Five Year Summary Report (2008- 2012)

Upper Cache la Poudre River

Collaborative Water Quality Monitoring Program

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EXECUTIVE SUMMARY

UPPER CACHE LA POUDRE COLLABORATIVE WATER QUALITY MONITORING PROGRAM

Sample collection for the Upper Cache la Poudre (CLP) Collaborative Water Quality Monitoring Program consists of eleven sampling events between April and November at ten sites on the Mainstem CLP and nine sites on the North Fork, including Seaman Reservoir. Water samples are analyzed for a total of up to 39 parameters. The collaborative Upper CLP monitoring program began in 2008.

The objective of this collaborative water quality monitoring program is to assist the City of Fort Collins, the City of Greeley and the Tri-Districts in meeting current and future drinking water treatment goals by reporting current water quality conditions and trends within the Upper CLP watershed.

SCOPE OF 2012 5-YEAR REPORT

The 2012 5-year report provides an in-depth analysis of the spatial and temporal trends in hydrology and water quality across the watershed since 2008. It also summarizes the major issues of concern within the upper watershed in respect to their potential to affect watershed processes and water quality, with significant discussion dedicated to the influences of recent wildfires (Section 4) and drought (Section 2). Summary graphs for all parameters and locations are presented in a separate attachments at the back of this document.

SIGNIFICANT EVENTS, ISSUES OF CONCERN & SPECIAL STUDIES

Climate Change. Changes in climate have are well documented at global, national, and regional scales, including within the State of Colorado. While there remains considerable uncertainty around how these observed changes will manifest at the local watershed scale, it is expected that long-term changes in climate will likely result in more variability in precipitation and temperature patterns. As a result, the greater variability in these patterns may produce more unexpected and unprecedented conditions within our local watersheds.

A review of air temperature records at two locations in the Upper CLP watershed identify significant increasing trends over the period of record. Daily average air temperatures at the at higher elevation site near Joe Wright Reservoir (Joe Wright SNOTEL) were estimated to have increased approximately 5 degrees F over the last 23 years. The lower elevation site, Poudre above North Fork (PNF) also exhibited a significant increase of 1.5 degrees F, over a much shorter 4 year period of record. It has yet to been seen if such climate-related changes will impact snowpack in the Upper CLP basin. There were no trends in snow water content observed at site Joe Wright SNOTEL from 2004 – 2012, suggesting that the snow water content at this site is mediated by a more complex set of climatic factors than air temperatures alone.

There are many other documented changes to increasing temperatures that affect watershed health including increased susceptibility of forests to insect outbreaks and disease (Joyce et al, 2008), longer duration of wildfire season and higher intensity wildfires (McKenzie et al., 2004), changes in the timing and intensity of spring snowmelt runoff as well as changes in base flow conditions (Christensen et al, 2004). These and other changes in watershed condition have the potential to affect the quality of the Poudre River as a municipal drinking water supply, and therefore, will continue to be an important focus of the Cooperative Upper CLP Water Quality Monitoring Program.

Drought. 2012 was characterized by above average temperatures and below average moisture for Northern Colorado. By August, the drought was rated as "severe" for most of Larimer County which includes much of the Upper CLP basin. The coincidence of drought and wildfires put considerable pressure on regional water supplies which lasted for the duration of the water year. Frequent or prolonged drought also has potential implications for water quality and watershed health, including higher concentrations of dissolved constituents, higher stream temperatures, taste and odor issues related to increased algae growth, and the increased risk of additional wildfires. During late 2012, some instances of elevated constituent concentrations were observed; however, it was not possible to discern whether higher concentrations were due to drought, runoff from wildfires, or a combination of influences based on available information.

Mountain Pine Beetle (MPB) Infestation. In response to decreased availability of healthy trees to attack, the expansion of the MPB infestation in Larimer County slowed significantly over recent years. During 2012, there was some limited MPB activity lower elevation Lodgepole and Ponderosa Pine stands along the Northern Colorado Front Range, with some continued mid-elevation forest mortality observed. Nearly 3.4 million acres have been affected since 1996. Significant portions of the 2012 High Park and Hewlett Fires occurred in MPB affected forests in the Upper Cache la Poudre watershed.

Hewlett and High Park Wildfires. The Hewlett Fire started on May 14, 2012 and burned until May 22, after flames from a camping stove ignited dry grass in Hewlett Gulch area. The fire burned 7,685 acres, including sub-watersheds that drain both to the Mainstem Poudre and into Seaman Reservoir on the North Fork Poudre River.

The High Park Fire ignited by lightning strike on June 9th and was declared contained on July 2nd. In total, the fire burned 87,415 acres and included numerous sub-drainages that are tributary to the Mainstem Poudre River and the South Fork of the Poudre River. Combined, the two fires created a contiguous burned area approximately 95,000 acres in size. While no homes were damaged in the Hewlett Fire, the High Park Fire destroyed 259 homes and cabins.

The immediate widespread loss of vegetation and burned soils resulted in an unstable watershed, susceptible to erosion and flooding. Immediately following the fires, localized summertime thunderstorms resulted in large sediment and debris flows into the Mainstem CLP and Seaman Reservoir. The movement of large volumes or ash, sediment and large debris into the river channel produced rapid and dramatic changes in water quality and posed a threat to the safety of people and homes in the Poudre Canyon. For the duration of 2012 and into 2013, rapid changes in river water quality (turbidity) were observed in response to even small rain events and changes in water surface elevation due to water releases from upstream reservoirs. Water quality changes in Seaman were less visible due to the lack of flow through the reservoir, long residence time and distance between the debris flow inputs and the reservoir outlet.

The City of Fort Collins, City of Greeley and the Tri-Districts responded to the fire and resulting debris flows by closing the intakes for Poudre River water supplies to avoid treating the sediment laden water. To understand the treatment challenges presented by the fire-impacted water supply, the City of Fort Collins and the City of Greeley worked in collaboration with several university and agency partners to understand potential issues related to taste and odor, metals contamination, nutrient loading and changes in treatability, such as changes in organic carbon and disinfection by-product formation potential.

In addition, these local water providers worked together to improve early warning capabilities that would signal the event of rainstorms and debris flows and decrease the amount of sediment in the water supply. These projects included:

- The installation of an in-stream water quality instrument provides 15-minute temperature, conductivity and turbidity measurement readings, available at the Fort Collins Water Treatment Facility (FCWTF) or external host website. This information allows water treatment operations to react quickly in the event that upstream water quality changes warrant the closure of the supply pipeline.

- Three rain gauges were installed at Hewlett Bridge, Hewlett Gulch and at the Fort Collins intake facility at Gateway as part of the City of Fort Collins Utilities flood-warning system. These gauges not only provide downstream flood warning, but they also provided important information to water treatment operations by signaling the potential for imminent changes in water quality.

- A new presedimentation basin was constructed to remove sediment from the Poudre River resulting from the 2012 wildfires and subsequent rain events and to provide more consistent water quality. The basin is located near the Pleasant Valley Pipeline next to the Munroe Canal on property owned by Northern Water. The presedimentation basin is designed to treat a maximum of 60 million gallons per day of raw water for both City of Fort Collins and the Tri-Districts Soldier Canyon Filter Plant.

Following the fires, water quality sampling efforts focused on routine monitoring to understand impacts of fire on background (non-storm event) water quality. Storm event monitoring was conducted to evaluate ‘worst case scenario’ constituent concentrations and to establish a baseline for watershed recovery. Samples were also collected in support of fire-related water quality studies. All post-fire sampling is expected to continue through 2013.

Emergency hillslope stabilization measures were undertaken in the High Park Fire burn areas by the US Forest Service on federal Forest Service lands and on private lands through a partnership between the Natural Resource Conservation Service (NRCS), the Cities of Fort Collins and Greeley and Larimer County. A combined 3,881 acres of burned land were treated by aerial applications of wood mulch or agricultural straw in 2012 in effort to decrease hillslope erosion. Additional mulching over the High Park burn area is planned for 2013 through the NRCS Emergency Watershed Protection program, which provides matching funds for co-sponsoring agencies.

Emergency stabilization measures on the Hewlett Fire burn area were coordinated by the NRCS and the City of Greeley in 2012 and included aerial straw mulching, seeding and tree felling into stream channels.

Attached Algae. As in previous years, attached green algae were abundant in the middle elevation reaches of the Poudre River. Dried and live filamentous green algae (*Ulothrix* sp.) were observed in the area. Areas colonized by the invasive diatom, *Didymosphenia geminata,* were also observed. Sampling results have not identified any sources of elevated nutrients that may have triggered the algal bloom. In addition, treatment plants did not experience any taste and odor (T&O) issues in Poudre water supplies during this time, suggesting that potential off-taste and odor compounds were either not strongly associated with this algae bloom, or were adequately volatilized, degraded, and/or diluted prior to reaching the raw water intakes. A particularly notable field observation was the dramatic decrease in visible algae between the July and August 2012 sampling dates. Reasons for the apparent abrupt decline are not currently known.

Winter/Spring Geosmin Occurrence. Sampling for geosmin, a naturally occurring organic compound that imparts an earthy odor to water, began following an outbreak that occurred during the winter of 2009-2010 in raw Poudre River water at the Fort Collins Water Treatment Facility (FCWTF). To date, results have not identified any point sources of nutrient or fecal contamination or established significant links between nutrients and geosmin occurrence. Typically, the highest geosmin concentrations occur during the winter months between November and February, with lower concentrations occurring during late spring and early summer months because of dilution effect from spring runoff (Oropeza et al., 2011). In 2012, the maximum geosmin concentration of 15.99 ng/L, was measured above Rustic in the month of April, just before the onset of spring runoff. Concentrations at the Poudre River intake facility did not exceed 4 ng/L.

An evaluation of 2012 spatial trends indicates that annual median geosmin concentrations decreased from upstream to downstream, as did the variability in concentrations for a given site. There was often great variability between sites, however, producing a lack of clear spatial trend for a given sample date. These results support previous findings that suggest that while the higher elevation sites around Rustic may be "hot spots" for geosmin production, the concentrations at these upper sites may not be good predictors for geosmin concentrations at the FCWTF intake. Rather, it appears that geosmin occurrence is regulated by site-specific conditions.

Colorado Nutrient Standards. As of June 2012, all designated "cold" water rivers and reservoirs within the Upper Cache la Poudre River Watershed are subject to Colorado's Regulation #31, which provides scientifically-based numerical nutrient values designed to protect the designated uses of waters in the state of Colorado, including aquatic life, recreation and municipal water supplies. Under the initial phase of implementation from 2012 – 2017, the Poudre River and tributaries are subject to interim numerical values for total phosphorus (TP) and nitrogen (TN). In addition to TN and TP, Seaman Reservoir, a designated Direct Use Water Supply Reservoir, is subject to interim chlorophyll-*a* standard. 2012 TN and TP concentrations on the Mainstem Poudre near City of Fort Collins and City of Greeley water supply intakes were well below the interim values. Seaman Reservoir, however, exceeded the interim numerical values for TN, TP and chlorophyll-*a*.

Colorado's 2012 Section 303(d) and monitoring and Evaluation (M&E) Lists. There are two segments of the North Fork of the Upper CLP River listed on the state of Colorado's Section 303(d) List of impaired waters, both which are currently designated medium priority for Total Maximum Daily Load (TMDL) development. There are also three segments that are listed on the Monitoring and Evaluation (M&E) List. A 2012 review of the listed segments by the State of Colorado Water Quality Control Division was postponed until 2016 due to staffing shortages.

Northern Water Collaborative Emerging Contaminant Study. The Cities of Greeley and Fort Collins have participated in the Northern Water collaborative emerging contaminant study since 2009 to determine the presence of pharmaceuticals, pesticides, hormones, and phenolic endocrine disrupting compounds in waters of the Colorado- Big Thompson system. Currently, samples are screened for 104 compounds. Two sites in the Upper Poudre Watershed have been included in this study: Poudre above North Fork (PNF) and North Fork at gage below Seaman Reservoir (NFG). These sites have been sampled 9 times and 8 times, respectively, through 2012. In 2012, one compound, Triclosan, was detected at PNF. Triclosan is an antibacterial and antifungal agent used in a variety of hand soaps and other personal care products. It was detected at a concentration of 32.2 ng/L. Previous detections at PNF include the recreational insecticide DEET of 20.8 ng/L (August 2011) and very low levels of progesterone in June of 2009 and 2010 (0.1 ng/L and 0.4 ng/L, respectively).

At the North Fork site, NFG, caffeine was detected at a concentration of 16.7 ng/L (Minimum Reporting Limit (MRL) of 10 ng/L) and Triclosan was detected at 41 ng/L (MRL 20 ng/L). In addition, the herbicide 2-4-D was detected in the August 2012 sample at a concentration of 6 ng/L.

The detected compounds DEET, Triclosan and caffeine are indicative of recreational use of the Poudre River. Detection of progesterone indicates the presence of wastewater potentially originating from upstream septic or vault systems in the watershed, and the herbicide 2-4-D likely originated from weed control measures conducted in the watershed. In all cases, it should be noted that concentrations were extremely low and near reporting limits. Caution should be exercised in terms of assigning any level of importance to results at or near these extremely low values. Furthermore, most compounds were not detected repeatedly, suggesting the sources were not persistent.

SIGNIFICANT RESULTS

Impacts of Wildfire on Water Quality

- Storm events resulted in large changes in water quality on the Mainstem, as measured at PNF. These changes were indicated by substantially elevated hardness, conductivity, pH, total dissolved solids (TDS), turbidity, total and dissolved nitrogen and phosphorus as well as metals concentrations.
- Contrary to expectations, changes in total organic carbon concentrations (TOC) were small, even during storm events.
- The observed water quality changes in response to storm events were typically short-lived.
- Mainstem water quality during non-storm event periods exhibited slightly elevated concentrations of ammonia (NH_3), Total Kjeldahl Nitrogen (TKN), ortho-phosphate (PO_4), and total phosphorus.
- Field observation and photographic evidence indicate that Seaman Reservoir was impacted by sediment and debris runoff from storm events. The impacts of these events on water quality remain uncertain.
- Increases in nutrients and turbidity were observed in Seaman Reservoir. Contributing influences likely include the extended period of low oxygen in the reservoir, which can result in internal nutrient loading from bottom sediments as well as the influx of fire ash and sediments from the surrounding watershed.

Snowpack and Hydrology

- The amount of water in the Upper CLP basin snow pack was significantly lower in 2012 than in previous years and resulted in a lower runoff compared to previous years.
- No trends in snow water equivalent (SWE) were observed at the Joe Wright SNOTEL site.

Temporal Trends in Water Quality

- Statistically significant increasing trends in air temperature were observed at Joe Wright SNOTEL site and at the Canyon Mouth gauge which is located downstream from PNF and PBD.
- Eight out of eleven Mainstem sites experienced statistically significant increasing trends in pH from 2008 – 2012, with estimated changes in pH ranging from 0.35 – 1.41 pH units. Similar increases were not observed for other factors that affect pH such as calcium, magnesium concentrations, or stream temperatures. Based on these results, trends in pH will continue to be reviewed on an annual basis.
- Five Mainstem sites experienced significant increases in ortho-phosphate, although many of the concentrations were below or near the reporting limits. Therefore, results will be treated as precautionary and trends in ortho-phosphate will continue to be reviewed on an annual basis.

- Two Mainstem locations, including PNF experienced statistically significant increases in total phosphorus since 2008.
- Seaman Reservoir has experienced significant increases in ammonia (NH_3), TKN, total nitrogen, ortho-phosphate (PO_4), total phosphorus and chlorophyll-a, magnesium, potassium concentrations and turbidity since 2008.
- Collectively, these changes indicate a progression towards a more nutrient enriched, or eutrophic reservoir over time. The trophic state index (TSI) values for chlorophyll-a, secchi depth and total phosphorus at the top of Seaman Reservoir are consistent with trends towards more eutrophic conditions.

Spatial Trends in Water Quality

- There were few evident upstream to downstream trends in water quality. Some slight differences in water quality between the two headwater sites, Poudre above Joe Wright (PJW) and Joe Wright Creek (JWC) were observed and likely reflect the proportions of water that each site receives from direct snowmelt and reservoir flow.
- The lowest elevation site, Poudre at the Bellvue Diversion (PBD), had the highest concentrations for many parameters. Constituent concentrations at PNF were generally similar to other upstream sites, but lower than PBD. The difference in water quality between these two sites can be attributed primarily to the influence of the North Fork and, following the 2012 wildfires, the presence of large amounts of sediment in the lower reaches of the river.
- Halligan and Seaman Reservoirs both affect downstream water quality on the North Fork CLP at NBH and NFG, respectively.
- As expected, water temperature increased from highest to the lowest elevation sites, due to the strong elevational gradient in the Upper CLP watershed.

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LIST OF ABBREVIATIONS & ACRONYMS

#/100 mL	number per 100 milliliters
%	percent
Ag	Silver
BMR	Barnes Meadow Outflow (routine monitoring site)
Ca	Calcium
Cd	Cadmium
CDPHE	Colorado Department of Public Health and Environment
CDWR	Colorado Division of Water Resources
CEC	Contaminant of Emerging Concern
cells/mL	cells per milliliter
cfs	cubic feet per second
CHR	Chambers Lake Outflow (routine monitoring site)
Cl	Chloride
CLP	Cache la Poudre River
Cr	Chromium
Cu	Copper
CU	University of Colorado, Boulder
cysts/L	cysts per liter
DEET	N,N-Diethyl-meta-toluamide
D.O.	Dissolved Oxygen
DBP	Disinfection By-Product
DOC	Dissolved Organic Carbon
EDC	Endocrine Disrupting Chemical
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FCWQL	Fort Collins Water Quality Lab
FCWTF	Fort Collins Water Treatment Facility
Fe	Iron
HSWMP	Halligan-Seaman Water Management Project
IPCC	Intergovernmental Panel on Climate Change
JWC	Joe Wright Creek above the Poudre River (routine monitoring site)

K	Potassium
LC/MS-MS	Liquid Chromatography with Tandem Mass Spectrometry
LC/TOF-MS	Liquid Chromatography – Time of Flight – Mass Spectrometry
LRT	Laramie River Tunnel (routine monitoring site)
m	meter
M&E List	Colorado's Monitoring & Evaluation List
MCL	Maximum Contaminant Level
MRL	Maximum Reporting Limit
Mg	Magnesium
mg/L	milligrams per liter
MPB	Mountain Pine Beetle
Na	Sodium
NBH	North Fork of the Poudre River below Halligan Reservoir (routine monitoring site)
NDC	North Fork of the Poudre River above Dale Creek Confluence (routine monitoring site)
NEPA	National Environmental Policy Act
NFG	North Fork of the Poudre River below Seaman Reservoir (routine monitoring site)
NFL	North Fork of the Poudre River at Livermore (routine monitoring site)
ng/L	nanograms per liter
NH_3	Ammonia
Ni	Nickel
NISP	Northern Integrated Supply Project
nm	nanometers
NO_2	Nitrite
NO_3	Nitrate
NTU	Nephelometric *Turbidity* Units
^oC	degrees Celsius
Pb	Lead
PBD	Poudre River at the Bellvue Diversion (routine monitoring site)
PBR	Poudre River below Rustic (routine monitoring site)
PCM	Pine Creek Mouth (routine monitoring site)

PCP	Personal Care Product
PJW	Poudre River above the confluence with Joe Wright Creek (routine monitoring site)
PNF	Poudre River above the North Fork (routine monitoring site)
PO_4	Phosphate
ppt	parts per trillion
PWSR	Protected Water Supply Reservoir
RCM	Rabbit Creek Mouth (routine monitoring site)
SCFP	Soldier Canyon Filter Plant
SCM	Stonewall Creek Mouth (routine monitoring site)
SFM	South Fork of the Poudre River above the Mainstem (routine monitoring site)
SO_4	Sulfate
SWE	Snow Water Equivalent
T&O	Taste & Odor
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSI	Trophic State Index
ug/L	micrograms per liter
UL	Underwriters Laboratories
uS/cm	microSeimens per centimeter
USFS	United States Forest Service
USGS	United States Geological Survey
WQCD	Water Quality Control Division
WQL	Water Quality Lab
WTP	Water Treatment Plant
Zn	Zinc

1.0 INTRODUCTION

1.1 Background

The Upper Cache la Poudre (CLP) River is an important source of high-quality raw water supply for communities served by the City of Fort Collins Water Treatment Facility (FCWTF), the City of Greeley-Bellvue Water Treatment Plant (COGWTP), and the Tri-Districts Soldier Canyon Filter Plant (SCFP). In the shared interest of sustaining this pristine water supply, the City of Fort Collins, the City of Greeley and the Tri-Districts partnered in 2007 to design the Upper Cache la Poudre River Collaborative Water Quality Monitoring Program. The Program was subsequently implemented in spring 2008. The over-arching goal of this monitoring partnership is to assist the participants in meeting current and future drinking water treatment goals by providing up-to-date information about water quality and trends within the Upper CLP watershed.

Raw Poudre River water quality parameters that have historically had the most impact on treatment at the three treatment plants include turbidity, total organic carbon (TOC), pH, alkalinity, temperature, pathogens (*Giardia* and *Cryptosporidium*), and taste and odor (T&O) compounds such as geosmin. A more in-depth discussion of TOC, geosmin, and pathogens and the challenges they present for water treatment is included in the program design document, "Design of a Collaborative Water Quality Monitoring Program for the Upper Cache la Poudre River" (Billica, Loftis and Moore, 2008). This design document also provides a complete description of the scope and objectives of the monitoring program as well as a detailed description of the watershed, sampling design and methods.

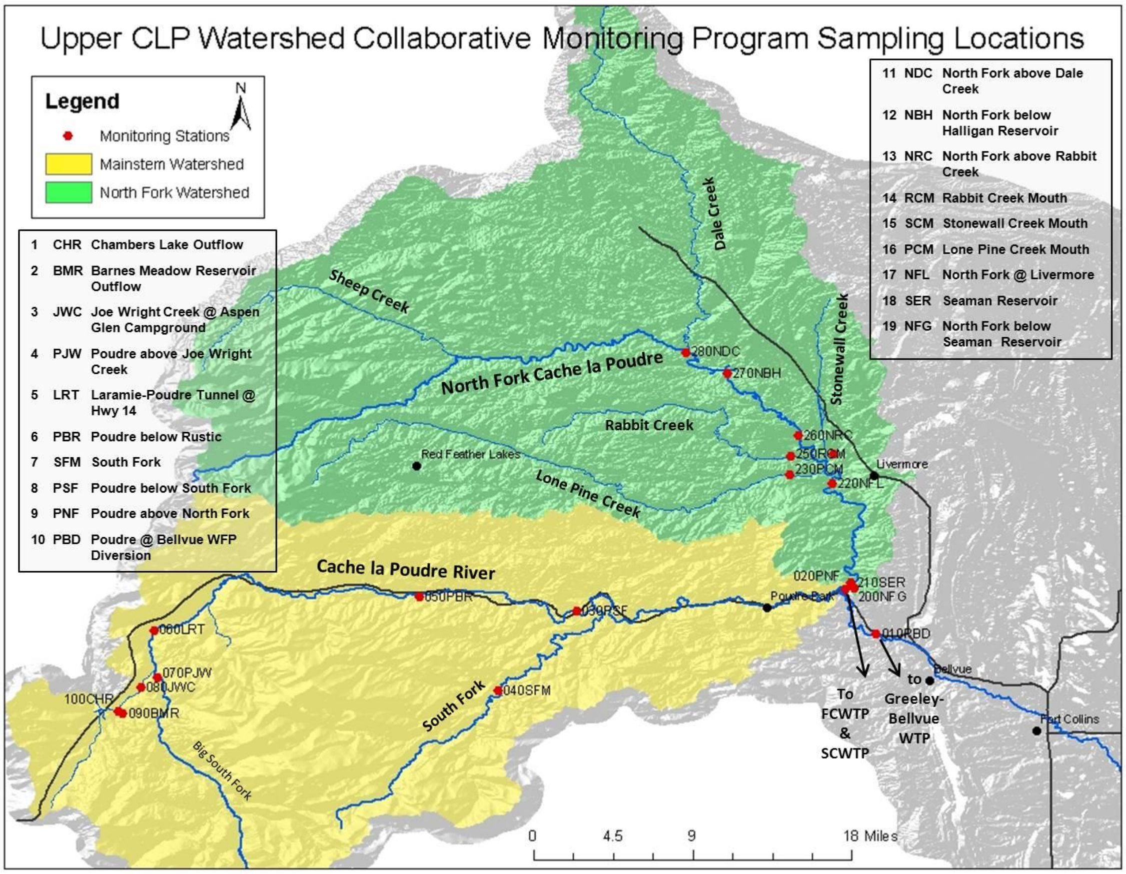
Two proposed water supply projects that impound Upper CLP waters are currently under consideration. The proposed Northern Integrated Supply Project (NISP) includes a new off-channel reservoir (Glade Reservoir) that will take water from the Upper CLP downstream of the North Fork confluence. The proposed Halligan-Seaman Water Management Project (HSWMP) includes the expansion of both Halligan Reservoir and Seaman Reservoir on the North Fork. NISP and HSWMP are currently undergoing review as part of the National Environmental Policy Act (NEPA) process. Water quality data collected for the Upper CLP Collaborative Water Quality Monitoring Program may be used to support the water quality studies conducted for these proposed projects and their respective Environmental Impact Statements.

1.2 Watershed Description and Sampling Locations

Sampling efforts are divided between the Mainstem and North Fork Poudre River drainages. Collectively these drainages encompass approximately 645,500 acres of forest, other natural land types and agricultural land (see Attachment 1). An additional 4,700 acres, representing less than 1% of land surface, is developed for commercial, industrial, utility, urban or residential purposes.

The monitoring network consists of 19 sampling locations selected to characterize the headwaters, major tributaries and downstream locations of the CLP near the City of Fort Collins, Tri-Districts and City of Greeley intake structures (Figure 1). The 19 sampling sites include one reservoir - Seaman Reservoir. A description and rationale for each site is provided in Attachment 2.

Figure 1. Map of the Upper CLP collaborative water quality monitoring network.



1.3 Sampling Schedule and Parameters

The sampling frequency for the Upper CLP Collaborative Water Quality Monitoring Program was determined based on both statistical performance and cost considerations. Parameters included in the monitoring program were selected based on analysis of historical data and aim to provide the best information possible within current budgetary constraints. A list of parameters is included in Attachment 3. Complete discussions of parameter selection and sampling frequency are provided in Sections 5.3 and 5.4, respectively, of the original design document by Billica, Loftis and Moore (2008). The 2012 sampling schedule is provided as Attachment 4 of this report.

1.4 Sample Collection and Analysis

Dr. William Lewis, from the University of Colorado at Boulder's Center for Limnology, was contracted by the City of Greeley in agreement with the City of Fort Collins and the Tri-Districts to perform sampling activities for the Upper CLP monitoring program at 17 of the 19 Mainstem and North Fork CLP sites. Staff from the City of Fort Collins, City of Greeley, and Tri-Districts collects samples at the remaining two locations: North Fork Poudre above confluence with Dale Creek (NDC) and North Fork Poudre below Halligan Reservoir (NBH). Sampling methods, including those for the collection of field measurements for temperature, pH, conductivity, and dissolved oxygen are documented in Section 5.5 of Billica, Loftis and Moore (2008). All bulk water samples were analyzed by the City of Fort Collins Water Quality Lab (FCWQL), except for *Cryptosporidium* and *Giardia* filter samples, which were delivered to CH Diagnostic and Consulting, Inc., in Berthoud, CO for analysis. In addition, phytoplankton samples were collected from April through November at the top and bottom of Seaman Reservoir. Phytoplankton samples were identified and enumerated at the species level by Dick Dufford (private consultant) of Fort Collins, CO. Analytical methods and detection limits for the FCWQL parameters are included in Attachment 5.

1.5 Scope of Report

Annual and five-year reports for the collaborative program are prepared by City of Fort Collins staff to keep participants informed about current issues and trends in water quality of the Upper CLP. The purpose of annual reports is to summarize hydrologic and water quality information for the current water year, provide a comparison with water quality from the preceding three years, describe notable events and issues, and summarize the results of special studies. Annual reports are currently available for the years 2008-2011.

2012 marks the 5th year of the Upper CLP Collaborative Water Quality Monitoring Program. Notably, the five-year reporting cycle also coincides with the aftermath of the two largest fires in the basin's history – the Hewlett Fire and High Park Fire - as well as a drought that began in mid-2011. This 2012 report provides an in-depth analysis of the spatial and temporal trends in hydrology and water quality across the watershed since 2008. It also summarizes the major issues of concern within the upper watershed in respect to their potential to affect watershed processes and water quality, with significant discussion dedicated to the influences of wildfire and drought.

2.0 SIGNIFICANT EVENTS, ISSUES OF CONCERN & SPECIAL STUDIES

2.1 Climate Change

Climate research conducted over the last thirty years has provided ample evidence that the climate is warming across the globe. Changes in temperature and precipitation patterns have been documented in the western United States and in the State of Colorado. Over the last 30 years, temperatures in Colorado have increased by about 2 ^{o}F across most of the state (Western Water Assessment, 2008). Changes in regional and global temperatures have the ability to influence climate patterns by altering the distribution of energy within the atmosphere (heat) across time and space, which in turn, affects the occurrence, duration and intensity of precipitation.

Climate change modeling has provided insights as to the types of changes that can be expected over broad spatial and temporal scales. These models, however, are currently less reliable for predicting changes at smaller scales (e.g. watershed level) because they are yet unable to adequately capture the influences of Colorado's complex topography. There is some evidence that changes in climate may proceed more slowly and be less pronounced in the mountainous areas of the state due to the moderating effect of elevation on temperature (Averyt et al., 2008). However, until models are able to predict regionally-specific outcomes, it can be safely assumed that long-term changes in climate will likely result in more variability in precipitation and temperature patterns. Consequently, greater variability in these patterns may bring about more unexpected and unprecedented conditions within our local watersheds.

According to the Intergovernmental Panel on Climate Change (IPCC),

"Water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change" (Bates et al., 2008).

The purpose of this discussion is not to catalog the possible outcomes of climate change scenarios, to promote specific cause or to make predictions about expected future changes. Rather, it is to acknowledge that changes in climate are expected to influence the condition of the Upper Cache la Poudre watershed and as a result, the quality and reliability of the Poudre River water supply, now and in the future.

Specifically, this report considers the role of the major climate variables - temperature and precipitation - in regulating hydrology and water quality and evaluates whether any trends exist in the available data records for the Upper Cache la Poudre River watershed. This report also provides significant discussion of several current issues related to weather and climate and their impacts on water quality, including the drought of 2012, the extensive forest mortality related to the recent mountain pine beetle outbreak, and the wildfires of 2012. A detailed review of temperature and precipitation trends is presented in Section 5.0.

2.2 Drought

2012 was a year marked by above average temperatures and below average moisture for Northern Colorado, which put heavy pressure on regional water supplies. According to the Colorado Climate Center, 2012 started out with a fairly good supply of available moisture, despite the small snowpack (*http://ccc.atmos.colostate.edu/*). By March, temperatures had already risen to well above average and spring precipitation had fallen to below average. Throughout the summer, drought conditions continued to worsen and by August, the drought was rated as "severe" for most of Larimer County which includes much of the Upper CLP basin (Figure 2). Monthly weather summaries from the Colorado State University, Fort Collins, CO station (*http://ccc.atmos.colostate.edu/dataaccess.php*) indicate that only 0.03 inches of precipitation fell in August 2012, which is 1.57 inches below the normal for the month, putting 2012 as the driest August on record in Fort Collins. By the end of September 2012, there had been 57 consecutive days with recorded temperatures above 90 $^{\circ}$F, breaking the previous record of 45 days that was set in 1960. The implications of extreme drought for water quality include potential increases in constituent concentrations due to the lower streamflow, increased algal abundance, increased stress on stream biota from higher stream temperatures and greater likelihood of future wildfire occurrence . Furthermore, drought conditions, if present over the next several years, will limit the rate of post-fire vegetation reestablishment, potentially resulting in prolonged watershed recovery.

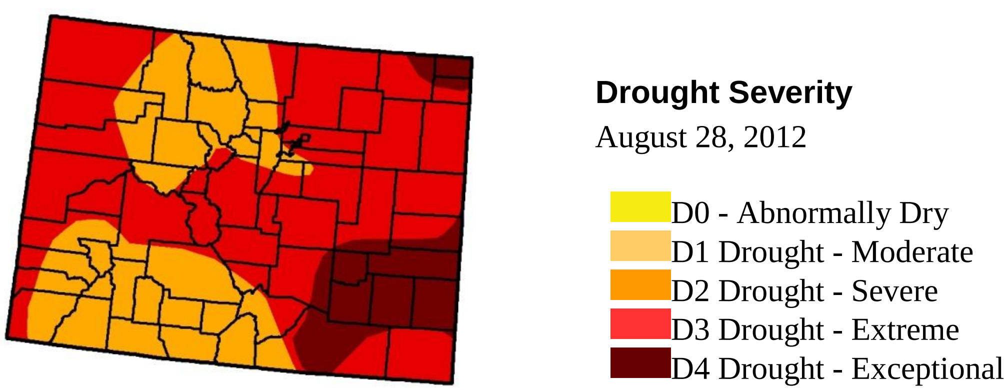


Figure 2. Colorado drought map for August 28, 2012. US Drought Monitor.

2.3 Mountain Pine Beetle in the Upper CLP Watershed

The mountain pine beetle (MPB), *Dendroctunus ponderosae*, is native to forests of western North America. Periodically, populations increase to result in regional outbreaks of beetle-related tree deaths. The current outbreak, which began in the late 1990's, has grown to ten times the size of the largest previously known outbreak and continues to expand through forests dominated by Lodgepole and Ponderosa pines (*Pinus contorta* and *Pinus ponderosa*). The result has been expansive swaths of dead and dying trees across the Rocky Mountain West (Figure 3).

Information from the US Forest Service (USFS) and Colorado State Forest Service 2012 Forest Health Aerial Survey provided by the USFS (http://www.fs.usda.gov/detail/r2/forest-grasslandhealth/?cid=stelprdb5348787) reports that the total number of infested acres in Colorado increased by 53,000 acres in 2012, bringing the total number of affected acres to 3.4 million since 1996. The reported affected acreage for 2012 may actually underestimate MPB activity due to the fact that the High Park Fire burned over 80,000 acres of affected forest prior to the aerial survey. However, the expansion of the MPB has slowed significantly over the last two years in response to decreased availability of trees to attack. In 2012, the MPB persisted in the lower elevation Lodgepole and Ponderosa pine stands along the Northern Colorado Front Range. Although the rate of MPB infestation declined dramatically in 2012, the Upper Cache la Poudre and the adjacent contributing watersheds (Laramie River and Michigan River) continue to experience tree mortality within the affected areas. A map of MPB mortality in the local watersheds is provided in Figure 4.

It is recognized that during the phase of forest dieback in which affected trees retain their needles, there is a short-term elevated risk of high severity wildfire (Romme, 2007). However, immediately following infestation even when needles are still green, the available fuel moisture declines as trees lose the ability to circulate water within their tissues. The warm, windy conditions and below average precipitation in 2012 exacerbated the effects of the MPB infestation on forest fuel moistures. Together, these factors likely contributed to the size and severity of the Hewlett and High Park Wildfires, which combined burned nearly 95,000 acres.

Figure 3. Mountain Pine Beetle mortality in Lodgepole Pine forest in Larimer County, CO. 2010.

Despite the large area burned by the fires, millions of acres of MPB and drought affected forest remain in the watershed. Research continues on forest management options to improve post-outbreak forest health (MacDonald and Stednick, 2003; Uunila et. al, 2006; Le Master et al., 2007), as well as options for protecting communities and critical water supplies against the effects of wildfire (Le Master et al., 2007; FRWWPP, 2009).

Potentially widespread changes in the vegetative cover that occur either as a result of extensive forest die-back or from wildfires pose a threat to water quality in the Upper CLP watershed. Specific concerns for water quality include potential changes in hydrology and water temperatures, sediment loads, as well as in-stream nutrient and TOC levels.

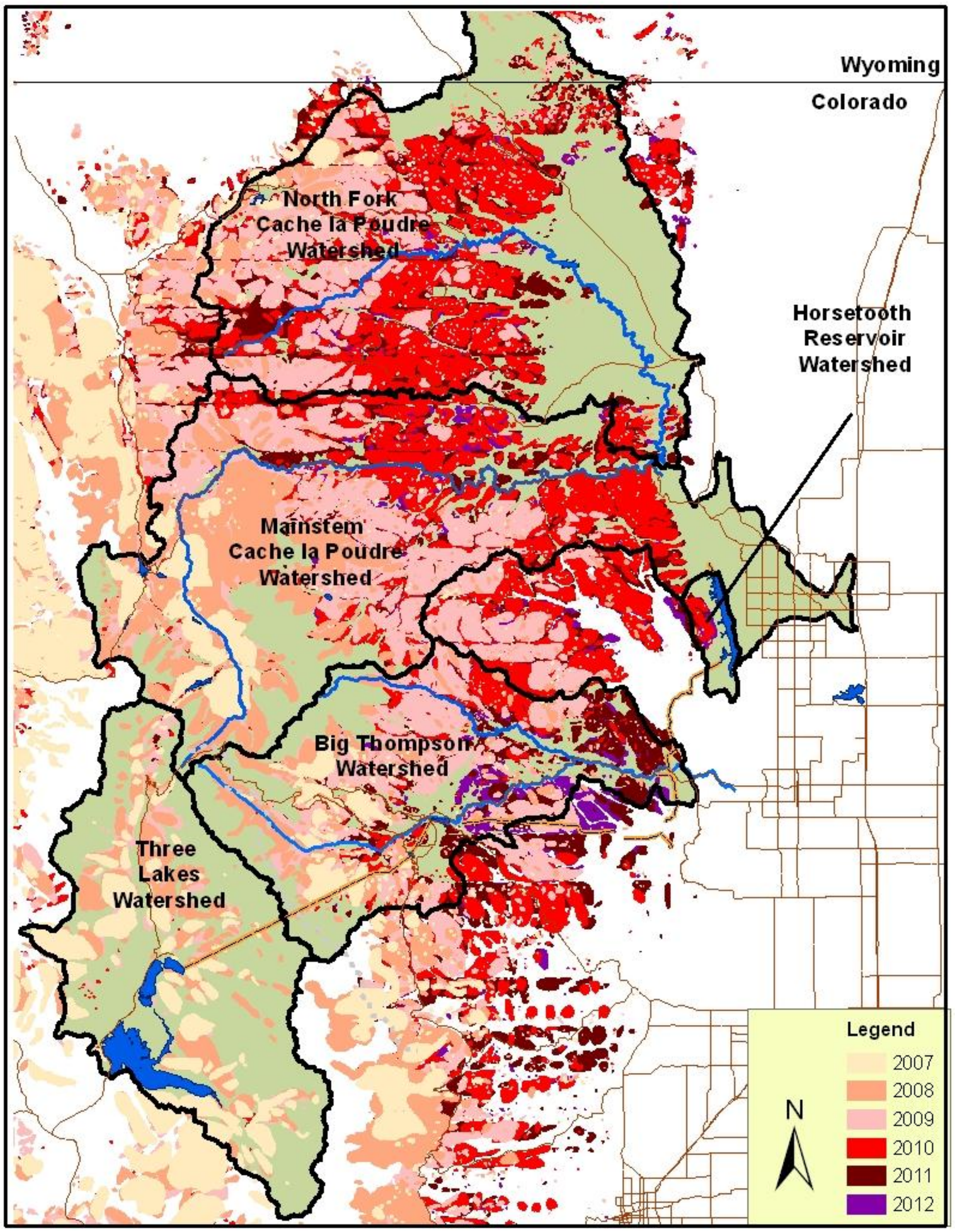


Figure 4. Mountain Pine Beetle (MPB) activity in the North Fork and Mainstem Cache la Poudre, Big Thompson, Horsetooth and Three Lakes Watersheds from 2007 through 2012.

2.4 Attached Algae Bloom in Poudre River

A summertime attached algae bloom was first observed in 2009, and has occurred each year since along the middle reaches of the Mainstem Poudre River, from areas near Big Bend Campground and the State fish hatchery to downstream of Indian Meadows, which corresponds to the Upper CLP monitoring site, Poudre below Rustic (PBR). In 2012, the algae bloom was similar in location during the months of April through June, but at lower abundance than seen in the previous two years. In August, an unexpected decrease in the visible algae occurred and appeared to be relatively less abundant for the duration of the sampling year.

Periphyton sampling was conducted to monitor algae populations and determine if the summer time algae blooms were related to taste and odor (T&O) issues in raw drinking water supplies at the FCWTF (Figure 5). Sampling locations and methods are described in detail in the 2011 Upper Cache la Poudre Water Quality Monitoring Report (Oropeza, 2012). No taste and odor (T&O) issues associated with raw Poudre water were reported at the treatment plants during periods of high algal abundance, suggesting that potential off-taste and odor compounds (including geosmin) were either not strongly associated with this algae bloom, or were adequately volatilized, degraded, and/or diluted prior to reaching the raw water intake. A detailed summary of geosmin monitoring results are presented in Section 2.5.

As in previous years, dense mats of dried filamentous algae covered rocks along the river banks in areas where high flows had receded, and live green algae was observed in areas of flowing and standing water throughout the summer (Figures 6.a & 6.b).

Field observations indicate that the dominant form of algae was the green algae, *Ulothrix* (sp). There were also observations of the diatom, *Didymosphenia geminata* at most sampling locations, but was more abundant at the uppermost sites, *Poudre above Rustic* and *Poudre below Rustic* (PBR; Figure 6.c). 2012 periphyton data were not available at the time of this report to verify these field observations, but will be provided as an addendum to this report upon receipt.

Although algal blooms typically occur in response to increased nutrient availability, there is no evidence, to date, of elevated nutrient concentrations at PBR or upstream locations from June through September (Oropeza and Billica, 2010). The prevalence of *Ulothrix sp*. and *Didymosphenia geminata* under low nutrient conditions and cold temperatures is not surprising, as it has been documented that both thrive under such conditions (Graham et al., 1985, Sundareshwar et al., 2011).

Figure 5. Periphyton collected from a river cobble using a fixed-area sampler.

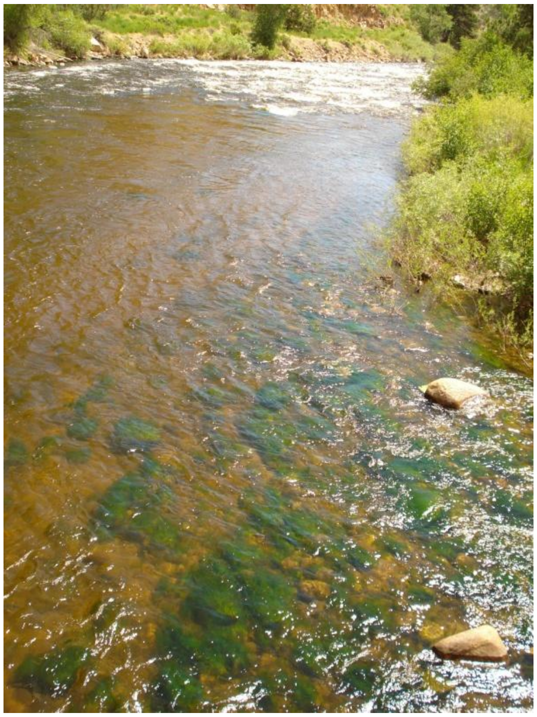


Figure 6.a. Live attached algae (*Ulothrix sp.*) on rocks near Poudre Below Rustic (PBR) monitoring site in June 2010.

Figure 6.b. Dried algae (*Ulothrix sp.*) on rocks near Eggers Fishing area in September 2009.

Figure 6.c. *Didymosphenia geminata* attached to stream bed cobbles at Poudre above Rustic in 2011.

2.5 Poudre River Geosmin

Geosmin is a naturally occurring organic compound that imparts an earthy odor to water and can be detected by the most sensitive individuals at concentrations as low as 4 nanograms per liter (ng/L) or 4 parts per trillion (ppt). Geosmin does not pose a public health risk, but it is of concern because its detectable presence can negatively affect customer confidence in the quality of drinking water. The Poudre River raw water supply is routinely monitored for geosmin concentrations from January through December. As shown in Figure 7, the Poudre River raw water supply has experienced periodic episodes of elevated geosmin concentrations above the 4 ng/L odor threshold over time, with the most recent outbreak occurring in early 2010. Geosmin continues to be monitored in the raw Poudre water supply at the Fort Collins Water Treatment Facility (FCWTF) on a routine basis.

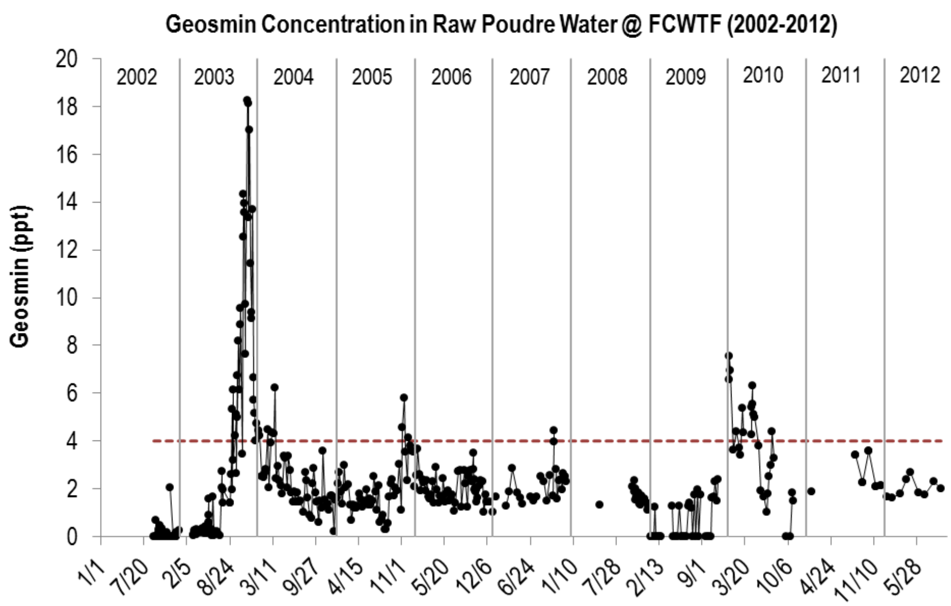


Figure 7. Geosmin concentrations in raw Poudre River water supply at the FCWTF from 2002 through 2012. The red dashed line indicates the odor threshold at 4 ppt (ng/L).

In response to the elevated geosmin in raw water supply in 2010, intensive sampling on the Mainstem of the Poudre River was initiated to evaluate in-stream concentrations and delineate the approximate area of elevated geosmin concentrations along the river. Geosmin monitoring activities on the Poudre River focus on the following objectives:

- Identify the areas on the Poudre River with high geosmin concentrations that are sources of geosmin to the FCWTF;
- Identify spatial and seasonal geosmin and nutrients trends in areas of geosmin production;
- Evaluate potential sources of nutrients to the target areas, and;
- Characterize the periphyton community and identify known geosmin-producing species, when possible.

For further detail on the intensive monitoring plan and subsequent monitoring refer to the "2011 Annual Report Upper Cache la Poudre River Collaborative Water Quality Monitoring Program" (Oropeza, 2012). In this report, results presented for the time period of May 2011 through November 2012 are referred to as Phase II routine monitoring. River sampling locations associated with Phase II routine monitoring included *Poudre above Rustic, Poudre below Rustic (PBR), Stevens Gulch, Mishawaka*, and the *Greyrock* bridge. For each sampling event, geosmin samples are also collected for the raw Poudre River water at the FCWTF, which is representative of water at the intake facility on the river. Samples are analyzed for geosmin, nutrients and periphyton.

In 2012, geosmin concentrations on the Poudre River frequently exceeded 4 ng/L at all river sites, whereas concentrations in raw Poudre at Fort Collins Water Treatment Facility (FCWTF) intake remained below the odor threshold for throughout the year (Figure 8).

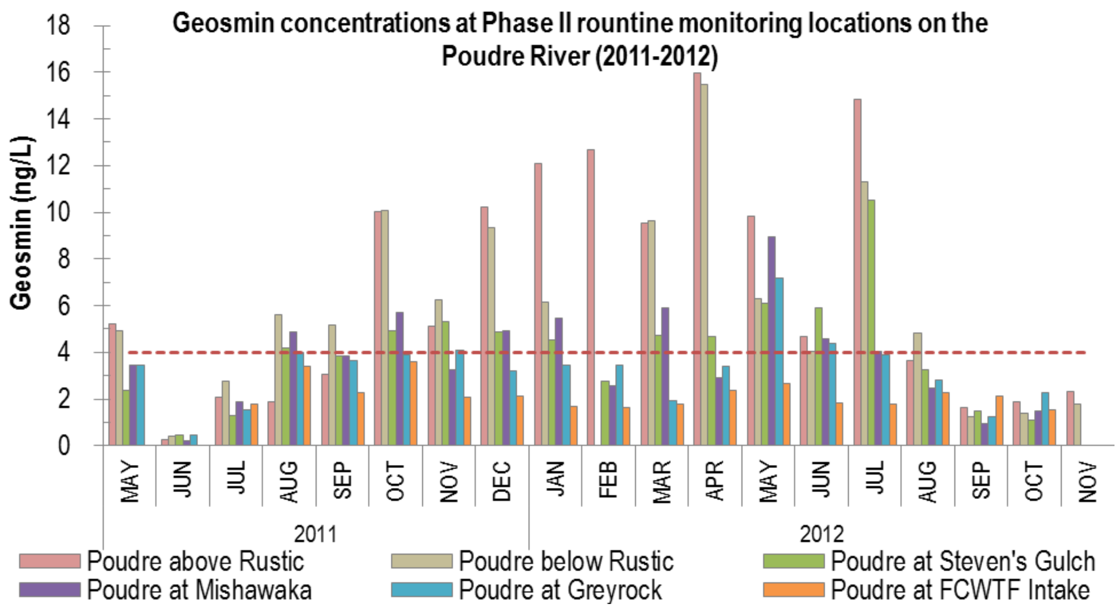


Figure 8. Monthly geosmin concentrations at Phase II routine monitoring locations on the Poudre River from May 2011 through November 2012. The red dashed line indicates the odor threshold at 4 ng/L.

The highest geosmin concentrations were measured on the Poudre River above and below the town of Rustic where concentrations exceeded 4 ng/L during 64% and 73% of sample dates in 2012, respectively (Figure 8).

Typically, the highest geosmin concentrations occur during the winter months between November and February, with lower concentrations occurring during late spring and summer months because of dilution effect from spring runoff (Oropeza et al., 2011). In 2012, the maximum geosmin concentration of 15.99 ng/L, was measured above Rustic in the month of April, just before the onset of spring runoff.

The influence of dilution on spring geosmin concentrations in 2012 was much less than in 2011 due to extreme differences in runoff; 2011 was one of the wettest snow years on record, while 2012 was one of the driest snow years on record. These differences in snow water equivalent (SWE; water stored in the snowpack) between years translated to extreme changes in streamflow in the Poudre River (Figure 9). The effect of lower streamflows in 2012 is illustrated by the relatively high concentrations from May to July.

Another noteworthy observation was the sharp decreases that began in August and continued through the remainder of the year. These unexpected decreases lead to annual minimum concentrations occurring later in the season when geosmin was expected to increase as streamflow returned to low flow conditions. The cause of the abrupt decrease in concentration is not currently known. It is notable however, that field observations also indicate a coincident decrease in visible green algae abundance in August.

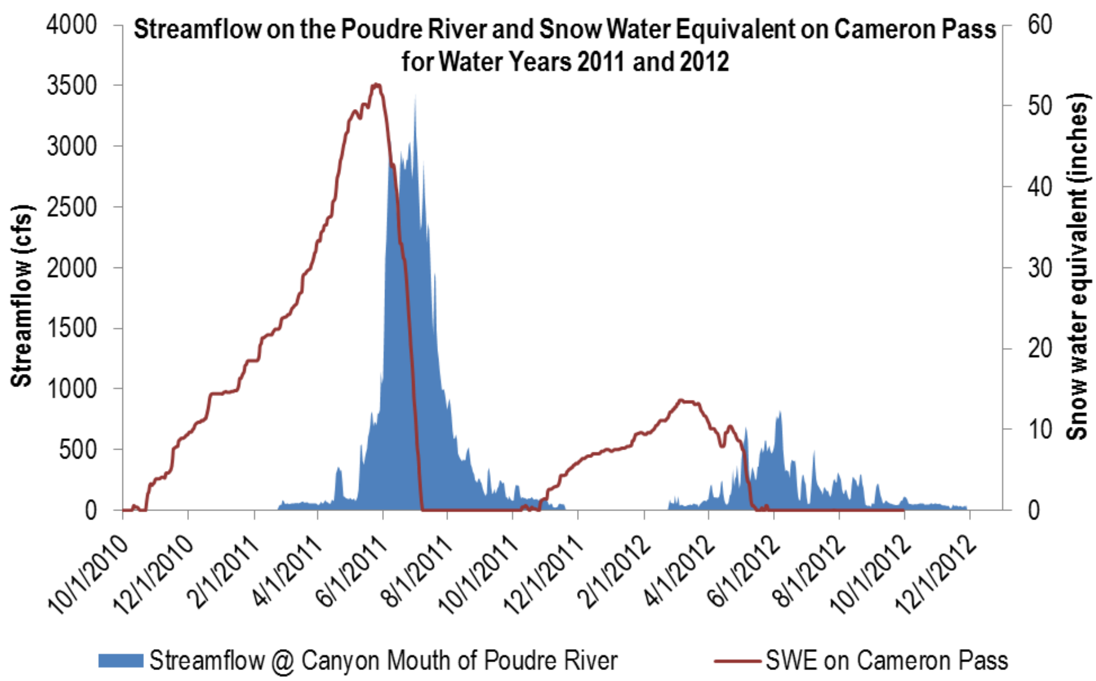


Figure 9. Streamflow, in cubic feet per second (cfs), measured at the Canyon Mouth of the Poudre River, and snow water equivalent (SWE) measured at Joe Wright Snow Telemetry (SNOTEL) site near Cameron Pass for water years (October 1 through September 31) 2011 and 2012.

To evaluate spatial trends (upstream to downstream) in geosmin concentration, annual statistics were used, because spatial trends are more difficult to identify on a monthly time scale (Figure 9). As can be seen in Figure 10, annual median geosmin concentrations show a decreasing trend ($R^2 = 0.75$) from the upper Poudre River Canyon to the lower Poudre River Canyon (Figure 10). The range in geosmin concentrations was more variable at monitoring sites higher in the watershed near Rustic, and the variability in concentrations decreased moving down the Poudre River Canyon to the FCWTF intake (Figure 10). In 2012, geosmin concentrations ranged from as high as 15.99 ng/L to as low as 1.65 ng/L at the Poudre River above Rustic, while the difference between maximum and minimum geosmin concentrations at the FCWTF intake was only 1.14 ng/L (Figure 10). These trends suggest that geosmin concentrations higher in the Poudre River watershed are not representative of concentrations observed at the FCWTF intake and the occurrence of geosmin is site specific.

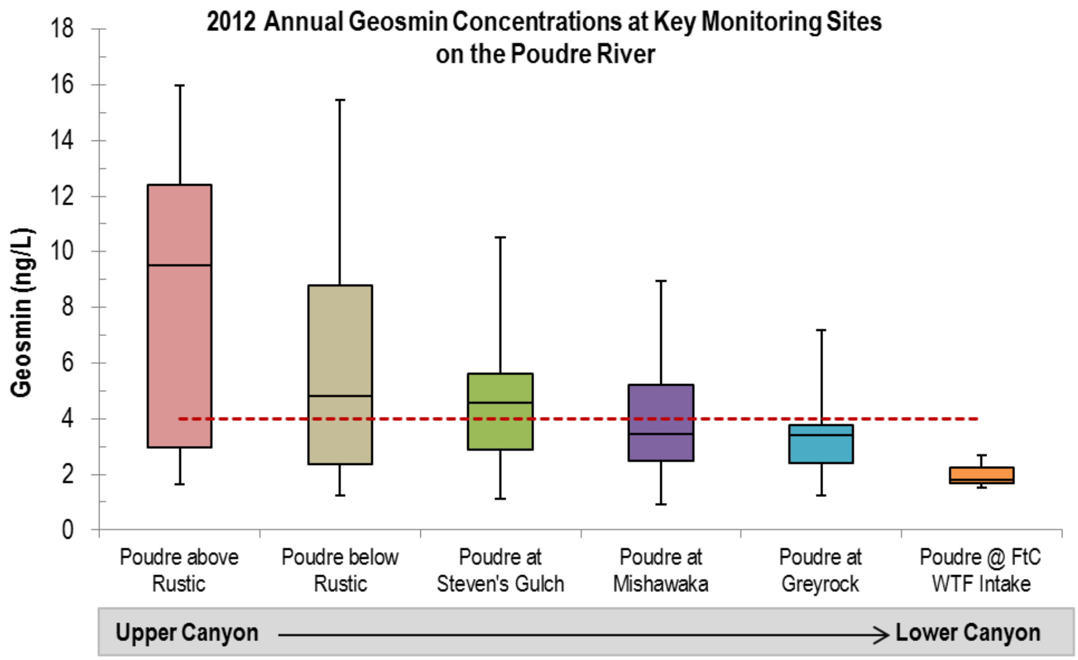


Figure 10. Box plots illustrating 2012 annual geosmin concentrations at key monitoring locations on the Poudre River. The middle line in the box represents annual median concentrations bound by upper (75%) and lower (25%) quartiles. The capped bars indicate annual maximum and minimum concentrations. The red dashed line indicates the odor threshold of 4 ng/L.

Consistent with previous years, nutrient concentrations of the total and dissolved nutrient fractions were generally low in the study area and were frequently below reporting limits (Figures 11.a-11.f). As a result, confidence in determining trends and cause and effect relationships associated with nutrient concentrations is limited. The most prevalent nutrients connected with geosmin sampling, at least those that were more often higher than reporting limits, appear to be Total Kjeldahl Nitrogen (TKN) and total phosphorus (Total P), (Figure 11.e and Figure 11.f).

Total P concentrations, and to a lesser degree TKN concentrations typically follow the seasonal patterns in streamflow (Oropeza, 2011). As discussed in the 2011 Upper CLP Water Quality Monitoring Report (Oropeza, 2011), an inverse relationship between geosmin and Total P was identified in 2011 (R=-0.542, p=0.000), which is similar to the observed relationship between geosmin and streamflow. It is expected that the negative correlation was more likely due to the shared effect of streamflow on both Total P and geosmin rather than direct relationship between the two parameters. This relationship was not observed in 2012, which is likely due to the below average streamflow.

Attached algae samples were collected to characterize changes in the periphyton community composition and estimate the relative abundance of known geosmin producing species over time. Periphyton data were not available prior to the completion of this report. A discussion on the periphyton communities will be added subsequent to receiving data.

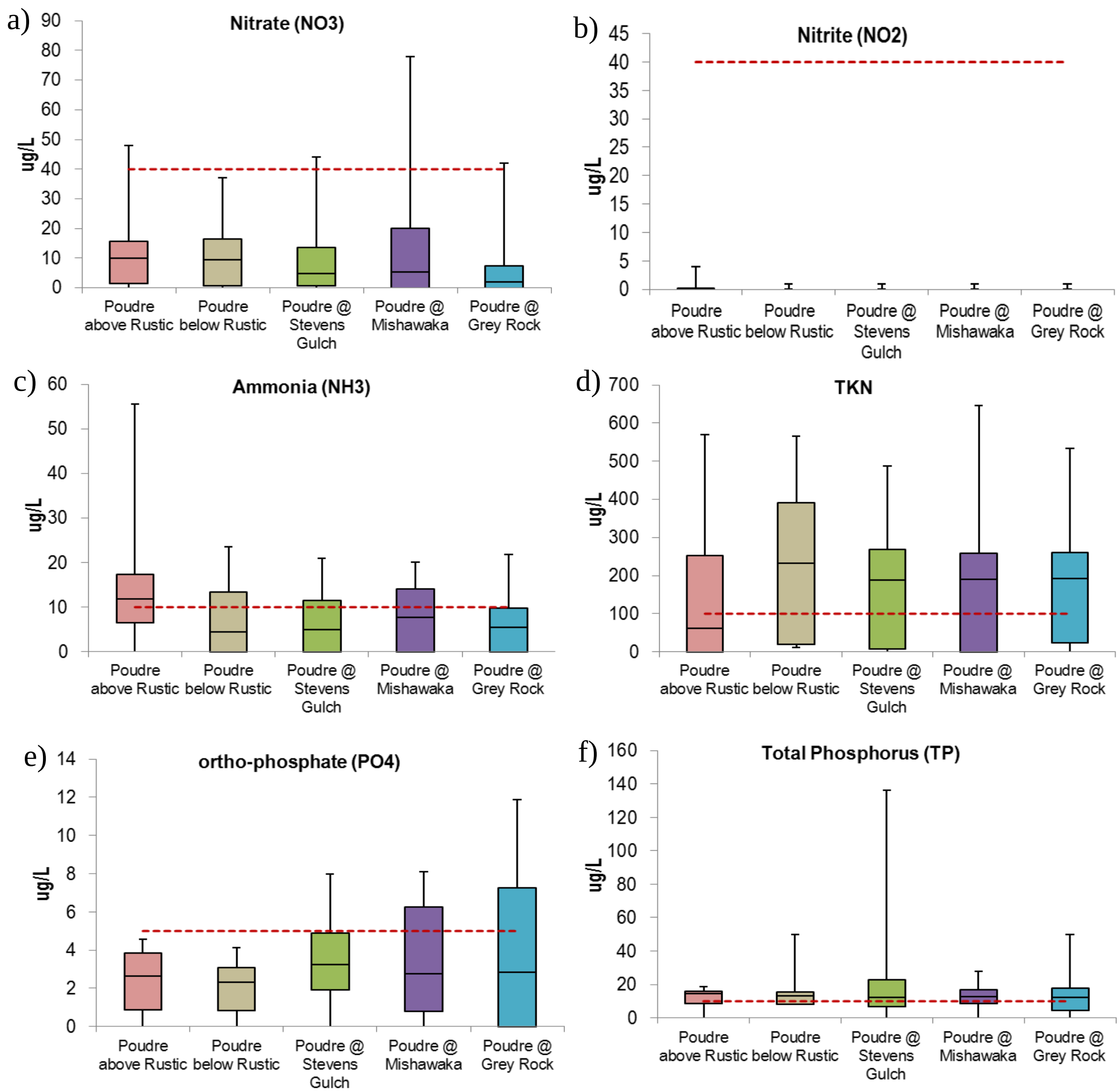


Figure 11. Box plots illustrating 2012 annual nutrient concentrations at key monitoring locations on the Poudre River. The middle line in the box represents annual median concentrations bound by upper (75%) and lower (25%) quartiles. The capped bars indicate annual maximum and minimum concentrations. The red dashed line indicates the laboratory reporting limit.

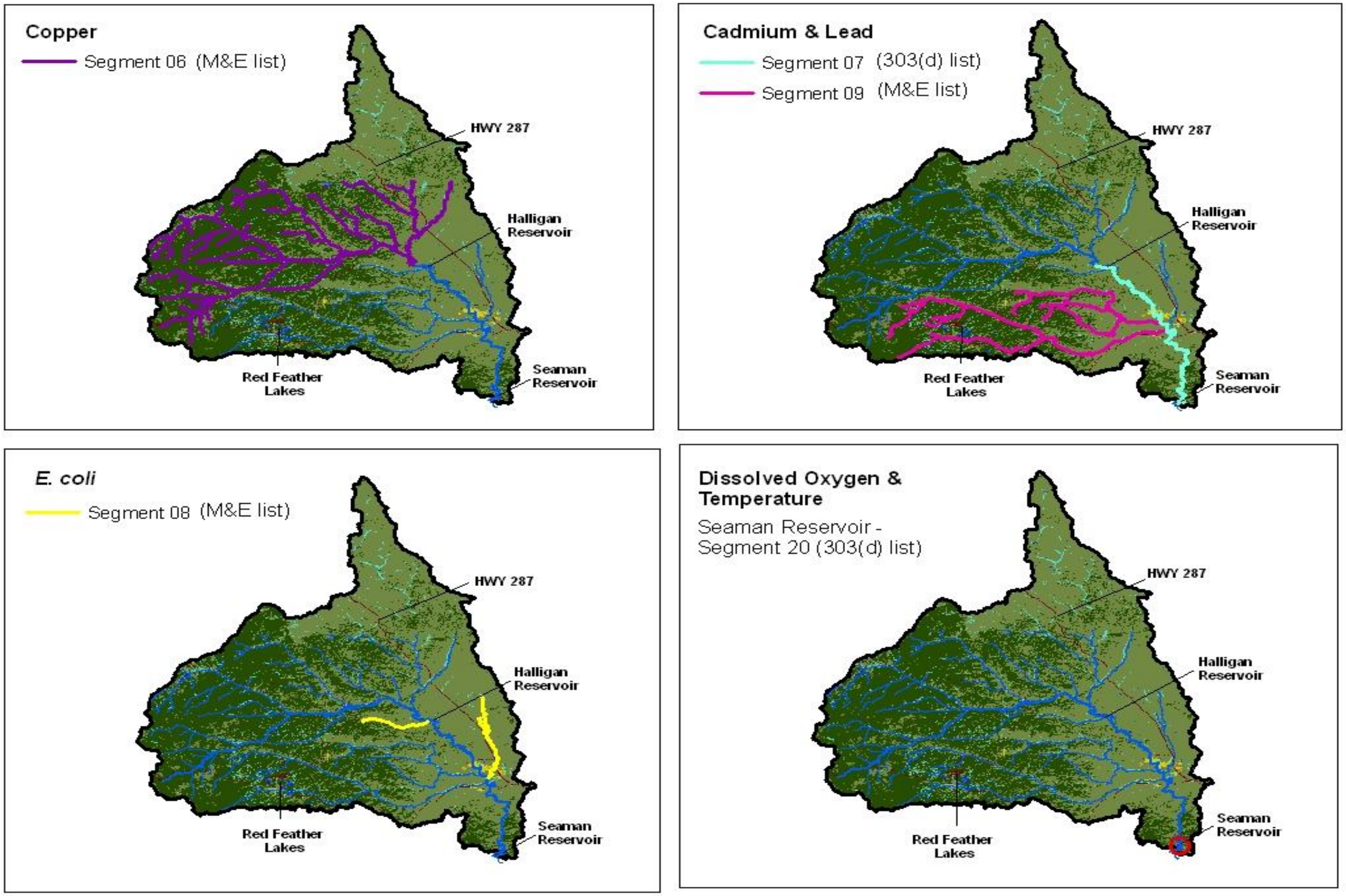
2.6 Colorado's 2010 Section 303(d) and Monitoring and Evaluation (M&E) Lists

Segments of the North Fork of the Cache la Poudre River that are on the state of Colorado's Section 303(d) List of impaired waters and Monitoring and Evaluation (M&E) List, as of April 30, 2010 are outlined on Table 1 and shown on Figure 12. Segments with a 303(d) impairment require total maximum daily loads (TMDLs) and are prioritized with respect to TMDL development. The two North Fork segments on the 303(d) List have both been assigned a medium priority. When water quality standard exceedances are suspected, but uncertainty exists regarding one or more factors (such as the representative nature of the data used in the evaluation), a water body or segment is placed on the M&E List. Three North Fork segments are currently on the M&E List. The North Fork sites listed below were scheduled for review in 2012 by the State of Colorado Water Quality Control Division, but due to staffing shortage and the need to work on large water projects, the Water Quality Control Commission postponed the next 303(d) listing hearing until 2016.

Table 1. Summary of Upper CLP segments on Colorado's 2010 Section 303(d) List of Impaired Waters and 2010 Monitoring and Evaluation (M&E) List

Segment	Segment Description	Portion	Monitoring & Evaluation Parameters	Section 303(d) Impairment	303(d) Priority
COSPCP06	Mainstem of the North Fork, including all tributaries from the source to inlet of Halligan Res.	all	Copper		
COSPCP07	Mainstem of the North Fork from Halligan Reservoir to confluence with CLP River.	all		Cadmium, Lead	Medium
COSPCP08	All tributaries to the North Fork from Halligan Res to confluence with CLP River, except for listings in Segment 9.	all	*E.coli*		
COSPCP09	Rabbit Creek & Lone Pine Creek from the source to the confluence with the North Fork	all	Cadmium, Lead		
COSPCP20	All lakes and reservoirs tributary to the North Fork, from Halligan Resevoir to confluence with CLP River.	Seaman Reservoir		dissolved oxygen	Medium

Figure 12. Upper CLP segments on Colorado's 2010 Section 303(d) List of Impaired Waters and 2010 Monitoring &Evaluation (M&E) List.



2.7 Colorado Nutrient Standards & Control Regulations

In June 2012, the Colorado Water Quality Control Commission adopted numerical Regulation #31, which provides for scientifically-based numerical nutrient values designed to protect the designated uses of waters in the state of Colorado, including the protection of aquatic life, recreation and municipal water supplies. The initial phase of implementation from 2012 – 2017 applies interim numerical values for phosphorus, nitrogen and chlorophyll-*a* for headwaters upstream of dischargers, Direct Use Water Supply Lakes and Reservoirs (chlorophyll-*a*) and where voluntary efforts to control nonpoint sources of nutrients under the Nutrient Control Regulation #85 are not effective.

All rivers and reservoirs within the Upper Cache la Poudre River Watershed are designated "cold" waters. For cold water streams, the interim nutrient limits are based on annual median values with a 1-in-5 year exceedance frequency. Proposed interim limits are 1,250 ug/L for Total N and 110 ug/L Total P.

To evaluate the current status of the Mainstem and North Fork Cache la Poudre Rivers in respect to these proposed standards, annual median value for Total N (2008-2012) and the annual median values (2008 – 2012) for Total P were calculated for three river locations: PNF on the Mainstem above the Fort Collins water supply intake facility, PBD above the Greeley-Bellvue water supply diversion, and NFG on the North Fork below Seaman Reservoir (Tables 2 & 3). Results indicate that the annual median Total N and Total P values at all three sites were well below the interim values.

Table 2. Comparison of annual median Total N concentrations (ug/L) at Mainstem CLP and North Fork CLP sites to 2012 CDPHE/WQCD proposed interim TN value of 1,250 ug/L.

	2007	2008	2009	2010	2011	2012
Poudre above North Fork (PNF)	-----	259.1	226.8	248.5	150.4	309.6
Poudre at Bellvue Diversion (PBD)	-----	247.7	329.0	214.9	477.4	295.1
North Fork Poudre at Gage below Seaman Reservoir (NFG)	-----	460.0	376.2	447.7	454.8	649.3

*All reported concentrations are expressed in ug/L.

Table 3. Comparison of annual median Total P concentrations (ug/L) at Mainstem CLP and North Fork CLP sites to 2012 CDPHE/WQCD proposed interim Total P value of 110 ug/L.

	2007	2008	2009	2010	2011	2012
Poudre above North Fork (PNF)	9.6	8.6	12.7	14.7	21.2	19.3
Poudre at Bellvue Diversion (PBD)	10.2	11.7	15.6	17.0	16.2	23.3
North Fork Poudre at Gage below Seaman Reservoir (NFG)	51.3	23.3	30.2	38.8	32.2	83.5

*All reported concentrations are expressed in ug/L.

The CDPHE/WQCD interim nutrient standards for cold water lakes and reservoirs for total nitrogen (Total N), total phosphorus (Total P), and chlorophyll-*a* were compared to values in Seaman Reservoir (Table 4). A reservoir or lake that directly supplies water to a water treatment facility may fall under the "Protected Water Supply Lake and Reservoirs" (PWSR) designation and be subject to the lower proposed standard for chlorophyll-*a* of 5 ug/L. Seaman Reservoir is not considered a PWSR site, and therefore, falls under the higher proposed standard of 8 ug/L chlorophyll-*a*. This comparison shows that Seaman Reservoir frequently does not meet the interim standards for Total N or Total P and has exceeded the chlorophyll-*a* interim standard in two out of the last three years. While it may be possible to manage nutrient concentrations through reservoir operations, the feasibility of this option may be limited by other legal and financial considerations.

Table 4. Comparison of Seaman Reservoir annual summer average (June – Sept) Total N, Total P and chlorophyll-*a* concentrations to the 2012 CDPHE/WQCD interim standards for nutrients.

Interim Proposed Standard	Seaman Reservoir Top (1 meter) Summer (June-Sept) Average	
TN: 426 ug/L (summer avg in mixed layer, 1 in 5 yr exceedance frequency)	2007: -- 2009: 370 ug/L **2011: 438 ug/L**	**2008: 514 ug/L** **2010: 487 ug/L** **2012: 1,464 ug/L**
TP: 25 ug/L (summer avg in mixed layer, 1 in 5 yr exceedance frequency)	2007: 12.8 ug/L 2009: 18.6 ug/L 2011: 19.34 ug/L	**2008: 25.5 ug/L** **2010: 30.3 ug/L** **2012: 37.3 ug/L**
Chlor-a: 8 ug/L (summer avg in mixed layer, 1 in 5 yr exceedance frequency)	2007: 7.8 ug/L 2009: 5.3 ug/L 2011: 4.31 ug/L	2008: 7.6 ug/L **2010: 10.9 ug/L** **2012: 60.3 ug/L**

2.8 Northern Water Collaborative Emerging Contaminant Study

Contaminants of emerging concern (CECs) and their presence in water have recently received national attention. Currently, no standard list of constituents exists and analytical methods continue to develop to address the presence of these constituents in raw water supplies. CECs are trace concentrations (at the nanogram/L or part per trillion level, or less) of the following types of chemicals:

- Personal care products (PCPs): fragrances, sunscreens, insect repellants, detergents, household chemicals
- Pharmaceuticals: prescription and non-prescription human drugs (including pain medications, antibiotics, β-blockers, anti-convulsants, etc) and veterinary medications
- Endocrine disrupting chemicals (EDCs): chemicals that interfere with the functioning of natural hormones in humans and other animals; includes steroid hormones (estrogens, testosterone, and progesterone), alkylphenols, and phthalates
- Pesticides and herbicides

In 2008, Northern Water began a collaborative emerging contaminant study to determine the presence of these compounds in waters of the Colorado- Big Thompson system. In 2009, two sites on the Upper Cache la Poudre (Poudre above North Fork (PNF), and North Fork at gage below Seaman Reservoir (NFG)) were added to the study with funding provided by the City of Fort Collins and the City of Greeley. The Poudre above North Fork (PNF) the North Fork below Seaman Reservoir (NFG) sites were sampled three times in 2012 (Feb., June, Aug.). A detailed summary report prepared by Northern Water that reviews data collected from 2008 to 2011 can be found at *http://www.northernwater.org/docs/WaterQuality/WQ_Reports/EmergingContaminants2012Report_FINAL.pdf*.

Laboratory Analysis. Samples are submitted to the Center for Environmental Mass Spectrometry Laboratory at the University of Colorado at Boulder (CU Lab) for analysis of 104 pharmaceuticals and pesticides by Liquid Chromatography – Time of Flight – Mass Spectrometry (LC/TOF-MS). Beginning with the June 2009 sampling event, samples were also submitted to Underwriters Laboratories (UL), Inc. for analysis of estrogens and other hormones (9 compounds, UL Method L211), and phenolic endocrine disrupting chemicals (8 compounds including bisphenol A, UL Method L200). Beginning in 2010, the CU Lab also began conducting low-level analysis by liquid chromatography with tandem mass spectrometry (LC/MS-MS) for a subset of 26 different pharmaceuticals, personal care products, and herbicides/pesticides in addition to the screening level analysis by LC/TOF-MS. In 2012, the CU Lab began conducting a low-level screening analysis for estrogen and other hormone samples and only samples that had detected hits during the initial screening were sent to UL for a full analysis.

Results through 2012. Since 2009,there have been five instances of compounds detected at the Poudre above the North Fork (PNF) site. In 2009 and 2010, the UL Lab reported very low levels of the hormone progesterone in the June samples (0.1 ng/L) and (0.4

ng/L), respectively, from the Poudre above North Fork site. The method reporting limit (MRL) for progesterone is 0.1 ng/L. In 2011, a detection of the recreational insecticide DEET of 20.8 ng/L was reported for the August sampling event. In August 2012, Triclosan was detected at a concentration of 32.2 ng/L. Triclosan is an antibacterial and antifungal agent used in a variety of hand soaps and other personal care products. The current MRL for both DEET and Triclosan is 20 ng/L. In cases such as these, caution must be exercised in terms of assigning any level of importance to results when concentrations are extremely low.

No compounds were detected by either laboratory in the June 2009, June 2010 or any 2011 sample dates samples collected from the North Fork below Seaman Reservoir site, NFG. In 2012, caffeine was detected at a concentration of 16.7 ng/L (MRL 10 ng/L) and Triclosan was detected at 41 ng/L (MRL 20 ng/L) at NFG. In addition, the herbicide 2-4-D was detected in the August 2012 sample at a concentration of 6 ng/L.

The presence of these detected compounds reflects the influences of recreation as well as land management activities in the watershed during the summer months, when activity on the river is high. In all cases, the detections occurred at very low levels and were not detected during subsequent sampling events suggesting that the sources of these compounds are not persistent.

2013 Sampling. In 2013, samples will be collected at both Upper CLP sites in February, June, and August. These sampling dates will span the range of conditions experienced by the Upper CLP, from low flow winter conditions, to high flow during spring runoff, to the period of peak summer recreational use.

3.0 HEWLETT & HIGH PARK WILDFIRES

3.1 Fire Activity and Affected Areas

The Hewlett Fire started on May 14, 2012 and burned until May 22, after flames from a camping stove ignited dry grass in Hewlett Gulch area. The fire burned 7,685 acres in dense Ponderosa Pine forest stands on the north-facing slopes, as well as shrub and grasslands that occupied much of the south-facing aspects. The burned area includes sub-watersheds that drain both to the Mainstem Poudre and into Seaman Reservoir on the North Fork Poudre River.

The High Park Fire was ignited by lightning strike on June 9th and declared contained on July 2nd. In total, the fire burned 87,415 acres of primarily forested landscape, characterized by Ponderosa and Lodgepole Pine at the lower elevations and mixed conifer species at the upper elevations. To a lesser degree, shrublands, grasslands and riparian areas were also impacted (Figure 13). The burned area includes numerous sub-drainages that are tributary to the Mainstem Poudre River and the South Fork of the Poudre River. The two fires were in close proximity to each other; the northeastern edge of the High Park Fire shares the southern boundary of the Hewlett Fire, creating a contiguous burned area approximately 95,000 acres in size (Figure 14). In total, the High Park Fire destroyed 259 homes and cabins.

Figure 13. Hewlett Fire burning in the riparian zone of the Poudre River.

No homes were damaged in the Hewlett Fire.

Approximately 400 acres along the eastern edge of the High Park Fire burned within a direct drainage area for Horsetooth Reservoir, the second of the two main sources of raw drinking water supplies for the Cities of Fort Collins and Greeley and the Tri-Districts. Impacts to that drainage area were relatively limited and will not be included in the discussion for the purposes of this report.

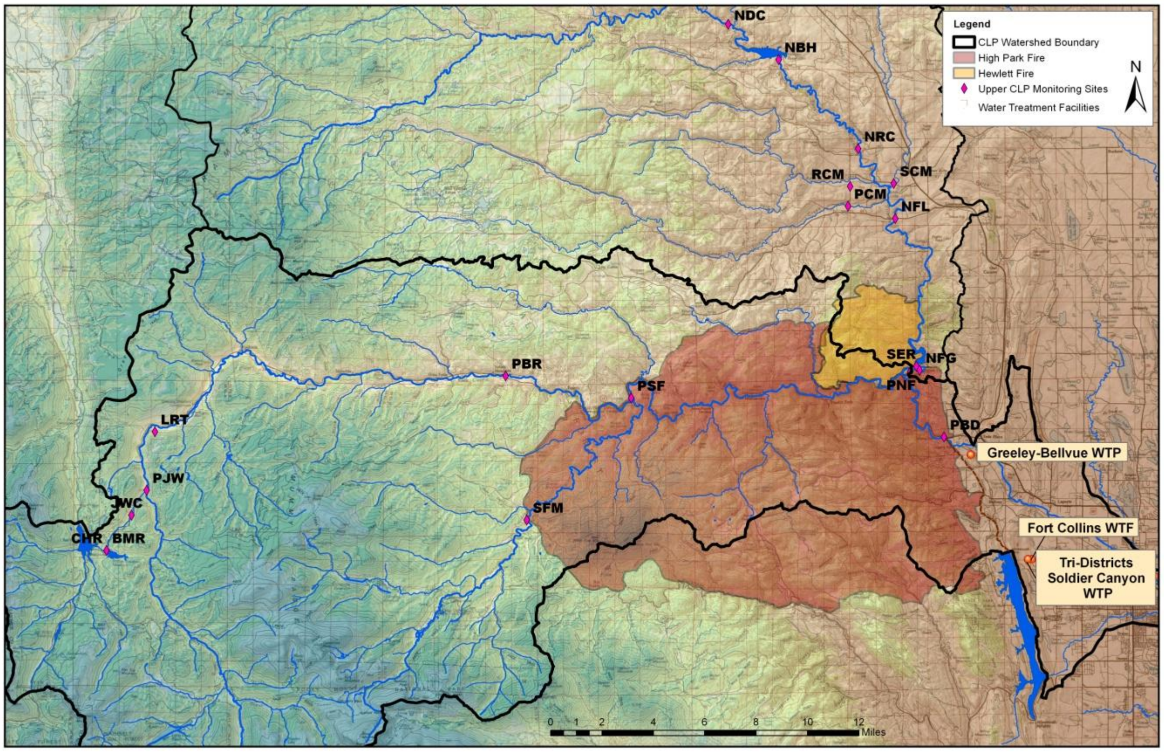


Figure 14. Map of the Upper CLP monitoring locations and the area affected by the Hewlett and High Park Fires.

3.2 Fire Effects on Forest Hydrology

The hydrology of forested ecosystems is largely controlled by the degree to which precipitation is intercepted by surface materials and the rate at which that precipitation infiltrates into the underlying soils. Tree canopy, surface vegetation, and accumulated surface organic matter increase infiltration rates by slowing the velocity and dispersing the impact of water droplets, while the organic matter on the forest floor absorbs soil moisture and provides a physical barrier against erosion. As long as infiltration exceeds the rate of precipitation during snow or rain events, the hydrology will be dominated by subsurface flow.

When surface vegetation is removed, by fire or other disturbance, the capacity to intercept precipitation and retain moisture is significantly diminished. Under these conditions, the hydrology can quickly shift from subsurface to overland flow pathways. The significance of a shift in forest hydrology from subsurface to overland flow is the tendency for overland flows to move quickly and consolidate along the paths of least resistance. The increase in flow volume and velocity dramatically increases the erosive capacity, which can quickly transform small ephemeral channels into active conduits for large sediment and debris flows following a fire (Moody and Martin, 2001).

A report issued by the Natural Resource Conservation Service (NRCS) on the increased flood potential in the High Park Fire burn area (Yochum, 2012) identified a substantial increase in the risks associated with flash flooding in several drainages in response to the shift to overland flow hydrology. The report outlines results of hydrologic model (HEC-HMS) simulations and predicts a much "flashier" system with substantial increases in peak flows and total flood flow volume, increased sediment transport, and channel destabilization in key drainages within the High Park Burn area (Figure 15). These hydrologic responses are expected to persist over the next several years.

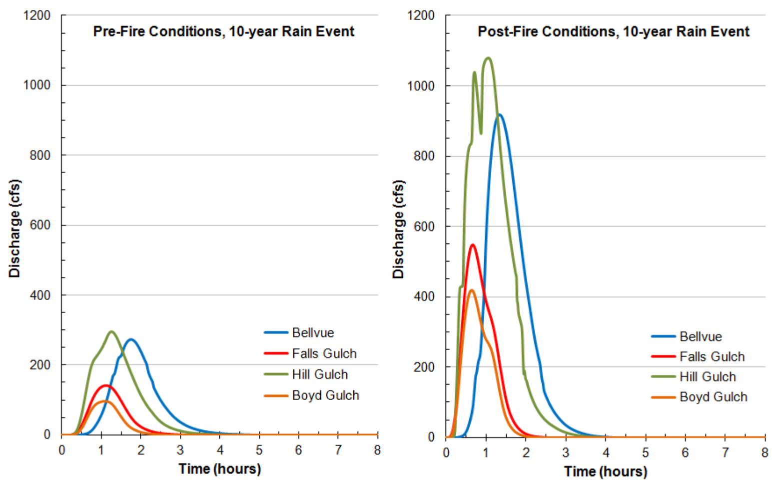


Figure 15. Pre-fire and post-fire discharge (cfs) in four key drainages in the High Park burn area under a simulated 10-yr rain event (Yochum, 2012).

A 2012 USGS analysis modeled the probabilities and volume of debris flows in all the identified drainages in the High Park Fire area under 2-yr, 10-yr, and 25-yr rain event scenarios (Verdin et al. 2012). Model results indicate that for the small and intermediate sized basins, the likelihood and size of debris flow increases with the size of the rain event. In contrast, the largest basins (Hewlett and South Fork) had low probabilities of producing debris flows even for large rain event scenarios. For example, results suggest that the South Fork of the Poudre is capable of producing debris flows of over 100,000 m^3, but the probability of such an event is only 4% and 6%, for 10-yr and 25-yr rain events, respectively.

Table 5 identifies the drainages that, according to the USGS analysis, have the highest likelihood (>50%) of delivering sediment and debris into the Mainstem Poudre River during a 10-yr-recurrence, 1-hour rain event.

Table 5. Drainages to the Mainstem Poudre River with estimated debris-flow volumes and probabilities >50% for a 10-year/1-hour precipitation event in the High Park Burn Area (USGS OFR 2012–1148).

Drainage	Area (km^2)	Probability (%)	Volume (m^3)
Skin Gulch	15.5	53	>100,000
Falls Gulch	3.5	62	32,000
Watha/Hill Gulch	14.4	57	>100,000
Boyd Gulch	3.2	75	32,000
Unnamed Creek near Hwy 14, west of mm 119	1.7	55	14,000
Unnamed Creek near Hwy 14, northwest of mm 119	3.0	69	25,000
Unnamed Creek near Hwy 14, northwest of mm 118	0.7	95	8,600
Unnamed Creek near Hwy 14, northwest of mm 118	0.5	92	6,200
Unnamed Creek near Hwy 14, between mm 115-116	0.7	86	8,100

These reports provide some spatially explicit information as to the predicted nature of streamflows and the estimated probabilities and size of debris flows out of key drainages in the burn area. Such information can be useful in the development of post-fire treatments to minimize the risk of post-fire erosion and sedimentation to human, cultural, and natural resources in the watershed. However, actual conditions will depend to a great extent on localized precipitation patterns and timing following the fire.

3.3 Burn Severity

Burn severity is a qualitative term that is used to characterize the energy that is released by a fire and the resulting impact on soils and water resources. Traditionally, fire severity for a given area is classified as low, moderate or high and depends on the amount, type and condition of fuels, the degree to which they are consumed by the fire and the amount of heat transferred into the soil profile during the fire (DeBano and Neary, 2005).

Both the High Park and Hewlett Fires burned as a mosaic of mixed burn severities according to the respective Burned Area Emergency Response (BAER) evaluations. Maps of fire extent and severity show approximately 41,113 acres (47%) of the High Park burn area and 2,152 acres (28%) of the Hewlett Fire area burned at the moderate or high severity level (Table 6 and Figure 16).

Burn severity can affect infiltration rates by altering the physical characteristics of soils, such as porosity and bulk density, and by producing hydrophobic, or water repellant soils. Hydrophobic soils occur following moderate to high-severity wildfires where soil particles have become coated with the organic waxes and other hydrocarbons from plant materials, causing water to bead-up on the surface (DeBano and Neary, 2005). Hydrophobic soils, which further promote overland flow development and increase recovery time, have been identified in the burn areas of the Upper Poudre watershed.

High Park Fire		
Burn Severity	**Acres**	**Percent of Burned Area**
Unburned	14,000	16%
Low	32,302	37%
Moderate	35,399	40%
High	5,714	7%
Total	**87,415**	
Hewlett Fire		
Burn Severity	**Acres**	**Percent of Burned Area**
Unburned	67	1%
Low	5,466	71%
Moderate	639	8%
High	1,513	20%
Total	**7,685**	

Table 6. Burn severity and acreage for High Park and Hewlett Fires.

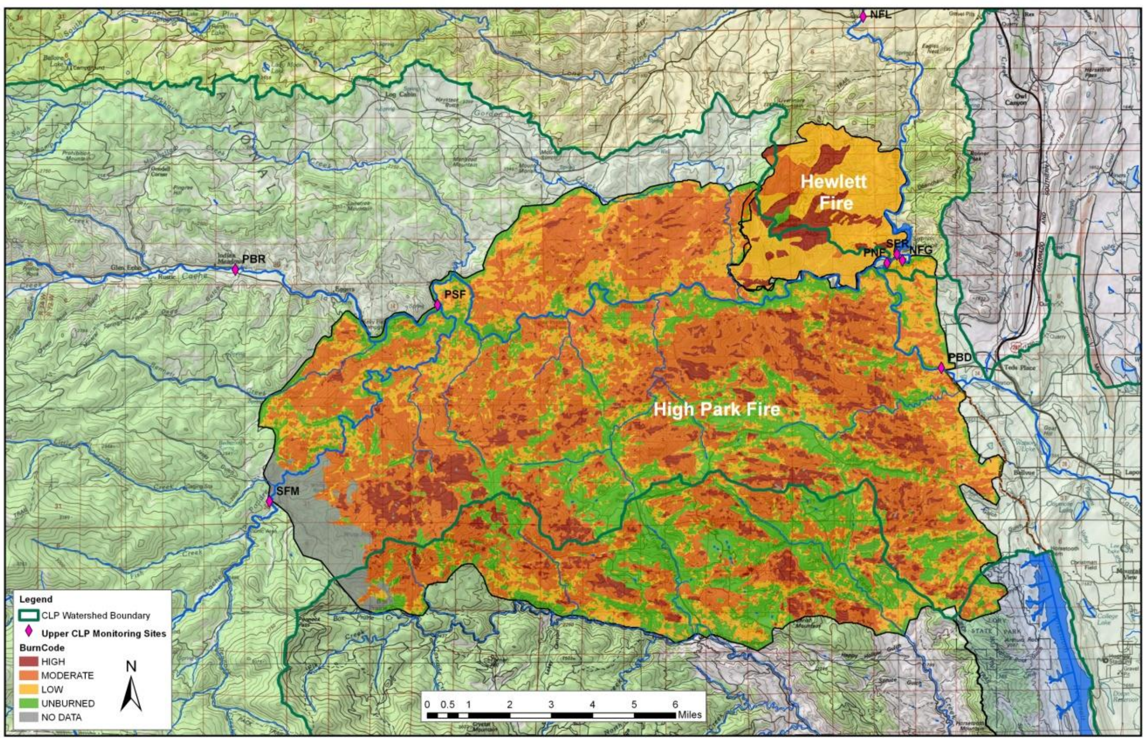


Figure 16. Soil burn severity map of 2012 High Park and Hewlett Fires in the Upper Cache la Poudre watershed.

3.4 Effects of Sediment Loading on Poudre River

Ultimately, it was not until precipitation fell on the burned landscape that the effects of the fires on vegetation and soils translated to changes in hydrology and water quality. Immediately following the containment of the 2012 fires, convective summertime thunderstorm activity began to occur over the burn area. These thunderstorms can be extremely localized and intense, as demonstrated by the July 7th storm event which delivered 1-2 inches of rain in some areas of the burn scar, over a short amount of time (CoCoRaHS). Consistent with predictions, mudslides and debris flows occurred in many burned drainages during this rain event and others throughout the summer, delivering massive quantities of ash and sediment into the South Fork and Mainstem of the Poudre River (Figure 17) as well as into Seaman Reservoir. Notably, during the first season following the fire, even small, localized precipitation events proved sufficient to cause dramatic changes in water quality and streamflow as shown by the numerous turbidity spikes shown in Figure 18.

Figure 17. Highly turbid Poudre River during the July 7 rain event.

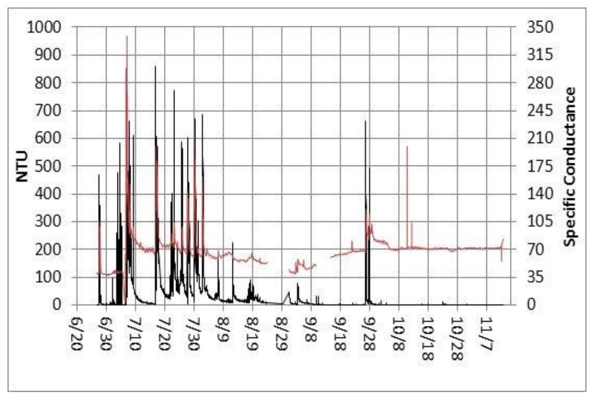


Figure 18. Turbidity (black solid line) and conductivity (red solid line) record from early warning system sonde located approximately four miles above the Fort Collins water supply intake facility.

Notably, the turbidity spike observed on September 28, 2012 occurred not as a result of a precipitation event, but as a result of a water release from an upstream reservoir. The release of water effectively elevated the river level and resulted in a re-suspension of fire sediments that had settled on the river banks during earlier summer storms. This event illustrates the extreme sensitivity of river water quality immediately following the fires.

The numerous alluvial fans that are evident along the Hwy 14 indicate actively eroding channels that will continue to provide sediment and debris to the river until vegetation recovers sufficiently to stabilize the hillslopes higher in the drainage areas. The rate of vegetation establishment will vary by location and aspect, as it depends on the remaining seed bank, the available soil nutrients and condition as well as how much precipitation the area receives in the coming year. In some areas where the soil seed bank remained, new grass and forb cover established by the end of the summer; many other areas remained bare (Figures 19, 20 and 21).

Water quality samples were collected for three storm events during the summer of 2012 in order to gain an understanding of the dissolved and particulate constituents in runoff from these fires. This sampling was beyond the scope of routine monthly sampling conducted as part of the cooperative Upper Cache la Poudre Monitoring Program, which is not designed to capture the impacts of short duration events. Storm samples were collected on June 26th (Hewlett Fire runoff), July 7th, and July 25th and were analyzed for metals, nutrients, major ions, turbidity, total dissolved solids (TDS), pH and conductivity. The results of the 2012 storm sampling are discussed in Section 4.0.

Figure 19. Post-fire vegetation recovery in meadows areas of the South Fork Poudre basin, August 2012.

To help ensure the safety of field personnel and improve the likelihood of capturing storm events, an automatic sampler was installed at the Fort Collins intake facility in 2013. The auto-sampler can triggered remotely from the Fort Collins Water Treatment Facility and capture samples from the Poudre River during in storm events.

Figure 20. Debris flow across Highway 14in the High Park burn area following a rain event during summer of 2012.

Figure 21. Woody debris accumulation in the lower segment of the South Fork above the confluence with the Mainstem Poudre September 2012.

3.5 Sediment Deposition

As water levels receded following the 2012 storm events, the water quality recovered fairly quickly. However, fine mineral sediments and ash settled along the depositional reaches of the river, creating significant banks of stored black fine sediment along the river channel (Figure 22).

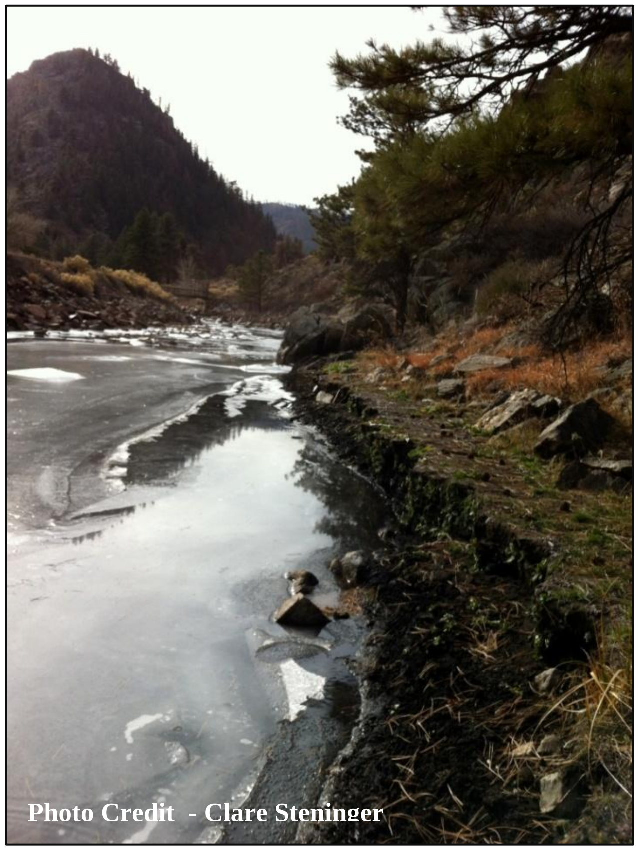


Figure 22. Riverbank deposits of sediment and ash from the High Park and Hewlett Fires on the Mainstem Poudre River.

It is expected that these stored riverbank sediments will persist until flows are sufficient to flush them downstream past water supply intake structures. However, even if flows from spring snowmelt runoff are sufficient to scour the riverbanks of these sediments, additional loading will likely occur during future rain events. The acute negative effects of these sediment deposits on water quality, as described above, occur any time water levels rise and stored sediments are re-suspended (i.e. during spring runoff, upstream water releases). The chronic water quality effects of theses sediments are largely unknown, but this and other questions are being addressed through collaborations with University of Colorado, Colorado State University, USGS, City of Greeley, Colorado Parks and Wildlife, Denver Water, Aurora Water, and Northern Water (See Table 7).

Despite the remaining uncertainties, it is well understood that the Poudre River water quality, which was once considered stable and reliable, is now less predictable and highly sensitive to even small precipitation events or changes in flows. These changes are expected to persist as long as sediments are present in the stream channel and hillslopes remain exposed. Continued reliance on the Poudre River as a source of drinking water supply under post-fire conditions demands increased responsiveness and planning on the part of water treatment operations and water resource managers.

3.6 Early Warning Capabilities

3.6.1 Water Quality Sonde

An early warning alert system is key to being able to respond quickly to rapid changes in Poudre River water quality. To this end, a multi-parameter water quality sonde was installed in the river approximately two miles upstream of the Fort Collins water supply intake facility immediately following the Hewlett Fire (Figure 23).

Figure 23. A multi-parameter water quality sonde provides real-time turbidity, conductivity and temperature measurements of the river as part of City of Fort Collins early-warning system.

The purpose of this installation is to provide the Cities of Fort Collins and Greeley and the Tri-Districts water treatment operations adequate warning time to bypass ash- and sediment-laden water at the intake facility in the event of a storm. The instrument provides real-time measurements of turbidity, specific conductance and temperature and has been programmed to send alerts when significant deviations from background levels are detected (See Figure 18 for example of graphical record). The turbidity and conductivity data generated from the sonde also serve as a proxy record of storms and other events that affect the water level in the river.

3.6.2 Rain Gauges

In addition, rain gauges were installed at the FCWTF intake at Gateway Park and on a privately owned ridge top in the Hewlett burn area by the City of Fort Collins Stormwater Utility. A third rain gauge and streamflow gauge were installed at the Hewlett Gulch Bridge in June of 2012. The Hewlett Ridge and the Gateway rain gauges are part of the City of Fort Collins Flood Warning System and provide real time precipitation reports that are available to the public on the City website (*http://www.fcgov.com/utilities/what-we-do/stormwater /flooding/warning-system/rainfall-report-by-gauge-location*). These gauges also provide early warning information to water treatment operations.

3.6.3 Munroe Diversion Turbidity Meters

An in-line turbidity meter was installed at the Munroe Tunnel diversion by Northern Water, the Cities of Fort Collins and Greeley and Tri-Districts to provide real time turbidity readings on the Poudre River. This instrument provides turbidity measurements on the river water that would be diverted into the Pleasant Valley Presedimentation basin (Section 3.7). It also provides indication of changes in water quality that occur as a result of storms that occur below the upstream water quality sonde and the FCWTF intake.

3.7 Pleasant Valley Presedimentation Basin

To address the water quality issues from the 2012 wildfires, Fort Collins Utilities began a fast-tracked design and construction project of improvements to the turnout structure for the Pleasant Valley Pipeline (PVP). The PVP is located adjacent to the Munroe Canal, due north of the mouth of the Poudre Canyon. The resulting project consists of a new presedimentation basin located on property owned by the Northern Colorado Water Conservancy District (NCWCD). The Tri-Districts and the City share the capacity in the PVP during the summer months. The project took 4-1/2 months from design to construction completion.

This project was necessary to address the removal of sediment in the Poudre River that resulted from the High Park and Hewlett Fires during the summer of 2012. While the intake structure for the pipeline currently is equipped with mechanical screening equipment, the screen will not function properly when faced with the large amount of sediment that is expected in the raw river water.

The presedimentation basin will reduce the variability of the Poudre River water quality prior to arriving at the water treatment facility, thereby increasing the efficiency of the treatment process. The basin will also aid in the removal of debris during normal spring snowmelt runoff, when pine needles and other debris move quickly in the river.

3.8 Emergency Fire Effects Mitigation

In the aftermath of each of the 2012 fires, an interagency Burned Area Emergency Response (BAER) Team was assembled, with resource specialists from the Natural Resources Conservation Service (NRCS), Larimer County, Colorado Department of Transportation (CDOT) and the U.S. Forest Service (USFS). This team evaluated the risks to life, property, natural and cultural resources resulting from the post-fire effects and identifies treatment options for mitigating those risks. In this process, the USFS assumes responsibility for mitigating fire effects on USFS lands, while the NRCS worked with private landowners and other local participants, including the City of Fort Collins, City of Greeley, and Larimer County to identify treatment priorities. Funding provided by the participants is eligible for a federal match through the NRCS Emergency Watershed Protection (EWP) Program.

Following a fire, debris flow originates from channel scour; however, the majority of the water originates from hillslope runoff. Therefore, first focus of post-fire mitigation is often to control hillslope runoff, with in-channel controls as secondary efforts.

Accordingly, the primary treatment identified through the High Park Fire BAER process was the aerial application of certified weed-free agricultural straw mulch to erosion prone hillslopes. Wood shred mulch was also identified as a treatment for high severity burn areas on steep slopes where the lighter agricultural straw was especially susceptible to being moved around by winds. The intent of both straw and wood mulch is to lend stability to fire-affected soils by reducing the impact of precipitation and helps retain soil moisture which facilitates seed establishment. Through the BAER process, the USFS identified 5,581 acres of federal land for mulching. In 2012, 881 acres of wood-shred mulch was applied, and an additional 4,700 additional acres of aerial straw mulching was completed in 2013. In addition, the NRCS identified 5,600 acres of private land for treatment – approximately 3,000 acres of which was treated with aerial application of straw mulch in 2012. Additional wood shred mulching and hillslope treatments are planned on private lands in 2013.

3.9 Key Uncertainties

In effect, the fire was a major destabilizing force within the watershed. How quickly the system will recover remains uncertain. As the recovery process continues, the Cities of Fort Collins and Greeley and the Tri-Districts must continue to rely on the Poudre River as an important municipal water supply. To understand future challenges related to water quality as well as cost-effectiveness of post-fire treatment options, water providers have worked closely with researchers from University of Colorado, Colorado State University, US Geological Survey as well as private consultants to investigate specific issues of concern. In 2012, the City of Fort Collins and/or City of Greeley contributed funding toward several post fire-related investigations, as outlined below in Table 7.

Table 7. Fire-related studies sponsored or co-sponsored by the City of Fort Collins and City of Greeley.

Study Description	**Key Questions Addressed**
Effectiveness of Aerial Mulching at Controlling Sediment Movement in the South Fork drainage of the Poudre River P.I. Sara Rathburn, Colorado State University Co-Funders: US Forest Service, City of Greeley, City of Fort Collins	Is mulching an effective treatment for reducing hillslope erosion and water quality impacts at the basin-scale? **Status:** started Spring 2013
Effects of Fire on TOC Character and Treatability P.I. – Fernando Rosario-Ortiz, University of Colorado Co-Funders: City of Fort Collins Utilities, CDPHE, Denver Water, Aurora Water, Northern Water, Water Research Foundation	How has Total Organic Carbon (TOC) character and Disinfection By-Product formation-potential changed post-fire and during recovery? Do those changes affect treatability? **Status**: ongoing
Leaching Study on the Effects of Stored Riverbank Fire Sediments on Poudre River Water Quality P.I. Clare Steninger, Colorado State University. Advisor: Pinar Omur-Ozbek Funder: City of Fort Collins Utilities	How do the stored sediments affect background river water quality? **Status:** Completed
Flavor Profile Analysis of Poudre River water for Fire-Related Taste & Odor Compounds P.I. Pinar Omur-Ozbek, Colorado State University Funder: City of Fort Collins Utilities	How do fire-related compounds in the Poudre River water affect taste and odor of raw water and water treated with powder activated carbon (PAC)? **Status:** Completed
Cache La Poudre River Post-Fire Sediment & Aquatic Insect Monitoring Co-Funders: Fort Collins Natural Areas, Fort Collins Utilities, Colorado Division of Parks and Wildlife, Colorado State University	What are the effects of fine fire sediment deposition on aquatic macroinvertebrate communities in the Poudre River? **Status:** Ongoing

4.0 WILDFIRE IMPACTS ON WATER QUALITY

Improvements in water quality are expected to follow the process of watershed recovery, although there is little certainty as to how long recovery will take, what specific changes in water quality can be expected or if it will even return to pre-fire condition. The availability of baseline water quality data collected as part of the Upper Cache la Poudre Cooperative Monitoring Program from 2008-2012 has allowed a quantitative comparison of pre- and post-fire water quality. Moving forward, routine and targeted monitoring will be essential to understanding the types of changes that have occurred and will continue to occur as watershed recovery proceeds.

In addition to routine water quality sampling, there was a focused effort on monitoring water quality during storm events, as storm samples indicate the progress of future watershed recovery (e.g. hillslope stability, hydrology, forest nutrient cycling). As previously mentioned, summertime convective thunderstorm activity began immediately following the containment of the 2012 wildfires and storm samples were collected on three occasions: June 27, July 6 and July 25.

4.1 Water Quality Impacts on the Mainstem CLP

The graphical presentations of pre- and post-fire data include routine monitoring data from the Poudre above the the North Fork (PNF), situated at the Fort Collins water supply intake. The results of the storm samples collected in 2012 near PNF are also included. Samples were analyzed by the Fort Collins WQL for nutrients, metals, hardness, and Total Dissolved Solids (TDS). The Fort Collins Water Treatment Facility Process Control Lab provided measurements for pH, Conductivity and Turbidity and Total Organic Carbon (TOC) data were provided by the US Geological Survey.

4.1.1 Conductivity, Alkalinity, Hardness and pH

Conductivity is an index of dissolved ionic solids in the water and hardness is an index of the total calcium and magnesium in the water. Alkalinity is a measure of the effective acid buffering capacity of the water, and is derived, in large part, from the dissociation of mineral carbonates (CO_3^-), bicarbonates (HCO_3^-) and hydroxides (OH^-). Conductivity, hardness and alkalinity are influenced by the local geology as well as the dissolved constituents derived from other watershed activities. Across the watershed, these three parameters along with pH generally track closely, with minimum values occurring during peak run-off when the concentrations of all dissolved constituents are diluted by large volume streamflows, with higher values occurring at times of low streamflow (Figures 24.a -24.d).

Late summer values for all four parameters were slightly elevated following the fires in background, non-storm event samples, but were within the range of annual variability observed from 2008 – 2012 (Figures 24.a & 24.b). Following storm events, hardness, conductivity, and pH values were substantially higher than in post-fire background samples, but concentrations returned to background levels following storm events.

Elevated hardness, conductivity, and pH following wildfires is well documented (DeBano et al, 1998; Marion et al, 1991) and is likely due to the concentration of elements such as calcium and magnesium in the surface ash and sediments that were initially washed into the river.

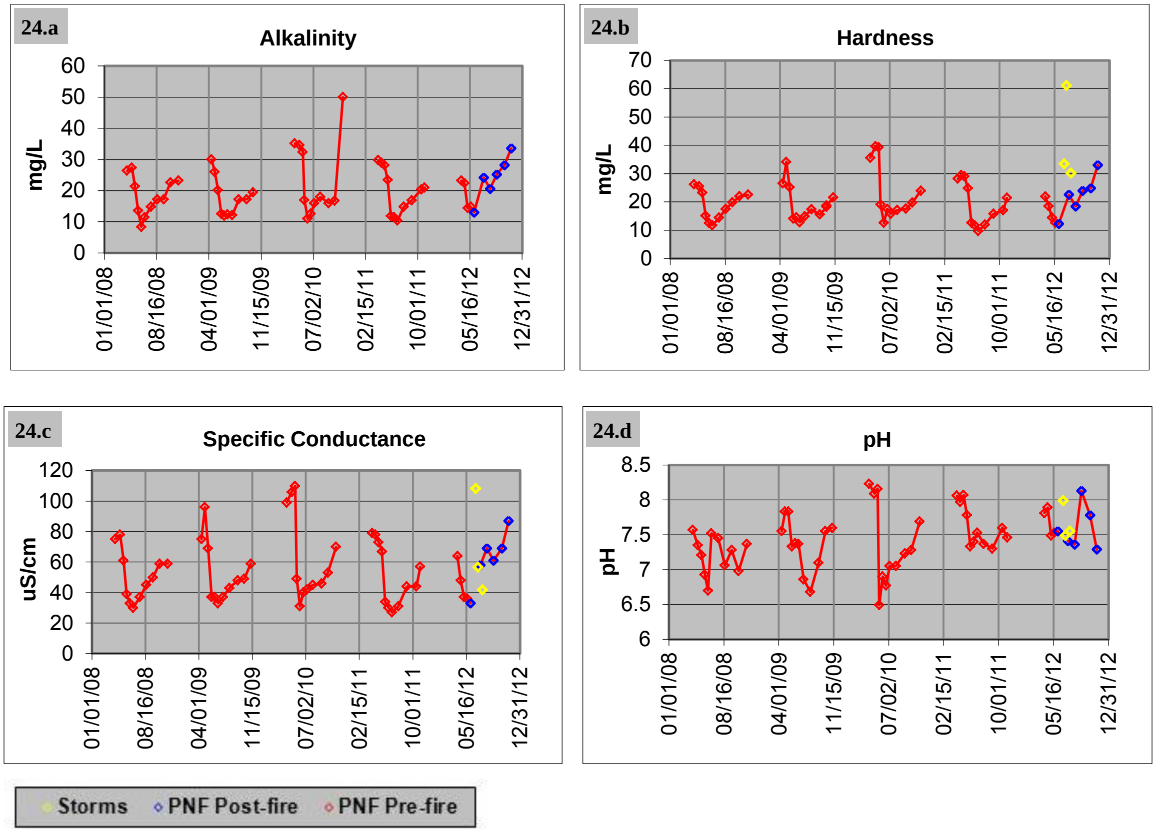


Figure 24(a-d). Pre- and post-fire alkalinity (a), hardness (b), conductance (c) and pH (d) values at PNF with storm event concentrations.

4.1.2 Total Dissolved Solids & Turbidity

The concentrations of total dissolved solids (TDS) in the Poudre River (PNF) range from near 20 to 80 mg/L during the years 2008-2012 (Figure 25) and closely follow the hydrograph. Peak concentrations occur during spring snowmelt runoff, followed by a steep decline during the summer months and a slight increase in concentrations again during late fall. Following the fire, concentrations spiked during storm events, but background concentrations do not indicate any sustained post-fire impact on TDS concentrations in the Poudre River (Figure 25).

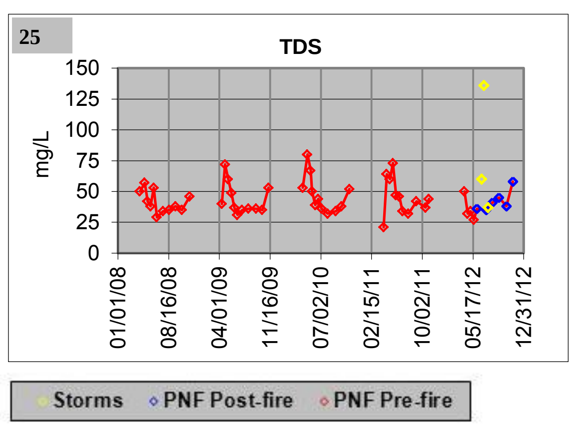


Figure 25. Pre- and post-fire Total Dissolved Solids (TDS) values at PNF with storm event concentrations.

Turbidity is a measure of the ability for light to penetrate the water column, and is influenced by the amount of suspended material in the water. Like TDS, turbidity also increases during the spring snowmelt runoff and quickly falls to low concentrations (typically below 3 Nephelometric Turbidity Units (NTU)) during the summer. Turbidity levels remained somewhat elevated (3.38 NTU) in July following the fires and were exceptionally high (14.6 NTU) during the August sampling event. Figure 26.a and 26.b illustrate the dramatic changes in turbidity that occurred during post-fire flash flooding events. Like other parameters, the concentrations seen during storm events were not sustained.

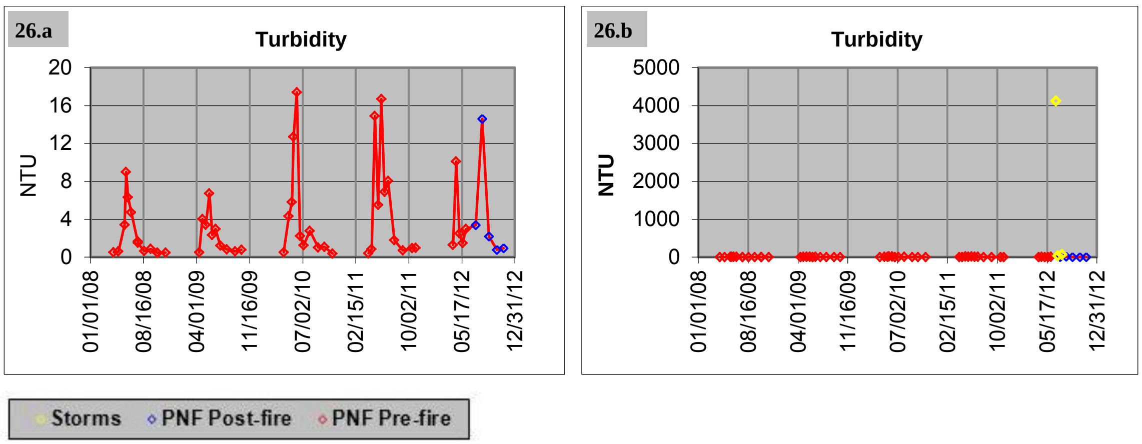


Figure 26 (a-b). Pre- and post-fire Turbidity (a) values at PNF with storm event concentrations (b).

4.1.3 Total Organic Carbon (TOC)

Total organic carbon (TOC) is the combined dissolved and particulate carbon that originates from the watershed soils and biological material in the river. TOC is of concern for water treatment due to its tendency to react with chlorine during the disinfection process and produce regulated disinfection by-products, or DBPs. Peak Total Organic Carbon (TOC) concentrations are also closely associated with the timing and magnitude of spring snowmelt runoff. The relatively low 2012 peak flows resulted in a lower than usual peak TOC concentration of 6.8 mg/L, compared to previous years (9.5-11mg/L; Figure 27). Background (non-event) TOC concentrations did not appear to be

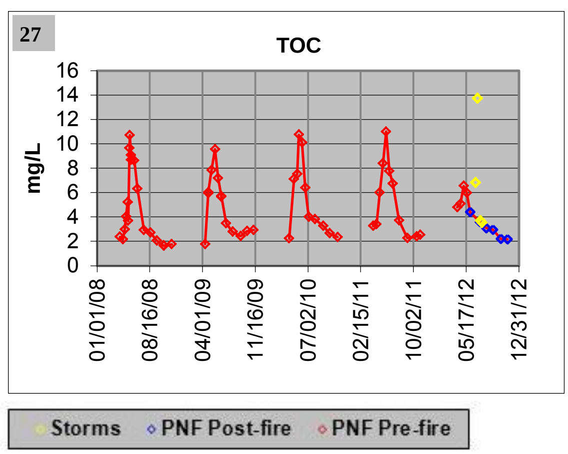


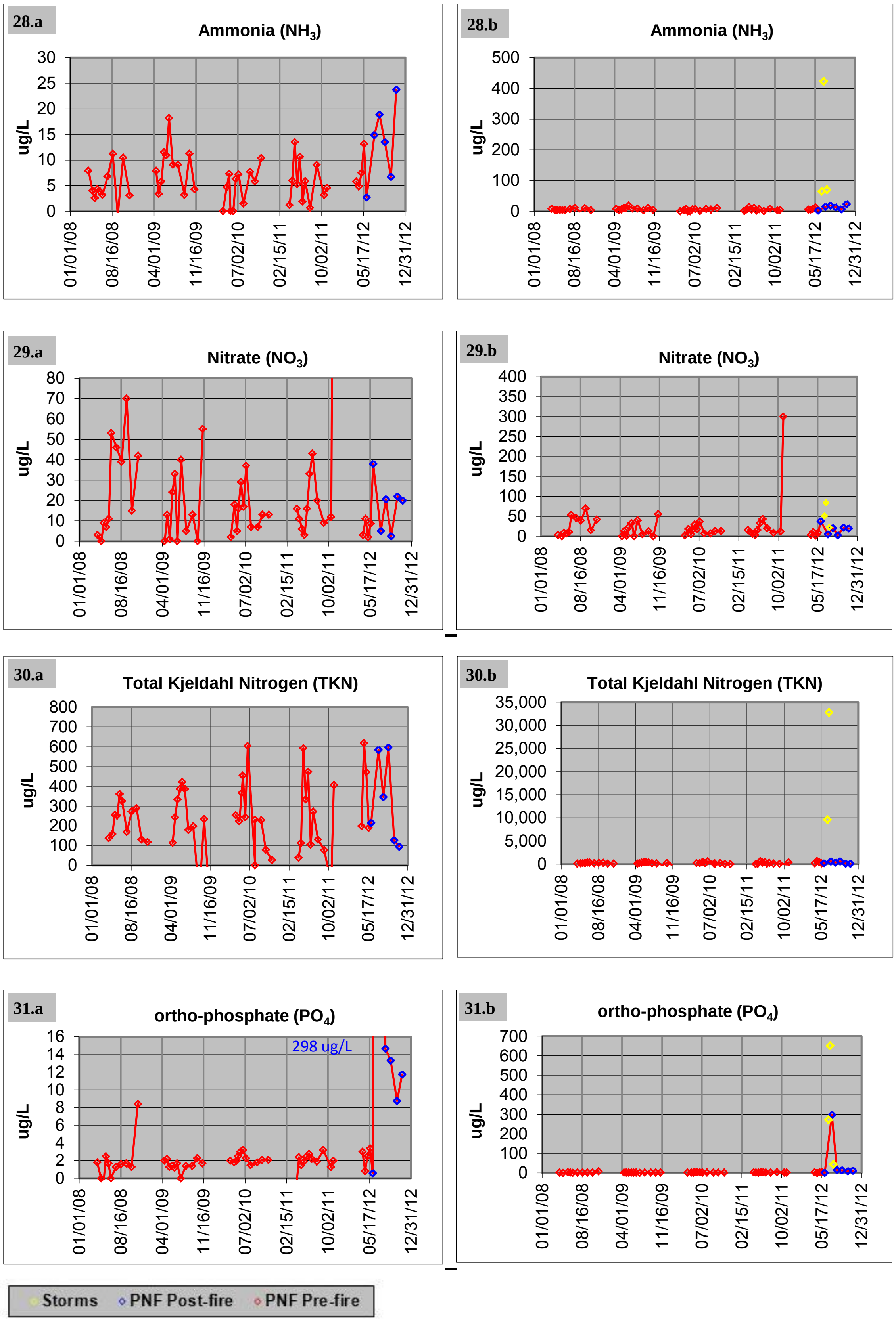
Figure 27. Pre- and post-fire Total Organic Carbon (TOC) concentrations.

affected by post-fire conditions. Storm events did mobilize organic carbon and resulted in elevated concentrations (3.7-13.7 mg/L); however the response was small and did not present conditions that pose concerns for water treatment.

4.1.4 Nutrients

In an unburned forested system, nutrients are made available to plants via microbial and physical decomposition of soil organic matter. In effect, the carbon (C), nitrogen (N), and phosphorus (P) bound within the organic matter is slowly liberated and transformed into biologically available forms that subsequently can become dissolved in subsurface water (soil solution). Fire results in instantaneous decomposition of forest floor organic matter, where during combustion, N and C are lost to the atmosphere by volatilization, primarily as nitrogen gas (N_2), carbon dioxide (CO_2) and other volatile organic compounds (Debano et al, 1998, Debano 1991). At high combustion temperatures nearly all N is lost as N_2, whereas at lower burning temperatures, some of the N remains on the soil surface as partially consumed organic matter or is converted to ammonium (NH_4) (Neary et al., 2005). Typically, less phosphorus is volatilized during a fire compared to nitrogen (Raison et al, 1985), resulting in more available phosphorus in the ash. If left undisturbed, these transformed nutrients will eventually become available for new plant growth; however, if these surface materials and the underlying mineral soils are subject to erosion, as they were following the 2012 fires in the Upper CLP watershed, the associated nutrients are transferred to the aquatic system in both dissolved and particulate forms.

Following the 2012 wildfires, the largest post-fire responses were observed for ammonia (NH_3) (indicative of NH_4 concentrations), Total Kjeldahl Nitrogen (TKN), ortho-phosphate (PO_4^-) and Total P (Figures 28-32). Concentrations of these nutrients remained elevated in post-fire background samples to different degrees, with exceptionally high concentrations observed during and following storm events. The higher than normal background concentrations and strong pulses following runoff events are most likely due to the movement hillslope materials into the river. It is notable that background nitrate (NO_3) concentrations in the water did not change following the fire and that runoff events produced only very small changes in concentrations. Nitrate is a highly mobile, dissolved form of nitrogen that is found primarily in the soil solution in intact forested systems and is made available to aquatic systems through subsurface flow pathways. The lack of nitrate response immediately following the fires may be due to the cessation of nitrate production in the soils (Neary et al., 2005), as well as a switch from subsurface flow pathways to predominantly overland flow (Bladon et al, 2008).



Figures 28-31 (a-b). Pre- and post-fire values (a) with storm event concentrations (b) at PNF for ammonia (Fig.28), nitrate (Fig.29), TKN (Fig.30), and ortho-phosphate (Fig.31).

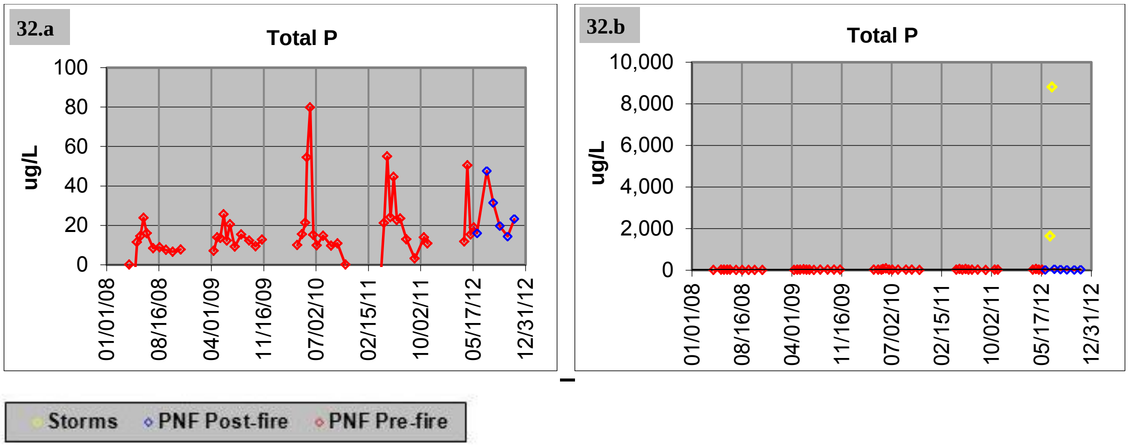


Figure 32 (a-b). Pre- and post-fire values (a) with storm event concentrations (b) at PNF for Total P.

4.1.5 Metals

The high temperatures necessary to volatilize heavy metals are not typically experienced during wildfires (Knoepp et al., 2005). Like other elements, metals are liberated from soils and organic matter during combustion and find their way into surface waters during storms and runoff events. Figures 33 and 34 show total and dissolved concentrations, respectively, of heavy metals that were observed in the three storm event water samples in 2012. The observed concentrations for total metals were two to three orders of magnitude greater than dissolved concentrations. Most national drinking water standards are based on dissolved fractions and relate to finished treated drinking water. However, it is helpful to understand what concentrations are present in the source waters in order to address potential problems before the treatment phase. Assessment of total concentrations provides an approximation of how much can potentially be released given the appropriate time and conditions.

For the post-fire storm samples, only aluminum (Al) exceeded drinking water standards (Table 8). Aluminum is subject to secondary drinking water standards, which are a non-enforceable guidelines for contaminants that may have cosmetic (i.e. color) or aesthetic (i.e. taste) effects, but do not pose public health concerns. The secondary standard for dissolved Al is 50 ug/L, and observed concentrations reached approximately 150 ug/L (Figure 34).

Table 8. National Primary and Secondary Drinking Water Standards for select metals.

Metal	EPA Maximum Contaminant Level (MCL) or Treatment Technique Standard (TT)	Secondary Standard
Mercury (Hg)	2 ug/L	
Silver (Ag)	100 ug/L	
Aluminum (Al)		50 ug/L
Arsenic (As)	10 ug/L	
Barium (Ba)	2,000 ug/L	
Beryllium (Be)	4 ug/L	
Cadmium (Cd)	5 ug/L	
Chromium (Cr) - Total	100 ug/L	
Iron (Fe)		300 ug/L
Manganese (Mn)		50 ug/L
Lead (Pb)	15 ug/L	
Antimony (Sb)	6 ug/L	
Selenium (Se)	50 ug/L	
Thallium (Tl)	2 ug/L	
Zinc (Zn)		5,000 ug/L

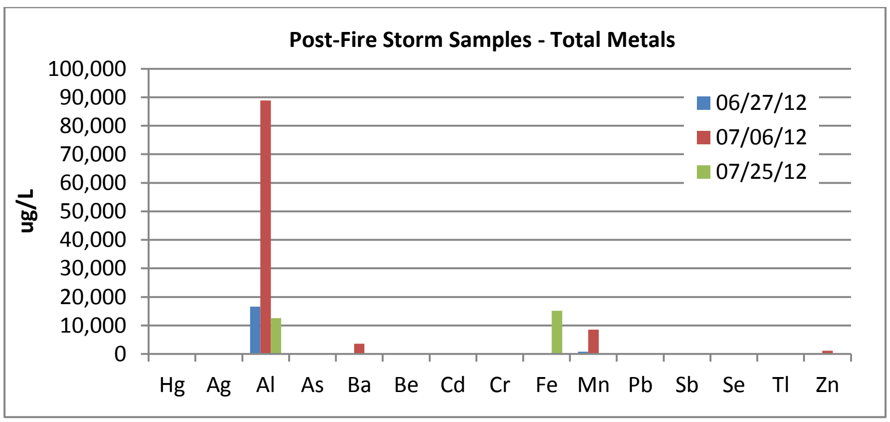


Figure 33. Concentrations of metals (total) in post-fire storm samples.

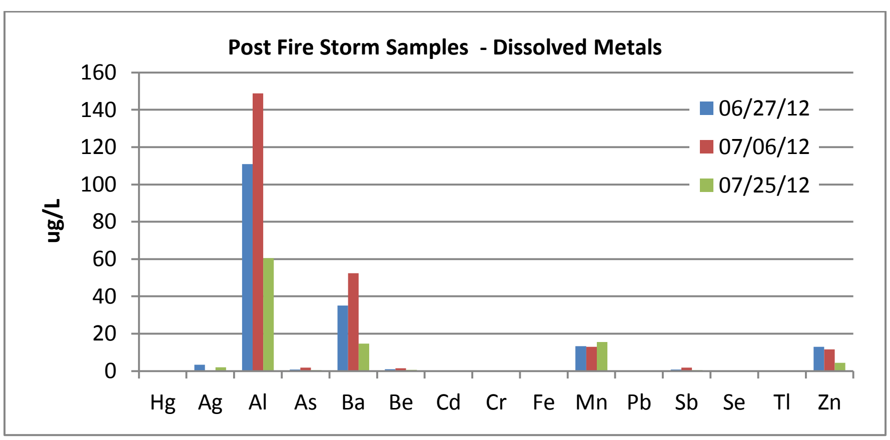
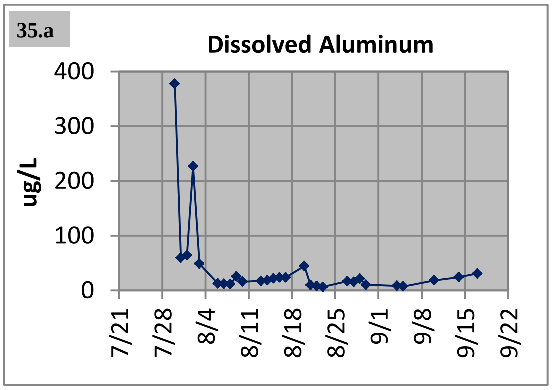


Figure 34. Concentrations of metals (dissolved) in post-fire storm samples.

In addition, daily grab samples were collected from the river from July 30 until September 17, while the Poudre River supply was off-line due to impaired water quality and loss of power and access at the intake facility. During this time, daily grab samples were analyzed for dissolved aluminum and manganese (Figures 35.a & 35.b). Like the storm event samples, the daily grab samples results indicated that storm events produce high concentrations of these metals, but concentrations decreased rapidly to low levels following rain events.



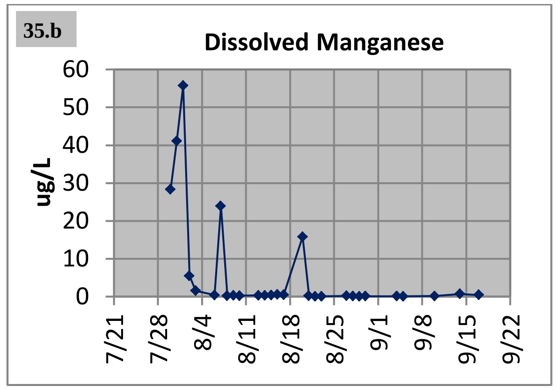


Figure 35(a-b). Concentrations of dissolved aluminum (a) and manganese (b) in daily grab samples from Poudre River (July 30 to September 17), following High Park and Hewlett Fires.

4.2 Water Quality Impacts to Seaman Reservoir

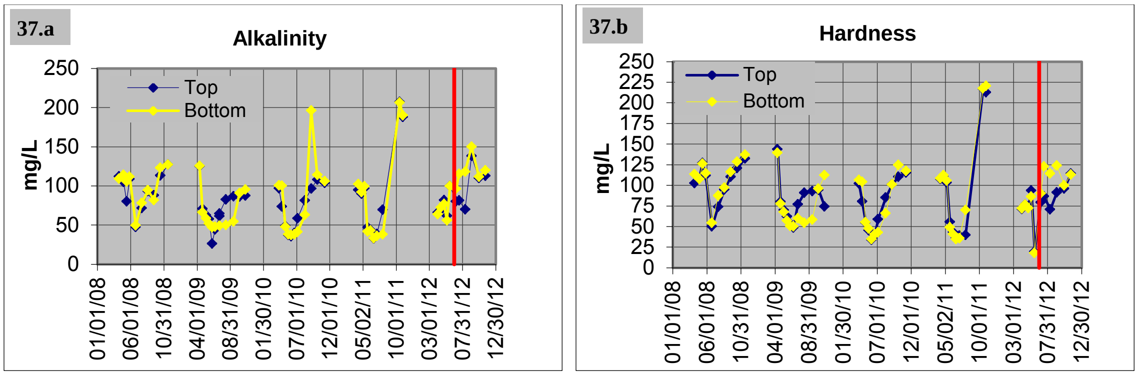
The Hewlett Fire burned an extensive area surrounding Seaman Reservoir, which is a major component of the City of Greeley's water supplies (See Figure 17). As on the Mainstem Poudre River, summer thunderstorm activity delivered a substantial amount of ash and sediment into Seaman Reservoir from some of the moderately and severely burned basins that drain directly into the upper reaches of the reservoir. This section will document the pre- and post-fire water quality collected near the spillway at the top and bottom of the reservoir.

In addition to fire-sediment loading, there were additional factors that likely affected the water quality, including drought and other limitations on reservoir operations that resulted in very little water being released from the reservoir during the 2012. The lack of fresh water circulation within the reservoir and above average temperatures in 2012 contributed to prolonged periods of low dissolved oxygen and algal blooms (indicated by chlorophyll-*a* concentrations). Additional discussion of non-fire related Seaman Reservoir water quality is provided in Section 6.3 - Temporal Trends in Seaman Reservoir. It should be noted that based on available data, the observed water quality impacts cannot be attributed solely to wildfire impacts, or any other single factor.

Figure 36. An aerial view of Seaman Reservoir captures the high chlorophyll-*a* concentrations that resulted from the 2012 mid-summer algal bloom.

4.2.1 Alkalinity and Hardness

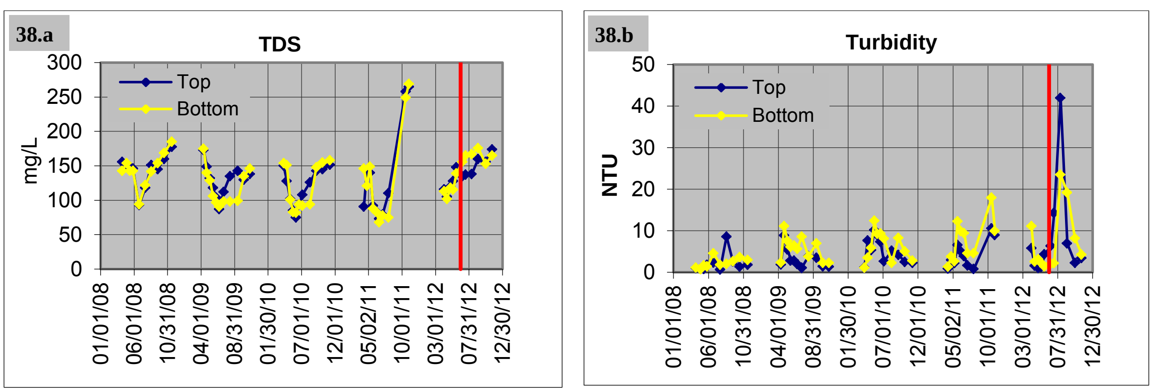
Post-fire concentrations of alkalinity and hardness were within the range of the mid- to late-summer concentrations seen in previous years (Figure 37.a & 37.b).

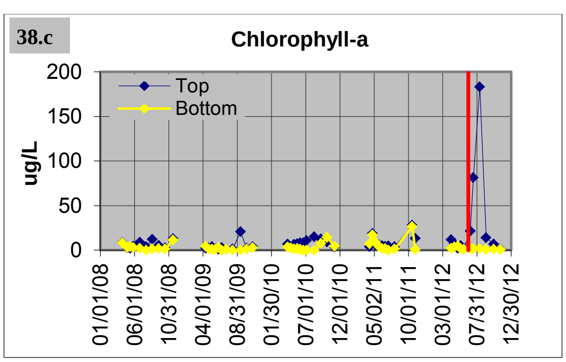


Figures 37 (a-b). Pre- and post-fire values for alkalinity (a), hardness (b) in Seaman Reservoir.

4.2.2 Total Dissolved Solids (TDS), Turbidity and Chlorophyll-a

TDS concentrations did not follow the typical seasonal pattern of spring dilution followed by late summer increases, most likely due to limited through-flow of water. However, all observed TDS concentrations were within the range of values seen in previous years. In contrast, chlorophyll-*a* and turbidity exhibit exceptionally high concentrations at the top of the reservoir on the August 13th sample date.





Figures 38 (a-c). Pre- and post-fire values for TDS (a), turbidity (b) and chlorophyll-a (c) in Seaman Reservoir. The red line indicates the June 24, 2012 start date of the Hewlett Fire.

These spikes in surface concentrations of chlorophyll-*a* and turbidity coincide with exceptionally high concentrations of dissolved oxygen (12.28 mg/L) at the surface of the reservoir (Figure 39). Together, these events suggest high rates of photosynthesis during this period, and provide evidence that the high turbidity values are due to algal production rather than an influx of inorganic fire sediments. Furthermore, the abrupt decreases in chlorophyll-a and dissolved oxygen concentrations indicate a subsequent period of algae die-off and/or consumption by zooplankton.

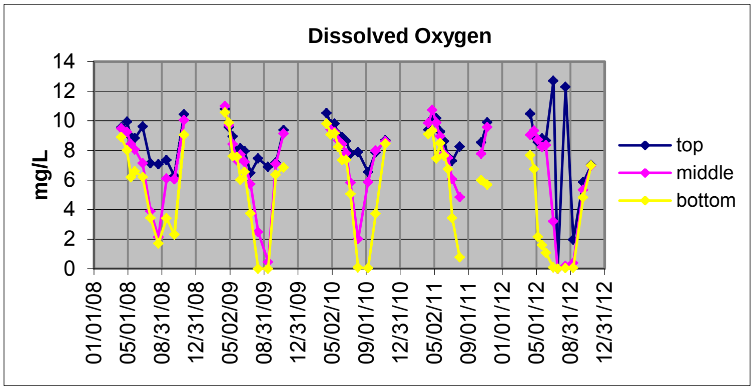


Figure 39. Dissolved oxygen concentrations at the top, middle and bottom of Seaman Reservoir for 2008- 2012.

4.2.3 Total Organic Carbon (TOC)

Concentrations of TOC do not appear to be affected by fire (Figure 40). Like other parameters, the timing of high concentrations of TOC at the top of the reservoir suggests that much of the available organic carbon may be derived from both dissolved and particulate matter from algal production and decomposition.

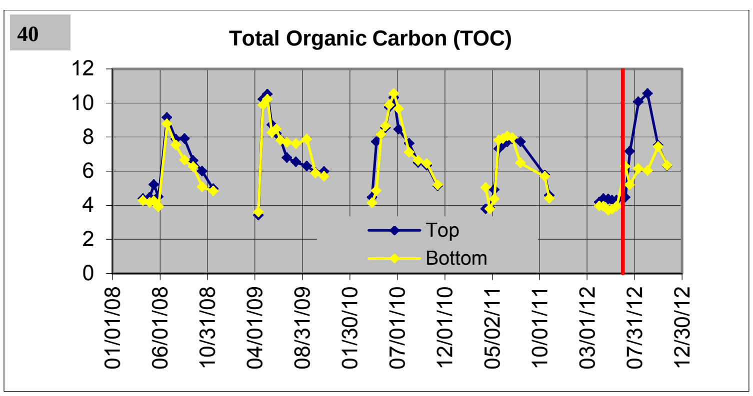
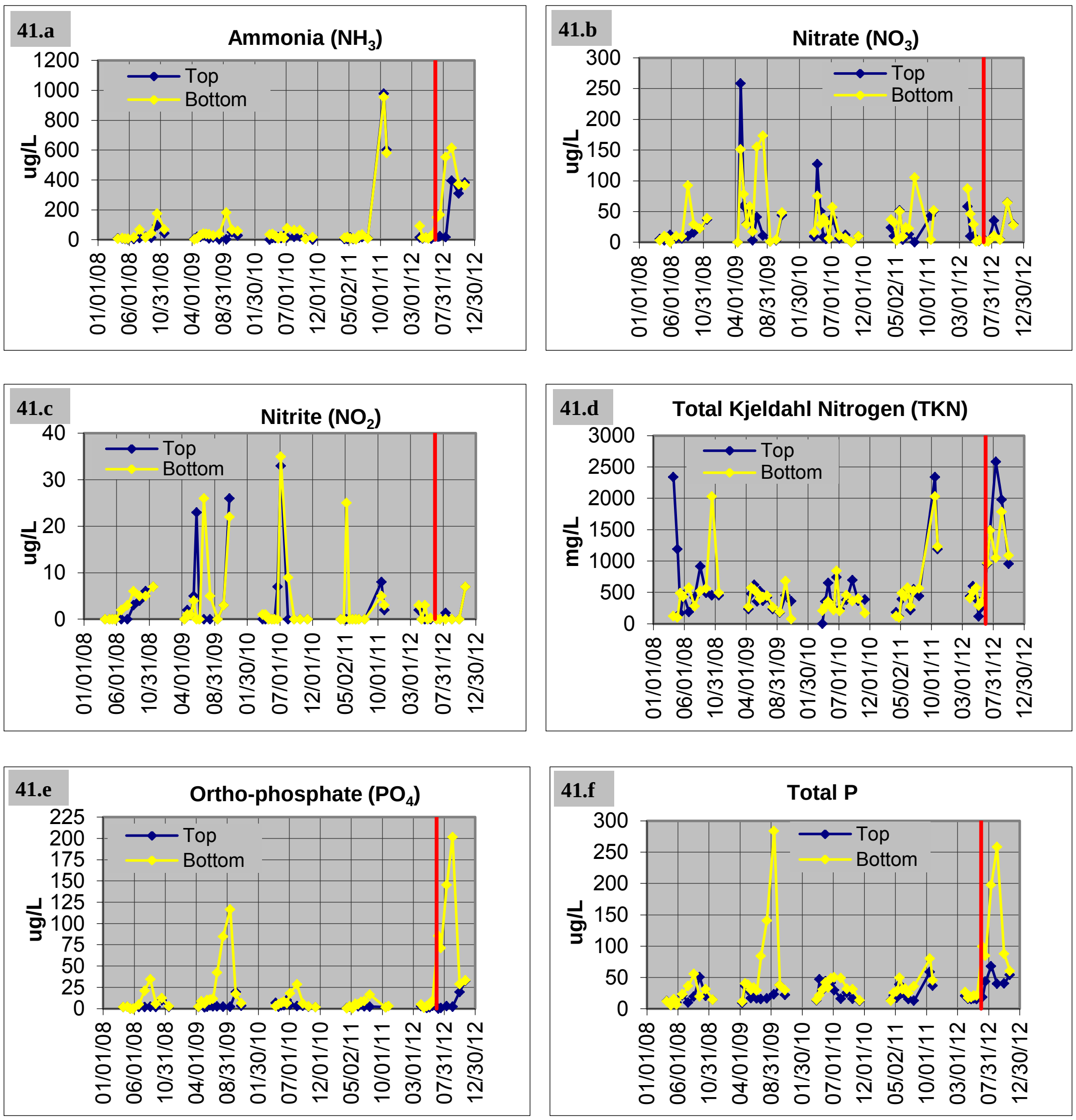


Figure 40. Pre- and post-fire concentrations of Total Organic Carbon (TOC) in Seaman Reservoir. The red line indicates the June 24, 2012 start date of the Hewlett Fire.

4.2.4 Nutrients

High concentrations of ammonia, Total Kjeldahl Nitrogen (TKN), ortho-phosphate and total phosphorus were observed during the summer following the fire (Figures 41.a, 41.e & 41.f). However, the timing of the 2012 spikes in concentrations were similar to previous years, and like other parameters, coincide with the seasonal period of low dissolved oxygen at the bottom of the reservoir. The magnitude of the spikes may be attributed to the particularly prolonged period of hypoxia, during which time nutrients are released from the sediments.



Figures 41(a-f). Pre- and post-fire values for ammonia (a), nitrate (b) and nitrite (c), TKN (d), ortho-phosphate (e) and Total phosphorus (f) in Seaman Reservoir. The red line indicates the June 24, 2012 start date of the Hewlett Fire.

In general, it appears that the influx of sediments from the surrounding burned hillslopes is not significantly affecting water quality at the outlet of the reservoir at this time. The apparent lack of response may be being masked by the larger influence of seasonal reservoir dynamics. It is also possible that the location of the sediment deposition is far enough away from the reservoir outlet, that in a year with little through-flow, the impacts on downstream water quality are not yet detectable. Because fire sediments can carry high concentrations of nutrients, metals and organic matter, it is expected that they will have a detectable impact on water quality in the reservoir. The timing of when those impacts become noticeable will depend upon the reservoir dynamics in the coming years.

4.3 Post-fire changes in monitoring

The availability of baseline data obtained from the Upper CLP water quality monitoring program from 2008-2012 provides an excellent opportunity to monitor changes in river and reservoir conditions following large scale events like the wildfires of 2012. Minor changes in the monitoring plan were made in 2012 to ensure that the effects of the fires were captured. These changes include increased frequency and locations at which metals are samples, as well as an increase in the number of metals monitored at each site. The new metals monitoring is outlined in Table 9 below. Refer to Figure 1 for sampling locations.

Table 9. Sampling locations and frequencies for metals sampling as part of Upper CLP Monitoring Program.

	NFL	SER-Top	SER-Bottom	NFG	PBR	PSF	PNF	PBD
Al[1]	3x/yr[2]	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr
As		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Cd		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Cr		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Cu		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Fe[1]	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr
Hg		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Mn[1]	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr	3x/yr
Pb		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Se		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Ag		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Ni		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr
Zn		3x/yr	3x/yr	3x/yr			3x/yr	3x/yr

[1]All metals analyzed for dissolved fractions; Al, Mn and Fe also analyzed for Total Digested fractions
[2] 3x/yr = samples to be collected in May, August, and October

5.0 HYDROLOGY, SNOWPACK & TEMPERATURE

The hydrology of the Upper Poudre Watershed plays an important role in regulating water quantity and quality. Precipitation events and snowmelt runoff largely control the quantity and timing of deliveries of material to the river, and the amount of water in the system at a given time affects the concentration of water quality constituents. Discharge is measured as part of the routine Upper CLP monitoring activities at two key sites on the Mainstem: Poudre above Joe Wright Creek (PJW) and South Fork Poudre (SFM). Discharge values presented for these sites represent instantaneous discharge measurements collected on the specified sampling dates.

Discharge measurements are also collected on four tributaries of the North Fork CLP: North Fork above Rabbit Creek (NRC), Rabbit Creek Mouth (RCM), Stonewall Creek Mouth (SCM), and Lone Pine Creek Mouth (PCM) for the North Fork tributaries, but are not included for the purposes of this discussion. A full graphical summary of all Upper CLP hydrology and water quality measurements is presented in (Attachment 6); data are available upon request from the City of Fort Collins.

Continuous streamflow data are obtained from U.S. Geological Survey (USGS) and Colorado Division of Water Resources (CDWR) online reporting sites for flow gauging stations at Joe Wright Creek (JWC), North Fork at Livermore (NFL), North Fork below Seaman Reservoir (NFG) and the Canyon Mouth (representing Poudre at Bellvue Diversion (PBD)). Stream discharge values at Poudre above North Fork (PNF) were calculated using continuous flow data from the Canyon Mouth gage and NFG as well as head gate flow values at the Poudre Valley Canal diversion, which were obtained from the Poudre River Commissioner, Mark Simpson. Discharge values for these sites are presented as daily averages.

5.1 Hydrology of the Mainstem and North Fork CLP

Both the Mainstem and North Fork sites exhibit snowmelt-dominated hydrographs, as shown in Figure 42. Typically, water is stored in the snowpack as precipitation accumulates through the winter and is released in the spring when temperatures allow the snowpack to melt. In an average year, runoff on the Mainstem begins in late-April to early May with streamflows peaking by mid to late June. Following spring runoff, the hydrograph recedes through the summer months returning to baseflow conditions in late fall. The North Fork of the Poudre follows a similar pattern. However, runoff and peak streamflows occur a week or two before the Mainstem because of differences in elevation.

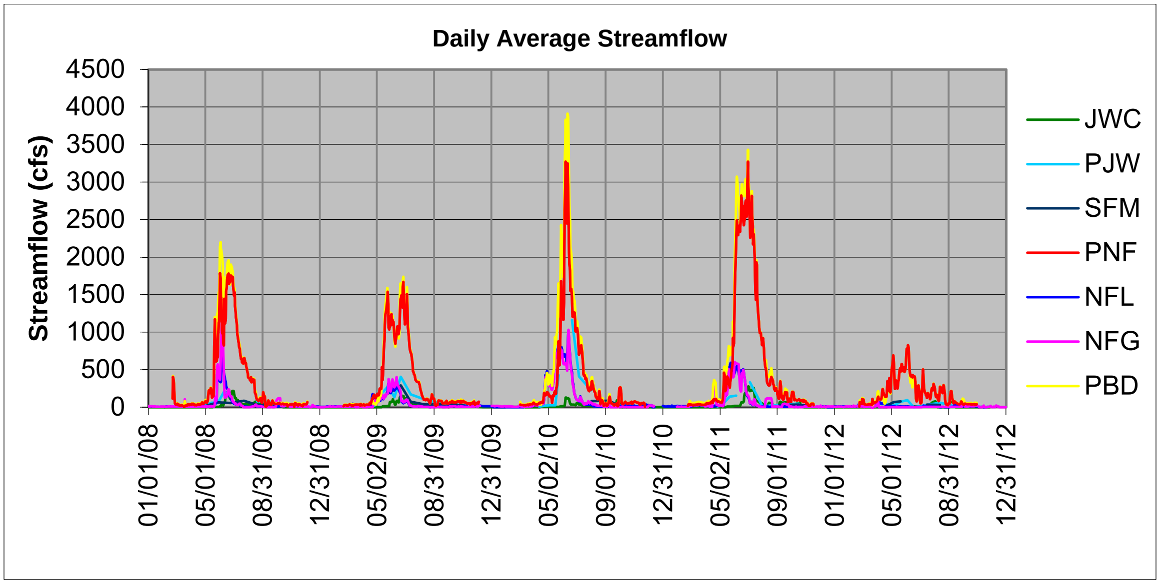


Figure 42. Daily average streamflow at key sites on the Mainstem and North Forks of the Poudre River.

In 2012, streamflows were significantly lower than the previous four years on both the Mainstem and North Fork. Peak flow on the Mainstem (PNF) was measured at 794 cubic feet per second (cfs) on June 7th and receded to below 100 cfs by June 22nd. The fact that water levels have not fallen below 200 cfs before the beginning of August in any of the previous four years illustrates the potential variability in streamflow and the severity of the water shortage in 2012 leading up to and during the Hewlett and High Park fires. Streamflows in the North Fork basin (NFL) were similarly low in 2012, and peaked at a meager 70 cfs on April 1st. Notably, there was little to no flow during the rest of the year at any of the North Fork sites. According to a Colorado Climate Center report, 2012 streamflows in many areas of Colorado were only slightly better than in the extreme drought years of 1934, 1954, 1977 and 2002 (Ryan and Deskin, 2012).

As expected, the timing and magnitudes of peak runoff at PBD were similar to PNF. Typically, the hydrograph for PBD tracks closely with PNF, as the Mainstem contributes the majority of flow at PBD, with relatively small contributions provided by North Fork flows out of Seaman Reservoir (NFG). Exceptions occur in years of greater than normal North Fork runoff or in the event of substantial releases from Seaman Reservoir, as was observed in 2008 and 2010. Events contributing to the higher 2008 North Fork flows at NFG and PBD are detailed in the 2008 Upper CLP annual report (Oropeza and Billica, 2009).

Multiple spikes in the hydrograph reflect natural fluctuation of the river levels that result from rainfall events and/or snowmelt in the lower elevations as well as the freeze-thaw cycles that are characteristic of early spring conditions in the Upper CLP watershed (Figure 43). Streamflow measurements on the Poudre River near the Canyon Mouth show the dramatic fluctuations in discharge that began immediately following the fires, in response to summertime thunderstorms and subsequent flash flooding (Figure 43).

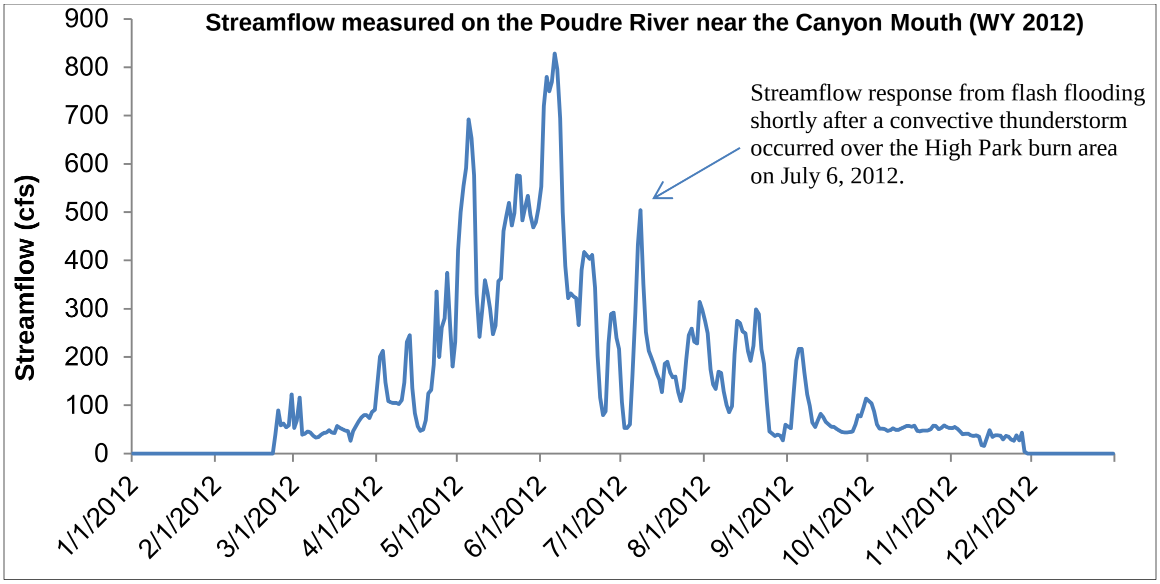


Figure 43. Streamflow measured on the Poudre River near the Canyon mouth showing annual variability in streamflow and streamflow response to flash flooding originating from a convective thunderstorm that occurred over the High Park burn area.

5.1.1 Mainstem Tributaries

There are a number of tributaries and diversions that contribute to the overall streamflow and water quality of the Mainstem CLP above the North Fork. Table 2 details the actual and percent contributions of Barnes Meadow Reservoir outflow (BMR), Chambers Lake outflow (CHR) and the Laramie River Tunnel (LRT) to Mainstem flows, as measured above the Munroe Tunnel and North Fork confluence (PNF + Munroe Tunnel). Figure 44 and Table 10 represent the proportional flows by month for 2012. Note that contributions from the South Fork of the Poudre (SFM) and Poudre above Joe Wright Creek (PJW) could not be estimated due to a lack of continuous flow measurements and missing peak flow values. Necessarily, the sum of contributions from these and other river segments and tributaries was calculated by subtraction, and categorized as “Other Mainstem Contributions”.

Table 10. 2012 tributary contributions by month to the Mainstem Cache la Poudre River above the Munroe Tunnel.

	Barnes Meadow Outflow (BMR)		Chambers Lake Outflow (CHR)		Laramie Tunnel (LRT)		Other Mainstream Contributions		Poudre above Munroe Tunnel & North Fork	
	AF/day	%	AF/day	%	AF/day	%	AF/day	%	AF/day	%
Jan	-		1,228	*	-		-		0	
Feb	-		1,148	*	-		-		755	
Mar	-	0%	703	24%	-	0%	2,286	76%	2,989	------
Apr	-	0%	1,687	13%	2,093	16%	9,041	71%	12,821	------
May	-	0%	3,635	10%	9,114	25%	24,339	66%	37,089	------
Jun	-	0%	4,558	13%	8,785	25%	21,221	61%	34,564	------
Jul	170	1%	3,780	20%	6,708	35%	8,397	44%	19,054	------
Aug	-	0%	4,178	24%	7,902	45%	5,479	31%	17,559	------
Sep	-	0%	1,986	31%	1,824	28%	2,693	41%	6,503	------
Oct	-	0%	333	14%	-	0%	2,099	86%	2,432	------
Nov	-	0%	-	0%	-	0%	1,732	100%	1,732	------
Dec	-		-		-		0		0	

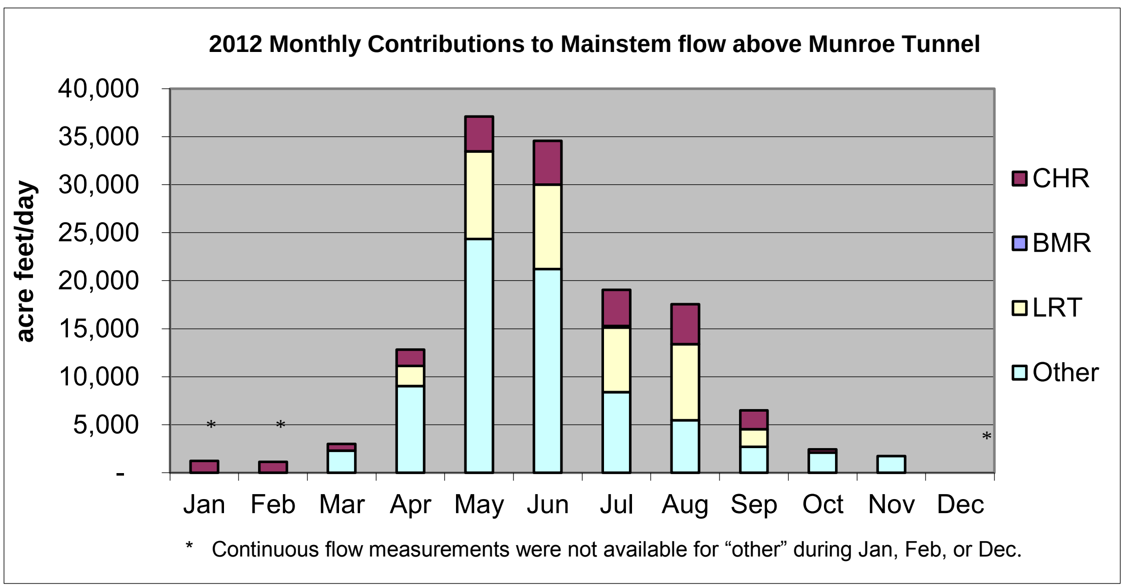


Figure 44. 2012 Tributary contributions by month to the Mainstem Cache la Poudre above the Munroe Tunnel.

Figure 44 shows that from May through September 34% - 79% of the total flow originated from either releases from Chambers Lake (CHR) or was diverted from the Laramie River through the Tunnel (LRT). This contrasts with 2011, where these sources contributed only 8%-35% of flows in the Mainstem (Oropeza, 2012).

5.2 Upper Cache la Poudre Basin Snowpack

To understand observed trends in discharge, one must also look at the spatial and temporal trends in snowpack and temperature, as these are the key factors that control the quantity, timing, and magnitude of streamflow in the Poudre River Basin.

Snow water equivalent (SWE) is a common snowpack measurement, which represents the amount of water contained in the snowpack. The SNOTEL network includes approximately 600 automated monitoring sites located in remote mountain watersheds throughout the United States that measure SWE, accumulated precipitation, and air temperature. Some more advance SNOTEL sites measure other climate variables such as, snow depth, soil moisture and temperature, wind speed, solar radiation, humidity, and atmospheric pressure. Snow course monitoring sites require manual surveying of snow depth and SWE, generally on the first of every month throughout the duration of the winter season. There are approximately 1,600 permanent snow courses national wide.

Snow water equivalent data was collected and plotted from four NRCS snow telemetry (SNOTEL) and three snow course monitoring sites to evaluate differences across the basin as well as between years. Deadman Hill and Red Feather Lakes sites represent snow conditions in the North Fork drainage, while Cameron Pass, Joe Wright, Big South, Hourglass and Long Draw represent conditions in the major basins of the Mainstem. The data suggest that on an annual basis, Cameron Pass receives significantly more SWE than any of the other sites, with the Big South and Hourglass Reservoir sites consistently maintain relatively lower SWE (Figure 45). These differences in SWE are driven primarily by differences in elevation and the orographic nature of winter storms in the Rocky Mountains.

While there do not appear to be any consistent trends in SWE over the last 4 years in the Upper CLP watershed Figures 45 and 46 effectively illustrate the extreme variability in SWE spatially throughout the Upper CLP, as well as temporally from year to year. Temporal differences are especially apparent between WY2011 and WY2012 (Figure 46) when one of the wettest years on record was followed by one of the driest years on record. In 2012, peak SWE measured at the Joe Wright SNOTEL was 13.9 inches compared to 52.7 inches measured in 2011. For comparison, during an average year, the peak SWE at the Joe Wright SNOTEL is 24.7 inches (Figure 46).

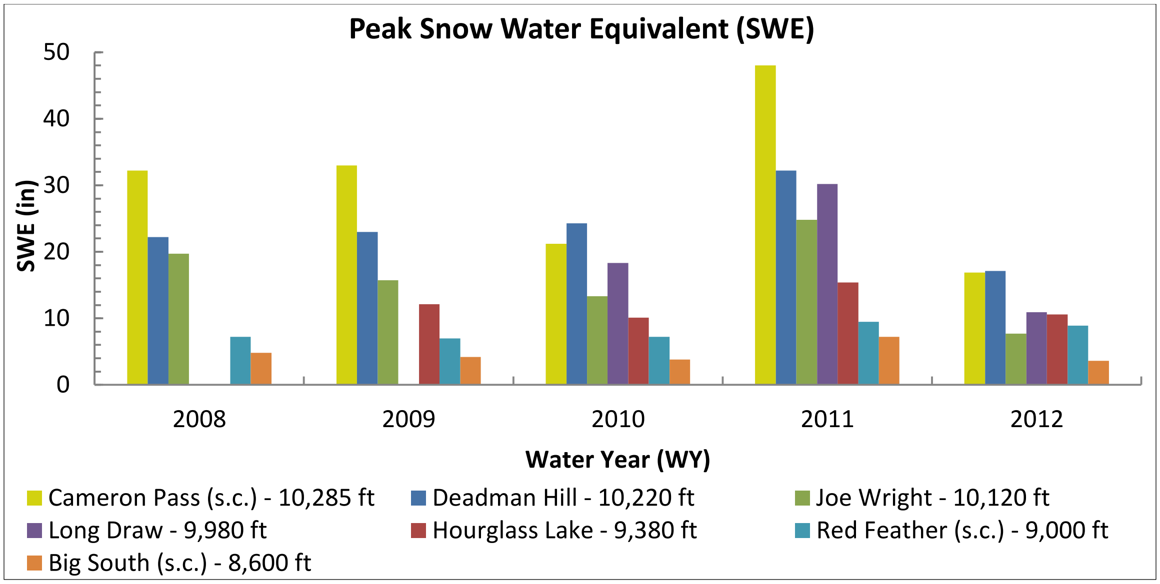


Figure 45. Peak snow water equivalent (SWE), as recorded at the NRCS SNOTEL and snow course (s.c.) sites for water years (WY) 2008 - 2012.

On the Mainstem CLP, there is a strong connection between annual average SWE in the upper basins and annual average stream discharge, as snowmelt largely flows uninterrupted to downstream locations (Figure 9, pg.13). In contrast, flows on the North Fork are highly regulated by a series of on channel reservoirs, including Panhandle, Halligan and Seaman Reservoirs, thereby weakening the connection between SWE and stream discharge.

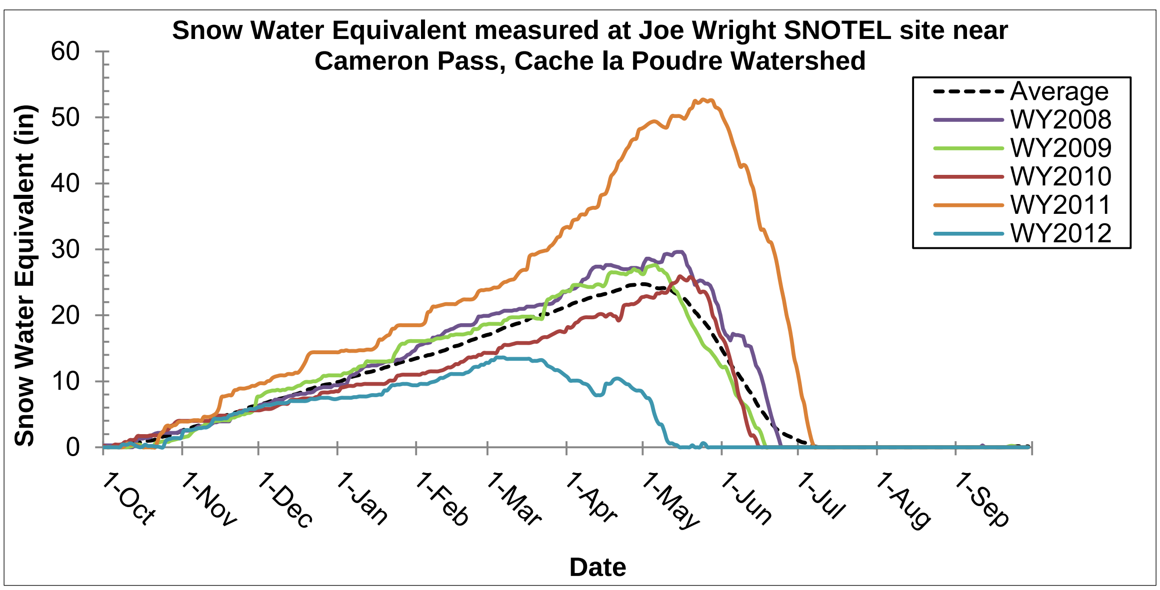


Figure 46. Snow Water Equivalent (SWE) measured at Joe Wright SNOTEL near Cameron Pass in the Cache la Poudre Watershed for water years (WY) 2005-2012. The average is based on a 32-year record.

5.3 Poudre Watershed Air Temperatures

The role of temperature in regulating peak streamflow can be observed by comparing SWE, air temperature, and discharge between 2010 and 2011. As shown above in Figure 44, the year 2011 had substantially higher peak SWE than in 2010 across all sites. Figure 45 indicates that the Joe Wright SNOTEL site had approximately 27 inches more water at the peak in 2011 than in 2010. Despite the differences in peak SWE between years, peak streamflow was nearly the same for both years (Figure 47).

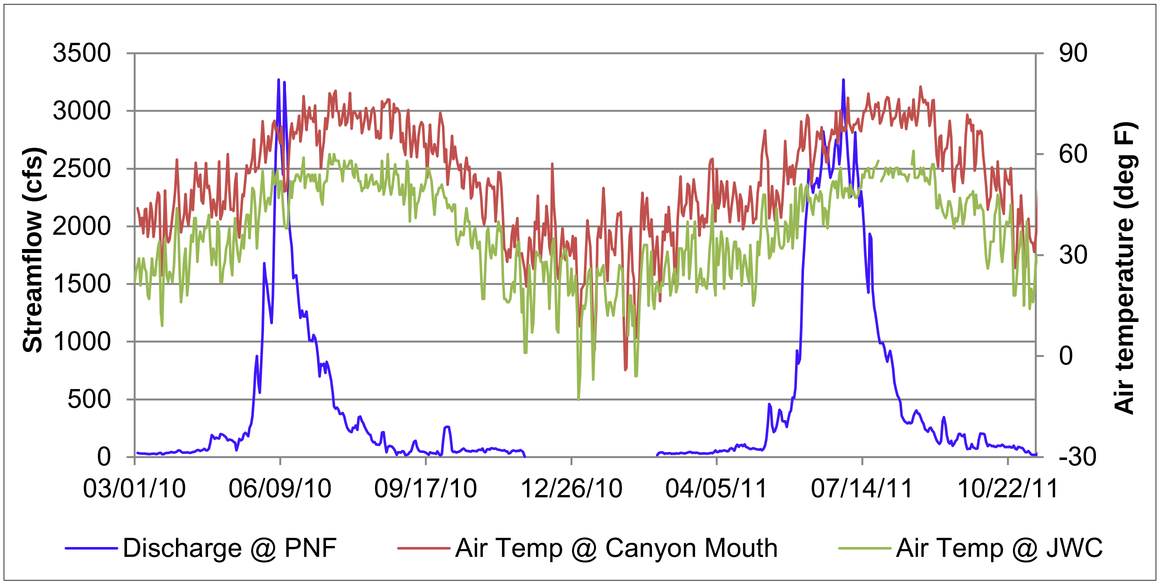


Figure 47. Streamflow on the Mainstem CLP at PNF and air temperatures at Joe Wright SNOTEL site and Canyon Mouth stream gage (CLAFTCO) for 2010-2011.

The combination of high snowpack and SWE set the stage for a potentially record setting peak streamflow in 2011. However, the observed peak streamflows in 2010 and 2011 at PNF were identical at 3,272 cfs. The lack of extreme flows was most likely due to the fact that air temperatures, which largely control the rate of snowmelt, were similar before and during the runoff period in both years (Figure 47). As a result, the primary difference in the hydrographs was the duration of snowmelt runoff. In 2011 there were 56 days of flows greater than 1,000 cfs compared to only 26 days in 2010. The benefits of a prolonged and larger snowmelt include lower summer stream temperatures and elevated water levels which translate to better water quality in the river.

Spring and early-summer air temperatures are important in determining the timing, magnitude, and intensity of snowmelt runoff, as well as the forms of precipitation (rain or snow) that occur. Snowmelt runoff from the upper reaches of the CLP watershed, in large part, regulate stream temperatures. In contrast, during the mid- to late-summer months the air temperatures more directly affect water temperatures, especially during low flow years such as 2012. Annual average maximum summertime air temperatures at the canyon mouth have increased over the last five years (Figure 48), with 2012 having the highest average maximum temperature of 85.2°F and a daily average temperature of 68.9°F. These temperatures were nearly four and five degrees Fahrenheit warmer, respectively, than those observed in 2011. Temperatures at the higher elevation Joe Wright SNOTEL site were also higher than in 2011, but did not exhibit any consistent trends over time (Figure 49).

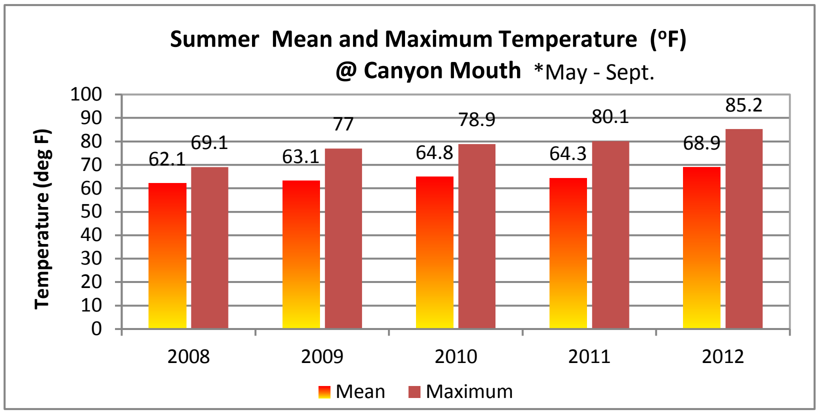


Figure 48. Summer (May-Sept) mean and maximum temperatures at the Canyon Mouth stream gauge for 2008-2012.

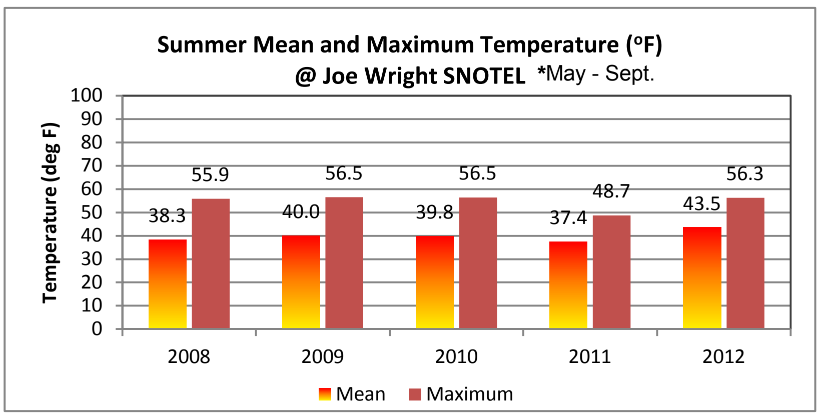


Figure 49. Summer (May-Sept) mean and maximum temperatures at the Joe Wright SNOTEL site for 2008-2012.

5.4 Water Temperature

In general, water temperature increases with decreasing elevation throughout the watershed (Figure 50). Peak temperatures occur mid-summer, with North Fork sites typically peaking a few days earlier than the Mainstem sites due to the influence of the warmer temperatures within this lower elevation drainage. In 2012, however, maximum temperatures on the Mainstem and North Fork both occurred on 7/16/12 and were 22.2 °C and 20.9 °C at PNF and NFL, respectively. The 2-4 degree difference in temperatures at NFG and NFL indicate that Seaman Reservoir effectively decreased the water temperature immediately downstream at NFG (Figure 50). However, the very low volume of water released from Seaman Reservoir during the summer months was not adequate to affect temperatures downstream of the confluence with the Mainstem (PBD). In 2012, maximum water temperatures on the Mainstem were warmer than the previous four years and were also warmer than maximum temperatures observed on the North Fork at NFL and NFG. The higher water temperatures in 2012 are likely due to the combination of lower streamflow and higher summer temperatures in the lower basin (Figure 50).

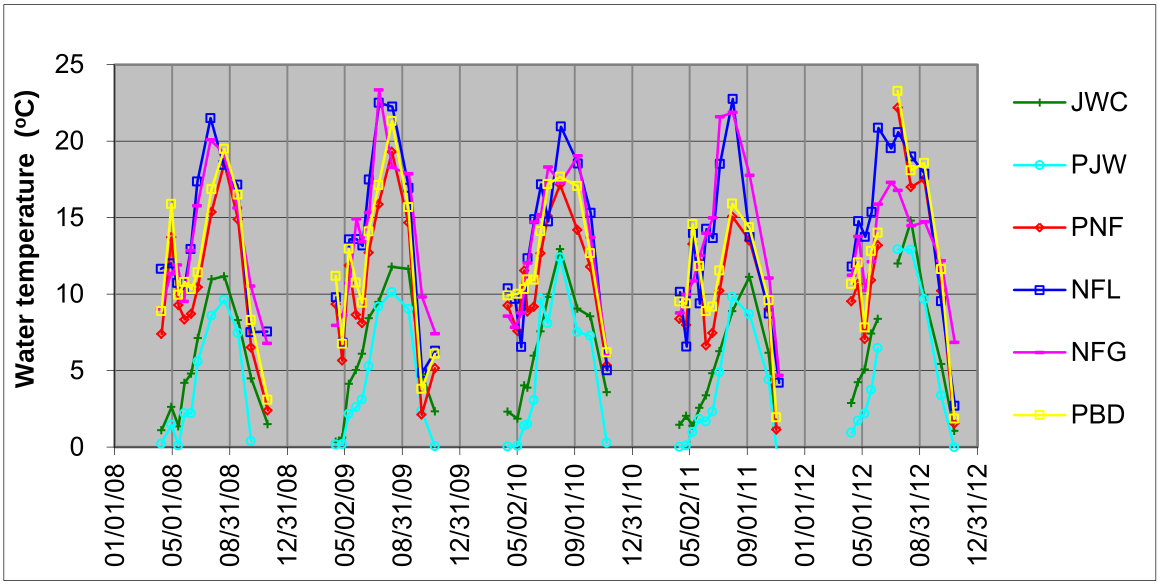


Figure 50. Water temperature at key Upper CLP monitoring sites.

5.5 Temporal Trends in Streamflow, Temperature and Snowpack

Trend analyses were conducted to evaluate whether or not there were long-term changes in hydrology, snowpack as well as air temperatures within the basin. Linear trend analyses were conducted using a seasonal regression on ranks. For trends that were determined to be statistically significant (p-value ≤ 0.10), the trend magnitude (slope), level of significance (p-value) and the total change over the period of record are presented in Attachment 7. Total change over time is determined by multiplying the trend slope by the length of data record, in days. Any conclusions about the statistical significance of trend and estimated change over time apply only to the period of record and cannot be used to predict future conditions.

An important limitation of linear regression is the increasing likelihood of a trend being determined statistically significant as the number of observations increases. As a result, small changes over time may be determined significant, but lack real-world importance. Therefore, trend analysis results should be considered in conjunction with a visual inspection of the data to help identify trends of practical significance.

To best describe actual conditions and to minimize the chance that any given year has too large of an influence over the trend, the longest periods of record (POR) were used, where historical data were available.

5.5.1 Streamflow

A regression analysis on streamflow was conducted for the Mainstem site PNF. PNF was selected because it represents the cumulative contributions of the major Mainstem tributaries and also has a continuous flow record. Results show that there was a significant increasing trend identified in stream discharge at PNF over the period of record from 2005-2012, when seasonality of flows was considered (p=0.001; Figure 52). For this analysis, the two primary flow seasons were defined as Peak Flow (May-July) and Low Flow (Aug-Dec, Jan-Apr). Streamflow trend analysis was not calculated on the North Fork due to the highly regulated nature of flows in this river segment.

In the case of Mainstem streamflows as PNF (Figure 51), 2010 and 2011 appear to be exceptional years and may skew the trend upwards, when in fact, it is possible that the trend may not hold over a longer period of record.

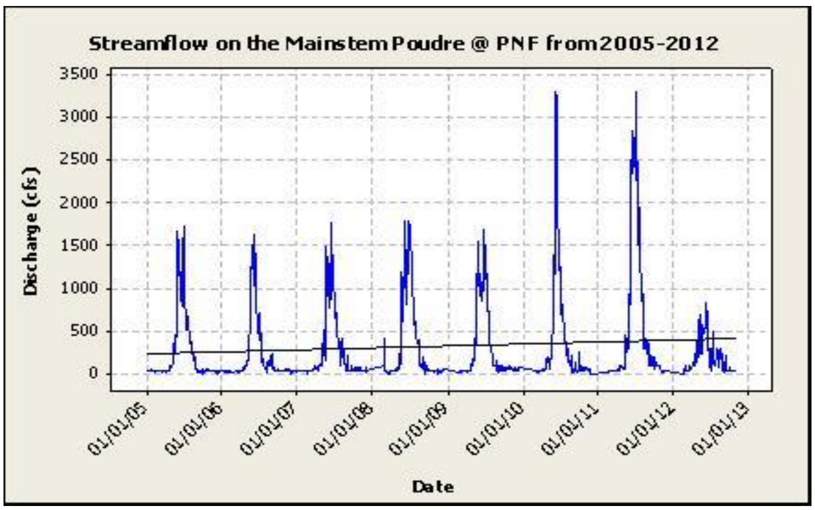


Figure 51. Streamflow on the Mainstem at PNF from 2005 – 2012.

5.5.2 Snowpack & Snow Water Equivalent (SWE)

No significant trends in snowpack depth (p=0.806) or snow water equivalent (p=0.898) were identified for the Joe Wright SNOTEL site from 2004 - 2012.

5.5.3 Air Temperature

However, significant increasing trends in air temperature were observed at Joe Wright SNOTEL(p=0.000; POR=23 yr) and at the Canyon Mouth gauge (p=0.009, POR=4.5 yr), which is located downstream from PNF and PBD (Figures 52 and 53, respectively).

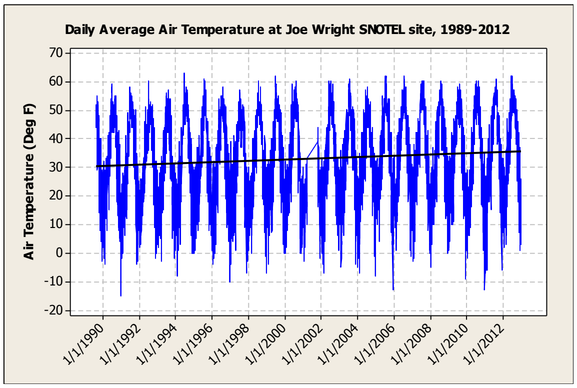


Figure 52. Daily average temperature at Joe Wright SNOTEL site, 1995-2012**.**

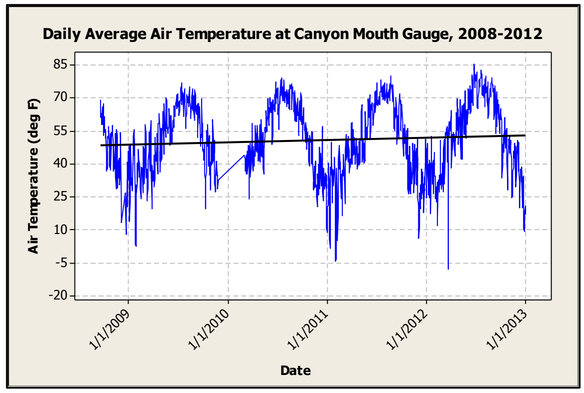


Figure 53. Daily average temperature at 2012the Canyon Mouth gage (CLAFTCO), 2009– 2012.

The trends at Joe Wright SNOTEL were investigated in greater depth to understand whether temperature increases were due to increasing minimum or maximum daily temperatures and whether seasonal increases were driving the overall trend. It was found that temperature increases were consistent regardless of how the data were grouped for evaluation. Figure 54 illustrates the observed increase in maximum summertime temperatures since 1995 at the Joe Wright SNOTEL site, which is situated in the relatively cool, upper reaches of the Mainstem basin.

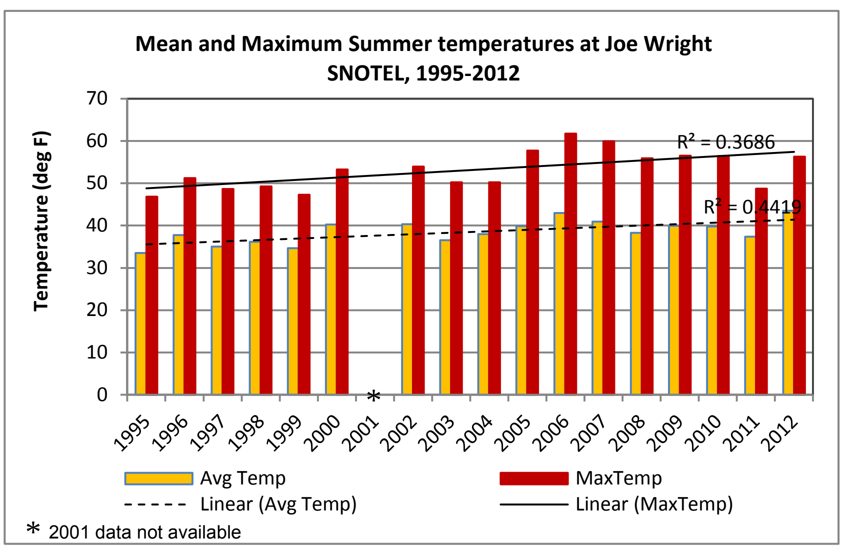


Figure 54. Mean and Maximum Summer (May-Sept) temperatures at Joe Wright SNOTEL, 1995-2012.

6.0 HISTORICAL WATER QUALITY TREND ANALYSIS

Trends in water quality were evaluated for the period of record from 2008 through 2012; however, where historical 2007 data were available, the extended period of record was utilized. Similar to analyses for hydrology, snowpack and temperature, trends were identified using linear regression on ranks, with adjustments for seasonal variation. Trends where $p > 0.10$ were considered statistically significant. The following discussion pertains to trends that were identified in Seaman Reservoir and those occurring at more than one location on the Mainstem and North Fork; a full summary of all trend analysis results is presented in Attachment 7.

6.1 Temporal Trends on the Mainstem Poudre River

6.1.1 pH

Eight out of eleven Mainstem sites experienced statistically significant increasing trends in pH from 2007 – 2012, with estimated changes in pH ranging from 0.35 – 1.41 pH units (Figure 55). pH provides an indication of how relatively acidic (H^+) or basic (OH^-) the water is. It is an important indicator of water quality due to the fact that many important chemical and biological processes that occur in aquatic systems are directly influenced by pH, including the solubility and bioavailability of constituents such as metals and nutrients. Changes in pH can also signal potential increases in pollution and other environmental changes. The estimated changes in pH on the Mainstem over the stated periods of record are sufficient to represent potentially important environmental changes.

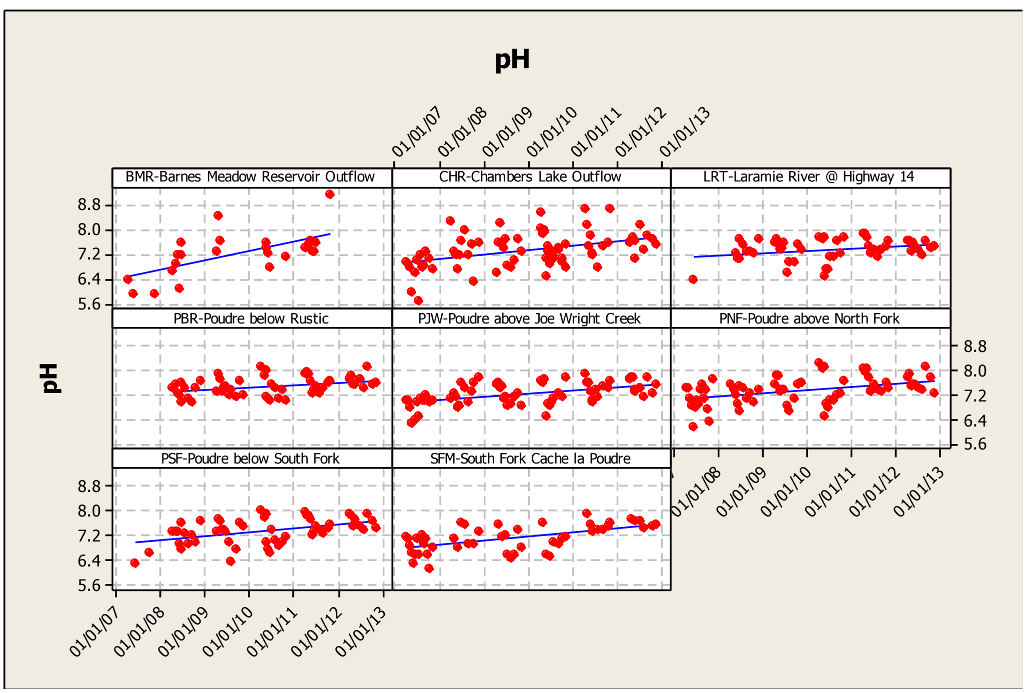


Figure 55. Significant pH trends on the Mainstem CLP.

The pH of the river is largely regulated by the alkalinity, which is derived from the dissolved carbonates and non-carbonate species present. Alkalinity effectively buffers the pH of the water. In the Poudre River, these carbonates are primarily associated with the cations calcium and magnesium. Due to the interrelated nature of pH, alkalinity and concentrations of cations (Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}), it would be expected that an increase in pH would be matched by a similar increase in one or more of these parameters; however, these trends were not observed (Attachment 7). To ensure that fire activity and/or drought conditions were not driving the trends in pH, regressions were performed without 2012 data, but results suggested that trends were not affected by 2012 data.

Because these trends are occurring across a large area of the Mainstem CLP watershed, and there do not appear to be individual years that are exerting a particularly large influence on the trend, we accept that these results are valid. However, at this time, predictions about future trends cannot be made nor can the causes of the observed increase in pH be identified. Close monitoring of the pH across the watershed will need to continue in future years.

6.1.2 Ortho-phosphate

Eight locations on the Mainstem were initially identified as having a statically significant increasing trend in ortho-phosphate concentrations from 2007 - 2013. Three of these sites had the potential to be affected by post-fire effects – PSF, PNF and PBD (See Fig.15). When 2012 values were removed from the record for these sites, PSF (Poudre below the South Fork) was the only site at which the increase remained significant. High Park Fire runoff from the South Fork drainage likely contributed to the elevated ortho-phosphate concentrations at PSF and therefore, the estimated rate of increase over time as reflected by the slope of the regression line (Figure 56).

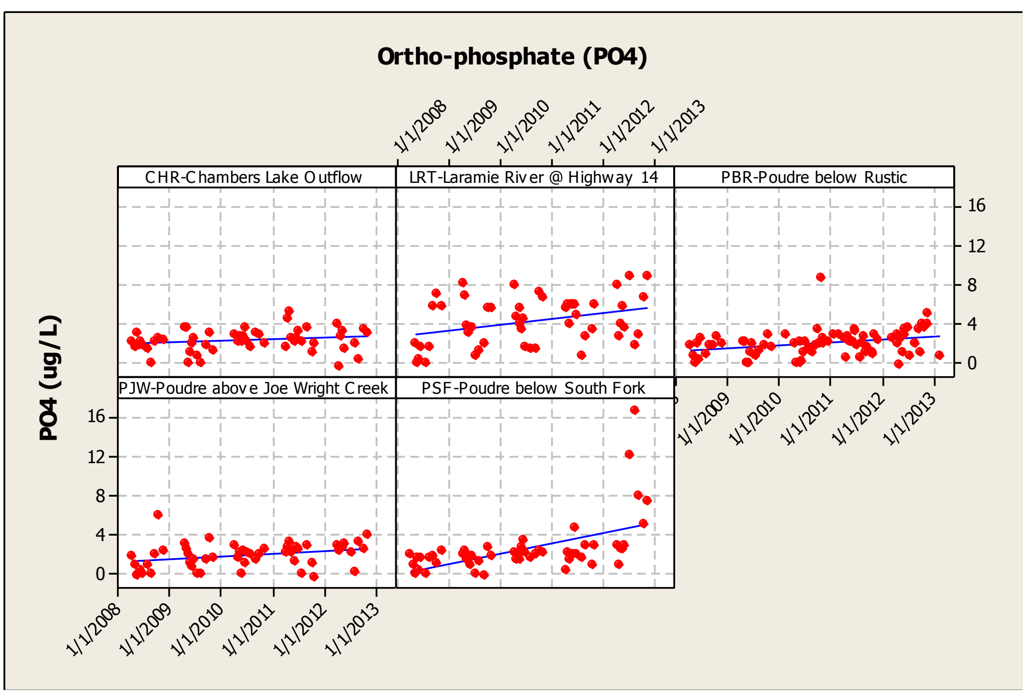


Figure 56. Significant ortho-phosphate (PO_4) trends on the Mainstem CLP.

The trends in ortho-phosphate observed within the Mainstem basin indicate that concentrations have increased over the period of record by an estimated 1.1 – 4.9 ug/L. Compared to more productive rivers, these changes are small, but in cold, low nutrient headwater streams, even small increases in nutrients have the potential to affect algal abundance and/or biomass (Lewis and McCutchan, 2010). Given the apparent increases in attached algae (Section 2.4) in recent years near these locations and indications of potentially increasing phosphate concentrations, sampling efforts related to paired nutrient and periphyton monitoring will remain a priority in the coming years.

It is important to note that most of the ortho-phosphate data are at or below the FCWQL reporting limit of 5 ug/L, which suggests that concentrations and/or trend may not indicate real changes in watershed conditions. As such, the results of this analysis will be treated as precautionary information, and trends in ortho-phosphate will continue to be reviewed on an annual basis. No information about potential source of increasing ortho-phosphate is currently available.

6.1.3 Total Phosphorus

Two Mainstem sites showed a significant increasing trend in total phosphorus concentrations, with increases estimated at 11.4 and 16.4 ug/L for PSF and PNF, respectively (Figure 57). 2012 values did not appear to unduly influence trends at either site.

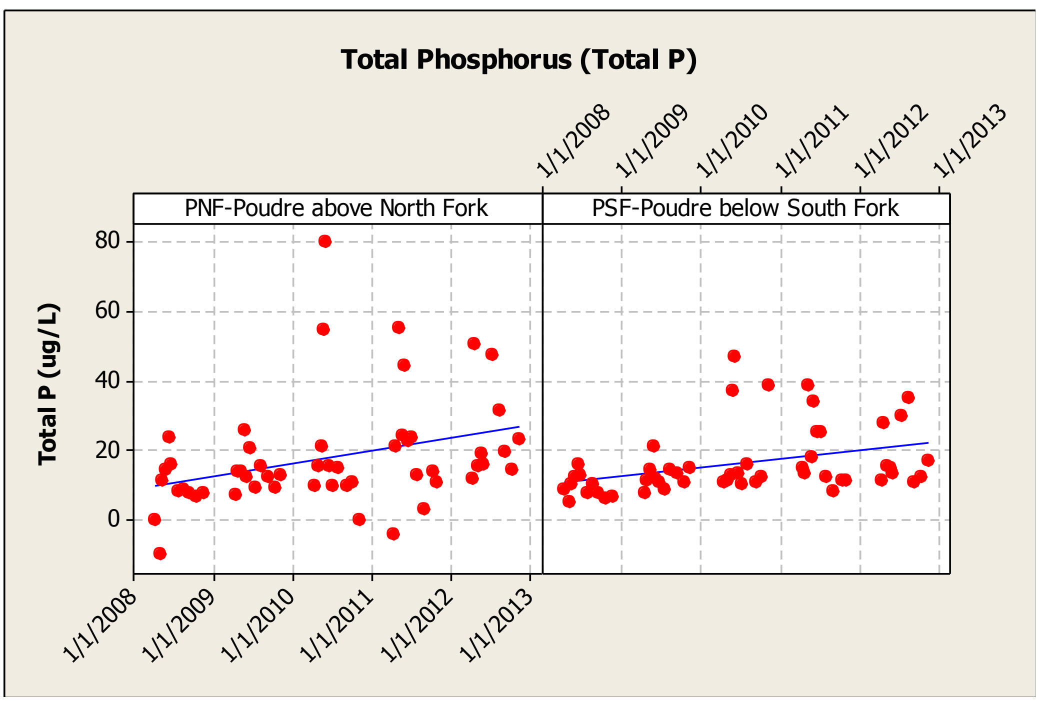


Figure 57. Significant Total Phosphorus trends on the Mainstem CLP.

6.2 Temporal Trends on the North Fork Poudre River

Several of the tributaries and the mainstem of the North Fork Poudre River saw significant increases in the alkalinity, TDS, Hardness, conductivity, and ions such as calcium, magnesium, sulfate and chloride over the period of record. These tributaries are characterized by low and intermittent flows and typically seeing higher concentrations of dissolved constituents compared to the Mainstem sites, especially during the summer and fall (Oropeza, 2012). The direction of trends often differed between tributaries for a given parameter (Attachment 7). For example, TDS increased significantly at Rabbit Creek (RCM) but showed a significant decrease at Stonewall Creek (SCM) over the same period of record, suggesting that these trends may be driven by drainage specific conditions, such as streamflow.

Both direct and indirect effects of in-channel reservoirs on North Fork water quality trends were observed on the North Fork below Halligan Reservoir (NBH) and North Fork below Seaman Reservoir (NFG). Significant increases in TKN, total nitrogen and ortho-phosphate were observed at NBH (Figure 58).

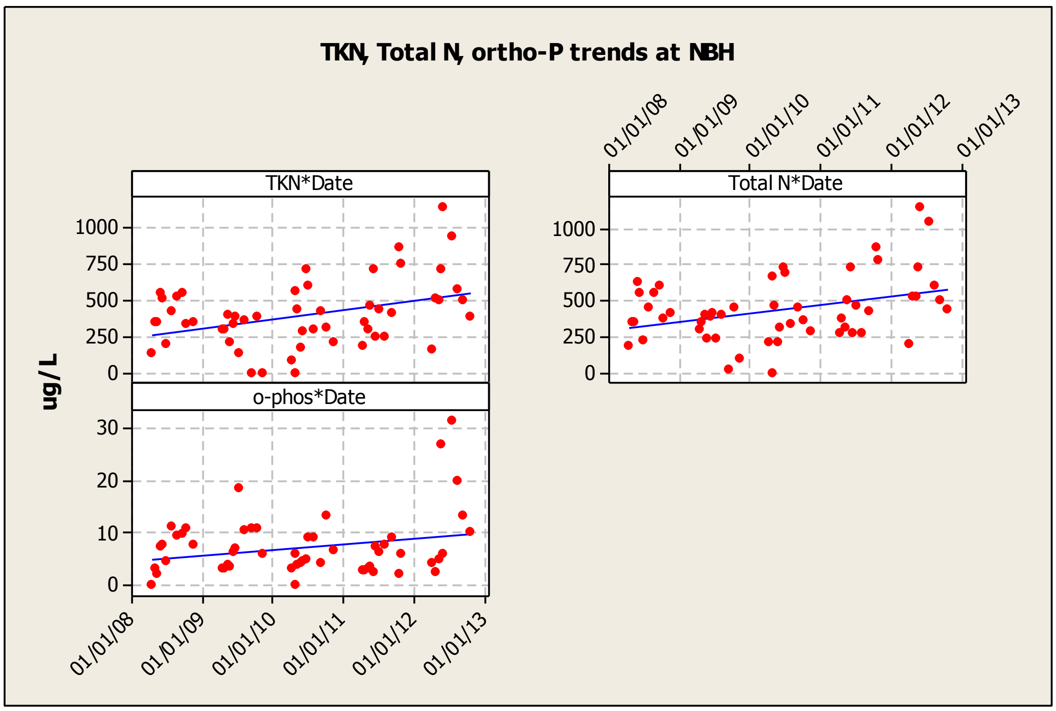


Figure 58. Significant trends in TKN, Total N and ortho-phosphate on the North Fork below Halligan Reservoir (NBH).

Because there is very little water quality information available for Halligan Reservoir, it is expected, but not currently known whether similar changes also occurred in the reservoir. However, the ortho-phosphate concentrations below Seaman Reservoir at NFG, appear to be related to ortho-phosphorus concentrations at the bottom of Seaman Reservoir (Figure 59). Significant increasing trends in ortho-phosphate concentrations were identified at both sites, although in both cases, the trends appear to be driven by the exceptionally high values in 2012. The coincidence of seasonal trends, however, suggests a direct downstream transfer of nutrients out of Seaman Reservoir.

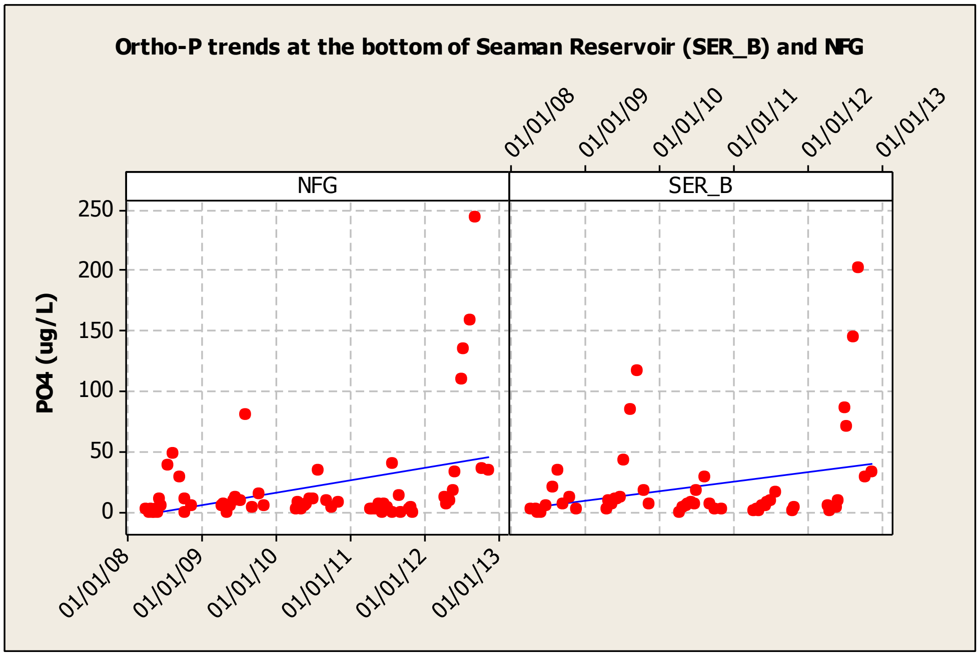


Figure. 59. Significant trends in ortho-P at the bottom of Seaman Reservoir and downstream on the North Fork at NFG.

In contrast, the difference in dissolved nitrogen fractions within Seaman Reservoir and downstream at NFG, illustrates a more indirect effect of reservoirs on river water quality trends. Within the reservoir, concentrations of ammonia showed a large and significant increase over time (See Section 6.3), which is likely due to prolonged periods of low oxygen at the bottom over time (Figure 39). In effect, these periods of hypoxia inhibit nitrification, the process by which ammonia is converted to nitrite and nitrate. When this water is once again released into the open channel of the North Fork, it is expected that the conversion of ammonia to nitrite and nitrate would proceed quickly. Concentrations of both nitrite and nitrate increased significantly, lending support for this expectation (Figure 60).

Despite the significant increase in nitrate and nitrite concentrations below Seaman Reservoir at NFG over time, concentrations downstream at PBD did not follow similar trends (Attachment 7).

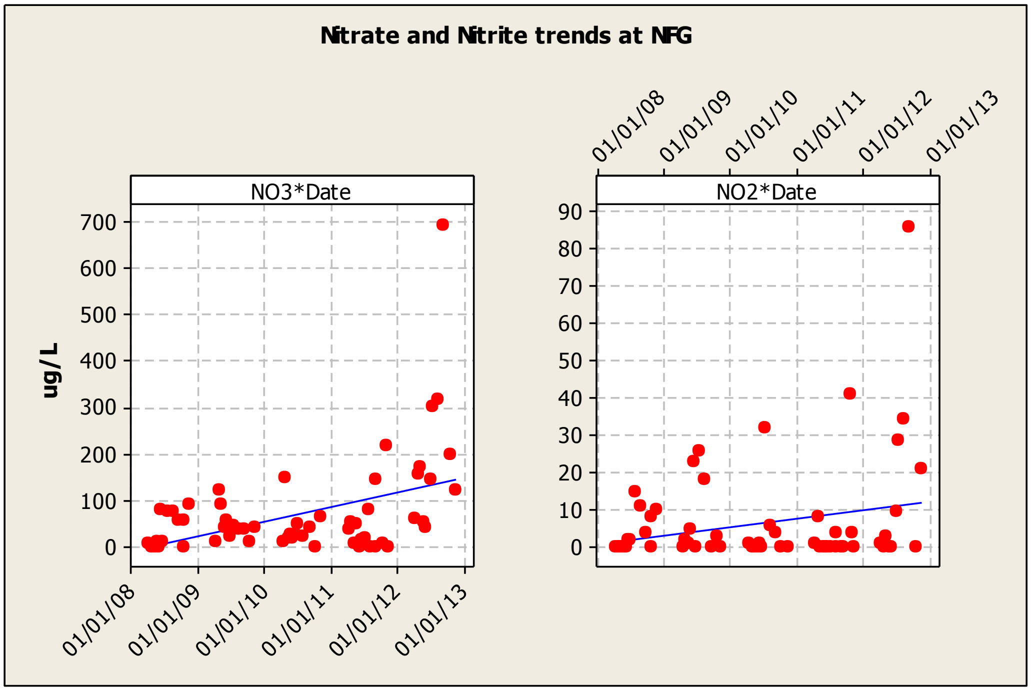


Figure 60. Significant trends in nitrate and nitrite on the North Fork at NFG.

6.3 Temporal Trends in Seaman Reservoir

Large and significant increasing trends in concentrations nutrients were observed both at the top and at depth in Seaman Reservoir, including ammonia, TKN, total nitrogen, ortho-phosphate, and total phosphorus. Trends in turbidity, chlorophyll-a, potassium and magnesium were also observed (Figures 61-69).

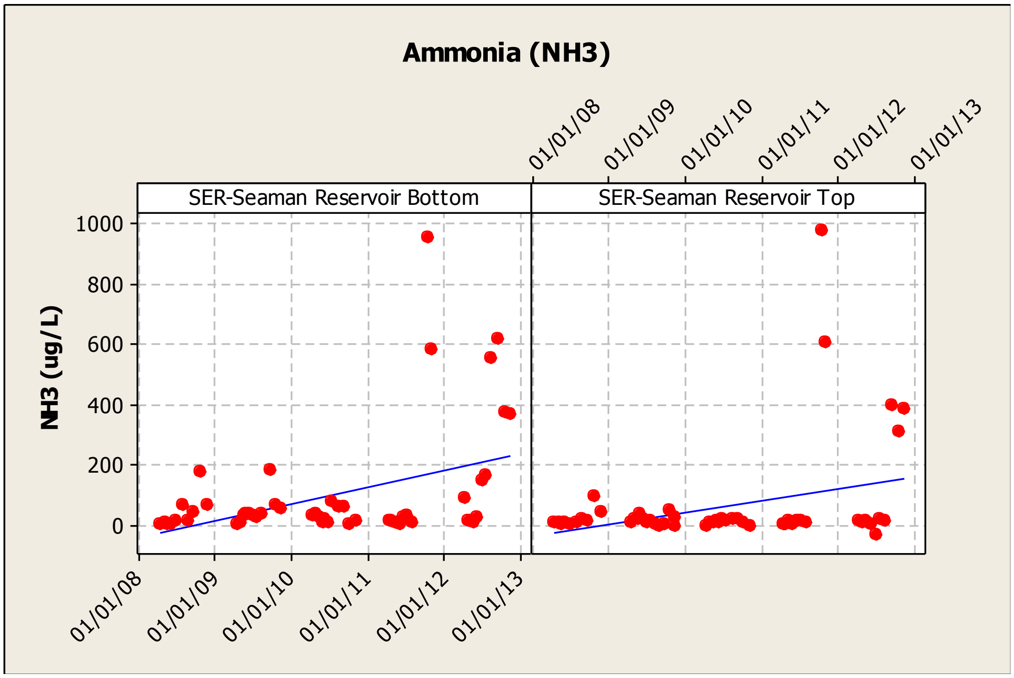


Figure 61. Significant trends in ammonia in Seaman Reservoir.

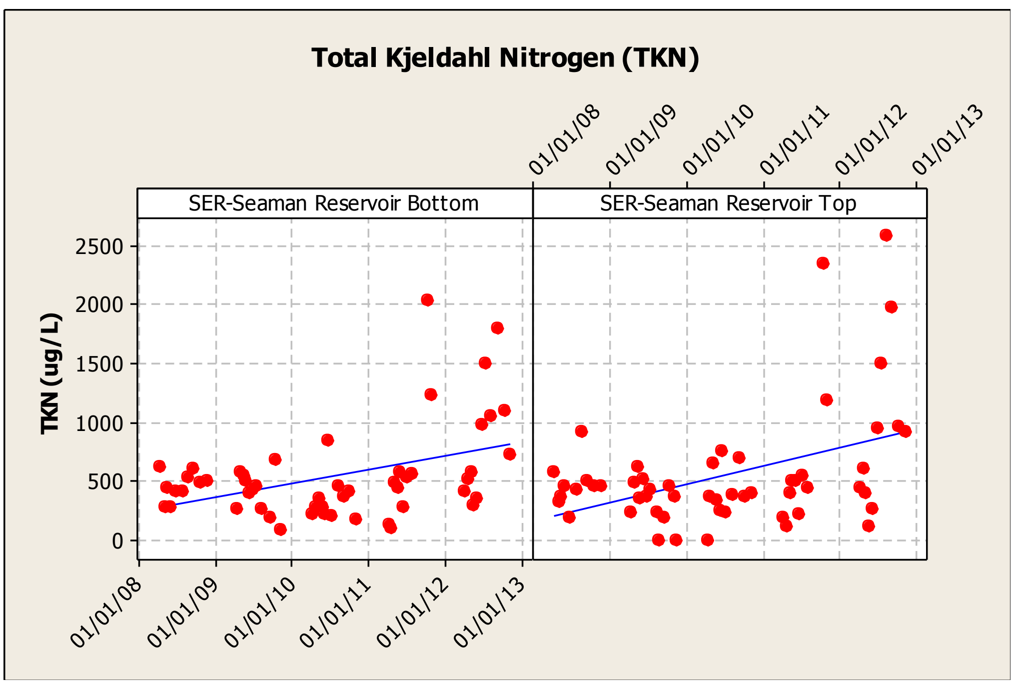


Figure 62. Significant trends in Total Kjeldahl Nitrogen (TKN) in Seaman Reservoir.

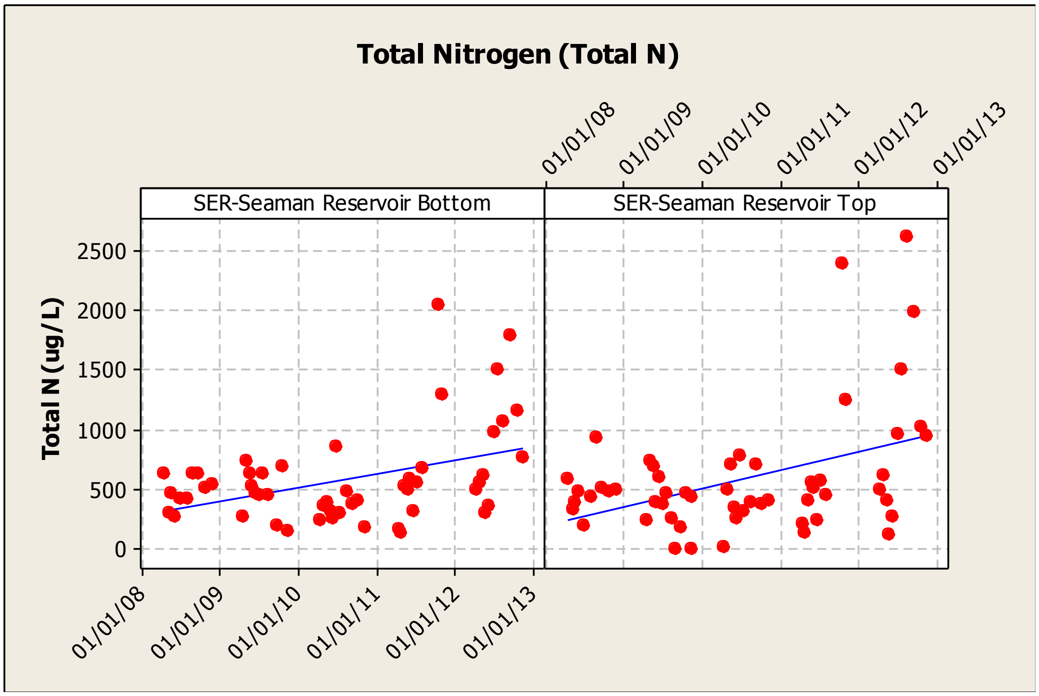


Figure 63. Significant trends in Total N in Seaman Reservoir.

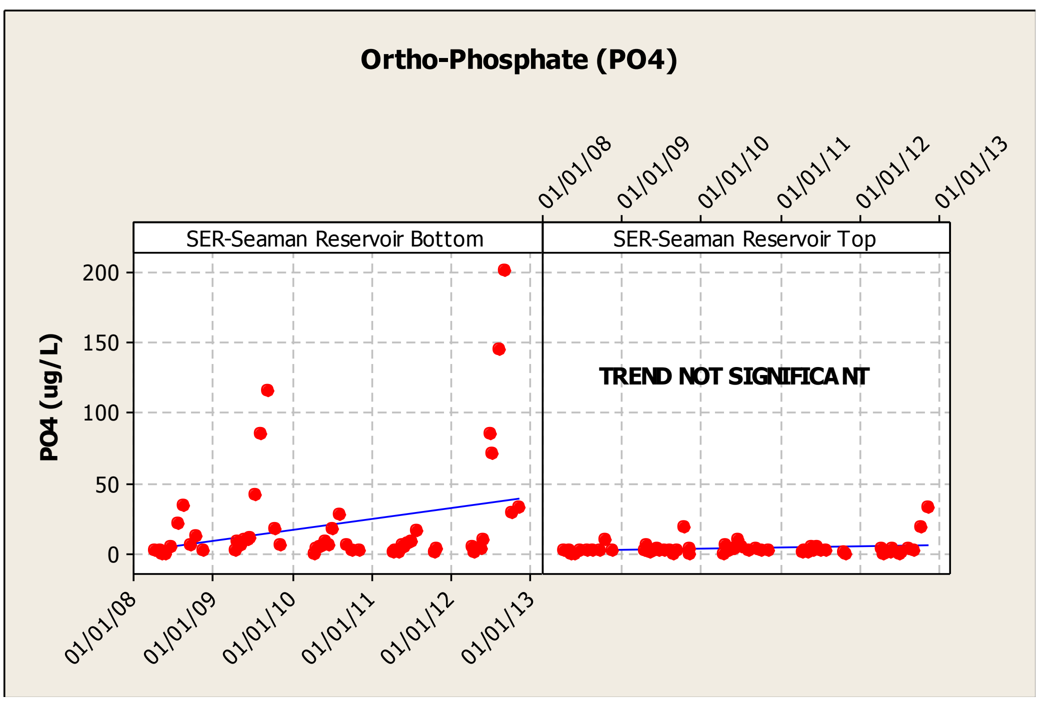


Figure 64. Significant trend in ortho-phosphate in Seaman Reservoir.

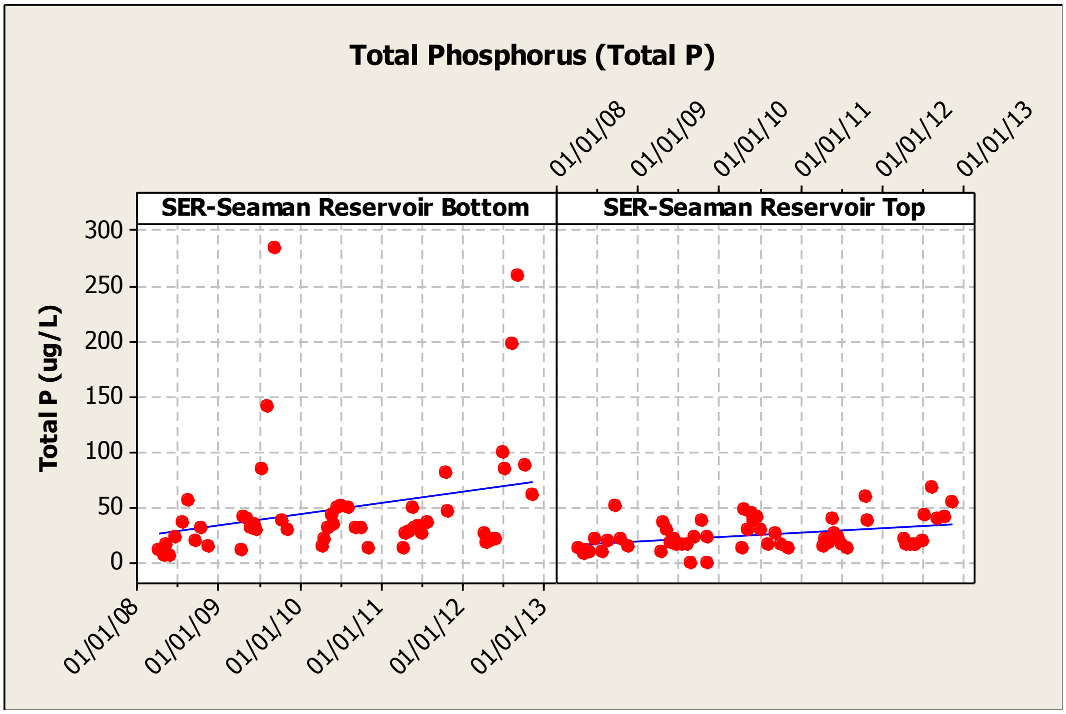


Figure 65. Significant trends in Total P in Seaman Reservoir.

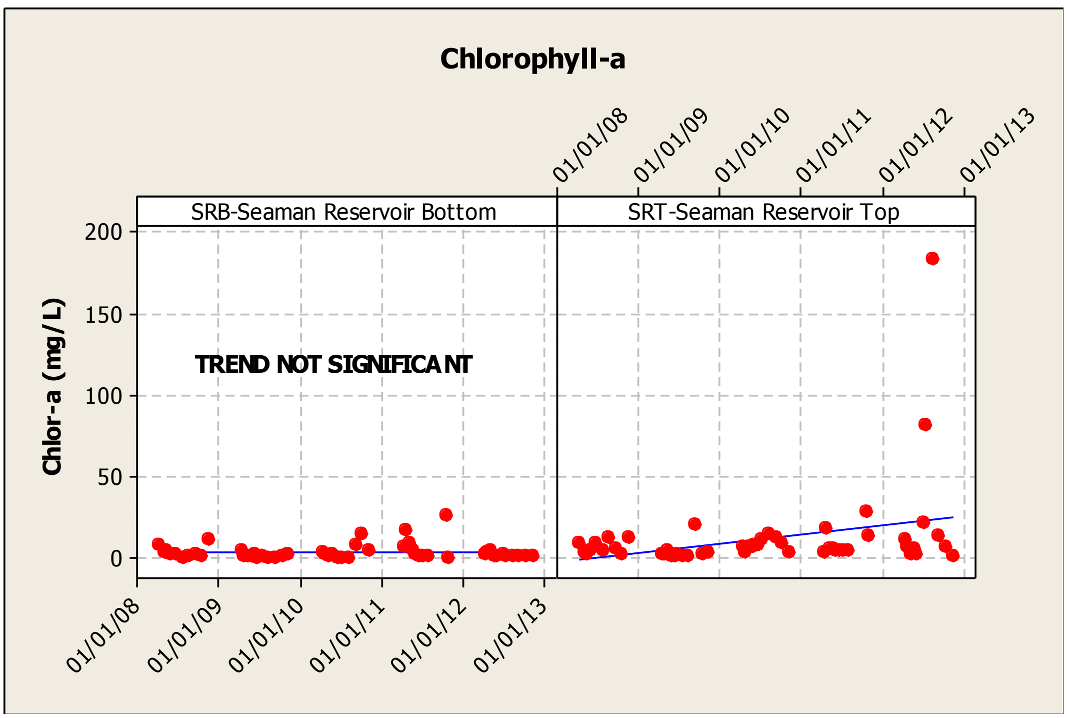


Figure 66. Significant trend in chlorophyll-*a* in Seaman Reservoir.

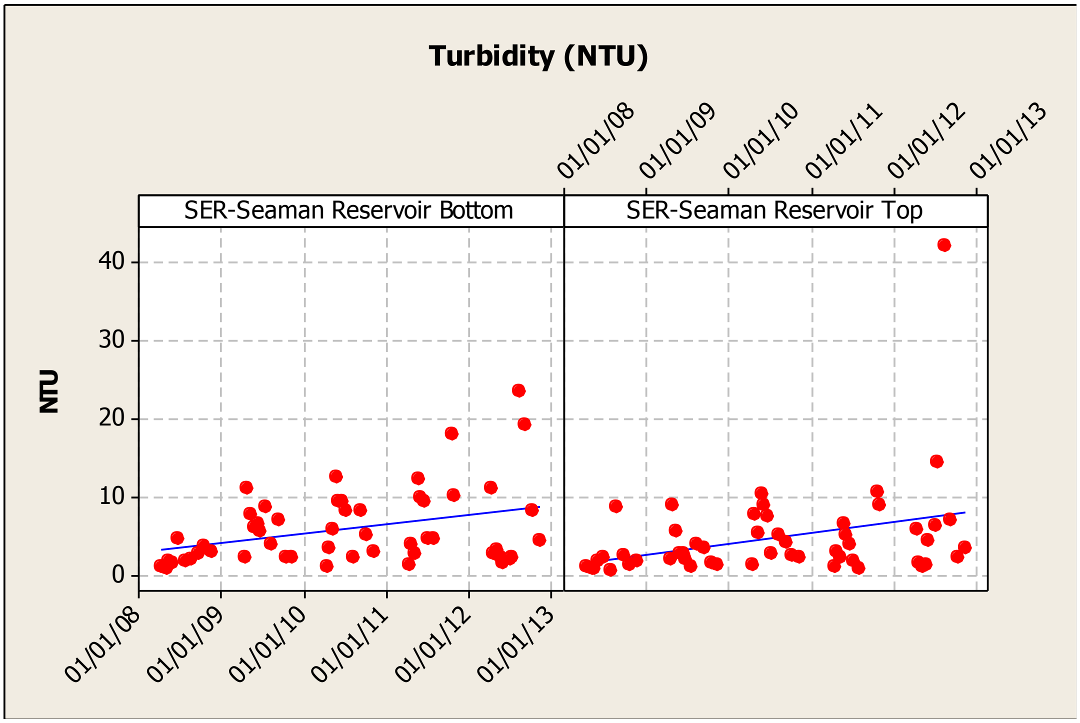


Figure 67. Significant Turbidity trends in Seaman Reservoir.

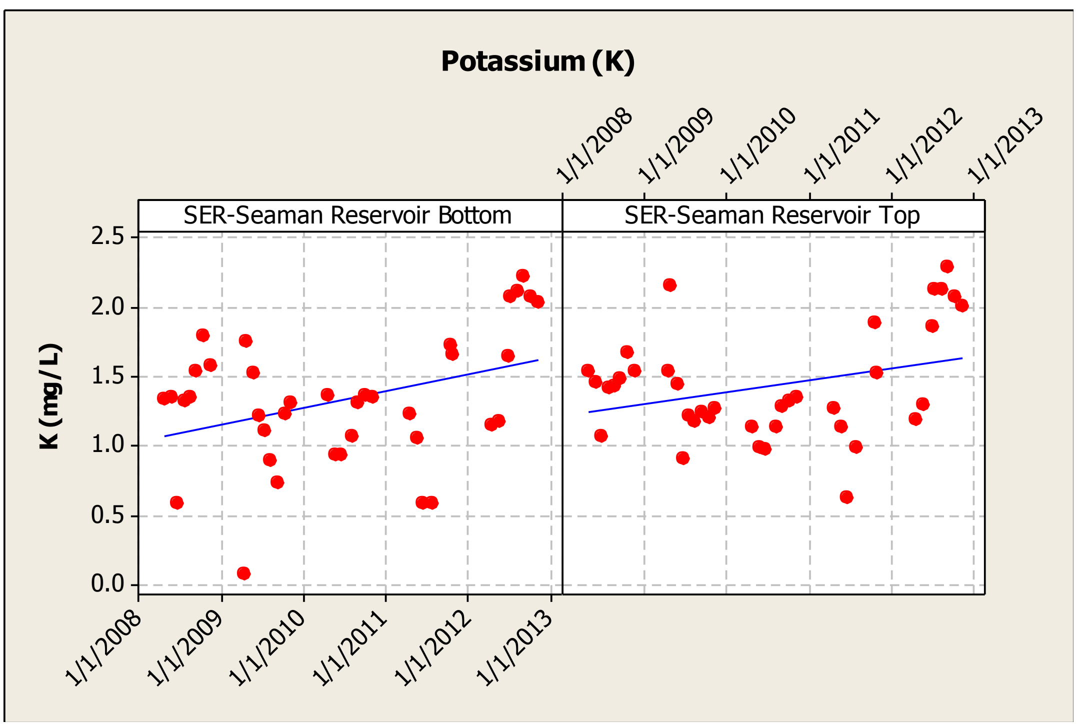


Figure 68. Significant Potassium trends in Seaman Reservoir.

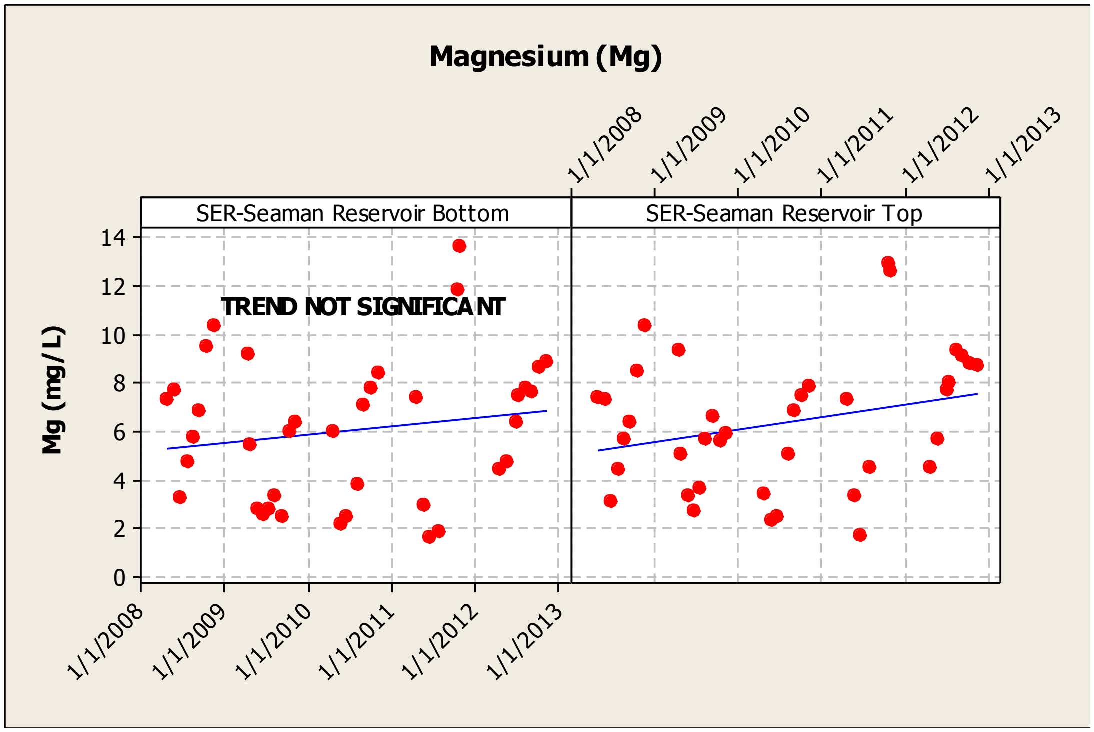


Figure 69. Significant Magnesium trend in Seaman Reservoir.

Collectively, these changes indicate a progression towards a more nutrient enriched, or eutrophic reservoir over time. The trophic state index (TSI) values for chlorophyll-a, secchi depth and total phosphorus at the top of Seaman Reservoir are consistent with trends towards more eutrophic conditions as illustrated in Figure 70 .

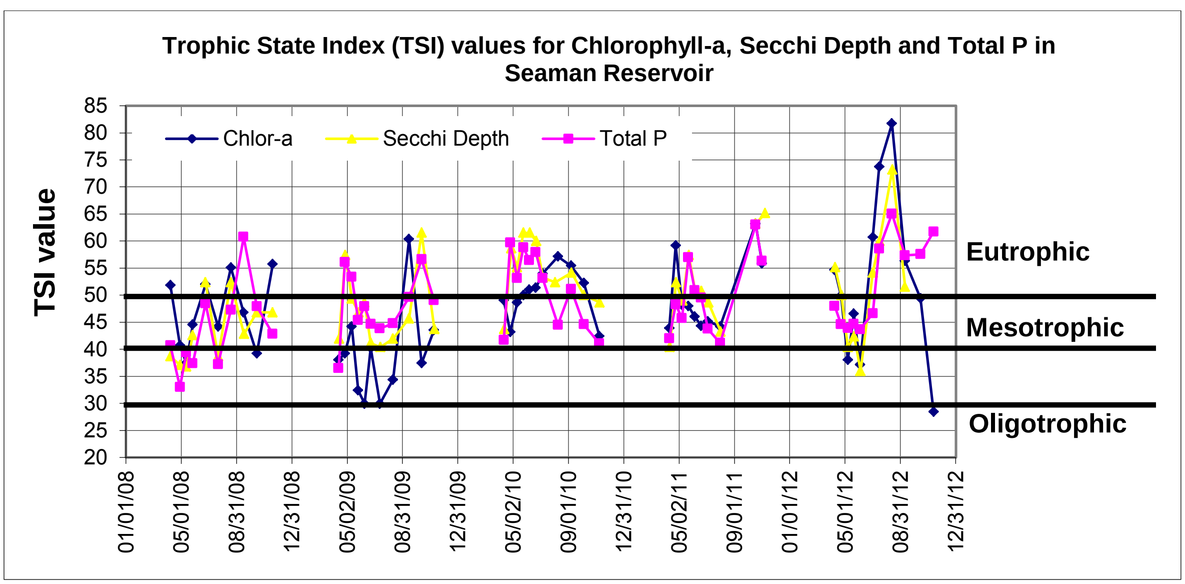


Figure 70. Carlson's Trophic State Index (TSI) values for chlorophyll-a, secchi depth and total phosphorus in Seaman Reservoir (Carlson, 1977).

For most parameters, trends were observed at both the top and bottom of the reservoir and in all cases, 2011 and 2012 appear to be significantly elevated over earlier years. Total and dissolved phosphorus show evidence of seasonal spikes in concentrations, during late summer and fall, which may indicate internal loading from bottom sediments when strong thermal stratification creates of periods of hypoxia in the reservoir. In 2012, a substantial amount of runoff from the Hewlett Fire burn area entered Seaman Reservoir. In addition, due to drought conditions and reservoir operations, there was very little water released from the reservoir throughout the year. The lack of through-flow likely contributed to the prolonged period of low oxygen at the bottom of the reservoir. It is likely these conditions contributed to the release of dissolved nitrogen and phosphorus from bottom sediments. However, based on the available information, it cannot be determined whether the source of higher nutrient levels are due to internal nutrient loading, sediment deposition from Hewlett Fire runoff, or a combination of these and other factors.

6.4 Spatial Trends in Water Quality

Six sites on the Mainstem CLP were selected to examine spatial trends in water quality from the highest elevation headwater sites to the lowest elevation sites at the Fort Collins and Greeley water supply intake facilities. In order of decreasing elevation, these sites included Joe Wright Creek (JWC), the Poudre above Joe Wright Creek (PJW), Poudre below South Fork (PSF), Poudre below Rustic (PBR), Poudre above the North Fork (PNF) and Poudre at the Bellvue Diversion (PBD). Boxplots for each water quality constituent were plotted by site to examine spatial trends in water quality. The important trends are included in the following discussion, with the full set of results presented in Attachment 8.

In general, there were few evident upstream to downstream trends in water quality. Some slight differences in water quality between the two headwater sites, PJW and JWC were observed. The differences likely stem from the proportions of water that each site receives from direct snowmelt and reservoir flow. Water quality at JWC reflects the combined influences of Joe Wright Reservoir, Chambers Lake, Barnes Meadow, whereas PJW flows directly from snowmelt runoff from pristine areas of Rocky Mountain National Park, but also receives some flow contributions from Long Draw Reservoir which is tributary to the Poudre above PJW. Both sites experience significant snow cover during the winter and receive the majority of streamflow from snowmelt. In general, constituents are somewhat more dilute at PJW with the exception of total organic carbon (TOC) and nitrate (NO_3). For these water quality parameters, PJW has higher median concentrations than all other sites in the basin (Figures 71 and 72).

The lowest elevation site, Poudre at the Bellvue Diversion (PBD), had the highest concentrations for many parameters, including alkalinity and turbidity (Figures 73 and 74). The nearest upstream site from PBD is Poudre above the North Fork (PNF). Constituent concentrations at PNF were generally similar to other upstream sites, but lower than PBD. The difference in water quality between these two sites can be attributed primarily to the influence of the North Fork and following the 2012 wildfires, the presence of large amounts of sediment in the river. Water temperature exhibited the strongest increasing trend from the highest to the lowest elevation sites (Figure 75), which is expected due to the strong elevational gradient in the Upper CLP watershed.

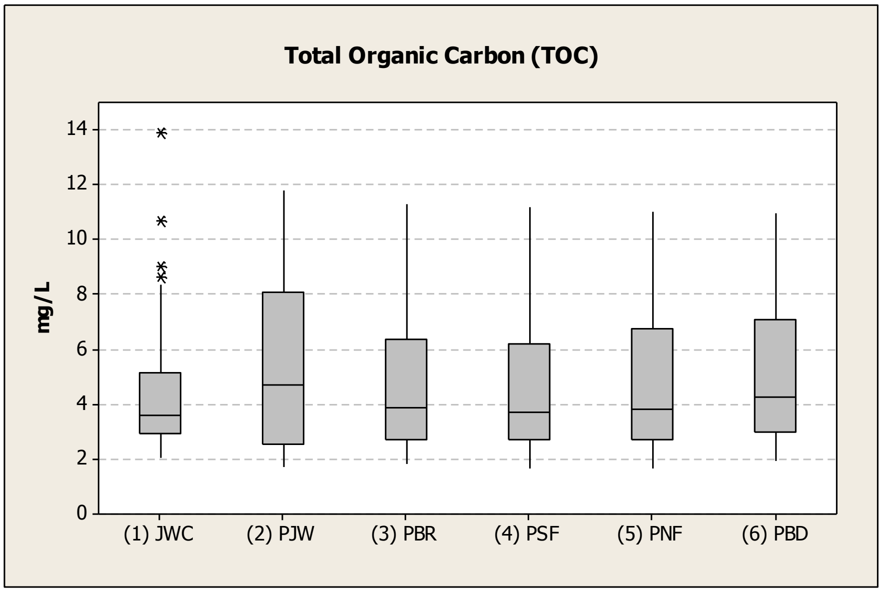


Figure71. Boxplots for TOC at key sites on the Mainstem, for years 2008-2012.

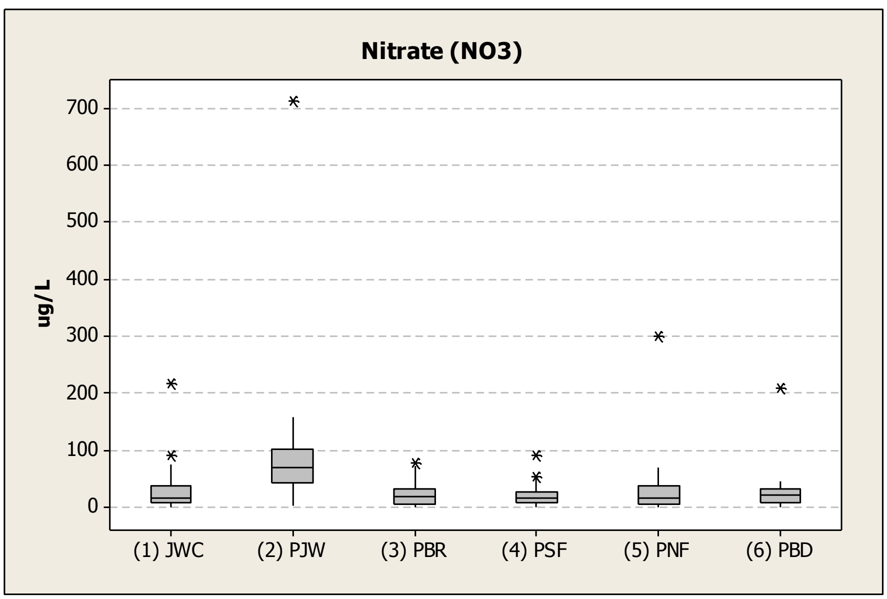


Figure72. Boxplots for nitrate at key sites on the Mainstem, for years 2008-2012.

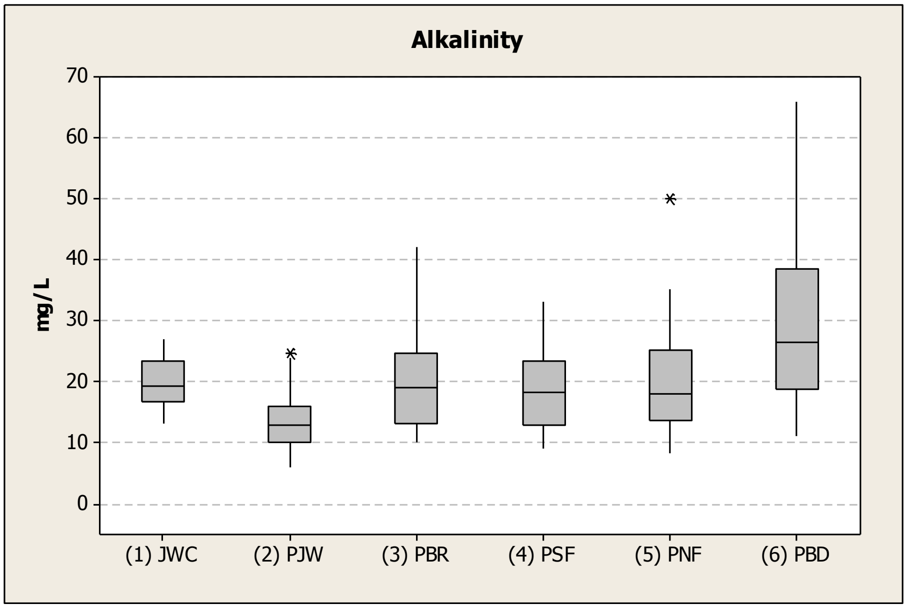


Figure73. Boxplots for alkalinity at key sites on the Mainstem, for years 2008-2012.

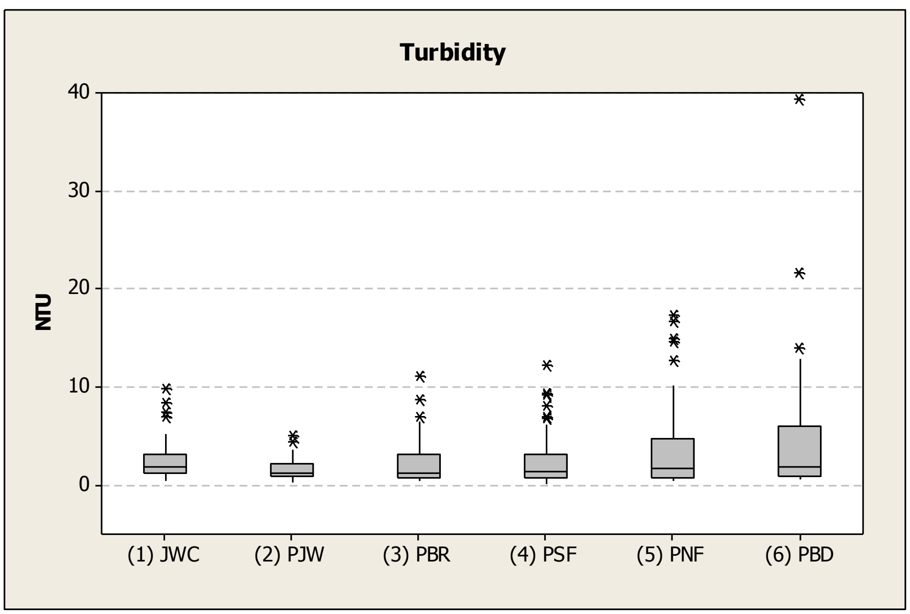


Figure74. Boxplots for turbidity at key sites on the Mainstem, for years 2008-2012.

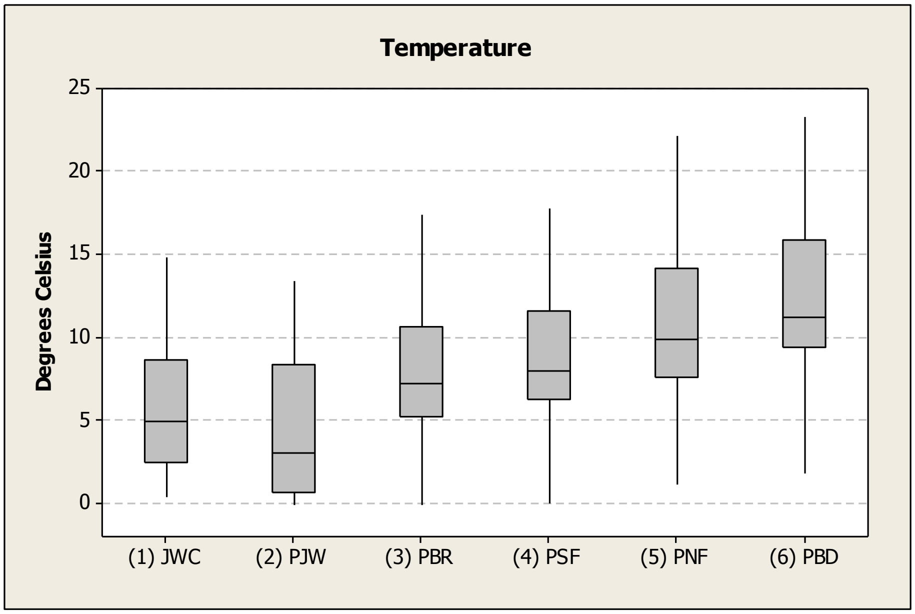


Figure75. Boxplots for water temperature at key sites on the Mainstem, for years 2008-2012.

7.0 SUMMARY

7.1 Program Performance

Review of the previous five years of Upper CLP Collaborative Monitoring Program data indicates that the program is in large part, adequately capturing the seasonal, temporal and spatial trends in water quality and provides a spatial context for examining notable events.

One exception is streamflow measurements. The current method for measuring streamflow (river transects using a hand held flow meter) at SFM and PJW is not adequate for capturing flow measurements at times when the river is unwadable. The result is the absence of peak flow measurements, which make calculating annual constituent loads impossible. Loading estimates are useful for understanding contributions of water quality constituents from major tributaries. Potential improvements for streamflow measurement will be evaluated in 2013 - 2014.

A second necessary program improvement is related to the availability of algae data. During the last two years, receipt of periphyton data for the Upper CLP and phytoplankton data for Seaman Reservoir was not available until after the annual review and reporting. This information gap will be addressed in 2013 in order to improve understanding and reporting of issues affecting and related to algal growth in the Upper CLP River.

7.2 Issues of Concern

Increasing air temperature trends are one of the most important changes occurring in the Upper CLP watershed, and while some impacts may be currently seen, many effects are expected to occur over the coming decades. The temperature increases are greater at the lower elevation site, PNF, but can also be observed at higher elevations, near Joe Wright Reservoir (Joe Wright SNOTEL). The importance of increasing temperatures hinges upon their ability to affect forest health (Joyce et al, 2008) and river hydrology (Christensen et al, 2004). Changes in timing and amount of precipitation, the timing of spring snowmelt and the impacts of drought on aging forests can in turn, affect nutrient cycling (Vose et al, 2012), frequency and intensity of wildfires (McKenzie et al., 2004), as well as the security of water supplies (Miller and Yates, 2005). Continued monitoring will help to stay informed of potential future trends and related changes in water quality.

7.3 Wildfire

The 2012 wildfires left an indelible mark on the landscape that will continue to affect the hydrology and water quality of the Upper CLP watershed within and below the fire perimeters. Storm events, which occur frequently during July and August, deliver large amounts of eroded hillslope sediments and cause major changes in water quality, specifically, turbidity, metals, conductivity, and nutrients.

Post-fire storm sampling has shown that these direct storm impacts are temporary, although longer term changes due to sediment storage in the stream channel remain uncertain. The intensity of the water quality response to precipitation events is expected to decrease with time, as watershed recovery proceeds. How long recovery will take depends upon how quickly the hillslope vegetation, soil stability and nutrient cycling processes reestablish. In the meantime, water operations for the Cities of Fort Collins and Greeley and the Tri-Districts will continue to focus on being responsive to changing conditions and are prepared to monitor water quality impacts for many years into the future.

It is expected that the river will remain in an annual cycle of sediment and debris erosion and deposition during the summertime, stored sediment on the riverbanks during the low flows of Fall and Winter, followed by riverbank scour during Spring snowmelt runoff.

Impacts to Seaman Reservoir from the Hewlett Fire runoff are expected. In 2012, water quality in the reservoir was characterized by higher nutrients and chlorophyll-*a*, low clarity (measured by secchi depth and turbidity), and an extended period of low dissolved oxygen. At this time, it is not possible to determine if the poor water quality was due to post-fire sediment influx or the lack through-flow in the reservoir in 2012.

7.4 Trends in Water Quality

Despite the temporary impacts of post-fire storms on water quality, background water quality remains very good in the Upper CLP, with many constituents remaining at or below reporting limits. Notable results of the trend analysis include the detection of significant increases in pH over the past 5 years at many Mainstem locations. Currently, the drivers of these changes are unknown; however, these trends will continue to be monitored carefully in the coming years.

In addition, there was a significant increase detected in ortho-phosphate concentrations below the South Fork at PSF as well as downstream at, PNF, near the FCWTF intake. The increase near the FCWTF is of potential concern, due to its tendency of phosphate to promote the algae growth, some of which produce undesirable taste and odor compounds, including geosmin. If concentrations continue to increases in the future or algal blooms occur, an investigation into the sources of nutrient within the watershed may be warranted.

Trend analysis results also indicate that Seaman Reservoir has become increasingly productive, or eutrophic, over the past five years, as reflected by its Trophic State Index (TSI) for nutrients, chlorophyll-*a* and clarity (measured as secchi depth).

7.5 Water Quality monitoring and Related Upper CLP activities for 2013

- **Routine Monitoring Program.** Samples will continue to be analyzed for all parameters in 2013. Changes to metals sampling are detailed in Section 4.2.5, Table 9.

- **Emerging Contaminant Monitoring.** The Northern Water collaborative study on emerging contaminants will continue in 2013, with samples to be collected at PNF and NFG in February, June and August.

- **Attached Algae.** The composition and density of the attached algae community on the Mainstem CLP will continue to be monitored in 2013.

- **Geosmin.** Geosmin monitoring will continue on the Mainstem CLP with an emphasis on the reach between Rustic and the treatment plant intakes. In addition, geosmin sampling will be conducted on the North Fork at the gage below Seaman Reservoir.

- **Post-Fire storm samples.** To understand water quality impacts of storms and monitor watershed recovery, storm samples will be collected near the Fort Collins water supply intake at PNF. Samples will analyzed by the Fort Collins Water Quality Lab.

- **Fire-Related Studies.** The City of Fort Collins is funding several studies related to the impacts of wildfires on river water quality, treatment effectiveness, taste and odor impacts to drinking water, and mulching effectiveness of controlling sediment erosion in the South Fork drainage. More details on these studies, including study objectives and principal investigators are provided in Section 3.9, Table 7.

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ATTACHMENT 1

Land use comparison of the North Fork and Mainstem CLP (areas calculated using USGS Seamless GIS data sets).

Land Use Comparison	North Fork (acres)	Main Stem (acres)	North Fork Area (%)	Main Stem Area (%)
Developed land (commercial, industrial, residential, urban, and utilities)	2,817	1,945	0.8	0.7
Agricultural use and grassland (Cropland, pasture, other agriculture, scrub and grasses)	183,719	54,765	52.3	18.3
Forest (forest and brush)	154,654	213,879	44.1	71.5
Natural lands (exposed rock, bare ground, wetlands, tundra, lakes)	9,926	28,473	2.8	9.5
Total	**351,116**	**299,062**	**100**	**100**

ATTACHMENT 2

Upper CLP collaborative water quality monitoring program sampling sites.

	MAIN STEM	Description	Rationale	GPS Coordinates
1	100CHR	Chambers Lake Outflow	Outflow from Chambers Lake	N 40° 36.039 W 105° 50.203
2	090BMR	Barnes Meadow Reservoir outflow	High TOC and nutrients compared to CHR	N 40° 36.039 W 105° 50.203
3	080JWC	Joe Wright Creek at Aspen Glen Campground	Joe Wright Creek above confluence with main stem	N 40° 37.233 W 105° 49.098
4	070PJW	Poudre at Hwy14 crossing (Big South Trailhead)	Above confluence Joe Wright Creek	N 40° 38.074 W 105° 48.421
5	060LRT	Laramie River at Tunnel at Hwy 14 crossing	Laramie River diversion water	N 40° 40.056 W 105° 48.067
6	050PBR	Poudre below Rustic	Midpoint between Laramie River Tunnel and South Fork; impacts to river from Rustic	N 40° 41.967 W 105° 32.476
7	040SFM	South Fork at bridge on Pingree Park Rd	Only access point on South Fork; South Fork water quality differs from main stem	N 40° 37.095 W 105° 31.535
8	030PSF	Poudre below confluence with South Fork - Mile Marker 101	Below confluence with South Fork	N 40° 41.224 W 105° 26.895
9	020PNF	Poudre above North Fork 1/2 mile upstream from Old FC WTP#1	Represents water diverted at Munroe Tunnel and at Old FC WTP #1	N 40° 42.087 W 105° 14.484
10	010PBD	Poudre at Bellvue Diversion	Greeley WTP Intake	N 40° 39.882 W 105° 12.995
	NORTH FORK			
11	280NDC	North Fork above Halligan Reservoir; above confluence with Dale Creek	Inflow to Halligan Reservoir	N 40° 53.852' W 105° 22.556'
12	270NBH	North Fork at USGS gage below Halligan Reservoir	Outflow from Halligan Reservoir	N 40° 52.654' W 105° 20.314'
13	260NRC	North Fork above Rabbit Creek	Main stem North Fork above Rabbit Creek; downstream of Phantom Canyon	N 40° 49.640 W 105° 16.776
14	250RCM	Rabbit Creek Mouth	Tributary to North Fork; drainage area includes agricultural/grazing lands; significant flows late spring to early summer only	N 40° 48.615 W 105° 17.146
15	240SCM	Stonewall Creek Mouth	Tributary to North Fork; drains area east of Hwy 287; significant flows late spring to early summer only	N 40° 48.458 W 105° 15.195
16	230PCM	Lone Pine Creek Mouth	Tributary to North Fork; drainage area includes Red Feather Lakes; significant flows late spring to early summer only	N 40° 47.696 W 105° 17.231
17	220NFL	North Fork at Livermore	At USGS gage	N 40° 47.269 W 105° 15.130
18	210SER	Seaman Reservoir	Reservoir profiles; impacts to water quality from nutrient loadings	N 40° 42.274 W 105° 14.210
19	200NFG	North Fork below Seaman Reservoir	At gage below Seaman Res; sample before flow enters Poudre main stem	N 40° 42.143 W 105° 14.064

ATTACHMENT 3

Upper CLP collaborative water quality monitoring program parameter list.

	Rationale	Notes
Field Parameters		
Conductance	Indicator of total dissolved solids.	Profile at Seaman Reservoir
Dissolved Oxygen	Profile indicates stratification, importance for aquatic life and chemical processes.	Profile at Seaman Reservoir
Secchi Disk	Measure of transparency.	Seaman Reservoir only
Temperature	Reflects seasonality; affects biological and chemical processes; water quality standard.	Profile at Seaman Reservoir
pH	Measure of acidity.	
General & Miscellaneous Parameters		
Alkalinity	Indicator of carbonate species concentrations; Acid neutralizing capacity of water; treatment implications.	
Chlorophyll-a	Reflects algal biomass.	Seaman Reservoir only
Discharge	Necessary for flow dependant analysis and load estimation.	Measured during sampling at NRC, RCM, SCM, PCM, PJW, SFM
Hardness	Treatment implications. Hard water causes scaling and soft water is considered corrosive.	
Total Dissolved Solids (TDS)	Indicator of overall water quality; includes both ionic and non-ionic species.	
Total Organic Carbon (TOC)	Important parameter for water treatment; precursor of disinfection byproducts.	
Turbidity	Indicator of suspended material; important for water treatment.	
Nutrients		
Nitrogen, Ammonia	Primary source of nitrogen to algae, indicator of pollution by sewage, septic tanks, agriculture; water quality standard.	
Nitrate	Primary source of nitrogen to algae; indicator of pollution by sewage, septic tanks, agriculture; water quality standard.	
Nitrite	Toxic inorganic nitrogen species; rarely encountered at significant concentrations; water quality standard.	
Total Kjeldahl Nitrogen	Sum of organic nitrogen and ammonia.	
Ortho-Phosphorus (Soluble Reactive Phosphorus)	Form of phosphorous (dissolved PO_4^{-3}) most available to algae; indicator of pollution by sewage, septic tanks, agriculture.	

Total Phosphorus	Includes dissolved and adsorbed, organic and inorganic forms of phosphorus, indicator of pollution by sewage, septic tanks, agriculture.	
Major Ions		
Calcium	Major ion.	Monitor for two years at half frequency (6x/yr)
Chloride	Major ion.	Monitor for two years at half frequency (6x/yr)
Magnesium	Major ion.	Monitor for two years at half frequency (6x/yr)
Potassium	Major ion, minor importance as a nutrient.	Monitor for two years at half frequency (6x/yr)
Sodium	Major ion.	Monitor for two years at half frequency (6x/yr)
Sulfate	Major ion.	Monitor for two years at half frequency (6x/yr)
Microbiological Constituents		
E. coli	Indicator of human or animal waste contamination; water quality standard.	Only from Rustic downstream, NFL, NFG, SER
Total Coliform	Indicator of human or animal waste contamination; naturally present in the environment	Only from Rustic downstream, NFL, NFG, SER
Cryptosporidium	Pathogen, indicator of human or animal waste contamination.	Above and below Halligan Reservoir, and below Seaman Reservoir
Giardia	Pathogen, Indicator of human or animal waste contamination.	Above and below Halligan Reservoir, and below Seaman Res
Algal Species Composition	Shows presence of nuisance species and trophic state.	Seaman Reservoir surface sample only
Metals		
Cadmium, dissolved	Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG (2x/yr)
Chromium, dissolved	Water quality standard.	Only PNF & NFG (2x/yr)
Copper, dissolved	Water quality standard.	Only PNF & NFG (2x/yr)
Iron, Total	Affects aesthetic quality of treated water.	Only PNF & NFG (2x/yr)
Iron, dissolved	Affects aesthetic quality of treated water.	Only PNF & NFG (2x/yr)
Lead, dissolved	Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG (2x/yr)
Nickel, dissolved	Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG (2x/yr)
Silver, dissolved	Indicator of pollution from mining activity at elevated levels.	Only PNF & NFG (2x/yr)
Zinc, dissolved	Indicator of pollution from mining activity at elevated levels.	Only PNF & NFG (2x/yr)
Mercury, Low Level	Accumulates in fish tissue even when present in very low concentrations.	Sample every 3 to 5 yrs.

ATTACHMENT 4

Collaborative Water Quality Monitoring Program 2012 Sampling Plan

	2012 Sampling Dates										
	Apr 9-10	Apr 23-24	May 7-8	May 21-22	Jun4-5	Jun 18-19	Jul 16-17	Aug 13-14	Sep 10-12	Oct 15-16	Nov 12-13
Station											
North Fork											
NDC[3]	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
NBH[3]	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
NRC	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,I,D
RCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D					
SCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D					
PCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D					
NFL	F,G,E	F,G,I	F,G,E	F,G,I	F,G,E	F,G,I	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
NFG	F,G,E	F,G,I,E	F,G,E	F,G,I,M,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,M,E	F,G,I,E
Main Stem											
CHR	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
BMR[2]	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
JWC	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
PJW	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,I,D
LRT	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
PBR	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
SFM		F,G,I,D		F,G,I,D		F,G,I,D		F,G,I,D		F,G,I,D	F,G,I,D
PSF	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
PNF	F,G,E	F,G,I,E	F,G,E	F,G,I,E,M	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E,M	F,G,I,E
PBD	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
Reservoir											
SER[1]	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,I,A,C,E

[1] Grab samples taken at two depths (Top & Bottom); meter samples at 1-m intervals.
[2] Call commissioner to find out if water is flowing. If not flowing, skip sample.
[3] Sampled by City of Fort Collins personnel; all other stations to be sampled by Dr. Bill Lewis' Team.

A = Algae (Lugol's); C = Chlorophyll (500 mL sample); D = Flow; F = Field data (Temp, pH, conductance streams + Secchi, DO for lake); G = 1 liter sampleor general, nutrients, TOC; E = *E. coli*, coliform (500 mL sterile bottle); I = Major ions; M = Metals; P = *Giardia/Cryptosporidium* (collected by City of Fort Collins personnel).

<u>**ATTACHMENT 5**</u>

Analytical methods, reporting limits, sample preservation, and sample holding times.

			Limit	vation	Time
Micro-biological	Total Coliform, *E.coli* - QT	SM 9223 B	0	cool, 4C	6 hrs
	Giardia & Cryptosporidium (CH Diagnostics)	EPA 1623	0	cool, 4C	4 days
	Algae I.D. (Phyto Finders)	SM 10200E.3, SM 10200F.2c1		Lugol's Solution, cool, 4C	12 mo
General & Misc.	Alkalinity, as $CaCO_3$	SM 2320 B	2 mg/L	cool, 4C	14 days
	Chlorophyll a	SM10200H modified	0.6 ug/L	cool, 4C	48 hrs
	Hardness, as $CaCO_3$	SM 2340 C	2 mg/L	none	28 days
	Specific Conductance	SM 2510 B		cool, 4C	28 days
	Total Dissolved Solids	SM 2540 C	10 mg/L	cool, 4C	7 days
	Turbidity (NTU)	SM2130B,EPA180.1	0.01 units	cool, 4C	48 hrs
Nutrients	Ammonia - N	Lachat 10-107-06-2C	0.01 mg/L	H_2SO_4	28 days
	Nitrate	EPA 300 (IC)	0.04 mg/L	cool, 4C (eda)	48 hrs
	Nitrite	EPA 300 (IC)	0.04 mg/L	cool, 4C (eda)	48 hrs
	Total Kjeldahl Nitrogen	EPA 351.2	0.1 mg/L	H_2SO_4 pH<2	28 days
	Phosphorus, Total	SM 4500-P B5,F	0.01 mg/L	H_2SO_4 pH<2	28 days
	Phosphorus, Ortho	SM 4500-P B1,F	0.005 mg/L	filter, cool 4C	48 hrs
Major Ions	Calcium	EPA 200.8	0.05 mg/L	HNO_3 pH <2	6 mos
	Chloride	EPA 300 (IC)	1.0 mg/L	none (eda)	28 days
	Magnesium, flame	EPA 200.8	0.2 mg/L	HNO_3 pH <2	6 mos
	Potassium	EPA 200.8	0.2 mg/L	HNO_3 pH <2	6 mos
	Sodium, flame	EPA 200.8	0.4 mg/L	HNO_3 pH <2	6 mos
	Sulfate	EPA 300 (IC)	5.0 mg/L	cool, 4C (eda)	28 days
Metals	Cadmium	EPA 200.8	0.1 ug/L	HNO_3 pH <2	6 mos
	Chromium	EPA 200.8	0.5 ug/L	HNO_3 pH <2	6 mos
	Copper	EPA 200.8	3 ug/L	HNO_3 pH <2	6 mos
	Iron, (total & dissolved)	EPA 200.8	10 ug/L	HNO_3 pH <2	6 mos
	Lead	EPA 200.8	1 ug/L	HNO_3 pH <2	6 mos
	Nickel	EPA 200.8	2 ug/L	HNO_3 pH <2	6 mos
	Silver	EPA 200.8	0.5 ug/L	HNO_3 pH <2	6 mos
	Zinc	EPA 200.8	50 ug/L	HNO_3 pH <2	6 mos
TOC	TOC	SM 5310 C	0.5 mg/L	H_3PO_4pH <2	28 days
Analysis conducted by City of Fort Collins Water Quality Lab (FCWQL), unless otherwise noted.					
Reporting Limit = lowest reportable number based on the lowest calibration standard routinely used.					

ATTACHMENT 6

2012 Seaman Reservoir Phytoplankton Data

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Top [ ] Potential geosmin producing cyanophyta	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CYANOPHYTA (blue-green algae)											
Anabaena flos-aquae				14.4		36.8	8000.0	720.0			
Anabaena crassa				131.2	54.4	3520.0	4400.0	5320.0	1092.5		
Anabaena lemmermannii				69.6		4.8					
Anabaena planctonica		5.6		9.6	14.4	620.0	13080.0	40400.0	2200.0		
Anabaena sp.				3.2							
Aphanizomenon flos-aquae					43.2	3620.0	1080.0	4000.0	5820.0	10600.0	
Aphanocapsa conferta						1125.0					
Aphanocapsa delicatissima				720.0		3875.0		3000.0			2500.0
Aphanocapsa holsatica	10000.0				187.5						
Aphanothece clathrata				3750.0							
Aphanothece smithii	1000.0			15500.0	5343.8	5062.5	1750.0		2125.0		7875.0
Coelosphaerium aerugineum											
Cuspidothrix issatschenkoi											
Cyanobium sp.											
Dactylococcopsis acicularis	10.0										
Dactylococcopsis sp.	280.0		50.0	40.0							
Geitlerinema sp.											
Gloeotrichia echinulata							240.0				
Jaaginema sp.											
Limnothrix sp.											
Lyngbya birgei											
Merismopedia sp.											
Merismopedia tenuissima											
Microcystis flos-aquae							43.2	156.0	2800.0	1260.0	
Microcystis wesenbergii			8.0								
Myxobaktron hirudiforme											
Oscillatoria tenuis											
Planktolyngbya limnetica											
Planktothrix agardhii											
Pseudanabaena limnetica											2.4
Pseudanabaena mucicola										440.0	
Pseudanabaena sp.											
Romeria leopoliensis											
Snowella litoralis											
Synechococcus capitatus											
Synechococcus nidulans				250.0							
Synechocystis sp.											
Woronichinia naegeliana											
TOTAL CYANOPHYTA	**11,290**	**5.6**	**58.0**	**20,488**	**5,643**	**17,864**	**28,593**	**53,596**	**14,038**	**12,300**	**10,377**

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Top	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CHRYSOPHYTA (golden-brown algae)											
Chromulina parvula	1500.0	10000.0	5875.0	625.0	62.5		2000.0	5500.0	375	3375.0	750.0
Chrysococcus sp.											
Dinobryon bavaricum			1.6								
Dinobryon cylindricum var. *alpinum*											
Dinobryon cylindricum											
Dinobryon cylindricum var. *palustre*	293.0										
Dinobryon divergens											
Dinobryon sociale var. *americanum*	554.0	440.0	440.0								
statospore of *Dinobryon*											
Mallomonas akrokomos											
Mallomonas caudata											
Mallomonas sp.	12.0		4.0		0.8						
cyst of *Mallomonas* sp.											
Ochromonas minuscula				250.0				1000.0			
Synura petersenii	36.0		4.8								
Uroglenopsis americana											
TOTAL CHRYSOPHYTA	**2,395**	**10,440**	**6,325**	**875.0**	**63.3**	**0.0**	**2,000**	**6,500**	**375.0**	**3,375**	**750.0**
XANTHOPHYTA											
Gloeobotrys limneticus						1.6					
BACILLARIOPHYTA (diatoms)											
Amphora sp.											
Asterionella formosa	118.0	184.8	55.0	4.0	58.8	2.0					
Aulacoseira ambigua											
Aulacoseira granulata var. *angustissima*			23.2	70.0			19.2		2.4		3.6
Aulacoseira italica						4.4					
Aulacoseira italica var. *tenuissima*	70.0			105.0							
Aulacoseira subarctica											
Cyclostephanos sp.	10.0										
Cymatopleura solea											
Diatoma anceps											
Diatoma moniliformis											
Diatoma tenuis											
Discostella glomerata	240.0			100.0							
Discostella pseudostelligera											
Discostella stelligera											
Fragilaria crotonensis	318.0	93.6	182.5	308.0	112.8	261.2	972.5				
Fragilaria sp.											

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Top	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
BACILLARIOPHYTA (diatoms) CONT'D											
Gomphonema sphaerophorum											
Gyrosigma acuminatum											
Melosira varians											0.6
Navicula capitatoradiata											
Navicula lanceolata											
Navicula rhynchocephala											
Navicula tripunctata											
Nitzschia archibaldii											
Nitzschia draveillensis	2.0		1.6	14.8							
Nitzschia fonticola											
Nitzschia gracilis				0.4							
Nitzschia linearis											
Nitzschia sigma											
Nitzschia sp.											
Nitzschia supralitorea			20.0								
Punticulata bodanica								1.0			0.2
Stephanocyclus meneghiniana		2.0	0.2								
Stephanodiscus medius											
Stephanodiscus niagarae											
Stephanodiscus parvus	160.0										
Synedra acus											
Synedra cyclopum											
Synedra delicatissima var. *angustissima*											
Synedra radians			1.2								
Synedra rumpens var. *familiaris*	17.0			9.2	0.4						
Synedra rumpens											
Synedra tenera				2.4							
Synedra ulna var. *danica*				0.8							
Synedra ulna var. *subaequalis*											
Synedra ulna	1.0										
Tabellaria fenestrata		0.4			0.4						
Urosolenia eriensis											
TOTAL BACILLARIOPHYTA	**936.0**	**280.8**	**283.7**	**614.6**	**172.4**	**267.6**	**991.7**	**1.0**	**2.4**	**0.0**	**4.4**
HAPTOPHYTA											
Chrysochromulina parva	1360.0	1440.0		3800.0	170.0	2130.0		720.0			

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Top	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CRYPTOPHYTA											
Chroomonas coerulea		1.0									0.2
Chroomonas nordstedtii											
Cryptomonas borealis	66.0	7.0	44.8	4.4	2.8	0.4		20.0		1.2	1.6
Cryptomonas curvata	2.0		6.8	31.6	81.6	0.2	0.6		168.8	8.8	3.2
Cryptomonas erosa											
Cryptomonas marsonii					6.4	0.4					
Goniomonas truncata								20.0			
Hemiselmis sp.											
Komma caudata	29.0										
Plagioselmis nannoplanctica	1240.0	120.0	0.8	2.0	120.0	260.0	40.0	80.0	80.0	40.0	20.0
cyst of *Cryptomonas*											
TOTAL CRYPTOPHYTA	**1337**	**128**	**52.4**	**38**	**210.8**	**261**	**40.6**	**120**	**248.8**	**50**	**25**
DINOPHYTA											
Ceratium hirundinella			0.2	2.0	0.2	4.0	0.6	56.0	1.2		
Gymnodinium aeruginosum				4.0							
Gymnodinium fuscum											
Peridinium lomnickii		1.2		2.8							
Peridinium willei											
Woloszynskia coronata			9.6								
TOTAL DINOPHYTA	**0**	**1.2**	**9.8**	**8.8**	**0.2**	**4**	**0.6**	**56**	**1.2**	**0**	**0**
EUGLENOPHYTA											
Euglena sp.											
Euglena viridis											
Lepocinclis acus											
Lepocinclis oxyuris											
Trachelomonas dybowskii											
Trachelomonas hispida											
Trachelomonas volvocina											
TOTAL EUGLENOPHYTA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PRASINOPHYTA											
Monomastrix sp.											
Pyramimonas sp.											
Scourfieldia sp.				20.0						10.0	
Tetraselmis cordiformis	10.0	1.6	6.4	27.2							
TOTAL PRASINOPHYTA	**10**	**2**	**6**	**47**	**0**	**0**	**0**	**0**	**0**	**10**	**0**

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Top	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CHLOROPHYTA (green algae)											
Acutodesmus acuminatus						1.6					
Acutodesmus dimorphus											
Ankistrodesmus falcatus	10.0		0.4	0.8							
Ankyra judayi					0.4	90.0	220.0			110.0	330.0
Botryococcus braunii											
Chlamydomonas dinobryonis		20.0									
Chlamydomonas globosa									40.0		
Chlamydomonas snowiae											
Chlamydomonas sp. 1									80.0		
Chlamydomonas sp. 2											
Chlamydomonas tetragama											20.0
Chlorella minutissima	6500.0		625.0	875.0	968.8	62.5					500.0
Chlorella sp.				120.0							
Chloromonas sp.											
Choricystis minor	1500.0			1250.0							
Closterium aciculare											
Closterium acutum var. *variabile*											
Closterium dianae											
Closterium moniliferum											
Coelastrum indicum											
Coelastrum pseudomicroporum	8.0										
Coelastrum pulchrum											
Coenochloris fottii			1.6				20.8		7.2	38.4	4.8
Cosmarium bioculatum											
Cosmarium candianum		0.2									
Cosmarium depressum var. *achondrum*						0.4					
Desmodesmus armatus		1.6									
Desmodesmus bicaudatus											
Desmodesmus communis	4.0		6.4	3.2	1.6						
Desmodesmus intermedius var. *balatonicus*	4.0										
Dictyosphaerium pulchellum var. *minutum*	48.0										
Elakatothrix viridis					0.8						
Eudorina elegans											
Gonatozygon kinahanii											
Heimansia pusilla											
Keratococcus sp.											
Micractinium pusillum											
Monoraphidium contortum	50.0		2.8	0.4							
Monoraphidium minutum				10.0							

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Top	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CHLOROPHYTA (green algae) CONT'D											
Monoraphidium sp.	3.0		0.4								
Mougeotia sp.											
Nephrocytium limneticum											
Oocystis apiculata											2.4
Oocystis borgei											
Oocystis parva						3.2					
Oocystis pusilla											
Pandorina charkowiensis											
Pandorina smithii		1.2									
Pediastrum boryanum											
Pediastrum duplex											
Pediastrum tetras											
Pseudodictyosphaerium elegans											
Pseudodictyosphaerium sp.				120.0							
Pseudodidymocystis planctonica	20.0										
Quadrigula sp.											
Raphidocelis contorta											
Raphidocelis sp.											
Scenedesmus arcuatus											
Scenedesmus ellipticus				8.0							
Schroederia setigera											
Staurastrum planctonicum						0.8	0.4				
Tetraedron minimum											
Tetraspora lemmermannii				6.4		1.6	4.8				
Volvox sp.											
TOTAL CHLOROPHYTA	**8,147**	**23.0**	**637**	**2,394**	**972**	**160**	**246**	**0.0**	**127**	**148**	**857**
TOTAL ALGAE DENSITY (cells/mL)	**25,475**	**12,320**	**7,372**	**28,265**	**7,232**	**20,688**	**31,872**	**60,993**	**14,792**	**15,883**	**12,014**

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Bottom Potential geosmin producing cyanophyta	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CYANOPHYTA (blue-green algae)											
Anabaena flos-aquae							18.4	0.4			
Anabaena crassa						109.2	55.2	21.0			
Anabaena lemmermannii						298.8		1.0			
Anabaena planctonica						10.4	36.0	91.0	7.6		
Anabaena sp.											
Aphanizomenon flos-aquae						34.8	128.4	35.0	21.4	42.4	
Aphanocapsa conferta											
Aphanocapsa delicatissima				1000.0	5000.0						
Aphanocapsa holsatica											
Aphanothece clathrata				375.0	125.0						
Aphanothece smithii			750.0	625.0	4000.0	37500.0	15250.0	309.0	1593.0	309.0	
Coelosphaerium aerugineum											
Cuspidothrix issatschenkoi											
Cyanobium sp.							750.0	11900.0	24205.0		
Dactylococcopsis acicularis											
Dactylococcopsis sp.	250.0	80.0		160.0							
Geitlerinema sp.	12.0										
Gloeotrichia echinulata											
Jaaginema sp.											
Limnothrix sp.											
Lyngbya birgei											
Merismopedia sp.											
Merismopedia tenuissima											
Microcystis flos-aquae								12.0		120.0	
Microcystis wesenbergii		7.2									
Myxobaktron hirudiforme											
Oscillatoria tenuis											
Planktolyngbya limnetica						100.0	340.0		1593.0	117.0	
Planktothrix agardhii											
Pseudanabaena limnetica							7.2			47.6	8.0
Pseudanabaena mucicola										104.0	
Pseudanabaena sp.											
Romeria leopoliensis											
Snowella litoralis											
Synechococcus capitatus						20.0					
Synechococcus nidulans			125.0								
Synechocystis sp.	6500.0										
Woronichinia naegeliana											
TOTAL CYANOPHYTA	**6,762**	**87.2**	**875.0**	**2,160**	**9,125**	**38,073**	**16,585**	**12,369**	**27,420**	**740**	**8**

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Bottom	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CHRYSOPHYTA (golden-brown algae)											
Chromulina parvula	750.0	9250.0	500.0	2125.0							
Chrysococcus sp.											
Dinobryon bavaricum											
Dinobryon cylindricum var. *alpinum*		2.0									
Dinobryon cylindricum											
Dinobryon cylindricum var. *palustre*	224.0										
Dinobryon divergens	5.0	0.8									
Dinobryon sociale var. *americanum*		0.4	1.2								
statospore of *Dinobryon*			0.4								
Mallomonas akrokomos											
Mallomonas caudata		4.0									
Mallomonas sp.		2.0									
cyst of *Mallomonas* sp.											
Ochromonas minuscula		125.0		125.0	750.0						
Synura petersenii											
Uroglenopsis americana											
TOTAL CHRYSOPHYTA	**979**	**9,384**	**502**	**2,250.0**	**750.0**	**0.0**	**0**	**0**	**0.0**	**0**	**0.0**
XANTHOPHYTA											
Gloeobotrys limneticus											
BACILLARIOPHYTA (diatoms)											
Amphora sp.											
Asterionella formosa	11.0	129.6	144.0	3.2		1.6					
Aulacoseira ambigua	4.0										
Aulacoseira granulata var. *angustissima*		146.4	65.6				4.8	1.2		1.6	
Aulacoseira italica	3.0									2.4	
Aulacoseira italica var. *tenuissima*	136.0			250.0	5.2	2.4					
Aulacoseira subarctica											
Cyclostephanos sp.	2.0										
Cymatopleura solea											
Diatoma anceps											
Diatoma moniliformis											
Diatoma tenuis											
Discostella glomerata											
Discostella pseudostelligera											
Discostella stelligera		40.0		0.4							
Fragilaria crotonensis	272.0	522.5	241.6	225.0		72.0	140.8				
Fragilaria sp.	32.0										

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Bottom	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
BACILLARIOPHYTA (diatoms) CONT'D											
Gomphonema sphaerophorum											
Gyrosigma acuminatum											
Melosira varians										0.8	0.6
Navicula capitatoradiata											
Navicula lanceolata											
Navicula rhynchocephala	4.0										
Navicula tripunctata											
Nitzschia archibaldii	2.0			5.2							
Nitzschia draveillensis	4.0		2.4	21.6							
Nitzschia fonticola											
Nitzschia gracilis		0.4	0.8	6.4							
Nitzschia linearis				0.4							
Nitzschia sigma											
Nitzschia sp.											
Nitzschia supralitorea											
Punticulata bodanica											
Stephanocyclus meneghiniana											
Stephanodiscus medius											
Stephanodiscus niagarae											
Stephanodiscus parvus											
Synedra acus											
Synedra cyclopum											
Synedra delicatissima var. *angustissima*											
Synedra radians											
Synedra rumpens var. *familiaris*	2.0										
Synedra rumpens											
Synedra tenera											
Synedra ulna var. *danica*				0.4							
Synedra ulna var. *subaequalis*											
Synedra ulna											
Tabellaria fenestrata											
Urosolenia eriensis											
TOTAL BACILLARIOPHYTA	**472.0**	**838.9**	**454.4**	**512.6**	**5.2**	**76.0**	**145.6**	**1.2**	**0.0**	**4.8**	**0.6**
HAPTOPHYTA											
Chrysochromulina parva		280.0									

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Bottom	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CRYPTOPHYTA											
Chroomonas coerulea	1.0	5.6	10.0	2.5							
Chroomonas nordstedtii											
Cryptomonas borealis	8.0	4.4		7.5	0.4						
Cryptomonas curvata	3	17.6	14.8	75.0	1.2						0.4
Cryptomonas erosa											
Cryptomonas marsonii											
Goniomonas truncata											
Hemiselmis sp.											
Komma caudata											
Plagioselmis nannoplanctica	1.0	40.0									27.0
cyst of *Cryptomonas*					0.4						
TOTAL CRYPTOPHYTA	**13**	**67.6**	**24.8**	**85**	**2**	**0**	**0**	**0**	**0**	**0**	**27.4**
DINOPHYTA											
Ceratium hirundinella											
Gymnodinium aeruginosum											
Gymnodinium fuscum											
Peridinium lomnickii		0.8		2.4							
Peridinium willei											
Woloszynskia coronata											
TOTAL DINOPHYTA	**0**	**0.8**	**0**	**2.4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
EUGLENOPHYTA											
Euglena sp.			6.0								
Euglena viridis	1.0	8.4	10.4	24.4				0.2			
Lepocinclis acus											
Lepocinclis oxyuris	1.0										
Trachelomonas dybowskii											
Trachelomonas hispida											
Trachelomonas volvocina											
TOTAL EUGLENOPHYTA	**2**	**8.4**	**16.4**	**24.4**	**0**	**0**	**0**	**0.2**	**0**	**0**	**0**
PRASINOPHYTA											
Monomastrix sp.		20.0									
Pyramimonas sp.											
Scourfieldia sp.											
Tetraselmis cordiformis	7.0	4.0	4.0								
TOTAL PRASINOPHYTA	**7**	**24**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Bottom	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CHLOROPHYTA (green algae)											
Acutodesmus acuminatus			0.8								
Acutodesmus dimorphus				4.8							
Ankistrodesmus falcatus	1.0	4.0	0.8	2.0	3.2						
Ankyra judayi										22.5	153.0
Botryococcus braunii											
Chlamydomonas dinobryonis			0.8								
Chlamydomonas globosa											
Chlamydomonas snowiae											
Chlamydomonas sp. 1				40.0							
Chlamydomonas sp. 2											
Chlamydomonas tetragama		2.0									
Chlorella minutissima	250.0	250.0	1625.0	750.0	5500.0	2000.0				72.1	1236.0
Chlorella sp.											
Chloromonas sp.											
Choricystis minor											
Closterium aciculare											
Closterium acutum var. *variabile*											
Closterium dianae											
Closterium moniliferum											
Coelastrum indicum											
Coelastrum pseudomicroporum											2.4
Coelastrum pulchrum											
Coenochloris fottii	6.0									28.8	33.6
Cosmarium bioculatum											
Cosmarium candianum											
Cosmarium depressum var. *achondrum*					0.2						
Desmodesmus armatus	4.0			1.6							
Desmodesmus bicaudatus											
Desmodesmus communis		0.8		6.4	6.4						
Desmodesmus intermedius var. *balatonicus*											
Dictyosphaerium pulchellum var. *minutum*											
Elakatothrix viridis											
Eudorina elegans		24.8									
Gonatozygon kinahanii											
Heimansia pusilla											
Keratococcus sp.											
Micractinium pusillum											
Monoraphidium contortum			0.4		1.2						
Monoraphidium minutum											

Phytoplankton Densities (cells/mL)	SAMPLING DATE										
Seaman Reservoir - Bottom	9-Apr-12	23-Apr-12	7-May-12	21-May-12	4-Jun-12	2-Jul-12	16-Jul-12	13-Aug-12	11-Sep-12	15-Oct-12	13-Nov-12
CHLOROPHYTA (green algae) CONT'D											
Monoraphidium sp.											
Mougeotia sp.											
Nephrocytium limneticum											
Oocystis apiculata											
Oocystis borgei											
Oocystis parva											
Oocystis pusilla											
Pandorina charkowiensis											
Pandorina smithii											
Pediastrum boryanum					9.6						
Pediastrum duplex	8.0										
Pediastrum tetras		0.8									
Pseudodictyosphaerium elegans											
Pseudodictyosphaerium sp.											
Pseudodidymocystis planctonica			0.8	80.0	4.0						
Quadrigula sp.											
Raphidocelis contorta											
Raphidocelis sp.											
Scenedesmus arcuatus											
Scenedesmus ellipticus											
Schroederia setigera											
Staurastrum planctonicum						0.4					
Tetraedron minimum											
Tetraspora lemmermannii											
Volvox sp.											
TOTAL CHLOROPHYTA	**269**	**282.4**	**1,629**	**885**	**5,525**	**2,000**	**0**	**0.0**	**0**	**123**	**1,425**
TOTAL ALGAE DENSITY (cells/mL)	**8,504**	**10,974**	**3,505**	**5,919**	**15,407**	**40,150**	**16,731**	**12,371**	**27,420**	**868**	**1,461**

ATTACHMENT 7

Liner Regression Analysis Results:

Characteristic	Site Name	Period of Record			Slope if Significant (α=0.10)	p-value	Change over POR	Units
		Begins	Through	Years	Concentration units / day			
pH (field)	BMR - Barnes Meadow Reservoir Outflow	04/10/07	11/07/11	4.58	0.00084120	0.001	1.4065	
	CHR - Chambers Lake Outflow	04/10/07	11/13/12	5.60	0.00041517	0.000	0.8486	
	SFM - South Fork Poudre River	04/10/07	11/13/12	5.60	0.00036833	0.000	0.7529	
	PSF - Poudre below confluence of South Fork	06/05/07	11/13/12	5.45	0.00036063	0.000	0.7169	
	PNF - Poudre above confluence with North Fork	04/10/07	11/13/12	5.60	0.00030582	0.000	0.6251	
	PJW - Poudre above confluence of Joe Wright Creek	04/10/07	11/13/12	5.60	0.00029683	0.000	0.6067	
	LRT - Laramie River Tunnel	06/05/07	11/13/12	5.45	0.00018475	0.043	0.3673	
	NFL - North Fork at Livermore	04/03/07	11/14/12	5.62	0.00017565	0.003	0.3604	
	PBR - Poudre below Rustic	04/09/08	11/13/12	4.60	0.00020842	0.007	0.3499	
	NRC - North Fork above Rabbit Creek	04/03/07	11/14/12	5.62	0.00016113	0.000	0.3306	
	PCM - Lone Pine Creek Mouth	04/03/07	06/05/12	5.18	0.00011504	0.054	0.2174	
	Raw Poudre @ FCWTF	01/01/07	12/31/12	6.00	0.00003893	0.000	0.0853	
Specific Conductance (field)	PCM - Lone Pine Creek Mouth	04/03/07	06/05/12	5.18	-0.0805	0.010	-152.145	uS/cm
Temperature (field)								
Alkalinity	RCM - Rabbit Creek Mouth	05/27/08	05/21/12	3.99	0.04408	0.029	64.136	mg/L
Hardness	RCM - Rabbit Creek Mouth	05/27/08	05/21/12	3.99	0.05793	0.006	84.288	mg/L
	NFL - North Fork at Livermore	04/08/08	11/13/12	4.60	0.02889	0.077	48.535	mg/L
	NDC - North Fork above Dale Creek	04/09/08	10/15/12	4.52	0.003438	0.1	5.673	mg/L
	CHR - Chambers Lake Outflow	04/09/08	11/13/12	4.60	-0.0014159	0.106	-2.377	mg/L
	PJW - Poudre above confluence of Joe Wright Creek	04/09/08	11/13/12	4.60	-0.0015307	0.061	-2.570	mg/L
Turbidity	SER_T - Seaman Reservoir (Top)	04/08/08	11/13/12	4.60	0.003739	0.02	6.282	NTU
	SER_B - Seaman Reservoir (Bottom)	04/08/08	11/13/12	4.60	0.003362	0.008	5.648	NTU
	SCM - Stonewall Creek Mouth	04/08/08	06/04/12	4.16	-0.002591	0.021	-3.933	NTU
	NFL - North Fork at Livermore	04/08/08	11/13/12	4.60	-0.002905	0.066	-4.880	NTU
Total Dissolved Solids (TDS)	RCM - Rabbit Creek Mouth	05/27/08	05/21/12	3.99	0.05473	0.02	79.632	mg/L
	CHR - Chambers Lake Outflow	04/09/08	11/13/12	4.60	-0.006279	0.004	-10.542	mg/L
	SCM - Stonewall Creek Mouth	04/08/08	06/04/12	4.16	-0.011327	0.053	-17.194	mg/L
Nitrate (NO3)	NFG - North Fork below Seaman Reservoir	04/08/08	11/13/12	4.60	0.08659	0	145.471	ug/L
	CHR - Chambers Lake Outflow	04/09/08	11/13/12	4.60	0.015494	0.037	26.014	ug/L
	PBR - Poudre at the Bellvue Diversion	04/09/08	11/13/12	4.60	-0.006845	0.084	-11.493	ug/L
	NFL - North Fork at Livermore	04/08/08	11/13/12	4.60	-0.013994	0.036	-23.510	ug/L
	JWC - Joe Wright Creek above Poudre	04/09/08	11/13/12	4.60	-0.014955	0.084	-25.109	ug/L
	PCM - Lone Pine Creek Mouth	04/08/08	06/04/12	4.16	-0.06471	0	-98.230	ug/L
	RCM - Rabbit Creek Mouth	05/27/08	05/21/12	3.99	-0.12566	0	-182.835	ug/L

Linear Regression Analysis Results (Cont'd)

Characteristic	Site Name	Period of Record			Slope if Significant (α=0.10)	p-value	Change over POR	Units
		Begins	Through	Years	Concentration units / day			
Nitrite (NO2)	NFG - North Fork below Seaman Reservoir	04/08/08	11/13/12	4.60	0.006421	0.052	10.787	ug/L
Ammonia (NH3)	SER_B - Seaman Reservoir (Bottom)	04/08/08	11/13/12	4.60	0.15264	0.002	256.435	ug/L
	SER_T - Seaman Reservoir (Top)	04/08/08	11/13/12	4.60	0.10592	0.016	177.946	ug/L
	BMR - Barnes Meadow Reservoir Outflow	04/09/08	11/01/11	3.56	0.015494	0.001	20.158	ug/L
	PNF - Poudre above the North Fork	04/09/08	11/13/12	4.60	0.002614	0.05	4.389	ug/L
	PBR - Poudre above Rustic	04/09/08	11/13/12	4.60	-0.008536	0.017	-14.332	ug/L
Total Kjeldahl Nitrogen (TKN)	SER_T - Seaman Reservoir (Top)	04/08/08	11/13/12	4.60	0.4217	0.001	708.034	ug/L
	SER_B - Seaman Reservoir (Bottom)	04/08/08	11/13/12	4.60	0.31718	0.002	532.862	ug/L
	NBH - North Fork below Halligan Reservoir	04/09/08	10/15/12	4.52	0.16887	0.005	278.636	ug/L
Total N (NO2+NO3+TKN)	SER_T - Seaman Reservoir (Top)	04/08/08	11/13/12	4.60	0.4174	0.002	701.232	ug/L
	SER_B - Seaman Reservoir (Bottom)	04/08/08	11/13/12	4.60	0.30757	0.002	516.718	ug/L
	NBH - North Fork below Halligan Reservoir	04/09/08	10/15/12	4.52	0.16461	0.007	271.607	ug/L
	RCM - Rabbit Creek Mouth	05/27/08	05/21/12	3.99	-0.24097	0.018	-350.611	ug/L
Ortho-phosphate (PO4)	NFG - North Fork below Seaman Reservoir	04/08/08	11/13/12	4.60	0.028709	0.003	48.231	ug/L
	SER_B - Seaman Reservoir (Bottom)	04/08/08	11/13/12	4.60	0.0215	0.038	36.120	ug/L
	PBD - Poudre at the Bellvue Diversion	04/09/08	11/13/12	4.60	0.006132	0.002	10.296	ug/L
	PNF - Poudre above the North Fork	04/09/08	11/13/12	4.60	0.004105	0.001	6.892	ug/L
	NBH - North Fork below Halligan Reservoir	04/09/08	10/15/12	4.52	0.00301	0.065	4.967	ug/L
	PSF - Poudre below the South Fork	04/09/08	11/13/12	4.60	0.0029254	0	4.912	ug/L
	CHR - Chambers Lake Outflow	04/09/08	11/13/12	4.60	0.0016562	0.067	2.781	ug/L
	LRT - Laramie River Tunnel	05/13/08	11/13/12	4.51	0.0016497	0.014	2.714	ug/L
	PJW - Poudre above confluence of Joe Wright Creek	04/09/08	11/13/12	4.60	0.0008062	0.016	1.354	ug/L
	PBR - Poudre above Rustic	04/09/08	11/13/12	4.60	0.000663	0.029	1.113	ug/L
	NFL - North Fork at Livermore	04/08/08	11/13/12	4.60	-0.0019139	0.009	-3.215	ug/L
	RCM - Rabbit Creek Mouth	05/27/08	05/21/12	3.99	-0.017322	0	-25.204	ug/L
Total P	SER_B - Seaman Reservoir (Bottom)	04/08/08	11/13/12	4.60	0.02816	0.057	47.309	ug/L
	SER_T - Seaman Reservoir (Top)	04/08/08	11/13/12	4.60	0.010739	0.005	18.042	ug/L
	PNF - Poudre above the North Fork	04/09/08	11/13/12	4.60	0.009908	0.016	16.636	ug/L
	PSF - Poudre below the South Fork	04/09/08	11/13/12	4.60	0.00676	0.006	11.350	ug/L
	NFL - North Fork at Livermore	04/08/08	11/13/12	4.60	-0.010788	0.079	-18.124	ug/L
Total Organic Carbon (TOC)	BMR - Barnes Meadow Reservoir Outflow	04/09/08	11/01/11	3.56	-0.0006228	0.001	-0.810	mg/L
	NFL - North Fork at Livermore	04/08/08	11/13/12	4.60	-0.0010822	0.076	-1.818	mg/L
	RCM - Rabbit Creek Mouth	05/27/08	05/21/12	3.99	-0.004054	0.001	-5.899	mg/L
Chlorophyll-a	SER_T - Seaman Reservoir (Top)	04/08/08	11/13/12	4.60	0.00445	0.044	7.476	mg/L

Linear Regression Analysis Results (Cont'd)

Characteristic	Site Name	Period of Record			Slope if Significant (α=0.10)	p-value	Change over POR	Units
		Begins	Through	Years	Concentration units / day			
Sulfate (SO4-)	CHR - Chambers Lake Outflow	4/30/2008	11/13/12	4.54	-0.0002907	0.074	-0.482	mg/L
	PCM - Lone Pine Creek Mouth	04/29/08	05/21/12	4.06	-0.00229	0.051	-3.396	mg/L
Chloride (Cl-)	RCM - Rabbit Creek Mouth	05/27/08	05/21/12	3.99	0.011894	0.007	17.306	mg/L
Calcium (Ca)	RCM - Rabbit Creek Mouth	5/27/2008	5/21/2012	3.99	0.013323	0.079	19.385	mg/L
	NFL - North Fork at Livermore	4/29/2008	11/13/2012	4.55	0.009134	0.097	15.153	mg/L
Magnesium (Mg)	RCM - Rabbit Creek Mouth	5/27/2008	5/21/2012	3.99	0.004568	0.062	6.646	mg/L
	NFL - North Fork at Livermore	4/29/2008	11/13/2012	4.55	0.003423	0.027	5.679	mg/L
	SER_T - Seaman Reservoir (Top)	4/29/2008	11/13/2012	4.55	0.0014062	0.094	2.333	mg/L
	JWC - Joe Wright Creek above Poudre	4/30/2008	11/13/2012	4.54	0.0001247	0.102	0.207	mg/L
	SCM - Stonewall Creek Mouth	4/29/2008	5/21/2012	4.06	-0.003802	0.031	-5.638	mg/L
Potassium (K)	RCM - Rabbit Creek Mouth	5/27/2008	5/21/2012	3.99	0.000671	0.109	0.976	mg/L
	SER_T - Seaman Reservoir (Top)	4/29/2008	11/13/2012	4.55	0.0002399	0.046	0.398	mg/L
	NFG - North Fork below Seaman Reservoir	4/29/2008	11/13/2012	4.55	0.000214	0.072	0.355	mg/L
	SER_B - Seaman Reservoir (Bottom)	4/29/2008	4/29/2008	0.00	0.0003319	0.02	0.000	mg/L
	SCM - Stonewall Creek Mouth	4/29/2008	5/21/2012	4.06	-0.0004755	0.002	-0.705	mg/L
Sodium (Na)	SCM - Stonewall Creek Mouth	4/29/2008	5/21/2012	4.06	-0.0013764	0.033	-2.041	mg/L
Sum of Cations	RCM - Rabbit Creek Mouth	5/27/2008	5/21/2012	3.99	0.0235	0.049	34.193	mg/L
Daily Average Air Temperature (F)	PNF - Poudre above the North Fork	9/18/2008	12/31/2012	4.29	0.0009361	0.006	1.465	deg F
Daily Max Air Temperature (F)	JWC - Joe Wright Creek above Poudre(23 yr POR)	8/9/1989	12/31/2012	23.41	0.00078738	0	6.728	deg F

ATTACHMENT 8

Spatial Trends

General Parameters

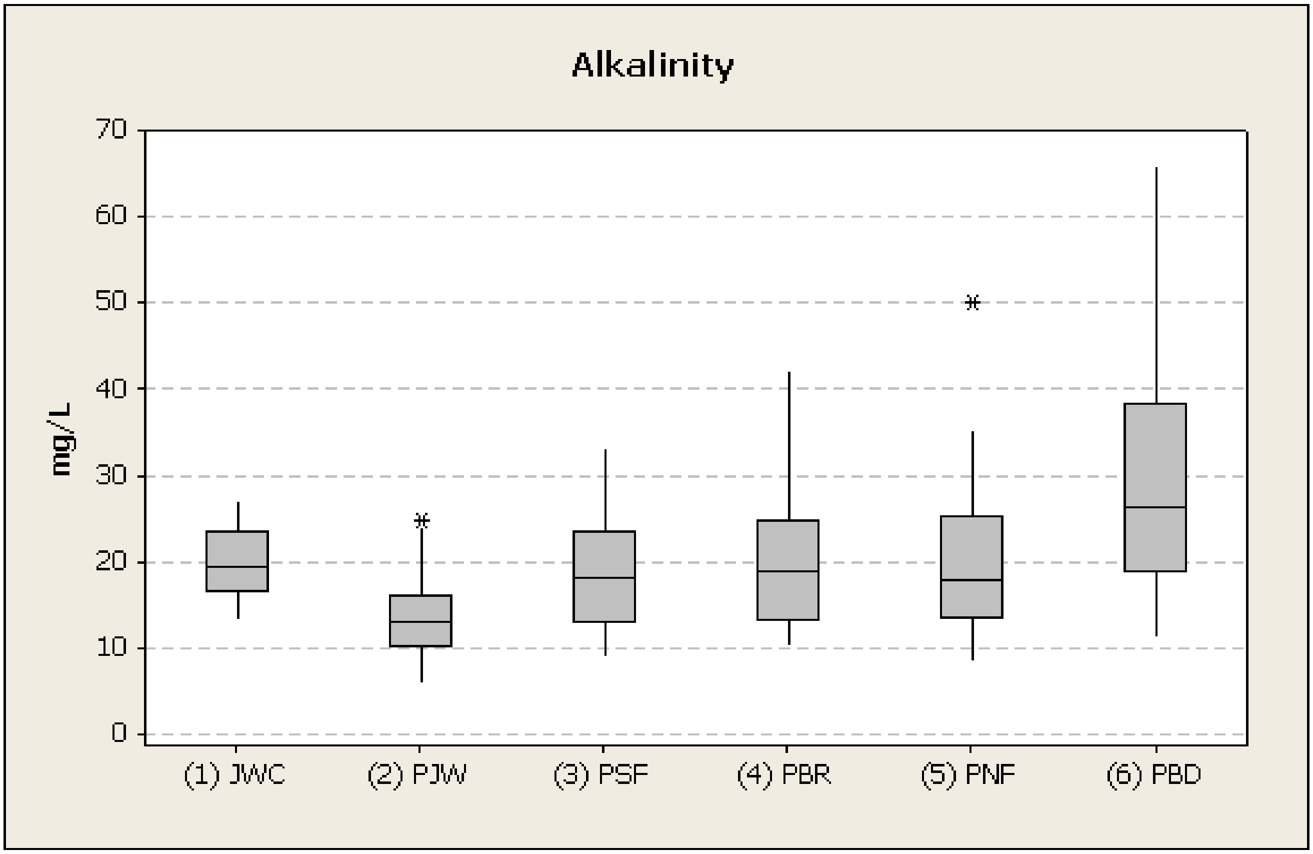


Figure 1. Boxplots of Alkalinity at key sites on the Mainstem CLP

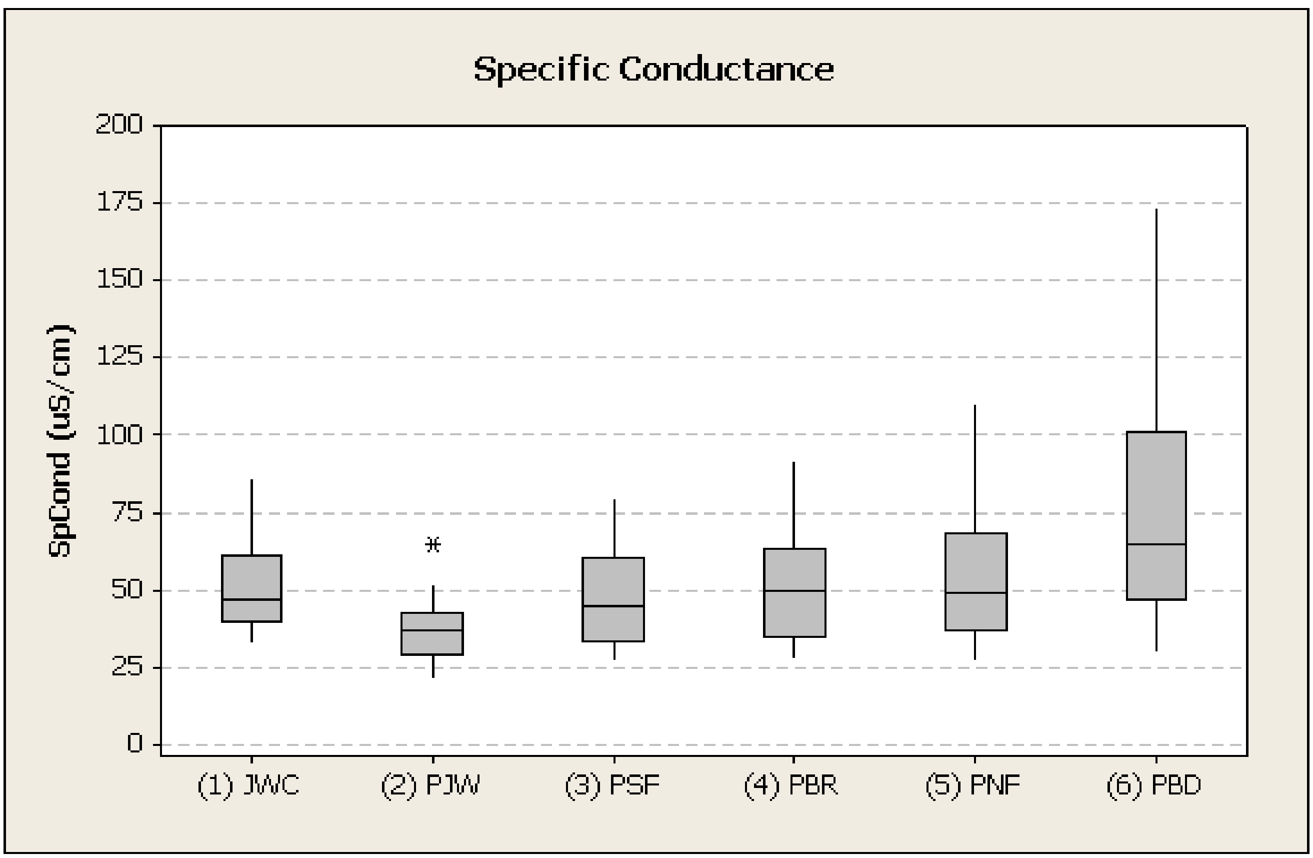


Figure 2. Boxplots of Specific Conductance at key sites on the Mainstem CLP

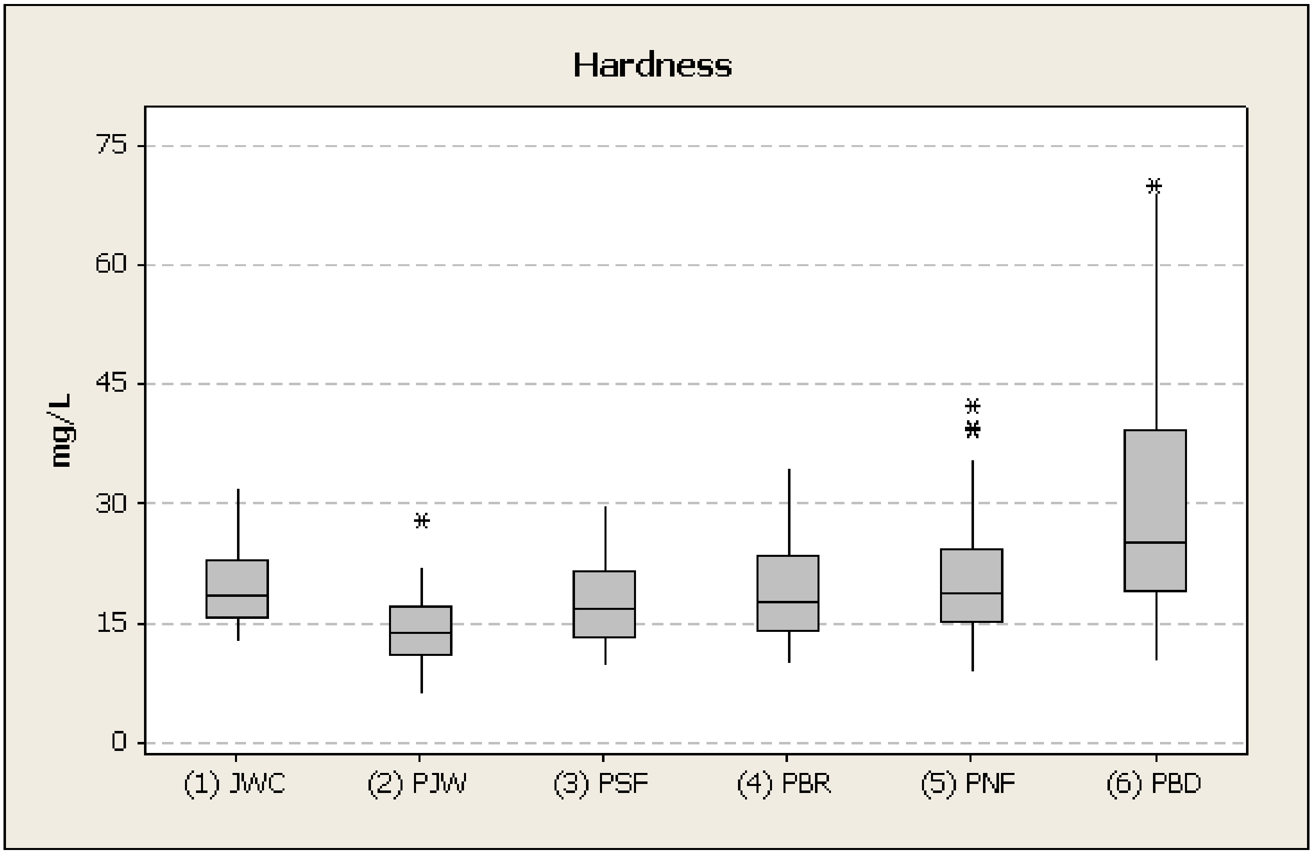


Figure 3. Boxplots of Hardness at key sites on the Mainstem CLP

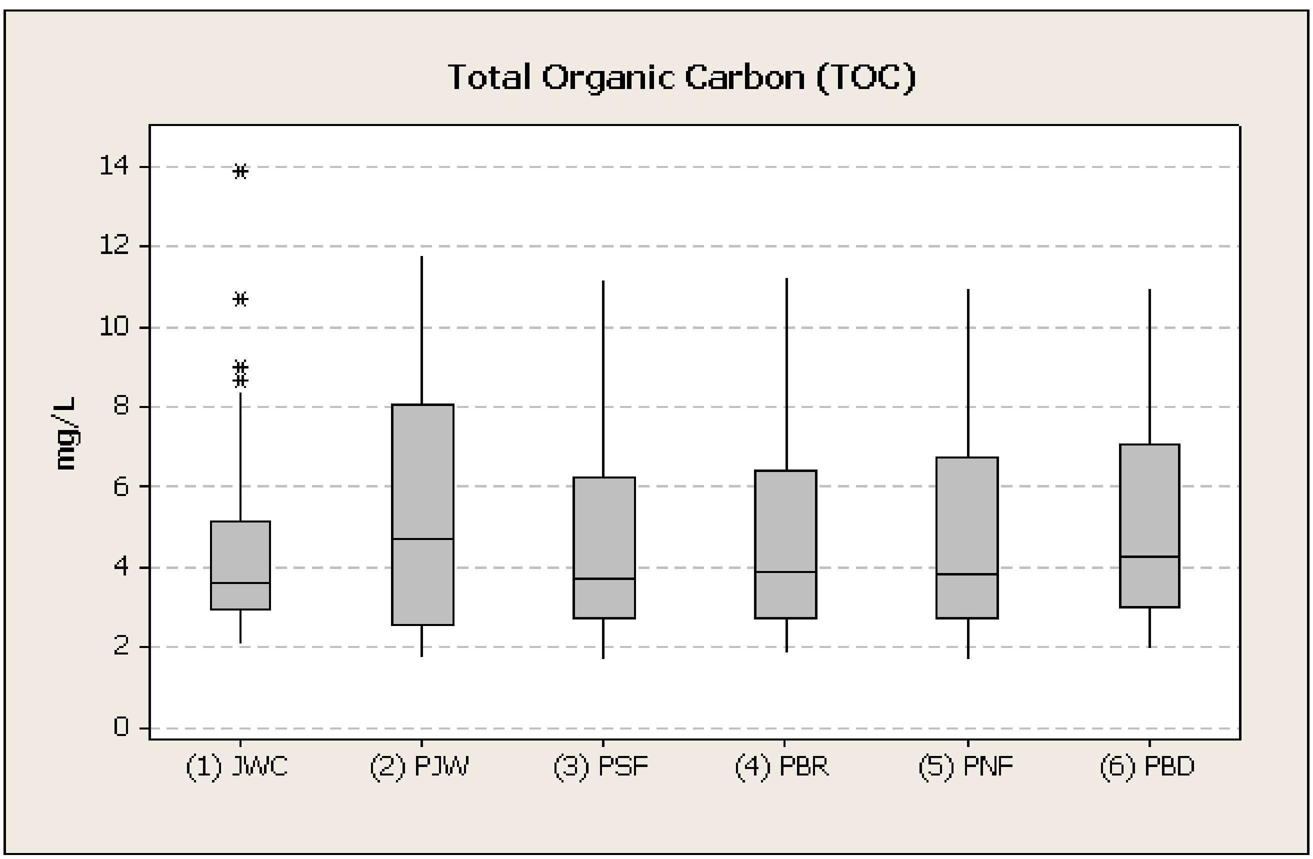


Figure 4. Boxplots of Total Organic Carbon (TOC) at key sites on the Mainstem CLP

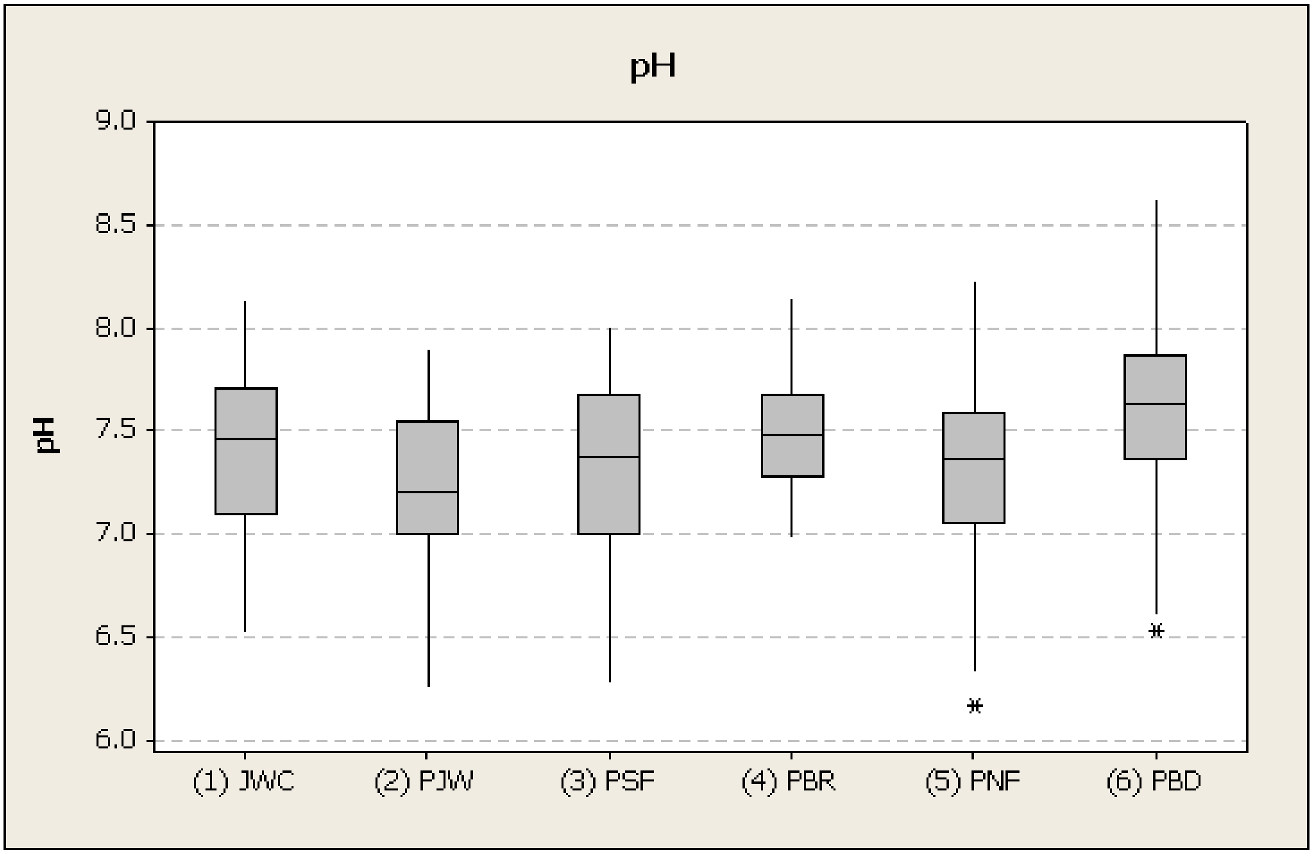


Figure 5. Boxplots of pH at key sites on the Mainstem CLP

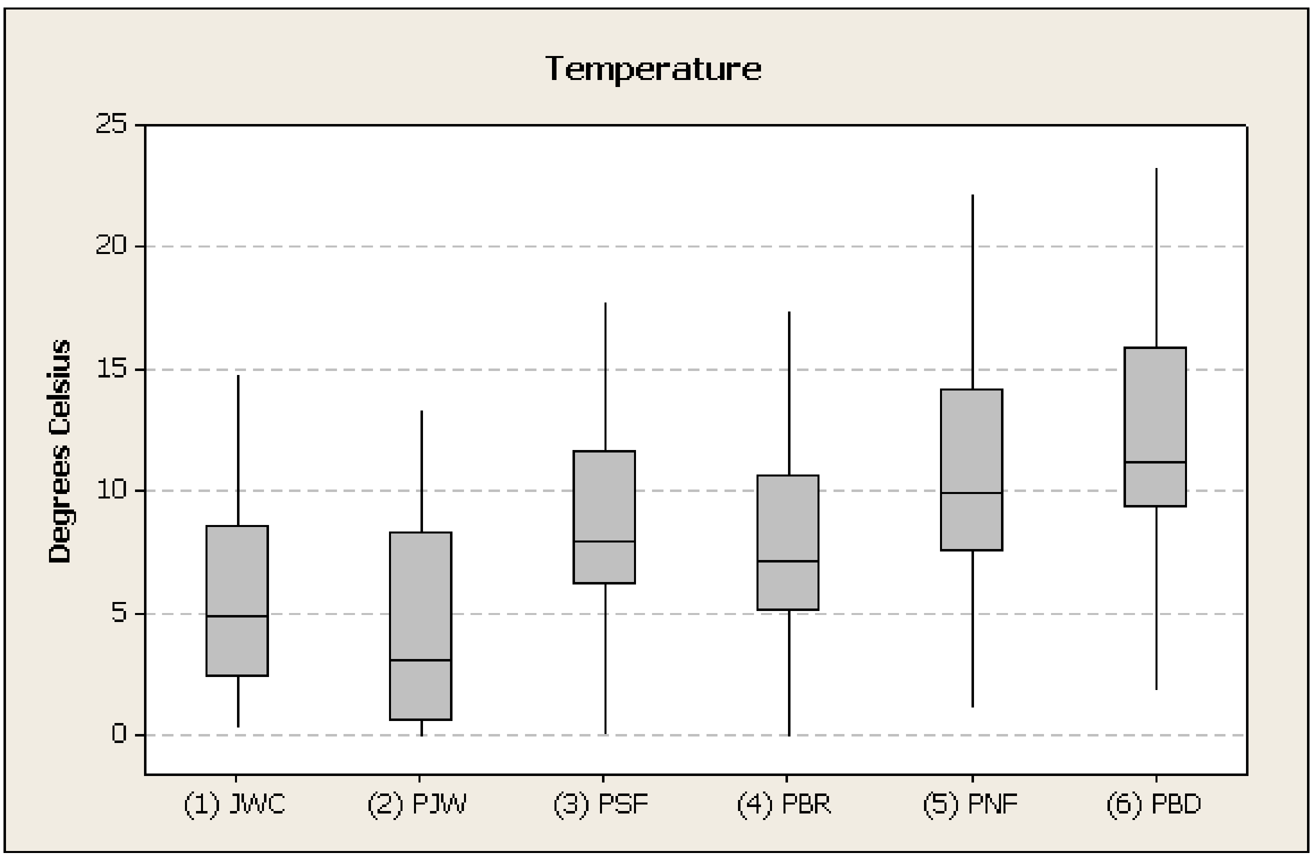


Figure 6. Boxplots of Temperature at key sites on the Mainstem CLP

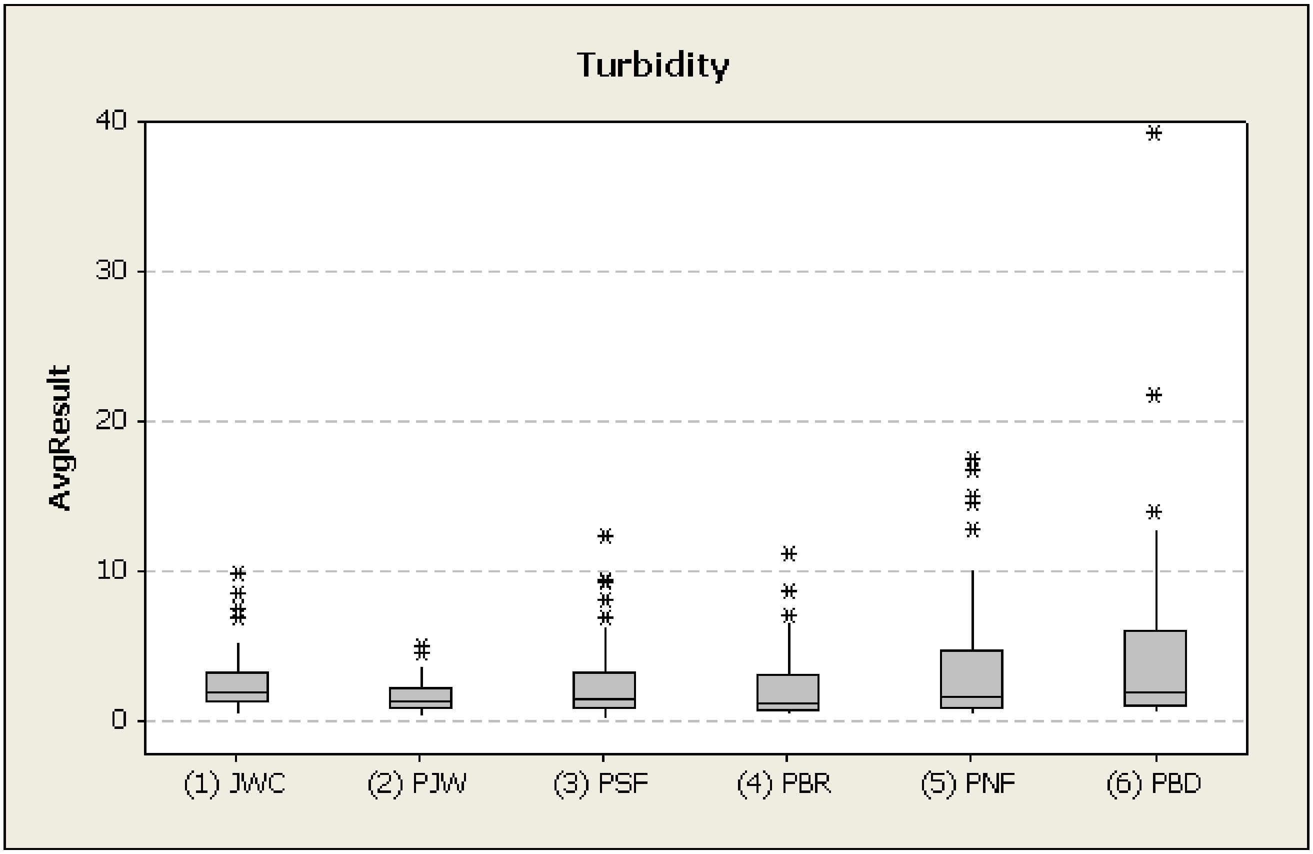


Figure 7. Boxplots of Turbidity at key sites on the Mainstem CLP

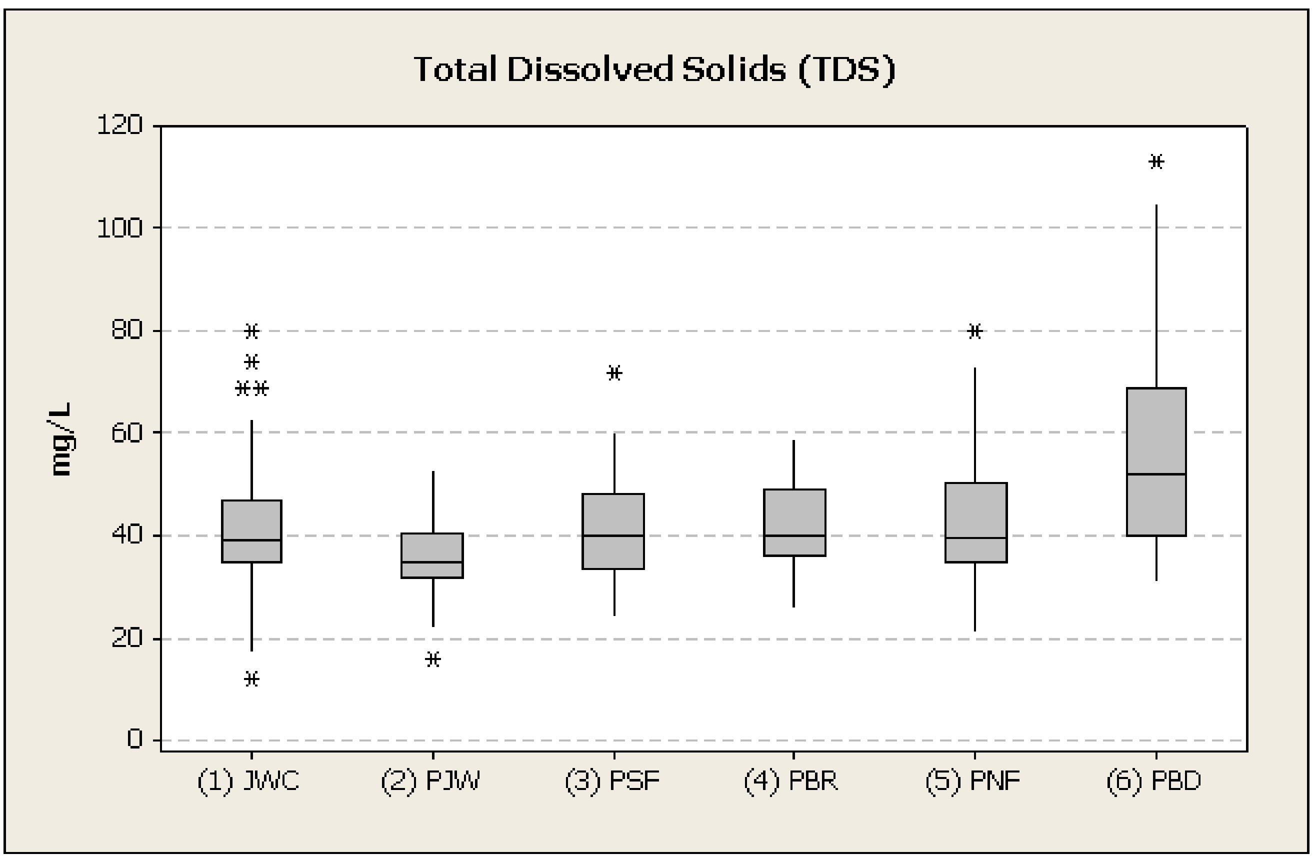


Figure 8. Boxplots of Total Dissolved Solids (TDS) at key sites on the Mainstem CLP

Nutrients

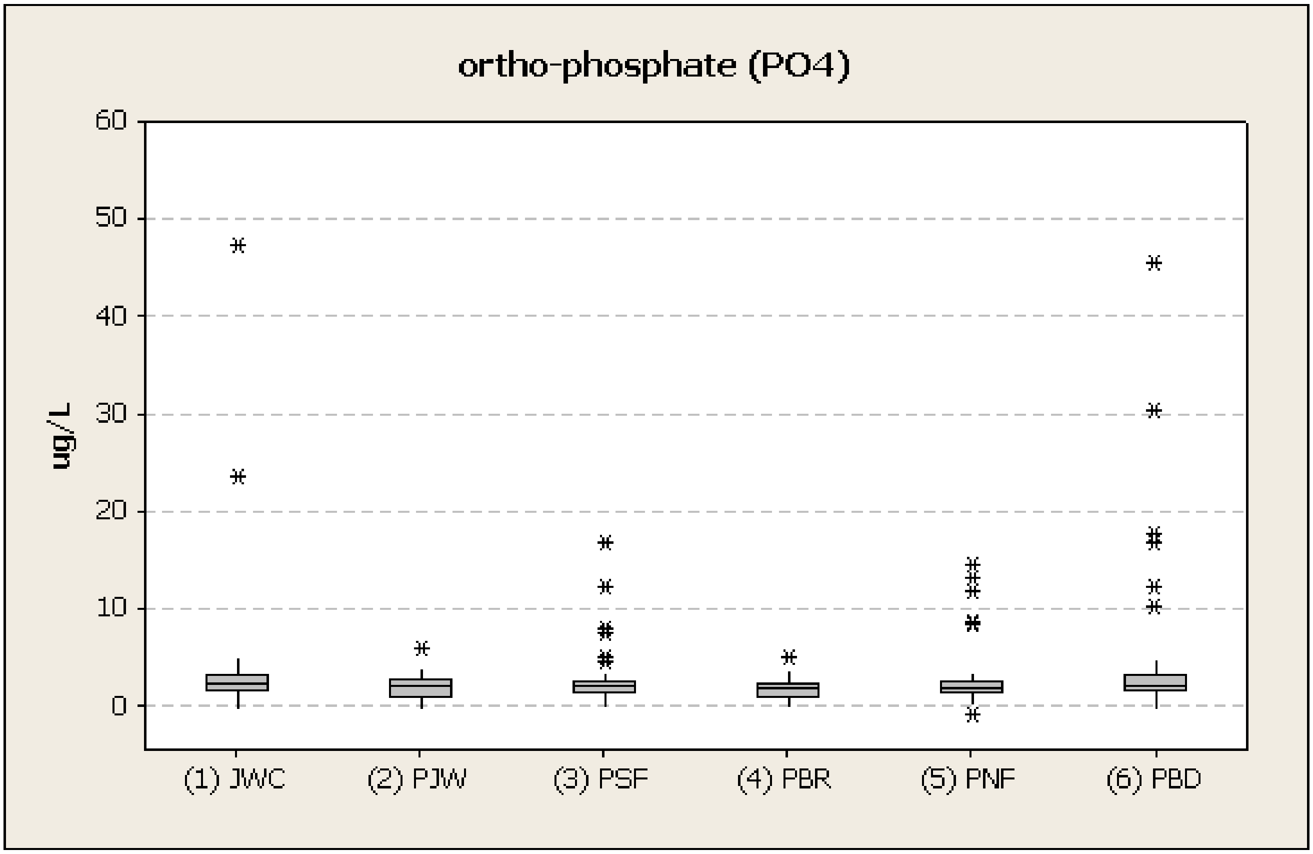


Figure 9. Boxplots of Ortho-phosphate (PO4) at key sites on the Mainstem CLP

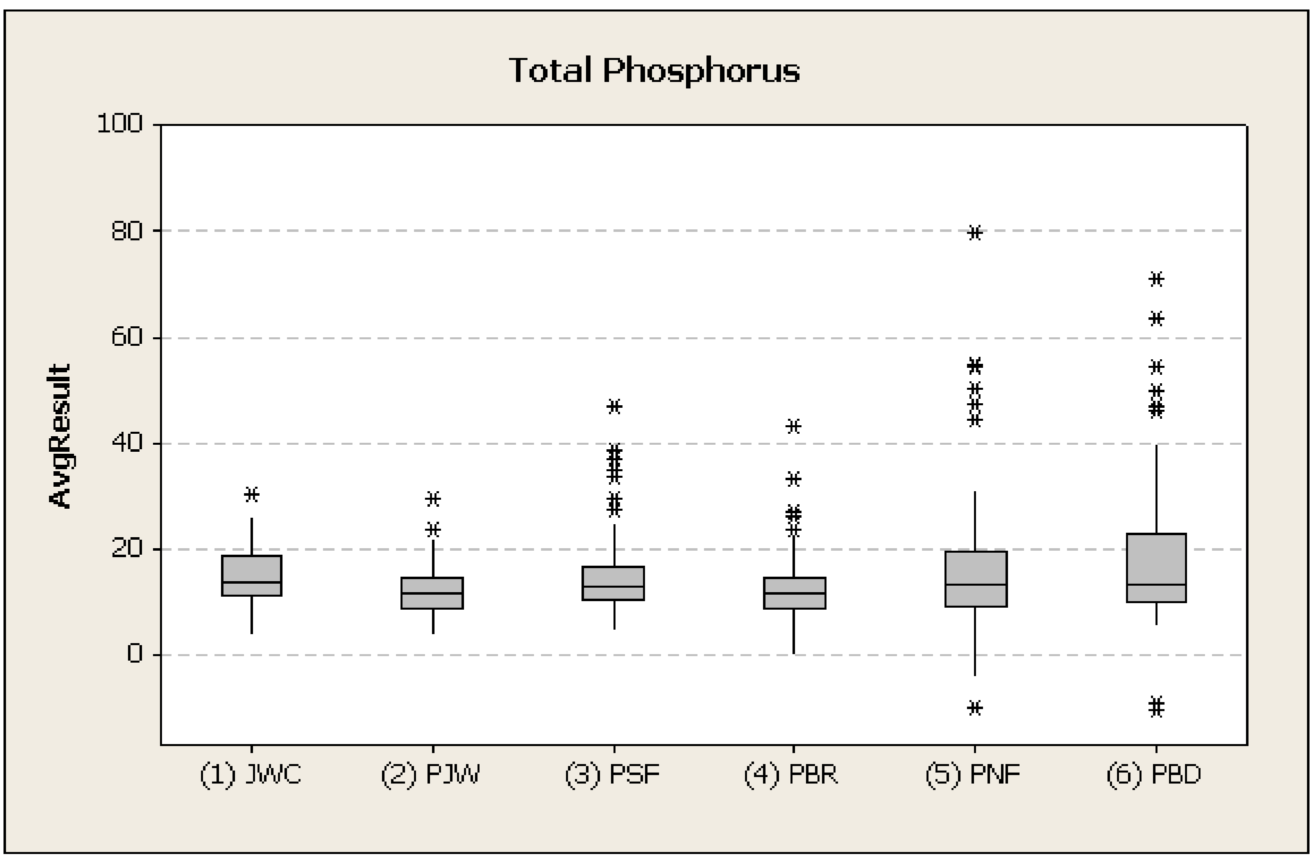


Figure 8. Boxplots of Total Phosphorus at key sites on the Mainstem CLP

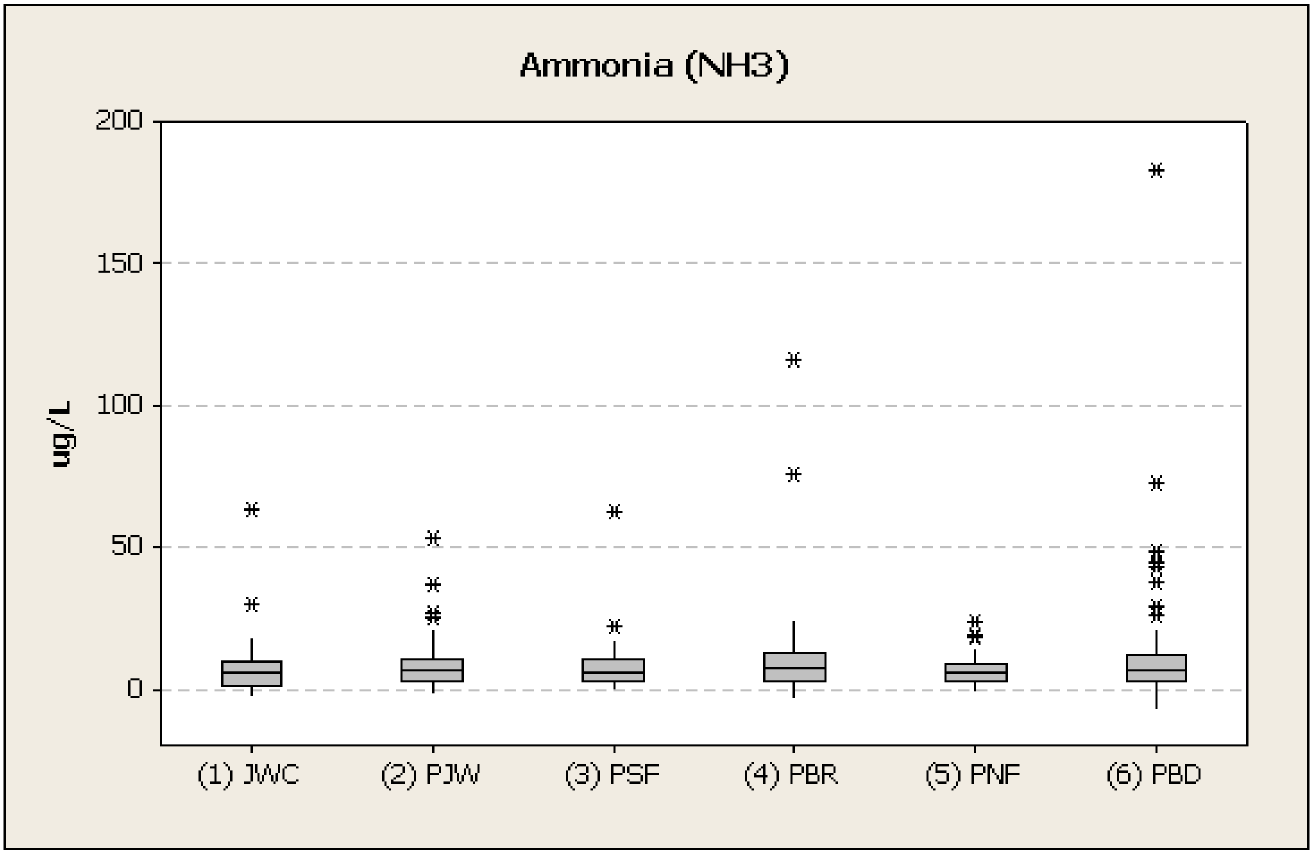


Figure 10. Boxplots of Ammonia (NH3) at key sites on the Mainstem CLP

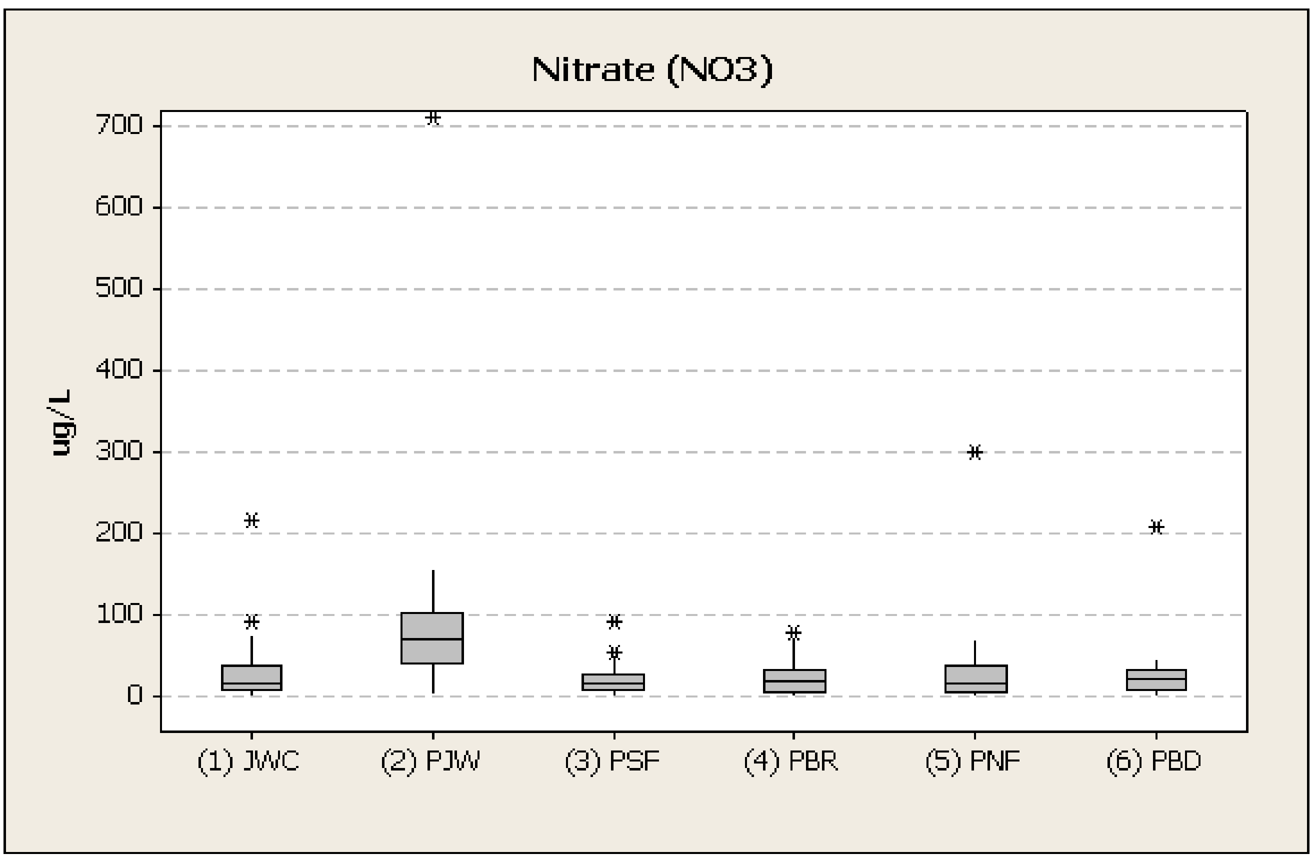


Figure 11. Boxplots of Nitrate (NO3) at key sites on the Mainstem CLP

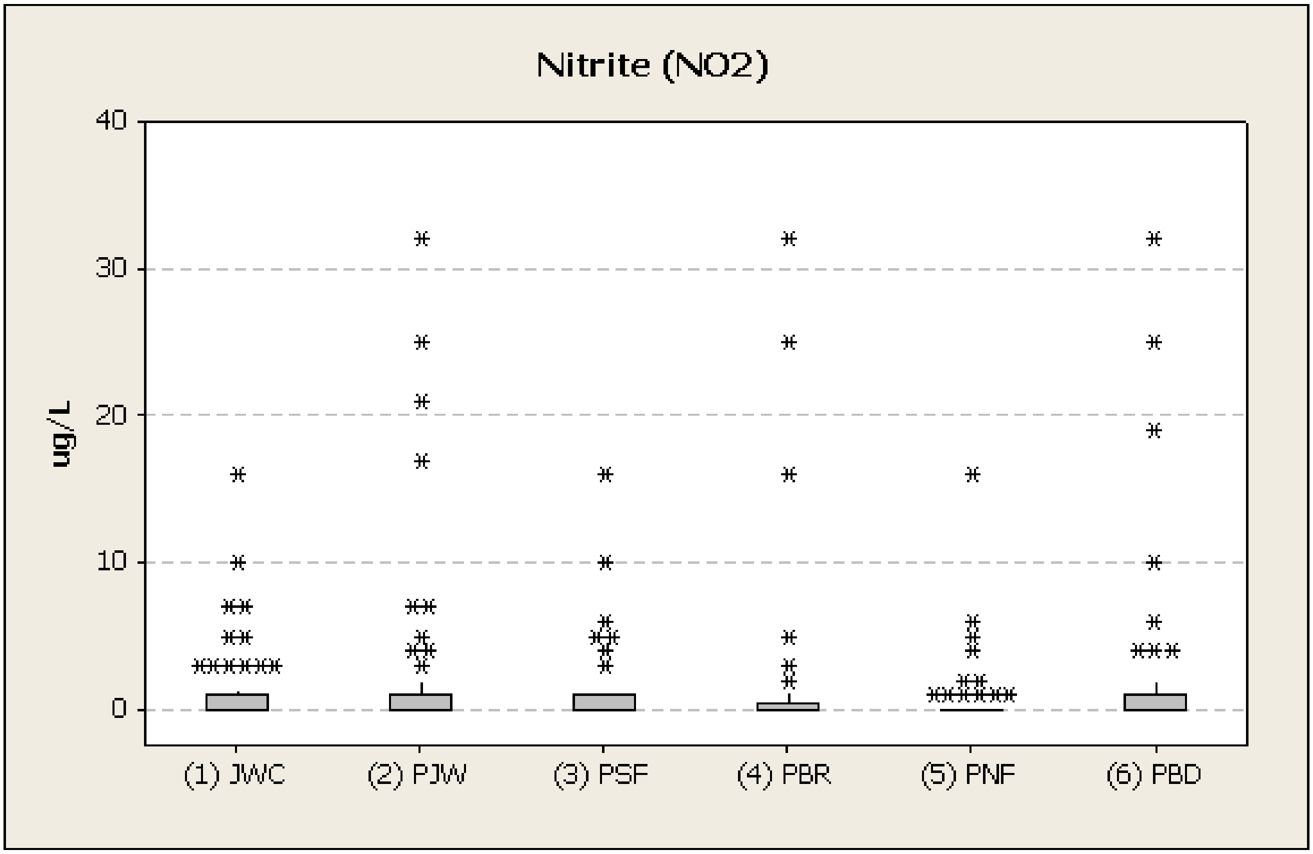


Figure 12. Boxplots of Nitrite (NO2) at key sites on the Mainstem CLP

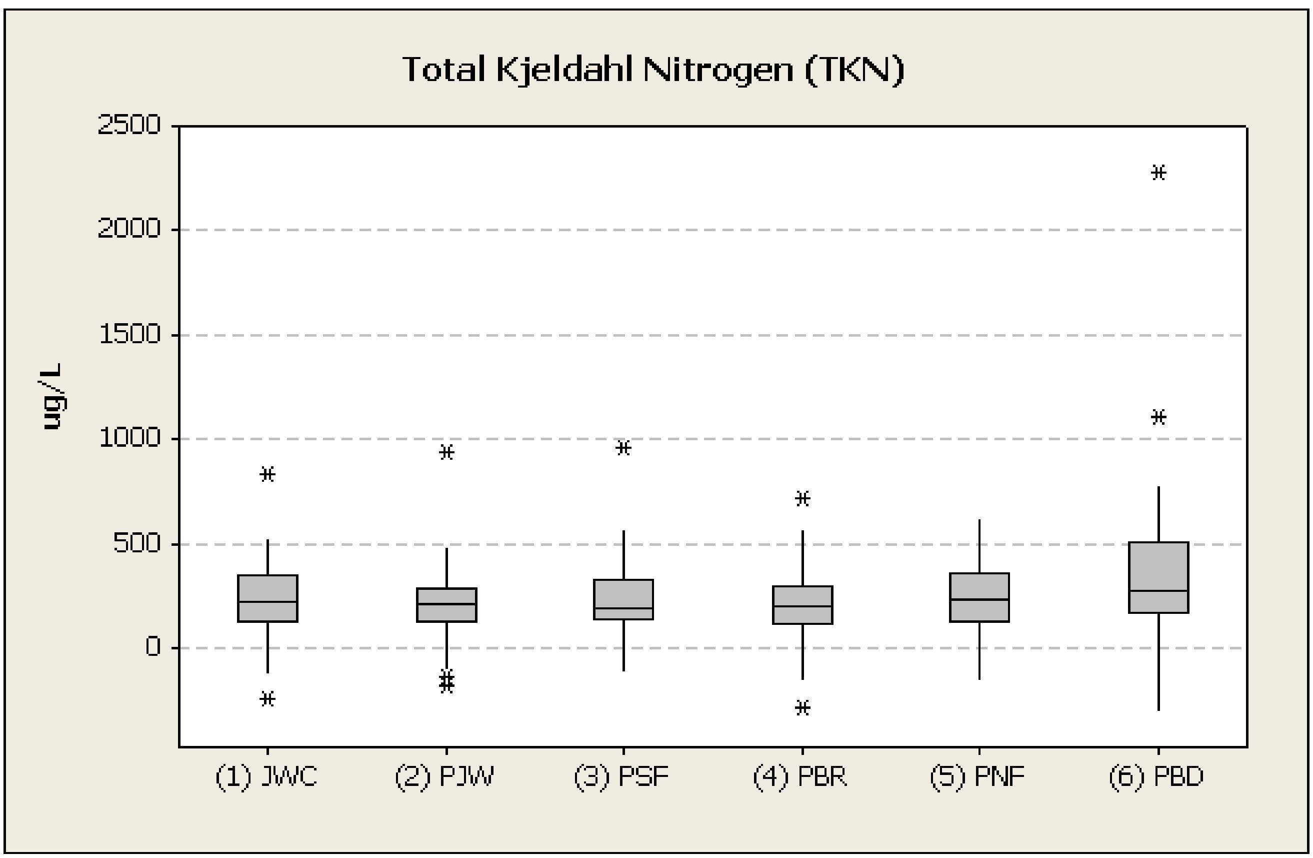


Figure 13. Boxplots of Total Kjeldahl Nitrogen (TKN) at key sites on the Mainstem CLP

Microbial Constituents

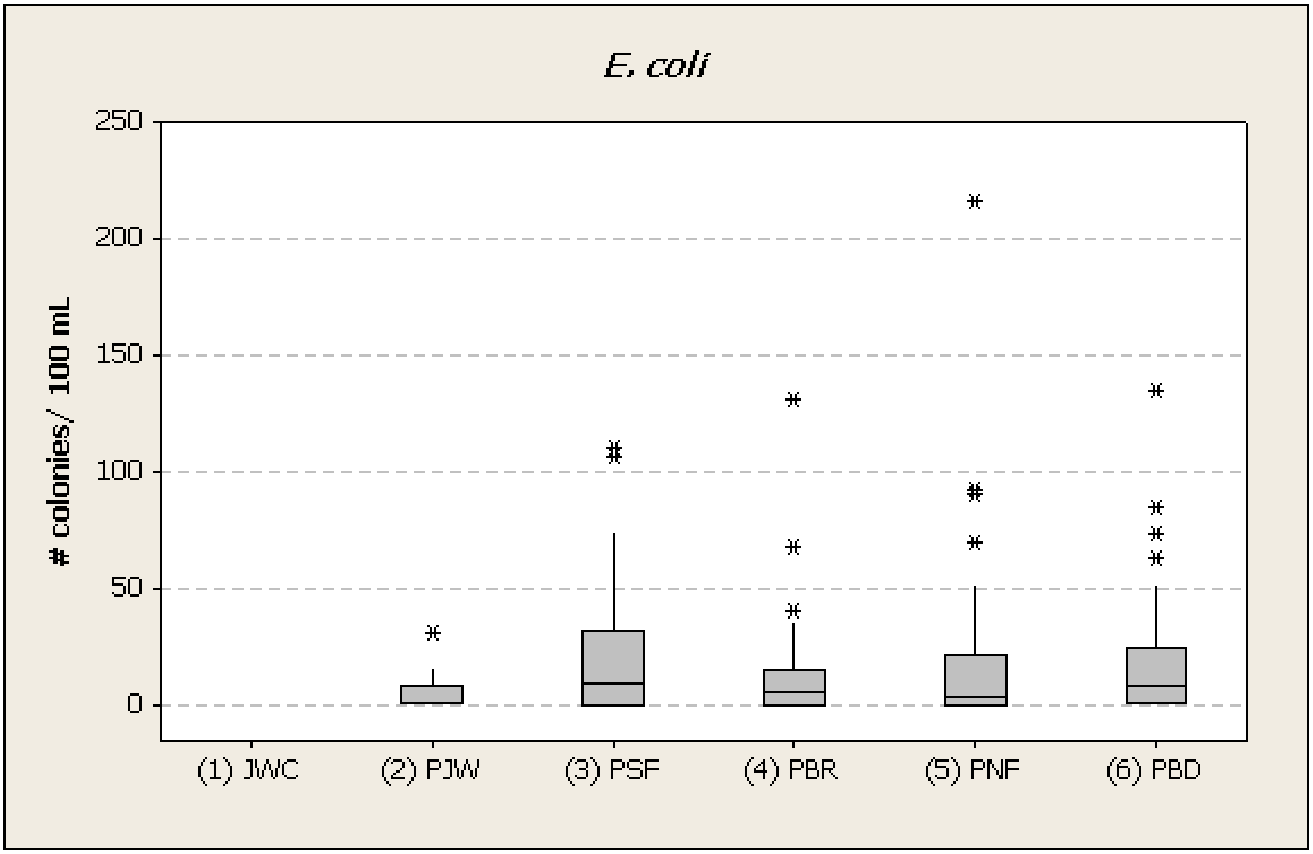


Figure 14. Boxplots of *E. coli* at key sites on the Mainstem CLP

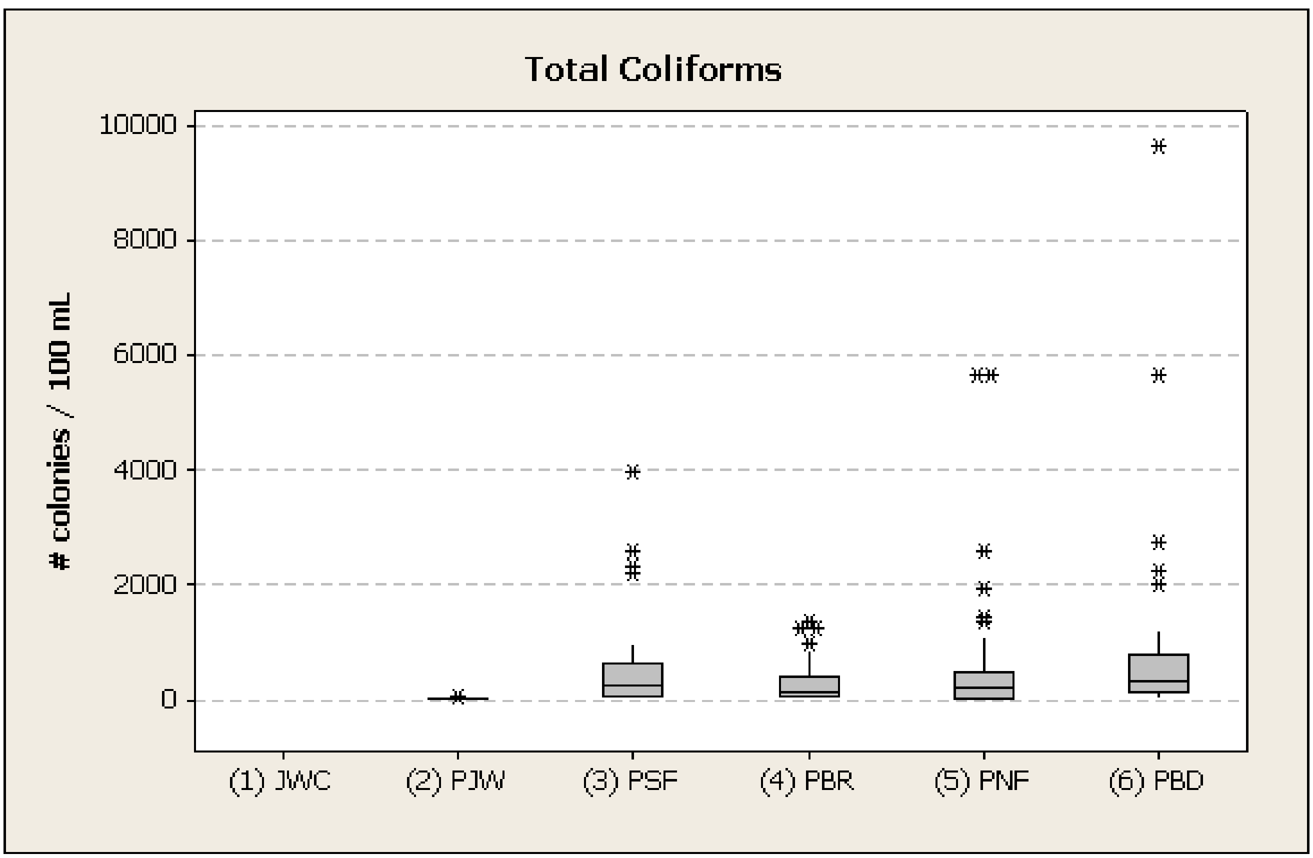


Figure 15. Boxplots of Total Coliforms at key sites on the Mainstem CLP

Major Ions

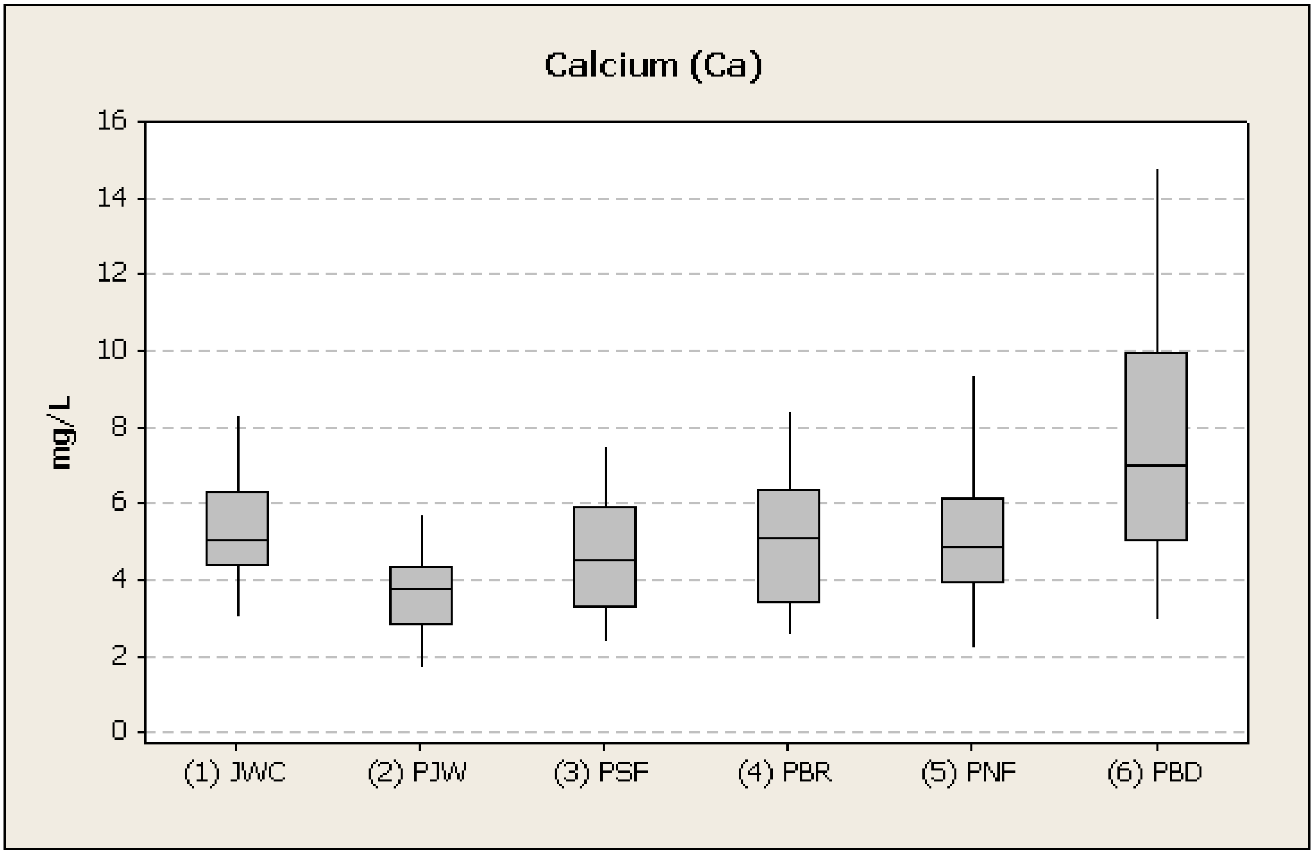


Figure 16. Boxplots of Calcium (Ca) at key sites on the Mainstem CLP

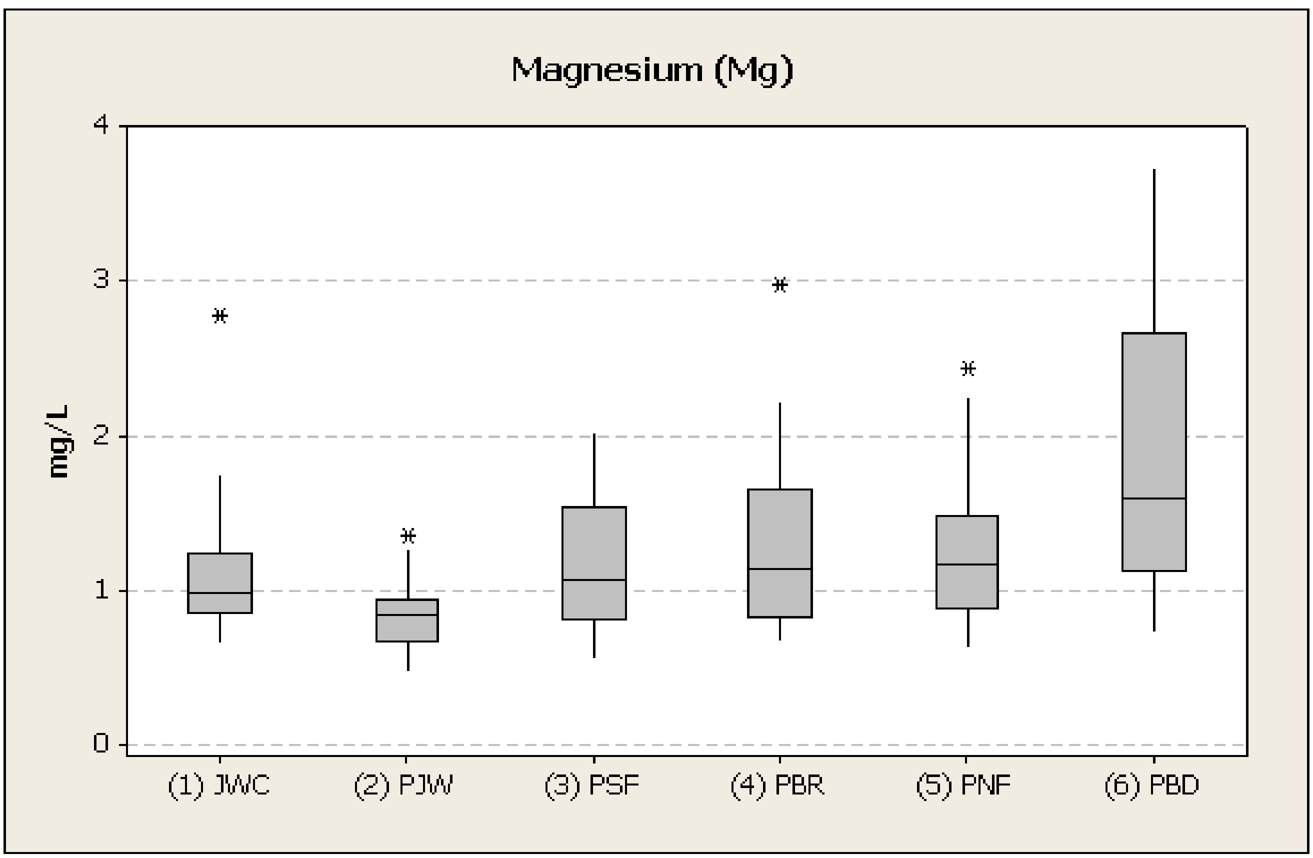


Figure 17. Boxplots of Magnesium (Mg) at key sites on the Mainstem CLP

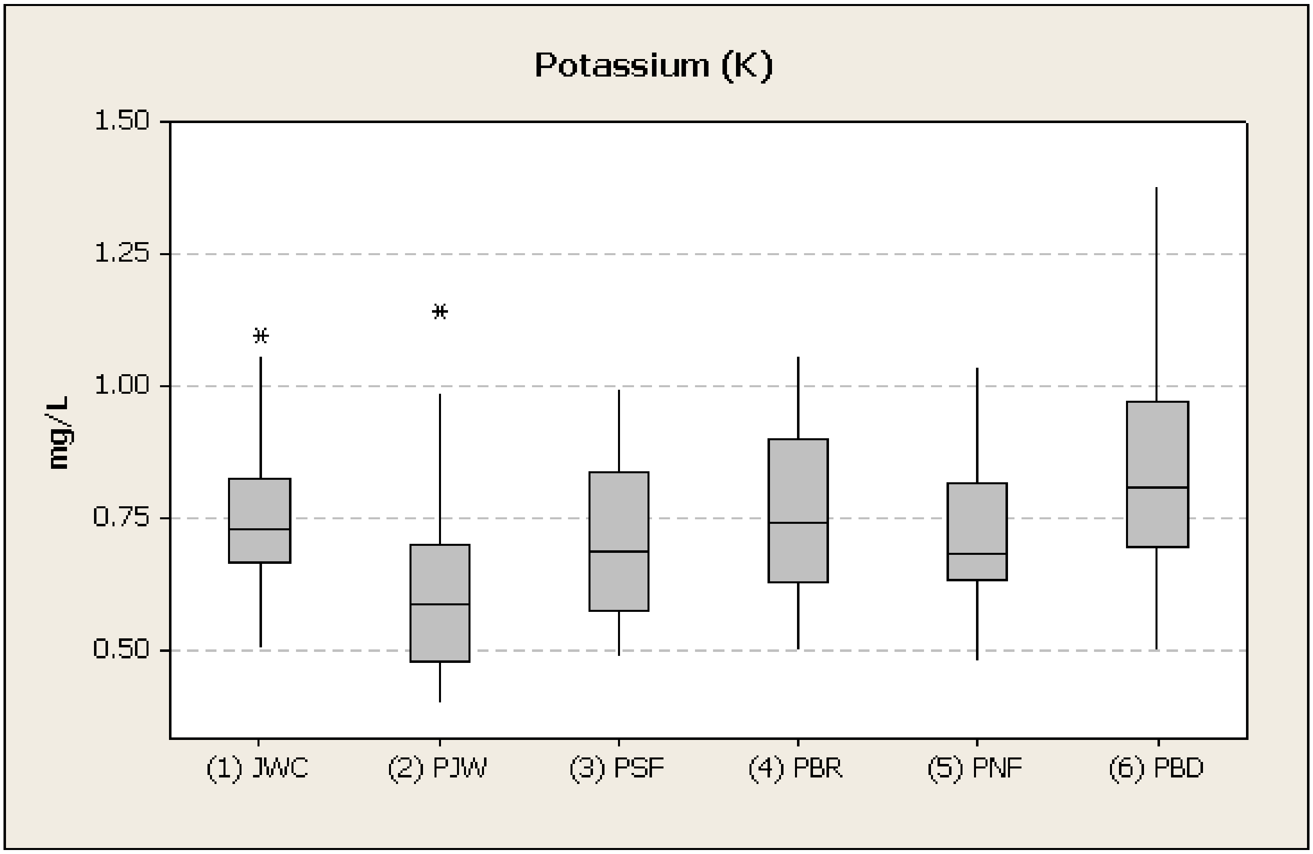


Figure 18. Boxplots of Potassium (K) at key sites on the Mainstem CLP

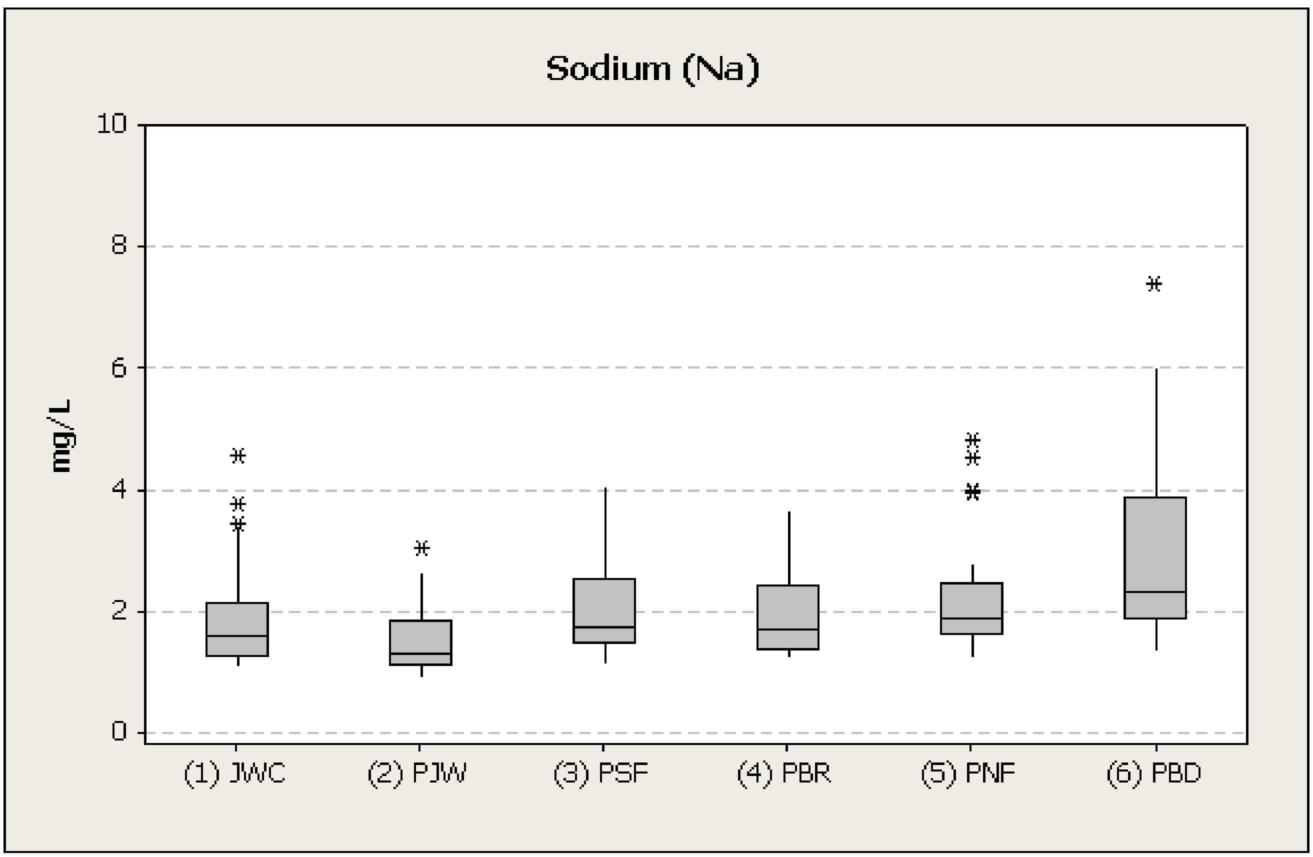


Figure 19. Boxplots of Sodium (Na) at key sites on the Mainstem CLP

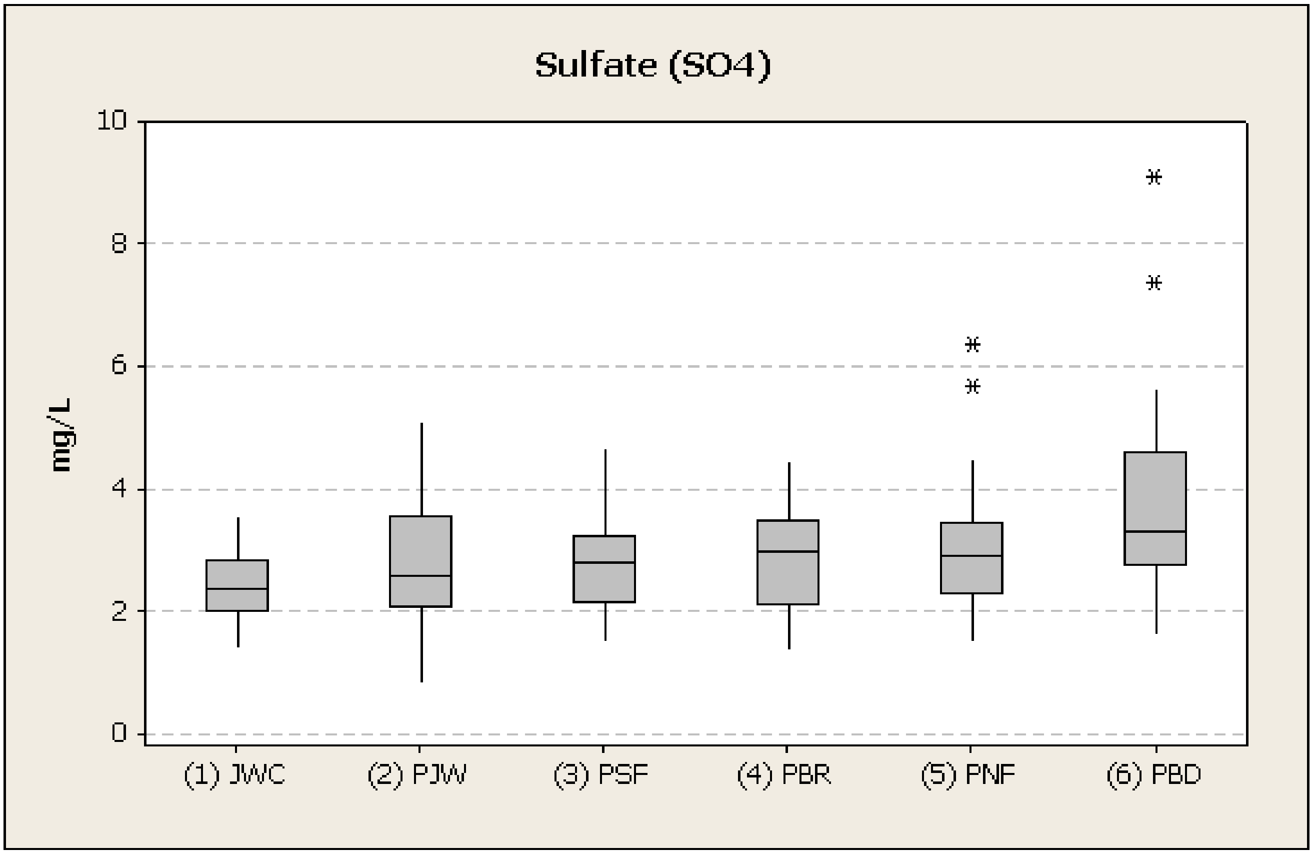


Figure 20. Boxplots of Sulfate (SO4) at key sites on the Mainstem CLP

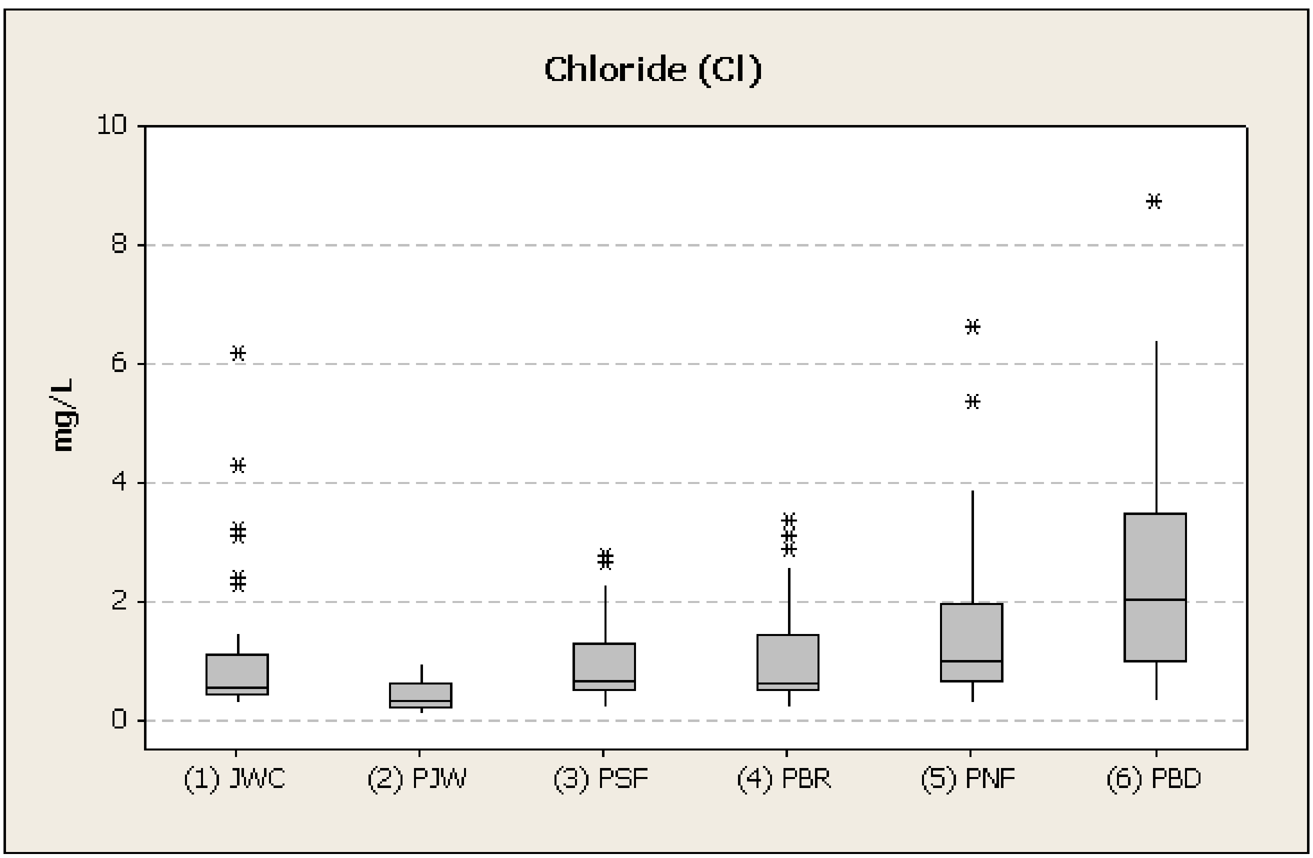


Figure 21. Boxplots of Chloride (Cl) at key sites on the Mainstem CLP

ATTACHMENT 9

2012 Upper CLP Collaborative Water Quality Monitoring Program

Graphical Summary

Mainstem and North Fork CLP: Daily Average Stream Flow

Figure 1 (a & b). Daily average stream flow on the Mainstem and North Fork CLP

Figure 1.a. 2012 Daily average stream flow on the Mainstem and North Fork CLP

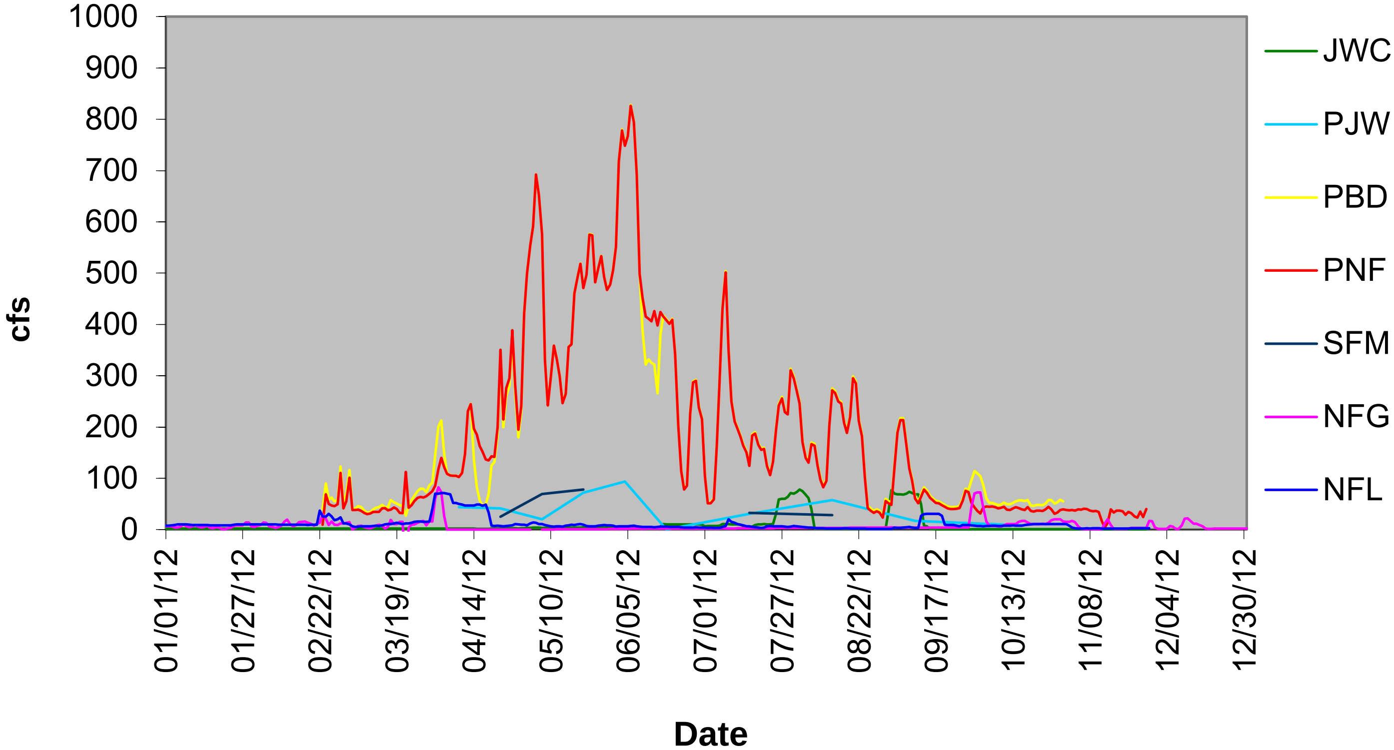


Figure 1.b. 2009 - 2012 Daily average stream flow on the Mainstem and North Fork CLP

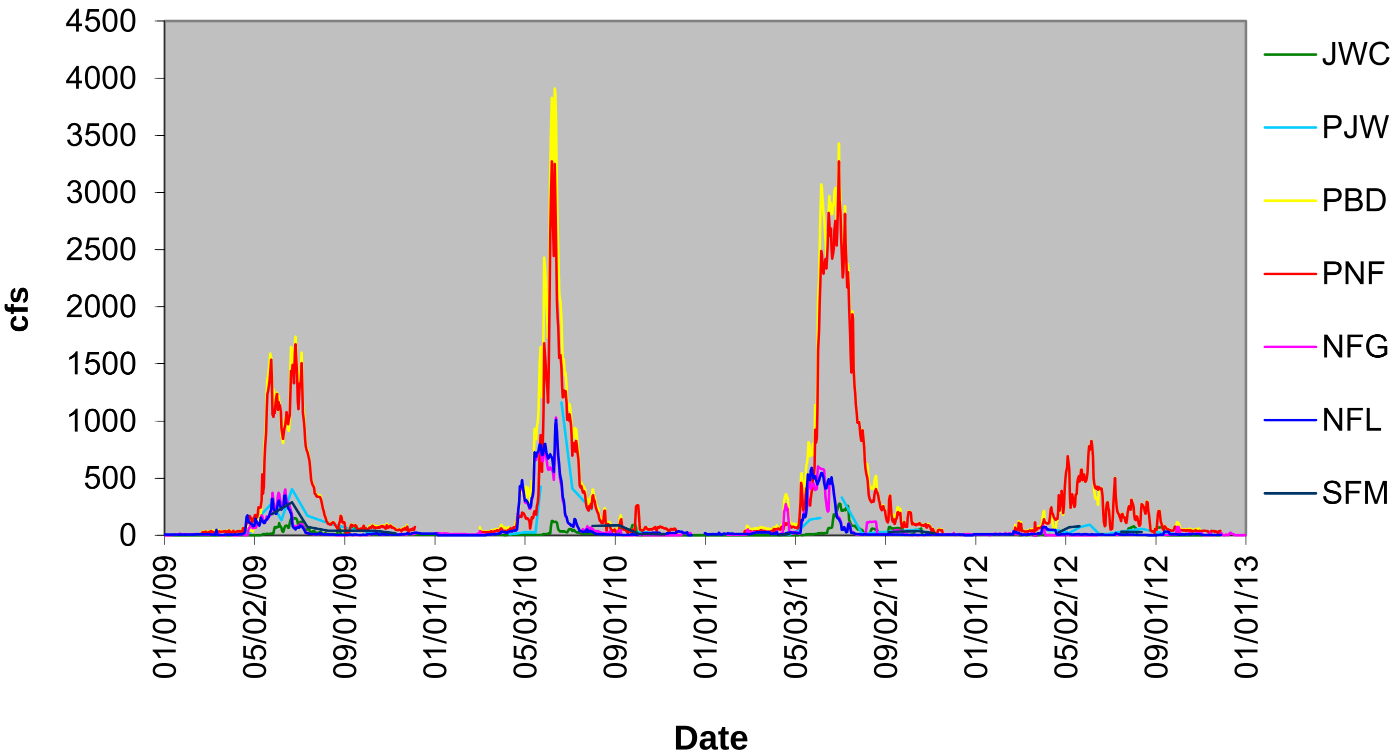


Figure 2 (a & b). Daily average stream flow on the North Fork tributaries

Figure 2.a. 2012 Daily average stream flow on the North Fork tributaries

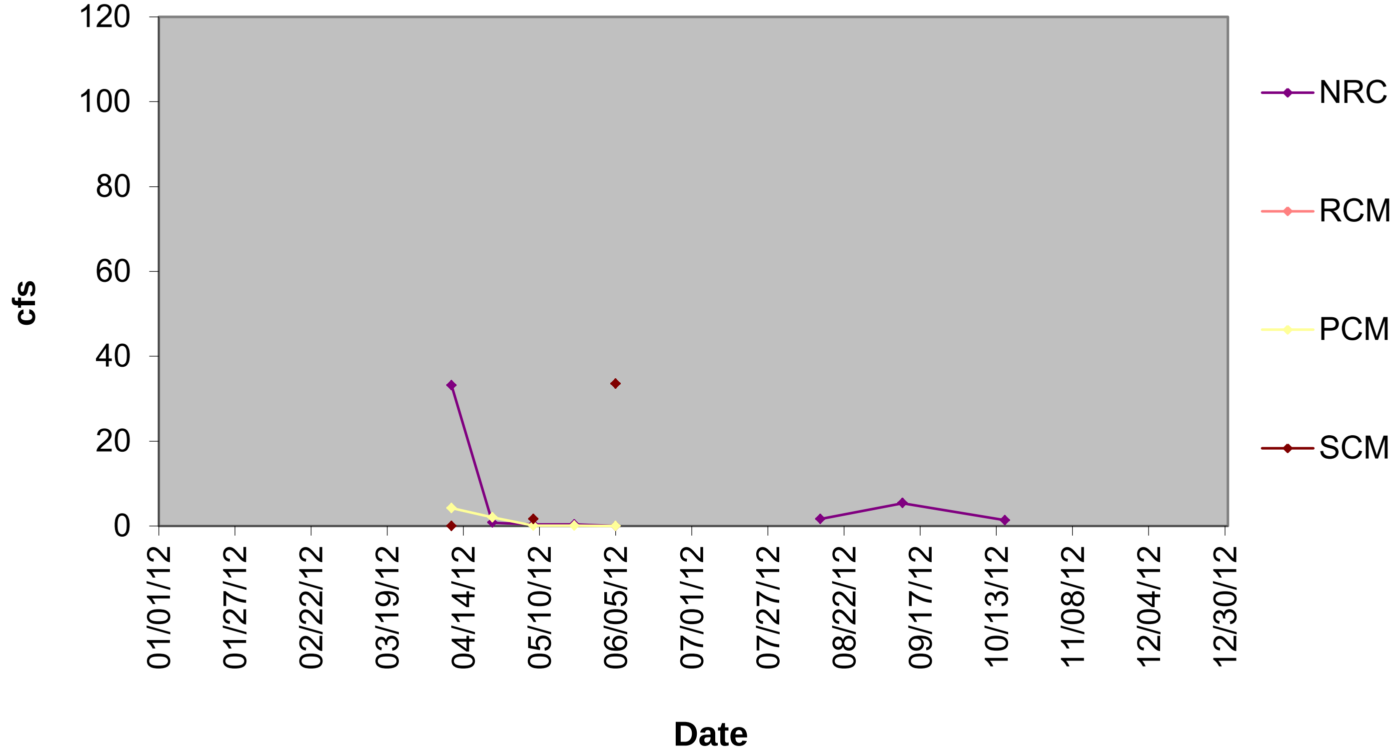
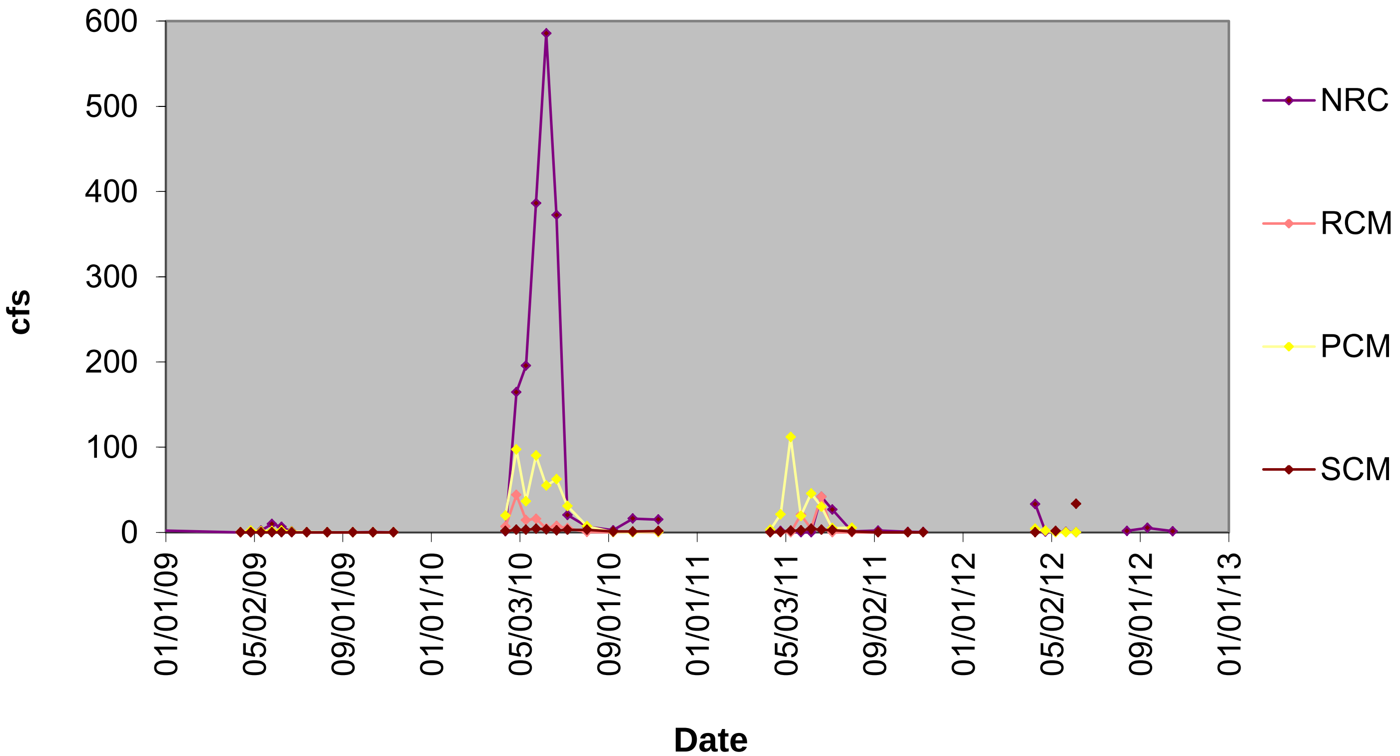


Figure 2.b. 2009 - 2012 Daily average stream flow on the North Fork tributaries



Mainstem and North Fork CLP:
General Parameters

Figure 3 (a & b). Water temperature

Figure 3.a. Water temperature on the Mainstem CLP

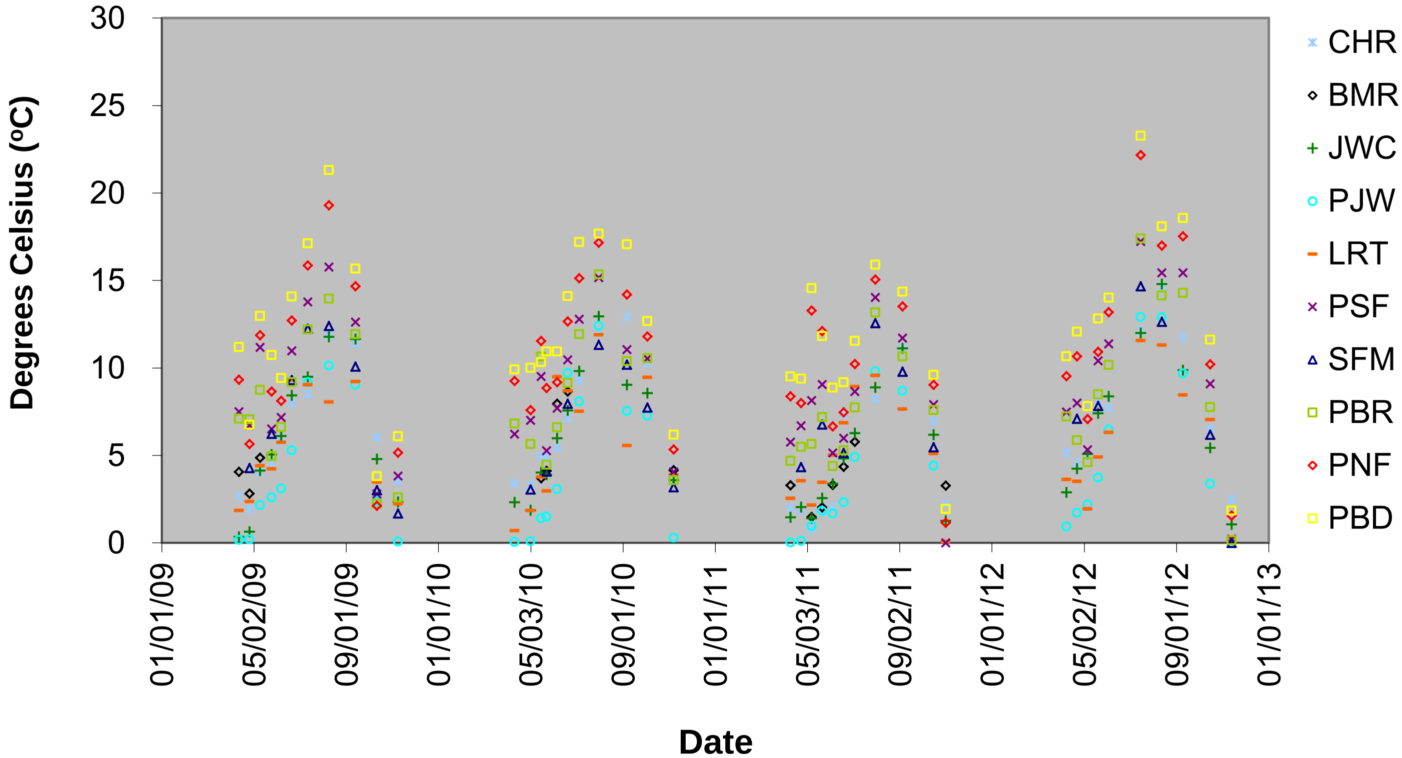


Figure 3.b. Water temperature on the North Fork CLP

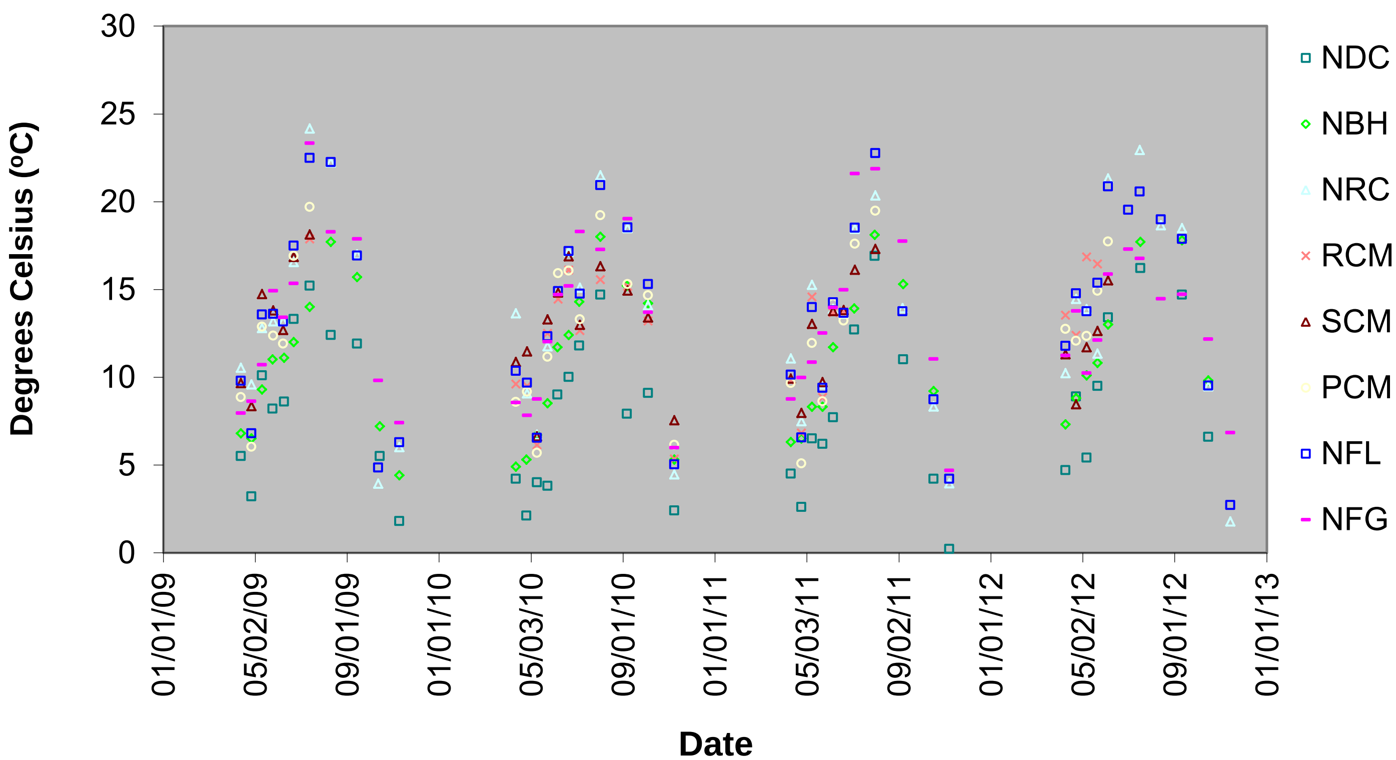


Figure 4 (a & b). pH

Figure 4.a. pH on the Mainstem CLP

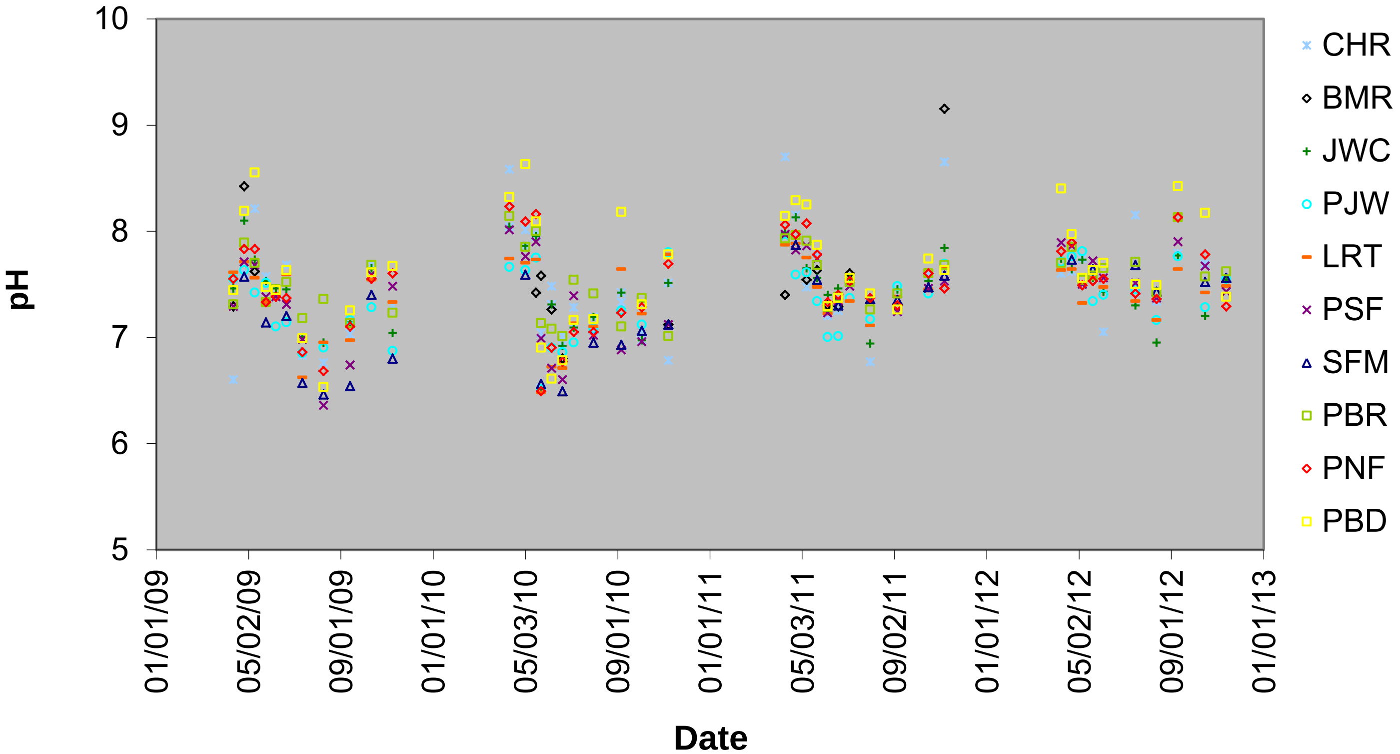


Figure 4.b. pH on the North Fork CLP

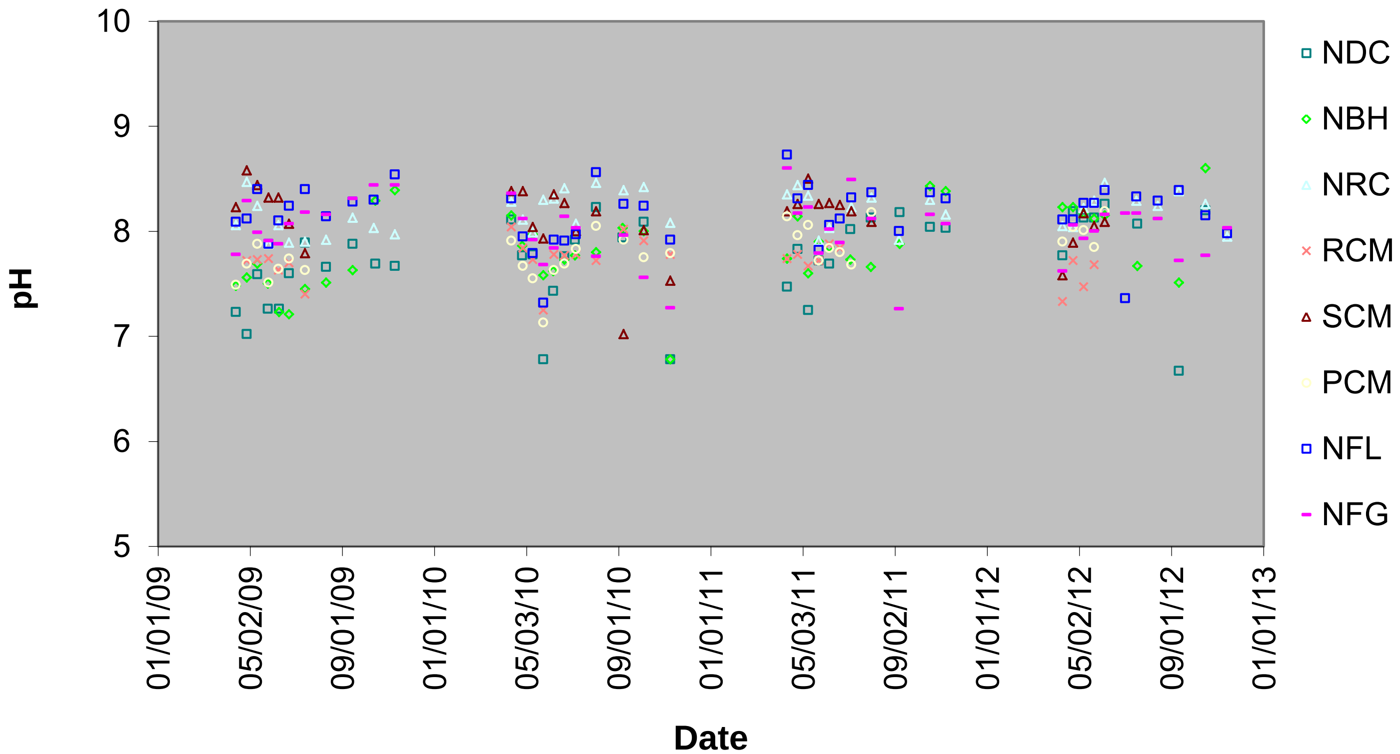


Figure 5 (a & b). Specific Conductance

Figure 5.a. Specific Conductance on the Mainstem CLP

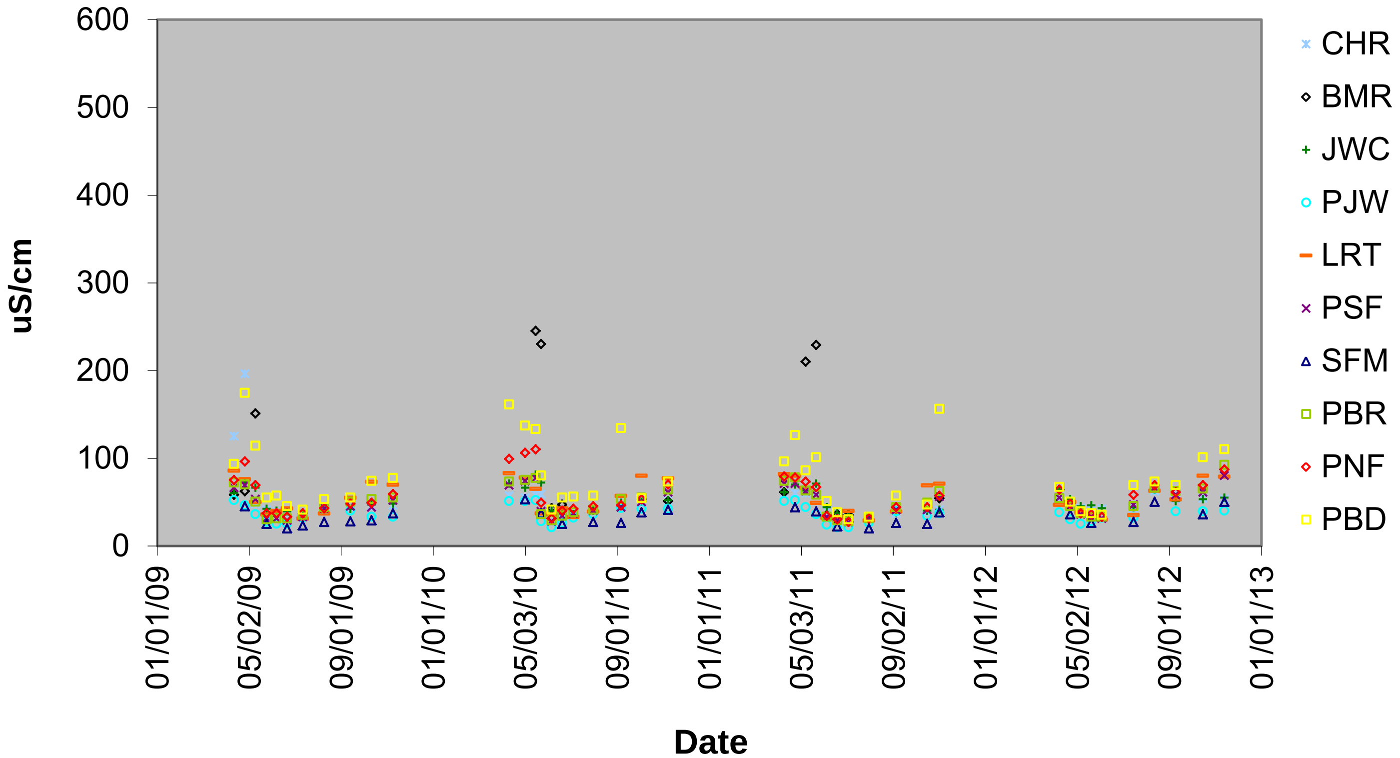


Figure 5.b. Specific conductance on the North Fork CLP

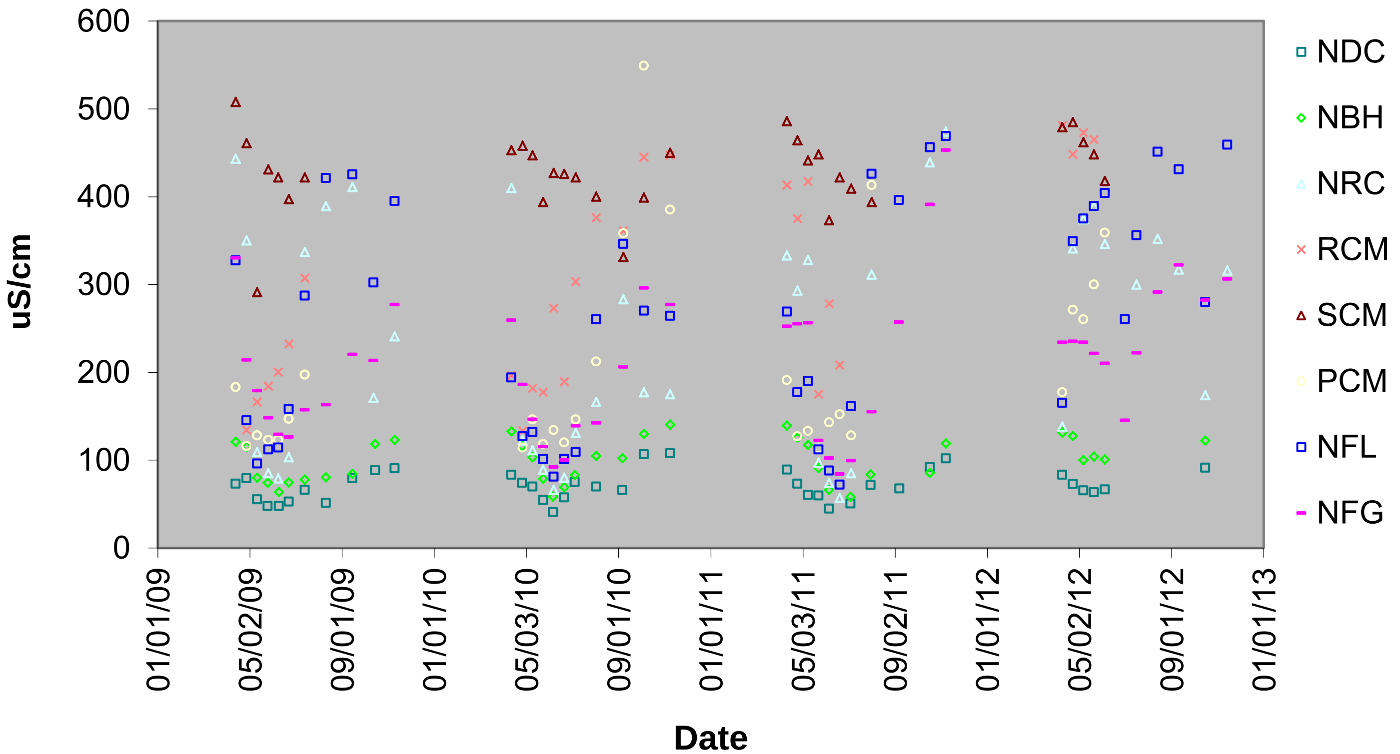


Figure 6 (a & b). Hardness

Figure 6.a. Hardness on the Mainstem CLP

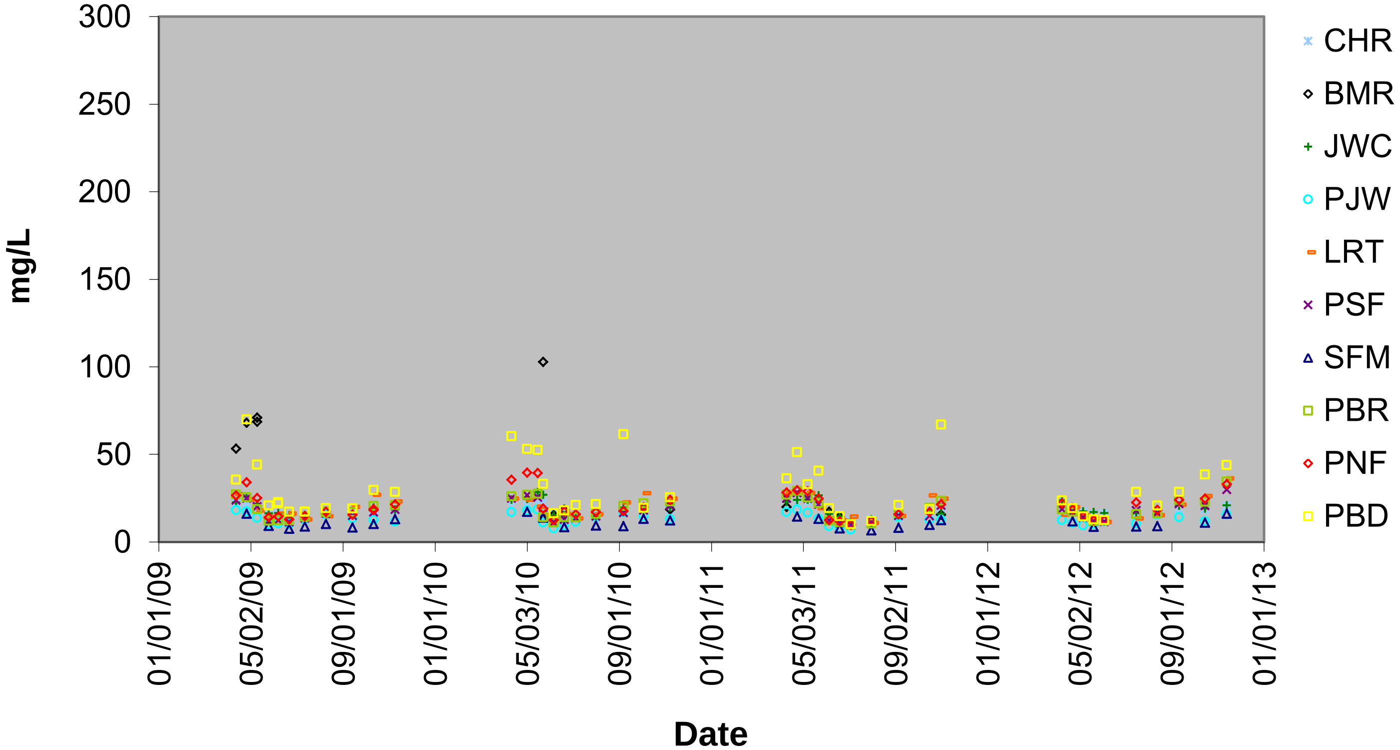


Figure 6.b. Hardness on the North Fork CLP

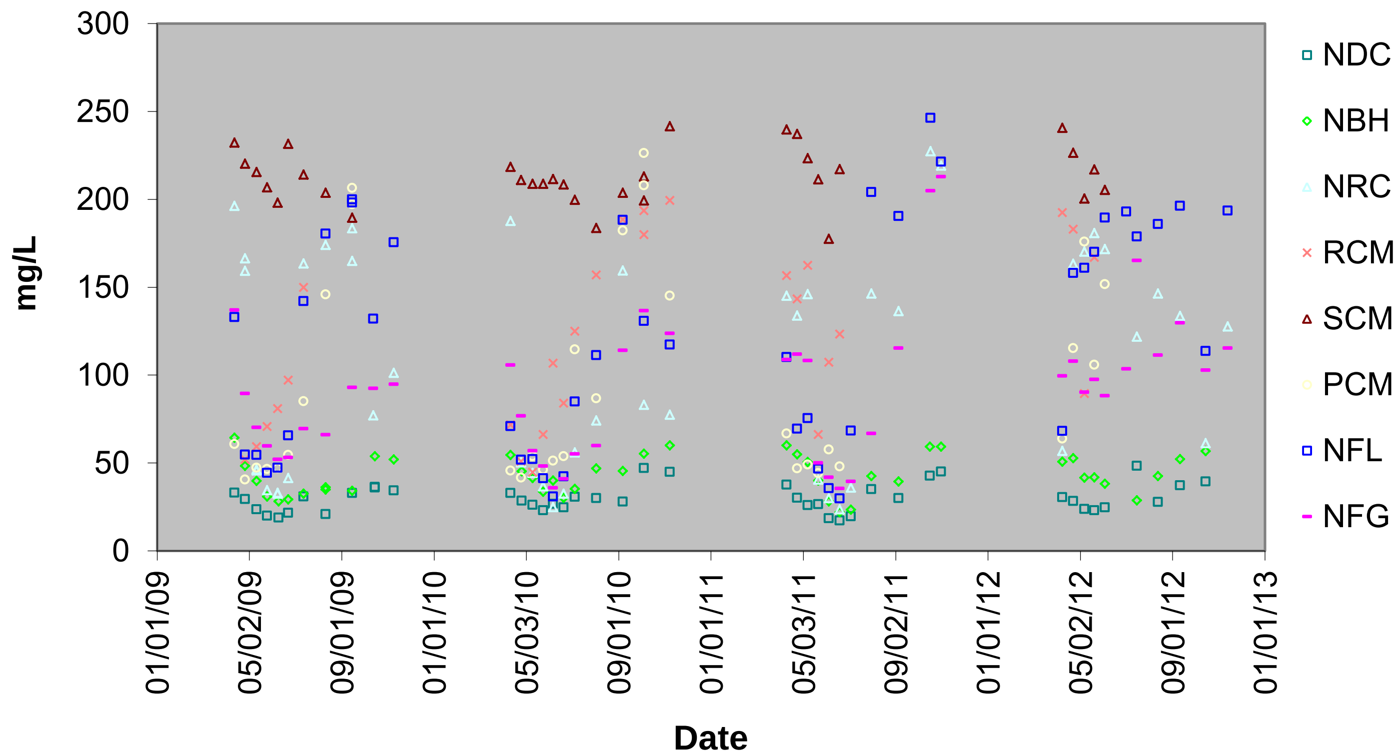


Figure 7 (a & b). Alkalinity

Figure 7.a. Alkalinity on the Mainstem CLP

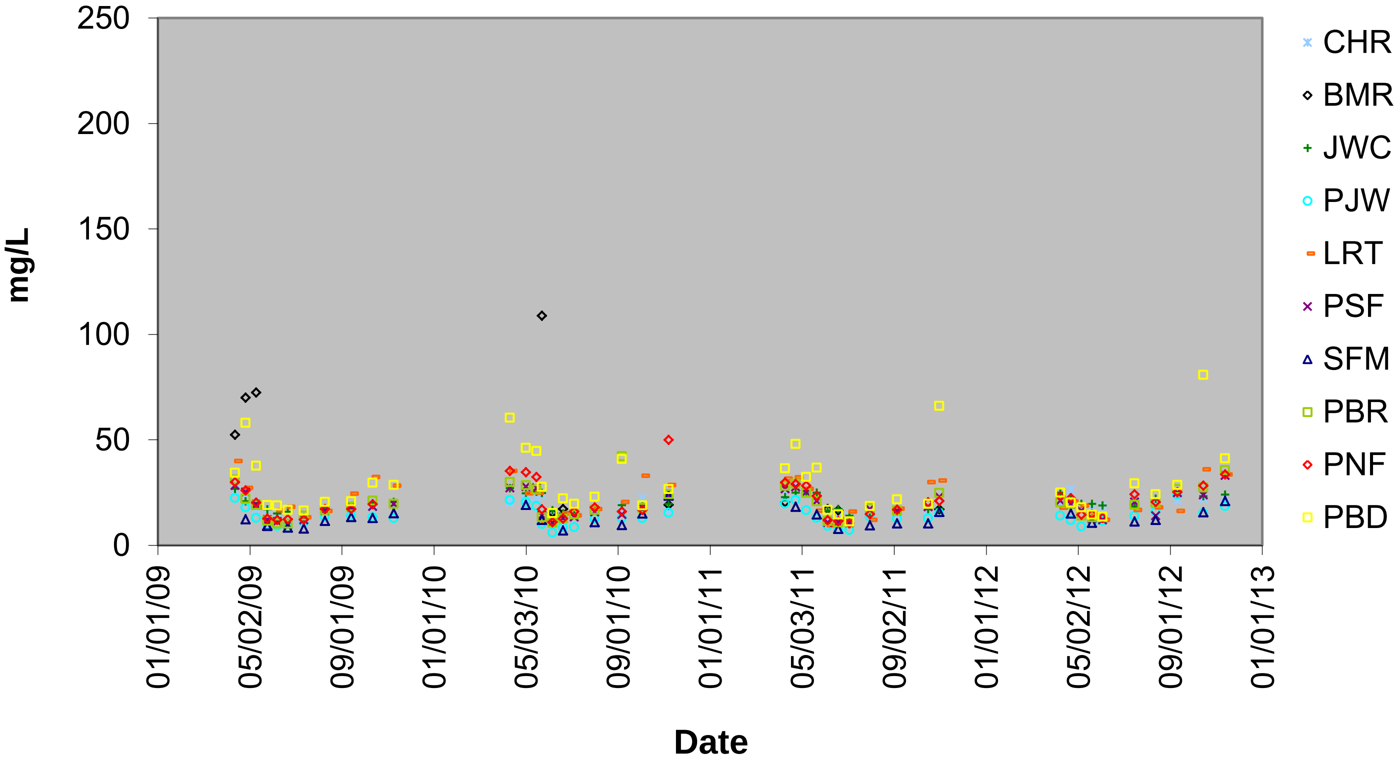


Figure 7.b. Alkalinity on the North Fork CLP

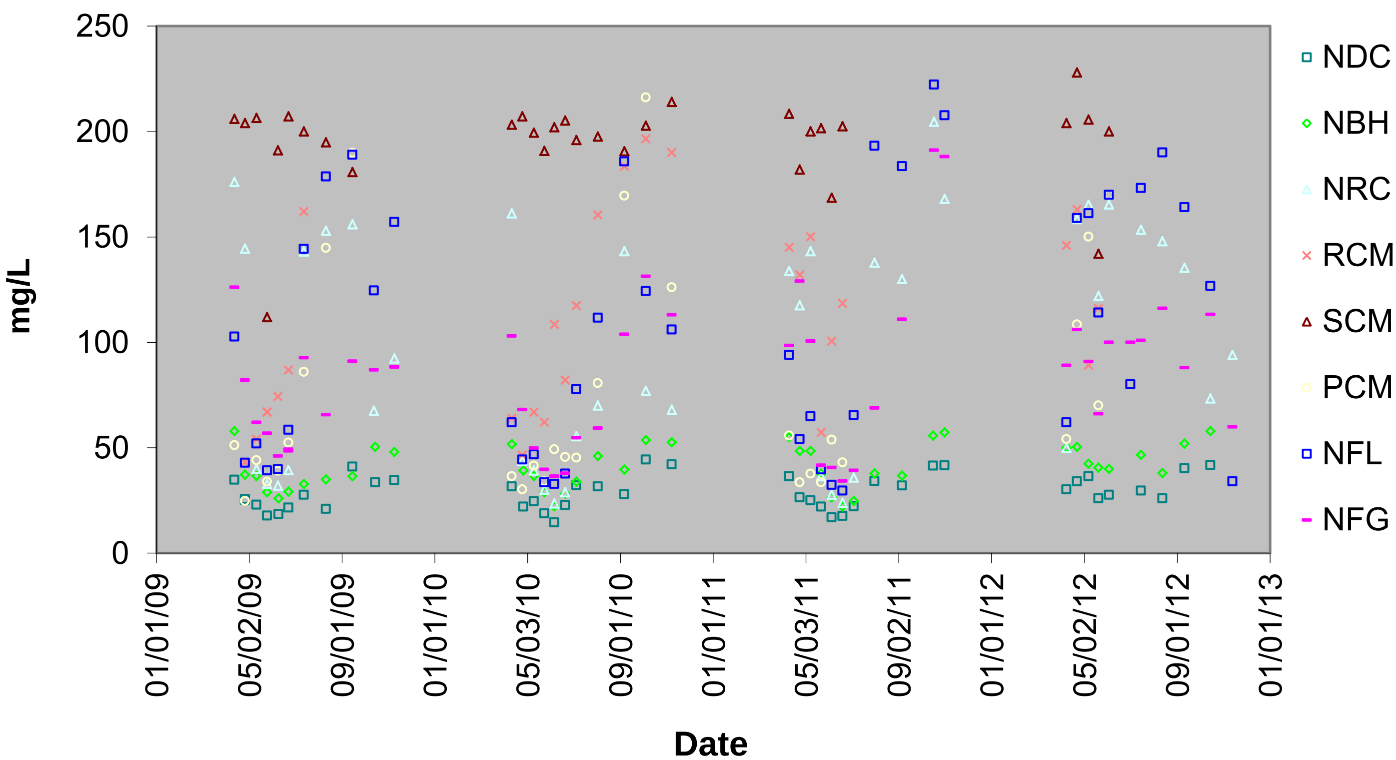


Figure 8 (a & b). Turbidity

Figure 8.a. Turbidity on the Mainstem CLP

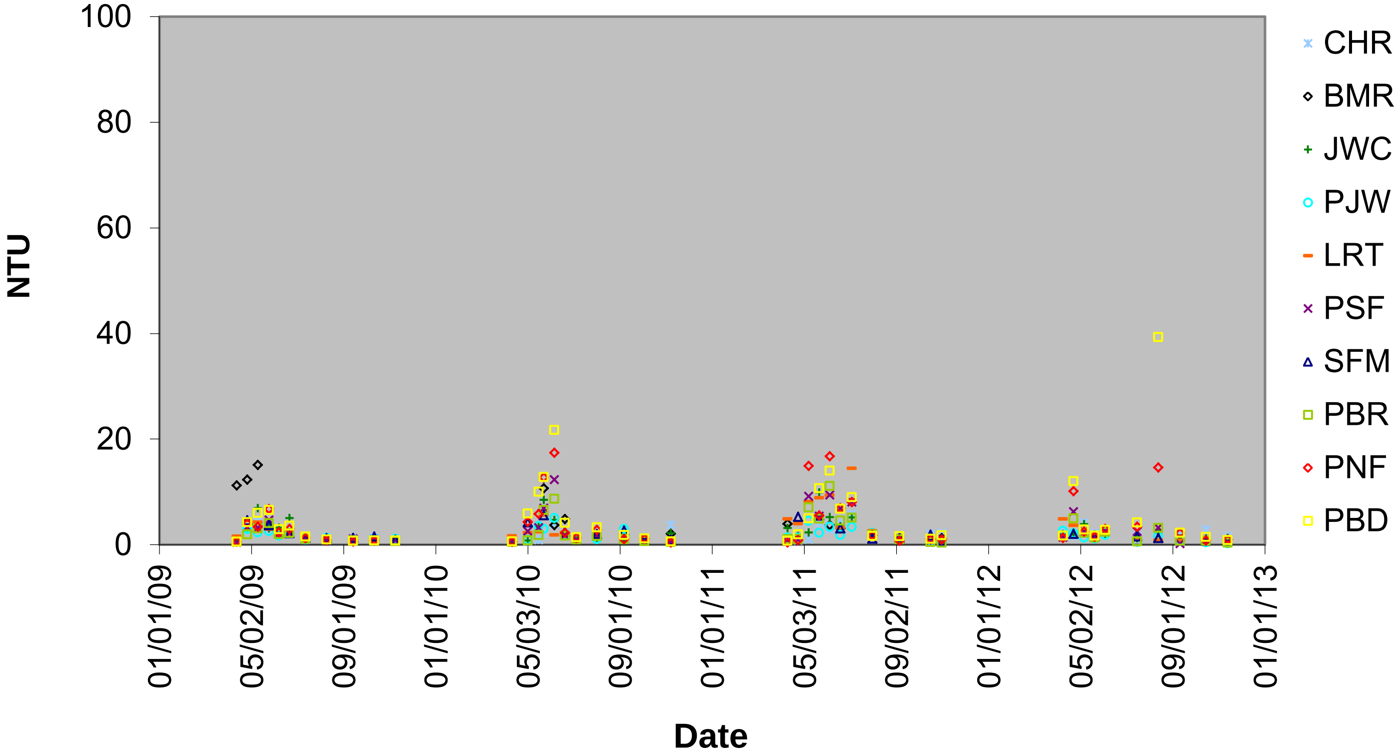


Figure 8.b. Turbidity on the North Fork CLP

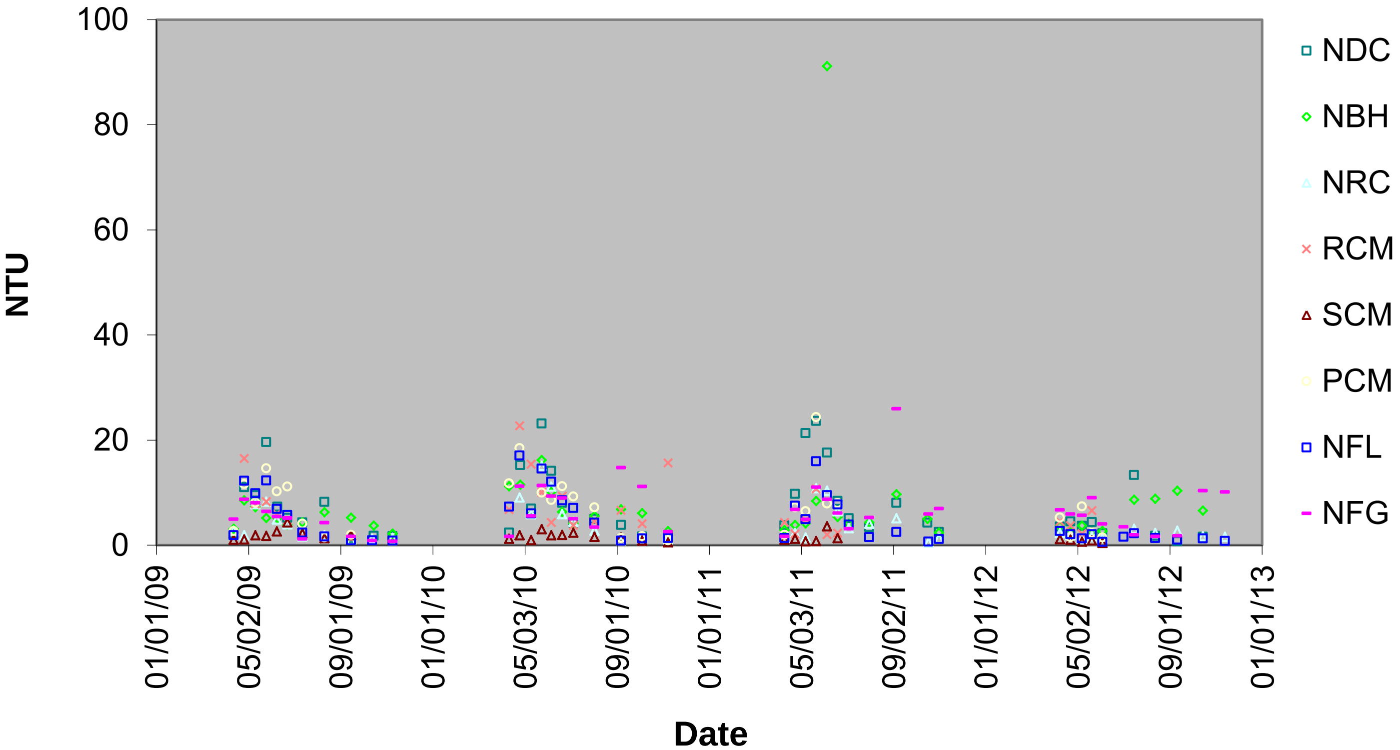


Figure 9 (a & b). Total Dissolved Solids (TDS)

Figure 9.a. TDS on the Mainstem CLP

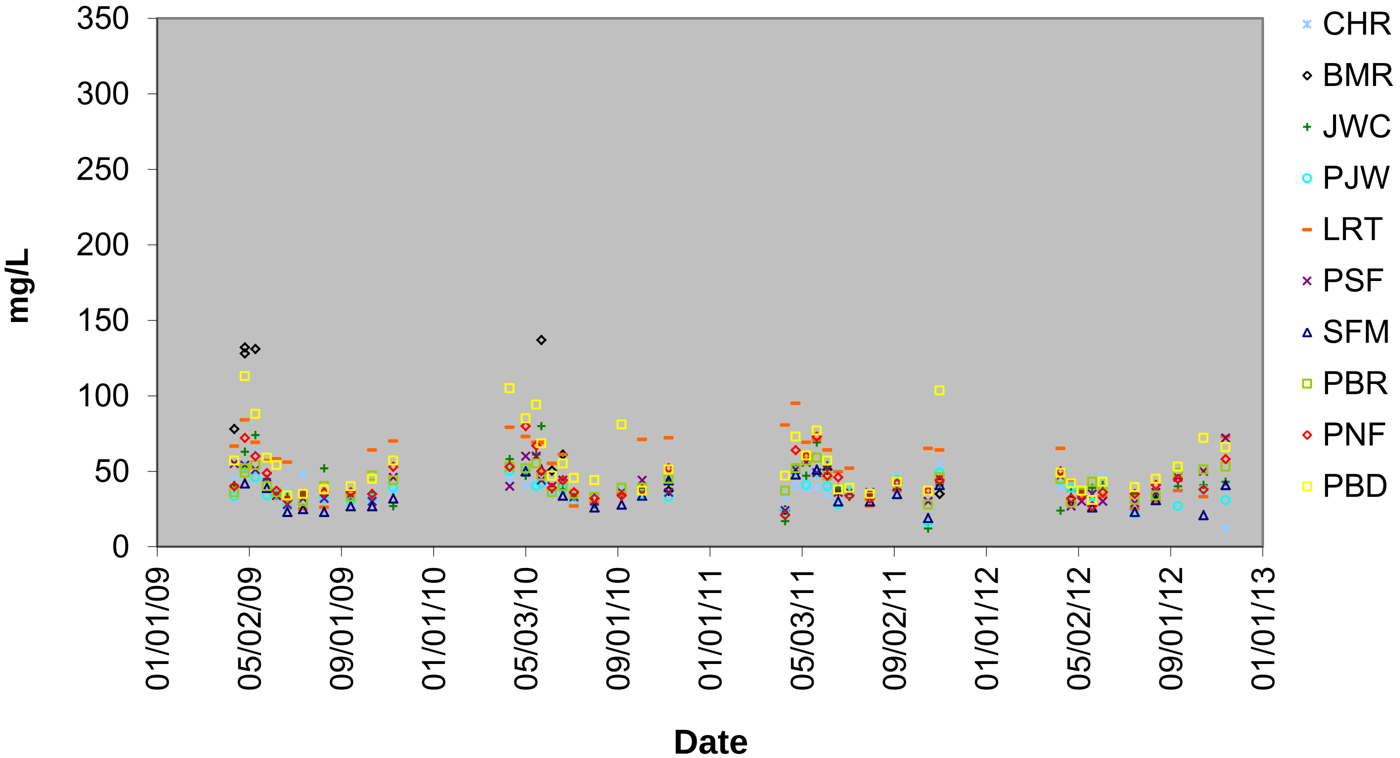
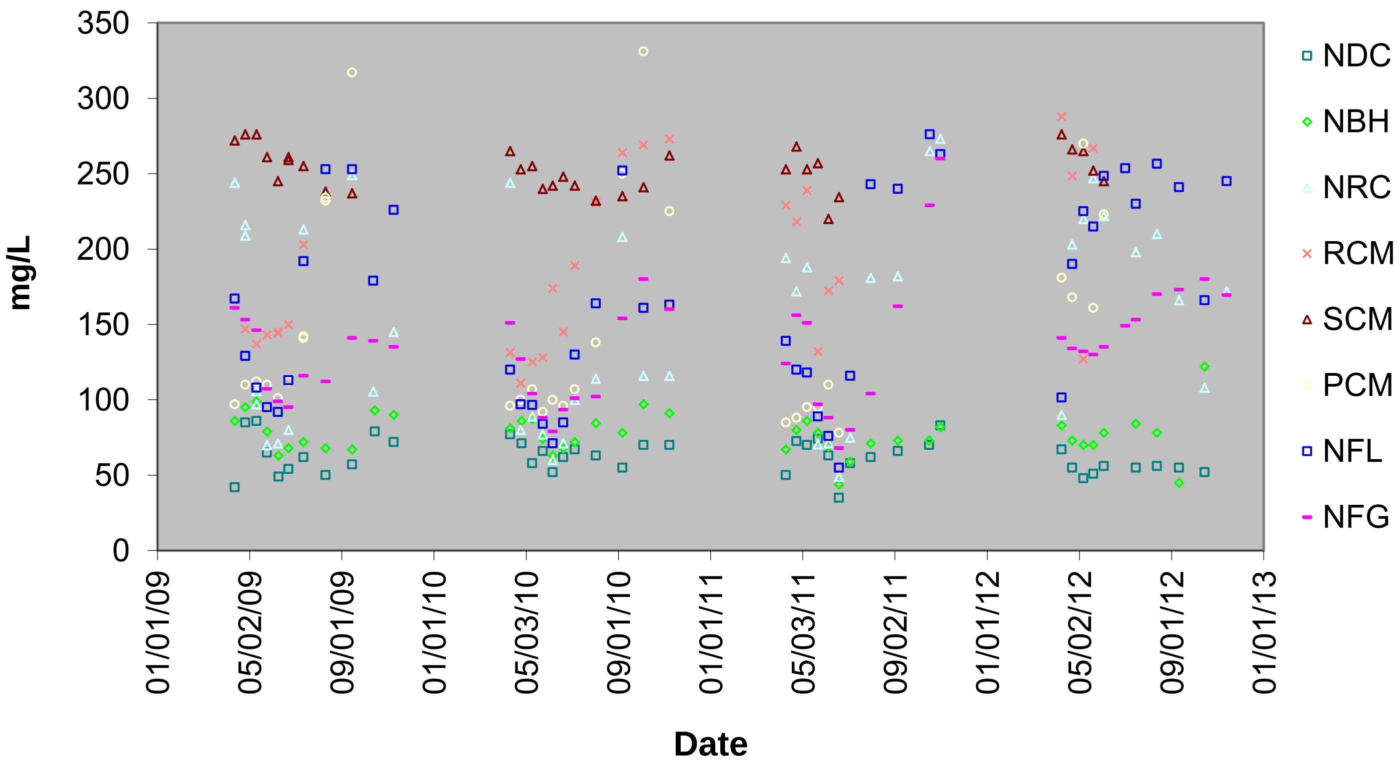


Figure 9.b. TDS on the North Fork CLP



(EPA Secondary Drinking Water Standard for TDS: 500 mg/l)

Figure 10 (a & b). Total Organic Carbon (TOC)

Figure 10.a. TOC on the Mainstem CLP

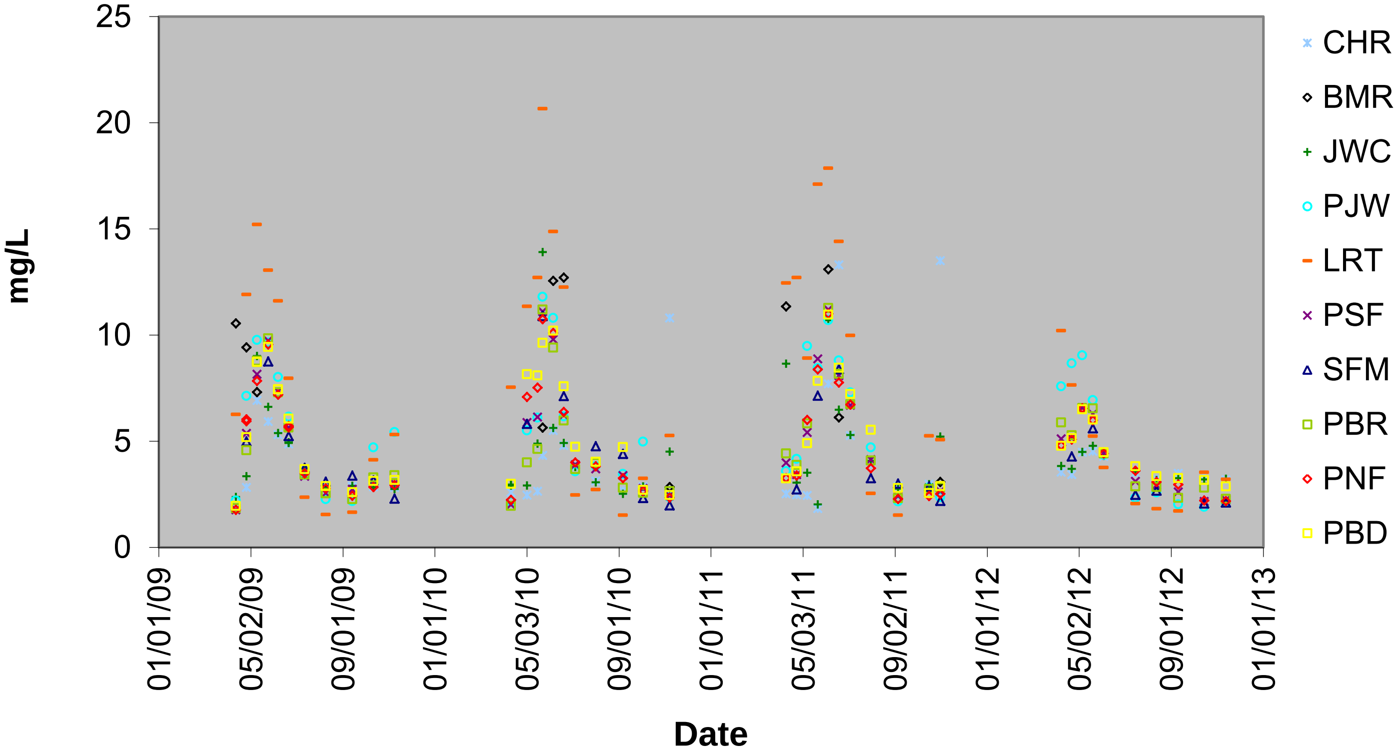
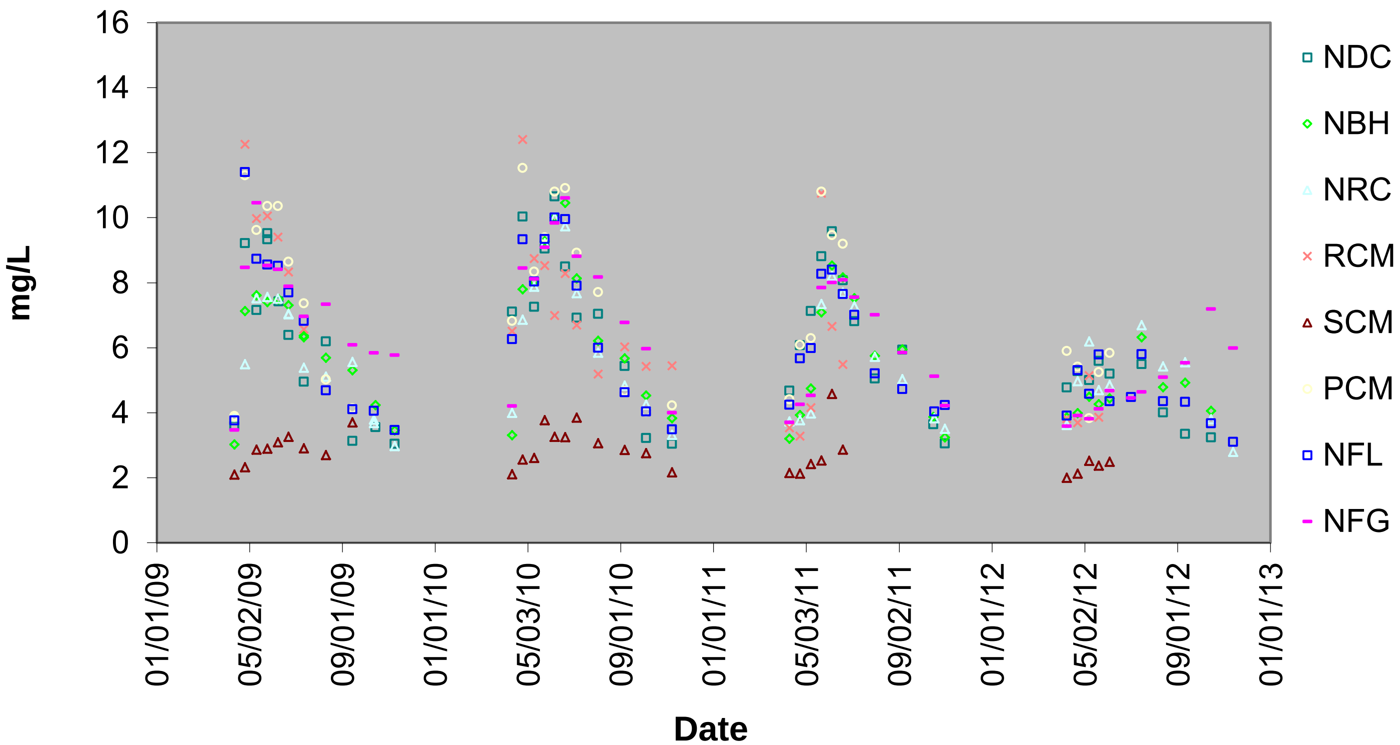


Figure 10.b. TOC on the North Fork CLP



Mainstem and North Fork CLP:
Nutrients

Figure 11 (a & b). Ammonia as N (NH_3-N)

Figure 11.a. Ammonia as N (NH_3-N) on the Mainstem CLP

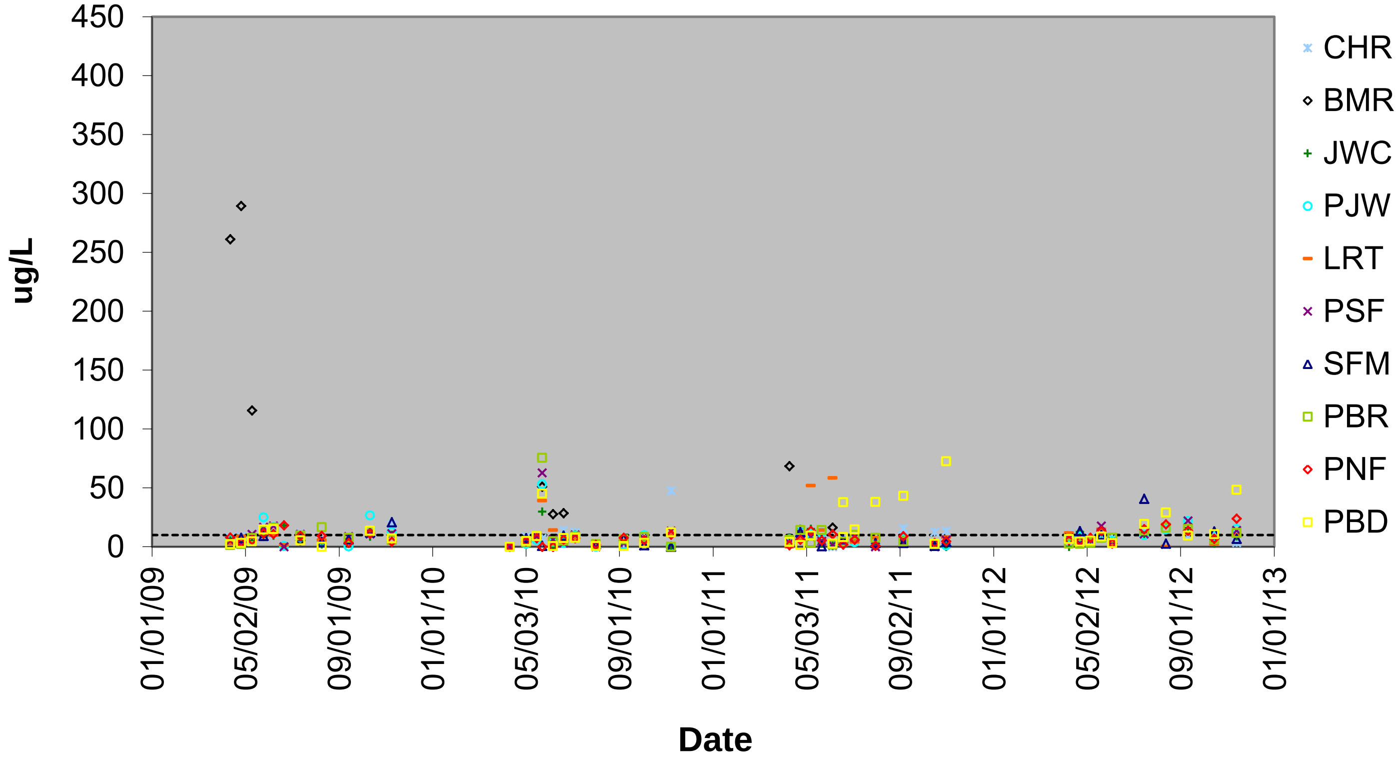
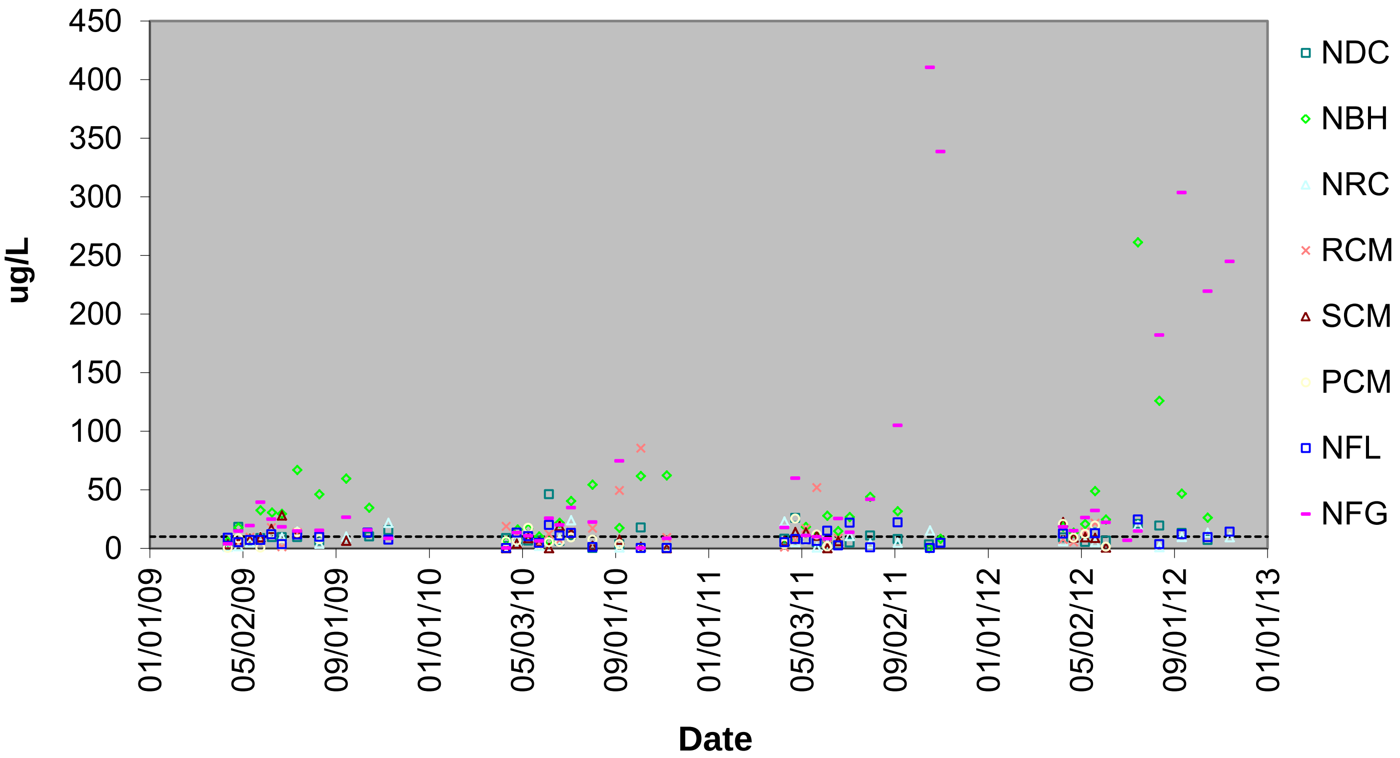


Figure 11.b. Ammonia as N (NH_3-N) on the North Fork CLP



(------- FCWQL Reporting Limit: 10 ug/L)

Figure 12 (a & b). Nitrate as N (NO_3-N)

Figure 12.a. Nitrate as N (NO_3-N) on the Mainstem CLP

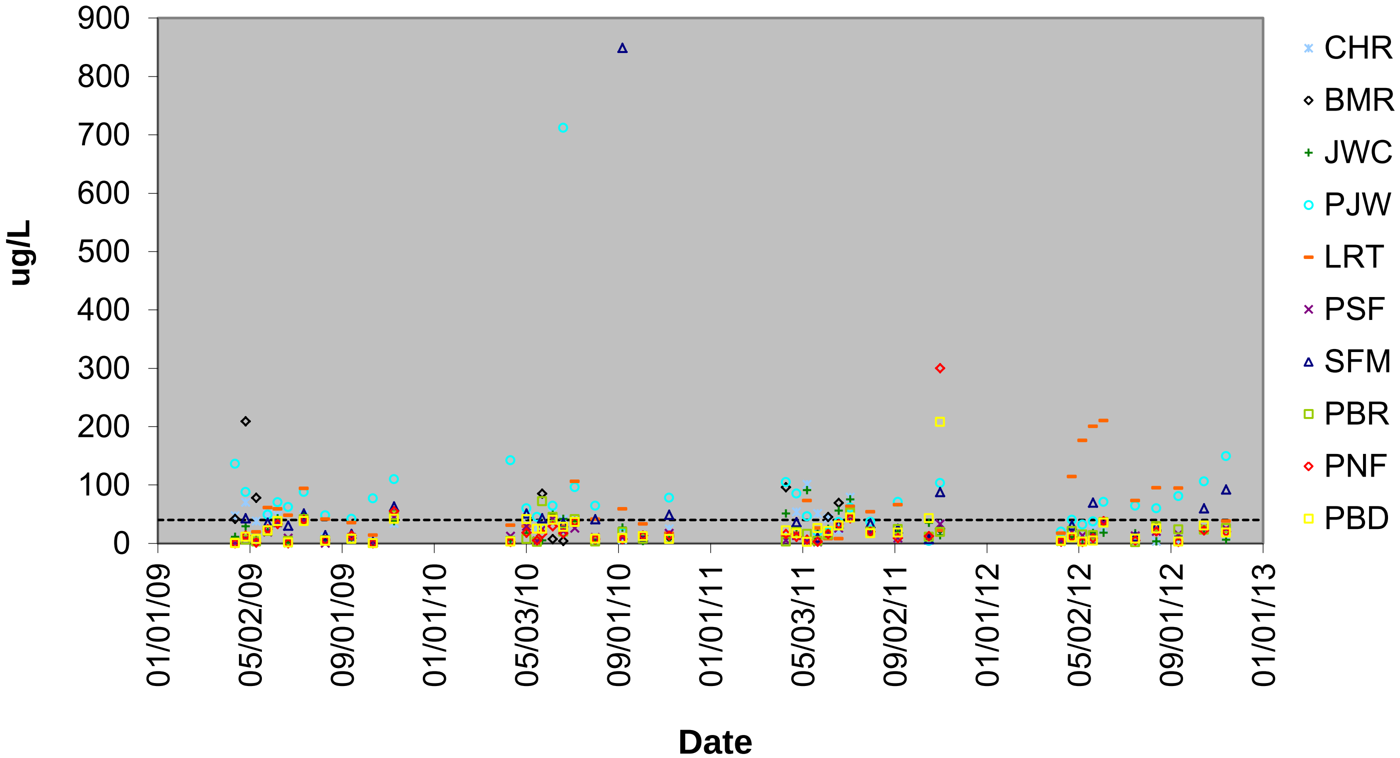
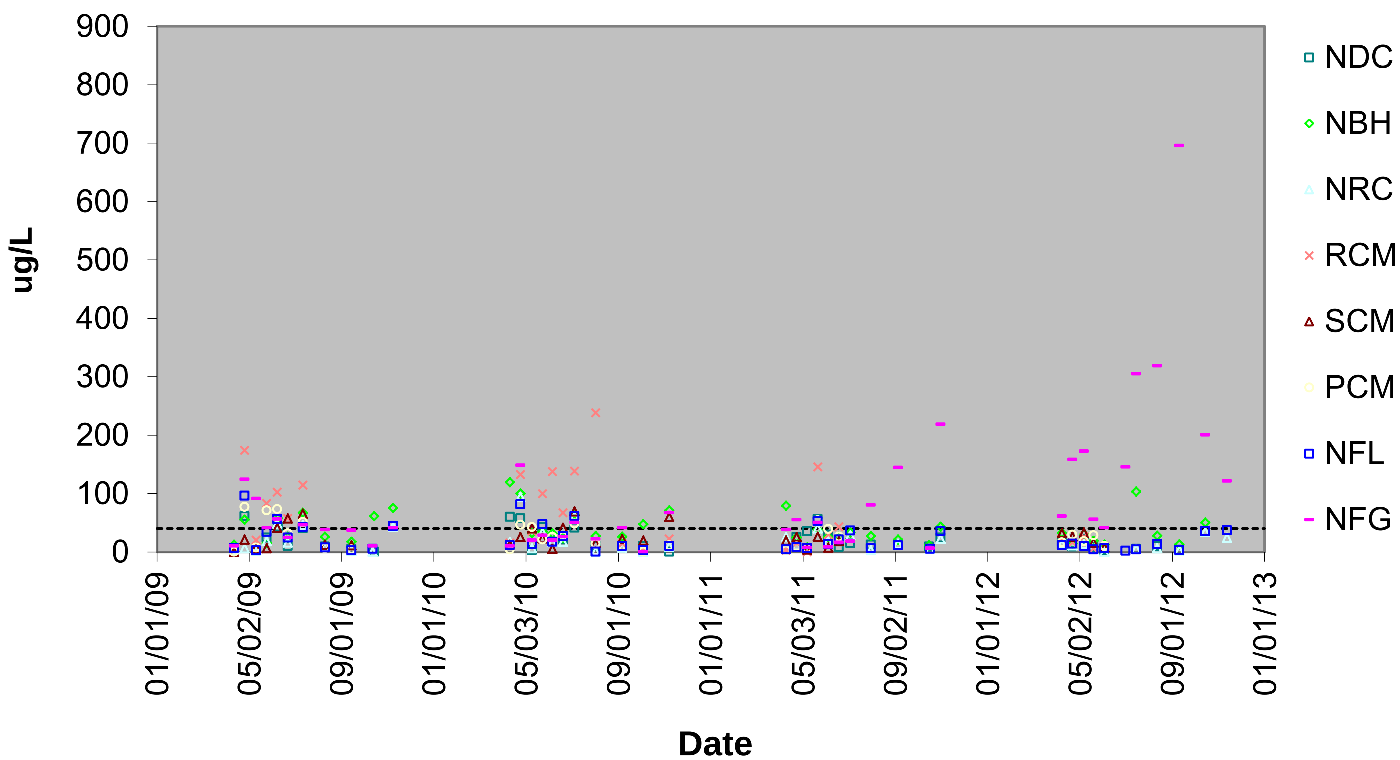


Figure 12.b. Nitrate as N (NO_3-N) on the North Fork CLP



(------- FCWQL Reporting Limit: 40 ug/L)

(EPA Maximum Contaminant Level: 10,000 ug/L as N)

Figure 13 (a & b). Nitrite as N (NO_2-N)

Figure 13.a. Nitrite as N (NO_2-N) on the Mainstem CLP

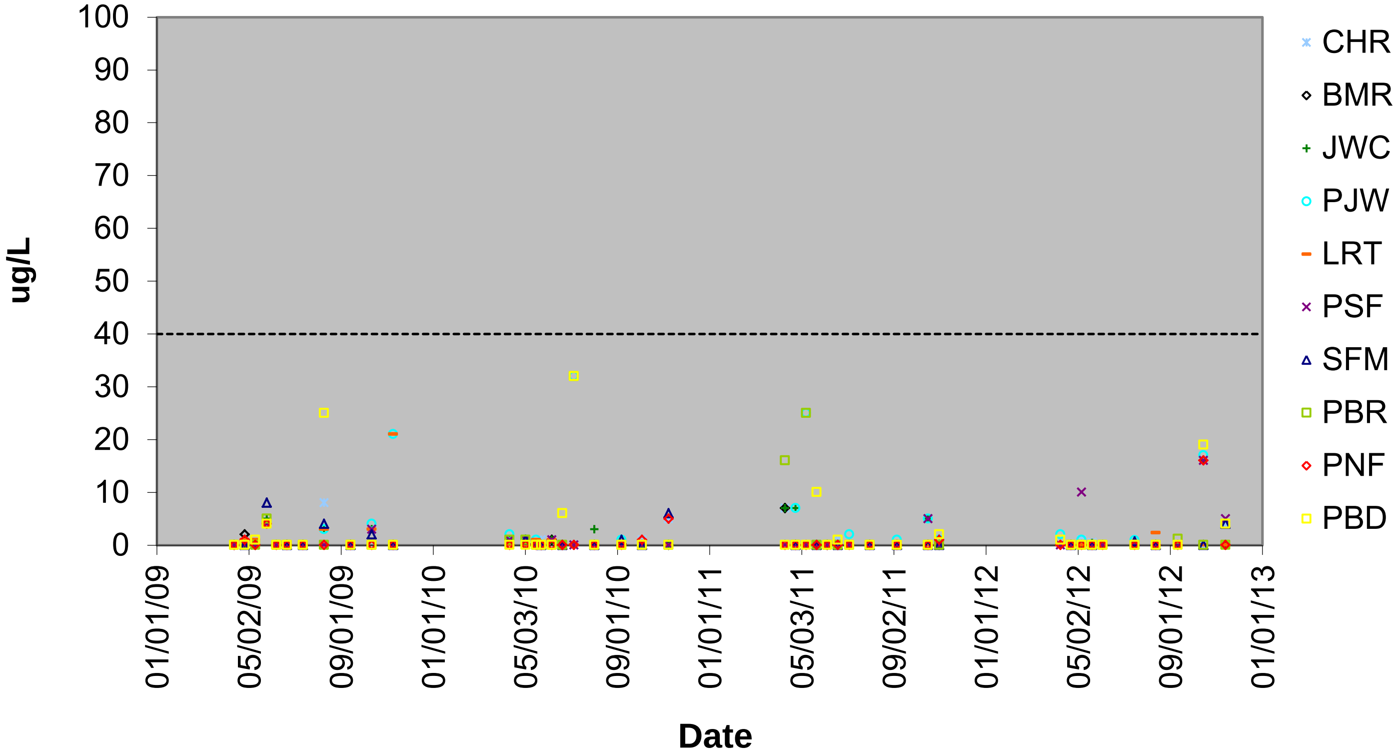
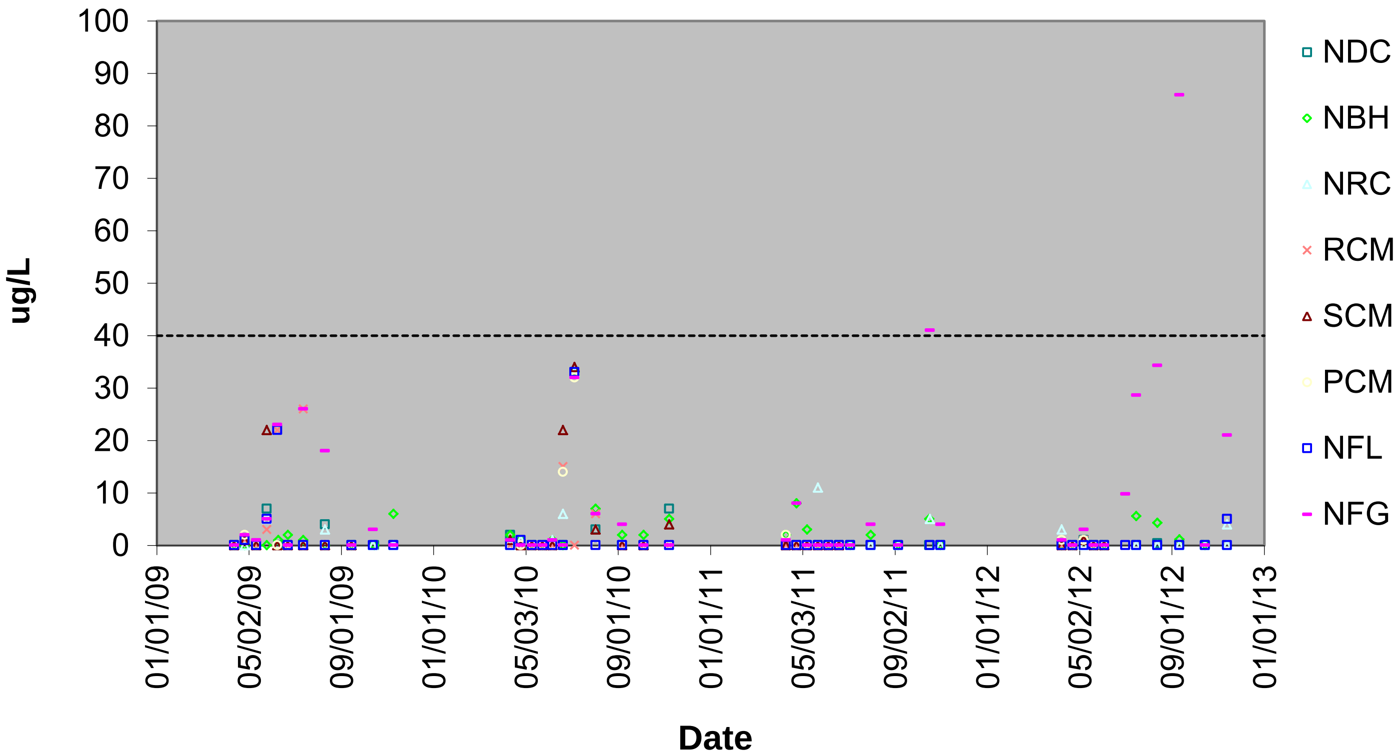


Figure 13.b. Nitrite as N (NO_2-N) on the North Fork CLP



(------- FCWQL Reporting Limit: 40 ug/L)

(EPA Maximum Contaminant Level: 1,000 ug/L as N)

Figure 14 (a & b). Total Kjeldahl Nitrogen (TKN)

Figure 14.a. TKN on the Mainstem CLP

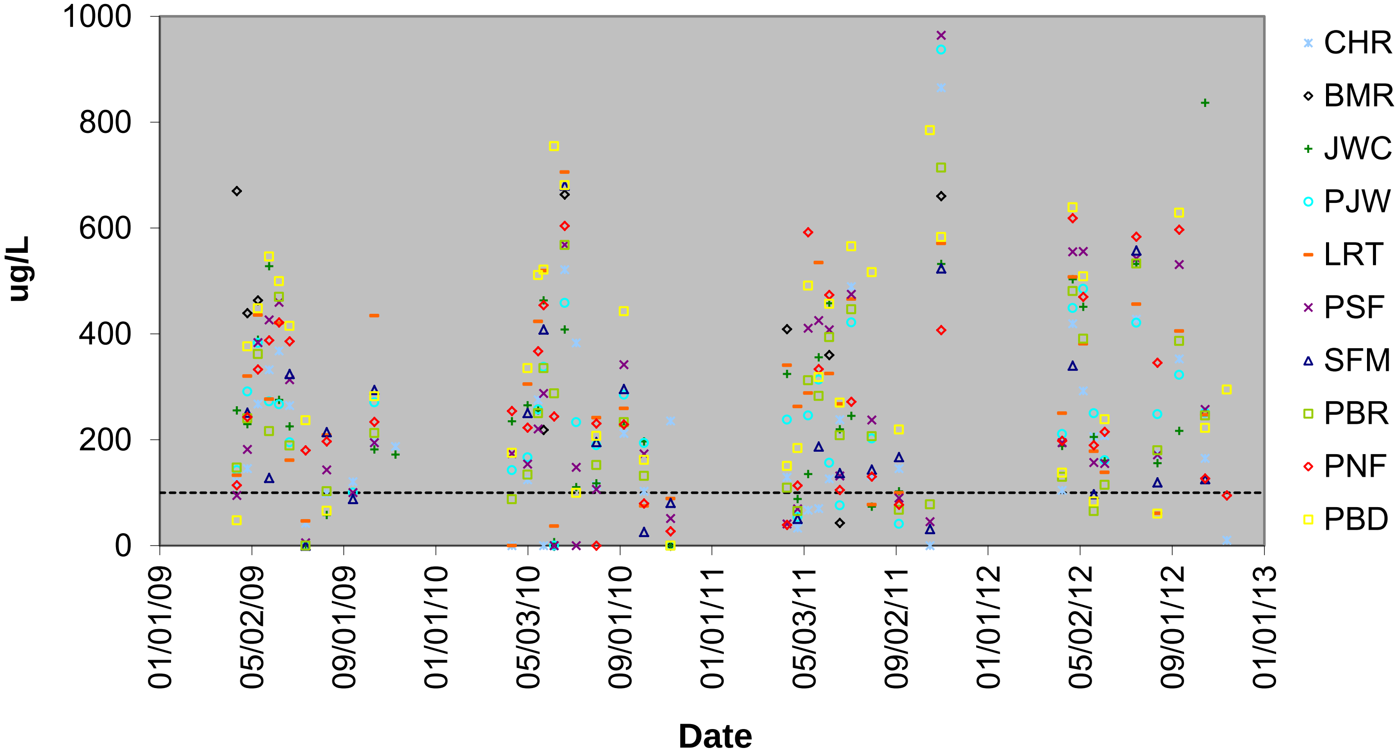
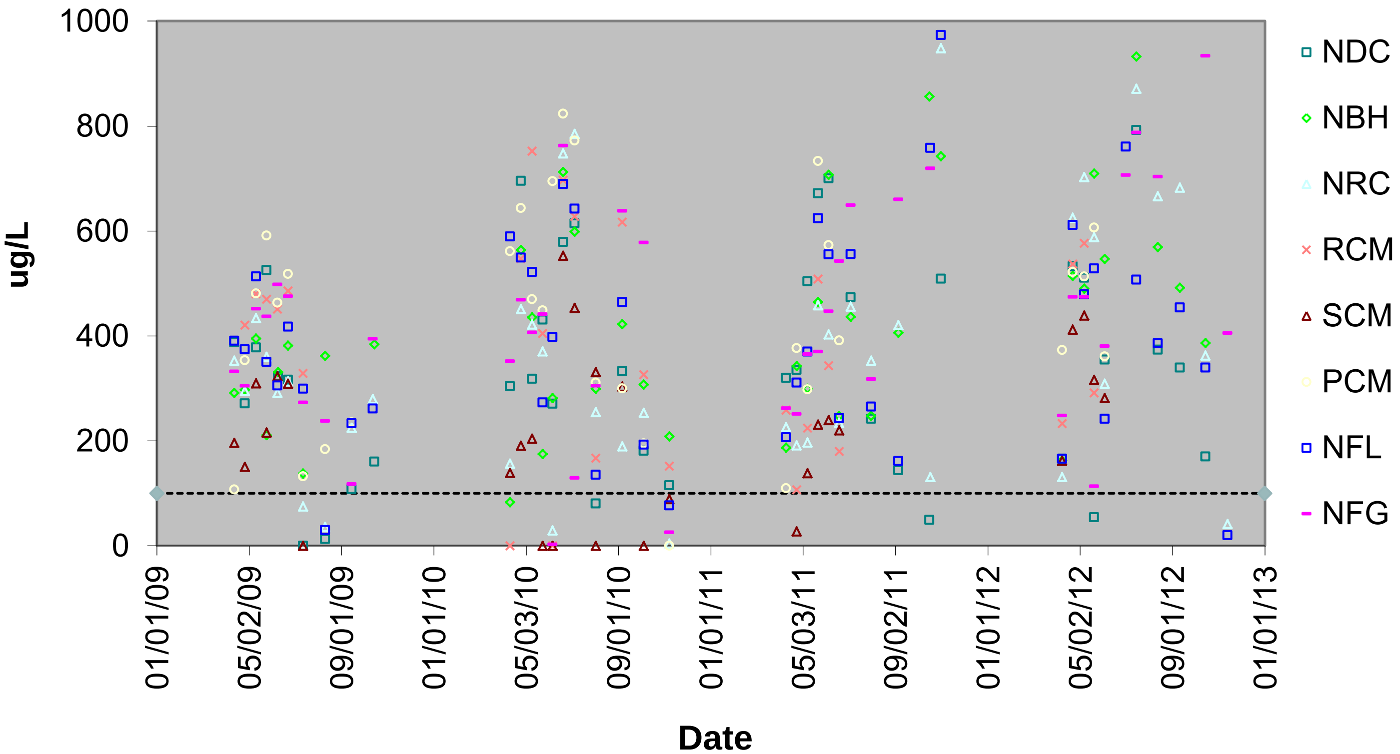


Figure 14.b. TKN on the North Fork CLP



(------- FCWQL Reporting Limit: 100 ug/L)

Figure 15 (a & b). Total Nitrogen (TKN+NO_3+NO_2)

Figure 15.a. Total N on the Mainstem CLP

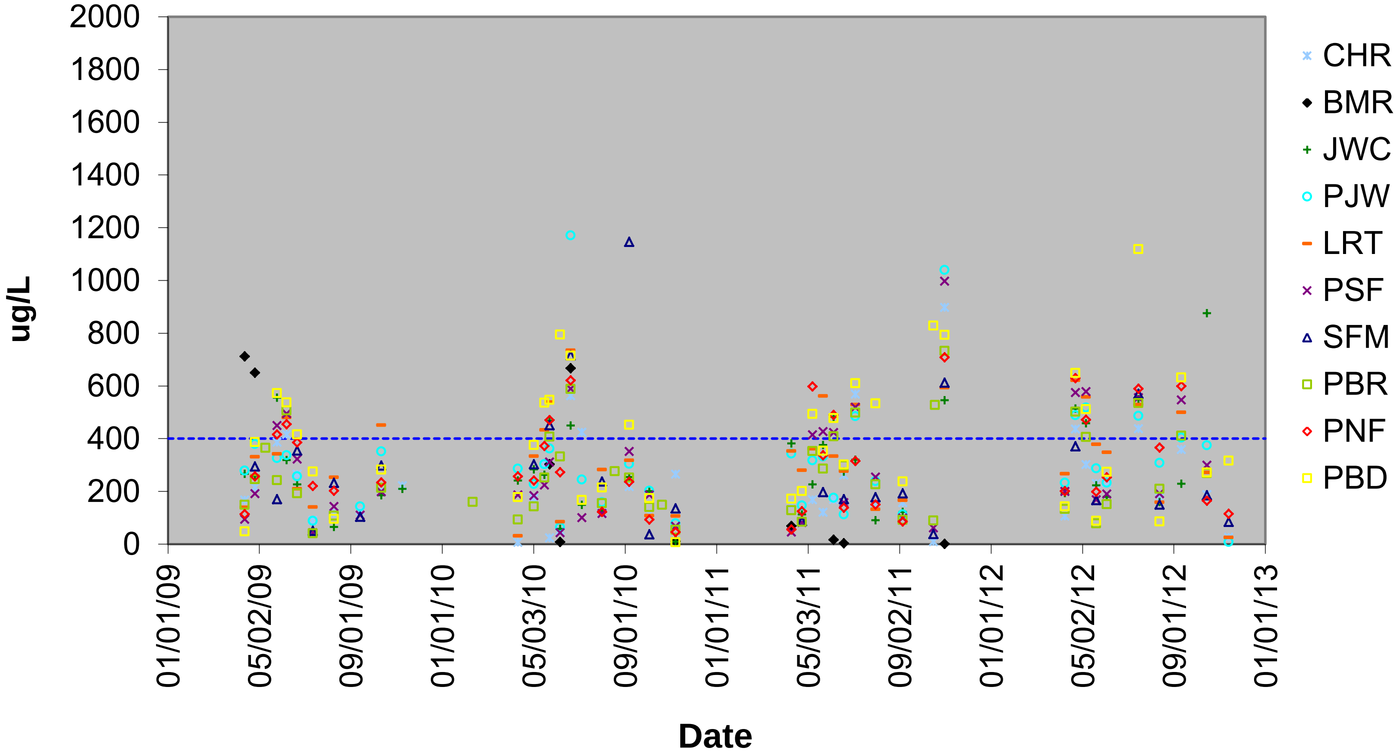
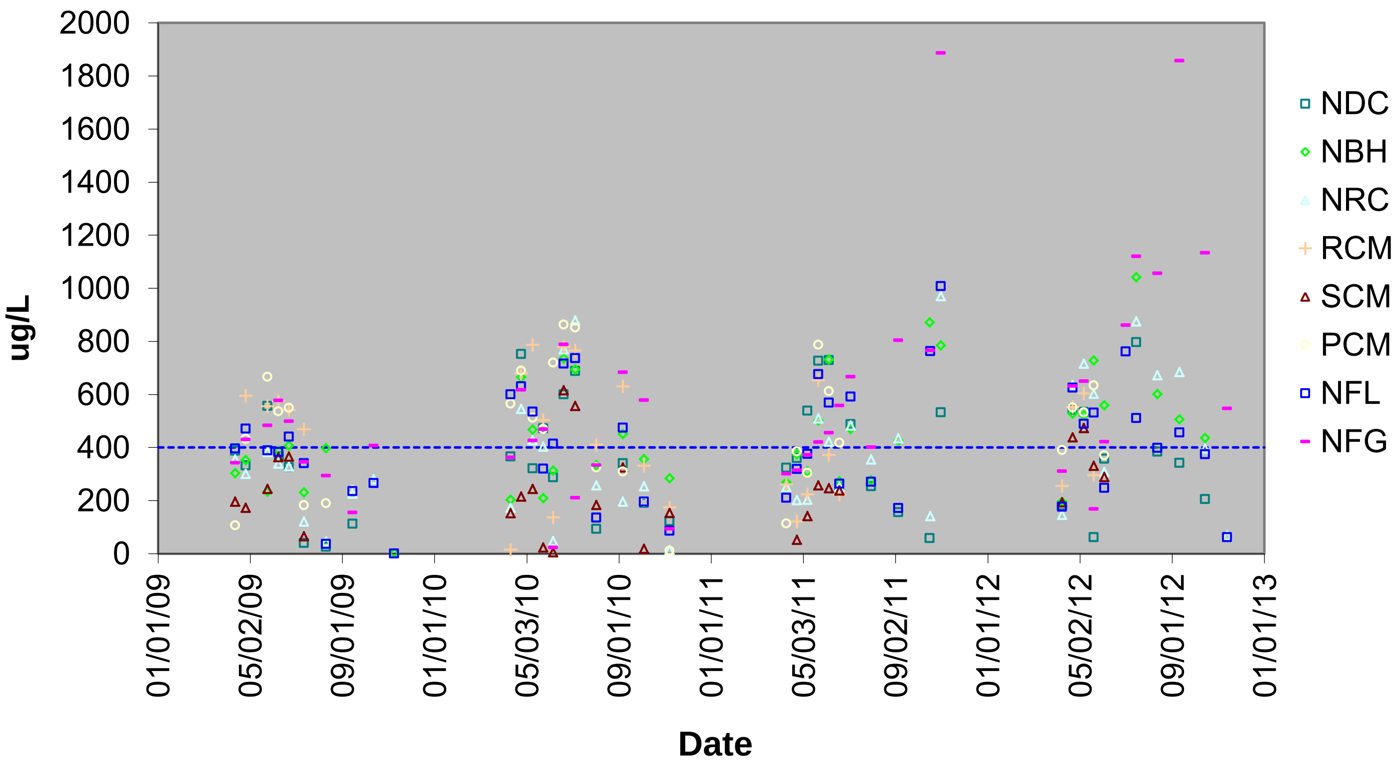


Figure 15.b. Total N on the North Fork CLP



(------- 2012 CDPHE/WQCD proposed cold water stream standard for Total N: 400 ug/L)

Figure 16 (a & b). Ortho-phosphate (PO_4)

Figure 16.a. Ortho-phosphate (PO_4) on the Mainstem CLP

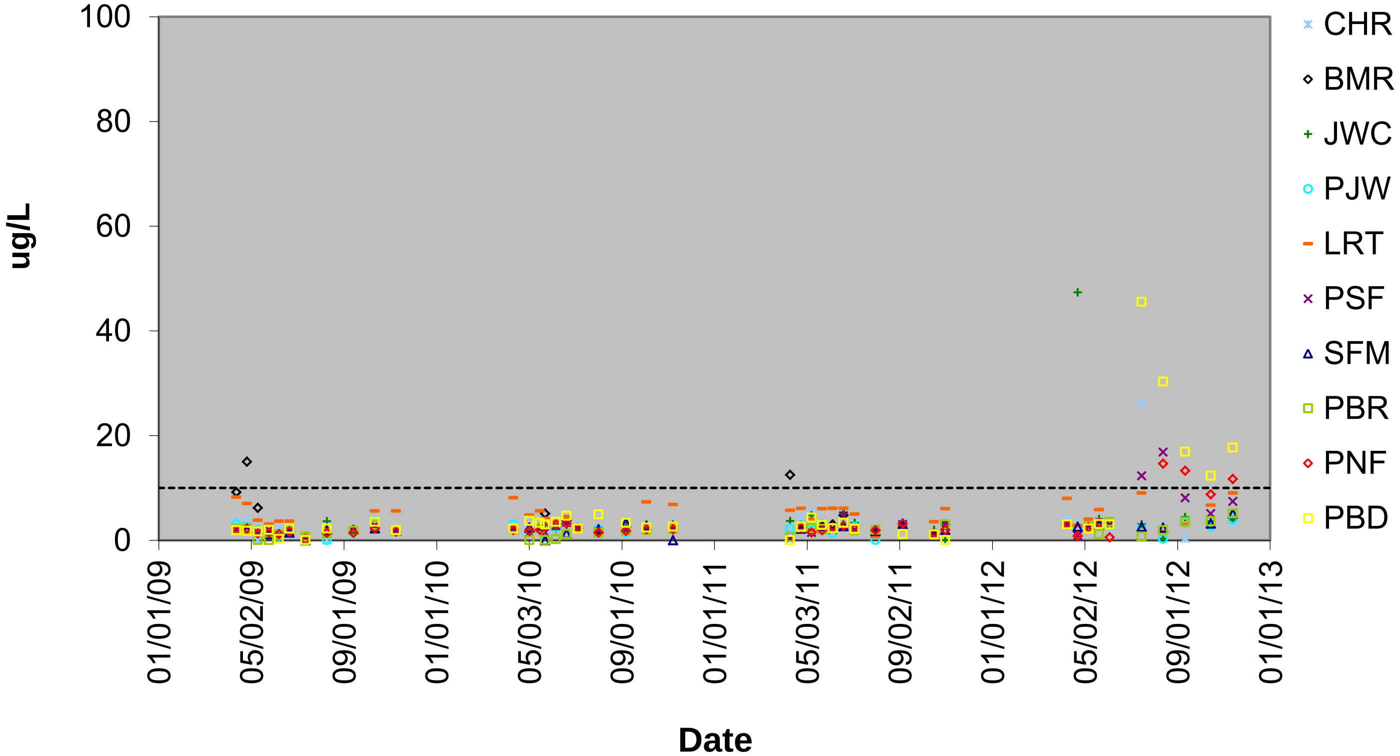
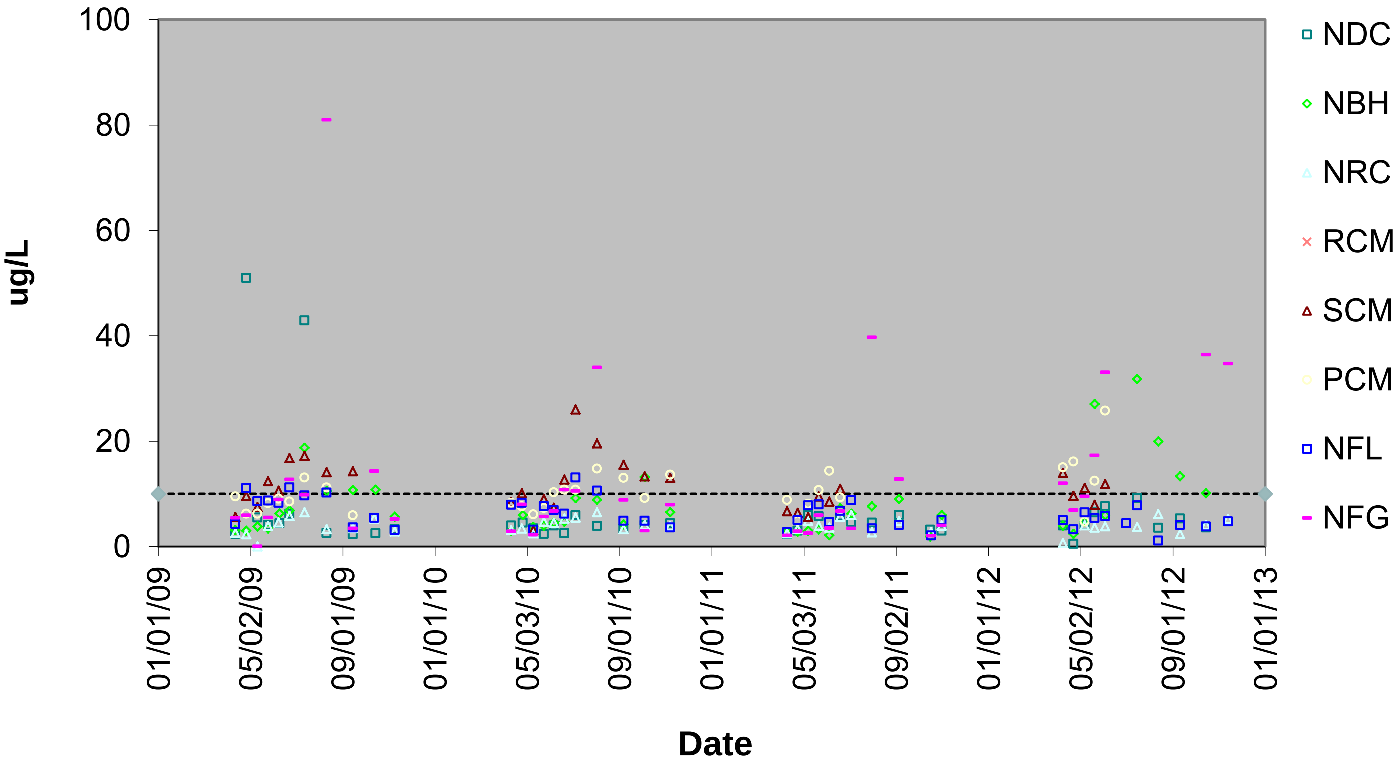


Figure 16.b. Ortho-phosphate (PO_4) on the North Fork CLP



(------- FCWQL Reporting Limit: 5 ug/L)

Figure 17 (a & b). Total Phosphorus (P)

Figure 17.a. Total P on the Mainstem CLP

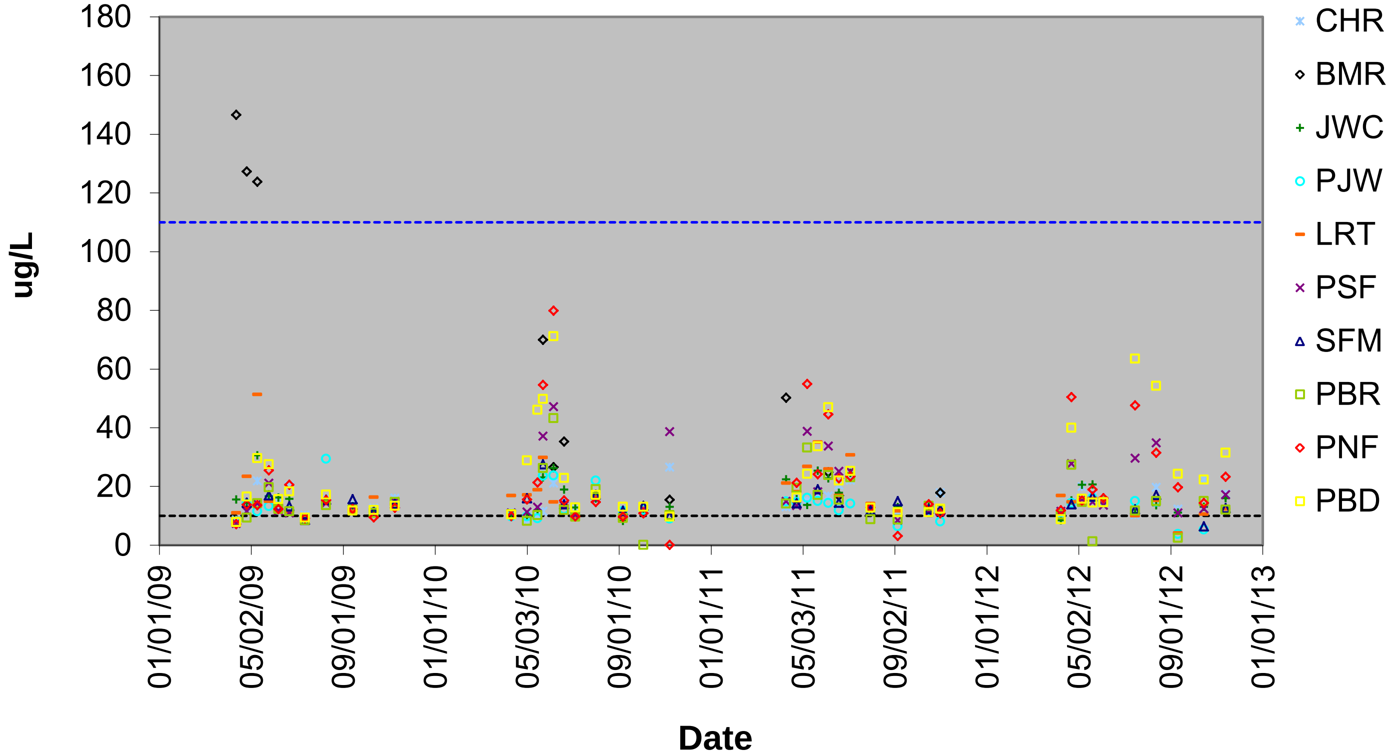
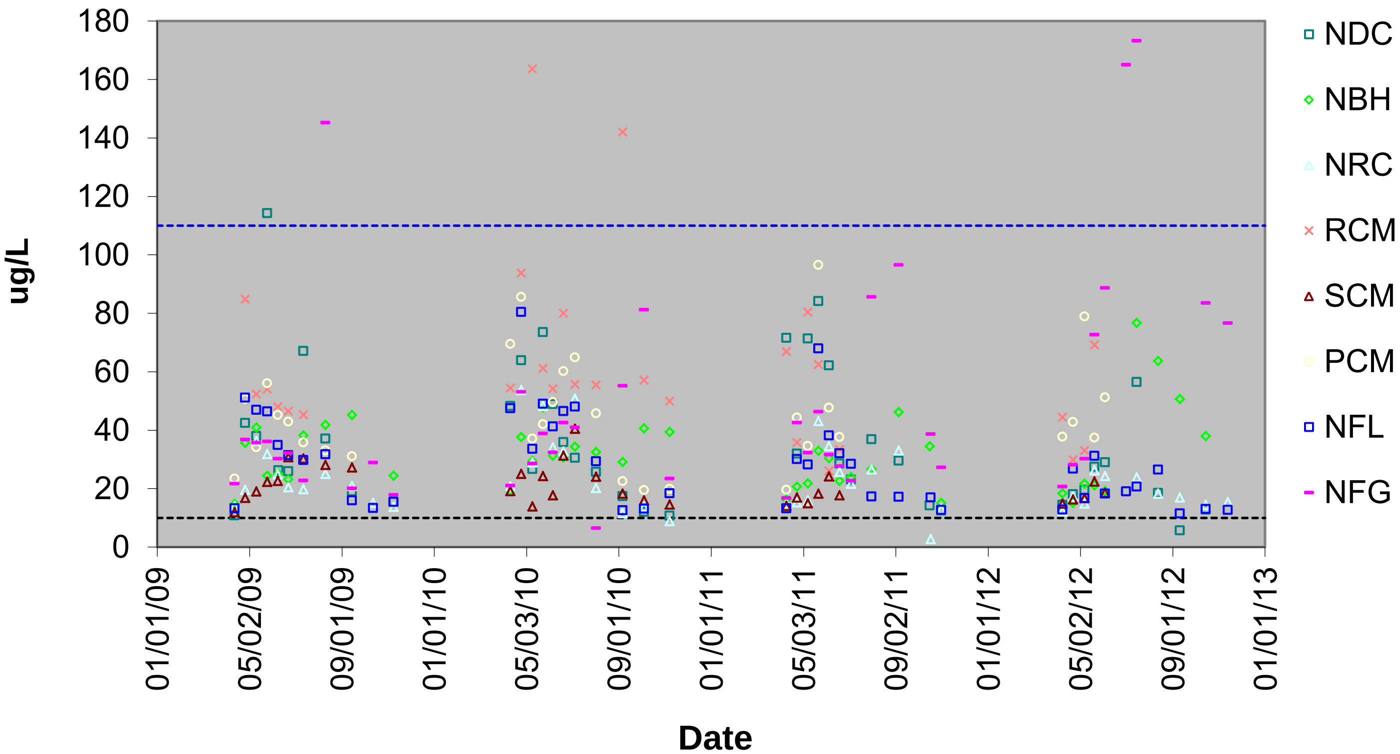


Figure 17.b. Total P on the North Fork CLP

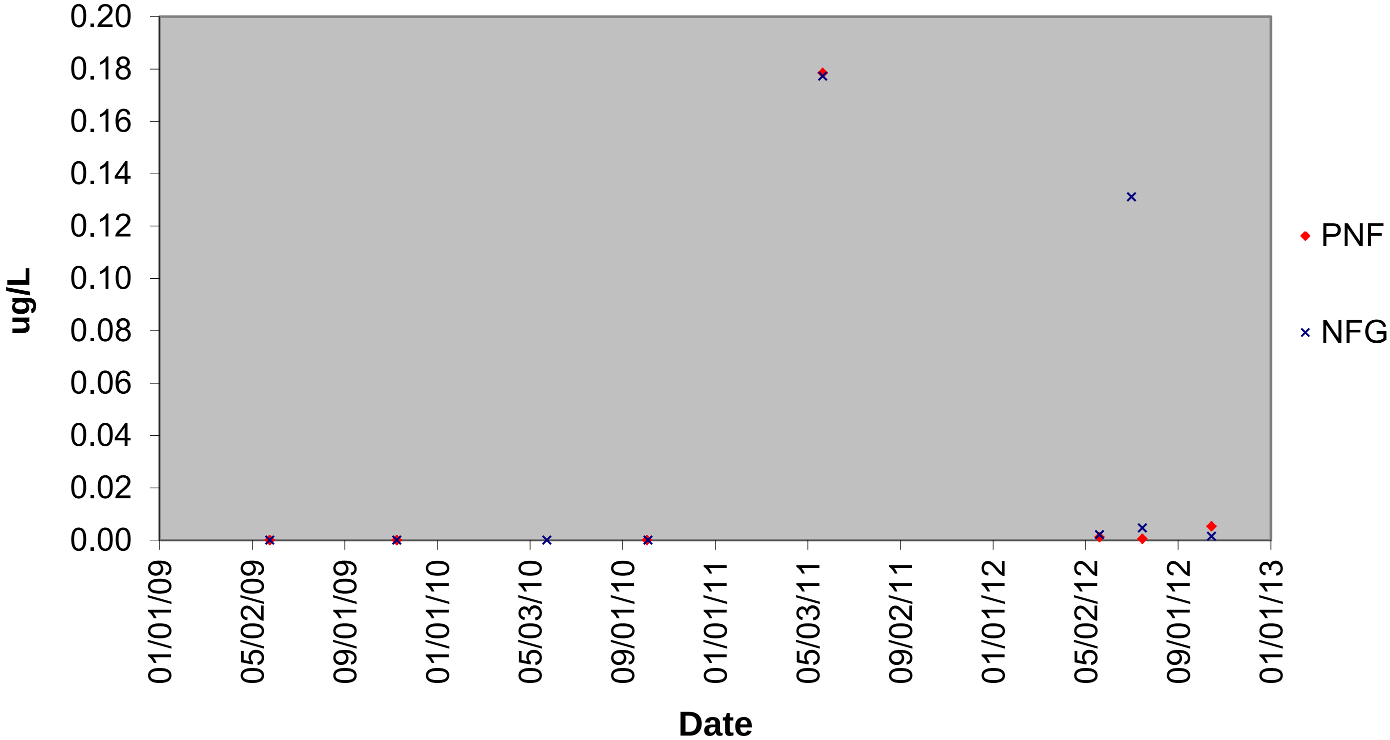


(------- FCWQL Reporting Limit: 10 ug/L)

(------- 2012 CDPHE/WQCD proposed cold water stream standard for Total P: 110 ug/L)

Mainstem and North Fork CLP:
Metals

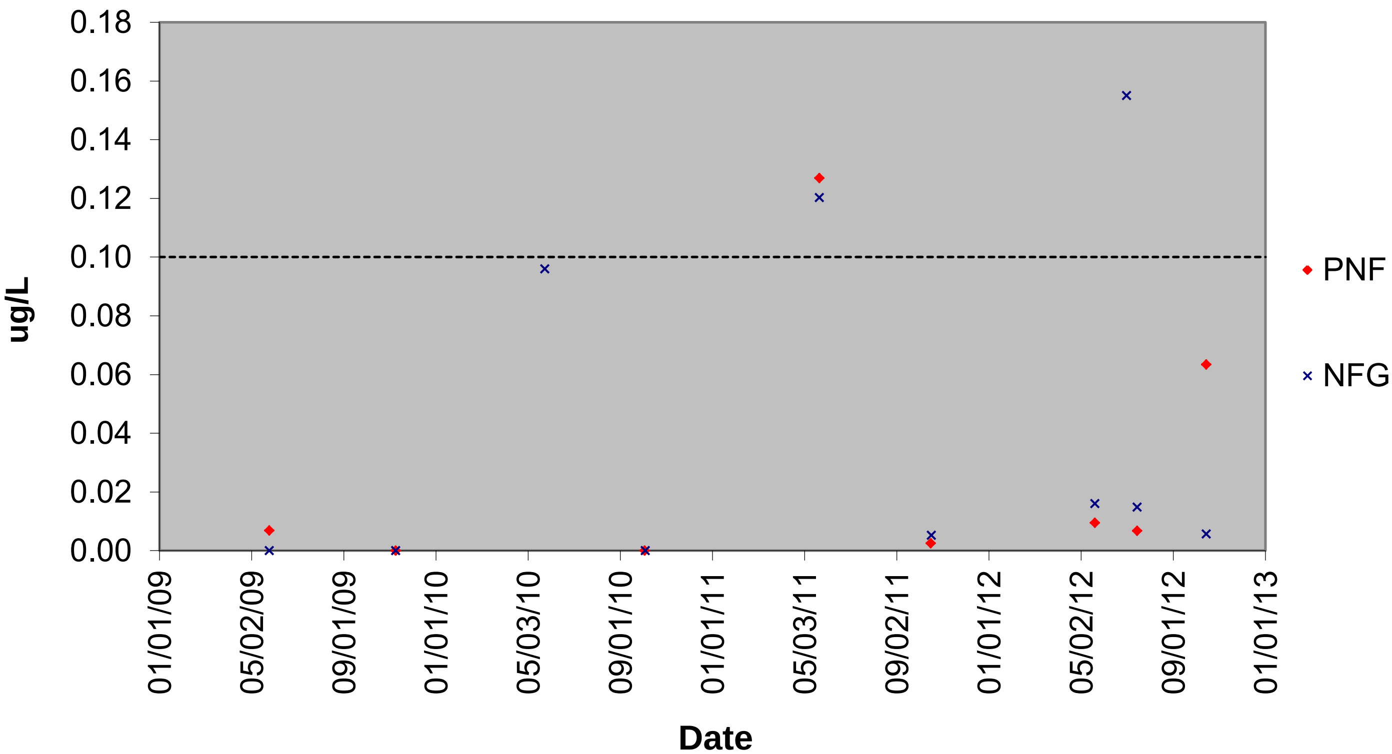
Figure 18. Dissolved silver (Ag) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 0.5 ug/L)

(EPA Secondary Drinking Water Standard: 100ug/L)

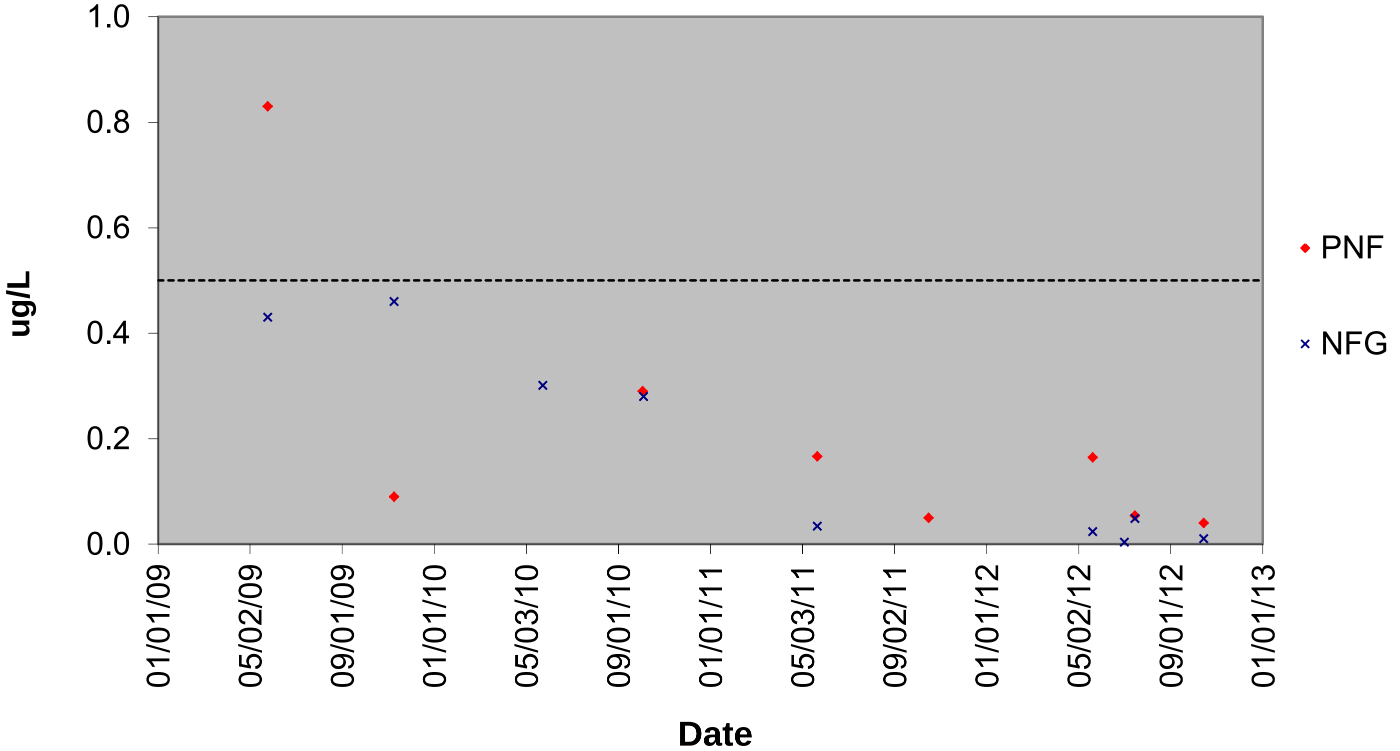
Figure 19. Dissolved cadmium (Cd) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 0.1 ug/L)

(EPA Maximum Contaminant Level: 5 ug/L)

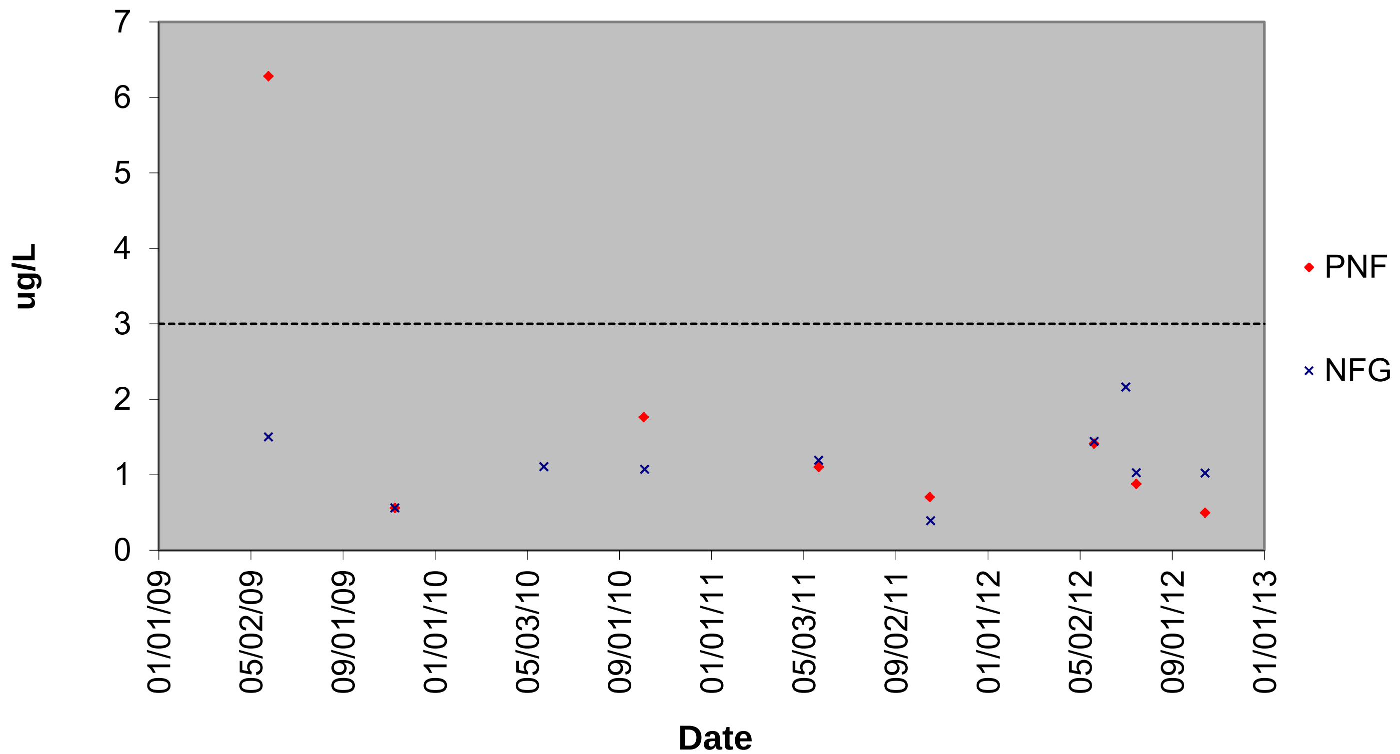
Figure 20. Dissolved chromium (Cr) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 0.5 ug/L)

(EPA Maximum Contaminant Level: 100ug/L)

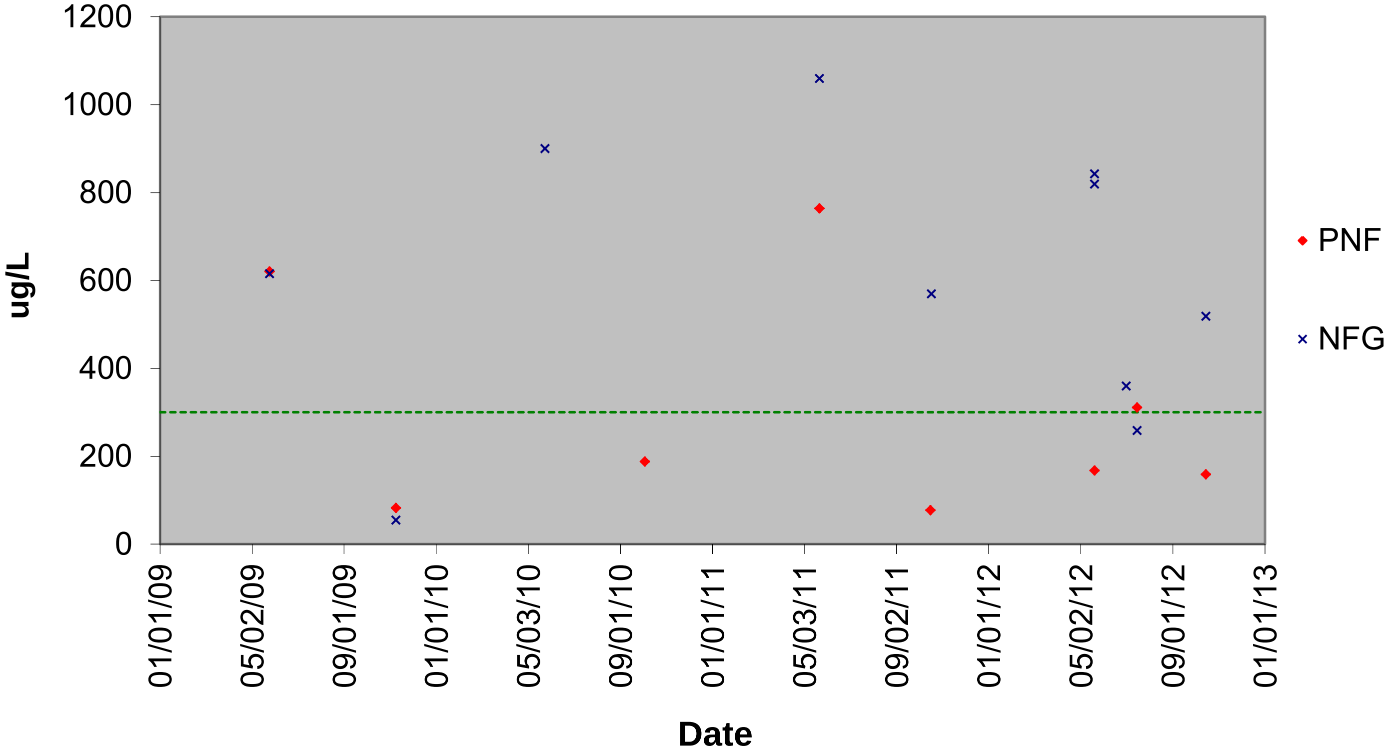
Figure 21. Dissolved copper (Cu) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 3.0 ug/L)

(EPA Maximum Contaminant Level: 1,300 ug/L)

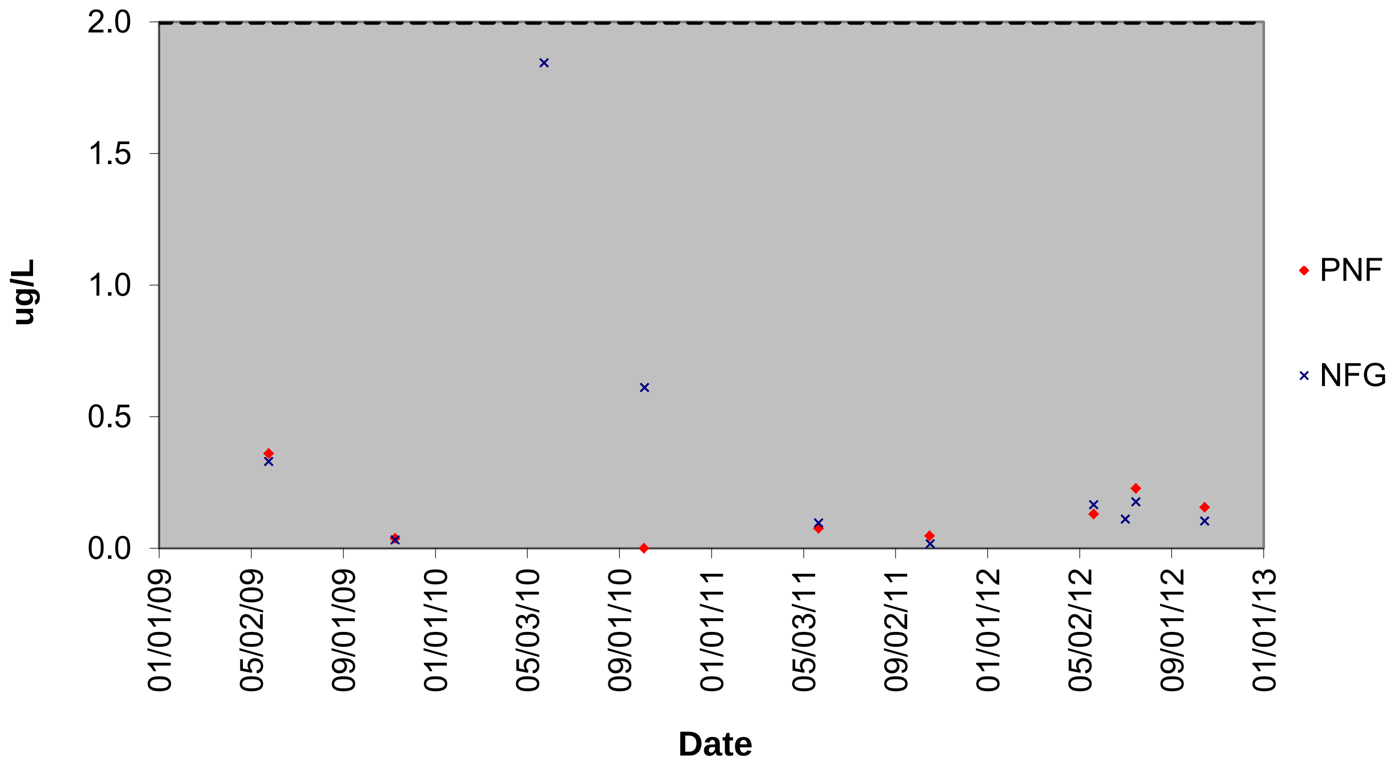
Figure 22. Total iron (Fe) on the Mainstem and North Fork CLP



(----- FCWQL Reporting Limit: 0.5 ug/L)

(----- EPA Secondary Drinking Water Standard: 300 ug/L)

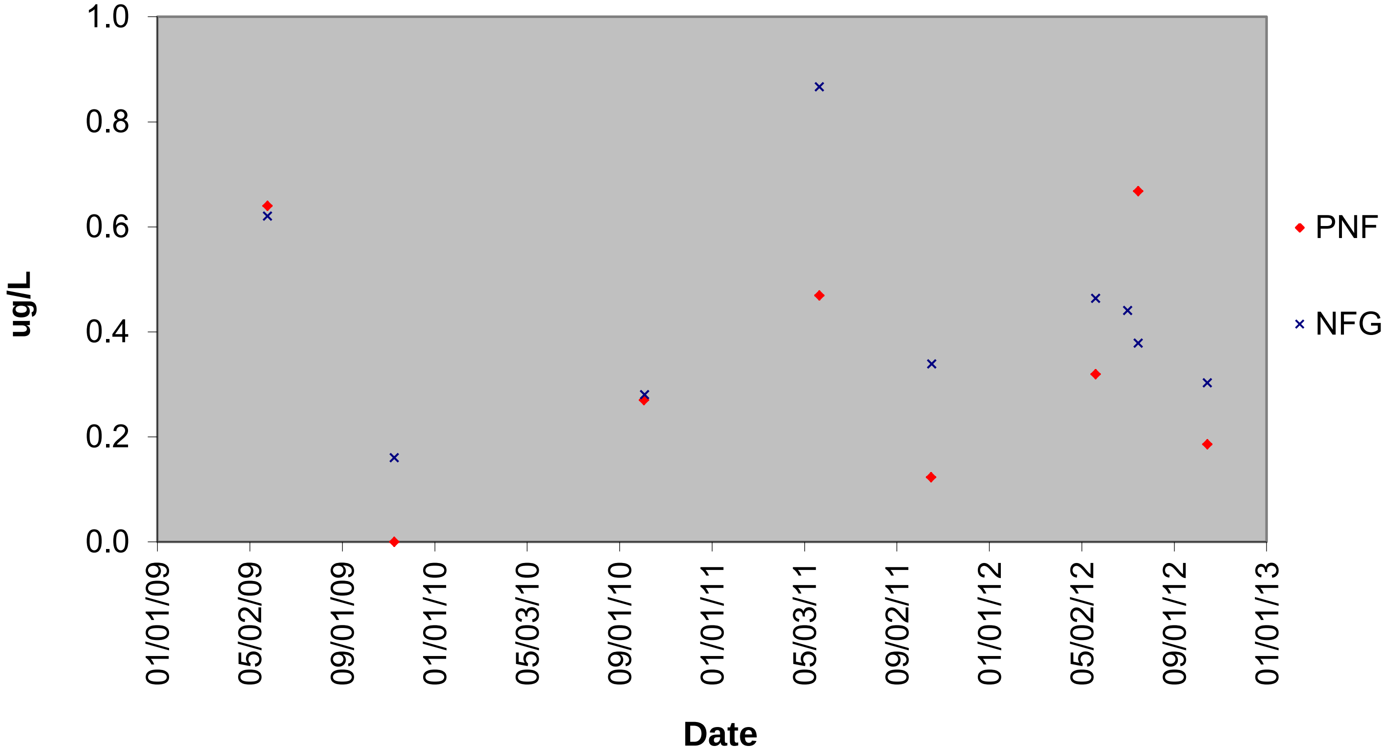
Figure 23. Dissolved iron (Fe) on the Mainstem and North Fork CLP



(----- FCWQL Reporting Limit: 0.5 ug/L)

(----- EPA Secondary Drinking Water Standard: 300 ug/L)

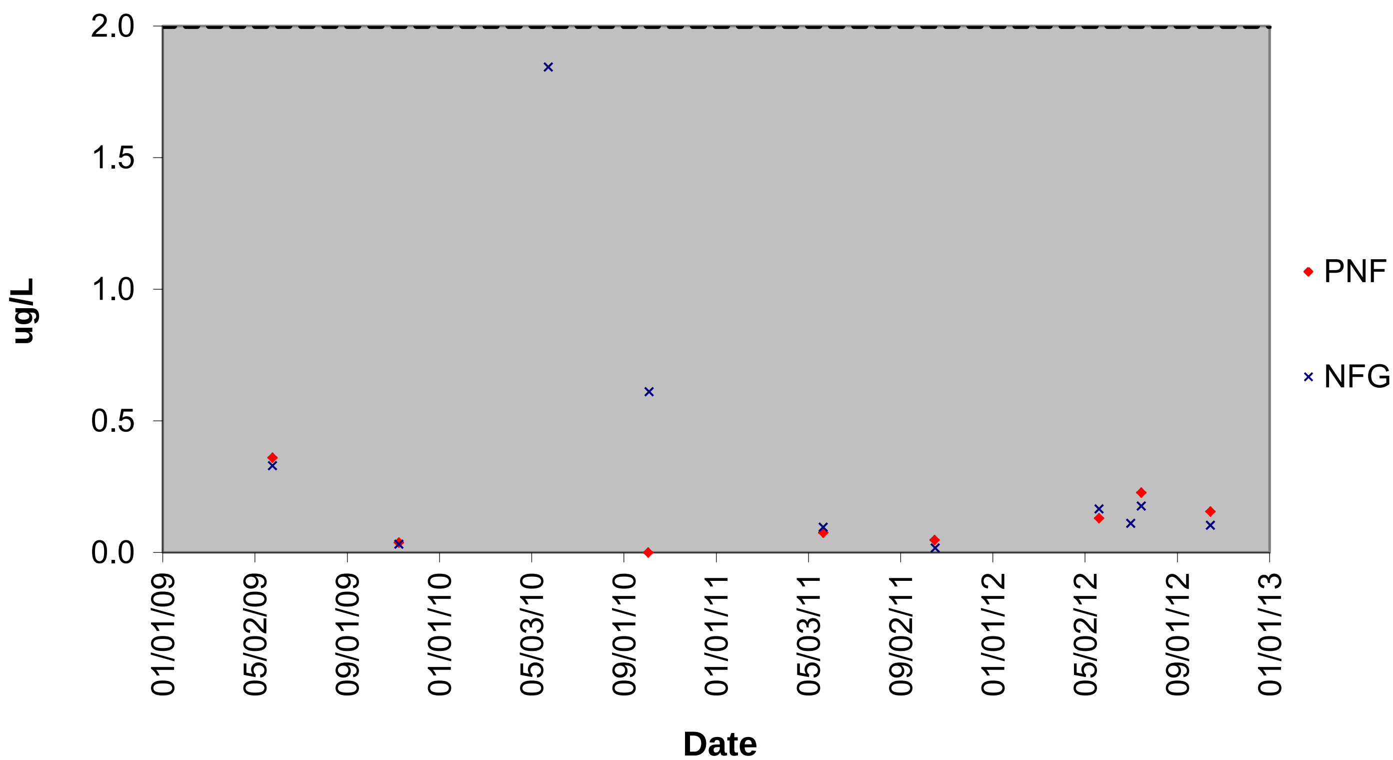
Figure 24. Dissolved nickel (Ni) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 2.0 ug/L)

(EPA Maximum Contaminant Level: 15 ug/L)

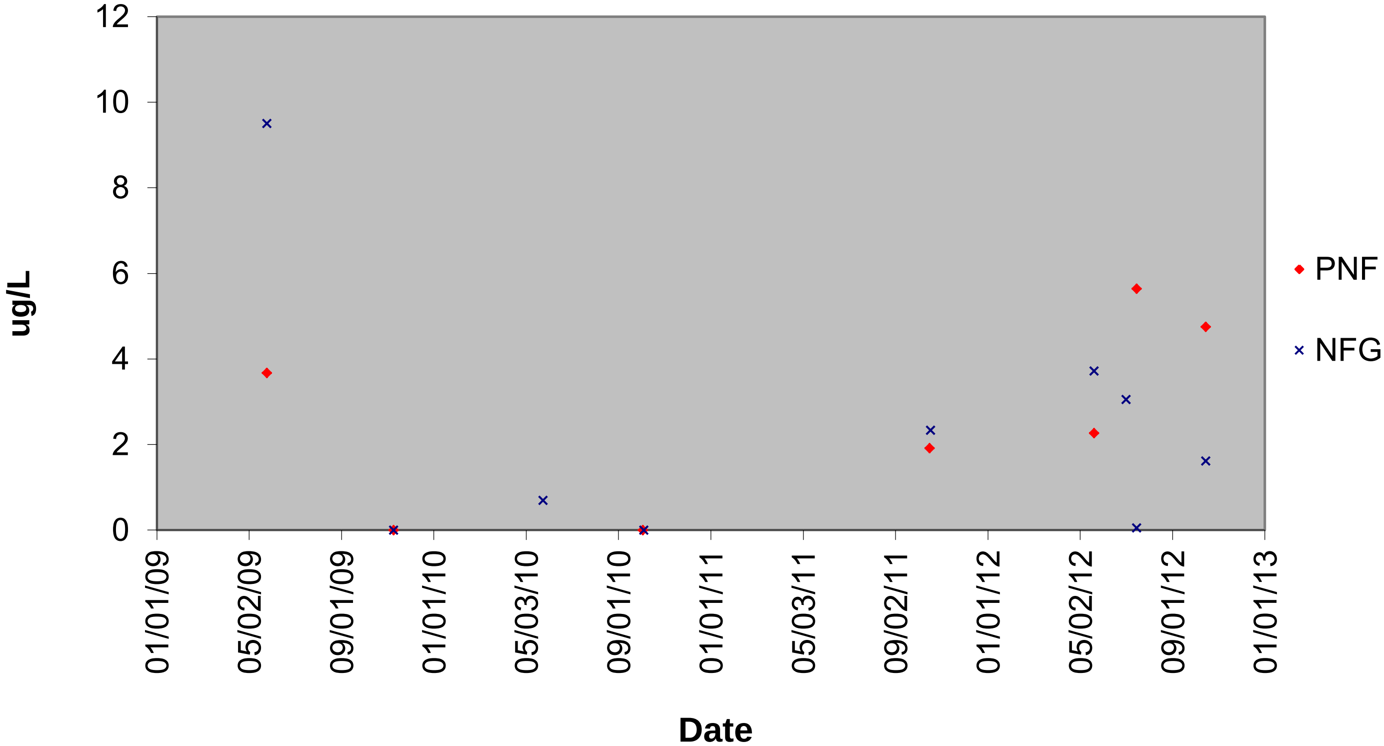
Figure 25. Dissolved lead (Pb) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 2.0 ug/L)

(EPA Maximum Contaminant Level: 15 ug/L)

Figure 26. Dissolved Zinc (Zn) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 50 ug/L)

(EPA Secondary Drinking Water Standard: 5,000 ug/L)

Mainstem and North Fork CLP:
Major Ions

Figure 27 (a & b). Calcium (Ca)

Figure 27.a. Calcium (Ca) on the Mainstem CLP

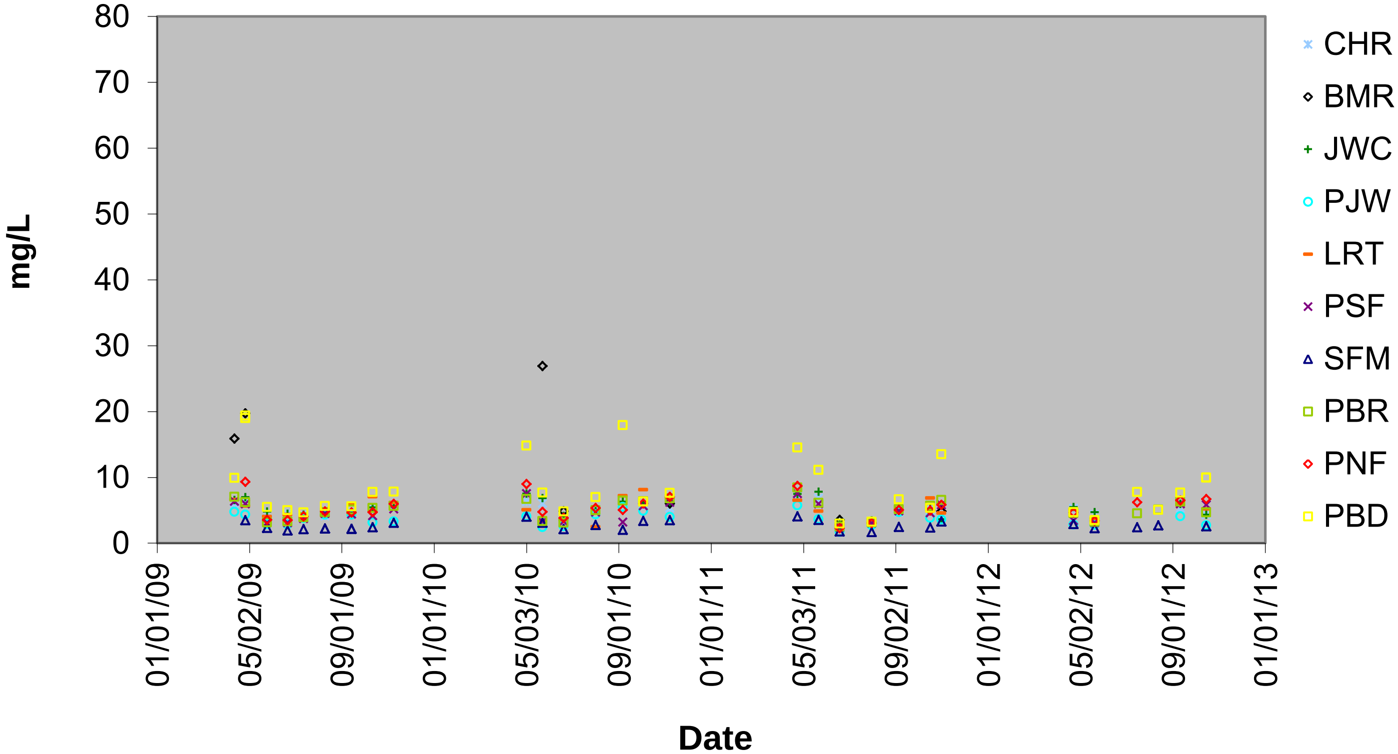


Figure 27.b. Calcium (Ca) on the North Fork CLP

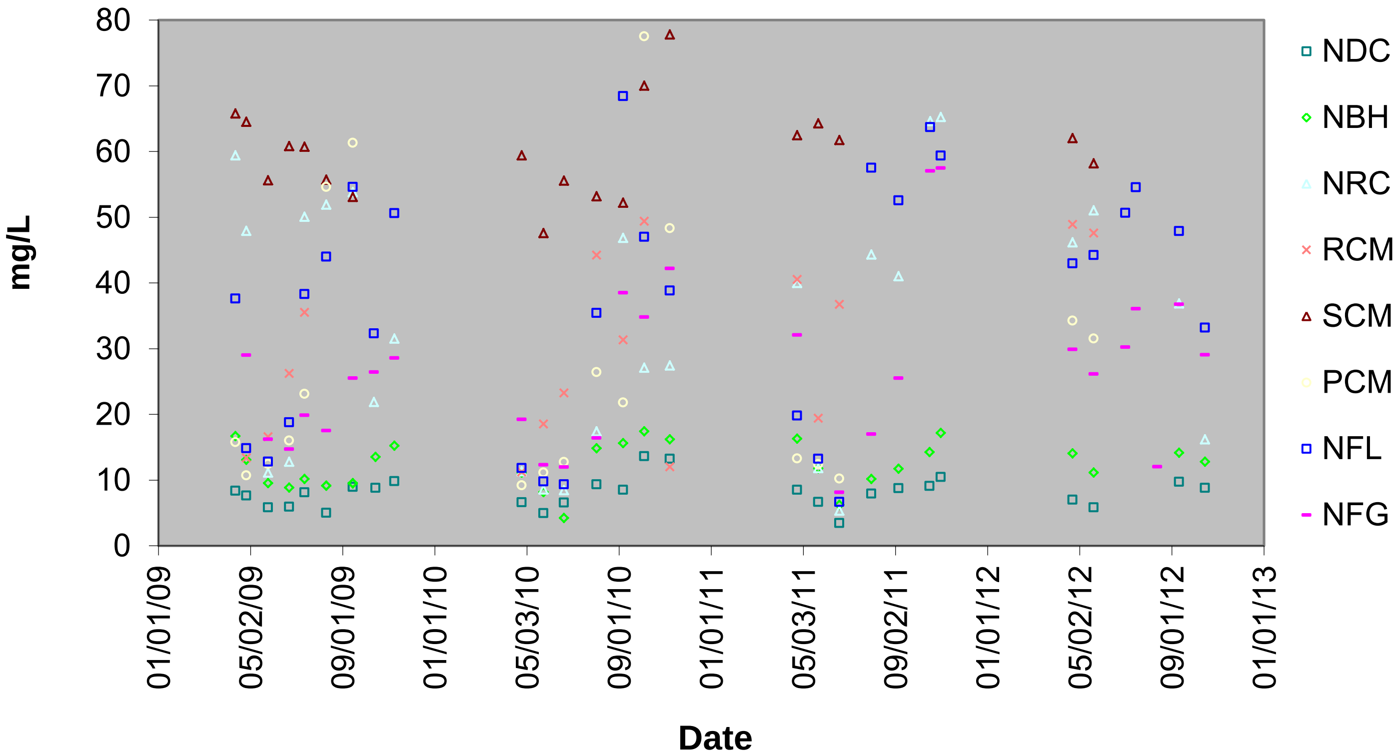


Figure 28 (a & b). Magnesium (Mg)

Figure 28.a. Magnesium (Mg) on the Mainstem CLP

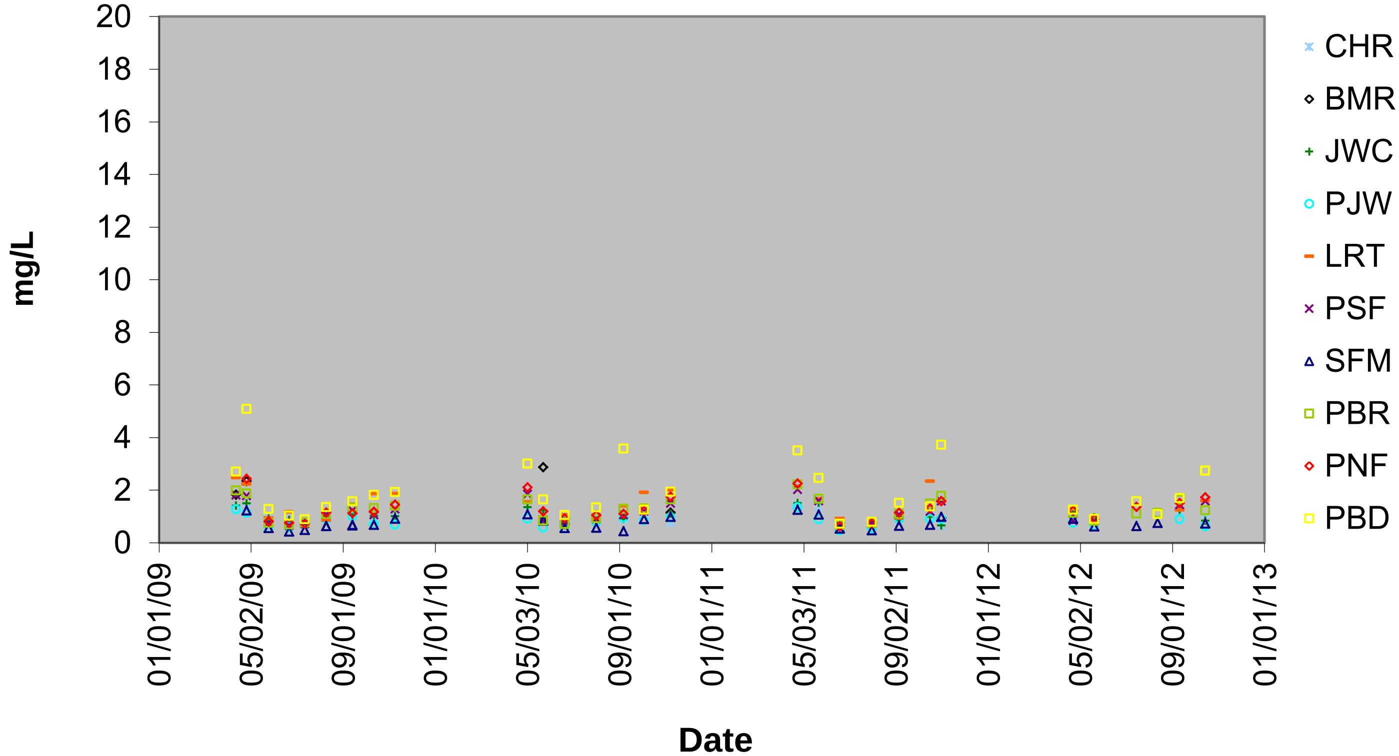


Figure 28.b. Magnesium (Mg) on the North Fork CLP

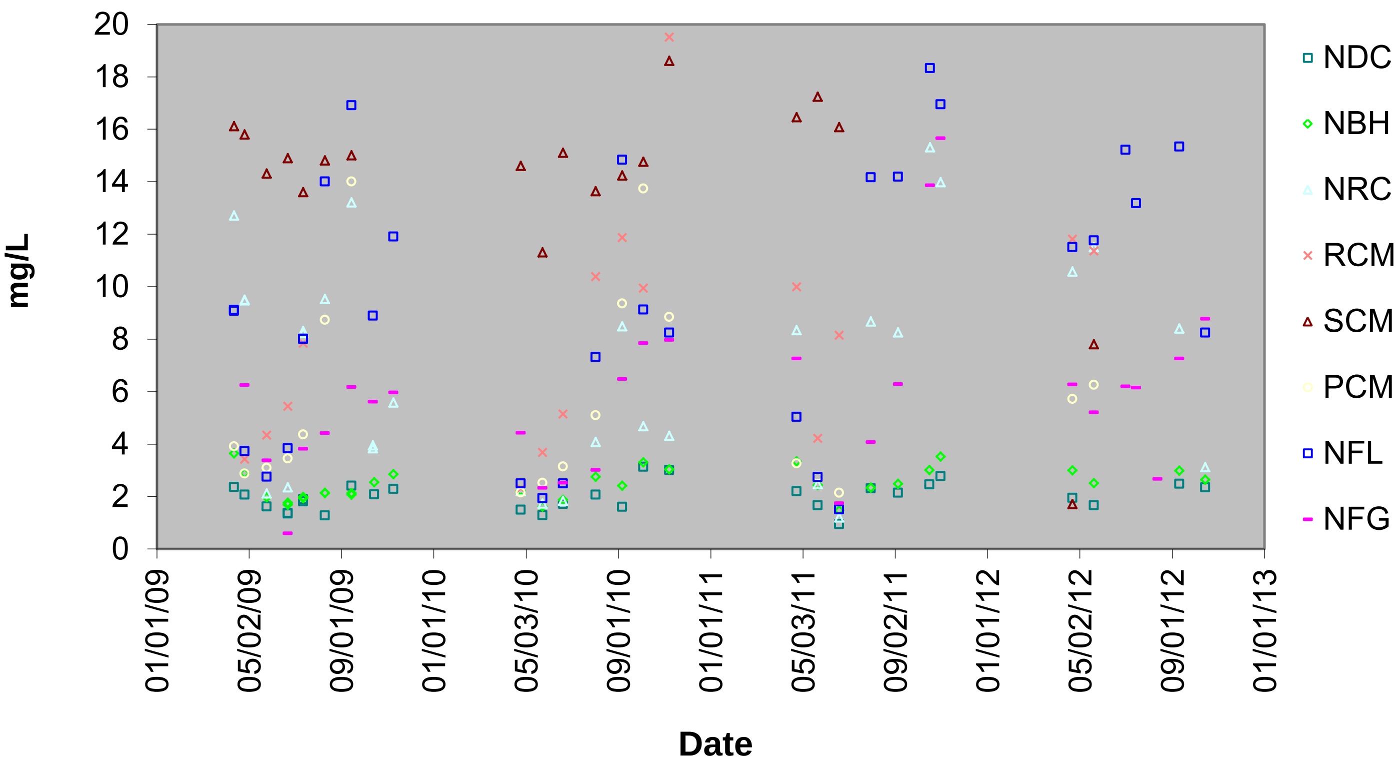


Figure 29 (a & b). Potassium (K)

Figure 29.a. Potassium (K) on the Mainstem CLP

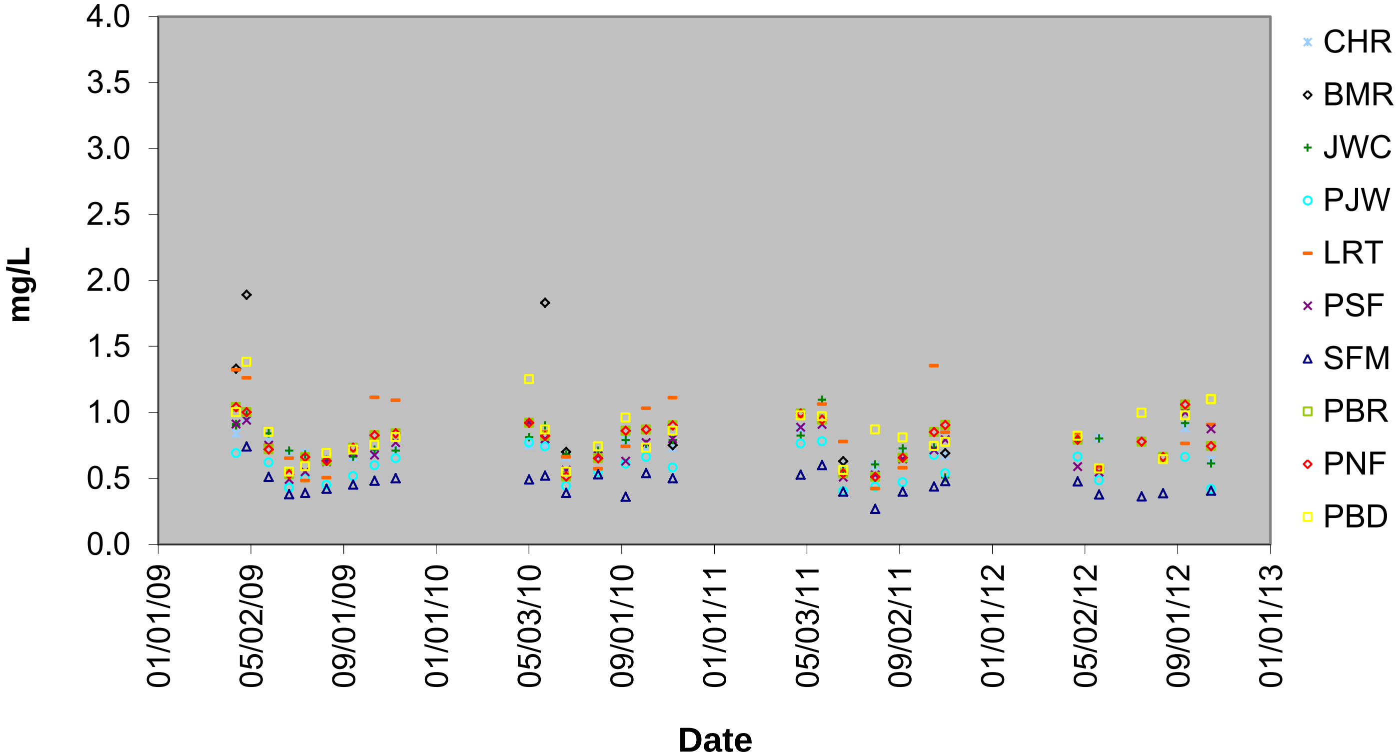


Figure 29.b. Potassium (K) on the North Fork CLP

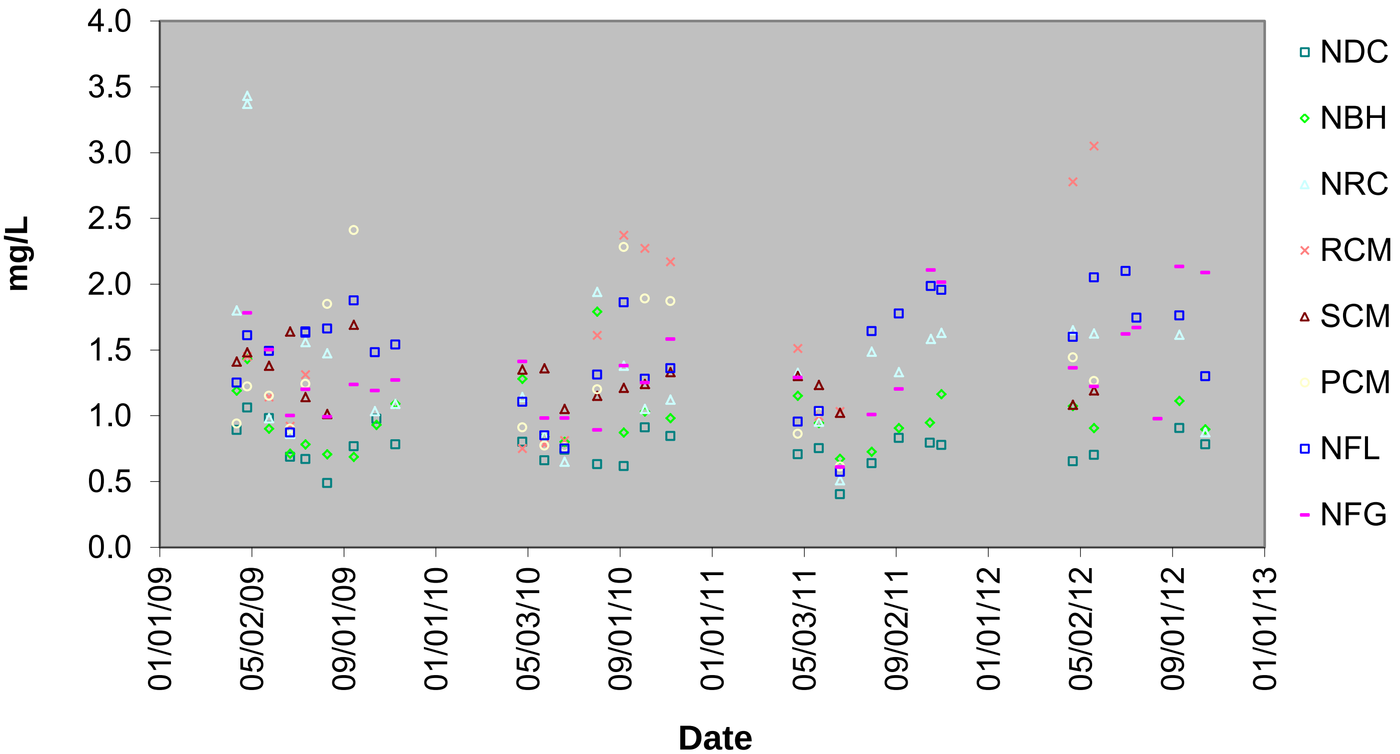


Figure 30 (a & b). Sodium (Na)

Figure 30.a. Sodium (Na) on the Mainstem CLP

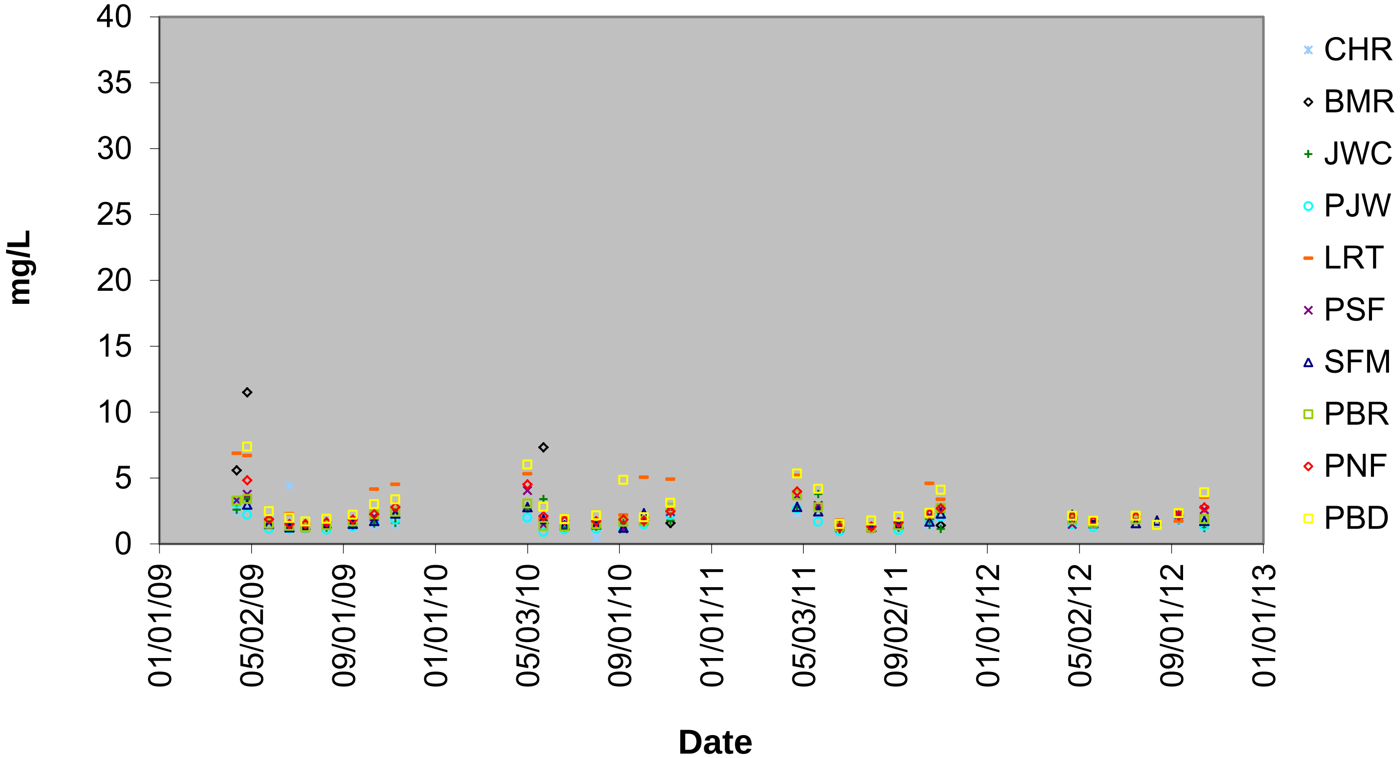


Figure 30.b. Sodium (Na) on the North Fork CLP

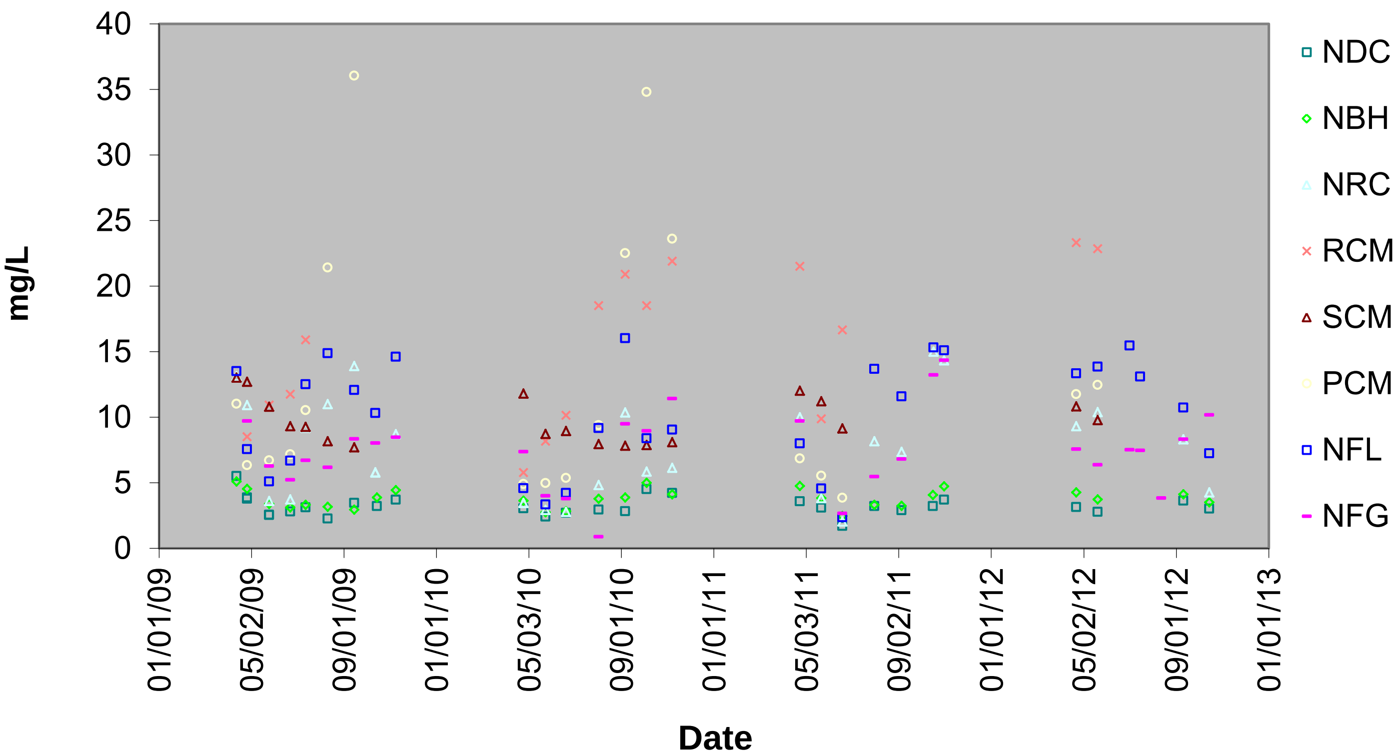


Figure 31 (a & b). Chloride (Cl)

Figure 31.a. Chloride (Cl) on the Mainstem CLP

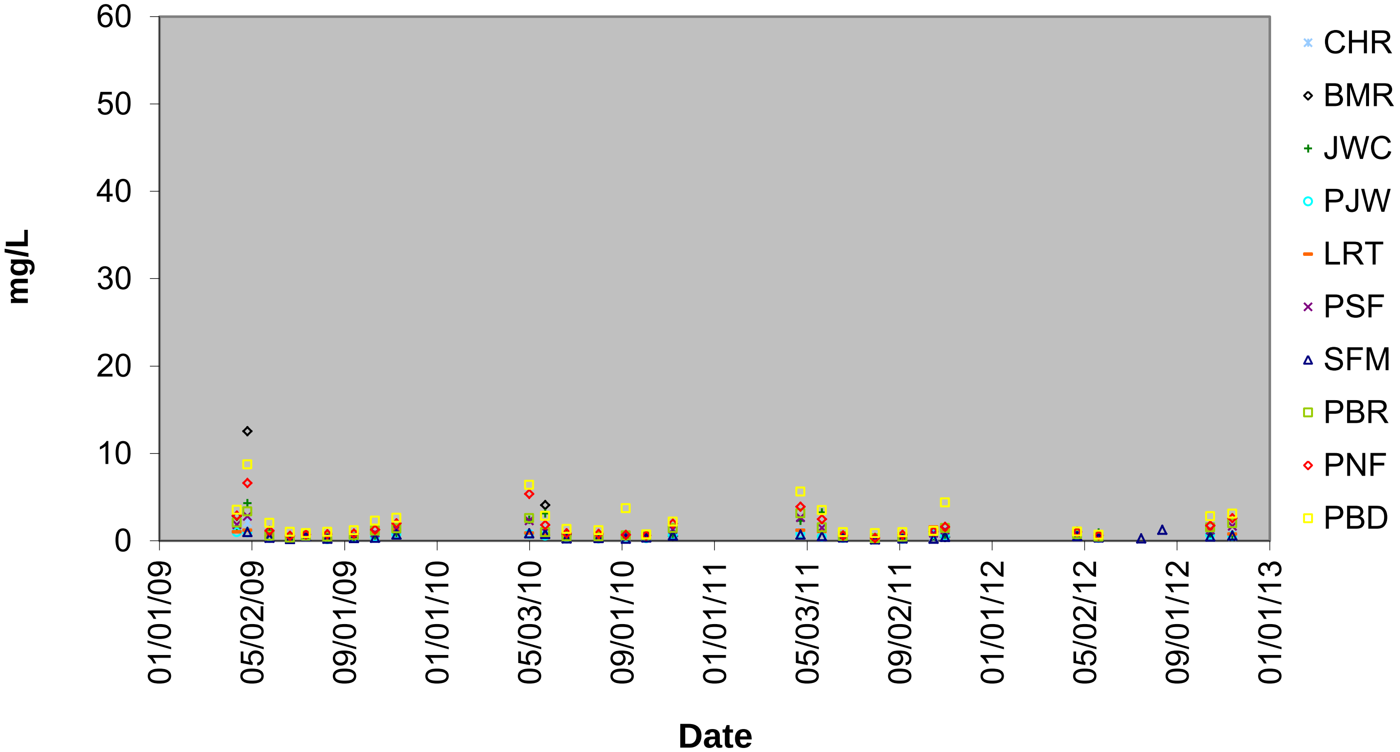


Figure 31.b. Chloride (Cl) on the North Fork CLP

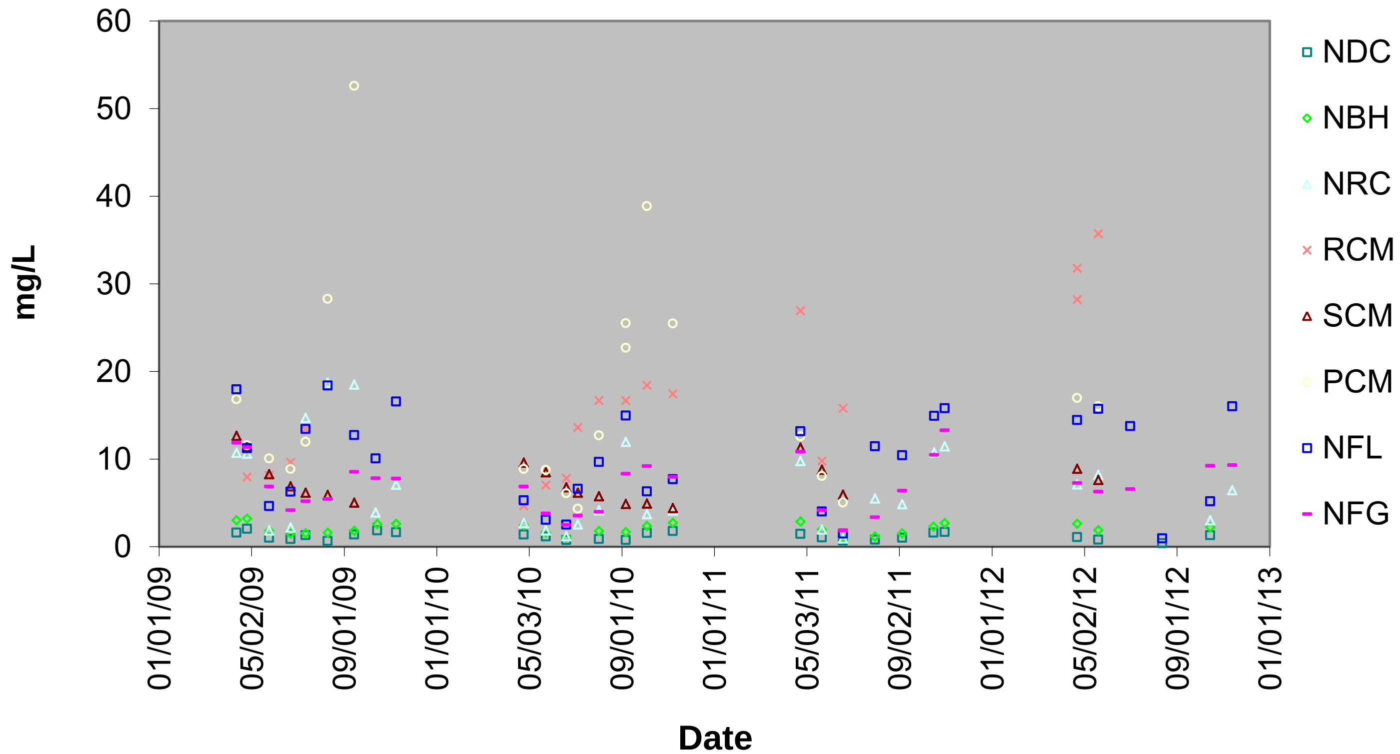


Figure 32 (a & b). Sulfate (SO_4)

Figure 32.a. Sulfate (SO_4) on the Mainstem CLP

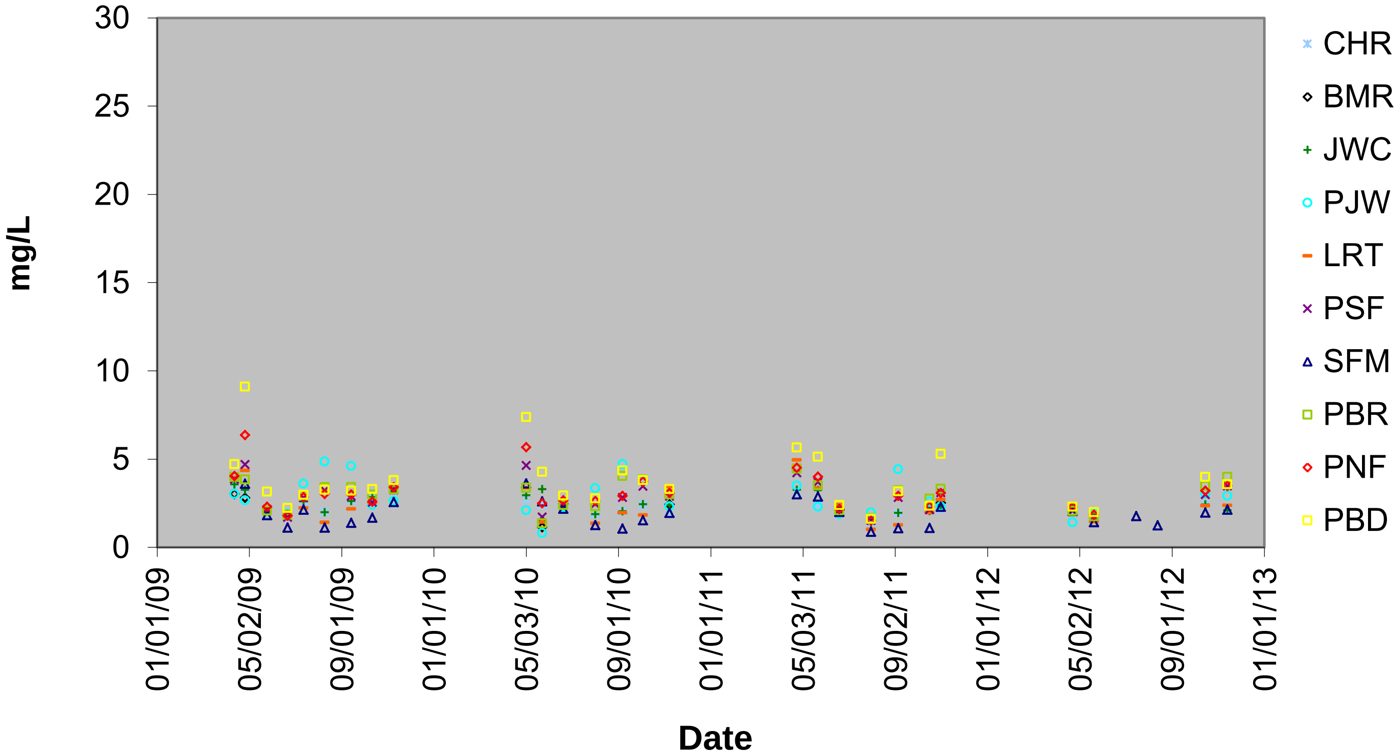
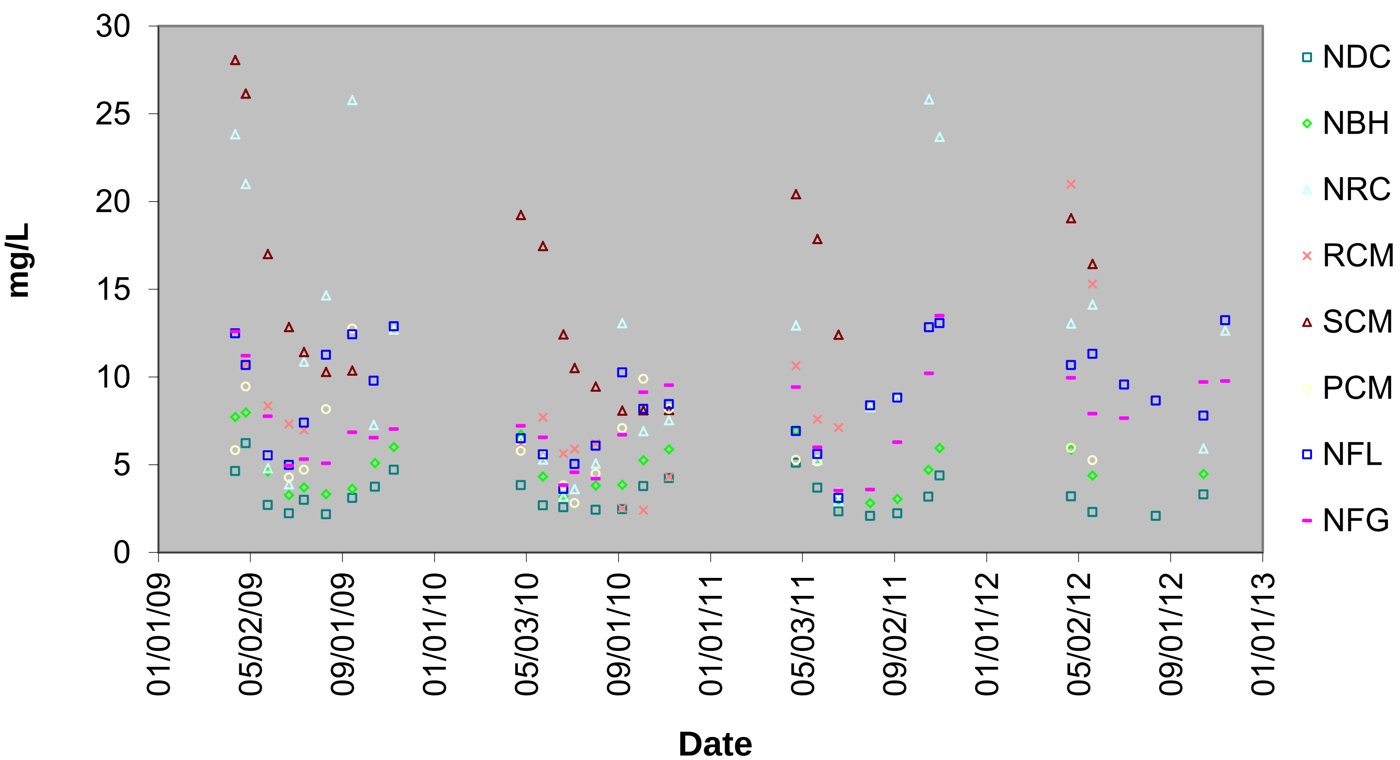


Figure 32.b. Sulfate (SO_4) on the North Fork CLP



(EPA Secondary Drinking Water Standard: 250 ug/L)

Mainstem and North Fork CLP: Microbiological Constituents

Figure 33. Total coliforms on the Mainstem and North Fork CLP

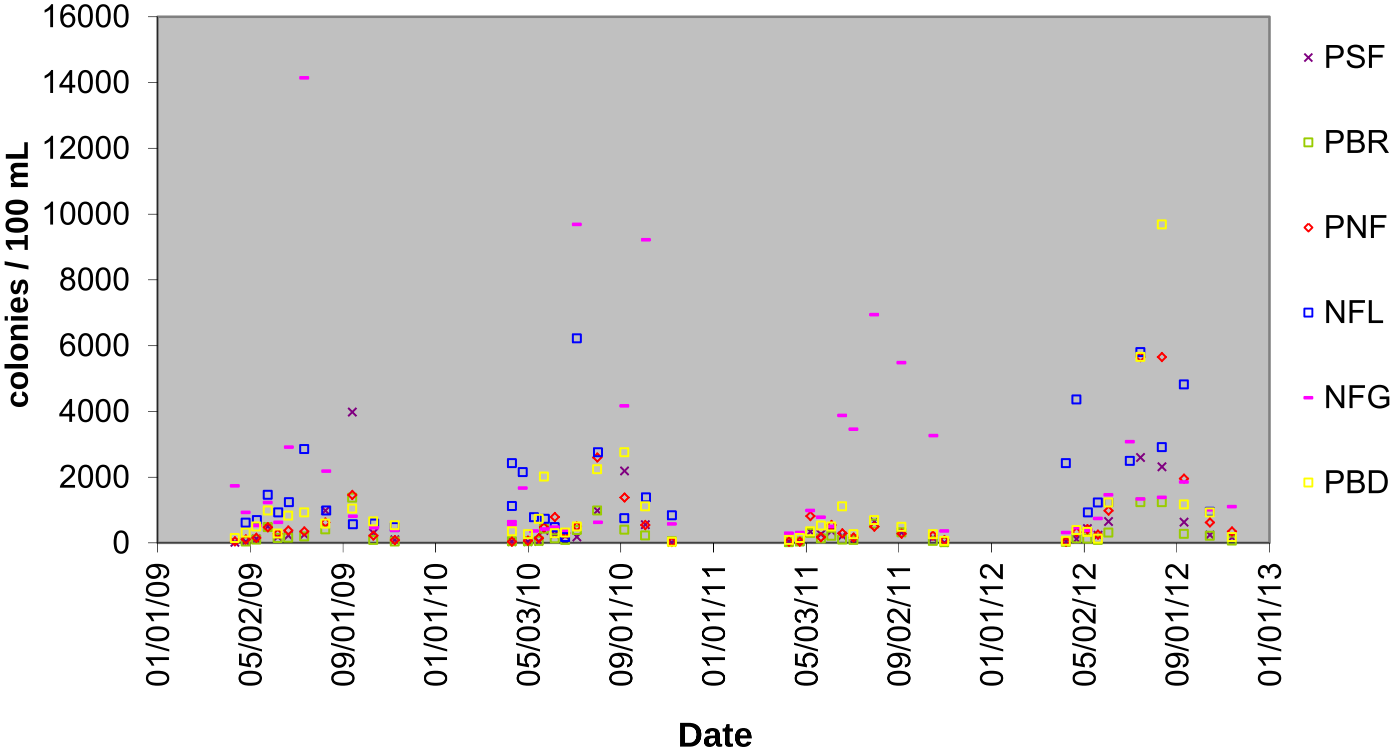


Figure 34. *E.coli* on the Mainstem and North Fork CLP

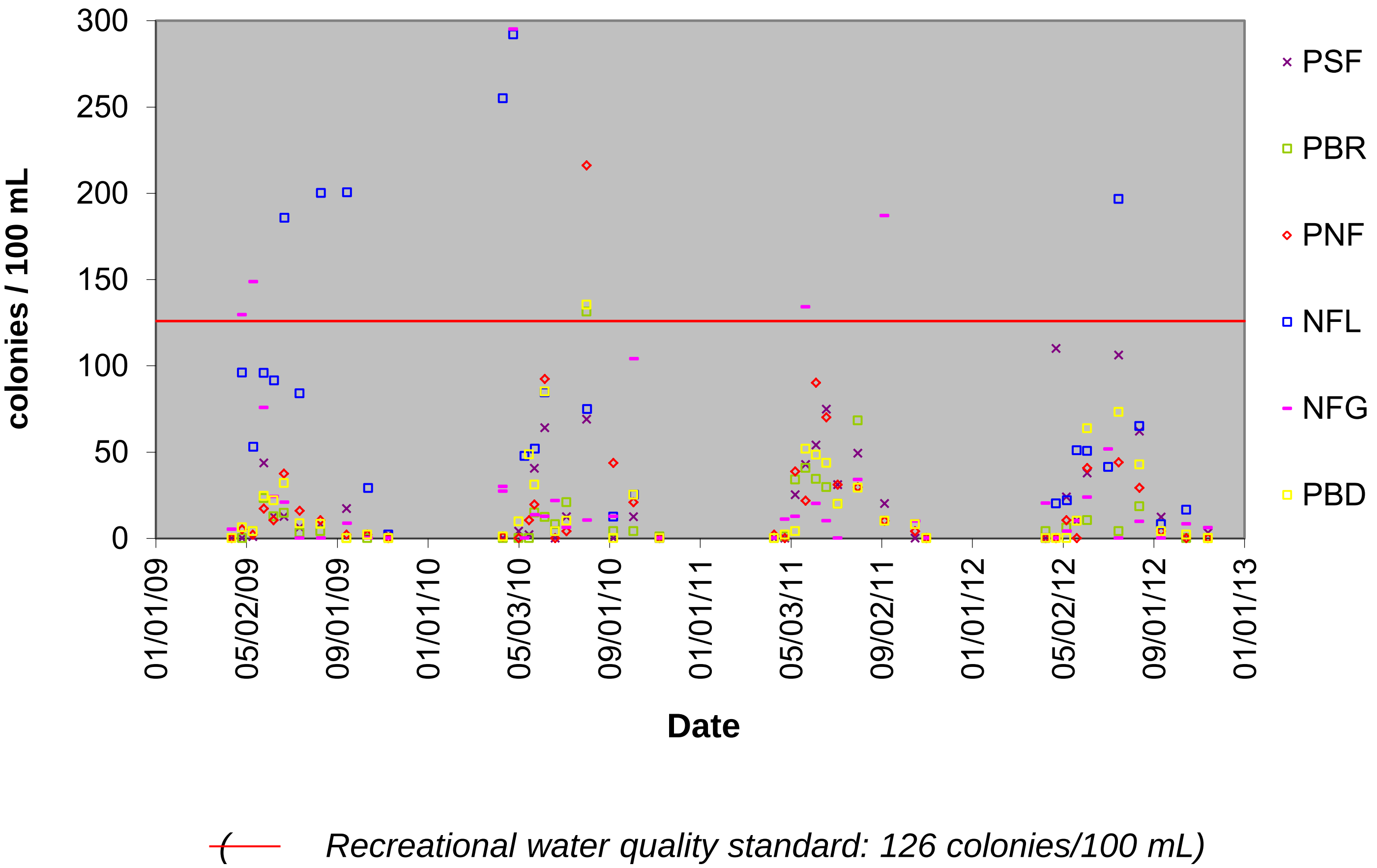


Figure 35. *Giardia* on the Mainstem and North Fork CLP

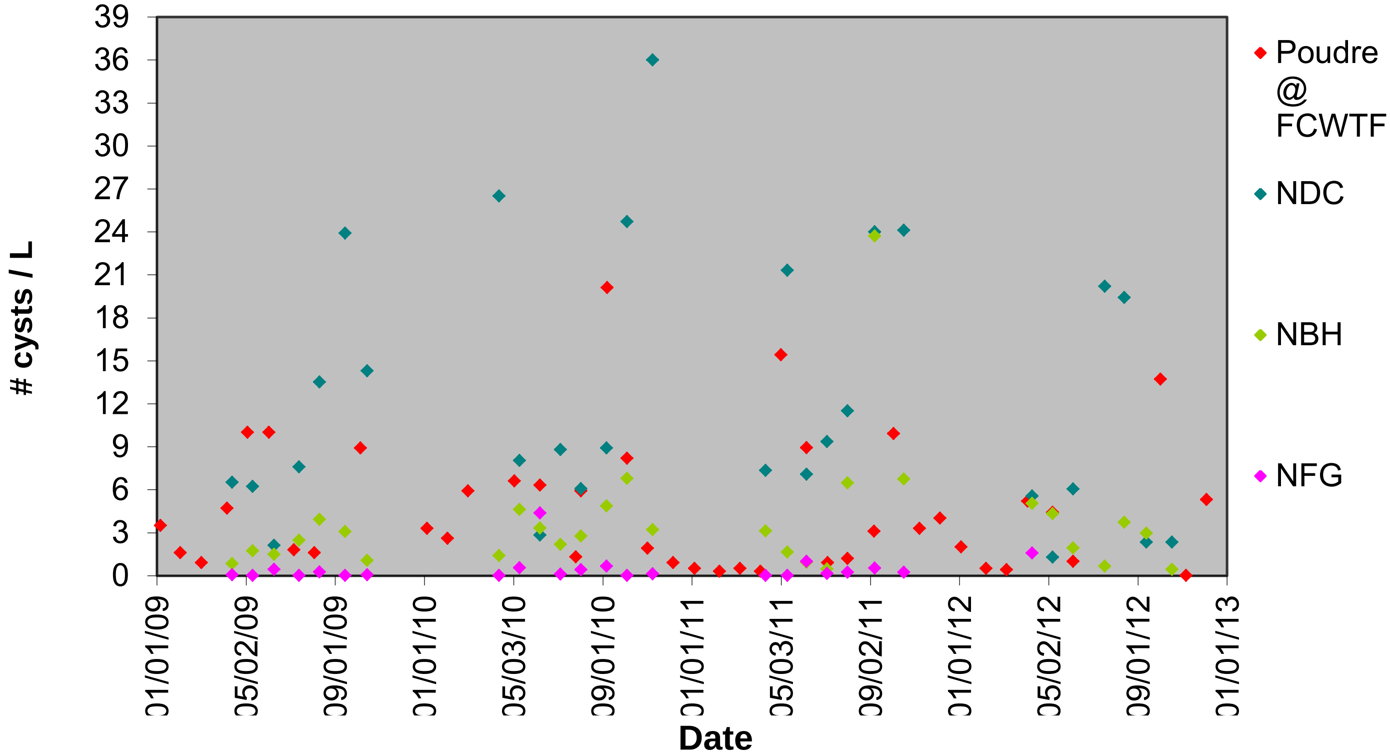
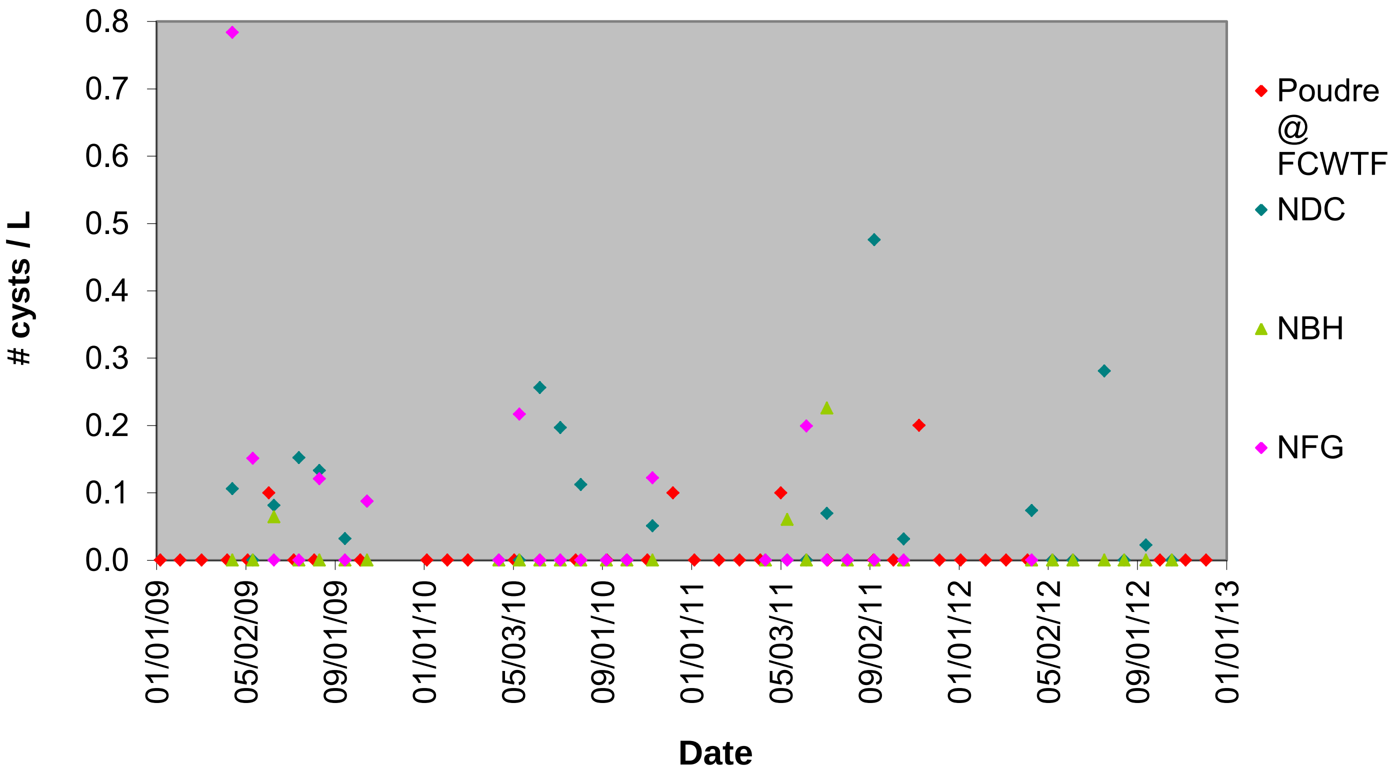
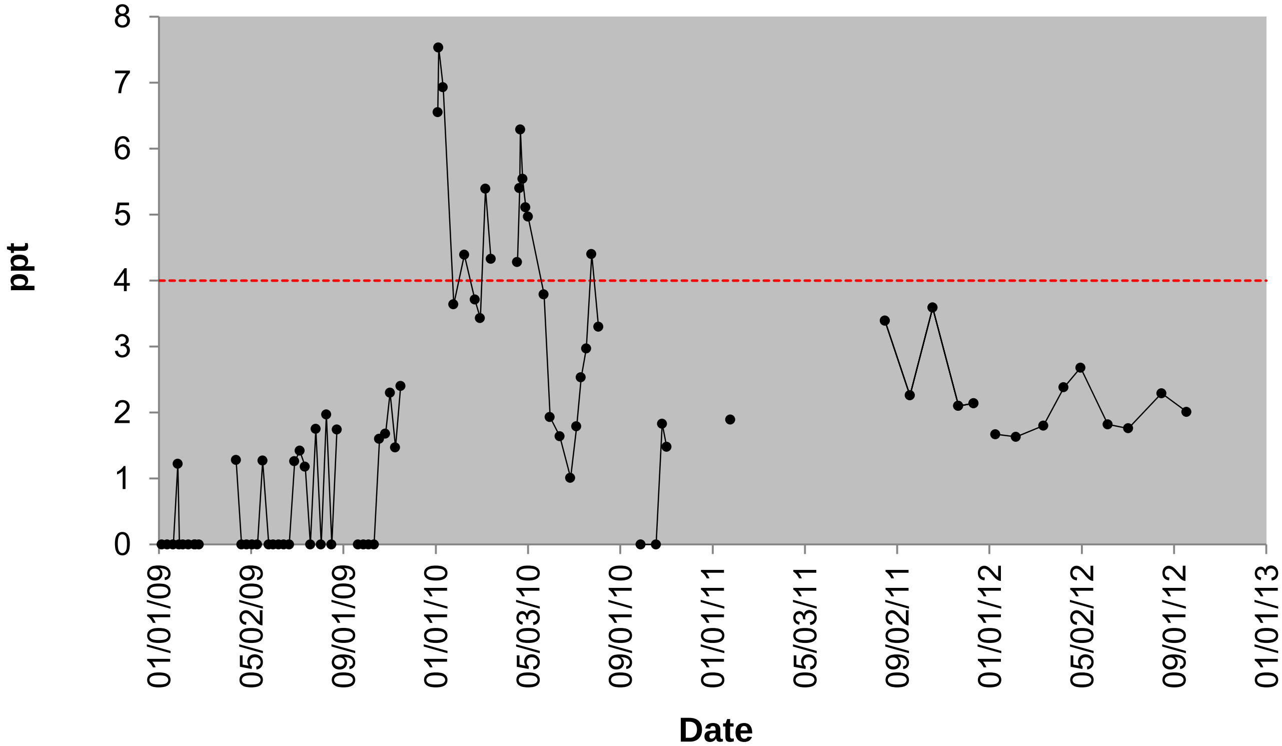


Figure 36. *Cryptosporidium* on the Mainstem and North Fork CLP



Mainstem and North Fork CLP: Geosmin

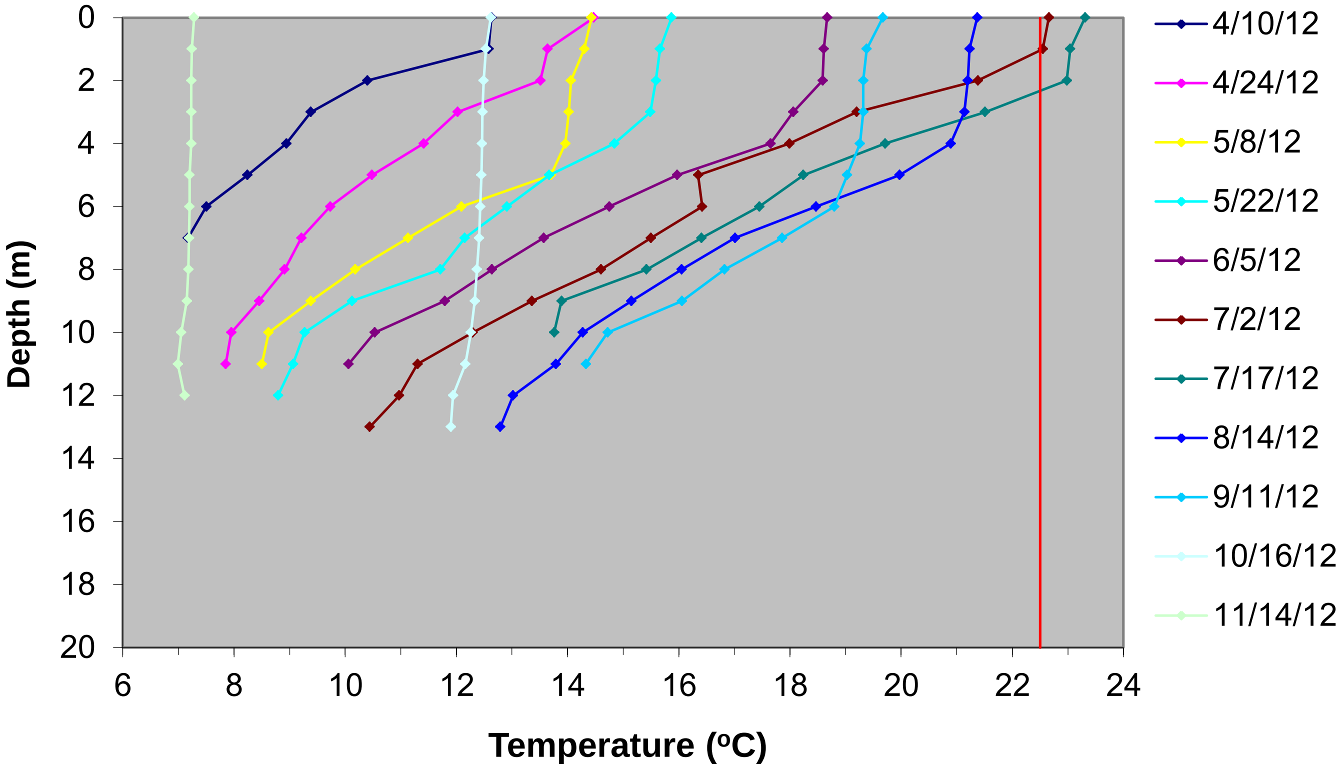
Figure 37. Geosmin on the Mainstem CLP collected at the FCWTF



(----- Taste and odor threshold for geosmin: 4 ppt)

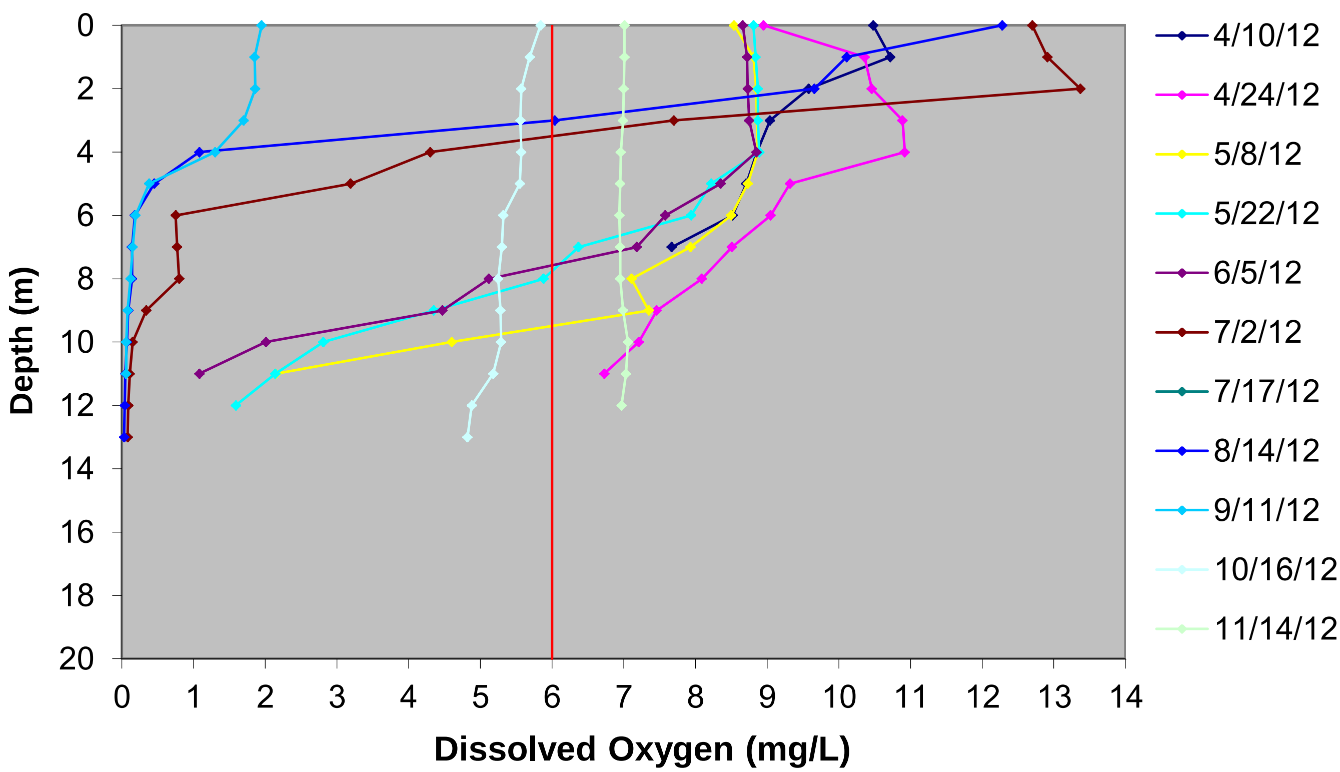
Seaman Reservoir:
Depth Profiles
(Temperature, D.O., pH & Conductance)

Figure 38. 2011 Seaman Reservoir temperature profiles



(Water quality standard for cold water aquatic life: 6.0 mg/L D.O.)

Figure 39. 2011 Seaman Reservoir dissolved oxygen (D.O.) profiles



(Water quality standard for cold water aquatic life: 6.0 mg/L D.O.)

Figure 40. 2011 Seaman Reservoir pH profiles

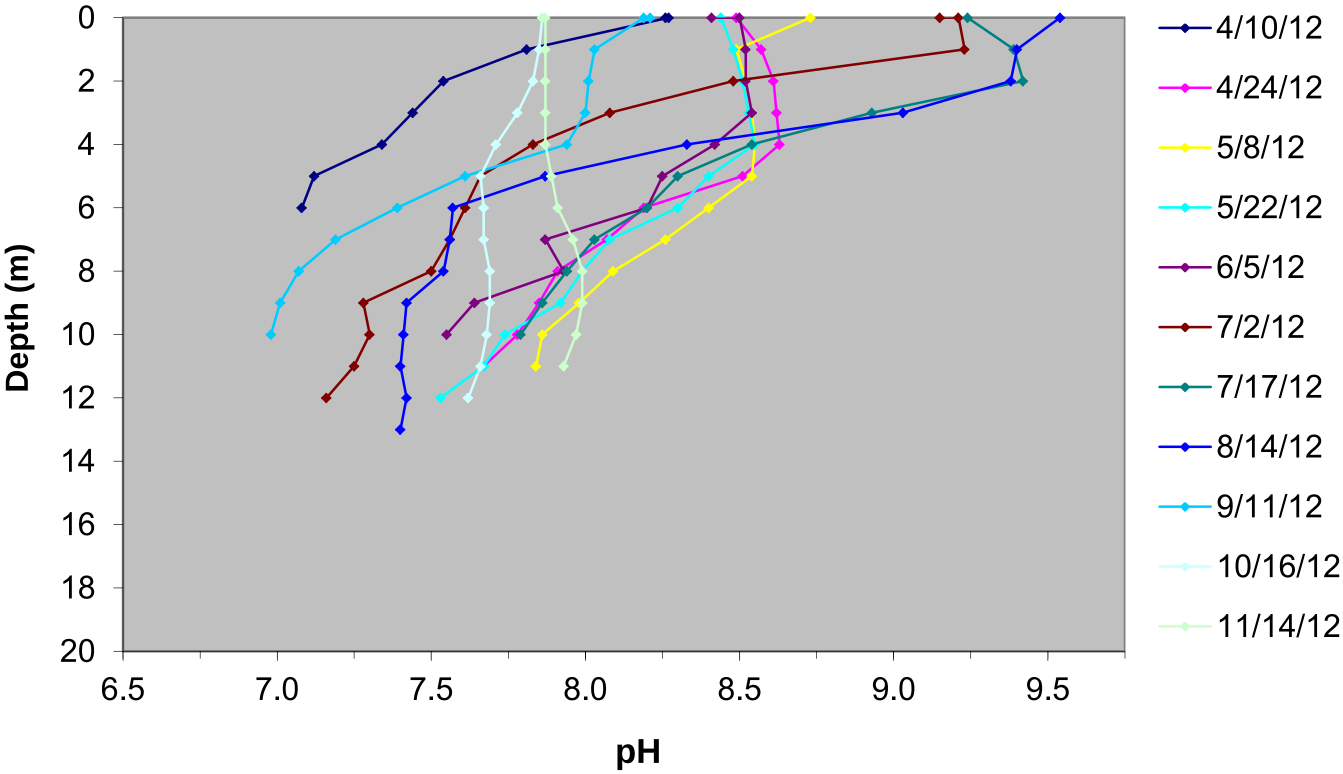
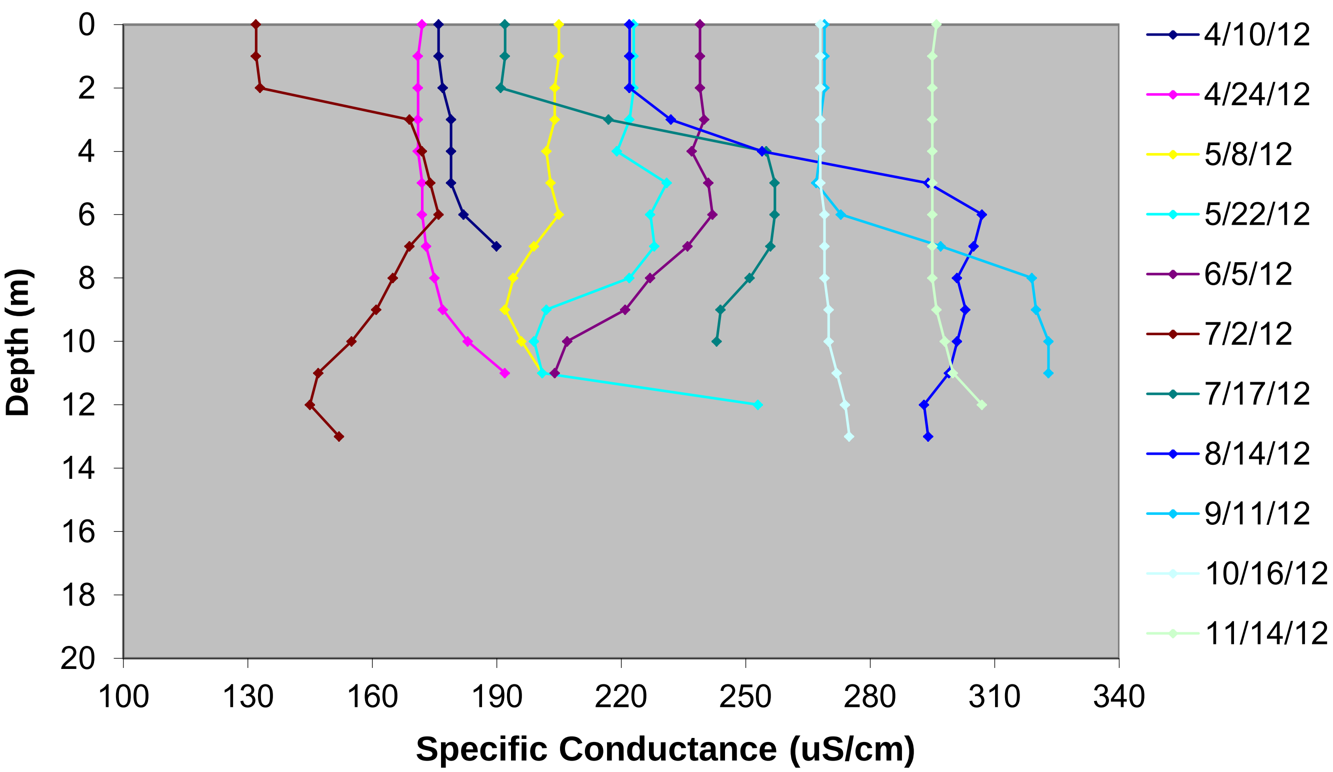


Figure 41. 2011 Seaman Reservoir specific conductance profiles



Seaman Reservoir:
General Parameters

Figure 42. Alkalinity concentrations in Seaman Reservoir

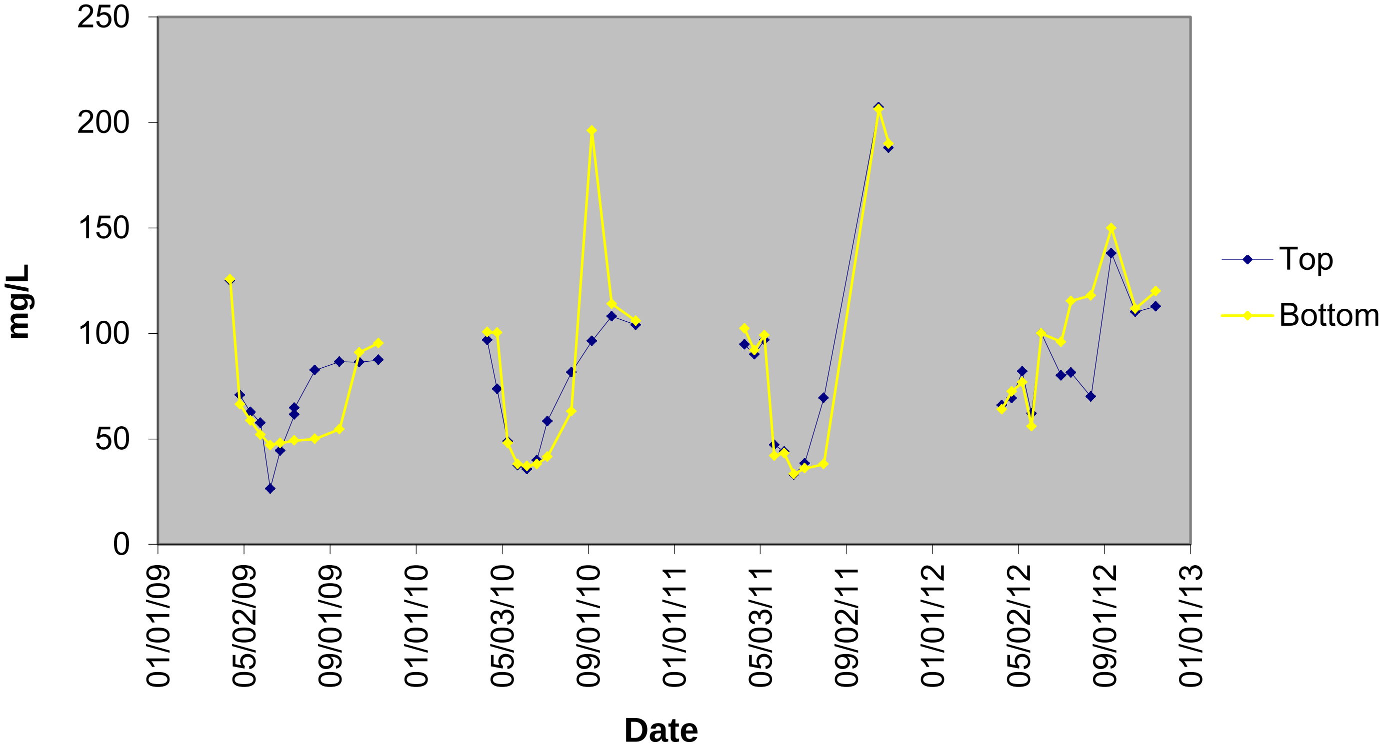


Figure 43. Hardness concentrations in Seaman Reservoir

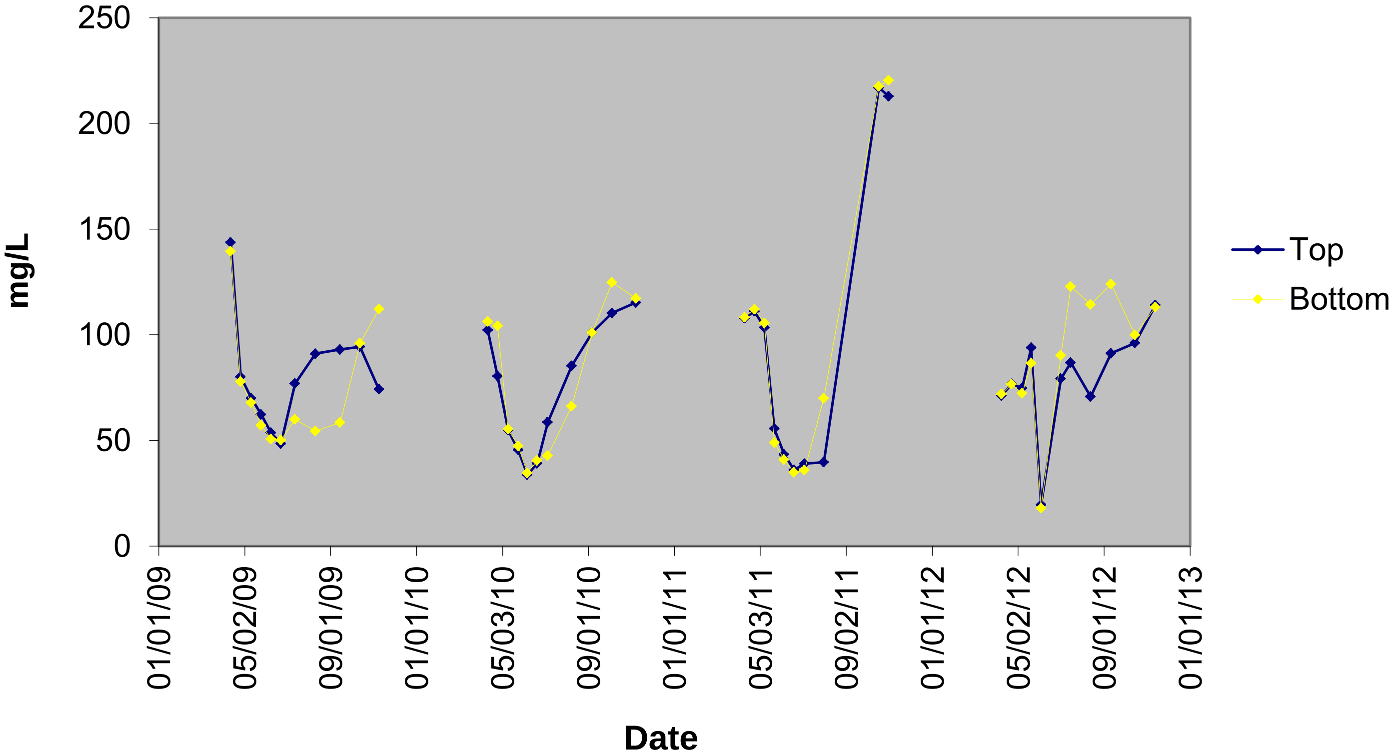


Figure 44. Turbidity in Seaman Reservoir

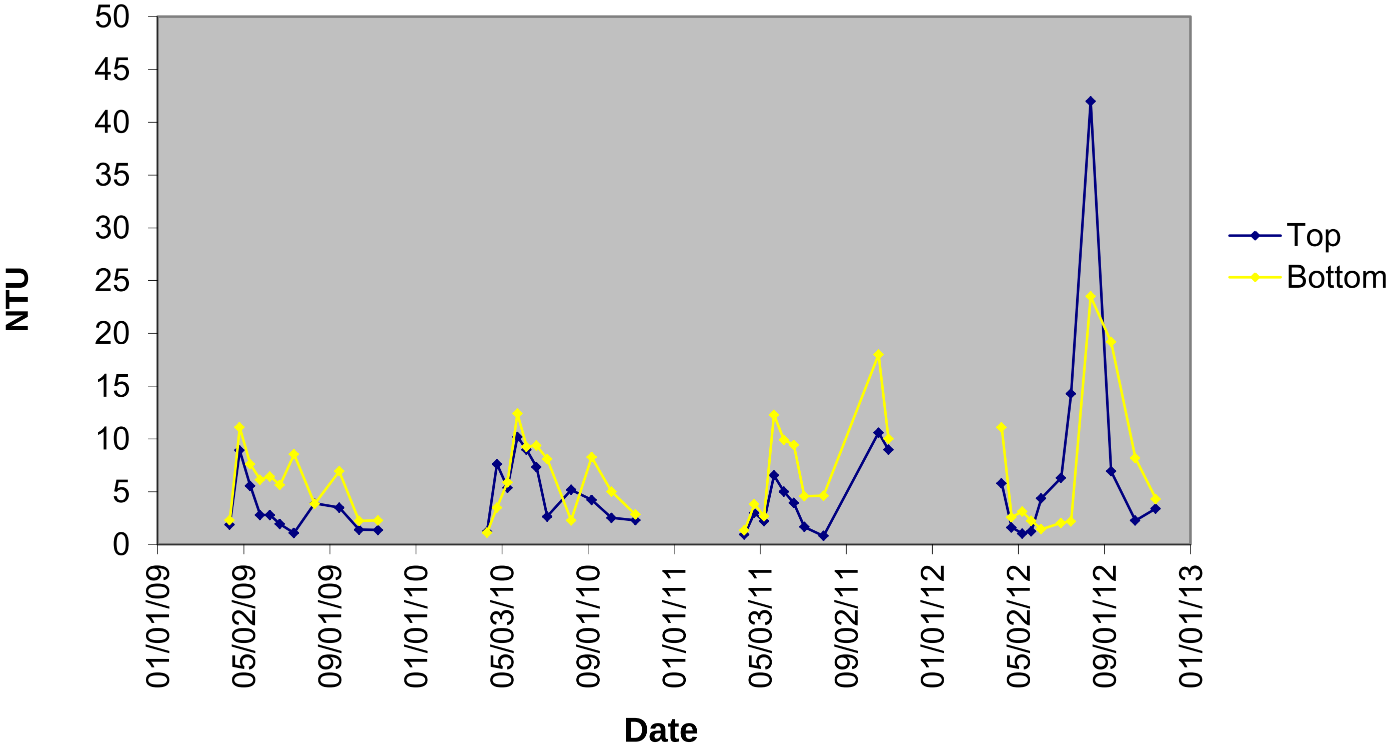
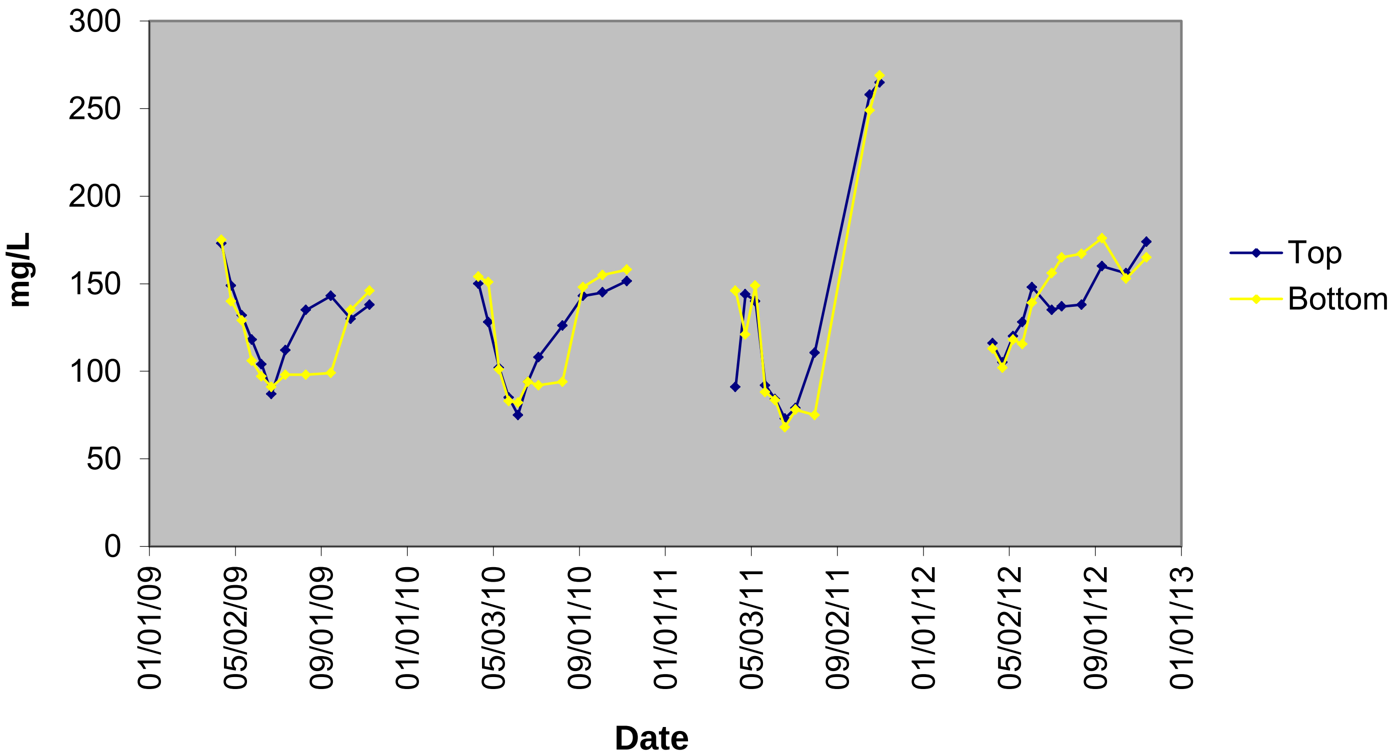
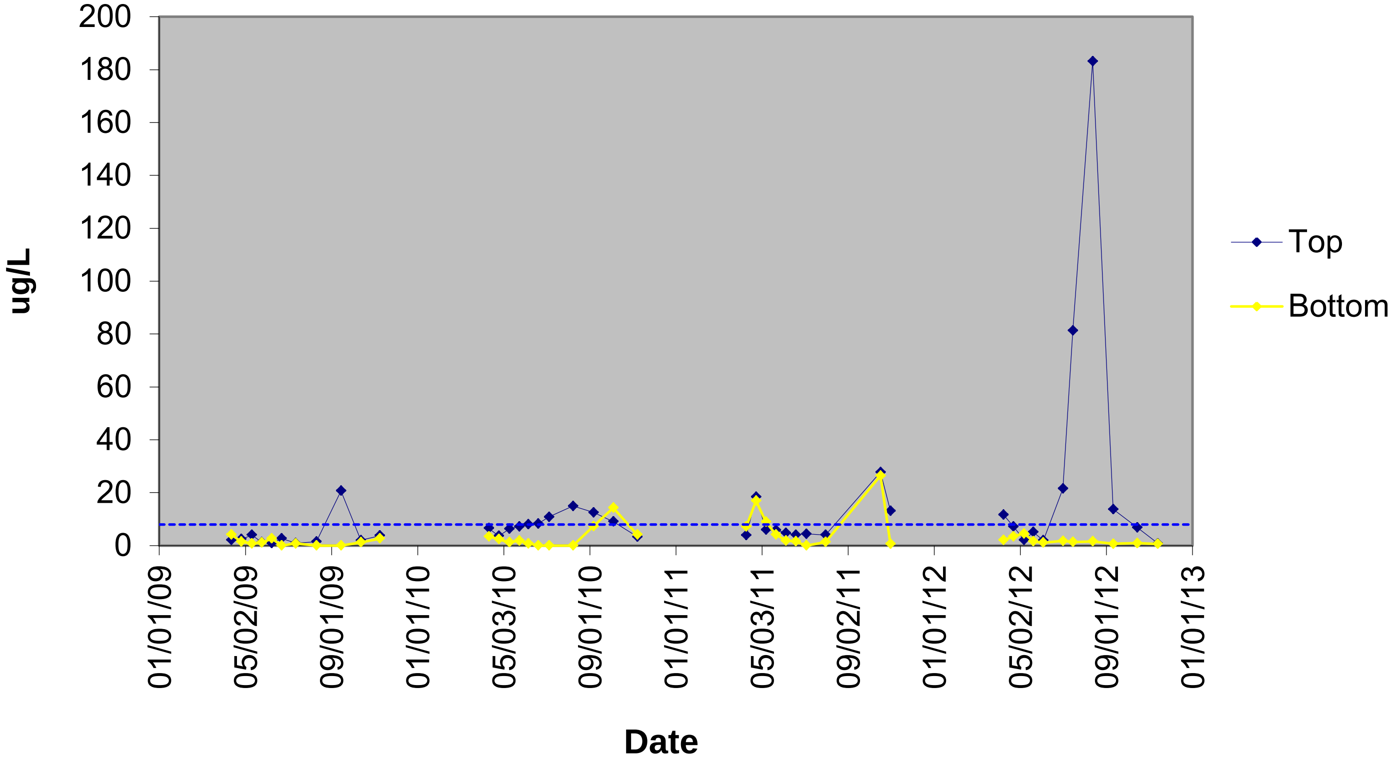


Figure 45. Total dissolved solids (TDS) in Seaman Reservoir



(EPA Secondary Drinking Water Standard: 500 ug/L)

Figure 46. Chlorophyll-a concentrations in Seaman Reservoir



(------- 2012 CDPHE/WQCD proposed cold water reservoir standard for chlorophyll-a: summer average of 8 ug/L in the mixed (top) layer)

Figure 47. Total organic carbon (TOC) in Seaman Reservoir

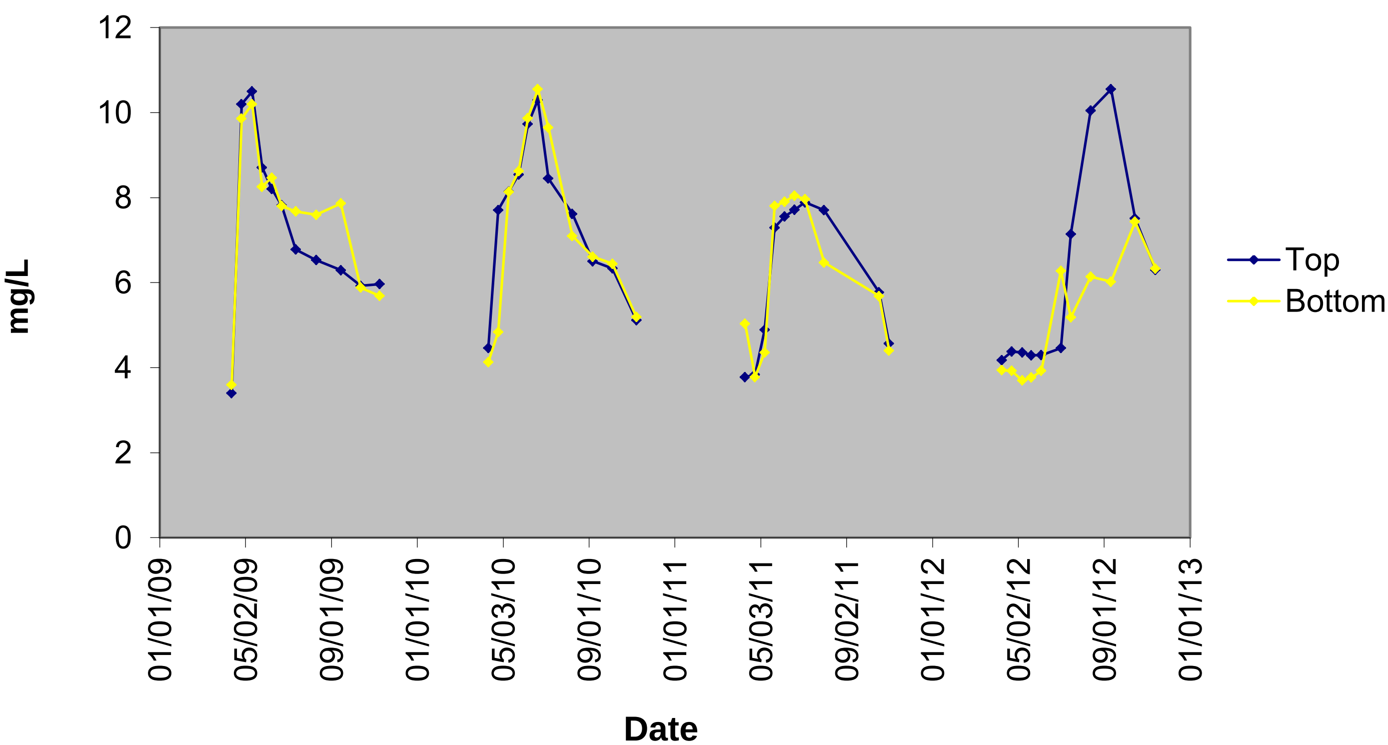
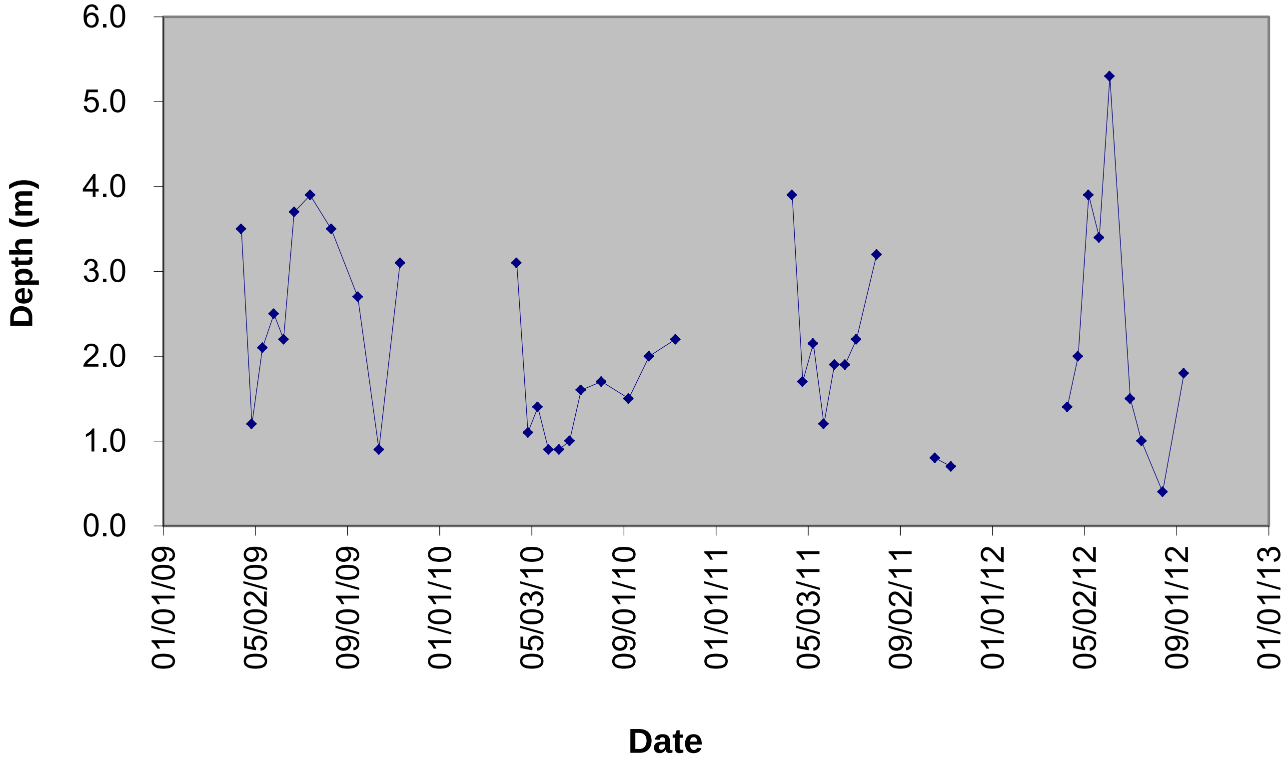
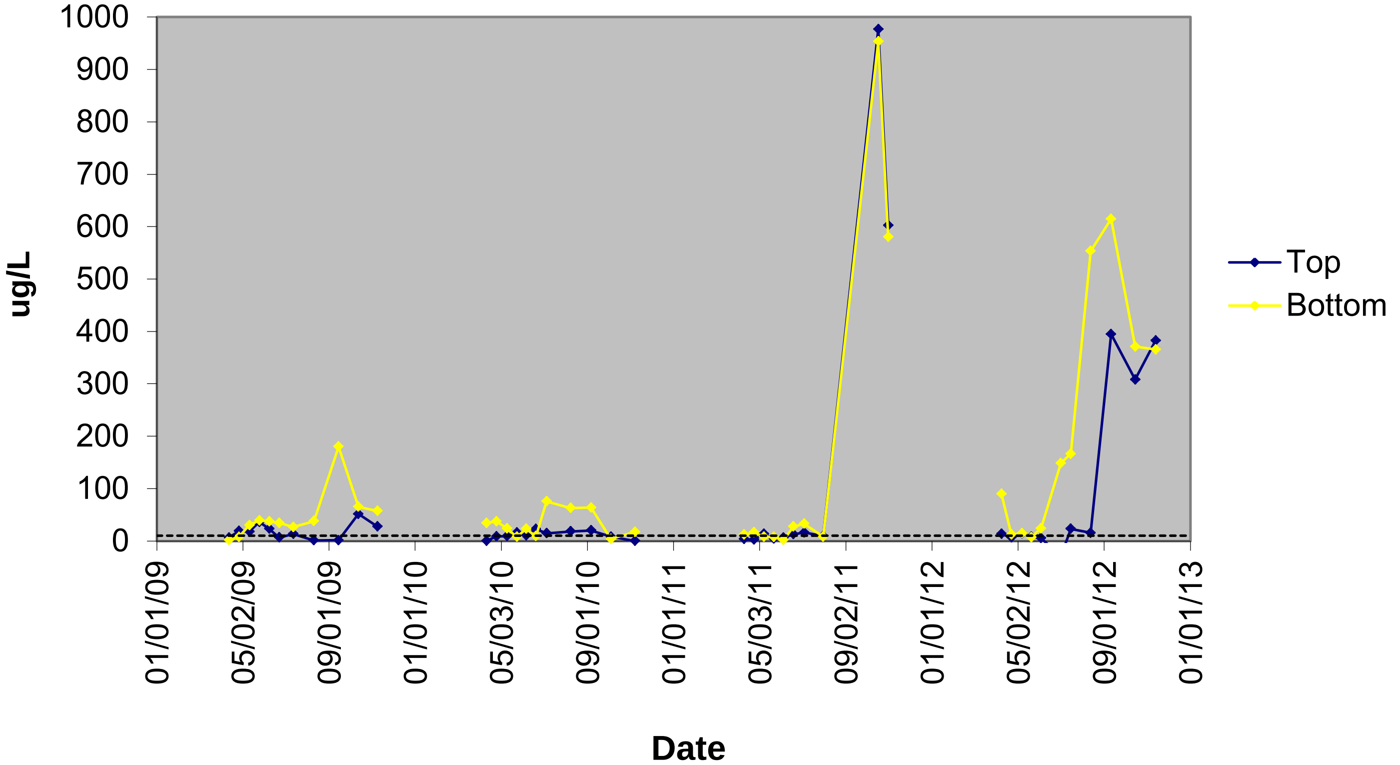


Figure 48. Secchi disk depth in Seaman Reservoir



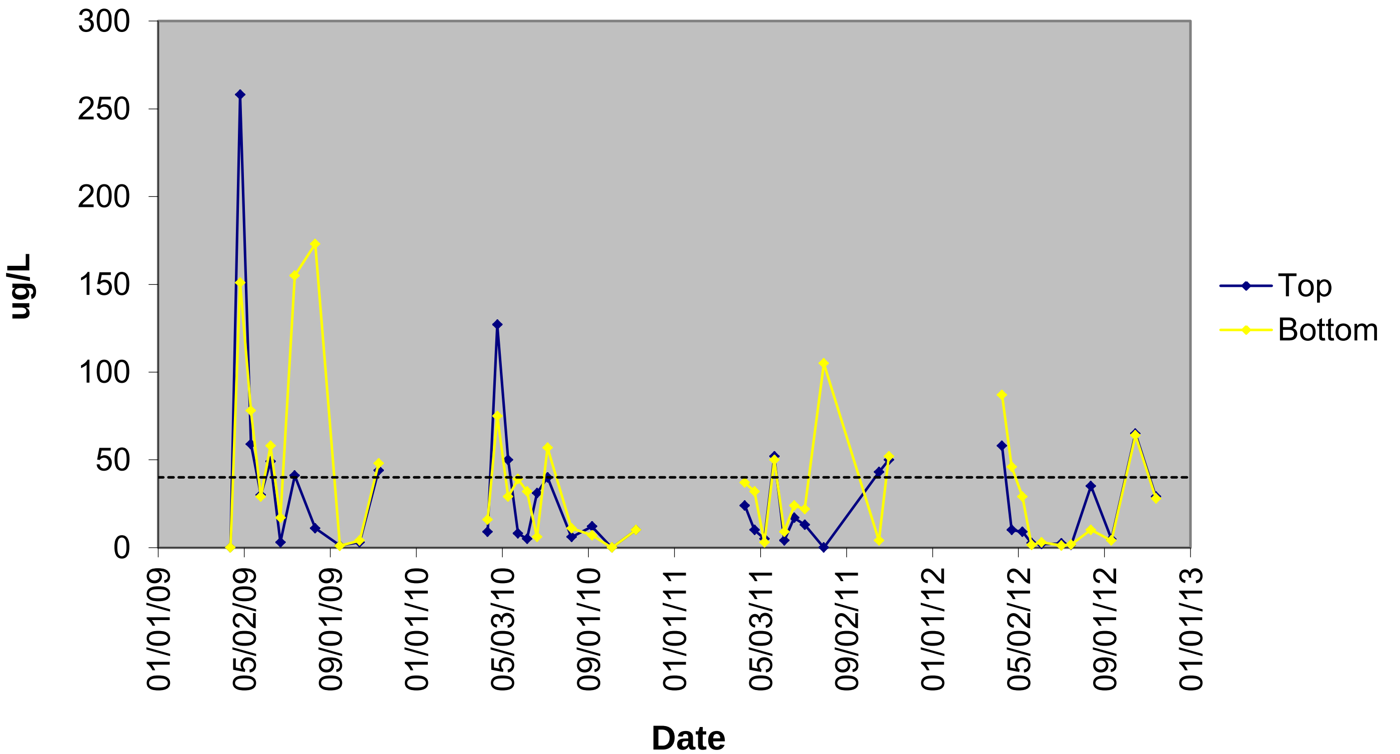
Seaman Reservoir:
Nutrients

Figure 49. Ammonia as N (NH3-N) concentrations in Seaman Reservoir



(----- FCWQL Reporting Limit: 10 ug/L)

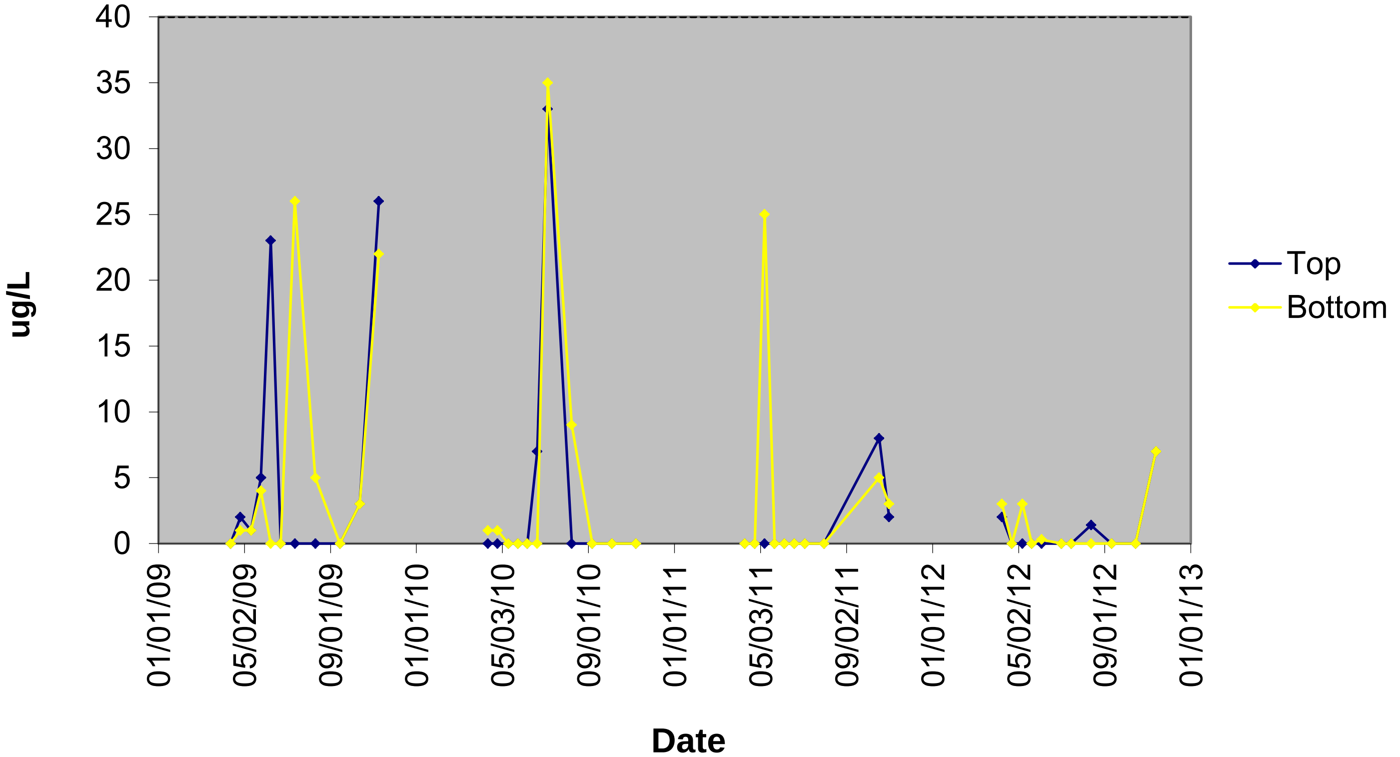
Figure 50. Nitrate as N (NO_{3-}-N) concentrations in Seaman Reservoir



(----- FCWQL Reporting Limit: 40 ug/L)

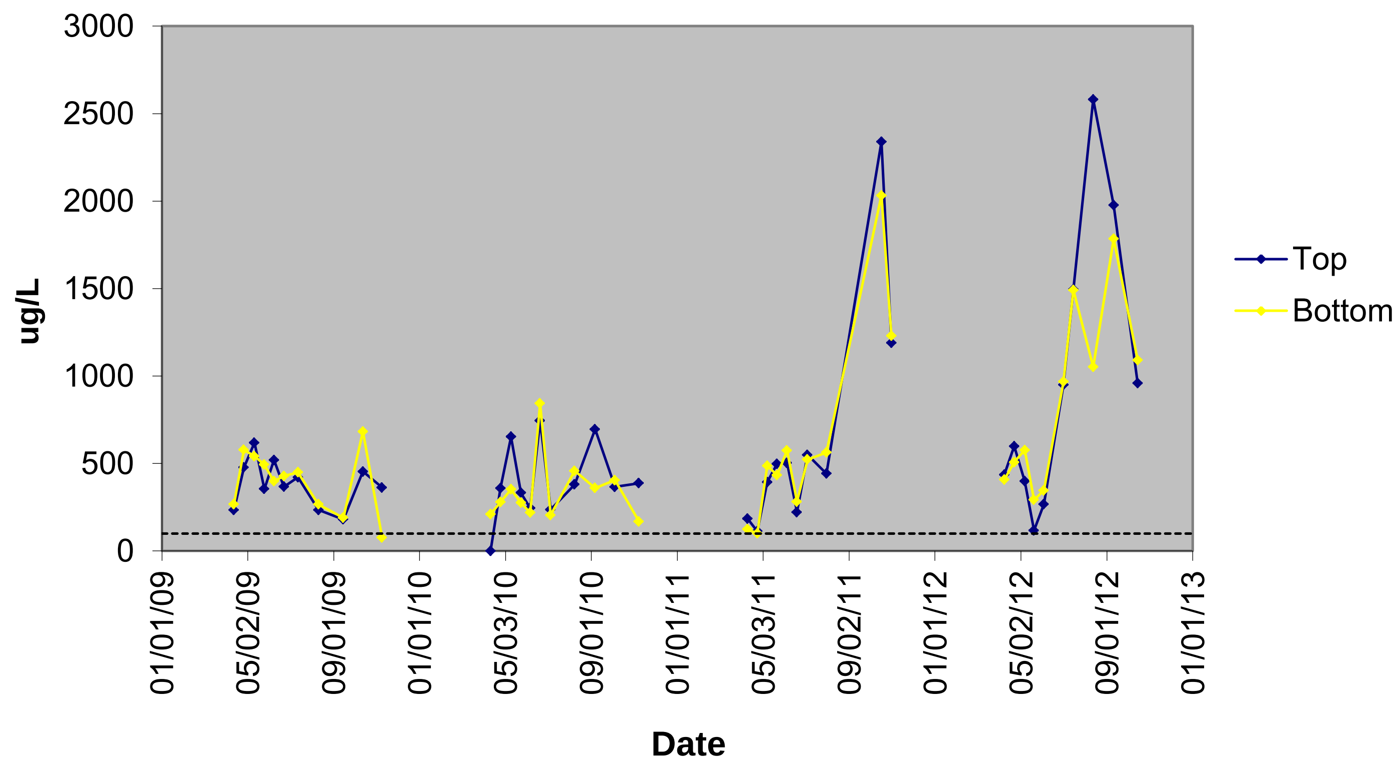
(EPA Maximum Contaminant Level: 10,000 ug/L)

Figure 51. Nitrite as N (NO_2-N) concentrations in Seaman Reservoir



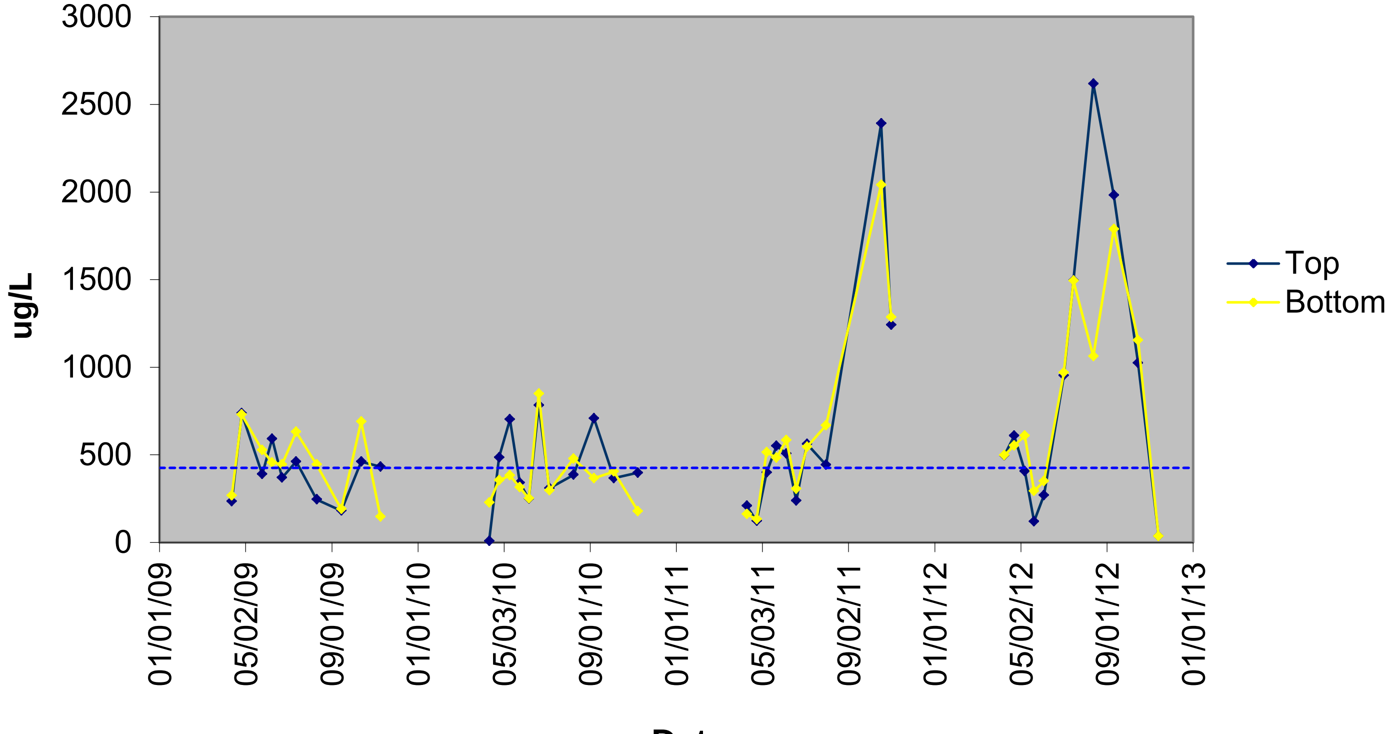
(----- FCWQL Reporting Limit: 40 ug/L)

Figure 52. Total Kjeldahl Nitrogen (TKN) concentrations in Seaman Reservoir



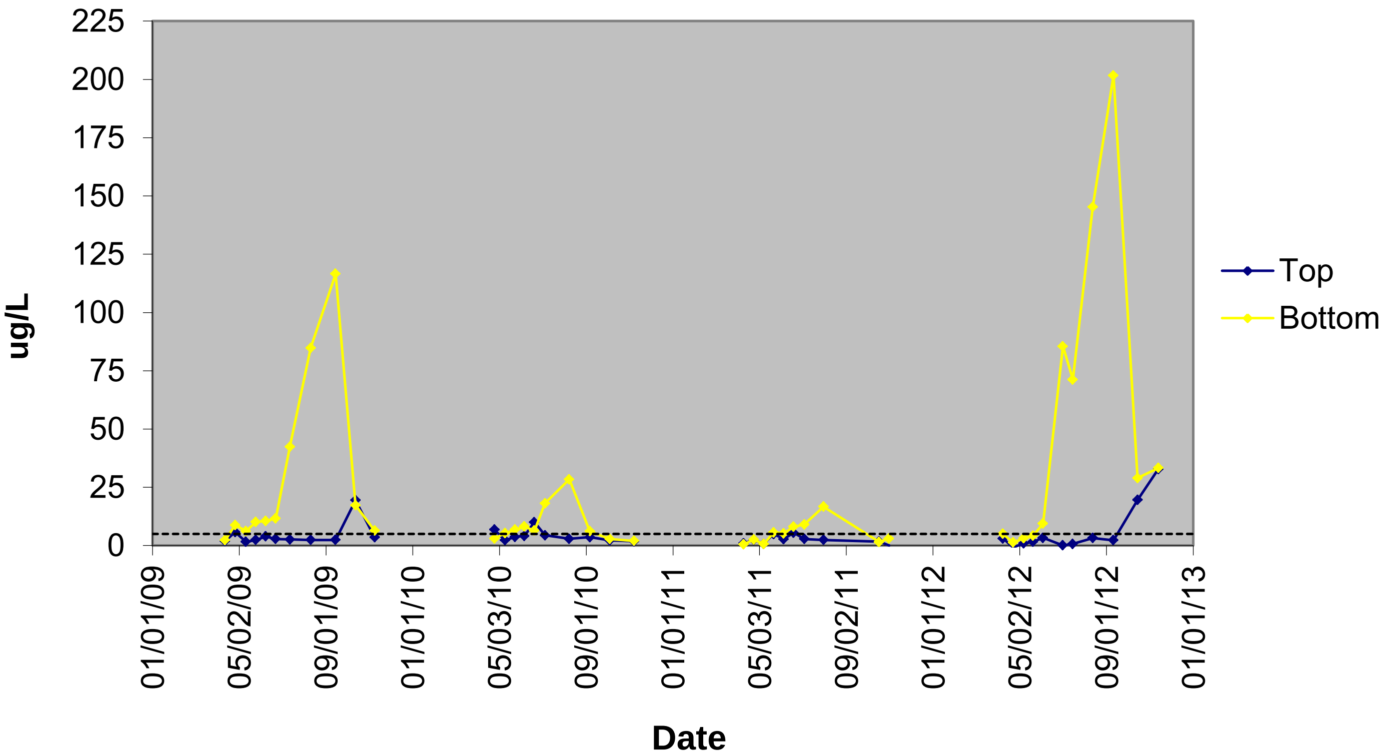
(----- FCWQL Reporting Limit: 100 ug/L)

Figure 53. Total Nitrogen (TKN+NO_3+ NO_2) concentrations in Seaman Reservoir



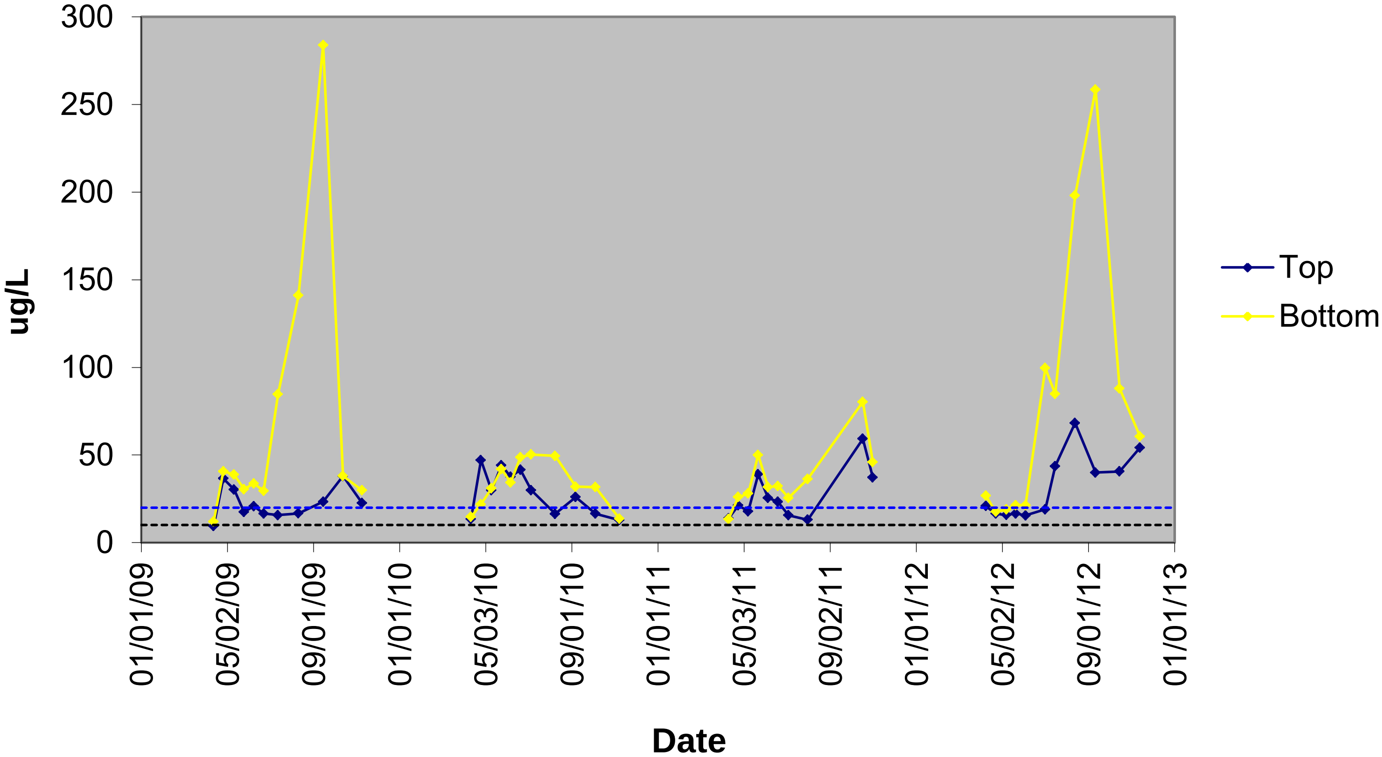
(------- 2012 CDPHE/WQCD proposed cold water reservoir standard for Total N: summer average of 426 ug/L in the mixed (top) layer)

Figure 54. Ortho-phosphate (PO_4) concentrations in Seaman Reservoir



(----- FCWQL Reporting Limit: 5 ug/L)

Figure 55. Total phosphorus (P) concentrations in Seaman Reservoir



(----- FCWQL Reporting Limit: 10 ug/L)

(------- 2012 CDPHE/WQCD proposed cold water reservoir standard for Total P: summer average of 25 ug/L in the mixed (top) layer)

Seaman Reservoir:
Major Ions

Figure 56. Calcium (Ca) concentrations in Seaman Reservoir

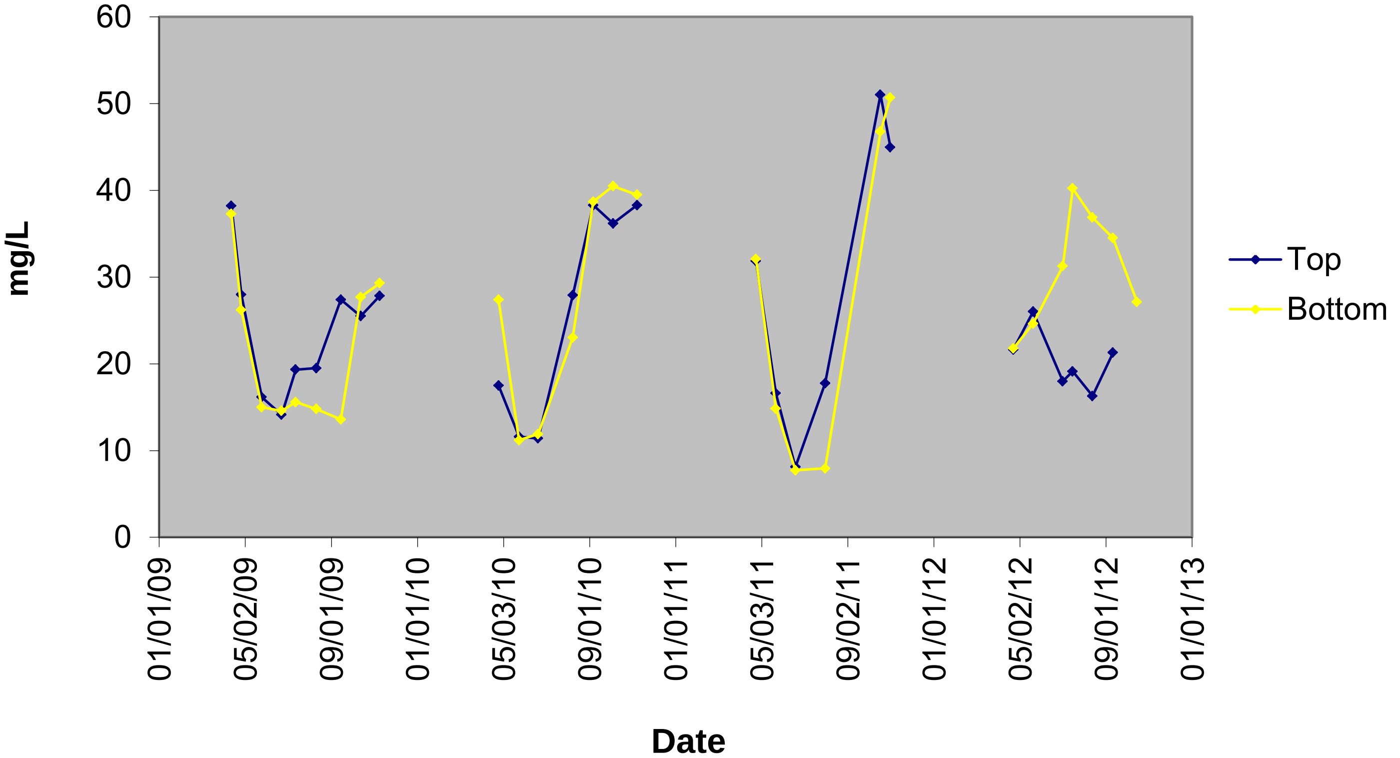


Figure 57. Magnesium (Mg) concentrations in Seaman Reservoir

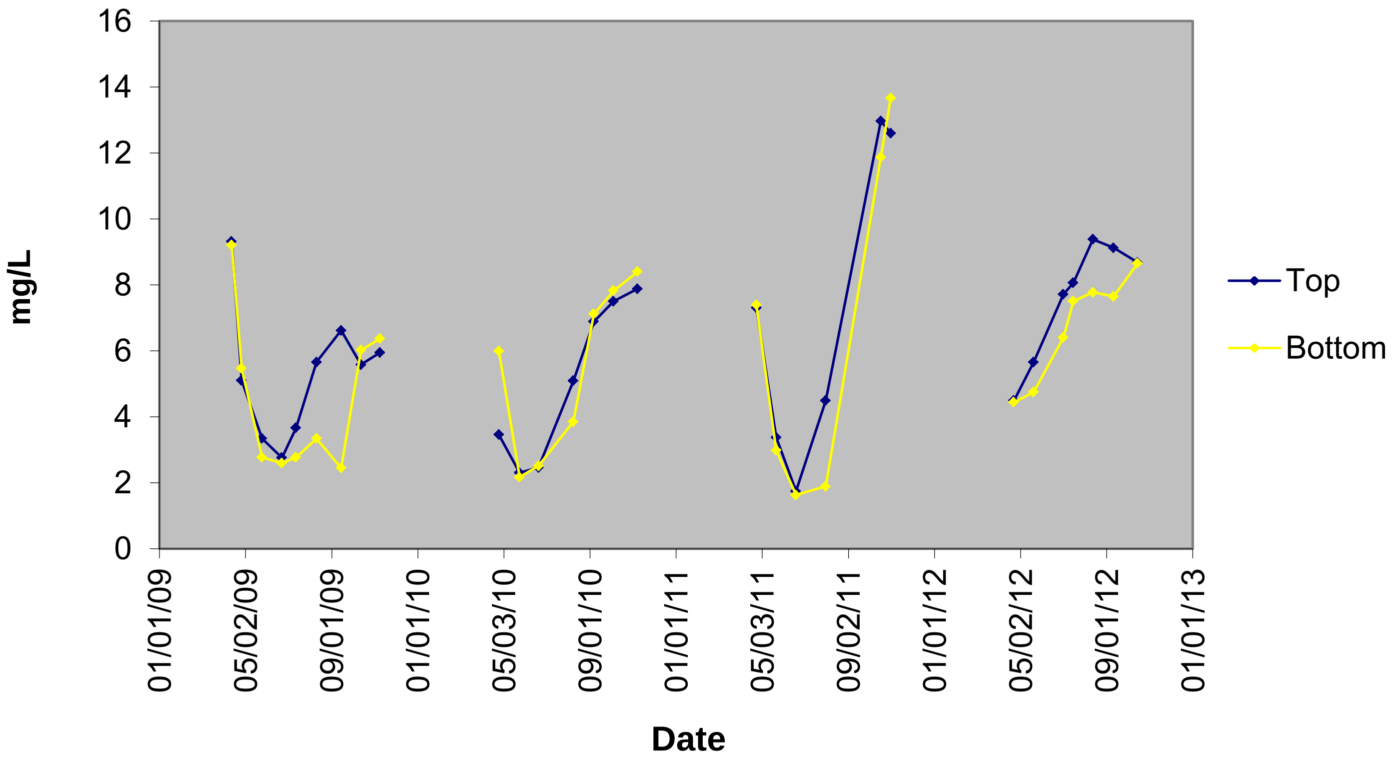


Figure 58. Potassium (K) concentrations in Seaman Reservoir

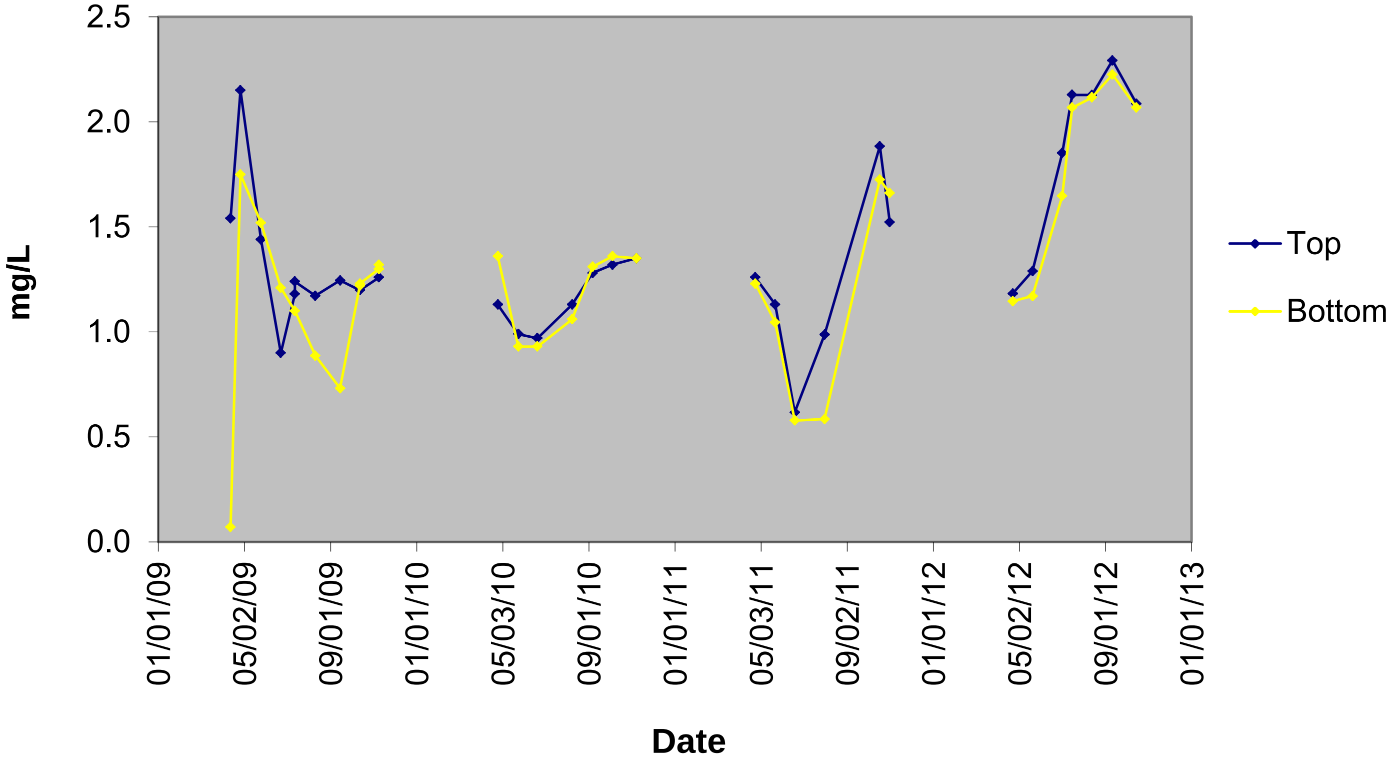


Figure 59. Sodium (Na) concentrations in Seaman Reservoir

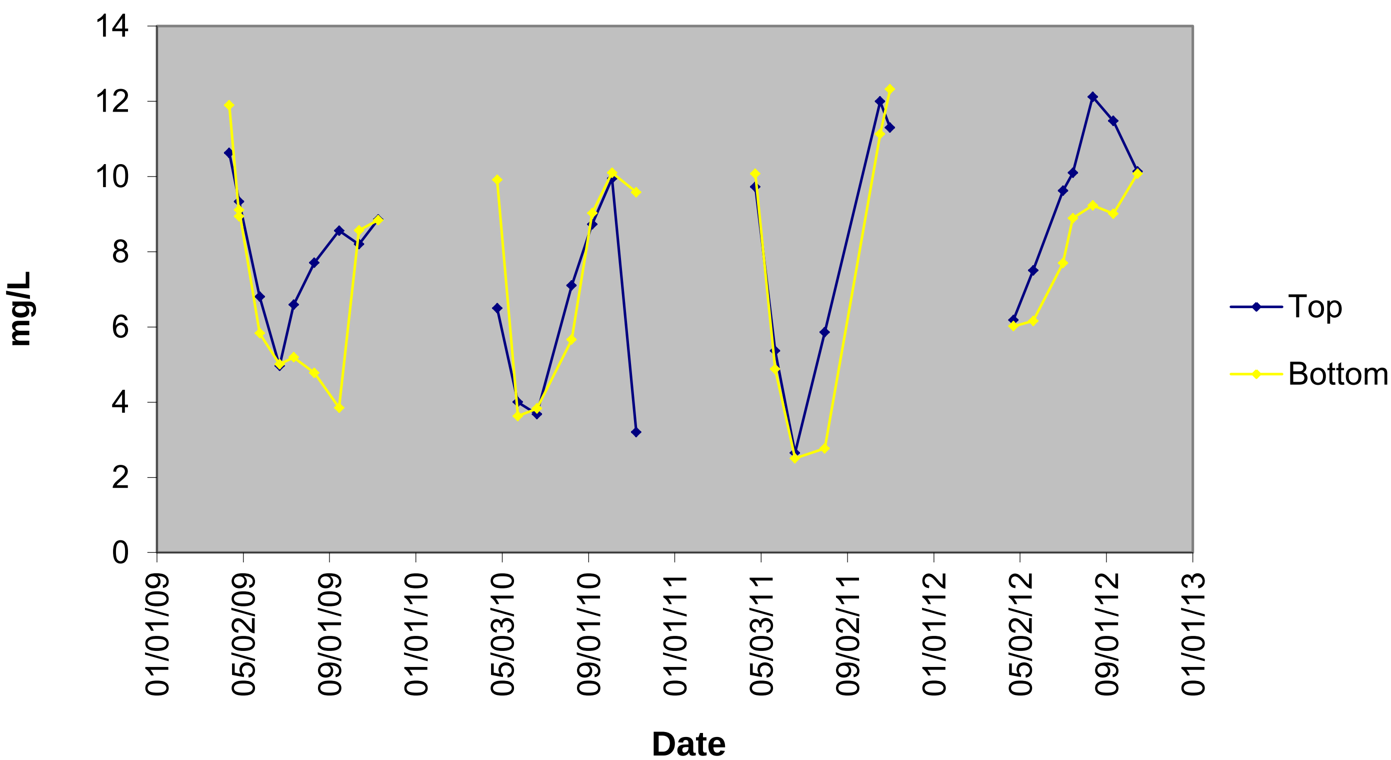


Figure 60. Chloride (Cl) concentrations in Seaman Reservoir

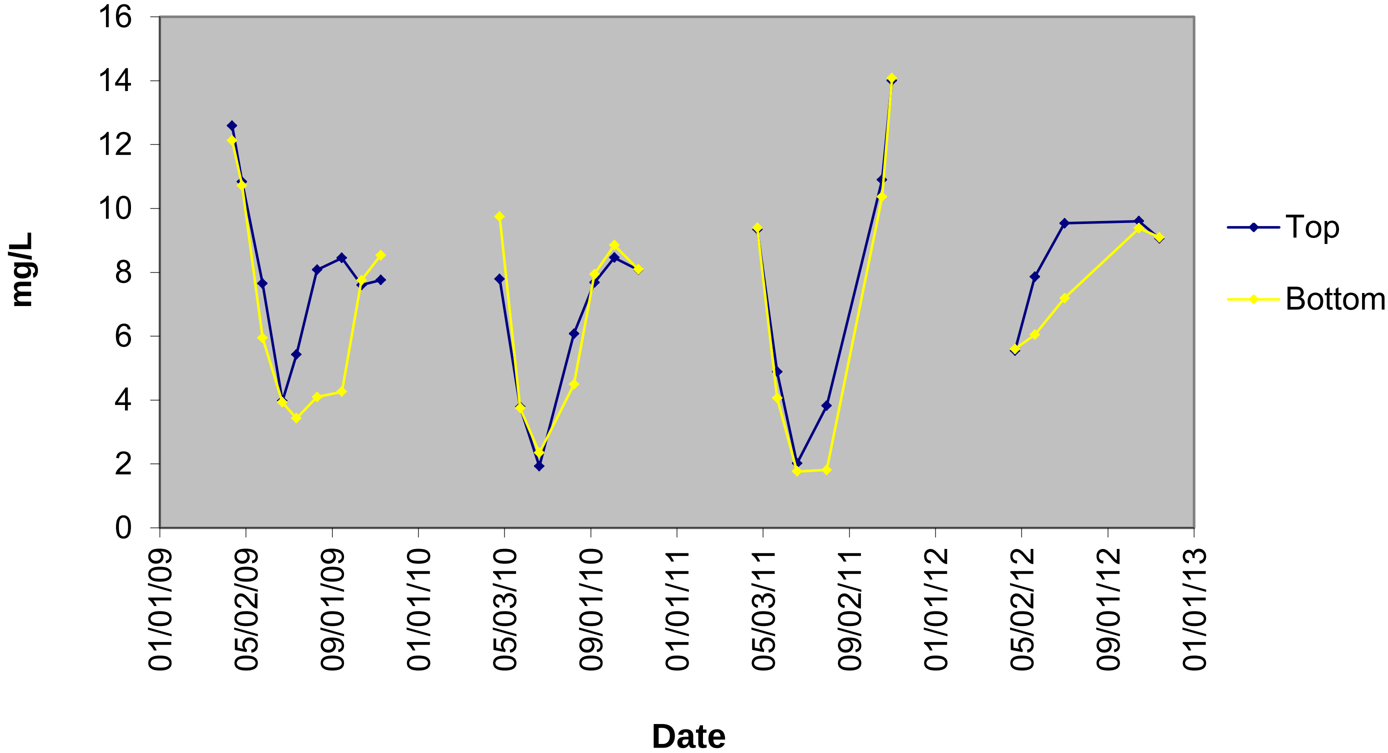
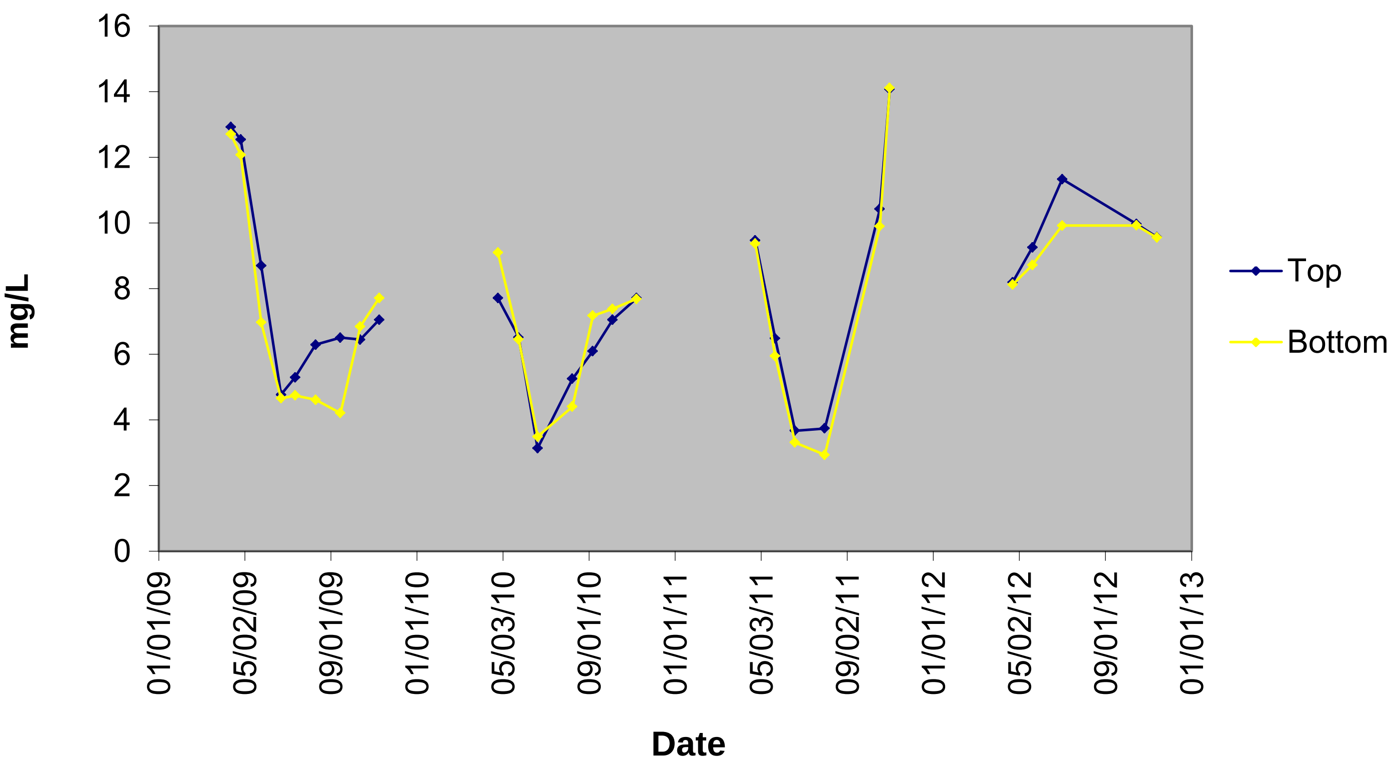


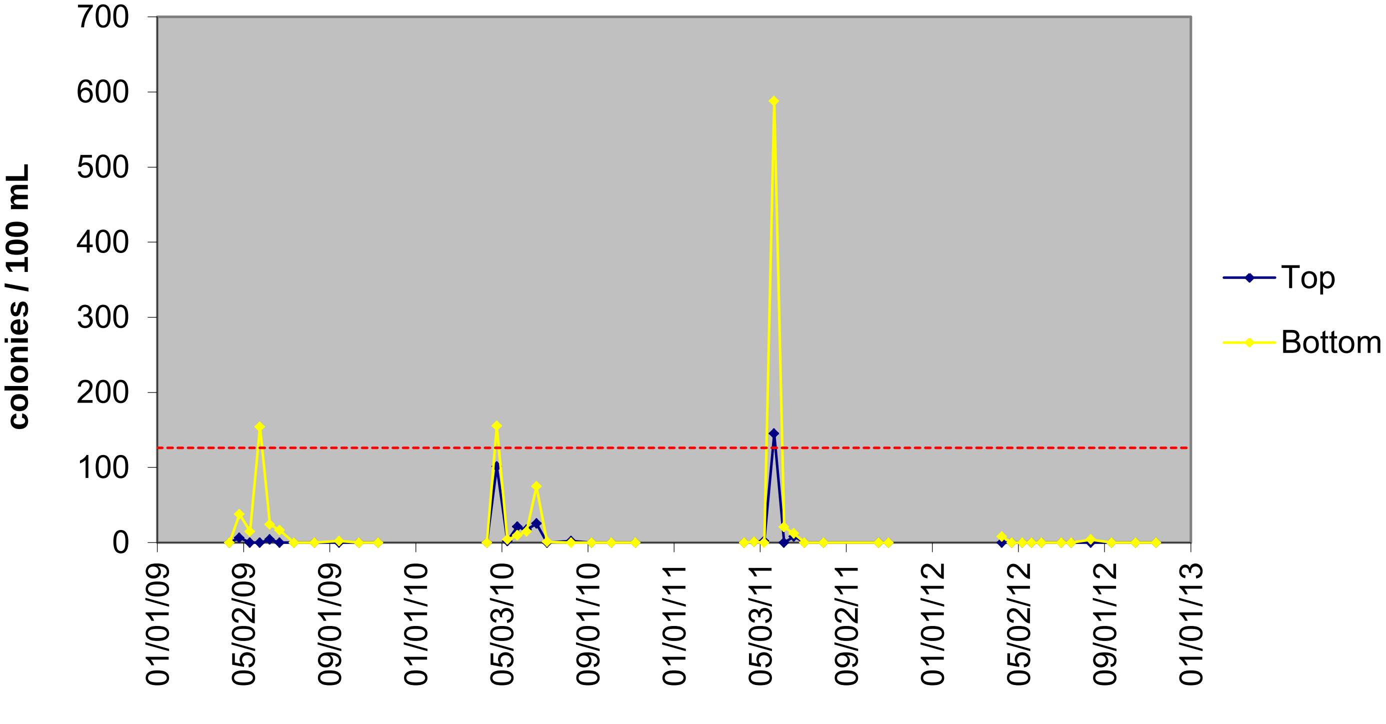
Figure 61. Sulfate (SO_4) concentrations in Seaman Reservoir



(EPA Secondary Drinking Water Standard: 250 mg/L)

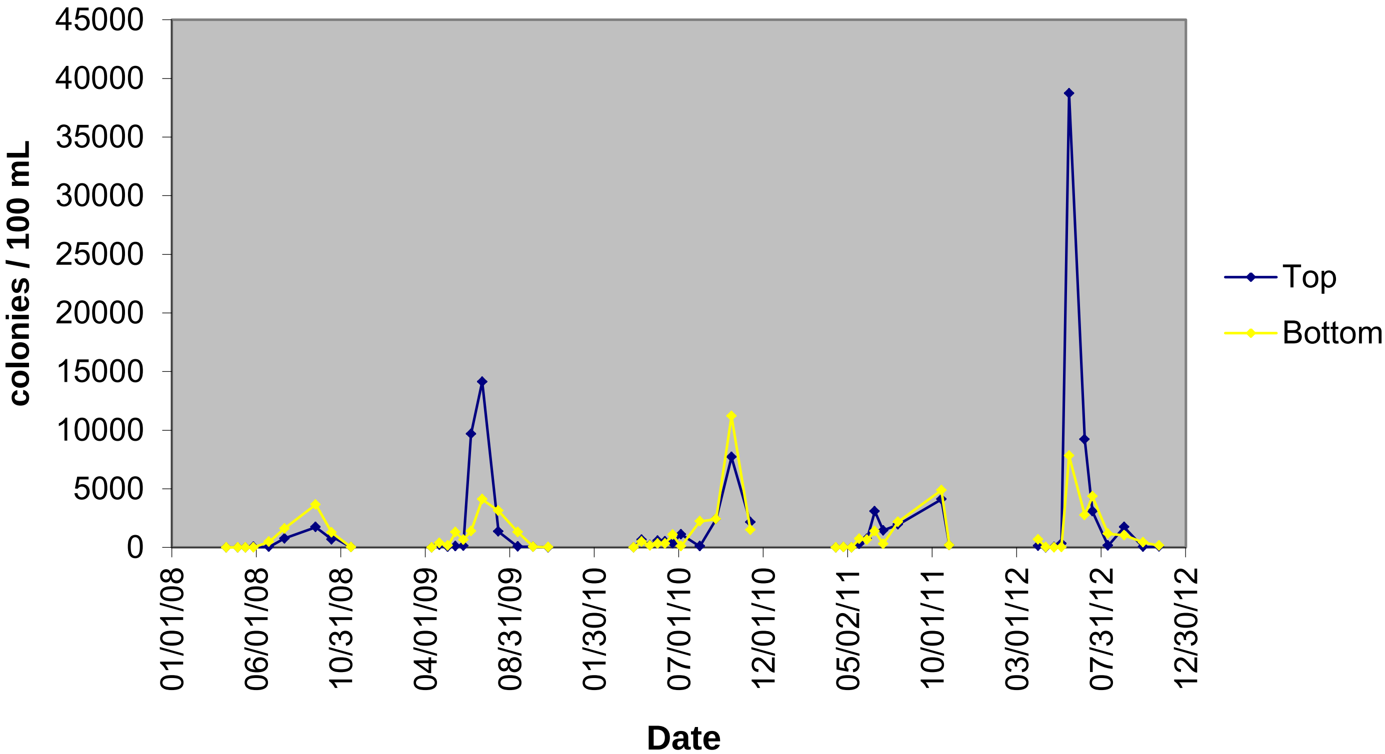
Seaman Reservoir: Microbiological Constituents

Figure 62. *E. coli* concentrations in Seaman Reservoir



(Recreational water quality standard: 126 colonies/100 mL)

Figure 63. Total coliform concentrations in Seaman Reservoir



Seaman Reservoir:
Phytoplankton

Figure 64. Phytoplankton densities at the top of Seaman Reservoir from 2009-2012.

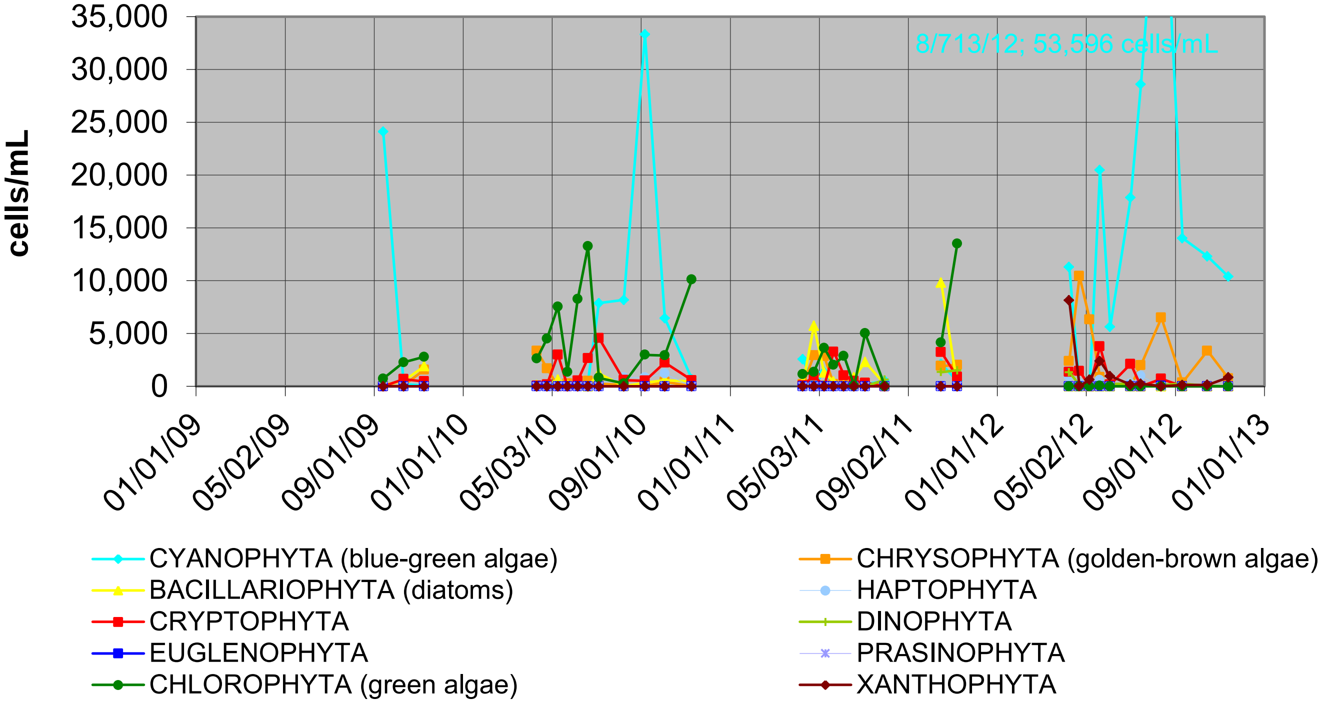


Figure 65. Phytoplankton densities at the bottom of Seaman Reservoir from 2009-2012.

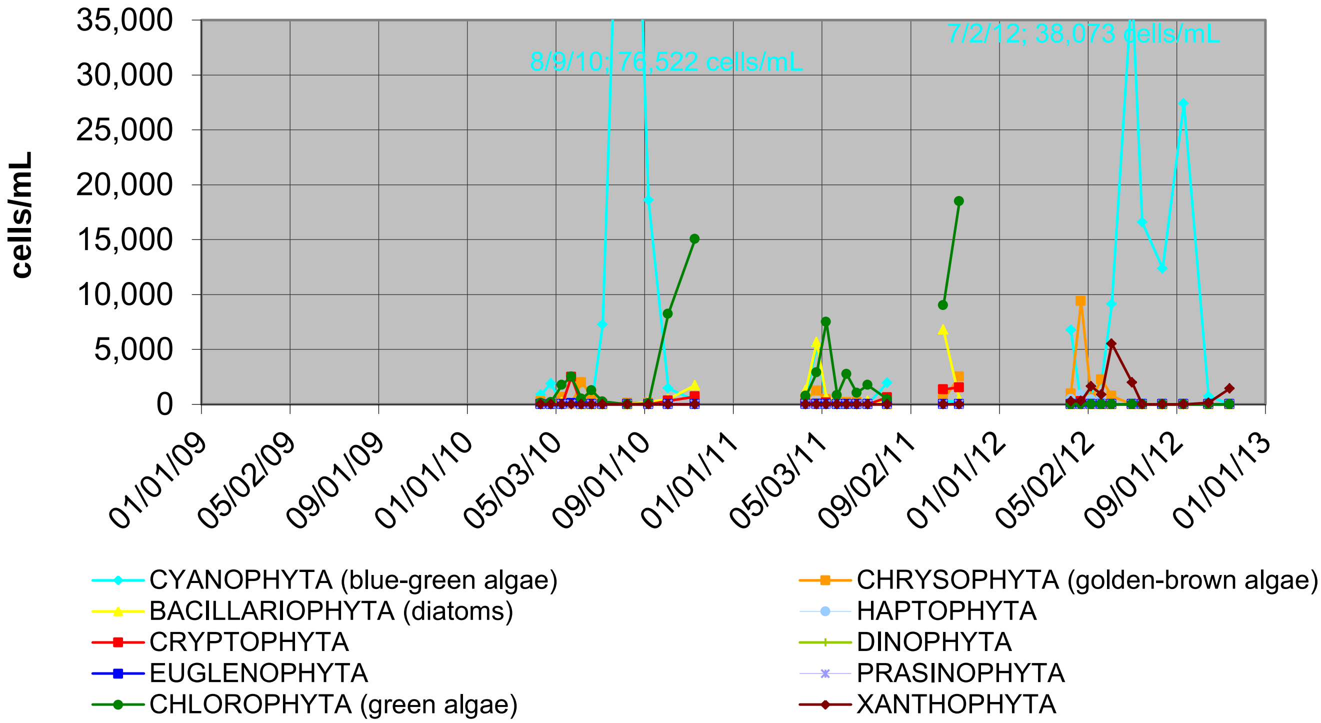
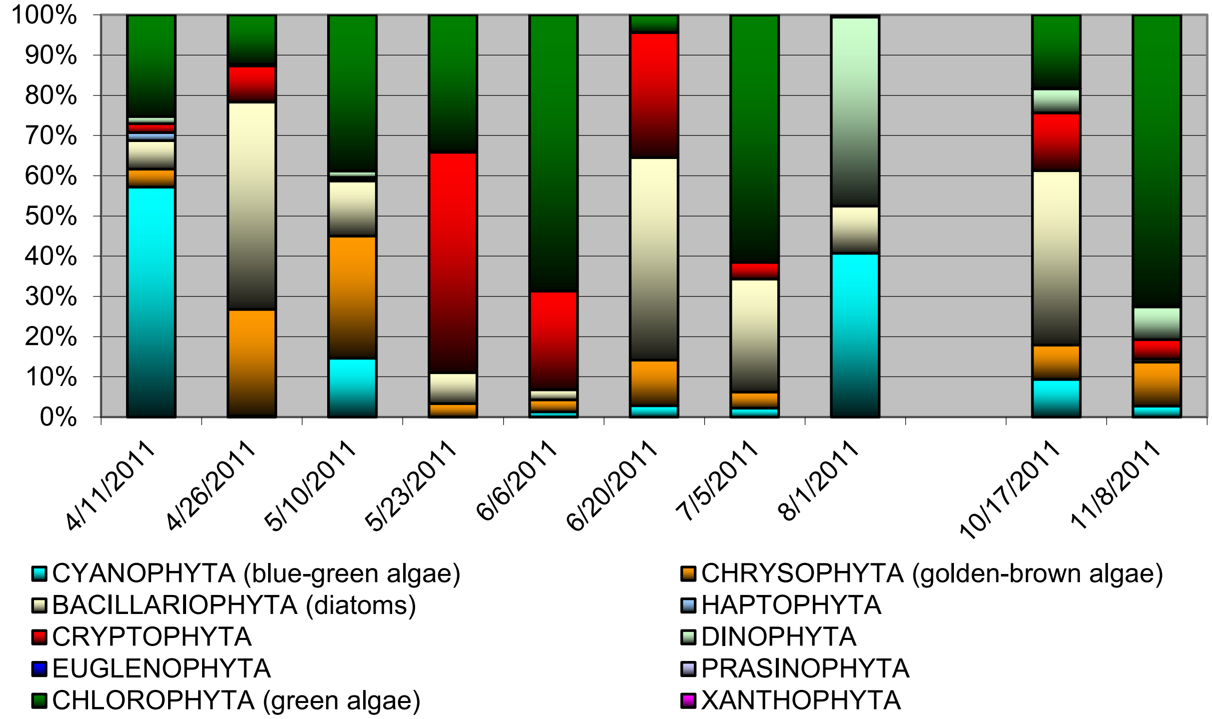


Figure 66 (a-b). Relative abundance of phytoplankton in *top* of Seaman Reservoir in a. 2011 and b 2012.

a.



b.

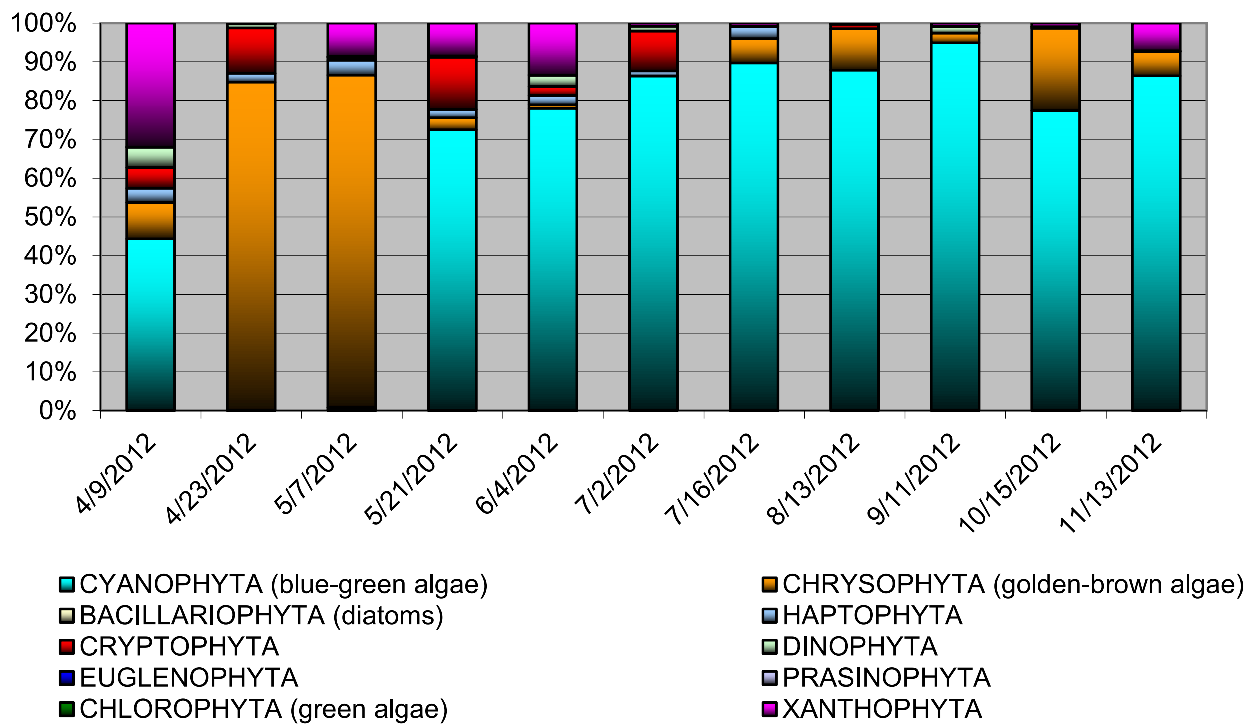
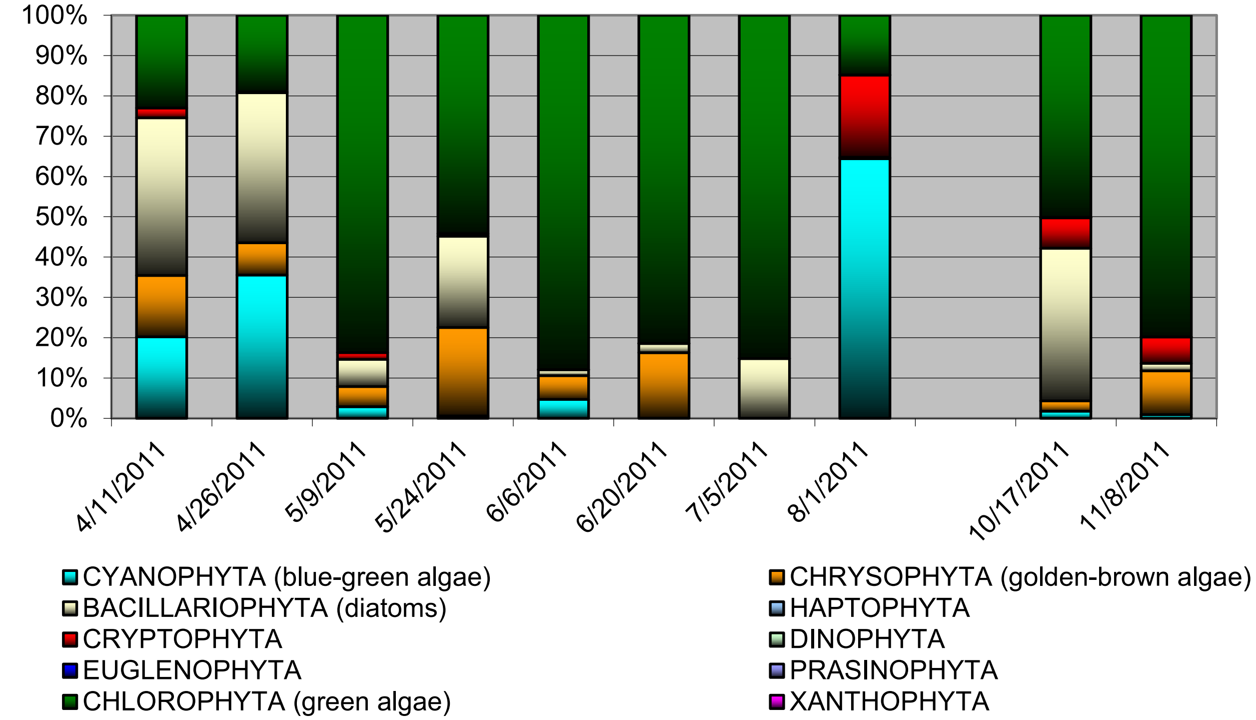


Figure 67 (a-b). Relative abundance of phytoplankton in *bottom* of Seaman Reservoir in a. 2011 and b. 2012.

a.



b.