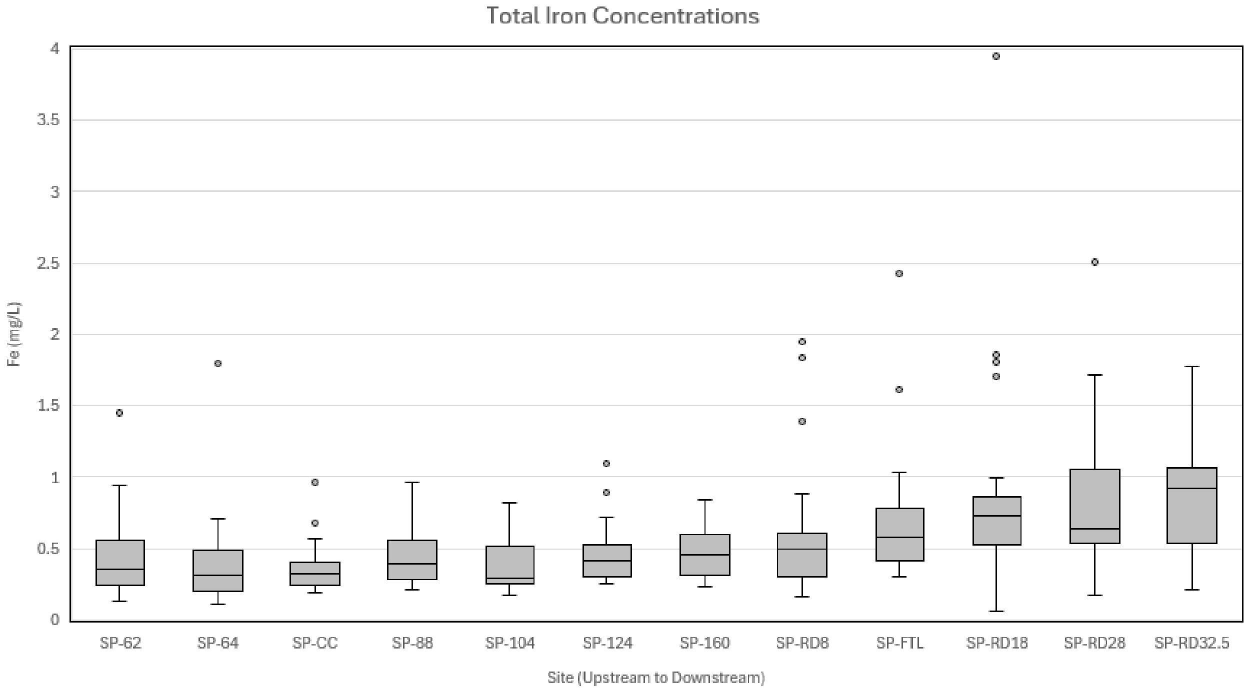


Figure 19. 2024 concentrations of total iron from 62nd Avenue to Weld County Road 32.5.

Manganese

Manganese is a mineral that naturally occurs in rocks and soil. In low concentrations, it produces objectionable stains on surfaces with which it comes in contact. Deposits also collect in pipelines and tap water may contain sediment and turbidity due to precipitated manganese. The EPA Secondary Drinking Water Regulations recommend a limit of 50 ug/L dissolved manganese due to potential staining, as well as taste and odor issues. However, human health is not a concern until concentrations are an order of magnitude higher. The Segment 15 water supply standard for dissolved manganese is 400 ug/L, while the Segment 1a standard is based on the secondary drinking water standard of 50 ug/L. The mean dissolved manganese concentrations in the Segment 1a sites were 49.9 ug/L in 2024 (Figure 20). Elevated manganese in both segments is likely the result of groundwater inputs, as dissolved manganese concentrations in monitoring wells are typically well above 400 ug/L. The range of dissolved manganese concentrations upstream of the RWHTF outfalls at SP-62 and SP-64 is greater than the downstream range, indicating that the effluent concentrations are more consistent than the upstream ambient concentrations.

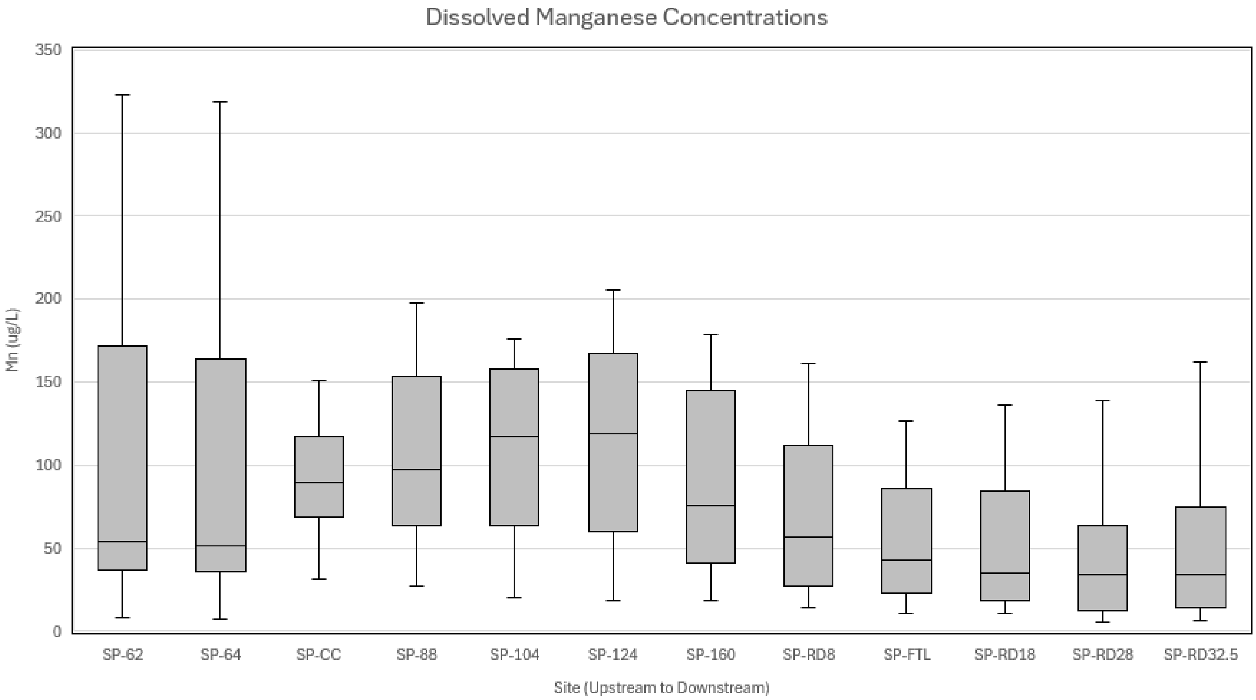


Figure 20. 2024 concentrations of dissolved manganese from 62nd Avenue to Weld County Road 32.5.

Selenium

Selenium is a naturally occurring element that is nutritionally essential but can be toxic to aquatic life where concentrations are elevated. It is toxic to cormorants and other birds that consume aquatic organisms containing excessive levels of selenium. Toxic levels of selenium in water bodies have mostly been related to irrigation of western soils that are naturally high in selenium. Risks stem from aquatic life eating food that is contaminated with selenium rather than from direct exposure to selenium in the water. Although selenium bioaccumulates, i.e., accumulates in tissues of aquatic organisms, it is not significantly biomagnified, unlike mercury or PCBs. The chronic aquatic life standard for Segments 15 and 1a is 4.6 ug/L. There was a temporary modification for the chronic standard in Segment 1a (6.9 ug/L) that expired at the end of 2015. Data from 2024 sampling indicate that all sites are below the 4.6 ug/L standard (Figure 21).

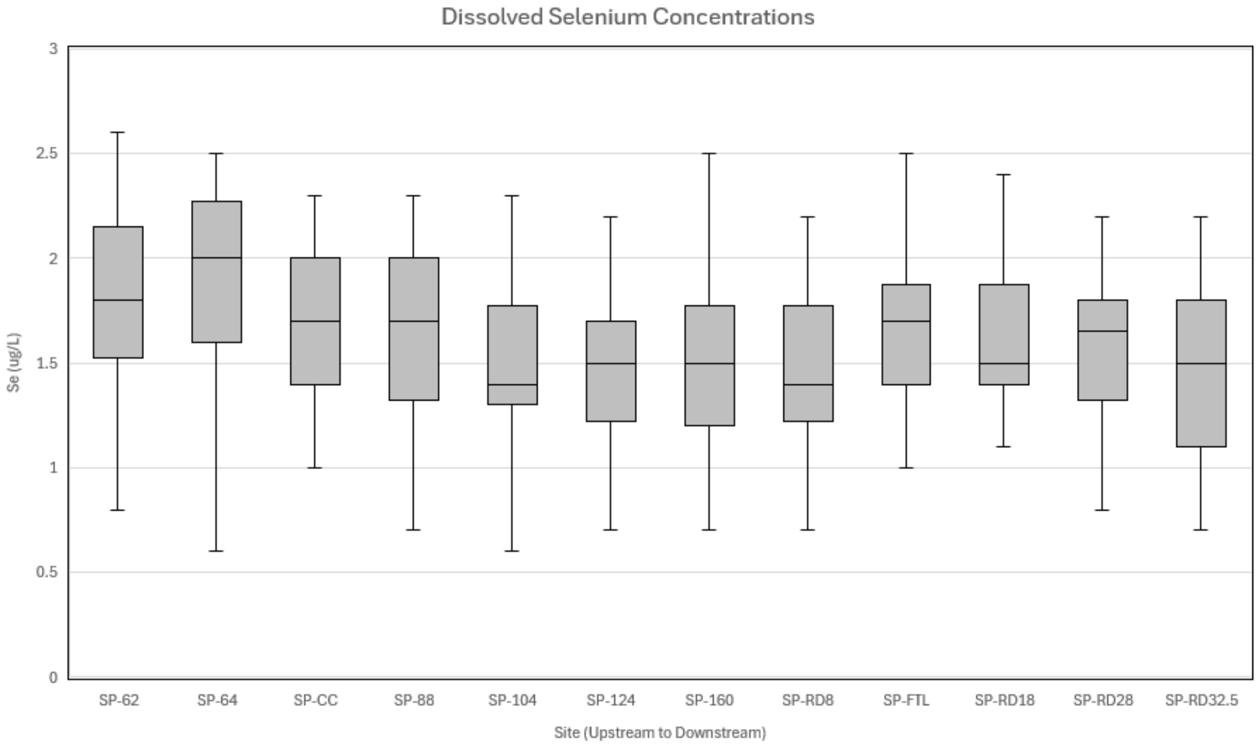


Figure 21. 2024 concentrations of dissolved selenium from 62nd Avenue to Weld County Road 32.5.

Biology

Fish

Metro has been collecting fish data since 1986, using traditional electroshocking techniques. The collection of fisheries data provides the backbone of aquatic life assessment along the South Platte River. Since 1986, 34 species of fish have been found in Segments 15 and 1a. On average, 17 fish species are collected per year primarily because catch efficiencies on large river systems are low and some species are more likely to be missed than others. In 2024, 19 fish species were found during eleven sampling events (Table 13). Of the nineteen species, ten were native to the South Platte Basin, and nine were introduced species. Most of the species not documented in 2024 are either rare, non-native species, or are typically residents of tributaries. According to historical records, 23 species are native to the South Platte basin, indicating that resident populations were in place before settlers arrived in the West. A few of these species, such as plains topminnow and plains killifish are commonly found in warmer environments and periodically found in Segment 1a. Others have become rare in the basin and are unlikely to be found again in Segment 15 or 1a, such as the suckermouth minnow and northern redbelly dace.

Most of the fish species native to the South Platte basin are considered to be tolerant because of the geomorphology of the river itself. As the South Platte River flows out onto the eastern plains, the river gradually subdivides into a braided series of parallel, sandy channels. The channels are often shallow and warm because of a lack of canopy and riparian vegetation. Many species needed to adapt to drought, flooding, high turbidity, and changing habitat conditions (Woodling 1985). Species considered to be tolerant include the fathead minnow, green sunfish, creek chub, and black bullhead (Pflieger 1997).

Two of the nine introduced species are considered invasive, the common carp and western mosquitofish. The invasive nature of these fish species indicates that they have a negative impact on native fish populations and habitat in the river. Western mosquitofish are prolific, reproducing three to four times in a single summer and can compete with native populations for food resources (Pflieger 1997). In fact, their presence has been linked to the decline of native warm water fish species including the plains topminnow (Pasbrig et al., 2012) and plains killifish (Schumann et al., 2015). Common carp were introduced in the 1800s as a source of food and have since become one of the most widespread species across the United States. Carp are voracious eaters, consuming both plant and animal material and often cause habitat deterioration, increase turbidity, and destroy aquatic vegetation in the process (Pflieger 1997). Carp are also one of the largest fish species in the South Platte River, often reaching lengths of 25 inches (Pflieger 1997). The remaining six introduced species are game fish that wash out of reservoirs stocked for fishing.

Scientific Name	**Common Name**	**Distribution**	**Total #**	**Relative Abundance (%)**
Pimephales promelas	Fathead Minnow	Native	3822	43.2
Catostomus commersoni	White Sucker	Native	1725	19.5
Notropis stramineus	Sand Shiner	Native	1405	15.9
Rhinichthys cataractae	Longnose Dace	Native	1005	11.3
Catostomus catostomus	Longnose Sucker	Native	322	3.6
Semotilus atromaculatus	Creek Chub	Native	226	2.6
Gambusia affinis	Western Mosquitofish	Introduced	99	1.1
Lepomis cyanellus	Green Sunfish	Native	66	0.7
Cyprinus carpio	Common Carp	Introduced	56	0.6
Micropterus salmoides	Largemouth Bass	Introduced	40	0.5
Etheostoma exile	Iowa Darter	Native	36	0.4
Etheostoma nigrum	Johnny Darter	Native	30	0.3
Micropterus dolomieui	Smallmouth Bass	Introduced	10	0.1
Pomoxis nigromaculatus	Black Crappie	Introduced	4	<0.1
Lepomis macrochirus	Bluegill	Introduced	3	<0.1
Culaea inconstans	Brook Stickleback	Native	2	<0.1
Oncorhynchus mykiss	Rainbow Trout	Introduced	2	<0.1
Pomoxis annularis	White Crappie	Introduced	2	<0.1
Sander vitreus	Walleye	Introduced	2	<0.1

Table 13. Fish species found in 2024.

Like previous years, fathead minnows, longnose dace, sand shiners and white suckers were the dominant native species found in the South Platte River in 2024. The most abundant fish in 2024 was the fathead minnow, a relatively tolerant species found at every sampling location, including 1,396 individuals at the upstream of Clear Creek monitoring location. The next most abundant fish was the white sucker, including 463 individuals observed at the Phase III instream habitat improvement site at 144th Avenue. The third most abundant species was the sand shiner, a species commonly found in shallow, slow-moving water along sandy margins. There were 728 individual sand shiners collected at the Phase I instream habitat improvement site upstream of 120th Avenue. The next most abundant fish was the longnose dace. These native minnows preferred microhabitats are narrow riffles and they have been observed in high numbers in constructed riffles designed as part of Metro's instream habitat improvement projects. In 2024, the highest numbers of longnose dace (797 individuals) were observed in the constructed riffle at the Phase III Habitat Improvement site at 144th Avenue.

In 2006, Metro and CDM conducted a comprehensive study to assess alternatives and develop recommendations on methods to protect and improve aquatic life and habitat throughout Segment 15 (CDM 2006). After comprehensive fish, habitat, and flow surveys, the report detailed recommendations for habitat improvements along different sections of river adding either backwater habitat, riffle and pool habitats, or increasing protective cover. Phases I and II of the habitat improvement were constructed upstream of 120th Avenue and included constructed riffles, a backwater wetland pond, large woody debris installations, a spur dike field, rock snags, lunker structures, boulder clusters and bank protection. The Phase III habitat improvement project was completed in 2013 and is located at 144th Avenue. Features for this phase included constructed riffles, bioengineered bank stabilization, a secondary channel and cottonwood rootwad installations along the streambank. 2024 sampling included the tenth year of post-construction sampling for this Phase III habitat improvement site. Fish surveys show a significant increase in the abundance of native fish, as well as an increase in the total number of fish species observed (Figure 24). In 2013, only 24 individual fish representing five species were observed, compared to 1,417 fish and eleven different species in 2024. The most recent Phase IV habitat improvement project was constructed in 2018 downstream of 88th Avenue and included constructed riffles, boulder clusters, a large secondary channel, backwater habitat and anchored large woody debris installations. All phases of the habitat improvement projects have been successful in creating sorely needed microhabitat for the native fish of the South Platte River. Metro staff will continue to survey all of these habitat sites in future years to document further evidence of improvements.

Overall, there are no significant longitudinal patterns in the total number of fish (Figure 22), indicating that site-specific habitat availability is likely still a limiting factor. In fact, in *The South Platte River Segment 15 Aquatic Life/Habitat Assessment* (PAR 991) conducted by CDM, a Limiting Factors Analysis was conducted which determined that of all chemical, biological, and physical impacts on fish species within the Segment, habitat limitation was the most critical issue. There is also year-to-year variability in terms of fish caught. Analyzing the full length of Metro's fish count dataset (1986-2024) are no long-term trends in the species richness (number of species observed) for native species. However, there has been a statistically significant increase (Mann Kendall Test, $p < 0.01$) in the number of non-native species observed during this time period).

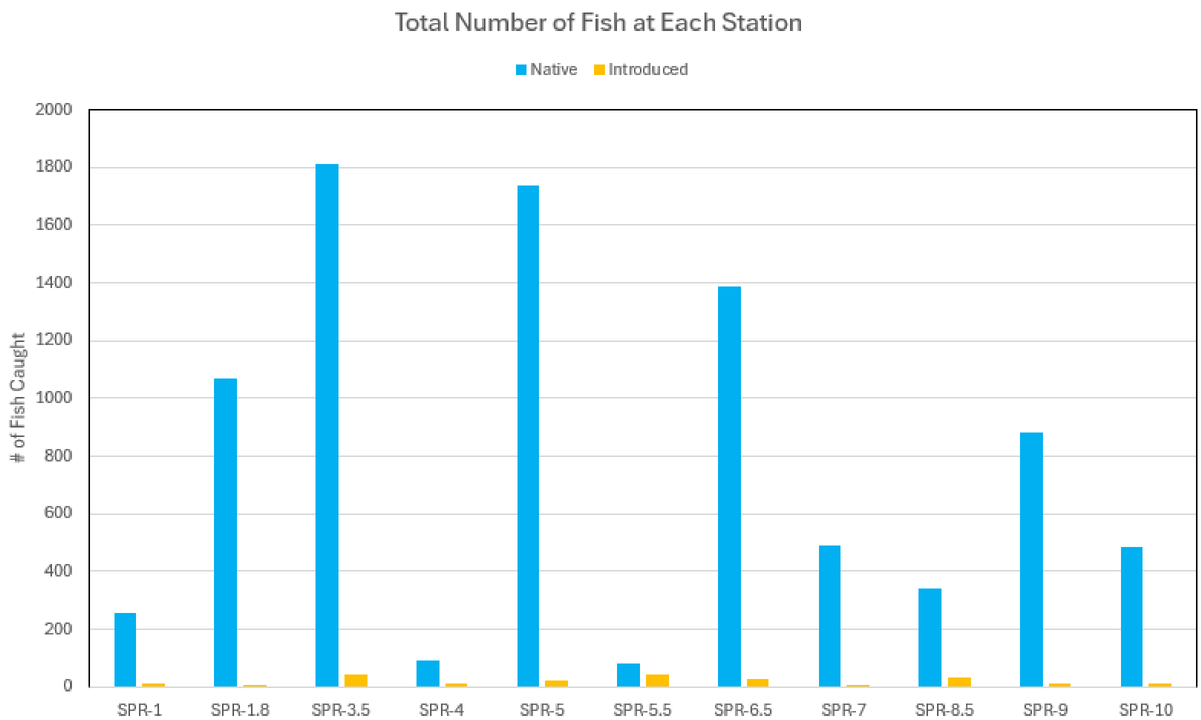


Figure 22. Total number of fish found at each sampling location in 2024 (includes all species).

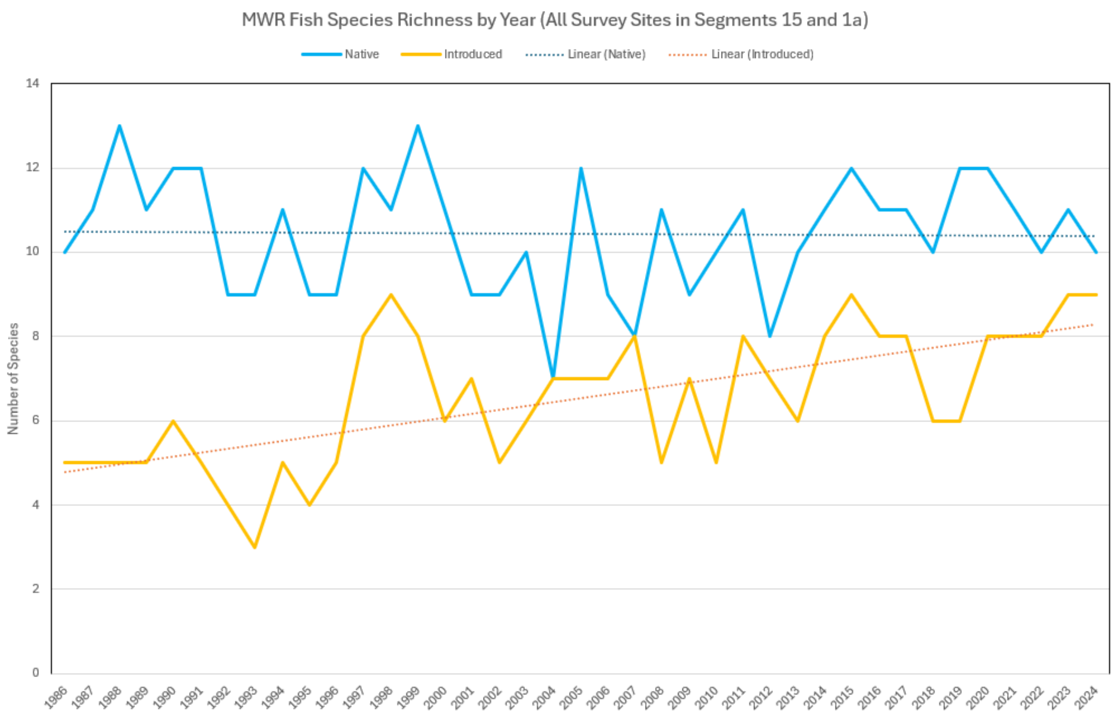


Figure 23. Species richness by year for all MWRD survey sites (1986-2024).

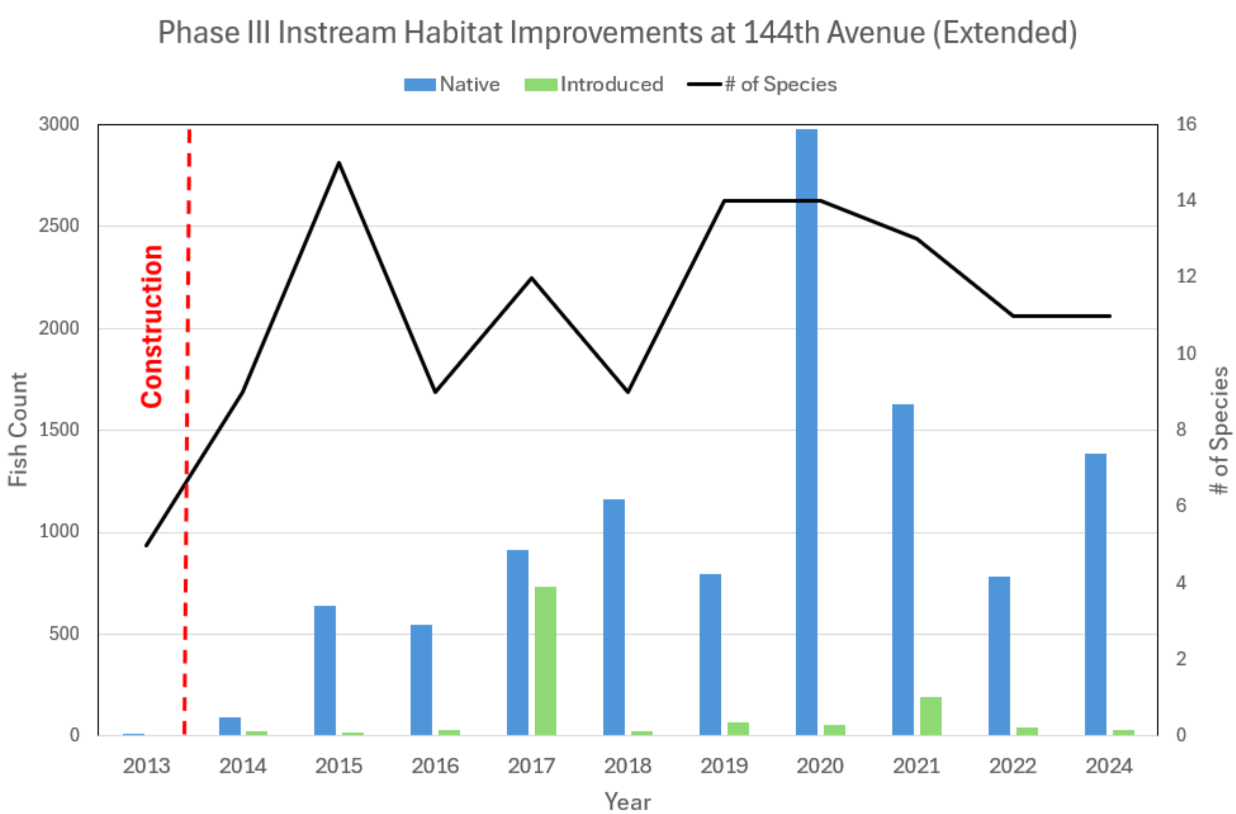


Figure 24. Summary of fish count data at Phase III Instream Habitat site before and after construction.

Macroinvertebrates

In 2024, eight macroinvertebrate samples were collected along the South Platte River. Most samples were collected at Metro's fish sampling locations, but a few additional samples were taken at bi-weekly stream sampling sites. For all eight samples, both a kick net (benthic organisms in a riffle) and dip net (multi-habitat) sample were taken.

Macroinvertebrate data are used in Colorado as the primary indicator of aquatic life health in streams and rivers. The Colorado Water Quality Control Division uses a Multi-Metric Index (MMI) to evaluate a given stream using data collected with a kick net. For plains streams, the index is based on the percent EPT (Ephemeroptera, Plecoptera, Trichoptera) excluding *Baetidae* of all individuals in the sample (caddisflies, mayflies and stoneflies), the total number of taxa in the sample, the total number of intolerant taxa (like mayflies and dragonflies), the number of facultative predator taxa, the percent facultative scrapers, non-insect taxa as a percentage of total taxa and the number of sprawler taxa in the sample (a classification based on habit). Each of these categories is associated with species characteristics that are defined by current biological research and categorization. Any score above 42 indicates attainment and any score below 29 indicates impairment.

Currently, the MMI is not applied to large rivers including the South Platte River because, according to the CDPHE "Aquatic Life Use Attainment" policy document, large rivers have different populations and different habitat conditions (CDPHE, 2017). Calculating the scores for the South Platte River can provide insight into current aquatic condition in the river. In 2024, scores in Segments 15 and 1a have ranged from 18.4 to 49.7, with an average of 32.2 (Figure 25). The three highest MMI scores of all the 2024 samples were observed at 88th Avenue (39.0), Fort Lupton (39.0) and at Weld County Road 18 (49.7). The lowest MMI score (18.4) was from the biological monitoring site upstream of the Clear Creek confluence, approximately 1.2 miles downstream of the RWHTF outfalls. There were no significant longitudinal patterns in the MMI scores in 2024.

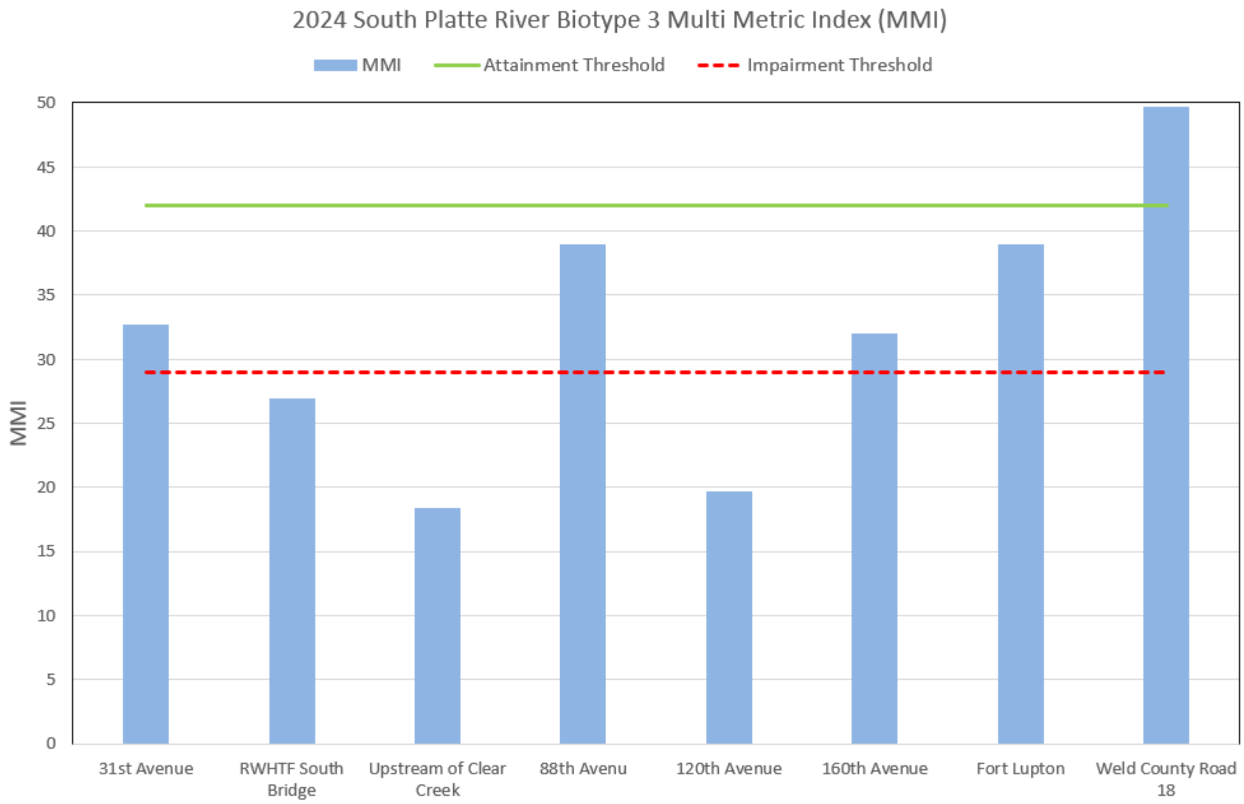


Figure 25. 2024 Multi Metric Index scores at eight monitoring sites.

Two auxiliary metrics in Policy 10-1 are relevant to macroinvertebrate assessment: the Hilsenhoff Biotic Index (HBI) and the Shannon Diversity Index (SDI). The HBI is a widely used indicator of organic pollution. Higher values of the index indicate a predominance of tolerant organisms (i.e., the sensitive species may not be present). In 2024, all macroinvertebrate samples except for the upstream of Clear Creek site had an HBI of less than 7.6 (average = 6.0), the auxiliary metric threshold for attainment. In general, following completion of the South Secondary Complex Improvements at the RWHTF in 2014 that led to drastically lower instream ammonia concentrations, the HBI scores have been lower downstream of the outfalls (Figure 26). The SDI characterizes species richness (number of species) and evenness (relative abundance) of the species present, with a higher value indicating better richness and evenness. In 2024, the average SDI score for all samples was 2.8, above the attainment threshold of 2.4. One site had an SDI scores below the 2.4 attainment threshold, the location upstream of the Clear Creek confluence (SDI = 2.2). As with the HBI, the SDI scores have improved at the macroinvertebrate monitoring locations downstream of the RWHTF outfalls since 2014 (Figure 27). Metro staff will continue to monitor these biological communities in 2024 and hopes to learn more about the complicated stressor-biological health relationship.

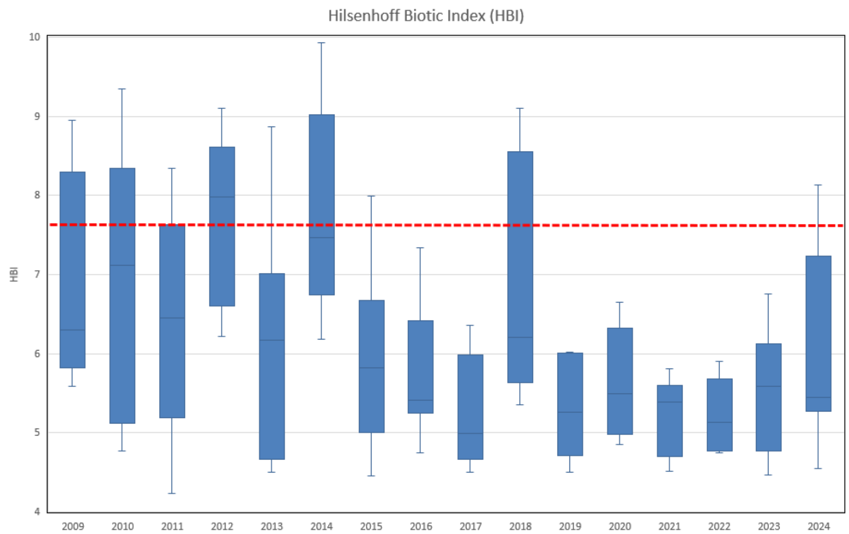


Figure 26. Box plot of HBI scores at all macroinvertebrate sites by year.

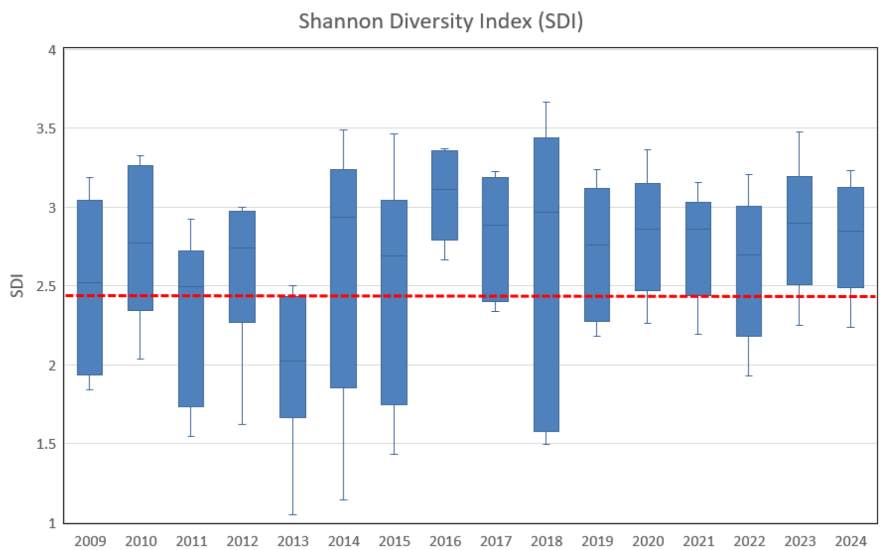


Figure 27. Box plot of SDI scores at all macroinvertebrate sites by year.

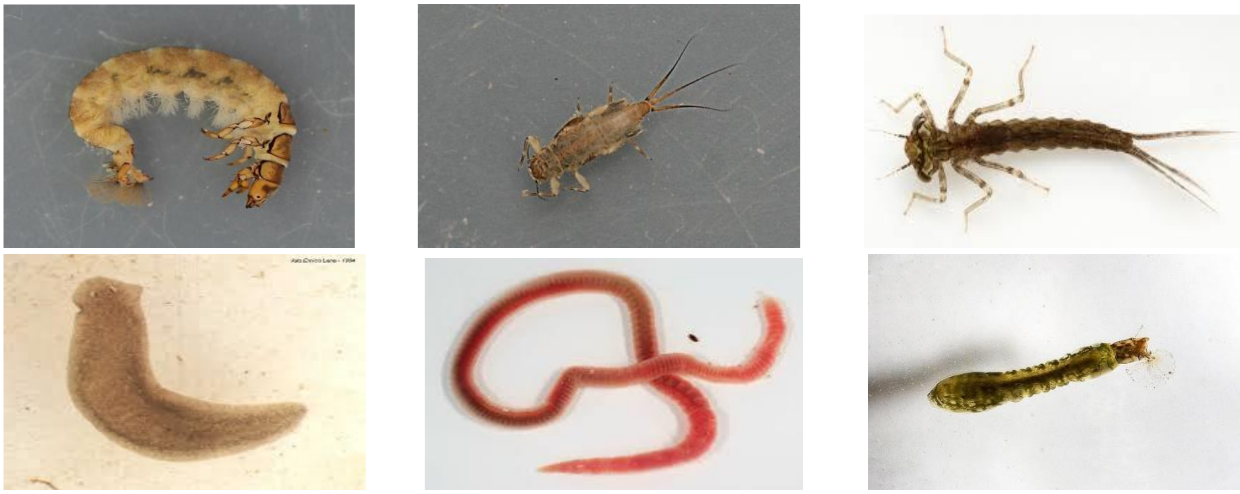


Figure 28. Examples of macroinvertebrates found in South Platte River. Upper left to right: Hydropsyche sp. (EPT taxon), Tricorythodes explicatus (EPT and sprawler taxon) and Coenagrionidae (predator taxon) Lower left to right: Dugesia sp. (tolerant taxon), Tubificidae sp. (tolerant taxon) and Similium sp. (tolerant taxon).

Special Studies

Temperature

Long-term temperature series data are routinely collected by Water Quality Division staff for the South Platte River at 11 mainstem locations, 3 tributaries, the North and South Final Effluents of the RWHTF and the NTP effluent as it leaves Pond #3. Wherever possible, the data logging thermistors are co-located with the bi-weekly stream sampling sites. This temperature information has several uses. Seasonal trends in temperature of the South Platte River below the effluent discharge, as well as the daily cycling of temperature, are important to the calculation of ammonia limits. In 2009, the Water Quality Control Commission adopted temperature regulations for cold and warm streams throughout the state. Long-term series data will allow Metro staff to evaluate seasonal and spatial variability of temperature in the South Platte River to evaluate the compliance status of the South Platte River below Metro's point of discharge as judged by the applicable aquatic life temperature standards. In the past, temperature compliance for the South Platte River below the outfalls has been assessed by use of the bi-weekly monitoring data for temperature.

The 2024 temperature data demonstrate that both the North and South Final Effluents are consistently above the wintertime stream chronic standard. While the upstream river site (64th Avenue) was in attainment throughout the winter, the monitoring sites immediately downstream of the RWHTF exceeded the stream standard (Figures 29). For the chronic standard, there were wintertime exceedances downstream to 124th Avenue, approximately eleven river miles downstream of the RWHTF outfalls. In many cases, these exceedances occurred during the abrupt change to the winter standard (December through February). While the river exhibits a gradual warming and cooling, the standard itself does not reflect this seasonal pattern. The Colorado Water Quality Control Division is in the process of revising how they assess temperature exceedances, and these proposals may provide some regulatory relief during the shoulder seasons. However, even with these proposed changes, the South Platte River will likely still exceed the chronic wintertime standard between the RWHTF outfalls and 88th Avenue (3.6 miles downstream). The river was in full attainment at the 160th Avenue monitoring site during the winter months. In 2024, there were not any summer month exceedances of the chronic temperature standard in the South Platte River mainstem sites. In previous years, there were occasional exceedances in the summer months due to high air temperatures and low flow conditions.

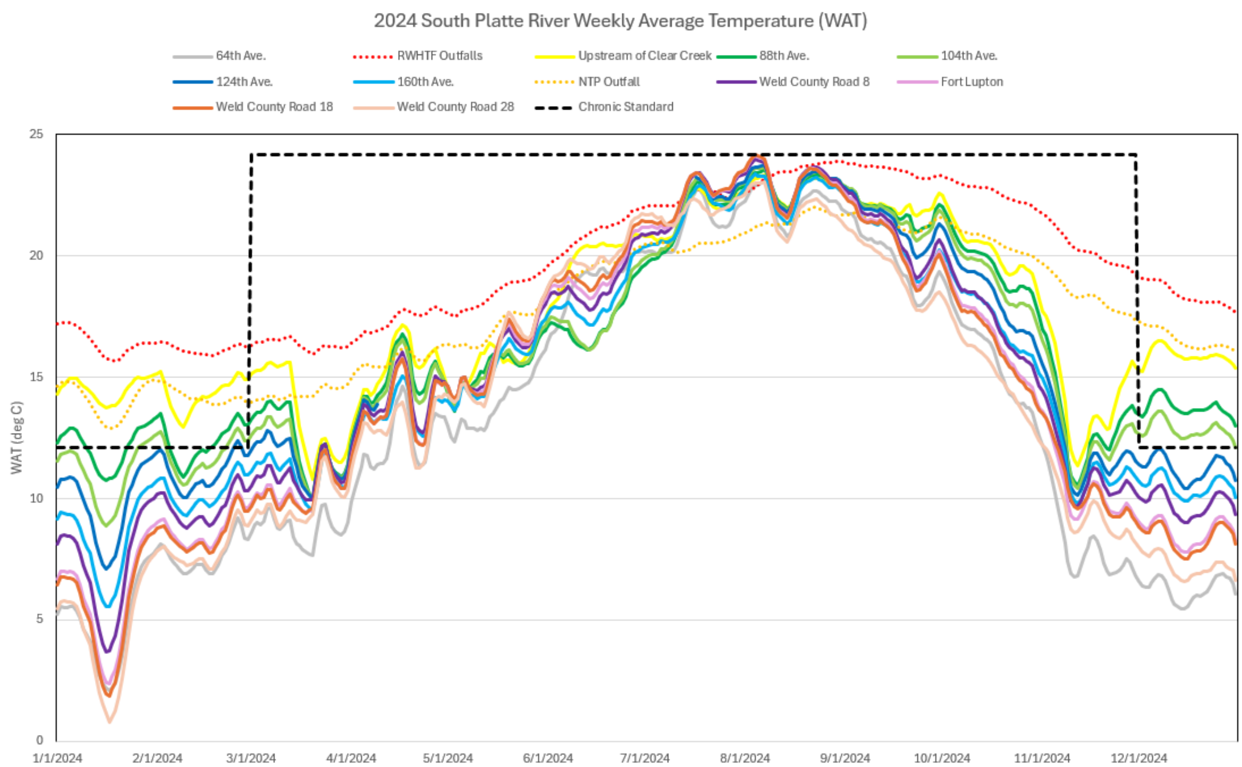


Figure 29. Rolling weekly average temperature calculations for RWHTF effluents and South Platte River mainstem temperature monitoring locations.

30-Hour Studies

Periodically, Water Quality staff is asked to sample the river repeatedly over a 30-hour time frame to provide data for calibration of Metro's South Platte Water Quality Model. This data is used to assess diurnal changes in water quality, especially in relation to biological processes including photosynthesis and respiration. Metro staff conducted one of these 30-hour studies in December 2024. Data from 2024 is particularly important for the modeling efforts as it provides information of current conditions since full-scale biological phosphorus removal has been implemented. The model relies on monthly calibration and staff hopes to collect data for the remaining uncharacterized months in 2026.

Longitudinal Nutrient Study

In 2024, nine sites were sampled monthly to determine nutrient concentrations from Segment 1a to the Colorado-Nebraska border. In past years, concentrations of both TN and TP declined as the river approached the border, with the sharpest decrease occurring between County Road 8 and Milliken. However, this pattern has changed since 2015 and the sharp decrease in TN at the lower portion of Segment 1a was not observed in 2024 (Figures 30 and 31). Both the TN and TP concentrations were lower at all sites in 2015-2024 compared to previous years, likely due to the nutrient reductions in the RWHTF effluent. This is an encouraging finding, demonstrating that the treatment upgrades are resulting in lower nutrient concentrations further downstream on the river than previously seen.

Concentrations of TN were highest at the Kersey sampling site (mean = 5.0 mg/L; Figure 30). For reference purposes, the interim numeric value for TN that would apply to the South Platte River in 2027 is 2.01 mg/L. Preliminary analysis indicates that all locations currently sampled could be impaired.

Prior to full scale biological phosphorus removal at the RWHTF in January 2021, TP concentrations were elevated at Weld County Road 8 and declined consistently as the river flowed to the Colorado-Nebraska border. However, the 2024 border nutrient data reflects the significant reduction of phosphorus concentrations in Segment 15 and 1a. In fact, the highest annual average TP concentration in 2024 was at Kersey. The averages ranged from 0.15 mg/L at Julesburg to 0.53 mg/L at Kersey (Figure 31). For reference purposes, the interim numeric value for TP that would apply to the South Platte River in 2027 is 0.17 mg/L. As with TN, preliminary analysis indicates that all locations currently sampled along the South Platte River could be impaired for TP.

Sampling of nutrient concentrations to the Colorado-Nebraska border is planned to continue until nutrient regulations are fully implemented to help establish baseline conditions and to document any improvement in river conditions due to treatment upgrades at the RWHTF.

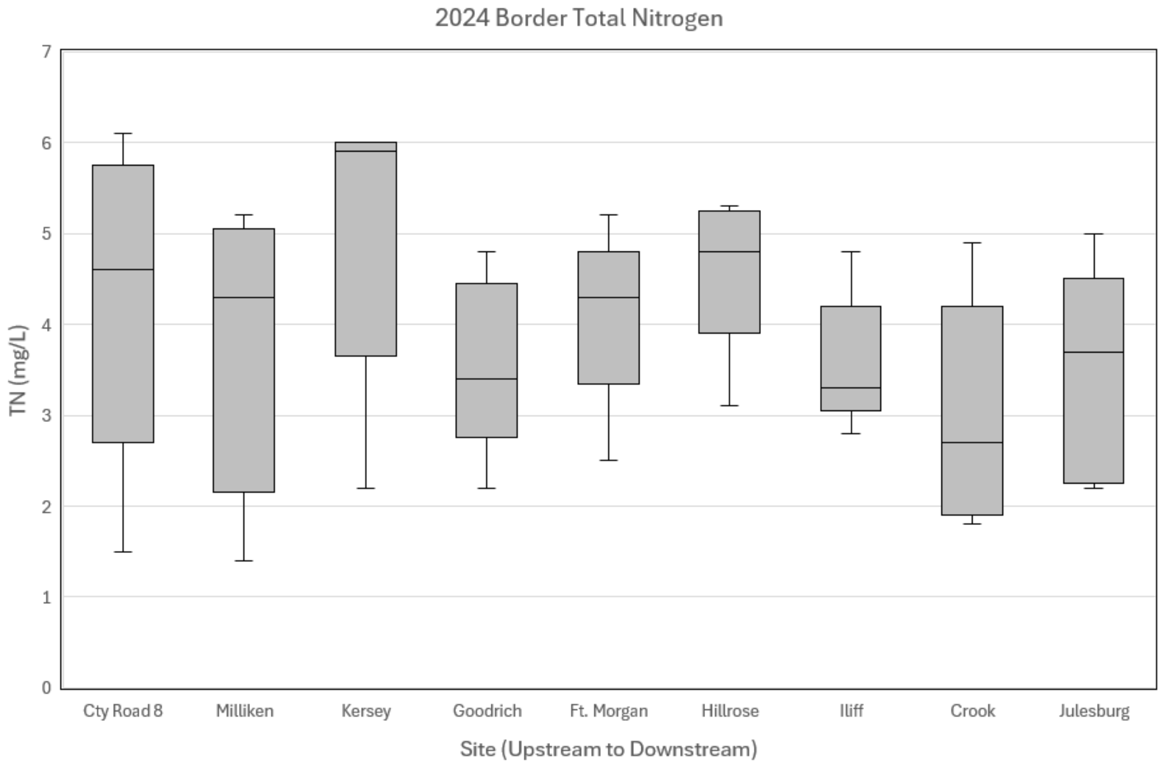


Figure 30. Box plot of TN concentrations from Weld County to the State Line.

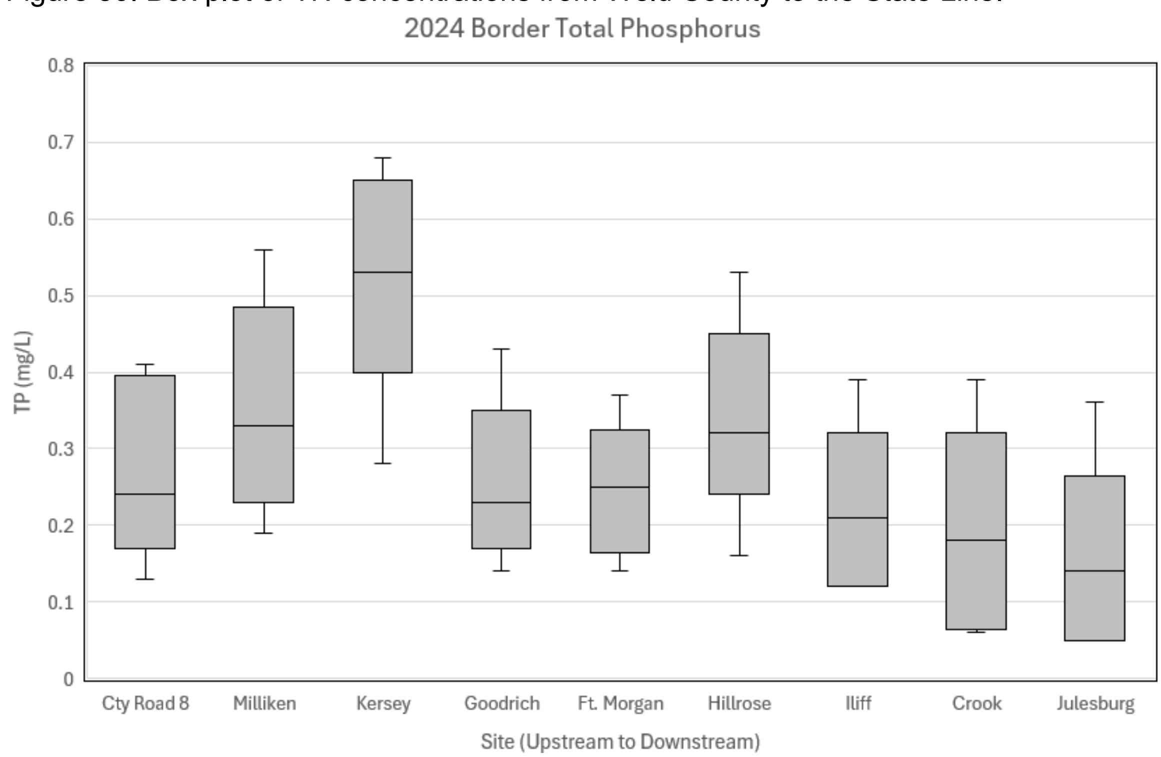


Figure 31. Box plot of TP concentrations from Weld County to the State Line.

Reservoirs Program

Barr and Milton have been routinely monitored by Metro water quality scientists since June of 2002. The five-year period between 2003 and 2007 is considered the pre-TMDL phase and the 2024 water quality data will be compared to this 5-yr period to show how water quality has changed over the years. Climate and flow patterns were average across the historic 5-yr period, however, reservoir management included pumping of Metro's effluent to Barr via the Burlington Ditch. The 2013 Phased TMDL for pH and DO requires a 92% annual load reduction for internal and external sources of phosphorus. Today, an 84% reduction has been achieved from point and non-point sources across the watershed.

Water Quantity

Reservoir management, water rights, snowpack, and regional weather patterns determine when and how much water enters both reservoirs. In turn, quantity and timing have a major influence on water quality year-round. Wet years allow for longer retention times, while droughts cause major drawdowns. Deeper water columns are an impetus for algal blooms as deeper water allows for stronger thermal stratification that leads to anoxic bottom water and triggers internal loading of phosphorus. Timely inputs during the summer can also trigger algal blooms.

Colorado's water year (WY) starts November 1st and ends October 31st. Base flows from the South Platte River typically refill both reservoirs from November through February. Barr typically refills before Milton. Spring rains and snow runoff keep the reservoirs full until the irrigation season begins in June. Both reservoirs filled in 2024 due to a wet 2023. Both reservoirs started off the 2024 WY above average for water depth, with both reservoirs remaining above average until mid-summer. Barr underwent dam repairs on both outlets in the fall which required a major drawdown to occur between October and November. Full pool lasted a total of 151 days in Barr. Milton's water depth and management for 2024 resembled an average year (Figure 33).

Metro effluent reaches Barr via the Beebe Pipeline, a 36-inch pipeline (rated at 50 cfs) that diverts from the South Platte River just downstream of the 124th Avenue crossing (Figure 32). This pipe, owned and operated by United Water, delivers river water necessary to meet water rights in Barr. River water is pumped through the pipeline directly from the S. Platte River or from two storage reservoirs. Approximately 5,600 acre-feet of water was diverted in 2024. Historically, Metro's treated effluent was discharged into the Burlington Ditch and delivered to Barr via Burlington pumps. The pipeline, owned and operated by Denver Water and in management agreement with FRICO and City of Thornton, has not been activated since February 10, 2012. The September 2013 flood caused major erosion on the west bank of Sand Creek which washed out the pipeline and permanently disabled the delivery of treated effluent via the Burlington Ditch.

The lack of effluent pumping to the Burlington Ditch has not prevented the reservoir from being filled. During the period of 2014 to 2024, the Burlington Head Gate swept the South Platte River, on average, 36% of the time. This equates to 133 days per year that the South Platte River is completely diverted down the Burlington Ditch. Barr has reached full pool for the past 12 years. In 2024, a total of 55,300 acre-feet of water was diverted into Barr. Of that, 49,700 acre-feet came

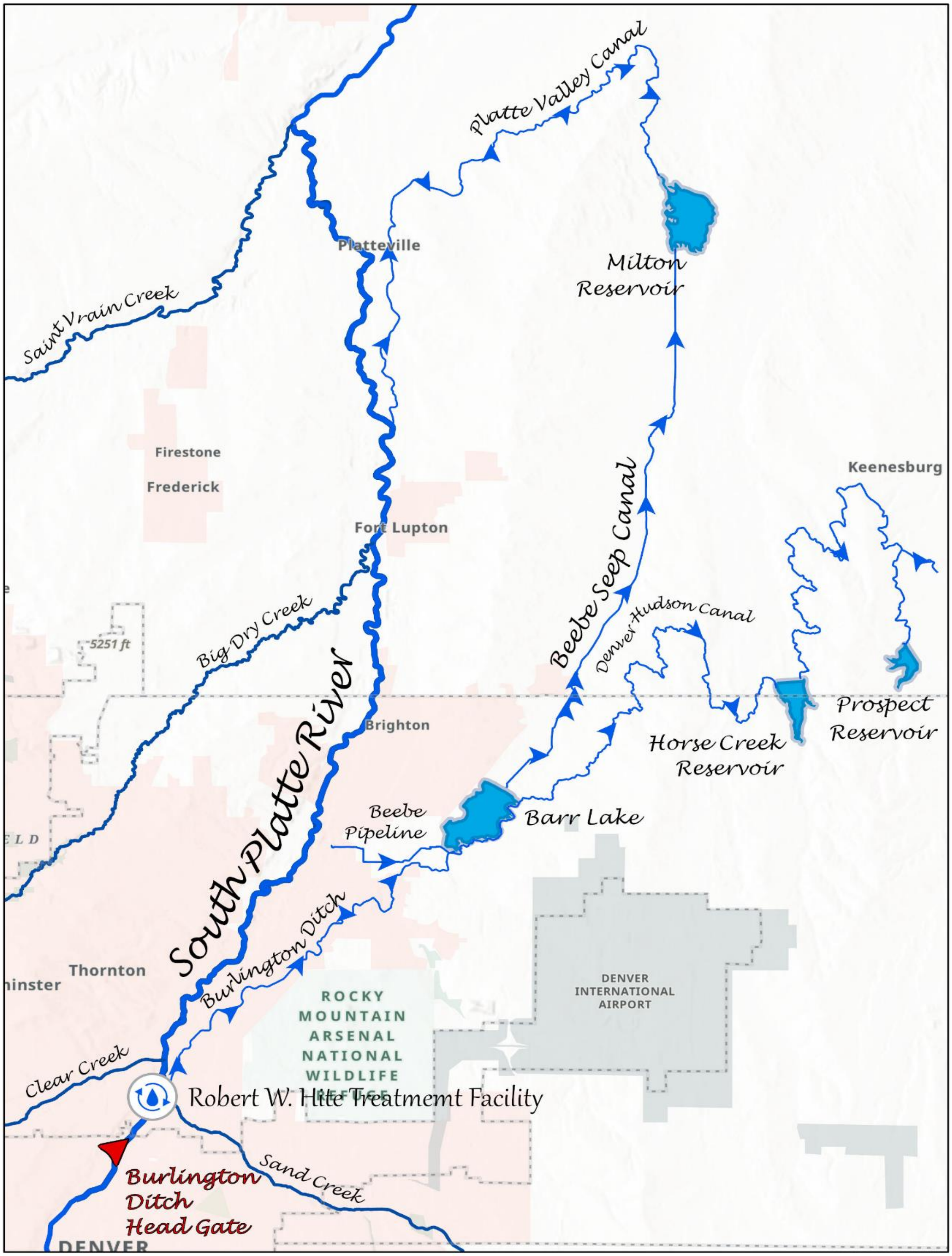


Figure 32. Overview of South Platte diversions and off-channel reservoir inputs

from the South Platte River via the Burlington Head Gate. The Burlington Head Gate swept the South Platte River 19% of the year (70 days) and was diverting 92.6 % of the time (339 days). Of the 242,700 acre-feet of water that was in the South Platte River at the Burlington Head Gate, 49% was diverted to the Burlington Ditch past the BURCANCO flow gauge. Not all the BURCANCO flows go to Barr - 42% of ditch flows were delivered to Barr, while the remaining 58% went to the Denver-Hudson Canal delivering water to Horse Creek Reservoir and Prospect Reservoir, or lost to groundwater and evaporation.

Milton reached full pool in February. For the 2024 WY, a total of 43,400 acre-feet of water entered Milton, with 37,400 acre-feet sourced from the Platte Valley Canal diverting off the South Platte River and 6,000 acre-feet sourced from the Beebe Draw connecting Barr and Milton. This was a 6:1 split between the two inlets, respectively. The Beebe Draw flowed 100% of the time while the Platte Valley Canal flowed 72% of the time. Of the 352,500 acre-feet of water that was in the South Platte River at the Evans #2 diversion, 22% was diverted to Evans #2 ditch. Of the 78,000 acre-feet diverted, 48% or 37,400 acre-feet entered Milton via the Platte Valley Canal. Milton's 2024 flow management was very similar to 2023.

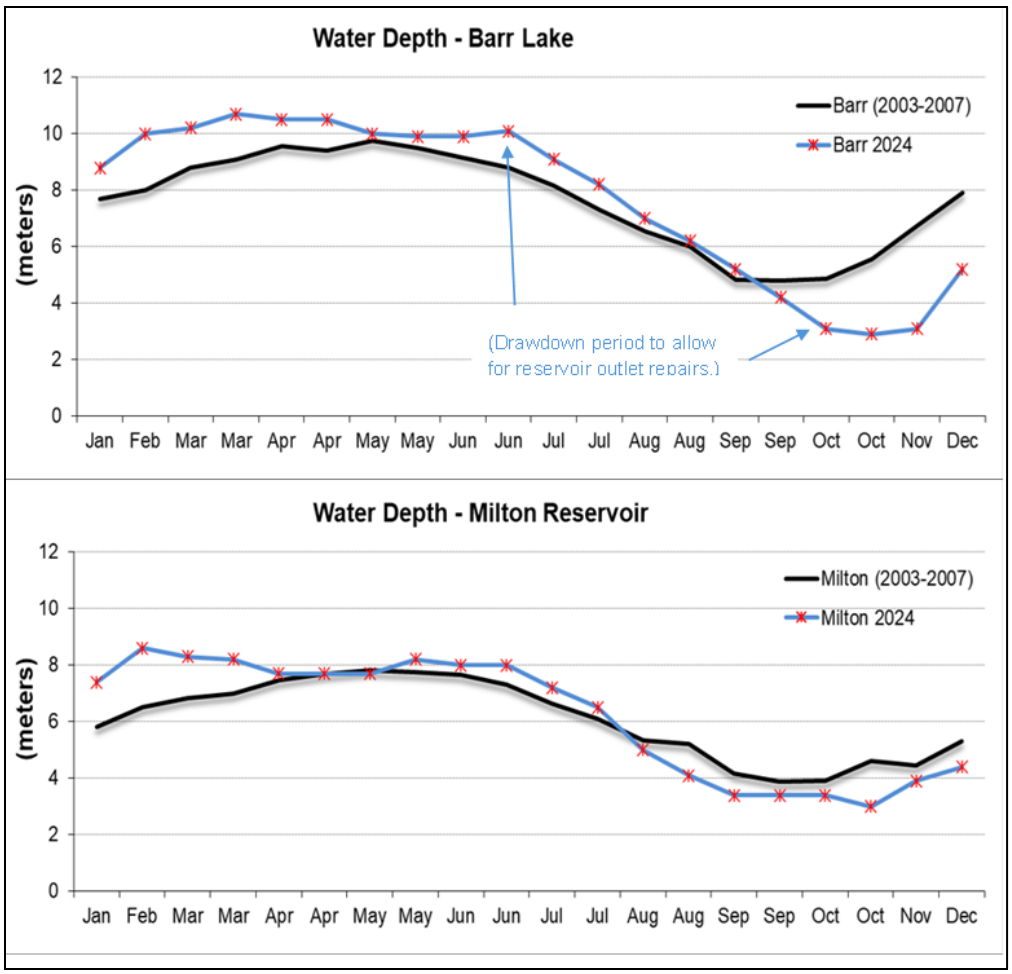


Figure 32. Seasonal variability of water depth in 2024

Water Quality

Nutrients (nitrogen and phosphorus), pH, chlorophyll-a (chl-a), water clarity, alkalinity, temperature, and dissolved oxygen (DO) are key parameters for the reservoir monitoring program. Eutrophication occurs when nutrients accumulate, triggering algal growth and a series of compounding water quality responses. Both reservoirs have experienced cultural eutrophication (human caused) for the past 135+ years and have been listed on the 303(d) list since 2002 as impaired for pH, DO, and ammonia. Barr was removed from the list for ammonia in 2015.

Phosphorus (TP and SRP)

Total phosphorus (TP) is the summation of all phosphorus forms: particulate vs. soluble, organic vs. inorganic, reactive vs. non-reactive, and biologically available vs. non-available. TP is used as an endpoint for the phased pH/DO TMDL. Soluble reactive phosphorus (SRP) is the phosphorus that is readily available in dissolved inorganic form, mainly as orthophosphate. SRP determines how much phosphorus in the water is readily available for primary productivity. When TP is mostly SRP, this can help with source identification. Wastewater and internal loading are two typical sources of SRP. Alternatively, phosphorus coming from stormwater runoff is typically in particulate and insoluble form.

In 2024, 20 phosphorus samples were collected from both the epilimnion (top mixing layer) and the hypolimnion (bottom 3 meters) at both reservoirs. The annual average TP_{epi} for Barr was 197 µg/L (compared to the 2002 – 2007 average of 670 µg/L), and 113 µg/L (compared to the 2002-2007 average of 567 µg/L) for Milton. Both annual averages are greater than the numeric standard value of 47 µg/L for warm-water lakes. The annual average SRP_{epi} for Barr was 72 µg/L and 18 µg/L for Milton. The summer season (July 1 – September 30) TP_{epi} average for Barr was 222 µg/L and 112 µg/L for Milton. The summer season SRP_{epi} average was 88 µg/L for Barr and 0 µg/L for Milton. Nutrient concentrations for the summer season are the most important because length of day and warm water temperatures promote algal growth and impact the peak season for recreational use.

Despite being lower than the 2003-2007 average, both reservoirs still had relatively high levels of phosphorus. Two important highlights with phosphorus are: 1) SRP_{epi} is noticeably less thanTP_{epi} and there were 36 SRP values below 100 µg/L. 2) TP_{hypo} values that are greater than the TP_{epi} values coincide when there are anoxic conditions. As soon as DO goes below 1.0 mg/L, internal loading occurs (Table 14). Lower phosphorus levels were observed for the 11th year in a row when compared to the 2003-2007 averages.

Table 14: 2024 Barr and Milton epilimnion phosphorus data (µg/L)

Month	Barr Lake (µg/L)			Milton Reservoir (µg/L)		
	TP_{epi}	TP_{hypo}	SRP_{epi}	TP_{epi}	TP_{hypo}	SRP_{epi}
Jan	160	***200***	10	130	110	<10
Feb	220	***360***	30	180	180	30
Mar	200	140	50	210	120	10
Mar	190	160	20	150	100	<10
Apr	120	140	70	80	80	<10
Apr	160	170	130	90	90	50
May	130	130	90	70	***120***	20
May	130	***270***	90	70	80	40
Jun	130	***270***	80	40	60	<10
Jun	170	***270***	140	70	70	20
Jul	**200**	***240***	170	**70**	60	<10
Jul	**320**	190	110	**60**	80	<10
Aug	**240**	180	90	**110**	150	<10
Aug	**210**	160	70	**180**	110	<10
Sep	**200**	150	70	**180**	-	<10
Sep	**160**	140	20	**140**	-	<10
Oct	240	-	<10	150	-	<10
Oct	240	-	20	120	-	10
Nov	320	-	50	120	-	50
Dec	190	<10	<10	100	110	<10

1. **Red bold** values indicate exceedances of the standard. 2. ***Blue bold italic*** values indicate internal phosphorus loading caused by low oxygen or unusual flow patterns.

The seasonal variability of TP is consistent year-to-year due to the annual flow regime. The increase in TP between November and February is based on the South Platte River TP concentrations and the quantity of water that is diverted to refill each reservoir. The winter recharge of phosphorus supports a community of diatoms, greens, and blue-green algae in the spring that help consume some phosphorus. The baseline TP_{epi} concentration going into the summer season was noticeably less for Milton than for Barr. Milton had the lowest phosphorus concentrations since monitoring began in 2002. There was a noticeable increase in phosphorus driven mainly by internal loading in July and late August-September for Barr and Milton, respectively. For the first time, the 2024 summertime bump in TP was as high or greater than the TP increase during the winter refill (Figure 34). Barr had a spike in TP in late July. This coincided with a large cyanobacteria bloom. SRP dropped at the same time, indicating there was biological uptake of phosphorus by algal biomass. For the remainder of the year, biologically available SRP declined due to ongoing primary productivity by algal biomass.

Internal loading in Barr occurred during late spring to early summer. The anoxic period occurred from 05/26/24 to approximately 07/05/24 with several additional days extending into August and September. Using 30-minute continuous DO data from an anchored In-Situ probe, there were 65 days of anoxia (i.e., >12-hrs per day below 1.0 mg/L) that allowed for internal loading of phosphorus (Figure 41). The reservoir volume that was anoxic on 05/24/24 was 3,594 acre-feet or 11% of the water volume. TP_{hypo} on 5/08/24 was 130 µg/L and later was 270 µg/L on from 5/24/24 - 7/09/24 (Table 14). The internal loading estimate during anoxia for 2024 was 1,400 pounds.

Milton had the lowest TP levels for most of 2024. Milton even came close to meeting the TMDL TP goal and had one TP value in June that was below the state TP standard. The refill from the South Platte River typically elevates the phosphorus and this is seen in the March TP spike. By

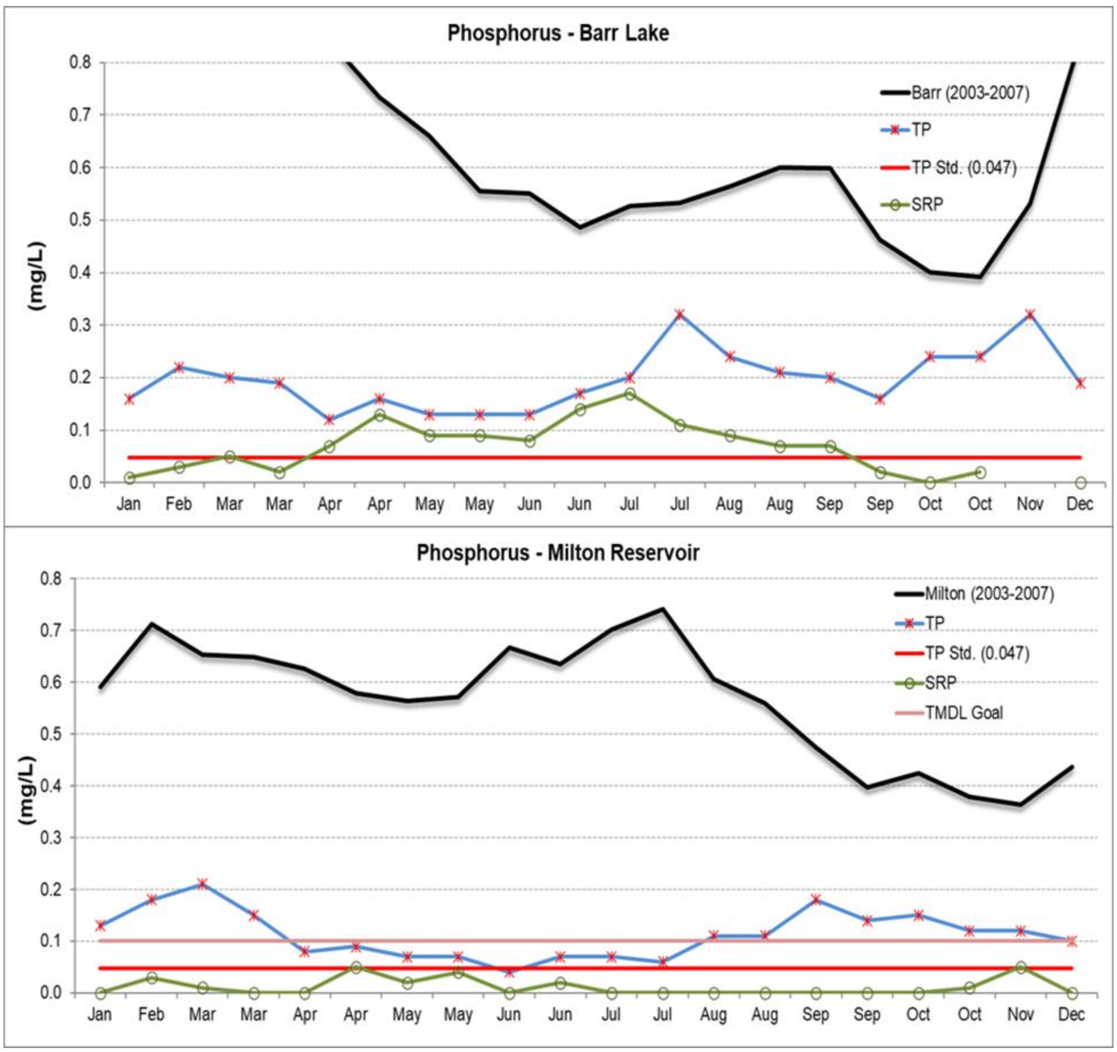


Figure 33. Seasonal variability of TP in 2024

June, the TP_{epi} concentration decreased by 81% (210 µg/L to 40 µg/L). TP in Barr remained below 300 µg/L for most of the year.

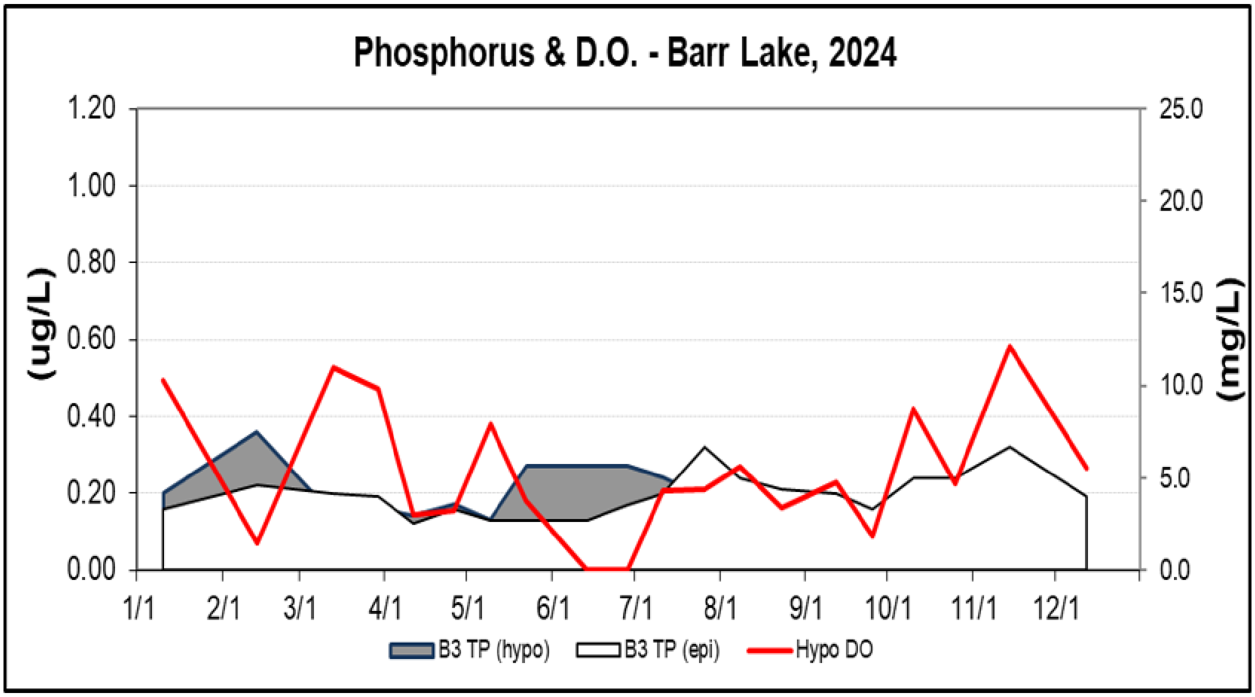


Figure 34. Comparison of TP for epilimnion and hypolimnion with bottom water DO levels

Nitrogen (NH3, NO2, NO3, TKH, TN)

Due to excess phosphorus concentrations in both reservoirs, nitrogen is typically the limiting factor with respect to algal growth. When total nitrogen to total phosphorus ratios (TN:TP) are less than 15, nitrogen is limiting and cyanobacteria can use aqueous nitrogen gas to outcompete other algal species. This is a key advantage of cyanobacteria and often the reason for surface forming algal blooms.

In 2024, 20 nitrogen epilimnion samples were analyzed for each reservoir. For reference, the updated TN standard for warm water reservoirs greater than 25 acres during the summer season is 0.67 mg/L (Table 15). The average TN_{epi} for Barr in 2024 was 2.50 mg/L (compared to the 2002 – 2007 average of 4.86 mg/L) and 1.86 mg/L (compared to the 2002 – 2007 average of 3.63 mg/L) for Milton. These values are higher than each reservoir's respective summer season TN_{epi} averages (Summer Barr = 2.04 mg/L, Summer Milton = 1.17 mg/L). Typically, the summer seasonal average is lower than the annual average due to the winter fill period, as well as increased biologic activity and nutrient uptake during the growing season.

The seasonal variability of TN is consistent from year to year. Like TP, TN tends to increase during the fill period and then decline until early September. TN usually increases around September, likely caused by atmospheric nitrogen fixation by cyanobacteria and internal recycling resulting from bloom decomposition (Figure 36).

In 2024, both reservoirs followed the annual cycle. Barr did see a large increase in TN in late July as TN spiked due to a large cyanobacteria bloom. Barr did see an increase in TN in late September due to TKN which can be an indication of algal growth as cyanobacteria fix atmospheric nitrogen and increase the overall nitrogen pool within a waterbody. Total Kjeldahl Nitrogen (TKN) is the summation of organic nitrogen, ammonia, and ammonium. In both reservoirs, TKN is dominated by organic nitrogen and is usually stable during the year.

Nitrate and nitrite are quickly depleted by June or July due to assimilation. Nitrate (NO_3) concentrations typically decrease below detection limits by mid-summer. Some of that nitrogen is converted to organic nitrogen. The nitrate standard of 10 mg/L was attained during all of 2024 in both reservoirs.

Table 15: Barr and Milton 2024 epilimnion nitrogen data (mg/L).

	Barr Lake (mg/L)						Milton Reservoir (mg/L)					
Month	**NH_3**	**NO_3**	**NO_2**	**TKN**	**TN**	**TN:TP**	**NH_3**	**NO_3**	**NO_2**	**TKN**	**TN**	**TN:TP**
Jan	0.05	1.26	0.04	1.3	2.60	16	0.15	0.10	0.04	1.6	1.74	13
Feb	0.09	1.21	0.05	1.7	2.96	13	0.09	0.71	0.04	1.9	2.65	15
Mar	0.13	1.28	0.05	1.7	3.03	15	0.08	0.60	0.03	2.2	2.83	13
Mar	0.02	1.04	0.06	1.9	3.00	16	0.03	0.45	0.03	2.0	2.48	17
Apr	0.39	0.86	0.04	1.6	2.50	21	0.19	0.39	0.02	1.3	1.71	21
Apr	0.72	0.78	0.05	1.5	2.33	15	0.65	0.57	0.03	1.5	2.10	23
May	0.47	0.80	0.05	1.8	2.65	20	0.85	0.59	0.03	2.2	2.82	40
May	0.49	0.52	0.06	1.5	2.08	16	0.50	0.70	0.04	1.7	2.44	35
Jun	0.33	0.37	0.06	1.8	2.23	17	0.20	.064	0.06	1.8	2.50	63
Jun	0.45	0.31	0.05	1.4	1.76	10	0.16	0.51	0.06	1.2	1.77	25
Jul	0.39	0.21	0.05	1.3	**1.56**	8	0.12	0.16	0.04	1.1	**1.30**	19
Jul	0.02	<0.02	<0.02	2.9	**2.90**	9	0.01	<0.02	<0.02	1.0	**1.10**	17
Aug	0.02	<0.02	<0.02	2.5	**2.50**	10	<0.01	<0.02	<0.02	1.1	**1.10**	10
Aug	<0.01	<0.02	<0.02	2.0	**2.00**	10	<0.01	<0.02	<0.02	1.2	**1.20**	11
Sep	0.01	<0.02	<0.02	1.7	**1.70**	9	0.03	<0.02	<0.02	1.2	**1.20**	7
Sep	0.03	<0.02	<0.02	1.6	**1.60**	10	0.01	<0.02	<0.02	1.2	**1.20**	10
Oct	0.03	<0.02	0.03	2.2	2.23	9	<0.01	<0.02	0.03	1.6	1.60	11
Oct	0.47	<0.02	<0.02	3.1	3.10	13	0.01	<0.02	<0.02	1.1	1.10	9
Nov	0.35	0.09	<0.02	3.5	3.59	11	0.04	0.39	<0.02	1.8	2.19	18
Dec	0.20	0.69	0.07	2.9	3.66	19	0.02	0.64	0.05	1.5	2.19	22
Note: **Red bold** values indicate exceedances of the standard												

Milton was placed on the 303(d) list for ammonia in 2010. Barr was delisted from the 2012 Monitoring/Evaluation list for ammonia because of attainment. Both Barr and Milton had no ammonia exceedances in 2024. The ammonia (NH_3) standard is based on an acute and a chronic standard. The acute ammonia standard varies throughout the year as ammonia toxicity is dependent upon pH and temperature, thus, a calculation is used to determine the standard based on these parameters and their corresponding ambient values. The acute standard is generally above 1.0 mg/L, while both reservoirs typically stay below 0.50 mg/L of ammonia. Similarly, the chronic standard also uses a pH and temperature-based calculation which varies according to two seasons: early life stages absent (ELSA) from August 1 to March 31 and early life stages present (ELSP) from April 1 to July 31. During the winter months of January and February, both reservoirs can experience a buildup of ammonia under the ice due to the process of ammonification which can deplete oxygen. Fortunately, the lower temperatures and pH levels characteristic to the winter sustain the less toxic ionized form of ammonia.

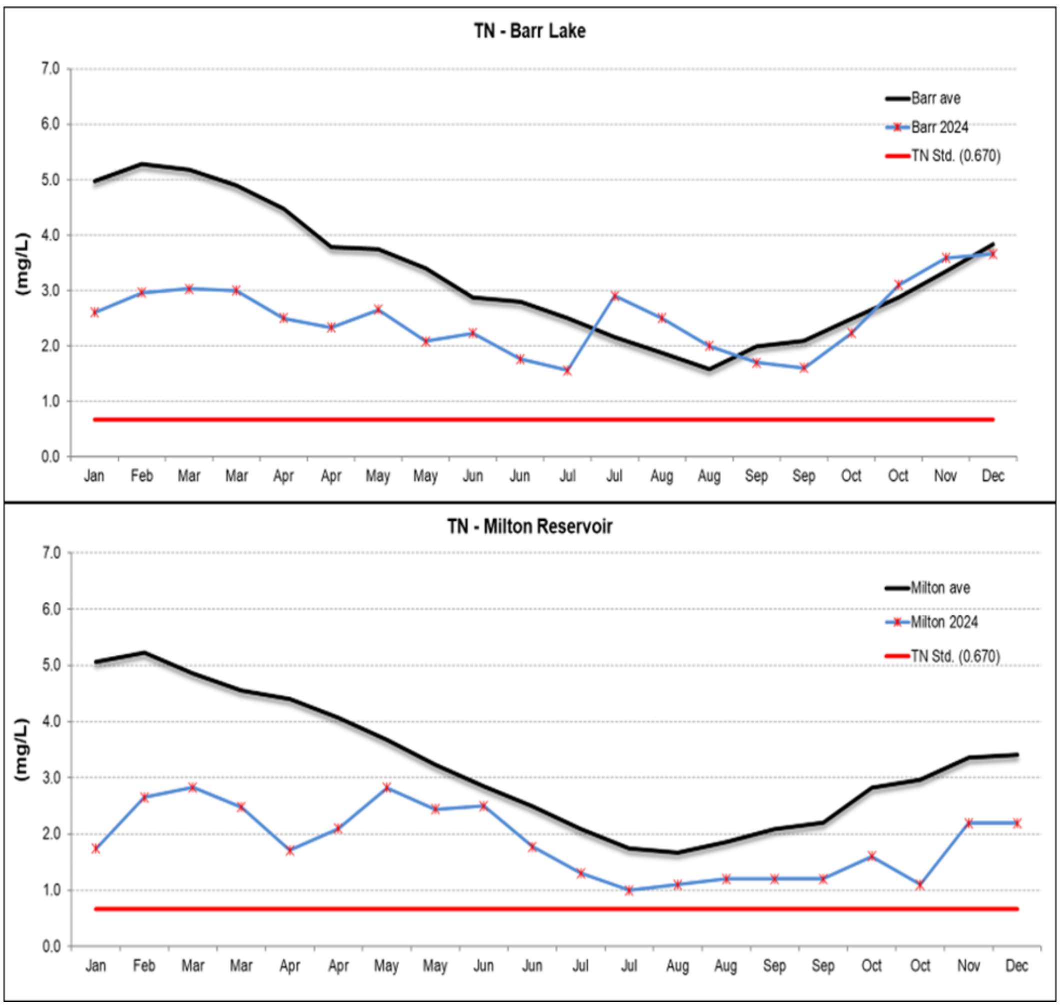


Figure 35: Seasonal variability of TN in 2024

Chlorophyll-a

Chlorophyll-a (chl-a) is an indirect measurement of algal biomass and a response parameter to nutrients. As nutrients and water temperature increase, chl-a, pH, and surface DO can increase. As primary productivity increases, DO initially increases and as algal biomass accumulates, water clarity decreases and eventually DO drops with the decomposition of excess algae. Different species of algae produce different quantities of chl-a. Diatoms do not produce as much chl-a as cyanobacteria but can affect water clarity and DO. Milton less algal growth during the growing season with no visual signs of surface blooms. The chl-a standard during the summer season for warm-water reservoirs is 20 µg/L. Both reservoirs did not meet the standard, but did have some data points below the standard.

Table 16: Barr and Milton chlorophyll-a data (µg/L) for 2024

Month	Chl-a (Barr)	Chl-a (Milton)
Jan	58.2	59.1
Feb	51.1	56.9
Mar	61.8	92.1
Mar	39.9	74.8
Apr	1.1	11.5
Apr	<0.1	<0.1
May	15.3	7.1
May	2.8	6.7
Jun	4.1	12.8
Jun	6.9	18.6
Jul	5.4	16.9
Jul	**194.0**	15.7
Aug	**73.0**	**48.1**
Aug	**108.0**	**33.1**
Sep	**94.9**	**98.1**
Sep	**54.5**	**37.6**
Oct	146.0	86.1
Oct	148.0	94.4
Nov	217.0	69.1
Dec	133.0	55.3

Chl-a can change drastically in a short period of time, even on an hourly time scale (Table 16). When summarizing chl-a data, medians are calculated to avoid skewing the data with extreme values. In 2024, the median chl-a for Barr was 56.4 µg/L (compared to the 2002 – 2007 median of 37.0 µg/L) and 42.9 µg/L (compared to the 2002 – 2007 median of 12.7 µg/L) for Milton. The summer season median for Barr was 84.0 µg/L (compared to the 2002 – 2007 median of 53.5 µg/L) and 35.4 µg/L (compared to the 2002 – 2007 median of 23.7 µg/L) for Milton. In contrast to previous years (2003-2015), Milton's annual median in 2024 is larger than the summer median due to less algae during the summer and more growth during the fall and winter.

Since 2019, the fall through spring algal growth has overshadowed the summer cyanobacteria growth. The post ice-off season produces large biomass at a critical time of the year when the water column is stratified. Decomposition after the spring growth triggers lower oxygen and completes the phosphorus cycle with internal loading that sets up the summer season of growth. Barr Lake did have a major cyanobacteria bloom in July followed by a second cycle of blooms in fall during very low water conditions. Milton had above average spring growth of algae followed by a long period of little growth. Milton was productive during the growing season but never showed visual signs of a cyanobacteria bloom (Figure 37).

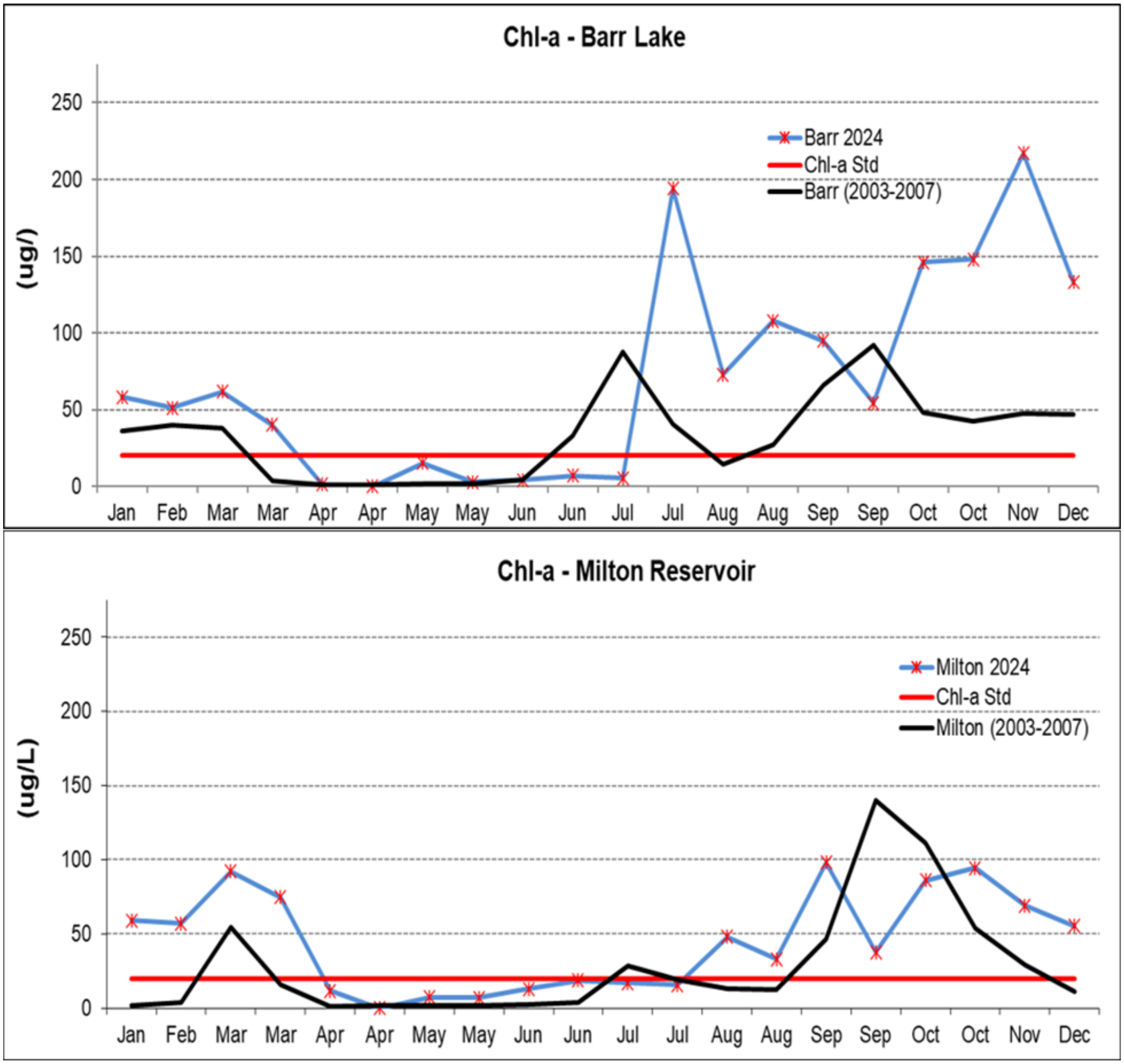


Figure 36: Seasonal variability of chl-a in 2024

Water Clarity

Water clarity is measured with an 8-inch diameter, black and white, Secchi disk. In addition to measuring water clarity, the Secchi disk depth is also closely correlated with chl-a, TP, and a trophic state index score (TSI) developed by Bob Carlson (Carlson, 1977). Both reservoirs experienced enough algal growth to impact water clarity for most of the year.

The average Secchi depth for Barr in 2024 was 1.69 m (compared to the 2002 – 2007 average of 1.87m) and 0.86 m (compared to the 2002 – 2007 average of 1.85m) for Milton. Water clarity closely follows algal growth throughout the year. Both reservoirs experienced a clearing phase between April and June (Table 17). Milton had a shallower and shorter clearing phase despite having better than average chl-a values. Barr's clearing phase was deeper than average and extended further into the growing season. The TSI scores varied from mesotrophic (<50) to hypereutrophic (>70) for both reservoirs.

Table 17: Barr and Milton 2024 Secchi Depth data (meters)

	Barr Lake		Milton Reservoir	
Month	**Secchi Depth (meters)**	**TSI Score**	**Secchi Depth (meters)**	**TSI Score**
Jan	0.98	69	0.80	69
Feb	0.85	71	0.78	71
Mar	1.05	70	0.70	74
Mar	0.86	70	0.62	72
Apr	2.05	51	0.98	61
Apr	6.10	40	2.40	41
May	1.95	61	0.70	60
May	4.65	51	1.95	55
Jun	5.20	52	2.40	53
Jun	2.90	57	0.70	63
Jul	2.98	57	0.80	62
Jul	0.80	78	0.75	62
Aug	0.74	73	0.65	69
Aug	0.45	76	0.40	70
Sep	0.40	76	0.35	77
Sep	0.30	75	0.40	72
Oct	0.30	80	0.30	76
Oct	0.27	81	0.35	75
Nov	0.40	81	0.50	72
Dec	0.60	75	0.65	69

The summer season average Secchi depth for Barr was 0.95 m (compared to the 2002 – 2007 average of 1.24m) and 0.56 m (compared to the 2002 – 2007 average of 1.09m) for Milton. Water clarity was less than average for most of the year. The summer TSI average for Barr was 73 (compared to the 2002 – 2007 average of 73) and 69 (compared to the 2002 – 2007 average of 74) for Milton. These scores are considered "eutrophic".

The seasonal variability in water clarity closely follows the chl-a pattern. Water clarity is at, or below, 1.0 meter during any major algal growth. In the spring after algae have ceased blooming, zooplankton graze on the available algae, clearing biomass and improving clarity throughout the water column for one to three months. This phenomenon is reflected with the averages for both reservoirs (Figure 38). During the clearing phase, both reservoirs experienced a sudden growth in early May creating a major shift in clarity. Barr decreased from 6.10 meters in April to 1.95 meters in early May, and then increased back to 4.95 meters by the end of May. Milton has a similar pattern but not with as much clarity. The summer season growth did occur earlier in Milton but not as intense. It is desirable to have water clarity greater than one meter for recreational uses. There is no water clarity standard for Colorado.

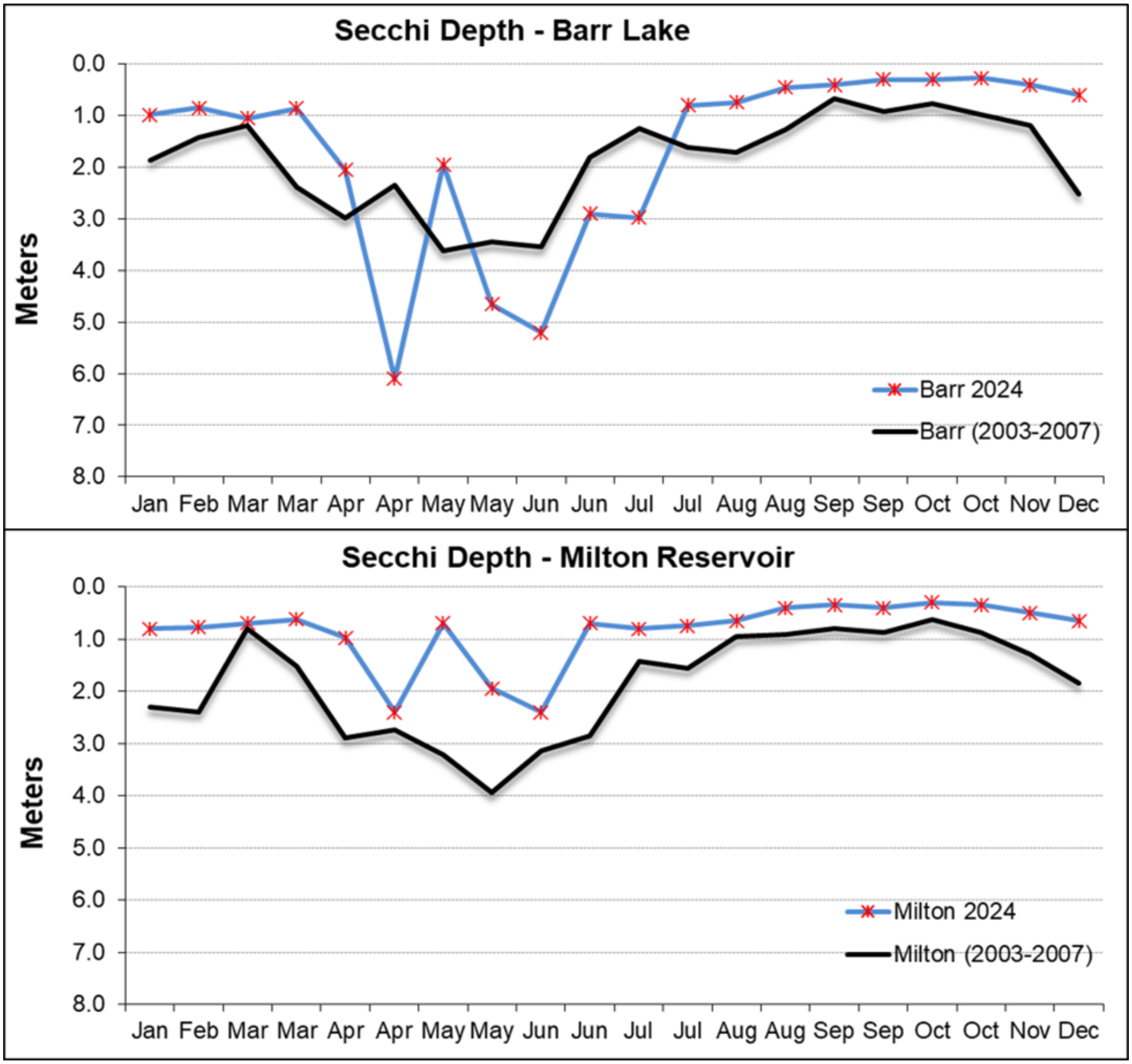


Figure 37. Seasonal variability of water clarity for 2024

Dissolved Oxygen

DO is an important response parameter when determining the health of a lake or reservoir. Oxygen enters the water via two pathways - from the atmosphere and through photosynthesis. When at 100% saturation, respiration (i.e., production of carbon dioxide) equals photosynthesis (i.e., production of oxygen). DO can decrease below 100% when respiration is greater than photosynthesis. The opposite can also occur. DO can exceed 100% when there is an increased rate of primary productivity. Understanding DO throughout the water column assists in understanding the overall condition of a waterbody both from a productivity standpoint and from an internal loading perspective.

The DO standard is applied as an average of the upper mixed layer (0.5 – 2.0 meters) of a reservoir and cannot go below 5.0 mg/L at any time when the water depth is greater than 5 meters. If less than 5 meters, then the top 40% of the water column is analyzed for compliance. There is no upper limit or frequency of violations for DO.

In 2024, 20 DO averages were recorded for each reservoir (Table 18). Barr's lowest DO average was 5.6 mg/L (62.7%) in April. Milton's lowest DO average was 6.0 in April. Both reservoirs met the DO standard for 2024. For both reservoirs, a decline in DO always occurred following a major algal bloom. Barr experienced large blooms and subsequent large demands on DO due to decomposition. The average oxygen consumption rate in Barr between April to June was 5,000 Kg of oxygen/day. The average oxygen consumption rate in Milton between April and the end of May was 4,100 Kg of oxygen/day. Milton's demand was lower due to the overall lower production of biomass compared to Barr.

Table 18: 2024 Barr and Milton epilimnion DO data (mg/L and %)

Month	Barr DO mg/L & %	Milton DO mg/L & %
Jan	15.1 (132.8%)	14.4 (131.6%)
Feb	20.7 (196.1%)	18.8 (176.4%)
Mar	13.6 (133.1%)	14.5 (142.2%)
Mar	13.3 (138.0%)	13.0 (132.4%)
Apr	6.9 (73.8%)	8.8 (95.9%)
Apr	5.6 (62.7%)	6.0 (68.3%)
May	8.5 (98.3%)	7.5 (85.3%)
May	6.2 (81.4%)	6.8 (87.7%)
Jun	6.3 (87.6%)	8.6 (120.6%)
Jun	6.5 (94.1%)	7.5 (105.0%)
Jul	6.0 (84.3%)	7.8 (109.2%)
Jul	13.4 (193.0%)	9.0 (126.2%)
Aug	8.1 (113.0%)	8.2 (113.9%)
Aug	10.3 (150.3%)	6.7 (93.4%)
Sep	9.5 (128.8%)	6.3 (83.8%)
Sep	12.9 (173.6%)	9.3 (116.5%)
Oct	9.1 (112.3%)	10.7 (132.4%)
Oct	7.4 (84.9%)	13.6 (154.3%)
Nov	12.2 (116.6%)	12.6 (117.4%)
Dec	6.1 (54.4%)	14.9 (127.3%)

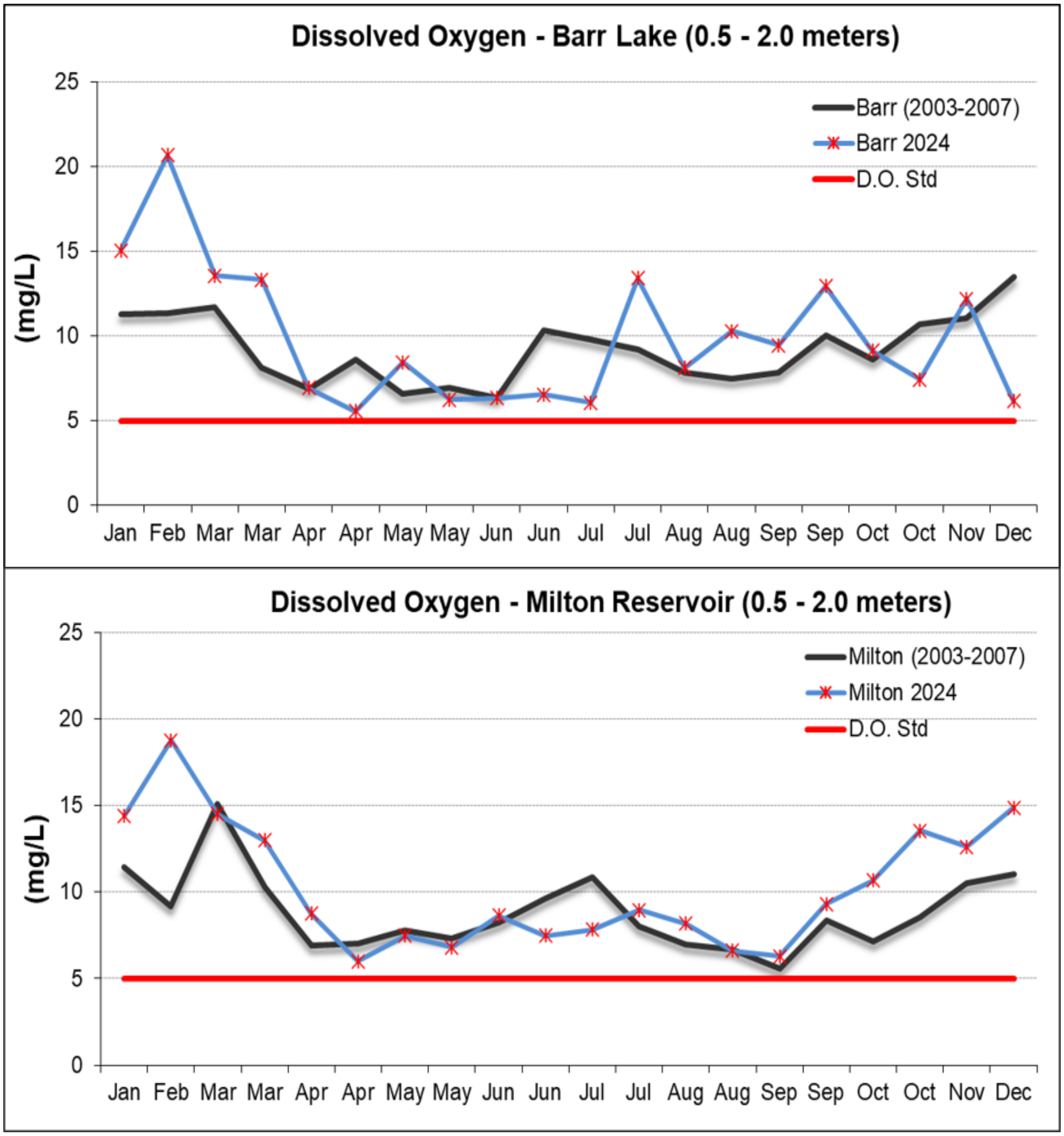


Figure 38. Seasonal variability of DO for top two meters of water column.

Two factors that create lower oxygen levels in the spring are microbial decomposition of biomass and respiration by grazing zooplankton. Oversaturation of oxygen (>100%) indicates algal growth due to high rates of photosynthesis. The first three months of 2024 saw oversaturated conditions above 100%, indicating ongoing algal growth. Both reservoirs hit their annual minimum for DO in late April (Figure 39). The April DO drop marked the beginning of the spring clearing phase where zooplankton consume algae throughout the water column along with ciliates and other microbes. Oxygen demand due to decomposition pushed Barr's hypolimnion towards anoxia, although recorded DO values did not fall below 4.0 mg/L (Figure 39).

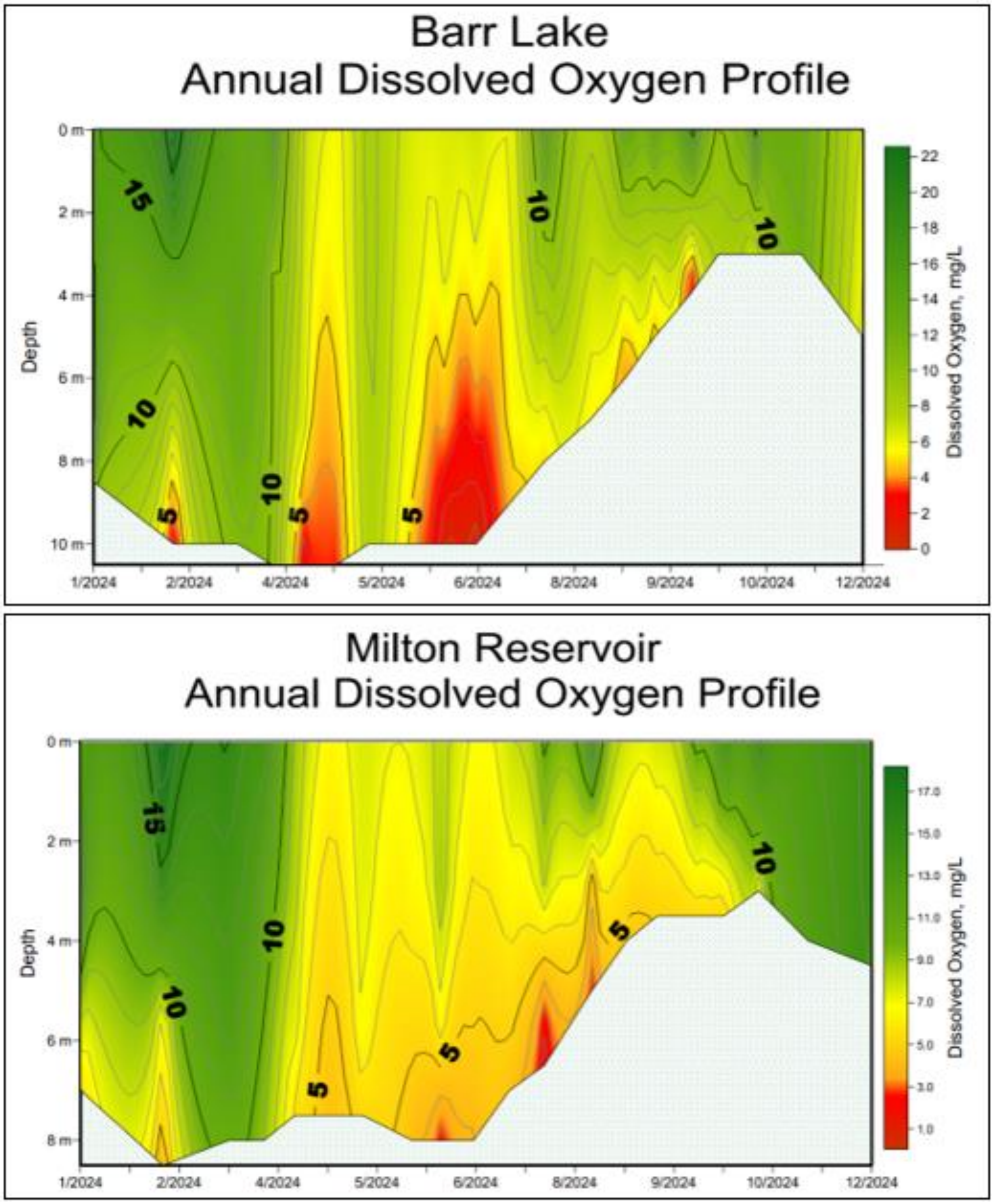


Figure 39. Seasonal variability of DO throughout the water column

In addition to bi-weekly profile data, continuous DO data were collected for Barr Lake via anchored sensors at the epilimnion, metalimnion, and hypolimnion (Figure 40). Extreme temperatures in June triggered a period of thermal stratification throughout Barr's water column which trapped anoxic water at the bottom of the reservoir. Anoxic conditions near the sediment activated internal loading of phosphorus (i.e., DO below 1.0 mg/L for greater than 12-hrs per day) for 65 days lasting from early June into July with periodic occurrences during the fall (Figure 41). The release of phosphorus into the water column throughout this period helped initiate the major cyanobacterial bloom for the growing season. The summer season DO average for Barr was 10.0 mg/L (compared to 2002 – 2007 average of 8.7 mg/L) and 7.9 mg/L (compared to 2002 – 2007 average of 7.8 mg/L) for Milton. These fluctuations in oxygen mimic the changes in chl-a throughout the year. Barr appeared to have an increase in DO during major blooms followed by a decline in DO due to decomposition, particularly in early October and December.

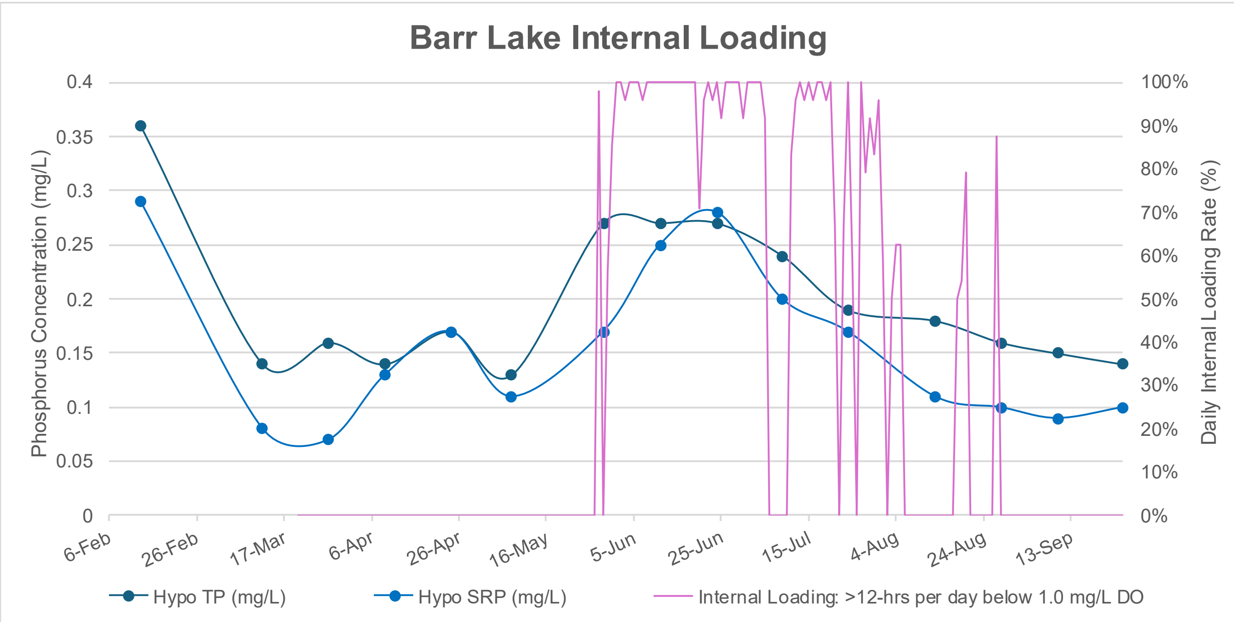


Figure 40. Calculated timeframe and rates of internal loading within Barr Lake

pH

pH measurements are taken at half meter increments throughout the water column, and measurements in the top two meters are averaged. In 2024, 20 pH averages were recorded for each reservoir (Table 19). Based on the state standard criteria, the 2024 85th percentile pH value was 8.96 (compared to the 2002 – 2007 average of 9.26) for Barr and 8.87 (compared to the 2002 – 2007 average of 9.19) for Milton. Both reservoirs met the pH standard for 2024.

The seasonal variability of pH follows the other parameters mentioned. pH increases when photosynthesis increases. Both reservoirs experienced decreases in pH when algal productivity declined (Figure 42). For a sixth year at Barr, the summer cyanobacteria bloom did not cause a pH violation for the entire summer season. The lower pH values, especially at Milton, highlighted the less intense algal growth for 2024.

Table 19. 2024 Barr and Milton epilimnion pH data

Month	pH (Barr)	pH (Milton)
Jan	7.60	7.82
Feb	8.10	7.86
Mar	8.82	8.87
Mar	7.85	8.00
Apr	8.59	8.63
Apr	7.81	7.76
May	8.14	7.99
May	8.05	8.13
Jun	8.16	8.41
Jun	7.88	8.26
Jul	8.08	8.27
Jul	**9.05**	8.49
Aug	8.91	8.18
Aug	8.96	8.40
Sep	8.97	8.30
Sep	8.93	8.64
Oct	8.49	8.79
Oct	8.22	**9.12**
Nov	**9.15**	8.88
Dec	7.84	8.91

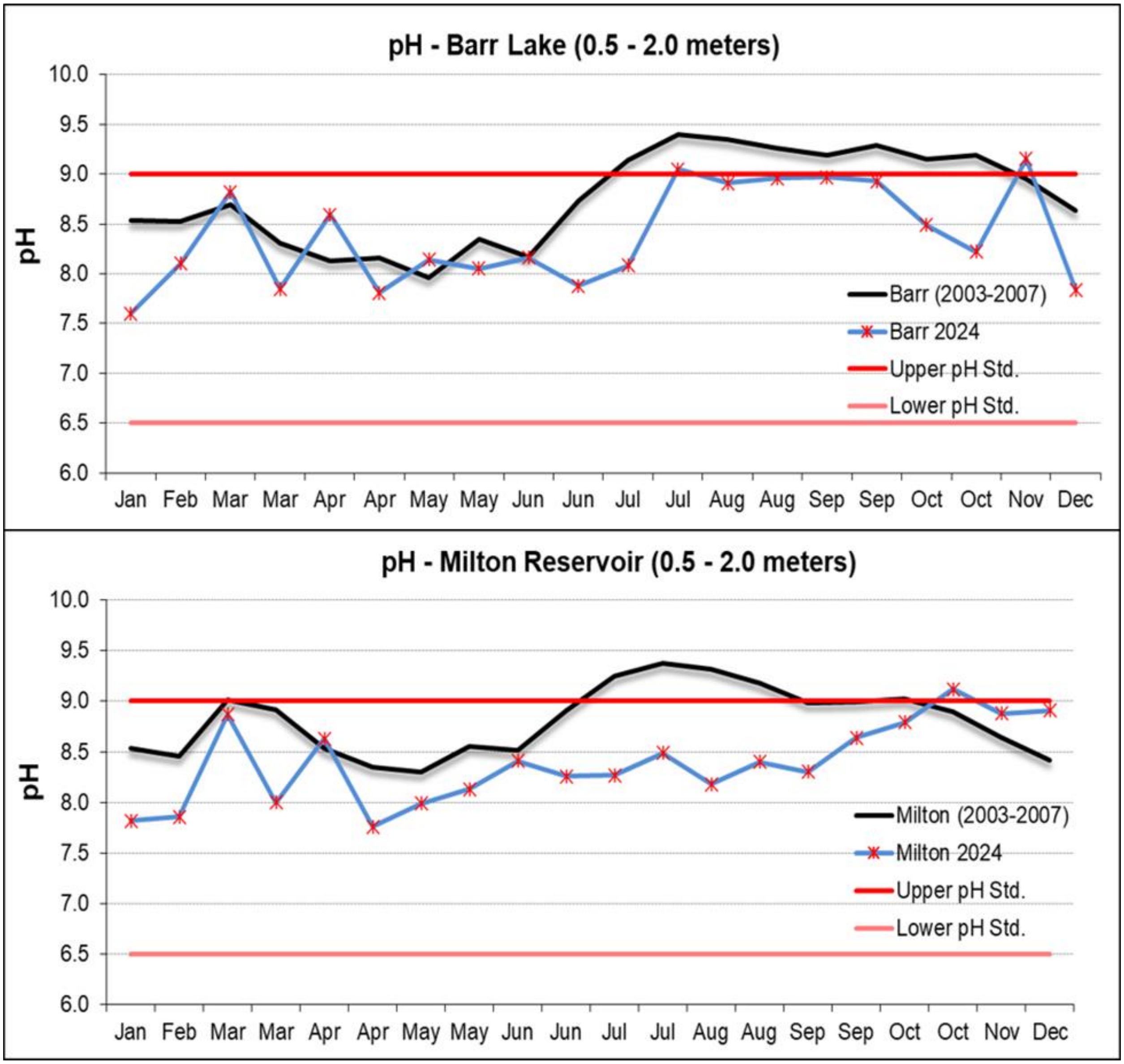


Figure 41. Seasonal variability of pH for 2024

Temperature

The temperature standard for warm water lakes deeper than 5 meters only applies to the epilimnion (0.5 – 2.0 meters). Upper limit exceedance values are 26.2°C (chronic) and 29.3°C (acute) between April and December, and lower limit exceedance values are13.1°C (chronic) and 24.1°C (acute) between January and March. Acute temperature standards are calculated as a daily maximum average, and chronic standards are the maximum weekly average during the summer season. A reservoir can exceed these temperatures if there is deeper water that meets both the temperature and DO standards.

Temperature data are collected throughout the water column in half-meter increments and the epilimnion data are averaged. In 2024, 20 temperature averages were recorded for each reservoir. The temperature standard was attained in both reservoirs. The summer average for Barr was 22.6°C (compared to the 2002 – 2007 average of 21.2) and 21.9°C (compared to the 2002 – 2007 average of 22.0) for Milton. Both reservoirs seem to have increased summertime water temperatures over a longer period of time over the past 20 years.

The seasonal variability of water temperature in both reservoirs is greatly influenced by air temperature and length of day. Due to water's thermal properties, gradual warming and cooling throughout the year resembles a well-defined bell curve as shown in Figure 43. Ice cover forms in December or January and melts off in early March, with peak temperatures occurring mid-summer in July to August. A strong warming or cooling trend can alter the reservoir's temperature on a weekly time scale. 2024 was the world's warmest year on record according to NOAA's National Centers for Environmental Information, and Barr and Milton's seasonal temperature patterns responded. February temperatures were well above average, and ice cover cleared approximately four weeks earlier than normal. In early summer, top layer water temperatures on 6/24/24 were 24.2°C at Barr and 23.3°C at Milton. These water temperatures are typically seen in late July during the peak of the maximum water temperatures. Both reservoirs exceeded just over 110 days where surface layer water temperatures were 20.0°C or greater. 2024 had an extended growing season based on surface water temperatures. Water temperatures did not decrease to average temperatures until November of 2024.

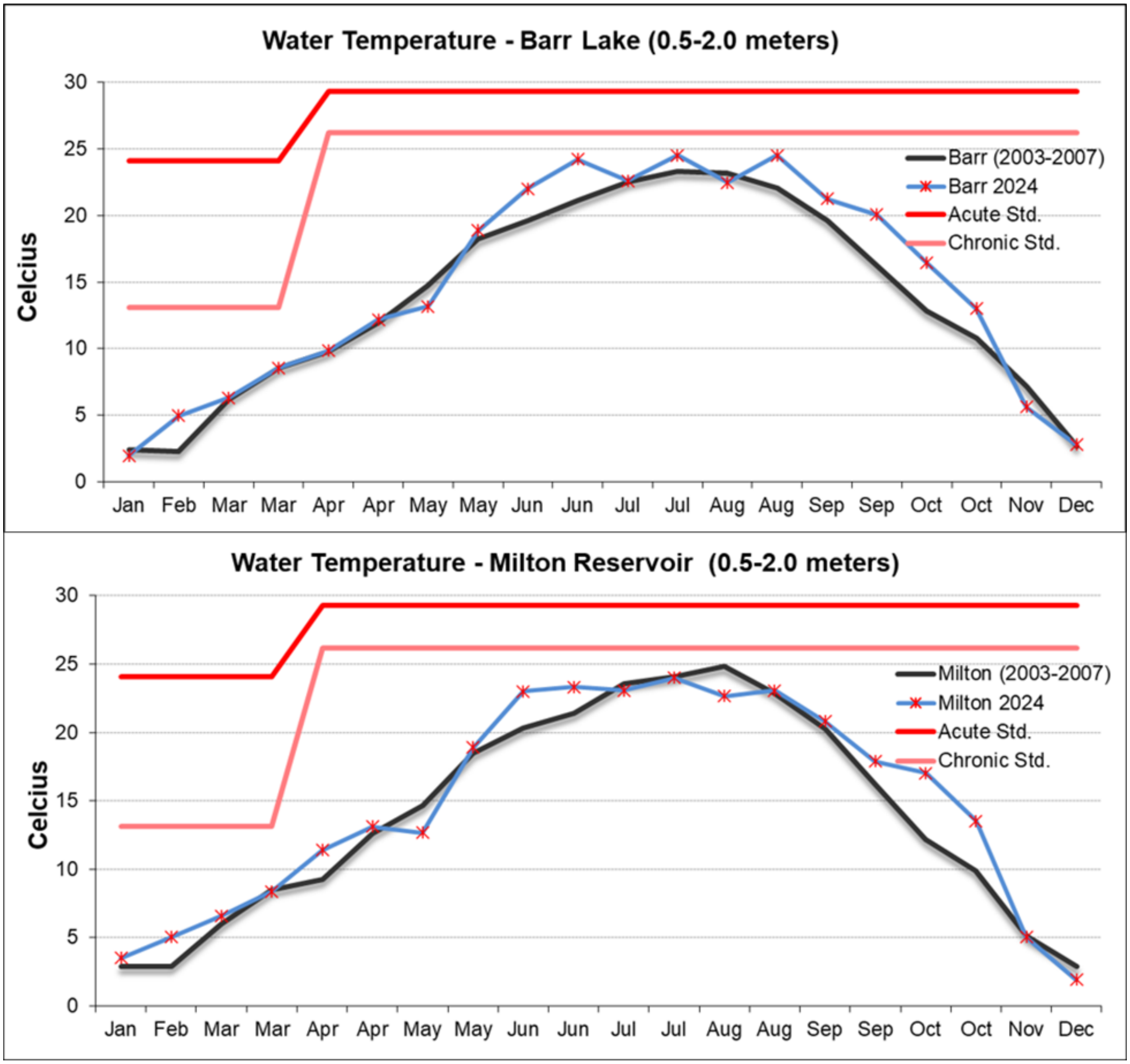


Figure 42. Seasonal variability of water temperature for 2024

Seasonal Variability

The annual water quality changes in Barr and Milton are strongly influenced by the annual hydrologic cycle. The hydrologic residence time for Barr is 7.5 months and 6.4 months for Milton (Boyer, 2008). Barr and Milton fill during the winter, remain full for 2-4 months in the spring, and then water is released throughout the irrigation season. Reservoir depth driven by water rights and water temperature driven by weather conditions determine how the water column mixes throughout the year. When deeper than 7-8 meters, Barr and Milton are both dimictic (i.e., full, isothermal water column mixing in the spring and fall). However, once the water depth falls below eight meters during late summer through fall, wind can cause frequent periods of full or partial mixing of the water column (i.e., polymictic). Stratification occurs during winter underneath ice coverage and during summer, although the gradient of stratification is often weak, allowing for periodic mixing of the water column. Mixing and entrainment of sediment occurred within Barr in the spring after ice off. Periods of thermal stratification were evident in June and July as (Figure 45; Figure 45) as thermal energy warmed the upper layer of the lake separating the cooler, denser water at the epilimnion sank. Stronger stratification in June likely contributed to anoxia within the hypolimnion and thereby internal loading of phosphorus occurred throughout June into July. As nutrient-rich water migrates up to the photic zone, blooms are generated.

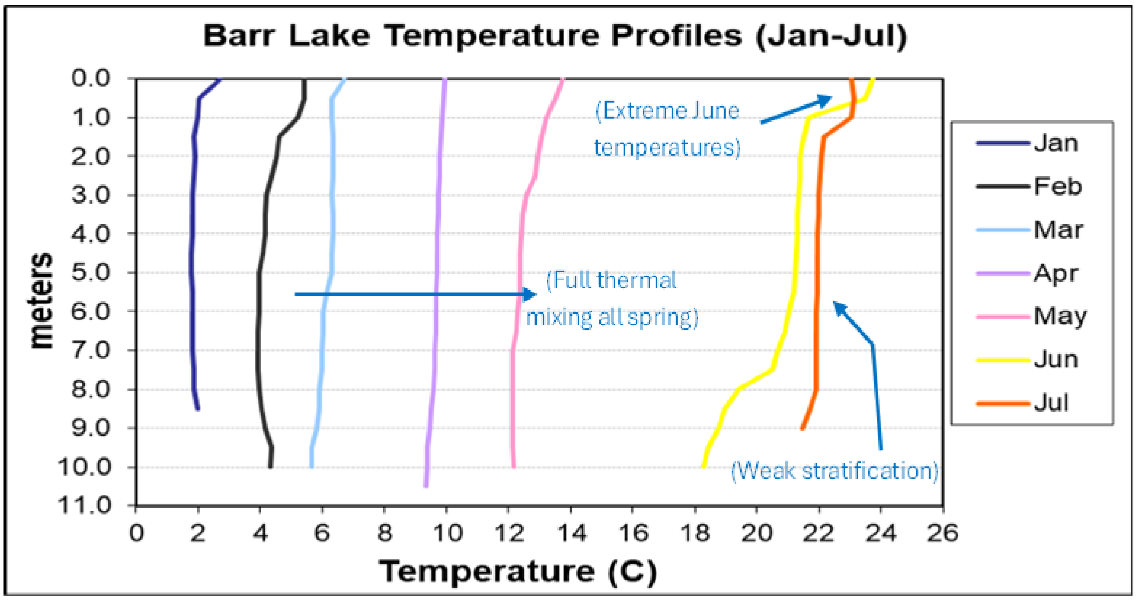
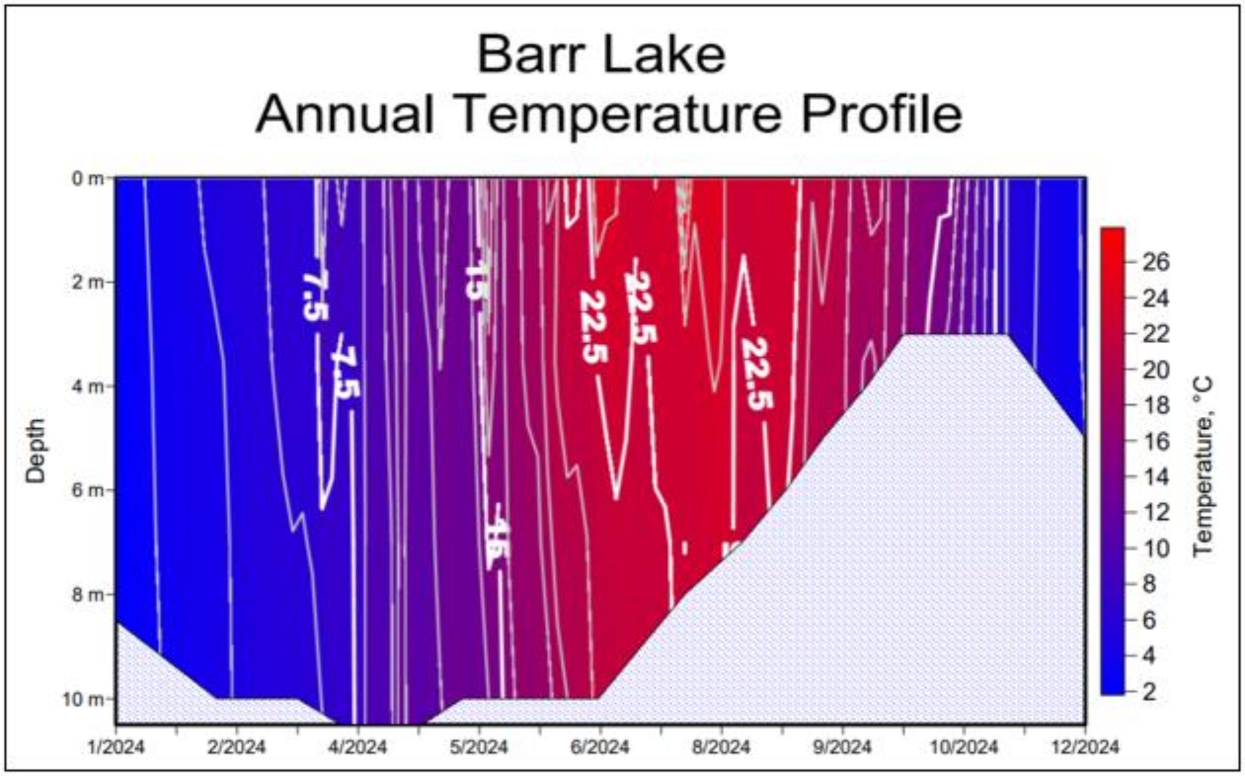


Figure 43. Barr Lake water temperature profiles for first half of 2024



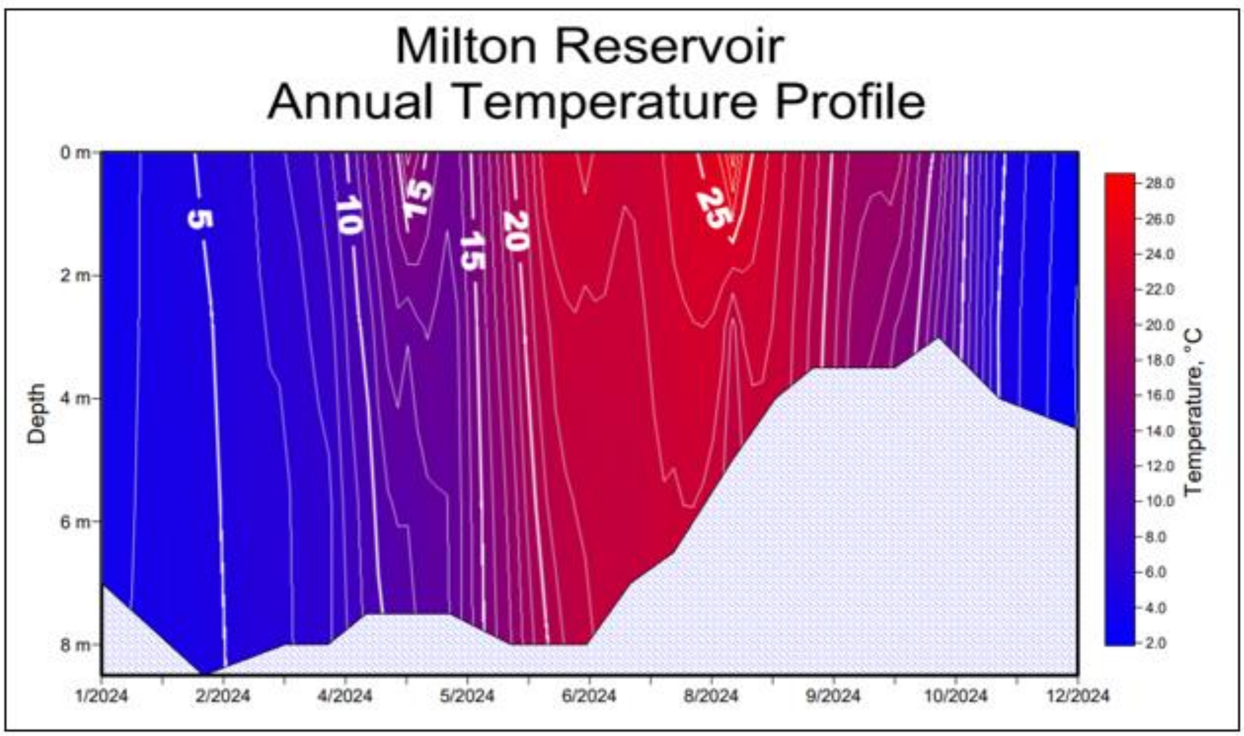


Figure 44. Annual temperature profiles Barr Lake and Milton Reservoir

2024 Water Quality Summary

Barr and Milton met both pH and DO standards for 2024 and had the lowest TP concentrations since monitoring started in 2002. Milton's summer TP concentration average was 79% less than the 2003-2007 average. This is the largest decrease since implementation of the TMDL started in 2013. Despite lower TP levels, Barr Lake had the highest growing season chl-a levels ever recorded. These conditions in water quality are likely due to the following: 1) Point Source Reductions, 2) Hotter Weather, 3) Projects at both Reservoirs, and 4) Flow Regime.

1. Point Source Reductions – Metro started enhanced biological nutrient removal in 2021 which has kept effluent TP concentrations down for the past four years for the S. Platte River. Effluent TP concentrations have decreased from 3.0 mg/L to ~0.35 mg/L. This is an 88% reduction. South Platte Renew, the second largest treatment plant upstream of Barr and Milton, started tertiary chemical treatment for phosphorus in 2023 with the use ferric sulfate and aluminum sulfate. Stormwater treatment projects and best management practices have also increased over the past 20+ years to address water quality concerns outlined within TMDL. The stormwater management community has focused on reducing the magnitude of hydrologic peaks during storms which helps sequester phosphorus loads within urban landscapes and ultimately reduce TP concentrations entering downstream reservoirs after a storm. These point source reductions in phosphorus concentrations have noticeably reduced TP in the South Platte River just upstream of the Burlington head gate and the Platte Valley Canal (Evans #2) head gate. These river reductions lead to TP concentration reductions in both reservoirs. 2024 TP reservoir concentrations decreased by 71% and 79% for Barr and Milton, respectively, in comparison to TP concentrations from 2003 and 2007 (Figure 46). The reductions also occurred during the growing season (July-September) with 59% and 79% reductions for Barr and Milton.

2. Hotter Weather – 2024 was officially the hottest year on record and the impacts were measured locally at Barr and Milton. Denver experienced the third hottest year in 2024, tying 2012. Both reservoirs experienced higher than average water temperatures for most of 2024 starting with ice off four weeks earlier than normal in February. This allowed for a longer open water growing period in the spring, while extreme temperature in June exacerbated thermal stratification and, as a result, internal loading. Water temperatures during the fall were above average until November. Warmer temperatures and longer growing seasons associated with climate change are one of the greatest concerns for water quality of lakes and reservoirs as such increases the seasonal conditions that facilitate algal growth. 2024 was a year that provided both a longer growing season such that the annual chl-a peak for Barr occurring late October.

3. Major Draw Down - There were a few reservoir management projects in 2024 that are worth highlighting because they did impact the overall water quality story for each reservoir. Barr Lake had three individual projects in 2024 focusing on the outlet structures, inlet structure, and dike road. Reservoir drawdown to dead pool started in early July. Barr remained drained from September to early November during dam outlet repairs. This provided a very shallow, small pool (i.e., dead pool) during the warmer than average

fall. During this major draw down, the inlet structure was removed and replaced with an updated bifurcation. This structure limited inlet flows during the fall. The dike road that borders the eastern side of Barr Lake was in its second year of rehabilitation. All trees and vegetation within about 20 feet of the high-water mark along the dike road were removed to allow for reinforcement of the dike road. Removal of shoreline vegetation and large woody debris can have an impact on dissipating wave energy and fish habitat.

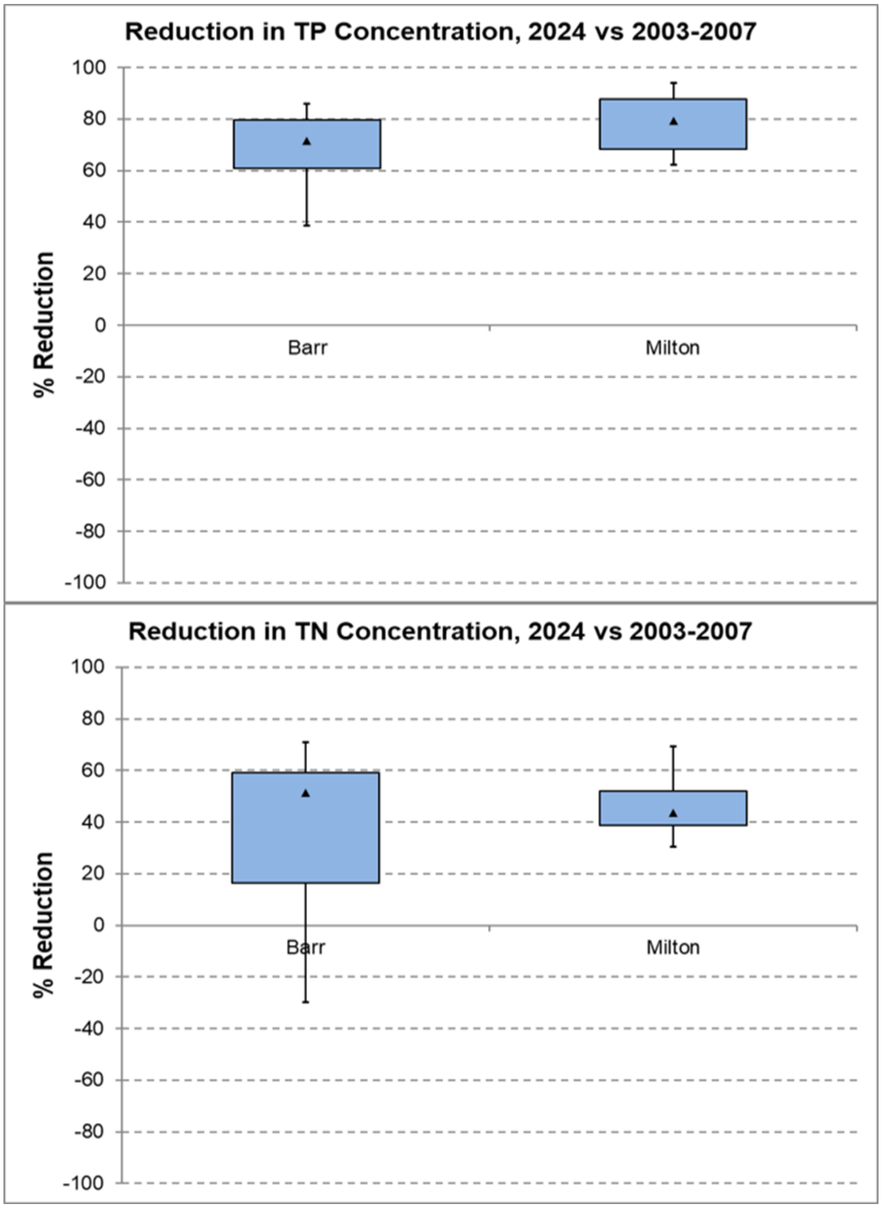


Figure 45. Percent changes in TP and TN in 2024 compared to 2003-2007

4. Flow Regime – The management of flows into and out of Barr and Milton has a major impact on water quality. Reservoir management decisions and the annual flow regime for Barr in 2024 had a major impact on the second half of the year (Figure 47). The monthly percent flows for 2024 matched the pattern in recent years with the exception for some above normal flows in June followed by extremely low flows July through November. The overall flow pattern for Milton was typical while Barr experienced some changes due to the above-mentioned reservoir management projects.

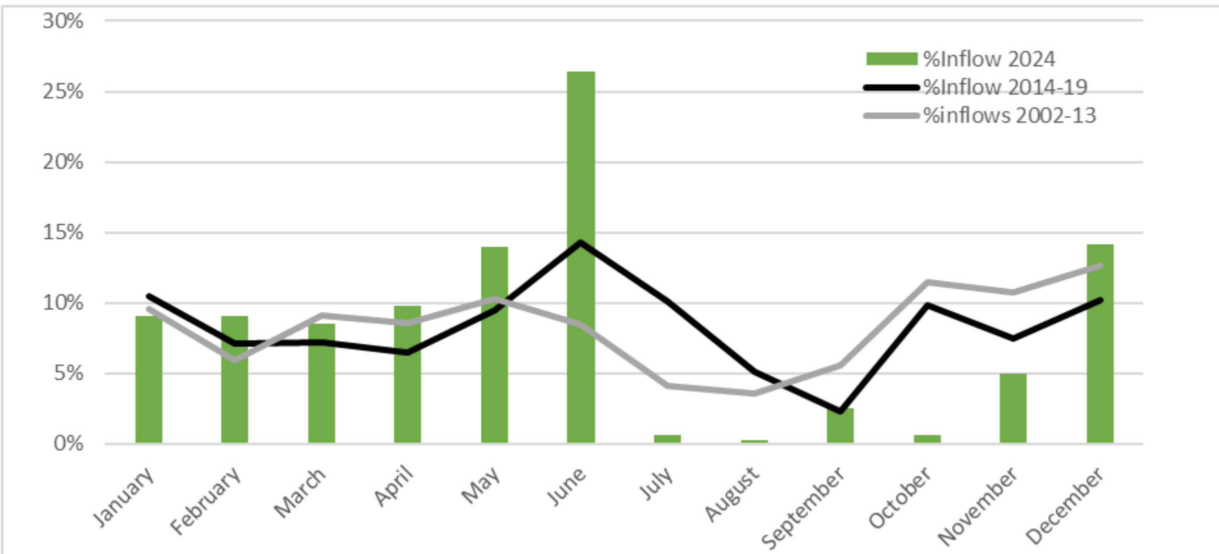


Figure 46. Monthly flows into Barr for 2024 compared to historic averages (2003-2007 and 2014-2019)

Biology

In addition to monthly water quality sampling, phytoplankton and zooplankton sampling occurred 20 times throughout 2024 for Barr Lake and Milton Reservoir. Phytoplankton samples are collected from the photic zone of each reservoir. When water clarity is two meters or less, phytoplankton are collected as a grab sample at one meter below the water's surface. When water clarity exceeds three meters, a composite sample is taken representing the extent of the photic zone with sub-samples taken at a depth of one meter, the recorded Secchi depth, and 1.5 times the Secchi depth. Phytoplankton are then analyzed via flow cytometry using a FlowCam 8100 and the associated software VisualSpreadsheet 6.0.2 to evaluate total biovolume, community distribution, and cyanobacteria cell concentrations.

Algal cycles resembled a typical year for Barr with high rates of productivity lasting from early summer through late fall, while Milton experienced lower than average productivity throughout the year (Figure 48). Barr and Milton began the year with moderate productivity during the winter and into early spring. Algal biovolume remained steady through March for both reservoirs until grazing by thriving zooplankton populations led to the spring clearing phase between April and June. Algal production picked back up in June followed by significant annual peaks in late July for both reservoirs. Sustained algal growth continued within Barr through November due to a cyanobacterial bloom which lasted until late September and then transitioned to a diatom bloom peaking in late October. Milton's annual peak in late July was attributed to a short-lived cyanobacterial bloom, during which algal production remained relatively mild compared to previous years. Beyond July, Milton exhibited less extreme peaks overall and consistently lower biovolume relative to Barr.

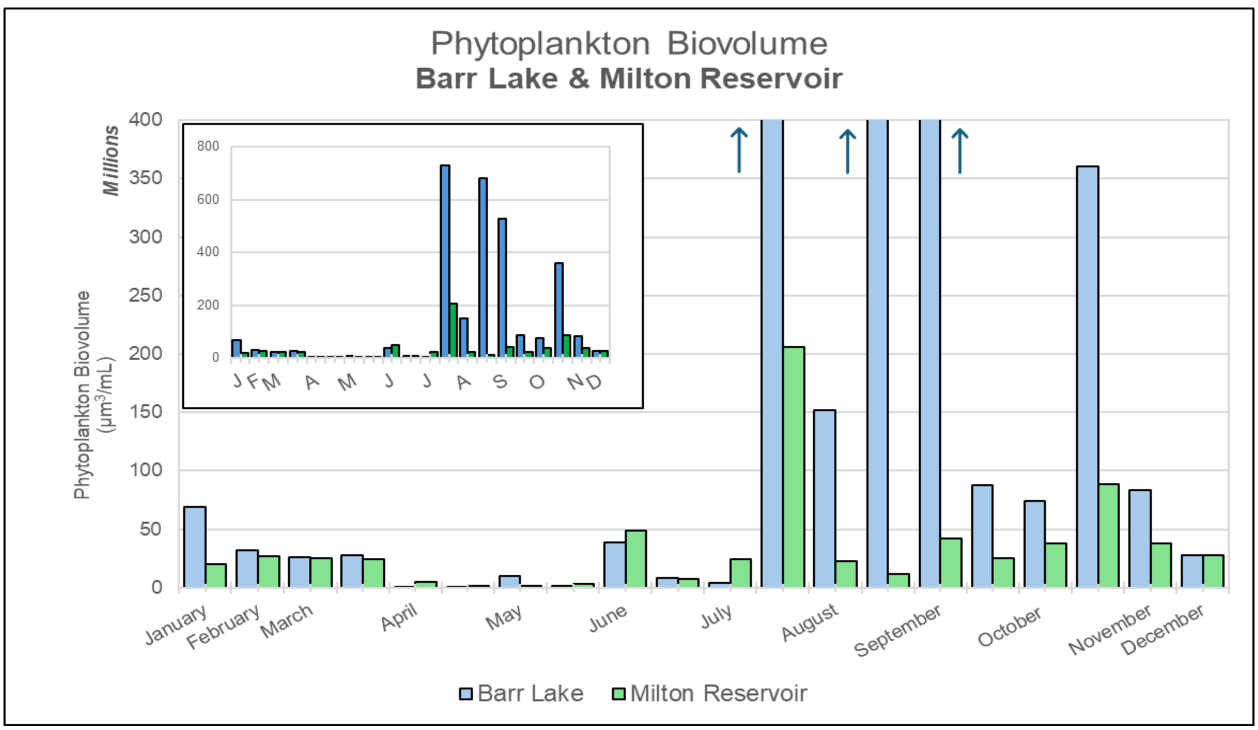


Figure 47. Total biovolume of phytoplankton population

External nutrient loads continue to drive phytoplankton community dynamics (Figure 49). Cyanobacteria were abundant within Barr at the beginning of the year due to a bloom persisting from 2023. Nutrient loads sourced from the winter fill period can support blooms of filamentous cyanobacteria due to their ability to adapt to low light conditions and tolerance of cooler temperatures, in particular *Planktothrix agardhii* and *Pseudanabaena limnetica* (Napiorkowska-Krzebietke et al., 2021) which dominated the winter bloom in Barr. Diversity improved as cyanobacteria declined, comprising less than 40% of the total algae population from February through June. Cryptophyta, Chlorophyta, and Bacillariophyta contributed to overall diversity and are favorable components of pelagic food webs as nutrient dense phytoplankton which support upper trophic levels. For Milton, low cyanobacteria presence allowed for ideal diversity throughout the first half of the year, where cyanobacteria remained below 15% among the overall population despite a temporary increase in cyanobacteria in June. Cryptophyta, Chlorophyta and diatoms dominated the overall winter to spring phytoplankton population.

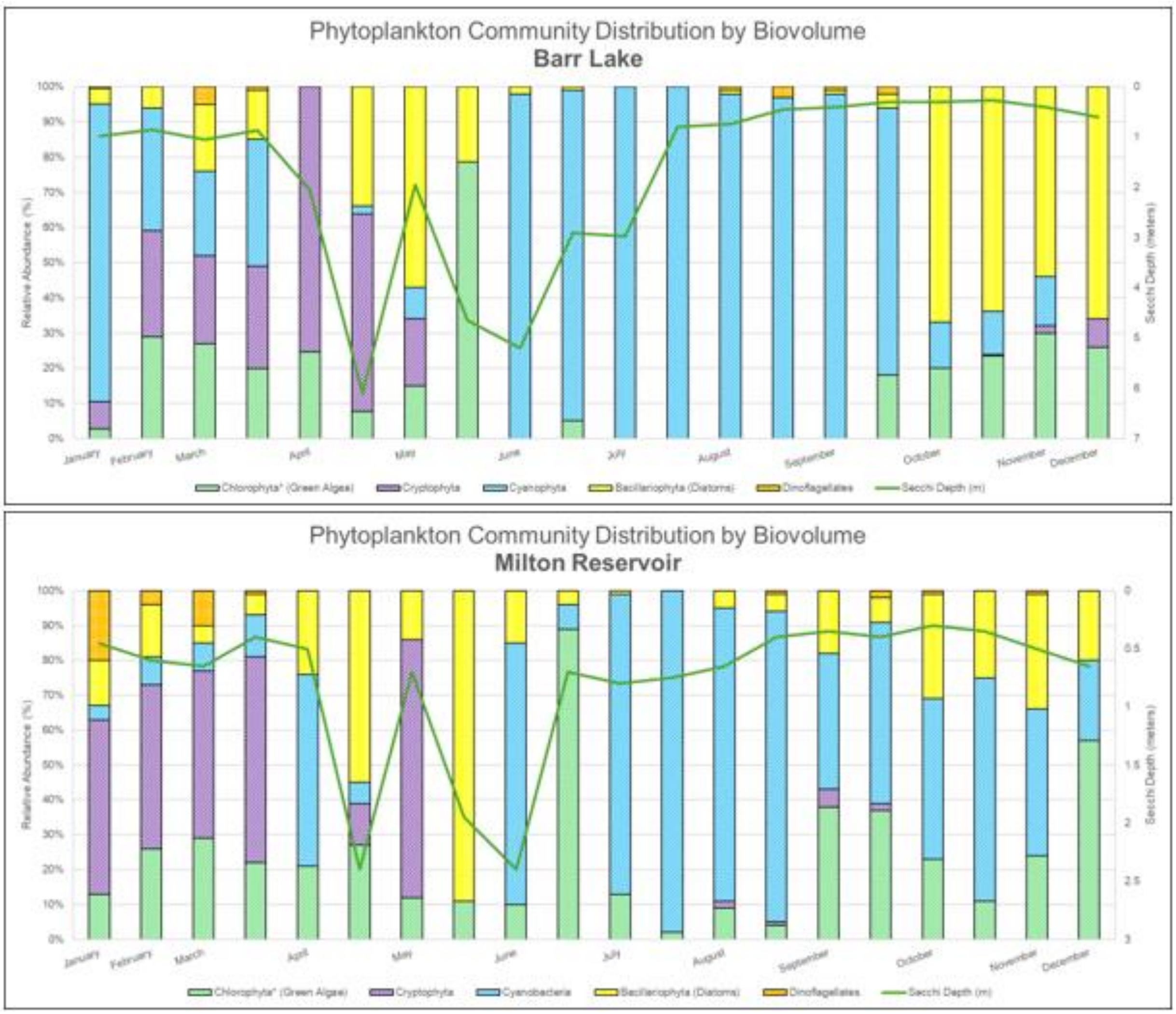


Figure 48. Community relative abundance of major phytoplankton phyla

Historically, both reservoirs have produced a massive monoculture of cyanobacteria annually from June to October. Barr was consistent with this cycle, where internal loading of phosphorus throughout June and into July triggered the cyanobacterial bloom lasting from July to September. Despite a growing season dominated by cyanobacteria, blooms did not cause an exceedance of the pH standard during high productivity periods and DO did not fall below the standard during mass senescence. Cyanobacteria abundance quickly declined moving into October and centric diatoms transitioned as the dominant algae alongside Chlorophyta (i.e. green algae). Improvements to water quality associated with declining external nutrient loads were most evident at Milton as the reservoir exhibited no visible signs of cyanobacterial blooms throughout all of 2024. Analysis revealed that cyanobacteria were present throughout the year, particularly during peak summer months. However, during months when cyanobacteria dominated the algal population, total biovolume did not reach the magnitude of historical blooms. Moreover, an increase in Chlorophyta during June and September indicates a declining contribution of cyanobacteria to relative community abundance throughout the growing season.

As the Barr-Milton TMDL aims to reduce nutrient loads to address pH and DO exceedances, reducing cyanobacterial blooms is a key element within that process. The annual recurrence of severe, long-lasting blooms at Barr and Milton can negatively impact the reservoirs' classified uses while posing a potential threat to public health, ecosystems, and economies. Given that blooms generally coincide with peak months for recreation, preventative measures to protect public health often result in limiting recreational activities based on the presence of cyanotoxins. Unfortunately, cyanotoxin testing has disadvantages as it can be costly, labor intensive, and yield delayed turnaround times or inaccuracies depending upon the method applied.

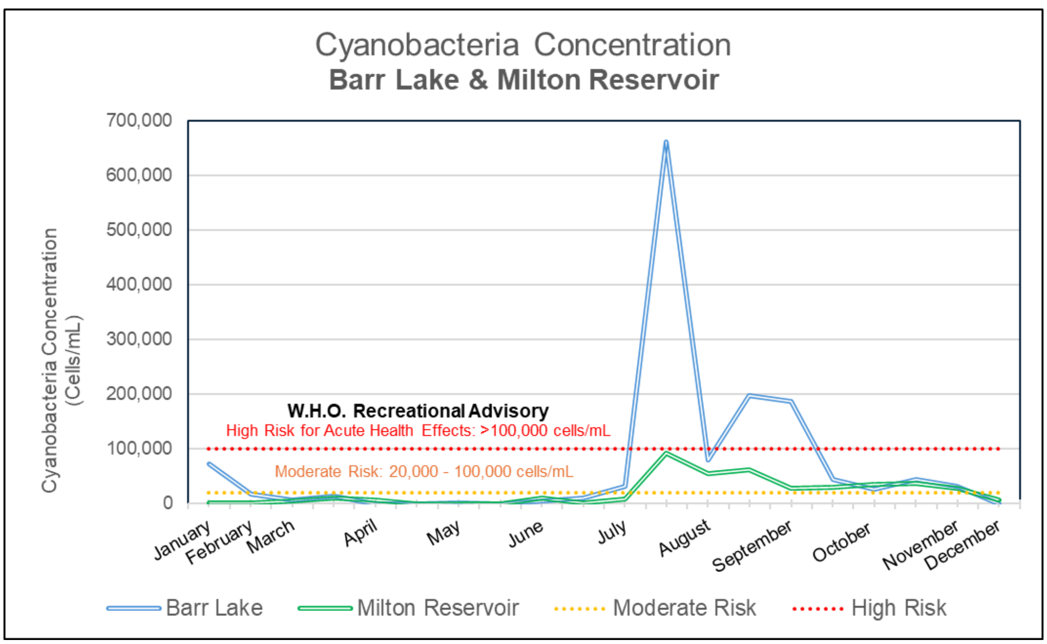


Figure 49. Cyanobacteria cell concentration with reference to W.H.O. Recreational Advisory Guidelines (2003)

Metro's monitoring program estimates cyanobacteria cell densities using flow cytometry in conjunction with microscopy to support monitoring of Barr and Milton which may inform recreational managers or help prompt toxin analysis. The three genera dominating Barr's July to September bloom were *Aphanizomenon, Microcystis*, and *Dolichospermum*. All three of these genera are known for their potential to produce cyanotoxins, although toxicity may vary depending upon environmental factors and some individuals among these genera may be non-toxin producing. Regardless of uncertainty, it is generally recognized that adverse risk to public health increases as cell densities of potentially toxigenic cyanobacteria proliferate. According to advisory guidelines established by the World Health Organization (WHO) and recommended by the Environmental Protection Agency (EPA), Barr Lake posed a high risk for acute health effects during three sampling events across July, August, and September (i.e., >100,000 cells/mL) (Figure 50). All other sampling occurrences between July and November were designated as moderate risk (i.e., 20,000 – 100,000 cells/mL), in addition to the one sampling event in January. Milton remained within the moderate risk category from late July to November, never exceeding the high-risk threshold. The state of Colorado does not have criteria for cyanobacteria cell concentrations, but does provide advisory guidelines for cyanotoxin concentrations.

The link between phytoplankton and zooplankton is key to pelagic food webs. Phytoplankton are the base of aquatic ecosystems while zooplankton feed on algae, bridging the connection and transfer of energy to higher trophic levels such as aquatic insects, fish, and beyond. In addition to phytoplankton, zooplankton are analyzed for their overall community distribution and abundance. Zooplankton are collected by performing a vertical tow of the water column (i.e., 1-m above bottom to water surface) using a Wisconsin tow net. A complete water column tow is necessary as zooplankton migrate diurnally, swimming to greater depths during the day to avoid predation before returning to the surface at night to graze on algae.

Rotifers dominated the zooplankton population in Barr for the first few months of the year (Figure 52). Rotifers are small-bodied filter feeders which tend to feed on small particles at lower rates and serve as a key food source for larger zooplankton. Food sources (i.e., phytoplankton) were lower quality in January and February due to cyanobacterial abundance, although rotifers have been shown to tolerate and even graze on cyanobacteria along with the genus Bosmina (Fulton & Paerl, 1988; Harris et al., 2024). Bosmina are smaller-bodied Cladocerans which prefer nutritious Chlorophyta, but can tolerate Cyanophyta blooms due to their ability to switch between selective feeding and generalist feeding. Bosmina were present in Barr in January and February.

In Barr, the zooplankton population was highest during the beginning of the year (Figure 51), peaking in early April when food quality and availability were highest with phytoplankton dominated by Cryptophyta and Chlorophyta. Quality food availability triggered the spring clearing phase of algae beginning in April, which was facilitated by a slight increase in the Daphnia population and a rise in copepods. Daphnia are large-bodied, generalist feeders with the greatest capacity to consume and clear algae from the water column. Copepods are microscopic freshwater crustaceans including Cyclopoids, Calanoids, and their juvenile form, Nauplii. Relative to Daphnia, they are small-bodied, selective grazers.

The clearing phase continued through June, followed by the major cyanobacteria bloom starting in July and lasting until September. Although Daphnia have a competitive advantage given their ability to consume larger particles, their inability to graze selectively can contribute to their population decline with long-term Cyanophyta abundance. Cyanophyta are nutritionally poor due to their lack of essential lipids and production of cyanotoxins. When Daphnia are unable to adapt to toxicity, poor nutrition and ingestion of toxins are the main cause of their decline. As a result, the Daphnia population quickly died off in July and selective feeders took over (i.e., copepods, rotifers, Bosmina) as Cyanophyta persisted. These zooplankton use chemosensory detection to selectively graze on nutritious particles and effectively reject cyanobacteria (Hansen et al., 1997). The total zooplankton population experienced a slight rebound in early August due to a brief decline in Cyanophyta, but tolerant Bosmina regained dominance with another peak in Cyanophyta. As diatoms transitioned into dominance in October, zooplankton diversity improved by December with all six groups co-existing amongst a low overall population size.

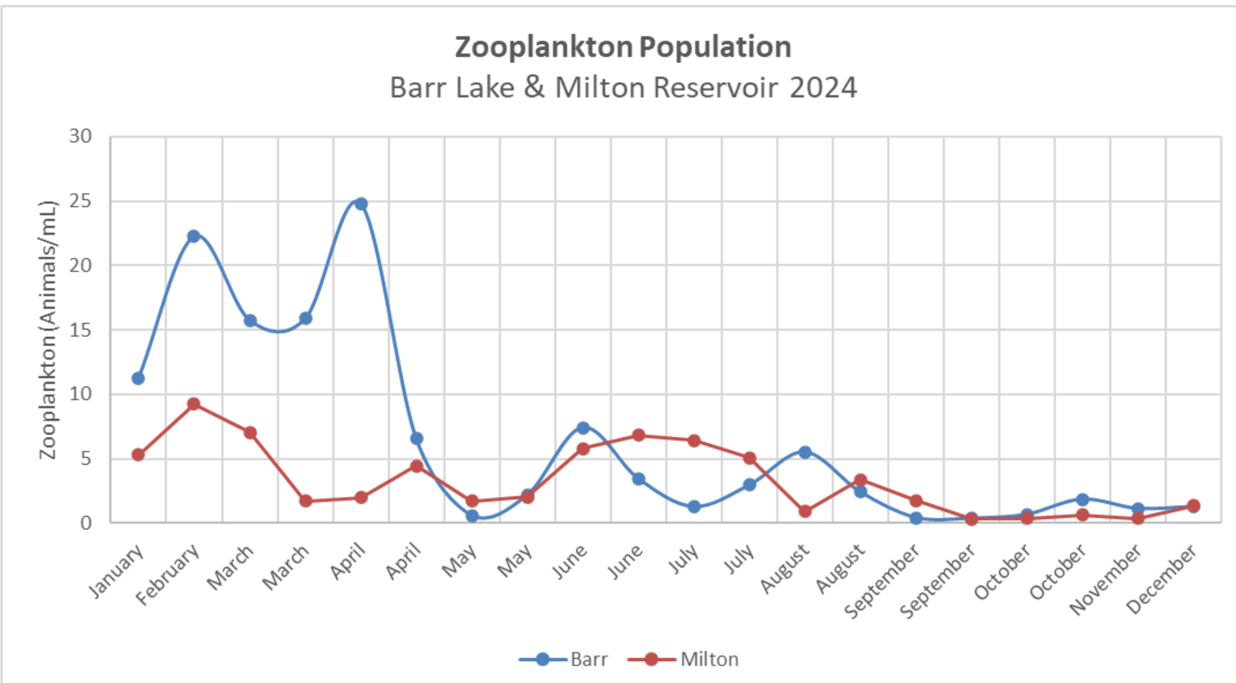


Figure 50. Zooplankton concentration reflecting overall population

Milton began the year with lower phytoplankton productivity relative to Barr, and thus, a less dense zooplankton population (Figure 51). However, despite relatively lower food quantity, the availability of nutrient-rich Cryptophyta and Chlorophyta supported a more even distribution among the six zooplankton groups (Figure 52). Water clarity improved with a rise in Daphnia in April, marking the spring clearing phase through mid-June. The effects of the short-lived, low magnitude bloom in late July were observed in early August as the overall population dropped, and Daphnia disappeared alongside an increase in selective grazers. By late August, the Daphnia population had rebounded. Cyanophyta maintained a slight dominance for the remainder of the growing season with diatoms and Chlorophyta gradually improving nutrition available to zooplankton before ending the year with a small overall population.

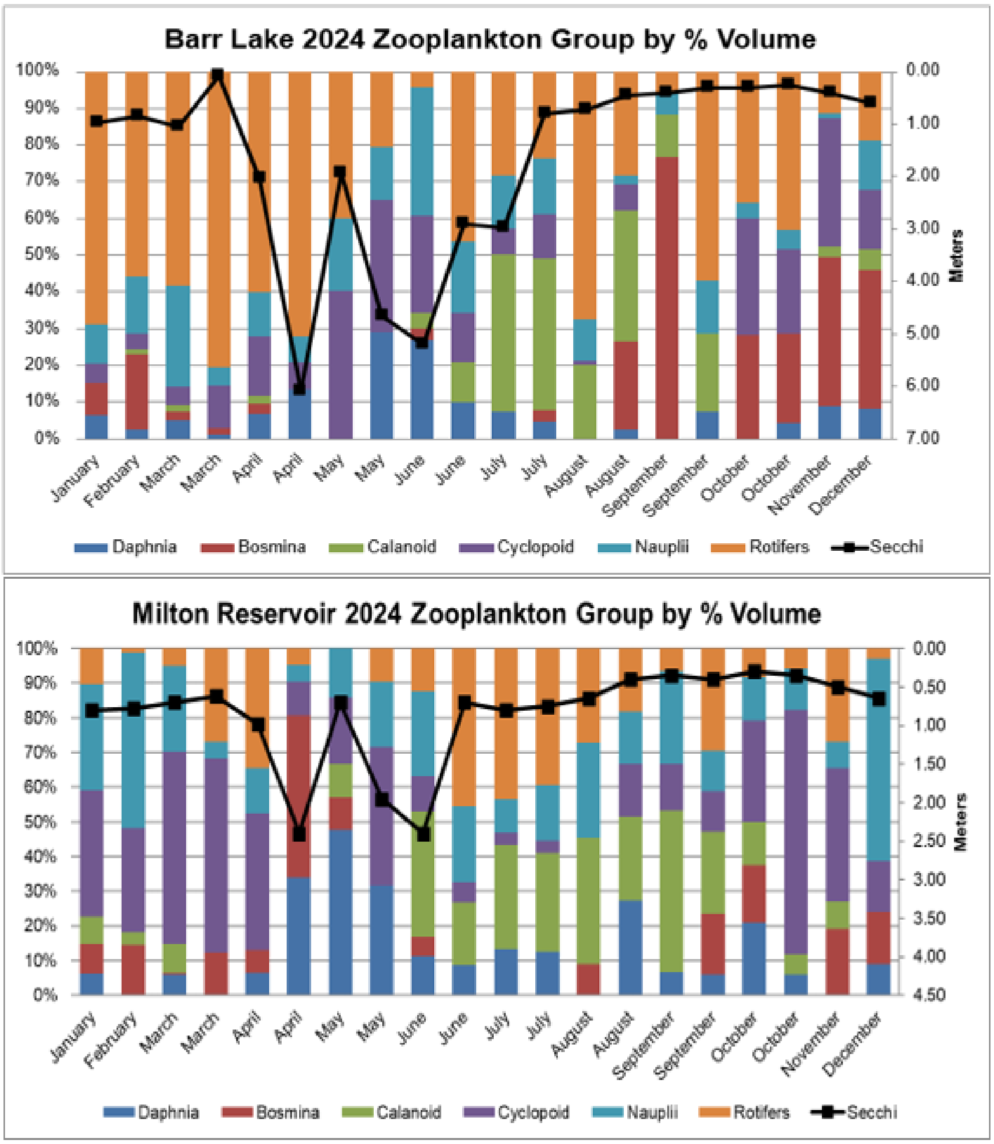


Figure 51. Community relative abundance of major zooplankton groups

Bibliography

Boyer, J. M. (2008). Barr Lake Water Quality Assessment Final Report. Denver, CO, The Barr-Milton Watershed Association.

Boyer, J. M. (2008). Milton Reservoir Water Quality Assessment Final Report. Denver, CO, The Barr-Milton Watershed Association.

Carlson, R. E. (1977). "A trophic state index for lakes." Limnology and Oceanography **22**(2): 361-370.

CDM South Platte River Segment 15 Water Quality: A Historical Perspective.

CDM (2006). South Platte River Segment 15 - Aquatic Life/Habitat Assessment Project (PAR 991). Denver, Colorado.

CDPHE (2010). Aquatic Life Use Attainment: Methodology to Determine Use Attainment for Rivers and Streams Denver, CO.

CDPHE (2010). TMDL Assessment: Cadmium; South Platte River, Segment 15. Denver, CO.

CDPHE (2011). Cadmium Total Maximum Daily Load South Platte River - Segment 15. W. Q. C. Division. Denver.

Fulton, R. S., & Paerl, H. W. (1987). Toxic and inhibitory effects of the blue-green alga Microcystis aeruginosa on herbivorous zooplankton. *Journal of Plankton Research*, *9*(5), 837–855. https://doi.org/10.1093/plankt/9.5.837

Ger, K. A., Urrutia-Cordero, P., Frost, P. C., Hansson, L.-A., Sarnelle, O., Wilson, A. E., & Lürling, M. (2016). The interaction between cyanobacteria and zooplankton in a more eutrophic world. *Harmful Algae*, *54*, 128–144. https://doi.org/10.1016/j.hal.2015.12.005

Hansen, P. J., Bjørnsen, P. K., & Hansen, B. W. (1997). Zooplankton grazing and growth: Scaling within the 2-2,-μm body size range. *Limnology and Oceanography*, *42*(4), 687–704. https://doi.org/10.4319/lo.1997.42.4.0687

Harris, T. D., Reinl, K. L., Azarderakhsh, M., Berger, S. A., Berman, M. C., Bizic, M., Bhattacharya, R., Burnet, S. H., Cianci-Gaskill, J. A., De Senerpont Domis, L. N., Elfferich, I., Ger, K. A., Grossart, H. F., Ibelings, B. W., Ionescu, D., Kouhanestani, Z. M., Mauch, J., McElarney, Y. R., Nava, V., Zhan, Q. (2024). What makes a cyanobacterial bloom disappear? A review of the abiotic and biotic cyanobacterial bloom loss factors. *Harmful Algae*, *133*, 102599. https://doi.org/10.1016/j.hal.2024.102599

Lewis, W. M. J. and J. H. J. McCutchan (2013). Studies of Groundwater in Support of South Platte Water Quality Modeling.

Napiórkowska-Krzebietke, A., & Łuczyñski, M. (2022). Can the elimination of cyanobacteria by micro-sieving be an innovative lake purity improvement method? *Fisheries & Aquatic Life, 30*(4), 184-191. https://doi.org/10.2478/aopf-2022-0017

Pasbrig, C.A., Koupal, K.D., Schainost, S., Hoback, W.W., 2012. Changes in range-wide distribution of plains topminnow Fundulus sciadicus. Endanger. Species Res. 16, 235–247. https://doi.org/10.3354/esr00400

Pflieger, W. L. (1997). The Fishes of Missouri. Jefferson City, MO, Conservation Commission of the State of Missouri.

Schumann, D., Hoback, W., Koupal, K., 2015. Complex interactions between native and invasive species: investigating the differential displacement of two topminnows native to Nebraska. Aquat. Invasions 10, 339–346.

Wetzel, R. G. (1983). Limnology. Philidelphia, PA, Saunders College Publishing.

Woodling, J. (1985). Colorado's Little Fish. Denver, CO, Colorado Division of Wildlife.

WHO. 2003. Guidelines for Safe Recreational Water Environments: Volume 1: Coastal and Fresh Waters. World Health Organization.

Glossary

303(d) list – references the section of the Clean Water Act that directs the impairment of waterbodies

acute – a standard typically based on the value not to be exceeded by the concentration of a single sample or the calculation of samples collected in a one-day period, designed to address the toxic effects of a single exposure or multiple exposures in a short space of time

benthic macroinvertebrates - small animals living among the sediments and stones on the bottom of streams, rivers and lakes.

chlorophyll *a* – a specific form of chlorophyll used in oxygenic photosynthesis, typically used as a surrogate for algal presence

chronic – a standard typically based on the value not to be exceeded by the concentration of a single sample or the calculation of samples collected in a thirty-day period, designed to address toxic effects after continuous or repeated exposure

denitrification - a microbially facilitated process of nitrate reduction (performed by a large group of heterotrophic facultative anaerobic bacteria) that may ultimately produce molecular nitrogen through a series of intermediate gaseous nitrogen oxide products

dimictic – lakes that mix from the surface to bottom twice each year, during the summer they are thermally stratified and can be divided into an epilimnion and hypolimnion

epifaunal substrate – the variety of natural structures in the stream, such as cobble, large rocks, fallen trees, logs, branches and undercut banks.

epilimnion (epilimnetic) - the water layer overlying the thermocline of a lake (typically warmer)

eutrophic – a lake or stream that is rich in organic and mineral nutrients and supporting an abundant plant life, which in the process of decaying depletes the oxygen supply for animal life (a state in Carlson's trophic state index (TSI))

hypereutrophic – a lake or stream that is very nutrient rice, characterized by severe nuisance algal blooms and low transparency (a state in Carlson's trophic state index (TSI))

hypolimnion (hypolimnetic) - the part of a lake below the thermocline made up of water that is stagnant and of essentially uniform temperature except during the period of overturn (typically colder)

MDL – the minimum concentration of an analyte (substance) that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero as determined by the procedure. The MDL is based on the specific method and instrumentation used in the analysis

nitrification - the biological oxidation of ammonia with oxygen, then into ammonium, then into nitrite followed by the oxidation of these nitrites into nitrates

oligotrophic – a lake or stream that is poor in nutrients and plant life and rich in oxygen (a state in Carlson's trophic state index (TSI))

phytoplankton – flora of freely floating, often minute organisms that drift with water currents

polymictic – lakes that are too shallow to develop thermal stratification

riverine – of, relating to, formed in, living in, or growing in rivers and streams

thermocline – a horizontal plane across a lake at the depth of the most rapid vertical change in temperature and density in a stratified lake

un-ionized ammonia – NH_3, the form of ammonia that is toxic to aquatic life, toxicity depends on both temperature and pH of the water

zooplankton - small floating or weakly swimming animals that drift with water currents

Appendix 1: Metal Abbreviations

Ag	Silver
As	Arsenic
Be	Beryllium
Ca	Calcium
Cd	Cadmium
Cr	Chromium
Cu	Copper
Fe	Iron
K	Potassium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
Ni	Nickel
Pb	Lead
S	Sulfur
Sb	Antimony
Se	Selenium
Zn	Zinc

Appendix 2: Metro Laboratory Method Detection Limits (MDL)

Constituent	Unit	Lab Method	2023
Alkalinity, Tot., Man.	mg/L	SM2320B-97 21ed	20
Ammonia Nitrogen, AA	mg/L	EPA 350.1 rev2	0.01
Antimony, Tot.	ug/L	EPA 200.8 rev5.4	0.2
Arsenic, Tot.	ug/L	EPA 200.8 rev5.4	0.2
Beryllium, Tot.	ug/L	EPA 200.8 rev5.4	0.05
BOD, 5-Day	mg/L	SM5210B-01 21ed	0
Cadmium, Diss.	ug/L	EPA 200.8 rev5.4	0.02
Cadmium, Tot.	ug/L	EPA 200.8 rev5.4	0.1
Calcium, Diss.	mg/L	EPA 200.7 rev4.4	0.5
Calcium, Tot.	mg/L	EPA 200.7 rev4.4	0.5
Carbon, Sol., Organic	mg/L	ASTM D7573-09	1
CBOD, 5-Day	mg/L	SM5210B-01 21ed	0
Chloride, AA	mg/L	SM4500CL E 20ed	5
Chromium, Diss.	ug/L	EPA 200.8 rev5.4	0.02
Chromium, Tot.	ug/L	EPA 200.8 rev5.4	0.5
Conductivity, Field Measure	umho/cm	EPA 120.1	0.5
Copper, Diss.	ug/L	EPA 200.8 rev5.4	0.5
Copper, Tot.	ug/L	EPA 200.8 rev5.4	0.5
DO, Field Measure	mg/L	EPA 360.1	0.1
E-Coli, MPN Idexx Colilert	EC/100ml	SM9223B 20ed	1
Hardness, as CaCO3 (calc)	mg/L	SM 2340B 18ed	5
Iron, Diss.	mg/L	EPA 200.7 rev4.4	0.02
Iron, Tot.	mg/L	EPA 200.7 rev4.4	0.02
Lead, Diss.	ug/L	EPA 200.8 rev5.4	0.2
Lead, Tot.	ug/L	EPA 200.8 rev5.4	0.2
Magnesium, Diss.	mg/L	EPA 200.7 rev4.4	0.1
Magnesium, Tot.	mg/L	EPA 200.7 rev4.4	0.1
Manganese, Diss.	ug/L	EPA 200.8 rev5.4	0.5
Manganese, Tot.	ug/L	EPA 200.8 rev5.4	0.5
Molybdenum, Tot.	ug/L	EPA 200.8 rev5.4	0.03
Nickel, Diss.	ug/L	EPA 200.8 rev5.4	0.5
Nickel, Tot.	ug/L	EPA 200.8 rev5.4	0.5
Nitrite Nitrogen, AA	mg/L	EPA 353.2	0.02
NO3+NO2 as N - Cd Red.	mg/L	EPA 353.2 rev2	0.02
Orthophosphate as P, AA	mg/L	EPA 365.1 mod	0.03
pH, Field Measure	STD	EPA 150.1	0.1
Phosphorus, Tot., AA	mg/L	SM 4500-P-H 21ed	0.01

Potassium, Diss.	mg/L	EPA 200.7 rev4.4	0.5
Potassium, Tot.	mg/L	EPA 200.7 rev4.4	0.5
Selenium, Diss.	ug/L	EPA 200.8 rev5.4	0.5
Selenium, Tot.	ug/L	EPA 200.8 rev5.4	0.5
Silver, Diss.	ug/L	EPA 200.8 rev5.4	0.2
Silver, Tot.	ug/L	EPA 200.8 rev5.4	0.2
Sodium, Diss.	mg/L	EPA 200.7 rev4.4	1
Sodium, Tot.	mg/L	EPA 200.7 rev4.4	1
Solids, Tot. Dissolved	mg/L	SM2540C 20ed mod	50
Sulfate, AA	mg/L	SM4500-SO4	10
Temperature, Field Measure	Deg C	EPA 170.1	0.5
TKN, High Level, AA	mg/L	EPA 350.1	0.1
Total Suspended Solids	mg/L	USGS I-3765-85 m	1
Turbidity, Field Measure	NTU	EPA 180.1	0.1
Zinc, Diss.	ug/L	EPA 200.8 rev5.4	0.02
Zinc, Tot.	ug/L	EPA 200.8 rev5.4	0.02

Appendix 3: 2024 Groundwater Summary Statistics

Parameter	Sample Fraction	Unit	Count	Minimum	Maximum	Mean
Alkalinity total	Total	mg/L	67	129	337	205.66
Aluminum	Dissolved	ug/L	67	0.7	764	20.76
Aluminum	Total	ug/L	67	0	68800	1600.31
Ammonia-nitrogen	Total	mg/L	67	0	1.96	0.2
Antimony	Total	ug/L	67	0	1.9	0.69
Arsenic	Total	ug/L	67	0.6	13.4	2.4
Beryllium	Total	ug/L	67	0	7.02	0.15
Cadmium	Dissolved	ug/L	67	0	32.4	1.35
Cadmium	Total	ug/L	67	0	76.3	2.76
Calcium	Dissolved	mg/L	67	53.6	177	110.28
Calcium	Total	mg/L	67	54.6	209	112.36
Chromium	Dissolved	ug/L	67	0	1.1	0.14
Chromium	Total	ug/L	67	0	67.5	1.7
Conductivity	Total	umho/cm	67	917	2910	1668.19
Copper	Dissolved	ug/L	67	0	21.7	3.19
Copper	Total	ug/L	67	0	120	6.81
Dissolved oxygen (DO)		mg/L	67	0.3	8.5	2.43
Inorganic nitrogen (NO5)		mg/L	67	0	19.5	1.94
Inorganic nitrogen (TIN)	Total	mg/L	67	0.01	19.5	2.14
Iron	Dissolved	mg/L	67	0	3	0.41
Iron	Total	mg/L	67	0	86.2	2.6
Kjeldahl nitrogen		mg/L	67	0	2.3	0.5
Lead	Dissolved	ug/L	67	0	3	0.14
Lead	Total	ug/L	67	0	111	2.93
Magnesium	Dissolved	mg/L	67	11.8	41.6	24.94
Magnesium	Total	mg/L	67	11.5	43.1	25.86
Manganese	Dissolved	ug/L	67	0.7	4550	770.7
Manganese	Total	ug/L	67	2.4	7580	1201.91
Molybdenum	Total	ug/L	67	2.1	18.9	7.33
Nickel	Dissolved	ug/L	67	0.8	6.1	3.26
Nickel	Total	ug/L	67	0.9	61.4	4.96
Nitrite	Total	mg/L	66	0	0.26	0.05
Nitrogen	Total	mg/L	66	0.1	19.5	2.46
Organic Carbon	Total	mg/L	66	2	9	4.29
pH			67	6.68	8.12	7.25

Phosphorus	Dissolved	mg/L	67	0.03	1.73	0.34
Phosphorus	Total	mg/L	67	0.04	4.51	0.48
Potassium	Dissolved	mg/L	67	3.9	16.7	9.83
Potassium	Total	mg/L	67	4.3	17.7	10.2
Selenium	Dissolved	ug/L	67	0	26	4.04
Selenium	Total	ug/L	67	0	19.4	3.28
Silver	Dissolved	ug/L	67	0	0.45	0.01
Silver	Total	ug/L	67	0	0.4	0.02
Sodium	Dissolved	mg/L	67	106	323	172.07
Sodium	Total	mg/L	67	110	346	177.79
Temperature, water		deg C	67	6.7	20.4	14.39
Total suspended solids		mg/L	67	0	928	42.03
Turbidity		NTU	67	0	4691	80.57
Zinc	Dissolved	ug/L	67	0	136	14.35
Zinc	Total	ug/L	67	0	299	24.6