GEI Consultants

Geotechnical
Water Resources
Environmental and
Ecological Services

Cherry Creek Reservoir 2007 Annual Aquatic Biological Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facilities Monitoring

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Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Executive Summary

The purpose of this report is to present the 2007 water quality data collected by GEI Consultants, Inc. (GEI), on behalf of the Cherry Creek Basin Water Quality Authority (Authority). The data were collected to evaluate Cherry Creek Reservoir water quality with respect to standards and goals identified in the Cherry Creek Reservoir Control Regulation No. 72, selected water quality standards identified for the Reservoir in Regulation No. 38, and to evaluate the effectiveness of the Authority's pollutant reduction facilities (PRFs) on Cottonwood Creek. Additionally, this report provides comparisons for many parameters to the long-term monitoring data collected on behalf of the Authority since 1987.

1.1 Phosphorus Loading

The total inflow of gaged tributary streams and ungaged surface water flows was 26,537 ac-ft/yr and contributed 18,408 lbs of phosphorus to the Reservoir. Annual precipitation accounted for 1,049 ac-ft of water and contributed 331 lbs of phosphorus, while the alluvial inflow was assumed to be a constant 2000 ac-ft/yr, and contributed 1,033 lbs of phosphorus to the Reservoir.

Combined, the total external load to the Reservoir was 19,772 lbs in 2007, which exceeded the phased Total Maximum Annual Load (TMAL) of 14,270 lbs/yr specified in Control Regulation No. 72. The 2007 external load is the largest estimated phosphorus load since monitoring began, although the flow-weighted total phosphorus concentration of 0.67 lbs/ac-ft (246 µg/L) was within the range of past observations.

1.2 Total Phosphorus

Total phosphorus concentrations in the upper 3 m layer of the Reservoir ranged from 81 to 155 µg/L during the July to September sampling events, with a seasonal mean of 118 µg/L. The 2007 in-lake total phosphorus concentration was considerably greater than the phosphorus goal of 40 µg/L, which has been met only once since 1987. The seasonal long-term average total phosphorus concentration for the Reservoir is 82 µg/L.

1.3 Chlorophyll *a*

Chlorophyll *a* concentrations in the upper 3 m layer of the Reservoir ranged from 4.4 to 23.5 µg/L during the July to September sampling events, with a seasonal mean of 12.6 µg/L. Despite the record external total phosphorus load and in-lake total phosphorus concentration for the Reservoir, this is the second consecutive year that the Reservoir has met the chlorophyll *a* standard. In fact, this was the lowest seasonal mean chlorophyll *a* concentration since 1991. The seasonal long-term average chlorophyll *a* concentration for the Reservoir is 20.0 µg/L.

1.4 Temperature and Dissolved Oxygen

The winter of 2006-2007 was particularly cold in the Denver area which allowed a substantial ice-cover to develop on the Reservoir. The winter period for many front-range reservoirs is often a time of concern, because high algal activity, followed by mortality and microbial decomposition can create optimal conditions for reservoir anoxia. This phenomenon may potentially lead to a fish kill during the ice-covered period or even during spring turnover. Dissolved oxygen profiles collected during the ice-covered period indicated concentrations were sufficient to support aquatic life and did not pose a threat of a fish kill in 2007, even during the spring turnover period. Following spring turnover, the Reservoir was well mixed and oxygenated from March to early May 2007. From mid May through July, the Reservoir was often stratified, with brief periods of natural mixing that were induced by wind/storm events. By early June, thermal stratification created conditions conducive for deep water anoxia (<2 mg/L) that promoted internal nutrient loading from the sediment. Soluble reactive phosphorus concentrations observed at depth provide further evidence of internal nutrient loading during this low oxygen period.

The Reservoir was also evaluated for compliance with the dissolved oxygen criteria (>5 mg/L) for Class I Warm Water lakes and reservoirs. As a conservative estimate, regardless of stratification, the mean dissolved oxygen concentration for the 0 to 6 m water layer was computed for each sampling event and revealed the Reservoir met the standard during all sample events in 2007.

1.5 Pollutant Reduction Facility Effectiveness

The Cottonwood Creek Peoria Pond PRF was effective in removing 374 pounds or 34 percent of the phosphorus load from Cottonwood Creek. Further downstream, the Cottonwood Creek Perimeter Pond was effective in reducing an additional 390 pounds of phosphorus to the Reservoir, or a 17 percent reduction at this point in 2007. The effectiveness of both PRFs is based primarily on the ability to remove phosphorus from the stream flow via sedimentation and biological uptake, as well as reducing the water load through the system by evaporation. When combined, the Perimeter Pond and Peoria Pond PRF's accounted for a 4 percent reduction in the total external phosphorus load to the Reservoir in 2007.

2.0 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 (CCBWQA). This Authority 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 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 within a net annual load 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 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. In May 2001 at the CWQCC hearing, a new control regulation was adopted for the Cherry Creek Reservoir, which maintained the annual allowable total phosphorus load (total maximum annual load [TMAL]) of 14,270 lbs/year as part of a phased total maximum daily load (TMDL) for 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 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., and continues to perform the annual monitoring duties of Cherry Creek Reservoir (GEI 2007). 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 the concentrations of selected nutrients, primarily nitrogen and phosphorus compounds, in Cherry Creek Reservoir, major tributary inflows, and the Reservoir outflow.

- Determine the pounds of phosphorus entering Cherry Creek Reservoir from streams and precipitation and leaving the Reservoir through its outlet.

- Determine biological productivity in Cherry Creek Reservoir, as measured by algal biomass (chlorophyll *a* concentration) and algal densities. In addition, determine species composition of the algal assemblage.

- Determine relationships between the nutrient levels and biological productivity in Cherry Creek Reservoir through correlation of the various measurements made during the study.

- Assess the effectiveness of pollutant reduction facilities (PRF) on Cottonwood Creek to reduce phosphorus loads into the Reservoir.

This report presents the 2007 water quality data collected from Cherry Creek Reservoir and its three primary tributaries, Cherry Creek, Shop Creek, and Cottonwood Creek, and provides comparisons for many parameters to the long-term monitoring data collected since 1987. The report also examines the nutrient removal efficiency of the CCBWQA PRFs located on Cottonwood Creek, evaluates their effectiveness in reducing phosphorus loads to the Reservoir, and provides comparisons to historical data.

3.0 Study Area

Cherry Creek was impounded in 1950 by the U.S. Army Corps of Engineers (USACE) to protect the City of Denver from flash floods that may originate in the 995 square kilometers (385 square miles) drainage basin. The Reservoir has maintained a surface area of approximately 350 ha (approximately 852 acres) since 1959. The Reservoir and surrounding state park has also become an important recreational site, providing activities that include fishing, boating, swimming, bicycling, bird watching, and hiking.

3.1 Sampling Sites

Sampling in 2007 was conducted at 10 sites, including three sites in Cherry Creek Reservoir, six sites on tributary streams, and one site on Cherry Creek downstream of the Reservoir (Figure 1). The sampling sites are summarized below:

3.1.1 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 following determination that this site exhibited similar characteristics to the other two sites in this well-mixed 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).

3.1.2 Shop Creek

SC-3 This site was established on Shop Creek in 1990 upstream of the Perimeter Road and downstream of the Shop Creek detention pond and wetland system. In 1994, this site was moved just downstream of the Perimeter Road and again moved farther downstream to a location just upstream of its confluence with Cherry Creek in 1997. This site serves to monitor the water quality of Shop Creek as it joins Cherry Creek.

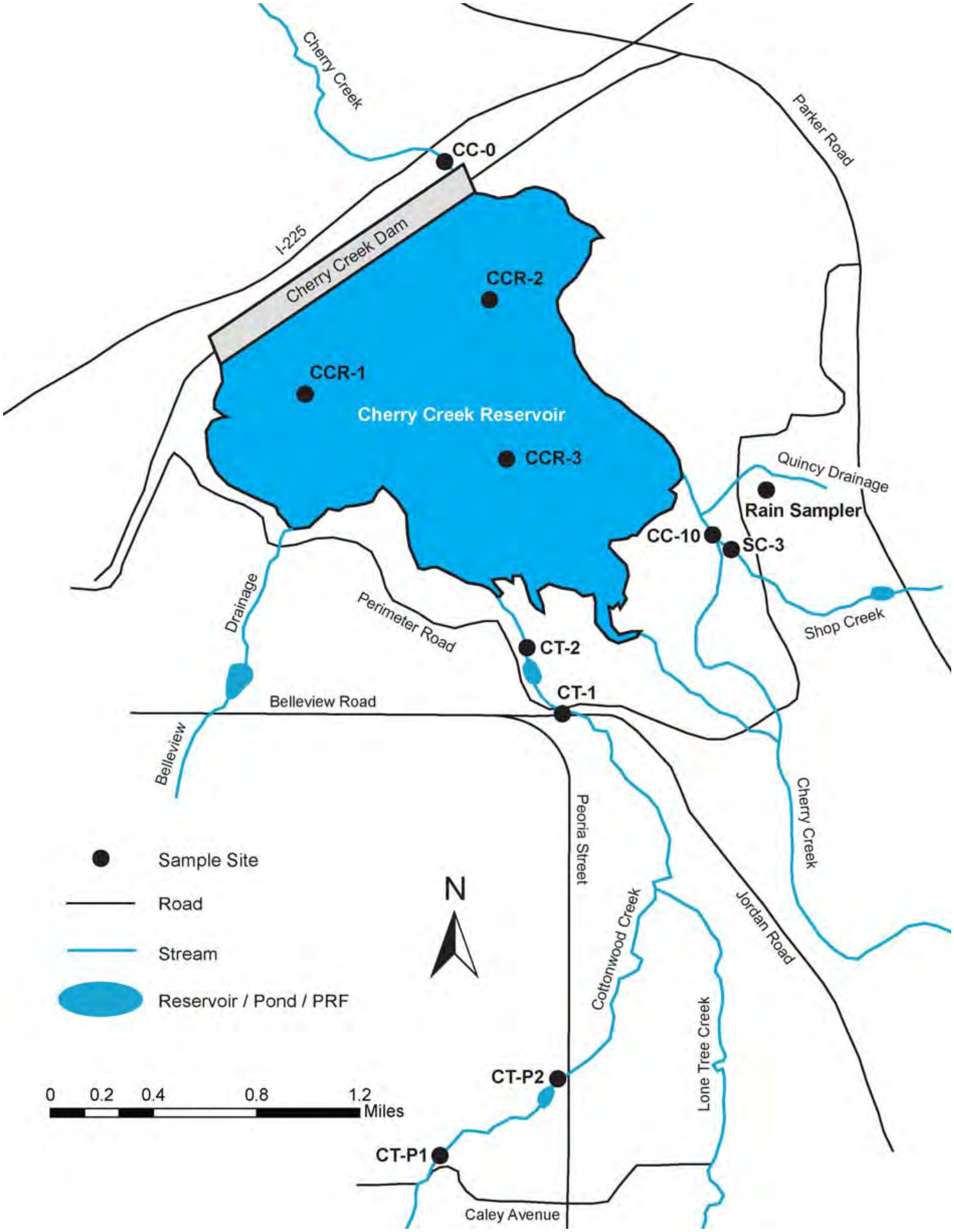

Figure 1: Sampling sites on Cherry Creek Reservoir and selected streams, 2007.

3.1.3 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 kilometers (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 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 CC-10 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 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 USGS gage. Site CC-O (i.e., CC-Outflow) monitors the water quality of Cherry Creek downstream of the Reservoir outlet.

3.1.4 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.

CT-2 This site was established in 1996 and 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. 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.

4.0 Methods

4.1 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 (CEC 2003b, Appendix A).

4.1.1 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 16 reservoir sampling events were conducted in 2007. The December 2007 sampling event could not being performed due to unsafe ice conditions.

Table 1: Sampling trips per sampling period.

Sampling Period	Frequency	Planned Trips/Period	Actual Trips/Period
Jan – Apr	Monthly	4	4
May – Sept	Bi-Monthly	10	10
Oct – Dec	Monthly	3	2
	Total	17	16

During each sampling event on the Reservoir, three main tasks were conducted, including: 1) determining water clarity; 2) collecting physicochemical depth profiles 3) collecting water samples for chemical and biological analyses.

4.1.1.1 Water Clarity

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

4.1.1.2 Profile Measurements

The second task involved collecting dissolved oxygen, temperature, conductivity, pH, and oxidation reduction potential (ORP) measurements every meter from the surface to near the bottom of the Reservoir to develop depth profiles for each site during each sampling episode. Data were collected using a Yellow Springs Instrument (YSI) meter, with Model #600 XL multi-probe sonde, that was calibrated prior to each sampling event to ensure accuracy of the measurements.

4.1.1.3 Water Sampling

Water samples for nutrient, phytoplankton, and chlorophyll *a* 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, 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.

4.1.1.4 Fish Population Data

Historically, this monitoring study has also reviewed fish stocking and population data collected by the Colorado Division of Wildlife (CDOW). As part of their sampling schedule to reduce mortality to a walleye brood-stock population in Cherry Creek Reservoir, CDOW has sampled fish populations every 2 to 3 years in the past. However, the most recent fish population survey was conducted in 2004 by the CDOW (personal communication with Harry Vermillion, CDOW). Therefore, only the 2007 fish stocking data are presented herein.

4.1.2 Stream Sampling

4.1.2.1 Base Flow Sampling

Base flow stream sampling was conducted on a monthly basis (11 events; April event excluded, see below) in conjunction with the routine reservoir sampling trips to Cherry Creek Reservoir. This sampling was performed in order 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. However, in 2007 there was one exception to this basic premise. On April 24th, base flow water quality samples were scheduled to be collected; however an extreme precipitation event on that day resulted in storm samples being collected. The flow on this day and for the remainder of the month is categorized as storm event flows (i.e., >90th percentile flow), and is not representative of base flow conditions. For the purposes of estimating total phosphorus loads, the April base flow data was interpolated, using March and May base flow data.

4.1.2.2 Storm Sampling

Storm events sampled at the inflow sites on Cherry Creek, Cottonwood Creek, and Shop Creek characterize non-base flow conditions during the 2007 sampling season (Table 2). A detailed outline of storm sampling protocols can be found in the Sampling and Analysis Plan (Appendix A).

Table 2: Number of storm samples collected from tributary streams to Cherry Creek Reservoir, 2007. See Appendix C for sample dates.

	Sites					
	CC-10	SC-3	CT-P1	CT-P2	CT-1	CT-2
Number of Storm Samples	5	5	7	7	7	6

4.1.3 Surface Hydrology

Pressure transducers attached to ISCO Series 4200 or 6700 flowmeters measured and recorded water levels (stage) at six sites on the three 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 Sites CC-10, SC-3, CT-1, CT-P1 using stage-discharge relationships developed for each stream site. For Sites CT-2 and CT-P2, where the flow meters are located inside 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. For a complete description of streamflow determination, see Appendix D.

4.2 Laboratory Procedures

4.2.1 Nutrient Laboratory Analysis

Physicochemical and biological analyses from the Reservoir and stream water quality samples were performed by the GEI analytical laboratory in Littleton, Colorado (Table 3). Randomly selected QA water samples were also sent to the University of Colorado, Center for Limnology, for nutrient analyses as a quality assurance check. Detailed methodologies and laboratory Quality Assurance/Quality Control (QA/QC) procedures are available from GEI, with the comparison of inter-laboratory data provided in Appendix F.

4.2.2 Biological Laboratory Analysis

Biological analyses of the Reservoir phytoplankton samples were conducted by the University of Colorado Center of Limnology and GEI. The University of Colorado performed phytoplankton identification and enumeration, which provided cell counts per unit volume (cells/mL) and taxa richness, while GEI performed the chlorophyll *a* concentrations (µg/L). 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, 2007.

Parameter	Method	Detection Limit
Total Phosphorus	QC 10-115-01-1-U	2 µg/L
Total Dissolved Phosphorus	QC 10-115-01-1-U	2 µg/L
Soluble Reactive Phosphorus	QC 10-115-01-1-T	3 µg/L
Total Nitrogen	APHA 4500-N B (modified)	4 µg/L
Total Dissolved Nitrogen	APHA 4500-N B (modified)	4 µg/L
Ammonia	QC 10-107-06-3-D	3 µg/L
Nitrate and Nitrite	QC 10-107-04-1-B	5 µg/L
TSS	APHA 2540D	4 mg/L
TVSS	APHA 2540E	4 mg/L
Chlorophyll *a*	APHA 10200 H (modified)	1 µg/L

APHA = American Public Health Association, 1998.

4.3 Quality Assurance/Quality Control

To ensure data quality, a number of quality assurance checks were used. Chain of custody procedures were observed during the field sampling and delivery of samples to GEI, and for samples shipped to the Center for Limnology, University of Colorado. During each reservoir sampling event, a QA sample was randomly collected at one of the Reservoir sites, and analyzed by the University of Colorado, Center for Limnology. No QA samples were collected from the stream sites during any of the stream sampling events. These QA samples resulted in approximately 7 percent of the total samples collected during the year as having a duplicate sample, and provided a reasonable independent assessment of lake water nutrient analyses conducted by GEI.

In addition, field sampling quality control included the use of a field blank. This field blank contained laboratory grade deionized water in a sample container identical to those used in the field collections and was carried through the entire sampling episode. The cap of this container was removed at each Reservoir site and left open during the regular sampling effort at that site. Upon completion of sampling at that site, the cap was replaced. One field blank was used for every sampling trip. The field blanks and duplicate samples were analyzed for all the parameters, identical to a routine sample.

Detailed methods and results of QA/QC checks performed on the water quality data from the Reservoir for 2007, with comparison between labs, are located in Appendix F. This analysis showed that results from the analytical labs were similar. As such, all values reported herein are based on results obtained from the GEI analytical laboratory.

4.4 Calculation of Phosphorus Loading

During the past few years, there has been extensive dialogue with the Colorado Water Quality Control Division (WQCD) regarding the calculation of phosphorus loads when placed in the context of long-term modeling and the predictive use for control regulation usage. From these discussions, a methodology was agreed upon that would create some continuity among Colorado reservoirs with control regulations in place, and also create a long-term database using consistent methodologies based on contemporary scientific understandings. The historical external load data presented in this report has been revised using the current methodology, thus comparisons to historical data are appropriate. The long-term statistics have changed slightly from past reports and reflect the current understanding of the system and methodologies. Detailed discussion of the streamflow measurements and derivation of loads can be found in Appendix D.

4.5 Calculation of Long-Term Trends in Cherry Creek Reservoir

Long-term seasonal trends were evaluated for Secchi depth, chlorophyll *a*, and total phosphorus using whole-lake mean values from 1987 to 2007 and linear regression analysis (described below). Additionally, 95 percent confidence intervals provided information on data dispersal around the mean annual values. These analyses were used to determine whether there were significant increasing or decreasing trends in Secchi depth, total phosphorus, and chlorophyll *a* levels over time.

Linear regression analyses were also used to evaluate QA/QC relationships between labs, and comparisons of biological and physical parameters for each site were conducted using SPSS 2006 or NCSS 2000 statistical software (Hintze 2001). 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. 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 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.

5.0 Results and Discussion

5.1 Reservoir Water Quality

5.1.1 2007 Transparency

The whole-reservoir mean Secchi depth varied from 0.69 m in April to 1.53 m in late May (Figure 2). The seasonal (July to September) whole-reservoir mean Secchi depth was 1.07 m (Figure 3). The depth at which 1 percent of photosynthetically active radiation (PAR) penetrated the water column (i.e., photic zone depth) ranged from 2.10 m in early October to a maximum depth of 4.46 m in late July (Figure 2). With exception to the mid July reading, the period from early May through late October represented a time when Reservoir water clarity was at its best, with 1 percent light transmittance averaging 3.7 m. There was no significant relationship between 1 percent PAR transmittance and chlorophyll *a* concentration.

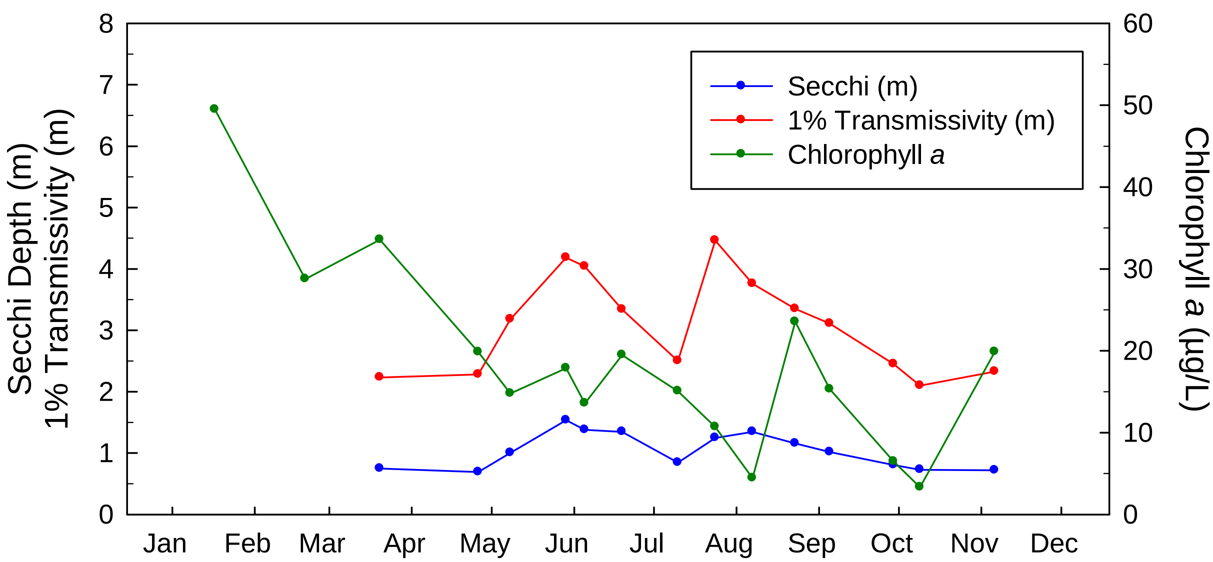

Figure 2: Annual patterns for mean whole-lake Secchi depth, 1% transmissivity, and chlorophyll *a* in Cherry Creek Reservoir, 2007.

5.1.2 Long-Term Secchi Transparency Trends in Cherry Creek Reservoir

In general, seasonal mean (July-to-September) Secchi depths increased from 1987 to 1996, then decreased in 1997 and have been relative stable since (Figure 3). There is not, however, a statistically significant long-term upward or downward trend for seasonal mean Secchi depths over the period of record. The 2007 seasonal whole-reservoir mean Secchi depth is similar to the long-term mean value of 1.06 m since 1992.

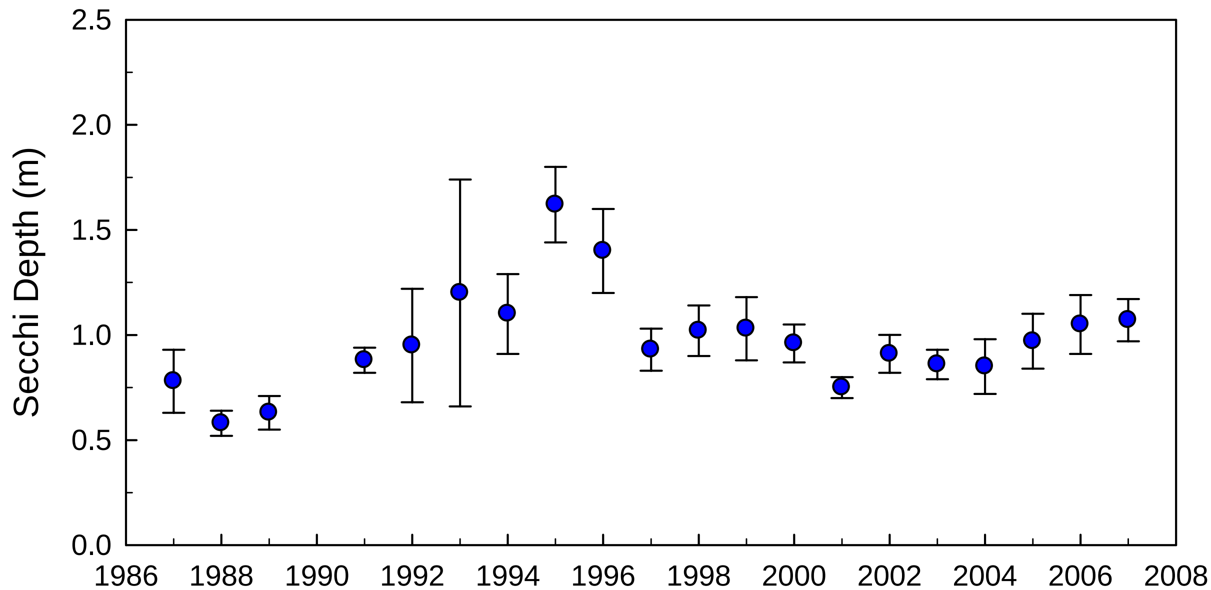

Figure 3: Whole-lake seasonal mean (July to September) Secchi depths (m) measured in Cherry Creek Reservoir, 1987 to 2007. Error bars represent a 95 percent confidence interval for each mean.

5.1.3 2007 Temperature and Dissolved Oxygen

Analysis of past Cherry Creek Reservoir temperature profiles indicates that stratification typically occurs when there is greater than 2°C difference between the surface and bottom water temperatures (Jones 1998). Differences of less than 1°C between the surface and bottom waters suggest 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. Dissolved oxygen profiles are also used to evaluate periods of stratification when temperature differences are less than 1°C. Using the above criteria, Cherry Creek Reservoir was evaluated for periods of potential stratification and low dissolved oxygen levels.

The 2006-2007 winter was particularly cold in the Denver area which allowed a substantial ice-cover to develop on the Reservoir. During the January and February sample events, ice thickness ranged from 8 to 11 inches and provided a safe sampling platform at the three Reservoir sites. In early March, the ice layer melted and on March 20th, 2007 the reservoir was sampled using a boat. During the ice-covered period, YSI profiles indicate dissolved oxygen levels decreased slightly in the deeper waters (> 4 m) at Site CCR-1. However, dissolved oxygen content remained greater than the Aquatic Life Standard of 5 mg/L. At Site CCR-2, decreased oxygen levels were also observed in the deeper waters, with the dissolved oxygen content at the bottom of the Reservoir being slightly less than the standard.

Notably, this layer is not considered during dissolved oxygen criteria evaluation, because the sediment layer has a large influence on the bottom 1 meter layer of water. Data profiles collected during the ice-covered period indicate that dissolved oxygen concentrations were sufficient to support aquatic life and did not pose a threat (i.e., anoxia fish kill) during the spring turnover period.

Water temperatures in Cherry Creek Reservoir ranged from 0.44 °C beneath the ice in January to 25.7 °C at the surface in late July. Following the spring turnover in early March, the Reservoir was well mixed and oxygenated in March, April, and May. By June, the Reservoir began showing signs of thermal stratification which is also supported by dissolved oxygen profiles. During this period, dissolved oxygen concentrations were often less than 5 milligrams per liter (mg/L) at depths greater than 4 m and even less than the upper threshold (2 mg/L) conducive for internal loading. These conditions in the deep layers of the Reservoir may pose relatively little effect to the warm water biological community, because the mixed layer remained well oxygenated. However, deep water anoxia (< 2 mg/L) created favorable conditions for internal nutrient loading during most of the summer period. Periods of thermal stratification were observed in the Reservoir at all lake sites (Section 4.1.3.1). From early May through June and in Mid-August, the Reservoir was thermally stratified, while in mid-July stratification only lasted a few days.

Water column dissolved oxygen profiles were also compared to the basic standards table value for Class 1 Warm Water lakes and reservoirs (5 mg/L). The Colorado Department of Public Health and Environment ([CDPHE] 2007) established this value as the year round warm water aquatic life standard for lakes and reservoirs. During periods of stratification, the dissolved oxygen criterion is intended to apply to the epilimnion and metalimnion strata of the reservoir, (CDPHE 2007). As such, during periods of reservoir stratification (i.e., greater than a 2 °C difference from surface to bottom), the 5 mg/L criteria would apply to the water column from the surface to a depth of approximately 5 m. However, during periods of whole lake mixing, the 5 mg/L standard would apply to the entire water column, except for the bottom 1 m layer. As a conservative estimate, the mean dissolved oxygen concentration for the 0 to 6   water layer, was computed for each sampling event regardless of stratification, and ranged from 5.1 mg/L in early August to 16.3 mg/L in late March. While the mean whole-reservoir dissolved oxygen content approached the lower threshold in early August, the Reservoir met the Class 1 warm water criteria during all sample events.

From early May to late July, the Reservoir periodically stratified allowing the bottom 1 m layer to become anoxic (< 2 mg/L) in June and July. The brief periods of mixing observed from May to late July were generally not strong enough to disrupt the bottom one meter layer, thus allowing internal loading to occur throughout most of the summer period (see Section 4.1.4). Notably, the August 7th sample event captured a whole-lake mixing event resulting from early August storms. This whole-lake mixing event brought anoxic water up from the deeper depths, decreasing the whole-lake oxygen content to 5.1 mg/L.

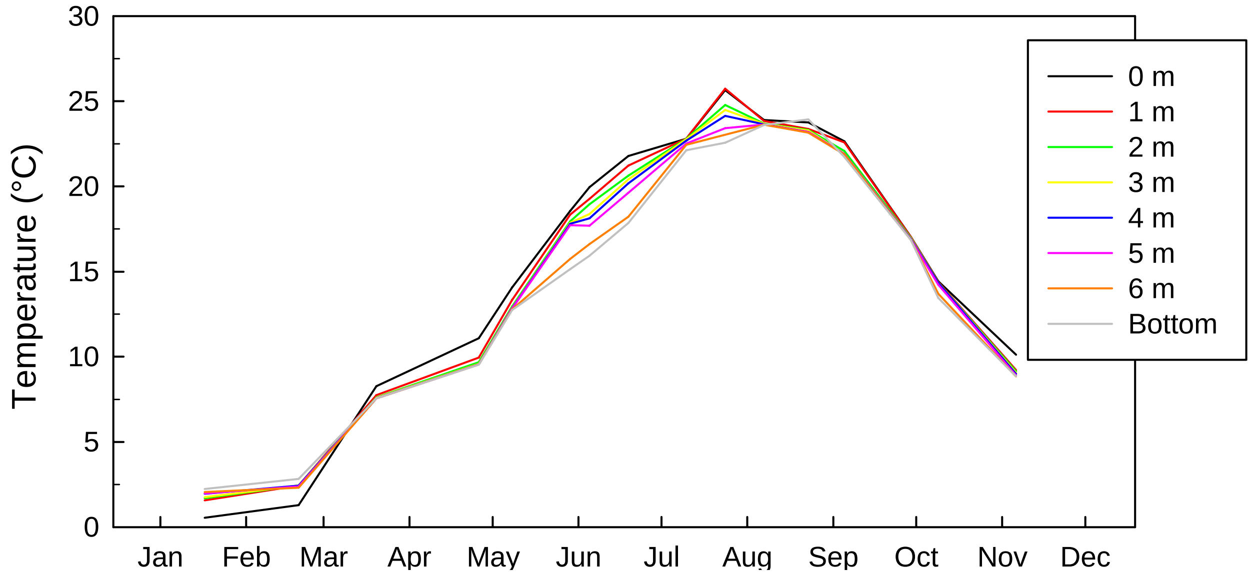

Figure 4: Temperature (°C) recorded at depth during routine monitoring at Site CCR-1 in 2007.

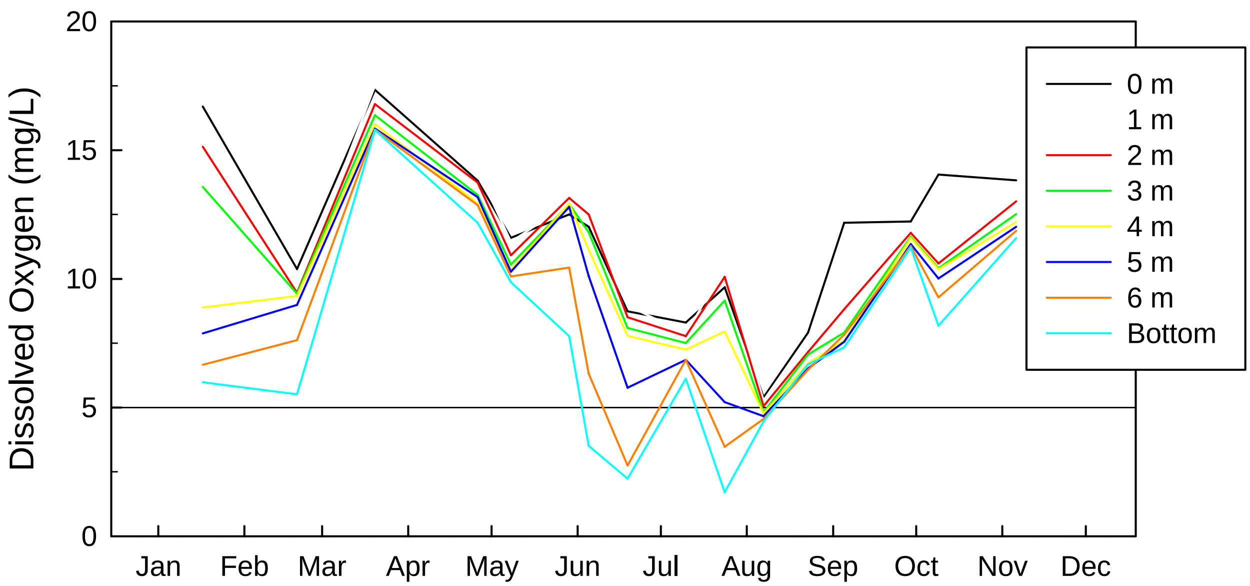

Figure 5: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at Site CCR-1 in 2007. The dissolved oxygen basic standards table value for Class 2 warm water lakes and reservoirs is provided for comparison (5 mg/L).

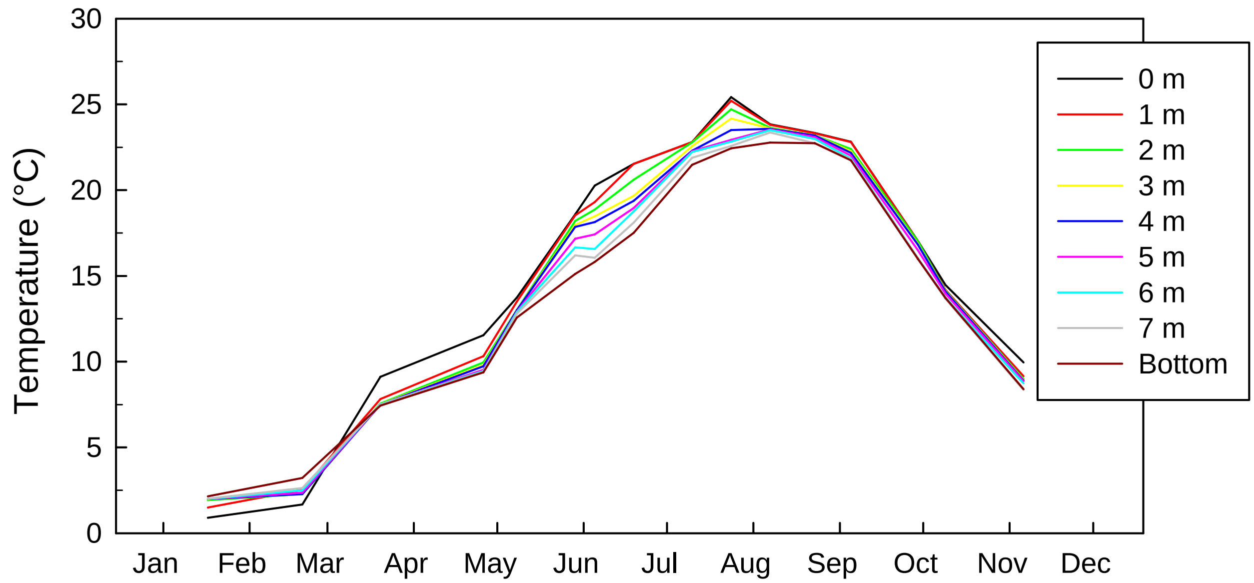

Figure 6: Temperature (°C) recorded at depth during routine monitoring at Site CCR-2 in 2007.

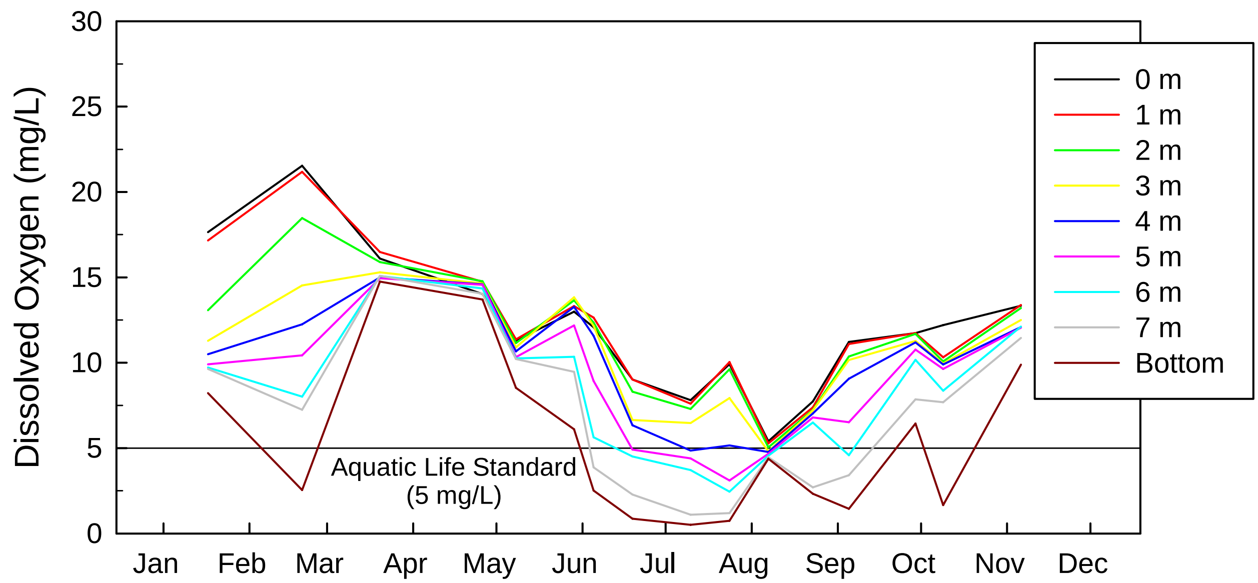

Figure 7: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at Site CCR-2 in 2007. The dissolved oxygen basic standards table value for Class 2 warm water lakes and reservoirs is provided for comparison (5 mg/L).

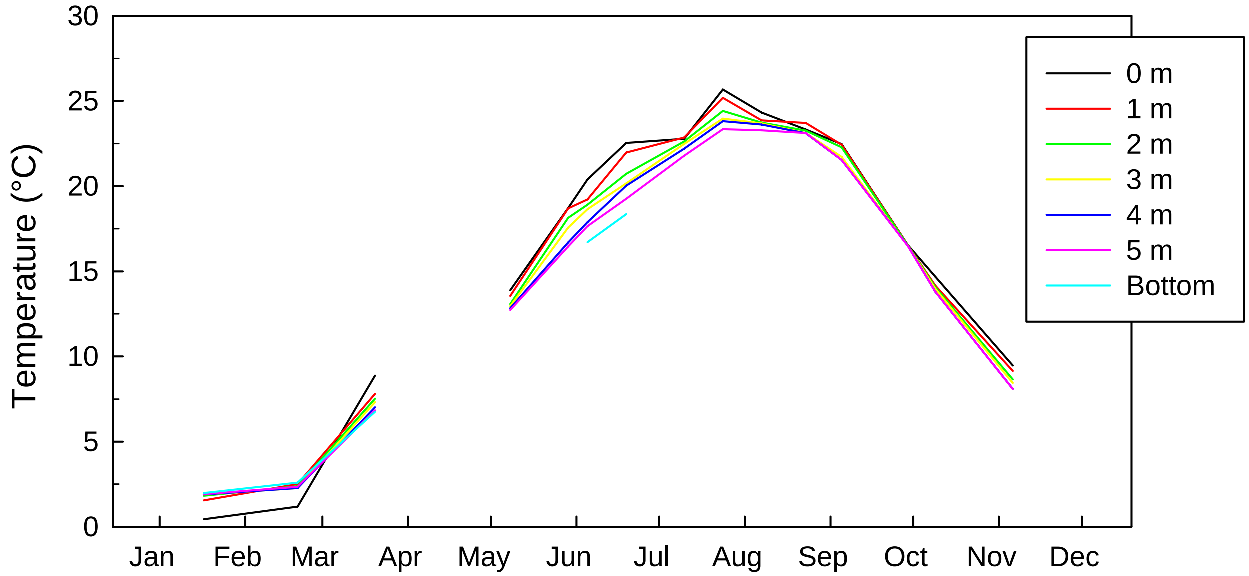

Figure 8: Temperature (°C) recorded at depth during routine monitoring at Site CCR-3 in 2007.

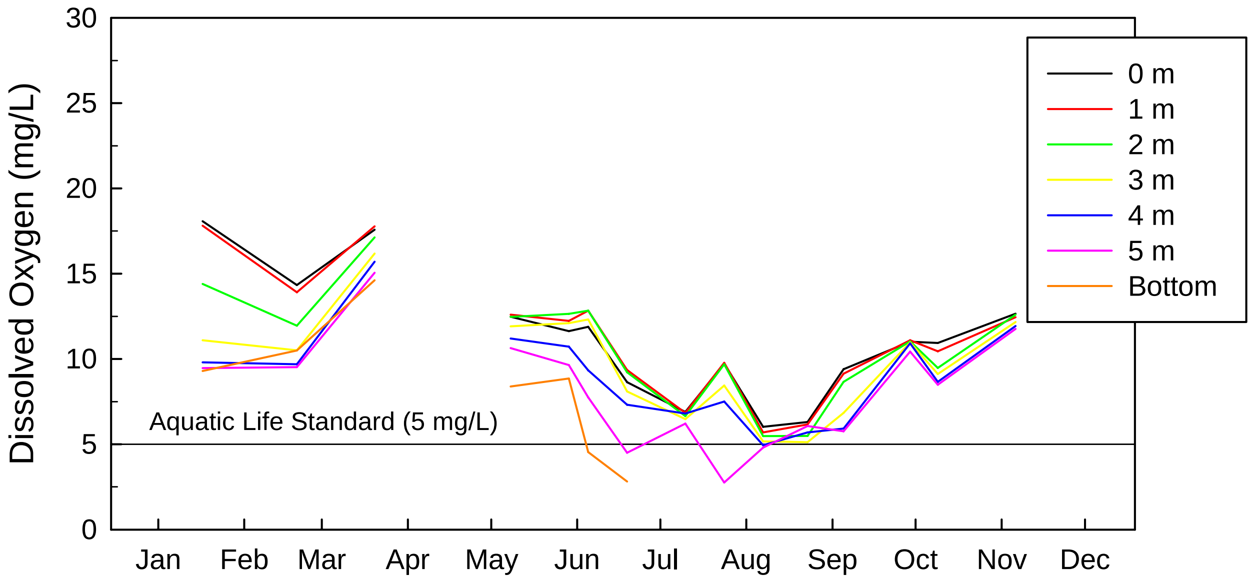

Figure 9: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at Site CCR-3 in 2007. The dissolved oxygen basic standards table value for Class 2 warm water lakes and reservoirs is provided for comparison (5 mg/L).

5.1.3.1 Continuous Temperature Monitoring

In May 2008, temperature loggers were deployed in anticipation for monitoring the efficiency of the destratification system at mixing the water column. Using the > 2°C difference criteria from the surface to bottom, Cherry Creek Reservoir was investigated for periods of stratification using the continuous temperature record at depths for all three Reservoir sites from May 11th to October 8th. By the time the temperature loggers were deployed on 11 May 2007, the reservoir was thermally stratified, with periodic thermal stratification periods occurring through early August (Figures 10-12). Reservoir mixing events that occurred on May 23rd, June 6th, August 5th, and August 24th were strong enough to mix the entire water column. However, the June 26th and July 13th mixing events were not strong enough to completely mix the bottom waters. By early June, the deeper water layers of the reservoir at sites CCR-1 and CCR-2, began to exhibit dissolved oxygen concentrations less than the Aquatic Life Standard and often less than 1 mg/L at the water/sediment interface. Even though the reservoir experienced periodic mixing events due to precipitation or wind, low dissolved oxygen levels persisted in the deep water layers until August 5th when the reservoir experienced a complete mixing event.

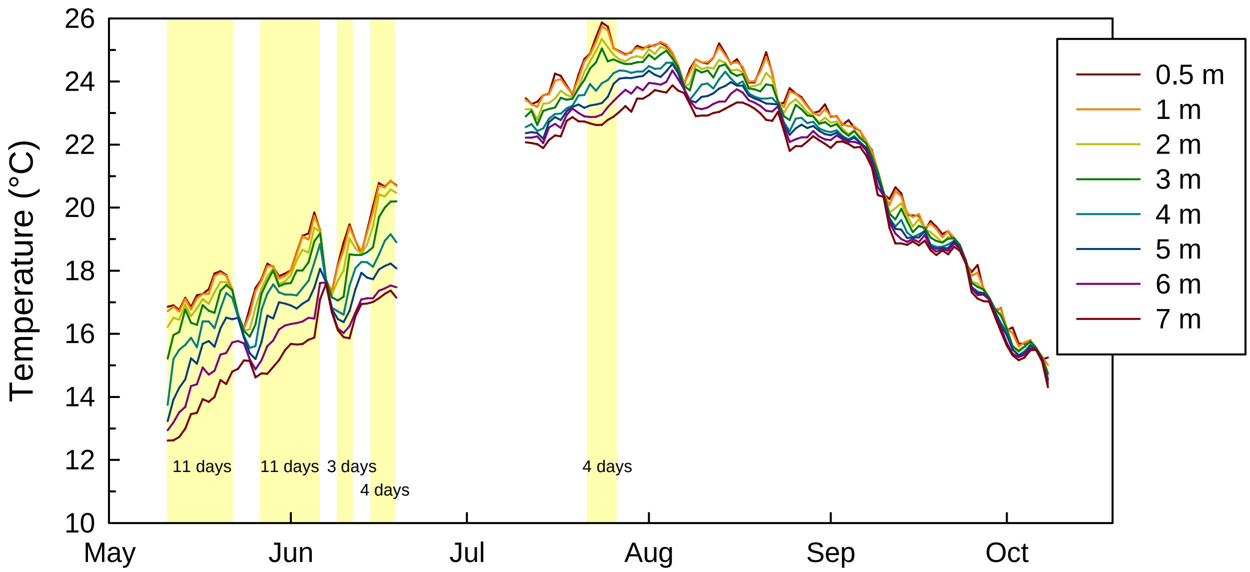

Figure 10: Daily mean temperature recorded at depth for Site CCR-1 based on 15-minute interval data collected by temperature loggers. Shaded areas and time durations denote periods of thermal stratification. Data gap resulted from loss of temperature loggers.

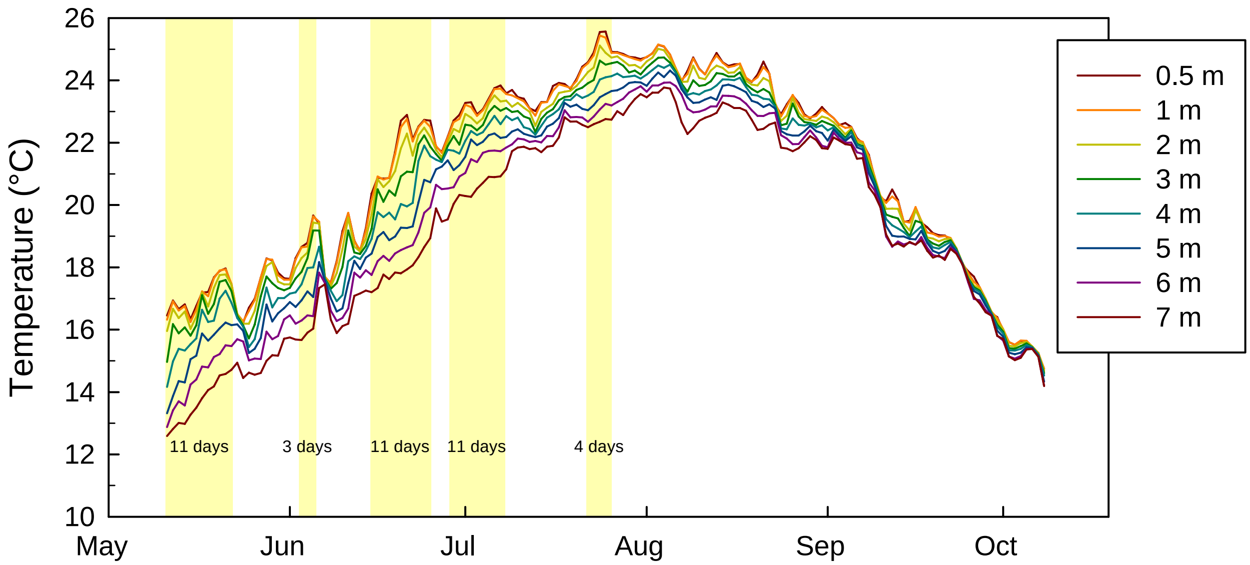

Figure 11: Daily mean temperature recorded at depth for Site CCR-2 based on 15-minute interval data collected by temperature loggers. Shaded areas and time durations denote periods of thermal stratification.

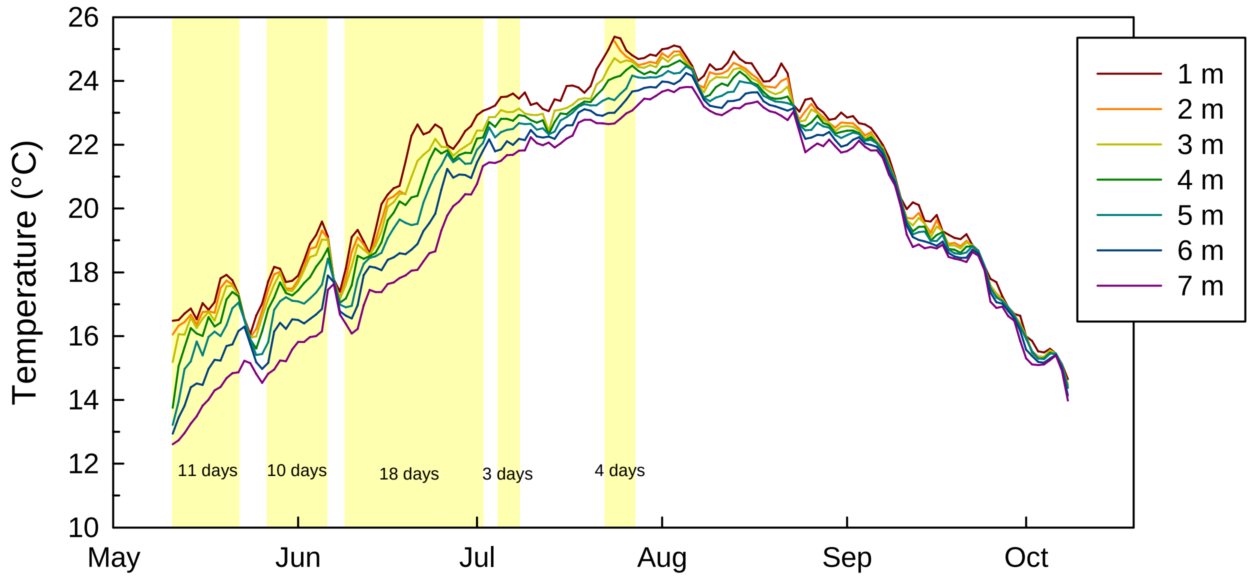

Figure 12: Daily mean temperature recorded at depth for Site CCR-3 based on 15-minute interval data collected by temperature loggers. Shaded areas and time durations denote periods of thermal stratification.

5.1.4 2007 Nutrients

Monitoring at Cherry Creek Reservoir has focused on the concentrations of phosphorus and nitrogen, because these inorganic nutrients are often the limiting factor in the growth of algae (Cole 1979; Goldman and Horne 1983; 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.

In 2007, the photic zone mean concentration of total phosphorus ranged from 76 to 155 µg/L with an overall annual mean of 106 µg/L. The seasonal photic zone mean (July-to-September) concentration ranged from 81 to 155 µg/L, with a seasonal mean of 118 µg/L (Figure 13). Monthly reservoir phosphorus concentrations did not correlate with monthly USACE inflow or phosphorus loads. The annual phosphorus pattern indicates internal loading contributed to summer phosphorus concentrations substantially.

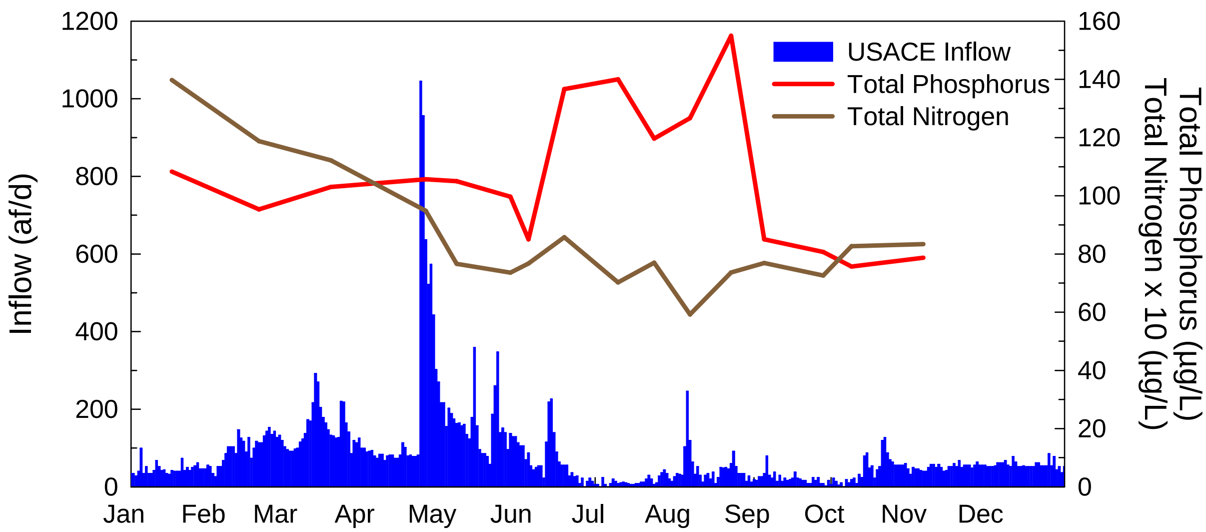

Figure 13: Annual pattern of photic zone total phosphorus, total nitrogen and USACE inflow in Cherry Creek Reservoir, 2007.

Patterns in total phosphorus concentrations collected along depth profiles at Site CCR-2 showed a well-mixed Reservoir during the spring and fall (Figure 14). There were periods of nutrient release from bottom sediments from early June through August as evidenced by increasing TP concentrations in the deeper layers of the Reservoir (Figure 14).

Photic zone total nitrogen concentrations ranged from 592 to 1,398 µg/L, with an annual average of 859 µg/L. During the July-to-September period, the photic zone mean total nitrogen concentration ranged from 592 to 770 µg/L, with a mean concentration of 716 µg/L. There was no correlation between monthly reservoir total nitrogen concentrations and monthly USACE inflow.

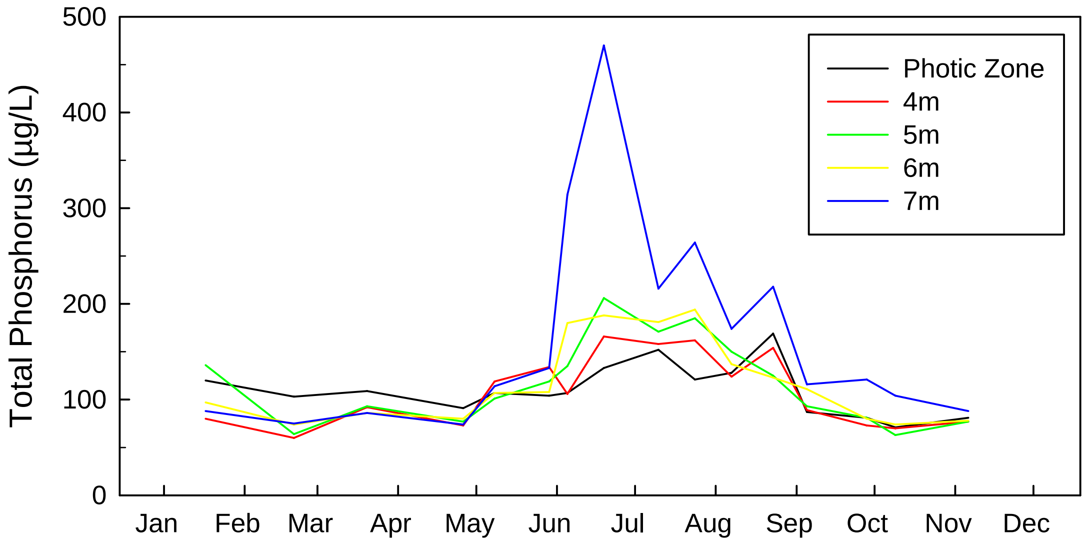

Figure 14: Total phosphorus concentrations recorded for the photic zone and at depth during routine monitoring in 2007.

5.1.5 Long-Term Phosphorus Trends in Cherry Creek Reservoir

In any long-term database, consistency in data analysis (i.e., analytical chemistry) is paramount, especially when evaluating long-term trends. Differences in methodologies or analytical laboratories may bias the data, which hinders the evaluation of potential trends. This is particularly evident in the total phosphorus and chlorophyll *a* database for Cherry Creek Reservoir. This database represents a variety of data produced by different analytical laboratories, and while the same standard method may have been utilized, subtle differences are apparent in the database. Over the monitoring period, analytical method detection limits varied and the precision of the analyses have increased with time. During the late 1990s, a transition from Metro Wastewater analytical services to GEI occurred, with the period from 1999 to 2007 representing the most consistent data processing methodologies. Furthermore, 1999 represents a time when a concerted effort started to implement best management practices throughout the basin, along with PRFs being established along Shop Creek and Cottonwood Creek to control storm flow and reduce the amount of phosphorus entering the Reservoir. Therefore, GEI also evaluated more recent trends in the data from 1999 through 2007.

Routine monitoring data collected since 1987 indicates a general increasing pattern in summer mean concentrations of total phosphorus (Figure 15). In 2007, the July to September mean concentration of total phosphorus was 118 µg/L. This is the highest observed value since monitoring began in 1987 and is considerably greater than the greater than the long-term median value of 82 µg/L (Table 4). Regression analyses performed on 1987 to 2007 seasonal mean TP data indicates a significant ($p < 0.01$) increasing trend, though the relationship is likely a result of the shift in the data that occurred in 1997. With the exception of the seasonal mean value observed in 1989 (39 µg/L), seasonal mean concentrations have consistently exceeded the goal of 40 µg/L over the past 20 years of monitoring.

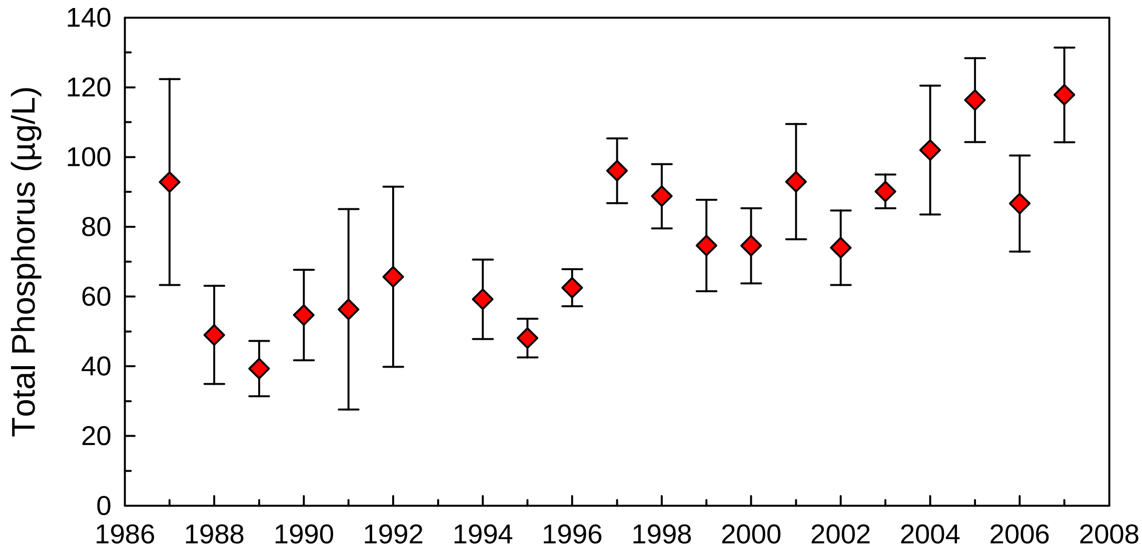

Figure 15: Seasonal mean (July to September) total phosphorus concentrations (µg/L) measured in Cherry Creek Reservoir, 1987 to 2007. Error bars represent a 95 percent confidence interval for each mean.

Table 4: Comparison of annual mean (monitoring period) and July to September mean phosphorus, nitrogen, and chlorophyll *a* levels in Cherry Creek Reservoir, 1987 to 2007.

Year	Total Nitrogen (µg/L)		Total Phosphorus (µg/L)		Mean Chlorophyll *a* (µg/L)	
	Annual	Jul-Sep	Annual	Jul-Sep	Annual	Jul-Sep
1987	1,580	741	86	93	11.1	8.3
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	790	970	54	66	12.2	17.4
1993	790	826	50	62	12.6	14.8
1994	1,134	1,144	56	59	11.4	15.4
1995	910	913	48	48	13.9	15.6
1996	889	944	54	62	13.8	18.2
1997	976	1,120	75	96	16.5	22.2
1998	850	880	82	89	21.7	26.6
1999	715	753	80	81	20.7	28.9
2000	784	802	81	81	21.9	25.1
2001	740	741	81	87	26.8	26.1
2002	847	858	70	74	21.7	18.8
2003	990	1,121	87	90	23.2	25.8
2004	923	977	84	102	17.0	18.4
2005	907	990	93	116	16.1	17.1
2006	897	914	81	87	15.9	14.7
2007	859	716	106	118	18.5	12.6
Mean	**903**	**926**	**72**	**77**	**16.1**	**18.2**
Median	**889**	**914**	**80**	**81**	**16.1**	**17.4**

5.1.6 2007 Chlorophyll a Levels

The annual pattern of photic zone chlorophyll *a* concentrations revealed relatively high concentrations (33 to 50 µg/L) of chlorophyll *a* during the winter ice-cover period (January and February), and during spring turnover (March). From late April through early November, chlorophyll *a* concentrations ranged from 3 to 24 µg/L (Figure 16). The 2007 annual mean chlorophyll *a* concentration was 18.5 µg/L, while the July to September mean chlorophyll *a* concentration was 12.6 µg/L. This is the second consecutive year that the Reservoir has met the seasonal chlorophyll *a* standard.

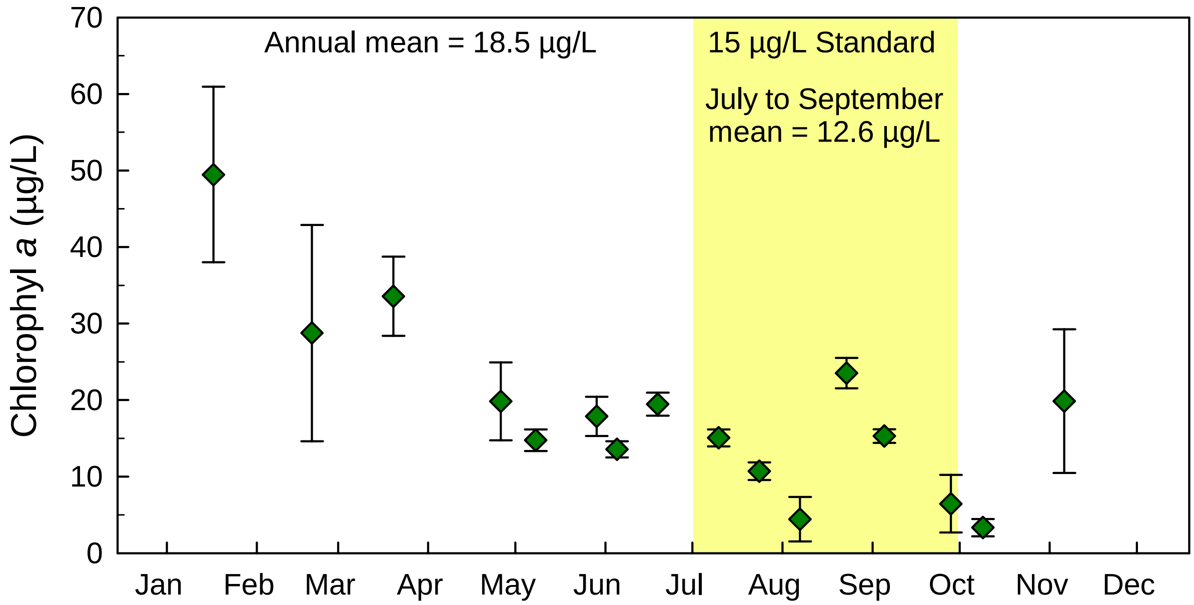

Figure 16: Concentration of chlorophyll *a* (µg/L) in Cherry Creek Reservoir, 2007. Error bars represent 95 percent confidence interval around each mean. Highlighted area denotes the seasonal period for the chlorophyll *a* standard.

5.1.7 Long-term Chlorophyll a Trends in Cherry Creek Reservoir

The seasonal mean chlorophyll *a* concentration has met the standard of 15 µg/L only six of the past 21 years (Figure 17). Since 1987, there is no significant trend in the seasonal mean chlorophyll *a* concentration (Figure 17). However, since 1999 there has been a steady decline in the seasonal mean chlorophyll *a* concentration, with the Reservoir meeting the standard in 2007 for the second consecutive year.

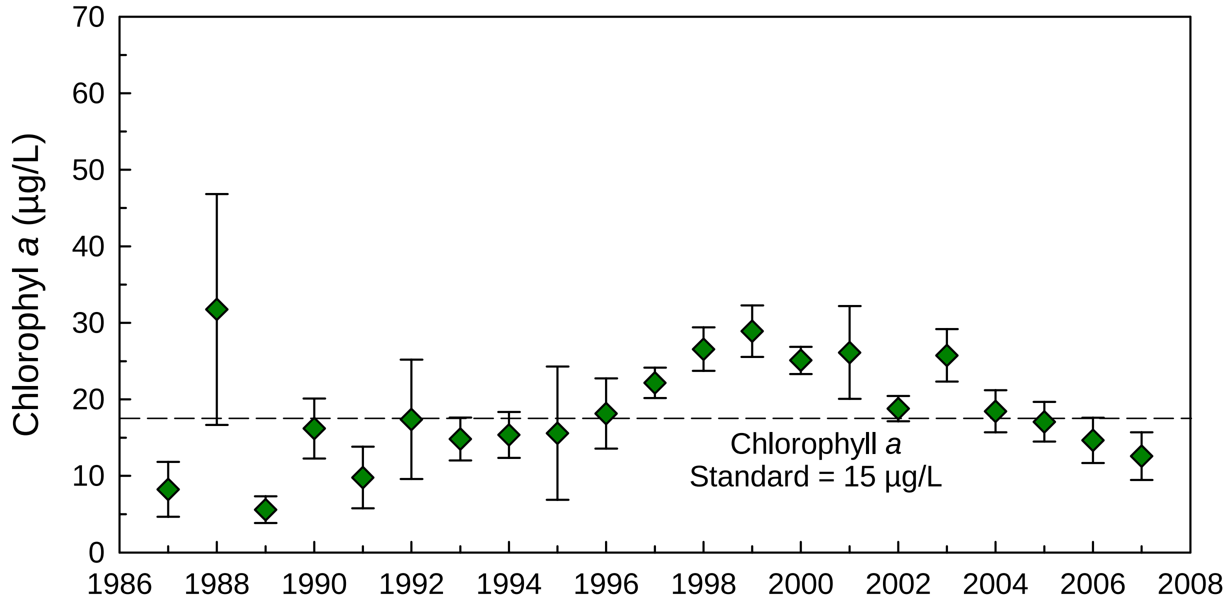

Figure 17: Seasonal mean (July to September) chlorophyll *a* concentrations measured in Cherry Creek Reservoir, 1987 to 2007. Error bars represent 95 percent confidence interval around each mean.

5.2 Reservoir Biology

5.2.1 2007 Phytoplankton

Phytoplankton density in the photic zone ranged from 24,000 cells/mL on May 29th to 262,716 cells/ml on October 9th (Table 5). The number of algal taxa present in the Reservoir ranged from 14 on February 20th to 58 on October 9th. Annually, the assemblage was dominated in terms of density by blue-green algae, with green algae being the second most abundant taxonomic group (Figure 18).

Regression analysis revealed no significant correlation between phytoplankton density and total or soluble reactive phosphorus concentrations during 2007. Additionally, no significant relationship was observed between phytoplankton density and chlorophyll *a*. Monthly average chlorophyll *a* concentrations did not correlate well with monthly average total phosphorus concentrations, but did reveal a significant correlation ($p < 0.001$, $R^2 = 0.76$) with Reservoir total nitrogen concentrations. These relationships suggest that algal biomass (chlorophyll *a*) was limited by nitrogen during 2007, and support conclusions made by Lewis *et al.* (2004) that algal biomass was often limited by nitrogen given the surplus of phosphorus in the system. During their study, May to October 2003, photic zone phosphorus concentrations would need to be reduced to approximately 30 µg/L, to induce phosphorus limitation in the algal assemblage.

Table 5: Density (cells/mL) of phytoplankton and total number of taxa collected from all three sites on Cherry Creek Reservoir, 2007.

Taxa	17 Jan	20 Feb	20 Mar	26 Apr	8 May	29 May	5 Jun	19 Jun
Diatoms								
Centrics	1200	40	180	370	840	250	7,841	130
Pennates	18	15	560	5,840	1564	3,061	13081	3580
Green Algae	137,775	65,160	44,430	44,677	30,016	14,935	5,516	23,015
Blue-Green Algae	19,120	4,585	2,880	25513	47,820	5,009	80	6,715
Golden-Brown Algae	1000	0	0	1060	0	0	0	0
Yellow-Green Algae	0	0	0	0	0	0	0	0
Euglenoids	0	0	0	10	0	0	0	0
Dinoflagellates	35	3	400	0	0	0	0	0
Cryptomonads	1,805	6,558	6,645	5255	4,856	725	373	440
Haptomonads	15120	11440	12640	4800	0	0	0	0
Microflagellates	0	0	520	0	40	20	0	0
Total Density	**176,073**	**87,801**	**68,255**	**87,525**	**85,136**	**24,000**	**26,891**	**33,880**
Total Taxa	**20**	**14**	**20**	**28**	**40**	**24**	**19**	**20**
Taxa	**10 Jul**	**24 Jul**	**7 Aug**	**23 Aug**	**15 Sep**	**28 Sep**	**9 Oct**	**6 Nov**
Diatoms								
Centrics	182	35	525	2480	488	1617	8111	6628
Pennates	611	5	18	1	211	330	275	40
Green Algae	17,551	8438	39,897	29,220	10,361	5,460	24,387	62,506
Blue-Green Algae	55,420	145248	170,650	178189	136,530	148,408	227,505	93,093
Golden-Brown Algae	0	230	0	40	50	0	0	0
Yellow-Green Algae	0	0	0	0	1	0	1	0
Euglenoids	6	15	7	1238	14	10	2	1
Dinoflagellates	69	20	12	20	11	5	0	20
Cryptomonads	13,148	1001	2,756	2890	2,410	4,220	1,635	6,320
Haptomonads	0	22640	80	0	0	0	400	160
Microflagellates	0	245	8	480	1160	2880	400	400
Total Density	**86,987**	**177,877**	**213,953**	**214,558**	**151,236**	**162,930**	**262,716**	**169,168**
Total Taxa	**43**	**55**	**46**	**41**	**54**	**48**	**58**	**51**

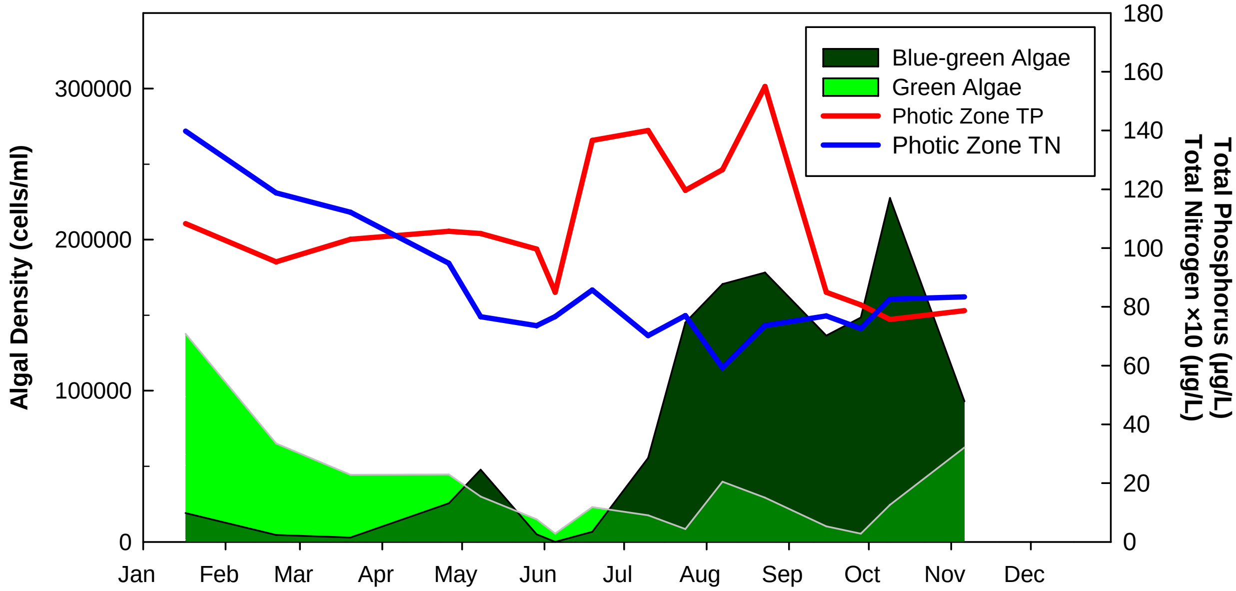

Figure 18: Annual pattern of blue-green and green algal densities and photic zone total phosphorus and total nitrogen concentrations in Cherry Creek Reservoir, 2007.

5.2.2 Long-Term Phytoplankton

In 2007, the phytoplankton assemblage was dominated, in terms of density, by blue-green algae (49 percent) and green algae (36 percent), and distantly followed by diatoms (8 percent; Table 5). Historically, the blue-green algae have been the most abundant algae, especially during the late summer season. Both the cryptomonad and haptomonad algae comprised approximately four percent of the algal assemblage, and was greater than their respective long-term median values (Appendix E).

5.2.3 Fish Populations

Historically, the fish assemblage has been composed of many species that represent a variety of trophic levels, which include omnivores, insectivores, zooplanktivores, and piscivores. Fish can exert a strong influence on the structure and productivity of phytoplankton and zooplankton assemblage through food web pathways between different levels (phytoplankton, zooplankton, and fish) of the aquatic ecosystem (Carpenter et al. 1985). In addition, these trophic dynamics can affect the variability, distribution, and ratios of limiting nutrients, such as phosphorus and nitrogen (Vanni et al. 1996). Mechanisms that may possibly result because of fish predation include decreased herbivory by zooplankton when fish are abundant, modification of nutrient recycling rates by herbivorous zooplankton as fish abundance varies, and nutrient recycling by fish (Vanni and Layne 1996).

Stocking data from the Colorado Division of Wildlife (CDOW) shows that 11 species and three hybrids have been stocked in Cherry Creek Reservoir from 1985 to 2007 (Appendix E).

The three stocked hybrids have been the wiper, striped bass × white bass, the tiger musky, northern pike × muskellunge, and a trout hybrid, rainbow × cutthroat trout. Of these 14 stocked fish taxa, rainbow trout and walleye have been stocked every year. In 2007, four fish taxa were stocked (Appendix E): rainbow trout, walleye, wiper, and channel catfish.

5.3 Stream Water Quality

5.3.1 2007 Phosphorus Concentrations in Streams

The median annual total phosphorus concentration for base flow conditions ranged from 60 µg/L at CT-P2 to 217 µg/L at CC-10 (Table 6). At most stream sites, the median seasonal (July-to-September) base flow concentration was greater than the annual median concentration. The seasonal median concentration of total phosphorus ranged from 64 µg/L at Site CT-2 to 218 µg/L at Site CC-10. At all stream sites, the storm flow TP concentration was greater than concentrations during base flow conditions. The annual median storm flow concentration ranged from 167 µg/L at Site SC-3 to 366 µg/L at Site CC-10.

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, 2007.

Stream, Site	Base Flow				Storm Flow	
	Summer		Annual		Annual	
	TP (µg/L)	TSS (mg/L)	TP (µg/L)	TSS (mg/L)	TP (µg/L)	TSS (mg/L)
Cherry Creek						
CC-10	218	10	217	23	366	83
CC-O	145	19	106	20	--	--
Cottonwood Creek						
CT-1	83	27	83	27	250	133
CT-2	64	42	81	39	230	76
CT-P1	116	15	61	13	309	128
CT-P2	77	18	60	15	192	43
Shop Creek						
SC-3	210	14	69	10	167	29

5.3.2 Long-Term Trends in Phosphorus Concentrations in Cherry Creek Reservoir Tributaries

Long-term patterns (1995-2007) in total phosphorus and soluble reactive phosphorus concentrations were evaluated for the three main tributary sites (CC-10, SC-3, 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 (CC-10) and Shop Creek (SC-3) are 214 µg/L and 104 µg/L, respectively (Table 7), with storm flow concentrations being approximately 60 percent greater (Table 8). In Cottonwood Creek (CT-2), the long-term median annual base flow total phosphorus concentration is 84 µg/L; however, the long-term median storm flow concentration is approximately 160 percent greater. Soluble reactive phosphorus fractions for base flows in Cherry Creek and Shop Creek were approximately 78 percent and 70 percent, respectively, of the total phosphorus concentrations, while soluble reactive phosphorus fractions in Cottonwood Creek (CT-2) have been approximately 19 percent of total phosphorus concentrations.

Table 7: Comparison of base flow median annual total phosphorus and soluble reactive phosphorus concentrations for Sites CC-10, SC-3, and CT-2 from 1995 to 2007.

Year	CC-10		SC-3		CT-2	
	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)
1995	177	148	83	63	--	--
1996	145*	155*	77	70	100	78
1997	202	184	104	83	108	62
1998	264	229	78	71	105	66
1999	258	195	99	60	87	37
2000	284	195	156	125	87	24
2001	222	165	164	126	74	18
2002	193	147	160	125	72	11
2003	205	162	81	66	93	14
2004	214	154	163	105	81	8
2005	216	176	140	80	81	12
2006	157	134	128	63	64	7
2007	217	177	69	43	81	9
Median	**214**	**165**	**104**	**71**	**84**	**16**

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

Table 8: Comparison of storm flow median annual total phosphorus and soluble reactive phosphorus concentrations for Sites CC-10, SC-3, and CT-2 from 1995 to 2007.

Year	CC-10		SC-3		CT-2	
	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)
1995	181	161	122	95	--	--
1996	323	270	132	85	336	160
1997	402	316	175	74	391	221
1998	378	277	155	124	314	108
1999	348	247	141	112	118	58
2000	673	274	407	166	277	93
2001	293	172	227	84	209	33
2002	251	171	207	110	175	21
2003	365	171	197	134	204	35
2004	285	237	208	100	208	35
2005	354	187	190	129	175	26
2006	477	221	161	122	259	74
2007	366	195	167	78	230	27
Median	**354**	**221**	**175**	**110**	**220**	**47**

Base flow total phosphorus and soluble reactive phosphorus concentrations revealed no trends over time at Site CC-10 (Figures 19 and 20). At Site SC-3, base flow phosphorus concentrations for both total and SRP fractions, have exhibited a significant ($p < 0.05$) increasing trend over time (Figures 21 and 22). However, the increased variability in data since 1999 may have resulted in the significant trend. This may be an indication of potentially reduced effectiveness of the Shop Creek wetlands over time.

Both the total phosphorus and soluble reactive phosphorus concentrations reveal a significant ($p < 0.05$) decreasing trend at Site CT-2 (Figures 23 and 24) during base flow conditions. The observed decreasing trend and greatly reduced variability in soluble reactive phosphorus concentrations at Site CT-2 from 1995 to 2007 is the result of the effectiveness of the PRFs near the Perimeter Road and Peoria Street, along with habitat restoration on Cottonwood Creek. There appears to be a seasonal pattern in phosphorus concentration at all sites, which is not specifically addressed in the trend analysis.

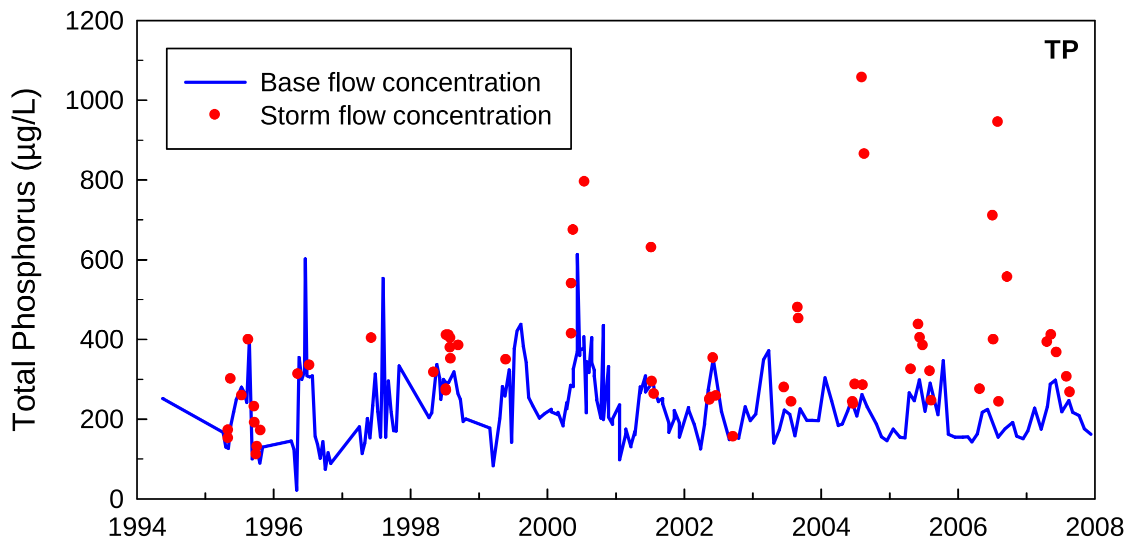

Figure 19: Base flow and storm flow total phosphorus concentrations measured in Site CC-10, 1994 to 2007.

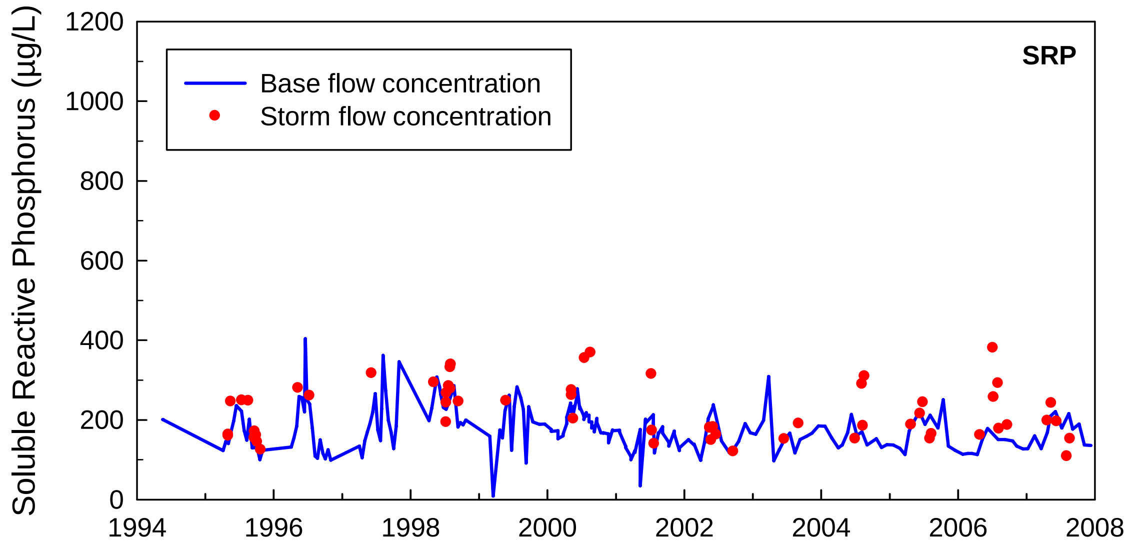

Figure 20: Base flow and storm flow soluble reactive phosphorus concentrations measured in Site CC-10, 1994 to 2007.

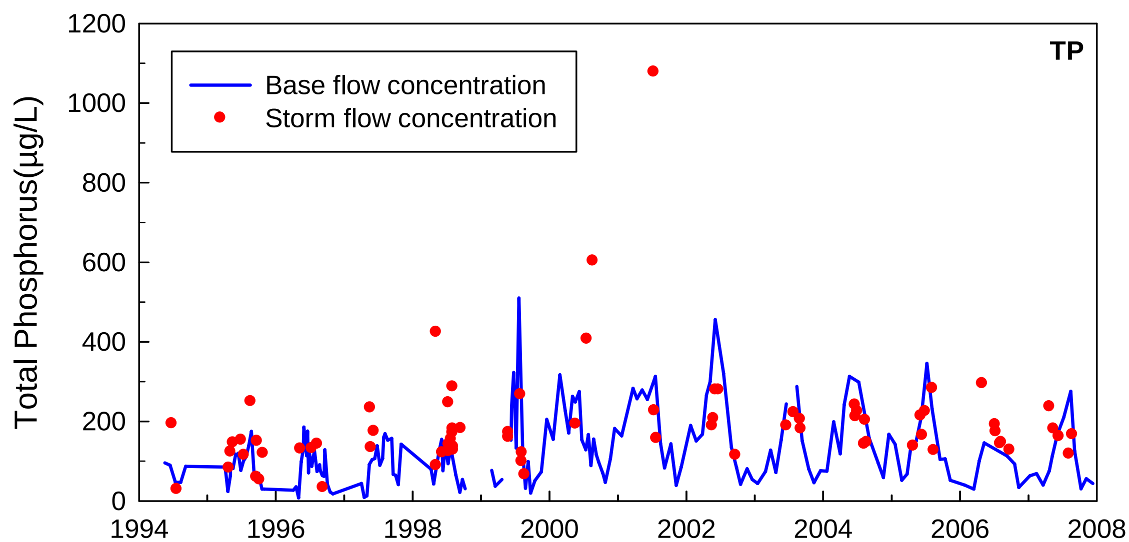

Figure 21: Base flow and storm flow total phosphorus concentrations measured in Site SC-3, 1994 to 2007.

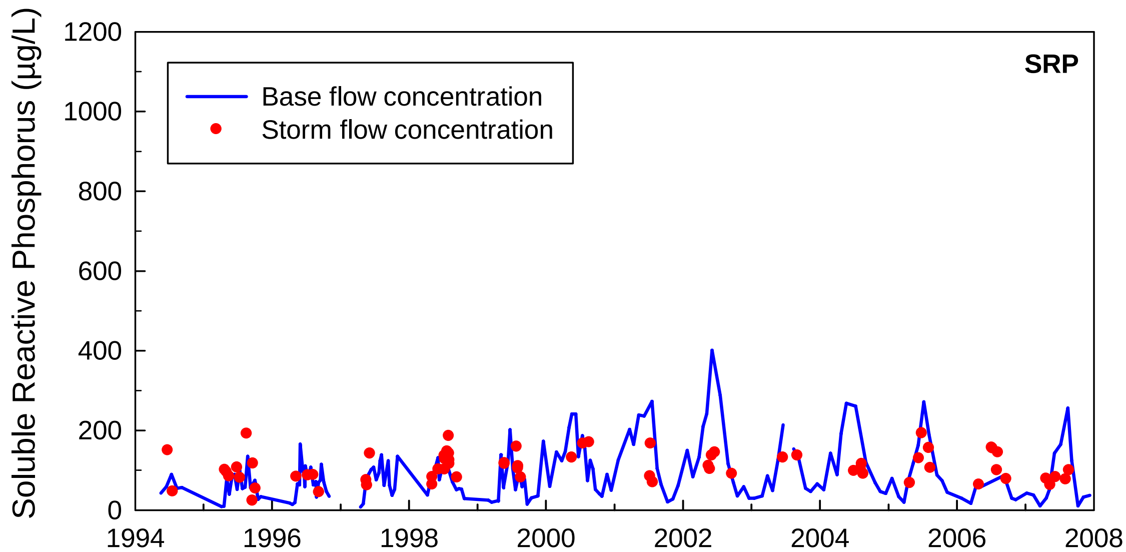

Figure 22: Base flow and storm flow soluble reactive phosphorus concentrations measured in Site SC-3, 1994 to 2007.

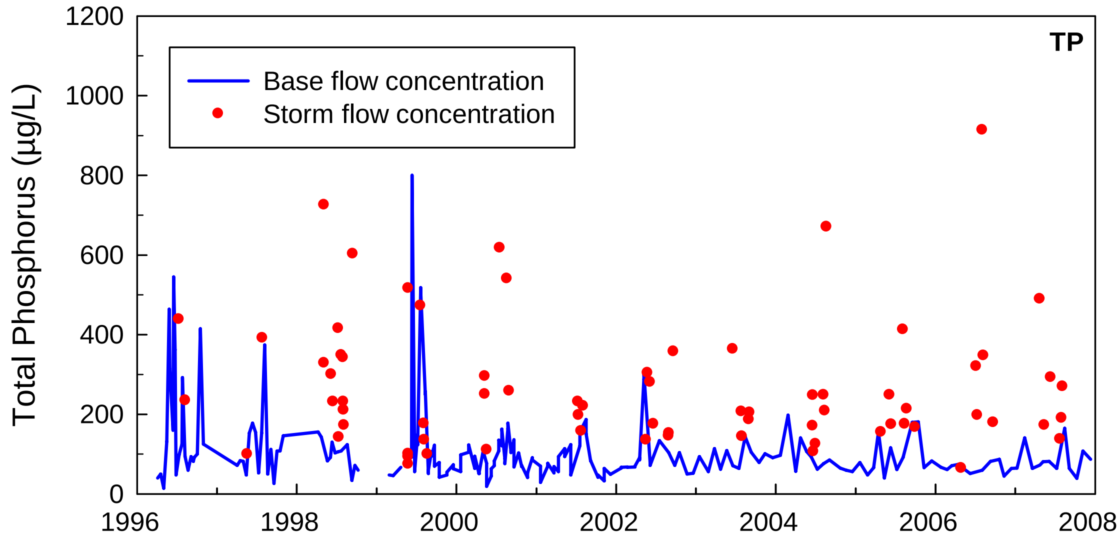

Figure 23: Base flow and storm flow total phosphorus concentrations measured in Site CT-2, 1996 to 2007.

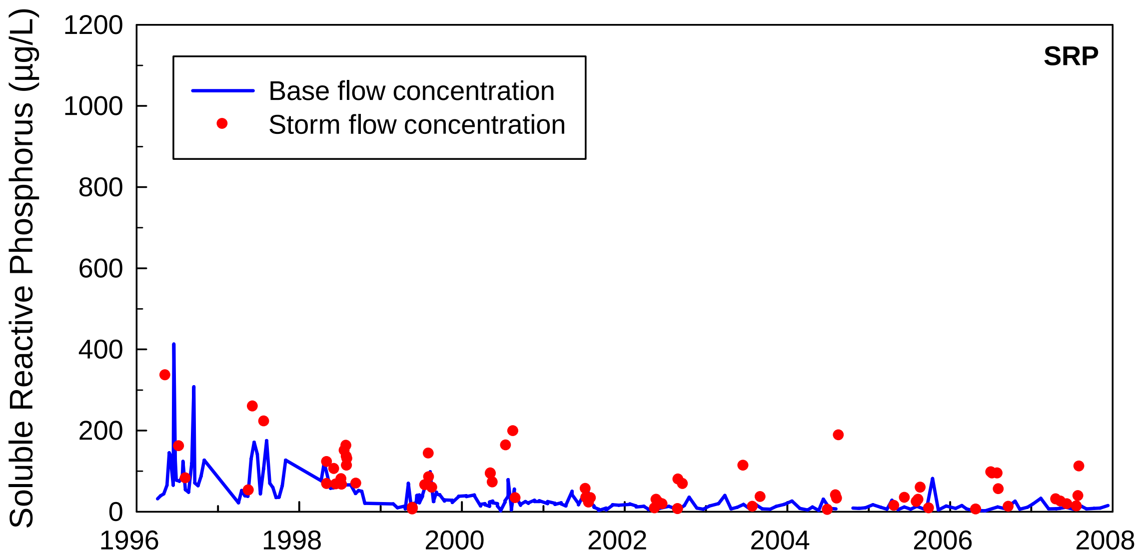

Figure 24: Base flow and storm flow soluble reactive phosphorus concentrations measured in Site CT-2, 1996 to 2007.

5.3.3 Long-Term Trends in Phosphorus Concentrations in Cherry Creek Reservoir Alluvium

Alluvial phosphorus data were obtained from JCHA for Site MW-9, and are used to estimate the alluvial phosphorus load component, as summarized in Appendix D (JCHA 2001 through 2008). Given the ability of alluvium to filter out particulates, total dissolved phosphorus was used as a surrogate to total phosphorus. Alluvial total dissolved phosphorus concentrations show a slight, but significant ($p < 0.05$), increasing trend over time (1994 – 2007) at Site MW-9 (Figure 25).

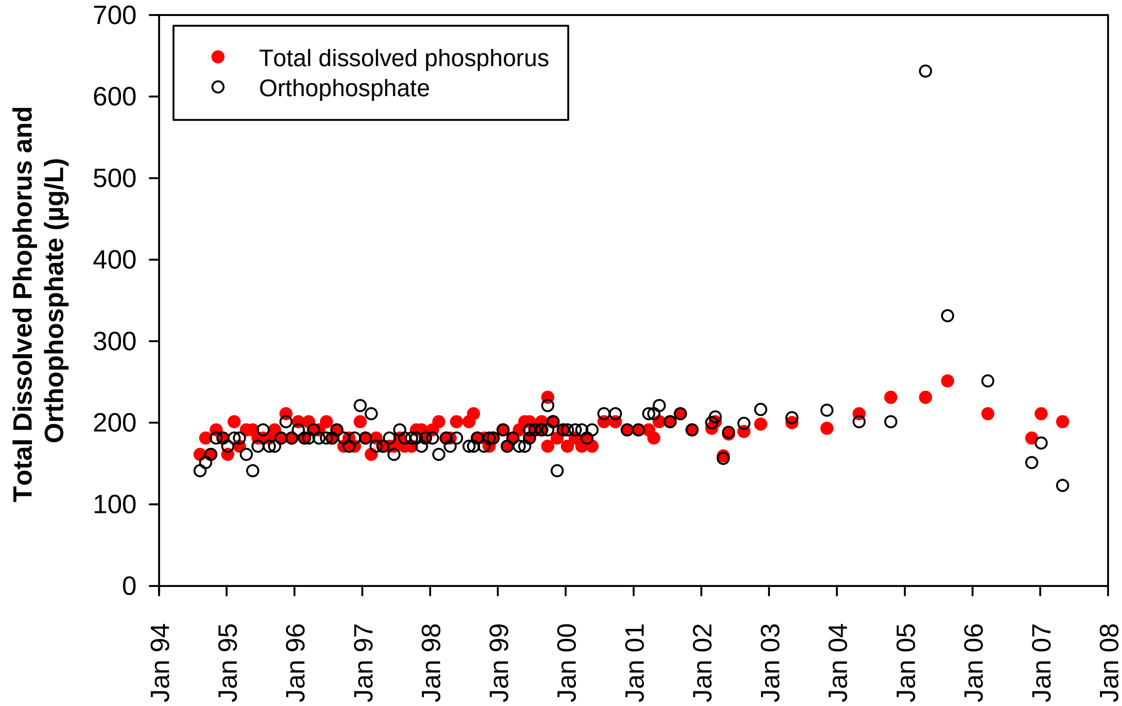

Figure 25: Total dissolved phosphorus and soluble reactive phosphorus concentrations measured at Site MW-9 (1994 to 2007).

5.4 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 (Goldman and Horne 1983). However, the release of phosphorus from sediment during anoxic water conditions is the most substantial component of internal loading, and has been previously estimated to be 4,000 pounds per year in Cherry Creek Reservoir (Nürnberg and LaZerte 2000; and LaZerte and Nürnberg 2000). Recent 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. (2005) 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 concentrated on phosphorus loading. In 2006, changes were made to the phosphorus loading methodology in response to comments from WQCD, with all historical loads being recalculated using the revised load methodology (Appendix D). 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.

5.4.1 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 for that site were categorized as storm flows. The greatest proportion (81 percent) of the total phosphorus load to the Reservoir was from Cherry Creek mainstem flows (16,025 lbs). Because Cherry Creek is monitored downstream of Shop Creek, the 117 lbs (<1 percent) contributed by Shop Creek has been subtracted from the total load calculated for Site CC-10. Cottonwood Creek accounted for 11 percent of the phosphorus load, or 2,133 lbs. In 2007, the total phosphorus load to Cherry Creek Reservoir from tributary streams was 18,275 lbs (Table 8).

5.4.2 Phosphorus Export from Reservoir Outflow

The total outflow from Cherry Creek Reservoir as measured by the USACE was 26,033 ac-ft in 2007 (Appendix D). Monthly total phosphorus data collected from Site CC-O near the dam outlet rather than the USGS gage was used to estimate the phosphorus export (8,042 lbs/yr) leaving the Reservoir in 2007 (Table 9).

Table 9: Normalized phosphorus loads and export (lbs/year) for Cherry Creek Reservoir, 1992 to 2007.

Year	Shop Creek	Cherry Creek	Cottonwood Creek	Stream & Ungaged Residual Load	Cherry Creek Alluvium	Direct Precipitation	External Load	Cherry Creek Outflow*	Net External Load	Flow-weighted TP (lbs/ac-ft)
1992	105	3,142	408	3,925	1,010	429	5,364	1,443	3,921	0.58
1993	69	1,524	179	1,773	1,027	314	3,114	928	2,186	0.53
1994	100	2,437	164	2,700	857	227	3,785	1,055	2,730	0.54
1995	73	2,251	1,402	4,160	1,015	561	5,736	1,434	4,302	0.49
1996	95	2,467	599	3,161	916	349	4,425	1,323	3,102	0.58
1997	145	3,110	884	4,139	1,033	487	5,659	1,599	4,060	0.54
1998	162	9,963	1,633	11,840	1,033	449	13,322	4,010	9,311	0.64
1999	--	11,788	1,314	16,167	1,033	471	17,672	6,759	10,913	0.64
2000	--	10,714	1,644	12,357	1,033	398	13,788	4,426	9,362	0.74
2001	--	5,642	1,820	7,707	1,033	359	9,099	4,697	4,402	0.53
2002	--	1,815	505	2,320	916	288	3,525	1,843	1,681	0.47
2003	--	6,337	974	7,934	1,033	423	9,390	4,673	4,717	0.63
2004	--	5,710	1,753	7,486	1,033	454	8,974	3,421	5,553	0.52
2005	--	7,843	1,502	9,345	1,033	346	10,725	3,644	7,080	0.58
2006	--	3,813	1,272	5,084	1,033	375	6,492	3,287	3,206	0.51
2007	--	16,142	2,133	18,408	1,033	331	19,772	8,042	11,730	0.67
Median	**100**	**4,727**	**1,293**	**6,285**	**1,033**	**386**	**7,733**	**3,354**	**4,352**	**0.56**

* In January 2007, the Cherry Creek Outflow site was relocated upstream to a location between the I-225 bridge and the concrete outlet structure.

5.4.3 Phosphorus Load from Precipitation

In 2007, a total of 14.8 inches of precipitation was recorded at the KAPA meteorological station located at Centennial Airport. When scaled to the areal extent of the Reservoir (852 acres), precipitation accounted for a total of 1,049 acre-feet of inflow to the Reservoir. The long-term (1995 to 2005) median total phosphorus concentration of 116 µg/L was used to calculate the 2007 annual total phosphorus load of 331 lbs/yr. This long-term median TP 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 1987 to 2007 is 386 lbs (Table 10).

Table 10:
Phosphorus loading into Cherry Creek Reservoir from precipitation, 1987 to 2007.

Year	Precipitation (inches/yr)	Total Phosphorus Load (lbs/yr)
1987	18.1	405
1988	23.3	522
1989	13.0	292
1990	15.2	341
1991	16.5	370
1992	18.5	414
1993	15.6	349
1994	11.0	245
1995	25.1	561
1996	14.6	328
1997	21.7	487
1998	20.0	449
1999	21.0	471
2000	17.8	398
2001	16.0	359
2002	12.9	288
2003	18.9	423
2004	20.3	454
2005	15.5	346
2006	16.7	376
2007	14.8	331
Median	**16.7**	**376**

5.4.4 Phosphorus Load from Alluvium

In 2007, the alluvial inflow quantity was set as a constant 2000 ac-ft/yr with the rationale being summarized in Appendix D. The long-term (1994 to 2006) 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 2007 (Table 9).

5.4.5 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.

In 2007, the USACE calculated inflow was 29,586 ac-ft/yr, while the GEI calculated stream inflow was 22,875 ac-ft/yr (Appendix D). To compare these two inflow values, the USACE inflow was adjusted for precipitation (1,049 ac-ft/yr) and alluvial inflows (2,000 ac-ft/yr), which resulted in an adjusted USACE inflow of 26,537 ac-ft/yr. The difference between the adjusted USACE inflow and the GEI stream inflow was 3,662 ac-ft of water. A majority of this residual water volume (3,487 ac-ft) was reapportioned to both Cherry Creek and Cottonwood Creek, while 175 ac-ft were categorized as Ungaged Residual Flow in April 2007. Flow-weighted total phosphorus concentrations for Cherry Creek and Cottonwood Creek were used to calculate the combined reapportioned load of 2,341 lbs. A flow-weighted concentration based on three external sources of flow and loads (i.e., GEI stream inflow, alluvial inflow, and precipitation) was used to estimate the Ungaged Residual Load of 133 lbs for April 2007.

Following the water balance normalization process, flow from the two tributary streams and the ungaged residual component accounted for a total phosphorus load of 18,408 lbs to the Reservoir in 2007 (Table 9). The alluvial inflow contributed 1,033 lbs of phosphorus, with precipitation events contributing 331 lbs to the Reservoir. The total external load of phosphorus to the Reservoir in 2007 was 19,772 lbs (Figure 26), which exceeds the TMAL of 14,270 lbs/yr.

The Reservoir outflow phosphorus load was estimated to be 8,042 lbs. Consistent with the TMAL, these values do not include any estimates of internal phosphorus loads. The flow-weighted total phosphorus concentration for all external sources of inflow to the Reservoir is 0.67 lbs/ac-ft and the flow-weighted export concentration for the Reservoir is 0.31 lbs/ac-ft. The difference of 0.36 lbs/ac-ft was retained by the Reservoir. The net external phosphorus load to the Reservoir was 11,730 lbs in 2007.

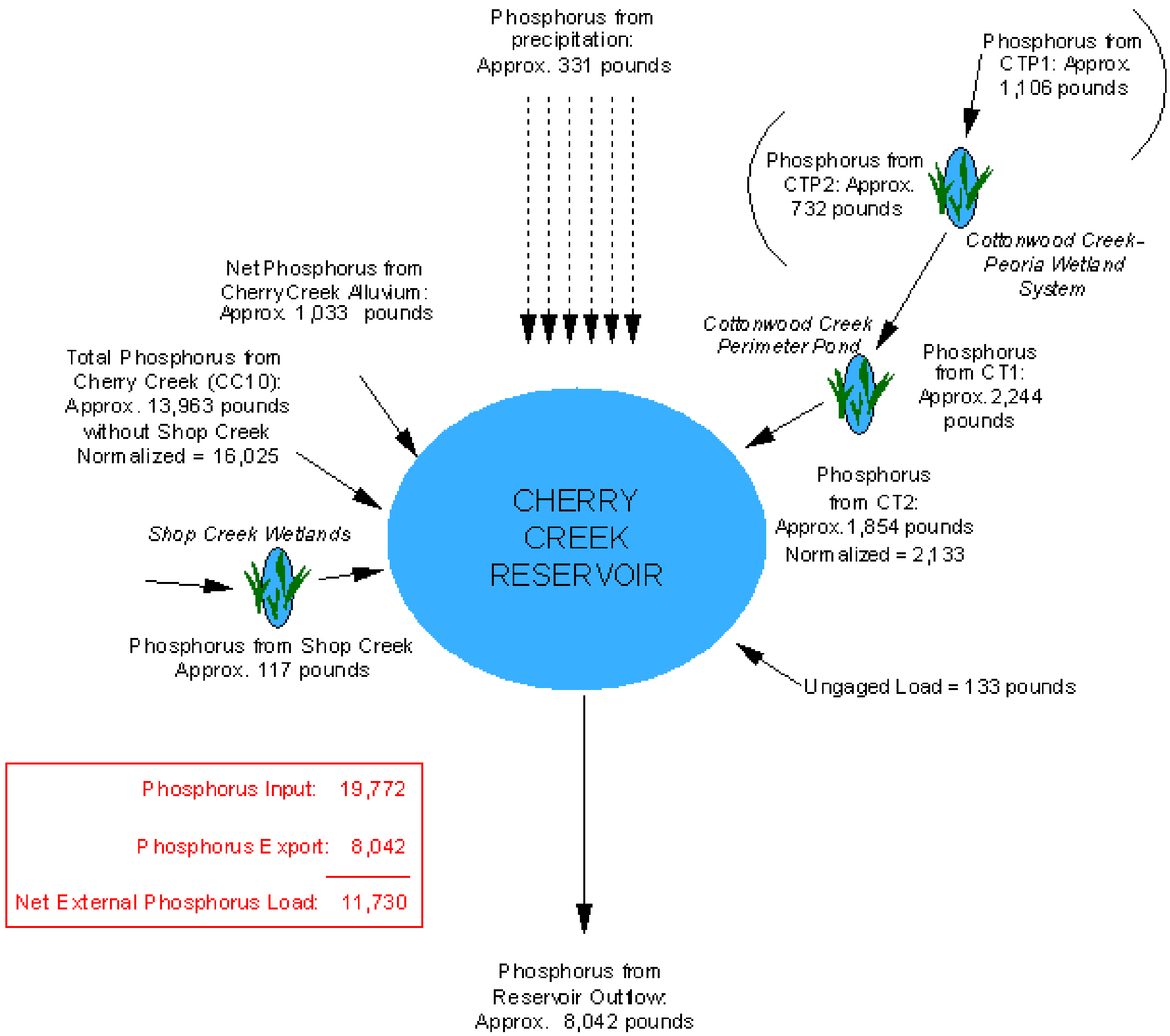

Figure 26: Mass balance diagram of phosphorus loading in Cherry Creek Reservoir, 2007.

5.5 Effectiveness of Pollutant Reduction Facilities

5.5.1 Cottonwood Creek Peoria Pond

The effectiveness of the Cottonwood Creek Peoria Pond is gaged by monitoring the concentrations of phosphorus and total suspended solids (TSS), and the loading of phosphorus upstream and downstream of the facility. Notably, the loads 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. In 2007, the mean total phosphorus concentration downstream of the PRF was considerably less than the upstream concentration (Table 11). A similar relationship was observed for total suspended solids (Table 11). The water budget for the Peoria Pond also showed a slight decrease in flow (~250 ac-ft/yr), and when combined with the change in phosphorus content, revealed a 34 percent decrease downstream of the PRF. This reduction in load resulted in a 2 percent decrease in the external load at the Reservoir. The flow-weighted total phosphorus concentration upstream and downstream of the PRF was 0.48 lbs/ac-ft to 0.36 lbs/ac-ft, respectively, which indicates a high efficiency in removing phosphorus from flow.

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 2007.

Parameter	Year	Sampling Sites		Difference	Percent Change Downstream
		CT-P1	CT-P2		
Mean Total Phosphorus Concentration (µg/L) (base flow and storm flow samples combined)	2002	138	152	14	10
	2003	101	92	-9	-9
	2004	142	123	-19	-13
	2005	92	101	9	10
	2006	132	133	1	1
	2007	179	125	-54	-30
	Mean	**131**	**121**	**-10**	**-5**
Mean Total Suspended Solids (mg/L)	2002	66	79	13	20
	2003	31	34	3	10
	2004	87	53	-34	-39
	2005	47	51	4	9
	2006	38	47	9	24
	2007	79	42	-37	-47
	Mean	**58**	**51**	**-7**	**-4**
Total Phosphorus Load (pounds)	2002	142	89	-53	-37
	2003	628	620	-8	-1
	2004	839	897	58	7
	2005	621	633	12	2
	2006	705	533	-172	-24
	2007	1106	732	-374	-34
	Mean	**674**	**584**	**-90**	**-15**

5.5.2 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). In 2007, the mean concentration of total phosphorus greatly decreased from 213 to 148 µg/L after passing through the PRF, representing a 31 percent reduction in phosphorus concentration (Table 12). The mean concentration of TSS also decreased, from 81 mg/L upstream to 71 mg/L downstream of the PRF. The total phosphorus load decreased downstream of the pond by 17 percent, with the flow-weighted concentration showing a reduction from 0.59 lbs/ac-ft to 0.43 lbs/ac-ft. This load reduction similarly resulted in a 2 percent decrease in the external load at the Reservoir.

This PRF is effective in reducing the overall hydrologic load through this section of Cottonwood Creek, by evapotranspiration or percolation, and appears to be more efficient in removing phosphorus from stream flows than the Peoria Pond. The reduction in the flow-weighted concentration indicates that this PRF continues to be effective in reducing total phosphorus loads to Cherry Creek Reservoir.

In past years, greater flow-weighted concentrations observed at Site CT-1, when compared to Site CT-P2, indicated potential loading from stream channel erosion or additional inputs from Lonetree Creek, which is a tributary to Cottonwood Creek upstream of Site CT-1. In an effort to reduce phosphorus loading in the Reservoir from the stream itself, channel reconstruction was conducted on Cottonwood Creek downstream of the Cottonwood Creek – Peoria wetland system in 2004, with completion of Phase II pending in 2008. While the channel reconstruction or inputs from Lonetree Creek may have accounted for the increased loads observed between these two existing PRFs, the flow-weighted concentration downstream of the Cottonwood Creek Perimeter Pond indicates that this PRF continues to be effective in reducing the total phosphorus load to Cherry Creek Reservoir.

5.5.3 Shop Creek and Quincy Drainage Pond

Historical sampling of the PRFs on Shop Creek and Quincy Drainage indicate efficient phosphorus removal in these streams. Shop Creek was monitored for 10 years from 1990 to 2000 at sites upstream and downstream of PRF stations (detention pond and wetlands). The Shop Creek PRF had an average annual phosphorus load reduction of 173 lbs, with an average of 63 percent reduction in load. Quincy Drainage was even more efficient with 99 percent reduction in loads over the period of 1996 to 1999. The average phosphorus load reduction was 138 lbs. GEI has not monitored the Shop Creek and Quincy Drainage PRFs for effectiveness since 2000. Based on past data, loads from these two drainages averaged less than 1 percent of total external load to the Reservoir.

Table 12: Historical total phosphorus and total suspended solids concentrations and total phosphorus loads upstream and downstream of the Cottonwood Creek Perimeter Pond (1997-2007).

Parameter	Year	Sampling Sites		Difference	Percent Change Downstream
		CT-1	CT-2		
Average Total Phosphorus Concentration (µg/L) (baseflow and storm samples combined)	1997	200	133	-67	-34
	1998	289	210	-79	-27
	1999	158	157	-1	-1
	2000	187	149	-38	-20
	2001	165	114	-51	-31
	2002	146	143	-3	-2
	2003	144	129	-15	-10
	2004	212	151	-61	-29
	2005	180	142	-38	-21
	2006	170	161	-9	-5
	2007	213	148	-65	-31
	Mean	**188**	**149**	**-39**	**-19**
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	130	79	-51	-39
	2003	84	62	-22	-26
	2004	155	77	-78	-50
	2005	126	66	-60	-48
	2006	86	95	9	10
	2007	81	71	-10	-12
	Mean	**147**	**76**	**-71**	**-40**
Loading of Total Phosphorus (pounds)	1997	2,359	614	-1745	74
	1998	1,556	1,070	-486	31
	1999	1,140	984	-156	14
	2000	1,617	1,057	-560	35
	2001	1,181	1,212	31	-3
	2002	636	801	165	-26
	2003	1,356	864	-492	36
	2004	2,023	1,433	-590	29
	2005	1,575	1,725	150	-10
	2006	1,924	1,220	-704	37
	2007	2,244	1,854	-390	17
	Mean	**1,601**	**1,167**	**-434**	**-21**

6.0 Summary and Conclusions

6.1 Transparency

The period in late May through June, and August 2007, represented a time when Reservoir water clarity was at its best. The whole-reservoir mean Secchi depth was 1.07 m during the July-to-September period. This value represents the deepest mean value since 1998, and is similar to the long-term mean value (Table 13).

Table 13: Water quality and total phosphorus loads for Cherry Creek Reservoir, (1992 to 2007). Shaded cell indicates value meets the respective standard, goal, or phased-TMAL value.

Year	Jul-Sep Secchi Depth (m)	Jul-Sep Total Phosphorus (µg/L)	Jul-Sep Total Nitrogen (µg/L)	Jul-Sep Chlorophyll *a* (µg/L)	USACE Inflow (ac-ft)	External Phosphorus Load (lbs/yr)	Flow Weighted Concentration (lbs/ac-ft)
1992	0.95	66	970	17.4	9,210	5,364	0.58
1993	1.20	62	826	14.4	5,851	3,114	0.53
1994	1.10	59	1,144	15.4	6,998	3,785	0.54
1995	1.62	48	913	15.6	11,788	5,736	0.49
1996	1.60	62	944	20.5	7,654	4,425	0.58
1997	1.00	96	1,120	22.3	10,391	5,659	0.54
1998	1.09	89	880	26.5	20,902	13,322	0.64
1999	1.03	81	753	28.9	27,604	17,672	0.64
2000	0.96	81	802	25.2	18,611	13,788	0.74
2001	0.75	87	741	26.1	17,246	9,099	0.53
2002	0.91	74	858	18.8	7,511	3,525	0.47
2003	0.86	90	1,121	25.8	14,953	9,390	0.63
2004	0.85	102	977	18.4	17,203	8,974	0.52
2005	0.97	116	990	17.1	18,534	10,725	0.58
2006	1.05	87	914	14.7	12,799	6,492	0.51
2007	1.07	118	716	12.6	29,586	19,772	0.67
Mean	**1.06**	**82**	**917**	**20.0**	**14,803**	**8,803**	**0.57**
Median	**1.02**	**84**	**914**	**18.6**	**13,876**	**7,733**	**0.56**

6.2 Temperature and Dissolved Oxygen

The Reservoir was well mixed and oxygenated from March to early May 2007. From early June through July the Reservoir showed signs of thermal stratification, which was supported by evidence of an oxycline throughout the Reservoir. During this period, dissolved oxygen concentrations were often less than 5 mg/L at depths greater than 4 m. Microbial mediated anoxia may create favorable conditions for nutrient loading via the sediments. Soluble reactive phosphorus concentrations observed at depth also provide evidence of internal nutrient loading during this low oxygen period. Dissolved oxygen profiles were also compared to the basic standards table value for Class 1 Warm Water lakes and reservoirs. As a conservative estimate, the mean dissolved oxygen concentration for the 0 to 6 m water layer, was computed for each sampling event and revealed that the Reservoir met the standard.

6.3 Total Phosphorus

Total phosphorus concentrations during the July to September period ranged from 81 to 155 µg/L, with a seasonal mean of 118 µg/L (Table 12). Since 1987, the goal of 40 µg/L total phosphorus has only been met once in 1989.

6.4 Chlorophyll *a*

Chlorophyll *a* concentrations ranged from 3.3 µg/L in early October to 49.5 µg/L in January, with the annual mean chlorophyll *a* concentration being 14.2 µg/L. The seasonal (July-to-September) mean chlorophyll *a* concentration was 12.6 µg/L (Table 12), and is the second consecutive year that the Reservoir met the chlorophyll *a* standard of 15 µg/L.

6.5 Phosphorus Loading

The total inflow of gaged tributary streams and ungaged surface water flows was 26,537 ac-ft/yr and contributed 18,408 lbs of phosphorus to the Reservoir. Annual precipitation accounted for 1,049 ac-ft of water and contributed 331 lbs of phosphorus, while the alluvial inflow was assumed to be a constant 2000 ac-ft/yr, and contributed 1,033 lbs of phosphorus to the Reservoir.

Combined, the total external load to the Reservoir was 19,772 lbs in 2007, which exceeded the phased Total Maximum Annual Load (TMAL) of 14,270 lbs/yr specified in Control Regulation No. 72. The 2007 external load is the largest estimated phosphorus load since monitoring began, although the flow-weighted total phosphorus concentration of 0.67 lbs/ac-ft (246 µg/L) was within the range of past observations.

6.6 Pollutant Reduction Facility Effectiveness

The Cottonwood Creek Peoria Pond PRF was effective in removing 374 pounds or 34 percent of the phosphorus load from Cottonwood Creek at the pond. This load reduction is primarily the result of the PRF’s efficiency in reducing outflow phosphorus concentrations as well as reducing the water load through the system. Historically, this PRF has not been as efficient as the Perimeter Pond in removing phosphorus or suspended solids from the surface flows, though its ability to reduce the water load directly reduces the phosphorus load. The Cottonwood Creek Perimeter Pond was effective in reducing the total phosphorus load to the Reservoir by 390 pounds or 17 percent in 2007. The effectiveness of the PRF lies in both reducing the water load through the system and removing phosphorus from the stream flows. The flow-weighted phosphorus concentration decreased by 27 percent from upstream to downstream of the system. When combined, the Perimeter Pond and Peoria Pond PRF's accounted for a 4 percent reduction in the total external phosphorus load to the Reservoir in 2007.

In past years, greater flow-weighted phosphorus concentrations observed at Site CT-1, when compared to Site CT-P2, indicated potential loading from stream channel erosion or additional inputs from Lonetree Creek, which is a tributary to Cottonwood Creek upstream of Site CT-1. In an effort to reduce phosphorus loading to the Reservoir from the stream itself, channel reconstruction was conducted on Cottonwood Creek downstream of the Cottonwood Creek - Peoria wetland system in 2004, with completion of Phase II in 2008. While the channel reconstruction or inputs from Lonetree Creek may have accounted for the increased loads observed between these two existing PRFs, the flow-weighted concentration downstream of the Cottonwood Creek Perimeter Pond indicates that this PRF continues to be effective in reducing the total phosphorus load to Cherry Creek Reservoir.

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Appendix A

Cherry Creek Reservoir Sampling and Analysis Plan

CHERRY CREEK RESERVOIR

AQUATIC BIOLOGICAL AND NUTRIENT SAMPLING AND LABORATORY ANALYSES

SAMPLING, ANALYSIS, AND QUALITY ASSURANCE WORK PLAN

MAY 2003

Submitted to:

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TABLE OF CONTENTS

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 recent legislation, the Board was reconstituted in 2001 and now includes Arapahoe and Douglas Counties, 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. This 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 stormwater, 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).

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 2003. This Sampling and Analysis Plan sets out 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 nitrogen and phosphorus 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 pounds of phosphorus entering Cherry Creek Reservoir from streams and precipitation and leaving the reservoir through the outlet.

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.

This Sampling and Analysis Plan presents the proposed 2003 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.

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.

Project Manager

The Project Manager for the aquatic biological and field sampling portions of the study is responsible for fiscal oversight and technical management of the project and for ensuring that all work is conducted in accordance with 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, and whenever the data quality objective of 100% completeness is not met.

- Maintain a central file, which contains or indicates the location of all documents relating to this project.

- Review and update of this Sampling and Analysis Plan, as needed.

- Coordinate with the Authority, the WQCD, and the Authority's other consultants to ensure compliance with the Cherry Creek Reservoir Control Regulation No. 72.

Quality Assurance Manager

Quality Assurance oversight will be provided by a qualified individual with specific education and experience in water quality sampling and analysis. 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.

Analytical and Biological Laboratory Managers

The Analytical Laboratory Manager shall ensure that all water quality 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.

The Biological Laboratory Manager shall ensure that all biological samples are analyzed in a technically sound and timely manner. The Biological 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 Biological 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.

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 Project Manager. The Sampling Crew shall be responsible for following all procedures for sample collection, including complete and accurate documentation.

AQUATIC BIOLOGICAL AND NUTRIENT SAMPLING

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).

Cherry Creek Reservoir

CCR-1 This site is also called the Dam site and corresponds to the northwest trident when partitioning the lake by estimations of volume.

CCR-2 This site is also called the Swim Beach site and corresponds to the northeast trident when partitioning the lake by estimations of volume.

CCR-3 This site is also called the Inlet site and corresponds to the south trident when partitioning the lake by estimations of volume.

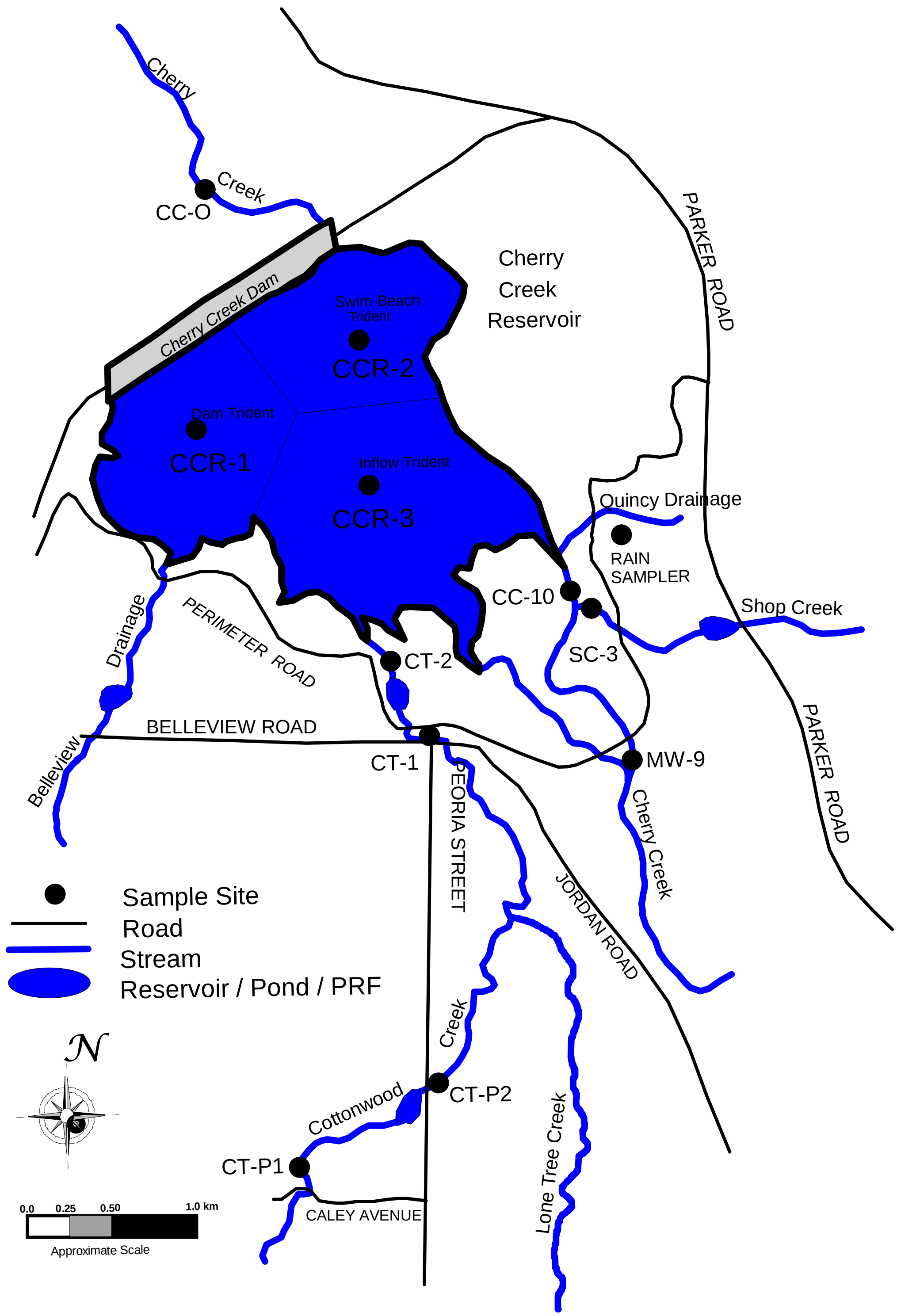

Figure 1: Sampling sites on Cherry Creek Reservoir and selected streams.

Stream Monitoring Sites

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 measures loads from Cherry Creek and Shop Creek that enter the reservoir.

CC-O This site is on Cherry Creek downstream of Cherry Creek Reservoir near the USGS gaging station within the Kennedy Golf Course.

Cottonwood Creek

CT-2 This site is immediately downstream of the phosphorus control facility (PRF), upstream of Cherry Creek Reservoir (i.e., Perimeter Road Pond). Although this site also measures the performance of the Perimeter Road Pond PRF, it is included in the reservoir portion of the effort since it is needed to measure loads to the reservoir from Cottonwood Creek.

PRF Monitoring Sites

Shop Creek

SC-3 This site is downstream of the Shop Creek detention pond and wetland complex above the confluence with Cherry Creek mainstem, and downstream of the Perimeter Road.

Cottonwood Creek

CT-P1 This site is located on Cottonwood Creek upstream of the new detention pond PRF at Peoria Street.

CT-P2 This site is located on Cottonwood Creek just downstream of Peoria Street Pond PRF and in the upper end of the streambank stabilization reach.

CT-1 This site is on Cottonwood Creek just downstream of Belleview Avenue, upstream of the Cherry Creek Park Perimeter Road. Note that Site CT-2 is included in the reservoir monitoring requirements.

<u>Precipitation Sampling Site</u>

This site is located near the Quincy Drainage, upstream of the Perimeter Road. The sampler consists of a clean, inverted plastic trash can lid used to funnel rain into a one-gallon container.

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 analysis.

Analyte	Standard Methods*	Other Method Designations	Recommended Hold Times	Detection Limit
Manual Analyses				
pH		Denver Instrument pH/ATC Ag/AgCl combination electrode	24 hrs.	
Alkalinity	2320 B		24 hrs.	2 mg/$CaCO_3$/L
Hardness	2340 C (modified)	HACH Method 8266, ManVer 2 Buret Titration	24 hrs.	2 mg/$CaCO_3$/L
Total Suspended Solids	2540 D		7 days	4 mg/L
Total Volatile Suspended Solids	2540 E		7 days	4 mg/L
Chlorophyll	10200 H (modified)	Hot Ethanol Extraction	-24 hrs. before filtration	0.1 mg/m^3
Nutrient Analyses				
Orthophosphate	4500-P G	QuickChem 10-115-01-1-T	48 hrs.	3 µg/L
Total Phosphorus	4500-P G	QuickChem 10-115-01-1-U, with manual digestion	-24 hrs. before digestion	2 µg/L
Nitrate + Nitrite	4500-NO3 I	QuickChem 10-107-04-1-B	48 hrs.	5 µg/L
Total Nitrogen	4500-N B (modified)		-24 hrs. before digestion; -7 days after digestion	4 µg/L
Ammonia	none	QuickChem 10-107-06-3-D	24 hrs.	3 µg/L
Biological Analyses				
Phytoplankton	University of Colorado, Center for Limnology			

* From *Standard Methods for Examination of Water and Waste Water* (20th Edition).

Sampling Schedule

Reservoir Sampling

The general sampling schedule includes regular sampling trips to the reservoir at varying frequency over the annual sampling period, as outlined below. Sampling in our winter months (November - February) will depend on ice conditions and safety concerns.

TABLE 2: Reservoir Sampling Schedule

Sampling Period	Frequency	Trips/Period
January to April (not February)	Monthly	3
May to September	Every 2 Weeks	11
October to November (not December)	Monthly	2
	Total	16

Stream Sampling

Standard sampling is conducted monthly concurrent with the regular reservoir sampling trips when possible to generally provide information during non-storm event periods, corresponding to the low-flow ambient samples collected in earlier studies.

TABLE 3: Stream Sampling Schedule

Sampling Period	Frequency	Trips/Period
January to December	Monthly	12
	Total	12

Representative Storm Event Sampling

There are six stream sites for storm event sampling(i.e., S-3, CC-10, CT-1, CT-2, CT-P1, and CT-P2). 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..

Precipitation Sampling

Precipitation samples are to be collected after “significant” 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 insignificant amounts of precipitation contaminating the sample by allowing “dry-fall” to be washed into the sampler between significant events.

Field Methodologies

Reservoir Sampling

Transparency

Transparency shall be determined using a Secchi disk and a combined-deck photometer. The Secchi reading would be taken from the shady side of the boat. If this is not possible, sunglasses or other shading will be used to reduce glare. The disk is lowered slowly 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.

A second method to measure the depth of the euphotic zone is to determine the depth at which 1% of the light penetrates the water column. This is considered the point at which, on average, light no longer can sustain photosynthesis in excess of oxygen consumption from respiration (Goldman and Horne 1983). This is accomplished by using a double-deck photometer. One photocell remains on the surface, and the other is lowered into the water on the sunny side of the boat. Both photocells are attached to a data logger, which records the amount of light in micromoles per second per square meter. The underwater photocell is lowered until the value displayed on the data logger is 1% of the value of the surface photocell, and then the depth is recorded.

Depth Profile Measurements

Measurements for dissolved oxygen, temperature, conductivity, and pH shall be taken at 1 m intervals using a YSI meter, Model # 600XL multi-probe meter. This meter shall be calibrated at the C&A Laboratory prior to each sampling episode to ensure accurate readings. To determine maximum depth, a Secchi disk will be lowered until it reaches the bottom. This reading will be taken on the opposite side of the boat from where water samples are being taken to minimize chances of sample contamination from the sediment. Profile measurements are taken no deeper than 0.5 m off the bottom to minimize potential contamination of the probes.

Water Samples

A primary task is sampling of water for nutrient and biology analyses. An upper-reservoir composite sample shall be taken at each of the three reservoir sites, kept separate for each site, and analyzed individually for nutrients and chlorophyll. A composite comprised of equal contributed aliquots collected with a vertical Van Dorn water sampler (approximately 3 L) at 1 m increments beginning at the surface and continuing to the 3 m depth (the upper 3 m of the reservoir represents 71% of the lake volume).

Samples are collected using a vertical Van Dorn sampler (3 L volume) by lowering to the appropriate depth (as outlined above). A "messenger" is sent to trip the sampler, and the water is brought to the boat and transferred to a clean plastic bucket for splitting into aliquots, as described above. The sampler is rinsed thoroughly with lake water between samples and between sites. Aliquots are taken from the photic composite for chemical analyses consisting of three 4-L just (two for chlorophyll and one for nutrients).

Water sample depth profile sampling is also conducted at Site CCR-2 in the deepest area in the reservoir. At this site, additional water samples shall be obtained at the 4, 5, 6, and 7 m depths. The last sample (7 m) would be collected roughly 1 m off the bottom, to minimize disturbance of bottom sediments during sampling. With variation in reservoir elevation throughout the year, it may not be possible to actually collect a sample at the 7 m depth every sampling episode. Samples are collected using a vertical Van Dorn sampler (3 L volume). The sampler is lowered to the appropriate depth (as outlined above). A "messenger" is sent to trip the sampler, and the water is brought to the boat and transferred to a clean bucket for splitting into aliquots, as described above. The sampler is rinsed thoroughly with lake water between samples and between sites.

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

TABLE 4: Samples per Station/Sampling Episode

Location		Photic Composite	1-m Increment Depth Samples
Dam	(CCR-1)	1	0
Swim Beach	(CCR-2)	1	4
Inflow	(CCR-3)	1	0
Total Samples/Sample Episode		3	4
Grand Total		7	

Water Quality Analyses

1. Nutrients, alkalinity, hardness, and pH analyses conducted in all reservoir water samples.

2. Chlorophyll would be analyzed in the 3 m photic depth profile samples only from June - September, one set per month.

3. Phytoplankton would be sampled twice monthly from April - October, and monthly from November - March from the 0-3 m water composite samples.

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

Stream Sampling

One sample shall be collected from each of the stream sampling sites during the sampling period, when there is sufficient flow. Samples shall be taken as mid-stream mid-depth grab samples with a polyethylene scoop and composited in a 5-gallon plastic bucket. Aliquots shall be taken from the composite for chemical analyses consisting of two 4-L jugs for analysis of parameters, as listed in Table 5.

During these sampling episodes, water was collected from each of the seven stream sampling sites (sites on tributary streams and on Cherry Creek downstream of the reservoir) and analyzed for nutrients and suspended solids. No samples were collected at Site CC-O during January, February, October, and December due to lack of water. With the exception of Site SC-3 in July, flows were sufficient at each tributary site through the year to obtain all scheduled samples. Two samples were collected for chemical and suspended solids analysis from each of the stream sampling sites and consisted of a mid-stream, mid-column grab sample using two 1 L bottles. After collecting water samples, dissolved oxygen, temperature, conductivity, pH, and oxidation-reduction potential readings were taken at each stream site. Readings were taken with a YSI meter, model #600 XL multi-probe meter.

Automatic Sampler

Each stream sampling station upstream of the reservoir also contains an Authority-owned ISCO flow meter and sampling device, which is powered by a 12-volt battery. The flow meter is a pressure transducer that measures stream water level. Rating curves were 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. The Authority has developed such a relationship for each site over the years. Since stage-discharge relationships can change over the years, the relationship is calibrated annually using a flow meter to take stream flow measurements three to four times per year at a range of flows. These data shall be combined with previous data to validate and modify the stage-discharge relationship for that site.

Water level data are stored in the ISCO sampler and must be downloaded to calibrate the station. Downloading of the data shall occur at least monthly to minimize the risk of a bad battery or other power failure resulting in a loss of data. The flow data and stage-discharge rating curves shall be checked throughout the year by comparing calculated flow estimates to actual flow measurements taken in the field with a flowmeter. Flow at time of sampling shall be calculated using stage-discharge relationships and is used to develop the flow-to-phosphorus relationship necessary to calculate daily loads (which are totaled for monthly and annual loads). The Corps is also contacted and daily precipitation and inflows/outflows from the reservoir obtained.

Storm Event Sampling

Samples from stormwater flow events are collected with ISCO automatic samplers, which collects samples when the water reaches a pre-set level. The level is determined by analyzing annual hydrographs from each stream and determining storm levels. When the pre-set level 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 pre-set 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 shall be composited (timed composite) and transferred to water jugs 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 taken. During the seasons in which no storm samples are taken, the storm samplers are disabled.

Precipitation Sampling

After each significant storm, the sample bottle shall be removed and taken to a qualified laboratory for analysis of total phosphorus, total nitrogen, and nitrite-nitrate. If sufficient volume remains, samples shall be tested for alkalinity, water hardness, pH, and suspended solids. The sampler shall be inspected and cleaned of any accumulations of insignificant precipitation on a weekly basis. This will prevent extraneous "dry fall" from being washed into the sampler between significant storm events.

Field-Related Quality Assurance/Quality Control

To ensure data quality, a number of quality assurance checks will be used. During each standard sampling episode, 1-split from the reservoir and 1-split from the stream (i.e., 28 total samples) shall be shipped to CU laboratory for analysis.

Field sampling quality control will consist of the use of a field blank. This field blank shall contain laboratory-grade deionized water that will be carried through the entire sampling episode. The cap of this jug will be removed at a particular site and left open during the regular sampling effort, after which time the cap will be replaced. One field blank will be used for every sampling trip. The field blanks and trip duplicates will be analyzed for the same parameters as a routine sample and later compared to samples analyzed by a qualified laboratory to provide QA/QC checks. Chain of custody procedures will be observed during the field sampling and delivery of samples to a qualified laboratory and to the CU laboratory.

LABORATORY PROCEDURES

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 below.

TABLE 5: List of Analytes by Sample Depth

3-m Photic Composite Samples	1-m Increment Depth Samples	Stream Samples Precipitation Samples
pH, Conductivity, and Temperature	TP, TDP, SRP	TD, TDP, SRP
Total Phosphorus (TP), Total Dissolved Phosphorus (TDP), and Soluble Reactive Phosphorus (SRP)	TN, TDN, NO_3+NO_2, Ammonia	TN, TDN, NO_3+NO_2, Ammonia
Total Nitrogen (TN, Total Dissolved Nitrogen (TDN), NO_3+NO_2, and Ammonia		Total Suspended Solids (TSS)/ Total Volatile Suspended Solids (TVSS) (not on precipitation)
Chlorophyll		
Phytoplankton (sampled on reservoir sampling dates: twice monthly from April - October, and monthly from November - March from the 0-3 m water composite samples)		

Biological Laboratory Analysis

Biological analyses for the samples collected in the study, as described above, will be conducted at a qualified laboratory and analyzed for chlorophyll *a*. The methods of these analyses, with appropriate QA/QC procedures shall be in accordance with the methods provided in Table 1. Phytoplankton samples will be sent to the Colorado University Center for Limnology to be analyzed by Dr. Jim Saunders.

DATA VERIFICATION, REDUCTION, AND REPORTING

Data verification shall be conducted to insure 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 ten 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.

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Appendix B

2007 Reservoir Water Quality Data

CCR-1 C&A Water Chemistry Data									
Analytical Detection Limits		2	2	2	2	2	2	3	
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)**
17/Jan/07	CCR-1 Photic	87	19	4	1159	584	5	41	37.9
20/Feb/07	CCR-1 Photic	74	23	17	1050	705	127	154	17.2
20/Mar/07	CCR-1 Photic	99	18	10	1161	509	2	13	38.8
26/Apr/07	CCR-1 Photic	76	22	10	979	496	<2	13	19.5
08/May/07	CCR-1 Photic	94	49	33	726	437	2	7	13.9
29/May/07	CCR-1 Photic	96	61	45	736	495	8	15	18.7
05/Jun/07	CCR-1 Photic	66	35	26	911	634	<2	24	14.2
19/Jun/07	CCR-1 Photic	135	76	52	1006	706	5	27	19.8
10/Jul/07	CCR-1 Photic	122	75	57	582	456	<2	4	14.0
24/Jul/07	CCR-1 Photic	116	79	62	766	554	<2	16	11.6
07/Aug/07	CCR-1 Photic	132	107	102	558	584	2	69	3.2
23/Aug/07	CCR-1 Photic	148	61	61	849	553	5	11	23.0
05/Sep/07	CCR-1 Photic	90	46	43	815	588	<2	18	15.9
28/Sep/07	CCR-1 Photic	96	22	15	631	419	<2	61	2.7
09/Oct/07	CCR-1 Photic	77	24	6	780	509	3	13	2.4
06/Nov/07	CCR-1 Photic	80	14	6	781	494	<2	6	26.2

CCR-2 C&A Water Chemistry Data									
Analytical Detection Limits		2	2	2	2	2	2	3	
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)**
17/Jan/07	CCR-2 photic	120	46	7	1628	903	29	36	56.8
17/Jan/07	CCR-2 4m	80	31	7	1261	853	113	85	ND
17/Jan/07	CCR-2 5m	136	46	6	1947	1031	3	28	ND
17/Jan/07	CCR-2 6m	97	31	6	1206	849	82	75	ND
17/Jan/07	CCR-2 7m	88	32	6	1264	871	117	104	ND
20/Feb/07	CCR-2 photic	103	35	12	1328	730	200	58	42
20/Feb/07	CCR-2 4m	60	18	14	996	713	152	147	ND
20/Feb/07	CCR-2 5m	64	43	34	1087	852	256	230	ND
20/Feb/07	CCR-2 6m	74	51	36	1096	859	271	228	ND
20/Feb/07	CCR-2 7m	75	47	42	1096	950	285	290	ND
20/Mar/07	CCR-2 photic	109	21	11	1100	476	21	10	31.5
20/Mar/07	CCR-2 4m	92	19	9	949	494	21	12	ND
20/Mar/07	CCR-2 5m	93	15	9	1097	472	23	13	ND
20/Mar/07	CCR-2 6m	86	21	9	967	472	19	13	ND
20/Mar/07	CCR-2 7m	86	14	7	1063	490	19	12	ND
26/Apr/07	CCR-2 photic	91	24	13	909	446	<2	6	24.5
26/Apr/07	CCR-2 4m	73	24	10	835	402	<2	12	ND
26/Apr/07	CCR-2 5m	77	22	14	827	397	<2	3	ND
26/Apr/07	CCR-2 6m	80	23	9	821	395	<2	7	ND
26/Apr/07	CCR-2 7m	74	24	13	812	384	<2	12	ND
08/May/07	CCR-2 photic	107	52	36	781	404	<2	5	14.2
08/May/07	CCR-2 4m	119	64	38	703	431	4	17	ND
08/May/07	CCR-2 5m	101	51	39	729	449	7	27	ND
08/May/07	CCR-2 6m	107	57	39	704	423	7	27	ND
08/May/07	CCR-2 7m	114	72	38	646	427	5	16	ND
29/May/07	CCR-2 photic	104	59	43	746	470	9	10	19.6
29/May/07	CCR-2 4m	134	60	44	783	503	8	11	ND
29/May/07	CCR-2 5m	119	73	53	896	513	11	13	ND
29/May/07	CCR-2 6m	108	63	48	787	483	10	10	ND
29/May/07	CCR-2 7m	133	88	84	685	525	58	41	ND
05/Jun/07	CCR-2 photic	107	38	25	701	482	<2	8	12.5

CCR-2 C&A Water Chemistry Data									
Analytical Detection Limits		2	2	2	2	2	2	3	
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)**
05/Jun/07	CCR-2 4m	106	46	37	744	458	<2	9	ND
05/Jun/07	CCR-2 5m	135	74	63	769	522	10	121	ND
05/Jun/07	CCR-2 6m	180	150	143	718	614	54	116	ND
05/Jun/07	CCR-2 7m	314	243	244	874	790	55	260	ND
19/Jun/07	CCR-2 photic	133	80	56	804	493	4	14	18.0
19/Jun/07	CCR-2 4m	166	112	95	792	562	19	97	ND
19/Jun/07	CCR-2 5m	206	110	93	826	551	19	92	ND
19/Jun/07	CCR-2 6m	188	116	102	802	597	32	116	ND
19/Jun/07	CCR-2 7m	470	379	360	1144	986	29	473	ND
10/Jul/07	CCR-2 photic	152	74	61	710	461	<2	18	15.3
10/Jul/07	CCR-2 4m	158	84	72	663	449	<2	11	ND
10/Jul/07	CCR-2 5m	171	101	81	701	448	<2	16	ND
10/Jul/07	CCR-2 6m	181	117	105	680	466	<2	20	ND
10/Jul/07	CCR-2 7m	216	142	136	634	440	<2	47	ND

CCR-2 C&A Water Chemistry Data									
Analytical Detection Limits		2	2	2	2	2	2	3	
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)**
24/Jul/07	CCR-2 photic	121	83	67	816	583	<2	17	9.6
24/Jul/07	CCR-2 4m	162	124	104	700	526	3	69	ND
24/Jul/07	CCR-2 5m	185	144	122	746	542	3	114	ND
24/Jul/07	CCR-2 6m	194	151	135	874	640	4	154	ND
24/Jul/07	CCR-2 7m	264	185	175	909	723	3	249	ND
07/Aug/07	CCR-2 photic	128	103	99	669	623	4	75	2.7
07/Aug/07	CCR-2 4m	124	110	112	553	564	4	77	ND
07/Aug/07	CCR-2 5m	150	110	4	705	567	6	100	ND
07/Aug/07	CCR-2 6m	137	99	97	626	501	4	61	ND
07/Aug/07	CCR-2 7m	174	121	122	809	617	36	114	ND
23/Aug/07	CCR-2 photic	169	58	58	739	454	3	8	25.5
23/Aug/07	CCR-2 4m	154	63	62	711	439	3	9	ND
23/Aug/07	CCR-2 5m	125	57	58	651	431	3	7	ND
23/Aug/07	CCR-2 6m	123	55	56	648	409	5	9	ND
23/Aug/07	CCR-2 7m	218	127	93	800	418	5	41	ND
05/Sep/07	CCR-2 photic	87	41	38	761	584	<2	13	15.6
05/Sep/07	CCR-2 4m	89	43	41	697	497	<2	16	ND
05/Sep/07	CCR-2 5m	93	53	53	728	511	<2	51	ND
05/Sep/07	CCR-2 6m	111	71	73	816	640	3	144	ND
05/Sep/07	CCR-2 7m	116	66	70	796	570	<2	133	ND
28/Sep/07	CCR-2 photic	81	34	16	838	392	<2	60	7.7
28/Sep/07	CCR-2 4m	73	21	17	688	414	<2	19	ND
28/Sep/07	CCR-2 5m	81	45	18	787	367	<2	39	ND
28/Sep/07	CCR-2 6m	80	25	18	740	336	<2	34	ND
28/Sep/07	CCR-2 7m	121	29	26	815	327	<2	68	ND
09/Oct/07	CCR-2 photic	71	57	11	874	476	3	10	3.2
09/Oct/07	CCR-2 4m	70	26	8	719	460	2	12	ND
09/Oct/07	CCR-2 5m	63	33	13	641	490	4	20	ND
09/Oct/07	CCR-2 6m	74	48	15	724	492	5	39	ND
09/Oct/07	CCR-2 7m	104	39	32	984	519	6	65	ND
06/Nov/07	CCR-2 photic	81	16	6	870	538	<2	13	10.5
06/Nov/07	CCR-2 4m	77	14	5	786	487	<2	7	ND

CCR-2 C&A Water Chemistry Data									
Analytical Detection Limits		2	2	2	2	2	2	3	
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)**
06/Nov/07	CCR-2 5m	77	17	6	821	468	<2	8	ND
06/Nov/07	CCR-2 6m	78	15	5	762	495	<2	10	ND
06/Nov/07	CCR-2 7m	88	21	7	799	489	<2	8	ND
17/Jan/07	CCR-3 Photic	118	21	6	1408	613	25	73	53.7
20/Feb/07	CCR-3 Photic	109	36	31	1185	729	273	84	27.1
20/Mar/07	CCR-3 Photic	101	20	9	1104	458	2	6	30.4
26/Apr/07	CCR-3 Photic	150	82	64	957	513	112	24	15.5
08/May/07	CCR-3 Photic	114	56	36	792	429	3	8	16.2
29/May/07	CCR-3 Photic	99	62	47	726	461	8	7	15.3
05/Jun/07	CCR-3 Photic	82	36	27	689	491	<2	12	14.0
19/Jun/07	CCR-3 Photic	142	74	53	761	484	4	12	20.6
10/Jul/07	CCR-3 Photic	146	91	69	815	536	<2	31	15.9
24/Jul/07	CCR-3 Photic	122	78	63	728	489	<2	18	10.9
07/Aug/07	CCR-3 Photic	120	108	99	550	546	7	52	7.4
23/Aug/07	CCR-3 Photic	148	92	64	621	398	3	7	22.1
05/Sep/07	CCR-3 Photic	78	44	41	731	538	<2	13	14.4
28/Sep/07	CCR-3 Photic	65	26	20	710	416	<2	22	9.0
09/Oct/07	CCR-3 Photic	79	25	12	825	513	7	31	4.4
06/Nov/07	CCR-3 Photic	75	16	6	850	507	<2	11	22.9

CCR University of Colorado Water Chemistry Data						
Analytical Detection Limits		**2**	**2**	**3**	**5**	**3**
Sample Date	**Sample Name/ Location**	**Total Phosphorus mg/L**	**Total Dissolved Phosphorus mg/L**	**Ortho-Phosphate mg/L**	**NO3+NO2-N mg/L**	**NH4-N mg/L**
17/Jan/07	CCR-2 photic	96.0	55.8	3.3	49.5	45.8
20/Feb/07	CCR-3 photic	77.3	48.0	22.8	287.4	82.4
20/Mar/07	QA	67.5	26.7	8.0	0.0	20.9
26/Apr/07	CCR-1 photic	73.0	27.3	10.4	0.0	28.8
08/May/07	CCR-3 photic	100.6	60.3	39.2	0.0	21.5
29/May/07	CCR-1 photic	2.6	2.5	0.9	286.9	133.3
05/Jun/07	CCR-3 photic	77.7	44.0	26.6	0.0	22.4
19/Jun/07	CCR-1 photic	109.5	73.3	49.4	0.0	9.2
10/Jul/07	CCR-1 photic	115.6	79.3	58.9	0.0	59.6
24/Jul/07	CCR-2 photic	110.7	85.8	66.6	0.0	17.4
07/Aug/07	CCR-3 photic	150.2	128.0	102.6	28.1	60.2
23/Aug/07	CCR-1 photic	130.0	85.3	66.5	0.0	10.5
05/Sep/07	CCR-3 photic	103.5	61.9	43.1	0.0	11.3
28/Sep/07	CCR-1photic	69.7	34.1	-	0.0	-
09/Oct/07	CCR-3 photic	70.2	30.1	7.5	0.0	26.9
06/Nov/07	CCR-3 photic	65.6	19.9	3.7	24.8	10.4

CCR GEI Water Chemistry Data						
Analytical Detection Limits		**2**	**2**	**3**	**5**	**3**
Sample Date	**Sample Name/ Location**	**Total Phosphorus mg/L**	**Total Dissolved Phosphorus mg/L**	**Ortho-Phosphate mg/L**	**NO3+NO2-N mg/L**	**NH4-N mg/L**
17/Jan/07	CCR-2 photic	120	46	7	29	36
20/Feb/07	CCR-3 photic	101	20	9	2	6
20/Mar/07	QA	66	29	19	8	79
26/Apr/07	CCR-1 photic	76	22	10	<2	13
08/May/07	CCR-3 photic	114	56	36	3	8
29/May/07	CCR-1 photic	96	61	45	8	15
05/Jun/07	CCR-3 photic	82	36	27	<2	12
19/Jun/07	CCR-1 photic	135	76	52	5	27
10/Jul/07	CCR-1 photic	122	75	57	<2	4
24/Jul/07	CCR-2 photic	121	83	67	<2	17
07/Aug/07	CCR-3 photic	120	108	99	7	52
23/Aug/07	CCR-1 photic	148	61	61	5	11
05/Sep/07	CCR-3 photic	78	44	41	<2	13
28/Sep/07	CCR-1 photic	96	22	15	<2	61
09/Oct/07	CCR-3 photic	79	25	12	7	31
06/Nov/07	CCR-3 photic	75	16	6	<2	11

CHERRY CREEK
D.O. DATA, 2007
Site CCR-1

Date	01/17/07			
Secchi	ND			
1%	ND			
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	0.55	597	16.69	8.63
1	1.57	610	16.00	8.52
2	1.69	610	15.13	8.47
3	1.76	625	13.57	8.18
4	1.95	645	8.88	7.91
5	1.97	646	7.88	7.89
6	2.06	651	6.66	7.83
7	2.24	659	5.98	7.74

Date	02/20/07			
Secchi	ND			
1%	ND			
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	1.29	593	10.38	7.97
1	2.43	627	9.56	7.93
2	2.44	627	9.46	7.93
3	2.44	627	9.42	7.93
4	2.43	627	9.33	7.93
5	2.38	628	8.99	7.88
6	2.31	640	7.62	7.78
7	2.83	660	5.52	7.69

Date	03/20/07			
Secchi	0.75	m		
1%	2.25	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	8.27	675	17.34	8.35
1	7.75	659	17.50	8.36
2	7.61	659	16.79	8.36
3	7.59	658	16.36	8.35
4	7.57	660	16.01	8.33
5	7.56	660	15.84	8.34
6	7.56	660	15.80	8.35
7	7.55	660	15.78	8.35

Date	04/26/07			
Secchi	0.71	m		
1%	2.60	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	11.08	685	13.81	8.32
1	9.96	662	14.23	8.36
2	9.68	664	13.74	8.36
3	9.58	663	13.26	8.37
4	9.56	664	12.93	8.37
5	9.55	666	13.17	8.40
6	9.55	666	12.86	8.39
7	9.54	665	12.18	8.39

Date	05/08/07			
Secchi	0.96	m		
1%	3.10	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	14.06	656	11.60	8.46
1	13.33	640	11.44	8.44
2	12.94	636	10.92	8.40
3	12.88	635	10.56	8.36
4	12.85	634	10.36	8.36
5	12.82	634	10.28	8.35
6	12.77	633	10.09	8.34
7	12.74	633	9.87	8.32

Date	05/29/07			
Secchi	1.62	m		
1%	4.23	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	18.56	714	12.50	8.72
1	18.34	712	12.94	8.69
2	17.94	707	13.14	8.69
3	17.86	706	12.91	8.70
4	17.80	705	12.93	8.70
5	17.72	706	12.80	8.69
6	15.74	677	10.44	8.63
7	15.14	665	7.77	8.28

Date	06/05/07			
Secchi	1.43	m		
1%	4.12	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	19.95	752	12.02	8.73
1	19.27	750	12.36	8.62
2	18.95	737	12.50	8.58
3	18.38	727	11.81	8.53
4	18.13	723	11.13	8.50
5	17.69	717	10.11	8.42
6	16.61	701	6.32	8.12
7	15.93	690	3.51	7.97

Date	06/19/07			
Secchi	1.40	m		
1%	3.50	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	21.78	757	8.74	8.59
1	21.22	747	8.96	8.64
2	20.63	735	8.51	8.62
3	20.42	732	8.09	8.59
4	20.18	729	7.79	8.59
5	19.63	722	5.77	8.35
6	18.22	699	2.75	8.03
7	17.85	690	2.24	7.91

CHERRY CREEK
D.O. DATA, 2007
CCR-1 DO Data Continued

Date 07/10/07
Secchi 1.00 m
1% 2.75 m

Depth (m)	Temp °C	Cond.	DO	pH
0	22.79	891	8.30	8.71
1	22.81	899	7.88	8.62
2	22.80	900	7.77	8.59
3	22.77	900	7.51	8.56
4	22.69	900	7.25	8.53
5	22.52	899	6.85	8.48
6	22.45	896	6.85	8.47
7	22.12	893	6.12	8.41

Date 07/24/07
Secchi 1.28 m
1% 4.71 m

Depth (m)	Temp °C	Cond.	DO	pH
0	25.65	975	9.67	8.49
1	25.73	979	10.43	8.54
2	24.78	965	10.08	8.56
3	24.48	962	9.16	8.53
4	24.14	959	7.96	8.47
5	23.42	950	5.21	8.29
6	23.03	946	3.48	8.18
7	22.57	942	1.71	8.06

Date 08/07/07
Secchi 1.26 m
1% 3.48 m

Depth (m)	Temp °C	Cond.	DO	pH
0	23.90	907	5.40	8.03
1	23.84	907	5.28	7.99
2	23.70	904	5.05	7.98
3	23.67	904	4.81	7.99
4	23.65	905	4.77	7.98
5	23.63	903	4.66	7.98
6	23.62	903	4.56	7.98
7	23.61	903	4.46	7.98

Date 08/23/07
Secchi 1.24 m
1% 3.71 m

Depth (m)	Temp °C	Cond.	DO	pH
0	23.75	834	7.91	8.86
1	23.37	833	7.75	8.70
2	23.31	832	7.16	8.71
3	23.27	832	7.06	8.73
4	23.19	830	6.72	8.73
5	23.19	831	6.52	8.73
6	23.16	830	6.47	8.77
7	23.93	826	6.68	8.79

Date 09/05/07
Secchi 1.02 m
1% 3.32 m

Depth (m)	Temp °C	Cond.	DO	pH
0	22.65	834	12.18	7.81
1	22.58	829	10.06	7.85
2	22.08	824	8.82	7.84
3	21.91	821	7.91	7.81
4	21.89	821	7.60	7.81
5	21.89	822	7.56	7.83
6	21.88	822	7.83	7.84
7	21.73	819	7.34	7.85

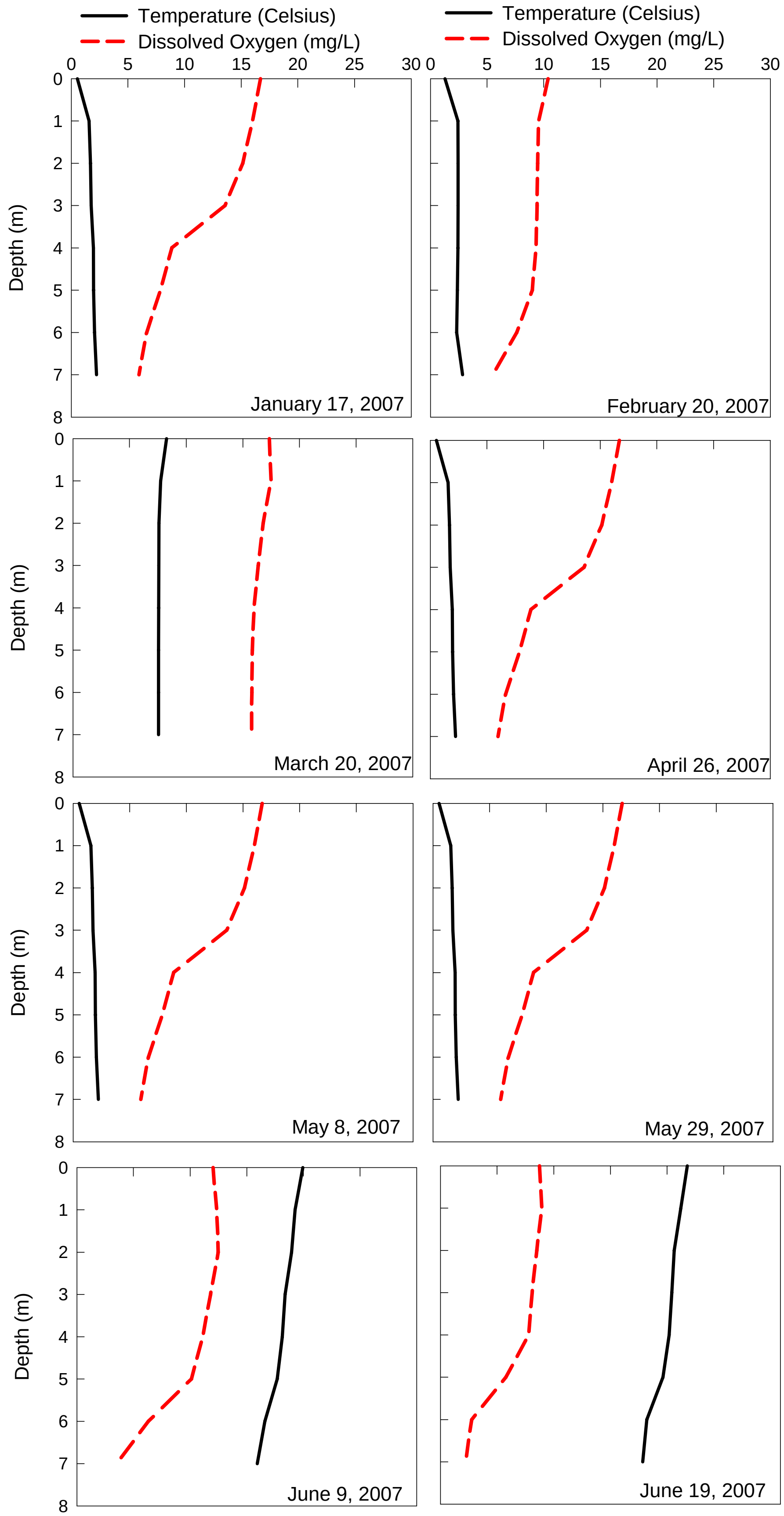
Date 10/09/07
Secchi 0.73 m
1% 2.00 m

Depth (m)	Temp °C	Cond.	DO	pH
0	14.43	715	14.05	7.87
1	14.38	714	10.92	7.90
2	14.35	714	10.60	7.92
3	14.34	714	10.41	7.93
4	14.33	714	10.37	7.95
5	14.23	714	10.01	7.95
6	13.70	705	9.28	7.94
7	13.45	703	8.18	7.92

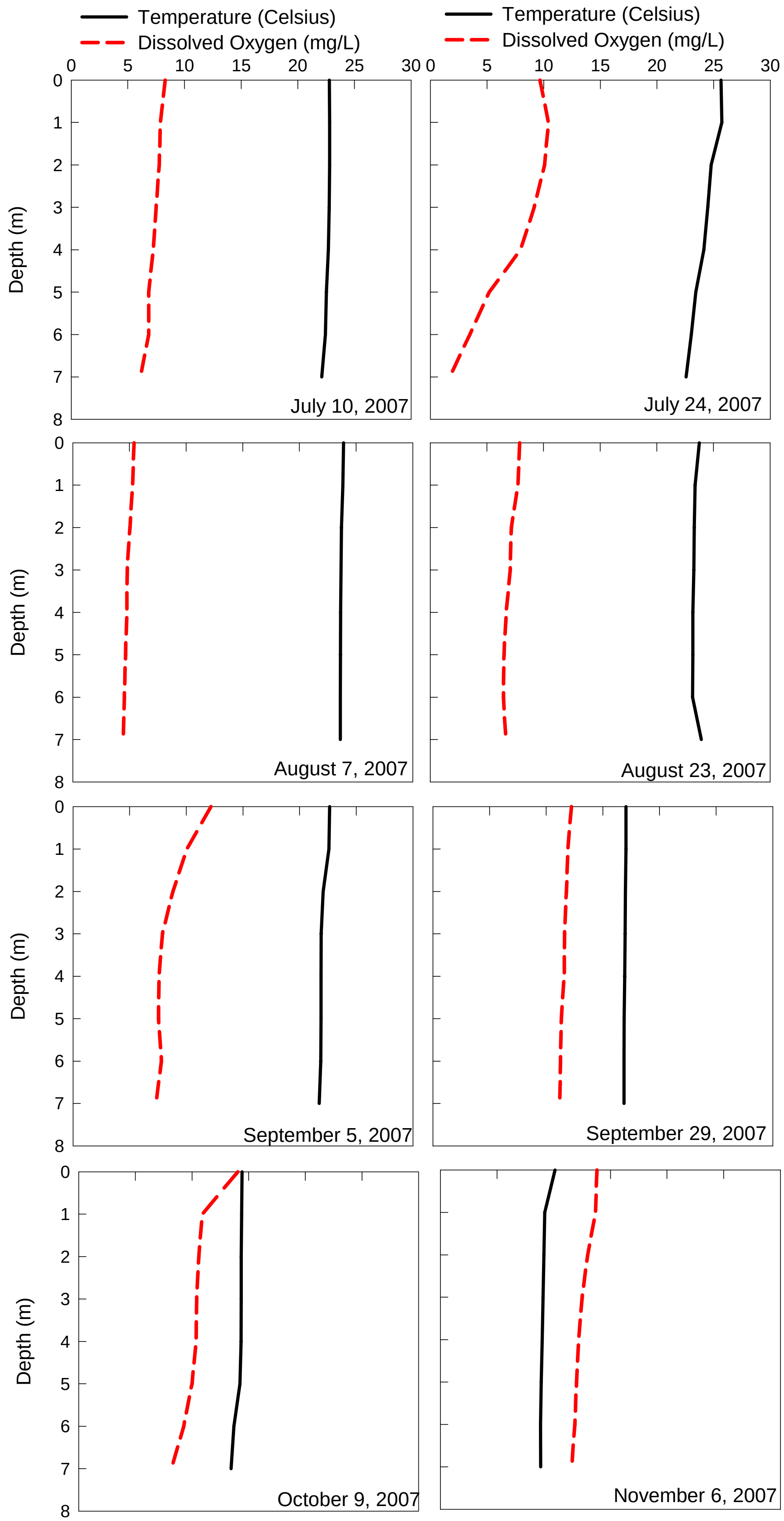
Date 11/06/07
Secchi 0.74 m
1% 2.42 m

Depth (m)	Temp °C	Cond.	DO	pH
0	10.12	655	13.83	8.28
1	9.22	634	13.70	8.21
2	9.14	636	13.01	8.18
3	9.06	636	12.52	8.17
4	8.99	633	12.21	8.13
5	8.90	633	12.02	8.15
6	8.84	632	11.87	8.16
7	8.85	632	11.59	8.14

CCR-1


Temperature (Celsius)
Dissolved Oxygen (mg/L)
Depth (m)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8
January 17, 2007
February 20, 2007
March 20, 2007
April 26, 2007
May 8, 2007
May 29, 2007
June 9, 2007
June 19, 2007

CCR-1


Temperature (Celsius)
Dissolved Oxygen (mg/L)
Depth (m)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8
July 10, 2007
July 24, 2007
August 7, 2007
August 23, 2007
September 5, 2007
September 29, 2007
October 9, 2007
November 6, 2007

CHERRY CREEK
D.O. DATA, 2006
Site CCR-2

Date 01/17/07
Secchi ND
1% ND

Depth (m)	Temp °C	Cond.	DO	pH
0	0.90	606	17.65	8.65
1	1.50	614	17.16	8.56
2	1.93	632	13.08	8.11
3	1.98	634	11.29	8.07
4	1.99	638	10.50	8.04
5	2.00	639	9.91	8.03
6	2.00	639	9.72	8.03
7	2.01	639	9.63	8.20

Date 02/20/07
Secchi ND
1% ND

Depth (m)	Temp °C	Cond.	DO	pH
0	1.68	583	21.54	8.75
1	2.53	619	21.18	8.58
2	2.28	623	18.48	8.30
3	2.28	625	14.53	8.10
4	2.27	626	12.25	8.06
5	2.36	635	10.43	7.85
6	2.50	640	8.01	7.77
7	2.64	664	7.24	7.74

Date 03/20/07
Secchi 0.75 m
1% 2.25 m

Depth (m)	Temp °C	Cond.	DO	pH
0	9.12	666	16.10	8.43
1	7.82	638	16.48	8.42
2	7.55	637	15.89	8.35
3	7.52	637	15.30	8.32
4	7.50	638	14.99	8.31
5	7.51	640	14.95	8.32
6	7.51	642	15.08	8.34
7	7.50	642	15.09	8.33

Date 04/26/07
Secchi 0.76 m
1% 2.74 m

Depth (m)	Temp °C	Cond.	DO	pH
0	11.54	692	14.02	8.47
1	10.32	673	14.74	8.50
2	9.95	670	14.77	8.48
3	9.80	667	14.64	8.45
4	9.73	666	14.59	8.45
5	9.52	663	14.56	8.44
6	9.45	660	14.35	8.42
7	9.40	660	14.04	8.41

Date 05/08/07
Secchi 1.05 m
1% 3.15 m

Depth (m)	Temp °C	Cond.	DO	pH
0	13.74	649	11.30	8.52
1	13.50	647	11.37	8.52
2	13.02	639	11.16	8.48
3	13.00	638	10.90	8.44
4	12.99	640	10.66	8.42
5	12.92	639	10.33	8.39
6	12.88	638	10.25	8.39
7	12.79	632	10.22	8.38

Date 05/29/07
Secchi 1.50 m
1% 4.12 m

Depth (m)	Temp °C	Cond.	DO	pH
0	18.58	720	12.99	8.85
1	18.52	719	13.31	8.85
2	18.20	714	13.65	8.86
3	17.97	711	13.83	8.85
4	17.85	710	13.27	8.81
5	17.17	703	12.19	8.75
6	16.66	696	10.35	8.60
7	16.19	689	9.46	8.51

Date 06/05/07
Secchi 1.38 m
1% 4.00 m

Depth (m)	Temp °C	Cond.	DO	pH
0	20.26	756	12.08	8.71
1	19.30	741	12.64	8.73
2	18.86	731	12.35	8.73
3	18.48	726	12.15	8.71
4	18.14	722	11.58	8.66
5	17.42	715	8.93	8.47
6	16.57	699	5.63	8.15
7	16.05	692	3.87	7.96

Date 06/19/07
Secchi 1.37 m
1% 3.02 m

Depth (m)	Temp °C	Cond.	DO	pH
0	21.54	749.292	9.02	8.82
1	21.53	747.438	9.02	8.83
2	20.61	733.679	8.30	8.76
3	19.66	722.364	6.64	8.55
4	19.37	719.176	6.33	8.48
5	18.96	715.467	4.92	8.33
6	18.76	709.818	4.51	8.16
7	18.10	6991.75	2.28	8.01

CHERRY CREEK
D.O. DATA, 2006
CCR-2 DO Data Continued

Date 07/10/07
Secchi 0.75 m
1% 2.26 m

Depth (m)	Temp °C	Cond.	DO	pH
0	22.79	892	7.81	8.54
1	22.79	894	7.60	8.55
2	22.78	894	7.29	8.53
3	22.55	894	6.46	8.46
4	22.29	892	4.86	8.34
5	22.26	892	4.40	8.28
6	22.22	893	3.71	8.22
7	21.88	888	1.10	8.06

Date 07/24/07
Secchi 1.20 m
1% 4.45 m

Depth (m)	Temp °C	Cond.	DO	pH
0	25.42	982	9.92	8.62
1	25.21	976	10.04	8.65
2	24.71	970	9.62	8.63
3	24.18	965	7.93	8.53
4	23.50	961	5.16	8.34
5	22.93	955	3.10	8.20
6	22.83	953	2.44	8.12
7	22.58	953	1.19	8.04

Date 08/07/07
Secchi 1.37 m
1% 3.90 m

Depth (m)	Temp °C	Cond.	DO	pH
0	23.84	907	5.40	8.03
1	23.80	907	5.28	7.99
2	23.63	904	5.05	7.98
3	23.60	904	4.81	7.99
4	23.58	905	4.77	7.98
5	23.54	903	4.66	7.98
6	23.50	903	4.56	7.98
7	23.36	903	4.46	7.98

Date 08/23/07
Secchi 0.98 m
1% 3.10 m

Depth (m)	Temp °C	Cond.	DO	pH
0	23.33	831	7.73	8.89
1	23.31	831	7.39	8.91
2	23.19	829	7.23	8.94
3	23.19	829	7.21	8.90
4	23.18	830	7.03	8.89
5	23.09	829	6.80	8.89
6	22.99	826	6.50	8.86
7	22.74	829	2.69	8.63

Date 09/05/07
Secchi 1.03 m
1% 3.27 m

Depth (m)	Temp °C	Cond.	DO	pH
0	22.82	834	11.22	8.05
1	22.79	833	11.10	8.13
2	22.40	828	10.36	8.12
3	22.27	825	10.16	8.10
4	22.17	825	9.07	8.06
5	22.00	825	6.51	7.95
6	21.84	824	4.58	7.85
7	21.79	824	3.42	7.79

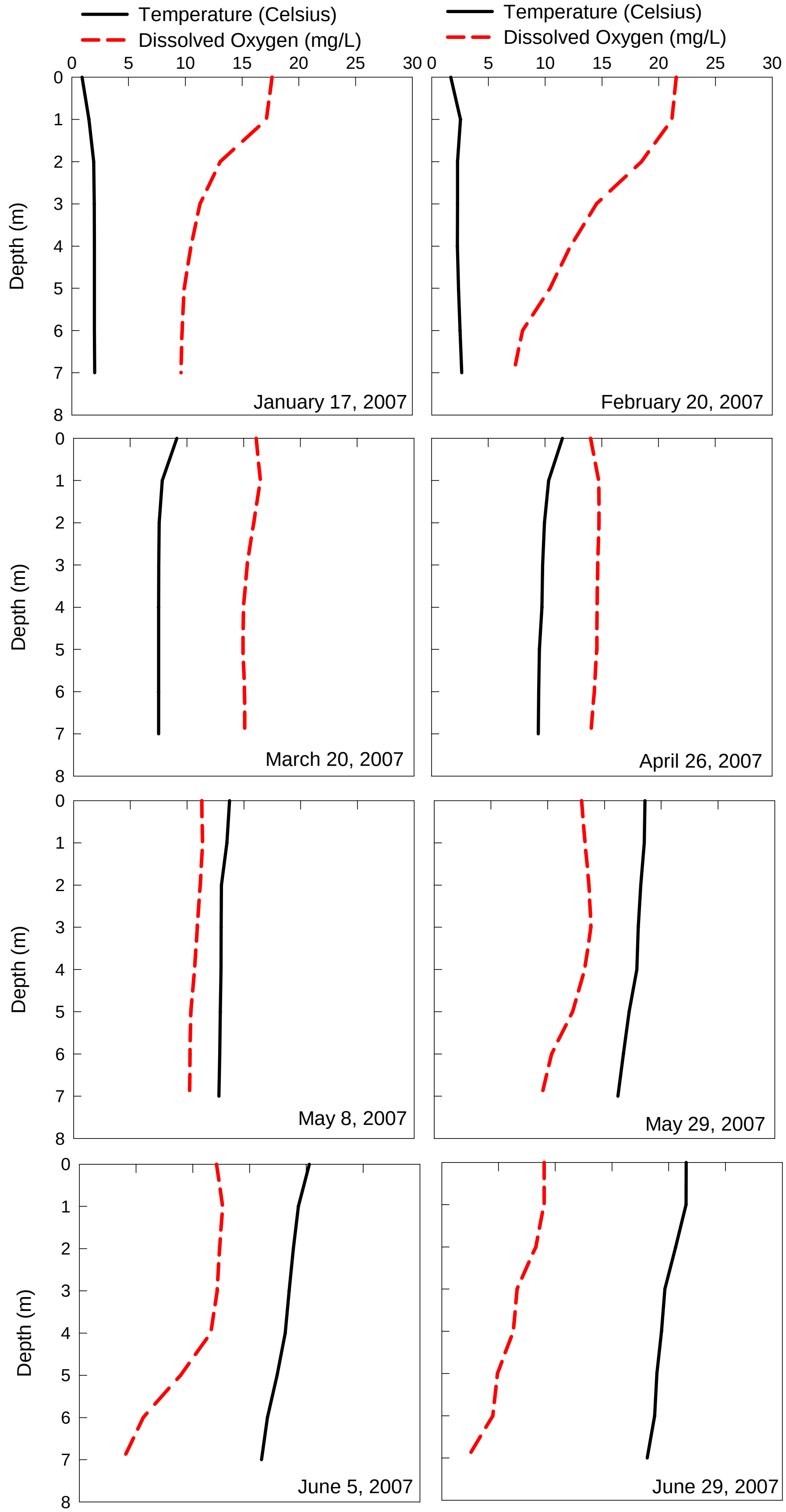
Date 10/09/07
Secchi 0.73 m
1% 2.25 m

Depth (m)	Temp °C	Cond.	DO	pH
0	14.47	716	12.20	8.17
1	14.18	710	10.31	8.18
2	14.13	710	10.07	8.18
3	14.11	710	9.96	8.18
4	14.08	709	9.90	8.18
5	13.96	707	9.63	8.17
6	13.74	704	8.36	8.13
7	13.67	707	7.69	8.10

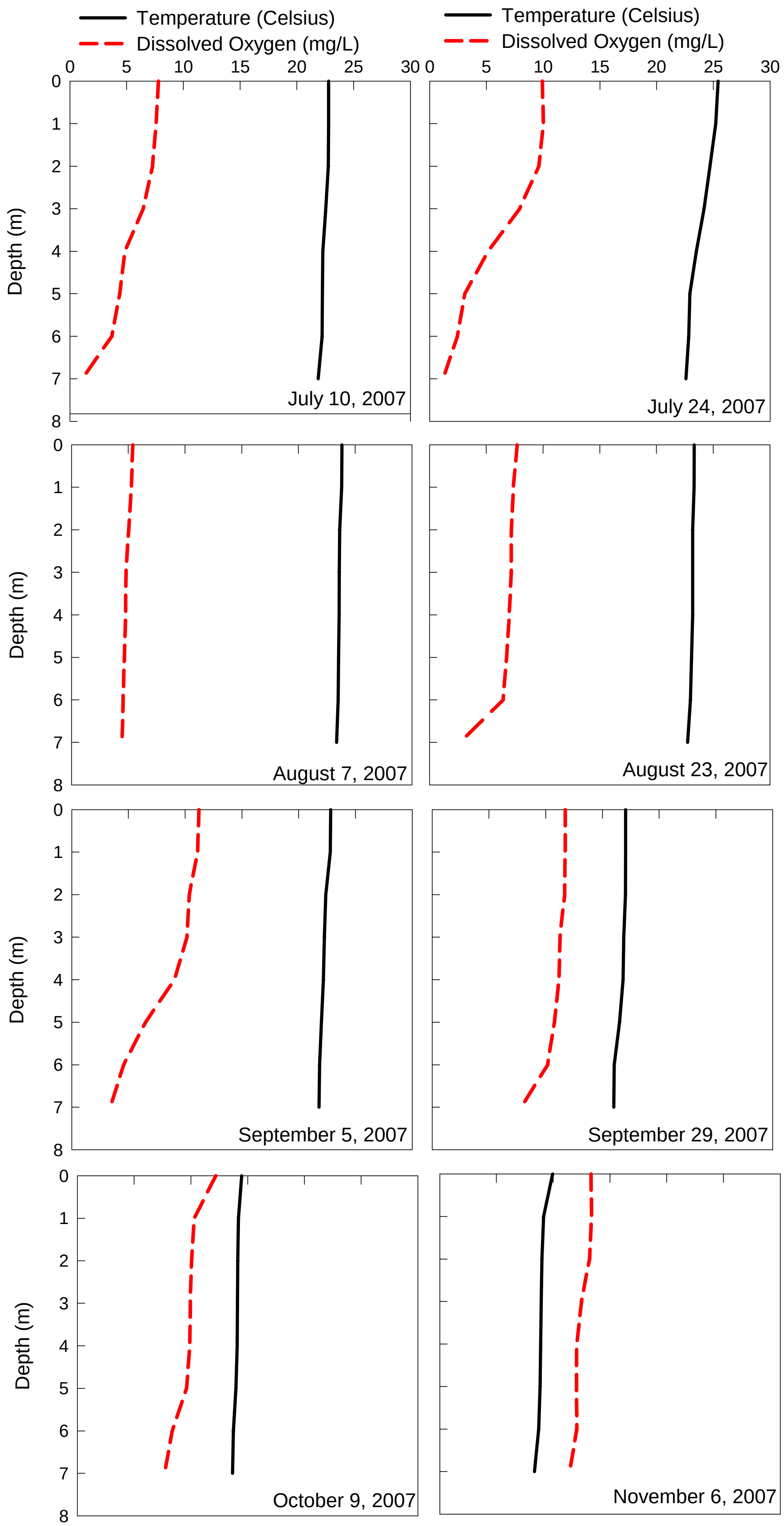
Date 11/06/07
Secchi 0.68 m
1% 2.20 m

Depth (m)	Temp °C	Cond.	DO	pH
0	9.96	648	13.34	8.33
1	9.15	633	13.39	8.35
2	9.00	632	13.21	8.34
3	8.94	631	12.50	8.33
4	8.90	630	12.09	8.32
5	8.85	630	12.05	8.32
6	8.73	628	12.11	8.31
7	8.35	622	11.45	8.29

CCR-2


Temperature (Celsius)
Dissolved Oxygen (mg/L)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
January 17, 2007
February 20, 2007
March 20, 2007
April 26, 2007
May 8, 2007
May 29, 2007
June 5, 2007
June 29, 2007

CCR-2


Temperature (Celsius)
Dissolved Oxygen (mg/L)
Temperature (Celsius)
Dissolved Oxygen (mg/L)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
July 10, 2007
July 24, 2007
August 7, 2007
August 23, 2007
September 5, 2007
September 29, 2007
October 9, 2007
November 6, 2007

CHERRY CREEK
D.O. DATA, 2007
Site CCR-3

Date	01/17/07			
Secchi	ND			
1%	ND			
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	0.44	597	18.08	8.29
1	1.54	608	17.81	8.23
2	1.82	625	14.40	7.92
3	1.89	631	11.10	7.87
4	1.89	631	9.80	7.89
5	1.92	634	9.46	7.89
6	1.97	685	9.30	7.88
7	2.04	659	8.83	7.85

Date	02/20/07			
Secchi	ND			
1%	ND			
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	1.18	565	14.33	8.08
1	2.50	616	13.92	7.99
2	2.38	621	11.95	7.85
3	2.28	624	10.51	7.84
4	2.27	628	9.69	7.83
5	2.35	633	9.52	7.81
6	2.59	685	10.50	7.89
7	2.62	689	11.00	7.89

Date	03/20/07			
Secchi	0.74	m		
1%	2.20	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	8.87	680	17.58	8.54
1	7.81	656	17.78	8.46
2	7.52	654	17.13	8.39
3	7.32	650	16.18	8.36
4	7.02	648	15.70	8.29
5	6.84	648	15.06	8.26
6	6.75	650	14.61	8.22
7	6.71	650	13.79	8.17

Date	04/26/07			
Secchi	0.60	m		
1%	1.50	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0				
1				
2				
3	YSI non-functional			
4				
5				
6				
7				

Date	05/08/07			
Secchi	1.00	m		
1%	3.29	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	13.88	650	12.47	8.60
1	13.55	643	12.60	8.56
2	13.08	636	12.46	8.51
3	12.95	636	11.91	8.46
4	12.83	636	11.20	8.43
5	12.73	635	10.64	8.39
6	12.62	632	8.38	8.16

Date	05/29/07			
Secchi	1.48	m		
1%	4.20	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	18.72	722	11.64	8.78
1	18.69	724	12.23	8.80
2	18.14	716	12.64	8.82
3	17.56	710	12.10	8.77
4	16.69	698	10.72	8.63
5	16.46	694	9.64	8.55
6	ND	693	8.85	8.47

Date	06/05/07			
Secchi	4.32	m		
1%	4.00	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	20.39	761	11.89	8.69
1	19.22	740	12.83	8.73
2	18.91	734	12.83	8.71
3	18.64	726	12.32	8.69
4	17.89	726	9.33	8.46
5	17.65	720	7.75	8.35
6	16.71	708	4.54	8.11
7	16.70	707	3.87	8.05

Date	06/19/07			
Secchi	1.27	m		
1%	3.50	m		
Depth (m)	**Temp °C**	**Cond.**	**DO**	**pH**
0	22.53	764.195	8.64	8.79
1	21.97	755.808	9.36	8.84
2	20.72	732.986	9.22	8.82
3	20.16	727.666	8.09	8.73
4	20.02	728.914	7.32	8.67
5	19.25	719.124	4.51	8.38
6	18.36	707.132	2.82	8.17

CHERRY CREEK
D.O. DATA, 2007
CCR-3 DO Data Continued

Date 07/10/07
Secchi 0.78 m
1% 2.50 m

Depth (m)	Temp °C	Cond.	DO	pH
0	22.78	916	6.89	8.41
1	22.85	915	6.83	8.41
2	22.61	913	6.65	8.41
3	22.48	913	6.48	8.40
4	22.20	910	6.80	8.40
5	21.78	906	6.21	8.36

Date 7/24/2007
Secchi 1.26 m
1% 4.23 m

Depth (m)	Temp °C	Cond.	DO	pH
0	25.68	982	9.73	8.61
1	25.18	948	9.77	8.62
2	24.41	938	9.69	8.61
3	23.96	930	8.44	8.54
4	23.82	930	7.51	8.48
5	23.35	927	2.75	8.14
6	23.13	923	1.70	8.07

Date 08/07/07
Secchi 1.41 m
1% 3.90 m

Depth (m)	Temp °C	Cond.	DO	pH
0	24.32	915	6.02	8.14
1	23.86	904	5.69	8.10
2	23.73	901	5.48	8.08
3	23.68	897	5.17	8.07
4	23.61	895	4.94	8.05
5	23.27	866	4.81	8.04

Date 08/23/07
Secchi 1.25 m
1% 3.24 m

Depth (m)	Temp °C	Cond.	DO	pH
0	23.32	828	6.31	8.83
1	23.71	831	6.16	8.85
2	23.26	830	5.49	8.82
3	23.12	830	5.12	8.79
4	23.11	830	5.69	8.82
5	23.12	830	6.07	8.83
6	23.12	833	6.31	8.88

Date 09/05/07
Secchi 1.00 m
1% 2.74 m

Depth (m)	Temp °C	Cond.	DO	pH
0	22.47	835	9.40	8.01
1	22.44	833	9.14	8.01
2	22.28	830	8.66	8.01
3	21.72	826	6.84	7.94
4	21.53	825	5.92	7.88
5	21.53	827	5.76	7.86

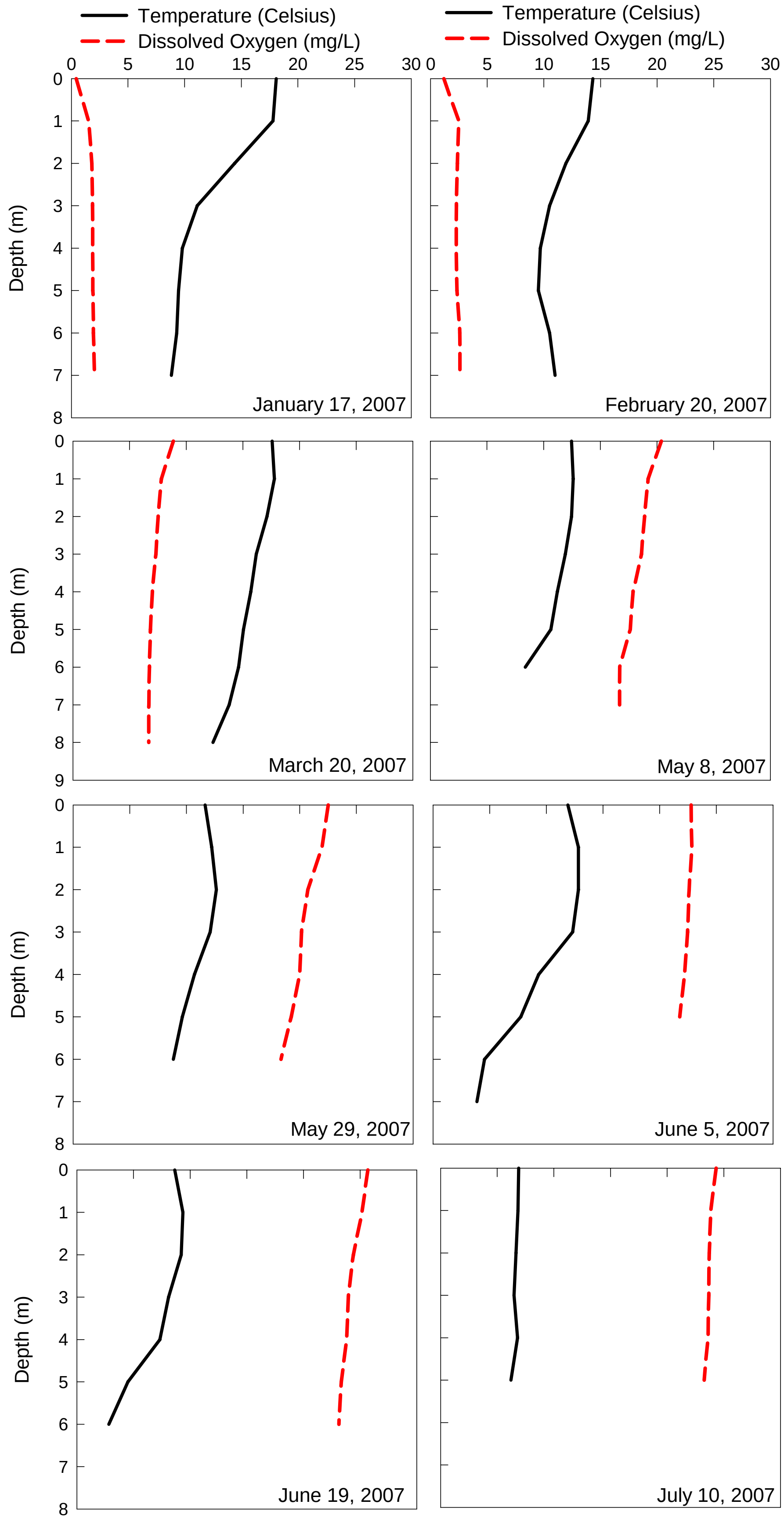
Date 10/09/07
Secchi 0.72 m
1% 2.04 m

Depth (m)	Temp °C	Cond.	DO	pH
0	14.68	721	10.94	8.20
1	14.15	714	10.45	8.19
2	14.06	709	9.48	8.14
3	13.96	709	9.12	8.11
4	13.80	706	8.66	8.11
5	13.79	706	8.49	8.09
6	13.79	704	8.43	8.09

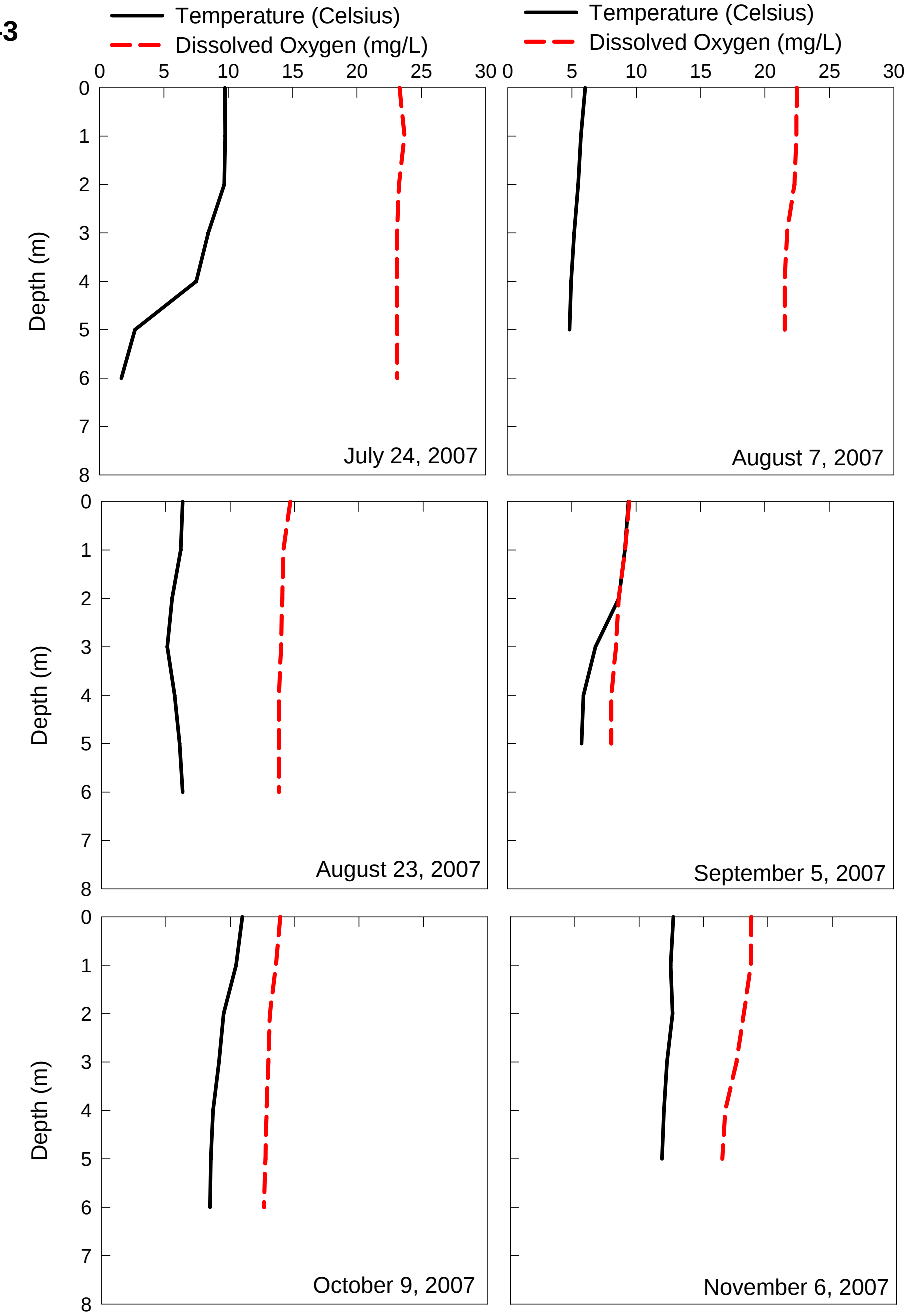
Date 11/06/07
Secchi 0.74 m
1% 2.36 m

Depth (m)	Temp °C	Cond.	DO	pH
0	9.46	639	12.65	8.37
1	9.15	634	12.45	8.38
2	8.65	626	12.59	8.39
3	8.44	623	12.16	8.36
4	8.09	618	11.93	8.35
5	8.08	617	11.77	8.34

CCR-3


Temperature (Celsius)
Dissolved Oxygen (mg/L)
Temperature (Celsius)
Dissolved Oxygen (mg/L)
0 5 10 15 20 25 30
0 5 10 15 20 25 30
Depth (m)
Depth (m)
Depth (m)
Depth (m)
January 17, 2007
February 20, 2007
March 20, 2007
May 8, 2007
May 29, 2007
June 5, 2007
June 19, 2007
July 10, 2007

CCR-3


Temperature (Celsius)
Dissolved Oxygen (mg/L)
Depth (m)
July 24, 2007
August 7, 2007
August 23, 2007
September 5, 2007
October 9, 2007
November 6, 2007
0
5
10
15
20
25
30
1
2
3
4
6
7
8

Cherry Creek Reservoir Secchi and 1% Transmissivity Depths for 2007

	CCR-1				CCR-2				CCR-3		
Date	**Secchi (m)**	**1% Trans (m)**	**Ratio**	**Date**	**Secchi (m)**	**1% Trans (m)**	**Ratio**	**Date**	**Secchi (m)**	**1% Trans (m)**	**Ratio**
17/Jan/07	ND	ND	N/A	01/17/07	ND	ND	N/A	01/17/07	ND	ND	N/A
20/Feb/07	ND	ND	N/A	02/20/07	ND	ND	N/A	02/20/07	ND	ND	N/A
20/Mar/07	0.75	2.25	3.00	03/20/07	0.75	2.25	3.00	03/20/07	0.74	2.20	2.97
26/Apr/07	0.71	2.60	3.66	04/26/07	0.76	2.74	3.61	04/26/07	0.60	1.50	2.50
08/May/07	0.96	3.10	3.23	05/08/07	1.05	3.15	3.00	05/08/07	1.00	3.29	3.29
29/May/07	1.62	4.23	2.61	05/29/07	1.50	4.12	2.75	05/29/07	1.48	4.20	2.84
05/Jun/07	1.43	4.12	2.88	06/05/07	1.38	4.00	2.90	06/05/07	4.32	4.00	0.93
19/Jun/07	1.40	3.50	2.50	06/19/07	1.37	3.02	2.20	06/19/07	1.27	3.50	2.76
10/Jul/07	1.00	2.75	2.75	07/10/07	0.75	2.26	3.01	07/10/07	0.78	2.50	3.21
24/Jul/07	1.28	4.71	3.68	07/24/07	1.20	4.45	3.71	07/24/07	1.26	4.23	3.36
07/Aug/07	1.26	3.48	2.76	08/07/07	1.37	3.90	2.85	08/07/07	1.41	3.90	2.77
23/Aug/07	1.24	3.71	2.99	08/23/07	0.98	3.10	3.16	08/23/07	1.25	3.24	2.59
05/Sep/07	1.02	3.32	3.25	09/05/07	1.03	3.27	3.17	09/05/07	1.00	2.74	2.74
Average	1.15	3.43	3.03	**Average**	1.10	3.30	3.03	**Average**	1.37	3.21	2.72
Median	1.24	3.48	2.99	**Median**	1.05	3.15	3.00	**Median**	1.25	3.29	2.77

"ND" denotes "No data"

Appendix C

2007 Stream Water Quality and Precipitation Data

CC-10 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	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**	**TSS mg/L**	**TVSS mg/L**
1/9/07	CC-10	171	134	128	1524	1433	1134	40	14.2	<4.0
2/13/07	CC-10	228	167	160	1267	1218	778	24	37.4	4.4
3/20/07	CC-10	175	140	128	1095	943	597	13	23.0	4.8
5/8/07	CC-10	288	216	209	1187	1007	663	20	49.0	7.6
6/5/07	CC-10	298	214	221	1212	1072	640	32	35.2	4.6
7/9/07	CC-10	218	191	180	710	628	296	36	8.0	<4.0
8/15/07	CC-10	247	207	216	776	737	720	57	21.0	<4.0
9/5/07	CC-10	217	177	177	750	674	316	9	9.8	<4.0
10/9/07	CC-10	209	199	190	621	580	327	23	7.8	<4.0
11/6/07	CC-10	176	144	137	1096	1096	693	46	24.5	<4.0
12/11/07	CC-10	162	133	136	1770	1612	1023	214	31.5	4.2
4/24/07	CC-10 storm	392	220	197	1597	1275	593	132	126.5	19.0
5/15/07	CC-10 storm	410	265	241	1610	1276	645	60	82.5	16.0
6/13/07	CC-10 storm	366	223	195	1423	1066	498	16	64.0	8.8
8/6/07	CC-10 storm	305	119	108	2386	1723	1185	282	123.0	16.6
8/24/07	CC-10 storm	266	205	152	1103	887	494	27	43.8	6.0

SC-3 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	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**	**TSS mg/L**	**TVSS mg/L**
1/9/07	SC-3	63	51	43	2867	2787	2626	94	10.4	<4.0
2/13/07	SC-3	69	45	38	1596	1526	1302	19	4.4	<4.0
3/20/07	SC-3	40	15	11	451	365	63	6	8.1	<4.0
5/8/07	SC-3	112	88	50	1279	934	653	7	5.0	4.4
6/5/07	SC-3	167	154	143	484	455	141	16	5.2	<4.0
7/9/07	SC-3	210	183	165	600	498	19	49	10.4	<4.0
8/15/07	SC-3	276	257	256	394	330	63	26	13.8	<4.0
9/5/07	SC-3	126	117	124	375	333	10	42	13.8	<4.0
10/9/07	SC-3	31	19	11	440	379	131	18	12.8	<4.0
11/6/07	SC-3	56	37	33	734	731	492	6	14.5	<4.0
12/11/07	SC-3	44	36	37	2930	2716	2666	15	4.6	<4.0
4/24/07	SC-3 storm	237	95	78	1947	1520	861	292	114.0	24.0
5/15/07	SC-3 storm	181	108	62	1805	1563	848	206	29.0	13.0
6/13/07	SC-3 storm	162	101	82	1113	891	514	12	8.4	<4.0
8/6/07	SC-3 storm	118	77	76	935	760	431	22	15.6	<4.0
8/24/07	SC-3 storm	167	145	99	1914	1731	1428	13	34.6	8.0

CT-P2 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	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**	**TSS mg/L**	**TVSS mg/L**
1/9/07	CT-P2	39	17	12	1510	1385	983	63	15.0	4.0
2/13/07	CT-P2	98	60	47	1144	1097	675	48	10.6	<4.0
3/20/07	CT-P2	41	11	5	963	877	534	17	16.8	4.6
5/8/07	CT-P2	68	35	18	1235	1111	681	38	14.6	4.8
6/5/07	CT-P2	56	14	10	1199	1028	659	22	14.8	4.6
7/9/07	CT-P2	77	46	26	1424	1230	718	49	11.3	<4.0
8/15/07	CT-P2	102	36	26	1416	972	62	21	23.0	8.0
9/5/07	CT-P2	68	34	22	1328	1023	549	18	18.2	4.8
10/9/07	CT-P2	36	22	13	1284	1164	402	27	15.0	4.2
11/6/07	CT-P2	60	52	15	1493	1407	927	37	21.0	4.0
12/11/07	CT-P2	13	9	6	1382	1252	883	62	9.8	<4.0
4/24/07	CT-P2 storm	380	64	50	1464	776	313	200	265.3	38.7
5/15/07	CT-P2 storm	138	30	16	1390	1048	530	107	36.0	13.5
6/13/07	CT-P2 storm	179	91	73	1616	1342	951	20	46.0	9.6
7/26/07	CT-P2 storm	217	105	96	2255	1821	764	196	42.5	11.3
8/2/07	CT-P2 storm	192	61	44	1624	1052	460	22	35.0	14.0
8/6/07	CT-P2 storm	304	109	107	1487	919	504	29	129.5	18.0
8/24/07	CT-P2 storm	183	85	51	1455	980	553	26	36.2	8.8

CT-P1 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	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**	**TSS mg/L**	**TVSS mg/L**
1/9/07	CT-P1	46	20	11	1566	1459	879	89	12.8	4.4
2/13/07	CT-P1	111	72	60	1175	1104	649	40	6.6	<4.0
3/20/07	CT-P1	35	7	4	838	641	244	22	7.4	<4.0
5/8/07	CT-P1	66	33	10	1084	924	557	43	7.8	4.4
6/5/07	CT-P1	53	8	7	1068	872	360	63	34.6	8.0
7/9/07	CT-P1	123	57	24	1153	869	300	36	12.5	4.0
8/15/07	CT-P1	116	23	14	1232	640	552	15	26.0	9.2
9/5/07	CT-P1	83	17	14	1259	810	256	20	15.4	5.0
10/9/07	CT-P1	61	23	9	1054	902	416	46	14.4	4.0
11/6/07	CT-P1	37	11	6	1021	898	510	18	4.8	<4.0
12/11/07	CT-P1	14	15	5	1217	1082	643	75	13.6	<4.0
4/24/07	CT-P1 storm	459	51	41	1458	745	277	216	370.7	35.3
5/15/07	CT-P1 storm	564	16	4	2298	964	549	7	345.5	57.0
6/13/07	CT-P1 storm	198	38	22	1505	932	382	77	39.6	8.8
7/26/07	CT-P1 storm	247	54	48	2510	1914	710	162	ND	ND
8/2/07	CT-P1 storm	309	71	57	1866	1142	440	136	128.0	32.0
8/6/07	CT-P1 storm	532	113	109	1827	904	437	43	273.5	34.0
8/24/07	CT-P1 storm	168	64	34	1334	807	404	7	32.6	9.6

CT-2 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	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**	**TSS mg/L**	**TVSS mg/L**
1/9/07	CT-2	65	25	19	2527	2380	1490	687	24.8	5.8
2/13/07	CT-2	141	43	33	1887	1680	847	487	51.6	6.0
3/20/07	CT-2	64	14	7	2399	2301	1514	324	30.4	6.2
5/8/07	CT-2	81	36	8	1991	1784	852	640	27.2	7.0
6/5/07	CT-2	82	15	11	3929	3669	3177	130	53.8	8.2
7/9/07	CT-2	64	12	6	2344	2119	1361	210	21.5	5.4
8/15/07	CT-2	165	31	13	1383	642	252	14	42.2	14.6
9/5/07	CT-2	64	9	7	3387	3028	2049	361	42.0	6.8
10/9/07	CT-2	39	22	8	2869	2547	2057	27	39.0	5.6
11/6/07	CT-2	108	18	9	3178	2965	1899	665	66.2	8.0
12/11/07	CT-2	87	18	15	3657	3296	2342	697	39.0	6.2
4/24/07	CT-2 storm	489	41	29	1873	1129	458	326	419.5	37.0
5/15/07	CT-2 storm	172	43	24	2053	1550	718	382	61.0	13.0
6/13/07	CT-2 storm	292	27	17	3484	2605	1925	285	111.7	19.7
7/26/07	CT-2 storm	137	25	12	2703	2178	1247	153	43.7	9.0
8/2/07	CT-2 storm	190	50	37	1989	1324	665	70	55.0	19.5
8/6/07	CT-2 storm	269	109	110	1830	1006	447	66	91.5	13.0
8/24/07	CT-2 storm	ND	ND	ND	ND	ND	ND	ND	51.4	8.6

CT-1 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	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**	**TSS mg/L**	**TVSS mg/L**
1/9/07	CT-1	73	28	22	2835	2527	1622	869	30.2	5.0
2/13/07	CT-1	146	43	35	1908	1779	930	476	64.6	7.8
3/20/07	CT-1	88	17	14	2809	2542	1791	390	45.6	6.8
5/8/07	CT-1	78	42	18	2262	1994	963	845	26.6	6.8
6/5/07	CT-1	160	22	19	4614	4272	3690	17	130.2	13.8
7/9/07	CT-1	52	21	11	2914	2683	2223	41	13.0	<4.0
8/15/07	CT-1	83	24	21	1349	1044	284	10	26.6	7.2
9/5/07	CT-1	200	27	19	3494	3240	2194	467	26.6	4.4
10/9/07	CT-1	125	72	50	2954	2736	13	196	15.4	<4.0
11/6/07	CT-1	56	22	15	3706	3515	2142	845	14.8	<4.0
12/11/07	CT-1	75	20	17	4002	3487	2560	750	46.6	6.4
4/24/07	CT-1 storm	1160	53	40	2296	961	383	326	132.5	19.0
5/15/07	CT-1 storm	222	31	16	1714	1281	694	216	119.0	18.5
6/13/07	CT-1 storm	198	23	12	1742	1252	766	19	84.2	9.2
7/26/07	CT-1 storm	172	24	12	2323	1652	898	11	81.7	12.8
8/2/07	CT-1 storm	250	60	44	2813	1286	695	46	183.0	32.0
8/6/07	CT-1 storm	372	108	108	1512	1036	415	47	231.3	19.8
8/24/07	CT-1 storm	329	57	31	2094	1396	697	268	182.4	16.2

CC-O at I-225 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	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**	**TSS mg/L**	**TVSS mg/L**
2/20/07	CC-Out at I225	92	50	47	1195	974	222	414	48.8	4.4
3/20/07	CC-Out at I226	84	22	7	866	472	23	25	20.8	7.2
4/26/07	CC-Out at I227	85	26	18	801	393	<2	3	25.0	9.4
5/8/07	CC-Out at I228	115	52	36	769	462	4	9	10.8	4.8
5/29/07	CC-Out at I229	133	91	83	669	484	53	44	13.6	ND
6/5/07	CC-Out at I230	305	234	232	915	784	48	219	11.0	4.4
7/24/07	CC-Out at I231	263	195	200	925	725	17	270	12.4	4.8
8/7/07	CC-Out at I232	145	105	99	636	457	9	80	19.4	6.4
9/28/07	CC-Out at I233	111	34	25	872	397	<2	121	41.7	7.7
10/9/07	CC-Out at I234	51	44	40	1056	751	124	10	27.0	8.0
11/6/07	CC-Out at I235	100	19	8	988	631	<2	15	20.0	6.8
12/11/07	CC-Out at I236	60	12	8	972	477	6	15	10.2	11.0
4/27/07	CC-Out at I225 storm	32	28	20	515	501	<2	33	14.6	5.4

CC-Out C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	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**	**TSS mg/L**	**TVSS mg/L**
2/20/07	CC-Out	88	49	43	1220	990	221	384	10.6	5.6
3/20/07	CC-Out	87	14	7	899	462	22	14	20.6	6.8
4/26/07	CC-Out	80	24	10	779	381	<2	8	17.4	9.0
5/8/07	CC-Out	105	45	34	667	456	3	6	13.8	6.0
5/29/07	CC-Out	121	83	74	706	496	43	22	13.6	ND
6/5/07	CC-Out	265	197	189	827	620	47	128	14.4	4.8
7/24/07	CC-Out	268	207	191	999	847	36	218	ND	ND
8/7/07	CC-Out	136	94	94	740	534	32	64	16.2	5.4
9/28/07	CC-Out	64	30	23	806	431	7	83	36.6	6.1
10/9/07	CC-Out	121	65	45	958	653	25	153	25.6	6.8
11/6/07	CC-Out	82	16	7	854	518	<2	8	18.0	6.4
12/11/07	CC-Out	60	10	9	877	508	17	26	12.2	5.0
4/27/07	CC-Out storm	30	32	19	493	483	<2	32	67.6	10.4

Rain Gauge C&A Water Chemistry Data								
Analytical Detection Limits		2	2	2	2	2	2	3
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**
7/9/07	Rain Gauge	1428	1161	972	7914	5017	1456	19
7/26/07	Rain Gauge storm	3750	2510	2185	11242	8896	817	ND
8/1/07	Rain Gauge storm	136	96	84	1224	1021	546	162
8/2/07	Rain Gauge storm	88	54	45	2451	2401	637	1446
8/24/07	Rain Gauge storm	499	30	20	1361	785	628	364
11/1/07	Rain Gauge storm	52	7	2	691	593	313	206

"ND" denotes "No data"

Appendix D

2007 Streamflow, Rainfall, Phosphorus Loading Calculations and Final Inflow and Load Data Normalized to the U.S. Army Corps of Engineers Inflow Data.

Streamflow Determination

Water levels (stage) were monitored on 15-minute intervals using ISCO Model 4220 and 6700 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, SC-3, CT-P1, CT-P2, and CT-1 by measuring stream discharge (ft3/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 2007 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 combined with the 2007 data.

Rating curves were developed for CC-10, SC-3, CT-P1, and CT-1 by fitting a nonlinear regression model to the data (Table D-2). For sites CC-10, SC-3, and CT-P1 a two-stage rating curve was developed to more accurately estimate flows at these sites. A rating curve was also developed for Site CT-P2, but was only used for quality control to evaluate the multi-level weir equation for the Peoria Pond outlet structure. A multi-level weir equation was also used to estimate flows through the Perimeter Pond outlet structure. The weir equations for sites CT-P2 and Site CT-2 (Table D-2) were provided by Muller Engineering (unpublished data, 2004).

While water levels for Cherry Creek, Shop Creek, and Cottonwood Creek are monitored on a fairly continuous basis, there were periods of time when daily mean flows were estimated due to a dead battery, flow meter malfunction, icing, 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. In 2007, Site CC-10 revealed no strong relations with any of the GEI monitored stream sites. Therefore a model was developed with the USGS Cherry Creek Gage near Parker (#393109104464500), using only data from January 1, 2007 to April 30, 2007, to estimate levels for CC-10 in mid-April 2007. Similarly, data from October 1, 2007 to November 30, 2007 was used to estimate missing levels for CC-10 in October 2007.

Table D-1: Stage-discharge data used to develop rating curves for sites CC-10, SC-3, CT-P1, CT-P2, and CT-1 in 2007.

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
SC-3	2005	25-Apr-05	0.79	0.836	2.64
SC-3	2005	19-May-05	0.22	0.165	0.08
SC-3	2005	26-May-05	0.20	0.231	0.06
SC-3	2005	01-Jun-05	0.28	0.280	0.27
SC-3	2005	16-Aug-05	0.25	0.413	0.54
SC-3	2005	13-Oct-05	0.29	0.361	0.51
SC-3	2006	20-Apr-06	0.02	0.150	0.03
SC-3	2006	13-Jun-06	0.06	--	0.13
SC-3	2007	13-Mar-07	0.06	0.145	0.24
SC-3	2007	10-May-07	0.32	0.255	0.18
SC-3	2007	26-Jul-07	0.11	0.120	0.004
SC-3	2007	9-Aug-07	0.32	0.337	0.22
CT-P1	2002	27-Jun-02	0.45	0.430	0.80
CT-P1	2002	11-Jul-02	0.60	0.580	2.43
CT-P1	2002	04-Sep-02	0.36	0.359	0.43
CT-P1	2003	04-Feb-03	0.50	0.502	1.35
CT-P1	2003	18-Jun-03	1.10	1.072	12.04
CT-P1	2003	30-Jul-03	0.72	0.726	3.18
CT-P1	2003	20-Nov-03	0.53	0.530	0.70
CT-P1	2004	09-Jan-04	0.49	0.483	0.42

Site	Year	Date	Staff Gage Level (ft)	Transducer Level (ft)	Discharge (cfs)
CT-P1	2004	24-Feb-04	0.54	0.552	0.87
CT-P1	2004	27-May-04	0.51	0.508	0.71
CT-P1	2004	22-Jun-04	0.89	0.890	5.08
CT-P1	2004	23-Jun-04	0.69	0.677	1.99
CT-P1	2004	24-Aug-04	0.59	0.595	1.44
CT-P1	2005	01-Apr-05	0.66	0.655	1.88
CT-P1	2005	14-Apr-05	1.16	1.188	13.36
CT-P1	2005	25-Apr-05	1.39	1.369	15.62
CT-P1	2005	19-May-05	0.56	0.549	1.06
CT-P1	2005	26-May-05	0.55	0.575	0.77
CT-P1	2005	01-Jun-05	0.73	0.739	2.74
CT-P1	2005	16-Aug-05	0.96	1.120	7.40
CT-P1	2005	13-Oct-05	0.94	0.934	7.73
CT-P1	2006	20-Apr-06	0.55	0.540	0.64
CT-P1	2006	13-Jun-06	0.51	0.515	0.47
CT-P1	2006	12-Jul-06	0.66	0.631	1.57
CT-P1	2006	08-Aug-06	0.83	0.844	4.97
CT-P1	2006	27-Dec-06	0.76	--	2.16
CT-P1	2007	13-Mar-07	0.68	0.668	1.51
CT-P1	2007	26-Apr-07	0.99	0.956	7.33
CT-P1	2007	26-Jul-07	0.82	0.832	2.97
CT-P1	2007	9-Aug-07	0.70	0.718	1.73
CT-P1	2007	13-Nov-07	0.59	0.597	0.24
CT-P2	2004	09-Jan-04	0.32	0.327	0.79
CT-P2	2004	27-May-04	0.33	0.332	0.67
CT-P2	2004	22-Jun-04	3.25	3.257	12.00
CT-P2	2004	23-Jun-04	1.07	1.051	2.75
CT-P2	2005	01-Apr-05	1.04	1.038	2.81
CT-P2	2005	14-Apr-05	3.84	3.858	11.86
CT-P2	2005	25-Apr-05	4.13	4.153	19.02
CT-P2	2005	19-May-05	0.43	0.428	1.44
CT-P2	2005	26-May-05	0.42	0.438	1.12
CT-P2	2005	01-Jun-05	1.44	1.377	4.56
CT-P2	2005	16-Aug-05	3.40	3.417	13.90
CT-P2	2005	13-Oct-05	3.10	3.172	11.56
CT-P2	2006	20-Apr-06	0.38	0.380	1.45
CT-P2	2006	13-Jun-06	0.29	0.293	0.85
CT-P2	2006	12-Jul-06	1.22	1.260	2.79
CT-P2	2006	08-Aug-06	2.24	2.204	8.18
CT-P2	2007	13-Mar-07	2.30	2.308	5.24
CT-1	2007	26-Apr-07	2.98	2.935	18.56
CT-1	2007	26-Jul-07	2.54	2.545	9.81
CT-1	2007	9-Aug-07	2.24	2.248	4.76
CT-1	2007	13-Nov-07	2.16	2.175	0.84

Table D-2: Discharge (Q, cfs) and stage height (H, ft) relationships for all sites. Rating curves are developed for Sites CC-10, SC-3, 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
CC-10	< 3.0	Q = EXP((H+0.444)/0.8925)	0.83
	> 3.0	Q = EXP((H+6.8201)/2.2757)-26.1446	0.93
SC-3	< 0.5	Q = EXP((H-0.4814)/0.1372)	0.73
	> 0.5	Q = (H-0.1424)/0.2484)	0.79
CT-P1	<1.5	Q = EXP((H+0.3172)/0.5314)-4.2269	0.93
	>1.5		
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		Q = (H-2.0637)/0.0485	0.98
CT-2	< 0.95	Q = ((3.3)*(2)*(H)^(1.5))	
	0.95 - 1.35	Q = ((7.2)+(3.3)*(2)*(H)^(1.5))	
	> 1.35	Q = ((7.2)+(3.3)*(2)*(H)^(1.5))+((3.3)*(2)*(H-1.0)^(1.5))+((3.3)*(2)*(H-0.50)^(1.5))	

H_{adj} = Mean daily level - 0.25 ft

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, Apr	CC-10 Level = 8.5997*Ln(Parker Level) - 9.667	0.75	4%
CC-10, Oct	CC-10 Level = 15.06*Ln(Parker Level) - 18.509	0.73	2%
SC-3, Jan-Feb	SC-3 Level = 1.5844*(CT-P1 Level) - 0.809	0.15	9%
SC-3, Apr-May	SC-3 Level = 1.353*(CTP1 Level) - 0.7646	0.64	3%
SC-3, Jun-Sep	SC-3 Level = 0.246 (2007 median SC-3 level)		28%*
CT-P1	CT-P1 Level = (CT-1 Level - 1.1554)/1.6093	0.91	14%
CT-P2	CT-P2 level = 2.0354*(CT-1 Level) - 3.599	0.45	6%
CT-1	CT-1 Level = 1.5469*(CT-P1 Level)+1.0287	0.86	3%
CT-2	CT-2 Level = 0.2955*(CT-P2 Level)+0.4845	0.79	12%

* Extensive data loss due to laptop computer theft.

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 (CC-10 and CT-2 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 MW-9 (1995-2006, 190 µg/L). Notably, flow and loads for sites upstream of 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.

Tributary Streams

Once the annual 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 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 2007.

Site	90th Percentile (cfs)
CC-10	52.65
SC-3	0.55
CT-1	11.59
CT-2	13.64
CTP-1	6.28
CTP-2	5.85

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 inflow 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 annual 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,

µg/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 2007.

Month	CC-O	CC-10	SC-3	CT-P1	CT-P2	CT-1	CT-2
January	73	171	63	46	39	73	65
February	92	228	69	111	98	146	141
March	84	175	40	35	41	88	64
April	85	232	76	51	55	83	73
May	124	288	112	66	68	78	81
June	305	298	167	53	56	160	82
July	263	218	210	123	77	52	64
August	145	247	276	116	102	83	165
September	111	217	126	83	68	200	64
October	51	209	31	61	36	125	39
November	100	176	56	37	60	56	108
December	60	162	44	14	13	75	87
Annual storm flow median	--	348	173	354	228	386	258

Note: Shaded cells represent interpolated data. The July base flow samples were categorized as storm flow samples (see methods for discussion).

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. In 2006, concerns were raised about the appropriateness of using water quality data collected at the CC-O site which may not accurately represent conditions with the reservoir. Following many discussions between the Authority's consultants and WQCD, it was agreed upon that water quality data collected downstream of the reservoir would be more appropriate to use when estimating the export load, given the geological underpinnings and the potential for seepage at the base of the dam, as well as the uncertainties associated with the relative differences in depth between the outflow structure (~13 m) and the bottom waters sampled at CCR-2 (~7 m).

Therefore, in 2007, GEI monitored water quality of the outflow at two locations on Cherry Creek, Site CC-O and a site located approximately 75 m downstream of the concrete outflow structure at the base of the dam (CC-O @ I-225). Outflow phosphorus concentrations were compared to the in-lake CCR-2 7 m phosphorus concentrations to evaluate which data would be more appropriate to use when determining the export load (Figure D-1). While ANOVA of log transformed data revealed no statistical differences between the three sources of data, the water quality data collected from Site CC-O @ I-225 consistently revealed greater correlation with the in-lake concentration. Furthermore, the slopes of the regressions for CC-O @ I-225 were always closer to the 1:1 line than for slopes of the regressions for data collected at CC-O. Therefore, the monthly total phosphorus concentration collected from Site CC-O @ I-225 was applied to the USACE outflow to estimate the 2007 export load (Equation 1).

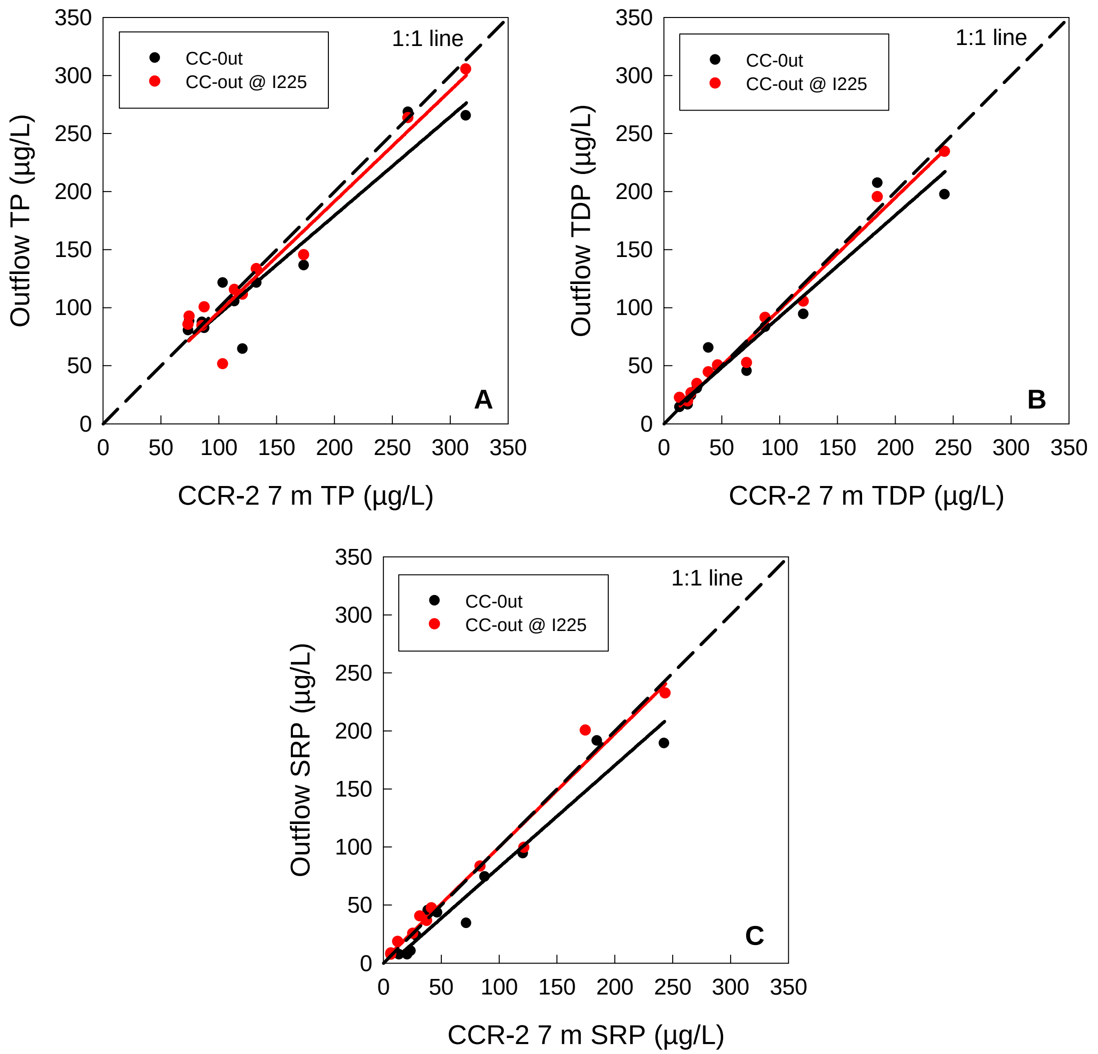


Figure D-1: Relationship between outflow phosphorus concentrations (Panel A-TP, Panel B-TDP, Panel C-SRP) and in-lake phosphorus concentrations with best-fit linear regression lines and the 1:1 line for reference.

Precipitation

Precipitation data collected at Denver/Centennial Airport (KAPA) was used to estimate phosphorus loading due to precipitation in 2007 (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 (1987-2005) 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.

Alluvium

The alluvial water component remains one of the unmonitored sources of inflow to the reservoir; however there is agreement among the Authority's consultants and WQCD that the annual flow is relatively constant given the boundaries of the of the alluvium in relation to the reservoir. The majority of the alluvial water monitored at MW-9 flows 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 acres and extended further into the reservoir to an approximate depth of 2 ft. At depths greater than 2 ft 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 2007 alluvial component was defined as a constant source of water to the reservoir that accounts for 2000 ac-ft/yr, with no seasonal fluctuations. The long-term (1994-2005) median total dissolved phosphorus concentration for MW-9 (190 μg/L) was used to estimate the alluvial load component (Equation 3).

EQUATION 3:

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

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

Redistributed Inflows

In 2007, 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 enter 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 values.

Additionally, when the redistributed inflow is greater than 1000 ac-ft/mo, the first 1000 ac-ft will be redistributed among the two streams, and the remainder will be placed into an "Ungaged Inflow" category. The reasoning behind this potentially new 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.

Month	Unadjusted Flow (ac-ft/mo)										Normalized Flow (ac-ft/mo)	
	USACE Inflow	USACE Outflow	CC-10	SC-3	CT-P1	CT-P2	CT-1	CT-2	Precip	Alluvium	CC-10	CT-2
January	1,422	468	744	24	133	126	264	277	88	170	892	272
February	2,846	2,493	2,093	3	260	233	467	359	42	153	2,263	388
March	4,586	4,542	3,632	12	223	172	397	429	90	170	3,868	457
April	6,417	5,223	5,023	89	316	280	616	668	217	164	5,327	708
May	5,131	5,762	2,920	37	312	313	463	677	189	170	3,732	866
June	1,970	1,916	980	10	135	123	246	298	4	164	1,381	421
July	442	274	231	11	175	147	213	253	86	170	89	98
August	1,480	1,218	502	11	270	258	378	489	111	170	607	591
September	647	811	256	11	124	107	183	220	26	164	246	211
October	1,365	780	547	26	205	164	322	322	133	170	669	393
November	1,527	964	704	19	78	65	129	180	6	164	1,081	276
December	1,753	1,583	937	35	72	67	136	184	58	170	1,275	251
Annual Total	**29,586**	**26,033**	**18,569**	**288**	**2,303**	**2,055**	**3,814**	**4,306**	**1,049**	**2,000**	**21,430**	**4,932**
Month	**Unadjusted Total Phosphorus Load (lbs/mo)**										**Normalized Load (lbs/mo)**	
	USACE Inflow	**USACE Outflow (CC-O)**	**CC-10**	**SC-3**	**CT-P1**	**CT-P2**	**CT-1**	**CT-2**	**Precip**	**Alluvium**	**CC-10**	**CT-2**
January	--	92	346	9	17	13	96	40	28	88	415	48
February	--	624	1,526	1	135	80	289	173	13	79	1,649	187
March	--	1,038	2,812	4	84	48	190	179	28	88	2,996	191
April	--	1,207	4,345	41	219	127	463	341	68	85	4,609	361
May	--	1,943	2,495	16	172	147	300	368	60	88	3,189	470
June	--	1,589	839	4	33	38	155	121	1	85	1,182	170
July	--	196	137	6	98	58	91	91	27	88	53	35
August	--	480	368	8	198	126	289	296	35	88	445	358
September	--	245	151	4	28	26	100	38	8	85	145	37
October	--	108	311	7	113	56	223	111	42	88	380	135
November	--	262	337	5	8	11	20	53	2	85	517	81
December	--	258	413	11	3	2	28	44	18	88	562	59
Annual Total	**--**	**8,042**	**14,080**	**116**	**1,108**	**732**	**2,244**	**1,854**	**331**	**1,033**	**16,142**	**2,133**

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)	Redist-ributed Inflow (ac-ft/mo)	Redistri-buted Load (lbs/mo)	CC-10 Percent of GEI Inflow	CT-2 Percent of GEI Inflow	CC-10 Redistri-buted Flow (ac-ft/mo)	CT-2 Redistri-buted Flow (ac-ft/mo)	Ungaged Residual Flow (ac-ft/mo)	CC-10 Redistri-buted Load (lbs/mo)	CT-2 Redistri-buted Load (lbs/mo)	Ungaged Residual Load (lbs/mo)
January	1,164	972	193	77	77%	23%	148	45	0	69	8	0
February	2,651	2,452	199	138	85%	15%	170	29	0	124	14	0
March	4,326	4,061	265	195	89%	11%	237	28	0	183	12	0
April	6,036	5,691	345	284	88%	12%	305	40	0	263	21	0
May	4,773	3,597	1,175	796	81%	19%	812	188	175	694	102	133
June	1,802	1,278	523	393	77%	23%	401	122	0	343	49	0
July	187	484	-297	-140	48%	52%	-142	-156	0	-84	-56	0
August	1,198	991	208	139	51%	49%	105	102	0	77	62	0
September	457	476	-19	-8	54%	46%	-10	-9	0	-6	-2	0
October	1,062	868	194	94	63%	37%	122	72	0	69	25	0
November	1,357	884	473	208	80%	20%	376	96	0	180	28	0
December	1,526	1,121	405	165	84%	16%	339	67	0	149	16	0
Annual Total	**26,537**	**22,875**	**3,662**	**2,341**	**--**	**--**	**2,861**	**626**	**175**	**2,062**	**280**	**133**

Appendix E

Biological Data

Table E-1: 2007 Cherry Creek Reservoir Phytoplankton

	2007															
	17-Jan	20-Feb	20-Mar	26-Apr	8-May	29-May	5-Jun	19-Jun	10-Jul	24-Jul	7-Aug	23-Aug	15-Sep	28-Sep	9-Oct	6-Nov
BACILLARIOPHYTA																
Order Centrales																
Aulacoseira granulata var. angustissima			120	350	800	240	7,800	60	135	14	4		8	675	270	260
Aulacoseira granulata var. granulata			60											60	480	
Aulacoseira italica				20												
Cyclostephanos tholiformis					10		40			1					40	20
Cyclotella ocellata									3						20	160
Stephanocyclus (Cyclotella) meneghiniana					10				1					2		
Stephanodiscus hantzschii					20								480		20	20
Stephanodiscus niagarae						10	1	70	33		1				1	8
Stephanodiscus parvus	1,200	40							10	20	520	2,480		880	7,280	6,160
Order Pennate																
Asterionella formosa					2	2,260	2,680	310	38							
Diatoma vulgaris							1									
Fragilaria crotonensis					2	750	10,200	3,270	563							
Fragilaria sp.						50										
Nitzschia draveillensis	10	10	400	2,880	240	1	200		10	5	10			20	20	
Nitzschia gracilis	6	3		560	80								2	35	75	
Nitzschia linearis																30
Nitzschia palea											8			35		
Nitzschia paleacea													200	240	180	10
Nitzschia tubicola													1			
Synedra radians		3	160													
Synedra rumpens var. familiaris	2			2,400	1,240							1	8			
CHLOROPHYTA																
Ankistrodesmus falcatus			20		1					40		4				3
Ankyra judayi						220	160	10	40		1					160
Chlamydomonas ehrenbergii															5	
Chlamydomonas globosa	10		240							80		560		880	160	1,120
Chlamydomonas reinhardtii						20				15					1	
Chlamydomonas sp.							875			40		160	240	320		500
Chlorella minutissima	137,000	65,000	43,750	43,097	26,500	12,000	3,750	14,000	11,500	2,500	500	2,000	3,500		9,000	20,000
Chlorogonium sp.										80		80	10	320	80	
Chlorogonium tetragamum			20							40		20				
Choricystis sp.					1,500	1,000	250	7,500	4,500		36,500	25,000			7,500	26,000
Closterium acutum var. variabile									55	15					1	3
Coelastrum microporum									30							
Coelastrum sphaericum				80	70											
Coenochloris fottii													50			
Cosmarium sp.															2	
Crucigenia tetrapedia					90	10				1,760	160		1,600	320	320	2,240
Dictyosphaerium pulchellum					225										40	
Diplochloris lunata					160				80		160	320	3,040	160	5,280	4,800
Eudorina elegans									135							

Table E-1: 2007 Cherry Creek Reservoir Phytoplankton

	2007															
	17-Jan	20-Feb	20-Mar	26-Apr	8-May	29-May	5-Jun	19-Jun	10-Jul	24-Jul	7-Aug	23-Aug	15-Sep	28-Sep	9-Oct	6-Nov
Kirchneriella irregularis																80
Kirchneriella lunaris														160		
Kirchneriella obesa	5								10					160		400
Micractinium pusillum					240						480			80		480
Monoraphidium contortum														20		
Monoraphidium irregulare	600	160	400									640	80	320	80	160
Monoraphidium minutum										40						
Monoraphidium sp.				20	40											
Nephrocytium agardhianum									8							
Oocystis apiculata								20	15	240	120					
Oocystis borgei						30			20	160	240					
Oocystis lacustris							4	5			10					
Oocystis parva															200	1,520
Oocystis solitaria						5										
Pandorina smithii								960	30			60	240	80		
Pediastrum boryanum					20		32								26	50
Pediastrum duplex var. duplex						1,560	395	520	65	8		16	18	270	236	
Pediastrum duplex var. gracillimum										22						
Pediastrum simplex													8		4	
Pediastrum tetras										8			15		24	
Pseudodictyosphaerium sp.				640	720					1,600				160		
Pteromonas aculeata									5				240	40	400	
Quadrigula sp.														640	320	
Raphidocelis microscopica									280	520	1,200	240	80	480		1,760
Scenedesmus acuminatus					160				160				10	320	4	
Scenedesmus armatus											20			20	4	
Scenedesmus bicaudatus													320			
Scenedesmus communis				340	70				160	240	20		20	40	8	1,120
Scenedesmus ecornis																160
Scenedesmus ellipticus					18	90	50		160	70	20		10	50	8	65
Scenedesmus intermedius				160					200	480	320		160	480	640	640
Scenedesmus obliquus															4	
Scenedesmus obtusus																80
Scenedesmus subspicatus				320										20		
Schroederia setigera					40					120	3		80	40		40
Spermatozopsis exsultans									40	320	80	80	160			
Spondylosium planum											3					
Staurastrum sp.																5
Tetraedron caudatum				20	1				20							
Tetraedron minimum										40	40		240	80	40	320
Tetraspora lemmermannii									38							
Tetrastrum elegans	160				1								160			160
Tetrastrum staurogeniaeforme					160											640
Treubaria triappendiculata											20	40	80			

Table E-1: 2007 Cherry Creek Reservoir Phytoplankton

	2007															
	17-Jan	20-Feb	20-Mar	26-Apr	8-May	29-May	5-Jun	19-Jun	10-Jul	24-Jul	7-Aug	23-Aug	15-Sep	28-Sep	9-Oct	6-Nov
CYANOPHYTA																
Anabaena flos-aquae						9	80	875		8						
Anabaena spiroides var. crassa									80	42			130	18		
Anabaenopsis elenkinii												96				
Aphanizomenon flos-aquae								840	290	12						
Aphanizomenon issatschenkoi															34	
Aphanocapsa delicatissima				7,065	1,000				12,500	1,920	27,500	40,000			34,000	30,000
Aphanocapsa incerta									2,500	141,750	120,000	105,000	100,000	14,880	100,500	47,000
Aphanothece clathrata		4,500		4,946		5,000				320	2,500					
Aphanothece smithii	19,000			5,652	45,250			5,000	40,000	22	20,000	25,000	30,250	127,500	77,000	9,000
Coelosphaerium kuetzingianum									50							
Cyanobium sp.					250						250	400	1,120		125	
Dactylococcopsis acicularis		5	320	6,400	200						40			160	400	160
Dactylococcopsis sp.	120	80	560	80	80					320	80	400	320	160	160	80
Geitlerinema lemmermannii				1,280								28				
Merismopedia tenuissima			2,000							640		2,560	1,000	5,440	15,000	4,160
Microcystis sp.										8			2,080			
Planktolyngbya limnetica											30		640			
Planktothrix agardhii															86	453
Pseudanabaena limnetica				90	1,040					206	170	1,825	750	250	200	2,240
Rhabdoderma sp.												1,680				
Synechococcus sp.											80	1,200	240			
CHRYSOPHYTA																
Chromulina sp.				1,060								40				
Dinobryon divergens										230			50			
Ochromonas sp.	1,000															
XANTHOPHYTA																
Goniochloris fallax															1	
Isthmochoron lobulatum													1			
EUGLENOPHYTA																
Euglena acus										2			1			1
Euglena oxyuris										2	1	2			1	
Euglena polymorpha										1		1,200				
Euglena sp. 1										6				10		
Euglena sp. 2				10						1						
Euglena viridis									5	2	1	35	2			
Phacus caudatus										1						
Phacus pleuronectes												1	1		1	
Phacus sp.									1							
Trachelomonas volvocina											5		10			

Table E-1: 2007 Cherry Creek Reservoir Phytoplankton

	2007															
	17-Jan	20-Feb	20-Mar	26-Apr	8-May	29-May	5-Jun	19-Jun	10-Jul	24-Jul	7-Aug	23-Aug	15-Sep	28-Sep	9-Oct	6-Nov
DINOPHYTA																
Bernardinium sp.																
Ceratium hirundinella									1	9	2	5	1			
Peridiniopsis kulczynskii	35	3	400													
Peridiniopsis penardiforme									15	2	10	15	10	5		20
Peridiniopsis polonicum									53	9						
CRYPTOPHYTA																
Chroomonas coerulea				320	40						5			640	20	
Chroomonas nordstedtii	280			320	80						13			880	40	320
Chroomonas sp.													160			
Cryptomonas (Campylomonas reflexa) curvata	135	155	220	50	403	150	60	155	28	40	135	300	160	280	165	160
Cryptomonas (rostratiformis) curvata		3	5	5	10	70	33	35		1	3	10	5	100	10	
Cryptomonas erosa	40		420			210		5								
Cryptomonas (Campylomonas) marsonii	30				3	15		5					5			
Komma caudata	1,200	6,400	6,000	4,560	4,320	240	280	160	13,120	960	2,600	2,560	2,080	2,320	1,360	5,600
Plagioselmis sp.	120					40		80				20			40	240
HAPTOPHYTA																
Chrysochromulina parva	15,120	11,440	12,640	4,800						22,640	80				400	160
PRASINOPHYTA																
Monomastix sp.			40			20						160				
Nephroselmis olivacea					40					40		160		2,400	320	160
Scourfieldia complanata													40			
Tetraselmis cordiformis			480							205	8	160	1,120	480	80	240
TOTAL DENSITY (cells/mL)	176,073	87,801	68,255	87,525	85,136	24,000	26,891	33,880	86,987	177,877	213,953	214,558	151,236	162,930	262,716	169,168
TOTAL TAXA	20	14	20	28	40	24	19	20	43	55	46	41	54	48	58	51

Table E-2: Reservoir mean phytoplankton density (cells/mL) and number of taxa in Cherry Creek Reservoir, 1984 to 2007.

Metric	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	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 Taxa	28	27	32	133	151	142	93	89	42	11	40	45

Table E-2: Reservoir mean pTable E-2: Reservoir mean phytoplankton density (cells/mL) and number of taxa in Cherry Creek Reservoir, 1984 to 2007.

Metric	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	**Long-term Median**
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	**77,516**
Taxa	10	11	8	19	12	3	21	27	19	19	21	**12**
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	**18,688**
Taxa	18	18	18	71	56	27	70	75	66	63	63	**46**
Diatoms												
Density	1,109	628	838	12,019	5,256	978	2,026	1,720	3,610	32,036	60,127	**2,354**
Taxa	8	18	16	34	22	24	22	26	24	21	21	**21**
Golden-Brown Algae												
Density	227	56	--	391	1,346	34	44	57	335	542	2,380	**158**
Taxa	2	2	--	14	13	3	5	5	4	5	3	**4**
Euglenoids												
Density	838	698	1,252	126	91	22	308	24	39	1,549	1,303	**231**
Taxa	3	3	1	6	4	3	9	11	8	10	10	**3**
Dinoflagellates												
Density	--	18	45	80	157	193	20	57	60	330	595	**38**
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	**1,393**
Taxa	1	1	1	4	6	4	8	8	9	12	9	**3**
Miscellaneous												
Density	--	--	--	1,923	5,714	15	1,294	164	2,014	4,855	73,435	**1,969**
Taxa	--	--	--	1	1	1	3	6	6	6	7	**5**
Total Density	25,838	49,553	18,855	225,182	197,323	4,511	116,278	227,093	278,282	2,103,767	2,028,986	**121,357**
Total Taxa	39	55	46	157	120	70	141	164	142	141	139	**89**

Table E-3: Quantity and size of fish stocked in Cherry Creek Reservoir, 1985 to 2007.

Year	Species	Size (inches)	Number
1985	Black crappie	5	7,234
	Channel catfish	2-8	116,784
	Rainbow trout	8-12	75,753
	Walleye	0.3	2,346,000
	Yellow perch	2	90,160
1986	Bluegill	1	111,968
	Channel catfish	4	25,594
	Cutthroat trout	6	52,228
	Rainbow trout	2-18	414,136
	Tiger musky	5-6	4,723
	Walleye	0.3	1,734,000
	Wiper	0.2	80,000
1987	Bluegill	0.2	70,000
	Channel catfish	4	25,600
	Largemouth bass	5	10,000
	Rainbow trout	2-26	129,715
	Tiger musky	7	4,000
	Walleye	0.2	1,760,000
1988	Channel catfish	3	16,000
	Largemouth bass	5	10,000
	Rainbow trout	9-10	293,931
	Tiger musky	8	4,500
	Walleye	0.2	1,760,000
1989	Channel catfish	2-4	10,316
	Largemouth bass	6	8,993
	Rainbow trout	8-22	79,919
	Walleye	0.2	1,352,000
	Wiper	0.2	99,000
1990	Channel catfish	3-4	25,599
	Rainbow trout	9-15	74,986
	Tiger musky	8	2,001
	Walleye	0.2	1,400,000
	Wiper	1	8,996
1991	Channel catfish	3	13,500
	Rainbow trout	9-10	79,571
	Tiger musky	5-8	6,500
	Walleye	0.2	1,300,000
	Wiper	1	9,000
1992	Blue catfish	3	9,000
	Channel catfish	4	13,500
	Rainbow trout	9-10	101,656
	Tiger musky	7	4,940
	Walleye	0.2	2,600,000

Year	Species	Size (inches)	Number
	Wiper	10	15,520
1993	Channel catfish	4	13,500
	Rainbow trout	9-10	92,601
	Tiger musky	9	4,500
	Walleye	0.2	2,600,000
	Wiper	1	9,003
1994	Blue catfish	3	21,000
	Channel catfish	4	23,625
	Cutthroat trout	9	9,089
	Flathead catfish	1	148
	Tiger musky	8	900
	Walleye	0.2	2,600,000
	Wiper	1-4	26,177
	Rainbow trout	9-18	62,615
1995	Channel catfish	4	18,900
	Rainbow trout	9-20	139,242
	Tiger musky	8	4,500
	Walleye	0.2	2,600,000
	Wiper	1	4,500
1996	Channel catfish	3	8,100
	Cutthroat trout	9-10	85,802
	Tiger musky	7	3,500
	Rainbow trout	4-22	163,007
	Walleye	0.2	3,202,940
	Wiper	1	8,938
1997	Channel catfish	3	13,500
	Cutthroat trout	3-9	22,907
	Rainbow trout	10-24	74,525
	Tiger musky	6	4,500
	Walleye	0.2	2,600,000
	Wiper	1	9,000
1998	Channel catfish	4	7,425
	Rainbow trout	10-12	59,560
	Tiger musky	7	4,000
	Walleye	1.5	40,000
	Wiper	1.3	9,000
1999	Channel catfish	3.5	13,500
	Rainbow trout	10-19	32,729
	Tiger musky	7	3,000
	Walleye	0.2	2,400,000
	Wiper	1.3	9,000
2000	Channel catfish	4.1	13,500
	Northern pike	▪	46
	Rainbow trout	4.5-20.3	180,166

Year	Species	Size (inches)	Number
	Rainbow/Cutthroat trout hybrid	▪	5,600
	Tiger musky	8	4,086
	Walleye	0.23	2,400,000
2001	Channel catfish	3.5	13,500
	Rainbow trout	10-19	23,065
	Tiger musky	7	4,000
	Walleye	0.2	2,400,000
2002	Rainbow trout	10	13,900
	Tiger musky	7	4,000
	Walleye	0.2	2,519,660
2003	Rainbow trout	10-11	30,111
	Walleye	0.25	4,136,709
	Channel catfish	2-2.5	33,669
2004	Rainbow trout	10-11	43,553
	Walleye	0.25	2,874,100
	Channel catfish	2.5	13,500
2005	Rainbow trout	10.4	43,248
	Walleye	0.25	2,579,939
	Wiper	0.18	200,000
	Channel catfish	2.2	13.500
2006	Rainbow trout	10.8	47,150
	Snake River cutthroat	16.1	204
	Rainbow × cutthroat hybrid	10.6	7,895
	Walleye	0.24	2,788,825
	Wiper	2.1	5,000
	Channel catfish	2.8	13,500
	Black crappie	2.5	300
	Largemouth bass	2.1	195
2007	Rainbow trout	12	4,800
	Rainbow trout	10	37,709
	Walleye	1	7,998
	Walleye	0.25	4,300,000
	Wiper	1.5	4,600
	Channel Catfish	3	9360

Appendix F

2007 Quality Assurance/Quality Control

Independent Laboratory QC Results

Duplicate water quality samples analyzed by the University of Colorado, Center for Limnology were generally within acceptable limits except for ammonium ion (i.e., overall less than 25 percent relative difference for an analyte). While the total dissolved phosphorus and soluble reactive phosphorus analyses were generally in close agreement, the relationship between both laboratories for the total phosphorus raised concern. The slope of the relationship was 0.45 with outlier and 0.77 without the outlier, with the University of Colorado results generally less than GEI results. One possible explanation for this difference is the total phosphorus methods used by each laboratory. GEI uses an automated LACHAT method (QC 10-115-01-1-U) to analyze total phosphorus, whereas the University of Colorado calculates the total phosphorus content as the sum of total particulate phosphorus and total dissolved phosphorus, based upon manual colorimetric methods (Lagler and Hendrix 1982; Murphey and Riley 1962; and Valderrama 1981). While both methods use similar digestion techniques, the automated method is not necessarily more accurate than the manual method. However, the automated method is subject to less variability because it eliminates the errors associated with analyzing large batches of samples by hand. Furthermore, additional error may also be introduced by the manual methods, given the summation of two individual analyses. In an effort to evaluate the potential bias within GEI analyses, GEI re-evaluated each batch QC standard, spikes, and blanks with all samples passing the 20 percent relative difference requirement. GEI also purchased total phosphorus standards from Wibby Environmental (DMRQA Nutrient #2, TKN-TP standard, Lot# 8502-11) to compare in-house results with the known concentration. All results were within 10 percent of the known standard. Therefore, GEI elected to use their total phosphorus results rather than computing the mean value of the duplicate samples when estimating total phosphorus loads.

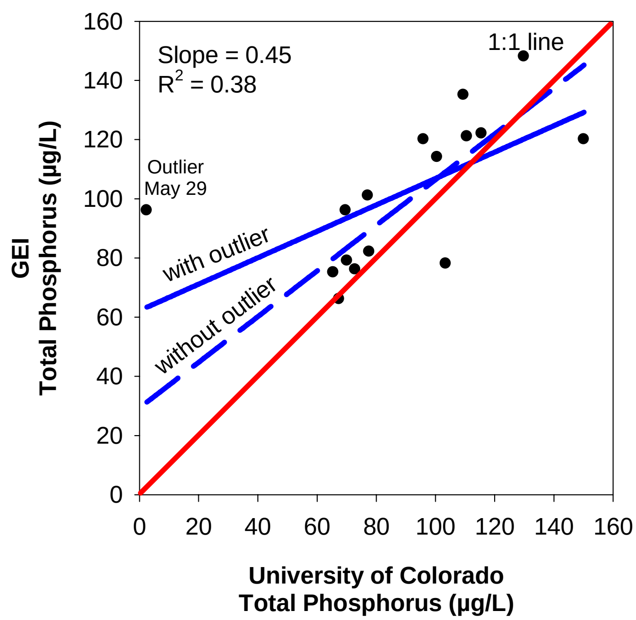


Figure F-1: Relationship between GEI total phosphorus and University of Colorado total phosphorus for 2007.

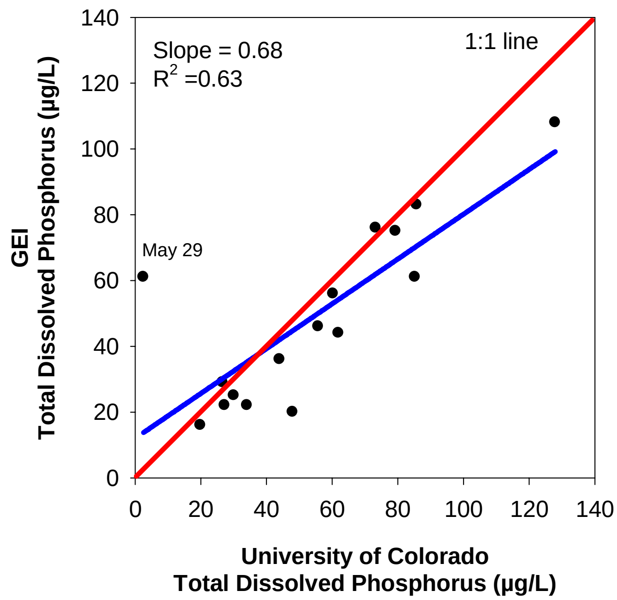


Figure F-2: Relationship between GEI total dissolved phosphorus and University of Colorado total dissolved phosphorus for 2007.

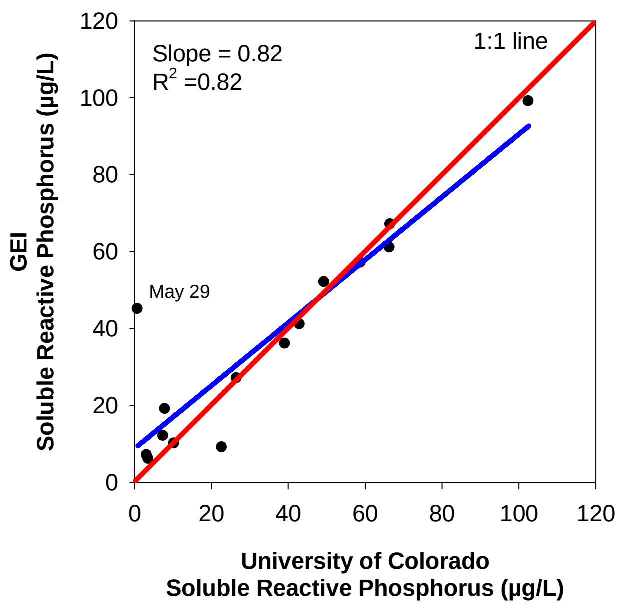


Figure F-3: Relationship between GEI soluble reactive phosphorus and University of Colorado soluble reactive phosphorus for 2007.

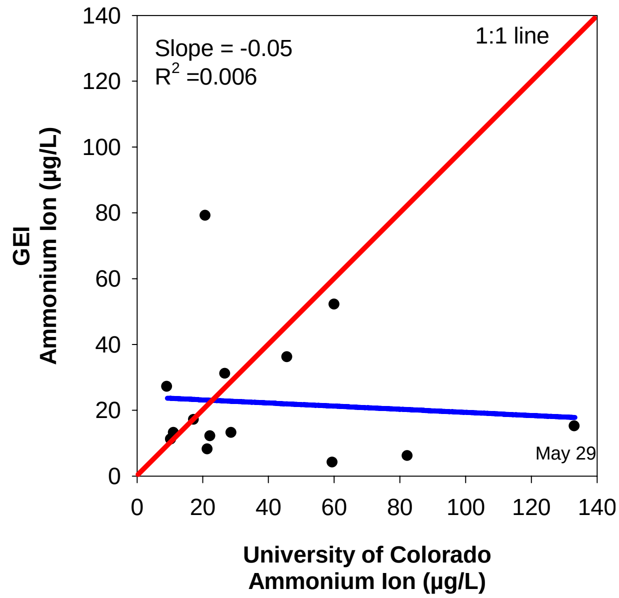


Figure F-4: Relationship between GEI ammonium ion and University of Colorado ammonium ion for 2007.

Reference:

Lagler, C. L., and P. F. Hendrix. 1982. Evaluation of persulfate digestion method for particulate nitrogen and phosphorus. Water Res. 16: 145 l-l 454.

Murphy, J. and J. Riley. 1962. A modified single solution for the determination of phosphate in natural waters. Anal. Chim. Acta v.27 p.31-36.

VALDERRAMA, J. C. 1981. Simultaneous analysis of total nitrogen and total phosphorus in natural waters. Mar. Chem. 10: 109-122.