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Cherry Creek Reservoir 2014 Water Year Aquatic Biological Nutrient Monitoring and Pollutant Reduction Facilities Monitoring

Submitted to:
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List of Acronyms & Abbreviations

ac	acres
ac-ft	acre-feet
ANOVA	analysis of variance
APHA	American Public Health Association
CCBWQA	Cherry Creek Basin Water Quality Authority
CDPHE	Colorado Department of Public Health and Environment
CEC	Chadwick Ecological Consultants, Inc.
cfs	cubic feet per second
CPW	Colorado Parks and Wildlife
CWQCC	Colorado Water Quality Control Commission
CY	calendar year
DM	daily maximum
DRCOG	Denver Regional Council of Governments
ed.(s)	editor(s)
ft	feet
GEI	GEI Consultants, Inc.
ha	hectare
JCHA	John C. Halepaska & Associates, Inc.
KAPA	Denver/Centennial Airport
km	kilometer
lb	pound
m	meter
mg	milligram
mg/L	milligrams per liter
mL	milliliter
mo	month
mph	miles per hour
mV	millivolt
MWAT	maximum weekly average temperature
ORP	oxidation reduction potential
PAR	photosynthetically active radiation
PRF	pollutant reduction facilities
Reservoir	Cherry Creek Reservoir
TDP	total dissolved phosphorus
TMAL	total maximum annual load
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
SRP	soluble reactive phosphorus
µg/L	micrograms per liter
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WY	water year
yr	year

Executive Summary

The purpose of this report is to present the 2014 water year (WY) data collected by GEI Consultants, Inc. (GEI), on behalf of the Cherry Creek Basin Water Quality Authority (CCBWQA). The data were collected to evaluate Cherry Creek Reservoir (Reservoir) water quality conditions with respect to selected standards identified in Regulations No. 31 & 38 and goals identified in the Cherry Creek Reservoir Control Regulation No. 72, as well as to evaluate the effectiveness of the CCBWQA's pollutant reduction facilities (PRFs) on Cottonwood Creek and other stream reclamation projects within the Cherry Creek Basin. Additionally, this report summarizes data collected during special studies such as cyanotoxin monitoring as well as trends observed in the long-term monitoring data collected on behalf of the CCBWQA since 1987.

ES 1.1 Temperature and Dissolved Oxygen

Water temperatures during routine profile measurements in the Reservoir ranged from 1.1°C immediately beneath the ice cover in mid-February 2014 to 24.5°C at the surface in mid July 2014. Temperature profile data showed a fairly well mixed reservoir in early spring with increasing stratification starting in mid-May 2014.

From October 2013 to mid-May 2014, the dissolved oxygen concentrations remained greater than 5 milligrams per liter (mg/L) throughout the water column. From mid-May through September, the deeper 5-7 m layers and water/sediment interface were consistently less than 5 mg/L. The dissolved oxygen standard for warm water lakes is 5.0 mg/L and is applicable to the 0.5 m to 2.0 m layers of the Reservoir. However, when summer water temperatures increase, the deeper, cooler water becomes more important for fish refuge and if dissolved oxygen conditions are less than 5.0 mg/L, the Reservoir conditions become less conducive for fish. The Reservoir exhibited periodic peaks in dissolved oxygen concentrations near the surface which were indicative of algal production and the release of oxygen during photosynthesis, as well as influence from wind-driven mixing events.

Reservoir profiles were also evaluated to determine the attainment of the dissolved oxygen standard. Over the course of the monitoring year, 100 vertical water column profiles were collected in the Reservoir. For each profile, the 1 m and 2 m dissolved oxygen values were averaged and evaluated for attainment of the Class 1 Warm Water table value standard (5 mg/L) for lakes and reservoirs that are greater than 5 m deep (CDPHE 2011). The Reservoir was in attainment of the dissolved oxygen standard for 99 of 100 profiles. The single exceedance occurred on August 26th, 2014 following a storm event when dissolved oxygen concentrations averaged 4.2 mg/L at Site CCR-3. During the July to September growing season, the average dissolved oxygen concentration in the 1m to 2m layer was 7.8 mg/L for all vertical profiles.

ES 1.2 Total Phosphorous in Cherry Creek Reservoir

During the 2014 WY, the photic zone mean concentration of total phosphorus ranged from 40 to 130 µg/L with an overall water year mean of 86 µg/L. The seasonal (July through September) photic zone mean concentrations ranged from 40 to 120 µg/L (Figure 17), with a seasonal mean of 87 µg/L which is equal to the long-term median total phosphorus concentration for the Reservoir.

ES 1.3 Chlorophyll *a*

The annual pattern of chlorophyll *a* concentrations was quite variable throughout the 2014 WY ranging from 6.1 µg/L to 43.3 µg/L with a 2014 WY mean chlorophyll *a* concentration of 23.4 µg/L. The July through September seasonal mean chlorophyll *a* concentration was 24.4 µg/L, with a peak seasonal reservoir mean concentration of 34.8 µg/L. The highest observed concentration occurred in February under the ice cover, while the lowest observed concentration occurred in late June. However, the lowest observed chlorophyll *a* concentration was preceded by a nuisance cyanobacteria bloom (*Anabaena flos-aquae*) that resulted in 37.5 µg/L of chlorophyll *a*. A wind-driven mixing event caused the cyanobacteria population to crash just prior to sampling the Reservoir on June 24th. Following the cyanobacteria population crash in late June, a mix of beneficial algae (cryptophytes, diatoms, and green algae) grew well and resulted in high chlorophyll *a* concentrations (35 µg/L) during July. Based solely on chlorophyll *a* concentrations, the June and July events are the nearly identical, yet different algae assemblages were responsible for the same level of chlorophyll *a*. Chlorophyll *a* concentrations averaged 19.3 µg/L in late summer (August and September).

ES 1.4 Phytoplankton

In 2014, the destratification system was not operated to evaluate the response of the algae assemblages and to establish conditions without aeration under the current phytoplankton analyst. Based on the calendar year, the phytoplankton assemblage was dominated in terms of density by chlorophytes (green algae, 47%), with cryptomonads and diatoms being the next most abundant taxonomic groups at 30% and 16%, respectively. In 2014, the relative percent density of cyanobacteria was 2.2%. When the size (e.g., biovolume) of each alga is considered, green algae were the most dominant algal group (28%) observed over the course of the year, followed by cryptophytes (22%) and diatoms (17%). Both the dinoflagellates and cyanobacteria accounted for approximately 15% of the total algal biovolume. Patterns in algal biovolume show typical seasonal succession patterns of many temperate lakes and reservoirs with cryptomonads and diatoms being most abundant in the spring, while green algae were abundant throughout the year and comprising a larger component of the assemblage in winter and fall. The Reservoir experienced a nuisance cyanobacteria bloom that began in late May and peaked in early June. Multiple samples were collected from different locations in the Reservoir to document the abundance of cyanobacteria (*Anabaena flos-aquae*) which comprised between 41% and 84% of the total algal biovolume during the bloom event. Other cyanobacteria species (*Aphanizomenon flos-aquae* and *Aphanothece* sp. - picoplankton) were observed from late May through early August, but their biovolume accounted for less than 2.6% and 0.1% of the total algal biovolume, respectively.

ES 1.5 Zooplankton

Zooplankton density ranged from 139 organisms/L in late March to 1,239 organisms/mL in early July 2014. Over the WY, the zooplankton assemblage contained a total of nine zooplankton crustacean species—seven cladocerans and two copepods with immature copepodids and nauplius—and nine species of rotifers were collected during the 15 sampling events. There was one species that was collected during all sampling events: a relatively smaller cladoceran (*Bosmina longirostris*). The immature copepods (copepodids and nauplius) were also observed during all 15 sampling events. The copepod (*Diacyclops thomasi*) was collected at 14 of the 15 sampling events. *Bosmina longirostris* have been found to be the dominant cladoceran in other eutrophic lakes. One rotifer (*Keratella cochlearis*) was collected during 12 of the 15 sampling events and one cladoceran (*Daphnia sp.*) was collected during 11 of the 15 sampling events. While the zooplankton assemblage showed some response to the algal assemblages and biomass, there is no correlation between the zooplankton density and chlorophyll *a* (surrogate for algal biomass). Similarly, there was no correlation between zooplankton density and algal density or algal biomass.

ES 1.6 Total Phosphorous in Streams

The median annual total phosphorus concentration for base flow conditions ranged from 36 µg/L at Site CT-P1 to 340 µg/L at Site MCM-1. At the two Reservoir inflow sites CC-10 and CT-2, the median annual total phosphorus concentrations were 197 µg/L and 48 µg/L, respectively. The median annual total phosphorus concentration for the Reservoir outflow was 98 µg/L. The seasonal (July through September) base flow total phosphorous concentrations were greater than the annual median concentration at these three sites. The seasonal median concentration of total phosphorus ranged from 49 µg/L at Site CT-P1 to 500 µg/L at Site MCM-1. At sites where both base flow and storm flow samples are collected, the storm flow total phosphorous concentrations were also greater than concentrations measured during base flow conditions. The annual median storm flow total phosphorous concentrations ranged from 97 µg/L at Site CT-2 to 472 µg/L at Site CC-10.

ES 1.7 Mass Balance/Net Loading of Phosphorous to the Reservoir

The U.S. Army Corps of Engineers (USACE) calculated inflow to the Reservoir was 14,352 ac-ft/yr, while the GEI measured stream inflow was 14,181 ac-ft/yr. Following the water mass balance and normalization process to account for different inflow methodologies, the inflow from both Cherry Creek and Cottonwood Creek accounted for 6,076 lbs of total phosphorus loading to the Reservoir during the 2014 WY. The alluvial inflow contributed 1,033 lbs of phosphorus, with precipitation events contributing 310 lbs to the Reservoir. The external total phosphorus load to the Reservoir was 7,419 lbs. The Reservoir export total phosphorus load was 4,408 lbs; therefore, the Reservoir retained 3,011 lbs of the total external load.

The flow-weighted total phosphorus concentration for all external sources of inflow to the Reservoir was 190 µg/L and the flow-weighted export concentration for the Reservoir is 119 µg/L. The difference of 71 µg/L was retained by the Reservoir.

ES 1.8 Pollutant Reduction Facility Effectiveness

The Cottonwood Creek Peoria Pond continues to be effective in reducing the amount of total suspended solids and total phosphorus as stream flow passes through this system. The total suspended solids were reduced by approximately 41% in 2014, with the long-term average reduction of 28%. The flow-weighted total phosphorus concentration upstream and downstream of the PRF was 145 µg/L and 135 µg/L, respectively, which indicates efficiency in removing phosphorus from flow. Over the life of the project, the PRF shows approximately an average 18% reduction in the flow-weighted total phosphorus concentration at the downstream site.

The effectiveness of the Cottonwood Creek Perimeter Pond is similar to the upstream PRF and reduced the total suspended solids concentration by approximately 61% in 2014, with the long-term average reduction 32%. The flow-weighted total phosphorus concentration upstream and downstream of the PRF was 112 µg/L and 81 µg/L, respectively, which indicates a high efficiency in removing phosphorus from flow. Over the life of the project, the PRF shows an average 23% reduction in the flow-weighted total phosphorus concentration at the downstream site.

The Cottonwood Creek Stream Reclamation project, between the two PRF ponds, has shown to be very effective in reducing the suspended solids load to the downstream PRF, as well as being effective in reducing the flow-weighted total phosphorus concentration. Since the completion of the project, the combination of these three PRFs (treatment train approach) has effectively reduced the flow-weighted total phosphorus concentration entering the Reservoir, via Cottonwood Creek, from a pre-project WY average of 143 µg/L to a post-project WY average of 74 µg/L, nearly a 50% reduction.

Base flow water quality samples collected from McMurdo Gulch revealed total phosphorous concentrations upstream of current development (MCM-1) ranging from 266 to 564 µg/L with a WY median concentration of 340 µg/L. Total phosphorous concentrations downstream of the stream reclamation reach (MCM-2) and development were less, ranging from 177 to 335 µg/L with a WY median concentration of 300 µg/L. Total suspended solids concentrations were slightly greater at the downstream location with a WY median total suspended solids concentration of 11.6 mg/L, as compared to 5.7 mg/L at the upstream site.

ES 1.9 Special Study: Cyanotoxin Monitoring

Owing to the CCBWQA's decision to not operate the destratification system in 2014, there were concerns that nuisance cyanobacteria would proliferate in the absence of aeration, and potentially impact the recreational beneficial use. Cyanobacteria are often associated with nuisance algal blooms, and can produce toxins that inhibit growth of competing algae, inhibit zooplankton grazing, and potentially affect recreational use. Therefore, cyanotoxin analyses were initiated at multiple locations the Reservoir. Coincidentally, while the CCBWQA was developing a sampling regime for cyanotoxin analyses, the Reservoir began showing signs of a cyanobacteria bloom in early June 2014. On June 10th filamentous cyanobacteria was visible on the surface at CCR-2 and a cyanotoxin sample was collected. Based on the World Health Organization (WHO) microcystins thresholds for recreational water contact, there was a moderate human health risk at CCR-2 on June 10th (10 µg/L ELISA and 9.3 µg/L LC-MS). During the June 13th sampling event, cyanotoxin samples were collected at CCR-2, the Marina, and the Swim Beach. Microcystins levels were <1.0 µg/L for all of these samples and posed a very low human risk. On June 17th, the cyanobacteria bloom was wind swept along the face of dam and presented a high risk to human health, based on WHO thresholds, because the microcystins concentration was 24 µg/L ELISA (15.3 LC-MS).

Beginning on June 24th, two cyanotoxin samples were collected on a weekly basis (photic composite sample from CCR-1, CCR-2, and CCR-3), and a surface grab sample at the Swim Beach. A total of 20 out of the 27 samples were recorded as a non-detect for cyanotoxins. The remaining 7 samples were all ≤ 0.29 µg/L for microcystins which indicated a very low risk to human health for the remainder of the summer, including the samples collected at the swim beach.

ES 1.10 Special Study: Organic Carbon Monitoring

For reservoir model development purposes, total organic carbon (TOC) and dissolved organic carbon (DOC) concentrations were measured in the Reservoir, and in the Cherry Creek and Cottonwood Inflows. The organic carbon data was used to develop relationships with other water quality parameters to facilitate model development, because in a sense carbon is the currency that the model is based upon. TOC concentrations ranged from 5.7 mg/L to 7.5 mg/L in the photic zone at CCR-2, and DOC content was approximately 82% of the total fraction. In Cherry Creek, TOC concentrations ranged from 3.8 mg/L to 5.2 mg/L, and DOC content was approximately 89% of the total fraction. In Cottonwood Creek, TOC concentrations ranged from 5.7 mg/L to 10 mg/L, and DOC content was approximately 83% of the total fraction.

1. Historical Perspective

An inter-governmental agreement was executed in 1985 by several local governmental entities within the Cherry Creek basin to form the Cherry Creek Basin Water Quality Authority (CCBWQA). The CCBWQA was created for the purpose of coordinating and implementing the investigations necessary to maintain the quality of water resources of the Cherry Creek basin while allowing for further economic development. Based on a clean lakes water study (Denver Regional Council of Governments [DRCOG] 1984), the Colorado Water Quality Control Commission (CWQCC) set standards for phosphorus, and a total maximum daily load (TMDL) for phosphorus. The Reservoir was classified as Class 1 Warm Water for aquatic life, with an in-lake phosphorus standard of 35 micrograms per liter (µg/L) and seasonal mean chlorophyll *a* goal of 15 µg/L. Subsequently, a phosphorus TMDL was prepared for Cherry Creek Reservoir (Reservoir) allocating loads among point sources, background sources, and nonpoint sources with a total maximum annual load (TMAL) of 14,270 pounds (lbs) total phosphorus.

The Cherry Creek Basin Master Plan (DRCOG 1985), approved by the CWQCC in 1985, was adopted in part as the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.0, 5C.C.R.3.8.11). An annual monitoring program (In-Situ, Inc. 1986, as amended, Advanced Sciences, Inc., 1994a and 1994b) was implemented at the end of April 1987 to assist in the assessment of several aspects of the Master Plan. These monitoring studies have included long-term monitoring of: 1) nutrient levels within the Reservoir and from tributary streams during base flows and storm flows; 2) nutrient levels in precipitation; and 3) chlorophyll *a* levels within the Reservoir.

In September 2000, following a hearing before the CWQCC, the standard for Cherry Creek Reservoir (Regulation #38) was changed to a seasonal July to September mean value of 15 µg/L of chlorophyll *a* to be met 9 out of 10 years, with an underlying total phosphorus goal of 40 µg/L, also as a July to September mean value. In addition, the limit for wastewater effluent total phosphorus concentration was set at 50 µg/L, to be met as a 30-day mean value. In May 2001 at the CWQCC hearing, the Control Regulation (#72) was adopted for the Cherry Creek Reservoir, which maintained the annual TMAL of 14,270 lbs/year as part of a phased TMDL for the Reservoir. During the March 2009 Rulemaking Hearing, Regulations 38 and 72 were again refined to reflect the most current feasibility-based chlorophyll *a* standard and flow-weighted inflow total phosphorus goal for Cherry Creek Reservoir. The current chlorophyll *a* standard is 18 µg/L with an exceedance frequency of once in 5 years. The control regulation changed from a phosphorus load-based TMAL to a flow-weighted concentration such that the annual flow-weighted total phosphorus concentration goal is 200 µg/L for all combined sources of inflow to the Reservoir.

From 1993 to 1998, Dr. John Jones of the University of Missouri contributed greatly to the Cherry Creek Reservoir annual monitoring program (Jones 1994 to 1999, 2001), and assisted with the transition of the program to Chadwick Ecological Consultants, Inc. (CEC) in 1994. Results of the aquatic biological and nutrient analyses have been summarized in annual monitoring reports (CEC 1995 to 2006). In 2006, CEC merged with GEI Consultants, Inc. (GEI), and continues to perform the annual monitoring duties of Cherry Creek Reservoir (GEI 2007, 2008b, 2009 to 2013). The present study was designed to continue the characterization of the relationships between nutrient loading (both in-lake and external) and Reservoir productivity. The specific objectives of this annual monitoring study include the following:

- Determine baseflow and stormflow concentrations for nitrogen and phosphorus fractions in tributary inflows, as well as concentrations in Cherry Creek Reservoir and the outflow.
- Determine the hydrological inflows and nutrient loads entering Cherry Creek Reservoir, including Reservoir exports. These data provide the necessary information to calculate flow-weighted nutrient concentrations for the Reservoir.
- Determine biological productivity in Cherry Creek Reservoir, as measured by algal biomass (chlorophyll *a* concentration). In addition, determine species composition of the algal assemblages to characterize the types of algae responsible for chlorophyll *a*, and determine zooplankton species composition to better characterize the plankton community.
- Evaluate relationships between the biological productivity and nutrient concentrations within Cherry Creek Reservoir and total inflows.
- Assess the effectiveness of pollutant reduction facilities (PRFs) on Cottonwood Creek, McMurdo Gulch and Cherry Creek to reduce phosphorus loads into the Reservoir.
- Assess the effectiveness of the destratification system in minimizing periods of thermal stratification, increasing the dissolved oxygen concentrations in the deepest water layers, reducing the internal nutrient release of phosphorus and nitrogen from the sediments, reducing peak and seasonal mean chlorophyll *a* concentrations, and reducing the production of cyanobacteria via vertical mixing.

In 2008, the CCBWQA implemented a new Reservoir destratification management strategy that was designed to increase the circulation of the water column, to promote a greater exchange of dissolved oxygen at the surface layer, and to circulate the reaerated water into the deeper depths of the Reservoir. A goal of this management strategy is to increase the dissolved oxygen concentrations near the water/sediment interface which should help reduce the internal phosphorus loading component of the Reservoir (AMEC 2005). The sediment phosphorus load accumulates over time from external sources, including from the Reservoir, and is geochemically transformed and released when the sediment surface becomes anoxic (Nürnberg and LaZerte 2008). This internal release of phosphorus facilitates the growth of all algae; thus by reducing the internal load, algae growth should be reduced too. In addition, a goal of the design of the destratification system was to vertically mix algae and to disrupt the suitable habitat of large filamentous cyanobacteria which have the ability to regulate their buoyancy, fix atmospheric nitrogen, and rapidly grow at the surface of the Reservoir. In theory, when these design considerations are placed in the context of each other, the destratification system should have reduced chlorophyll *a* concentrations and helped to achieve the site-specific chlorophyll *a* standard while protecting the beneficial uses. However, after operating the destratification system for a period of 6 years, the reservoir appeared to have reached a new state of conditions that was characterized by internal nutrient loading and higher than expected algal biomass (chlorophyll *a*) conditions that resulted in the seasonal mean chlorophyll *a* concentration being exceeded 4 out of the 6 years. In addition, a laboratory change in 2009 resulted in phytoplankton data that was different than historical data which confounded the comparison of algae species composition data. As a result, the destratification system was not operated in 2014 to reassess the phytoplankton community dynamics in the absence of aeration and to better understand whether the destratification system was vertically mixing the algae and disrupting the suitable habitat for large filamentous cyanobacteria. The objectives of the annual monitoring study remained the same as stated above; although two special studies were included to better understand the potential concern for cyanotoxins in the context of beneficial uses and to better understand organic carbon dynamics in the system. The 2014 data will also be used to inform the development of the Reservoir hydrodynamic model.

2. Study Area

Cherry Creek was impounded in 1948 and the dam was completely finished in 1950 by the U.S. Army Corps of Engineers (USACE) to protect the City of Denver from flash floods that originated in the 995 square kilometers (km^2) (385 square miles) drainage basin. The CCBWQA performed a bathymetric survey in November 2013, and the Reservoir surface area was 875 acres (ac) at the multipurpose storage pool elevation of 5,550 feet (ft). The volume of the Reservoir was 13,522 acre-feet (ac-ft). The Reservoir and surrounding state park has also become an important recreational site, providing activities that include fishing, boating, swimming, bicycling, bird watching, and walking.

2.1 Sampling Sites

Sampling during the 2014 WY was routinely conducted at 12 sites, including three sites in Cherry Creek Reservoir, eight sites on tributary streams, and one site on Cherry Creek downstream of the Reservoir (Figures 1 and 2). In addition to these routine monitoring sites, 10 transect sites (D1 to D10) were established from the approximate mid-point of the dam extending perpendicular across the destratification zone in the Reservoir, as well as three continuous temperature logging sites near the routine reservoir monitoring sites. The routine sampling sites are summarized below.

2.1.1 *Cherry Creek Reservoir*

CCR-1 This site is also called the Dam site, and was established in 1987. Site CCR-1 corresponds to the northwest area within the lake (Knowlton and Jones 1993). Sampling was discontinued at this site in 1996 following determination that this site exhibited similar characteristics to the other two sites in this polymictic Reservoir. Sampling recommenced in July 1998 at the request of consultants for Greenwood Village.

CCR-2 This site is also called the Swim Beach site, and was established in 1987. Site CCR-2 corresponds to the northeast area within the lake (Knowlton and Jones 1993).

CCR-3 This site is also called the Inlet site and was established in 1987, corresponding to the south area within the lake (Knowlton and Jones 1993).

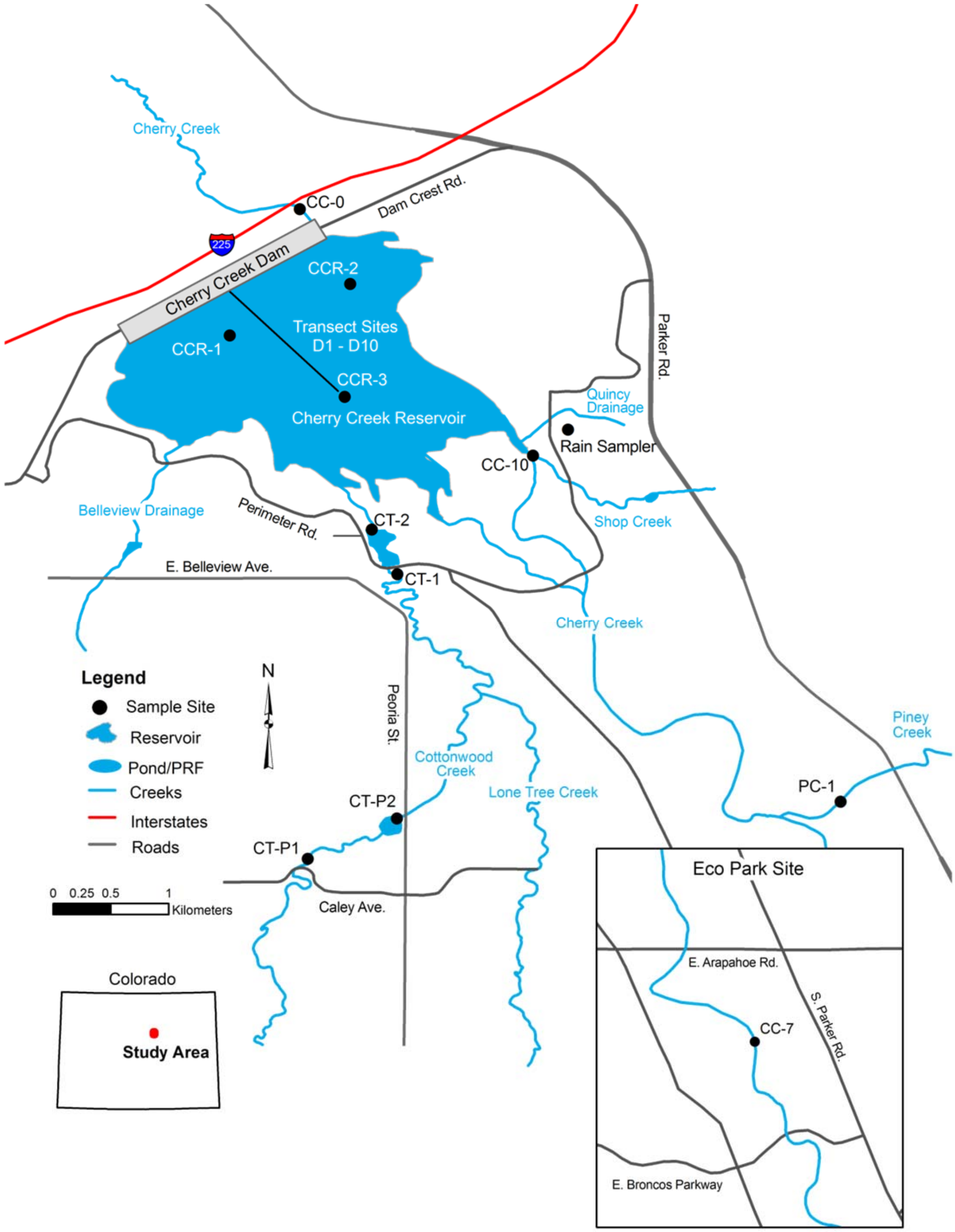

Figure 1: Sampling sites on Cherry Creek Reservoir and selected streams, 2014.

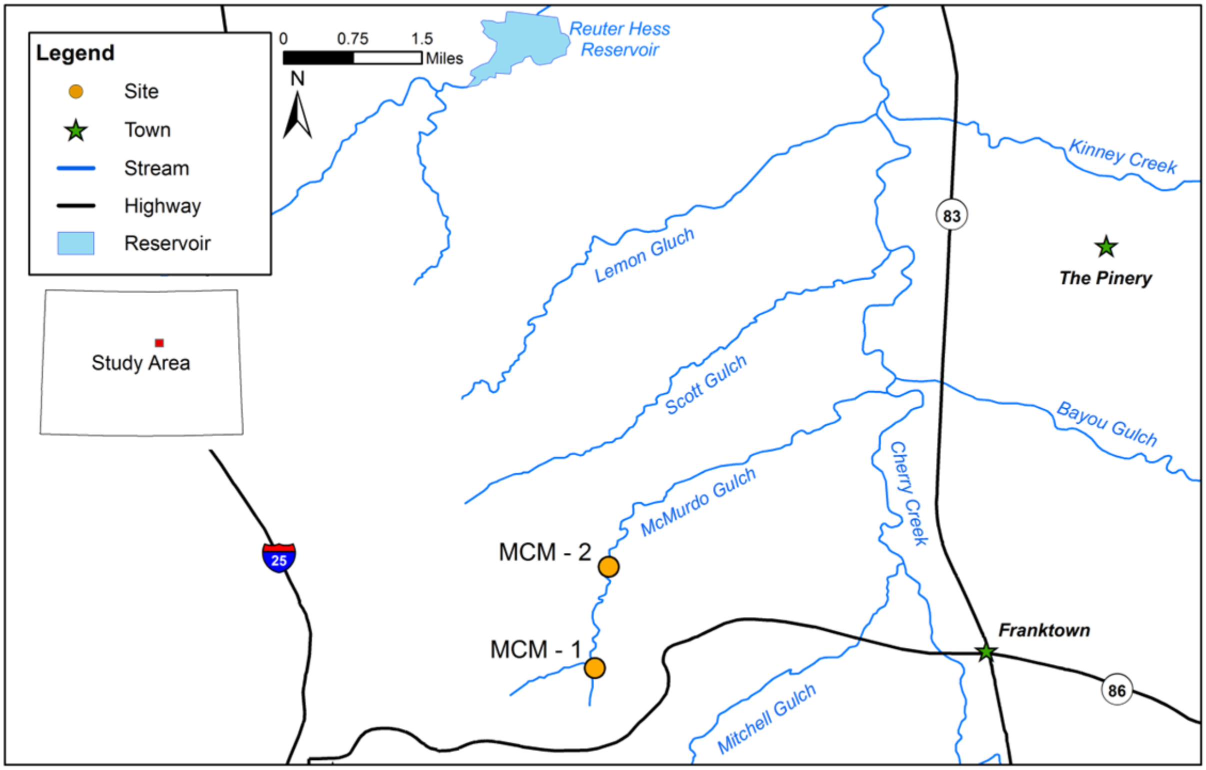

Figure 2: Sampling sites on McMurdo Gulch, 2014.

2.1.2 *Cherry Creek*

CC-7 (EcoPark) This site was established in 2013 on Cherry Creek at the downstream boundary of Cherry Creek Valley Ecological Park (EcoPark). This site is approximately 1.7 kilometers (km) upstream of Arapahoe Road, and serves to monitor water quality conditions downstream of the EcoPark Stream Reclamation Project (PRF). This site also provides more accurate flow estimates in this reach of Cherry Creek.

CC-10 This site was originally established in 1987 on Cherry Creek near the historic U.S. Geological Survey (USGS) Melvin gage, approximately 3.5 km upstream of the Reservoir (roughly due west of the intersection of Parker Road and Orchard Road). This location is in an area of Cherry Creek that frequently becomes dry during summer months as a result of the natural geomorphology and alluvial pumping for domestic water supply (John C. Halepaska & Associates, Inc. [JCHA] 1999 and 2000).

In 1995, this site was relocated farther downstream between the Perimeter Road and the Reservoir, approximately 800 meters (m) upstream of the Reservoir. This site was moved still farther downstream in 1996, just upstream of the confluence with Shop Creek and closer to the Reservoir. In 1999, it was moved below the confluence with Shop Creek to eliminate the effect of a stream crossing on the site's hydrograph. Since 1995, Cherry Creek has been monitored in a reach with perennial flow, allowing for more accurate monitoring of water quality and surface flow in Cherry Creek before entering the Reservoir. Historically, this site has been referred to as CC or CC-I (i.e., CC-Inflow), but was renamed Site CC-10 in 1997 to place it in context with concurrent monitoring in Cherry Creek mainstem upstream of the Reservoir (JCHA 1999 to 2007).

CC-O — This site was established in 1987 on Cherry Creek downstream of Cherry Creek Reservoir and upstream of the Hampden Avenue-Havana Street junction in the Kennedy Golf Course near the historical USGS gage (06713000). In 2007, Site CC-O (also identified as Site CC-Out @ I225) was relocated immediately downstream of the dam outlet structure and serves to monitor the water quality of the Reservoir outflow.

2.1.3 *Cottonwood Creek*

CT-P1 — This site was established in 2002 and is located just north of where Caley Avenue crosses Cottonwood Creek, and west of Peoria Street. This site monitors the water quality of Cottonwood Creek before it enters the Peoria Pond PRF, also created in 2001/2002 on the west side of Peoria Street.

CT-P2 — This site was established in 2002 and is located at the outfall of the PRF, on the west side of Peoria Street. The ISCO stormwater sampler and pressure transducer is located inside the outlet structure. This site monitors the effectiveness of the PRF on water quality.

CT-1 — This site was established in 1987 where the Cherry Creek Park Perimeter Road crosses Cottonwood Creek. It was chosen to monitor the water quality of Cottonwood Creek before it enters the Reservoir. During the fall/winter of 1996, a PRF, consisting of a water quality/detention pond and wetland system, was constructed downstream of this site. As a result of the back-flow from this pond inundating this site, this site was relocated approximately 250 m upstream near Belleview Avenue in 1997. In 2009, this site was relocated approximately 75 m upstream of the Perimeter Road as it crosses Cottonwood Creek, due to the stream reclamation project. This site is now approximately 200 m upstream of the PRF.

CT-2 — This site was established in 1996 and was originally located downstream of the Perimeter Pond on Cottonwood Creek. The ISCO pressure transducer and staff gage was located in a section of the stream relatively unobstructed by vegetation, and approximately 50 m downstream of the PRF. However, over the years the growth of vegetation considerably increased along the channel, creating problems with accurately determining stream flow. Eventually, when no accurate and reliable streamflow measurements could be performed in 2003, other locations were evaluated. In August 2004, the pressure transducer and staff gage were relocated inside of the outlet structure for the PRF to mitigate problems associated with streamflow measurements by providing a reliable multilevel weir equation. In 2013, modifications to the PRF overflow elevation and the partial closure of the downstream control gate changed the relationship of the multilevel weir equation, resulting in unreliable stream flow estimates. In April 2014, the weir and overflow elevations were surveyed and the control gate was fully opened, and adjustments were made to the weir equations accordingly. Water quality samples are collected from the outlet structure as well. This site monitors the effectiveness of the PRF on Cottonwood Creek water quality and provides information on the stream before it enters the Reservoir.

2.1.4 *McMurdo Gulch*

MCM-1 This site was established in 2012 on McMurdo Gulch, approximately 150 m upstream of the McMurdo Gulch Stream Reclamation Project boundary. This site is also 120 m upstream of the confluence with an unnamed tributary that receives runoff from the Castle Oaks Subdivision. This site serves as the upstream monitoring location for the McMurdo Gulch Stream Reclamation Project.

MCM-2 This site was established in 2012 on McMurdo Gulch, approximately 80 m upstream of the Castle Oaks Drive Bridge crossing of McMurdo Gulch, near the North Rocky View Road intersection. This site serves as the downstream monitoring location for the McMurdo Gulch Stream Reclamation Project. This site is located within the project boundary, and consistently maintained base flows, whereas the reach further downstream was often dry due to surface flow becoming subsurface.

3. Methods

3.1 Sampling Methodologies

Field sampling protocols and analytical methods used for monitoring the Reservoir and stream sites as outlined in the Cherry Creek Reservoir Sampling and Analysis Plan (GEI 2008a; Appendix A).

3.1.1 *Reservoir Sampling*

The general sampling schedule included regular sampling trips to the Reservoir at varying frequencies over the annual sampling period, as outlined below, with increased sampling frequency during the summer growing season (Table 1). A total of 22 reservoir sampling events were conducted during the 2014 WY. The December 2013 and January 2014 sampling events were not performed due to unsafe ice conditions. During 15 of the 22 sampling events on the Reservoir, three main tasks were conducted, including: 1) determining water clarity, 2) collecting physicochemical depth profiles, and 3) collecting water samples for chemical and biological analyses. During the remaining 7 out of 22 sampling events on the reservoir, only cyanotoxin samples, physiochemical depth profiles and water clarity were collected for a special study that was initiated in summer 2014. This special study was conducted to evaluate changes in cyanobacteria and cyanotoxins because the destratification system was not operated in 2014.

Table 1: Sampling trips per sampling period, 2014 WY.

Sampling Period	Frequency	Planned Trips/Period	Actual Trips/Period
Oct - Apr	Monthly	7	5
May - Sept	Bi-Monthly	10	17
Total		**17**	**22**

3.1.1.1 Water Clarity

Transparency was determined using a Secchi disk and LI-COR quantum sensors (ambient and underwater). Detailed methods of both instruments can be found in the Sampling and Analysis Plan (Appendix A).

3.1.1.2 Profile Measurements

A Hydrolab MS5 Surveyor and Sonde was used for the collection of dissolved oxygen, temperature, conductivity, pH, and oxidation reduction potential (ORP) profile measurements from the surface to the bottom of the Reservoir.

3.1.1.3 Water Sampling

Water samples for nutrient, phytoplankton, zooplankton, chlorophyll *a*, and suspended solids analyses were collected at the three Reservoir sites. Data collected from each site during a single sampling event (i.e., three replicate samples), are averaged to provide a whole-reservoir mean estimate for each parameter. Sample event means are then used to calculate annual or seasonal mean values for key parameters such as chlorophyll *a* and total phosphorus and to facilitate comparison with regulatory standards and goals that apply to the Reservoir. Depending upon the distributional characteristics of each parameter, annual values may be compared to either the long-term mean or median value. Secchi depth and chlorophyll *a* are two parameters that reveal normal distributions, thus it is more appropriate to compare annual values with the long-term mean. Conversely, the total phosphorus data exhibit a log normal distribution; therefore it is more appropriate to compare annual values to the long-term median value. The Sampling and Analysis Plan (Appendix A) outlines the detailed methods used to collect lake water samples, as well as the laboratory methods in sample handling and preparation.

3.1.1.4 Cyanotoxin Data

Two cyanotoxin samples were collected from the Reservoir during each sampling event from early June to late September. One sample was collected a composite of the three photic zone samples (sites CCR-1, CCR-2, and CCR-3). Each photic zone consisted of equal volumes of water collected from the surface, 1m, 2m and 3m depths. This sampling regime is the same process used for collecting the phytoplankton sample, so the data are comparable. A second sample was also collected as a surface water grab sample from the Swim Beach water area. In addition, four "worse-case" surface water grab samples were collected from different locations within the reservoir where the nuisance algal bloom conditions existed. All samples were submitted to GreenWater Laboratories for analysis of the following cyanotoxins: anatoxins, microcystins, cylindrospermopsins, and saxitoxins.

3.1.1.5 Fish Population Data

Historically, this monitoring study has also reviewed fish stocking and population data collected by the Colorado Parks and Wildlife (CPW). The most recent fish population survey was conducted in the late summer 2014by the CPW (personal communication with Paul Winkle, CPW). However, these data were not available to GEI at the time of finalizing the 2014 Cherry Creek Monitoring Report.

3.1.2 *Stream Sampling*

3.1.2.1 Base Flow Sampling

Base flow stream sampling was conducted on a monthly basis (12 events) in coordination with the routine Reservoir sampling trips to Cherry Creek Reservoir. This sampling was performed to characterize base flow conditions, which corresponds to the low-flow ambient samples collected in past studies. Monthly samples are assumed to be representative of non-storm, base flow periods on Cherry Creek, Cottonwood Creek, and McMurdo Gulch.

3.1.2.2 Storm Sampling

Storm events sampled at the inflow sites on Cherry Creek and Cottonwood Creek characterize non-base flow conditions during the sampling season (Table 2). A detailed outline of storm sampling protocols can be found in the Sampling and Analysis Plan (Appendix A). Storm samples were not collected on McMurdo Gulch.

Table 2: Number of storm samples collected from tributary streams to Cherry Creek Reservoir, 2014 WY. See Appendix C for sample dates.

	Sites					
	EcoPark	**CC-10**	**CT-P1**	**CT-P2**	**CT-1**	**CT-2**
Number of Storm Samples	6	6	7	7	7	7

3.1.3 *Surface Hydrology*

Pressure transducers attached to ISCO Series 6700 or 6712 flowmeters measured and recorded water levels (stage) at six sites on the two tributaries to Cherry Creek Reservoir (Figure 1). These flow meters are programmed to record water level data on 15-minute intervals year round. Streamflow (discharge) was estimated at CC-10, CT-1, and CT-P1 using a stage-discharge relationship developed for each stream site. For sites CT-2, CT-P2, and EcoPark, where the flow meters are located inside or connected to the concrete outlet structure, multi-level orifice and weir equations were used to estimate discharge. Periodic stream discharge measurements were collected during a range of flow conditions using a Marsh McBirney Model 2000 flowmeter to develop the stage-discharge relationships. For a complete description of streamflow determination, see Appendix D.

In 2012, a modification to the Site CT-2 outlet works structure and dam embankment occurred during maintenance to the PRF system which altered the flow characteristics inside the weir. In April 2014, the weir was surveyed and it was observed that the control gate was partially closed. The weir equations were modified to account for the effects of the partially closed gate. The gate was fully opened at this time and the weir equations were adjusted again for unobstructed flow.

3.2 Laboratory Procedures

3.2.1 *Nutrient Laboratory Analysis*

Physicochemical and biological analyses from the Reservoir and stream water quality samples were performed by the GEI analytical laboratory (Table 3). Quality Assurance/ Quality Control protocols for the low level nutrient analyses were performed by the GEI Laboratory, with all results being reported in Appendix B.

The methods for these analyses, with appropriate QA/QC procedures, are available from GEI.

Table 3: Parameter list, method number, and detection limits for chemical and biological analyses of water collected from Cherry Creek Reservoir and tributaries.

Parameter	Method	Detection Limit
Total Phosphorus	QC 10-115-01-4-B	2 µg/L
Total Dissolved Phosphorus	QC 10-115-01-4-B	2 µg/L
Soluble Reactive Phosphorus	QC 10-115-01-1-T	2 µg/L
Total Nitrogen	QC 10-107-04-4-B	2 µg/L
Total Dissolved Nitrogen	QC 10-107-04-4-B	2 µg/L
Ammonium Ion	QC 10-107-06-2-A	3 µg/L
Nitrate and Nitrite	QC 10-107-04-1-C	2 µg/L
TSS	APHA 2540D	4 mg/L
TVSS	APHA 2540E	4 mg/L
Chlorophyll *a*	APHA 10200 H (modified)	0.1 µg/L
Phytoplankton	APHA 10200 C.2	--
Zooplankton	APHA 10200 G	--

APHA = American Public Health Association, 1998.

3.2.2 *Biological Laboratory Analysis*

Biological analyses of the Reservoir phytoplankton samples were conducted by Aquatic Analysts, Friday Harbor, Washington. Aquatic Analysts performed phytoplankton identification and enumeration and biovolume (μm^3) per unit volume [#/milliliter (mL)], while GEI performed the chlorophyll *a* concentrations (µg/L). Water's Edge Scientific LLC, Baraboo, Wisconsin performed zooplankton identification, enumeration, and biomass (µg/L). Cyanotoxin samples were analyzed by GreenWater Laboratory, Palatka, Florida; when toxin levels were greater than recommended thresholds, the laboratory also identified and enumerated the types of cyanobacteria present which likely produced the toxins.

3.3 Evaluation of Long-Term Trends in Cherry Creek Reservoir

Long-term seasonal trends were evaluated for Secchi depth, chlorophyll *a*, and total phosphorus using whole-reservoir mean values from 1987 to 2014 and linear regression analysis (described below). Additionally, 95% confidence intervals provided information on data dispersal around the mean annual values. These analyses were used to determine whether there was significant increasing or decreasing trends in Secchi depth, total phosphorus, and chlorophyll *a* levels over time.

Comparisons of biological and physical parameters for each site were conducted using NCSS 2007 statistical software (Hintze 2009). Basic descriptive statistics were used to evaluate the distributional characteristics of the data, and to determine whether a variable required transformation to meet the basic assumptions of normality or whether outliers existed in the data. Logarithmic transformations were used to increase the symmetry of the data about the mean, approximating a normal distribution. If the transformation did not improve normality, the untransformed data were used in subsequent analyses.

The least-squares linear regression was used to estimate slope, with analysis of variance (ANOVA) being used to determine if the slope was significantly different than zero.
A probability of < 0.05 was used to indicate statistical significance. In the cases of the linear regressions, the R^2 value provided a measure of how well the variance is explained by the regression equation. R^2 values measure the proportion of total variation that is explained or accounted for by the fitted regression line (i.e., it is a measure of the strength of the relationship with the observed data).

4. Results and Discussion

4.1 Reservoir Water Quality

4.1.1 *2014 WY Transparency*

The whole-reservoir mean Secchi depth varied from 0.69 m in mid-October to 3.19 m in late June (Figure 3). The seasonal (July through September) whole-reservoir mean Secchi depth was 1.10 m (Figure 4). The depth at which 1% of photosynthetically active radiation (PAR) penetrated the water column (i.e., photic zone depth) ranged from 1.89 m in mid-October to a maximum depth 5.70 m in late June (Figure 3). The greatest level of whole-reservoir chlorophyll *a* concentration of 43.3 µg/L was observed in mid-February 2014, beneath the ice cover, while the next greatest level was observed in early June 2014 (37.5 µg/L, Figure 3). The water clarity observed on June 24th was the deepest recorded Secchi depth (3.2 m) for the Reservoir since data collection began in 1987, and occurred immediately after the crash of a large filamentous cyanobacteria population which resulted in the peak chlorophyll *a* concentration in early June. The water clarity in late May (1.5 m) facilitated the rapid growth of the cyanobacteria population along with other Reservoir conditions such as temperature and nutrients.

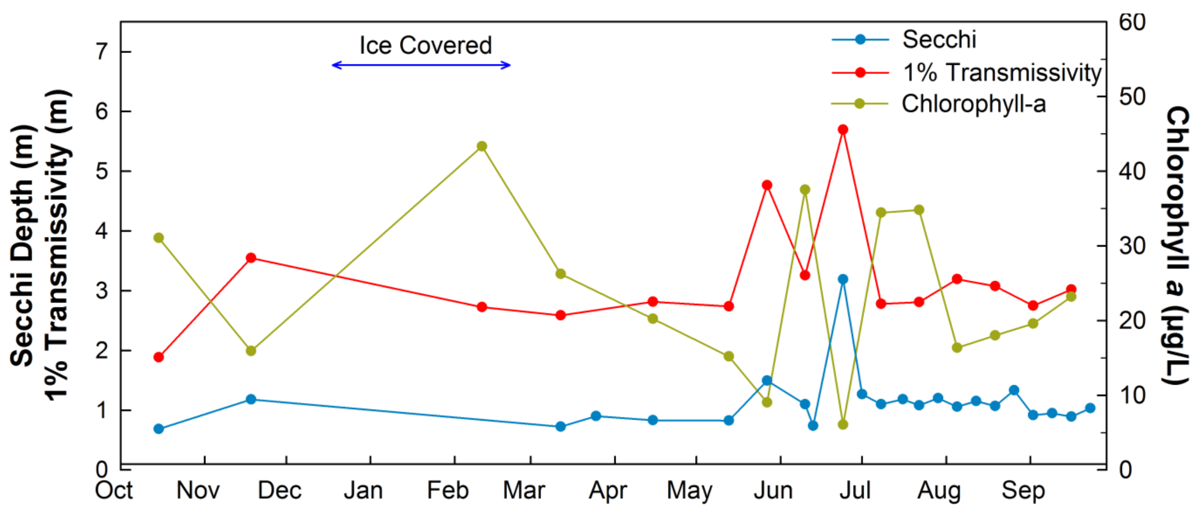

Figure 3: Patterns for mean whole-reservoir Secchi depth, 1% transmissivity, and chlorophyll *a* in Cherry Creek Reservoir, 2014 WY.

4.1.2 *Long-Term Secchi Transparency Trends in Cherry Creek Reservoir*

In general, seasonal mean (July through September) Secchi depths increased from 1987 to 1996, then decreased in 1997 at which time they have been relatively stable until the past few years (Figure 4). The 2014 seasonal whole-reservoir mean Secchi depth was 1.10 m, which is greater than the present long-term (1987 to present) mean value of 0.95 m. In terms of water clarity, the 2014 Reservoir conditions were very similar to historical conditions (i.e., prior to 2008) in the absence of destratification management.

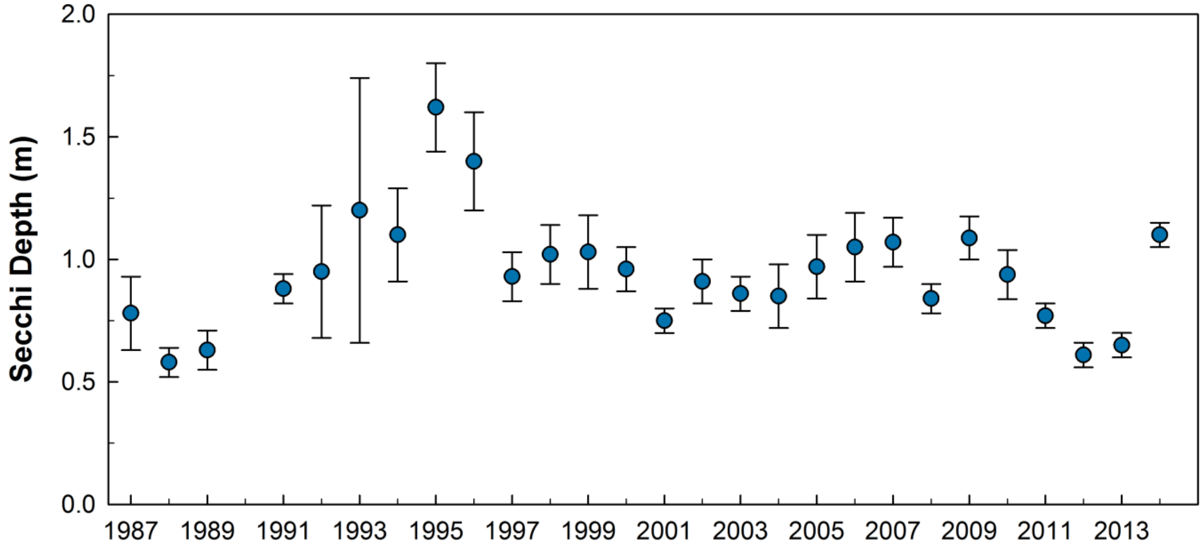

Figure 4: Whole-reservoir seasonal mean (July through September) Secchi depth (m) measured in Cherry Creek Reservoir. Error bars represent a 95% confidence interval for each mean.

4.1.3 *2014 WY Temperature and Dissolved Oxygen*

Analysis of past Cherry Creek Reservoir temperature profiles indicates that stratification typically occurs when there is greater than 2°Celsius (C) difference between the surface and bottom water temperatures (Jones 1998). Differences of less than 1°C between the surface and bottom waters indicate mixing (Jones 1998). This criterion is generally supported by the classical definition of a thermocline, as being the layer with the greatest rate of change in temperature or dt/dz greater than 1°C/m. However, given the relatively shallow nature of the Reservoir and the temperature-density relationships, the Reservoir can become stratified even though the greatest rate of change may be less than 1°C. In addition, relative thermal resistance to mixing (RTRM) can be used to evaluate stratification as a function of temperature differentials in the water column (Wetzel 2001). Dissolved oxygen profiles are also used to evaluate periods of stratification when temperature differences are less than 1°C.

Water temperatures during routine profile measurements in the Reservoir ranged from 1.1°C immediately beneath the ice cover in mid-February 2014 to 24.5°C at the surface in mid-July 2014 (Figure 5, Figure 7, and Figure 9). Temperature profile data showed a fairly well-mixed reservoir in early spring with increasing stratification starting in mid-May 2014 (Figure 5, Figure 7, and Figure 9).

From October 2013 to mid-May 2014, the dissolved oxygen concentrations remained greater than 5 milligrams per liter (mg/L) throughout the water column (Figures 6, 8, and 10). From mid-May through September, the deeper 5-7 m layers and water/sediment interface were consistently below 5 mg/L (Figures 6, 8, and 10). The dissolved oxygen standard for warm water lakes is 5.0 mg/L and is applicable to the 0.5 m to 2.0 m layers of the Reservoir. However, when summer water temperatures increase, the deeper, cooler water becomes more important for fish refuge and if dissolved oxygen conditions are less than 5.0 mg/L, the Reservoir conditions become less conducive for fish. The periodic peaks in dissolved oxygen concentrations near the surface (Figures 6, 8, and 10) are indicative of algal production and the release of oxygen during photosynthesis, as well as influence from wind-driven mixing events.

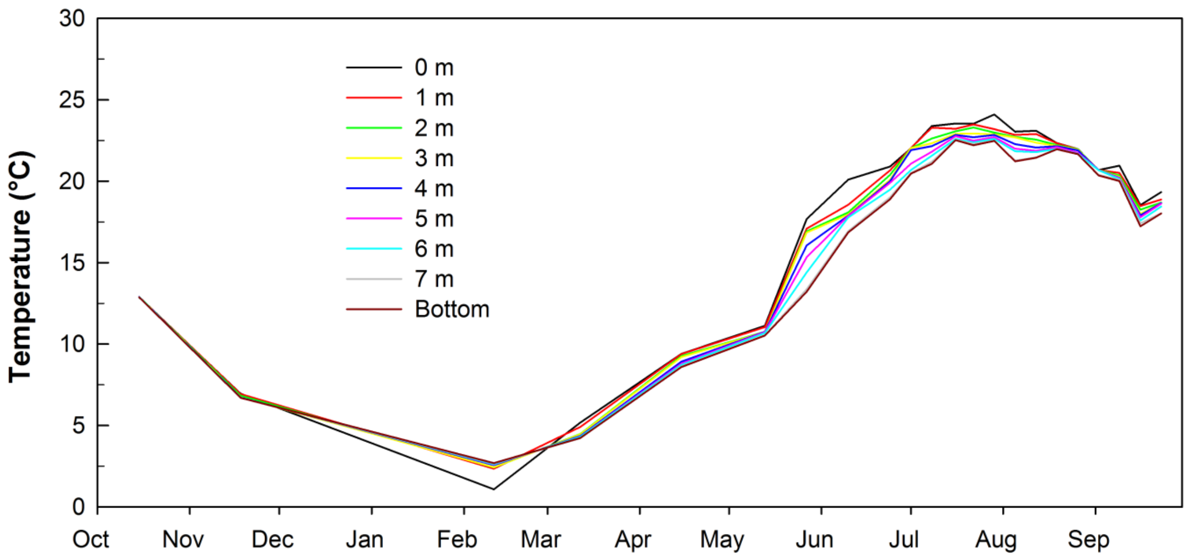

Figure 5: Temperature (°C) recorded at depth during routine monitoring at CCR-1 during the 2014 WY.

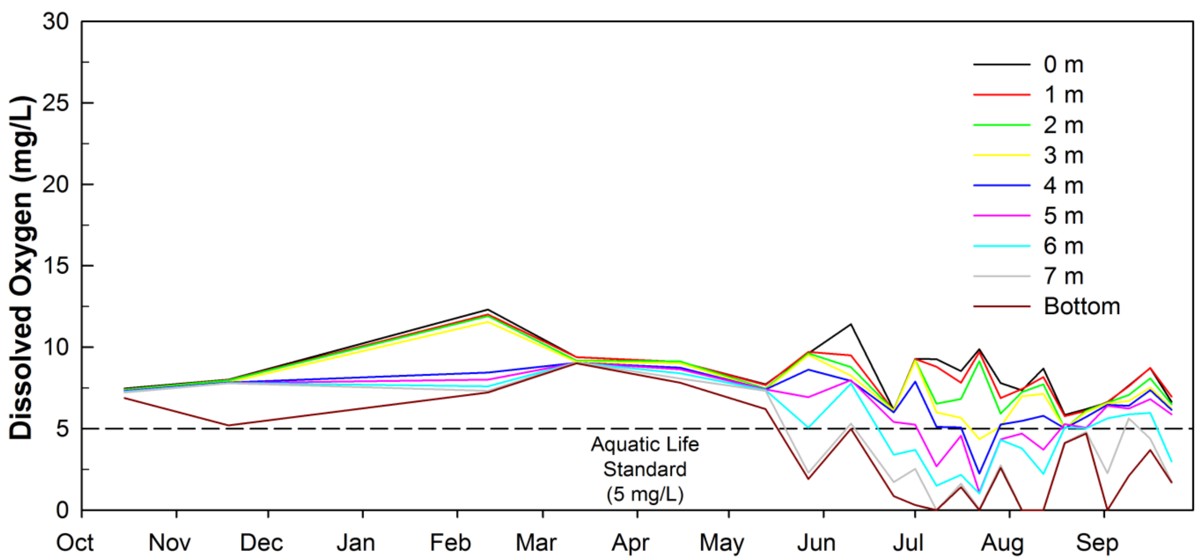

Figure 6: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at CCR-1 during the 2014 WY. The dissolved oxygen basic standards table value for Class 1 warm water lakes and reservoirs is provided for comparison (5 mg/L).

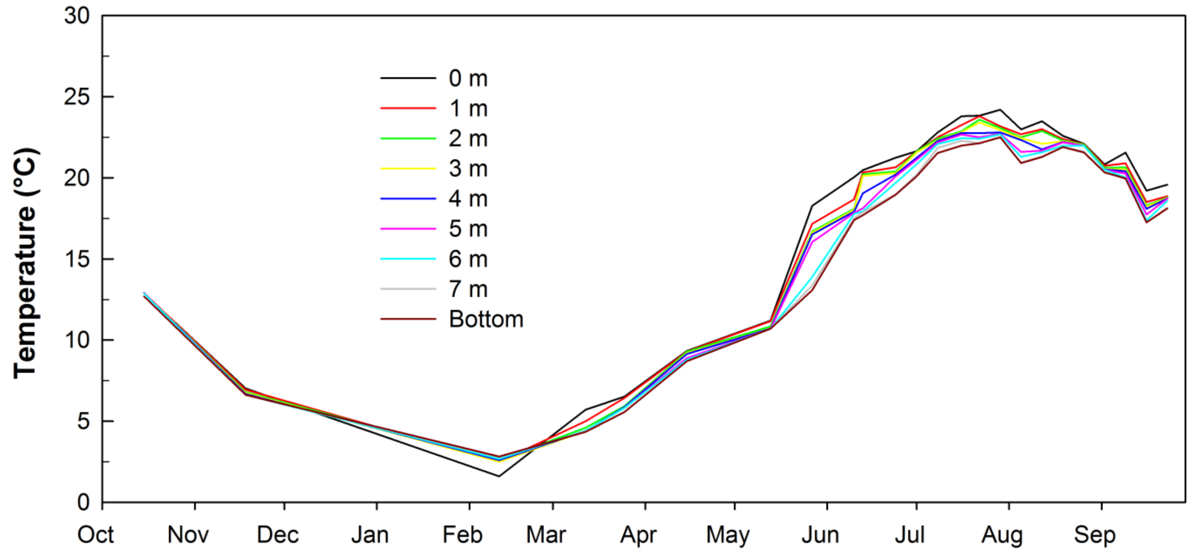

Figure 7: Temperature (°C) recorded at depth during routine monitoring at CCR-2 during the 2014 WY.

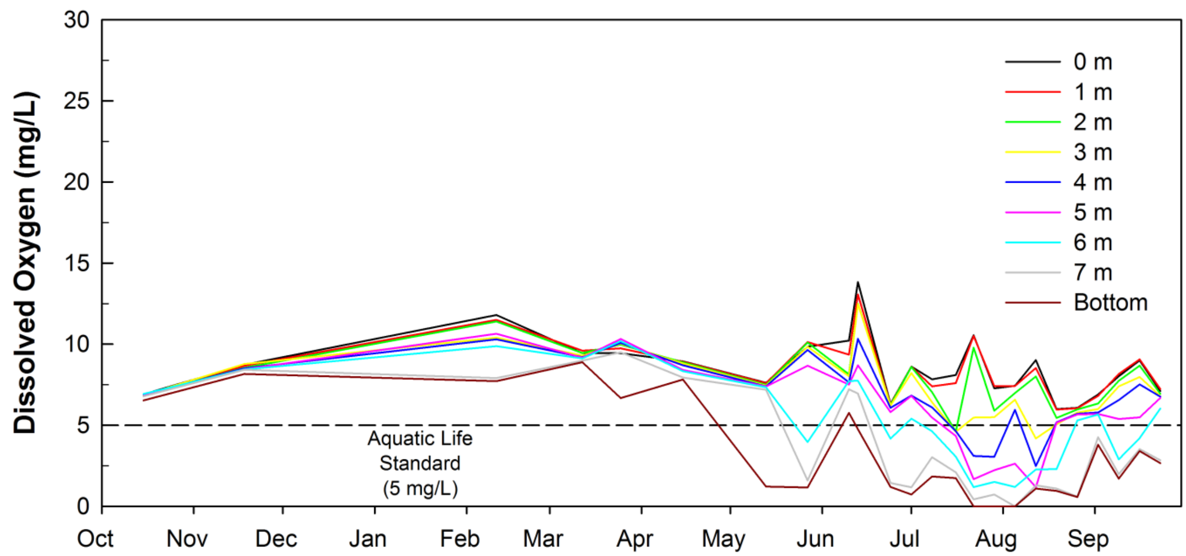

Figure 8: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at CCR-2 during the 2014 WY. The dissolved oxygen basic standards table value for Class 1 warm water lakes and reservoirs is provided for comparison (5 mg/L).

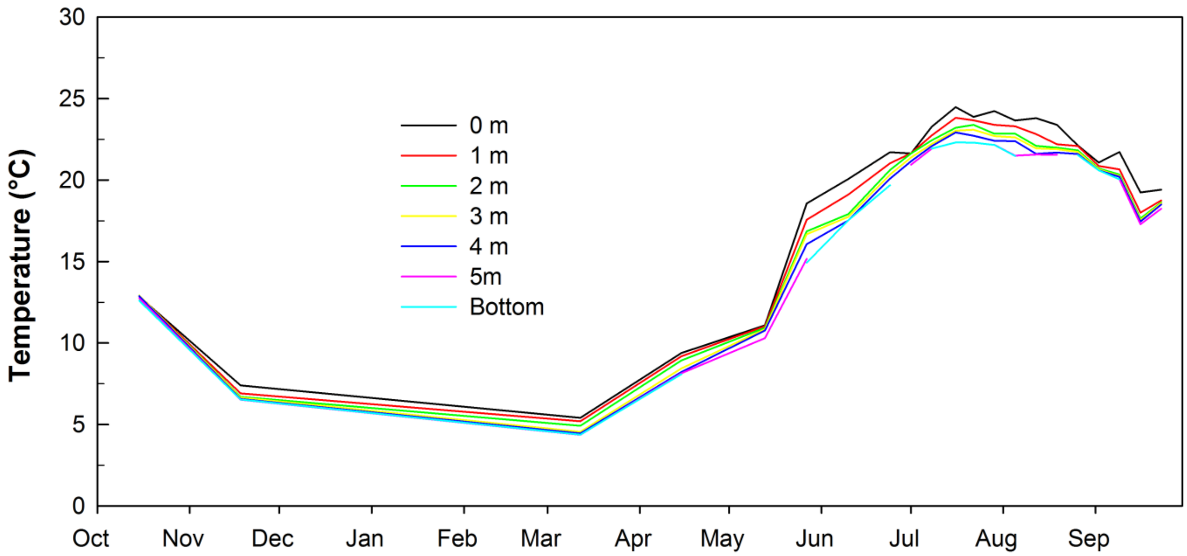

Figure 9: Temperature (°C) recorded at depth during routine monitoring at CCR-3 during the 2014 WY.

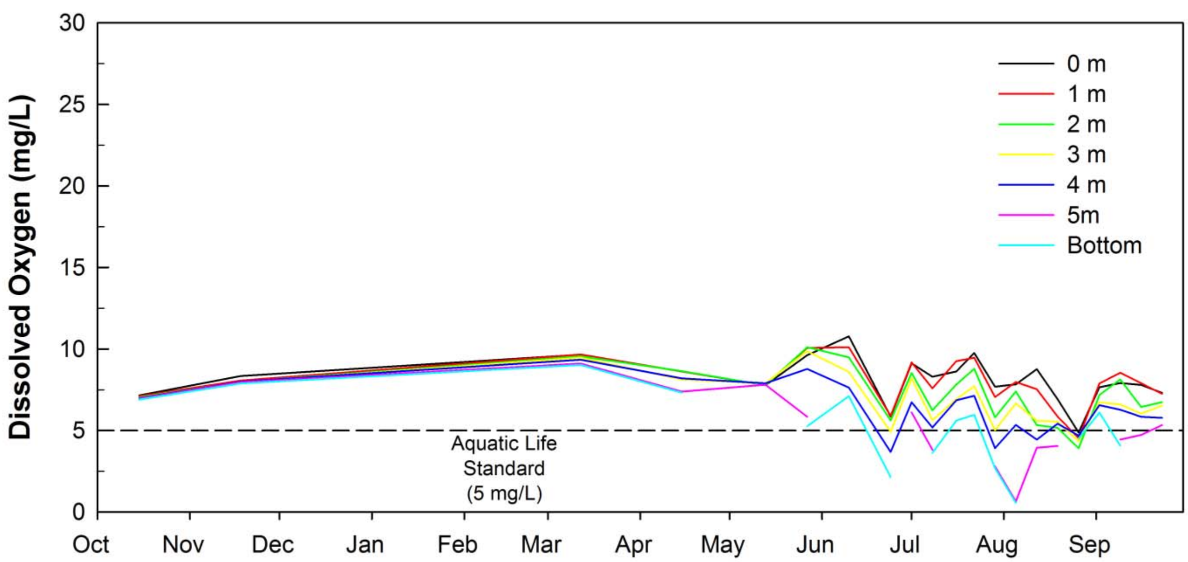

Figure 10: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at CCR-3 during the 2014 WY. The dissolved oxygen basic standards table value for Class 1 warm water lakes and reservoirs is provided for comparison (5 mg/L).

Relative thermal resistance to mixing (RTRM) was calculated to evaluate stratification as a function of density gradients in the water column. From June through September 2014 the RTRM gradients in the deeper water are minimal, with the exception of July 3rd and August 7th (Figure 11). The RTRM values for the 4 to 6 m layers on these dates indicate the water column was only weakly stratified. Greater RTRM values were observed in the upper layers of the Reservoir on June 12th, July 10th, July 31st, and September 11th (Figure 11). These values are limited to the upper layers and indicate solar heating in the top portion of the water column and are not indicative of typical stratification in the water column. However, the RTRM condition observed on June 12th indicates a resistance to mixing near the surface which also corresponds to the *Anabaena-flos aquae* bloom that was observed from June 9th through June 23rd. This condition likely related to the bloom or at least facilitated the bloom given the relatively strong resistance to mixing near the surface (0 to 2 m). Despite the low levels of thermal stratification and low RTRM which indicate a well-mixed Reservoir for most of the growing season, the sediment oxygen demand (SOD) remained very high. This indicates that even a few centimeters of anoxic bottom water is sufficient for creating a reducing environment and internal load release of nutrients.

By the second sampling event in May 2014, dissolved oxygen concentrations began decreasing at depths greater than 6 m with values less than the upper threshold (2 mg/L) conducive for internal loading at the sediment boundary. These conditions in the deep layers of the Reservoir, at this time of year, may pose relatively little harm to the warm water biological community, because the upper layers remained well oxygenated. However, deep water anoxia (< 2 mg/L) at the sediment boundary created favorable conditions for internal nutrient loading for several weeks during the summer period.

On June 10th, dissolved oxygen profiles indicated that the water column had become mixed with dissolved oxygen concentrations ranging from 11.4 mg/L at the surface to 5.0 mg/L at the sediment boundary (Figure 6, Figure 8, and Figure 10). By June 24th, dissolved oxygen concentrations once again began decreasing at depths greater than 6 m with values less than the upper threshold (2 mg/L). This deep water anoxia continued throughout the Reservoir until August 26th (Figure 6, Figure 8, and Figure 10).

Reservoir profiles were also evaluated to determine the attainment of the dissolved oxygen standard. Over the course of the monitoring year, 100 vertical water column profiles were collected in the Reservoir. For each profile, the 1 m and 2 m dissolved oxygen values were averaged and evaluated for attainment of the Class 1 Warm Water table value standard (5 mg/L) for lakes and reservoirs that are greater than 5 m deep (CDPHE 2011). The Reservoir was in attainment of the dissolved oxygen standard for 99 of 100 profiles. The single exceedance occurred on August 26th, 2014 with a minimum average dissolved oxygen value of 4.2 mg/L which occurred at Site CCR-3; followed a storm event that occurred the day before. During the July to September growing season, the average dissolved oxygen concentration of the upper layer was 7.8 mg/L for all vertical profiles.

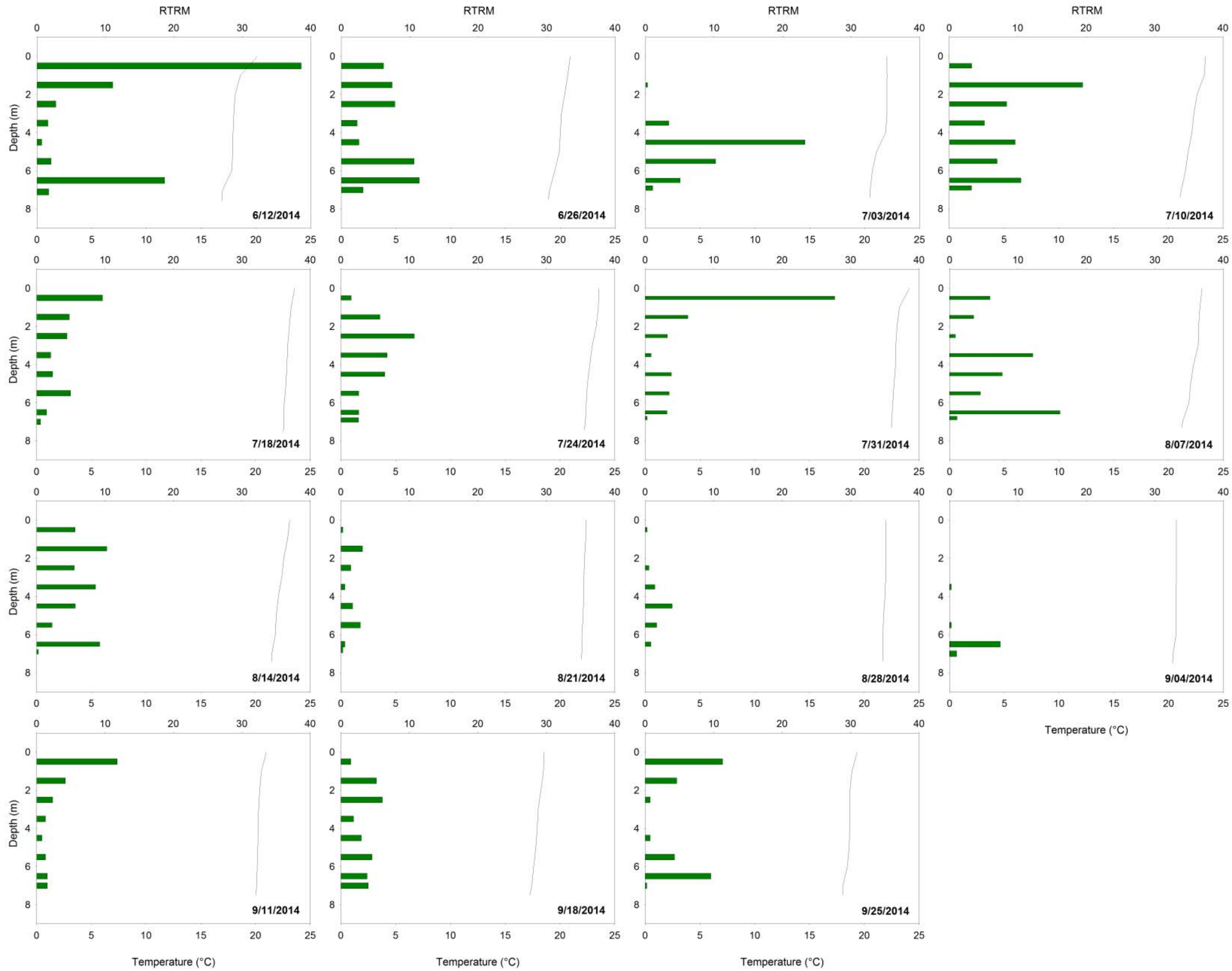

Figure 11: Relative thermal resistance to mixing gradients and temperature profiles for Cherry Creek Reservoir, June – September, 2014.

4.1.3.1 Continuous Temperature Monitoring

On April 15, 2014, temperature loggers were deployed for monitoring the efficiency of the destratification system at mixing the water column. Using the > 2°C difference criteria from the surface to the bottom, Cherry Creek Reservoir was evaluated for periods of stratification using the continuous temperature record at depths for all three Reservoir sites from April 15th to November 4th (Figure 12, Figure 13, and Figure 14). Due to a deployment issue, temperature data was not recorded at the 1 m layer for the three Reservoir sites from April 15th through June 24th; therefore, temperature data from the 2 m layer was used to assess Reservoir stratification during that timeframe. The Reservoir exhibited several periods of thermal stratification, but days of thermal stratification did vary slightly by site throughout the monitoring period and not all sites were stratified on the exact same dates (Figure 12, Figure 13, and Figure 14). Overall, the Reservoir exhibited several periods of thermal stratification that occurred from approximately April 21st - April 24th, May 3rd - May 9th, May 18th – June 5th, June 13th – June 14th, June 21st – June 22nd, June 25th – June 27th, June 30th – July 4th, July 2nd – July 3rd, July 9th – July 11th, August 1st – August 4th, August 12th – August 13th, and September 18th – September 21st (Figure 12, Figure 13, and Figure 14). From April 15th through November 1st the Reservoir was stratified for approximately 46 days. This is a greater number of stratification events compared to 2013, and is likely due to the fact that the destratification system was not in operation during 2014.

The temperature standards for Class I Warm Water lakes and reservoirs are 29.5°C (acute, ac) and 26.3°C (chronic, ch) for summer months and 14.8°C (ac) and 13.2°C (ch) for winter months (CDPHE 2011). The Reservoir daily maximum (ac) and weekly average temperatures did not exceed the warm water standards during the summer months.

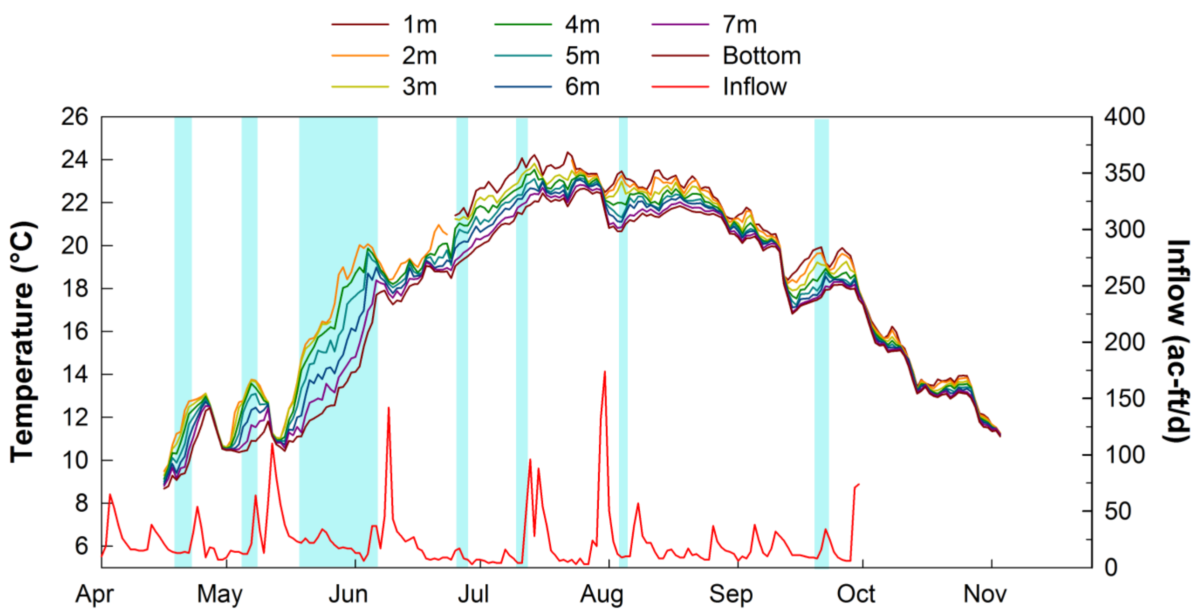

Figure 12: Daily mean temperature (°C) recorded at depth for CCR-1 based on 15-minute interval data collected by temperature loggers, with USACE inflow in 2014. Shaded areas denote periods of thermal stratification.

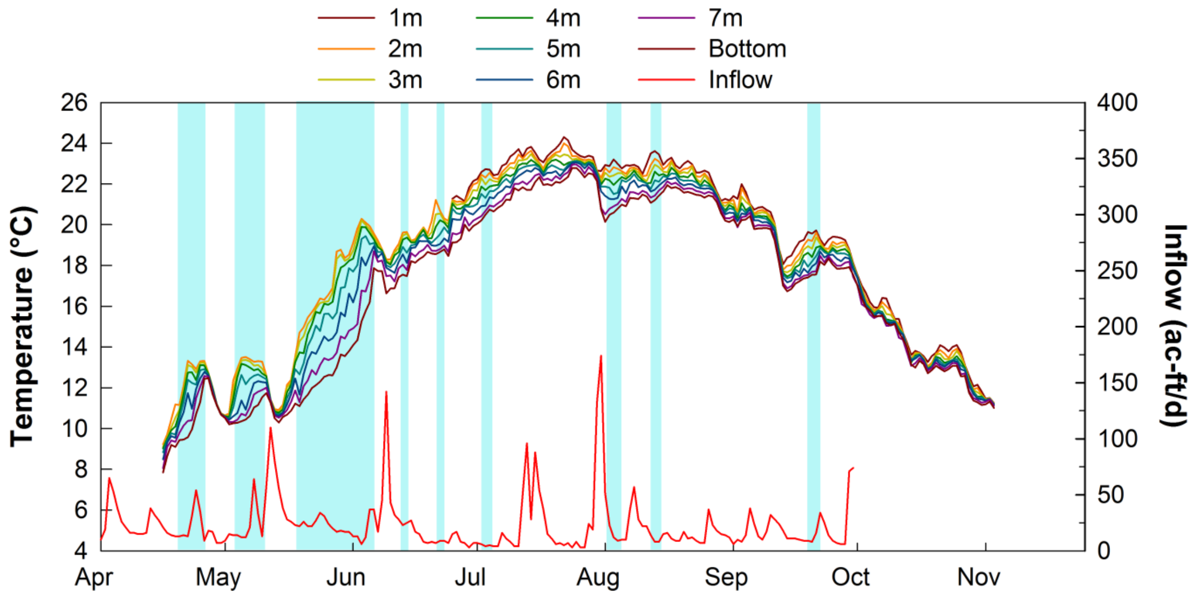

Figure 13: Daily mean temperature (°C) recorded at depth for CCR-2 based on 15-minute interval data collected by temperature loggers, with USACE inflow in 2014. Shaded areas denote periods of thermal stratification.

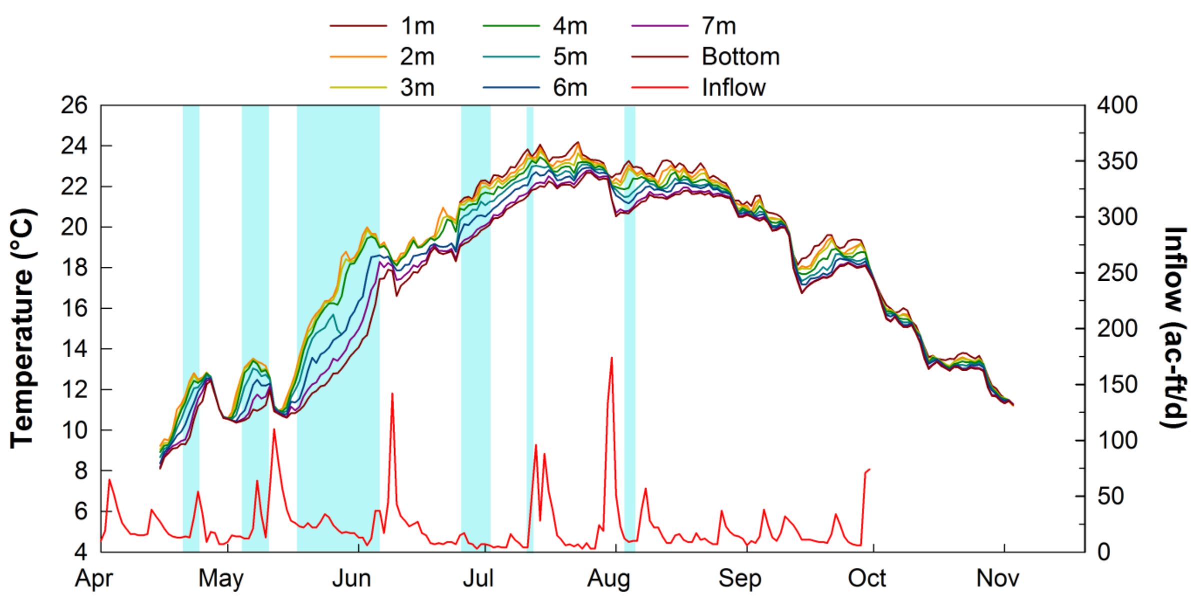

Figure 14: Daily mean temperature (°C) recorded at depth for CCR-3 based on 15-minute interval data collected by temperature loggers, with USACE inflow in 2014. Shaded areas denote periods of thermal stratification.

4.1.3.2 Dissolved Oxygen and Oxidation-Reduction Potential Transect

The water quality transect was established in the Reservoir originating from approximately the mid-point of the dam and extending southward across the Reservoir, towards the inlet region (see Figure 1). As part of the destratification monitoring program, water column dissolved oxygen and oxidation reduction potential profiles were continued to be collected at 10 locations along the transect and the nearby Site CCR-3 location (D-10), on three sample dates (Figure 15). These data help document the areal extent of low dissolved oxygen and reducing conditions near the water/sediment interface. Low dissolved oxygen conditions (i.e., < 2 mg/L) facilitate the internal release of soluble nutrients that promotes algae growth during the summer.

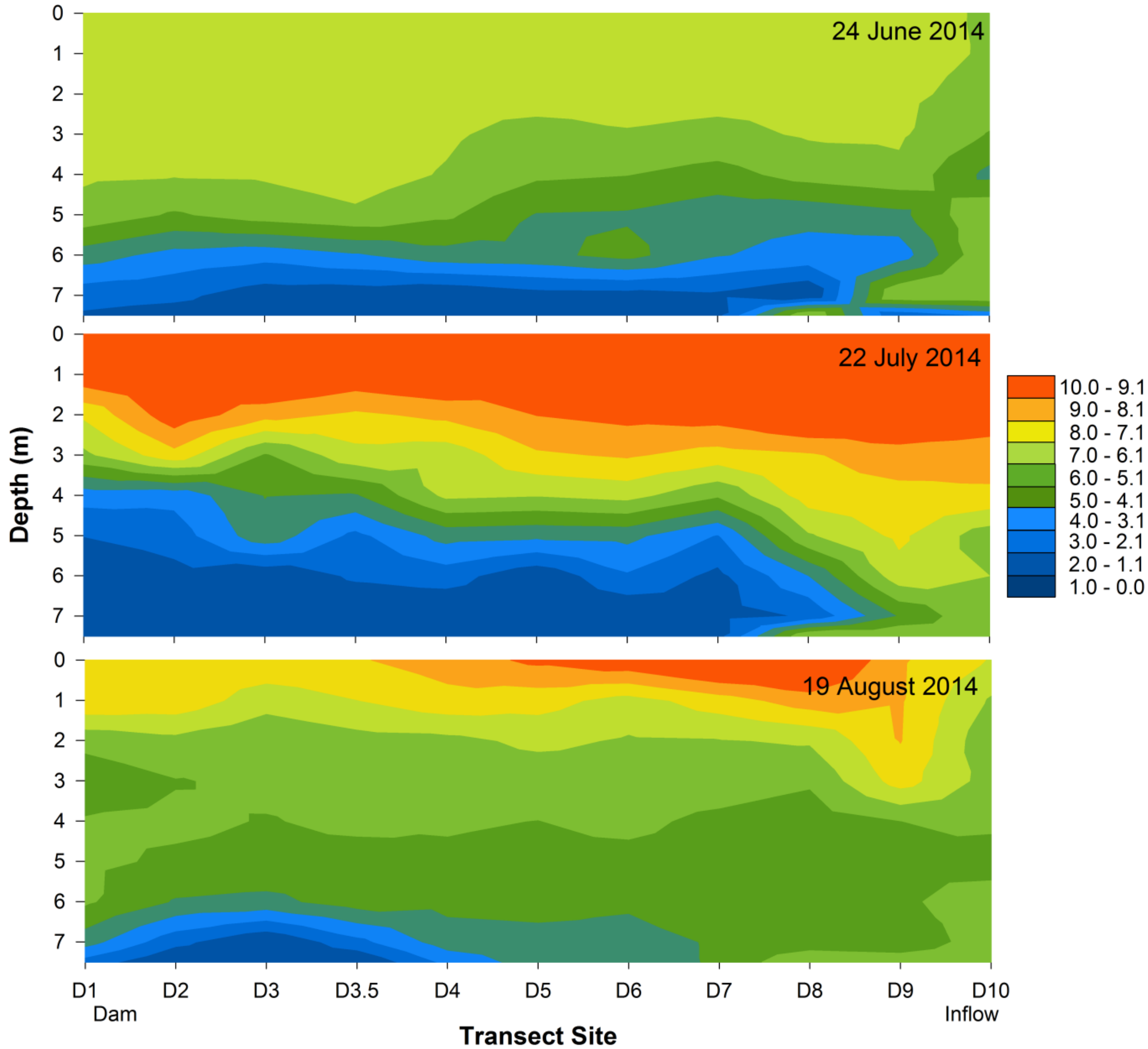

Figure 15: Dissolved oxygen conditions in Cherry Creek Reservoir for three dates based on transect profile data during the 2014 WY.

During the first sample date on June 24th, the Reservoir was well oxygenated (i.e., > 5 mg/L) from the surface down to a depth of approximately 4 m (Figure 15). This pattern was consistent from D1 near the dam to D10, at which point the maximum Reservoir depth became shallower. The average dissolved oxygen concentration for the 1 m and 2 m depths along the transect was 6.3 mg/L indicating the Reservoir was in attainment of the dissolved oxygen standard. Low dissolved oxygen conditions (<2 mg/L) were evident in the lower portion of the Reservoir (6 m, 7 m, and bottom), and this zone continued to expand higher into the water column by mid-July (Figure 15; Appendix B). The average dissolved oxygen concentration for depths from 6 m to the bottom was 1.44 mg/L.

The July 22nd transect profiles documented the continued expansion of the anoxic zone upward into the water column (Figure 15). The average dissolved oxygen concentration of the 1 m and 2 m layer values along the transect was 9.7 mg/L which indicated the Reservoir was in attainment of the warm water standard (5 mg/L). The dissolved oxygen concentrations in the upper portion of the Reservoir were greater during this sampling event versus the June 24th event (Figure 15). The lower portion of the Reservoir showed anoxic conditions (<2 mg/L) for most sites at the 6 m, 7 m, and the water-sediment interface. The average dissolved oxygen concentration for these depths was 0.79 mg/L.

The last transect profile was collected on August 19th and showed decreased dissolved oxygen concentrations in the Reservoir in the upper layer (1 m and 2 m); however, dissolved oxygen concentrations in the deeper layers of the Reservoir was improved compared to the two previous sampling events (Figure 15). The average dissolved oxygen concentration for the 1 m and 2 m depths along the transect was 6.6 mg/L indicating the Reservoir was in attainment of the dissolved oxygen standard. The extent of the anoxic zone in the bottom portion of the Reservoir decreased dramatically from the previous two sampling events (Figure 15). The average dissolved oxygen concentration at these depths was 3.16 mg/L which is a large increase from the previous sampling events.

Oxidation reduction potential (ORP) measurements are used to quantify the exchange of electrons that occur during oxidation-reduction reactions (redox reactions), with electrical activity being reported in millivolts (mV), very similar to a pH probe. At the water-sediment boundary layer, microbial organisms facilitate the chemical reactions but do not actually oxidize or reduce the compounds. The redox reactions provide energy for microbial cells to carry out their metabolic processes (Wetzel 2001). The combination of microbial organisms and redox reactions are responsible for the breakdown of organic matter and development of anoxic conditions near the sediment boundary in reservoirs during the summer, and as a result soluble nutrients (nitrogen and phosphorus) are released as well as other forms of iron, manganese and sulfur.

In Cherry Creek Reservoir, the water column ORP measurements will often range between 100 to 300 mV depending upon the seasonal conditions. On any given date, the water column ORP conditions, from the surface waters down to approximately the 6 m layer, will be relatively uniform because there is sufficient dissolved oxygen in the water column to maintain compounds in their most oxidized state. However, when anoxic conditions exist at depths greater than 6 m or near the water-sediment interface, the redox potential will sharply decrease, often ranging from -200 to 0 mV, indicating conditions that facilitate internal nutrient loading as well as other elemental releases. When reviewing ORP profile measurements (Figure 16), the occurrence of a sharp inflection point (i.e., low or negative values) in the profile indicates where conditions are favorable for redox reactions to occur.

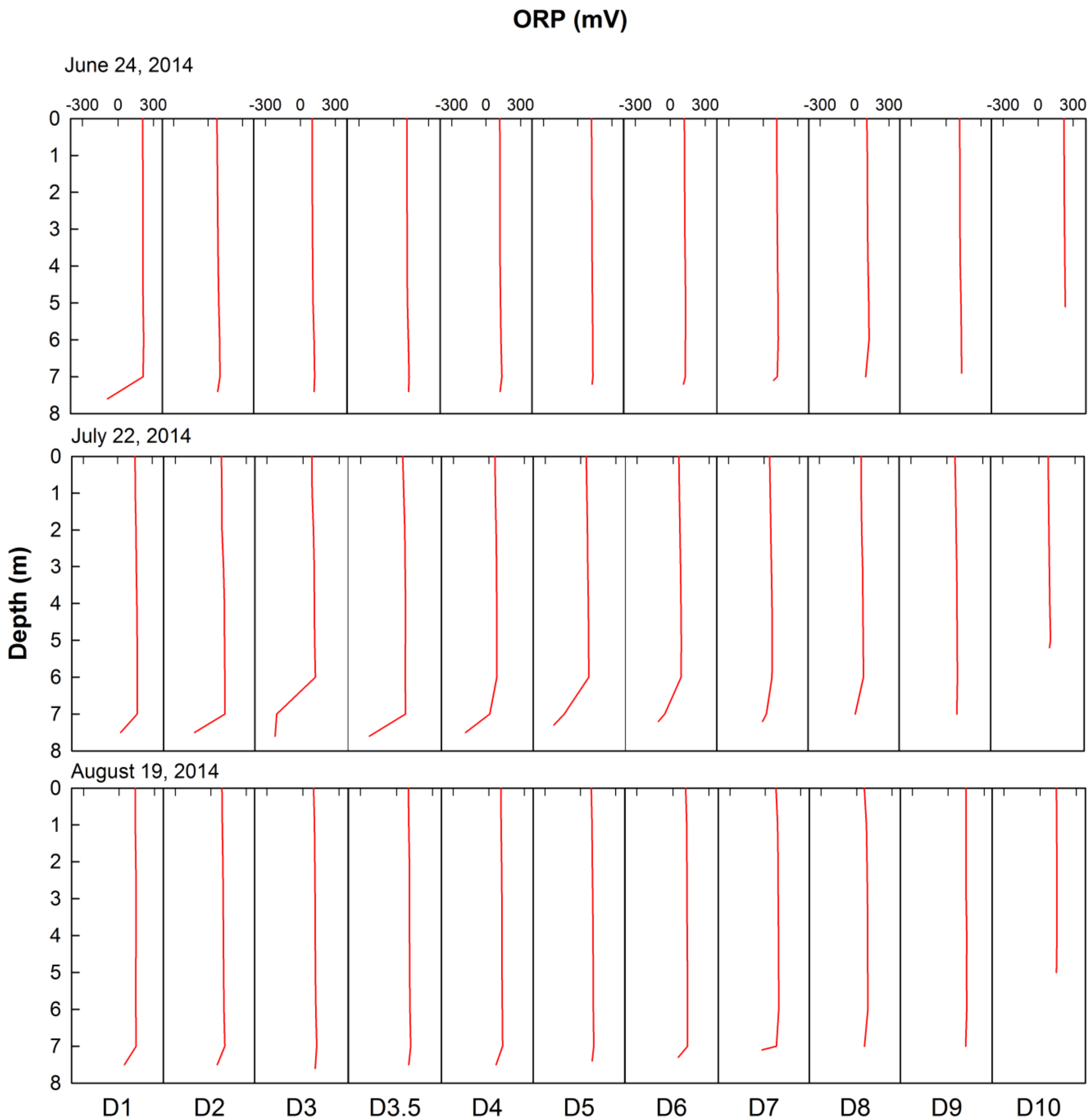

Figure 16: Oxidation reduction potentials (ORP) in Cherry Creek Reservoir for three dates based on transect profile data during the 2014 WY. The ORP scales for each transect are all relative to each other within and among sampling events.

The June 24th ORP conditions near the water-sediment interface do not indicate a strong reducing environment such as observed on July 22nd, yet the dissolved nutrient conditions near the bottom indicate loading was occurring. The August 19th ORP conditions were also less indicative of a strong redox condition near the bottom, and dissolved nutrient conditions show that loading was considerably less than the June 24th sampling event.

The oxidation-reduction potential profiles on July 22nd indicate that conditions were favorable for a reducing environment at the water-sediment interface (Figure 16). This interface acts as a barrier to the free exchange of soluble phosphorus between water and sediment, and when conditions are favorable (e.g., anoxic-reducing environment) phosphorus is released (i.e., internal load) at rates as much as 1,000 times faster than during well oxygenated conditions (Horne and Goldman 1994). Although the rate of exchange of nutrients (mainly phosphorus) at this interface remains unknown for Cherry Creek Reservoir, the internal loading component of the Reservoir has been estimated to account for approximately 25% of the cumulative total phosphorus load from 1992 to 2006 (Nürnberg and LaZerte 2008).

4.1.4 *2014 WY Nutrients*

Monitoring at Cherry Creek Reservoir has focused on the concentrations of phosphorus and nitrogen, because these inorganic nutrients are often the contributing or limiting factor in the growth of algae (Cole 1979; Horne and Goldman 1994; Wetzel 2001; Cooke et al. 1993). Excessive amounts of these nutrients in aquatic systems often result in algal blooms that create aesthetic problems as well as potentially unsuitable conditions for aquatic life. An imbalance in the nitrogen and phosphorous relationships (i.e., ratios) can result in one element limiting algal growth, or both could be limiting at different times of the year. Ultimately, the nutrient concentrations need to be relatively less to greatly reduce algal biomass as measured by chlorophyll *a*.

During the 2014 WY, the photic zone mean concentration of total phosphorus ranged from 40 to 130 µg/L with an overall water year mean of 86 µg/L. The seasonal (July through September) photic zone mean concentrations ranged from 40 to 120 µg/L (Figure 17), with a seasonal mean of 87 µg/L. In May and June 2014, storm-induced external loads likely contributed to the total phosphorus content within the photic zone; however, other factors such as internal loading and algal uptake also affected the seasonal pattern.

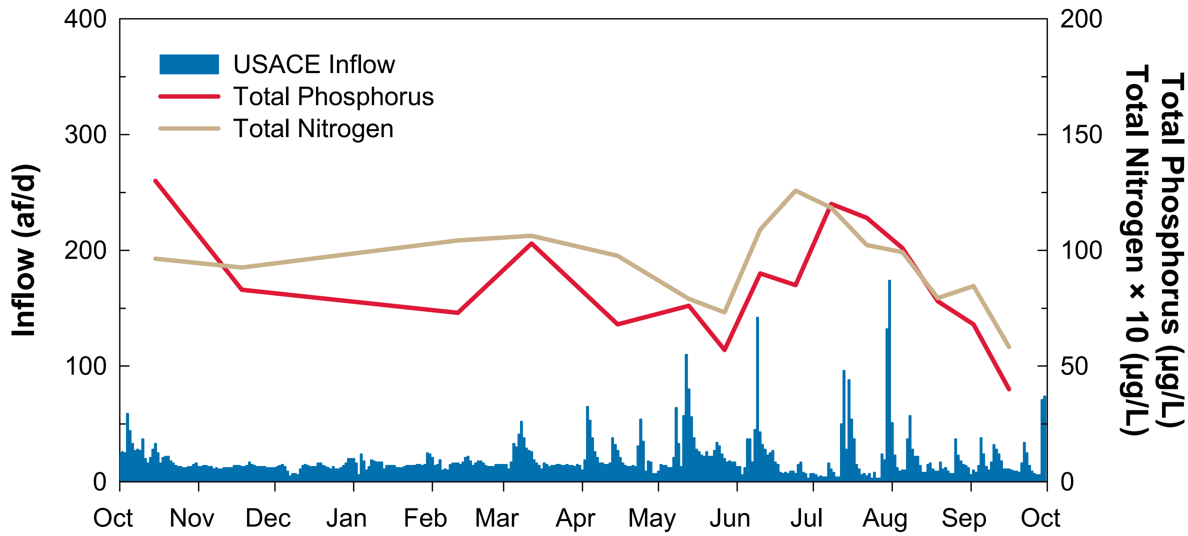

Figure 17: Annual pattern of photic zone total phosphorus, total nitrogen and USACE inflow in Cherry Creek Reservoir, 2014 WY.

Patterns in soluble reactive phosphorus concentrations collected during profile sampling at Site CCR-2 showed a well-mixed Reservoir from October to mid-May (Figure 18). There was an extended period of nutrient release from bottom sediments from mid-May through late August as revealed by the pattern of increasing total phosphorus concentrations for 7 m layer as compared with concentrations observed at the same layers during the spring and late fall periods (Figure 18). The period of internal phosphorous loading shows a substantial increase in phosphorus at the 7 m depth from mid-June to mid-August. During this period, the soluble reactive phosphorus fraction in the 7 m water layer accounted for approximately 57 to 85% of the total phosphorus content, also supporting evidence that phosphorus was being released from the sediment during that time.

During 2014, the aeration system was not operating in the Reservoir because the CCBWQA decided to re-evaluate phytoplankton dynamics in the absence of aeration to provide more information for the Reservoir model development. In previous years when the aeration system was operational, there was more consistency within the upper layers due to the upward diffusion of phosphorus from the sediment layer at approximately 7 m, and the eventual circulation within the upper layers by the aeration system. In terms of nutrient concentrations, the aeration system appears to create a well-mixed layer from the surface down to approximately the 6 m depth (GEI 2013), which is slightly above the aerator heads (approximately 0.75 m above the sediment). However, this consistency in the upper layers of the Reservoir was not as apparent during June through September 2014, as in recent years when the destratification system was operating.

Photic zone total nitrogen mean concentrations ranged from 583 to 1,258 µg/L, with a 2014 WY average of 951 µg/L (Figure 17). During the July through September period, the photic zone total nitrogen concentration also ranged from 583 to 1,184 µg/L, with a mean concentration of 904 µg/L (Figure 17).

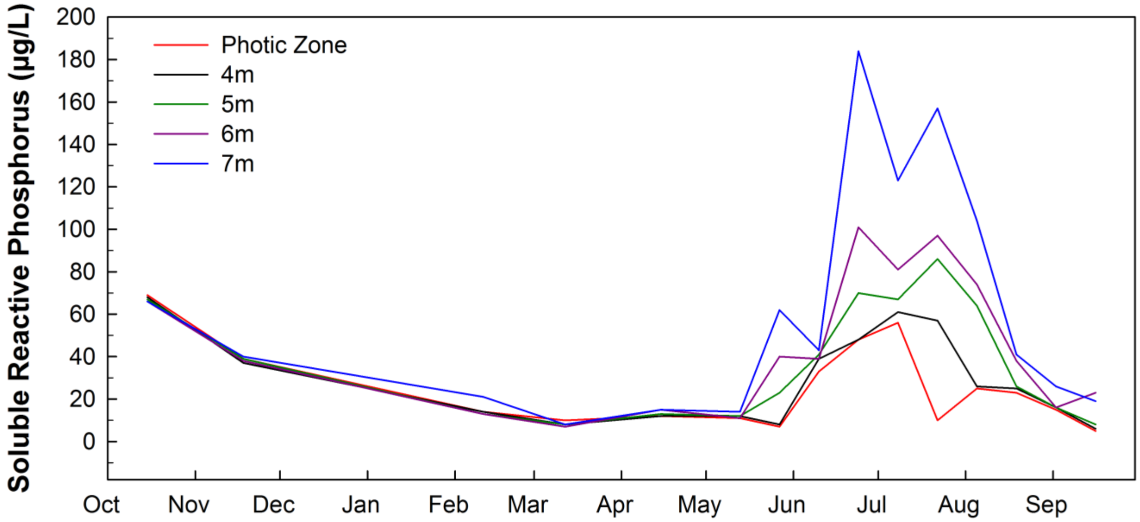

Figure 18: Soluble phosphorus concentrations recorded for the photic zone and at depth during routine monitoring during the 2014 WY at CCR-2.

4.1.5 *Long-Term Phosphorus Trends in Cherry Creek Reservoir*

Routine monitoring data collected since 1987 indicates a general increasing pattern in summer mean concentrations of total phosphorus in the photic zone of the Reservoir (Figure 19). In 2014, the July through September mean concentration of total phosphorus was 87 µg/L. This value is less than last year's 125 µg/L concentration, and it is equal to the long-term median value of 87 µg/L (Table 4). Regression analyses performed on 1997 to 2014 seasonal mean total phosphorous data indicates a significant ($p = 0.006$) increasing trend. The 2014 seasonal mean total phosphorus concentration is within the range of historical conditions absent aeration (i.e., prior to 2008) and reflect the variability observed in the algal biomass data (i.e., chlorophyll *a*). The 2011, 2012, and 2013 seasonal mean concentrations also reflect the more uniform conditions observed in the algal biomass data. Algal biomass or its relative phosphorus content is included in the total phosphorus fraction which is apparent in the total phosphorus data.

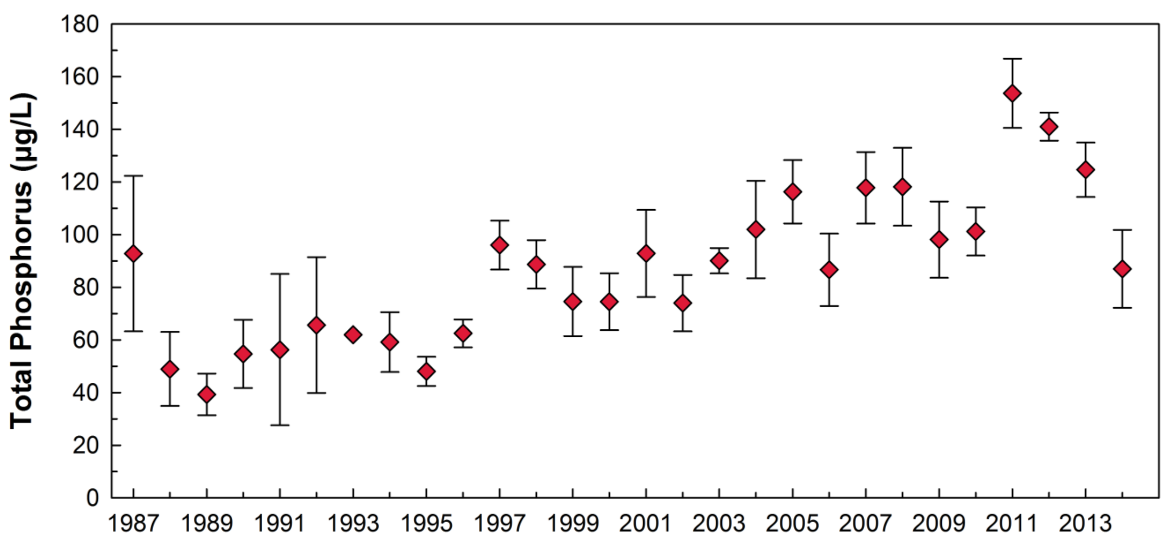

Figure 19: Seasonal mean (July through September) total phosphorus concentrations (µg/L) measured in Cherry Creek Reservoir, 1987 to 2014. Error bars represent a 95% confidence interval for each mean.

Table 4: Comparison of water year mean and July through September mean phosphorus, nitrogen, and chlorophyll *a* levels in Cherry Creek Reservoir, 1988 to 2014.

Year	Total Nitrogen (µg/L)		Total Phosphorus (µg/L)		Mean Chlorophyll *a* (µg/L)	
	WY	Jul-Sep	WY	Jul-Sep	WY	Jul-Sep
1988	902	1,053	52	49	21.8	31.8
1989	803	828	45	39	8.5	5.6
1990	600	--	58	55	2.3	8.6
1991	1,067	1,237	86	56	9.7	9.8
1992	931	970	52	66	12.2	17.4
1993	790	826	55	62	12.6	14.8
1994	1,134	1,144	53	59	11.4	15.4
1995	910	913	46	48	12.7	15.6
1996	889	944	35	62	13.4	18.2
1997	981	1,120	70	96	16.4	22.2
1998	763	880	77	89	18.4	26.6
1999	709	753	76	81	21.6	28.9
2000	774	802	80	81	22.3	25.1
2001	764	741	84	87	26.0	26.1
2002	825	858	70	74	21.7	18.8
2003	987	1,121	83	90	22.7	25.8
2004	929	977	85	102	19.1	18.4
2005	916	990	93	116	16.3	17.1
2006	874	914	96	87	13.7	14.7
2007	880	716	108	118	21.4	12.6
2008	795	800	92	118	15.8	16.6
2009	1,173	1,236	85	98	12.4	13.2
2010	925	974	92	101	23.6	31.0
2011	904	987	110	154	25.6	26.7
2012	891	923	114	141	24.0	27.1
2013	995	983	101	125	24.8	26.8
2014	951	904	86	87	23.4	24.4
Mean	**891**	**946**	**77**	**87**	**17.5**	**20.0**
Median	**902**	**937**	**83**	**87**	**18.4**	**18.4**

4.1.6 *2014 WY Chlorophyll a Levels*

The annual pattern of chlorophyll *a* concentrations was quite variable throughout the 2014 WY. From October 2013 through September 2014, chlorophyll *a* concentrations ranged from 6.1 µg/L to 43.3 µg/L with a 2014 WY mean chlorophyll *a* concentration of 23.4 µg/L (Figure 20). During the regulatory growing season (July through September) 5 of the 6 Reservoir mean chlorophyll *a* concentrations were greater than 18 µg/L standard (Figure 20), and showed considerable variability early in the growing season. The July through September seasonal mean chlorophyll *a* concentration was 24.4 µg/L, with a peak seasonal reservoir mean concentration of 34.8 µg/L. The winter (February) under ice chlorophyll *a* level was the highest observed concentration and was followed by the transitional period from a winter to a spring algae assemblage which resulted in a decreasing chlorophyll a pattern. This pattern is typical of historical conditions, absent the destratification system, when Reservoir conditions typically resulted in the lowest chlorophyll *a* concentrations in June. While the Reservoir again revealed the lowest observed chlorophyll *a* concentration in June, this event was preceded by a cyanobacteria bloom (*Anabaena flos-aquae*) that resulted in 37.5 µg/L of chlorophyll *a*. A wind-driven mixing event caused the cyanobacteria population to crash just prior to sampling the Reservoir on June 24th. Following the cyanobacteria population crash in late June, different algae assemblages resulted in the high chlorophyll *a* concentrations in July which are very similar to the cyanobacteria driven event. Based solely on chlorophyll *a* concentrations, the June and July events are the nearly identical, yet different algae assemblages were responsible for the same level of chlorophyll *a*. A late July storm event, again affected Reservoir conditions which caused the shift in chlorophyll a concentrations; though not as drastic as observed in late June. Chlorophyll *a* concentrations averaged 19.3 µg/L in late summer (August and September).

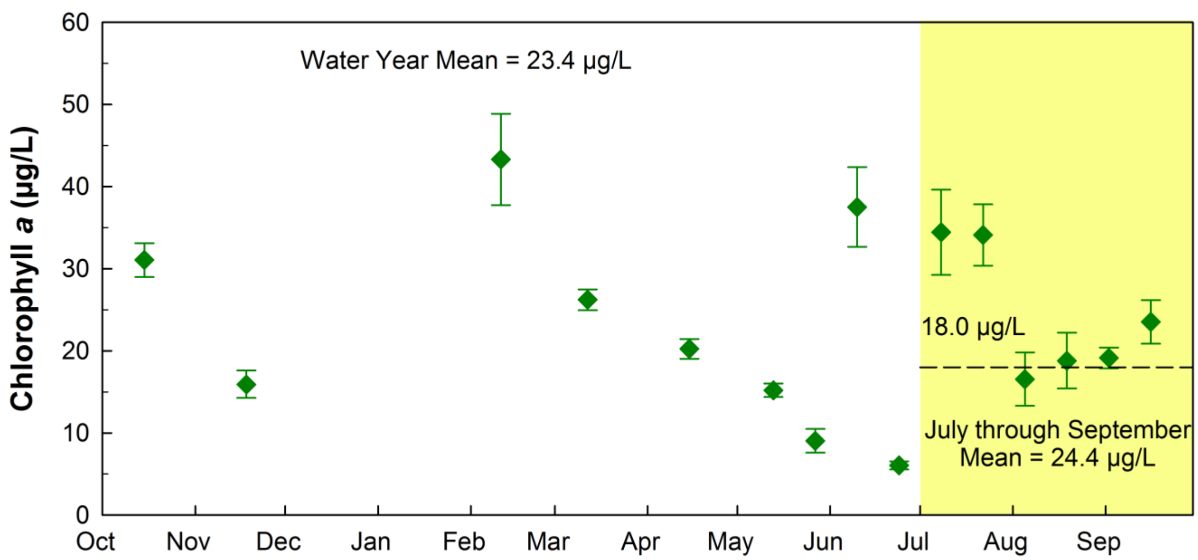

Figure 20: Concentration of chlorophyll *a* (µg/L) in Cherry Creek Reservoir, 2014 WY. Error bars represent a 95% confidence interval around each mean. Highlighted area denotes the seasonal period for the chlorophyll *a* standard.

4.1.7 *Long-term Chlorophyll a Trends in Cherry Creek Reservoir*

Since 1987, there is no significant increasing or decreasing trend in the seasonal mean chlorophyll *a* concentration over time (Figure 21); although patterns in the data correspond to different annual conditions (e.g. dry summer, 2002; wet summers, 2007 and 2009) or different reservoir management strategies (2008-2013). In the summer of 2008, the seasonal operation of the Reservoir destratification system began and continued through 2013. In 2014, the destratification system was not operated to specifically examine the phytoplankton community dynamics in terms of both composition and biomass (chlorophyll) to the absence of continuous mixing by the destratification system. Under destratification management, the period from 2010 through 2013 represented a new state of conditions for the Reservoir. The 2010 seasonal mean chlorophyll *a* concentration (31.0 µg/L) represents the highest seasonal level observed during destratification operation or for the history of the Reservoir, and highlights the propensity of algae to respond to optimal growing conditions. The 2011 through 2013 seasonal mean chlorophyll *a* concentrations averaged 28.6 µg/L, and were considerably greater than the chlorophyll *a* standard. While the destratification was not operated in 2014, the chlorophyll a concentration remained relative high at 24.4 µg/L and is statistically indistinguishable from the previous 4 years.

For regulatory assessment purposes (i.e. 303d listing), the site-specific chlorophyll *a* standard has two assessment components – a numeric level and an allowable exceedance frequency. In essence, the Reservoir is allowed to exceed the numerical standard one time over a 5-year sequential period. The 2014 seasonal mean chlorophyll *a* concentration represents the fifth consecutive year the Reservoir has exceeded the numeric standard, as well as the allowable exceedance frequency (Figure 21).

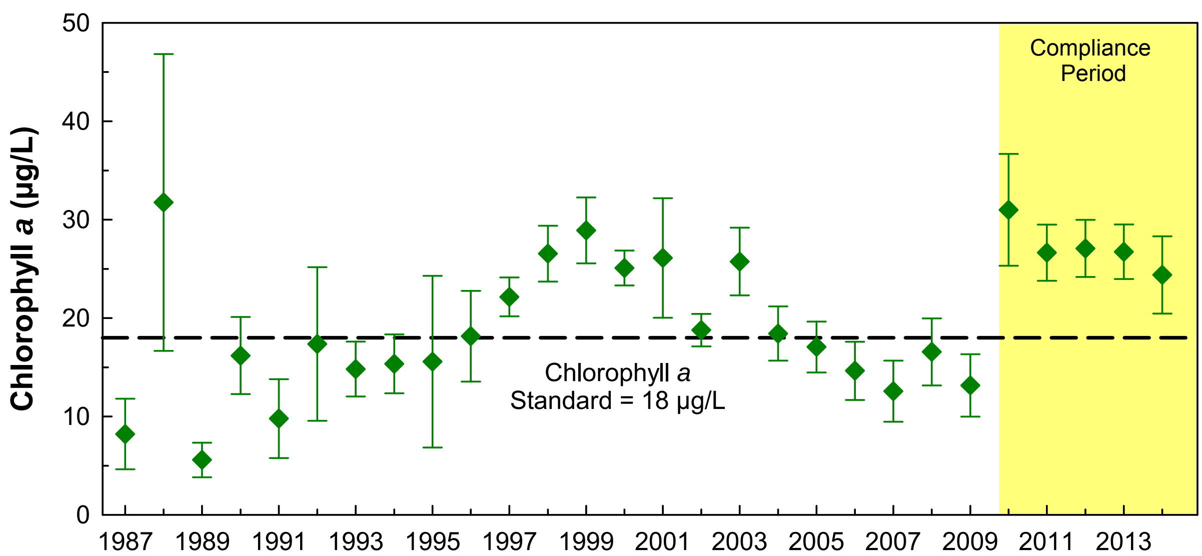

Figure 21: Seasonal mean (July through September) concentrations of chlorophyll *a* (µg/L) measured in Cherry Creek Reservoir, 1987 to 2014. Error bars represent a 95% confidence interval around each mean. The Reservoir destratification system was operated from 2008 through 2013.

4.2 Reservoir Biology

4.2.1 *2014 Phytoplankton*

The 2014 summer season represented conditions in the reservoir absent the influence of the destratification system. More specifically, the destratification system was not operated to evaluate the response of the algae assemblages and to establish conditions without aeration under the current phytoplankton analyst (Aquatic Analysts). Given the absence of continuous mixing, there were stakeholder concerns regarding the potential development of large filamentous cyanobacteria which may also produce cyanotoxins. As such, additional opportunistic phytoplankton samples were collected during the summer to document the June cyanobacteria bloom in different areas of the Reservoir, including the swim beach area.

During the routine sampling events, the phytoplankton total density in the photic zone composite samples (CCR-1, CCR-2, and CCR-3) ranged from 838 #/mL on June 24th to 15,489 #/mL on October 14th (Table 5). These samples are representative of the algal populations that were present within the upper 3 m of the water column at the time of sampling. The number of algal taxa present during each of these sampling events ranged from 8 on February 11th, to 31 on May 13th. A number of opportunistic samples were collected from June 10th through June 24th to document the cyanobacteria bloom. On June 9th, GEI was notified that an algae bloom was occurring in the Marina area as well as the other parts of the Reservoir; therefore, multiple surface water samples were collected on June 10th in addition to the routine photic zone composite sample. The CCR-1 and CCR-2 surface composite sample and the CCR-2 surface sample revealed total phytoplankton densities of 52,234 #/mL and 62,999 #/mL, respectively, and with a total of 10 taxa each. The Marina surface water sample revealed a total density of 9,020 #/mL, and 14 total taxa. In both open water surface samples, *Anabaena flos-aquae* (large filamentous cyanobacteria containing gas vacuoles) accounted for greater than 96% of the algae identified, and greater than 80% of the algae identified in the Marina surface water sample. The differences observed in the *Anabaena flos-aquae* density between the photic zone composite sample (1,481 #/mL) and other surface water samples (50,102 #/mL and 61,590 #/mL) highlights this species ability to rapidly grow at the surface by regulating their buoyancy via their gas vacuoles (Table 5). On June 13th, GEI also received a request from the CCBWQA to collect additional samples, prior to the weekend, to document conditions of the cyanobacteria bloom. Samples were collected from Site CCR-2, the Marina, and the swim beach area with phytoplankton total density ranging from 3,178 #/mL to 9,020 #/mL. Cyanobacteria accounted for more than 73% of the individuals identified in the swim beach and Site CCR-2 samples and 40% of the individuals identified in the Marina sample. On June 17th, the cyanobacteria bloom had accumulated along the face of the dam and created a visually dense layer of biomass on the surface of the Reservoir. A single surface water sample was collected from near the outlet tower, and represented a worse-case scenario for the cyanobacteria bloom. Cyanobacteria density was 226,402 #/mL and represented over 98% of the algae identified in the sample.

During this cyanobacteria bloom, cyanotoxin samples were also collected (Section 4.6.1) and analyzed by GreenWater Laboratory and when cyanotoxins were present the laboratory identified and enumerated the cyanobacteria in the sample to help document the species likely responsible for the toxins. While these samples were not preserved (toxin analyses require raw water) and identified using a different phytoplankton method, their results are consistent with Aquatic Analysts. For example, GreenWater Laboratory reported a cyanobacteria density of 54,807 #/mL for the CCR-2 surface water sample collected on June 10th (Appendix E) while Aquatic Analysts reported a cyanobacteria density of 61,590 #/mL for the same sample. Similarly, GreenWater Laboratory reported a cyanobacteria density of 133,411 #/mL for Dam surface water sample collected on June 17th, while Aquatic Analysts reported a cyanobacteria density of 226,402 #/mL for the same sample.

Based on the calendar year, the assemblage was dominated in terms of density by chlorophytes (green algae, 47%), with cryptomonads and diatoms being the next most abundant taxonomic groups at 30% and 16%, respectively (Figure 22). In 2014, the relative percent density of cyanobacteria was 2.2%. In February, green algae were the dominant algal group (81%) followed by cryptomonads (15%). In March, cryptomonads were the dominant algal group (72%) followed by green algae (12%). Green algae abundance was variable throughout 2014; however, they were relatively abundant throughout many of the sampling events (Figure 22). Cryptomonads were especially abundant during the March, late June, and early July sampling events (Figure 22).

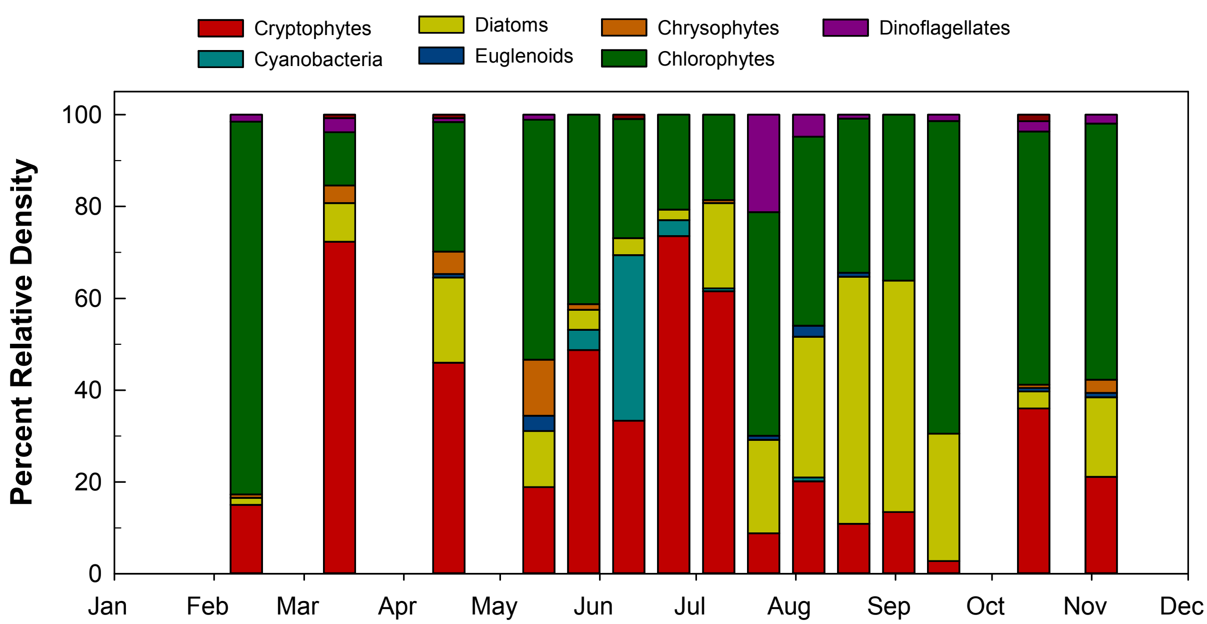

Figure 22: Percent relative density of algal groups for each routine photic zone composite sample collected in Cherry Creek Reservoir, 2014 CY.

Table 5: Density (#/mL) of phytoplankton and total number of taxa for routine photic zone composite samples representative of the three samples sites on Cherry Creek Reservoir, and for opportunistic grab/composite samples in other Reservoir locations, 2014 CY.

Sample Date	Taxonomic Group									
	Diatoms	Green Algae	Cyano-bacteria	Golden Algae	Euglenoid	Dino-flagellate	Crypto-monads	Unidentified Flagellate	Total Density	Total Taxa
Routine Photic Zone Composite Samples (CCR1,2,3)										
2/11/2014	113	6,089	--	56	--	113	1,128	--	7,498	8
3/12/2014	349	476	--	159	--	127	2,985	32	4,129	16
4/15/2014	593	902	--	155	26	26	1,469	26	3,196	21
5/13/2014	413	1,766	--	413	113	38	639	--	3,383	31
5/27/2014	204	1,923	204	58	--	--	2,272	--	4,661	22
6/10/2014	152	1,063	1,481	--	--	--	1,367	38	4,100	15
6/24/2014	19	173	29	--	--	--	617	--	838	11
7/08/2014	1,298	1,298	45	45	--	--	4,295	--	6,980	14
7/22/2014	674	1,611	--	--	29	703	293	--	3,309	28
8/05/2014	671	900	18	--	53	106	441	--	2,188	25
8/19/2014	1,162	726	--	--	18	18	236	--	2,161	21
9/02/2014	2,553	1,830	--	--	--	--	681	--	5,063	23
9/16/2014	1,718	4,209	--	--	--	86	172	--	6,185	22
10/14/2014	569	8,542	--	114	114	342	5,581	228	15,489	18
11/04/2014	2,182	7,032	--	364	121	242	2,667	--	12,609	22
Opportunistic Grab/Composite Samples										
6/10/2014[a]	82	1,394	50,102	--	--	--	656	--	52,234	10
6/10/2014[b]	70	634	61,590	--	--	--	705	--	62,999	10
6/10/2014[c]	150	1,353	9,772	--	--	--	902	--	12,177	13
6/13/2014[b]	50	752	7,316	--	--	--	902	--	9,020	14
6/13/2014[c]	68	1,128	1,264	--	--	--	683	34	3,178	16
6/13/2014[d]	117	933	5,132	--	--	--	467	--	6,648	15
6/13/2014[e]	237	576	2,713	--	--	--	170	--	3,696	14
6/17/2014[f]	--	2,706	226,402	--	--	--	902	--	230,010	5
6/24/2014[d]	31	194	31	--	--	--	398	--	654	10

[a] CCR-1 and CCR-2 surface
[b] CCR-2 surface
[c] Marina surface
[d] CCR-2 photic composite
[e] Swim beach surface
[f] Dam surface

When the size (e.g., biovolume) of each alga is considered during each routine photic zone composite sample (Figure 23), green algae were the most dominant algal group (28%) observed over the course of the year, followed by cryptophytes (22%) and diatoms (17%). Both the dinoflagellates and cyanobacteria accounted for approximately 15% of the total algal biovolume. Patterns in algal biovolume show typical seasonal succession patterns of many temperate lakes and reservoirs with cryptomonads and diatoms being most abundant in the spring, while green algae were abundant throughout the year and comprising a larger component of the assemblage in winter and fall.

In February 2014, the green algae (*Chlamydomonas sp.*), and the flagellated cryptomonad algae (*Cryptomonas erosa*) were the most abundant in terms of biovolume and density. In March, the biovolume of green algae decreased substantially and cryptomonads were the dominant algal group. In the Rocky Mountain region, cryptomonads appear to prefer colder water (Kugrens and Clay 2003) which explains their abundance in late winter and spring. This could partially explain the increased density of cryptomonads during the sampling events. In April, cryptophytes continued to be dominant in terms of density; however, the diatoms (*Astrionella formosa* and *Stephanodiscus astraea minutula*) were dominant in terms of biovolume. In early May, *Scenedesmus quadricauda* (green algae) was the most abundant species in terms of density, but *Cryptomonas erosa* continued to dominant biovolume. In late May, the cryptomonad (*Rhodomonas minuta*) was the most abundant species in terms of density, while the cyanobacterium (*Anabaena flos-aquae*) comprised a larger percentage of the biovolume.

Factors contributing to the cyanobacteria bloom in June were evident in the data collected during the May 27th sampling event. The May 27th temperature and dissolved oxygen profiles and the CCR-2 7m soluble reactive phosphorus data all indicated that thermal stratification was present and that internal phosphorus loading was beginning to occur. When these data are considered in the context of the phytoplankton biovolume data, the Reservoir conditions were conducive for the subsequent algal bloom in June. On May 27th, a cyanobacterium (*Anabaena flos-aquae*) accounted for 41% of the total algal biovolume, and by June 10th their biovolume accounted for 84% of the total biovolume. *Anabaena flos-aquae* is a filamentous cyanobacterium whose trichome is composed of many individual cells, including a gas-vacuole, to form one physiological entity that has the ability to fix atmospheric nitrogen (Komárek et al. 2003). These physiological characteristics allowed this species to grow very rapidly at the surface of the Reservoir and create a visible algal biomass layer that covered much of the Reservoir surface. Following their population crash in late June, *A. flos-aquae* accounted for 11% of the biovolume, while cryptomonads (*Cryptomonas erosa* and *Rhodomonas minuta*) became the most dominant taxa in terms of biovolume at 72%. Other cyanobacteria taxa were present during the routine sampling events from late May through early August which included *Aphanizomenon flos-aquae* and *Aphanothece* sp. (picoplankton) but their biovolume accounted for less than 2.6% and 0.1% of the total algal biovolume, respectively. The cyanobacteria (e.g., *Aphanizomenon flos-aquae* and *Anabaena flos-aquae)* typically dominate late summer algal assemblages (Whitton and Potts 2000; James et al. 1992; Padisák 1985, Konopka and Brock 1978; Pollingher 1987) which makes the *A. flos-aquae* bloom in early June unique, including for Cherry Creek Reservoir.

During late July, the algal assemblage was transitioning from a diatom – cryptomonad dominated community to one dominated by dinoflagellates (77%), in terms of biovolume. In early August, the algal assemblage was more balanced when euglenoids (11%), cryptophytes (16%), diatoms (17%), green algae (22%), and dinoflagellates (31%) contributed more evenly to the total biovolume. From late August through September, the algal assemblage again transitioned to assemblages dominated (i.e., biovolume) by diatoms and green algae. These observed successional patterns of algal dominance are closely coupled with reservoir conditions such as cooler water temperature during the spring followed by the warmer water and longer photoperiod conditions of the summer and the cool down during the fall. In addition, nutrient resources are a key component to the successional pattern as well as the ability of each taxon to outcompete other taxa for the resources. Other biological factors such as zooplankton and forage fish grazing influence the algal succession pattern too.

The relative density and biovolume of algae is largely a response to bottom-up factors that promote growth such as inorganic nutrients, light, temperature, and pH which are closely coupled with top-downs factors such as predation (i.e., zooplankton grazing), life history traits (i.e., cyst production) and outflow (Pollingher 1987). The bottom-up factors were evident during the summer season when internal phosphorus loading began in May.

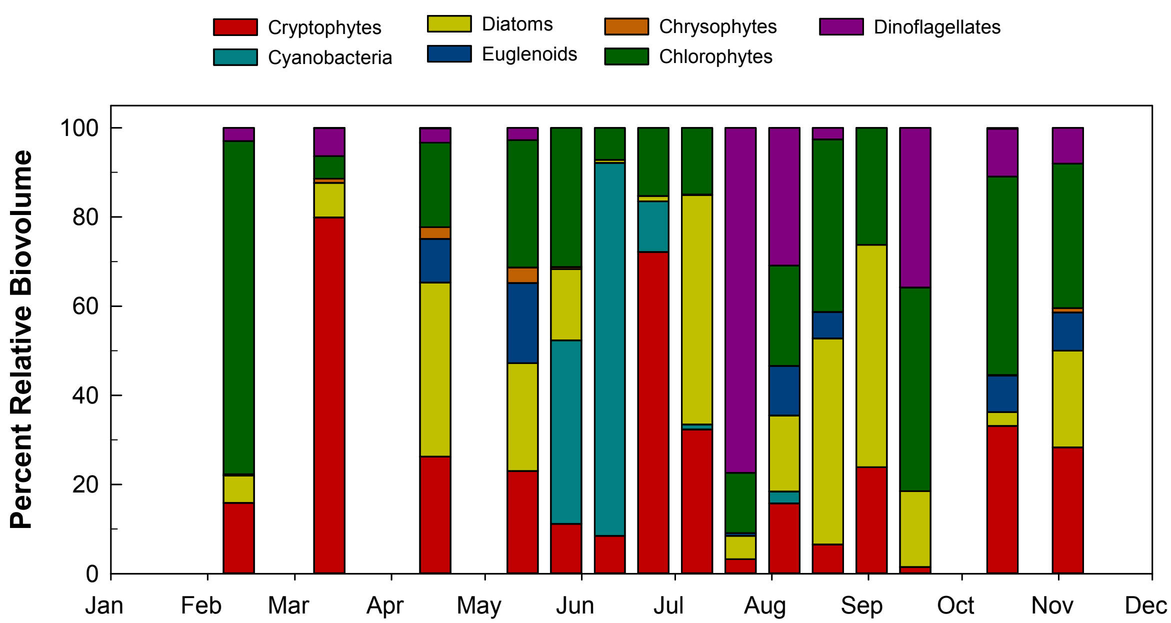

Figure 23: Percent relative biovolume of algal groups for each routine photic zone composite sample collected in Cherry Creek Reservoir, 2014 CY.

A key aspect in the algal successional patterns is that cyanobacteria were only dominant during a few weeks in late-May and early June (Figures 22 and 23). Only 14 days after the cyanobacteria bloom was observed on June 10th, this group comprised less than 5% of the assemblage in terms of density and approximately 27% in terms of biovolume.

In the event of reduced top-down pressure such as low zooplankton grazing, the algal assemblage can maximize their relative density given the influence of the bottom-up factors. It is unlikely that the zooplankton population was able to effectively exert top-down controls on the algal population during the summer 2014 conditions. The large gizzard shad (forage fish) population may be over-grazing the zooplankton population such that algae growth remained unchecked during their peak growing period. Communities dominated by large zooplankton populations tend to show reduced algal biomass yields as these herbivores effectively reduce the number of algae in the water column (Sarnelle 1992; Mazumder 1994; Mazumder and Lean 1994). These patterns are not observed in the Reservoir. However, this relationship can be affected by the relative biomass (e.g., size) of the individual algae. For example, if the algal assemblage is dominated by filamentous or colonial cyanobacteria, zooplankton will preferentially graze on more palatable and preferred algae such as diatoms, cryptomonads, and green algae (Vanni and Temte 1990). This condition was apparent during early July when the zooplankton assemblage responded to the more palatable algae – diatoms and cryptomonads.

In 2014 the Reservoir exhibited high biomass levels (i.e., chlorophyll *a*) at various periods throughout the year. In February 2014, the high chlorophyll *a* concentration of 43.3 µg/L was associated with primarily with the high density and biovolume of *Chlamydomonas sp.* (green algae). In early June 2014, the high chlorophyll *a* concentration of 37.5 µg/L was associated with the high density and biovolume of *Anabaena flos-aquae* (cyanobacteria, 84%). The chlorophyll *a* concentration in late June decreased to 6.1 µg/L which was associated with the crash of the cyanobacteria bloom and subsequent low algal density in the Reservoir (838 #/mL, Table 5). Following this marked decrease in the chlorophyll *a* concentration, high chlorophyll *a* concentrations were observed during both July sampling events (34.5 and 34.8 µg/L). These chlorophyll *a* concentrations were associated with the increased density and biovolume of *Melosira ganulata* (diatom), *Cryptomonas erosa* (cryptomonad) and *Peridinium cinctum* (dinoflagellate).

4.2.2 *Long-Term Phytoplankton*

In previous years, phytoplankton data was compared based on the pre- and post-aeration system timeframe; however, due to circumstances in 2009 there was a change in laboratory regarding the phytoplankton analyses. This laboratory change confounded the pre/post destratification results regarding algal density. After extensive discussion about the datasets and laboratory methodologies, it was determined that the differences resulted in data not directly comparable. The methodological differences centered on each laboratory's ability to document picoplankton to the genus/species level and to document biovolume estimates for all types of algae. Neither laboratory was able or is able to document both types of information. The current laboratory provides both density and biovolume data to adequately characterize the large filamentous cyanobacteria which are the "algae of concern" and which destratification management is designed to control or reduce. The current laboratory also provides both density and biovolume data that adequately characterizes the algae assemblage to document which types of algae contribute to the chlorophyll *a* concentration (algae biomass), as well as providing data suitable for modeling purposes.

Therefore, phytoplankton data collected prior to 2009 are not discussed in the context of long-term phytoplankton analyses, and the focus has shifted to the period from 2009-2014 with the current laboratory. This period contains 5 years of data with destratification and one year without destratification (2014).

From 2009 through 2014, algal percent relative density has been variable among the years (Figure 24). Reservoir conditions in 2009, were different from the other years in the sense that seasonal mean chlorophyll *a* concentration was low (13.2 µg/L) compared to other years under aeration when concentrations have ranged from 24.1 µg/L to 31µg/L. In 2009, the cryptomonads dominated algal abundance (45%), and were followed by diatoms (23%) and green algae (22%) (Figure 24), yet in terms of biovolume, the diatoms comprised the largest percentage (60%) of the community (Figure 25). In 2009, the cyanobacteria density accounted for 0.7% of the community, and their relative biovolume accounted for 2.2% of the community. From 2010 through 2013, there was more consistency with respect to their relative densities among the three dominant types of algae (cryptomonads, diatoms, and green algae; Figure 24); although the relative biovolume data showed more variability with diatoms, euglenoids, and cyanobacteria (Figure 25). The relative biovolume for both cryptomonads and green algae were consistent during this period. In terms of biovolume, cyanobacteria accounted for 17.4%, 4.2%, 18.5%, and 5.3% over the four year period from 2010 to 2013.

In 2014, some algae groups revealed density and biovolume conditions that were slightly different than the previous 4 years, yet most of the algae groups revealed conditions within the range of conditions previously observed. In 2014, the green algae revealed greater percentages for both density and biovolume as compared to previous years, while the same metrics for the diatoms were both less than the previous years. Cyanobacteria relative percent density (2.2%) and biovolume (15%) were both in the range of conditions previously observed for the Reservoir.

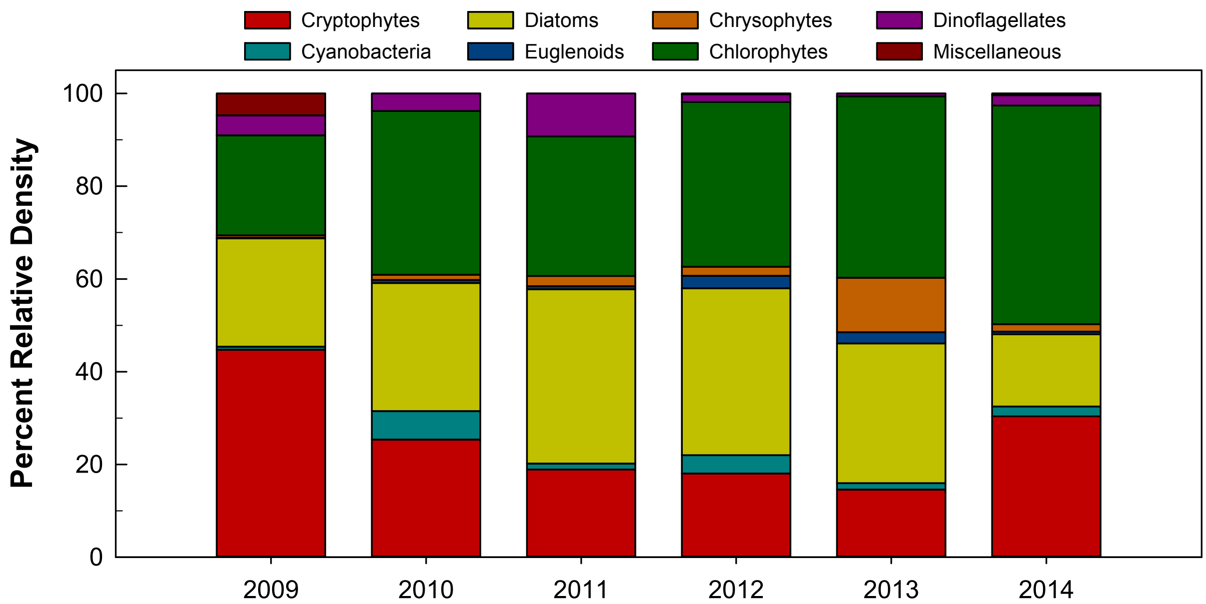

Figure 24: Percent algal density of major taxonomic groups in Cherry Creek Reservoir from 2009 through 2014, by CY.

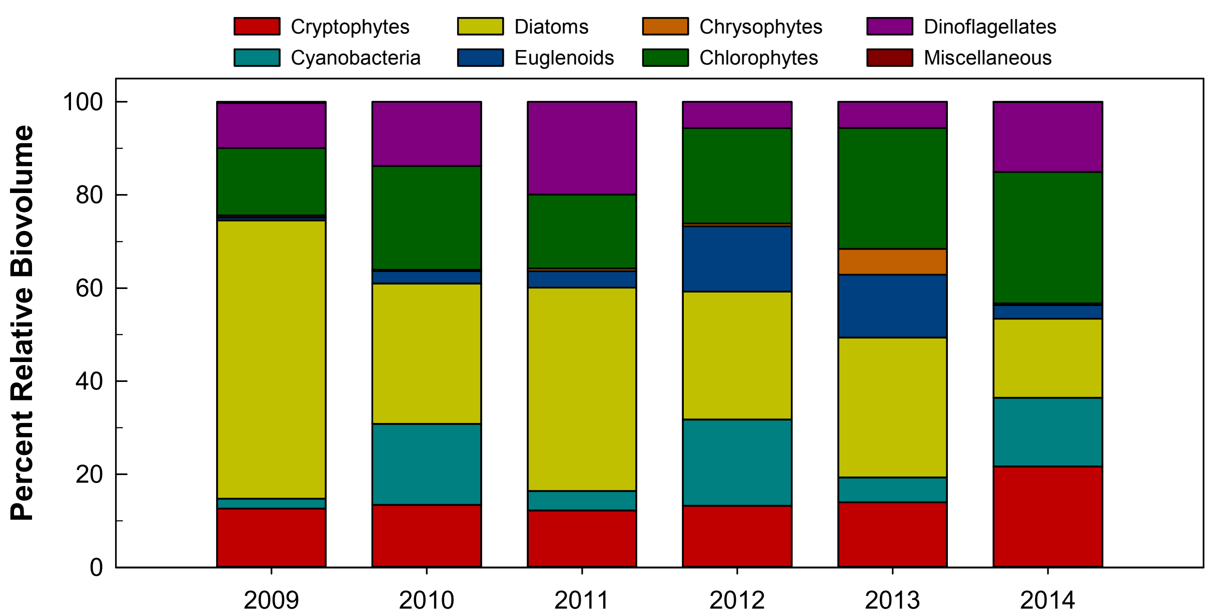

Figure 25: Percent algal biovolume of major taxonomic groups in Cherry Creek Reservoir from 2009 through 2014, by CY.

4.2.3 *2014 Zooplankton*

Zooplankton density ranged from 139 organisms/L in late March to 1,239 organisms/mL which occurred in early July 2014 (Figure 26). Over the WY, the zooplankton assemblage contained a total of nine zooplankton crustacean species—seven cladocerans and two copepods with immature copepodids and nauplius—and nine species of rotifers were collected during the

15 sampling events (Appendix E). There was one species that was collected during all sampling events: a relatively smaller cladoceran (*Bosmina longirostris*). The immature copepods (copepodids and nauplius) were also observed during all 15 sampling events. The copepod *(Diacyclops thomasi*) was collected at 14 of the 15 sampling events (Appendix E). *Bosmina longirostris* have been found to be the dominant cladoceran in other eutrophic lakes (Harman et al. 1995). One rotifer (*Keratella cochlearis*) was collected during 12 of the 15 sampling events and one cladoceran (*Daphnia sp.*) was collected during 11 of the 15 sampling events (Appendix E).

Cladocera were low in abundance throughout the late winter and early spring; however, they became relatively abundant during mid-May through July 2014. Copepods did comprise the majority of the zooplankton assemblage during most sampling events (Figure 26). Both the copepods and rotifers substantially increase their density during the early July algal bloom that was comprised mainly of diatoms and cryptomonads. While the zooplankton assemblage showed some response to the algal assemblages and biomass, there is no statistical correlation between the zooplankton density and chlorophyll *a* (surrogate for algal biomass). Similarly, there was no correlation between zooplankton density and algal density or algal biomass.

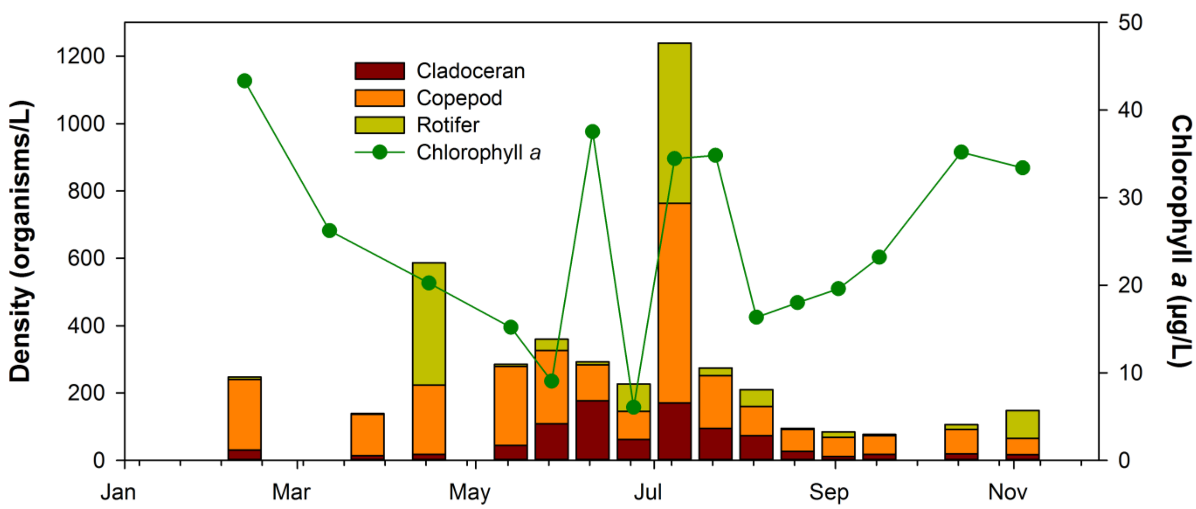

Figure 26: Total density of zooplankton groups and chlorophyll *a* concentration by sample date in Cherry Creek Reservoir, 2014 CY.

Ideally, the pattern between zooplankton density and chlorophyll *a* (algal biomass) should be inversely related, as herbivorous zooplankton could theoretically affect algal biomass via grazing pressure, provided planktivorous fish are not suppressing the zooplankton populations (Harman et al. 1995). However, in Cherry Creek Reservoir, the increased abundance of gizzard shad has likely increased the grazing pressure on the zooplankton assemblage, thereby reducing the zooplankton density and reducing their ability to effectively control the algal assemblage. Notably, the cladoceran – *Daphnia lumholtzi* – was observed in the Reservoir from early August through November 2014. This species is considered an Aquatic Nuisance Species (ANS) and was also observed in 2011 and 2012.

This species has two relatively long spines on the head and tail which may affect fish that feed on zooplankton, plus this species may out-compete other native cladocera for resources.

4.3 Stream Water Quality

4.3.1 *2014 WY Phosphorus Concentrations in Streams*

The median annual total phosphorus concentration for base flow conditions ranged from 36 µg/L at Site CT-P1 to 340 µg/L at Site MCM-1 (Table 6). The median seasonal (July through September) base flow total phosphorous concentration was greater than the annual median concentration at all three Cherry Creek sites (sites CC-10, CC-Out @ I225, and EcoPark) and three of the four Cottonwood Creek sites (sites CT-P1, CT-P2 and CT-1; Table 6). The seasonal median concentration of total phosphorous was 1 µg/L less than the median annual phosphorous concentration at Site CT-1 (Table 6). The seasonal median concentration of total phosphorus ranged from 49 µg/L at Site CT-P1 to 500 µg/L at Site MCM-1. At all stream sites, except McMurdo Gulch, where storm samples are not collected, the storm flow total phosphorous concentration was greater than concentrations during base flow conditions. The annual median storm flow total phosphorous concentrations ranged from 97 µg/L at Site CT-2 to 472 µg/L at Site CC-10 (Table 6).

Table 6: Comparison of median base flow and median storm flow concentrations of total phosphorus (TP) and total suspended solids (TSS) in tributaries to Cherry Creek Reservoir, 2014 WY.

	Base Flow				Storm Flow	
	July - September		Annual		Annual	
Stream/Site	TP (µg/L)	TSS (mg/L)	TP (µg/L)	TSS (mg/L)	TP (µg/L)	TSS (mg/L)
Cherry Creek						
EcoPark	133	15	122	8	472	155
CC-10	213	7	197	11	326	84
CC-Out @ I225	154	13	98	12	--	--
Cottonwood Creek						
CT-P1	49	16	36	10	240	123
CT-P2	68	20	38	13	189	58
CT-1	74	31	69	24	174	59
CT-2	47	12	48	15	97	23
McMurdo Gulch						
MCM-1	500	--	340	6	--	--
MCM-2	305	7	300[1]	12	--	--

[1] Outlier concentration (1.342 µg/L) was removed for assessment purposes.

Total suspended solids were generally consistent across all sites during base flow conditions during the 2014 WY. The annual median annual total suspended solids concentrations for base flow conditions ranged from 6 mg/L at MCM-1 to 24 mg/L at CT-1 (Table 6). The median seasonal (July through September) base flow total suspended solids concentrations were greater at five of the seven sites compared to the annual median concentrations, and ranged from 7 mg/L at Site CC-10 to 31 mg/L at Site CT-1.. At all stream sites, with the exception of McMurdo Gulch sites, the storm flow total suspended solids concentration was greater than concentrations during base flow conditions. The annual median storm flow total suspended solids concentrations ranged from 23 mg/L at Site CT-2 to 155 mg/L at Site CC-10 (Table 6).

4.3.2 *Long-Term Trends in Phosphorus Concentrations in Cherry Creek Reservoir Tributaries*

Long-term patterns (1995 to 2014) in total phosphorus and soluble reactive phosphorus concentrations were evaluated for the two main tributary sites (CC-10 and CT-2) to Cherry Creek Reservoir, for both base flow and storm flow conditions. The long-term median annual base flow total phosphorus concentration for Cherry Creek (Site CC-10) is 207 µg/L and (Table 7), with storm flow concentrations being approximately 74% greater with a median phosphorous concentration of 360 µg/L (Table 8). In Cottonwood Creek (Site CT-2), the long-term median annual base flow total phosphorus concentration is 69 µg/L; however, the long-term median storm flow concentration is approximately 2.5 times greater (175 µg/L). The long-term median soluble reactive phosphorus fraction in base flows for Cherry Creek were approximately 79% of the long-term median total phosphorus concentrations, while soluble reactive phosphorus fractions in Cottonwood Creek (Site CT-2) have been approximately 16% of total phosphorus concentrations.

In the Colorado regulatory proceedings there is precedence for only considering the last 5 years of data in the hearing for standard levels because conditions may change over time. Therefore, median values for the most recent 5-year period have been provided for comparison to long-term statistics (2010 through 2014, Tables 7 and 8). In Cottonwood Creek, total phosphorous concentrations have decreased (Tables 7 and 8) due to the CCBWQA's efforts in stream reclamation to reduce erosion, reductions in nutrient discharges from point sources and other storm management practices implemented within the watershed. In Cherry Creek, the long-term metrics are very similar to the last 5 years of data, with exception of the storm flow metrics. In the last 5 years, storm flow total phosphorous and soluble reactive phosphorus concentrations have increased by approximately 50 µg/L when compared to the long-term metric. However, the maximum storm flow total phosphorus and soluble reactive phosphorous concentrations have decreased over the years (Figures 27 and 28).

Base flow total phosphorus and soluble reactive phosphorus concentrations revealed significant ($p < 0.001$) decreasing trends during base flow conditions at site CC-10 and CT-2 over time

(Figures 27 through 30). The observed decreasing trend and greatly reduced variability in soluble reactive phosphorus concentrations at Site CT-2 from 1995 to 2014 is the result of the effectiveness of the PRFs near the Perimeter Road and Peoria Street, along with the stream reclamation project along Cottonwood Creek. There is a seasonal pattern in phosphorus concentration at all sites, which is not specifically addressed in the trend analysis.

Table 7: Comparison of base flow median WY total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations for CC-10 and CT-2 from 1995 to 2014.

Water Year	CC-10		CT-2	
	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)
1995	218	169	--	--
1996	145[a]	153[a]	97	77
1997	176	170	108	64
1998	291	231	108	66
1999	258	200	94	39
2000	247	195	83	24
2001	239	168	84	22
2002	191	144	69	13
2003	213	158	83	13
2004	214	164	92	8
2005	200	163	66	10
2006	162	134	67	7
2007	217	160	65	11
2008	200	143	69	5
2009	176	129	50	6
2010	217	168	61	7
2011	226	165	56	7
2012	181	147	56	6
2013	181	141	53	7
2014	197	176	48	12
Median (1995-2014)	**213**	**164**	**69**	**11**
Median (2010-2014)	**197**	**165**	**56**	**7**

[a] Results for total phosphorus and soluble reactive phosphorus are obtained independently and are within the 10% analytical error rate for all data used to calculate the median annual value.

Table 8: Comparison of storm flow median WY total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations for CC-10 and CT-2 from 1995 to 2014.

Water Year	CC-10		CT-2	
	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)
1995	181	161	--	--
1996	323	270	336	160
1997	402	316	391	221
1998	378	277	314	108
1999	348	247	118	58
2000	673	274	277	93
2001	293	172	209	33
2002	251	171	175	21
2003	365	171	204	35
2004	285	237	208	35
2005	354	187	175	26
2006	477	221	259	74
2007	366	195	230	27
2008	271	207	79	14
2009	378	180	78	24
2010	307	178	97	24
2011	409	197	113	29
2012	471	210	110	19
2013	414	197	60	16
2014	326	171	97	8
Median (1995-2014)	**360**	**197**	**175**	**29**
Median (2010-2014)	**409**	**197**	**97**	**19**

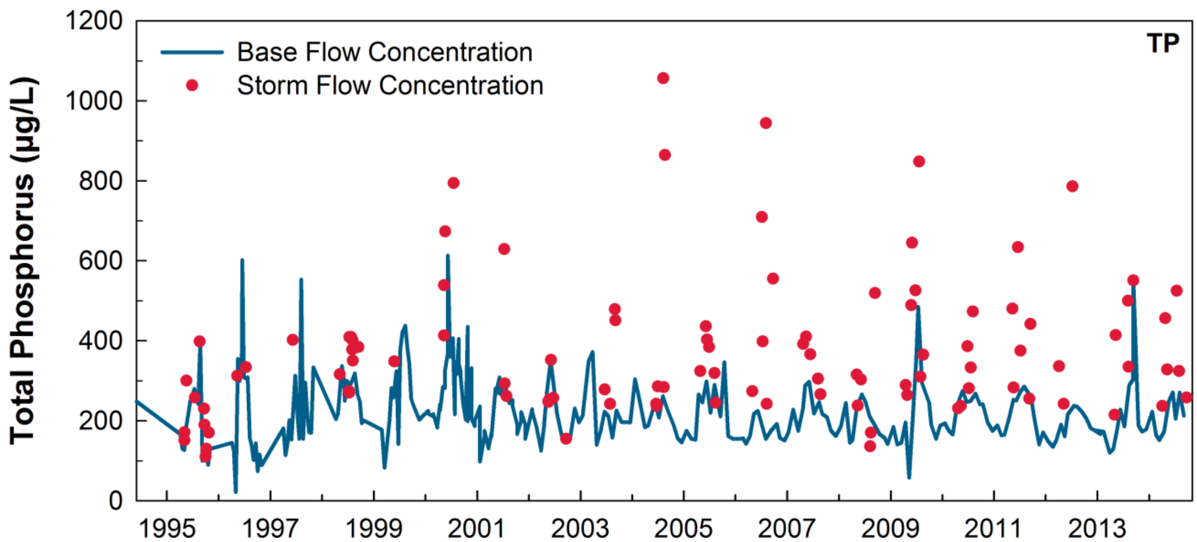

Figure 27: Base flow and storm flow total phosphorus concentrations measured at CC-10, 1994 to 2014.

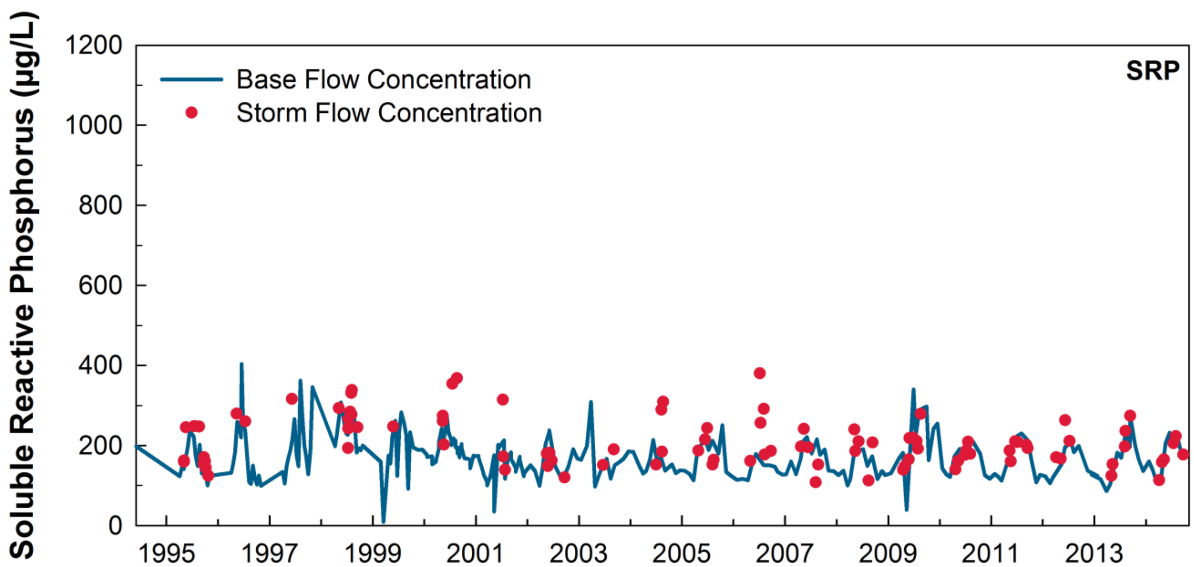

Figure 28: Base flow and storm flow soluble reactive phosphorus concentrations measured at CC-10, 1994 to 2014.

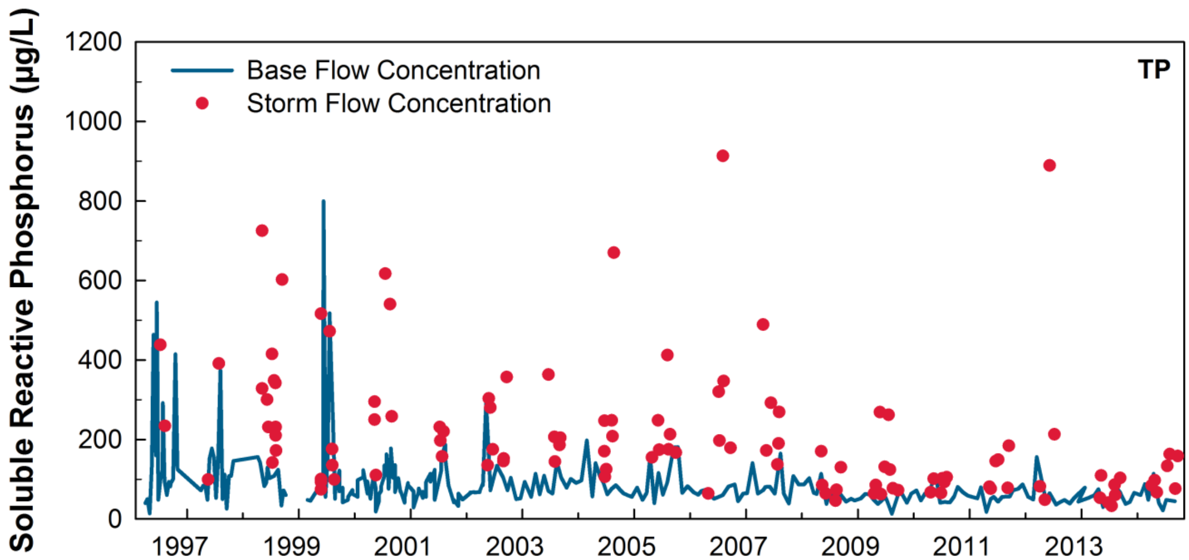

Figure 29: Base flow and storm flow total phosphorus concentrations measured at CT-2, 1996 to 2014.

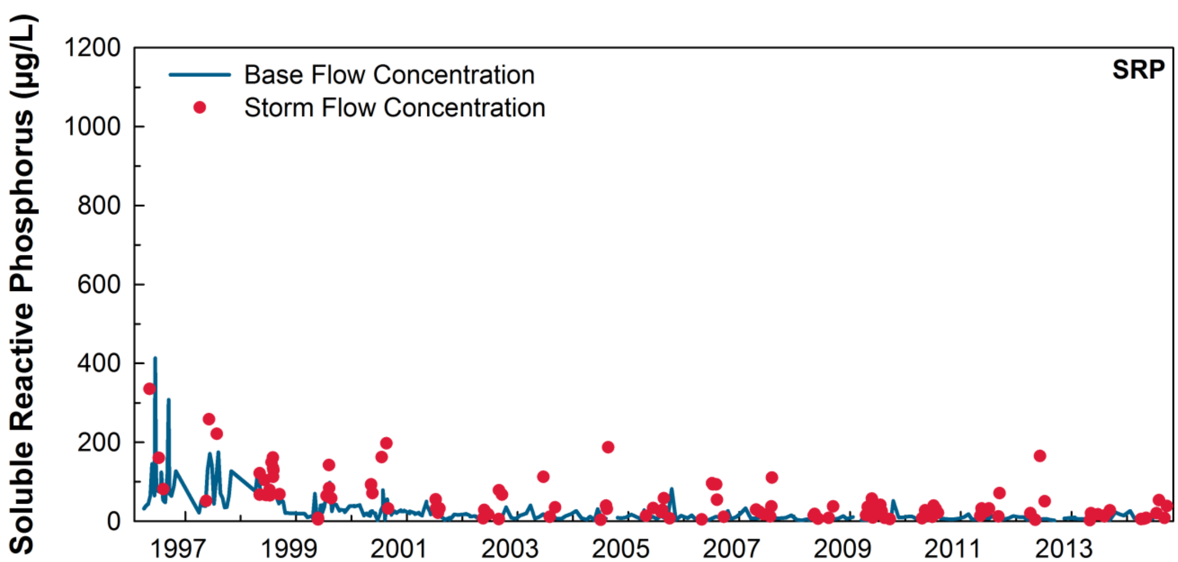

Figure 30: Base flow and storm flow soluble reactive phosphorus concentrations measured at CT-2, 1996 to 2014.

4.3.3 *Long-Term Trends in Phosphorus Concentrations in Cherry Creek Reservoir Alluvium*

In April 2014, monthly sampling began at Site MW-9 to better characterize the alluvial nutrient concentrations upstream of the Reservoir, and to provide additional information for the Reservoir model development. Monthly total phosphorous concentrations ranged from 168 to 202 µg/L with a median concentration of 195 µg/L which is greater than the long-term median of 190 µg/L (1994-2014).

Alluvial phosphorus data for Site MW-9 were used to estimate the alluvial phosphorus load component, as summarized in Appendix D (JCHA 2001 through 2010; GEI 2012 - 2014). Total dissolved phosphorus is used as a surrogate to total phosphorus, because the alluvium filters out the particulate fraction common to surface water. Alluvial total dissolved phosphorus concentrations show a significant ($p < 0.001$), increasing trend over time (1994 to 2014) at Site MW-9 (Figure 31).

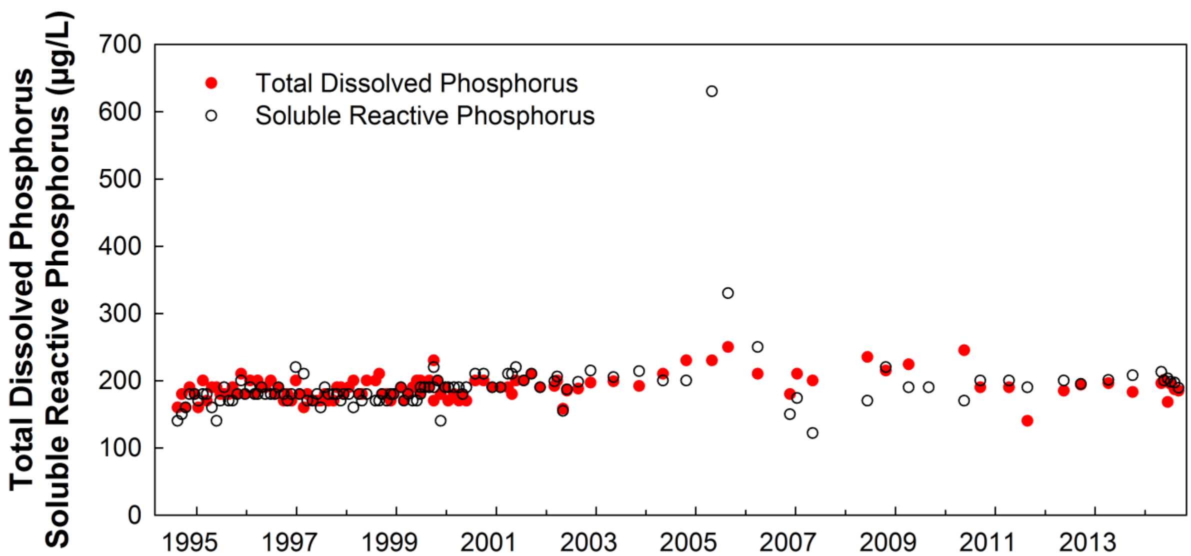

Figure 31: Total dissolved phosphorus and soluble reactive phosphorus concentrations measured at MW-9, 1994 to 2014.

4.4 Reservoir Phosphorus Loads and Export

Nutrients that limit or enhance algal growth in Cherry Creek Reservoir have many sources, both within the Reservoir (internal loading) or from outside the Reservoir (external loading). The direct release of nutrients from sediment, fish and plankton excrement, and the decay of organic matter are all internal sources of nutrients in a reservoir (Horne and Goldman 1994). However, the release of soluble reactive phosphorus from sediment during anoxic water conditions accounts for approximately 2,000 pounds per year (lbs/yr) in Cherry Creek Reservoir (Nürnberg and LaZerte 2008). Other studies evaluating internal loading from the sediments suggest lower estimates of internal phosphorus loading ranging between 810 lbs/yr and 1,590 lbs/yr (AMEC et al. 2005).

External sources of nutrients include flow from streams, direct precipitation and the alluvium, which carry nutrients from soil erosion, agricultural and residential runoff, treated wastewater, and airborne particulates. While both phosphorus and nitrogen are potentially important, past studies have concluded that Cherry Creek Reservoir was generally phosphorus limited (DRCOG 1985). However, a more recent nutrient enrichment study by Lewis et al. (2004) indicated that nitrogen was often the primary limiting nutrient in Cherry Creek Reservoir during the growing season.

Phosphorus (unlike nitrogen) does not have a gas phase. Thus, phosphorus concentrations cannot be reduced by interactions with the atmosphere or gases within the water column. For these reasons, efforts in past years and during the present study have focused on phosphorus loading and flow-weighted phosphorus concentrations. Total phosphorus loads were determined for several primary sources, including the tributary streams Cherry Creek, Shop Creek, and Cottonwood Creek, as well as from precipitation and alluvium, as summarized in Appendix D. The flow-weighted concentrations represent the relationship between the total annual phosphorus load divided by total annual flow at a site.

4.4.1 *Phosphorus Load from Tributary Streams*

Monthly base flow phosphorus concentrations, along with the annual storm flow median concentration were applied to their respective flow to estimate loads for each stream site. Stream flows that were greater than the 90th percentile of all flows measured during the respective year and for that site were categorized as storm flows. The greatest proportion (75%) of the normalized total phosphorus load to the Reservoir was from Cherry Creek mainstem flows (5,567 lbs). Cottonwood Creek accounted for 7% of the phosphorus load, or 546 lbs. During the 2014 WY, the total phosphorus load to Cherry Creek Reservoir from tributary streams was 6,076 lbs (Table 9).

4.4.2 *Phosphorus Export from Reservoir Outflow*

The total outflow from Cherry Creek Reservoir as measured by the USACE was 13,648 ac-ft in 2014 (Appendix D). Monthly total phosphorus data collected from Site CC-Out @ I225 near the dam outlet was used to estimate the phosphorus export at 4,408 lbs/yr for the Reservoir in 2014 (Table 9).

Table 9: Normalized phosphorus loads and export (lbs/year) for Cherry Creek Reservoir, 1992 to 2014 WY.

Water Year	Cherry Creek Load	Cottonwood Creek Load	Stream & Ungaged Residual Load	Cherry Creek Alluvial Load	Direct Precipitation Load	External Load	Cherry Creek Export	Net External Load
1992*	3,024	334	3,620	750	360	4,796	1,328	3,468
1993	1,521	229	1,750	1,024	313	3,162	1,000	2,162
1994	2,525	168	2,692	874	271	3,907	964	2,943
1995	2,064	1,396	3,886	992	608	5,556	1,366	4,190
1996	2,548	600	3,147	935	353	4,509	1,382	3,126
1997	2,131	616	2,747	1,008	447	4,299	1,129	3,171
1998	10,007	1,838	11,925	1,033	449	13,574	4,139	9,434
1999	10,495	1,290	14,830	1,033	540	16,403	6,388	10,015
2000	11,801	1,379	13,180	1,034	368	14,582	4,113	10,469
2001	6,283	2,101	8,627	1,033	408	10,068	5,524	4,544
2002	2,091	438	2,530	913	303	3,746	1,971	1,776
2003	6,199	1,052	7,868	1,033	457	9,359	4,774	4,584
2004	4,307	1,640	5,965	1,034	379	7,377	2,682	4,695
2005	8,757	1,347	10,104	1,033	382	11,518	3,964	7,554
2006	3,568	1,224	4,792	1,033	349	6,174	3,251	2,923
2007	15,987	2,072	18,189	1,033	379	19,601	7,891	11,710
2008	7,254	832	8,085	1,015	283	9,384	4,785	4,599
2009	13,591	936	14,584	1,033	435	16,052	9,483	6,569
2010	12,049	1,037	13,086	1,003	399	14,488	7,880	6,609
2011	7,341	652	7,992	1,024	285	9,301	4,114	5,187
2012	5,531	588	6,119	1,020	323	7,462	3,478	3,984
2013	6,043	846	7,164	1,033	391	8,588	3,378	5,210
2014	5,567	508	6,076	1,033	310	7,419	4,408	3,011
Median (1992-2014)	6,043	936	7,164	1,033	379	8,588	3,964	4,584
Median (2010-2014)	6,043	652	7,164	1,024	323	8,588	4,114	5,187

* 1992 WY totals are calculated using January through September data.

4.4.3 *Phosphorus Load from Precipitation*

During the 2014 WY, a total of 14.3 inches of precipitation was recorded at the KAPA meteorological station located at Centennial Airport. When scaled to the areal extent of the Reservoir (875 acres), precipitation accounted for a total of 1,045 ac-ft of inflow to the Reservoir. The long-term (1995 to 2014) median total phosphorus concentration of 109 µg/L was used to calculate the 2014 WY total phosphorus load of 310 lbs/yr. This long-term median total phosphorous concentration represents a combination of dry fall and precipitation as measured near the Reservoir. The long-term median total phosphorus load from precipitation events collected from 1992 to 2014 is 379 lbs (Table 9).

4.4.4 *Phosphorus Load from Alluvium*

During the 2014 WY, the alluvial inflow constant was 2,000 ac-ft/yr (see Appendix D). The long-term (1994 to 2014) median total dissolved phosphorus concentration of alluvial flows from Site MW-9 is 190 µg/L. The alluvial phosphorus load to the Reservoir was estimated to be 1,033 lbs in 2014 (Table 10).

4.4.5 *Mass Balance/Net Loading of Phosphorus to the Reservoir*

The USACE calculates daily inflow to Cherry Creek Reservoir as a function of change in storage (i.e., reservoir volume) based on: 1) changes in reservoir level; 2) measured outflow; 3) precipitation; and 4) evaporation. This method for calculating reservoir volume accounts for groundwater inflow via alluvium, but does not directly quantify the flow. GEI monitors surface water inflow to the Reservoir using gaged stations on the three main surface inflows, Cherry Creek, Cottonwood Creek, and Shop Creek. Given the differences in the two methods for determining inflow, combined with the potential for unmonitored multiple Cherry Creek channels in the wetlands adjacent to the Reservoir, unmonitored surface flow (i.e., Belleview and Quincy drainages), and the potential for the USACE calculations to underestimate dam leakage (Lewis and Saunders 2002), an exact match between USACE and GEI calculated inflows is not expected.

During the 2014 WY, the USACE calculated inflow was 14,352 ac-ft/yr, while GEI calculated stream inflow was 14,181 ac-ft/yr (Appendix D). To compare these two inflow values, the USACE inflow was adjusted for precipitation (1,045 ac-ft/yr) and alluvial inflows (2,000 ac-ft/yr), which resulted in an adjusted USACE inflow of 11,308 ac-ft/yr. The difference between the adjusted USACE inflow and the GEI stream inflow was -2,874 ac-ft of water. This water volume difference was reapportioned between Cherry Creek (78%), Cottonwood Creek (22%). Flow-weighted total phosphorus concentrations for Cherry Creek and Cottonwood Creek were used to calculate the combined reapportioned load of -1,663 lbs (Appendix D).

Following the water balance normalization process, flow from Cherry Creek and Cottonwood Creek accounted for a total phosphorus load of 6,076 lbs to the Reservoir during the 2014 WY (Figure 32). The alluvial inflow contributed 1,033 lbs of phosphorus, with precipitation events contributing 310 lbs to the Reservoir. The total external load of phosphorus to the Reservoir in 2014 WY was 7,419 lbs (Figure 32).

The Reservoir outflow phosphorus load was estimated to be 4,408 lbs. The flow-weighted total phosphorus concentration for all external sources of inflow to the Reservoir is 190 µg/L and the flow-weighted export concentration for the Reservoir is 119 µg/L (Table 10). The difference of 71 µg/L was retained by the Reservoir. The net external phosphorus load to the Reservoir was 3,011 lbs during the 2014 WY.

Table 10: Flow-weighted phosphorus concentrations (µg/L) for Cherry Creek Reservoir, 1992 to 2014 WY.

Water Year	Cherry Creek Flow-weighted Concentration	Cottonwood Creek Flow-weighted Concentration	Inflow Flow-weighted Concentration	Outflow Flow-weighted Concentration
1992	270	170	246	91
1993	251	187	198	92
1994	248	88	196	73
1995	189	203	178	63
1996	232	332	208	87
1997	264	184	200	88
1998	279	178	237	81
1999	268	135	234	102
2000	312	159	265	83
2001	257	130	198	127
2002	221	88	171	107
2003	287	138	229	140
2004	247	157	201	96
2005	247	120	208	78
2006	231	132	187	115
2007	295	149	254	115
2008	205	84	177	104
2009	276	62	218	148
2010	239	78	200	115
2011	263	81	212	108
2012	244	91	200	118
2013	291	59	190	120
2014	231	73	190	119
Median (1992-2014)	251	132	200	104
Median (2010-2014)	244	78	200	118

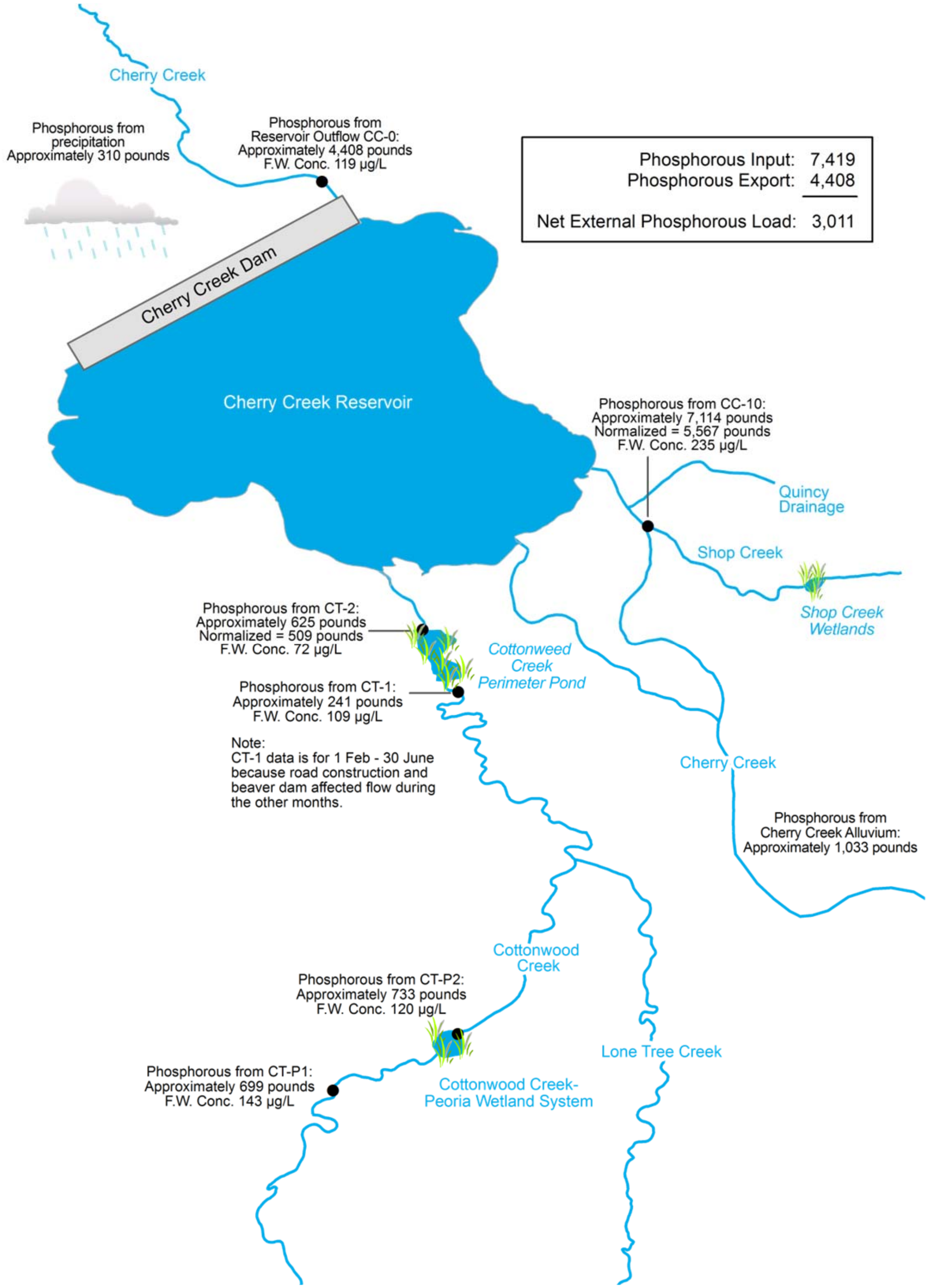

Figure 32: Mass balance diagram of phosphorus loading in Cherry Creek Reservoir, 2014 WY.

4.5 Effectiveness of Pollutant Reduction Facilities

4.5.1 *Cottonwood Creek Peoria Pond*

The effectiveness of the Cottonwood Creek Peoria Pond is gaged by monitoring the concentrations of phosphorus and total suspended solids, and determining the flow-weighted phosphorus concentrations upstream and downstream of the facility. Notably, the loads and flows used to evaluate the effectiveness of the PRF are not affected by the "normalization" of GEI inflow to USACE inflow values for Cherry Creek Reservoir. The ISCO at Site CT-P1 was lost during the September 2013 storm event and was replaced on January 21, 2014; therefore, PRF efficiency in terms of flow-weighted total phosphorous was based on the months of February through December 2014.

This PRF continues to be effective in reducing the amount of total suspended solids and total phosphorus as stream flow passes through this system. The total suspended solids were reduced by approximately 41% in 2014, with the long-term average showing a 28% reduction. The flow-weighted total phosphorus concentration upstream and downstream of the PRF was 145 µg/L and 135 µg/L, respectively, which indicates efficiency in removing phosphorus from flow (Table 11). Over the life of the project, the PRF shows approximately an average 18% reduction in the flow-weighted total phosphorus concentration at the downstream site.

This PRF was particularly effective at reducing the total suspended solids and total phosphorous load during multiple storm events during the 2014 WY. During the April 24, 2014 storm event, the inflow total suspended solids concentration at Site CT-P1 was 207 mg/L while the outflow total suspended solids concentration at Site CT-P2 was 92 mg/L. Similarly, the total phosphorous concentration entering the PRF during the storm event was 654 µg/L while the outflow concentration was 371 µg/L. During this storm event the PRF removed approximately 56% of the total suspended solids and 43% of the total phosphorous in Cottonwood Creek flows. During the storm event on July 15, 2014, the inflow total suspended solids concentration at Site CT-P1 was 462 mg/L while the outflow total suspended solids concentration at Site CT-P2 was 220 mg/L. The total phosphorous concentration entering the PRF during this storm event was 660 µg/L while the outflow concentration was 396 µg/L. During this storm event the PRF removed approximately 53% of the total suspended solids and 40% of the total phosphorous in Cottonwood Creek flows.

Table 11: Historical total phosphorus and total suspended solids concentrations and total phosphorus loads upstream and downstream of the Cottonwood Creek – Peoria Pond, 2002 to 2014 WY.

Parameter	Water Year	Sampling Sites		Difference	Percent Change Downstream
		CT-P1	CT-P2		
Mean Total Suspended Solids (mg/L)	2002	81	74	-7	-9
	2003	30	33	3	10
	2004	104	51	-53	-51
	2005	50	53	3	6
	2006	13	13	0	0
	2007	78	41	-37	-47
	2008*	36	34	-2	-6
	2009	48	27	-21	-44
	2010	34	26	-8	-24
	2011	48	30	-18	-38
	2012	121	55	-66	-55
	2013	97	35	-62	-64
	2014	66	39	-27	-41
	Mean	**62**	**39**	**-23**	**-28**
Flow-weighted Total Phosphorus Concentration (µg/L)	2002	142	118	-24	-17
	2003	117	109	-8	-7
	2004	132	132	0	0
	2005	129	119	-10	-8
	2006	146	140	-6	-4
	2007	156	120	-36	-23
	2008*	128	92	-36	-28
	2009	114	83	-31	-27
	2010	106	96	-10	-9
	2011	153	131	-22	-14
	2012	193	127	-66	-34
	2013	267	113	-154	-58
	2014	145	135	-10	-7
	Mean	**148**	**117**	**-32**	**-18**

* Eight months of operation.

4.5.2 *Cottonwood Creek Perimeter Pond*

The effectiveness of the Cottonwood Creek storm water Perimeter Pond in reducing phosphorus loads to the Reservoir is similarly gaged by comparing data from sites upstream and downstream of the PRF (Table 12). The total suspended solids were reduced by approximately 61% in 2014, with the long-term average showing a 32% reduction. The flow-weighted total phosphorus concentration upstream and downstream of the PRF was 112 µg/L and 81 µg/L, respectively, which indicates a high efficiency in removing phosphorus from flow (Table 12). Over the life of the project, the PRF shows approximately an average 23% reduction in the flow-weighted total phosphorus concentration at the downstream site.

This PRF was particularly effective at reducing the total suspended solids and total phosphorous load during multiple storm events during the 2014 WY. During the September 5, 2014 storm event, the inflow total suspended solids concentration at Site CT-1 was 444 mg/L while the outflow total suspended solids concentration at Site CT-2 was 44 mg/L. Similarly, the total phosphorous concentration entering the PRF during the storm event was 478 µg/L while the outflow concentration was 76 µg/L. During this storm event the PRF removed approximately 90% of the total suspended solids and 84% of the total phosphorous in Cottonwood Creek flows.

In 2014, streamflow at Site CT-1 was greatly affected by the construction along the Perimeter Road and the bridge work over Cottonwood Creek. In addition, a beaver dam inundated the monitoring site in mid-summer which altered the hydrology throughout the reach. In terms of accurately measuring stream flow at this site, the months from February through June 2014 represented "typical" base flow and storm flow conditions. Data collected during this period were used to evaluate the efficiency of the PRF.

Table 12: Historical total phosphorus and total suspended solids concentrations and total phosphorus loads upstream and downstream of the Cottonwood Creek Perimeter Pond, 1997 to 2014 WY.

Parameter	Water Year	Sampling Sites		Difference	Percent Change Downstream
		CT-1	CT-2		
Average Total Suspended Solids (mg/L)	1997	207	87	-120	-58
	1998	311	129	-182	-59
	1999	267	68	-199	-75
	2000	96	64	-32	-33
	2001	79	43	-36	-46
	2002	150	86	-64	-43
	2003	83	58	-25	-30
	2004	156	128	-28	-18
	2005	123	65	-58	-47
	2006	31	20	-11	-35
	2007	93	64	-29	-31
	2008*	31	59	28	90
	2009	31	32	1	3
	2010	33	33	0	0
	2011	48	30	-18	-38
	2012	NA	NA	NA	NA
	2013	57	21	-36	-63
	2014	56	22	-34	-61
	Mean	**109**	**59**	**-50**	**-32**
Flow-weighted Total Phosphorus Concentration (µg/L)	1997	485	183	-302	-62
	1998	311	176	-135	-43
	1999	143	129	-14	-10
	2000	266	161	-105	-39
	2001	163	146	-17	-10
	2002	124	105	-19	-15
	2003	193	124	-69	-36
	2004	194	149	-45	-23
	2005	141	120	-21	-15
	2006	165	135	-30	-18
	2007	170	148	-22	-13
	2008*	87	86	-1	-1
	2009	70	61	-9	-13
	2010	77	77	0	0
	2011	101	81	-20	-20
	2012	NA	NA	NA	NA
	2013	119	59	-62	-52
	2014	112	81	-31	-28
	Mean	**172**	**119**	**-53**	**-23**

* Nine months of operation.

4.5.3 *McMurdo Stream Reclamation*

Using a proactive approach to control stream erosion along McMurdo Gulch, before extensive land use development occurs along McMurdo Gulch, the town of Castle Rock and the CCBWQA implemented a stream reclamation project along three miles of stream between the Cobblestone Ranch and Castle Oaks subdivisions. Once the reclamation activities were completed in fall 2011, two water quality monitoring sites were established by CCBWQA. Site MCM-1 was established in January 2012 on McMurdo Gulch, approximately 150 m upstream of the McMurdo Gulch Stream Reclamation Project Boundary. This site is also 120 m upstream of the confluence with an unnamed tributary that receives runoff from the Castle Oaks Subdivision. This site serves as the upstream monitoring location for the McMurdo Gulch Stream Reclamation Project. Site MCM-2 was also established in January 2012 on McMurdo Gulch, approximately 80 m upstream of the Castle Oaks Drive Bridge crossing of McMurdo Gulch, near the North Rocky View Road intersection. This site serves as the downstream monitoring location for the McMurdo Gulch Stream Reclamation Project. This site is located within the project boundary, and consistently maintained base flows, whereas reaches further downstream were dry due to flow going subsurface.

Base flow water quality samples were collected on a monthly basis at sites MCM-1 and MCM-2) during the 2014 WY. Total phosphorous concentrations at Site MCM-1 ranged from 266 to 564 µg/L with a WY median concentration of 340 µg/L. Total phosphorous concentrations at Site MCM-2 were reduced compared to Site MCM-1 and ranged from 177 to 335 µg/L[2] with a WY median concentration of 300 µg/L. Total suspended solids concentrations were slightly greater at the downstream location (Site MCM-2) with a WY median total suspended solids concentration of 11.6 mg/L, as compared to 5.7 mg/L at the upstream site (MCM-1).

Because Site MCM-1 is located upstream of the McMurdo Gulch Stream Reclamation Project Boundary and Site MCM-2 is located downstream of the PRF, the reduction in phosphorous from Site MCM-1 to Site MCM-2 indicates that the stream reclamation project is reducing total phosphorous concentrations in McMurdo Gulch, although the total suspended solids data shows mixed results.

4.6 2014 WY Special Studies

4.6.1 *Cyanotoxin Monitoring in Cherry Creek Reservoir*

Owing to the CCBWQA's decision to not operate the destratification system in 2014, there were concerns that nuisance cyanobacteria would proliferate in the absence of aeration, and potentially impact the recreational beneficial use. Cyanobacteria are often associated with

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[2] Outlier concentration (1.342 µg/L) was removed for assessment purposes.

nuisance algal blooms, and can produce toxins that inhibit growth of competing algae as well as inhibit grazing by zooplankton that rely on algae as a food source. The most common cyanobacteria genera that are known to produce toxins and have been observed in Cherry Creek Reservoir include *Anabaena*, *Aphanizomenon*, *Microcystis*, and *Planktothrix*. Over the past 10 years, *Anabaena* sp. have been observed in 51 of the 148 phytoplankton samples collected, *Aphanizomenon* sp. in 36 samples, *Planktothrix* sp. in 4 samples, and *Microcystis* sp.in 3 samples. The historical context for both *Anabaena* and *Aphanizomenon* occurrence provided bases to monitor for cyanotoxins given the concern for potential nuisance cyanobacteria growth in the absence of aeration. Coincidentally, while the CCBWQA was developing a cyanotoxins monitoring program, the Reservoir began showing signs of a cyanobacteria bloom in early June 2014. On June 10th filamentous algae was visible on the surface at CCR-2 and a cyanotoxin sample was collected (Photo 1). Based on the World Health Organization microcystins thresholds for recreational water contact, there was a moderate human health risk at CCR-2 on June 10th (10 µg/L ELISA and 9.3 µg/L LC-MS; Figure 33). During the June 13th sampling event, cyanotoxin samples were collected at CCR-2, the Marina, and the Swim Beach. Microcystins levels were <1.0 µg/L for all of these samples and posed a very low human risk (Figure 33). On June 17th, the cyanobacteria bloom was reported along the dam face of the Reservoir (Photo 2). GEI personnel walked the face of the dam in the late morning of June 17th, and documented that the bloom was more pronounced near the Reservoir outlet tower. A surface grab sample was collected from what appeared to represent the worse-case scenario for the bloom (Photo 2). Based on the World Health Organization microcystins thresholds for recreation, there was a high risk to human health as well as for other animals that used this area of the Reservoir on June 17th (24 µg/L ELISA and 15.3 LC-MS; Figure 33).

Photo 1: Cyanobacteria bloom at Site CCR-2 on 6/10/14 (10 µg/L microcystins).

Photo 2: Cyanobacteria bloom along the dam face (near the tower outlet structure) on 6/17/14 (25 µg/L microcystins).

Beginning on June 24th, two cyanotoxin samples were collected on a weekly basis (photic composite sample from CCR-1, CCR-2, and CCR-3), and a surface grab sample at the Swim Beach. A total of 20 out of the 27 samples were recorded as a non-detect for cyanotoxins

(Figure 33). The remaining 7 samples were all ≤ 0.29 µg/L for microcystins which indicates a very low risk to human health, including the samples collected at the swim beach.

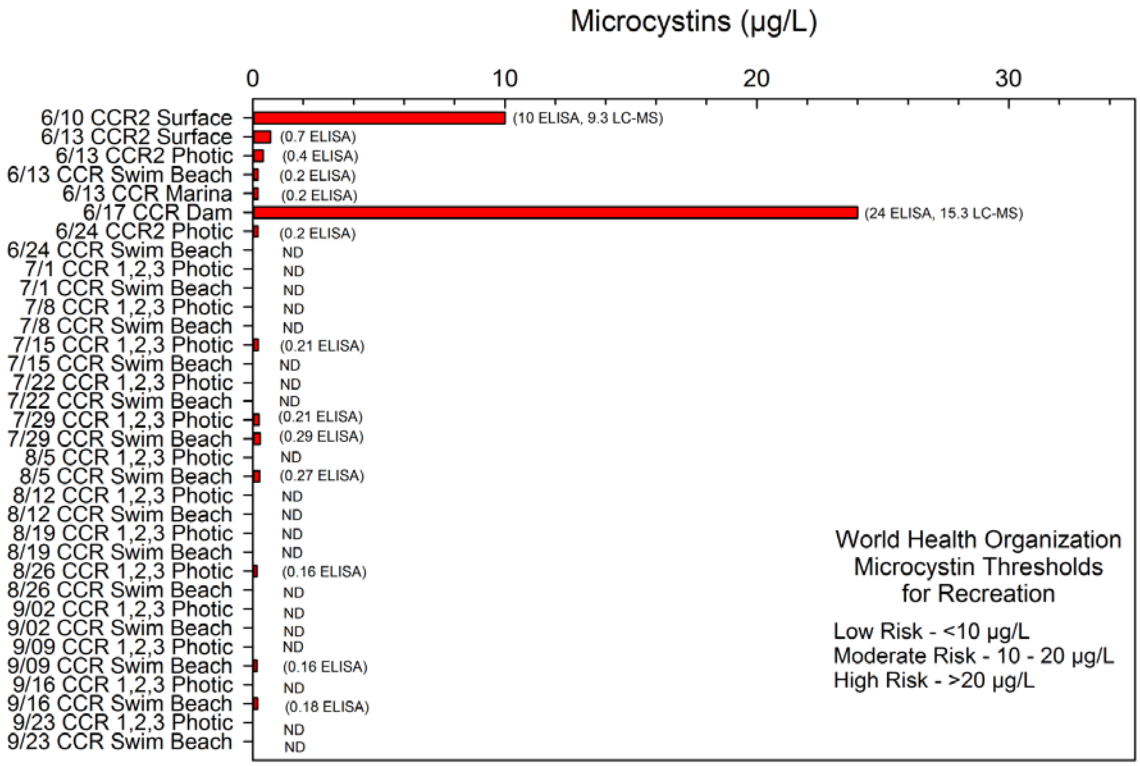

Figure 33: Cyanotoxin analyses for Cherry Creek Reservoir, June through September 2014.

4.6.2 *TOC and DOC Analyses in Cherry Creek Reservoir and Tributaries*

For reservoir model development purposes, total organic carbon (TOC) and dissolved organic carbon (DOC) concentrations were measured at the Reservoir and two tributaries (Cherry Creek (CC-10) and Cottonwood Creek (CT-2)) from February through September 2014 (Table 13). TOC concentrations ranged from 5.7 mg/L in mid-May to 7.5 mg/L in late July in the photic zone at CCR-2, and DOC concentrations ranged from 4.8 mg/L in mid-March to 6.2 mg/L in late July (Table 13). During February through September 2014, TOC and DOC concentrations at CCR-2 Photic averaged 6.6 and 5.4 mg/L, respectively.

From April through September 2014, TOC and DOC concentrations were monitored at the bottom of Reservoir near the water-sediment interface (CCR-2 7M; Table 13). TOC concentrations ranged from 5.8 mg/L in mid-May to 6.7 mg/L in late June and early July at CCR-2 7M, and DOC concentrations ranged from 4.7 mg/L in mid-May to 6.1 mg/L in late July (Table 13). During April through September 2014, TOC and DOC concentrations at CCR-2 7M averaged 6.3 and 5.3 mg/L, respectively. These concentrations are similar to the TOC and DOC concentrations recorded in the photic zone at CCR-2 (Table 13).

Table 13: Total organic carbon (TOC) and dissolved organic carbon (DOC) concentrations in Cherry Creek Reservoir and tributaries (CC-10 and CT-2), February through September 2014.

Sample Date	Sample Location	TOC (mg/L)	DOC (mg/L)	DOC/TOC (%)
2/11/2014	CCR-1 Photic	6.1	5.6	91.80
2/11/2014	CCR-2 Photic	6.1	5.9	96.72
2/18/2014	CT-2	7.2	6.5	90.28
2/18/2014	CC-10	3.9	3.8	97.44
3/12/2014	CCR-2 Photic	7.1	4.8	67.61
3/13/2014	CT-2	10.0	7.7	77.00
3/13/2014	CC-10	3.9	3.5	89.74
4/15/2014	CCR-2 Photic	6.8	4.9	72.06
4/15/2014	CCR-2 7M	6.6	4.8	72.73
4/17/2014	CT-2	7.5	5.6	74.67
4/17/2014	CC-10	4.5	3.6	80.00
5/13/2014	CCR-2 Photic	5.7	5.3	92.98
5/13/2014	CCR-2 7M	5.8	4.9	84.48
5/20/2014	CT-2	6.5	5.3	81.54
5/20/2014	CC-10	4.6	3.8	82.61
5/27/2014	CCR-2 Photic	6.7	5.0	74.63
5/27/2104	CCR-2 7M	6.1	4.7	77.05
6/10/2014	CCR-2 Photic	6.1	5.2	85.25
6/10/2014	CCR-2 7M	5.8	4.9	84.48
6/16/214	CT-2	7.5	6.6	88.00
6/16/2014	CC-10	5.2	4.7	90.38
6/24/2014	CCR-2 Photic	7.3	5.6	76.71
6/24/2014	CCR-2 7M	6.7	5.5	82.09
7/07/2014	CT-2	7.5	6.5	86.67
7/07/2014	CC-10	3.8	3.5	92.11
7/08/2014	CCR-2 Photic	6.6	5.5	83.33
7/08/2014	CCR-2 7M	6.7	5.6	83.58
7/22/2014	CCR-2 Photic	7.5	6.2	82.67
7/22/2014	CCR-2 7M	6.5	6.1	93.85
8/04/2014	CT-2	7.1	5.7	80.28
8/04/2014	CC-10	4.6	4.3	93.48
8/05/2014	CCR-2 Photic	6.5	5.6	86.15
8/05/2014	CCR-2 7M	6.2	5.4	87.10
8/19/2014	CCR-2 Photic	6.5	5.5	84.62
8/19/2014	CCR-2 7M	6.4	5.7	89.06
9/02/2014	CCR-2 Photic	6.4	5.1	79.69
9/02/2014	CCR-2 7M	5.8	4.9	84.48
9/03/2014	CT-2	5.7	4.8	84.21
9/03/2014	CC-10	4.1	3.4	82.93
9/16/2014	CCR-2 Photic	6.3	5.4	85.71
9/16/2014	CCR-2 7M	6.2	5.6	90.32

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Appendix A

Cherry Creek Reservoir Sampling and Analysis Plan

GEI Consultants

Geotechnical
Water Resources
Environmental and
Ecological Services

Cherry Creek Reservoir Aquatic Biological and Nutrient Sampling and Laboratory Analysis Sampling, Analysis, and Quality Assurance Work Plan

Submitted to:
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April 2008
Project 062450

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1.0 Introduction

An inter-governmental agreement was executed in 1985 by several local governmental entities within the Cherry Creek basin to form the Cherry Creek Basin Water Quality Authority (Authority). The Authority, initially created by an intergovernmental agreement, was specially authorized by legislation adopted in 1988. The Authority develops and implements the means to protect the water quality of Cherry Creek Basin and Reservoir. Following legislation in 2001, the Board was reconstituted to include Arapahoe and Douglas County, seven municipalities (Aurora, Castle Rock, Centennial, Foxfield, Greenwood Village, Lone Tree, and Parker), one member representing the seven special districts (Arapahoe, Cottonwood, Inverness, Meridian, Parker, Pinery, and Stonegate Village), and seven citizens appointed by the governor. The Authority was created for the purpose of coordinating and implementing the investigations necessary to protect and to preserve the quality of water resources of the Cherry Creek basin while allowing for further economic development.

The Cherry Creek Basin Master Plan (DRCOG 1985), approved by the Colorado Water Quality Control Commission (CWQCC) in 1985, was adopted in part as the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.0, 5C.C.R.3.8.11). An annual monitoring program was implemented at the end of April 1987 to assist in the assessment of several aspects of the Master Plan. These monitoring studies have included long-term monitoring of 1) nutrient levels within the reservoir and from tributary streams during base flows and storm flows, 2) nutrient levels in precipitation, and 3) chlorophyll *a* levels within the reservoir. This monitoring program has been modified over the years in response to changes in the Control Regulation, various research goals, and suggestions from outside reviewers, including input from the Water Quality Control Division (WQCD).

2.0 Project Description

The Authority has prepared this Sampling, Analysis, and Quality Assurance Work Plan (Sampling and Analysis Plan) for aquatic biological nutrient analyses to be conducted on Cherry Creek Reservoir and selected off-lake sampling sites in 2008. This Sampling and Analysis Plan identifies field and laboratory protocols necessary to achieve quality data designed to help characterize the potential relationships between nutrient loading (both in-lake and external) and reservoir productivity. The specific objectives of the Sampling and Analysis Plan study are:

1. Determine the concentrations of selected nutrients, primarily phosphorus and nitrogen species, in Cherry Creek Reservoir as well as in various streams flowing into the reservoir and measure nutrients in the reservoir outflow.

2. Determine the annual phosphorus load entering Cherry Creek Reservoir from streams and precipitation and the phosphorus export from the reservoir via the outlet structure.

3. Determine biological productivity in Cherry Creek Reservoir, as measured by chlorophyll *a* concentrations and algal densities.

4. Provide data on the effectiveness of pollutant removal from Pollutant Removal Facilities (PRF) constructed by the Authority.

5. Provide data on the effectiveness of the destratification system at mixing the reservoir water column.

This Sampling and Analysis Plan presents the proposed 2008 sampling and analyses requirements for Cherry Creek Reservoir and includes discussions of: 1) project organization and responsibilities; 2) quality assurance objectives for the measurement of data in terms of accuracy, representativeness, comparability, and completeness; 3) field sampling and sample preservation procedures; 4) laboratory processing and analytical procedures; and 5) guidelines for data verification and reporting, quality control checks, corrective actions, and quality assurance reporting.

3.0 Project Organization and Responsibilities

All personnel involved in the investigation and in the generation of data are implicitly a part of the overall project and quality assurance program. Certain individuals have specifically delegated responsibilities, as described below.

3.1 Project Manager

Steven Canton is the Project Manager who is responsible for fiscal oversight and management of the project and for ensuring that all work is conducted in accordance with the Scope of Service, Sampling and Analysis Plan, and approved procedures. Tasks include:

- Maintain routine contact with the project's progress, regularly review the project schedule, and review all work products.
- Evaluate impacts on project objectives and the need for corrective actions based on quality control checks.
- Review and update of this Sampling and Analysis Plan as needed.

3.2 Quality Assurance Manager

Craig Wolf is the Quality Assurance Manager who is responsible for the aquatic biological and field sampling portions of the study as well as the technical management of the monitoring program and reporting. The Quality Assurance Manager shall be responsible for evaluation and review of all data reports relevant to the project and perform data verification. The Quality Assurance Manager shall work with the Project Manager to determine the need for corrective actions and, together, will make recommendations for any needed changes to either sampling methodologies or laboratory analytical procedures. Tasks include:

- Ensure data collection is in accordance with the Sampling and Analysis Plan.
- Maintain a central file, which contains or indicates the location of all documents relating to this project.
- Coordinate with the Authority, the WQCD, and the Authority's other consultants to ensure compliance with the Cherry Creek Reservoir Control Regulation No. 72.

3.3 Analytical and Biological Laboratory Managers

Suzanne Pargee is the Analytical Laboratory Manager who will ensure that all water quality and chlorophyll *a* samples are analyzed in a technically sound and timely manner. The Analytical Laboratory Manager shall be responsible for ensuring all laboratory quality assurance procedures associated with the project are followed, including proper sample entry, sample handling procedures, and quality control records for samples delivered to the laboratory. The Analytical Laboratory Manager will be responsible for all data reduction and verification and ensure that the data is provided in a format agreed upon between the Project Manager, the Analytical Laboratory Manager, and the Authority.

GEI subcontracts the phytoplankton identification and enumeration to the University of Colorado, Center for Limnology. This Center for Limnology shall be responsible for ensuring all laboratory quality assurance procedures associated with the project are followed, including proper sample entry, sample handling procedures, and quality control records for samples delivered to the laboratory.

3.4 Sampling Crew

The field sampling efforts shall be conducted by individuals qualified in the collection of chemical, physical, and biological surface water samples. Field tasks and sampling oversight will be provided by the Quality Assurance Manager. The Sampling Crew shall be responsible for following all procedures for sample collection, including complete and accurate documentation.

4.0 Aquatic Biological and Nutrient Sampling

4.1 Reservoir Monitoring Sites

Sampling would be conducted at sites established during past sampling efforts, as modified herein (see Figure 1 for location of all sites).

4.1.1 Cherry Creek Reservoir

CCR-1 This site is also called the Dam site, and was established in 1987. CCR-1 corresponds to the northwest area within the lake (Knowlton and Jones, 1993). Sampling was discontinued at this site in 1996 and 1997 following determination that this site exhibited similar characteristics to the other two sites. Sampling recommenced in July 1998 at the request of consultants for Greenwood Village.

CCR-2 This site is also called the Swim Beach site, and was established in 1987. Site CCR-2 corresponds to the northeast area within the lake (Knowlton and Jones, 1993).

CCR-3 This site is also called the Inlet site and was established in 1987, corresponding to the south area within the lake (Knowlton and Jones, 1993).

4.2 Stream Monitoring Sites

4.2.1 Cherry Creek

CC-10 This site is on Cherry Creek immediately downstream of the Shop Creek confluence, approximately 0.5 km upstream of Cherry Creek Reservoir. This site provides data to estimate phosphorus loads to the Reservoir from Cherry Creek and Shop Creek.

CC-O In 2007, this site was relocated further upstream on Cherry Creek to a location approximately 75 m downstream of the reservoir outflow gates. Site CC-O (i.e., CC-Outflow) provides data to evaluate the water quality of the Reservoir outlet.

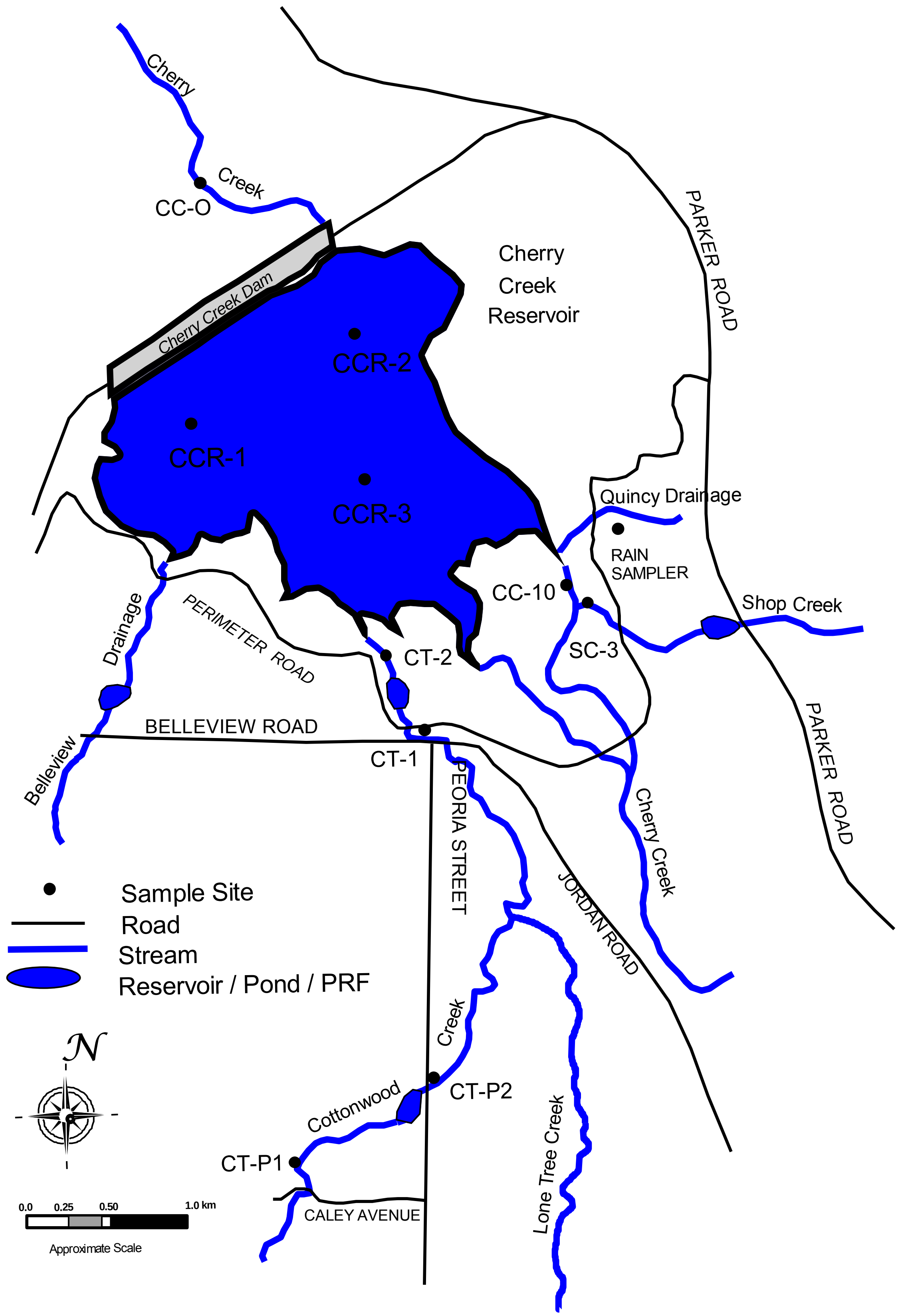


Figure 1: Sampling sites on Cherry Creek Reservoir and selected streams.

4.2.2 Cottonwood Creek

CT-2 This site is contained within the outflow weir structure for the Perimeter Pond PRF, upstream of Cherry Creek Reservoir. This site is included in the reservoir portion of the effort because the data is used to estimate phosphorus loads to the Reservoir from Cottonwood Creek. This site is also used to evaluate the performance of the Perimeter Pond PRF.

4.3 PRF Monitoring Sites

4.3.1 Shop Creek

SC-3 This site is located 35 m upstream of its confluence with Cherry Creek, and is used to monitor the water quality of Shop Creek before it joins Cherry Creek.

4.3.2 Cottonwood Creek

CT-P1 This site is located just north of where Caley Avenue crosses Cottonwood Creek, and west of Peoria Street. This site is used to monitor the water quality of Cottonwood Creek before it enters the Peoria Pond PRF.

CT-P2 This site is located at the outfall of the Peoria Pond PRF, on the west side of Peoria Street. The ISCO stormwater sampler and pressure transducer is located inside the outlet structure. This site is used to evaluate the performance of the PRF on water quality.

CT-1 This site is located 250 m upstream of the Cherry Creek Park Perimeter Road. The Cottonwood Creek Phase II Project will require the relocation of this site in 2008. Note that Site CT-2 is included in the reservoir monitoring requirements.

4.3.3 Precipitation Sampling Site

This site is located near the Quincy Drainage, upstream of the Perimeter Road. The sampler consists of a clean, inverted trash can lid used to funnel rainfall into a one-gallon container. While this collection vessel is maintained and cleaned on a routine basis, precipitation will wash any atmospheric dry fall that has accumulated between cleanings, into the one-gallon container. Therefore, these data more appropriately represent a “bulk” atmospheric deposition component for the Reservoir.

4.4 Analyte List

The sampling and analyses shall be conducted in accordance with the methods and detection limits provided in Table 1.

Table 1: Standard methods for sample analysis.

Parameter	Abbreviation	Analytical Method*	Recommended Hold Times	Detection Limit
Physicochemical				
Total Nitrogen	TN	4500-N B (modified)	< 24 hrs before digestion; < 7 days after digestion	2 µg/L
Total Dissolved Nitrogen	TDN	4500-N B (modified)	48 hrs	2 µg/L
Nitrate/Nitrite Nitrogen	NO_3+NO_2	4500-NO31	48 hrs	2 µg/L
Ammonium Ion Nitrogen	NH_4	QuickChem 10-107-06	24 hrs	3 µg/L
Total Phosphorus	TP	4500-P G	< 24 hrs before digestion	2 µg/L
Total Dissolved Phosphorus	TDP	4500-P G	48 hrs	2 µg/L
Soluble Reactive Phosphorus	SRP	4500-P G	48 hrs	2 µg/L
Total Suspended Solids	TSS	2540 D	7 days	4 mg/L
Total Volatile Suspended Solids	TVSS	2540 E	7 days	4 mg/L
Biological				
Chlorophyll *a*	Chl	10200 H (modified)	< 24 hrs before filtration	0.1 µg/L
Phytoplankton	--	Standard methods	NA	NA

* Analytical Methods are from American Public Health Association (APHA) 2005, unless otherwise noted.

4.5 Sampling Schedule

4.5.1 Reservoir Sampling

The Reservoir monitoring program includes collecting water quality data from three locations within the Reservoir, CCR-1, CCR-2, and CCR-3, as well as three stream sites, CC-10, CT-2 and CC-O that are important for characterizing the hydrological and mass balance budgets for the Reservoir. The Reservoir sampling schedule generally consists of monthly sampling from January to April and from October to December, with bimonthly reservoir samples collected from May to September (Table 2). Sampling during the winter months (November – February) will depend on ice conditions and safety concerns. The tributary inflow/outflow sites are sampled on a monthly basis from January to December and represent base flow conditions during each month. The sampling schedule for the reservoir and streams sites is summarized below:

Table 2: Cherry Creek reservoir and tributary inflow/outflow sampling.

	Sampling Period	Frequency	Trips/Period
Reservoir Sites CCR-1, CCR-2, and CCR-3	Jan – April	Monthly	4
	May – Sept	Bi-monthly	10
	Oct – Dec	Monthly	3
		Total	**17**
Stream Sites CC-10, CT-2, and CC-O	Jan – Dec	Monthly	12
		Total	**12**

4.5.2 PRF Sampling

The PRF sampling is conducted on a monthly basis, often concurrent with the regular reservoir sampling trips, to represent base flow conditions during each month (Table 3). These samples correspond to the low-flow ambient samples collected during earlier studies.

Table 3: PRF sampling.

Stream Sites CT-P1, CT-P2, CT-1, SC-3	Sampling Period	Frequency	Trips/Period
	Jan – Dec	Monthly	12
		Total	**12**

4.5.3 Storm Flow Sampling

To characterize storm flows, six stream sites are sampled during storm events (i.e., S-3, CC-10, CT-1, CT-2, CT-P1, and CT-P2). Automated samplers collect sequential storm flow samples when a threshold stream level is exceeded for each site. Storm samples are not collected at Site CC-O downstream of the reservoir, unless the Army Corps of Engineers (Corps) alerts the Consultant to an outflow event that could be tied to a storm-related inflow. Up to five storm events shall be collected over the summer for Cherry Creek (Site CC-10) and on Shop Creek (Site S-3). Up to seven storm events shall be collected at the four sites on Cottonwood Creek (CT-1, CT-2, CT-P1, and CT-P2). The actual number of storm events for which samples are obtained will be subject to weather patterns. The recommended storm sampling period is April through September to attempt to capture some of the late spring snowmelt events as well as the summer “monsoon” season.

4.5.4 Precipitation Sampling

Precipitation samples are to be collected after substantial rainfall events, defined as 0.5 inches or more. The sampler shall be inspected weekly and emptied of any accumulations of insignificant precipitation and the collector (inverted trash can lid) cleaned. This procedure is required to minimize small amounts of precipitation contaminating the sample between larger precipitation events.

4.6 Field Methodologies

4.6.1 Reservoir Sampling

4.6.1.1 Transparency

Transparency shall be determined using a Secchi disk and Licor quantum sensors. The Secchi reading shall be slowly lowered on the shady side of the boat, until the white quadrants disappear, at which point the depth is recorded to the nearest tenth of a meter. The disk is then lowered roughly 1 m further and slowly brought back up until the white quadrants reappear and again the depth is recorded. The Secchi disk depth is recorded as the average of these two readings.

Licor quantum sensors provide a quantitative approach to determine the depth at which 1 percent of the light penetrates the water column. This is considered the point at which light no longer can sustain photosynthesis in excess of oxygen consumption from respiration (Goldman and Horne 1983) and represents the deepest portion of the photic zone. This is accomplished by using an ambient and underwater quantum sensor attached to a Licor-1400 data logger. The ambient quantum sensor remains on the surface, while the underwater sensor is lowered into the water on the sunny side of the boat. The underwater sensor is lowered until the value displayed on the data logger is 1 percent of the value of the ambient sensor, and the depth is recorded.

4.6.1.2 Depth Profile Measurements

Measurements for dissolved oxygen, temperature, conductivity, pH, and oxidation/reduction potential (ORP) shall be collected at 1 m intervals, including the surface and near the water/sediment interface, using a YSI 600XL Multiparameter Sonde. The sonde shall be calibrated at the GEI Laboratory prior to each sampling episode to ensure accurate readings. In an effort to minimize probe contamination at the water/sediment interface, a depth sounding line is used to determine maximum depth. The bottom profile measurement is collected approximately 10 cm from the benthos.

4.6.1.3 Continuous Temperature Monitoring

The effectiveness of the destratification system at mixing the entire water column would be evaluated by deploying Onset HOBO® Water Temp Pro data loggers at three locations in the Reservoir (CCR-1, CCR-2, and CCR-3). At each site, temperature loggers would be deployed at 1 m increments, including the 0.5 m and bottom depths and configured to collect 15-minute interval temperature data.

The temperature arrays would be deployed using the State Park’s buoy system, beginning in March/April and operated through October, with periodic downloading of data to minimize potential loss of data. This deployment schedule would overlap with the proposed operational schedule of the destratification system.

In addition to the temperature loggers at the three monitoring sites, GEI will also perform three monthly ORP profiles during the July to September period at up to ten sample locations along a single transect through the deep-water zone. The sample locations and transect will be consistent with locations previously established by AMEC during their destratification feasibility study. Measurements of ORP will be performed from the waters surface to the sediment interface using the YSI 600XL Multiparameter Sonde.

4.6.1.4 Water Samples

A primary task of the monitoring program is to characterize the chemical and biological constituents of the upper 3m layers of the reservoir. This layer represents the most active layer for algal production (photic zone), and represents approximately 54 percent of the total lake volume given the typical lake level of 5550 ft. At each reservoir site, water from the surface, 1 m, 2 m, and 3 m depths is sampled individually using a 2-liter vertical Van Dorn water sampler and combined into a clean 5-gallon container to create a composite photic zone sample (Table 4). The vertical Van Dorn sampler is lowered to the appropriate depth, such that the middle of the sampler is centered on the selected depth. The “messenger” is sent to activate the sampler and the water is retrieved. Three one-liter aliquots are collected from the composite photic zone sample and stored on ice, until transferred to the laboratory for chemical and biological analyses.

At Site CCR-2, profile water samples are also collected on one-meter increments, starting from 4 m and continuing down to the 7 m depth. Given the recent lowering of the reservoir level by the USACE, in preparation for a 100-year flood event, the 7 m sample often represents a bottom water sample at Site CCR-2. This sample is collected as close to the water/sediment interface as possible, without disturbing the sediment. The sampler and 5-gallon container are rinsed thoroughly with lake water between sites.

Based on this sampling scheme, the number of samples collected at each site is as below:

Table 4: Number of reservoir samples collected.

Reservoir Site	Upper 3m Composite (Photic zone)	1-m Depth Profiles	Number of Samples
CCR-1	1	0	1
CCR-2	1	4	5
CCR-3	1	0	1
Total Samples/Sample Event	**3**	**4**	**7**

4.6.2 Water Quality Analyses

1. Nutrient analyses shall be performed on all reservoir water samples.
2. Chlorophyll analyses shall be performed on all photic zone composite samples.
3. Phytoplankton analyses shall be performed on all photic zone composite samples.

See Table 1 for the list of analytes, laboratory methods, and detection limits.

4.7 Stream Sampling

One sample shall be collected from each stream site on a monthly basis, when there is sufficient flow. Samples shall be collected as mid-stream mid-depth grab sample using a 5-gallon container. Two one-liter aliquots are collected from this grab sample and stored on ice, until transferred to the GEI laboratory for chemical analyses (Table 5).

4.7.1 Automatic Sampler

Each stream sampling station upstream of the reservoir also contains an Authority-owned ISCO flow meter and sampling device. The flow meter is a pressure transducer that measures stream water level. Rating curves are developed for each sampling site by measuring stream discharge (ft^3/sec) with a Marsh McBirney Model # 2000 flowmeter, and recording the water level at the staff gage (ft) and ISCO flowmeter (ft). Discharge is measured using methods outlined in Harrelson *et al.* 1994. To determine flow rate, the level must be translated into flow rate using a "stage-discharge" relationship. Since stage-discharge relationships can change over the years, the relationship is calibrated annually using a flow meter to record stream flow measurements three to four times per year at a range of flows. These data are combined with historical data, as long as stream geomorphology conditions are similar, to validate and modify the stage-discharge relationship for that site. If the staff gage is reset, moved to a new location, or geomorphology conditions have changed, then a new stage-discharge relationship is created for that site.

Water level data are collected on 15-minute intervals and stored in the ISCO sampler. These data are downloaded on a monthly basis to minimize the risk of data loss due to power failure or ISCO failure. The flow data and stage-discharge rating curves shall be checked throughout the year by comparing calculated flow estimates to actual flow measurements recorded in the field with a flowmeter.

The USACE also reports daily inflow to Cherry Creek Reservoir as a function of storage, based on changes in reservoir level. This daily inflow value incorporates information regarding measured outflow, precipitation, and evaporation. GEI monitors inflow to the Reservoir using gaging stations on Cherry Creek, Cottonwood Creek, and Shop Creek (the three main surface inflows) to provide a daily surface inflow record. Given the differences in the two methods for determining inflow, combined with the potential of unmonitored alluvial and surface flows that may result in greater seepage through the adjacent wetlands during storm events, and other unmonitored surface inflows (i.e., Belleview and Quincy drainages) an exact match between USACE and GEI calculated inflows is not expected. Therefore, GEI normalizes their streamflow data to match the USACE computed inflow value.

4.7.2 Storm Event Sampling

Samples from storm flow events are collected using ISCO automatic samplers, which are programmed to collect samples when the flow reaches a threshold level. The threshold level is determined by analyzing annual hydrographs from each stream and determining storm levels. When the threshold is reached, the ISCO collects a sample every 15 minutes for approximately 2.5 hours (i.e., a timed composite) or until the water recedes below the threshold level. This sampling procedure occurs at Sites S-3, CC-10, CT-1, CT-2, CT-P1, and CT-P2. Following the storm event, water collected by the automatic samplers is combined (timed composite) into a clean 5-gallon container, with two 1-liter aliquots collected from the composited sample and stored on ice until transferred to the laboratory for analysis. Approximately 4 L would be collected from the 24 bottles, with each bottle contributing a sample amount representative of the flow at which it was collected. During the seasons in which no storm samples are collected, the storm samplers are disabled.

4.8 Precipitation Sampling

After each substantial storm, the sample bottle shall be removed, stored on ice, and transferred to the laboratory for analysis of phosphorus and nitrogen fractions. The sampler shall be inspected and cleaned of any accumulations of unimportant precipitation on a weekly basis. This will minimize extraneous “dry fall” from being washed into the sampler between substantial storm events.

5.0 Laboratory Procedures

5.1 Chemical Laboratory Analysis

Chemical analyses for the water collected in the study (Table 1) will be conducted by a qualified laboratory. Water samples will be analyzed for the parameters listed in Table 5.

Table 5: List of Analytes performed on each type of sample.

Parameter	Reservoir Photic Zone Composite	Reservoir 1 m Interval	Stream Base Flow	Stream Storm Flow	Rain Fall
Physicochemical					
Total Nitrogen	X	X	X	X	X
Total Dissolved Nitrogen	X	X	X	X	X
Nitrate/Nitrite Nitrogen	X	X	X	X	X
Ammonium Ion Nitrogen	X	X	X	X	X
Total Phosphorus	X	X	X	X	X
Total Dissolved Phosphorus	X	X	X	X	X
Soluble Reactive Phosphorus	X	X	X	X	X
Total Suspended Solids	--	--	X	X	--
Total Volatile Suspended Solids	--	--	X	X	--
Biological					
Chlorophyll *a*	X	--	--	--	--
Phytoplankton	X	--	--	--	--

5.2 Biological Laboratory Analysis

Biological analyses for the samples collected in the study, include chlorophyll *a*, phytoplankton identification and enumeration. The methods of these analyses, with appropriate QA/QC procedures shall be in accordance with the methods provided in Table 1. Chlorophyll *a* samples are analyzed by the GEI Analytical Laboratory, while phytoplankton samples are analyzed by the University of Colorado, Center for Limnology.

5.3 Laboratory Quality Assurance/Quality Control Protocols

Analytical equipment calibrations are performed every time new standards are prepared (minimum of once per week). Instrument values are compared to known standard concentration and if the correlation coefficient of the standard curve is less than 0.999, the instrument is recalibrated or standards are remade, with the process being completed until the instrument passes the test. Pseudo-replicate analyses are performed on each sample analyzed (i.e., sample analyzed twice) and the percent difference must be within 10 percent, if the resultant concentration is above the minimum detection limit. If the difference of the pseudo-replicate analyses are >10 percent, a new analytical sample is placed in a clean test tube and analyzed. During a sample analysis run, check standards are analyzed between every 5 samples (or 10 replicates). The check standards consist of one high range standard, one mid range standard, and the control blank (zero). Check standards analyzed before and after each group of samples must be within 10 percent of the theoretical value. If standards are outside of this range, new analytical samples and standards are placed in clean test tubes and analyzed to try to determine the source of the error. Sample values are not accepted until the problem has been resolved and all check standards pass the QC criteria. One matrix spike is run for every 10 samples analyzed (or 20 replicates). The percent recovery for matrix spikes must be ± 20 percent.

Following sample analyses, a final QC check is performed to determine if all parameters measured are in agreement. Final analyses for each sample are compared to ensure that concentrations of total phosphorus ≥ total dissolved phosphorus ≥ orthophosphate and that the concentration of total nitrogen ≥ total dissolved nitrogen ≥ nitrate/nitrite and ammonia. If parameters are not in agreement samples are reanalyzed.

6.0 Data Verification, Reduction, and Reporting

Data verification shall be conducted to ensure that raw data are not altered. All field data, such as those generated during any field measurements and observations, will be entered directly into a bound Field Book. Sampling Crew members will be responsible for proof reading all data transfers, if necessary. At least 10 percent of all data transfers will be checked for accuracy.

The Quality Assurance Project Manager will conduct data verification activities to assess laboratory performance in meeting quality assurance requirements. Such reviews include a verification that: 1) the correct samples were analyzed and reported in the correct units; 2) the samples were properly preserved and not held beyond applicable holding times; 3) instruments are regularly calibrated and meeting performance criteria; and 4) laboratory QA objectives for precision and accuracy are being met.

Data reduction for laboratory analyses is conducted by Consultant's personnel in accordance with EPA procedures, as available, for each method. Analytical results and appropriate field measurements are input into a computer spreadsheet. No results will be changed in the spreadsheet unless the cause of the error is identified and documented.

A data control program will be followed to insure that all documents generated during the project are accounted for upon their completion. Accountable documents include: Field Books, Sample Chain of Custody, Sample Log, analytical reports, quality assurance reports, and interpretive reports.

Data shall be summarized and provided to the Authority's Technical Advisory Committee on a monthly basis and presented in an annual report.

7.0 References

American Public Health Association. 2005. *Standard Methods for Examination of Water and Wastewater*, 20th Edition. American Public Health Association, Washington, DC.

Denver Regional Council of Governments. 1985. *Cherry Creek Basin Water Quality Management Master Plan*. Prepared in Cooperation with Counties, Municipalities, and Water and Sanitation Districts in the Cherry Creek Basin and Colorado Department of Health.

Goldman, C.R., and A.J. Horne. 1983. *Limnology*. McGraw-Hill Company, NY.

Harrelson, Cheryl C., Rawlins, C.L., Potyondy, John P. 1994. *Stream channel reference sites: an illustrated guide to field technique.* Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

Knowlton, M.R., and J.R. Jones. 1993. *Limnological Investigations of Cherry Creek Lake*. Final report to Cherry Creek Basin Water Quality Authority.

Appendix B

2014 WY Reservoir Water Quality Data

CCR-1 GEI Water Chemistry Data											
Analytical Detection Limits		**2**	**2**	**2**	**2**	**6**	**2**	**5**	**0.1**	**4**	**4**
Sample Date	**Sample Name/ Location**	**Total Phosphorous (µg/L)**	**Total Dissolved Phosphorous (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Average Chlorophyll *a* (mg/m^3)**	**TSS (mg/L)**	**TVSS (mg/L)**
10/15/2013	CCR-1 Photic	143	51	64	1,033	588	19	43	33.1	23.4	8.2
11/18/2013	CCR-1 Photic	83	44	42	991	699	4	51	17.6	7.4	ND
2/11/2014	CCR-1 Photic	65	19	12	944	503	5	ND	38.5	6.0	4.0
3/12/2014	CCR-1 Photic	89	18	7	910	451	ND	22	26.2	12.5	6.7
4/15/2014	CCR-1 Photic	62	11	13	908	510	ND	25	20.9	11.2	6.2
5/13/2014	CCR-1 Photic	75	24	11	788	550	2	22	16.4	13.0	4.8
5/27/2014	CCR-1 Photic	51	28	9	802	594	4	29	7.1	5.0	ND
6/10/2014	CCR-1 Photic	66	28	31	1,083	834	14	43	37.7	9.6	6.6
6/24/2014	CCR-1 Photic	91	39	50	1,434	1,081	25	313	6.4	ND	ND
7/08/2014	CCR-1 Photic	87	69	48	1,227	702	ND	27	30.8	11.0	5.8
7/22/2014	CCR-1 Photic	116	29	10	1,024	635	8	26	33.2	19.4	6.7
8/05/2014	CCR-1 Photic	94	35	25	933	798	ND	22	15.5	6.8	ND
8/19/2014	CCR-1 Photic	71	45	23	737	579	ND	18	13.9	6.6	ND
9/02/2014	CCR-1 Photic	66	47	14	923	814	ND	22	21.4	8.4	4.2
9/16/2014	CCR-1 Photic	57	21	8	710	446	3	12	21.7	9.8	4.2

ND = below detection limit

CCR-2 GEI Water Chemistry Data											
Analytical Detection Limits		2	2	2	2	2	2	3	0.1	4	4
Sample Date	Sample Name/ Location	Total Phosphorous (µg/L)	Total Dissolved Phosphorous (µg/L)	Ortho-phosphate (µg/L)	Total Nitrogen (µg/L)	Total Dissolved Nitrogen (µg/L)	Nitrate+ Nitrite (µg/L)	Ammonia (µg/L)	Average Chlorophyll *a* (mg/m^3)	TSS (mg/L)	TVSS (mg/L)
10/15/2013	CCR-2 Photic	126	51	69	942	629	35	73	28.6	21.6	6.6
10/15/2013	CCR-2 4m	118	52	68	878	590	7	57	--	--	--
10/15/2013	CCR-2 5m	126	50	67	924	546	5	57	--	--	--
10/15/2013	CCR-2 6m	126	47	66	948	528	5	47	--	--	--
10/15/2013	CCR-2 7m	135	46	66	846	524	4	56	--	--	--
11/18/2013	CCR-2 Photic	87	41	39	1,032	683	6	38	17.0	10.0	4.2
11/18/2013	CCR-2 4m	89	45	37	823	571	3	44	--	--	--
11/18/2013	CCR-2 5m	75	39	39	767	485	3	42	--	--	--
11/18/2013	CCR-2 6m	83	40	38	804	493	40	37	--	--	--
11/18/2013	CCR-2 7m	80	40	40	728	453	3	31	--	--	--
2/11/2014	CCR-2 Photic	81	24	14	1,141	607	20	5	48.2	7.6	4.8
2/11/2014	CCR-2 4m	74	21	14	1,101	582	4	5	--	--	--
2/11/2014	CCR-2 5m	65	20	13	943	550	2	ND	--	--	--
2/11/2014	CCR-2 6m	62	22	13	946	621	3	5	--	--	--
2/11/2014	CCR-2 7m	80	27	21	889	508	6	10	--	--	--
3/12/2014	CCR-2 Photic	95	23	10	882	465	ND	19	25.1	9.7	7.0
3/12/2014	CCR-2 4m	86	19	8	916	470	ND	18	--	--	--
3/12/2014	CCR-2 5m	78	19	8	837	451	ND	17	--	--	--
3/12/2014	CCR-2 6m	81	18	7	833	474	2	19	--	--	--
3/12/2014	CCR-2 7m	88	20	8	901	499	ND	22	--	--	--
4/15/2014	CCR-2 Photic	82	12	12	1,106	532	ND	19	19.6	11.0	6.0
4/15/2014	CCR-2 4m	71	12	12	1,042	515	ND	26	--	--	--
4/15/2014	CCR-2 5m	72	14	13	1,014	543	ND	29	--	--	--
4/15/2014	CCR-2 6m	66	15	15	894	525	ND	22	--	--	--
4/15/2014	CCR-2 7m	74	12	15	911	527	ND	27	--	--	--
5/13/2014	CCR-2 Photic	76	25	11	746	491	3	30	14.4	10.4	4.0
5/13/2014	CCR-2 4m	77	25	12	839	502	6	33	--	--	--
5/13/2014	CCR-2 5m	75	30	12	777	605	2	40	--	--	--

CCR-2 GEI Water Chemistry Data											
Analytical Detection Limits		**2**	**2**	**2**	**2**	**2**	**2**	**3**	**0.1**	**4**	**4**
Sample Date	**Sample Name/ Location**	**Total Phosphorous (µg/L)**	**Total Dissolved Phosphorous (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Average Chlorophyll *a* (mg/m^3)**	**TSS (mg/L)**	**TVSS (mg/L)**
5/13/2014	CCR-2 6m	73	26	11	826	706	2	38	--	--	--
5/13/2014	CCR-2 7m	92	28	14	939	838	4	55	--	--	--
5/27/2014	CCR-2 Photic	54	40	7	760	548	3	17	9.0	5.6	ND
5/27/2014	CCR-2 4m	53	26	8	836	615	4	21	--	--	--
5/27/2014	CCR-2 5m	72	39	23	683	622	6	26	--	--	--
5/27/2014	CCR-2 6m	88	58	40	742	539	5	22	--	--	--
5/27/2014	CCR-2 7m	120	72	62	706	602	ND	25	--	--	--
6/10/2014	CCR-2 Photic	92	20	33	1,145	509	10	51	44.2	11.4	6.8
6/10/2014	CCR-2 4m	89	29	39	1,029	559	20	86	--	--	--
6/10/2014	CCR-2 5m	72	37	41	863	688	17	103	--	--	--
6/10/2014	CCR-2 6m	62	39	39	799	548	12	85	--	--	--
6/10/2014	CCR-2 7m	55	26	43	837	542	20	106	--	--	--
6/24/2014	CCR-2 Photic	92	43	48	1,135	975	23	301	5.8	ND	ND
6/24/2014	CCR-2 4m	59	51	48	1,123	950	22	325	--	--	--
6/24/2014	CCR-2 5m	89	85	70	1,242	1,223	21	375	--	--	--
6/24/2014	CCR-2 6m	110	108	101	1,303	1,131	19	424	--	--	--
6/24/2014	CCR-2 7m	217	136	184	1,388	1,155	17	556	--	--	--
7/8/2014	CCR-2 Photic	149	79	56	1,242	643	ND	23	42.8	10.5	6.7
7/8/2014	CCR-2 4m	195	115	61	1,191	610	ND	62	--	--	--
7/8/2014	CCR-2 5m	108	58	67	1,076	680	ND	94	--	--	--
7/8/2014	CCR-2 6m	153	85	81	1,162	766	2	144	--	--	--
7/8/2014	CCR-2 7m	182	137	123	1,340	865	ND	275	--	--	--
7/22/2014	CCR-2 Photic	111	32	10	1,045	573	7	23	38.2	16.3	7.1
7/22/2014	CCR-2 4m	174	86	57	1,130	613	8	28	--	--	--
7/22/2014	CCR-2 5m	151	96	86	880	676	8	37	--	--	--
7/22/2014	CCR-2 6m	165	113	97	870	587	7	59	--	--	--
7/22/2014	CCR-2 7m	276	167	157	1,026	700	6	159	--	--	--
8/5/2014	CCR-2 Photic	90	36	25	994	649	ND	22	13.2	6.9	ND

CCR-2 GEI Water Chemistry Data											
Analytical Detection Limits		**2**	**2**	**2**	**2**	**2**	**2**	**3**	**0.1**	**4**	**4**
Sample Date	**Sample Name/ Location**	**Total Phosphorous (µg/L)**	**Total Dissolved Phosphorous (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Average Chlorophyll *a* (mg/m^3)**	**TSS (mg/L)**	**TVSS (mg/L)**
8/5/2014	CCR-2 4m	92	35	26	937	592	ND	26	--	--	--
8/5/2014	CCR-2 5m	112	69	64	857	678	3	28	--	--	--
8/5/2014	CCR-2 6m	147	80	74	762	581	ND	42	--	--	--
8/5/2014	CCR-2 7m	169	115	104	997	635	2	92	--	--	--
8/19/2014	CCR-2 Photic	74	36	23	820	525	ND	19	22.6	6.2	ND
8/19/2014	CCR-2 4m	73	32	25	695	511	ND	19	--	--	--
8/19/2014	CCR-2 5m	70	33	26	846	698	ND	28	--	--	--
8/19/2014	CCR-2 6m	93	44	38	762	569	ND	46	--	--	--
8/19/2014	CCR-2 7m	140	33	41	893	580	ND	92	--	--	--
9/2/2014	CCR-2 Photic	63	27	15	779	781	ND	18	17.9	8.3	ND
9/2/2014	CCR-2 4m	93	26	16	658	628	ND	39	--	--	--
9/2/2014	CCR-2 5m	67	26	16	802	596	ND	37	--	--	--
9/2/2014	CCR-2 6m	59	26	16	817	590	ND	41	--	--	--
9/2/2014	CCR-2 7m	108	39	26	936	607	ND	61	--	--	--
9/16/2014	CCR-2 Photic	42	5	5	459	377	3	7	21.2	10.4	4.4
9/16/2014	CCR-2 4m	27	4	6	546	333	5	10	--	--	--
9/16/2014	CCR-2 5m	52	6	8	511	342	4	11	--	--	--
9/16/2014	CCR-2 6m	72	20	23	603	405	7	47	--	--	--
9/16/2014	CCR-2 7m	100	11	19	548	436	6	59	--	--	--

ND = below detection limit

CCR-3 GEI Water Chemistry Data											
Analytical Detection Limits		**2**	**2**	**2**	**6**	**6**	**2**	**5**	**0.1**	**4**	**4**
Sample Date	**Sample Name/ Location**	**Total Phosphorous (µg/L)**	**Total Dissolved Phosphorous (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Average Chlorophyll *a* (mg/m^3)**	**TSS (mg/L)**	**TVSS (mg/L)**
10/15/2013	CCR-3 Photic	122	47	67	916	541	9	60	31.6	18.6	6.0
11/18/2013	CCR-3 Photic	78	39	39	754	468	5	34	13.3	8.2	ND
2/11/2014	CCR-3 Photic	--	--	--	--	--	--	--	--	--	--
3/12/2014	CCR-3 Photic	126	18	6	1,396	526	ND	19	27.4	11.3	6.7
4/15/2014	CCR-3 Photic	59	18	14	914	526	ND	27	20.3	10.8	6.5
5/13/2014	CCR-3 Photic	77	30	14	840	583	11	31	14.9	10.8	4.4
5/27/2014	CCR-3 Photic	67	21	7	635	524	4	14	11.1	6.4	ND
6/10/2014	CCR-3 Photic	111	18	33	1,042	880	20	40	30.7	15.0	7.0
6/24/2014	CCR-3 Photic	73	55	55	1,204	1,087	22	350	6.1	ND	ND
7/08/2014	CCR-3 Photic	125	71	53	1,082	663	2	33	29.8	12.2	6.8
7/22/2014	CCR-3 Photic	115	27	13	1,001	659	6	27	33.2	18.8	7.4
8/05/2014	CCR-3 Photic	120	29	20	1,050	631	ND	30	20.5	10.9	4.5
8/19/2014	CCR-3 Photic	89	34	24	824	563	ND	23	17.6	9.8	4.4
9/02/2014	CCR-3 Photic	75	22	11	837	620	ND	38	19.6	11.3	4.3
9/16/2014	CCR-3 Photic	21	3	10	581	327	3	18	26.8	13.6	5.0

ND = below detection limit

Site CCR-1 Small Tables

Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
10/15/2013	0	12.87	1,020	7.46	7.82	264		
	1	12.91	1,020	7.41	7.82	263		
	2	12.91	1,020	7.40	7.81	262		
	3	12.90	1,021	7.34	7.81	262		
	4	12.90	1,020	7.32	7.81	261		
	5	12.89	1,021	7.28	7.80	261		
	6	12.89	1,020	7.26	7.79	260		
	7	12.88	1,021	7.22	7.79	260		
	7.7	12.88	1,021	6.87	7.78	170		
	--						1.73	0.68
11/18/2013	0	6.95	1,056	8.02	8.13	164		
	1	6.93	1,054	7.99	8.02	155		
	2	6.83	1,055	7.97	8.03	156		
	3	6.73	1,055	7.85	8.03	156		
	4	6.72	1,056	7.84	8.03	156		
	5	6.71	1,056	7.81	8.04	156		
	6	6.71	1,054	7.81	8.04	156		
	7	6.70	1,056	7.79	8.04	156		
	7.6	6.70	1,056	5.20	8.04	91		
	--						3.72	1.15
2/11/2014*	0	1.07	1,142	12.32	8.19	208		
	1	2.34	1,133	12.02	8.23	207		
	2	2.42	1,132	11.92	8.24	206		
	3	2.43	1,134	11.56	8.23	206		
	4	2.56	1,154	8.45	7.93	210		
	5	2.61	1,168	8.02	7.87	213		
	6	2.62	1,178	7.59	7.84	213		
	7	2.66	1,195	7.32	7.81	214		
	7.9	2.68	1,200	7.22	7.83	215		
	--						3.00	ICE
3/12/2014	0	5.17	1,611	9.39	8.62	21		
	1	4.90	1,609	9.39	8.59	50		
	2	4.47	1,608	9.18	8.57	73		
	3	4.45	1,610	9.10	8.57	88		
	4	4.35	1,612	9.05	8.59	116		
	5	4.31	1,611	9.05	8.57	130		
	6	4.30	1,611	9.06	8.56	138		
	7	4.22	1,621	9.07	8.56	152		
	7.5	4.23	1,623	9.02	8.56	161		
	--						2.55	0.73
4/15/2014	0	9.41	1,215	9.09	8.10	421		
	1	9.39	1,215	9.10	8.11	417		
	2	9.27	1,214	9.14	8.11	417		
	3	9.21	1,214	9.03	8.11	417		
	4	8.93	1,213	8.75	8.09	417		
	5	8.81	1,214	8.65	8.08	417		
	6	8.73	1,214	8.40	8.07	417		
	7	8.63	1,215	8.08	8.04	417		
	7.7	8.59	1,214	7.83	8.03	410		
	--						2.55	0.89

Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
5/13/2014	0	11.13	1,230	7.72	8.05	303		
	1	11.05	1,229	7.67	8.01	297		
	2	10.76	1,230	7.45	8.00	295		
	3	10.75	1,231	7.38	8.00	293		
	4	10.76	1,230	7.41	7.98	288		
	5	10.74	1,230	7.41	7.99	287		
	6	10.68	1,226	7.36	7.99	286		
	7	10.55	1,225	7.32	7.96	283		
	7.6	10.53	1,224	6.20	7.98	265		
	--						2.63	0.83
5/27/2014	0	17.68	1,231	9.63	8.18	192		
	1	17.09	1,231	9.72	8.20	189		
	2	16.93	1,231	9.63	8.20	188		
	3	16.85	1,230	9.53	8.20	188		
	4	16.06	1,229	8.63	8.13	189		
	5	15.34	1,230	6.93	7.96	194		
	6	14.40	1,231	5.06	7.74	198		
	7	13.37	1,230	2.28	7.46	205		
	7.6	13.22	1,231	1.91	7.42	205		
	--						4.75	1.62
6/10/2014	0	20.11	1,241	11.42	8.41	190		
	1	18.56	1,234	9.51	8.29	192		
	2	18.09	1,236	8.78	8.19	193		
	3	17.97	1,234	8.26	8.15	193		
	4	17.90	1,234	7.94	8.12	193		
	5	17.87	1,234	7.98	8.13	193		
	6	17.78	1,231	7.76	8.11	193		
	7	16.94	1,165	5.31	7.90	196		
	7.6	16.86	1,160	4.98	7.85	194		
	--						3.17	1.05
6/24/2014	0	20.90	1,245	6.14	8.30	300		
	1	20.67	1,244	6.09	8.30	292		
	2	20.39	1,242	6.12	8.35	272		
	3	20.09	1,242	6.12	8.35	272		
	4	20.00	1,241	5.99	8.34	271		
	5	19.90	1,242	5.40	8.28	271		
	6	19.48	1,246	3.39	8.09	275		
	7	19.02	1,248	1.72	7.90	280		
	7.5	18.89	1,249	0.85	7.79	282		
	--						5.66	3.42
6/26/2013	0	23.19	1,328	8.23	8.30	279		
	1	22.14	1,326	7.82	8.29	274		
	2	21.50	1,327	6.28	8.16	275		
	3	21.25	1,328	5.35	8.06	275		
	4	21.01	1,329	3.80	7.93	277		
	5	20.90	1,326	3.97	7.94	277		
	6	20.68	1,328	3.55	7.88	277		
	6.5	20.64	1,328	2.43	7.83	266		
	--						2.37	0.73

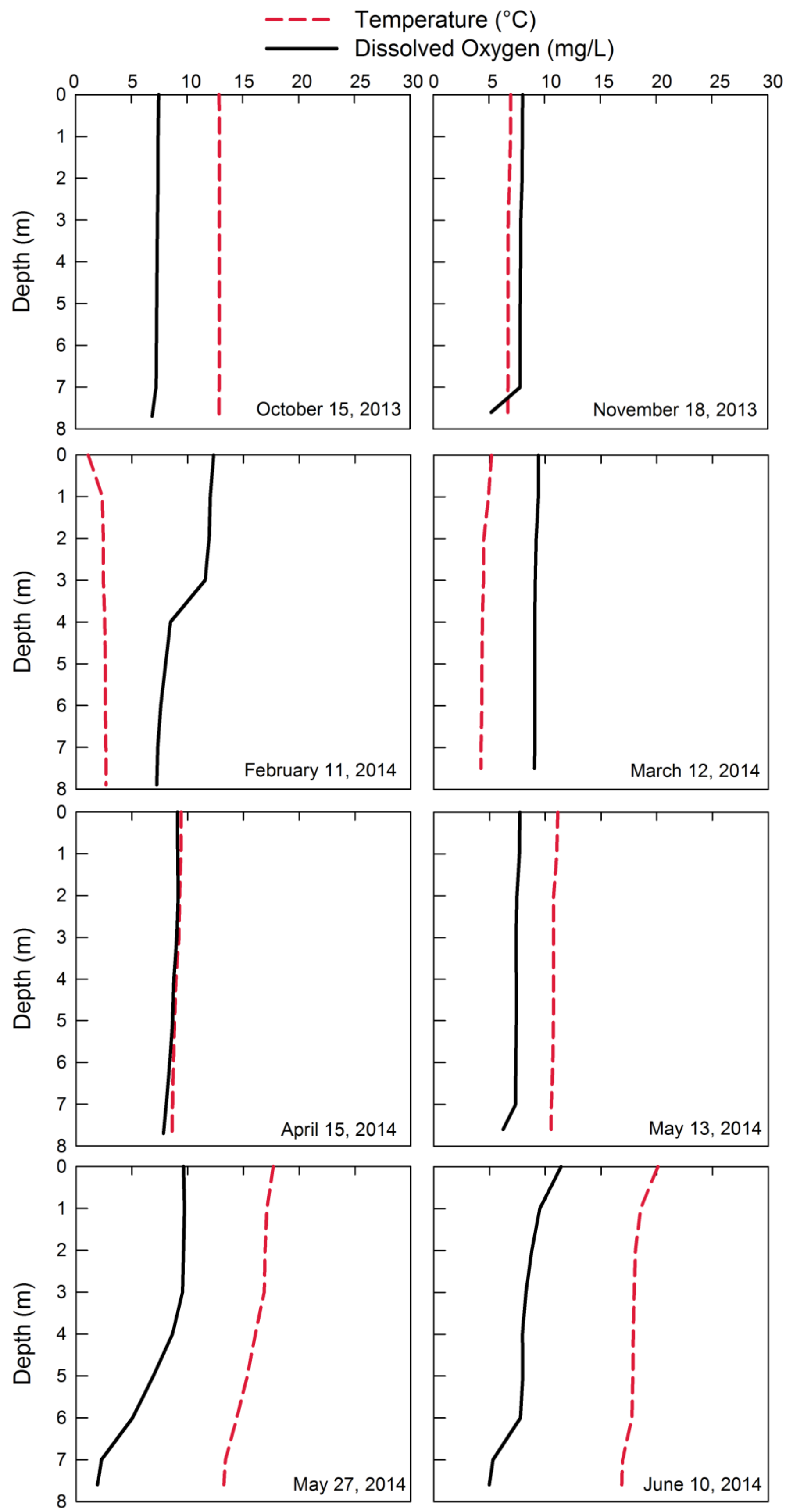
Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
7/01/2014	0	22.03	1,248	9.29	8.44	362		
	1	22.05	1,248	9.28	8.51	354		
	2	22.04	1,248	9.22	8.52	347		
	3	22.04	1,249	9.16	8.52	344		
	4	21.92	1,250	7.89	8.43	337		
	5	21.08	1,256	5.24	8.15	333		
	6	20.70	1,260	3.70	8.02	327		
	7	20.51	1,260	2.53	7.89	320		
	7.4	20.47	1,260	0.31	7.74	320		
	--						--	1.20
7/08/2014	0	23.40	1,243	9.27	8.54	262		
	1	23.29	1,243	8.80	8.51	258		
	2	22.63	1,247	6.53	8.36	257		
	3	22.34	1,249	6.00	8.32	254		
	4	22.16	1,250	5.11	8.25	253		
	5	21.82	1,254	2.68	8.02	255		
	6	21.57	1,254	1.50	7.89	256		
	7	21.19	1,258	0.00	7.75	222		
	7.4	21.07	1,259	0.00	7.69	-190		
	--						2.87	1.15
7/16/2014	0	23.55	1,230	8.54	8.39	249		
	1	23.23	1,230	7.83	8.35	249		
	2	23.07	1,231	6.82	8.28	249		
	3	22.92	1,233	5.66	8.18	249		
	4	22.85	1,233	5.07	8.15	249		
	5	22.77	1,232	4.56	8.11	248		
	6	22.60	1,232	2.16	7.95	248		
	7	22.55	1,233	1.62	7.91	247		
	7.5	22.53	1,234	1.41	7.90	185		
	--						--	1.05
7/22/2014	0	23.54	1,212	9.88	8.39	395		
	1	23.49	1,212	9.71	8.41	389		
	2	23.30	1,211	9.15	8.35	384		
	3	22.94	1,222	4.35	7.97	388		
	4	22.71	1,225	2.24	7.76	389		
	5	22.49	1,227	1.08	7.66	389		
	6	22.40	1,227	1.02	7.65	388		
	7	22.31	1,228	0.05	7.61	379		
	7.4	22.22	1,230	0.00	7.60	233		
	--						2.75	1.20
7/29/2014	0	24.11	1,216	7.81	8.47	195		
	1	23.20	1,214	6.87	8.34	196		
	2	22.99	1,217	5.92	8.23	198		
	3	22.88	1,219	5.13	8.13	199		
	4	22.85	1,218	5.25	8.15	198		
	5	22.72	1,219	4.34	8.06	200		
	6	22.60	1,221	4.31	8.03	199		
	7	22.49	1,224	2.75	7.85	202		
	7.3	22.48	1,224	2.58	7.84	10		
	--						--	1.20

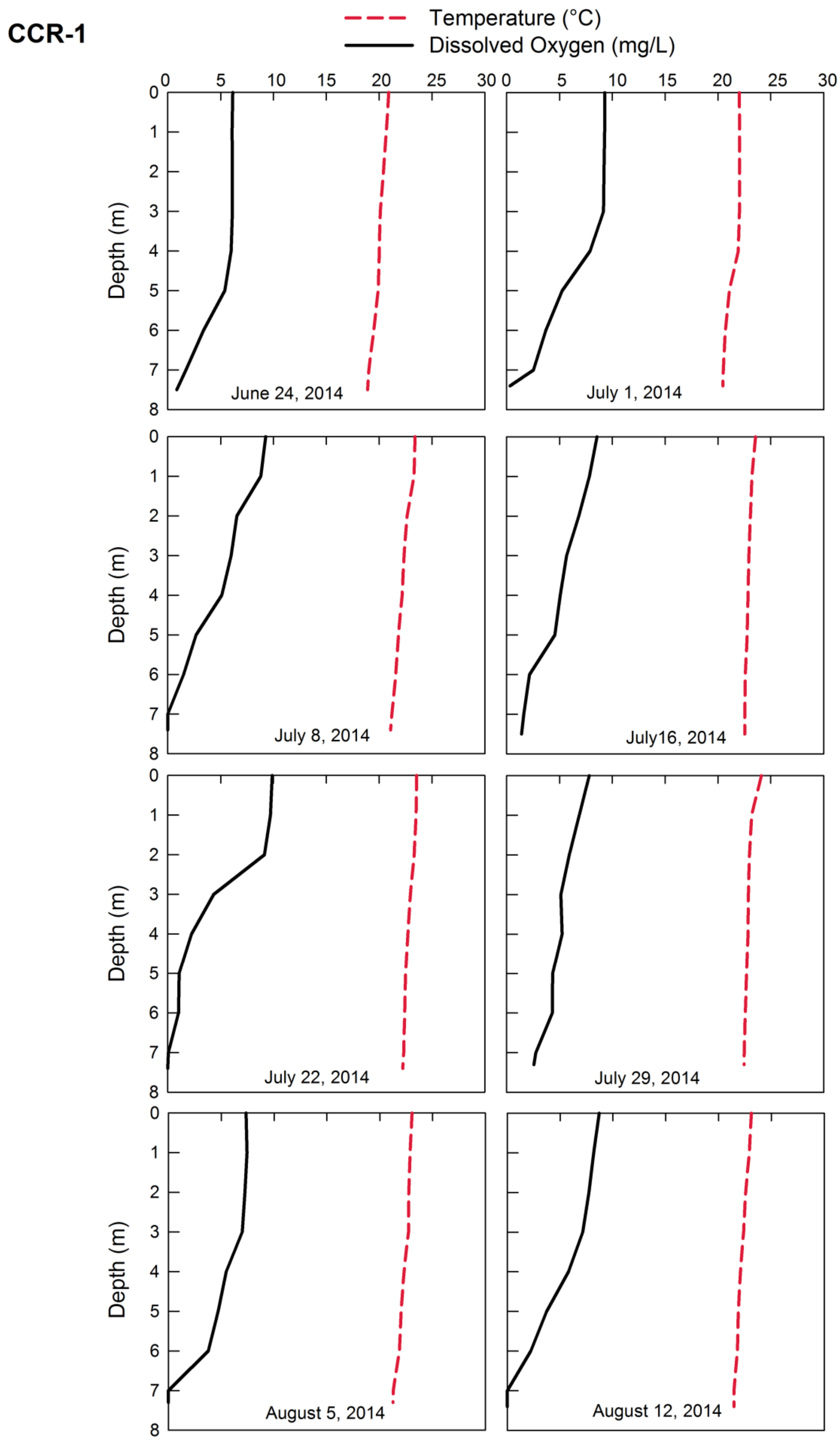
Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
8/05/2014	0	23.05	1,184	7.35	8.15	360		
	1	22.85	1,183	7.43	8.14	349		
	2	22.73	1,185	7.24	8.15	342		
	3	22.70	1,184	6.98	8.12	338		
	4	22.28	1,185	5.47	7.92	339		
	5	22.01	1,184	4.70	7.82	339		
	6	21.85	1,182	3.78	7.70	339		
	7	21.27	1,160	0.00	7.40	340		
	7.3	21.23	1,161	0.00	7.36	-40		
	--						3.38	1.12
8/12/2014	0	23.10	1,197	8.69	8.30	311		
	1	22.91	1,197	8.17	8.25	305		
	2	22.56	1,196	7.72	8.20	304		
	3	22.37	1,196	7.13	8.13	304		
	4	22.07	1,197	5.78	7.95	303		
	5	21.87	1,197	3.71	7.71	306		
	6	21.79	1,196	2.22	7.54	308		
	7	21.46	1,198	0.00	7.36	-202		
	7.4	21.45	1,200	0.00	7.35	-213		
	--						--	1.25
8/19/2014	0	22.35	1,203	5.84	8.10	171		
	1	22.34	1,203	5.76	8.07	170		
	2	22.23	1,203	5.01	8.00	171		
	3	22.18	1,203	5.01	8.00	171		
	4	22.16	1,203	5.02	7.99	171		
	5	22.10	1,202	5.27	8.02	170		
	6	22.00	1,203	5.07	8.00	170		
	7	21.98	1,204	4.14	7.90	168		
	7.3	21.97	1,204	4.11	7.90	39		
	--						3.43	1.15
8/26/2014	0	21.98	1,208	6.20	8.00	253		
	1	21.97	1,208	6.10	8.02	250		
	2	21.97	1,209	6.10	8.03	249		
	3	21.95	1,209	6.02	8.03	248		
	4	21.90	1,209	5.72	8.00	248		
	5	21.76	1,210	5.05	7.94	248		
	6	21.70	1,210	5.02	7.93	248		
	7	21.67	1,210	4.80	7.91	247		
	7.4	21.67	1,210	4.69	7.91	245		
	--						--	1.50
9/02/2014	0	20.70	1,197	6.60	7.88	252		
	1	20.70	1,197	6.64	7.90	247		
	2	20.70	1,198	6.60	7.91	244		
	3	20.70	1,197	6.55	7.92	241		
	4	20.69	1,197	6.46	7.91	239		
	5	20.69	1,197	6.40	7.92	237		
	6	20.68	1,198	5.63	7.86	237		
	7	20.40	1,203	2.26	7.61	240		
	7.5	20.36	1,202	0.00	7.11	33		
	--						2.85	1.00

Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
9/09/2014	0	20.96	1,197	7.64	8.17	227		
	1	20.52	1,197	7.60	8.19	227		
	2	20.36	1,197	7.06	8.12	228		
	3	20.27	1,198	6.69	8.11	228		
	4	20.22	1,198	6.40	8.06	229		
	5	20.19	1,199	6.23	8.04	229		
	6	20.14	1,198	5.87	8.01	229		
	7	20.08	1,198	5.63	7.99	229		
	7.5	20.02	1,203	2.10	7.35	-30		
	--						--	0.97
9/16/2014	0	18.54	1,207	8.73	8.27	276		
	1	18.48	1,206	8.74	8.24	275		
	2	18.26	1,207	8.10	8.21	274		
	3	18.00	1,209	7.52	8.16	275		
	4	17.92	1,208	7.36	8.14	274		
	5	17.79	1,208	6.81	8.09	275		
	6	17.59	1,211	5.96	8.02	275		
	7	17.42	1,211	4.37	7.88	277		
	7.5	17.24	1,212	3.68	7.81	276		
	--						3.02	0.95
9/23/2014	0	19.34	1211	6.64	8.06	222		
	1	18.88	1211	6.96	8.10	220		
	2	18.69	1210	6.49	8.05	220		
	3	18.66	1210	6.25	8.03	220		
	4	18.66	1210	6.15	8.02	220		
	5	18.63	1211	5.87	7.99	220		
	6	18.45	1212	2.98	7.78	224		
	7	18.04	1216	1.75	7.60	225		
	7.5	18.03	1216	1.69	7.58	218		
	--						--	0.95

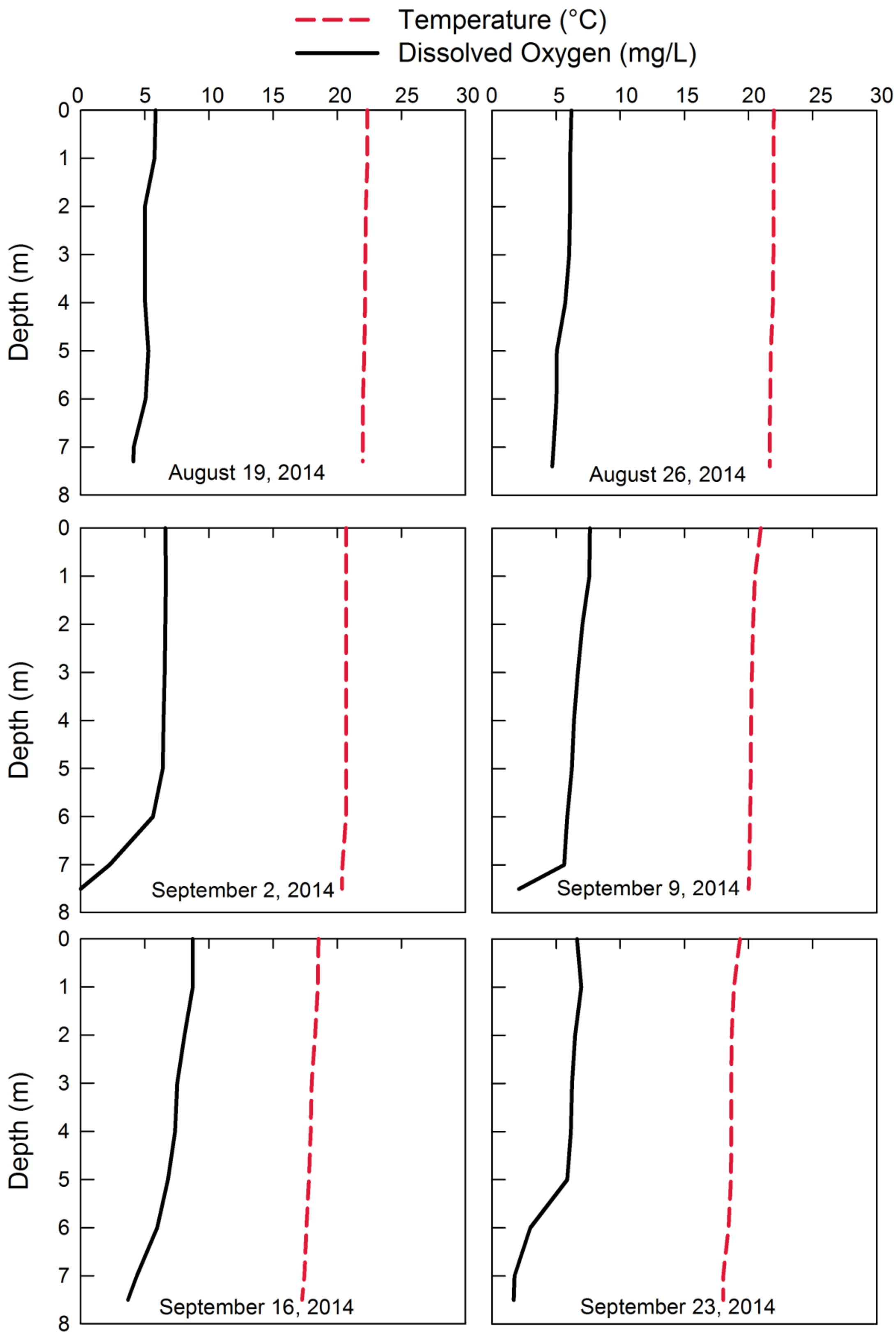
* Denotes data collected when Reservoir was ice-covered (approximately 0.20 m thick).

CCR-1


Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0
5
10
15
20
25
30
October 15, 2013
November 18, 2013
February 11, 2014
March 12, 2014
April 15, 2014
May 13, 2014
May 27, 2014
June 10, 2014


CCR-1
Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0 5 10 15 20 25 30
June 24, 2014
July 1, 2014
July 8, 2014
July16, 2014
July 22, 2014
July 29, 2014
August 5, 2014
August 12, 2014

CCR-1


Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
8
August 19, 2014
August 26, 2014
September 2, 2014
September 9, 2014
September 16, 2014
September 23, 2014

CCR-2 Small Tables

Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
10/15/2013	0	12.89	1,019	6.92	7.71	222		
	1	12.92	1,019	6.88	7.74	222		
	2	12.92	1,019	6.87	7.75	222		
	3	12.93	1,019	6.86	7.74	222		
	4	12.92	1,019	6.89	7.76	222		
	5	12.91	1,019	6.92	7.77	222		
	6	12.87	1,019	6.94	7.77	222		
	7	12.69	1,019	6.79	7.75	223		
	7.6	12.69	1,021	6.54	7.74	220		
	--						1.98	0.70
11/18/2013	0	7.02	1,053	8.74	8.02	142		
	1	6.94	1,056	8.67	7.97	143		
	2	6.80	1,057	8.55	7.95	144		
	3	6.74	1,057	8.78	7.98	144		
	4	6.67	1,057	8.52	7.97	145		
	5	6.62	1,057	8.46	7.97	146		
	6	6.62	1,057	8.45	7.97	146		
	7	6.62	1,057	8.43	7.97	146		
	7.5	6.62	1,057	8.17	7.96	146		
	--						3.42	1.19
2/11/2014*	0	1.60	1,125	11.80	8.23	226		
	1	2.50	1,130	11.50	8.22	224		
	2	2.60	1,129	11.40	8.22	224		
	3	2.50	1,140	10.40	8.10	225		
	4	2.60	1,145	10.30	8.11	225		
	5	2.68	1,152	10.65	8.13	225		
	6	2.67	1,183	9.88	8.00	227		
	7	2.78	1,203	7.92	7.77	230		
	7.7	2.82	1,200	7.73	7.78	231		
	--						2.45	ICE
3/12/2014	0	5.71	1,627	9.45	8.59	341		
	1	4.99	1,641	9.61	8.60	339		
	2	4.59	1,615	9.46	8.63	338		
	3	4.39	1,618	9.30	8.63	337		
	4	4.41	1,620	9.20	8.64	335		
	5	4.42	1,625	9.17	8.63	333		
	6	4.42	1,627	9.13	8.62	331		
	7	4.36	1,624	8.99	8.60	328		
	7.5	4.34	1,618	8.89	8.59	326		
	--						2.73	0.70
4/15/2014	0	9.34	1,214	8.95	8.06	394		
	1	9.31	1,215	8.93	8.07	394		
	2	9.29	1,214	8.88	8.08	394		
	3	9.21	1,214	8.82	8.08	394		
	4	9.15	1,215	8.70	8.08	394		
	5	8.89	1,214	8.42	8.06	394		
	6	8.79	1,213	8.34	8.05	395		
	7	8.70	1,214	7.95	8.02	395		
	7.6	8.71	1,213	7.83	8.03	393		
	--						2.98	0.80

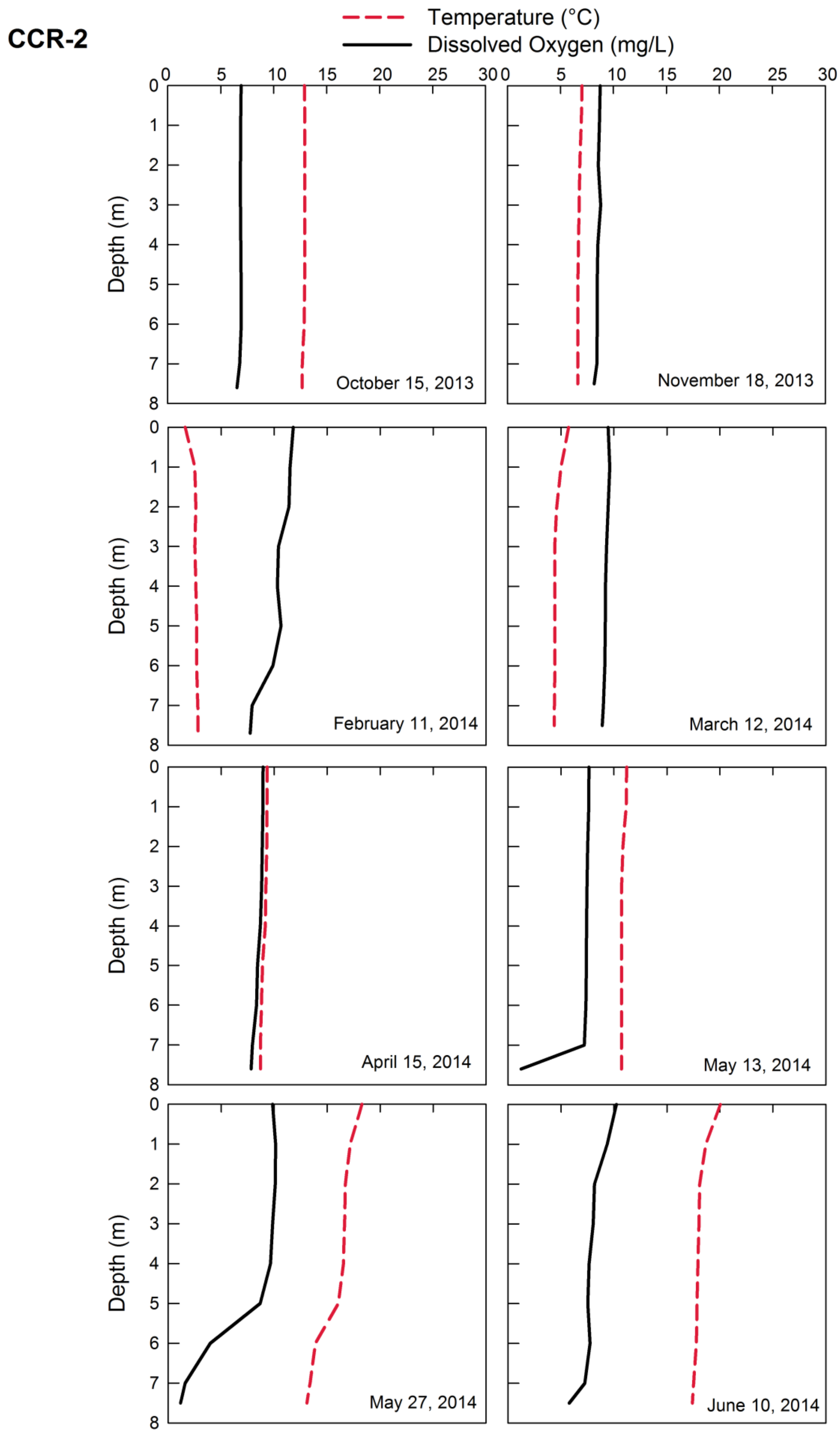
Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
5/13/2014	0	11.21	1,230	7.63	8.03	251		
	1	11.17	1,228	7.61	8.01	251		
	2	10.85	1,226	7.51	8.01	251		
	3	10.73	1,225	7.45	8.01	251		
	4	10.72	1,225	7.41	8.01	251		
	5	10.71	1,227	7.39	8.02	251		
	6	10.71	1,228	7.35	8.01	251		
	7	10.71	1,228	7.19	8.01	251		
	7.6	10.71	1,229	1.23	8.01	7		
	--						2.80	0.80
5/27/2014	0	18.28	1,233	9.85	8.27	100		
	1	17.17	1,231	10.14	8.30	101		
	2	16.71	1,230	10.11	8.29	102		
	3	16.63	1,230	9.85	8.28	103		
	4	16.52	1,230	9.65	8.26	104		
	5	16.05	1,230	8.68	8.18	106		
	6	13.89	1,232	3.97	7.68	119		
	7	13.37	1,231	1.60	7.46	124		
	7.5	13.08	1,232	1.17	7.42	124		
	--						5.00	1.52
6/10/2014	0	20.05	1,238	10.23	8.27	227		
	1	18.68	1,241	9.36	8.17	227		
	2	18.09	1,238	8.15	8.10	225		
	3	18.03	1,238	8.03	8.11	225		
	4	17.93	1,237	7.65	8.07	222		
	5	17.85	1,235	7.52	8.07	222		
	6	17.78	1,236	7.74	8.08	221		
	7	17.52	1,237	7.23	8.06	221		
	7.5	17.40	1,238	5.77	8.02	212		
	--						3.55	1.10
6/24/2014	0	21.25	1,244	6.33	8.40	248		
	1	20.66	1,242	6.29	8.39	248		
	2	20.41	1,242	6.26	8.38	248		
	3	20.31	1,242	6.22	8.38	248		
	4	20.22	1,242	6.08	8.36	248		
	5	20.10	1,243	5.82	8.35	249		
	6	19.71	1,245	4.18	8.19	251		
	7	18.99	1,249	1.45	7.89	255		
	7.3	18.97	1,249	1.21	7.79	223		
	--						6.50	3.65
7/01/2014	0	21.65	1,251	8.63	8.46	254		
	1	21.64	1,250	8.62	8.48	255		
	2	21.64	1,250	8.60	8.49	256		
	3	21.58	1,250	8.23	8.50	257		
	4	21.25	1,253	6.84	8.34	259		
	5	21.13	1,253	6.82	8.34	260		
	6	20.85	1,255	5.42	8.20	262		
	7	20.21	1,263	1.18	7.80	271		
	7.4	20.10	1,263	0.74	7.72	224		
	--						--	1.30

Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
7/08/2014	0	22.80	1,247	7.84	8.47	95		
	1	22.51	1,247	7.40	8.41	97		
	2	22.43	1,248	7.05	8.40	97		
	3	22.32	1,249	6.43	8.37	99		
	4	22.28	1,249	6.11	8.35	100		
	5	22.19	1,251	5.48	8.30	101		
	6	22.09	1,251	4.64	8.23	103		
	7	21.85	1,254	3.04	8.06	106		
	7.3	21.54	1,256	1.85	7.99	-15		
	--						2.82	1.10
7/16/2014	0	23.80	1,232	8.11	8.40	189		
	1	23.26	1,230	7.60	8.39	190		
	2	22.88	1,232	4.62	8.16	194		
	3	22.83	1,231	4.60	8.16	194		
	4	22.77	1,228	4.65	8.15	194		
	5	22.67	1,226	4.35	8.12	195		
	6	22.45	1,220	3.07	8.00	197		
	7	22.29	1,271	2.11	7.92	198		
	7.6	22.00	1,218	1.75	7.87	90		
	--						--	1.20
7/22/2014	0	23.84	1,211	10.56	8.54	283		
	1	23.81	1,210	10.52	8.52	281		
	2	23.59	1,213	9.79	8.48	279		
	3	23.42	1,215	5.48	8.27	285		
	4	22.76	1,225	3.12	7.81	288		
	5	22.50	1,228	1.68	7.70	290		
	6	22.42	1,228	1.19	7.64	291		
	7	22.14	1,231	0.44	7.57	65		
	7.4	22.14	1,234	0.00	7.55	-191		
	--						2.90	0.99
7/29/2014	0	24.20	1,217	7.28	8.38	142		
	1	23.18	1,217	7.42	8.36	143		
	2	23.08	1,217	5.91	8.22	147		
	3	22.95	1,218	5.51	8.18	148		
	4	22.80	1,222	3.06	7.93	154		
	5	22.72	1,224	2.24	7.79	157		
	6	22.68	1,225	1.52	7.71	159		
	7	22.52	1,225	0.74	7.64	160		
	7.2	22.50	1,225	0.00	7.62	-61		
	--						--	1.20
8/05/2014	0	22.99	1,184	7.44	8.12	318		
	1	22.69	1,185	7.43	8.09	310		
	2	22.51	1,184	6.99	8.03	304		
	3	22.45	1,184	6.58	8.00	302		
	4	22.34	1,185	5.96	7.95	300		
	5	21.61	1,176	2.64	7.54	306		
	6	21.30	1,174	1.20	7.40	308		
	7	20.95	1,161	0.00	7.31	10		
	7.4	20.92	1,159	0.00	7.29	-137		
	--						3.45	1.05

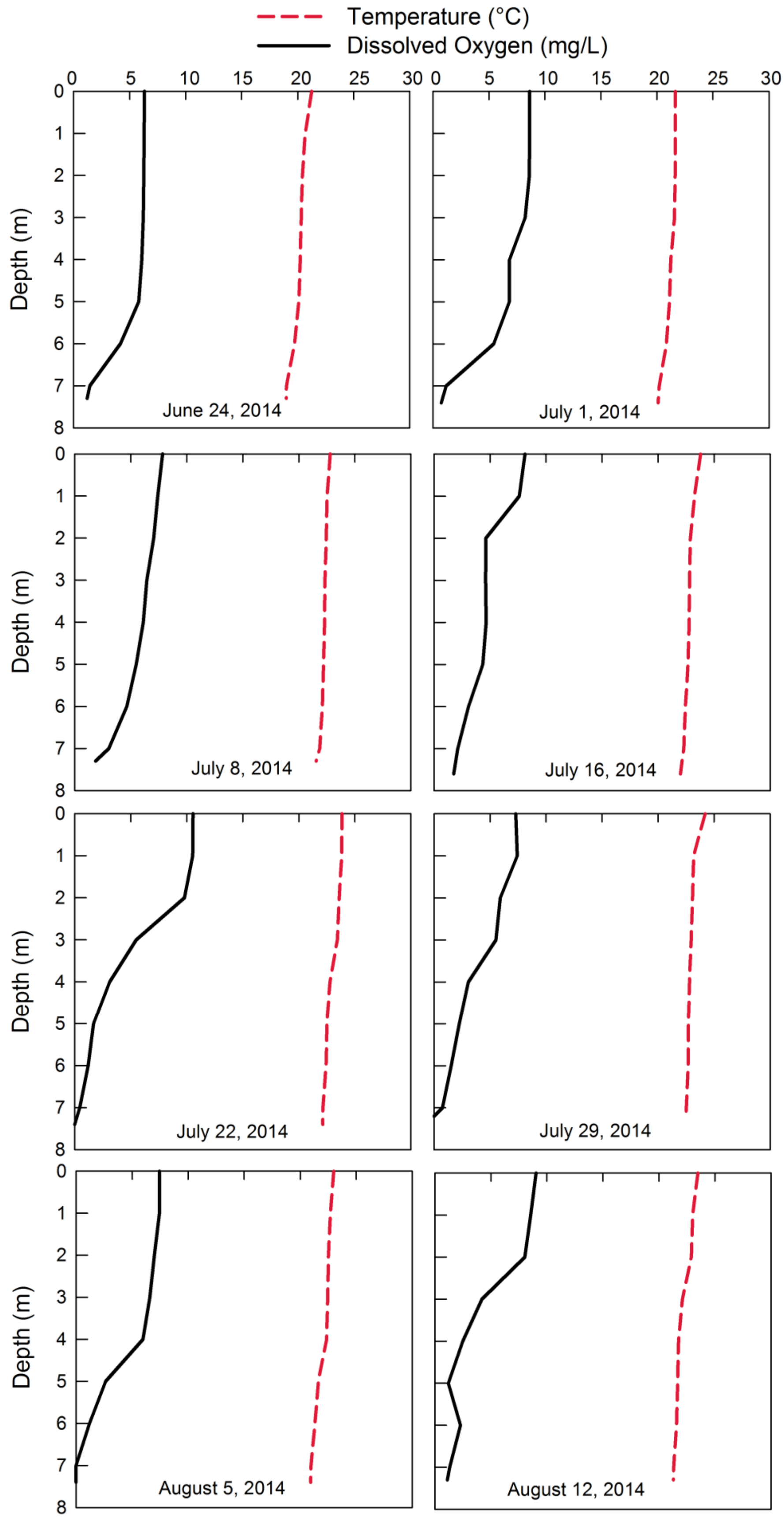
Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
8/12/2014	0	23.49	1,197	9.03	8.36	61		
	1	23.01	1,198	8.54	8.29	64		
	2	22.89	1,197	8.02	8.24	68		
	3	22.10	1,197	4.19	7.79	80		
	4	21.76	1,198	2.49	7.60	83		
	5	21.68	1,197	1.19	7.47	84		
	6	21.58	1,198	2.28	7.57	82		
	7	21.32	1,196	1.31	7.51	85		
	7.3	21.29	1,196	1.10	7.50	-21		
	--						--	1.15
8/19/2014	0	22.59	1,204	6.01	8.12	130		
	1	22.40	1,203	5.97	8.11	130		
	2	22.30	1,203	5.46	8.06	131		
	3	22.26	1,203	5.06	8.02	132		
	4	22.22	1,203	5.19	8.02	132		
	5	22.19	1,204	5.17	8.04	132		
	6	21.99	1,207	2.30	7.70	139		
	7	21.91	1,208	1.10	7.63	140		
	7.4	21.90	1,208	0.96	7.62	124		
	--						3.70	1.17
8/26/2014	0	22.11	1,210	6.08	7.99	221		
	1	22.08	1,210	6.06	7.97	220		
	2	22.06	1,210	5.98	7.96	220		
	3	22.01	1,210	5.79	7.97	220		
	4	22.00	1,210	5.72	7.97	220		
	5	22.00	1,210	5.67	7.93	220		
	6	21.98	1,210	5.30	7.91	221		
	7	21.63	1,216	0.61	7.49	229		
	7.3	21.57	1,217	0.58	7.46	229		
	--						--	1.50
9/02/2014	0	20.84	1,196	6.91	7.95	99		
	1	20.75	1,197	6.82	7.96	101		
	2	20.63	1,197	6.35	7.92	103		
	3	20.56	1,197	6.00	7.90	105		
	4	20.53	1,197	5.79	7.89	106		
	5	20.50	1,198	5.70	7.89	107		
	6	20.50	1,197	5.67	7.88	107		
	7	20.36	1,203	4.27	7.76	111		
	7.3	20.34	1,204	3.81	7.73	111		
	--						2.90	1.00
9/09/2014	0	21.56	1,198	8.03	8.25	77		
	1	20.91	1,196	8.17	8.24	81		
	2	20.65	1,197	7.75	8.20	84		
	3	20.53	1,197	7.40	8.19	86		
	4	20.42	1,197	6.56	8.12	90		
	5	20.27	1,201	5.39	7.97	94		
	6	20.03	1,201	2.91	7.76	98		
	7	19.95	1,202	1.99	7.70	99		
	7.3	19.97	1,201	1.72	7.69	84		
	--						--	0.98

Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
9/16/2014	0	19.22	1,209	9.00	8.31	259		
	1	18.52	1,206	9.07	8.29	258		
	2	18.31	1,207	8.68	8.26	258		
	3	18.24	1,207	7.98	8.23	259		
	4	18.09	1,207	7.53	8.18	259		
	5	17.75	1,209	5.49	8.06	262		
	6	17.38	1,212	4.22	7.87	263		
	7	17.26	1,213	3.54	7.81	264		
	7.5	17.26	1,213	3.42	7.80	260		
	--						--	0.94
9/23/2014	0	19.58	1,209	7.12	8.14	228		
	1	18.87	1,208	7.24	8.15	227		
	2	18.79	1,208	6.95	8.12	226		
	3	18.76	1,208	6.80	8.11	226		
	4	18.74	1,210	6.77	8.11	226		
	5	18.72	1,210	6.69	8.10	226		
	6	18.58	1,210	6.04	8.04	226		
	7	18.17	1,214	2.85	7.73	231		
	7.5	18.12	1,215	2.67	7.69	227		
	--						--	1.05

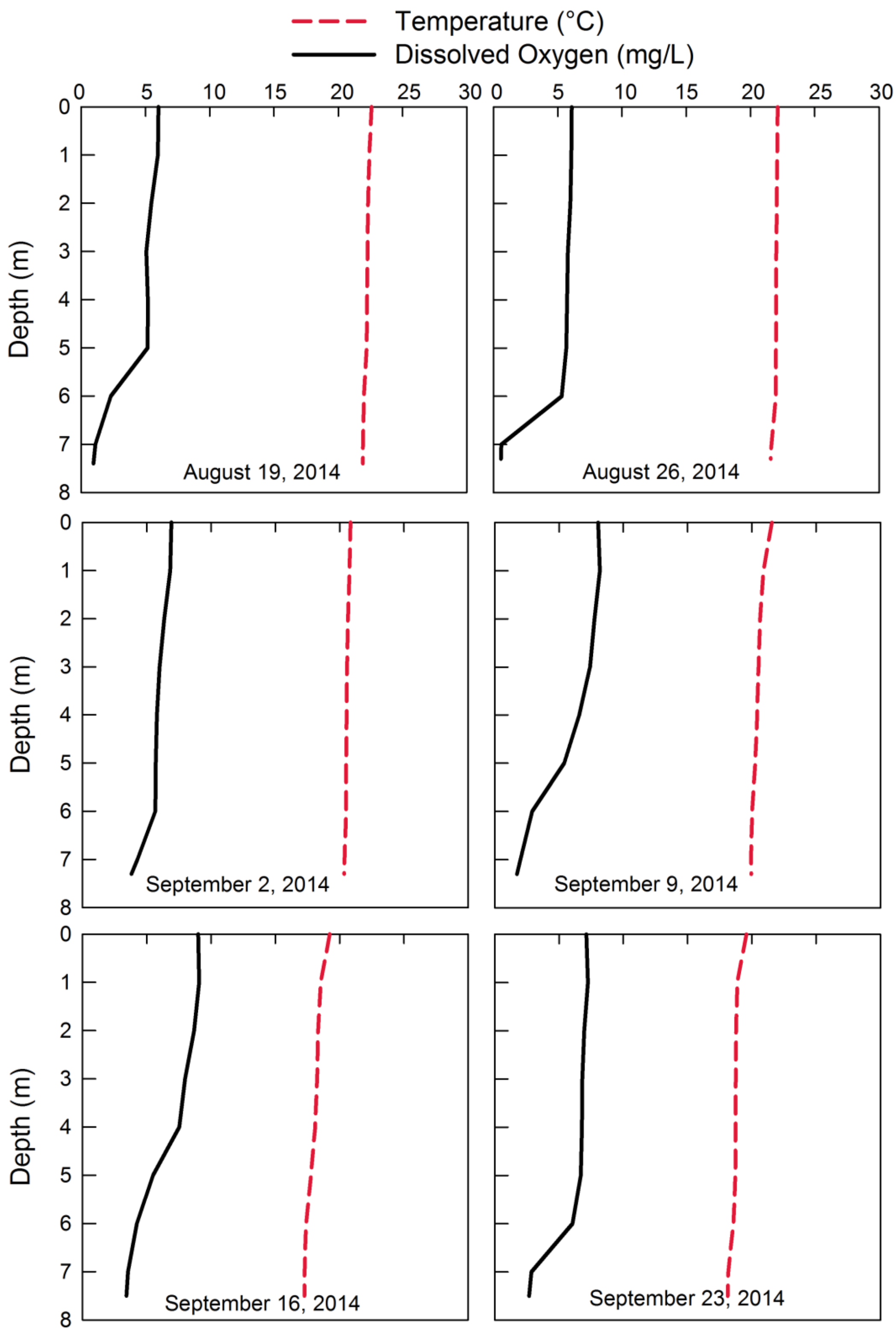
* Denotes data collected when Reservoir was ice-covered (approximately 0.20 m thick).


CCR-2
Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
October 15, 2013
November 18, 2013
February 11, 2014
March 12, 2014
April 15, 2014
May 13, 2014
May 27, 2014
June 10, 2014

CCR-2


Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0 5 10 15 20 25 30
June 24, 2014
July 1, 2014
July 8, 2014
July 16, 2014
July 22, 2014
July 29, 2014
August 5, 2014
August 12, 2014

CCR-2


Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
8
August 19, 2014
August 26, 2014
September 2, 2014
September 9, 2014
September 16, 2014
September 23, 2014

CCR-3 Small Tables

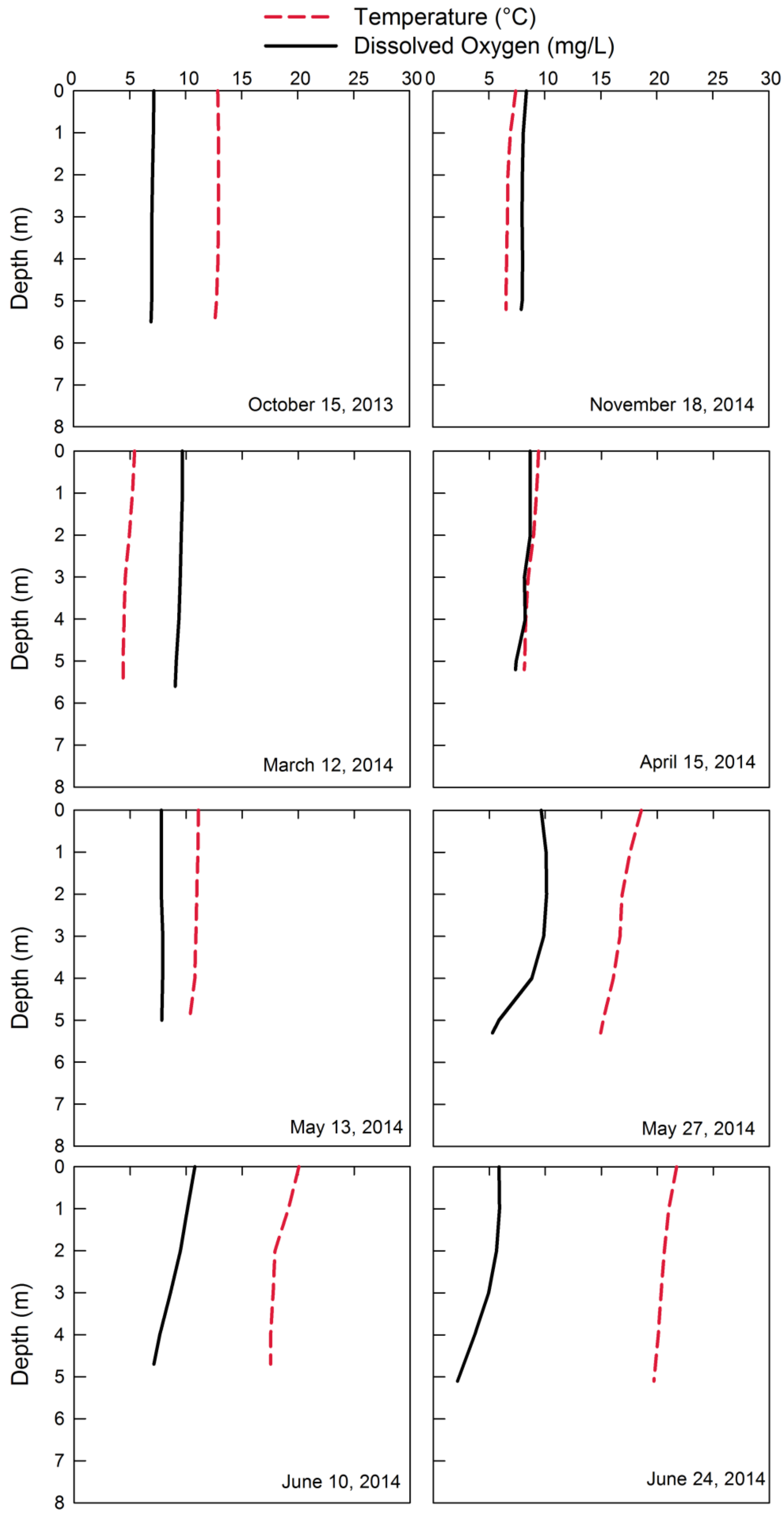
Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
10/15/2013	0	12.86	1,021	7.16	7.71	227		
	1	12.92	1,020	7.12	7.76	227		
	2	12.93	1,020	7.05	7.77	226		
	3	12.92	1,021	6.99	7.78	226		
	4	12.88	1,022	6.99	7.78	226		
	5	12.75	1,024	6.97	7.77	226		
	5.5	12.60	1,032	6.91	7.76	226		
	--						1.95	0.68
11/18/2013	0	7.39	1,053	8.35	8.03	178		
	1	6.91	1,053	8.07	7.99	179		
	2	6.69	1,055	7.99	7.97	180		
	3	6.65	1,054	7.96	7.97	180		
	4	6.56	1,054	8.00	7.97	179		
	5	6.52	1,055	7.97	7.98	179		
	5.2	6.53	1,053	7.89	7.97	179		
	--						3.50	1.20
3/12/2014	0	5.40	1,610	9.66	8.68	149		
	1	5.20	1,617	9.67	8.66	165		
	2	4.92	1,622	9.56	8.65	179		
	3	4.55	1,629	9.48	8.62	185		
	4	4.45	1,629	9.35	8.60	190		
	5	4.36	1,634	9.12	8.57	195		
	5.6	4.37	1,630	9.03	8.58	199		
	--						2.48	0.74
4/15/2014	0	7.86	1,164	10.90	7.91	202		
	1	6.43	1,145	11.13	7.92	203		
	2	6.03	1,145	10.51	7.88	205		
	3	5.75	1,145	10.33	7.85	206		
	4	5.41	1,152	9.26	7.79	208		
	4.8	5.40	1,151	9.06	7.78	209		
	--						3.45	0.97
5/13/2014	0	11.09	1,224	7.78	7.84	200		
	1	11.04	1,223	7.78	7.88	201		
	2	10.94	1,222	7.78	7.89	201		
	3	10.85	1,218	7.91	7.91	201		
	4	10.77	1,211	7.90	7.92	201		
	5	10.30	1,208	7.82	7.92	201		
	--						2.78	0.85
5/27/2014	0	18.57	1,242	9.63	8.16	119		
	1	17.57	1,236	10.07	8.20	118		
	2	16.86	1,233	10.12	8.23	118		
	3	16.68	1,233	9.87	8.21	118		
	4	16.07	1,232	8.78	8.11	121		
	5	15.17	1,235	5.85	7.88	127		
	5.3	14.94	1,234	5.27	7.81	126		
	--						4.55	1.35
6/10/2014	0	20.07	1,237	10.78	8.31	239		
	1	19.12	1,235	10.12	8.24	238		
	2	17.92	1,225	9.49	8.19	237		
	3	17.75	1,226	8.60	8.11	238		
	4	17.53	1,,221	7.64	8.02	238		
	4.7	17.54	1,222	7.12	8.03	230		
	--						3.05	1.15

Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
6/24/2014	0	21.72	1,249	5.86	8.37	223		
	1	21.04	1,246	5.90	8.36	223		
	2	20.63	1,247	5.63	8.33	224		
	3	20.35	1,247	4.93	8.27	226		
	4	20.09	1,250	3.69	8.18	229		
	5.1	19.70	1,251	2.15	8.01	233		
	--						4.93	2.50
6/26/2013	0	23.56	1,331	8.22	8.48	270		
	1	21.87	1,325	7.75	8.41	269		
	2	21.56	1,328	6.76	8.30	269		
	3	21.25	1,328	5.72	8.19	270		
	4	20.84	1,328	4.77	8.09	270		
	--						2.21	0.75
7/01/2014	0	21.64	1,249	9.13	8.58	226		
	1	21.65	1,249	9.18	8.56	226		
	2	21.64	1,250	8.54	8.56	227		
	3	21.39	1,251	8.21	8.48	228		
	4	21.16	1,253	6.74	8.40	230		
	5	20.95	1,256	6.12	8.35	230		
	--						--	1.30
7/08/2014	0	23.28	1,248	8.30	8.57	76		
	1	22.75	1,247	7.59	8.48	79		
	2	22.45	1,248	6.25	8.42	83		
	3	22.23	1,251	5.64	8.34	84		
	4	22.09	1,252	5.19	8.31	86		
	5	21.94	1,254	3.83	8.24	85		
	5.2	21.94	1,254	3.64	8.23	78		
	--						2.65	1.05
7/16/2014	0	24.48	1,231	8.63	8.46	148		
	1	23.83	1,228	9.26	8.50	147		
	2	23.22	1,227	7.83	8.39	150		
	3	23.04	1,227	6.93	8.31	152		
	4	22.93	1,218	6.86	8.28	152		
	4.7	22.32	1,152	5.62	8.13	156		
	--						--	1.30
7/22/2014	0	23.88	1,212	9.76	8.46	178		
	1	23.67	1,212	9.47	8.43	176		
	2	23.40	1,213	8.79	8.35	177		
	3	23.09	1,215	7.73	8.22	180		
	4	22.73	1,216	7.14	8.11	181		
	5.1	22.31	1,222	5.97	7.98	180		
	--						2.78	1.05
7/29/2014	0	24.24	1,219	7.69	8.39	119		
	1	23.40	1,215	7.06	8.28	122		
	2	22.85	1,218	5.82	8.16	125		
	3	22.71	1,220	5.03	8.06	128		
	4	22.42	1,226	3.93	7.96	132		
	5	22.17	1,234	2.80	7.78	137		
	5.2	22.16	1,236	2.69	7.80	130		
	--						--	1.20

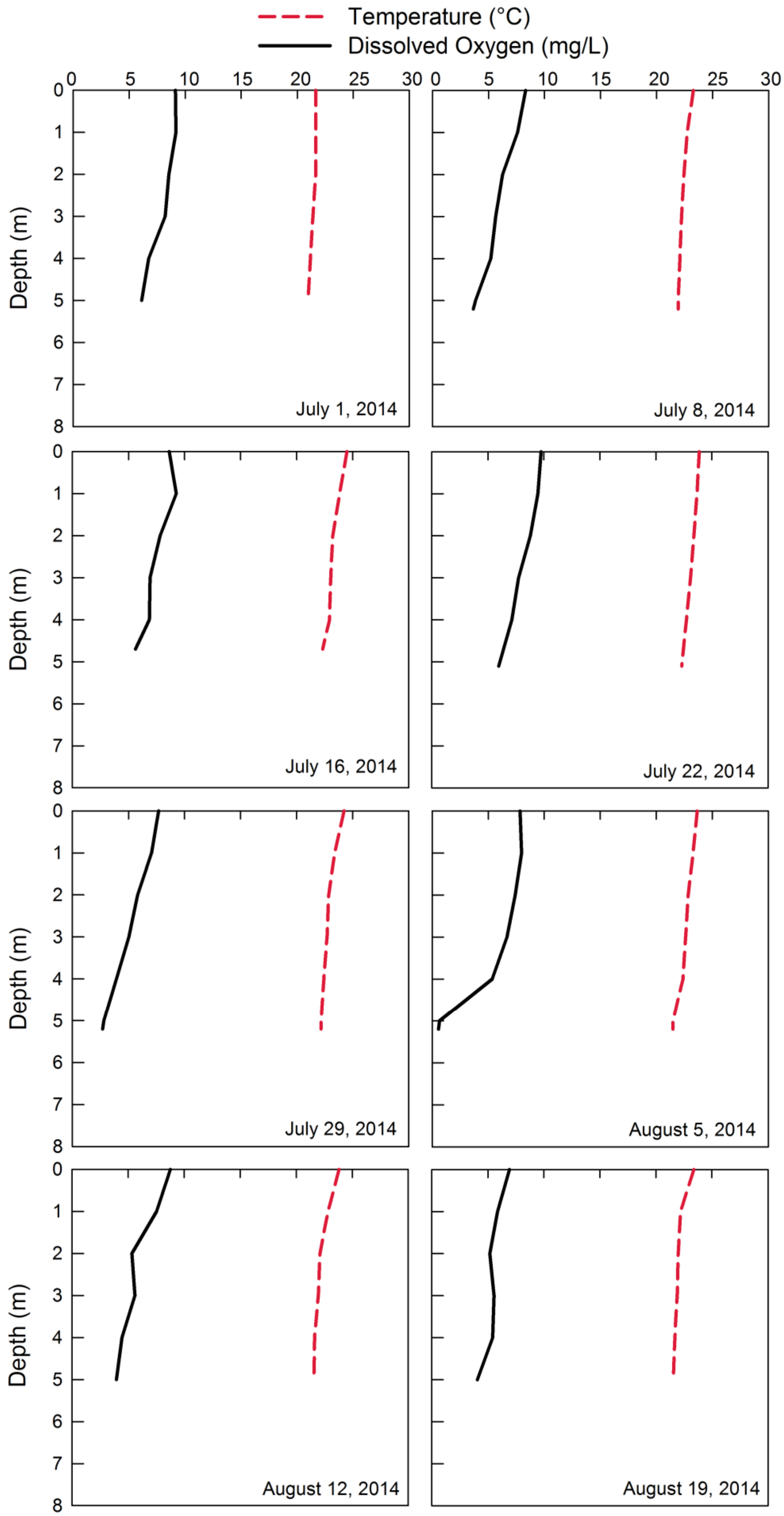
Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
8/05/2014	0	23.66	1,187	7.84	8.13	291		
	1	23.30	1,189	7.98	8.08	283		
	2	22.85	1,187	7.41	8.04	280		
	3	22.63	1,186	6.67	7.95	279		
	4	22.39	1,185	5.35	7.80	280		
	5	21.50	1,174	0.66	7.27	287		
	5.2	21.48	1,172	0.57	7.30	225		
	--						2.75	1.00
8/12/2014	0	23.81	1,201	8.77	8.33	81		
	1	22.83	1,197	7.54	8.19	82		
	2	22.10	1,197	5.34	7.94	91		
	3	21.95	1,197	5.61	7.97	91		
	4	21.62	1,196	4.45	7.81	95		
	5	21.57	1,197	3.95	7.77	96		
	--						--	1.06
8/19/2014	0	23.40	1,209	6.93	8.22	135		
	1	22.20	1,207	5.86	8.12	136		
	2	21.99	1,207	5.17	8.00	138		
	3	21.90	1,207	5.55	8.04	138		
	4	21.69	1,210	5.43	8.06	138		
	5	21.56	1,214	4.06	7.94	134		
	--						2.10	0.89
8/26/2014	0	22.13	1,213	4.88	7.85	215		
	1	22.09	1,212	4.54	7.76	215		
	2	21.83	1,212	3.92	7.72	216		
	3	21.74	1,213	4.35	7.76	214		
	4	21.61	1,212	4.69	7.81	214		
	4.9	21.54	1,211	4.51	7.80	214		
	--						--	1.00
9/02/2014	0	21.08	1,199	7.66	8.06	116		
	1	20.87	1,197	7.89	8.09	116		
	2	20.72	1,198	7.18	8.00	118		
	3	20.66	1,198	6.74	7.97	119		
	4	20.61	1,199	6.56	7.95	120		
	4.8	20.61	1,198	6.11	7.95	121		
	--						2.50	0.75
9/09/2014	0	21.73	1,197	7.92	8.24	93		
	1	20.66	1,195	8.55	8.26	94		
	2	20.35	1,196	8.14	8.17	99		
	3	20.26	1,196	6.60	8.09	102		
	4	20.21	1,198	6.28	8.07	104		
	5	20.06	1,199	4.45	7.89	110		
	5.1	20.05	1,198	4.08	7.85	24		
	--						--	0.90
9/16/2014	0	19.25	1,217	7.80	8.24	243		
	1	18.01	1,211	7.90	8.21	242		
	2	17.65	1,211	6.45	8.07	244		
	3	17.55	1,211	6.04	8.03	245		
	4	17.46	1,211	5.85	8.00	245		
	5	17.29	1,214	4.74	7.90	234		
	--						--	0.79

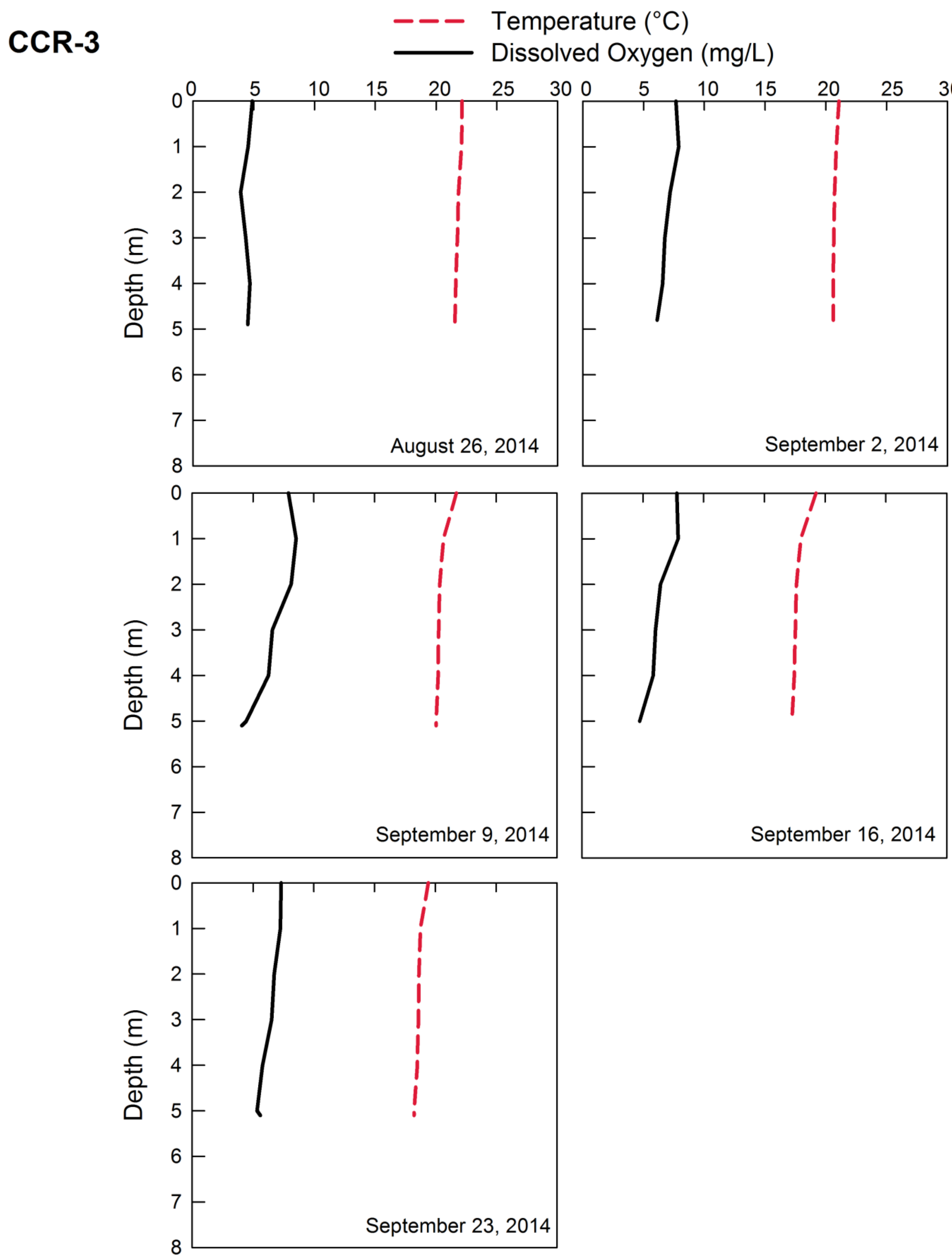
Sample Date	Depth (m)	Temperature (˚C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	1% Transmittance (m)	Secchi Disk (m)
9/23/2014	0	19.42	1,210	7.32	8.15	233		
	1	18.76	1,209	7.26	8.15	232		
	2	18.64	1,209	6.75	8.10	232		
	3	18.59	1,209	6.54	8.09	232		
	4	18.50	1,213	5.78	7.98	233		
	5	18.25	1,215	5.34	7.96	233		
	5.1	18.23	1,215	5.61	8.00	231		
	--						--	1.10

CCR-3


Temperature (°C)
Dissolved Oxygen (mg/L)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
October 15, 2013
November 18, 2014
March 12, 2014
April 15, 2014
May 13, 2014
May 27, 2014
June 10, 2014
June 24, 2014

CCR-3


Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8
July 1, 2014
July 8, 2014
July 16, 2014
July 22, 2014
July 29, 2014
August 5, 2014
August 12, 2014
August 19, 2014


CCR-3
Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
8
August 26, 2014
September 2, 2014
September 9, 2014
September 16, 2014
September 23, 2014

Cherry Creek Transect ORP Data

Sample Date	Depth (m)	Transect ORP (mV)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
6/24/2014	0	210	77	101	113	119	120	121	117	108	116	223
	1	210	80	102	114	120	121	122	118	111	117	223
	2	211	83	103	114	121	122	123	120	113	118	224
	3	211	85	104	115	122	124	125	122	114	119	226
	4	211	88	106	115	122	125	128	125	118	121	229
	5	212	93	109	117	125	128	131	129	124	127	233
	6	217	101	117	125	129	130	130	130	127	131	--
	7	213	103	122	131	137	132	130	122	97	--	--
	Bottom	-88	84	118	128	121	125	113	90	--	133	--

Sample Date	Depth (m)	Transect ORP (mV)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
7/22/2014	0	151	88	72	51	50	47	48	47	64	67	77
	1	152	92	75	59	54	53	52	53	65	74	79
	2	159	94	86	68	60	57	57	58	69	78	83
	3	161	106	91	71	64	60	62	63	76	82	87
	4	167	114	93	74	65	65	65	67	79	85	90
	5	169	115	95	73	67	67	68	68	82	86	96
	6	170	117	101	72	66	69	67	67	84	88	--
	7	169	119	-220	74	7	-139	-70	20	12	83	--
	Bottom	25	-138	-233	-227	-197	-227	-122	-12	--	--	88

Sample Date	Depth (m)	Transect ORP (mV)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
8/19/2014	0	137	95	88	99	101	91	106	90	65	149	135
	1	136	97	95	102	104	97	114	103	83	149	136
	2	142	102	98	107	108	100	116	107	88	149	138
	3	144	105	100	108	110	104	117	109	91	150	138
	4	143	106	101	109	111	106	118	111	94	155	138
	5	142	108	102	110	112	107	120	112	94	154	134
	6	142	111	106	112	114	108	121	113	95	155	--
	7	144	119	113	118	116	112	122	94	67	146	--
	Bottom	45	55	101	102	62	98	44	-27	--	--	--

Cherry Creek Transect Dissolved Oxygen Data

Sample Date	Depth (m)	Dissolved Oxygen (mg/L)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
6/24/2014	0	6.35	6.37	6.40	6.42	6.47	6.56	6.55	6.47	6.44	6.42	5.86
	1	6.30	6.36	6.41	6.45	6.44	6.56	6.54	6.47	6.44	6.36	5.90
	2	6.11	6.47	6.40	6.44	6.31	6.48	6.44	6.33	6.30	6.22	5.63
	3	6.15	6.42	6.59	6.56	6.14	5.61	5.91	5.73	6.10	6.14	4.93
	4	6.14	6.07	6.11	6.42	5.92	5.18	5.02	4.61	5.39	5.77	3.69
	5	5.66	4.87	5.46	5.83	5.17	3.93	3.86	3.36	3.25	3.68	2.15
	6	3.49	2.62	2.33	2.86	3.62	3.73	4.32	3.06	2.64	2.38	--
	7	1.36	1.25	0.43	0.33	0.00	0.52	0.53	0.76	0.00	--	--
	Bottom	0.87	0.50	0.39	0.28	0.00	0.00	0.39	0.70	--	1.01	--

Sample Date	Depth (m)	Dissolved Oxygen (mg/L)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
7/22/2014	0	9.60	9.66	10.80	10.46	10.81	10.86	10.59	10.96	10.42	10.37	10.76
	1	9.80	9.60	10.64	9.80	10.33	9.39	10.76	10.09	11.24	11.20	10.95
	2	7.16	9.65	8.35	7.79	8.24	9.02	9.31	9.48	10.46	9.96	9.58
	3	5.75	7.65	4.87	6.66	6.37	7.84	8.12	7.57	7.86	8.64	8.50
	4	2.40	2.31	4.03	3.88	6.21	6.05	6.35	5.13	7.49	7.61	7.79
	5	1.02	1.46	3.64	1.72	3.37	3.21	3.30	1.93	5.87	7.21	5.39
	6	0.04	0.66	0.17	1.16	1.45	0.20	1.86	0.72	2.97	6.60	--
	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	1.09	4.03	--
	Bottom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	--	--	5.18

Sample Date	Depth (m)	Dissolved Oxygen (mg/L)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
8/19/2014	0	7.74	7.82	7.79	7.91	8.47	9.23	9.84	10.86	10.77	8.12	6.93
	1	7.89	7.67	6.41	6.98	7.66	7.41	6.59	7.50	8.52	8.09	5.86
	2	5.26	5.70	5.15	5.62	5.71	6.24	5.89	5.94	6.11	8.04	5.17
	3	4.43	4.95	5.17	5.19	5.36	5.35	5.46	5.44	5.13	7.44	5.55
	4	5.07	5.16	4.96	5.15	5.06	4.99	5.19	4.79	4.48	4.99	5.43
	5	5.17	4.87	4.80	4.75	4.90	4.82	4.77	4.70	4.63	4.91	4.06
	6	5.15	3.90	3.70	4.47	4.29	4.37	4.14	4.66	4.88	4.67	--
	7	3.42	1.29	0.00	1.67	3.51	3.65	3.66	4.10	4.21	3.69	--
	Bottom	1.56	0.00	0.00	0.00	2.26	3.49	3.61	4.10	--	--	--

Appendix C

2014 WY Stream Water Quality and Precipitation Data

GEI Water Chemistry Data									
Analytical Detection Limits	2	2	2	6	6	2	5	4	4
Site/Sample Date	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Ortho-phosphate (µg/L)	Total Nitrogen (µg/L)	Total Dissolved Nitrogen (µg/L)	Nitrate+ Nitrite (µg/L)	Ammonia (µg/L)	Total Suspended Solids (mg/L)	Total Volatile Suspended Solids (mg/L)
CC-10									
10/16/2013	189	189	199	759	728	395	27	9.8	--
11/12/2013	173	138	164	710	660	376	62	6.0	--
12/11/2013	179	144	136	1,189	1,197	755	77	12.2	--
1/22/2014	223	123	160	1,238	1,177	856	37	67.0	10.0
2/18/2014	165	117	138	1,417	1,183	855	34	11	--
3/13/2014	152	105	112	1,056	921	631	38	10.8	--
4/17/2014	173	125	116	836	761	472	43	9.1	--
5/20/2014	250	209	207	864	778	453	57	11.6	--
6/16/2014	271	155	232	945	938	383	59	20	4.4
7/7/2014	205	174	206	907	798	351	9	--	--
8/4/2014	271	226	233	737	704	408	62	8.8	--
9/3/2014	213	183	188	780	773	394	54	5.6	--
CC-10 Storm									
4/4/2014	237	84	113	1,289	1,193	685	108	86	9.5
4/24/2014	456	151	158	1,237	1,199	589	121	166	16.5
5/8/2014	328	175	165	1,117	894	407	57	81.7	7.7
7/15/2014	525	204	205	985	836	305	137	208.5	35
7/31/2014	324	231	223	1,011	907	375	74	62.1	8.4
9/22/2014	258	150	177	785	652	385	34	28.6	--
CC-Out @ I225									
10/16/2013	140	48	67	1,032	540	4	54	19.6	6.6
11/12/2013	93	34	36	906	481	11	75	11.8	--
12/11/2013	108	61	42	905	650	38	54	5.4	--
1/22/2014	80	32	31	891	531	4	--	8.0	6.7
2/18/2014	70	21	15	944	552	--	--	11.7	7.0
3/13/2014	67	17	8	837	457	--	18	10.7	7.0
4/17/2014	94	16	15	909	502	--	32	15.2	6.4
5/20/2014	97	31	17	963	556	5	20	14.8	7.4
6/16/2014	105	31	67	1,241	889	21	175	24.8	9.8
7/8/2014	284	161	202	1,244	1,026	126	124	10.2	4.0
8/5/2014	154	101	93	869	539	4	54	13.1	4.3
9/2/2014	98	31	24	872	472	5	89	21.8	5.8

GEI Water Chemistry Data									
Analytical Detection Limits	2	2	2	6	6	2	5	4	4
Site/Sample Date	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Ortho-phosphate (µg/L)	Total Nitrogen (µg/L)	Total Dissolved Nitrogen (µg/L)	Nitrate+ Nitrite (µg/L)	Ammonia (µg/L)	Total Suspended Solids (mg/L)	Total Volatile Suspended Solids (mg/L)
CT-1									
10/16/2013	56	19	46	1,629	1,560	1,035	33	19.8	--
11/12/2013	56	12	20	2,441	2,276	1,651	122	24.6	--
12/11/2013	91	40	24	3,750	3,765	2,721	214	29.8	5.6
1/22/2014	74	27	33	3,369	3,306	2,355	290	22.8	5.6
2/18/2014	84	76	16	1,569	1,338	682	103	33.7	5.3
3/13/2014	68	19	18	1,202	1,072	657	45	21.6	4.6
4/17/2014	62	32	25	1,291	1,102	670	49	9.3	--
5/20/2014	61	26	17	1,182	1,141	400	219	14.2	4.2
6/16/2014	40	20	20	1,076	972	248	60	22.0	6.2
7/7/2014	95	21	13	1,244	1,064	204	112	54.0	7.5
8/4/2014	74	12	19	1,430	1,185	661	81	31.4	4.8
9/3/2014	69	25	10	1,395	1,233	723	96	31.0	--
CT-1 Storm									
4/4/2014	151	10	4	3,467	3,163	2,321	180	55.5	10
4/24/2014	220	27	20	2,673	2,325	1,279	321	63.5	14.0
5/8/2014	137	29	22	2,123	1,925	1,162	155	58.7	7.3
7/15/2014	252	149	105	1,326	1,097	559	136	59.3	9.3
7/31/2014	128	55	41	1,064	848	357	58	26.9	6.0
9/5/2014	478	21	15	2,670	1,885	992	118	444.0	32.0
9/22/2014	174	50	47	1,181	979	485	69	48.7	7.0
CT-2									
10/16/2013	38	6	23	1,399	1,290	764	53	15.2	--
11/12/2013	43	11	18	2,198	2,026	1,422	112	16.0	--
12/11/2013	66	33	14	4,368	4,227	3,324	275	19.8	4.2
1/22/2014	60	17	26	2,429	2,079	1,332	202	21.4	--
2/18/2014	88	8	8	1,515	1,292	597	131	43.7	6.3
3/13/2014	48	11	9	1,138	954	484	57	15.2	--
4/17/2014	114	--	8	1,279	1,027	507	103	39.4	6.2

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**6**	**6**	**2**	**5**	**4**	**4**
Site/Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
5/20/2014	41	11	4	1,097	815	184	189	12.4	4.0
6/16/2014	22	12	6	886	760	115	39	11.0	4.4
7/7/2014	48	9	16	968	833	25	58	6.8	--
8/4/2014	47	7	15	1,039	948	367	249	12.1	--
9/3/2014	45	27	5	959	790	270	31	12.4	--
CT-2 Storm									
4/4/2014	84	13	5	3,728	3,417	2,440	137	21.0	5.5
4/24/2014	97	9	6	1,543	1,410	610	175	23.3	6.3
5/8/2014	67	16	8	1,936	1,623	868	107	14.2	--
7/15/2014	133	33	20	1,131	1,066	340	113	40.8	7.5
7/31/2014	163	58	53	1,182	814	394	87	21.2	5.2
9/5/2014	76	9	8.0	1,664	1,323	763	29	44.0	7.0
9/22/2014	158	40	38	1,653	1,191	737	40	33.3	5.0
CT-P1									
10/16/2013	18	--	28	977	913	409	36	7.4	--
11/12/2013	14	4	18	773	771	354	65	4.0	--
12/11/2013	27	14	9	1,649	1,517	889	99	9.6	--
1/22/2014	20	10	28	1,302	1,191	776	44	5.3	--
2/18/2014	38	10	13	1,203	1,079	547	55	10.6	--
3/13/2014	45	11	10	1,093	930	475	71	9.6	--
4/17/2014	34	6	14	802	659	223	39	7.3	--
5/20/2014	27	21	8	809	786	219	78	5.1	--
6/16/2014	38	15	13	1,064	1,022	276	67	15.0	6.0
7/7/2014	49	6	15	1,044	926	247	75	24.2	5.3
8/4/2014	68	28	32	931	783	375	75	16.3	--
9/3/2014	49	25	23	899	753	355	64	9.5	--
CT-P1 Storm									
4/4/2014	286	20	22	2,042	1,666	669	435	110.0	15.5
4/24/2014	654	28	32	1,740	1,452	487	494	207.0	41.0
5/8/2014	240	48	43	1,691	1,410	433	402	124.0	20.0

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**6**	**6**	**2**	**5**	**4**	**4**
Site/Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
7/15/2014	660	43	38	1,631	1,191	431	282	462.0	61.1
7/31/2014	161	60	58	903	549	248	44	31.2	5.8
9/5/2014	227	32	33	1,384	1,017	538	128	122.7	18.7
9/22/2014	188	61	59	1,232	802	472	81	67.0	12.0
CT-P2									
10/16/2013	26	5	28	1,274	1,182	662	34	10.6	--
11/12/2013	32	7	21	1,127	1,124	663	95	15.2	--
12/11/2013	34	17	10	2,466	2,167	1329	194	10.6	--
1/22/2014	15	10	27	1,421	1,429	1011	35	5.4	--
2/18/2014	38	9	10	1,412	1,203	714	118	10.2	--
3/13/2014	37	11	23	1,090	978	562	48	8.2	4.0
4/17/2014	54	5	14	980	742	323	55	14.4	4.0
5/20/2014	43	29	13	1,189	980	430	130	10.8	--
6/16/2014	34	18	18	1,300	1,142	444	117	18.8	6.0
7/7/2014	50	21	17	1,245	1,176	425	126	17.0	--
8/4/2014	68	25	33	1,171	1,021	625	107	20.1	4.3
9/3/2014	117	23	21	1,189	1,007	510	115	52.1	7.8
CT-P2 Storm									
4/4/2014	160	23	25	1,826	1,550	615	306	44.0	9.5
4/24/2014	371	48	50	1,823	1,575	506	481	92.0	22.0
5/8/2014	189	62	54	1,683	1,505	527	345	71.0	14.0
7/15/2014	396	48	43	1,368	1,003	451	195	220.0	36.0
7/31/2014	125	64	61	806	677	274	47	19.4	5.4
9/5/2014	150	31	28	1,555	1,117	619	60	57.7	9.3
9/22/2014	202	64	59	1,223	906	544	58	47.5	10.5

GEI Water Chemistry Data									
Analytical Detection Limits	2	2	2	6	6	2	5	4	4
Site/Sample Date	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Ortho-phosphate (µg/L)	Total Nitrogen (µg/L)	Total Dissolved Nitrogen (µg/L)	Nitrate+ Nitrite (µg/L)	Ammonia (µg/L)	Total Suspended Solids (mg/L)	Total Volatile Suspended Solids (mg/L)
EcoPark									
10/16/2013	87	39	66	1,727	1,482	930	8	7.6	--
11/12/2013	106	56	69	2,016	2,004	1,338	64	8.4	--
12/11/2013	199	95	89	2,910	2,765	2,188	156	33.8	5.6
1/22/2014	126	70	96	2,906	2,901	2,494	35	15.2	4.5
2/18/2014	95	54	63	2,636	2,483	2,013	34	8.2	--
3/13/2014	85	43	44	1,592	1,491	1,180	23	7.8	--
4/17/2014	89	52	49	1,951	1,935	1,450	43	6.1	--
5/20/2014	154	117	107	1,325	1,243	797	56	--	--
6/16/2014	287	63	88	603	592	231	20	12.0	5.4
7/7/2014	118	114	106	386	355	6	5	5.9	--
8/4/2014	219	113	120	1,285	1,289	903	54	47.0	8.6
9/3/2014	133	88	86	1,364	1,386	835	54	15.1	--
EcoPark Storm									
4/4/2014	141	35	40	2,088	2,064	1,507	97	35.0	8.5
4/24/2014	545	109	112	2,145	2,108	1,499	151	155.0	29.0
5/8/2014	399	120	114	2,212	1,932	1,409	197	155.0	15.0
7/15/2014	1676	151	156	2,615	1,009	309	109	1,360.0	175.0
7/31/2014	566	142	139	1,482	869	437	183	311.0	41.0
9/22/2014	128	48	66	1,712	1,447	1,047	85	14.6	--

-- Denotes result less than MDL.

Appendix D

2014 WY Streamflow, Rainfall, Phosphorous Loading Calculations and Final Inflow and Load Data Normalized to the U.S. Army Corps of Engineers Inflow Data

D.1 Streamflow Determination

Water levels (stage) were monitored on 15-minute intervals using ISCO Model 6700 and 6712 flowmeters, with each unit being calibrated on a monthly basis using in situ staff gage measurements. Stage-discharge data were collected for sites CC-10, CT-P1, and CT-1 by measuring stream discharge (ft^3/sec) with a Marsh McBirney Model 2000 flowmeter, and recording the water level at the staff gage and ISCO flowmeter (Table D-1).

Stage-discharge data collected in the 2014 WY were combined with data collected during previous years to develop rating curves for each site, as long as historical data reflected no major changes to the streambed morphology, transducer, or staff gage. For example, if the transducer or staff gage was relocated or reset, then only the data collected post-change would be used to develop the rating curve.

Rating curves were developed for sites CC-10, CT-P1, and CT-1 by fitting a nonlinear regression model to the data (Table D-2). For all sites a two-stage rating curve was developed to more accurately estimate low or high flows at these sites. A multi-level weir equation is used to estimate flows at Site CT-P2 and Site CT-2 located in the outlet structure of each pond. The weir equations for sites CT-P2 (Table D-2) were provided by Muller Engineering (unpublished data, 2004). In 2012, the outlet weir structure and overflow at Site CT-2 was slightly modified which resulted in extremely high discharge values compared to previous years. In April 2014, the CT-2 weir and outlet structure were surveyed and at that time it was observed that the control gate on the outlet pipe was partially closed, restricting the flow of water during high flow events. The control gate was fully opened in April. Following the survey, two sets of weir equations were developed; a set with partial closure of the control gate, the other set with unobstructed flow. The appropriate set of weir equations was applied to either the obstructed flow period or unobstructed flow period.

While water levels for Cherry Creek and Cottonwood Creek are monitored on a continuous basis, there were periods of time when daily mean flows were estimated due to a dead battery, pressure transducer malfunction, ice, or flooding (Table D-3). To estimate mean daily water levels for periods of missing data, stage relationships were evaluated among nearby sites, with the best-fit linear regression model being used to estimate the missing level data.

Table D-1: Stage-discharge data used to develop rating curves for sites CC-10, CT-P1, CT-P2, and CT-1 in 2014.

Site	Year	Date	Staff Gage Level (ft)	Transducer Level (ft)	Discharge (cfs)
CC-10	2004	27-May-04	1.09	1.463	3.10
CC-10	2004	22-Jun-04	2.50	2.493	24.45
CC-10	2004	23-Jun-04	1.54	1.530	8.65
CC-10	2004	24-Aug-04	2.47	2.472	23.93
CC-10	2005	01-Apr-05	2.39	2.531	20.11
CC-10	2005	14-Apr-05	4.84	4.890	142.89
CC-10	2005	25-Apr-05	4.05	4.093	91.76
CC-10	2005	02-May-05	2.63	2.630	40.14
CC-10	2005	19-May-05	1.68	1.612	14.27
CC-10	2005	26-May-05	1.40	1.422	8.79
CC-10	2005	01-Jun-05	1.47	1.469	17.86
CC-10	2005	16-Aug-05	0.81	0.808	3.60
CC-10	2005	13-Oct-05	2.41	2.418	29.81
CC-10	2006	20-Apr-06	1.40	1.391	10.92
CC-10	2006	13-Jun-06	0.56	0.567	2.05
CC-10	2006	12-Jul-06	1.56	1.482	23.62
CC-10	2006	08-Aug-06	0.55	0.550	5.18
CC-10	2006	27-Dec-06	1.27	1.230	20.51
CC-10	2007	13-Mar-07	4.27	4.317	93.87
CC-10	2007	10-May-07	3.10	3.100	62.15
CC-10	2007	26-Jul-07	0.61	0.621	1.63
CC-10	2007	9-Aug-07	1.32	1.306	11.11
CC-10	2007	13-Nov-07	1.70	1.692	6.27
CC-10	2008	19-Feb-08	2.50	2.470	31.14
CC-10	2008	27-Mar-08	1.98	1.980	25.65
CC-10	2008	26-Jun-08	0.64	0.617	2.79
CC-10	2008	15-Aug-08	0.87	0.864	5.92
CC-10	2008	11-Dec-08	1.36	1.387	21.28
CC-10	2009	22-Jan-09	1.27	--	21.53
CC-10	2009	24-Mar-09	1.18	1.126	17.98
CC-10	2009	23-Jun-09	1.80	1.767	19.25
CC-10	2009	08-Dec-09	1.79	1.802	11.11
CC-10	2009	18-Aug-09	2.48	2.470	38.79
CC-10	2009	20-Nov-09	2.12	2.081	27.89
CC-10	2010	26-Jan-10	1.76	1.733	21.03
CC-10	2010	15-Apr-10	2.15	2.136	28.03
CC-10	2010	29-Jun-10	0.91	0.889	6.10
CC-10	2010	10-Aug-10	1.58	1.566	21.51
CC-10	2010	8-Sep-10	0.42	0.468	1.77

Site	Year	Date	Staff Gage Level (ft)	Transducer Level (ft)	Discharge (cfs)
CC-10	2011	1-Mar-11	1.76	1.767	21.17
CC-10	2011	31-Mar-11	1.52	1.656	22.81
CC-10	2011	27-Apr-11	1.48	1.414	18.63
CC-10	2011	11-May-11	2.35	2.485	29.56
CC-10	2011	4-Aug-11	1.15	1.153	5.36
CC-10	2011	27-Sep-11	0.78	0.662	1.88
CC-10	2012	6-Jan-12	1.35	1.344	12.05
CC-10	2012	24-Jan-12	1.60	1.542	18.59
CC-10	2012	8-Mar-12	1.58	1.584	12.82
CC-10	2012	18-Apr-12	2.02	2.016	20.40
CC-10	2012	24-May-12	2.31	2.320	24.74
CC-10	2012	16-Jun-12	1.74	1.650	8.29
CC-10	2012	1-Jul-12	0.98	0.973	2.24
CC-10	2012	17-Aug-12	0.40	0.424	1.20
CC-10	2013	2-Mar-13	1.17	1.168	11.81
CC-10	2013	26-Mar-13	2.04	2.069	29.63
CC-10	2013	28-Apr-13	1.60	1.613	17.61
CC-10	2013	25-May-13	1.44	1.440	11.29
CC-10	2013	11-Aug-13	1.15	1.130	4.61
CC-10	2013	13-Sep-13	1.90	1.900	25.87
CC-10	2014	24-Apr-14	2.40	2.411	35.88
CC-10	2014	5-Jun-14	1.90	1.900	16.66
CC-10	2014	9-Jun-14	3.89	3.892	89.59
CC-10	2014	15-Jul-14	3.28	3.249	80.69
SC-3	2009	24-Mar-09	0.18	0.021	0.13
SC-3	2009	26-May-09	1.04	1.014	6.29
SC-3	2009	18-Aug-09	0.75	0.684	1.29
SC-3	2009	20-Nov-09	0.30	0.376	0.11
SC-3	2010	29-Jun-10	0.26	0.237	0.08
SC-3	2010	10-Aug-10	0.35	0.349	0.75
SC-3	2011	04/27/2011	0.29	0.316	0.14
SC-3	2011	05/11/2011	1.10	1.000	5.28
SC-3	2012	16-Apr-12	0.40	0.202	0.16
SC-3	2012	24-May-12	0.59	0.690	2.61
SC-3	2012	14-Jun-12	0.10	0.153	0.01
CT-P1	2009	26-May-09	2.29	2.286	21.80
CT-P1	2009	23-Jun-09	1.42	1.401	1.27
CT-P1	2009	12-Aug-09	1.38	1.375	0.82
CT-P1	2009	18-Aug-09	2.00	1.916	12.43
CT-P1	2009	20-Nov-09	1.64	1.634	1.79
CT-P1	2010	26-Jan-10	1.50	1.497	0.78

Site	Year	Date	Staff Gage Level (ft)	Transducer Level (ft)	Discharge (cfs)
CT-P1	2010	20-Apr-10	1.51	1.511	1.15
CT-P1	2010	29-Jun-10	1.57	1.582	1.79
CT-P1	2010	10-Aug-10	1.72	1.704	3.29
CT-P1	2010	8-Sep-10	1.48	1.446	0.57
CT-P1	2011	1-Mar-11	1.46	1.463	0.57
CT-P1	2011	31-Mar-11	1.50	1.483	0.84
CT-P1	2011	27-Apr-11	1.65	1.639	2.97
CT-P1	2011	11-May-11	2.45	2.423	31.15
CT-P1	2011	26-May-11	1.64	1.632	2.23
CT-P1	2011	20-Jun-11	3.00	3.360	64.62
CT-P1	2011	4-Aug-11	1.50	1.502	0.62
CT-P1	2011	27-Sep-11	1.50	1.542	0.61
CT-P1	2012	6-Jan-12	1.59	1.590	0.95
CT-P1	2012	24-Jan-12	1.50	1.540	0.71
CT-P1	2012	6-Mar-12	1.60	1.607	0.56
CT-P1	2012	16-Apr-12	1.68	1.722	2.77
CT-P1	2012	24-May-12	2.06	2.042	12.55
CT-P1	2012	14-Jun-12	1.37	1.374	0.94
CT-P1	2012	29-Jun-12	1.36	1.364	0.94
CT-P1	2012	15-Aug-12	1.32	1.275	0.55
CT-P1	2013	24-Jan-13	1.40	1.366	0.51
CT-P1	2013	28-Feb-13	1.47	1.525	1.28
CT-P1	2013	27-Mar-13	1.62	1.615	4.85
CT-P1	2013	26-Apr-13	1.45	1.492	1.06
CT-P1	2013	23-May-13	1.45	1.473	1.34
CT-P1	2013	24-Jun-13	1.54	1.550	2.26
CT-P1	2013	9-Aug-13	2.00	1.959	12.72
CT-P1	2013	11-Sept-13	2.40	2.382	27.81
CT-P1	2014	22-Jan-14	1.41	1.413	1.24
CT-P1	2014	24-Apr-14	2.05	2.054	7.74
CT-P1	2014	9-Jun-14	1.87	1.871	6.37
CT-P1	2014	15-Jul-14	2.42	2.415	31.20
CT-1	2011	20-Jun-11	1.80	2.237	119.77
CT-1	2012	14-Jun-12	1.06	--	1.85
CT-1	2012	29-Jun-12	0.88	0.793	1.14
CT-1	2012	15-Aug-12	0.91	0.897	1.66
CT-1	2013	24-Jan-13	0.89	0.973	4.36
CT-1	2013	28-Feb-13	0.95	0.953	4.87
CT-1	2013	27-Mar-13	1.04	1.070	9.80
CT-1	2013	26-Apr-13	0.95	0.968	5.62
CT-1	2013	23-May-13	0.88	0.825	2.11

Site	Year	Date	Staff Gage Level (ft)	Transducer Level (ft)	Discharge (cfs)
CT-1	2013	24-Jun-13	0.96	0.955	5.64
CT-1	2013	9-Aug-13	1.30	1.257	11.79
CT-1	2013	11-Sept-13	1.68	1.645	49.03
CT-1	2014	24-Apr-14	1.28	1.308	22.57
CT-1	2014	9-Jun-14	1.10	1.124	19.50

Table D-2: Discharge (Q, cfs) and stage height (H, ft) relationships for all sites. Rating curves are developed for sites EcoPark, CC-10, CT-P1, and CT-1, while multi-level orifice and weir equations are used for sites CT-P2, and CT-2.

Site	Stage Interval	Discharge Equations	R^2
EcoPark	≤ 0.78	Q = 3.33*(H^(1.5))*(6-0.2*H)	
	> 0.78	Q = 3.33*(H-0.78)^(1.5)*(6+(H-0.78)*(13.06)*(2)) + 13.406	
CC-10	< 0.98	Q = EXP((H+0.2264)/0.7505)	0.77
	> 0.98	Q = EXP((H+8.8933)/2.6402)-36.9889	0.90
CT-P1	<1.49	Q = EXP(H-1.4896)/0.2551	0.87
	>1.49	Q = EXP(H)-4.1860/0.2537	0.96
CT-P2	< 0.60	Q = (3.3)*(1)*(H)^(1.5)	
	0.61 - 1.09	Q = (0.60)*(0.50)*((2*32.2*(H_{adj}))^(0.5)	
	1.10 - 1.99	Q = (0.60)*(0.50)*((2*32.2*(H_{adj}))^(0.5))+((3.33)*(1)*(H-1.0)^(1.5)	
	2.00 - 2.59	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((3.33) *(1)*(H-2.0)^(1.5)	
	2.60 - 2.99	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5)	
	3.00 - 3.59	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((3.3)*(1)*(H-3.0)^(1.5)	
	3.60 - 3.99	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((0.60)*(0.50)*(2*32.2*(H_{adj}-3.0)^(0.5)	
	4.00 - 4.49	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((0.60)*(0.50)*(2*32.2*(H_{adj}-3.0)^(0.5))+((3.3)(1)(H-4.0))^ (1.5)	
	4.50 - 5.19	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((0.60)*(0.50)*(2*32.2*(H_{adj}-3.0)^(0.5))+((0.60)(0.50)(2* 32.2*H_{adj}-4.0))^(0.5)	
	5.20 - 6.80	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((0.60)*(0.50)*(2*32.2*(H_{adj}-3.0)^(0.5))+((0.60)(0.50)(2* 32.2*H_{adj}-4.0))^(0.5))+((3.3)(1)(H-5.2)^(1.5)	
CT-1	<0.93	Q = EXP((H-0.6311)/0.2655)	0.73
	>0.93	Q = EXP((H+7.8925)/1.9121)-98.2899	0.96
CT-2[a]	0.50 – 1.09	Q = 4.2198*(H^3) + 15.437*(H^2) – 8.9773*(H)	
	1.10 – 2.59	Q = 7.5895*(H^2) – 7.7255*(H) + 13.727	
	2.60 – 3.69	Q = 0.8954*(H^3) – 8.9145*(H^2) + 32.481*(H) + 4.8161	
	≥3.70	Q = 2642.5*(H^2) – 18781*(H) + 33360	

H_{adj} = Mean daily level - 0.25 ft
[a] = CT-2 without blockage

Table D-3: Equations used to estimate missing daily mean data and percent of annual data estimated.

Site	Equations	R^2	Percent of Annual Data Estimated
CC-10, Mar - June	CC-10 Level = 0.7288*(EcoPark Level) + 0.9903	0.42	17%
CC-10, Oct	CC-10 Level = 1.9218*(EcoPark Level) + 0.2443	0.77	4%
CT-P1	CT-P1 Level = 0.2036*(CT-P2 Level) + 1.3461	0.97	5%
CT-P2	CT-P2 Level = 1.6377*(CT-2 Level) – 0.5564	0.27	3%
CT-1	CT-1 Level = 0.8058*(CT-2 Level) + 2.8495	0.56	3%
CT-2, Oct	CT-2 Level = 0.1855*(CT-1 Level + 0.5216)	0.39	4%
CT-2, Mar	CT-2 Level = 0.2135*EXP(1.6069*CT-1 Level)	0.87	< 1%
CT-2, Jun - Jul	CT-2 Level = 0.09393*(CT-1 Level) + 0.5673	0.17	7%

D.2 Phosphorus Loading

The USACE reports daily inflow to Cherry Creek Reservoir as a function of storage, based on changes in reservoir level. This daily inflow value incorporates information regarding measured outflow, precipitation, and evaporation. GEI monitors stream inflows to the reservoir using gaging stations on Cherry Creek, Cottonwood Creek, and Shop Creek (the three main surface inflows) to provide a daily surface inflow record. Given the differences in the two methods for determining inflow, combined with the potential of unmonitored surface flows that may result in greater seepage through the adjacent wetlands during storm events, an exact match between USACE and GEI calculated inflows is not expected.

In an effort to maintain a seasonality component in phosphorus loads and exports for the reservoir, the normalization process was performed on monthly data. Loads attributed to stream inflow, reservoir outflow, precipitation and the alluvium were still calculated on a daily basis, using the daily inflow records and respective concentration data, but summed to create a monthly inflow value. In the case of the alluvial inflow constant, the annual value was divided by the number of days in the year to create a daily value, and then summed to create a monthly value, with no seasonal dynamics. The monthly precipitation and alluvial inflow values are subtracted from the monthly USACE inflow value to create an Adjusted USACE Inflow. The monthly GEI stream flow (sites CC-10 and CT-1 flow) is subtracted from the Adjusted USACE Inflow to determine the quantity of flow that needs to be redistributed proportionally among the two primary surface inflow streams (Cherry Creek and Cottonwood Creek). If the monthly Redistributed Inflow is greater than 1,000 ac-ft, then the first 1,000 ac-ft is redistributed proportionally to the stream sites, with the remainder being placed in an Ungaged Flow category. This category represents unmonitored flow that may be attributed to wetland seepage, stream bank storage, or ungaged surface flows during the respective month. Once the redistributed inflows are apportioned to the stream sites, monthly loads are computed using their respective flow-weighted phosphorus concentrations and identified as "Normalized" to the USACE inflow. The alluvial load is based on the long-term median phosphorus concentration for Site MW-9 (1995 to 2014, 190 µg/L). Notably, flow and loads for sites upstream of Site CT-2 or on Shop Creek are not normalized. Only the unadjusted flow and load data was used to evaluate the effectiveness of the PRFs on Cottonwood Creek.

D.3 Tributary Streams

Once the water year flow record for each stream site was finalized, the mean daily flows were categorized as either base flow or storm flow events. If the mean daily flow was greater than the 90th percentile of the annual value (Table D-4), then the flow was categorized as storm flow. Flows less than the 90th percentile were categorized as base flows.

Table D-4: Threshold flow value used to categorize base flows and storm flows in 2014.

Site	90th Percentile (cfs)
CC-7-EcoPark	12.871
CC-10	20.914
CT-P1	6.887
CT-P2	5.734
CT-1	2.822
CT-2	9.934

For all streams, total phosphorus concentrations were determined for base flow samples collected on a monthly basis, and for storm flow samples collected at irregular intervals throughout the year (Appendix C). For each monitoring site, the monthly base flow TP concentration (Table D-5) was applied to the daily base flows during that month, while the annual median storm flow TP concentration was applied to storm flows (Equation 1). Daily loadings were then summed to obtain estimates of monthly and water year phosphorus loading for each stream site (Table D-6).

EQUATION 1:

$$L_{day} = \mu g/L \times Q_{in} \times \frac{86400\,sec}{day} \times \frac{28.3169\,L}{ft^3} \times \frac{2.205 \times 10^{-9}\,lbs}{\mu g}$$

where:

L_{day} = pounds per day phosphorus loading,

$\mu g/L$ = total phosphorus concentration of base flow or storm flow

Q_{in} = mean daily flow in ft^3/sec.

Table D-5: Monthly base flow TP concentrations (µg/L) and median annual storm flow TP concentration (µg/L) applied to respective flows in 2014.

Month	CC-O	EcoPark	CC-10	CT-P1	CT-P2	CT-1	CT-2
October 2013	140	87	189	18	26	56	38
November 2013	93	106	173	14	32	56	43
December 2013	108	199	179	27	34	91	66
January 2014	80	126	223	20	15	74	60
February 2014	70	95	165	38	38	84	88
March 2014	67	85	152	45	37	68	48
April 2014	94	89	173	34	54	62	114
May 2014	97	154	250	27	43	61	41
June 2014	105	287	271	38	34	40	22
July 2014	284	118	205	49	50	95	48
August 2014	154	219	271	68	68	74	47
September 2014	98	133	213	49	117	69	45
Water Year Storm Flow Median	--	472	326	240	189	174	97

D.4 Reservoir Outflow

The USACE monitors flows through the outlets gates on a regular interval and provides GEI with estimates of daily outflow for the reservoir. GEI monitors water quality of the outflow at a site located approximately 75 m downstream of the concrete outflow structure at the base of the dam (CC-O @ I-225). The monthly total phosphorus concentration collected from this site was applied to the USACE outflow to estimate the 2014 WY export load (Equation 1).

D.5 Precipitation

Precipitation data collected at Denver/Centennial Airport (KAPA) was used to estimate phosphorus loading due to precipitation in 2014 (Appendix D), with the basic premise that precipitation generally falls evenly across the reservoir, although rain showers in the Cherry Creek Reservoir area can be localized. Calculation of the phosphorus load into Cherry Creek Reservoir from precipitation was based on the long-term median phosphorus concentration of 109 µg/L (1995 to 2014) and Equation 2.

EQUATION 2:

$$L_{precip} = \frac{PR}{12in} \times A_{res} \times \frac{43650ft^2}{acre} \times \frac{\mu g}{L} \times \frac{28.3169L}{ft^3} \times \frac{2.205 \times 10^{-9} lbs}{\mu g}$$

where:

L_{precip} = pounds of phosphorus from precipitation,

PR = rainfall precipitation in inches,

A_{res} = surface area of the reservoir (852 ac), and

µg/L = 116 µg/L, long-term median TP concentration.

D.6 Alluvium

The alluvial water component remains one of the unmonitored sources of inflow to the reservoir. The annual flow is relatively constant given the boundaries of the alluvium in relation to the reservoir, with the majority of the alluvial water monitored at Site MW-9 flowing beneath the reservoir and under the dam, because the dam is not grounded on bedrock.

In 2005, Lewis et al. evaluated the ground water contribution and its relationship to the phosphorus budget to the reservoir. They observed a zone of high alluvial seepage located in the southeastern margin of the reservoir that covered approximately 1.5 ac and extended further into the reservoir to an approximate depth of 2 feet. At depths greater than 2 feet the composition of the sediment changed from one of coarse sand to one of high organic matter and carbonate content which greatly limited alluvial seepage. Lewis et al. used three different methods to derive the alluvial water component of 2,200 ac-ft/yr; direct measurements of alluvial inflow which included seepage estimates from the adjacent wetlands (submerged seepage meters and piezometers), ionic mass balance, and water budget balances.

Based on this study, and analysis of long-term residual inflow estimates, the 2014 alluvial component was defined as a constant source of water to the reservoir that accounted for 2,000 ac-ft/yr with no seasonal fluctuations. The long-term (1994-2014) median total dissolved phosphorus concentration for Site MW-9 (190 µg/L) was used to estimate the alluvial load component (Equation 3).

EQUATION 3:

$$L_{alluvium} = \mu g/L \text{ (} Q_{alluvium} \text{ (} \frac{2.205 \text{ H } 10^{-9} \text{ lbs}}{\mu g} \text{ (} \frac{1,233,482 \text{ L}}{\text{Ac-ft}}$$

where:

$L_{alluvium}$ = alluvial phosphorus loading in pounds per year

µg/L = 190 µg/L, long-term median TDP concentration

$Q_{alluvium}$ = alluvial inflow in ac-ft

D.7 Redistributed Inflows

During the 2014 WY, the repartitioning of the alluvial inflow component created a "Redistributed Inflow" category that is comprised of flows that are currently unaccounted for given the current monitoring regime. The majority of these flows are likely the result of bank full flooding that occurs along Cherry Creek, upstream of Site CC-10, which eventually enters the reservoir as seepage from the wetland area. Other flows in this category include unmonitored inflows from the Belleview and Quincy drainages, and surface inflows around the margin of the reservoir. The monthly "Redistributed Inflow" is calculated as presented below (Equation 4, Table D-6), and is either a positive or negative value depending on the monthly balance.

EQUATION 4:

Redistributed Inflow = (USACE Inflow - Precipitation - Alluvial Inflow) - GEI Stream Inflow

If the value is positive, then the inflow or load is added proportionally to Cherry Creek and Cottonwood Creek inflows. If the value is negative, the inflow or load value is subtracted proportionally from Cherry Creek and Cottonwood Creek inflows.

In the case when the redistributed inflow or load results in a negative monthly balance for a stream, the inflow or load for that stream is set to ZERO, with the remaining balance being subtracted from the other stream site. In the rare case when the redistributed inflow or load results in negative monthly balances for both streams, then the inflow or load for each stream is set to ZERO, with the remaining balance being subtracted from the monthly alluvial value.

Additionally, when the redistributed inflow is greater than 1,000 ac-ft/month (mo), the first 1,000 ac-ft will be redistributed among the two streams, and the remainder will be placed into an "Ungaged Inflow" category. The reasoning behind this category is if the redistributed inflow is truly this great, then the current inflow monitoring regime should be reevaluated to address such occurrences.

Table D-6: Unadjusted monthly flow and load data and the final normalized flow and load.

	Unadjusted Flow (ac-ft/mo)								Normalized Flow (ac-ft/mo)		
	USACE Inflow	USACE Outflow	CC-10	CT-P1	CT-P2	CT-1	CT-2	Precip	Alluvium	CC-10	CT-1/CT-2
October 2013	1,408	3,515	1,142	0	109	0	281	28	170	971	239
November 2013	772	562	692	0	72	0	151	7	164	493	107
December 2013	780	612	685	0	61	0	109	15	170	513	82
January 2014	942	1,068	665	22	73	65	159	55	170	579	138
February 2014	865	960	693	70	82	98	184	7	153	557	148
March 2014	1,208	1,022	832	148	171	189	326	54	170	707	277
April 2014	1,367	716	905	194	229	142	366	90	164	792	320
May 2014	1,829	1,783	1,013	251	303	214	382	120	170	1,117	421
June 2014	1,277	1,141	1,197	109	154	92	126	82	164	933	98
July 2014	1,672	822	817	353	364	14	242	285	170	939	278
August 2014	1,097	965	1,573	299	258	0	410	131	170	632	165
September 2014	1,137	484	758	351	374	0	473	171	164	493	308
Water Year Total	**14,352**	**13,648**	**10,972**	**1,797**	**2,250**	**814**	**3,209**	**1,045**	**2,000**	**8,726**	**2,582**

	Unadjusted Total Phosphorus Load (lbs/mo)								Normalized Load (lbs/mo)		
	USACE Inflow	USACE Outflow (CC-O)	CC-10	CT-P1	CT-P2	CT-1	CT-2	Precip	Alluvium	CC-10	CT-1/CT-2
October 2013	--	1,338	813	0	8	0	29	8	88	692	25
November 2013	--	142	326	0	6	0	18	2	85	232	13
December 2013	--	180	333	0	6	0	20	4	88	250	15
January 2014	--	232	403	1	3	13	26	16	88	351	23
February 2014	--	183	311	7	8	22	44	2	79	250	35
March 2014	--	186	367	54	49	68	65	16	88	312	55
April 2014	--	183	487	77	88	43	103	27	85	426	90
May 2014	--	470	744	106	119	74	80	36	88	820	88
June 2014	--	326	973	24	37	17	12	24	85	758	9
July 2014	--	635	546	186	155	4	53	85	88	627	61
August 2014	--	404	1,321	103	84	0	76	39	88	531	31
September 2014	--	129	492	141	170	0	100	51	85	320	65
Water Year Total	**--**	**4,408**	**7,114**	**699**	**733**	**241**	**626**	**310**	**1,033**	**5,567**	**509**

Table D-7: Calculation of the monthly redistributed inflow and load values and the apportioning of these data to sites CC-10 and CT-2.

Month	Adjusted USACE Inflow (USACE Precip Alluvium)	GEI Inflow CC-10 +CT-2 (ac-ft/mo)	Redistributed Inflow (ac-ft/mo)	CC-10 Percent of GEI Inflow	CT-2 Percent of GEI Inflow	CC-10 Redistributed Flow (ac-ft/mo)	CT-2 Redistributed Flow (ac-ft/mo)	Ungaged Residual Flow (ac-ft/mo)	Redistributed Load (lbs/mo)	CC-10 Redistributed Load (lbs/mo)	CT-2 Redistributed Load (lbs/mo)	Ungaged Residual Load (lbs/mo)
October 2013	1,210	1423	-213	80%	20%	-171	-42	0	-126	-122	-4	0
November 2013	601	843	-242	82%	18%	-199	-43	0	-99	-94	-5	0
December 2013	595	793	-198	86%	14%	-171	-27	0	-88	-83	-5	0
January 2014	717	823	-106	81%	19%	-86	-21	0	-55	-52	-3	0
February 2014	705	878	-173	79%	21%	-137	-36	0	-70	-61	-9	0
March 2014	984	1159	-175	72%	28%	-125	-49	0	-65	-55	-10	0
April 2014	1,112	1271	-159	71%	29%	-113	-46	0	-74	-61	-13	0
May 2014	1,539	1395	143	73%	27%	104	39	0	84	76	8	0
June 2014	1,031	1323	-292	90%	10%	-264	-28	0	-218	-215	-3	0
July 2014	1,217	1059	158	77%	23%	122	36	0	89	81	8	0
August 2014	796	1983	-1,186	79%	21%	-941	-245	0	-836	-790	-46	0
September 2014	801	1231	-430	62%	38%	-265	-165	0	-207	-172	-35	0
Water Year Total	**11,308**	**14,181**	**-2,874**	**78%**[1]	**22%**[1]	**-2,246**	**-628**	**0**	**-1,665**	**-1,548**	**-117**	**0**

1. Water year average and not water year total.

Appendix E

2014 Biological Data

Table E-1: Quantity and size of fish stocked in Cherry Creek Reservoir, 1985 to 1995.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Black crappie											
Size (inches)	5	--	--	--	--	--	--	--	--	--	--
Number	7,234	--	--	--	--	--	--	--	--	--	--
Blue catfish											
Size (inches)	--	--	--	--	--	--	--	3	--	3	--
Number	--	--	--	--	--	--	--	9,000	--	21,000	--
Bluegill											
Size (inches)	--	1	0.2	--	--	--	--	--	--	--	--
Number	--	111,968	70,000	--	--	--	--	--	--	--	--
Channel catfish											
Size (inches)	2 to 8	4	4	3	3	3.5	3	4	4	4	4
Number	116,784	25,594	25,600	16,000	10,316	25,599	13,500	13,500	13,500	23,625	18,900
Cutthroat trout											
Size (inches)	--	6	--	--	--	--	--	--	--	9	--
Number	--	52,228	--	--	--	--	--	--	--	9,089	--
Flathead catfish											
Size (inches)	--	--	--	--	--	--	--	--	--	1	--
Number	--	--	--	--	--	--	--	--	--	148	--
Largemouth bass											
Size (inches)	--	--	5	5	6	--	--	--	--	--	--
Number	--	--	10,000	10,000	8,993	--	--	--	--	--	--
Rainbow trout											
Size (inches)	8 to 12	2 to 18	2 to 26	9.5	8 to 22	9 to 15	9 to 10	9.5	9.5	9 to 18	9 to 20
Number	75,753	414,136	129,715	293,931	79,919	74,986	79,571	101,656	92,601	62,615	139,242
Tiger musky											
Size (inches)	--	5.5	7	8	--	8	5 to 8	7	9	8	8
Number	--	4,723	4,000	4,500	--	2,001	6,500	4,940	4,500	900	4,500
Walleye											
Size (inches)	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Number	2,346,000	1,734,000	1,760,000	1,760,000	1,352,000	1,400,000	1,300,000	2,600,000	2,600,000	2,600,000	2,600,000
Wiper											
Size (inches)	--	0.2	--	--	0.2	1	1	10	1	1 to 4	1
Number	--	80,000	--	--	99,000	8,996	9,000	15,520	9,003	26,177	4,500
Yellow perch											
Size (inches)	2	--	--	--	--	--	--	--	--	--	--
Number	90,160	--	--	--	--	--	--	--	--	--	--

Table E-1 (cont.): Quantity and size of fish stocked in Cherry Creek Reservoir, 1996 to 2006.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Black crappie											
Size (inches)	--	--	--	--	--	--	--	--	--	--	2.5
Number	--	--	--	--	--	--	--	--	--	--	300
Channel catfish											
Size (inches)	3	3	4	3.5	4.1	3.5	--	2.5	2.5	2.2	2.8
Number	8,100	13,500	7,425	13,500	13,500	13,500	--	33,669	13,500	14	13,500
Cutthroat trout											
Size (inches)	9.5	3 to 9	--	--	--	--	--	--	--	--	--
Number	85,802	22,907	--	--	--	--	--	--	--	--	--
Largemouth bass											
Size (inches)	--	--	--	--	--	--	--	--	--	--	2.1
Number	--	--	--	--	--	--	--	--	--	--	195
Northern pike											
Size (inches)	--	--	--	--	--	--	--	--	--	--	--
Number	--	--	--	--	46	--	--	--	--	--	--
Rainbow × cutthroat hybrid											
Size (inches)	--	--	--	--	--	--	--	--	--	--	10.6
Number	--	--	--	--	5,600	--	--	--	--	--	7,895
Rainbow trout											
Size (inches)	4 to 22	10 to 24	11	10 to 19	--	10 to 19	10	10.5	10.5	10.4	10.8
Number	163,007	74,525	59,560	32,729	--	23,065	13,900	30,111	43,553	43,248	47,150
Snake River cutthroat											
Size (inches)	--	--	--	--	--	--	--	--	--	--	16.1
Number	--	--	--	--	--	--	--	--	--	--	204
Tiger musky											
Size (inches)	7	6	7	7	8	7	7	--	--	--	--
Number	3,500	4,500	4,000	3,000	4,086	4,000	4,000	--	--	--	--
Walleye											
Size (inches)	0.2	0.2	1.5	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2
Number	3,202,940	2,600,000	40,000	2,400,000	2,400,000	2,400,000	2,519,660	4,136,709	2,874,100	2,579,939	2,788,825
Wiper											
Size (inches)	1	1	1.3	1.3	--	--	--	--	--	0.2	2.1
Number	8,938	9,000	9,000	9,000	--	--	--	--	--	200,000	5,000

Table E-1 (cont.): Quantity and size of fish stocked in Cherry Creek Reservoir, 2007 to 2014.

	2007	2008	2009	2010	2011	2012	2013	2014
Black crappie								
Size (inches)	--	--	1.4	--	1.1 to 1.2	0.7 to 1.8	1.6	0.9
Number	--	--	5,000	--	97,399	41,541	5,000	6,500
Channel catfish								
Size (inches)	3	--	3.3	2.7	3.4	2.5 to 6.6	4	3
Number	9,360	--	3,780	13,500	9,450	11,750	4,050	3,375
Cutthroat trout								
Size (inches)	--	--	--	12.5 to 14.7	15.1	--	--	--
Number	--	--	--	1,562	200	--	--	--
Rainbow × cutthroat trout								
Size (inches)	--	9.7	--	--	--	--	--	--
Number	--	4,001	--	--	--	--	--	--
Rainbow trout								
Size (inches)	10	10.1	4.8	9.6 to 17.7	10.1 to 10.9	10.1 to 17.0	9.6 to 9.9	9.6 to 10.3
Number	37,709	11,588	12,287	11,038	28,029	29,872	8,261	6,881
Size (inches)	12	--	10.2	9.8 to 10.2	10.6	--	9.7 to 16.7	10.3
Number	4,800	--	29,759	39,200	1,737	--	11,275	2,538
Size (inches)	--	--	14	--	--	--	10.1 to 10.7	10.3
Number	--	--	109	--	--	--	10,296	7,296
Walleye								
Size (inches)	0.3	0.2	0.2	0.2 to 1.1	0.2	0.23	0.2 to 1.2	0.2 to 1.2
Number	4,300,000	3,992,572	4,012,800	4,264,512	4,001,400	4,001,400	4,008,182	4,215,301
Size (inches)	1	--	1.3	--	--	1	--	--
Number	7,998	--	14,998	--	--	15,000	--	--
Wiper								
Size (inches)	1.5	--	--	1.6	--	--	--	2
Number	4,600	--	--	8,000	--	--	--	4,000

Table E-2: 2014 Cherry Creek Reservoir phytoplankton data represented in numbers per mililter (#/mL).

	2014														
	11-Feb	**12-Mar**	**15-Apr**	**13-May**	**27-May**	**10-Jun**	**24-Jun**	**8-Jul**	**22-Jul**	**5-Aug**	**19-Aug**	**2-Sep**	**16-Sep**	**14-Oct**	**4-Nov**
Bacillariophyta															
Centrales															
Coscinodiscus sp.	--	--	--	--	--	--	--	--	29	--	54	43	86	--	--
Cyclotella meneghiniana	--	--	--	--	--	--	--	--	59	35	--	--	--	--	--
Cyclotella stelligera	--	--	--	--	--	38	--	--	264	106	236	511	344	--	--
Melosira ambigua	--	--	--	--	29	--	--	--	--	--	--	--	--	--	--
Melosira distans alpigena	--	--	--	38	--	--	--		--	--	--	--	--	--	--
Melosira granulata	--	--	--	--	--	--	--	1,253	--	--	--	--	--	--	121
Melosira granulata angustissima	--	--	--	75	--	--	--	--	--	--	--	--	--	--	--
Stephanodiscus astraea minutula	--	127	129	--	--	38	--	--	176	229	127	170	86	--	364
Stephanodiscus hantzschii	--	32	52	75	29	76	10	45	59	247	635	596	1,031	569	1,576
Pennate															
Amphora ovalis	--	32	--	--	--	--	--	--	--	--	--	--	--	--	--
Amphora perpusilla	--	32	--	--	--	--	--	--	--	--	--	--	--	--	--
Asterionella formosa	56	64	155	38	29	--	--	--	--	--	--	43	--	--	--
Cymbella naviculiformis	--	--	--	--	29	--	--	--	--	--	--	--	--	--	--
Diatoma tenue	--	--	--	--	--	--	--	--	29	--	--	--	--	--	--
Fragilaria construens	--	--	--	38	--	--	--	--	--	--	18	--	--	--	--
Fragilaria pinnata	--	32	--	--	--	--	--	--	--	--	18	--	--	--	121
Fragilaria vaucheriae	--	--	--	--	--	--	--	--	--	--	18	--	--	--	--
Gomphonema olivaceum	--	32	--	--	--	--	--	--	--	--	--	--	--	--	--
Gomphonema subclavatum	--	--	--	--	--	--	--	--	--	18	--	--	--	--	--
Navicula sp.	--	--	--	38	--	--	--	--	--	--	--	--	--	--	--
Navicula cryptocephala veneta	--	--	--	--	--	--	--	--	--	35	--	--	--	--	--
Navicula viridula	--	--	--	--	--	--	--	--	29	--	18	--	--	--	--
Nitzschia acicularis	--	--	52	--	--	--	--	--	--	--	--	596	--	--	--
Nitzschia capitellata	--	--	--	--	--	--	--	--	--	--	--	213	86	--	--
Nitzschia dissipata	--	--	26	38	--	--	--	--	--	--	--	--	--	--	--
Nitzschia palea	--	--	--	--	--	--	10	--	--	--	18	--	--	--	--
Nitzschia paleacea	--	--	180	--	--	--	--	--	29	--	18	340	--	--	--
Synedra radians	--	--	--	38	87	--	--	--	--	--	--	--	--	--	--
Synedra rumpens	--	--	--	--	--	--	--	--	--	--	--	--	86	--	--
Synedra ulna	56	--	--	38	--	--	--	--	--	--	--	43	--	--	--
Chlorophyta															
Ankistrodesmus falcatus	56	159	129	113	--	76	39	89	117	141	73	43	387	1,594	1,940
Aphanothece sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Botryococcus braunii	--	--	--	--	--	--	--	45	--	--	--	--	--	--	--
Chlamydomonas sp.	--	127	52		29	38	--	--	59	88	454	43	86	683	606
Chodatella wratislawiensis	--	--	129	38	--	--	--	--	--	--	--	--	--	114	485
Cosmarium sp.	--	--	--	--	--	--	--	--	59	--	--	--	--	--	--
Crucigenia crucifera	--	--	--	--	--	--	10	--	--	35	--	128	43	--	--
Crucigenia quadrata	--	--	52	38	146	76	--	--	29	35	36	170	1,546	1,025	485
Crucigenia tetrapedia	--	--	--	--	--	38	--	--	29	35	18	128	172	456	--
Nephrocytium sp.	--	--	--	38	--	--	--	--	--	--	--	--	--	--	--
Oocystis lacustris	--	--	77	75	117	190	10	--	117	35	--	--	--	--	--
Oocystis pusilla	--	--	52	188	291	494	29	403	205	71	18	43	86	--	121

Table E-2 (cont.): 2014 Cherry Creek Reservoir phytoplankton data represented in numbers per mililter (#/mL).

	2014														
	11-Feb	12-Mar	15-Apr	13-May	27-May	10-Jun	24-Jun	8-Jul	22-Jul	5-Aug	19-Aug	2-Sep	16-Sep	14-Oct	4-Nov
Chlorophyta (cont.)															
Pediastrum boryanum	--	--	--	--	58	--	--	45	59	--	--	--	--	--	--
Pediastrum duplex	--	--	--	--	--	--	19	89	29	--	--	--	--	--	--
Scenedesmus abundans	--	--	26	75	146	38	--	--	88	18	36	255	344	797	242
Scenedesmus acuminatus	--	--	77	75	--	--	--	--	88	53	--	--	129	569	727
Scenedesmus bijuga	--	--	--	--	--	--	67	--	--	--	--	--	902	--	--
Scenedesmus quadricauda	--	127	155	526	845	76	--	537	527	318	91	553	43	1,139	242
Selenastrum minutum	--	64	155	376	58	--	--	--	--	35	--	128	--	569	364
Sphaerocystis schroeteri	--	--	--	38	29	--	--	--	59	--	--	43	--	114	--
Tetraedron minimum	--	--	--	150	146	38	--	45	88	--	--	213	430	1,139	1,697
Tetraedron regulare	--	--	--	38	29	--	--	45	59	35	--	--	43	--	--
Tetrastrum staurogeniaforme	--	--	--	--	29	--	--	--	--	--	--	85	--	342	121
Chrysophyta															
Chromulina sp.	--	--	--	38	--	--	--	--	--	--	--	--	--	114	121
Chrysococcus rufescens	--	127	--	--	--	--	--	--	--	--	--	--	--	--	121
Kephyrion sp.	--	32	--	113	--	--	--	--	--	--	--	--	--	--	121
Kephyrion littorale	--	--	155	263	58	--	--	--	--	--	--	--	--	--	--
Lagynion sp.	--	--	--	--	--	--	--	45	--	--	--	--	--	--	--
Rhodomonas minuta	338	858	1,237	226	2,098	797	77	2,729	117	194	182	170	129	4,328	1,576
Cyanobacteria															
Anabaena flos-aquae	--	--	--	--	146	1,481	29	45	--	--	--	--	--	--	--
Aphanizomenon flos-aquae	--	--	--	--	--	--	--	--	--	18	--	--	--	--	--
Aphanothece sp.	--	--	--	--	58	--	--	--	--	--	--	--	--	--	--
Euglenophycota															
Euglena sp.	--	--	--	38	--	--	--	--	29	--	--	--	--	--	--
Trachelomonas crebea	--	--	--	--	--	--	--	--	--	--	--	--	--	--	121
Trachelomonas hispida	--	--	26	38	--	--	--	--	--	18	--	--	--	--	--
Trachelomonas scabra	--	--	--	--	--	--	--	--	--	35	18	--	--	114	--
Trachelomonas volvocina	--	--	--	38	--	--	--	--	--	--	--	--	--	--	--
Pyrrophycophyta															
Ceratium hirundinella	--	--	--	--	--	--	--	--	--	--	--	--	43	--	--
Dinobryon sertularia	56	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Glenodinium sp.	113	127	26	38	--	--	--	--	205	53	18	--	--	342	242
Peridinium cinctum	--	--	--	--	--	--	--	--	498	53	--	--	43	--	--
Cryptophyta															
Cryptomonas erosa	789	2,128	232	413	175	569	540	1,566	176	247	54	511	43	1,253	1,091
Unidentified Flagellate															
Unidentified flagellate	--	32	26	--	--	38	--	--	--	--	--	--	--	228	--
Total Density (cells/mL)	1,466	4,129	3,196	3,383	4,661	4,100	838	6,980	3,309	2,188	2,161	5,063	6,185	15,489	12,609
Total Taxa	7	17	22	31	22	16	11	14	28	25	21	23	22	19	22

Table E-3: Total reservoir phytoplankton density (cells/mL) and number of taxa in Cherry Creek Reservoir, 1984 to 2014

	1984	1985	1986	1987	1988	1989	1991	1992	1993	1994	1995	1996
Blue-Green Algae												
Density	71,780	66,496	99,316	168,259	155,180	273,175	307,691	77,516	15,708	10,015	18,194	16,599
Taxa	7	7	6	18	24	24	14	16	7	3	7	9
Green Algae												
Density	5,864	11,760	25,595	11,985	19,177	55,415	18,688	41,899	1,198	314	355	738
Taxa	11	10	13	58	76	66	46	48	16	2	11	11
Diatoms												
Density	1,776	3,863	5,428	10,677	12,880	9,311	4,160	1,243	946	194	2,189	2,354
Taxa	6	4	7	34	30	31	21	11	15	2	15	13
Golden-Brown Algae												
Density	--	7	125	469	56	505	821	93	158	3	63	249
Taxa	--	1	1	6	4	7	5	4	1	1	2	4
Euglenoids												
Density	514	135	208	251	276	108	89	23	231	196	304	409
Taxa	2	1	1	9	9	6	3	5	2	1	2	3
Dinoflagellates												
Density	--	13	19	19	83	28	23	54	--	31	5	21
Taxa	--	1	1	2	4	3	2	2	--	1	2	4
Cryptomonads												
Density	1,513	718	1,113	1,090	2,689	1,689	628	529	332	450	919	1,104
Taxa	2	3	3	6	4	5	2	3	1	1	1	1
Miscellaneous												
Density	--	--	--	--	--	--	--	--	--	--	--	--
Taxa	--	--	--	--	--	--	--	--	--	--	--	--
Total Density (#/mL)	81,447	82,992	131,804	192,750	190,341	340,231	329,773	121,357	18,573	11,203	22,029	21,474
Total Number of Taxa	28	27	32	133	151	142	93	89	42	11	40	45

Table E-3 (cont.): Total reservoir phytoplankton density (cells/mL) and number of taxa in Cherry Creek Reservoir, 1984 to 2014.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Blue-Green Algae												
Density	19,716	44,951	15,263	164,290	148,691	941	54,114	165,677	79,154	665,696	1,266,765	1,124,197
Taxa	10	11	8	19	12	3	21	27	19	19	21	19
Green Algae												
Density	2,461	1,809	898	43,881	33,217	1,973	55,190	56,236	189,777	1,358,248	563,344	1,531,579
Taxa	18	18	18	71	56	27	70	75	66	63	63	67
Diatoms												
Density	1,109	628	838	12,019	5,256	978	2,026	1,720	3,610	32,036	60,127	27,681
Taxa	8	18	16	34	22	24	22	26	24	21	21	17
Golden-Brown Algae												
Density	227	56	--	391	1,346	34	44	57	335	542	2,380	6,270
Taxa	2	2	--	14	13	3	5	5	4	5	3	3
Euglenoids												
Density	838	698	1,252	126	91	22	308	24	39	1,549	1,303	259
Taxa	3	3	1	6	4	3	9	11	8	10	10	11
Dinoflagellates												
Density	--	18	45	80	157	193	20	57	60	330	595	722
Taxa	--	2	2	8	6	5	3	5	6	5	5	3
Cryptomonads												
Density	1,487	1,393	559	2,472	2,851	355	3,282	3,158	3,293	40,511	61,037	35,962
Taxa	1	1	1	4	6	4	8	8	9	12	9	11
Miscellaneous												
Density	--	--	--	1,923	5,714	15	1,294	164	2,014	4,855	73,435	53,330
Taxa	--	--	--	1	1	1	3	6	6	6	7	8
Total Density (#/mL)	25,838	49,553	18,855	225,182	197,323	4,511	116,278	227,093	278,282	2,103,767	2,028,986	2,780,000
Total Number of Taxa	39	55	46	157	120	70	141	164	142	141	139	139

Table E-3 (cont.): Total reservoir phytoplankton density (cells/mL) and number of taxa in Cherry Creek Reservoir, 1984 to 2014.

	2009	2010	2011	2012	2013	2014	Long-term
Blue-Green Algae							
Density	332	4,177	1,136	2,648	731	1,776	**60,305**
Taxa	3	6	3	2	2	3	**10**
Green Algae							
Density	10,733	19,202	26,055	23,851	21,270	32,506	**20,236**
Taxa	20	22	23	20	21	23	**23**
Diatoms							
Density	11,609	13,975	39,654	24,186	16,380	12,669	**4,708**
Taxa	25	30	21	34	22	30	**21**
Golden-Brown Algae							
Density	246	587	1895	1,304	6,371	16,363	**292**
Taxa	4	3	4	3	5	6	**4**
Euglenoids							
Density	83	272	570	1,802	1,308	474	**266**
Taxa	3	4	4	5	7	5	**4**
Dinoflagellates							
Density	4,497	2,556	6,253	1,158	326	1,857	**60**
Taxa	4	3	1	2	3	4	**3**
Cryptomonads							
Density	22,277	16,794	14,850	12,130	7,930	9,787	**2,081**
Taxa	2	2	2	2	2	1	**3**
Miscellaneous							
Density	--	--	--	94	--	323	**1,923**
Taxa	--	--	--	1	--	1	**3**
Total Density (#/mL)	49,777	57,563	90,413	67,173	54,316	75,755	**86,703**
Total Number of Taxa	61	70	58	68	62	73	**70**

Table E-4: 2014 Cherry Creek Reservoir zooplankton.

	2014														
	11-Feb	**25-Mar**	**15-Apr**	**13-May**	**27-May**	**10-Jun**	**24-Jun**	**8-Jul**	**22-Jul**	**5-Aug**	**19-Aug**	**2-Sep**	**16-Sep**	**14-Oct**	**4-Nov**
Cladocera															
Bosmina longirostris	29.6	13.9	17.3	33.6	82.3	94.7	36.7	133.8	28.3	21.9	11.8	6.6	12.1	12.8	10.0
Daphnia ambigua	--	--	--	2.4	6.2	6.2	4.9	--	--	--	--	--	--	--	--
Daphnia lumholtzi	--	--	--	--	--	--	--	--	--	47.9	14.2	4.5	5.1	2.8	2.9
Daphnia parvula	--	--	--	--	--	--	--	--	--	--	0.6	--	0.1	--	0.1
Daphnia rosea	--	--	--	1.1	5.3	--	--	--	--	--	--	--	--	--	--
Daphnia sp.	--	--	0.4	7.0	14.2	74.8	19.9	26.1	1.4	--	--	0.2	0.2	0.6	0.1
Pleuroxus sp.	--	--	--	--	0.9	--	--	--	--	--	--	--	--	--	--
Skistodiaptomus pallidus	1.2	--	--	--	--	0.9	0.4	10.2	65.5	3.3	0.2	0.1	0.2	2.8	4.2
Copepod															
Diacyclops thomasi	36.7	73.3	53.5	12.5	2.7	21.2	5.8	34.0	1.8	1.2	--	0.04	0.4	1.3	1.6
Immature instar (copepodid)	110.2	46.8	15.0	67.8	35.4	50.0	11.9	25.0	5.3	10.7	3.5	5.0	8.1	12.2	7.3
Mesocyclops edax	--	--	--	--	--	4.9	--	7.9	--	--	--	0.04	0.1	0.4	0.1
Nauplius	62.8	2.7	--	154.8	179.1	31.0	65.5	526.4	148.6	74.9	61.3	52.0	47.1	58.7	38.9
Rotifer															
Ascomorpha ovalis	--	--	--	--	--	--	--	8.8	--	--	--	--	--	--	--
Asplanchna sp.	5.8	--	--	--	0.4	--	34.9	90.7	9.3	1.5		1.8	1.4	3.2	1.4
Brachionus angularis	--	--	--	--	--	--	--	39.8	8.4	10.5	1.2	0.7	2.1	1.1	0.7
Brachionus calyciflorus	--	--	33.3	--	--	--	--	--	--	--	--	--	--	--	--
Brachionus sp.	--	--	--	--	--	--	1.8	--	--	--	--	--	--	--	--
Conochiloides sp.	--	0.9	327.0	--	--	--	--	2.2	0.9	37.2	0.6	--	--	--	--
Keratella cochlearis	0.9	0.9	--	4.4	31.8	8.4	2.2	278.7	4.9	--	0.3	0.4	--	2.1	75.0
Keratella quadrata	--	0.9	--	0.4	1.3	--	42.5	6.6	--	--	--	--	--	--	--
Polyarthra sp.	--	--	3.6	1.3	0.4	--	--	48.7	--	0.6	1.2	13.1	--	8.1	6.0
Total Concentration (#/mL)	247.2	139.3	450.1	285.4	360.0	291.9	226.5	1238.9	274.3	209.7	94.9	84.4	76.9	106.3	148.3
Total Number of Taxa	6	6	6	9	11	8	10	13	9	9	9	11	10	11	12

Table E-5: 2014 Routine weekly cyanotoxin sampling events (values in µg/L)

Anatoxin-A

Date	CCR 1,2,3 Comp			Swim Beach		
	Result	D.L.	Method	Result	D.L.	Method
6/13	--	--	--	ND	0.05	LC-MS/MS
6/24	--	--	--	ND	0.05	LC-MS/MS
7/1	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
7/8	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
7/16	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
7/22	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
7/29	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
8/5	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
8/12	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
8/19	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
8/26	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
9/2	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
9/9	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
9/16	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS
9/23	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS

Cylindrospermopsin

Date	CCR 1,2,3 Comp			Swim Beach		
	Result	D.L.	Method	Result	D.L.	Method
6/13	--	--	--	ND	0.1	ELISA
6/24	--	--	--	ND	0.1	ELISA
7/1	ND	0.1	ELISA	ND	0.1	ELISA
7/8	ND	0.1	ELISA	ND	0.1	ELISA
7/16	ND	0.1	ELISA	ND	0.1	ELISA
7/22	ND	0.1	ELISA	ND	0.1	ELISA
7/29	ND	0.1	ELISA	ND	0.1	ELISA
8/5	ND	0.1	ELISA	ND	0.1	ELISA
8/12	ND	0.1	ELISA	ND	0.1	ELISA
8/19	ND	0.1	ELISA	ND	0.1	ELISA
8/26	ND	0.1	ELISA	ND	0.1	ELISA
9/2	ND	0.1	ELISA	ND	0.1	ELISA
9/9	ND	0.1	ELISA	ND	0.1	ELISA
9/16	ND	0.1	ELISA	ND	0.1	ELISA
9/23	ND	0.1	ELISA	ND	0.1	ELISA

Mycrocystin

Date	CCR 1,2,3 Comp			Swim Beach		
	Result	D.L.	Method	Result	D.L.	Method
6/13	--	--	--	0.20	0.15	ELISA
6/24	--	--	--	ND	0.15	ELISA
7/1	ND	0.15	ELISA	ND	0.15	ELISA
7/8	ND	0.15	ELISA	ND	0.15	ELISA
7/16	ND	0.15	ELISA	ND	0.15	ELISA
7/22	0.21	0.15	ELISA	ND	0.15	ELISA
7/29	0.24	0.15	ELISA	0.29	0.15	ELISA
8/5	ND	0.15	ELISA	0.27	0.15	ELISA
8/12	ND	0.15	ELISA	ND	0.15	ELISA
8/19	ND	0.15	ELISA	ND	0.15	ELISA
8/26	0.16	0.15	ELISA	ND	0.15	ELISA
9/2	ND	0.15	ELISA	ND	0.15	ELISA
9/9	ND	0.15	ELISA	0.16	0.15	ELISA
9/16	ND	0.15	ELISA	0.18	0.15	ELISA
9/23	ND	0.15	ELISA	ND	0.15	ELISA

Saxitoxin

Date	CCR 1,2,3 Comp			Swim Beach		
	Result	D.L.	Method	Result	D.L.	Method
6/13	--	--	--	ND	0.05	ELISA
6/24	--	--	--	ND	0.05	ELISA
7/1	ND	0.05	ELISA	ND	0.05	ELISA
7/8	ND	0.05	ELISA	ND	0.05	ELISA
7/16	ND	0.05	ELISA	ND	0.05	ELISA
7/22	ND	0.05	ELISA	ND	0.05	ELISA
7/29	ND	0.05	ELISA	ND	0.05	ELISA
8/5	ND	0.05	ELISA	ND	0.05	ELISA
8/12	ND	0.05	ELISA	ND	0.05	ELISA
8/19	ND	0.05	ELISA	ND	0.05	ELISA
8/26	ND	0.05	ELISA	ND	0.05	ELISA
9/2	ND	0.05	ELISA	ND	0.05	ELISA
9/9	ND	0.05	ELISA	ND	0.05	ELISA
9/16	ND	0.05	ELISA	ND	0.05	ELISA
9/23	ND	0.05	ELISA	ND	0.05	ELISA

Table E-6: 2014 Opportunistic cyanotoxin sampling events(values in µg/L)

Date	CCR-2			CCR-2 Surface			CCR-2 Photic			DAM			Marina		
Anatoxin-A															
Date	Result	D.L.	Method	Result	D.L.	Method	Result	D.L.	Method	Result	D.L.	Method	Result	D.L.	Method
6/10	ND	0.05	LC-MS/MS	--	--	--	--	--	--	--	--	--	--	--	--
6/13	--	--	--	ND	0.05	LC-MS/MS	ND	0.05	LC-MS/MS	--	--	--	ND	0.05	LC-MS/MS
6/17	--	--	--	--	--	--	--	--	--	ND	0.05	LC-MS/MS	--	--	--
6/24	--	--	--	--	--	--	ND	0.05	LC-MS/MS	--	--	--	--	--	--
Cylindrospermopsin															
Date	CCR-2			CCR-2 Surface			CCR-2 Photic			DAM			Marina		
6/10	ND	0.1	ELISA	--	--	--	--	--	--	--	--	--	--	--	--
6/13	--	--	--	ND	0.1	ELISA	ND	0.1	ELISA	--	--	--	ND	0.1	ELISA
6/17	--	--	--	--	--	--	--	--	--	ND	0.1	ELISA	--	--	--
6/24	--	--	--	--	--	--	ND	0.1	ELISA	--	--	--	--	--	--
Mycrocystin															
Date	CCR-2			CCR-2 Surface			CCR-2 Photic			DAM			Marina		
6/10	10.0	0.15	ELISA	--	--	--	--	--	--	--	--	--	--	--	--
6/10	9.3	--	LC-MS	--	--	--	--	--	--	--	--	--	--	--	--
6/13	--	--	--	0.70	0.15	ELISA	0.40	0.15	ELISA	--	--	--	0.20	0.15	ELISA
6/17	--	--	--	--	--	--	--	--	--	25.00	0.15	ELISA	--	--	--
6/24	--	--	--	--	--	--	0.20	0.15	ELISA	--	--	--	--	--	--
Saxitoxin															
Date	CCR-2			CCR-2 Surface			CCR-2 Photic			DAM			Marina		
6/10	ND	0.05	ELISA	--	--	--	--	--	--	--	--	--	--	--	--
6/13	--	--	--	ND	0.05	ELISA	ND	0.05	ELISA	--	--	--	ND	0.05	ELISA
6/17	--	--	--	--	--	--	--	--	--	ND	0.05	ELISA	--	--	--
6/24	--	--	--	--	--	--	ND	0.05	ELISA	--	--	--	--	--	--

Table E-7: 2014 Cherry Creek Reservoir cyanobacteria identification and enumeration based on cyanotoxin presence (species units/mL.)

Cyanobacteria	2014		
	10-Jun	17-Jun	24-Jun
Aphanizomenon flos-aquae	--	280	--
Aphanizomenon sp.	30	--	6
Aphanocapsa sp.	--	--	7
Cyanophyte spp.	--	266	53
Dolichospermum cf. crassum	--	--	9
Dolichospermum cf. flos-aquae	--	132,865	219
Dolichospermum flos-aquae	--	--	--
Dolichospermum spp.	54,777	--	--