2014 ANNUAL REPORT

Upper Cache la Poudre Watershed

Collaborative Water Quality Monitoring Program

JULY 28, 2015

PREPARED FOR
Fort Collins Utilities
City of Greeley
Tri-Districts

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EXECUTIVE SUMMARY

UPPER CACHE LA POUDRE COLLABORATIVE WATER QUALITY MONITORING PROGRAM

The Upper Cache la Poudre Collaborative Water Quality Monitoring Program (hereafter referred to as the Upper CLP monitoring program) is designed 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 Cache La Poudre River (CLP) watershed and issues that potentially impact watershed health.

Sample collection for the Upper CLP monitoring program consists of eleven sampling events between the months of April and November at eleven monitoring sites on the Mainstem CLP (Mainstem) and nine monitoring sites on the North Fork CLP (North Fork), including Seaman Reservoir. In 2014, a new monitoring location was added on the Little South Fork (South Fork), upstream of the confluence with the Mainstem. Water samples were analyzed for a total of up to 39 parameters.

SCOPE OF 2014 ANNUAL REPORT

This annual report summarizes the hydrologic and water quality data collected in 2014 and provides a comparison with water quality information from the years 2011 – 2013. The report also summarizes significant events, issues of concern, and results from special studies.

The main body of the report focuses on eleven key sites that are considered representative of conditions on the Mainstem and North Fork CLP in addition to Seaman Reservoir. Summary graphs for all parameters and locations of monitoring sites are presented in separate attachments (Attachment 7 and 2, respectively).

STATE OF UPPER CACHE LA POUDRE WATERSHED WATER QUALITY

The Upper CLP watershed remains a high quality drinking water source for the City of Fort Collins, the City of Greeley, and the Tri-Districts, despite the continued influence of the Hewlett Gulch and High Park Wildfires that burned in 2012. Baseline water quality of the CLP continues to meet all water quality standards. Although noticeable changes in water quality continue to occur during storm events, these changes from baseline water quality conditions are generally short-lived. Peaks in streamflow and spikes in water quality constituents following high intensity precipitation events and debris flows are expected to continue as the watershed progresses towards recovery.

SIGNIFICANT EVENTS, ISSUES OF CONCERN & SPECIAL STUDIES

Geosmin

Geosmin is a naturally occurring organic compound that can impart an earthy odor to water and occurs episodically in the Mainstem. In 2014, geosmin concentrations remained at or below the odor threshold at two sampling locations on the CLP. Furthermore, there were no reported geosmin-related customer odor complaints.

Emerging Contaminants

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 and personal care products, pesticides, hormones, and phenolic endocrine disrupting compounds in waters of the Colorado-Big Thompson system and the Upper Poudre River.

Atrazine and DEET, which have been detected previous years, were not detected in 2014. Similar to previous years, the detected compounds were 2,4-D (herbicide), caffeine, and triclosan (an anti-bacterial/anti-fungal active ingredient), which indicate the presence of human activity in the upstream river and/or watershed.

Post-wildfire Watershed Recovery

The Hewlett Gulch Fire (May 14-May 22, 2012) burned 7,685 acres, including sub-watersheds that drain both to the Mainstem and into Seaman Reservoir on the North Fork. The High Park Fire (June 9-July 2, 2012) burned 87,415 acres and included numerous sub-drainages that are tributary to the Mainstem and the South Fork. Combined, the two fires created a contiguous burned area approximately 95,000 acres in size. No homes were damaged in the Hewlett Gulch Fire, but the High Park Fire destroyed 259 homes and cabins.

Since the fires ended, emergency hillslope stabilization measures have been implemented in the High Park Fire burn areas by the United States Forest Service (USFS) on federal Forest Service lands and on private lands through partnerships between the Natural Resource Conservation Service (NRCS), the Cities of Fort Collins and Greeley, Tri-districts, and Larimer County. In 2012 and 2013, 2,900 acres of wheat straw and 1,110 acres of wood mulch were applied to private land in the burn scar area. Additionally, the USFS applied 4,700 acres of agricultural straw and 1,131 acres of wood shred to USFS lands. In 2014, a total of 250 acres of wood shred mulch was applied primarily in the Little South Fork Basin. The total area mulched represents approximately 11 percent of the burned area. The final phase of the NRCS Emergency Watershed Protection program was completed in 2014.

Localized summertime thunderstorms continued to result in sediment and debris flows into the Mainstem CLP in 2014. In contrast to 2012 and 2013, the river appeared to recover more quickly following stormflows when turbidly levels returned to pre-storm values in two to four hours. It is presumed that much of the fine sediment and ash on burned hillslopes were flushed during the 2013 flood leaving behind larger soil particles that settled more readily.

Water quality sampling efforts in 2014 continued to focus on routine monitoring to understand impacts of fire on baseline (non-storm event) water quality. In addition, the storm event sampling at PNF, which was initiated in 2012 and continued in 2014, serves as an indicator of the progress of watershed recovery and water supply reliability over time. In 2014, most storm events occurred during the evening, night, or weekend making it difficult and dangerous to collect storm water samples resulting in a limited storm event data record. In 2015, an automated sampler will be installed at the Fort Collins Intake Facility to capture stormwater samples during flooding and debris events when staff is unavailable to collect samples.

Although storm samples were limited in 2014, the impact of the wildfires on water quality was still evident. Background nutrient concentrations remained elevated and multiple storm events occurring over the Upper CLP watershed caused increased streamflow and river turbidity levels. One event was sampled when turbidity values spiked greater than 200 NTU at on the Mainstem above the confluence with the North Fork (PNF) as a result of a high intensity precipitation event that produced debris flows and flooding from burned hillslopes during a routine sample event on July 14th. The impact on water quality from this one event was quite evident with notable spikes not only in turbidity, but also in alkalinity, hardness, metals, nutrients, and TOC concentrations. Prior to and after the stormflow, alkalinity, hardness, metals, and TOC were measured at normal concentrations. The elevated background nutrient concentrations and stormflow response on July 14th demonstrate that after-effects of the 2012 wildfires are still occurring, but the watershed remains on a path towards recovery. The Upper CLP monitoring program will continue to sample stormflow water quality in 2015 to track watershed recovery.

An early warning response system, located approximately four miles upstream of the City of Fort Collins raw water intake structure, helps the City of Fort Collins mitigate the effects of storm events on water treatment operations by signaling changes in upstream water quality. It provides adequate time for FCWTP water treatment operators to shut down the Poudre supply line and mitigate water quality impacts on treatment.

UPPER CLP WATER QUALITY

Mainstem & North Fork CLP

In 2014, winter baseflow conditions were elevated above average as a result of the September 2013 flood event. The maximum amount of water contained in the snowpack, measured as peak snow water equivalent (SWE), was greater in 2014 across the entire CLP watershed compared to the long-term average and was observed three weeks later than the normal peak date. A higher than normal and earlier peak streamflow was observed in 2014 as a result of the above average snowpack and warmer than average spring air temperatures.

Consistent with previous years, the Mainstem and the North Fork exhibited different water quality characteristics, due to differences in geology, land use, and elevation. No significant concerns were identified that would immediately impact drinking water quality or treatment operations, but during spring runoff, the typical challenges associated with elevated turbidity, low alkalinity, and high TOC were observed. General water quality parameters (temperature, conductivity, hardness, alkalinity, and pH) on both the Mainstem and North Fork exhibited normal trends and were within the expected range of values throughout the monitoring season. Peak turbidity values on the Mainstem at PNF, however, were nearly two times greater in 2014 compared to pre-fire and pre-flood conditions. In contrast, TOC dynamics on the Mainstem displayed similar seasonal patterns and were within the range of TOC values observed prior to and since the 2012 wildfires.

In general, nutrient concentrations were comparable between the North Fork and Mainstem sites. Nutrients on the Mainstem continued to be relatively low in 2014 at most sites, but the effects of the 2012 drought and wildfires were still apparent. The biggest effects were observed at wildfire impacted sites (PNF and PBD) where nutrients remained elevated in 2014. Pathogens remained relatively low except for the July 14th storm event when *E. coli* counts exceeded the recreational water quality standard. This storm event also produced the only detection of C*ryptosporidium* in raw Poudre Water (PNF). *Cryptosporidium* did not display seasonal or annual trends, but concentrations were higher at North Fork sites

Seaman Reservoir

Seaman Reservoir was at maximum capacity for much of the 2014 season as a result of the 2013 flood event. For most of the year, water from Seaman Reservoir spilled from the surface over the emergency spillway to the North Fork. Secchi depth and general water quality parameters indicated that Seaman Reservoir experienced relatively consistent water clarity near the surface in 2014. TOC concentrations were similar to those observed from 2011 to 2013. Algal growth production was low throughout much of the growing season, although a notable bloom was observed in October and November. Blue-green and green algae were the dominant algal types present during this time. Furthermore, geosmin producing species were present at very low levels;geosmin concentrations in the water supply were not measured. Both Total coliforms and *E. coli* were found in low concentrations in Seaman Reservoir in 2014.

Water Quality Regulations

The Upper CLP remains a high quality drinking water supply for Fort Collins, City of Greeley and surrounding communities served by the Tri-Districts. Accordingly, there were no observed exceedances of the EPA drinking water quality standards for nitrate (10 mg/L) or nitrite (1 mg/L) at any site on the Mainstem or the North Fork from 2011 through 2014. Similarly, annual median TN and TP concentrations on the Mainstem and North Fork did not exceed the EPA's interim nutrient standards of 1.25 mg/L and 0.11 mg/L, respectively.

All sites were below the State recreational standard for *E.coli* from 2011-2014 with the exception of two occasions where concentrations exceeded 126 cfu at the Fort Collins Water supply intake (PNF) and the Greeley-Bellvue site (PBD). These events occurred once each in 2013 and 2014 in response to storm events that occurred over the burn area, during which large amounts of sediment were deposited in the river from the surrounding hillslopes. As the vegetation reestablishes within the burn area over time, the impacts of these storm events on water quality are expected to diminish. Moreover, these events do not indicate any significant new source of contaminants requiring management action at this time. Water quality at the downstream locations on the North Fork (NFG) and at Greeley-Bellvue diversion (PBD) continues to consistently meet all applicable standards.

Program Performance

Review of the 2014 Upper CLP Collaborative Water Quality Monitoring Program data indicates that the program continues to adequately capture seasonal and annual trends in water quality, while providing a spatial context for examining notable events.

In 2014, field work was transitioned from contracted sampling (2008-2013), to in-house sampling for the Upper Cache la Poudre (CLP) monitoring program. In addition to improving the consistency and reliability of the results, the switch to in-house sampling provided an overall cost savings of $27,411, shared between the program collaborators, City of Fort Collins, City of Greeley and Tri-Districts.

Monitoring and Protection Efforts in 2015

The Upper CLP Collaborative Monitoring Program will continue water quality monitoring and protection efforts in 2015. The 2015 efforts are listed below:

- Routine Water Quality Monitoring Program
- Emerging Contaminant Monitoring
- Geosmin Monitoring
- Storm Water & Watershed Recovery Monitoring
- Little South Fork Streamflow Monitoring
- Support the Coalition for the Poudre River Watershed
- Development of a Source Water Protection Plan

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LIST OF ABBREVIATIONS & ACRONYMS

%	percent
Ag	Silver
HCO_3^-	Bicarbontes
BMR	Barnes Meadow Reservoir Outflow (routine monitoring site)
Ca	Calcium
CO_3^-	Carbonates
Cd	Cadmium
CDPHE	Colorado Department of Public Health and Environment
CDWR	Colorado Division of Water Resources
CEC	Contaminants of Emerging Concern
cfs	cubic feet per second
CHR	Chambers Lake Outflow (routine monitoring site)
Cl	Chloride
CLP	Cache la Poudre River
cfu/mL	colony forming units per milliliter
Cr	Chromium
Cu	Copper
D.O.	Dissolved Oxygen
DBP	Disinfection By-Product
C-DBP	Carbon-based Disinfection By-Product
N-DBP	Nitrogen-based Disinfection By-Product
EDC	Endocrine Disrupting Chemical
EPA	Environmental Protection Agency
FCWQL	Fort Collins Water Quality Lab
FCWTF	Fort Collins Water Treatment Facility
Fe	Iron
HAN4	Haloacetonitrile
HSWMP	Halligan-Seaman Water Management Project
H^+	Hydrogen ion
JWC	Joe Wright Creek above the Poudre River (routine monitoring site)
K	Potassium
LC/TOF-MS	Liquid Chromatography – Time of Flight – Mass Spectrometry
LRT	Laramie River Tunnel

m	meter
M&E List	Colorado's Monitoring & Evaluation List
Mg	Magnesium
mg/L	milligrams per liter
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)
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-N	Ammonia as nitrogen
Ni	Nickel
NISP	Northern Integrated Supply Project
NO_2-N	Nitrite as nitrogen
NO_3-N	Nitrate as nitrogen
NTU	Nephelometric Turbidity Units
OH^-	Hydroxide ion
^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
PPCP	Pharmaceuticals and Personal Care Product
PJW	Poudre River above the confluence with Joe Wright Creek
PNF	Poudre River above the North Fork (routine monitoring site)
PO_4	ortho-phosphate
ppt	parts per trillion
RCM	Rabbit Creek Mouth (routine monitoring site)
SCFP	Soldier Canyon Filter Plant
SCM	Stonewall Creek Mouth (routine monitoring site)
SFC	South Fork above confluence with the Mainstem (routine monitoring site)
SFM	South Fork of the Poudre River above the Mainstem (routine monitoring site)
SNOTEL	Snow telemetry network
SWE	Snow wáter equivalent

T&O	Taste & Odor
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
ug/L	micrograms per liter
uS/cm	microSeimens per centimeter
USGS	United States Geological Survey
WQCD	Water Quality Control Division
WTP	Water Treatment Plant
Zn	Zinc

1.0 INTRODUCTION

1.1 BACKGROUND

The Upper Cache la Poudre River (CLP) is an important source of high-quality drinking water supplies for communities served by the City of Fort Collins Water Treatment Facility (FCWTF), the City of Greeley-Bellvue Water Treatment Plant (WTP), 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 CLP Collaborative Water Quality Monitoring Program. The Program was subsequently implemented in spring 2008. The overarching 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 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.

Three proposed water supply projects in the Upper CLP 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 CLP River (North Fork) confluence. The formerly proposed Halligan-Seaman Water Management Project (HSWMP) aimed to expand both Halligan Reservoir and Seaman Reservoir on the North Fork. In early 2015, HSWMP separated into two separate projects, with the City of Fort Collins independently pursuing the Halligan Enlargement project and the City of Greeley pursuing the expansion of Seaman Reservoir.

Annual and five-year reports for the collaborative program are prepared by City of Fort Collins' staff to keep participants informed of 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. The five-year report provides a more in-depth analysis of both spatial and temporal trends in watershed hydrology and water quality, including concentrations. The first five-year report was completed for the years 2008-2012 (Oropeza & Heath, 2013). Upper CLP reports are available through the City of Fort Collins Utilities Source Water Monitoring website (www.fcgov.com/utilities/what-we-do/water/water-quality/source-water-monitoring).

1.2 WATERSHED DESCRIPTION AND SAMPLING LOCATIONS

Sampling efforts are divided between the Mainstem (including the South Fork) and North Fork Cache la Poudre River watersheds. 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 2014 monitoring network consists of 20 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 raw water intake structures (Figure 1.1). The 20 sampling sites include one reservoir - Seaman Reservoir. In 2014, an additional monitoring location was included on the South Fork upstream of the confluence (SFC) with the Mainstem Poudre River (Figure 1.2). This monitoring location was included in the monitoring network to evaluate the effects of the 2012 High Park Fire on water quality, and to track watershed recovery in the South Fork basin. The monitoring location includes continuous streamflow monitoring (Heath, 2014). A description and rationale for each site is provided in Attachment 2.

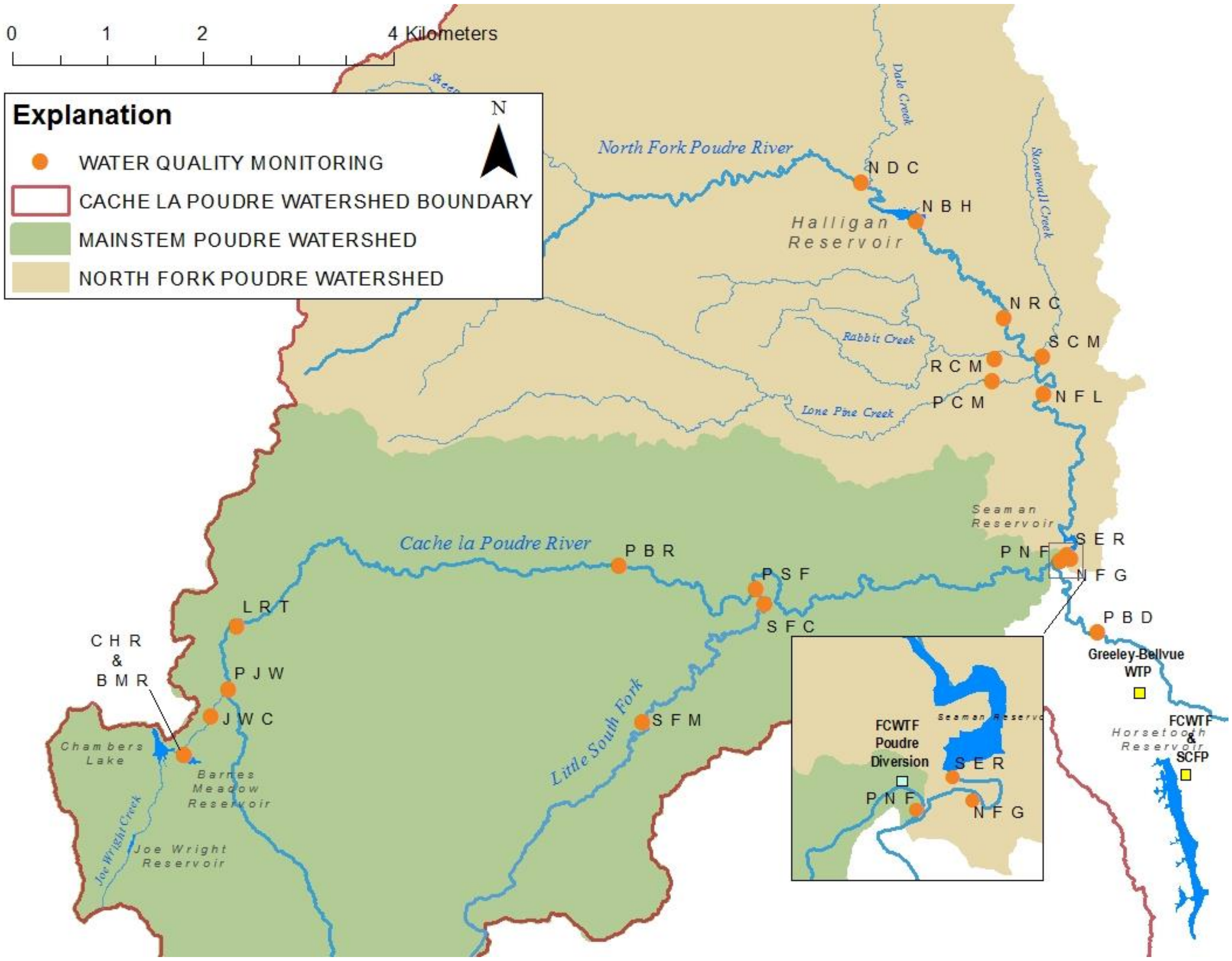


Figure 1.1 – Map of the Upper CLP collaborative water quality monitoring network.

1.3 SAMPLING SCHEDULE AND PARAMETERS

The sampling frequency for the Upper CLP 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 2014 sampling schedule is provided as Attachment 4 of this report.

1.4 SAMPLE COLLECTION AND ANALYSIS

Sampling was conducted by staff members from the City of Fort Collins, City of Greeley, and Tri-Districts. Sampling methods, including those for the collection of field measurements for temperature, pH, conductivity, and dissolved oxygen (D.O.) 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 July through October at the top and bottom of Seaman Reservoir in 2014. Phytoplankton samples were identified and enumerated at the species level by Dick Dufford (private consultant) of Fort Collins, CO. The analytical methods and detection limits for the FCWQL parameters are included in Attachment 5.

Consistent with the quality assurance guidelines outlined in Section 5.5 of Billica, Loftis and Moore (2008), approximately ten percent of total sample load consist of field blanks and field duplicate samples which are identified in annual the sampling plan (Attachment 4). These samples help identify potential contamination that may be introduced due to sampling error, equipment contamination or laboratory error. In addition, the City of Fort Collins Quality Assurance Coordinator reviews all Upper CLP water quality data produced by the Fort Collins Water Quality Laboratory to ensure that the data are free of sample contamination, analytical or data entry errors.

1.5 SCOPE OF 2014 ANNUAL REPORT

The 2014 annual report summarizes the hydrologic and water quality data collected for the Upper CLP monitoring program and highlights the significant events, issues of concern, and the results of special studies. This report compares water quality information from 2014 with the previous three years, 2011-2013.

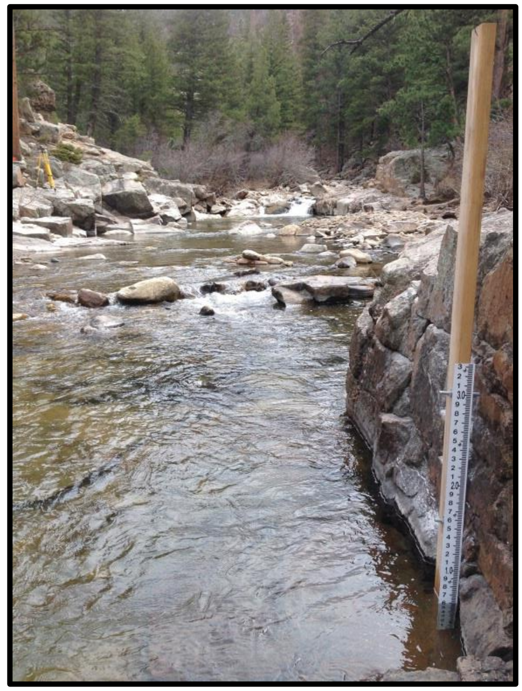


Figure 1.2 – Staff gage on the South Fork above confluence (SFC) monitoring location.

2.0 SIGNIFICANT EVENTS, ISSUES OF CONCERN & SPECIAL STUDIES

2.1 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 (CLP) raw water supply is routinely monitored for geosmin concentrations on a monthly basis. As shown in Figure 2.1, the CLP 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 CLP water supply at the FCWTF on a routine basis.

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

- Identify areas on the Poudre River with high geosmin concentrations that are sources of geosmin to the FCWTF;
- Identify spatial and seasonal geosmin and nutrient 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) and the “Five Year Summary Report (2008-2012) Upper Cache la Poudre River Collaborative Water Quality Monitoring Program” (Oropeza and Heath, 2013).

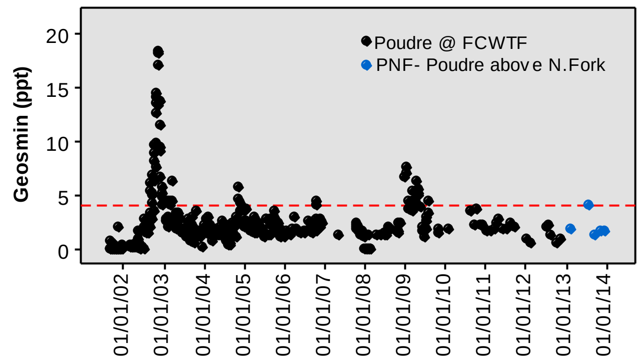


Figure 2.1 – Poudre River geosmin concentrations at the FCWTF and at the Fort Collins Poudre River intake facility (PNF) from 2002 through 2014.

(- - - - - Taste and Odor threshold: 4 ppt (ng/L)).

In 2013, geosmin concentrations were monitored at six locations on the CLP and included Poudre above Rustic, Poudre below Rustic, Poudre at Steven’s Gulch, Poudre at Mishawaka, Poudre at Greyrock and Poudre at the FC Intake. Concentrations above 4 ppt or ng/L were observed at all sites on at least one occasion except for the *Poudre at FC Intake*, which never exceeded the odor threshold in 2013. These results were consistent with previous monitoring reports that suggest that concentrations at the FCWTF Intake are not well-predicted by upstream concentrations (Heath and Oropeza, 2014).

Based on these results, a further reduction in monitoring locations was made in 2014. For the purpose of providing early warning of potential geosmin outbreaks on the river, samples were collected from June through November at one upper and one lower elevation monitoring site that corresponded with routine water quality monitoring locations. The upstream site, PBR, is located approximately 21 miles upstream of PNF. Geosmin concentrations at PNF are considered to be representative of concentrations at the previously monitored site Poudre at the FC Intake, which was sampled at the raw water tap at the FCWTF.

In 2014, geosmin concentrations remained at or below the odor threshold at both sampling locations on the Poudre River (Table1). Furthermore, there were no reported geosmin-related customer odor complaints.

Table 1 – Poudre River geosmin concentations (ppt or ng/L) in 2014 at Poudre above the North Fork (PNF) and Poudre below Rustic (PBR) monitoring locations.

Date	**Poudre below Rustic (PBR)**	**Poudre above North Fork (PNF)**
2/12/2014	3.13	-----
7/14/2014	BDL	3.99
8/12/2014	-----	BDL
9/15/2014	2.61	1.18
11/10/2014	BDL	1.57
12/18/2014	BDL	1.54

2.2 COLORADO'S SECTION 303(d) AND MONITORING & EVALUATION (M&E) LISTS

Colorado's Section 303(d) List and Monitoring and Evaluation (M&E) List (Regulation #93) establishes Colorado's list of impaired waters and list of waters suspect of water quality problems. Colorado's Section 303(d) List and M&E List for the 2012 listing cycle were adopted on February 13, 2012 and became effective on March 30, 2012. When water quality standard exceedances are suspected, but uncertainty exists regarding one or more factors (such as the representative nature of data used in the evaluation), a water body or segment is placed on the M&E List.

Segments of the North Fork on the State of Colorado's Section 303(d) List of impaired water and M&E List, as of March 30, 2012 are listed in Table 2. Segments with 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 (M) priority. Three segments on the North Fork are currently on the M&E List.

The North Fork sites listed below were scheduled for review in 2012 by the Colorado Department of Public Health and Environment's (CDPHE) Water Quality Control Division (WQCD). The Section 303(d) Listing Methodology and Colorado's Section 303(d) List is scheduled for review every two years. The most current hearings for the 2014 listing cycle were scheduled for 2013, but the Water Quality Control Division cancelled the hearings because of higher priority water supply projects and staff resource constraints. The hearings were postponed until 2015 to consider the 2016 Section 303(d) Listing Methodology and revisions to Colorado's 2016 Section 303(d) List.

Table 2 – Segments of Upper CLP waters listed on the State of Colorado's Section 303(d) List of impaired waters and Monitoring and Evaluations (M&E) Lists.

WBID	Segment Description	Portion	Colorado's Monitoring & Evaluation Parameter(s)	Clean Water Act Section 303(d) Impairment	303(d) Priority
COCSPCP06	Mainstem of the North Fork of the Cache la Poudre River, including all tribs from source to Halligan Reservoir	All	Cu		
COSPCP07	North Fork of the Cache la Poudre from Halligan Reservoir to the Cache la Poudre	All		Pb, Cd	M
COSPCP08	All tributaries to the North Fork of the Cache la Poudre from Halligan Reservoir to the Cache la Poudre	All	*E. coli*		
COSPCP09	Rabbit Creek and Lone Pine Creek	All	Cd, Pb		
COSPCP20	Lakes and reservoirs tributary to the North Fork of the Cache la Poudre from Halligan Reservoir to the Cache la Poudre River.	Seaman Reservoir		D.O.	M

2.3 EMERGING CONTAMINANTS

Contaminants of emerging concern (CEC) and their presence in drinking water have recently received national attention. Contaminants of emerging concern are trace concentrations (at the ng/L or ppt level, or less) of the following types of chemicals:

- Pharmaceuticals: prescription and non-prescription human drugs (including pain medications, antibiotics, β-blockers, anti-convulsants, etc) and veterinary medications

- Personal care products (PCPs): fragrances, sunscreens, insect repellants, detergents, household chemicals

- 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

The primary objective of this collaborative effort is to be proactive and develop a baseline of data on pharmaceuticals, PCPs, hormones, and pesticides in the source waters of interest that are associated with drinking water supplies, using a cost-sharing approach that minimizes the cost burden for each entity.

In 2008, the Northern Colorado Water Conservancy District (Northern Water) initiated an emerging contaminant study to determine the presence of these compounds in waters of the CBT system. In 2009, the program was opened up as a regional collaboration, and in that process, two monitoring sites on the Upper Cache la Poudre, the Poudre River above the North Fork and the North Fork below Seaman Reservoir (PNF and NFG, respectively) were added to the study with funding provided by the City of Fort Collins and the City of Greeley. In 2009, samples were collected once in June. Beginning in 2010, samples were collected three times per year (February, June and August) to more fully assess seasonal influences of spring runoff, recreational activities, weed management activities, reservoir stratification and turnover, as well as low stream flow conditions.

Each year the list of target compounds are reviewed by the collaborators and additions and/or deletions are made as needed. In 2014, two compounds were added to the low-level list – dextrorphan (a metabolite of dextromethorphan, the active ingredient found in cough syrup) and gabapentin (anti-epileptic). A full list of analytes can be found in the 2014 Emerging Contaminants Program Annual Report (Northern Water, 2014) at: http://www.northernwater.org/docs/WaterQuality/WQ_Reports/2014_EmergingContaminantsAnnReport.pdf.

All samples are submitted to the Center for Environmental Mass Spectrometry at the University of Colorado (CEMS) for laboratory analysis. Samples are analyzed using two primary methods. The presence/absence screening method (Liquid Chromatography/Time-Of-Flight Mass Spectrometry, LC/TOF-MS) is used for detection of constituents above the method reporting limits, but does not quantify the concentration. In 2014, 104 compounds were analyzed by LC/TOF-MS, which included 40 commonly used PCPs/pharmaceuticals and 64 herbicides/pesticides. The Low Level detection method (Liquid Chromatography/Mass Spectrometry/Mass Spectrometry, LC/MS/MS) has been used since 2010 to quantify concentrations of herbicides/pesticides, PCPs/pharmaceuticals and EDCs. Prior to 2010, hormones were analyzed by Underwriters Laboratory, Inc. In 2014, samples were analyzed for 29 herbicides/pesticides and personal care products/pharmaceuticals (subset from the LC/TOF-MS method) and 8 EDCs (hormones and hormone-mimicking compounds).

Below, findings from the 2014 Emerging Contaminants Program Annual Report (Northern Water, 2014) for emerging contaminants detected in Upper CLP surface waters during the 2014 monitoring season are summarized:

- Pharmaceuticals, Personal Care Products (PPCP) and EDCs were not detected at PNF or NFG, which indicates of absence of effluent from upstream waste water treatment facilities or septic systems.

- Atrazine and DEET, which have been detected at these sites in previous years, were not detected in 2014.

- Similar to previous years, the detected compounds were 2,4-D, caffeine, and triclosan (an anti-bacterial/anti-fungal active ingredient), which indicate the presence of human activity in the upstream river and/or watershed.
    - Triclosan was detected in February and June at PNF (reported as PR-NFU) site and in June only at NFG (reported as NF-PRU).
    - Caffiene was detected in June at PNF (reported as PR-NFU).
    - 2,4-D was detected in February and August at NFG (reported as NF-PRU). Concentrations were very low (5.1 ng/L) and likely associated with weed control in agricultural applications and along fences,highways, canals, and reservoirs in the North Fork watershed. A maximum contaminant level of 0.07 milligrams per liter (mg/L) (70,000 ng/L or ppt) has been set for 2,4-D by the United States Environmental Protection Agency (EPA)for finished drinking water.

2.4 POST-WILDFIRE WATERSHED RECOVERY

The Upper CLP watershed was impacted by two major wildfires in 2012. The Hewlett Gulch Fire (May 14- 22) 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 and into Seaman Reservoir on the North Fork Poudre River.

The High Park Fire (June 9 - July 2) 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 1). The burned area includes numerous sub-drainages that are tributary to the Mainstem and the South Fork. 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 Gulch Fire, creating a contiguous burned area approximately 95,000 acres in size. In total, the High Park Fire destroyed 259 homes and cabins. No homes were damaged in the Hewlett Gulch Fire.

Upper CLP monitoring sites that were impacted by the wildfires were limited to the middle to lower elevations of the watershed and included PSF, PNF, NFG, PBD, and Seaman Reservoir (Figure 1.1).

The 2012 wildfires had dramatic impacts on the Upper CLP landcover that have affected hydrology and water quality within and downstream of the burn scars. The impacts of the wildfires on water quality were still evident in 2014 with elevated background nutrient concentrations and multiple storm events occurring over the Upper CLP watershed causing increased streamflow and river turbidity levels. The river appeared to recover more quickly following stormflows in 2014 when turbidly levels returned to pre-storm values in two to four hours. It is presumed that much of the fine sediment and ash on burned hillslopes were flushed during the 2013 flood leaving behind larger soil particles that settle more readily.

In 2014, most storm events occurred during the evening, night, or weekend making it difficult and dangerous to collect storm water samples resulting in a limited data record. One event was measured when turbidity values spiked greater than 200 Nephelometric Turbidity Units (NTU) at PNF as a result of a high intensity precipitation event that produced debris flows and flooding from burned hillslopes during a routine sample event on July 14th. The impact on water quality from this one event was quite evident with notable spikes not only in turbidity, but also in alkalinity, hardness, metals, nutrients, and TOC concentrations. Prior to and after the stormflow, alkalinity, hardness, metals, and TOC were measured at normal concentrations.

Background nutrient concentrations, specifically nitrate as nitrogen (NO_3-N), ammonia as nitrogen (NH_3-N), and ortho-phosphate (PO_4), remained elevated in 2014 compared to pre-fire conditions, but concentrations were lower than post-fire conditions in 2012 and 2013. The highest concentrations of inorganic nitrogen (NO_3-N and NH_3-N) were observed during spring snowmelt. The inorganic nitrogen pulse during snowmelt is an expected seasonal response in river water quality following wildfires of high and moderate burn severity (Rhoades, 2011; Smith, 2011). The elevated NO_3-N concentrations persisted for most of the season, but the NH_3-N pulse was short-lived, likely due to the majority of NH_3-N being converted to NO_3-N by microorganisms. Despite the change in background concentrations, inorganic nitrogen concentrations at impacted monitoring sites are still quite low relative to drinking water standards.

In contrast, the storm event on July 14th caused a spike in all nutrients, but surprisingly inorganic nitrogen concentrations at impacted monitoring sites were only slightly elevated compared unimpacted sites. TKN concentrations, however, were notably higher at PNF and PBD, located in the lower canyon compared to the upstream PBR site, suggesting that a significant portion of TKN and TN was composed of organic nitrogen species derived from vegetation, forest floor material and eroded soils.

The elevated background nutrient concentrations and stormflow response on July 14th demonstrate that after-effects of the 2012 wildfires are still occurring. The Upper CLP Collaborative Monitoring Program will continue to sample stormflow water quality in 2015 to track watershed recovery.

3.0 UPPER CACHE LA POUDRE RIVER RESULTS

For the 2014 annual report, seven key sites were identified that are considered representative of conditions on the Mainstem and North Fork CLP Rivers. The selected sites are listed below:

- Mainstem above North Fork
  JWC – Joe Wright Creek above the Poudre River
  PJW – Poudre above Joe Wright Creek
  PBR – Poudre below Rustic
  PNF – Poudre above North Fork

- North Fork above Mainstem
  NFL – North Fork at Livermore
  (above Seaman Reservoir)
  NFG – North Fork at Gage
  (below Seaman Reservoir)

- Mainstem below North Fork Confluence
  PBD – Poudre at Bellvue Diversion

The PBR monitoring location is the closest upstream site to the 2012 High Park Fire burn area and serves as a useful reference for "unimpacted" versus "impacted" sites downstream. Discussion of the results will focus primarily on these seven key sites; however, data from all sites were reviewed and analyzed and any notable events and trends are included in the discussion. A full list of monitoring sites, abbreviations and descriptions is available in Attachment 2. All data summary graphs are located in Attachment 7; raw data are available upon request from the City of Fort Collins Source Watershed Program.

3.1 WATERSHED HYDROLOGY

The hydrology of the Upper CLP 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. Furthermore, the amount of water in the system at a given time influences the concentration of water quality constituents.

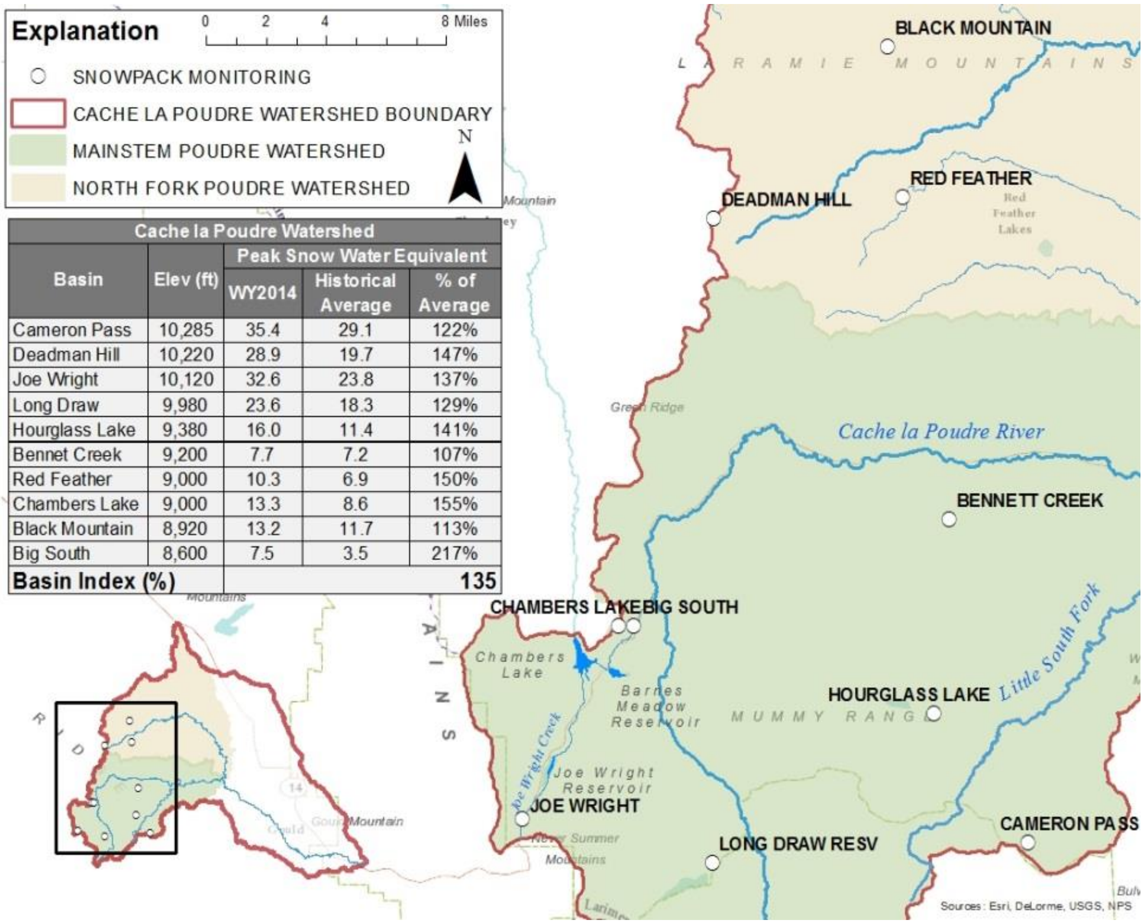
Discharge is measured as part of the routine Upper CLP monitoring activities at three key sites on the Mainstem: Poudre above Joe Wright Creek (PJW), South Fork of the Poudre above the Mainstem (SFM), and South Fork of the Poudre above the Confluence (SFC). Discharge values for PJW and SFM represent 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), 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).

Continuous streamflow data were obtained from the United States Geological Survey (USGS) and Colorado Division of Water Resources (CDWR) online reporting sites for flow gauging stations at JWC, NFL, NFG and PBD. Streamflow values at 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. Poudre Valley Canal diversion discharge measurements were obtained from the Poudre River Commissioner, Mark Simpson. Discharge values for these sites are presented as daily averages.

Cache la Poudre Basin Snowpack

To understand temporal trends in discharge, one must also examine spatial and temporal trends in snowpack, snow water equivalent, and temperature, as snowmelt is the dominant driver of peak discharge in the Upper CLP. Snow water equivalent (SWE) represents the depth of liquid water contained in the snowpack. The snow telemetry (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 nationwide. The SNOTEL and snow course network are managed and operated by the Natural Resource Conservation Service (NRCS). Peak SWE data were collected from five NRCS SNOTEL and



Cache la Poudre Watershed				
Basin	Elev (ft)	Peak Snow Water Equivalent		
		WY2014	Historical Average	% of Average
Cameron Pass	10,285	35.4	29.1	122%
Deadman Hill	10,220	28.9	19.7	147%
Joe Wright	10,120	32.6	23.8	137%
Long Draw	9,980	23.6	18.3	129%
Hourglass Lake	9,380	16.0	11.4	141%
Bennet Creek	9,200	7.7	7.2	107%
Red Feather	9,000	10.3	6.9	150%
Chambers Lake	9,000	13.3	8.6	155%
Black Mountain	8,920	13.2	11.7	113%
Big South	8,600	7.5	3.5	217%
Basin Index (%)				**135**

Figure 3.1 – Locations of SNOTEL and snow course monitoring sites in the UCLP.

five snow course monitoring sites to evaluate differences across the basin as well as between years (Figure 3.1). Deadman Hill, Red Feather, and Black mountain sites represent snow conditions in the North Fork basin; Cameron Pass and Hourglass Lake represent conditions in the South Fork basin; and Joe Wright, Long Draw, Big South, and Bennet Creek represent conditions in the Mainstem basin (Figure 3.1). On an annual basis, higher elevation sites receive significantly more SWE than lower elevation sites in the watershed. These differences in SWE are driven primarily by differences in elevation and the orographic nature of winter storms in the Front Range of the Rocky Mountains. In 2014, peak SWE across the entire Cache la Poudre Watershed was 135% of the expected peak SWE based on the long term average with all monitoring locations reporting well above their historic average (Figure 3.1).

Joe Wright SNOTEL contains the longest record of continuous SWE measurements in the Cache la Poudre Watershed dating back to 1978. The long-term data record provides a valuable tool for evaluating the progression of the snowpack, in terms of quantity of water, compared to the historical average, maximum, and minimum SWE (Figure 3.2).

The beginning of the 2014 snow accumulation season was near normal, but fell below normal in early November 2013 following several weeks of dry weather. SWE remained slightly below normal until February 2014. In early February, a significant snowfall event increased SWE above-normal. Storms continued to impact the Northern Mountains and Upper CLP through mid-April, until drier and warmer weather brought SWE near normal. Peak SWE is generally observed in late-April to early-May, but snowfall events continued through late May in 2014. A peak SWE of 32.6 inches was observed at Joe Wright on May 18th in 2014 compared to the historical average peak SWE of 23.8 inches measured on April 26th (Figure 3.2) Snowmelt began immediately after the date of peak SWE, and remained accelerated until the snow disappearance date. During this snowmelt period, average daily air

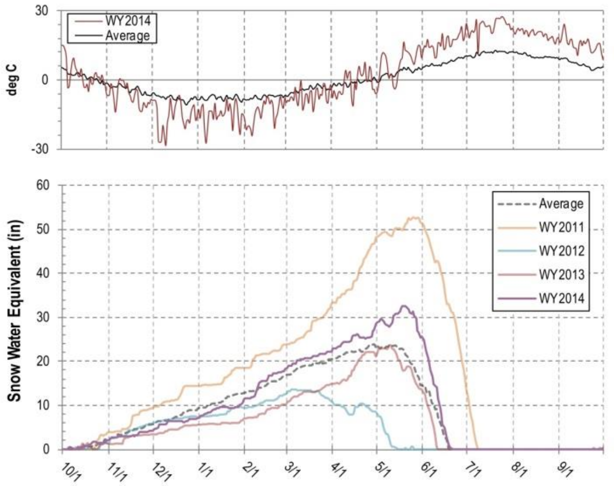


Figure 3.2 – Air temperature and snow water equivalent measured at Joe Wright SNOTEL site near Cameron Pass over the 2014 water year (October 1, 2013 – September 31, 2014).

temperatures measured at Joe Wright SNOTEL consistently remained above freezing, and also greater than the historical average. temperatures measured at Joe Wright SNOTEL consistently remained above freezing, and also greater than the historical average. The 2014 snowpack was completely melted at Joe Wright by mid-June (Figure 3.2).

Mainstem Cache la Poudre Watershed Streamflow

The Mainstem and North Fork watersheds exhibit snowmelt-dominated hydrographs. Water is stored in the snowpack as precipitation accumulates through the winter and is released later in the spring when there is more incident solar radiation to the earth surface causing a net gain of energy to the snowpack and hence snowmelt. The Cache la Poudre at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station managed by the CDWR (*http://www.dwr.state.co.us/*) contains the longest record of continuous streamflow in the upper CLP Watershed dating back to 1883. The streamflow monitoring station is located at the Canyon Mouth and includes streamflow contribution from both the Mainstem and North Fork watersheds. The long-term data record provides a valuable tool for evaluating the temporal progression of streamflow compared to the expected long-term average (Figure 3.3). In an average year, snowmelt runoff on the Mainstem begins in mid to late-April with streamflow peaking by mid-June. Following spring runoff, the hydrograph slowly recedes through the summer months returning to baseflow conditions in late fall (Figure 3.3).

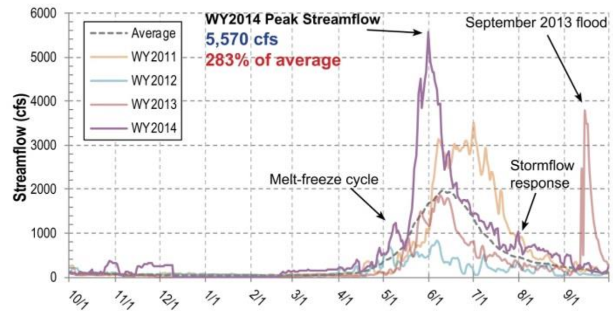


Figure 3.3 – Streamflow measured over the 2011-2014 water years at the CLP at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station.

Multiple spikes in the hydrograph reflect natural and human influenced fluctuations of river levels that result from snowmelt runoff, rainfall events, and reservoir releases and water diversions in the Upper CLP (Figure 3.3). Over the past several years, streamflow on the Poudre River near the Canyon Mouth displayed dramatic fluctuations in response to summertime thunderstorms and subsequent flash flooding of burned areas from the High Park and Hewlett Gulch Fires of 2012 (Figure 3.3).

In 2014, winter baseflow conditions were elevated above average as a result of the September 2013 flood event. Snowmelt in lower elevations of the watershed resulted in increased streamflow at the Canyon Mouth in early April, which was followed by several melt-freeze cycles corresponding with the late-April and early-May snow storms. Rapid snowmelt in late May resulted in a significant streamflow response and peak streamflow of 5,570 cubic feet per second (cfs) on May 31st at 283% of the long-term average. In comparison, the long-term average peak flow is 1,966 cfs on June 11th. Streamflow began to recede following the peak and remained near average through the remainder of the season.

Debris flows and flooding were common on the Mainstem during the 2014 monsoon season following high intensity, short duration precipitation events localized over burn scar areas in the Upper CLP watershed. The hydrograph response to rainfall driven flooding is a rapid increase shortly after or during the precipitation event, followed by a slower return to pre-storm flows. The response in streamflow is highly dependent on the location, magnitude, duration, and intensity of the precipitation event. Reservoir and diversion operations higher in the watershed also caused temporary increases in streamflow.

Mainstem Streamflow Contributions

An estimated 594,015 acre-feet of water flowed down the Poudre River above the Munroe Tunnel and North Fork in 2014. This is likely an underestimate of total water because streamflow records from PBD are not yet available for all months of the year (January and December). Total acre-feet for February and November are also underestimated because the stream gage was not online until late February and was taken offline on November 15th. Streamflow data for these months are usually estimated by the operating agency and will not be available until May 2015. In addition, the streamflow gage on the Little South Fork was not installed until late May 2014 and was taken offline for the season on November 11th.

There are a number of tributaries, diversions, and reservoirs that contribute to the overall streamflow and water quality on the Mainstem CLP above the North Fork. The two highest elevation diversions in the Upper CLP include Michigan River Ditch, which conveys water from the Upper North Platte basin to Joe Wright Reservoir and the Grand Ditch, which conveys water from the Upper Colorado River basin into Long Draw Reservoir. The contributions of these diversions are not discussed in the report, but contributions from releases from the reservoirs in which these waters are stored are addressed below.

In 2014, releases from Long Draw Reservoir contributed 29,316 acre-feet (5%) of water to the Poudre River. Most of this contribution occurred in July (10,938 acre-feet) with the highest percentage contribution (19%) in August (Table 2 and Figure 3.4).

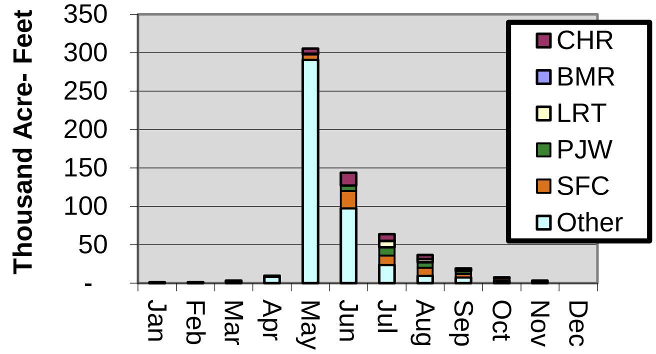


Figure 3.4 – Bar graph of tributary contributions by month to the Mainstem CLP above the Munroe Tunnel in 2014. Note that continuous flow measurements were not available for calculating "other" flow in January, February, and December.

Water from the Michigan Ditch is initially stored in Joe Wright Reservoir and then released down Joe Wright Creek to Chambers Lake before being released back into Joe Wright Creek, and then eventually, the CLP. Water releases from Chambers Lake contributed 47,022 acre-feet of water in 2014 accounting for 8% of the total water in the Poudre River basin (Table 3 and Figure 3.4). Streamflow below Chambers Lake follows a familiar snowmelt driven pattern with water contributions occurring from late-April through September.

Barnes Meadow Reservoir is owned and operated by the City of Greeley and is typically used to supply water during

Table 3 – Tributary contributions by month to the Mainstem Cache la Poudre River above the Munroe Tunnel in 2014. Contributions highlighted in red indicated underestimates due to incomplete data sets. **Note: AF = acre-feet**

	Barnes Meadow Outflow (BMR)		Chambers Lake Outflow (CHR)		Laramie Tunnel (LRT)		Poudre above Joe Wright (PJW)		Little South Fork Poudre (SFC)		Other Mainstream Contributions		Poudre above Munroe Tunnel & North Fork	
	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%
Jan	15		1,230		-		-		-			-	-	
Feb	295		1,041		-		-		-			-	**882**	
Mar	215	7%	1,107	34%	-		-		-		1,893	59%	3,215	------
Apr	282	3%	1,340	14%	-		16	0%	-		8,089	83%	9,727	------
May	1,152	0%	6,343	2%	-		41	0%	7,069	2%	290,546	95%	305,151	------
Jun	-		16,608	12%	-		7,448	5%	22,314	16%	97,436	68%	143,806	------
Jul	-		8,729	14%	8,501	13%	10,938	17%	12,098	19%	23,594	37%	63,860	------
Aug	-		5,550	15%	4,140	11%	7,132	19%	10,247	28%	9,705	26%	36,774	------
Sep	-		3,511	18%	-		3,528	18%	4,832	25%	7,347	38%	19,218	------
Oct	-		1,563	21%	-		215	3%	2,983	39%	2,801	37%	7,562	------
Nov	-		-		-		-		797	21%	3,024	79%	**3,821**	------
Dec	-		-		-		-		-		-		-	

the winter months. Water is released from Barnes Meadow into Joe Wright Creek, below Chambers Lake, before entering the Poudre River downstream. In 2014, Barnes Meadow Reservoir contributed 1,959 acre-feet of water, less than 1%, to the Poudre River. The greatest contribution occurred in March (Table 2 and Figure 3.4).

The Laramie River Tunnel (LRT), located downstream of the confluence of the Poudre River and Joe Wright Creek, conveys water from the Laramie River to the CLP. In general, the LRT diverts water beginning in late April through early September. In 2014, water was not diverted from the Laramie River until early July due to the above average streamflows on the Poudre River. The LRT contributed 12,641 acre-feet (2%) of water to the CLP in 2014. Contributions from the LRT ended on September 1st.

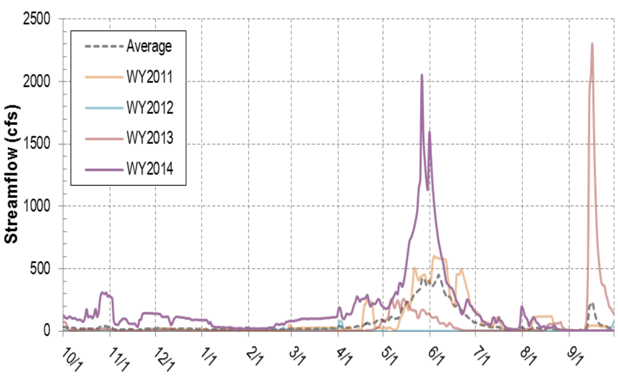


Figure 3.5 – Streamflow measured over the 2011-2014 water years at the North Fork CLP River below Seaman Reservoir (CLANSECO) streamflow monitoring station.

The largest tributary in the Upper CLP (above the confluence with the North Fork Poudre) is South Fork (SFC). Streamflow on the South Fork is primarily snowmelt driven with much of the late season flow coming from releases from Comanche and Hourglass Reservoirs, owned and operated by the City of Greeley. In 2014, the South Fork contributed 29,316 acre-feet (10%) of water to the CLP. The largest contributions occurred from August through November as a result of water releases from mountain reservoirs (Table 2 and Figure 3.4).

North Fork Cache la Poudre Watershed Streamflow

The North Fork follows a similar streamflow pattern to the Mainstem (Figure 3.5). The timing of runoff and peak streamflow on the North Fork occurs earlier than the Mainstem because it is lower in elevation. Streamflow

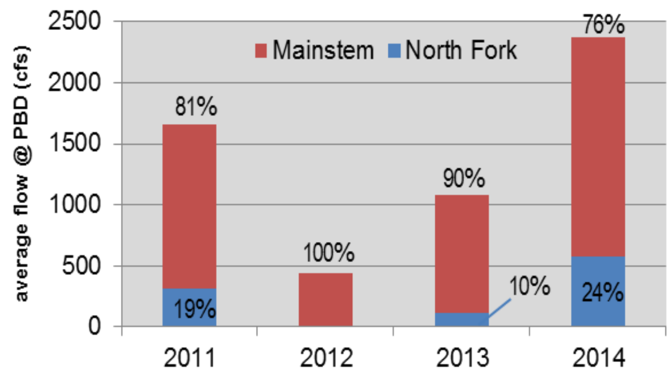


Figure 3.6 – Proportion of average Mainstem and North Fork flows at PBD during May and June from 2011 through 2014.

measured at NFL represents cumulative flows of the North Fork above Seaman Reservoir and provides information about the timing and magnitude of snowmelt runoff in the upper North Fork drainage. Streamflow measurements at NFG include contributions from both the North Fork and Seaman Reservoir and represent the total North Fork contributions to Mainstem flows (measured at PBD). Although, streamflow at NFG is influenced by reservoir operations, the snowmelt hydrographs for NFL and NFG are typically very similar. During snowmelt runoff, when Seaman Reservoir is at capacity, the majority of flow going into Seaman Reservoir spills over the emergency spillway, but when storage capacity is available water is stored in the reservoir if river administration allows. Reservoir operations generally influence streamflow later in the season following snowmelt runoff, as a result of water releases from both Halligan and Seaman Reservoirs.

In an average year, peak streamflow on the North Fork is observed the first week of June (Figure 3.5). In 2014, snowmelt runoff began in early March, reaching peak runoff on May 26th at a discharge of 2,050 cfs at NFG. Peak streamflow in 2014 was nearly five times average peak flow (435 cfs) recorded at NFG (2005-2014). Runoff decreased to near baseflow condition over the next month (Figure 3.5). Water was released periodically from the reservoir throughout the rest of the season. During the months of May through June from 2011 to 2013, the North Fork has comprised on average, 14% of water to the Mainstem at PBD. In 2014, the North Fork contributed 24% of flows to the Mainstem as a result of peak discharge at approximately 500% of average in May (Figure 3.6). This was the highest flow contribution from the North Fork over the four year period.

3.2 WATER TEMPERATURE

Water temperature increases with decreasing elevation throughout the watershed (Figure 3.7). The timing of peak water temperatures on the North Fork and the Mainstem are similar, and typically occur in mid-summer. In general, stream water temperatures are at a minimum during winter baseflow conditions when air temperatures are the lowest and at a maximum in July and/or August when air temperatures are the greatest and streamflow is low and no longer dominated by snowmelt. The highest stream temperatures generally occur on the lower North Fork (NFL and NFG) with the exception of 2012, presumably due to relatively low flows.

In 2014, water temperatures in the Upper CLP watershed followed similar temporal and spatial patterns to the three previous years. Water temperature throughout the Upper CLP watershed ranged from 0.22°C at PJW on April 21st to a maximum temperature of 19.8°C at NFG on July 16th. Maximum temperatures at sites along the Mainstem and NFL were observed in August (Figure 3.7). Temperatures at PJW and NFG were likely influenced by Long Draw and Seaman Reservoir operations, respectively, which can result in colder stream temperatures from colder water released from the bottom of these reservoirs. Following annual maximum water temperatures, water temperature decreased at all sites through the remainder of the monitoring season (Figure 3.7).

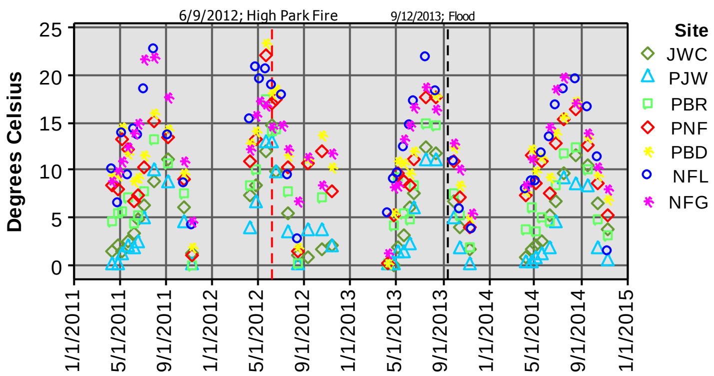


Figure 3.7 – Water temperature at key Upper CLP monitoring sites from 2011 through 2014.

3.3 GENERAL PARAMETERS

Conductivity, Hardness, and Alkalinity

Conductivity is an index of dissolved ionic solids in water and hardness is an index of the total calcium (Ca) and magnesium (Mg) in water. Alkalinity is a measure of the effective acid buffering capacity of water, and is derived from the dissociation of mineral carbonates (CO_3^-), bicarbonates (HCO_3^-), and hydroxides (OH^-). Conductivity, hardness and alkalinity are influenced by local geology, as well as other dissolved constituents derived from land use practices throughout the watershed.

Concentrations of these constituents are also largely influenced by the magnitude and timing of streamflow, and by the contributing watershed area. The highest concentrations are observed during times of low flow during the late-fall and winter months, while minimum concentrations are observed during dilution from snowmelt runoff. In general, concentrations increase with decreasing elevation as contributing watershed area increases.

In 2014, spatial and temporal patterns were similar to the previous three years with the exception of 2012. The extreme drought conditions and low streamflow in 2012 illustrate the effect of streamflow on concentrations when below average snowmelt runoff had little dilution effect on concentrations. Specific conductivity (Figure 3.8a), hardness (Figure 3.8b), and alkalinity (Figure 3.8c) concentrations were within the expected range of values throughout the 2014 monitoring season. North Fork watershed concentrations were higher and more variable across monitoring locations as compared to Mainstem sites. Reservoir operations may have diluted concentrations during water releases observed at NFL and NFG from September through October in 2014. Yet, the greatest factors driving higher concentrations throughout the North Fork watershed are land use and geology.

pH

pH is a measure of the amount of free hydrogen (H^+) and hydroxide (OH^-) ions in water and is measured on a logarithmic scale ranging from 0 to 14. Water with a pH near 7 is considered neutral, with more acidic conditions occurring below 7 and more basic, or alkaline, conditions occurring above 7. pH is an important water quality parameter to monitor because it influences the solubility and biological availability of chemical constituents, including nutrients and heavy metals.

In 2014, the pH in the Upper CLP watershed followed similar temporal and spatial patterns as was observed in alkalinity, conductivity and hardness concentrations (Figure 3.9). pH levels were within the expected range as compared to the previous three years (2011-2013). All sites experienced a particularly sharp decrease in pH during spring runoff. pH typically increased at all sites following snowmelt runoff; however, summer and fall pH trends varied between Mainstem and North Fork sites as well as between years. In 2014, pH on the Mainstem ranged from 7.36 at PJW on May 19th to 8.38 at PBD on November 11th. Values on the North Fork were greater than the Mainstem and ranged from 7.96 to 8.38 at NFL.

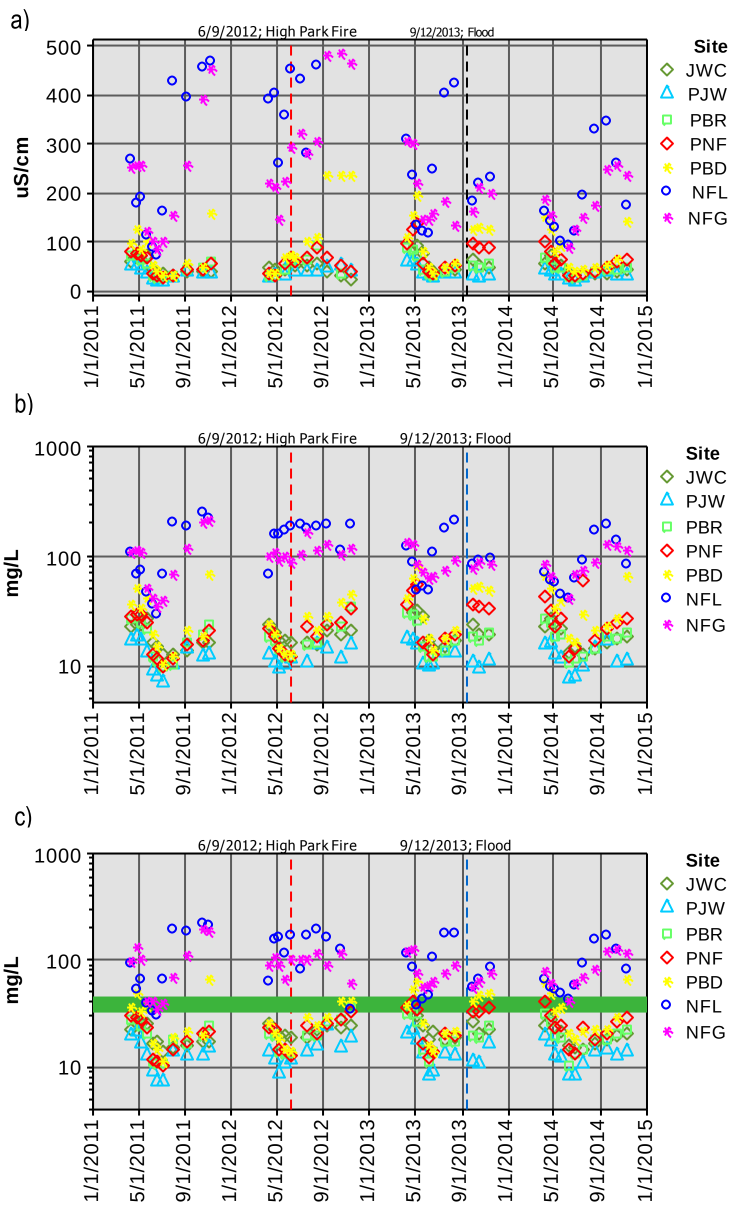


Figure 3.8 – General water quality parameters a) specific conductance, b) hardness, and c) alkalinity measured at key Upper CLP monitoring sites. The green bar indicates the WTFs target alkalinity concentration in finished water.

Turbidity

Turbidity is a measurement of the amount of light capable of passing through water. This water quality parameter is often monitored to track changes in water clarity, which is influenced by the presence of algae and/or suspended solids introduced to surface waters through various land use activities, including runoff and erosion, and urban storm water runoff and drainage from agricultural lands. Turbidity levels can signal changes in land use activity. For water treatment, turbidity is an important indicator of the amount suspended material that is available to harbor pollutants such as heavy metals, bacteria, pathogens, nutrients, and organic matter.

In general, turbidity on the Mainstem and North Fork peaks during the beginning of spring runoff. Higher streamflow velocities increase the transport capacity of sediment and organic material throughout the water column, and the increase in suspended sediment translates to increased turbidity levels. Turbidity values steadily decrease following peak snowmelt runoff to values below 1 NTU during baseflow conditions.

Turbidity values in 2014 followed similar trends to pre-fire and pre-flood conditions in 2011, however peak turbidity values were nearly two times greater in 2014 than 2011 (Figure 3.10). The higher peak turbidity values in 2014 may be associated with the 2013 flood event and the availability of sediment. A greater degree of variability was observed post-fire (2012 and 2013) as a result of debris flows and flooding from burned hillslopes transporting high volumes of sediment and organic matter to the Mainstem. The effect of the wildfires was still evident in 2014 when turbidity values spiked greater than 200 NTU at PNF on July 14th (Figure 3.10) as a result of a high intensity precipitation event that produced debris flows and flooding from burned hillslopes higher in the watershed (Figure 3.11).

The maximum values observed during snowmelt runoff in 2014 were 29.3 NTU on the Mainstem at PNF and 17.4 NTU on the North Fork at NFL. Overall, values ranged from 0.30 to 29.3 NTU, excluding the July 14th sampling event (Figure 3.10). As seen in previous years, occasional spikes in turbidity were observed in 2014 at NFG as a result of water being released from the outlet of Seaman Reservoir, but were not of sufficient magnitude to impact downstream turbidity at Greeley's water supply intake (PBD).

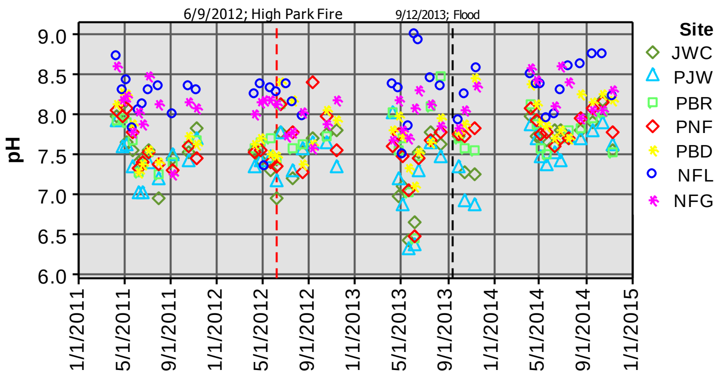


Figure 3.9 – pH levels measured at key Upper CLP monitoring locations from 2011 through 2014.

3.4 TOTAL ORGANIC CARBON

Total organic carbon (TOC) is a measure of the total concentration of dissolved and particulate organic matter in water. Total organic carbon is derived from both terrestrial and aquatic sources. Terrestrial TOC originates from soils and plant materials that are leached and/or delivered to surface waters during storms and spring snowmelt runoff, whereas aquatic-derived TOC originates from algal production and subsequent decomposition within surface waters.

Total organic carbon is an important indicator of water quality, particularly as it relates to water treatment. Water treatment requires the effective removal of TOC because the interaction between residual TOC and disinfectants can form regulated disinfection by-products (DBPs). DPBs are strictly regulated due to their carcinogenic potential. Increases in source water TOC concentrations pose concern due to the potential for higher residual TOC (post-filtration) and increased DBP formation potential.

Mainstem Poudre River

Seasonal and spatial patterns of TOC on the Mainstem are generally consistent from year-to-year. TOC concentrations at most sites are normally below 5 mg/L at the beginning of the monitoring season before snowmelt runoff. In an average year, annual maximum TOC values occur during the onset of spring snowmelt runoff in May and then begin to decrease throughout the rest of the monitoring season. The timing and magnitude of concentrations are highly dependent on the timing and magnitude of snowmelt runoff. In recent years, following the High Park Fire, debris flows and flooding from burned hillslopes have caused temporary increases in TOC concentrations in July and August. In some cases, these elevated concentrations were two times the peak snowmelt concentration, but concentrations recovered to background level concentrations shortly after the event. In addition, as noted in the 2013 Annual Report (Oropeza and Heath, 2014), unburned sites in portions of the watershed had elevated baseline TOC concentrations, whereas burned sites were within the range of expected baseline values. Oropeza and Heath (2014) suggested that these elevated TOC concentrations were likely associated with drought conditions in 2012 and the mobilization of drought impacted vegetation and soils during snowmelt in 2013.

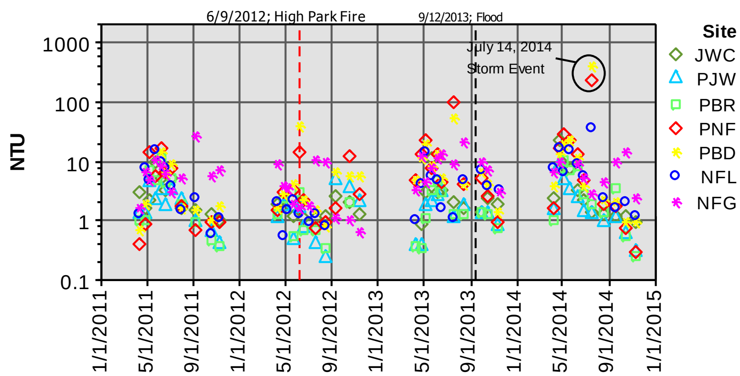


Figure 3.10 - Turbidity levels measured at key Upper CLP monitoring locations from 2011 through 2014.

Figure 3.11 – Photo looking downstream at PSF (left, pre-storm) and PNF (right; post-storm) on July 14th, 2014 highlighting the dramatic change in water quality and turbidity levels.

In 2014, TOC on the Mainstem exhibited the typical seasonal pattern of highest concentrations during snowmelt runoff, followed by a decrease to baseline concentrations during the summer months, which typically lasts from October to early April. This pattern is especially evident in 2011 and 2014 (Figure 3.12). Concentrations were below 5 mg/L at all sites on April 7th, but steadily increased to peak concentrations on May 5th, except for JWC and PBD. Peak TOC concentrations at JWC were observed on May 19th, which is to be expected because the onset of snowmelt runoff higher in the watershed preceeds runoff in the lower watershed. Peak TOC concentrations ranged from 7.6 mg/L to 10.5 mg/L at PBD and PJW, respectively. TOC concentrations at PNF and PBD did not show a significant response to the July 14th storm event that caused debris flows and flooding within the burned area (Figure 3.12).

North Fork Poudre River

Seasonal and spatial patterns of TOC on the North Fork Poudre River are less predictable from year to year than the Mainstem. In general, concentrations are higher on the North Fork compared to the Mainstem, which results in higher TOC contributions to PBD. In the North Fork watershed, TOC is normally highest at NDC during snowmelt runoff from April through May or June, but decreases to concentrations lower than all other sites on the North Fork. In contrast, TOC concentrations at NFG (below Seaman) and NBH (below Halligan) decrease following snowmelt runoff, but remain elevated relative to other sites in the upper CLP watershed. The elevated TOC levels at these sites suggest additional sources of TOC, which may include water from Halligan and Seaman Reservoirs, and runoff from agricultural lands. .

In 2014, TOC dynamics on the North Fork followed a similar seasonal pattern to that observed on the Mainstem (Figure 3.12). In early April, TOC concentrations were 3.9 mg/L at both NFL and NFG before increasing during snowmelt runoff to peak concentrations of 9.1 mg/L and 9.5 mg/L, respectively, on June 10th. Concentrations at NFL steadily decreased through the remainder of the year. A steady decrease in TOC concentrations was also observed at NFG near the end of June and through July. The slightly elevated TOC concentrations in August and September at NRG were effectively diluted by flows in the Mainstem, as evidenced by TOC measurements at PNF (above the North Fork confluence) and PBD (below the North Fork confluence) during those months.

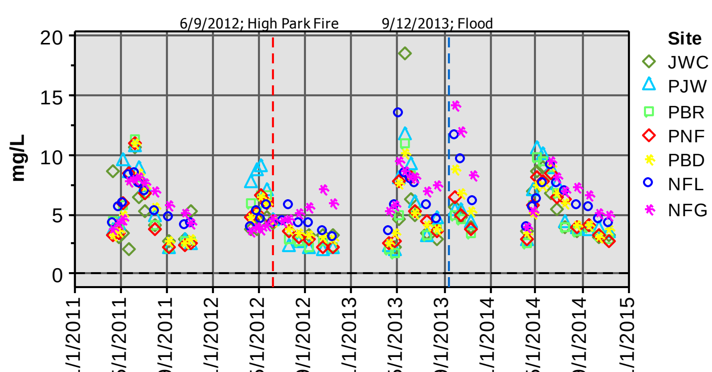


Figure 3.12 – Total organic carbon (TOC) concentrations measured at key Upper CLP monitoring locations from 2011 through 2014.

Wildfire Impacts on TOC Treatability

In 2013, the City of Fort Collins became a participant in the Water Research Foundation Study # 4524, entitled *"The Impact of Colorado Wildfires on Source Water and Implications for Water Treatment and Finished Water Quality"*. Principal investigators are Fernando L. Rosario-Ortiz and R. Scott Summers with the University of Colorado- Boulder and Pinar Omur-Ozbek with Colorado State University. Other participating entities include Denver Water, Northern Water, and City of Aurora. The main objective of this study is to evaluate the impact of forest fires on water quality and subsequent treatment, with a focus on dissolved organic matter (DOM) properties. This study is designed to evaluate the effectiveness of several different types of water treatment on source waters impacted by wildfires. The study is expected to be completed in late 2015.

A second study that focused on impacts of the High Park Fire on the treatability of Upper CLP has been completed and submitted for publication. This manuscript is entitled *Changes in Source Water Quality and Treatment Following a Wildfire* (Amanda Hohner, primary author, *submitted 2015*). This study looked at two sites in the Upper CLP watershed. PBR is the control or un-impacted site and is situated just upstream and outside of the burn perimeter. The PNF site is the downstream fire-impacted site and represents water quality at the Fort Collins Intake Facility. Samples collected throughout the year at these two sites are considered representative of background, or non-storm event conditions. Samples were also collected during rainstorm events to evaluate the worst case scenario for fire impacts on water quality. The following findings summarize some of the impacts of the wildfires on the treatability of the Poudre River.

- Comparisons between the upstream control site (PBR) and the burned site (PNF, above Fort Collins Intake Facility) show higher concentrations of turbidity, total organic carbon, nitrogen, and phosphorus at the burned site (PNF).

- The fire did not appear to affect the formation of some common carbon-based disinfection by-products (C-DBPs) like haloacetic acids and trihalomethanes, but it did result in an increase in chloropicrin (C-DBP) and other nitrogen-based DBPs (N-DBPs), specifically haloacetonitrile (HAN4) formation at the burned site. Unlike carbonaceous C-DBPs, nitrogenous N- DBPs are not currently regulated compounds.

- Samples from the fire-impacted site required a 10 mg/L higher mean alum dose for coagulation than control samples for DOC removal.

- Rainstorm events produced changes in water quality that made coagulation significantly more difficult, with some samples requiring up to 80 mg/L alum to treat and yielding higher haloacetonitrile (N-DBP) and chloropicrin (C-DBP) Furthermore, nutrients, turbidity and DOC concentrations were higher in storm event samples than in the background (non-rainstorm) samples.

3.5 NUTRIENTS

Nutrients are an important component of source water quality monitoring. In high concentrations and under certain environmental conditions nutrients can lead to algal growth. In extreme situations, nutrients can lead to abundant levels of cyanobacteria, which are responsible for the production of cyanotoxins and other compounds that can affect the taste and odor of drinking water supplies. Potential sources of nutrients in aquatic systems include animal waste, leaking septic systems, fertilizer run-off, and sediment loading.

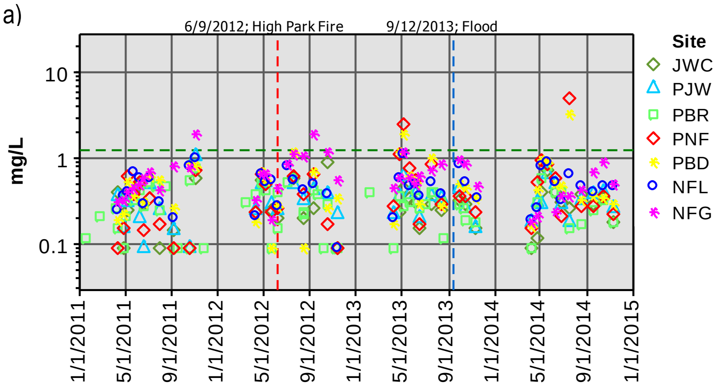
Ammonia (NH_3), nitrate (NO_3), nitrite (NO_2), and ortho-phosphate (PO_4) are dissolved forms of nitrogen and phosphorus that are readily available for plant uptake. Both Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP) serve as aggregate measures of potential nitrogen and phosphorus availability to the system. TKN is a measure of ammonia plus organic nitrogen. Total nitrogen (TN) is the sum of TKN and inorganic nitrogen (NO_3-N and NO_2-N). Likewise, TP is a measure of dissolved phosphorus as well as phosphorus bound to sediments and organic matter. For the purpose of this report, the discussion of results only pertains to values above the reporting limits currently used by the FCWQL. Current reporting limits are 0.005 mg/L (5 µg/L) for PO_4, 0.01 mg/L (10 µg/L) for ammonia and TP, and 0.04 mg/L (40 µg/L) for nitrate and nitrite. In the calculation of TN (TKN+ NO_3-N + NO_2-N), concentrations below their respective reporting limit were reported as half the reporting limit.

Mainstem Poudre River

Total Nitrogen (TN)

Nitrogen continued to persist at low concentrations on the Mainstem Poudre River in 2014 (Figure 3.13 and 3.14). Total nitrogen concentrations were similar between monitoring locations, and comparable to the previous three years (Figure 3.13a). The highest concentrations were observed in May during the onset of snowmelt, but steadily decrease to below 0.5 mg/L during the summer months. Concentrations did not exceed 1 mg/L in 2011 and 2012, except for one occasion at PSF in 2011. Following the wildfires, infrequent spikes in TN caused by debris flows and flooding resulted in greater variable at impacted monitoring sites (PNF and PBD) compared to previous years. In 2014, a storm event on July 14th caused TN concentrations to increase to 5.02 mg/L at PNF compared to a snowmelt peak of 0.93 mg/L on May 5th (Figure 3.13a). This storm event peak was the greatest concentration observed over the four year record. Concentrations at PNF decreased following the storm event, but remained higher than TN concentrations measured in the month prior to the storm.

a)



b)

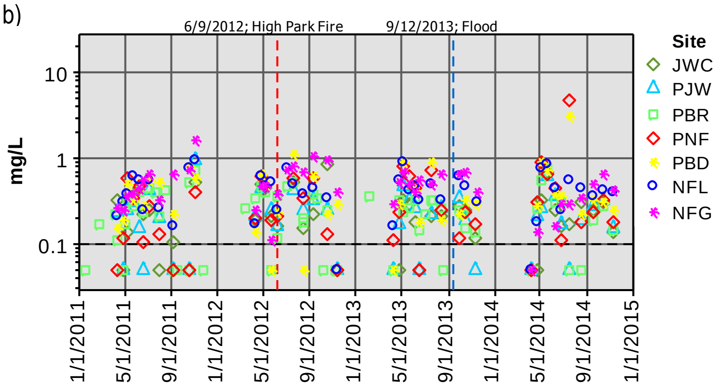


Figure 3.13 – Nutrient concentrations for a) TN and b) TKN at key Upper CLP monitoring locations.

(- - - - - CDPHE proposed cold water stream standard for TN, annual average of 1.25 mg/L with an allowable exceedance of 1-in-5 years.)

Total Kjeldahl Nitrogen (TKN)

TKN comprises the largest fraction of TN, with NO_3-N and NO_2-N representing lesser fractions, and therefore, tracks closely with TN. In 2014, TKN concentrations ranged from <0.01 mg/L to a peak concentration of 0.89 mg/L at PNF (Figure 3.13b). This concentration was slightly lower to the previous year's peak concentration of 0.81 mg/L at PNF, but greater than 2011 and 2012. The storm event on July 14th elevated TKN concentrations to 4.87 mg/L at PNF, which attenuated to 3.07 mg/L downstream at PDB as a result of dilution flows from the North Fork (Figure 3.13b). Concentrations decreased at PNF following the storm event, but were greater than TKN concentrations measured in the June.

Nitrate as Nitrogen (NO_3-N)

Nitrate concentrations remained elevated at all sites in 2014 compared to 2011 and 2012 (Figure 3.14a). In these years, NO_3-N was only detected at JWC and PJW, the higher elevation sites in the watershed. Elevated NO_3-N concentrations at lower elevation monitoring sites were only first observed in 2013. In 2014, NO_3-N concentrations ranged from <0.04 mg/L to 0.20 mg/L at PNF. The peak concentration was lower than 2013, but was still higher than the pre-wildfire years (2011 and 2012). The timing of the peak was similar to previous years and was observed on April 21st at the onset of snowmelt runoff. The storm event on July 14th elevated NO_3-N at PNF, but only to a concentration of 0.13 mg/L (Figure 3.14a). NO_3-N concentrations at PNF decreased after July and were measured below the reporting limit from September through the rest of the year. The snowmelt NO_3-N pulse and elevated NO_3-N concentrations during storm events at wildfire impacted monitoring sites has been observed in many studies that examined the impact of wildfires on water quality (Neary, 2005; Hibbert, 1974; Tiedemann, 1979) However, the cause of the elevated NO_3-N concentrations at unaffected monitoring locations is yet to be determined. The increase is possibly associated with the extreme drought conditions in 2012 that may have caused an increase in NO_3-N pools in soils associated with limited vegetation growth, and the subsequent release of NO_3-N from soils to surface waters. Despite the elevated concentrations in 2014, NO_3-N levels continued to persist at comparatively low concentrations.

Ammonia as Nitrogen (NH_3-N)

Ammonia concentrations on the Mainstem in 2014 were greater than 2011 and 2012, but similar to 2013 (Figure 3.14b). As was observed with NO3, NH3 concentrations were higher at all monitoring sites, and experienced a similar, but short-lived, pulse during snowmelt at wildfire impacted monitoring sites (PNF and PBD). Concentrations ranged from <0.01 mg/L to 0.06 mg/L. The peak concentration of 0.06 mg/L was measured at PNF during the storm event on July 14th. Ammonia concentrations decreased in the months following the storm event to levels below the reporting limit.

Nitrite as Nitrogen (NO_2-N)

Nitrite has never been detected above the reporting limit on the Mainstem over long-term data record (2008-2013). Due to the instability of this form of inorganic nitrogen, NO_2-N is readily converted to NO_3-N by microorganisms through the process of nitrification. In 2014, there were no detections of NO_2-N at any key sites. Nitrite was detected at PSF on April 21st at a concentration of 0.20 mg/L; however, NO_2-N was not detected at sites above or below PSF on this date. This strongly suggests, in combination with findings from the long-term data record, that this result may be erroneous.

Ortho-phosphate (PO_4)

Ortho-phosphate concentrations were low in 2014 with most concentrations below the reporting limit of 5 µg/L (Figure 3.15a). A maximum concentration of 30 µg/L, was measured at PNF during the storm event on July 14th. Ortho-phosphate concentrations remained elevated in 2014 at wildfire impacted sites, PNF and PBD. Elevated PO_4 concentrations were observed immediately after the fire, while pre-fire concentrations were consistently below the reporting limit at PNF. These elevated concentrations were also observed downstream at PBD. Reportable PO_4 concentrations were occasionally measured at unaffected sites (JWC, PJW, and PBR) in the watershed, but were at low levels.

Total Phosphorus (TP)

Total phosphorus concentrations on the Mainstem typically increase with snowmelt runoff, followed by a sharp decrease during the summer months. Concentrations are higher at lower elevations in the watershed (PNF and PBD). In 2014, the peak concentration during snowmelt was measured on May 5th at PNF at 96 µg/L. Concentrations rapidly decreased following the snowmelt pulse to near the reporting limit of 10 µg/L. The storm event on July 14th caused concentrations to increase to 1,028 µg/L at PNF and 595 µg/L at PBD. These were the highest concentrations observed over the four year period of record, but concentrations recovered to just above the reporting limit by the following monitoring event in August (Figure 3.15b).

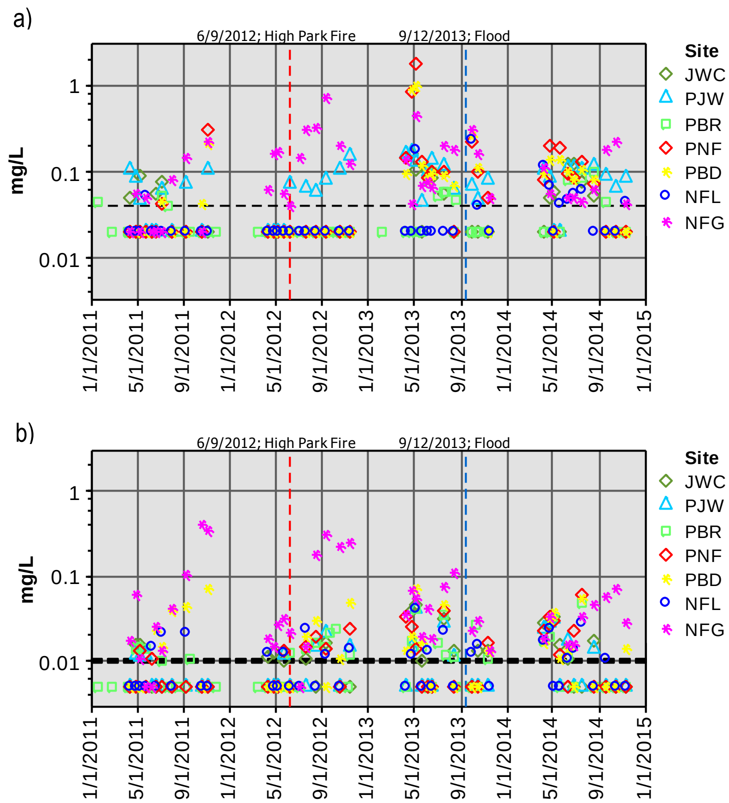


Figure 3.14 – Nutrient concentrations for a) nitrate as nitrogen and b) ammonia as nitrogen at key Upper CLP monitoring sites.

North Fork Poudre River

In general, nutrient concentrations were comparable between the North Fork and Mainstem sites. The exceptions are the two sites situated below Halligan (NBH) and Seaman (NFG) Reservoirs on the North Fork. These reservoirs appear to be sources of nutrients to the North Fork, as reflected by relatively high NO_3-N, NO_2-N, NH_3-N, TKN, TN, ortho- P and TP concentrations observed at NFG and NBH (Figure 3.13, Figure 3.14, and Figure 3.15).

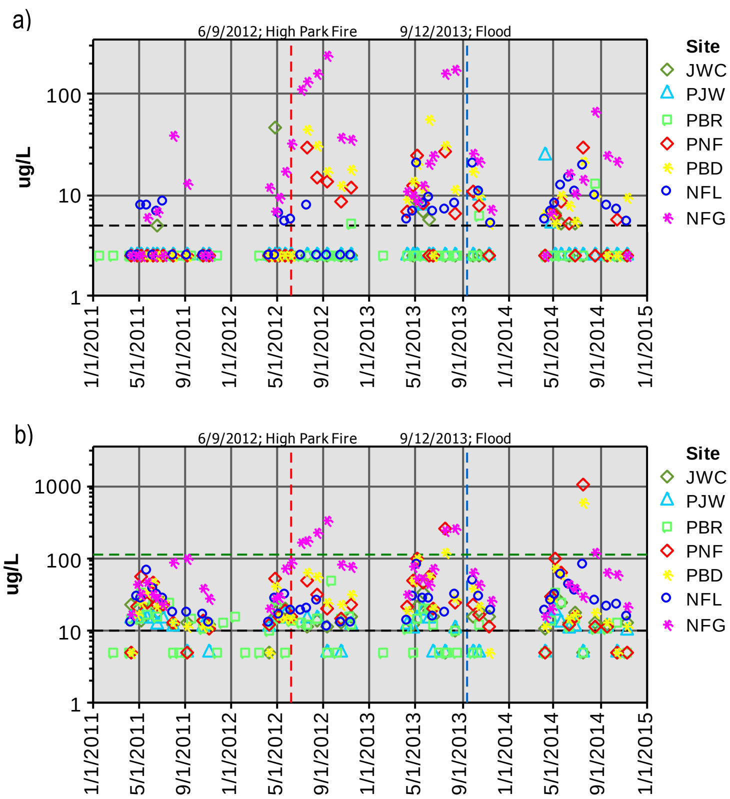


Figure 3.15 – Nutrient concentrations for a) ortho-phosphate and b) total phosphorus at key Upper CLP monitoring locations.

(- - - - - CDPHE proposed cold water stream standard for TP, annual average of 110 µg/L with an allowable exceedance of 1-in-5 years.)

Total Nitrogen (TN)

Nitrogen concentrations were similarly low on the North Fork. TN dynamics on the North Fork followed a similar pattern and concentrations to those observed at NFL in 2014 (Figure 3.13a). The highest concentrations were observed in May during the onset of snowmelt runoff, and steadily decrease during the early summer months before slightly increasing again by the end of the monitoring season. TN concentrations in 2014 at NFL were similar to previous years and ranged from 0.19 mg/L to a peak concentration of 0.91 mg/L on May 20th (Figure 3.13a). In contrast, TN at NFG was at a minimum concentration of 0.18 mg/L at the beginning of the monitoring season and steadily increased to a maximum concentration of 0.88 mg/L on October 10th. Concentrations were lower on November 11th and were more similar to NFL.

Total Kjeldahl Nitrogen (TKN)

TKN followed seasonal patterns that were similar to TN. TKN concentrations ranged from 0.02 mg/L on April 8th to 0.84 mg/L on May 10th, and then decreased to concentration near 0.5 mg/L for the remainder of the year (Figure 3.13b). Concentrations at NFG increased through the year from 0.08 mg/L in April to 0.64 mg/L on October 14th before decreasing to a level closer to that observed at NFL.

The inorganic forms of nitrogen (NO_3-N, NO_2-N, and NH_3-N) generally do not show seasonal characteristics related to snowmelt runoff and are quite variable. Nitrite was not detected above the reporting limit in 2014 or in the previous three years at NFL, but was detected above the reporting limit once in October 2011 and September 2012 at NFG.

Nitrate as Nitrogen (NO_3-N)

Similarly, NO_3-N concentrations at NFL were below the reporting limit in both 2011 and 2012, but in recent years concentrations have occasionally been reported above 0.04 mg/L (Figure 3.14a). In 2014, NO_3-N concentrations were at a maximum of 0.12 mg/L on April 8th at NFL and then decreased and fluctuated near the reporting limit for the remainder of the year. Concentrations at NFG followed a similar pattern, but began to increase in August to a maximum concentration of 0.22 mg/L measured on October 14th. By November, concentrations at NFG had decreased to 0.04 mg/L, which was also observed at NFL.

Ammonia as Nitrogen (NH_3-N)

Similar seasonal patterns were observed in NH_3-N concentrations (Figure 3.14b). Over the four year monitoring record, NH_3-N varied from year to year at NFL and NFG. The highest concentrations at NFL were observed in July in all years except 2013 when the maximum concentration was measured during the onset of snowmelt runoff. In 2014, concentrations ranged from <0.01 mg/L to 0.03 mg/L measured on July 15th (Figure 3.14b). Ammonia as nitrogen at NFL decreased to below the reporting limit following the peak concentration for the remainder of the year. Ammonia as nitrogen concentrations at NFG followed a similar pattern to NO_3-N concentrations, in which NH_3-N was detected at 0.11 mg/L on April 8th and then decreased and fluctuated around the reporting limit through July. Concentrations noticeably increased in the late summer and fall to a maximum concentration of 0.22 mg/L on October 14th. By November, concentrations at NFG had decreased to 0.04 mg/L, which was also observed at NFL.

Ortho-phosphate (PO4)

Ortho-phosphate concentrations at NFL were greater in 2014 compared to the previous years, while concentrations at NFG were similar (Figure 3.15a). Ortho-phosphate displayed increasing trends at both NFL and NFG during snowmelt runoff reaching peak concentrations of 15 µg/L and 16 µg/L on June 10th, respectively. The storm event in July had a similar influence on the North Fork, as was observed with elevated concentrations of PO_4 at both NFL and NFG. Concentrations were 14 µg/L and 19 µg/L on July 15th, respectively (Figure 3.15a). Following this event, PO_4 steadily decreased at NFG to just above the reporting limit of 5 µg/L on November 11th. This did not impact PO_4 concentrations at PBD (Greeley's water supply intake at Bellvue), and may indicate the diminishing effects of the Hewlett Gulch Fire on the reservoir.

Total Phosphorus (TP)

Total phosphorus on the North Fork at NFG and NFL followed similar patterns to PO_4 in 2014 (Figure 3.15b). Concentrations at NFL increased with snowmelt runoff to a peak of 58 µg/L on May 20th and then decreased during the summer months. A spike in TP was also observed at NFL on July 15th when concentrations reached 80 µg/L. TP at NFG was slighter lower than concentrations observed at NFL, but no storm response was observed on the July 15th monitoring event. Concentrations increased following the water release from Seaman Reservoir to a maximum of 118 µg/L on August 19th, and did not notably affect TP at PBD in August, September, or October As was observed with PO_4, the spike in TP at NFG was lower than the previous two years, but greater than 2011.

North Fork Nutrient Summary

Elevated nutrient concentrations are generally observed at upstream North Fork tributary sites during spring runoff. These higher concentrations likely occurred in response to flushing and suspension of sediment and dissolved nutrients during snowmelt. The relatively high concentrations of nutrients in these small tributaries are due, in large part, to low streamflows, especially during the summer months, and represent small contributions to overall streamflow and nutrient loads to NFL. Across all river sites, there were no observed exceedances of the EPA drinking water quality standards for nitrate (10 mg/L) or nitrite (1 mg/L) for the years 2011 through 2014.

Proposed Nutrient Standard

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 to 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.

Table 4 – Comparison of annual median TN concentrations (ug/L) at Mainstem CLP and North Fork CLP sites to 2012 CDPHE/WQCD proposed interim TN value of 1,250 ug/L (1.25 mg/L).

Site Description	2010	2011	2012	2013	2014
Poudre above North Fork (PNF)	276	170	320	360	365
Poudre at Bellvue Diversion (PBD)	396	496	307	497	429
North Fork Poudre at Gage below Seaman Reservoir (NFG)	446	487	666	627	352

Table 5 – Comparison of annual median TP concentrations (ug/L) at Mainstem CLP and North Fork CLP sites to 2012 CDPHE/WQCD proposed interm TP value of 110 ug/L.

Site Description	2010	2011	2012	2013	2014
Poudre above North Fork (PNF)	14.7	21.2	19.3	24.4	11.7
Poudre at Bellvue Diversion (PBD)	17.0	16.2	23.3	37.3	16.8
North Fork Poudre at Gage below Seaman Reservoir (NFG)	38.8	32.2	83.5	52.3	37.4

All rivers and reservoirs within the Upper CLP Watershed are designated "cold" waters. The interim nutrient standards for cold water streams are based on annual median values with an allowable exceedance frequency of 1-in-5 years. The proposed interim standard for TN is 1,250 µg/L (1.25 mg/L) and 110 µg/L (0.11 mg/L) for TP.

Annual median values for TN and TP were calculated for PNF, PBD, and NFG to evaluate the current status of the Mainstem and North Fork CLP Rivers with respect to the proposed standards (Table 4 and Table 5). Annual median values over the past five years did not exceed the proposed nutrient standards for TN and TP at these sites or any monitoring location in the Upper CLP. TN and TP concentrations measured routinely at PNF and PBD have historically been below the proposed standard. Impacts from the recent wildfires (storm events) have resulted in short-term exceedances of the valued standard, but these events are not frequent enough to result in annual median values that exceed the standard.

3.6 METALS

Naturally occurring metals are routinely detected at low concentrations in the North Fork and Mainstem. The presence of metals in in source water supplies is most often due to mineral weathering of the soils and subsequent erosion of those sediments into the river with snowmelt runoff, wind, precipitation and other natural processes.

Metals were sampled twice annually on the Mainstem at PNF and on the North Fork at NFG from 2010 through 2012. In 2013 and 2014, routine sample frequency was increased to three times per year and new analytes were added to the monitoring plan to better evaluate the effects of the 2012 wildfires. Additional sites, above and below the burn scar were also added (Attachment 4) and all samples were analyzed for total and dissolved metals. In 2014, SFC replaced SFM on the list of monitoring sites to be analyzed for metals on the South Fork. Samples were collected from the Mainstem on May 19th, July 14th, and October 13th and from the North Fork on the following day.

The most commonly detected metals were aluminum (Al), chromium (Cr), iron (Fe), and manganese (Mn). Silver (Ag), arsenic (As), cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), and selenium (Se) were detected below the reporting limit throughout the monitoring season, except during the July monitoring event (Table 5). Dissolved iron concentrations were just below the secondary drinking water quality standard of 300 µg/L during snowmelt (May 19th) at PBR, PSF, and PBD. Concentrations exceeded the standard on May 19th at SFC and PNF with concentrations of 340 µg/L and 319 µg/L, respectively (Table 5). While compounds regulated under the secondary drinking water standards are not a threat to public health, they may impact the aesthetics of the finished water, which affects customer perceptions of safety. Such aesthetic changes in water quality include associated taste and odors, coloration of the water, staining of fixtures and corrosion in the distribution system.

All metals (dissolved and total) were elevated at PNF and PBD as a result of the July 14th storm event. As was expected, total concentrations were considerably greater than the dissolved fraction. Al and Fe displayed the largest response during this event with total concentrations of 57,842 µg/L (0.05 mg/L) and 81,913 µg/L (0.08 mg/L) at PNF. The dissolved Fe concentration at PNF (637 µg/L) was two times greater than the secondary drinking water quality standard (Table 5). Concentrations were slightly lower at PBD due to dilution of North Fork flows. Ag was the only metal that did not show a response to the storm event. The high metals concentrations observed during storm events occur in response to the excessive inputs of mineral soils that are eroded from stream channels and burned hillslopes during storm events.

At NFG, reportable metal concentrations were lower in October compared to concentrations in May and July, except for dissolved fractions of Al, Cr, and Mn. Mn was measured at 122 µg/L at NFG, which exceeded the secondary drinking water quality standard of 50 µg/L. The higher concentrations of these metals at this site are likely associated with low streamflow and reservoir dynamics. Streamflow at NFG on October 14th was only 5 cfs, and all of the water contributing to streamflow was being released from the bottom of the reservoir.

Table 6 – Dissolved and total metals concentrations measured in 2014 on the Mainstem and North Fork of the Poudre River.

Metal	Site	May 19[a] - May 20[b]		July 14[a] - July 15[b]		October 13[a] - October 14[b]	
		Soluble	Total	Soluble	Total	Soluble	Total
Silver (Ag)	PBR	<0.5	<0.5	-----	-----	-----	-----
	SFC	<0.5	<0.5	<0.5	<0.5	<0.5	-----
	PSF	<0.5	<0.5	<0.5	<0.5	<0.5	-----
	PNF	<0.5	<0.5	<0.5	<0.5	-----	-----
	PBD	<0.5	<0.5	<0.5	<0.5	<0.5	-----
	NFL	-----	-----	-----	-----	-----	-----
	NFG	-----	-----	<0.5	<0.5	<0.5	<0.5
Aluminum (Al)	PBR	408	895	41	95	27	-----
	SFC	483	1,487	53	801	33	-----
	PSF	368	1,317	38	626	21	-----
	PNF	460	2,019	914	57,842	-----	-----
	PBD	352	1,847	37	16,349	50	-----
	NFL	-----	-----	11	1,616	36	<10
	NFG	-----	-----	14	159	17	<10
Arsenic (As)	PBR	<2	<2	<2	<2	<2	-----
	SFC	<2	<2	<2	<2	<2	-----
	PSF	<2	<2	<2	<2	<2	-----
	PNF	<2	<2	<2	8	-----	-----
	PBD	<2	<2	<2	2	<2	-----
	NFL	-----	-----	<2	<2	<2	<2
	NFG	-----	-----	<2	<2	<2	<2
Cadmium (Cd)	PBR	<0.1	<0.1	<0.1	<0.1	<0.1	-----
	SFC	<0.1	<0.1	<0.1	<0.1	<0.1	-----
	PSF	<0.1	<0.1	<0.1	<0.1	<0.1	-----
	PNF	<0.1	<0.1	<0.1	1	-----	-----
	PBD	<0.1	<0.1	<0.1	0.3	<0.1	-----
	NFL	-----	-----	<0.1	<0.1	<0.1	<0.1
	NFG	-----	-----	<0.1	<0.1	<0.1	<0.1
Chromium (Cr)	PBR	1	1	<0.5	<0.5	<0.5	-----
	SFC	1	2	<0.5	1	<0.5	-----
	PSF	1	2	<0.5	1	<0.5	-----
	PNF	1	3	1	107	-----	-----
	PBD	1	3	<0.5	27	<0.5	-----
	NFL	-----	-----	<0.5	1	<0.5	<0.5
	NFG	-----	-----	<0.5	<0.5	29	<0.5
Copper (Cu)	PBR	<3	<3	<3	<3	<3	-----
	SFC	<3	3	<3	<3	<3	-----
	PSF	<3	<3	<3	<3	<3	-----
	PNF	<3	3	<3	72	-----	-----
	PBD	<3	3	<3	20	<3	-----
	NFL	-----	-----	4	<3	<3	<3
	NFG	-----	-----	<3	<3	<3	<3

Table 6 (continued) – Dissolved and total metals concentrations measured in 2014 on the Mainstem and North Fork of the Poudre River. Concentrations highlighted in red indicate water quality standard exceedances.

Metal	Site	May 19[a] - May 20[b]		July 14[a] - July 15[b]		October 13[a] - October 14[b]	
		Soluble	Total	Soluble	Total	Soluble	Total
Iron (Fe)	PBR	286	797	59	169	89	-----
	SFC	340	1,567	75	973	110	-----
	PSF	271	1,398	56	835	80	-----
	PNF	319	2,077	637	81,913	-----	-----
	PBD	267	2,031	54	22,219	82	-----
	NFL	-----	-----	83	1,349	78	<10
	NFG	-----	-----	76	261	33	<10
Manganese (Mn)	PBR	4	16	3	9	3	-----
	SFC	5	33	4	40	3	-----
	PSF	4	29	4	25	2	-----
	PNF	5	50	4	1,345	-----	-----
	PBD	3	53	2	509	4	-----
	NFL	-----	-----	3	57	8	<1
	NFG	-----	-----	4	44	122	<1
Nickel (Ni)	PBR	<2	<2	<2	<2	<2	-----
	SFC	<2	<2	<2	<2	-----	-----
	PSF	<2	<2	<2	<2	<2	-----
	PNF	<2	<2	<2	67	-----	-----
	PBD	<2	-----	<2	20	<2	-----
	NFL	-----	-----	<2	<2	<2	<2
	NFG	-----	-----	<2	<2	<2	<2
Lead (Pb)	PBR	<1	<1	<1	<1	<1	-----
	SFC	<1	<1	<1	1	<1	-----
	PSF	<1	<1	<1	<1	<1	-----
	PNF	<1	1	<1	46	-----	-----
	PBD	<1	1	<1	16	<1	-----
	NFL	-----	-----	<1	<1	<1	<1
	NFG	-----	-----	<1	<1	<1	<1
Selenium (Se)	PBR	<1	<1	<1	<1	<1	-----
	SFC	<1	<1	<1	<1	<1	-----
	PSF	<1	<1	<1	<1	<1	-----
	PNF	<1	<1	<1	3	-----	-----
	PBD	<1	<1	<1	1	<1	-----
	NFL	-----	-----	<1	<1	<1	<1
	NFG	-----	-----	<1	<1	<1	<1
Zinc (Zn)	PBR	<50	<50	<50	<50	<50	-----
	SFC	<50	<50	<50	<50	<50	-----
	PSF	<50	<50	<50	<50	<50	-----
	PNF	<50	<50	<50	217	-----	-----
	PBD	<50	<50	<50	84	<50	-----
	NFL	-----	-----	<50	<50	<50	<50
	NFG	-----	-----	<50	<50	<50	<50

3.7 PATHOGENS

Total Coliforms and *E. coli*

Coliforms are types of bacteria found naturally in the environment in plant and soil material, but can also found in the digestive tract of animals, including humans. Disease causing bacteria or pathogens can be introduced to the raw drinking water supply from fecal contamination. The City of Fort Collins tests its source water supply for the presence of bacterial contamination by measuring the total amount of coliforms, an indicator organism for the presence of pathogenic bacteria. In addition, *Escherichia coli* (*E. coli*) is measured and used as an indicator of human or animal fecal waste pollution since the source of origin is more specific than total coliforms. Total coliform counts are greater than *E. coli* counts because total coliform includes all types and sources of coliform bacteria.

Water samples were collected and tested for both total coliform and *E. coli* at five monitoring locations – NFL, NFG, PBR, PNF, and PBD – along the Mainstem and North Fork Poudre Rivers. NFL was added as a sample site in 2009 to better understand the potential sources of total coliforms and *E. coli* within the North Fork watershed. An error in the 2011 sampling plan resulted in no samples being collected at this site. NFL was removed from the total coliform and *E. coli* sampling list in 2013. Hence, this report will discuss results from PBR, PNF, PBD, and NFG.

Total coliforms and *E. coli* exhibited a great degree of seasonal and annual variability (Figure 3.16). Total coliforms were low at the beginning of the monitoring season at all sites in all years, but increased during runoff and remained elevated until streamflow receded to baseflow levels in the fall (Figure 3.16a). Over the past four years cell counts in April were below 100 colony forming units (cfu) per 100 mL at all sites. Total coliforms were frequently greater on the North Fork (NFG) with counts that exceeded 100 cfu/100 mL, but remained below 500 cfu/100 mL. A significant increase in total coliforms was observed during the July 14th storm event when counts exceeded 10,000 cfu/100 mL at PNF and PBD (Figure 3.16a). A similar response was observed at these sites, and at NFG, in July 2013 when sampling followed a significant storm event. The considerable increases in total coliforms following storm events were expected at wildfire impacted sites due to the mobilization of soil and plant material from burned hillslopes into the Poudre River.

E. coli remained below the CDPHE recreational water quality standard of 126 cfu/100 mL over the four year period except for two occurrences at PNF and PBD (Figure 3.16b). In 2014, *E. coli* counts approached the recreational water quality standard during snowmelt runoff, but slowly decreased through the remainder of the monitoring season. A significant increase in *E. coli* was observed during the July 14th storm event when counts exceeded 1,000 cfu/100 mL at PNF and PBD (Figure 3.16b). The exceedance was short-lived and E. coli was 20 cfu/100 mL on the following sampling event in August.

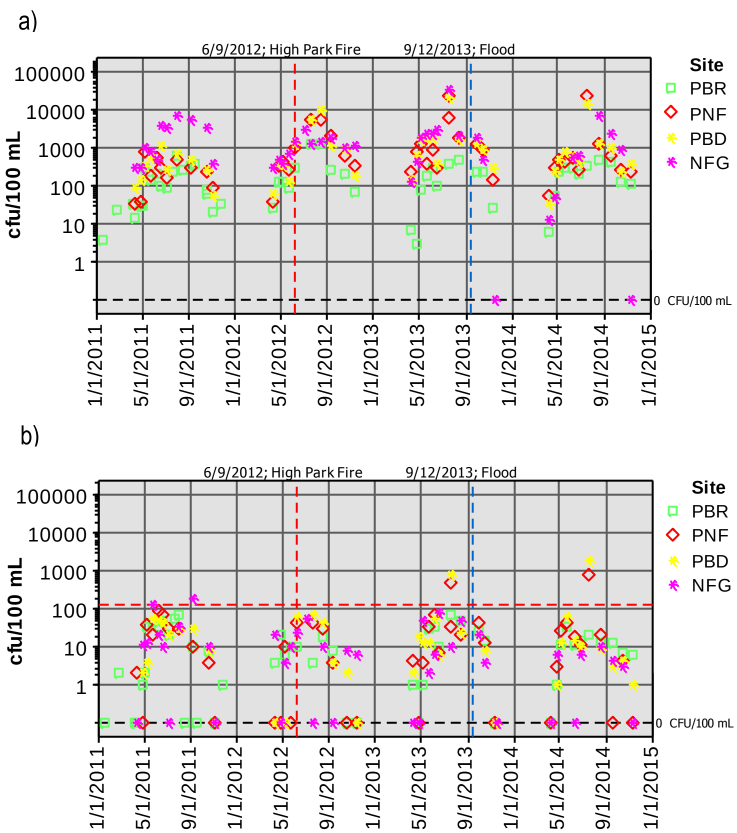


Figure 3.16 – Counts of a) total coliforms and b) *E. coli* on the Mainstem and North Fork CLP.

(- - - - - CDPHE water quality standard for E. coli, 126 cfu/100 mL.)

Cryptosporidium and *Giardia*

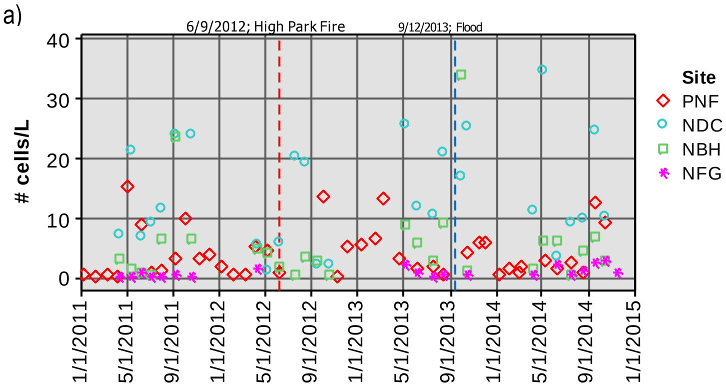
Giardia and *Cryptosporidium* are types of protozoa, or unicellular organisms, which live in the intestines of animals and humans. The main source of these organisms is animals, but leaking septic systems can also contribute to contamination of surface waters. Both *Giardia* and *Cryptosporidium* are found to be widespread in the environment, and the all water treatment facilities are required, under the EPA's Surface Water Treatment Rule, to filter and disinfect surface water for the removal of 99.9% of *Giardia* and *Cryptosporidium.*

Source water samples are collected from the raw CLP water supply at the FCWTF to test for *Giardia* and *Cryptosporidium*. Samples have been collected onsite since 2002 and are considered to be representative of concentrations at PNF because there are no additional inflows to water supply between the intake structure at PNF and the FCWTF. Testing on the North Fork includes the sites above and below Halligan Reservoir (NDC and NBH, respectively), which began in 2006. In 2008, the NDC sampling site was moved upstream of the confluence with Dale Creek to accommodate potential future expansion of Halligan Reservoir. This site represents the water quality of the North Fork, above Dale Creek, as source waters to Halligan Reservoir. Additional testing was included below Seaman Reservoir (NFG) in 2008.

Giardia and *Cryptosporidium* were detected on both the Mainstem and North Fork from 2011 through 2014, and *Giardia* was more abundant than *Cryptosporidium* (Figure 3.17). *Giardia* concentrations were relatively low at PNF from the winter through late summer when concentrations typically increased (Figure 3.17a). Concentrations rarely exceeded 10 cells/L throughout the year, but late summer and fall concentrations were slightly greater than 10 cells/L. The maximum concentration at PNF in 2014 was measured in September at 12.5 cells/L, which was similar to previous years. *Giardia* concentrations on the North Fork were greater than concentrations on the Mainstem, specifically above and below Halligan Reservoir (NDC and NBH). The highest concentrations on the North Fork were measured at NDC with a maximum concentration of 34.8 cells/L in May of 2014. This was the highest concentration observed on the North Fork from 2011 to 2014. Giardia concentrations decreased moving downstream to NFG below Seaman Reservoir where Giardia was measured below 5 cells/L over the entire monitoring season.

Cryptosporidium concentrations are generally low on both the North Fork and Mainstem. *Cryptosporidium* did not display seasonal or annual trends, but concentrations were higher at North Fork sites. The highest concentrations on the North Fork were observed at NFG with a maximum concentration of 0.68 cells/L measured on September 16th, 2014 (Figure 3.17b). *Cryptosporidium* on the Mainstem was low and rarely exceeded the reporting limit. In 2014, Cryptosporidium was detected once in raw Poudre Water (PNF) on July 16th, but was only slightly above the reporting limit (Figure 3.17b).

a)



b)

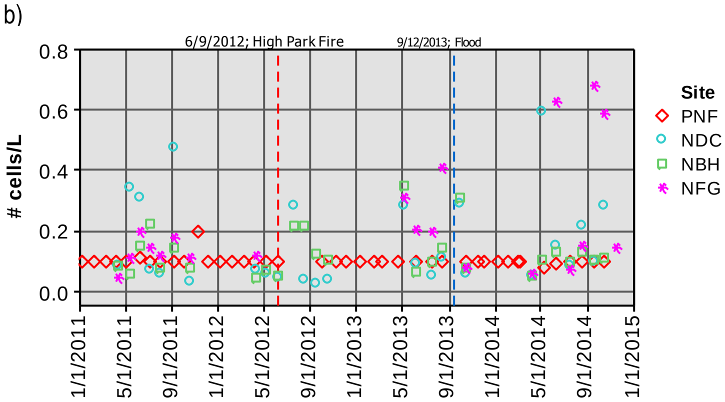


Figure 3.17 – Concentrations of a) giardia and b) *Cryptosporidium* on the Mainstem and North Fork CLP.

4.0 SEAMAN RESERVOIR

4.1 RESERVOIR OPERATIONS

Water from Seaman Reservoir can reach the North Fork via two modes of operation: releases from the outlet structure located near the bottom of the reservoir, or over the spillway when the reservoir is at maximum capacity. Water quality of outlet water (reservoir bottom) and water spilling over the spillway (reservoir surface) can vary depending on the time of year and the degree of state of thermal stratification at the time of release. The reservoir was at capacity for most of the 2014 season; after a release made in August, Seaman was again filled to capacity by mid-October.

4.2 DEPTH PROFILES

Reservoir depth profile data are used to monitor reservoir stratification (Figure 4.1). In 2014, Seaman Reservoir depth profiles were collected from July through October. Samples were not able to be collected during the months of April through June of 2014 due to repair work on one of the access bridges that was damaged in the September 2013 flood. Depth profiles for temperature, D.O., pH, and specific conductance are outlined in Figure 4.3.

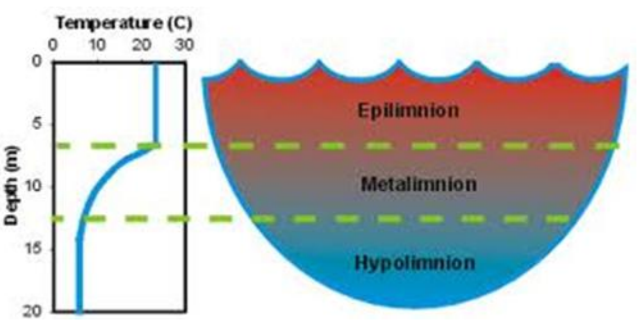


Figure 4.1 – Temperature profile and the corresponding layers of a thermally stratified lake. Image Source: Upstate Freshwater Institute.

When a lake or reservoir is stratified, three physically distinct layers can be identified (Figure 4.2) and are discussed in detail in the following sections. The uppermost layer, or *epilimnion*, is characterized by relatively warm, well oxygenated water where the majority of photosynthetic algae production can be found. The middle layer, or the *metalimnion*, is the transition zone between the upper and lower water column where temperature decreases rapidly. The bottom layer is termed the *hypolimnion* and is where dense, cold water resides. Oxygen concentrations become depleted in the hypolimnion throughout the season as microbes consume the available oxygen, and since the hypolimnion is physically isolated from the mixing action of the wind, oxygen production is limited. When oxygen levels decrease to concentrations near-zero (hypoxic) or zero (anoxic) in lakes and reservoirs, specialized anaerobic microbes facilitate the release of metals (particularly manganese and iron) and nutrients from bottom sediments.

Temperature

Seaman Reservoir temperature profiles show seasonal patterns similar to most deep temperate lakes and reservoirs. The coldest temperatures occur during the winter months. The reservoir begins to warm in the late spring and early summer with the warmest temperatures typically occurring from late July through August. Reservoir mixing, or turnover, typically occurs in September or October. Turnover occurs when the upper waters cool until the thermal barrier weakens sufficiently and the colder, denser upper waters sink, forcing the well-oxygenated surface waters to mix with the deeper, oxygen-deprived waters. Turnover typically results in nearly uniform distribution of water quality constituents throughout the water column. Upstream reservoir operations of Halligan Reservoir and operations of Seaman Reservoir can influence the onset and duration of stratification and the timing of turnover.

In 2014, thermal stratification was well underway on the first sampling event on July 16th (Figure 4.2a). Water temperatures increased throughout the water column, and progressive development and deepening of the thermocline (metalimnion) was observed on August 19th. The temperature profiles indicate water temperatures near the surface remained below the aquatic life temperature standard of 22.5°C throughout the monitoring season. On September 16th, water temperature was uniform throughout the water column, which is indicative of reservoir turnover. Water temperature continued to decrease and remained uniform throughout the water column on October 14th.

Dissolved Oxygen

Seaman Reservoir displays seasonal patterns in dissolved oxygen (D.O.). During the August 2014 sampling event, the reservoir simultaneously exhibited the highest D.O. concentration of 8.59 mg/L in the epilimnion and the lowest oxygen concentrations (~0 mg/L) in the hypolimnion (Figure 4.2b), indicating stratification. In 2014, the D.O. at the bottom of the reservoir was consistently below 6 mg/L from July to October. Following reservoir turnover, D.O concentrations throughout the entire water column remained below 6 mg/L for the rest of the monitoring season.

pH

pH values in Seaman Reservoir displayed seasonal trends comparable to temperature and D.O. Changes in pH are closely related to changes in temperature and D.O. with decreasing water temperature and D.O. correlating with decreasing pH. As expected, pH in the epilimnion of Seaman Reservoir increased throughout the summer as temperature increased in the surface waters. In contrast, pH decreased in the metalimnion and hypolimnion as D.O. was depleted throughout the summer monitoring season. The 2014 pH values ranged from 6.89 to 8.90, which fell within the pH water quality standard of 6.5 to 9.0 (Figure 4.2c).

Specific Conductance

Specific conductivity values in 2014 ranged from 108 microSeimens per centimeter (µS/cm) in July to 250 µS/cm in October (Figure 4.2d). Expected seasonal characteristics were observed in 2014. Lower specific conductivity values were observed after spring runoff because of the low specific conductivity of snowmelt water entering Seaman Reservoir. Specific conductivity increased throughout the rest of the monitoring season, but remained consistent throughout the water column on each monitoring event (Figure 4.2d).

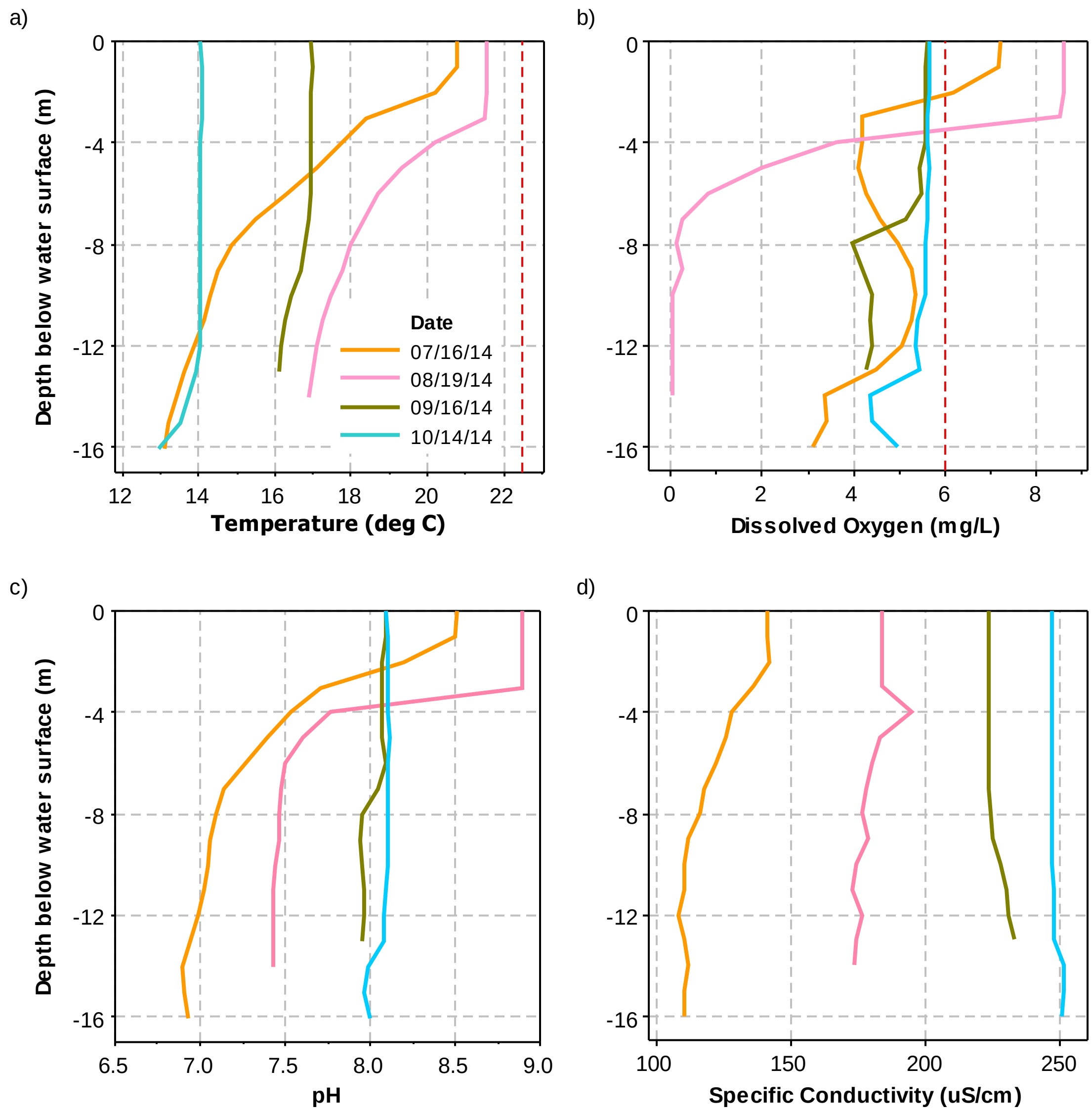


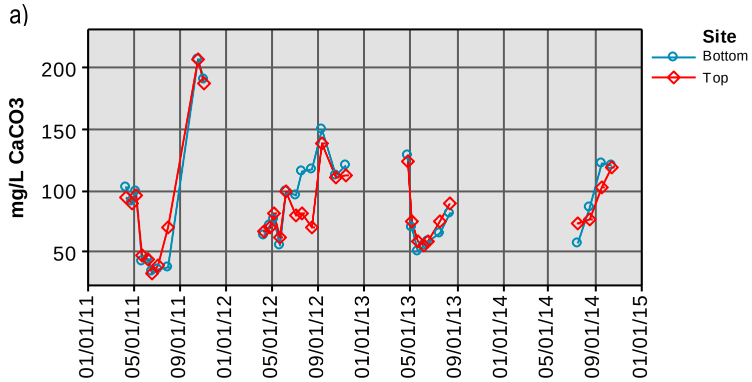
Figure 4.2 – Seaman Reservoir depth profiles for a) water temperature, b) dissolved oxygen, c) pH, and d) specific conductivity.

4.3 GENERAL PARAMETERS

Alkalinity and Hardness

Alkalinity and hardness concentrations in Seaman Reservoir follow similar trends through the year (Figure 4.3a and 4.3b, respectively). In most years, concentrations near the top of the reservoir are similar to bottom concentrations throughout the monitoring season for both alkalinity and hardness (Figures 4.3a-b). The highest concentrations are generally observed in the spring at the onset of snowmelt runoff and in the fall during low streamflows. The lowest concentrations typically occur during and following snowmelt runoff. In 2014, Seaman Reservoir monitoring did not begin until July 15th, and on this date, both alkalinity and hardness were at their observed annual minima of 57 mg/L and 59 mg/L, respectively, at the bottom of the reservoir. After the July monitoring event, alkalinity and hardness increased to annual maximum concentrations of 122 mg/L and 119 mg/L in September, which were observed near the bottom of the reservoir. As in previous years, alkalinity and hardness concentrations were similar and tracked closely throughout the year.

a)



b)

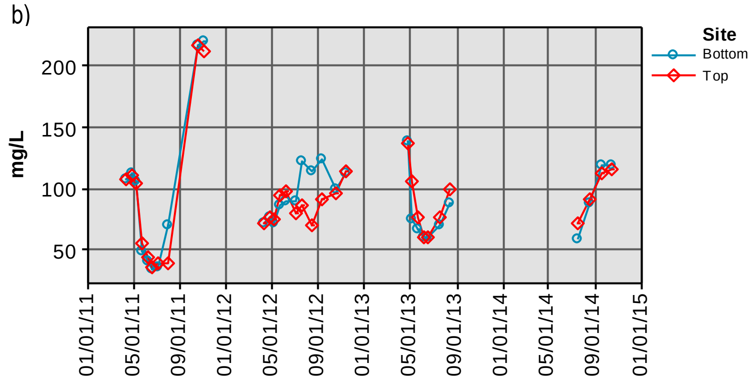


Figure 4.3 – General water quality parameters (a) alkalinity and b) hardness measured in Seaman Reservoir from 2011 through 2014.

4.4 TURBIDITY, CHLOROPHYLL-A AND SECCHI DEPTH

Turbidity

Turbidity in Seaman Reservoir follows seasonal trends in most years. During snowmelt runoff and periods of elevated stream flow associated with rain events and releases from Halligan Reservoir upstream, turbid water from the North Fork enters Seaman Reservoir increasing turbidity in the top and bottom of the reservoir. As elevated runoff declines, turbidity decreases slightly and water clarity improves. A second spike in turbidity is often observed in the late-summer and early fall when reservoir conditions typically favor algal growth. The late season spike in turbidity was especially distinct in 2012, but it is unclear if this extreme increase in turbidity was driven by drought conditions, nutrient and organic inputs from burned hillslopes surrounding the reservoir, or both. Turbidity usually decreases in the late-fall following reservoir turnover and when conditions no longer support algal growth.

Although the data was limited in 2014, expected seasonal trends were observed in turbidity. In July, turbidity was low in both the top and bottom of the reservoir. notable notable late-season increase occurred at the bottom of the reservoir in September and October, but it was of lower magnitude than spikes in previous years. Late season spikes in turbidity can be attributed to algae growth and/or the presence of dissolved inorganic particulates and/or organic matter. In 2014, turbidity ranged from 3.17 NTU to 12.4 NTU near the reservoir bottom and 1.08 NTU to 3.34 NTU near the surface of the reservoir (Figure 4.4a).

Chlorophyll-a

Chlorophyll-a samples were collected in 2014, but concentrations were below the reporting limit of 0.6 µg/L in both reservoir top and bottom samples on all monitoring dates. Uncharacteristic chlorophyll-a concentrations were observed and noted in the 2013 Horsetooth Reservoir Water Quality Monitoring Program Report (Heath and Oropeza, 2014). An investigation into the cause of the suspect data concluded that the analytical methods for quantifying chlorophyll-a were greatly underestimating concentrations. A new method was tested with success in early 2015, and will be used for future chlorophyll-a analysis on Seaman Reservoir samples.

Secchi Depth

Secchi depth measurements indicated that Seaman Reservoir experienced relatively consistent water clarity in 2014 (Figure 4.4b). A maximum Secchi depth (greatest light penetration) of 4.0 meters was observed on August 18th. An algal growth observed on Seaman Reservoir on October 14th likely resulted in the minimum recorded Secchi depth in 2014 (Figure 4.5).

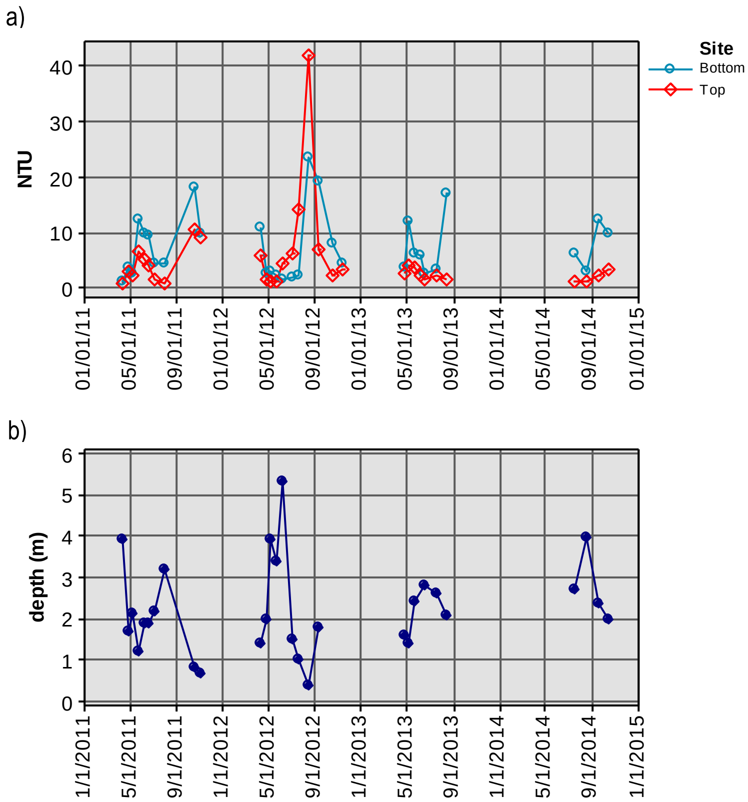


Figure 4.4 – Turbidity (a) and Secchi depth (b) measurements for Seaman Reservoir from 2011 through 2014.

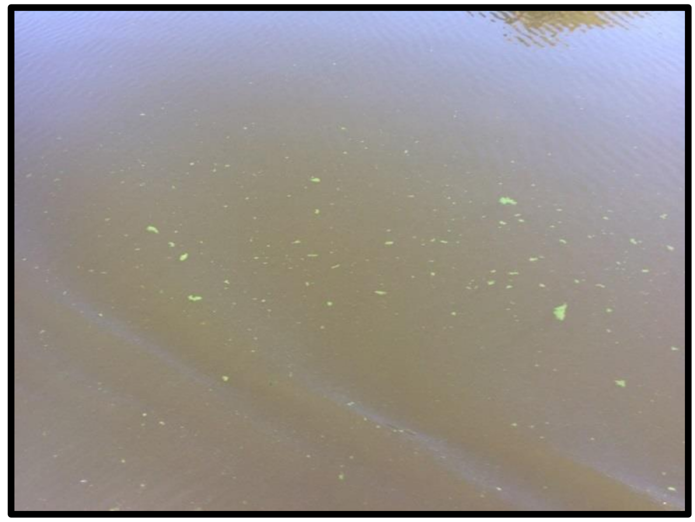


Figure 4.5 – Green algae bloom on Seaman Reservoir in October 2014.

4.5 NUTRIENTS

The processes of thermal stratification in the water column can influence the distribution and seasonality of nutrients in lakes and reservoirs. In aquatic ecosystems, nutrients are typically limited in availability, regulating the growth and survival of aquatic organisms and plants. In excess, nitrogen and phosphorus lead to nutrient pollution and eutrophication. Seasonal trends in nutrients are not consistent from year to year in Seaman Reservoir. This is likely due to recent impacts of fire and the influence of thermal stratification and D.O. dynamics. Following the Hewlett Gulch Fire in 2012, substantial inputs of hillslope sediments have been observed near the northwest end of the reservoir, and these sediments may be potential sources of nutrient enrichment.

Ammonia as Nitrogen (NH_3-N)

Ammonia as nitrogen (NH_3-N) in Seaman Reservoir varies from year to year, but low concentration are typical early in the season followed by a late season spike. The late season increase is caused by anoxic conditions in the hypolimnion and the subsequent release of NH_3-N from reservoir bottom sediments. In 2014, expected spatial and temporal trends were observed in ammonia as nitrogen (NH_3-N) concentrations. Concentrations were higher near the bottom of the reservoir compared to concentrations near the surface (Figure 4.6a). In general, this spatial trend was also observed in previous years. NH_3-N concentrations were the lowest in July and were measured slightly above the reporting limit of 0.01 mg/L. Concentrations increased through the remainder of the monitoring season to maximum concentrations of 0.16 mg/L and 0.11 mg/L, on October 14th, in the top and bottom of the reservoir, respectively (Figure 4.6a). NH_3-N concentrations were similarly low as compared to 2013. The usual late season spike, as observed in 2011 and 2012, was observed in 2014, but at a much lower concentration.

Nitrate as Nitrogen (NO_3-N) & Nitrite as Nitrogen (NO_2-N)

Nitrate (NO_3-N) concentrations recovered to expected levels in 2014 as compared to the elevated concentrations that were observed in 2013 (Figure 4.6b). Concentrations in top and bottom samples were below the reporting limit for most of the monitoring season. A maximum concentration of 0.15 mg/L was measured on July 15th near the reservoir bottom, but concentrations decreased to near or below the reporting limit following this date. Nitrite as nitrogen (NO_2-N) concentrations remained below the reporting limit throughout the entire 2014 monitoring season, as was observed in previous years. The relatively-elevated NO_3-N concentrations in 2014 are likely associated with impacts from the Hewlett Gulch Fire.

Total Kjeldahl Nitrogen (TKN) & Total Nitrogen (TN)

Total kjeldahl nitrogen (Figure 4.7a) and TN (Figure 4.7b) follow similar seasonal trends. TKN is composed primarily of NH_3-N and organic nitrogen, and because NO_3-N and NO_2-N were below their respective reporting limits, TKN dominated the calculation of TN. TKN and TN in Seaman Reservoir vary from year to year, with lower concentrations observed early in the season followed by increasing concentrations later in the season. The late season increase is likely caused by anoxic conditions in the hypolimnion and the subsequent release of nitrogen from reservoir bottom sediments. As previously discussed, the most common nitrogen species released during anoxic conditions in Seaman Reservoir appears to be NH_3-N, which explains why TKN and TN follow seasonal and annual trends that are analogous to NH_3-N. TKN measures the sum of NH_3-N and organic nitrogen in water.

In 2014, TKN and TN increased throughout the monitoring season. Maximum concentrations were observed in samples collected from the bottom of the reservoir, but were not significantly greater than surface concentrations. TKN concentrations ranged from a minimum of 0.38 mg/L to a maximum of 0.70 mg/L (Figure 4.7a), while TN concentrations ranged from a minimum of 0.40 mg/L to a maximum of 0.75 mg/L (Figure 4.7b).

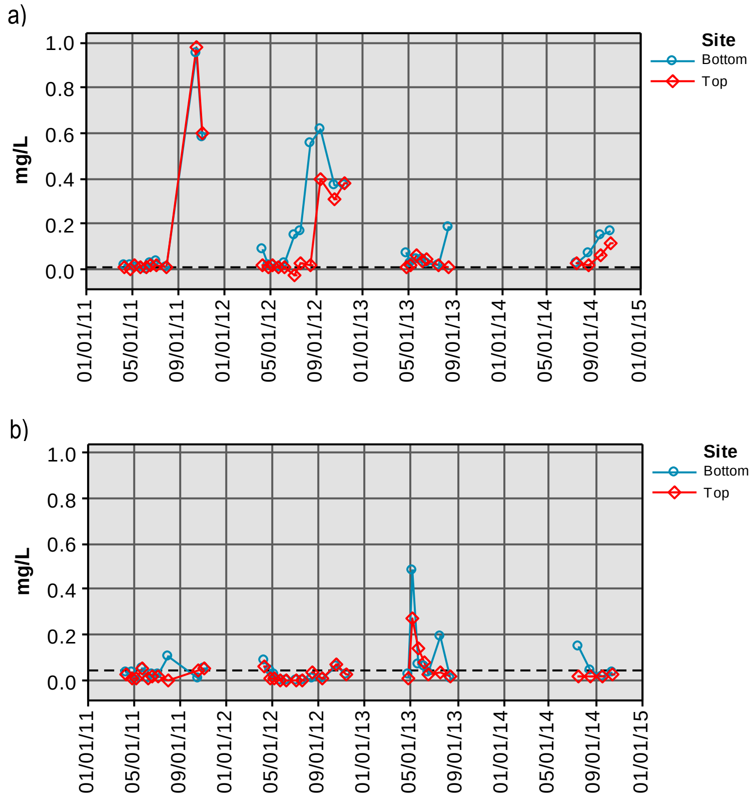


Figure 4.6 – Inorganic nitrogen concentrations for a) ammonia as nitrogen and b) nitrate as nitrogen measured in Seaman Reservoir from 2011 through 2014. Nitrite as nitrogen concentrations were below the reporting limit.

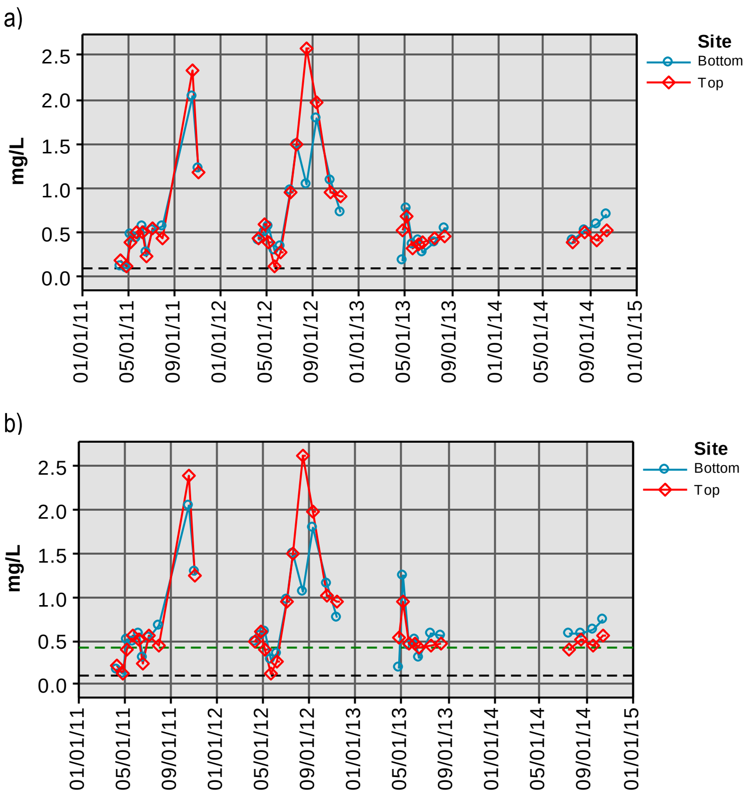


Figure 4.7 – Nutrient concentrations for a) TKN and b) TN measured in Seaman Reservoir from 2011 through 2014.

(- - - - - CDPHE proposed cold water reservoir (>25 acres) standard for TN, summer median of 426 µg/L with an allowable exceedance of 1-in-5 years.)

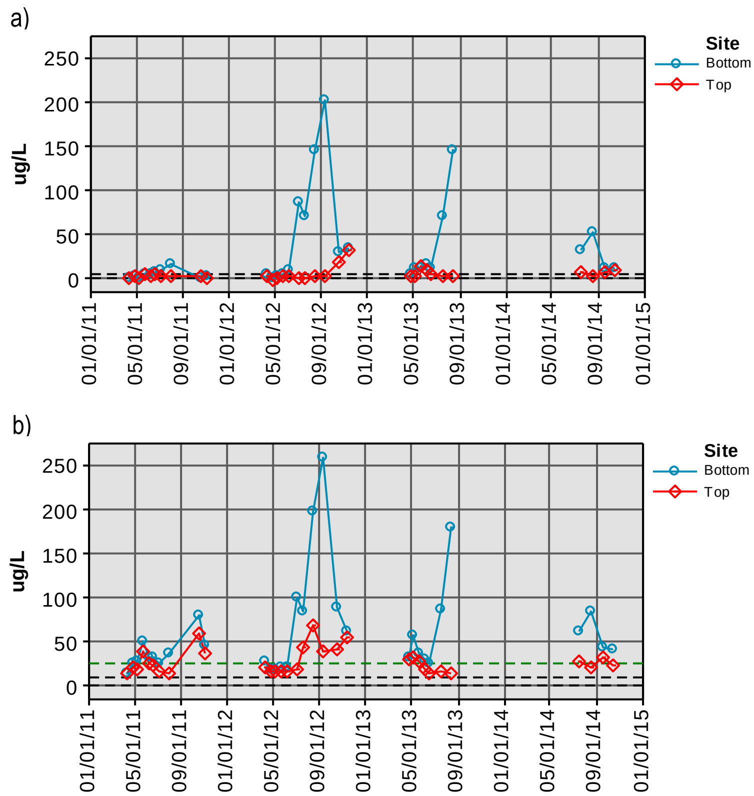


Figure 4.8 – Nutrient concentrations for a) ortho-phosphate and b) total phosphorus measured in Seaman Reservoir from 2011 through 2014.

(- - - - - CDPHE proposed cold water reservoir standard for TP, summer median of 25 µg/L with an allowable exceedance of 1-in-5 years.)

Ortho-phosphate (PO_4) & Total Phosphorus (TP)

Ortho-phosphate and TP generally follow similar seasonal patterns, except for concentrations observed near the top of the reservoir. PO_4 concentrations near the top of the reservoir are usually below the reporting limit except occasionally during spring and fall. In contrast, TP in the top of the reservoir increases during spring runoff and then decreases. The late season spike in concentrations near the bottom of the reservoir is often observed in both PO_4 and TP concentrations. Top and bottom concentrations are similar at the end of the monitoring season as a result of reservoir mixing and turnover.

Ortho-phosphate (Figure 4.8a) and TP (Figure 4.8b) concentrations in 2014 followed a similar seasonal pattern to 2011. Concentrations were mostly consistent throughout the monitoring season with higher concentrations near the bottom of the reservoir. In 2014, PO_4 and TP concentrations peaked at 52 µg/L and 83 µg/L on August 19th near the bottom of the reservoir (Figure 4.8a and 4.8b, respectively). Following this date, concentrations decreased to near the reporting limit as a result of reservoir turnover and were similar to levels measured near the top of the reservoir. Total phosphorus concentrations near the reservoir surface were slightly above the reporting limit, while PO_4 concentrations were below the reporting limit in July and August and slightly above in September and October. Concentrations near the surface were low due to the uptake by algae as this nutrient became readily available throughout the monitoring season.

4.6 TOTAL ORGANIC CARBON

In 2014, Seaman Reservoir TOC concentrations fell within the range of values observed over the 2011 to 2013 time period (Figure 4.9). Similar to the Mainstem and North Fork locations, TOC in Seaman Reservoir typically exhibits a seasonal peak that coincides with spring snowmelt, followed by a decrease throughout the summer.

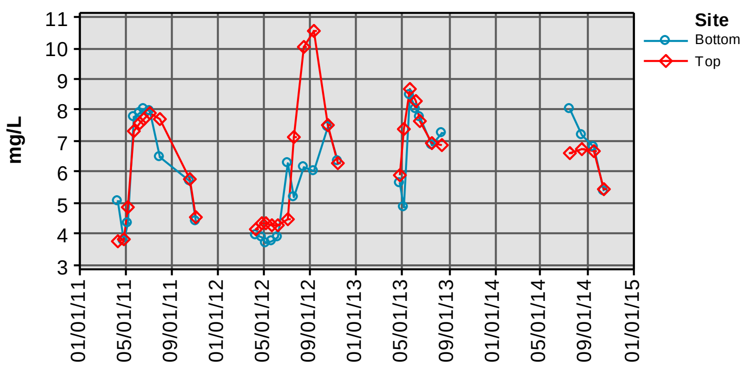


Figure 4.9 – Total organic carbon (TOC) concentrations in Seaman Reservoir from 2011 through 2014.

In 2014, concentrations were higher near the bottom of the reservoir in July and August at 8.03 mg/L and 7.21 mg/L compared to 6.60 mg/L and 6.72 mg/L near the surface of the reservoir (Figure 4.9). Total organic carbon concentrations were similar in top and bottom samples collected throughout the rest of the monitoring season, and reached an observed minimum concentration of 5.45 mg/L and 5.37 mg/L on October 14th for the top and bottom of the reservoir, respectively.

4.7 PATHOGENS

Total Coliforms

Total coliform counts were low in 2014 (Figure 4.10a). In most years, the highest concentrations are observed later in the monitoring season – generally in October. The timing and magnitude of peak total coliforms concentrations usually vary between years, but seasonally, top and bottom total coliform concentrations are generally comparable. In July 2014, however, concentrations of total coliforms were considerably higher near the surface of the reservoir compared to bottom concentrations (Figure 4.10a). This may have been associated with a large July 2014 storm event, resulting in elevated upstream North Fork discharge into Seaman Reservoir. After this date, top and bottom concentrations did not differ. For the months observed, total coliform concentrations ranged from a minimum of 69.1 cfu/100 mL on October 14th to a peak concentration of 12,997 cfu/100 mL on August 19th (Figure 4.10a).

Escherichia coli

In most years, *E. coli* is detected in the top and bottom of the reservoir, primarily during snowmelt runoff. The primary source of *E. coli* during this time of year is surrounding agricultural land, a non-point source of pollution in the North Fork watershed. *E. coli* were found in low concentrations in Seaman Reservoir in 2014 (Figure 4.10b). The greatest concentration was near the top of the reservoir measured at 4.1 cfu/100 mL. *E. coli* concentrations near the top of the reservoir decreased to levels below the reporting limit in August and September, but then slightly increased above the reporting limit to 1.0 cfu/100 mL on October 14th. The only *E. coli* detection of near the bottom of the reservoir was measured at 1.0 cfu/100 mL in September (Figure 4.10b).

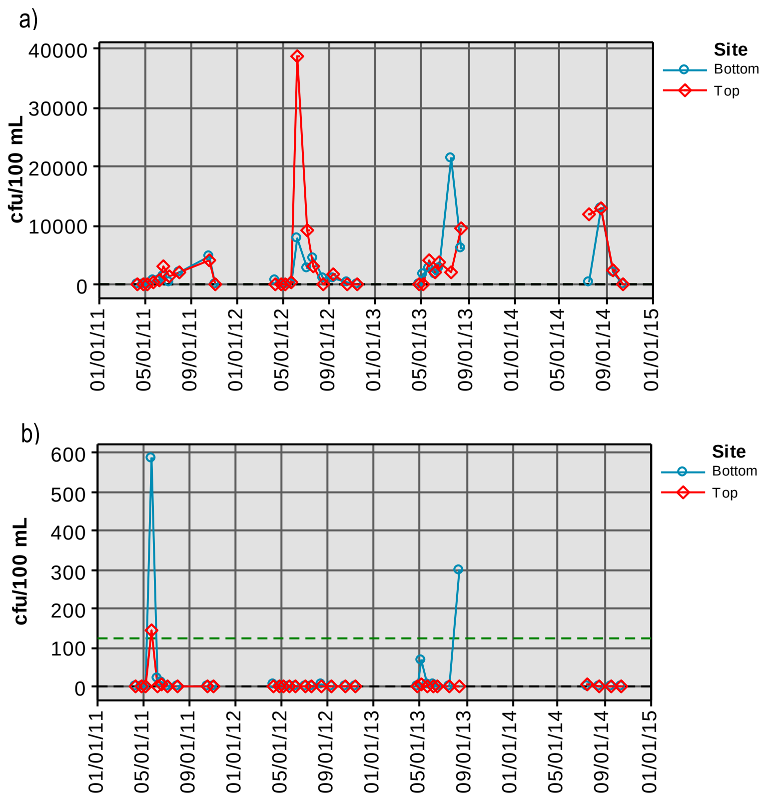


Figure 4.10 – Total coliforms (a) and *Escherichia coli* (b) colony counts in Seaman Reservoir from 2011 through 2014.

(- - - - - CDPHE recreational water quality standard, 126 cfu/100 mL.)

4.8 PHYTOPLANKTON

Phytoplankton, or algae, in raw water can lead to several problems during water treatment including, clogging of intake screens and filters, impacts during flocculation, increased coagulant and chlorine demand, increased disinfection by products, changes in pH, taste and odor issues, and the release of toxins. Cyanophytes, or blue-green algae, are of most concern because certain species produce compounds known as cyanotoxins that pose public health risks. Other species are responsible for the production of T&O compounds, including geosmin and MIB, which affect the aesthetic quality of drinking water and are difficult to remove during the water treatment process.

Phytoplankton samples were collected from the surface and bottom of Seaman Reservoir from July through October in 2014. Samples were analyzed to the species level by Dick Dufford (private consultant). A summary of the 2014 phytoplankton data is provided in Attachment 6. Make note that the July samples were not sufficiently preserved and are therefore, not included in this report.

In August of 2014, blue-green algae were the most abundant algae in both the top and bottom of the reservoir, but no species were identified as geosmin producing species (Figure 4.11a). During this time, the algae at the bottom of the reservoir was composed of 92% blue-green algae and the remaining 8% were chlorophytes (green algae). There was more algal diversity near the surface of the reservoir in August, which included green algae, cryptophytes, and bacillariophytes. Phytoplankton density was measured at 16,863 cells/mL near the bottom of the reservoir in August, which was the highest algal abundance observed in bottom waters in 2014 (Figure 4.11a).

In September, green algae dominated bottom waters in the reservoir at nearly 93% of total algae (Figure 4.11b). Blue-green algae composed 7.2% of the sample with 2.2% of the species capable of producing geosmin. The top of the water column was more diverse, but mostly dominated by green algae (50.3%) and blue-green algae (40.2%). No geosmin producing species were identified in the water surface sample. Phytoplankton density was measured at 16,719 cells/mL near the surface of the reservoir in September, which was the highest algal abundance observed in surface waters in 2014 (Figure 4.10b).

In October, blue-green algae dominated bottom waters at 86.9% with 3.4% of species identified as geosmin producing. Green algae were the most abundant in surface waters comprising 58.4% of the sample. Blue-green algae were 33.2% of the sample with 1.0% of the blue-green algae species capable of producing geosmin. October had the lowest density of algae in both bottom and surface waters (Figure 4.11c).

Although geosmin producing species were in low abundance in 2014, there is no correlation between the abundance of geosmin producing species and the production of geosmin.

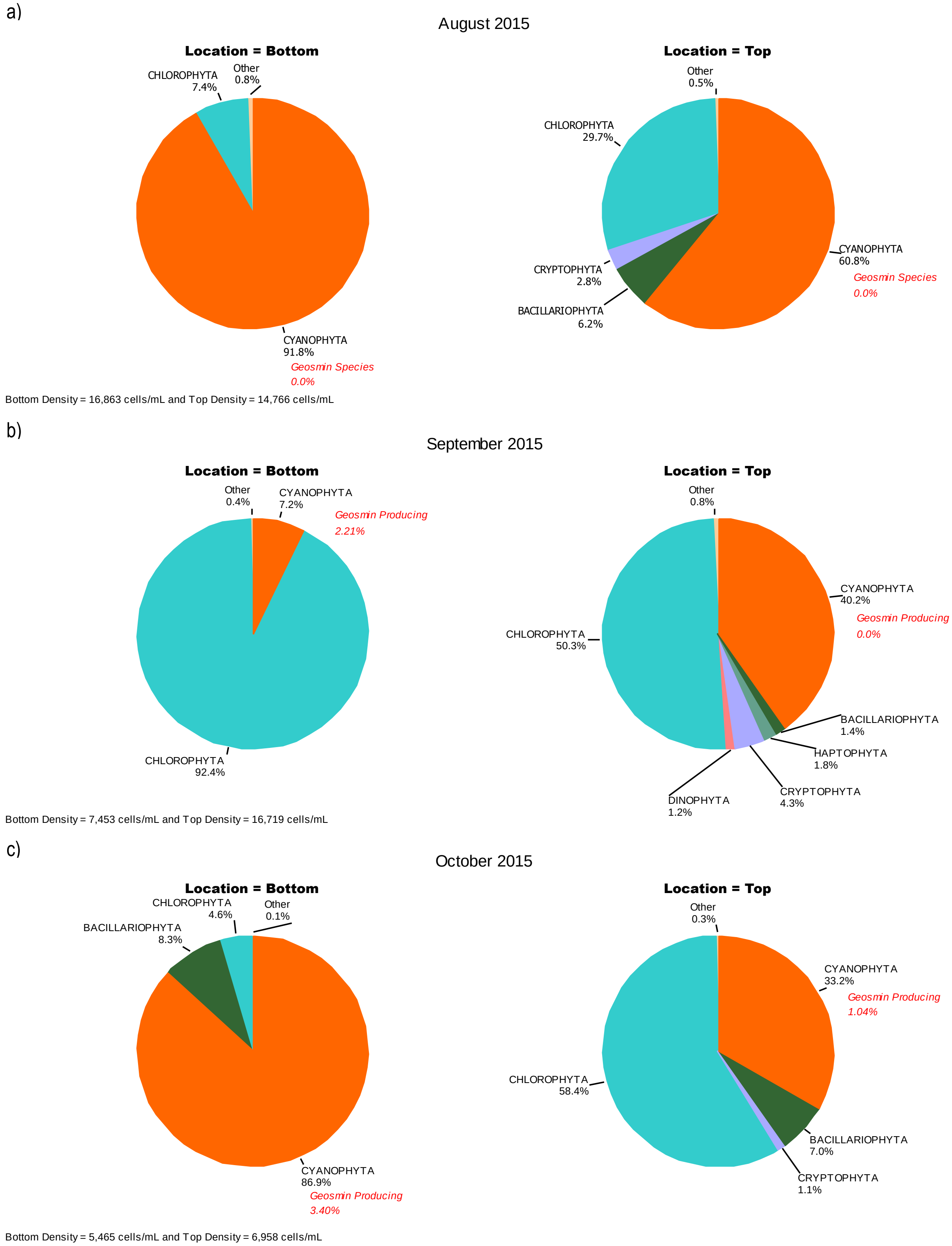


Figure 4.11 – Relative abundance of phytoplankton in the bottom and top of Seaman Reservoir on a) August 19th, b) September 16th, and c) October 14th in 2014.

5.0 SUMMARY

5.1 PROGRAM PERFORMANCE

Review of the 2014 Upper CLP monitoring program data indicates that the program adequately captures seasonal trends in water quality and provides a spatial context for examining notable events. In 2014, field work was transitioned from contracted sampling (2008-2013) to in-house sampling, which provided improved consistency and reliability of the water quality data as well as an overall cost savings of $27,411. The cost is shared between the program collaborators including the City of Fort Collins, City of Greeley and Tri-Districts.

5.2 HYDROLOGY

In 2014, peak snow water equivalent (SWE) in the Upper CLP watershed was above average. Peak SWE was observed one month later compared to the long-term data record, while peak streamflow was observed earlier and greater in magnitude than average due to accelerated spring snowmelt. The effects of the 2012 wildfires on streamflow continued to persist in 2014. Several storm events were observed during the monsoon season, which caused increased streamflow when localized over the High Park and Hewlett Gulch Gulch burn scars.

5.3 UPPER CACHE LA POUDRE RIVER WATER QUALITY

No significant water quality concerns were identified for the Mainstem or North Fork CLP that immediately impact drinking water quality or treatment operations. During spring runoff, the typical challenges for water treatment were observed on the Mainstem and the North Fork. During spring runoff, raw water from these two sources exhibited high TOC and turbidity levels, and dilute alkalinity and hardness concentrations, but concentrations were within the expected range of variability. Following spring runoff, the monsoon season resulted in debris flows and flooding from the High Park and Hewlett Gulch Gulch burn areas influencing downstream water quality. The early warning water quality sonde located above the City of Fort Collins' intake structure provided adequate warning time for water treatment operators to mitigate stormflows and degraded water quality conditions during these events.

Routine water quality monitoring and stormwater sampling provided evidence that the effects of the 2012 wildfires continued to persist in the Upper CLP watershed in 2014, but the watershed remains on a path towards recovery. A storm event on July 14th resulted in slightly elevated TOC concentrations at wildfire-impacted monitoring sites (PNF and PBD). The elevated concentrations at these sites remained in the range of expected annual TOC concentrations and did not exceed peak concentrations in 2014.

In general, nutrient concentrations were comparable between the Mainstem and North Fork, with the exception of concentrations below Halligan and Seaman Reservoirs on the North Fork and at wildfire-impacted monitoring sites on the Mainstem. Nutrients on the Mainstem continued to be relatively low in 2014, but inorganic nitrogen (NO_3-N and NH_3-N) and PO_4 remained elevated at wildfire impacted monitoring sites (PNF and PBD). All nutrients at wildfire impacted sites increased during the July 14th storm event, but recovered to background concentrations by the following sampling event.

Metals (dissolved and total) also increased at wildfire-impacted sites during the July 14th storm event. During this event, Fe was measured at a concentration that exceeded the secondary water quality standard. The most commonly detected metals in 2014 were aluminum (Al), chromium (Cr), iron (Fe), and manganese (Mn).

In 2014, *E. coli* counts approached the recreational water quality standard during snowmelt runoff, but slowly decreased through the remainder of the monitoring season. A brief standard-exceedance of *E. coli* was observed during the July 14th storm event at PNF and PBD. *Cryptosporidium* did not display seasonal or annual trends, but concentrations were higher at North Fork sites. In 2014, *Cryptosporidium* was detected once in raw CLP water (PNF) on July 14th, but was only slightly above the reporting limit.

5.4 SEAMAN RESERVOIR WATER QUALITY

In 2014, the reservoir remained at capacity for most of the season. General water quality parameters showed that Seaman Reservoir exhibited good water quality in 2014. Secchi depth measurements indicated that Seaman Reservoir experienced relatively consistent water clarity in 2014. Anoxic conditions in the reservoir's hypolimnion during August caused the release of inorganic nitrogen, PO_4, and metals from bottom sediments, which were observed immediately downstream at NFG, just upstream of the confluence with the Mainstem. Manganese exceeded the secondary drinking water quality standard on this date, which may have potential impacts on the aesthetics and taste of the finished water. Despite elevated concentrations of some constituents in Seaman Reservoir, water quality at the downstream Greeley-Bellvue diversion (PBD) met all applicable water quality standards. The differences in water quality on the North Fork and the Mainstem at PBD are due in part to the fact that North Fork typically represents a relatively small percentage of water delivered to PBD.

Seaman Reservoir TOC concentrations fell within the range of values observed over the 2011 to 2013 time period, and algal growth production was low. Blue-green and green algae were the dominant algal species, and geosmin producing species were present at very low levels. Both Total coliforms and *E. coli* were found in low concentrations in 2014.

5.5 MONITORING AND PROTECTION EFFORTS IN 2015

Planned water quality monitoring and other related Upper CLP activities for 2015 are summarized below:

- **Routine Monitoring Program:** Samples will continue to be analyzed for all parameters in 2015. The South Fork above Mainstem (SFM) site will not be sampled in 2015 and will be replaced by the South Fork above Confluence (SFC) monitoring site. Statistical analysis conducted in early 2015 indicated that the two sites were comparable.

- **Emerging Contaminant Monitoring:** The Source Watershed Program will continue to participate in Northern Water's Emerging Contaminants Program in 2015. Samples will be collected at PNF and NFG in February, June, and August.

- **Geosmin:** Geosmin monitoring will continue on the Mainstem CLP in 2015 at two key sites (PBR and PNF) during routine sampling events. Sampling will also be conducted through the winter months. It is also recommended that geosmin be added back into the monitoring plan for Seaman Reservoir in 2015, to provide advance notice of potential taste and odor concerns at the Greeley-Bellvue Diversion (PBD).

- **Watershed Recovery Monitoring:** Stormwater monitoring will continue through the summer of 2015. An automated sampler will be installed at the Intake Facility to capture stormwater samples during flooding and debris events when staff is unavailable to collect samples.

- **Little South Fork Streamflow Monitoring:** Streamflow monitoring will continue on the South Fork. The U.S. Forest Service permitted the project for five years. The monitoring site will be evaluated prior to the cessation of the permit to determine if continued streamflow monitoring is necessary.

- **Coalition for the Poudre River Watershed:** The City of Fort Collins Utilities and the City of Greeley provided financial support to the Coalition in 2014. Both entities hold reserved seats on the Board of Directors and participate on the Coalition's Science and Technical Advisory Committee. The restoration and planning work performed by CPRW aims to protect water quality of the Poudre River against past and future wildfires.

- **Source Water Protection Plan:** The City of Fort Collins Source Watershed Program is working with The Colorado Rural Water Association and the Colorado Department of Health and Environment (CDPHE), a non-profit that provides technical assistance and training to Colorado's public and private water and wastewater systems. Starting in 2015, the Colorado Rural Water Association will be assisting the City of Fort Collins with development and implementation of a Source Water Protection Plan.

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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 SITE

MAIN STEM	Description	Rationale	GPS Coordinates
100CHR	Chambers Lake Outflow	Outflow from Chambers Lake	N 40° 36.039 W 105° 50.203
090BMR	Barnes Meadow Reservoir outflow	High TOC and nutrients compared to CHR	N 40° 36.039 W 105° 50.203
080JWC	Joe Wright Creek at Aspen Glen Campground	Joe Wright Creek above confluence with main stem	N 40° 37.233 W 105° 49.098
070PJW	Poudre at Hwy14 crossing (Big South Trailhead)	Above confluence Joe Wright Creek	N 40° 38.074 W 105° 48.421
060LRT	Laramie River at Tunnel at Hwy 14 crossing	Laramie River diversion water	N 40° 40.056 W 105° 48.067
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
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
041SFC	South Fork above confluence with Mainstem	Capture 15% more watershed area than SFM	
030PSF	Poudre below confluence with South Fork - Mile Marker 101	Below confluence with South Fork	N 40° 41.224 W 105° 26.895
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
010PBD	Poudre at Bellvue Diversion	Greeley WTP Intake	N 40° 39.882 W 105° 12.995
NORTH FORK			
280NDC	North Fork above Halligan Reservoir; above confluence with Dale Creek	Inflow to Halligan Reservoir	N 40° 53.852' W 105° 22.556'
270NBH	North Fork at USGS gage below Halligan Reservoir	Outflow from Halligan Reservoir	N 40° 52.654' W 105° 20.314'
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
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
240SCM	Stonewall Creek Mouth	Tributary to North Fork; drains area east of Hwy 287	N 40° 48.458 W 105° 15.195
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
220NFL	North Fork at Livermore	At USGS gage	N 40° 47.269 W 105° 15.130
210SER	Seaman Reservoir	Reservoir profiles; impacts to water quality from nutrient loadings	N 40° 42.274 W 105° 14.210
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.	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

UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM 2014 SAMPLING PLAN

	2014 Sampling Dates										
	Apr 7-8	**Apr 21-22**	**May 5-6**	**May 19-20**	**Jun 9-10**	**Jun 23-24**	**Jul 14-15**	**Aug 18-19**	**Sep 15-16**	**Oct 13-14**	**Nov 10,12**
North Fork											
NDC	F,G,P	F,G,I	F,G,P	F,G,I	F,G,P	F,G,I	F,G,P	F,G,I,P	F,G,P	F,G,I,P	F,G,I,P
NBH	F,G,P	F,G,I,B	F,G,P	F,G,I	F,G,P	F,G,I	F,G,P	F,G,I,P	F,G,P	F,G,I,P	F,G,I,P
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,B	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,B					
NFL	F,G	F,G,I	F,G	F,G,I,M	F,G	F,G,I	F,G,,M	F,G,I	F,G	F,G,I,M	F,G,I
NFG	F,G,E,P	F,G,I,E	F,G,E,P	F,G,I,M,E,	F,G,E,P	F,G,I,E,	F,G,E,M,P	F,G,I,E,P,B	F,G,E,P	F,G,I,M,P,E	F,G,I,P,E
Mainstem											
CHR	F,G,B	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,B	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,B	F,G,I,D
LRT	F,G	F,G,I	F,G	F,G,I	F,G, B	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
PBR	F,G,E,T	F,G,I,E	F,G,E,T	F,G,I,E,M	F,G,E,T	F,G,I,E	F,G,E,M,T	F,G,I,E,T	F,G,E,T	F,G,I,E,M,T	F,G,I,E,T
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
SFC[3]	F,G,I,D	F,G,I,D	F,G,I,D	F,G,I,D,M	F,G,I,D	F,G,I,D	F,G,I,D,M	F,G,I,D	F,G,I,D	F,G,I,D,M	F,G,I,D
PSF	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,M,B	F,G,I,E	F,G,E	F,G,I,E,M	F,G,I,E
PNF	F,G,E,T, 2	F,G,I,E,2	F,G,E,T,2	F,G,I,E,M,2	F,G,E,T,2	F,G,I,E,2	F,G,E,M,T,2	F,G,I,E,T,2	F,G,E,T,2	F,G,I,E,M,T,2	F,G,I,E,T,2
PBD	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,M	F,G,I,E	F,G,E	F,G,I,EM	F,G,I,E,B
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,M	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E,M	F,G,I,A,C,E	F,G,A,C,E,B	F,G,I,A,C,E,M	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]SFC = South Fork above Confluence w/ Mainstem, new site in 2014 to capture fire impacts.
M = Metals analysis added in 2013 & 2014 to evaluate impacts of fires
Blanks analyzed for NH3, NO3, TOC, TDS, NTU and Cl^-

2 = Duplicate, A = Algae (Lugol's); B=Blank, 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*; T=Geosmin

ATTACHMENT 5

ANALYTICAL METHODS, REPORTING LIMITS, SAMPLE PRESERVATION, AND HOLDING TIMES

	Parameter	Method	Reporting Limit	Preser-vation	Holding 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_4 pH <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

2014 SEAMAN RESERVOIR PHYTOPLANKTON DATA

Phytoplankton Densities (cells/mL)	SAMPLING DATE					
= geosmin producing species	8/19/2014		9/16/2014		10/14/2014	
CYANOPHYTA (blue-green algae)	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Anabaena inaequalis						
Anabaena sp.						
Aphanizomenon flos-aquae			314.0		767.2	394.0
Aphanocapsa conferta						
Aphanocapsa delicatissima					1000.0	
Aphanocapsa holsatica	1000.0					
Aphanocapsa sp.						
Aphanothece clathrata						
Aphanothece smithii	7625.0		5500.0	375.0	375.0	750.0
Coelosphaerium aerugineum	101.6					
Cuspidothrix issatschenkoi						
Cyanobium sp.						
Dactylococcopsis acicularis			20.0	125.0		
Dactylococcopsis sp.						
Dolichospermum (Anabaena) flos-aquae						
Dolichospermum (Anabaena crassa) crassum			46.4		24.0	35.2
Dolichospermum (Anabaena) lemmermannii	247.6					
Dolichospermum (Anabaena planctonica) planctonicum			102.0			
Geitlerinema sp.						
Gloeotrichia echinulata						
Jaaginema sp.						
Limnothrix sp.						
Lyngbya birgei						
Merismopedia sp.						
Merismopedia tenuissima			720.0			
Microcystis flos-aquae						
Microcystis wesenbergii						
Myxobaktron hirudiforme						
Oscillatoria tenuis						
Planktolyngbya limnetica		15480.0		36.0		3260.0
Planktothrix agardhii						
Pseudanabaena limnetica						126.4
Pseudanabaena mucicola					6.0	
Pseudanabaena sp.						160.0
Rhabdogloea smithii						
Romeria leopoliensis						
Romeria sp.						
Snowella litoralis						
Synechococcus capitatus						
Synechococcus nidulans			20.0			
Synechocystis sp.						
Woronichinia naegeliana					139.2	25.6
TOTAL CYANOPHYTA	**8,974**	**15,480**	**6,722**	**536**	**2,311**	**4,751**

Phytoplankton Densities (cells/mL)	SAMPLING DATE					
	8/19/2014		9/16/2014		10/14/2014	
CHRYSOPHYTA (golden-brown algae)	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Chromulina parvula						
Chrysococcus sp.						
Dinobryon bavaricum			7.2			
Dinobryon cylindricum var. *alpinum*						
Dinobryon cylindricum						
Dinobryon cylindricum var. *palustre*						
Dinobryon divergens			116.8	0.2	16.0	2.4
Dinobryon sociale var. *americanum*						
statospore of *Dinobryon*						
Mallomonas akrokomos						
Mallomonas caudata						
Mallomonas sp.						
cyst of *Mallomonas* sp.						
Ochromonas minuscula						
Synura petersenii						
Uroglenopsis americana						
TOTAL CHRYSOPHYTA	**0**	**0**	**124**	**0**	**16**	**2**
XANTHOPHYTA						
Gloeobotrys limneticus						
BACILLARIOPHYTA (diatoms)						
Amphora sp.						
Asterionella formosa	12.8		14.4		4.8	10.4
Aulacoseira ambigua						
Aulacoseira granulata var. *angustissima*	3.6	3.2	35.2	6.4		43.2
Aulacoseira granulata				20.6		
Aulacoseira italica			88.0		87.2	28.8
Aulacoseira italica var. *tenuissima*			20.8		83.2	60.0
Aulacoseira subarctica						
Cyclostephanos sp.						
Cymatopleura solea						
Diatoma anceps						
Diatoma moniliformis						
Diatoma tenuis						
Discostella glomerata				0.8		
Discostella pseudostelligera						
Discostella stelligera			20.0			
Fragilaria crotonensis	897.5	125.2	61.2		311.2	313.6
Fragilaria sp.						
Gomphonema sphaerophorum						
Gyrosigma acuminatum						
Melosira varians						

Phytoplankton Densities (cells/mL)	SAMPLING DATE					
	8/19/2014		9/16/2014		10/14/2014	
BACILLARIOPHYTA (diatoms) continued	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Navicula capitatoradiata						
Navicula lanceolata						
Navicula rhynchocephala						
Navicula tripunctata						
Nitzschia archibaldii						
Nitzschia draveillensis						
Nitzschia fonticola						
Nitzschia gracilis						
Nitzschia linearis						
Nitzschia nana						
Nitzschia sigma						
Nitzschia sp.						
Nitzschia supralitorea						
Punticulata bodanica				0.2		
Stephanocyclus meneghiniana						
Stephanodiscus medius						
Stephanodiscus niagarae						
Stephanodiscus parvus						
Synedra acus						
Synedra cyclopum						
Synedra delicatissima var. *angustissima*						
Synedra radians						
Synedra rumpens var. *familiaris*						
Synedra rumpens						
Synedra tenera						
Synedra ulna var. *danica*						
Synedra ulna var. *subaequalis*						
Synedra ulna						
Tabellaria fenestrata						
Urosolenia eriensis						
TOTAL BACILLARIOPHYTA	**914**	**128**	**240**	**28**	**486**	**456**
HAPTOPHYTA						
Chrysochromulina parva			300.0			

Phytoplankton Densities (cells/mL)	SAMPLING DATE					
	8/19/2014		9/16/2014		10/14/2014	
CRYPTOPHYTA	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Chroomonas coerulea			7.2		6.8	1.2
Chroomonas nordstedtii			4.4			
Cryptomonas borealis	2.0		88.0	0.2	0.8	0.8
Cryptomonas curvata	6.0	0.4	16.0			
Cryptomonas erosa						
Cryptomonas marsonii			2.8			
Goniomonas truncata						
Hemiselmis sp.						
Komma caudata	160.0		600.0			
Plagioselmis nannoplanctica	240.0				70.0	
cyst of *Cryptomonas*						
TOTAL CRYPTOPHYTA	**408**	**0.4**	**718.4**	**0.2**	**77.6**	**2**
DINOPHYTA						
Ceratium hirundinella	20.0	2.0	200.0		0.6	
Gymnodinium aeruginosum						
Gymnodinium fuscum						
Peridinium lomnickii						
Peridinium willei						
Tovellia (Woloszynskia) coronata						
TOTAL DINOPHYTA	**20**	**2**	**200**	**0**	**1**	**0**
EUGLENOPHYTA						
Euglena sp.						
Euglena viridis						
Lepocinclis acus						
Lepocinclis oxyuris						
Trachelomonas dybowskii						
Trachelomonas hispida					1.2	
Trachelomonas volvocina					0.8	
TOTAL EUGLENOPHYTA	**0**	**0**	**0**	**0**	**2**	**0**
PRASINOPHYTA						
Monomastrix sp.	40.0					
Pyramimonas sp.						
Scourfieldia sp.	20.0					
Tetraselmis cordiformis			1.6			
TOTAL PRASINOPHYTA	**60**	**0**	**2**	**0**	**0**	**0**

Phytoplankton Densities (cells/mL)	SAMPLING DATE					
	8/19/2014		9/16/2014		10/14/2014	
CHLOROPHYTA (green algae)	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Acutodesmus acuminatus						
Acutodesmus dimorphus						
Ankistrodesmus falcatus						
Ankyra judayi	220.0		120.0	9.0	60.0	
Botryococcus braunii						
Chlamydomonas dinobryonis						
Chlamydomonas globosa						
Chlamydomonas snowiae						
Chlamydomonas sp. 1						
Chlamydomonas sp. 2						
Chlamydomonas tetragama	20.0		1900.0	4.5		
Chlorella minutissima	4125.0	1250.0	750.0	6875.0	4000.0	250.0
Chlorella sp.						
Chloromonas sp.						
Choricystis minor			5625.0			
Closterium aciculare						
Closterium acutum var. *variabile*						
Closterium dianae						
Closterium moniliferum						
Coelastrum indicum						
Coelastrum pseudomicroporum						
Coelastrum pulchrum						
Coenochloris fottii	17.6	2.4	4.8			1.4
Cosmarium bioculatum						
Cosmarium candianum						
Cosmarium depressum var. *achondrum*						
Desmodesmus armatus						
Desmodesmus bicaudatus						
Desmodesmus communis			1.6			
Desmodesmus intermedius var. *balatonicus*						
Dictyosphaerium pulchellum var. *minutum*						
Elakatothrix viridis						
Eudorina elegans	3.6		4.8		3.6	
Gonatozygon kinahanii						
Heimansia pusilla						
Keratococcus sp.						
Kirchneriella obesa						
Micractinium pusillum						
Monoraphidium contortum						
Monoraphidium minutum						
Monoraphidium sp.						
Mougeotia sp.						
Nephrocytium limneticum						

Phytoplankton Densities (cells/mL)	SAMPLING DATE					
	8/19/2014		9/16/2014		10/14/2014	
CHLOROPHYTA (green algae) continued	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Oocystis apiculata						
Oocystis borgei						
Oocystis parva						
Oocystis pusilla						
Pandorina charkowiensis						
Pandorina smithii			7.2			
Pediastrum boryanum	2.8					
Pediastrum duplex						1.6
Pediastrum tetras						
Pseudodictyosphaerium elegans						
Pseudodictyosphaerium sp.						
Pseudodidymocystis planctonica						
Quadrigula sp.						
Raphidocelis contorta						
Raphidocelis sp.						
Scenedesmus arcuatus						
Scenedesmus ellipticus						
Schroederia setigera						
Staurastrum planctonicum	1.2				0.2	0.2
Tetraedron minimum						
Tetraspora lemmermannii						
Volvox sp.						
TOTAL CHLOROPHYTA	**4,390**	**1,252**	**8,413**	**6,889**	**4,064**	**253**

ATTACHMENT 7

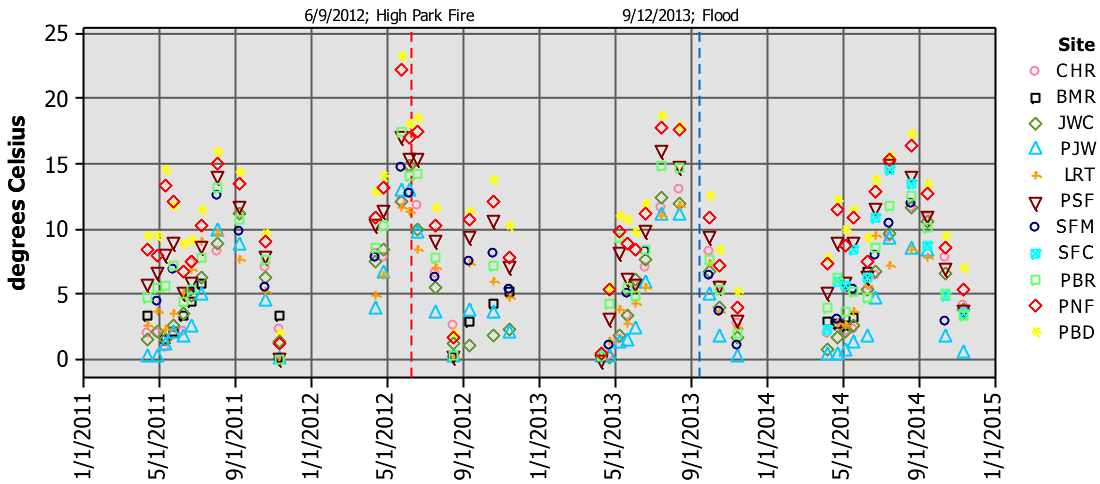
2014 UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM

GRAPHICAL SUMMARY

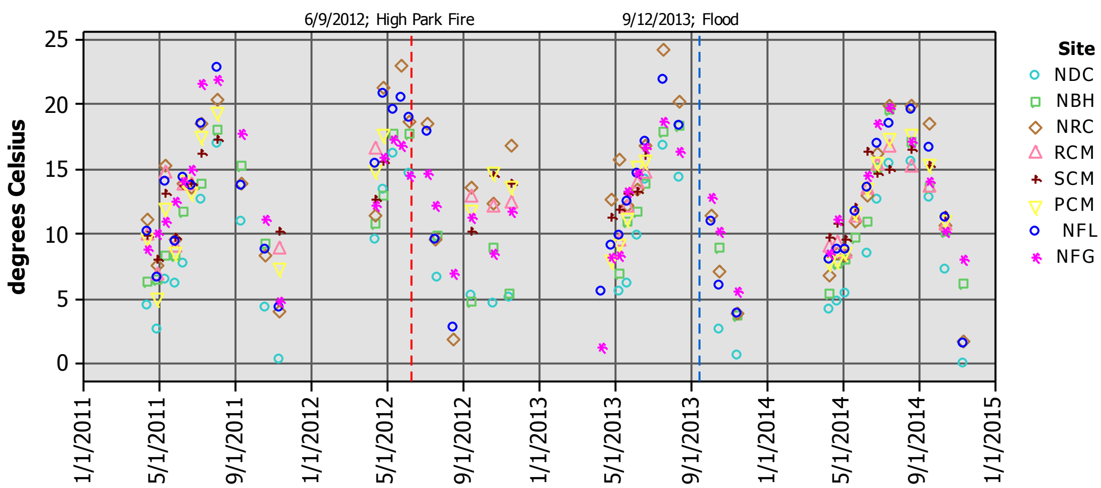
MAINSTEM & NORTH FORK CLP WATERSHEDS

GENERAL PARAMETERS

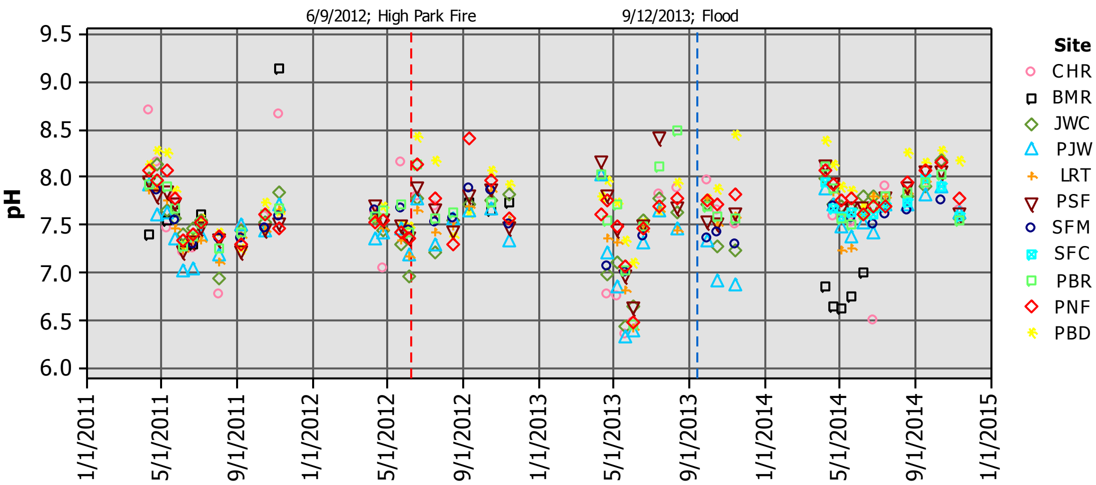
a) Temperature on the Mainstem CLP



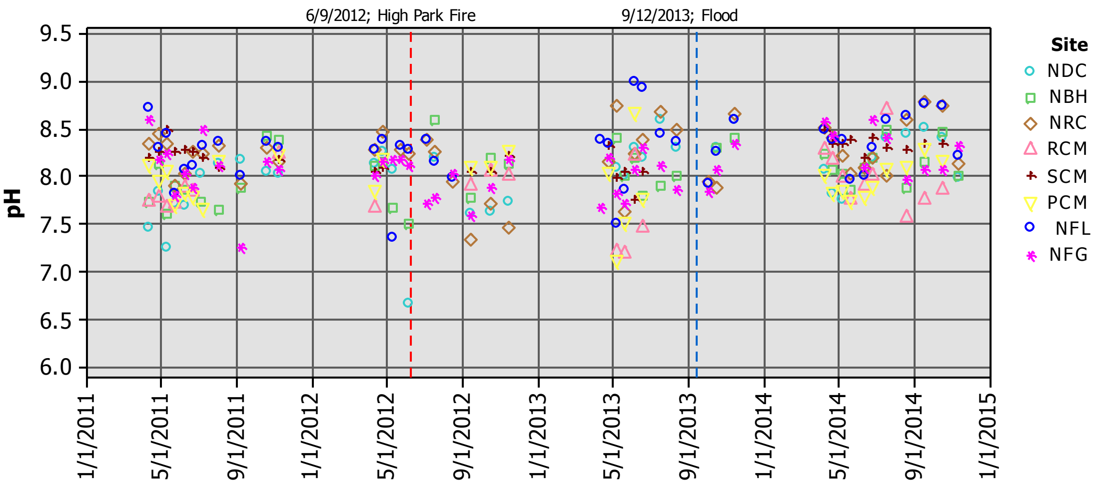
b) Temperature on the North Fork CLP



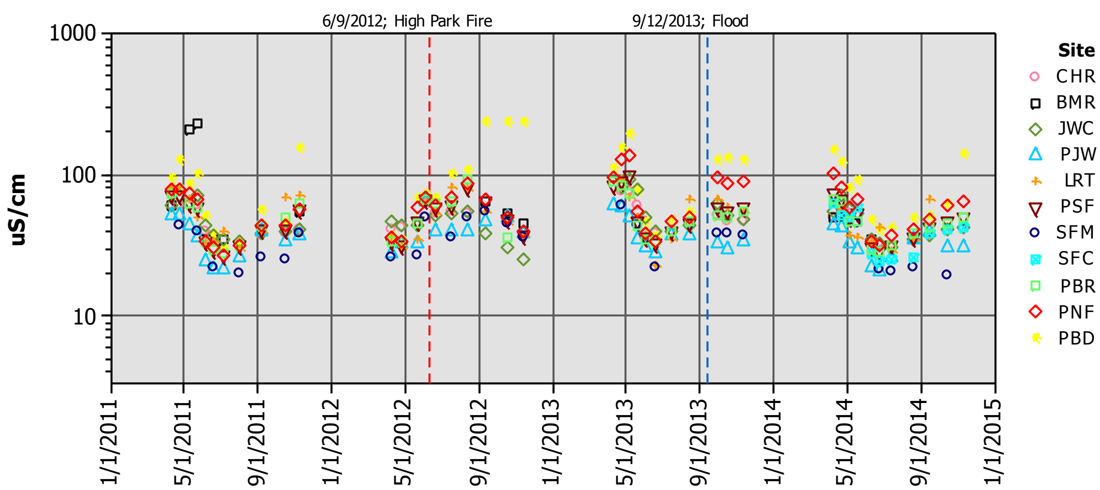
a) pH on the Mainstem CLP



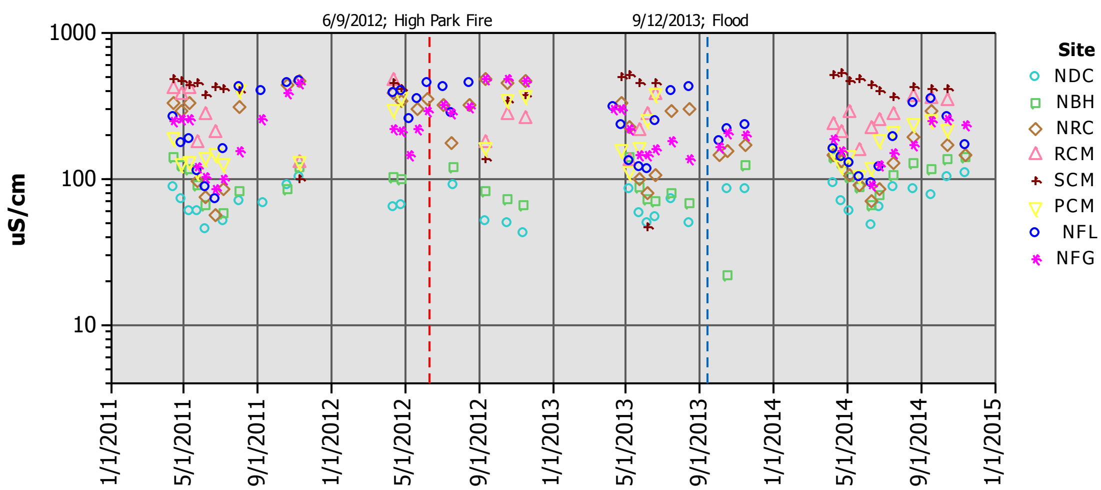
b) pH on the North Fork CLP



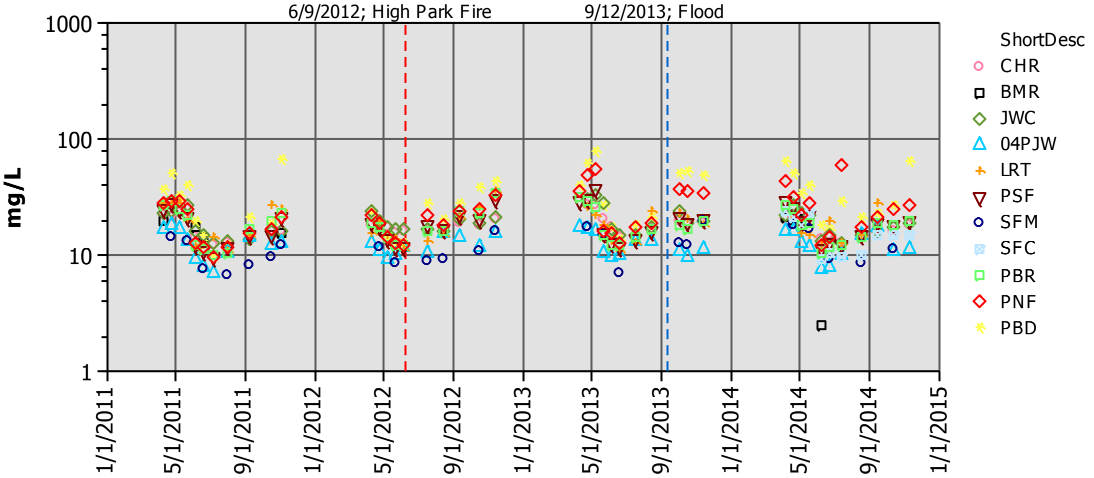
a) Specific Conductance on the Mainstem CLP



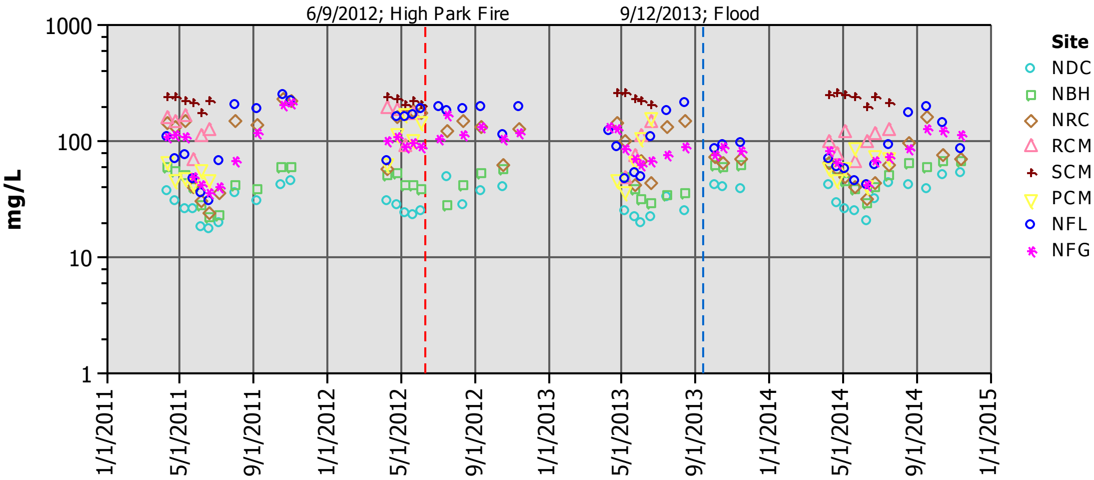
b) Specific Conductance on the North Fork CLP



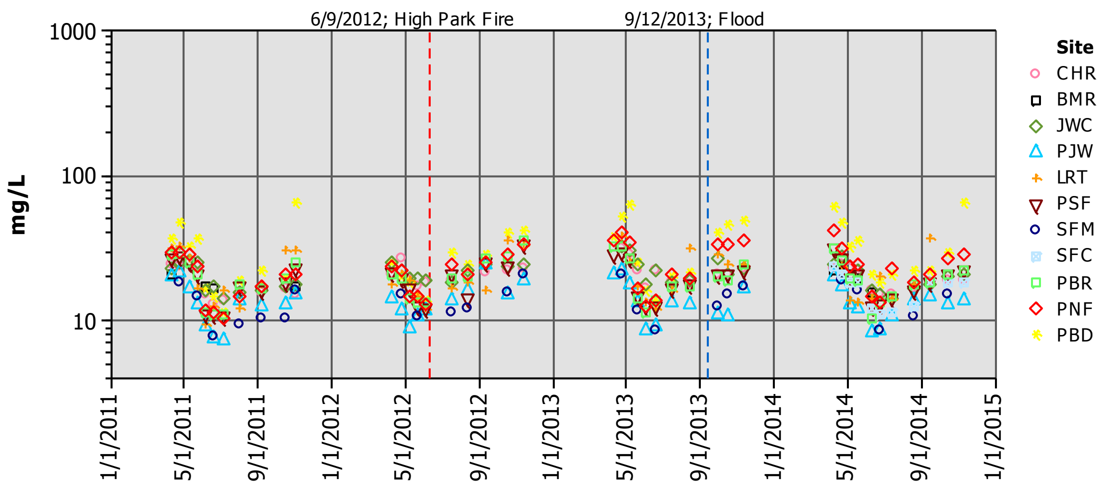
a) Hardness on the Mainstem CLP



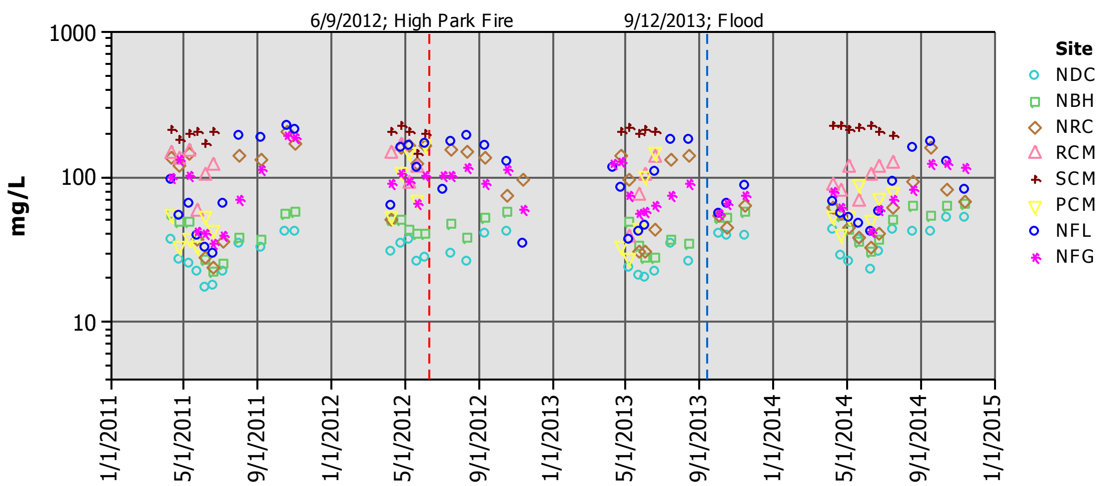
b) Hardness on the North Fork CLP



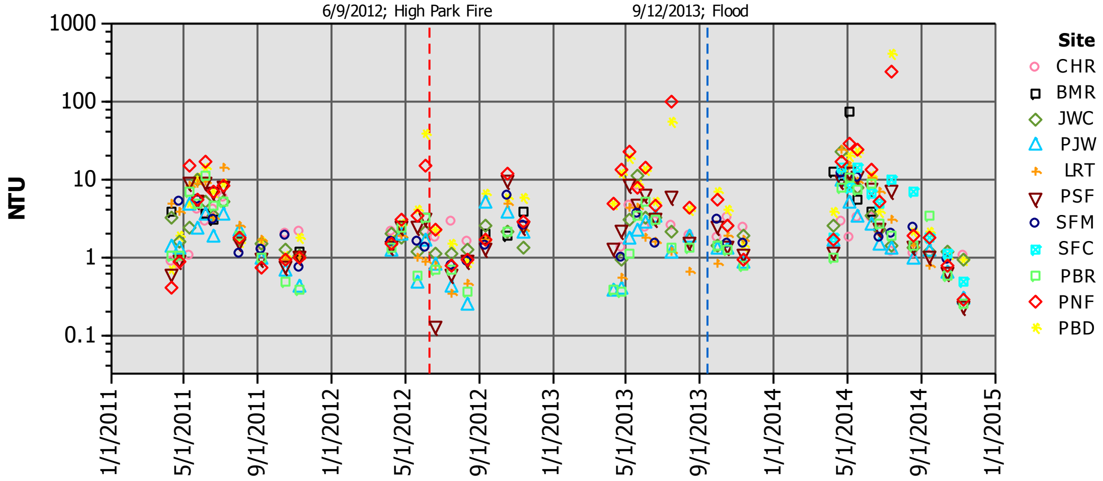
a) Alkalinity on the Mainstem CLP



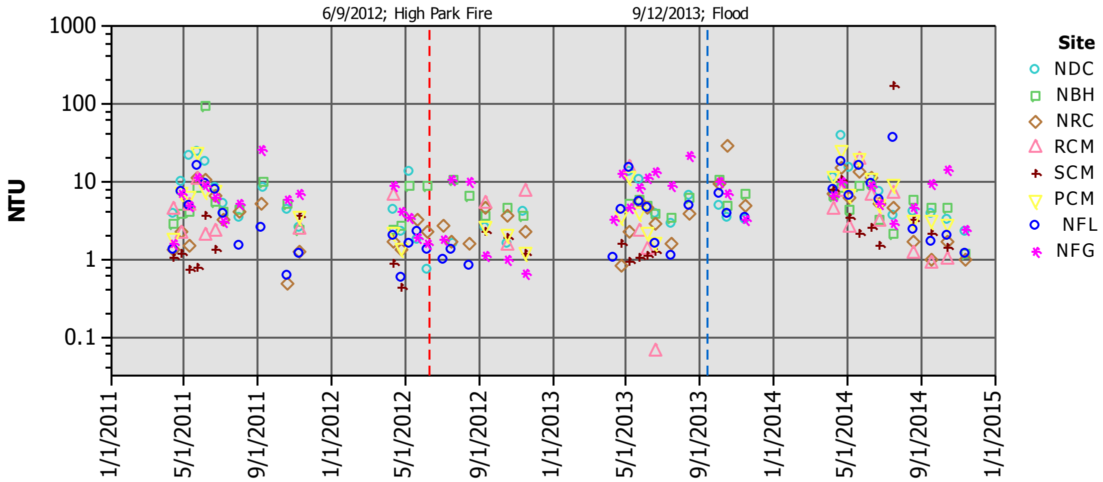
b) Alkalinity on the North Fork CLP



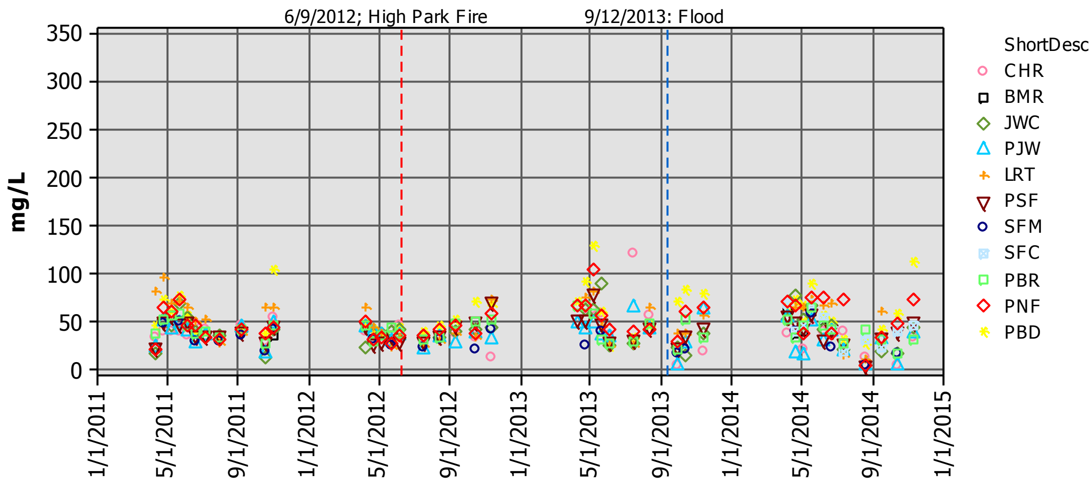
a) Turbidity on the Mainstem CLP



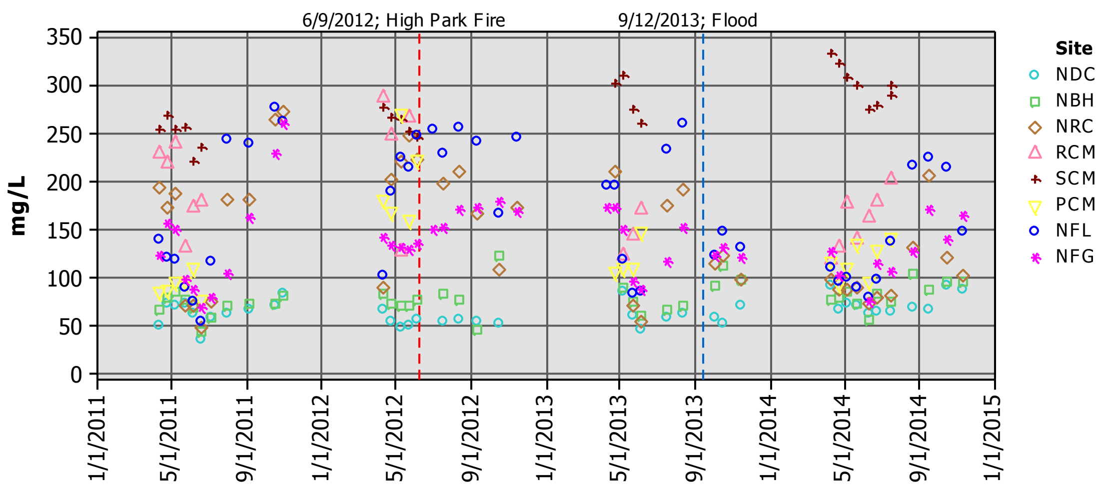
b) Turbidity on the North Fork CLP



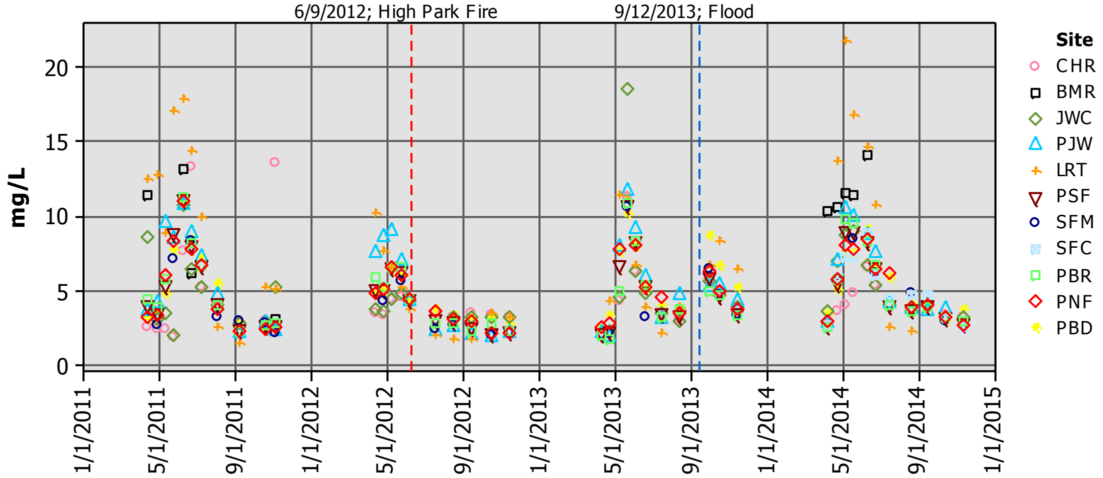
a) Total Dissolved Solids (TDS) on the Mainstem CLP



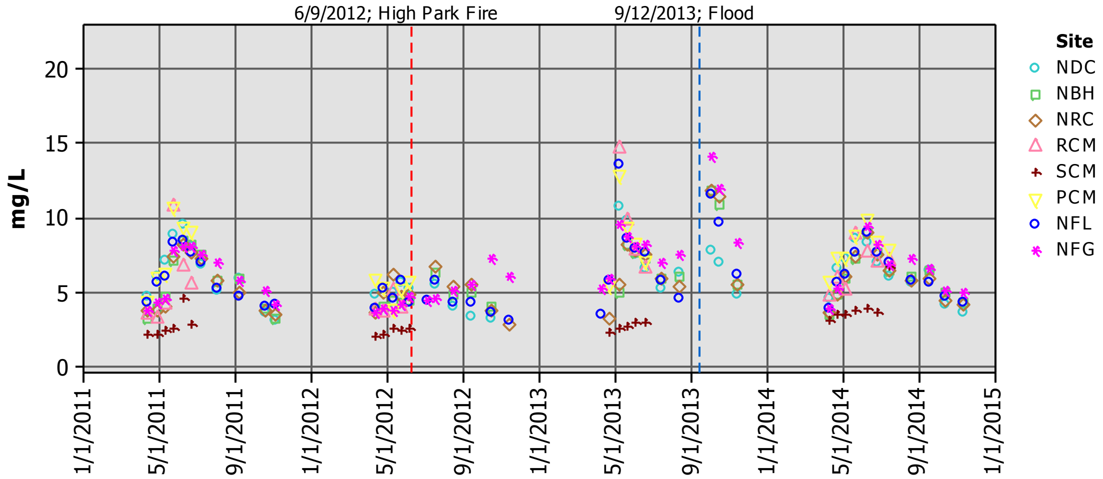
b) Total Dissolved Solids (TDS) on the Mainstem CLP



a) Total Organic Carbon (TOC) on the Mainstem CLP



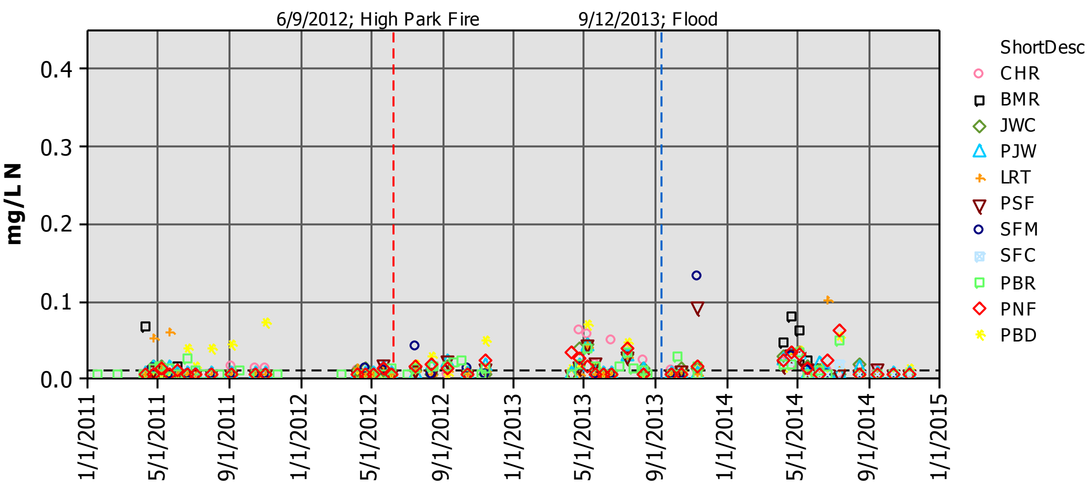
b) Total Organic Carbon (TOC) on the North Fork CLP



MAINSTEM & NORTH FORK CLP WATERSHEDS

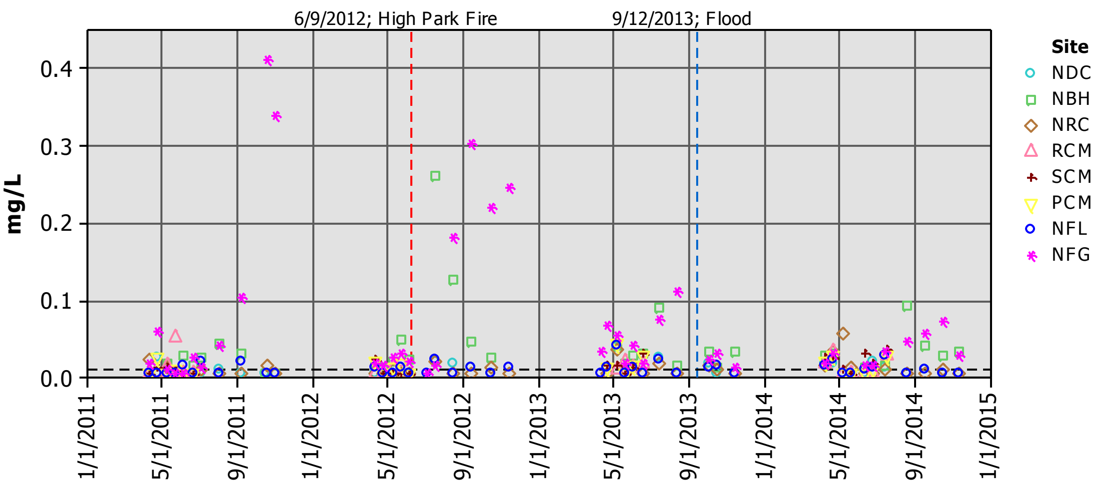
NUTRIENTS

a) Ammonia as Nitrogen (NH3-N) on the Mainstem CLP

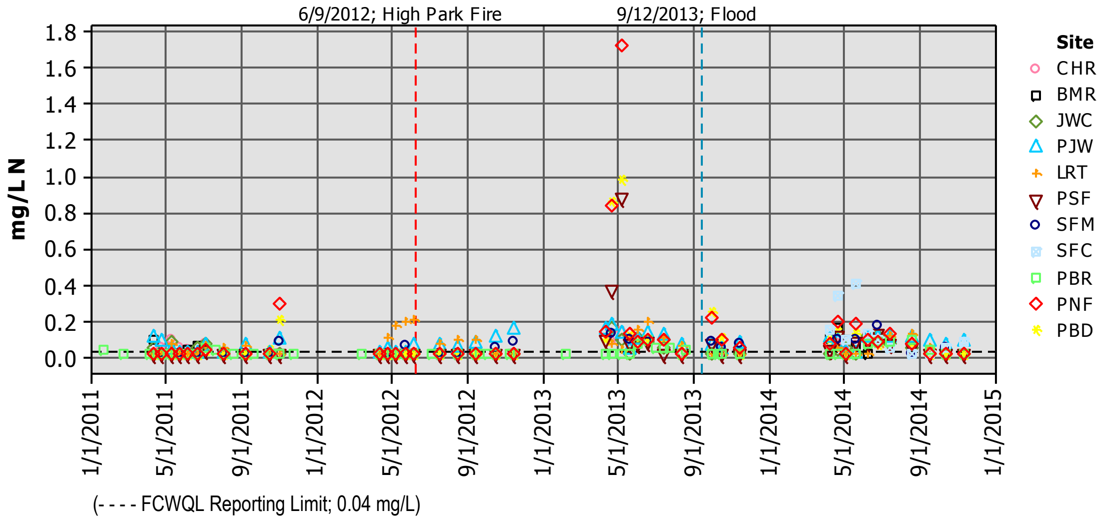


(- - - - FCWQL Reporting Limit; 0.010 mg/L)

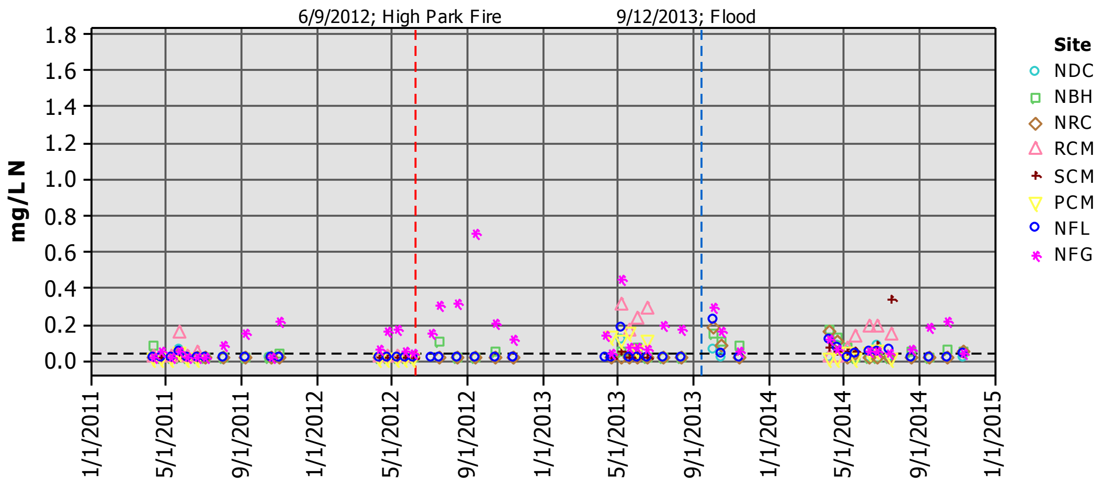
b) Ammonia as Nitrogen (NH3-N) on the North Fork CLP



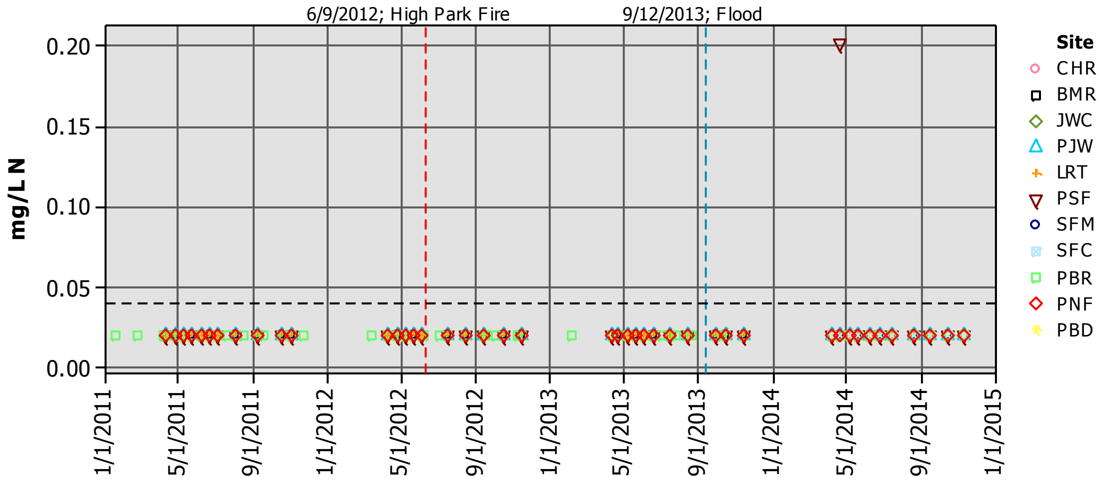
a) Nitrate as Nitrogen (NO3-N) on the Mainstem CLP



b) Nitrate as Nitrogen (NO3-N) on the North Fork CLP

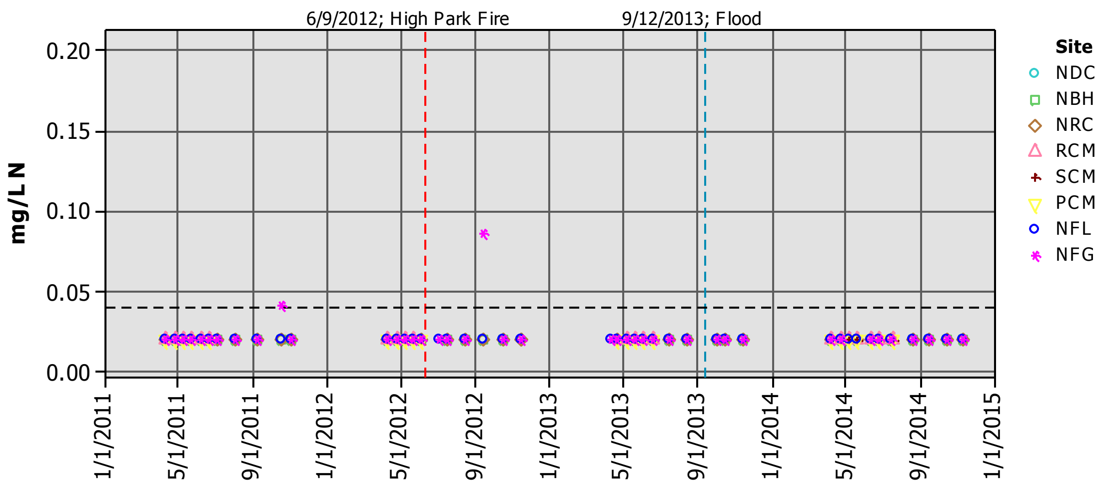


a) Nitrite as Nitrogen (NO2-N) on the Mainstem CLP

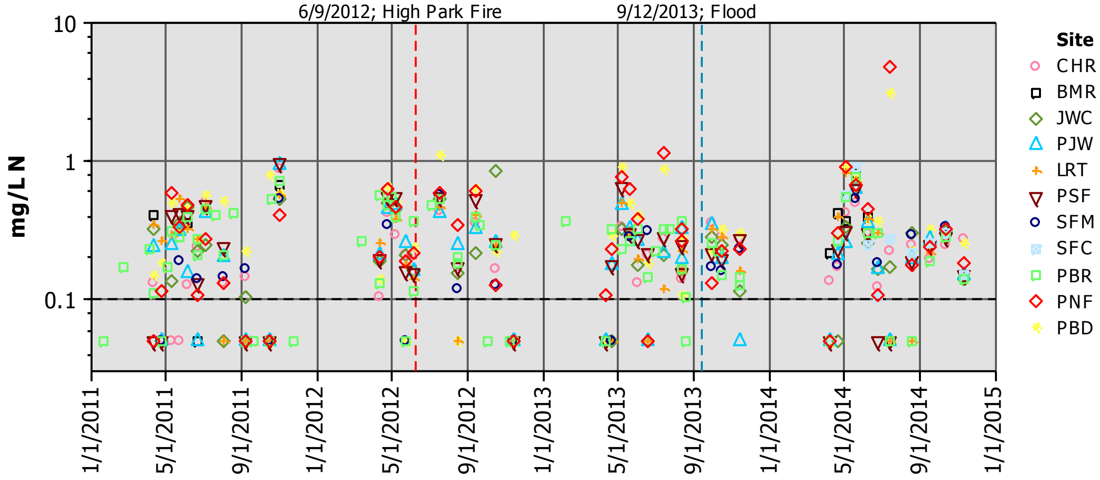


(- - - - FCWQL Reporting Limit; 0.04 mg/L)

b) Nitrite as Nitrogen (NO2-N) on the North Fork CLP

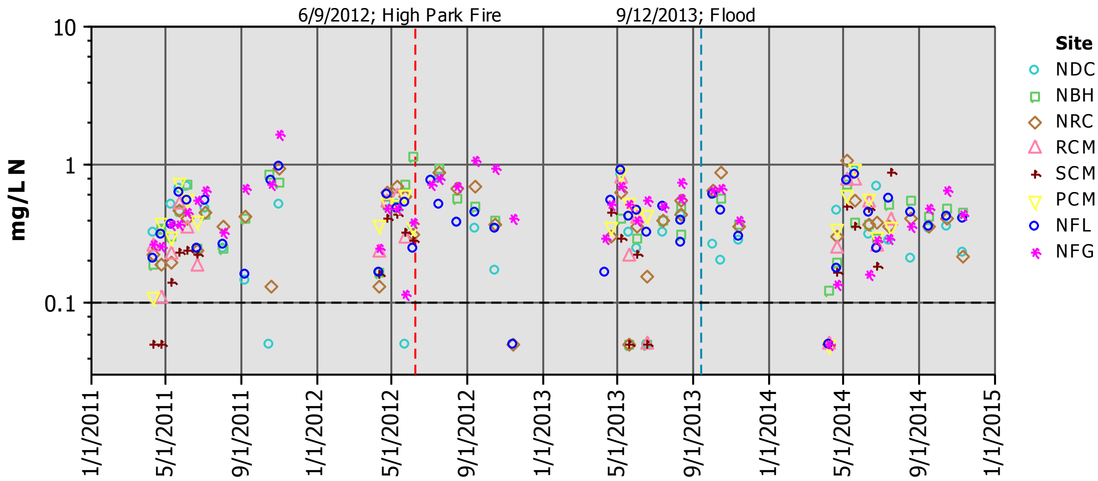


a) Total Kjeldahl Nitrogen (TKN) on the Mainstem CLP

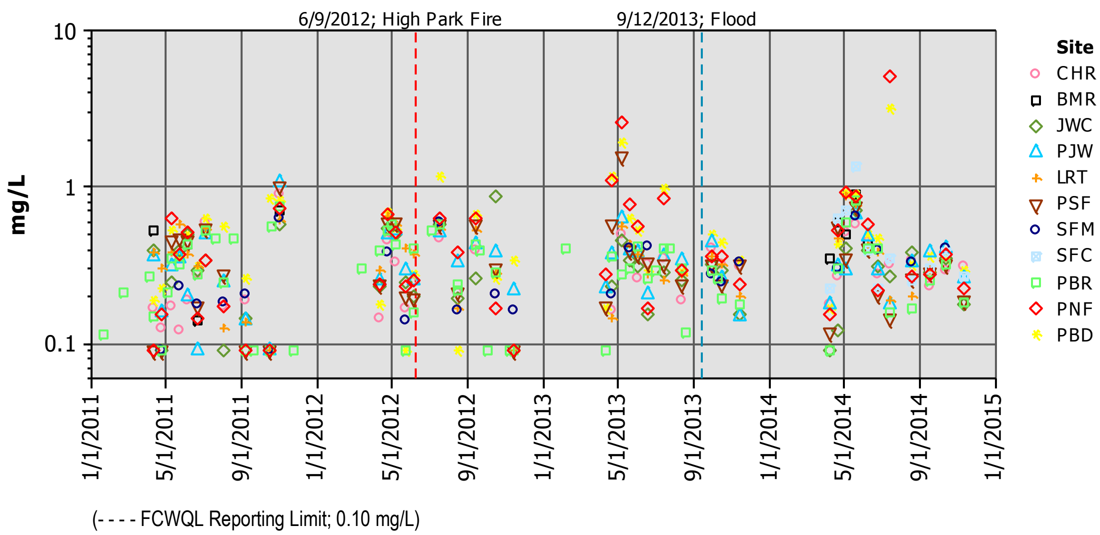


(- - - - FCWQL Reporting Limit; 0.100 mg/L)

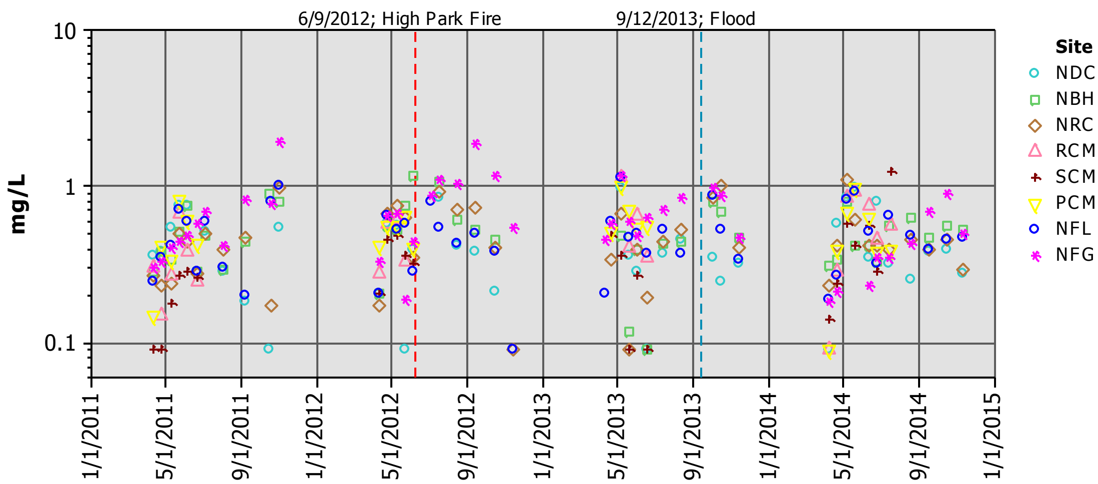
b) Total Kjeldahl Nitrgoen (TKN) on the North Fork CLP



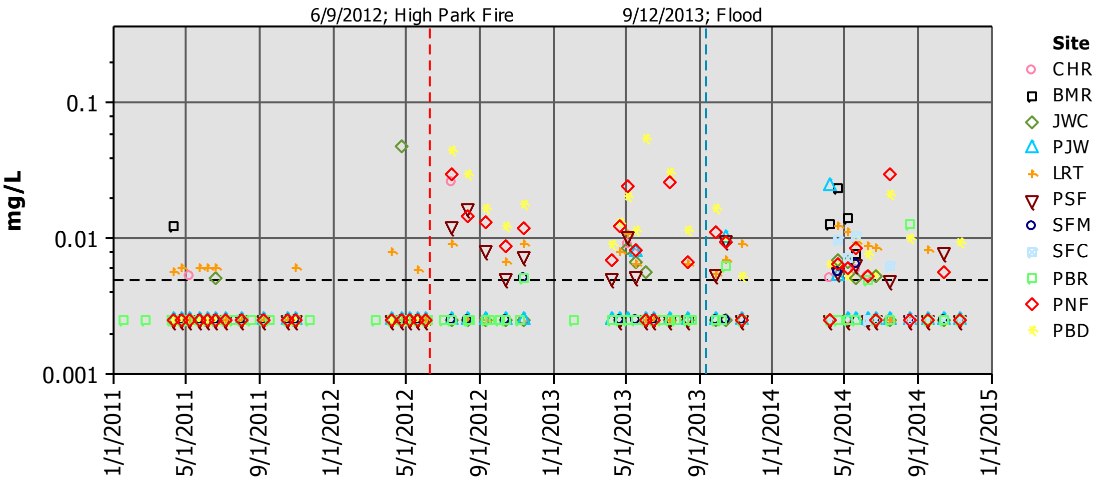
a) Total nitrogen (TN) on the Mainstem CLP



b) Total nitrogen (TN) on the North Fork CLP

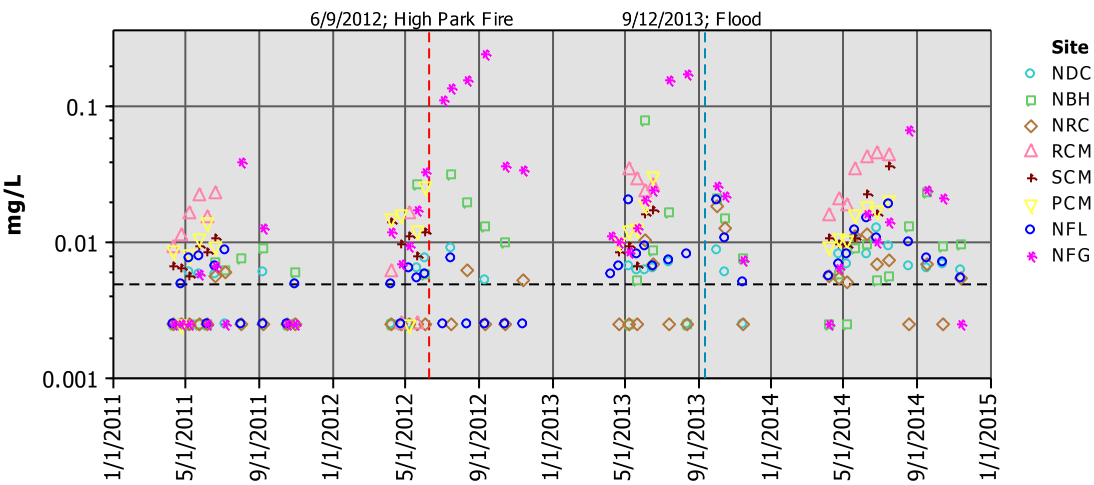


a) Ortho-phosphate (PO4) on the Mainstem CLP

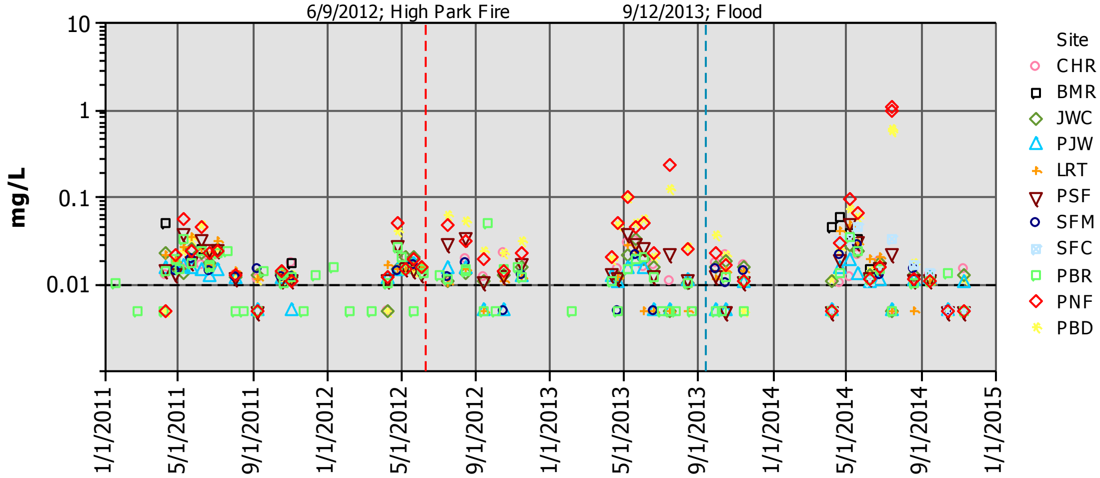


(- - - - FCWQL Reporting Limit; 0.005 mg/L)

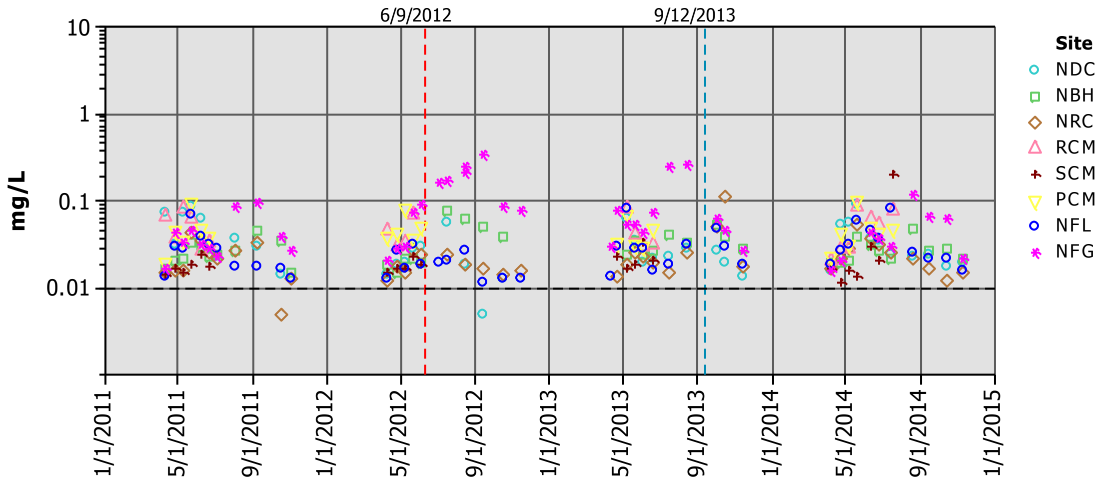
b) Ortho-phosphate (PO4) on the North Fork CLP



a) Total Phosphorus (TP) on the Mainstem CLP



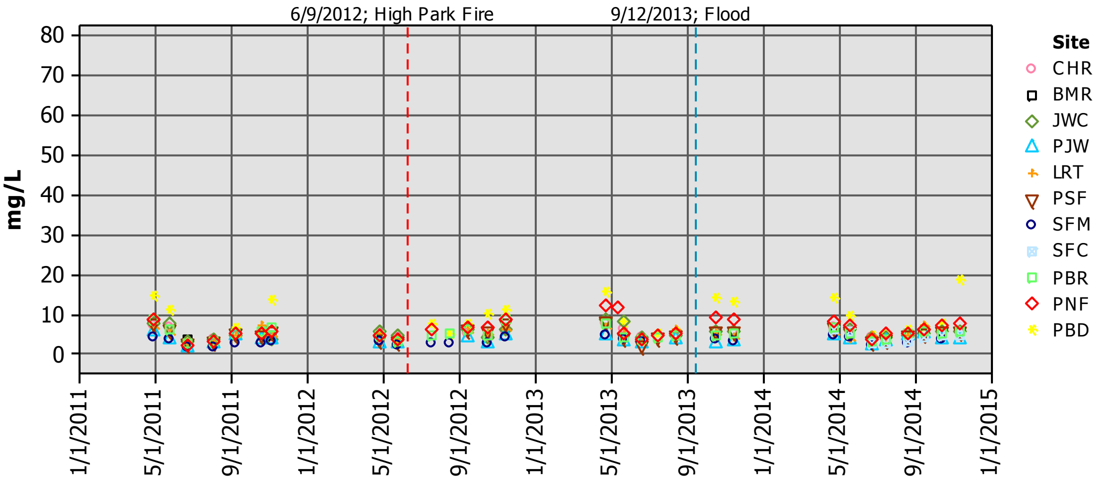
b) Total Phosphorus (TP) on the North Fork CLP



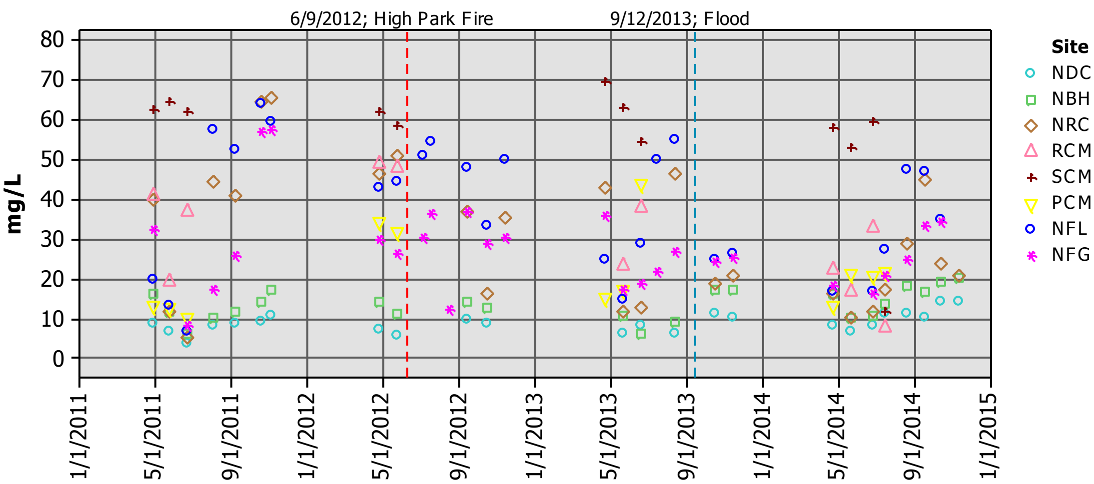
MAINSTEM & NORTH FORK CLP WATERSHEDS

MAJOR IONS

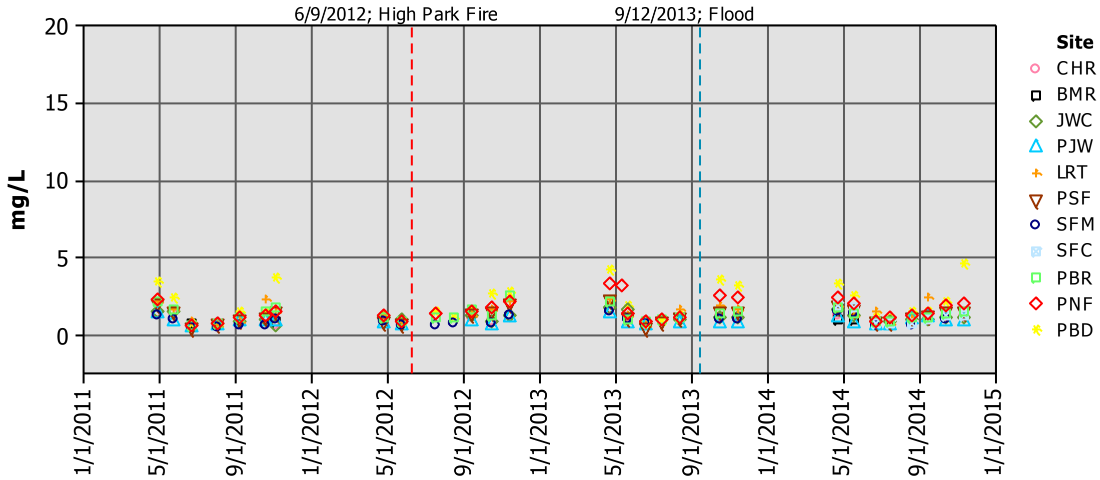
a) Calcium (Ca) on the Mainstem CLP



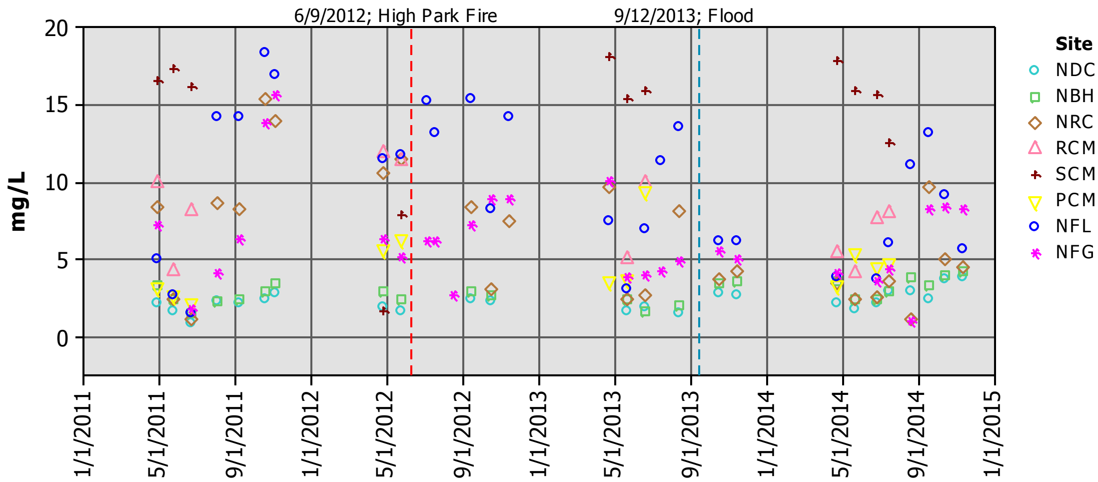
b) Calcium (Ca) on the North Fork CLP



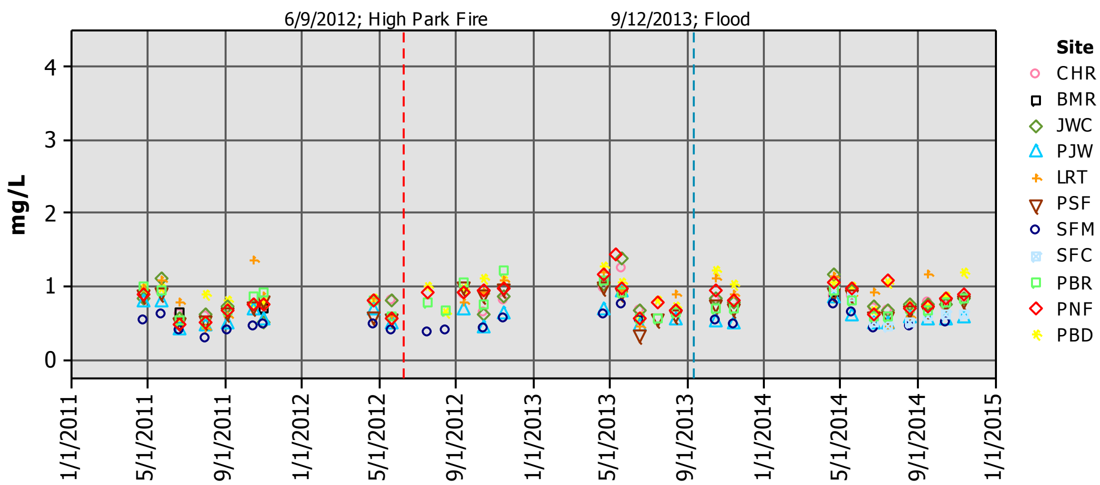
a) Magnesium (Mg) on the Mainstem CLP



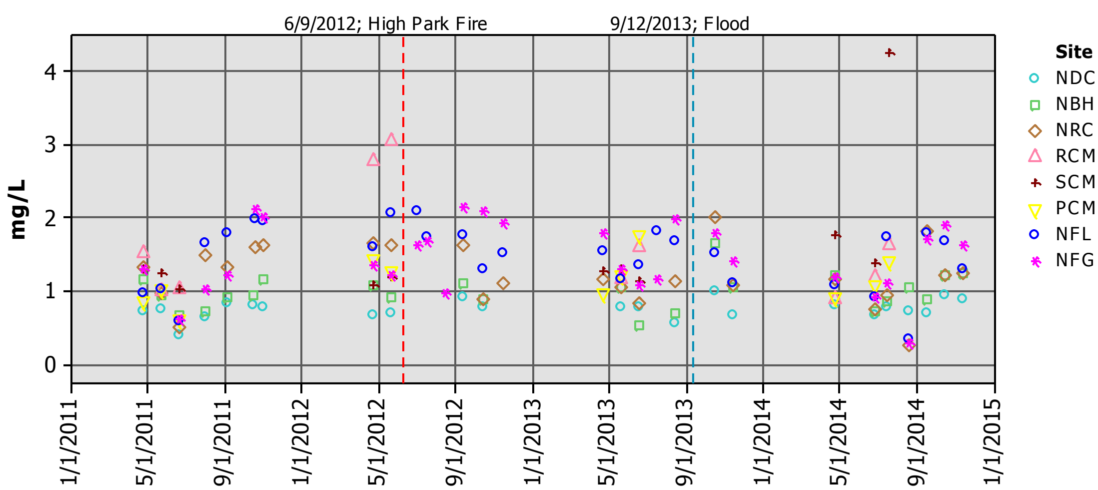
b) Magnesium (Mg) on the North Fork CLP



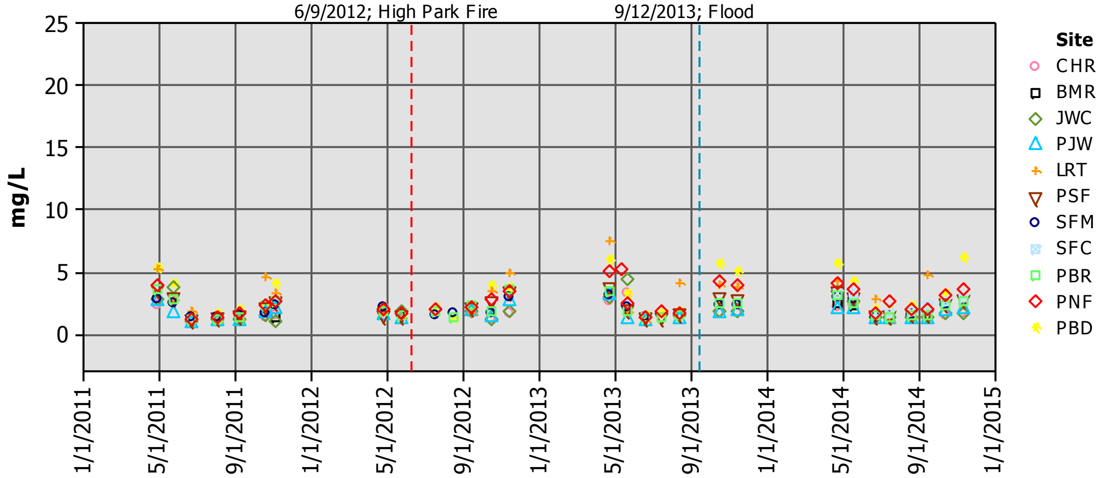
a) Potassium (K) on the Mainstem CLP



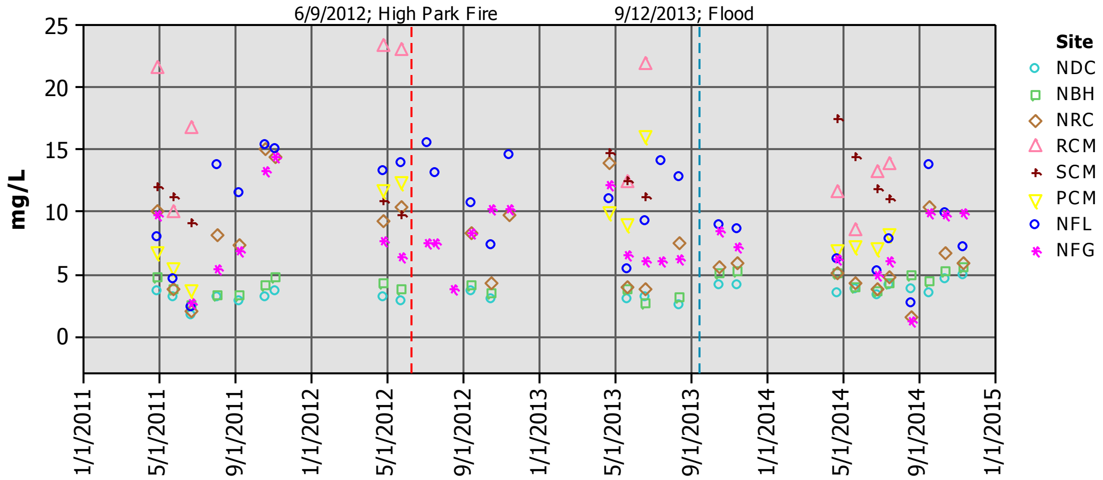
b) Potassium (K) on the North Fork CLP



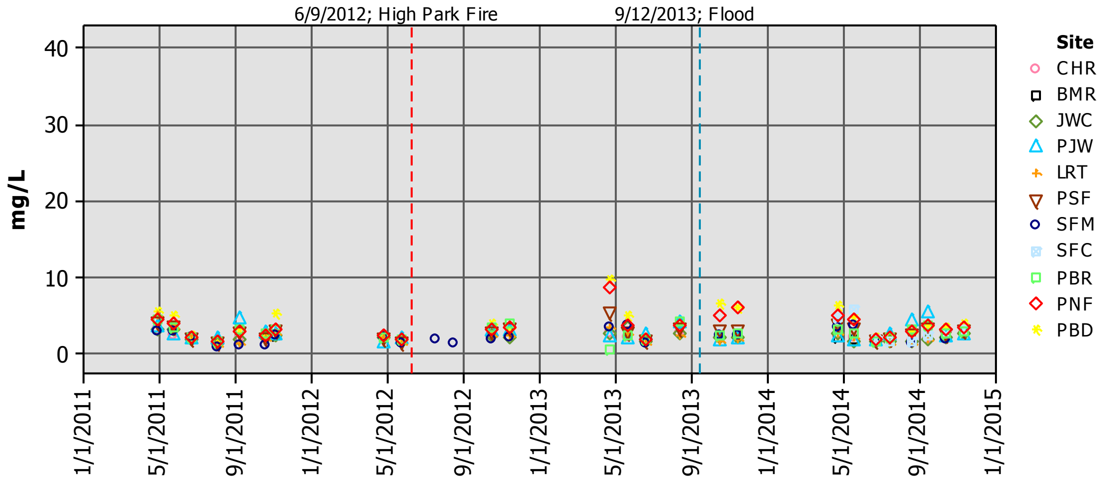
a) Sodium (Na) on the Mainstem CLP



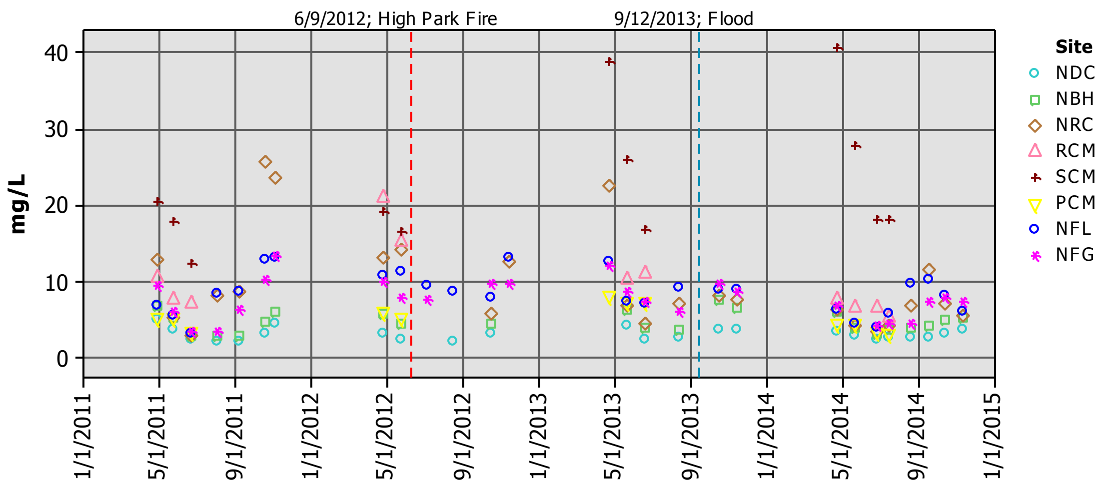
b) Sodium (Na) on the North Fork CLP



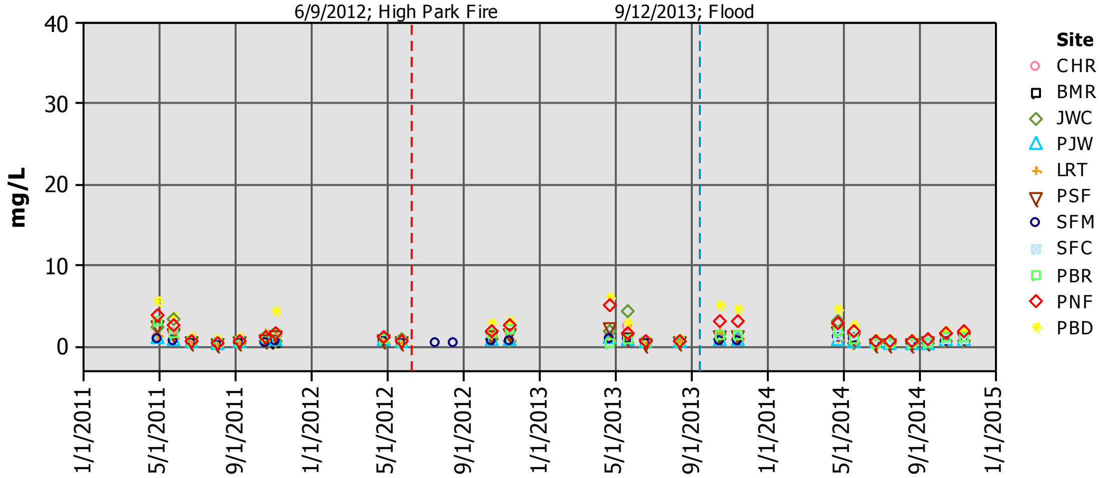
a) Sulfate (SO4) on the Mainstem CLP



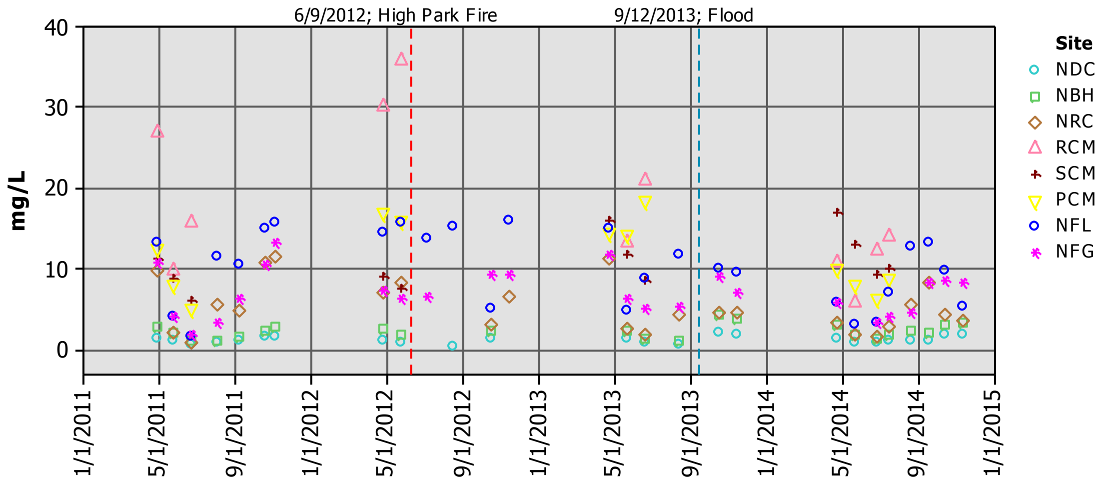
b) Sulfate (SO4) on the North Fork CLP



a) Chloride (Cl) on the Mainstem CLP



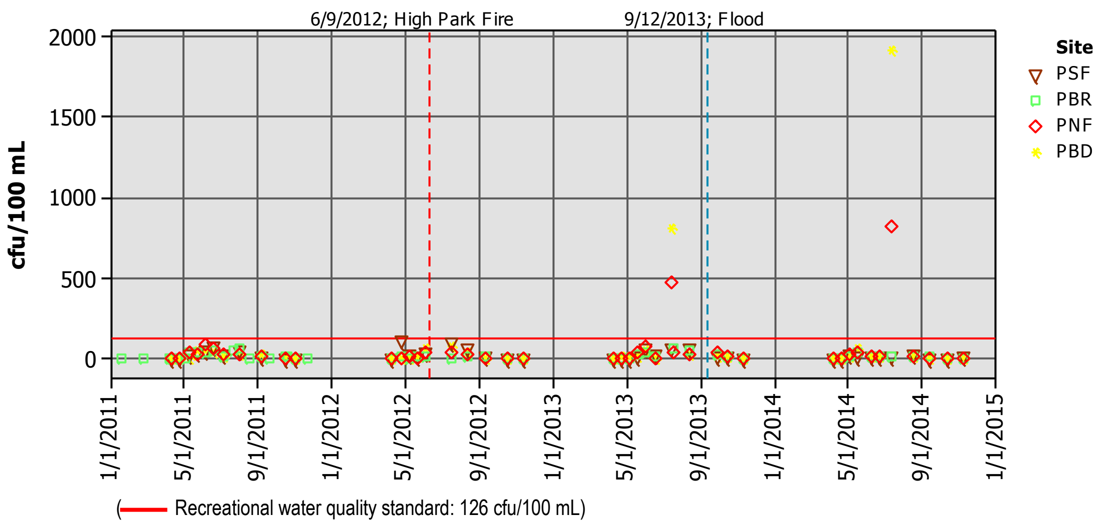
b) Chloride (Cl) on the North Fork CLP



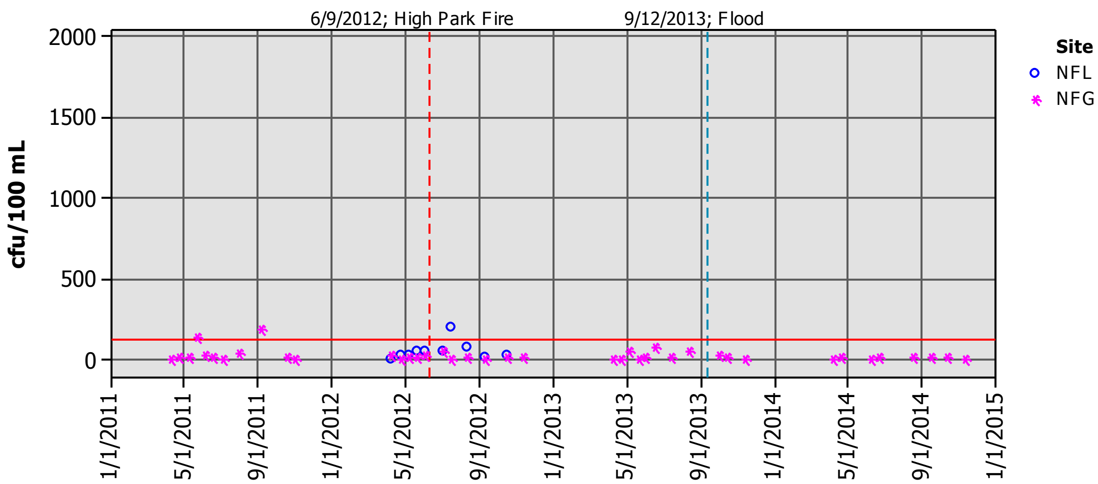
MAINSTEM & NORTH FORK CLP WATERSHEDS

MICROBIOLOGICAL

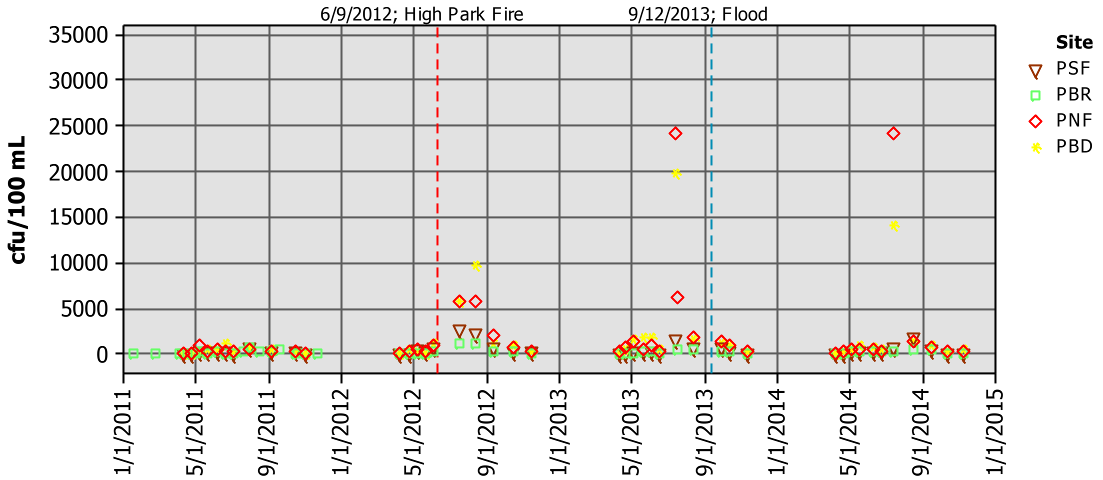
a) E. coli on the Mainstem CLP



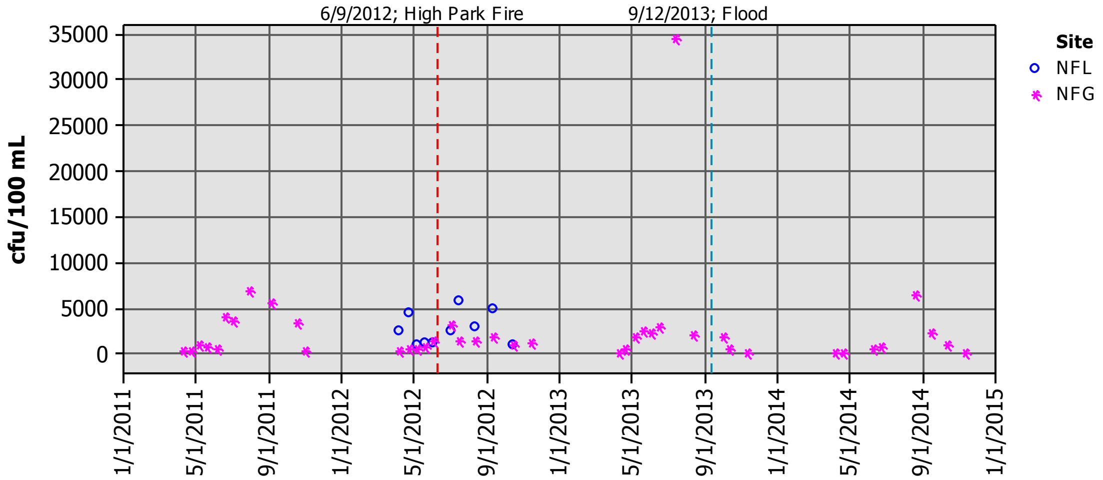
b) E. coli on the North Fork CLP



a) Total coliforms on the Mainstem CLP



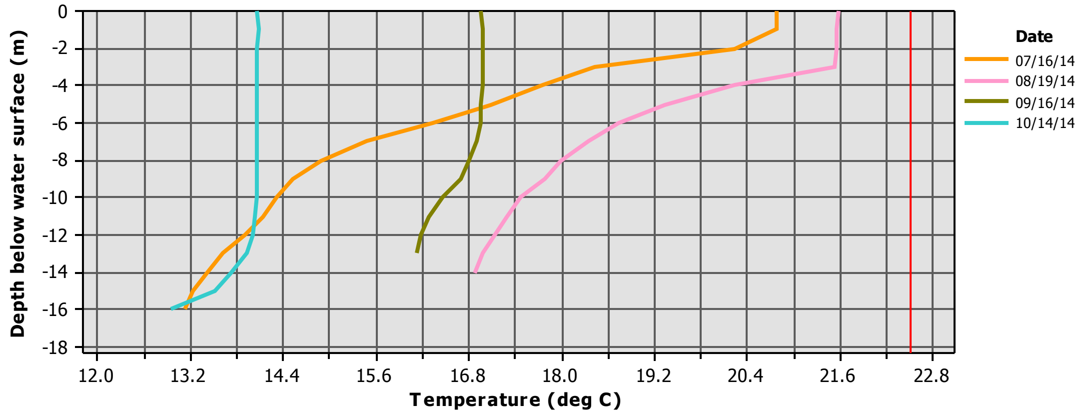
b) Total coliforms on the North Fork CLP



SEAMAN RESERVOIR

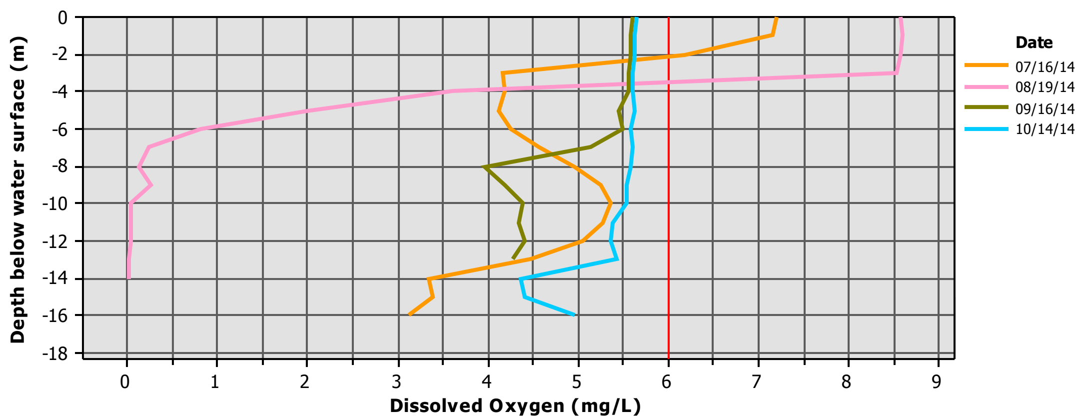
DEPTH PROFILES

Temperature profiles measured in Seaman Reservoir (2014)



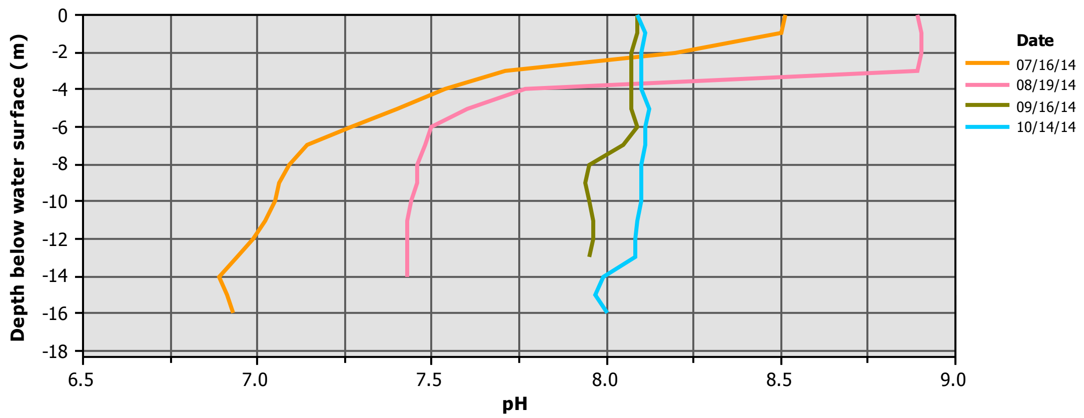
(— Water quality standard for cold water aquatic life: 22.5 degress C)

Dissolved Oxygen profiles measured in Seaman Reservoir (2014)

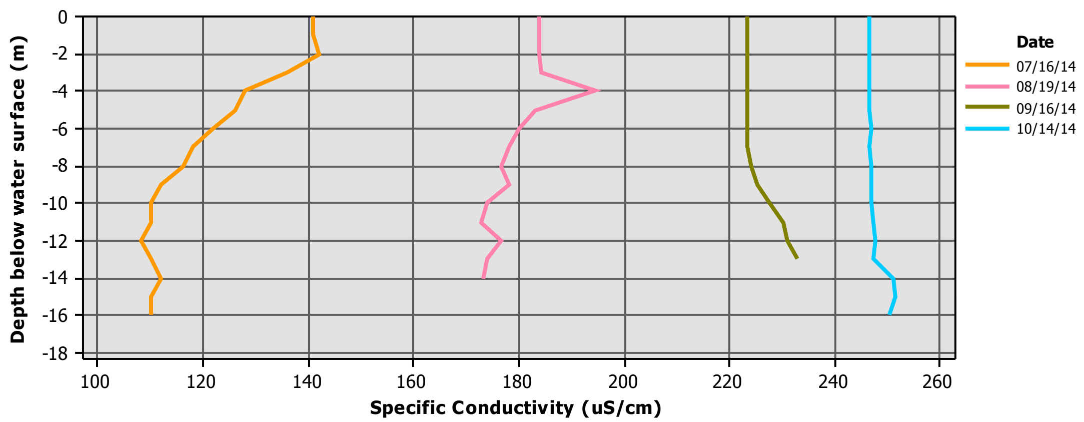


(— Water quality standard for cold water aquatic life: 6.0 mg/L D.O.)

pH profiles measured in Seaman Reservoir (2014)



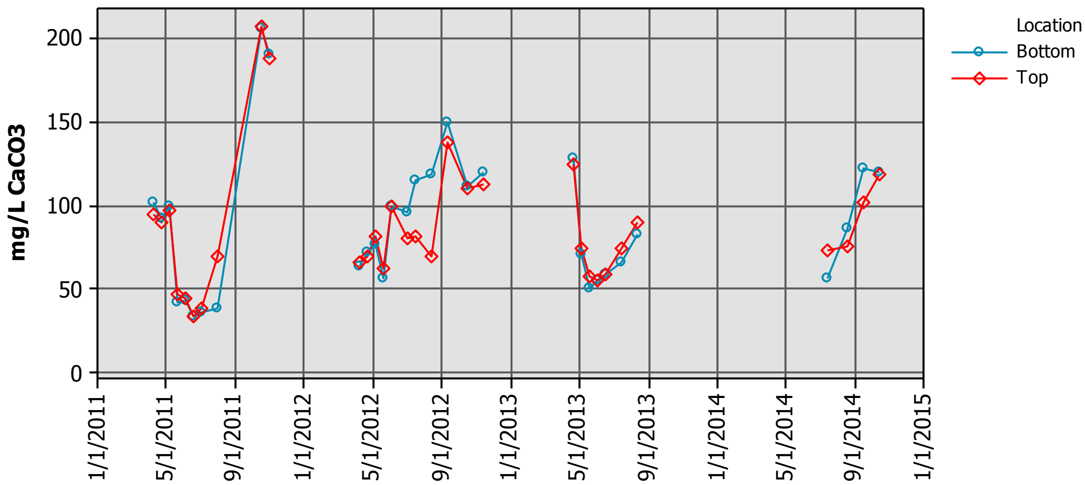
Specific Conductivity profiles measured in Seaman Reservoir (2014)



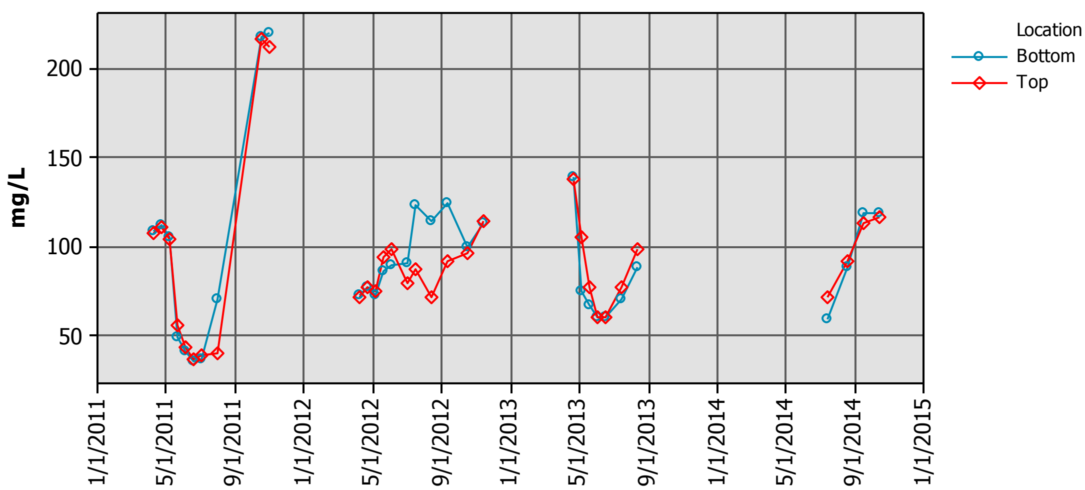
SEAMAN RESERVOIR

GENERAL PARAMETERS

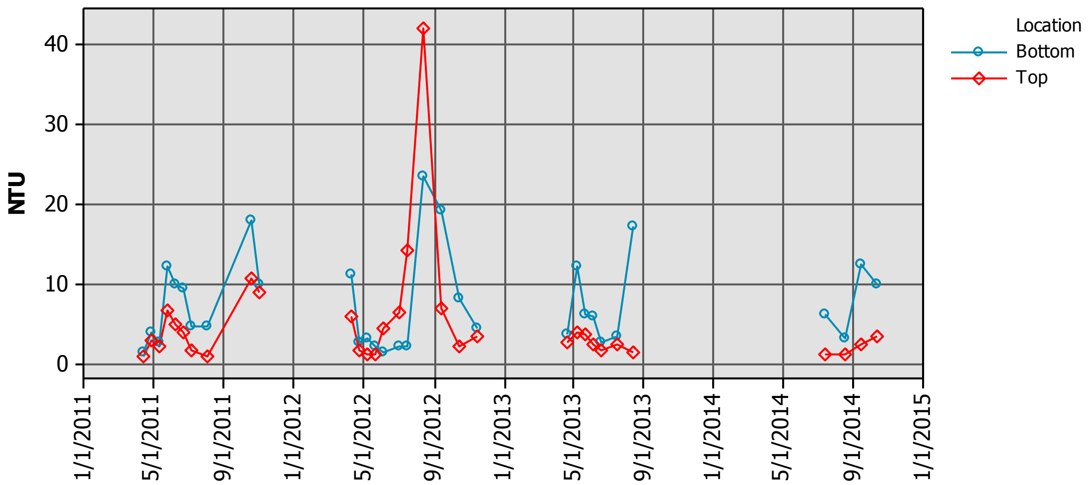
Alkalinity in Seaman Reservoir (SER)



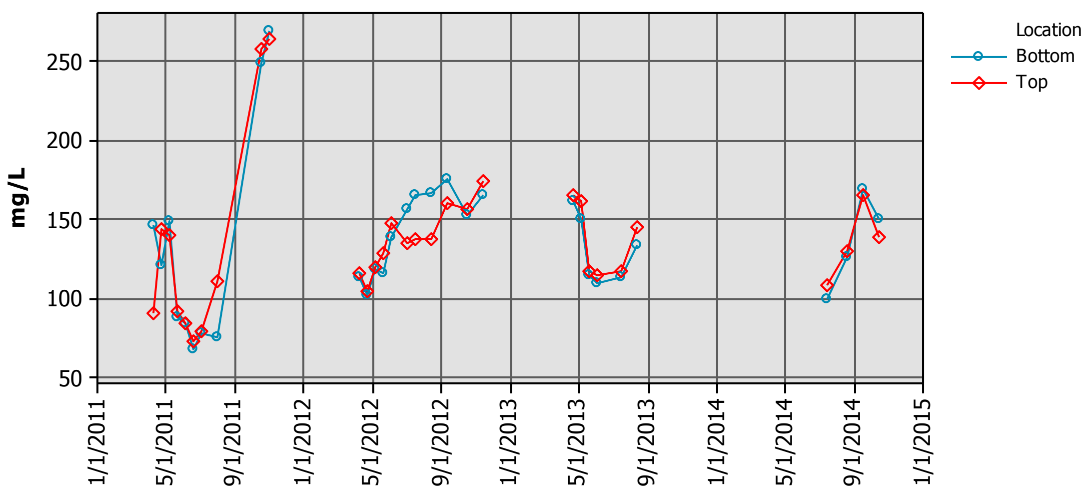
Hardness in Seaman Reservoir (SER)



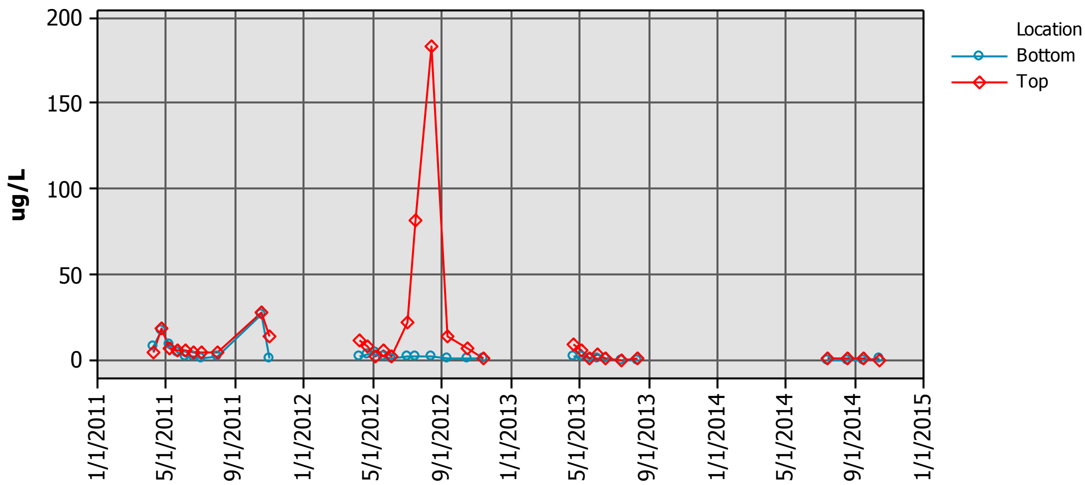
Turbidity in Seaman Reservoir (SER)



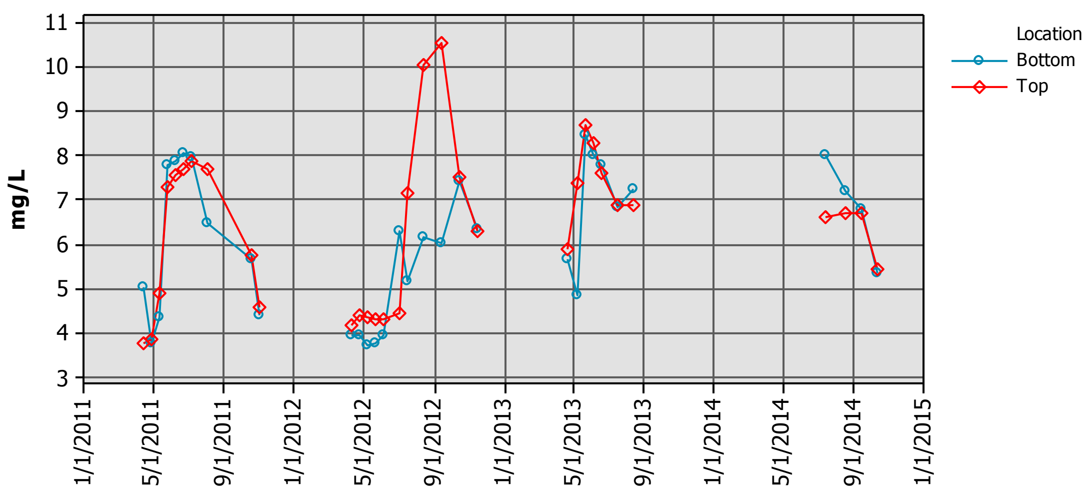
Total Dissolved Solids (TDS) in Seaman Reservoir (SER)



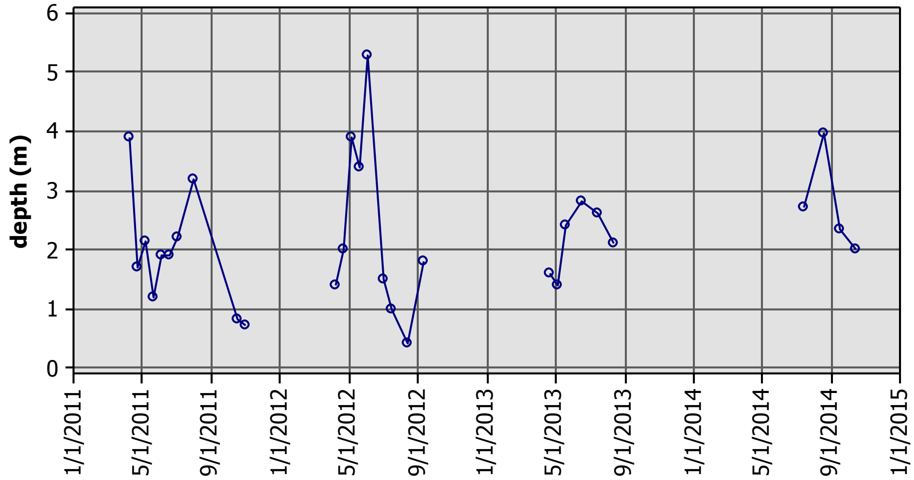
Chlorophyll-a iin Seaman Reservoir (SER)



Total Organic Carbon (TOC) in Seaman Reservoir (SER)



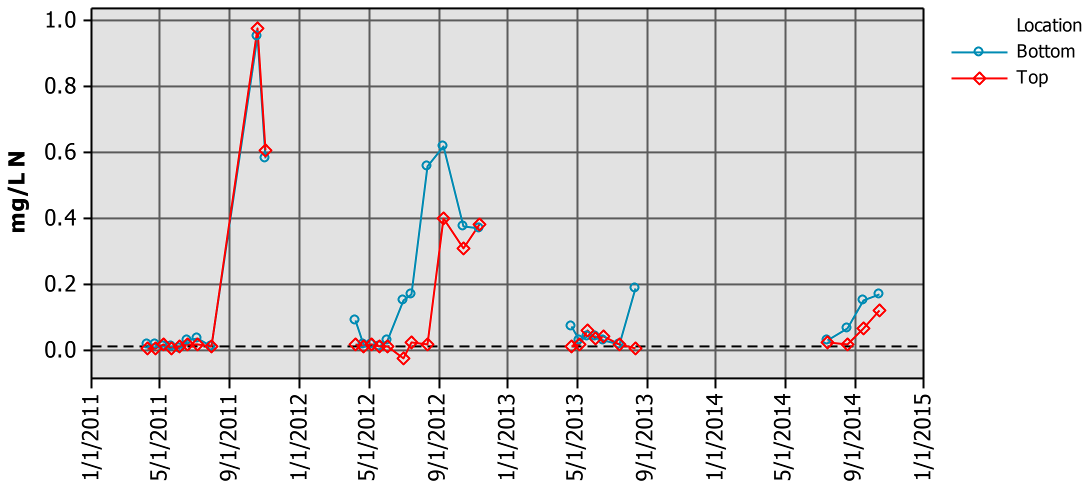
Secchi depth in Seaman Reservoir



SEAMAN RESERVOIR

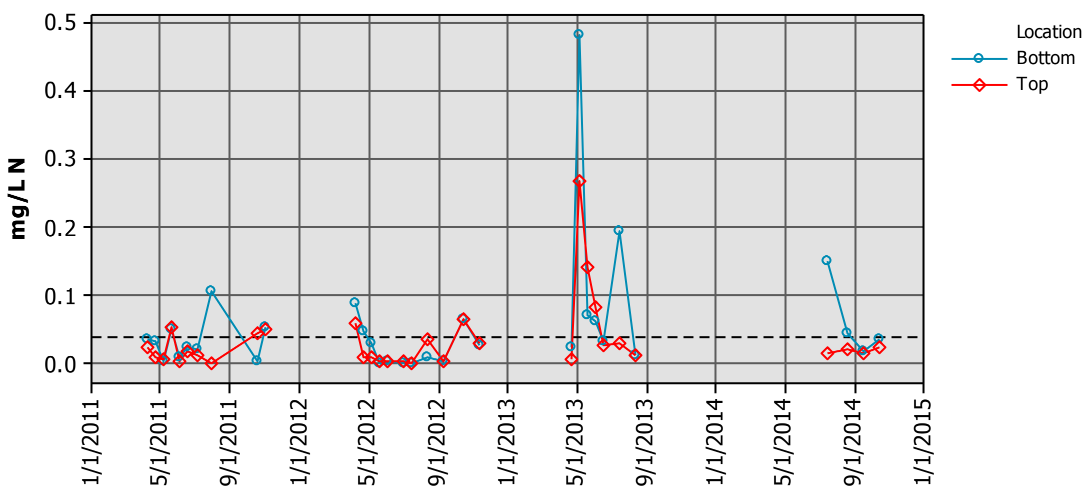
NUTRIENTS

Ammonia as nitrogen (NH3-N) in Seaman Reservoir (SER)



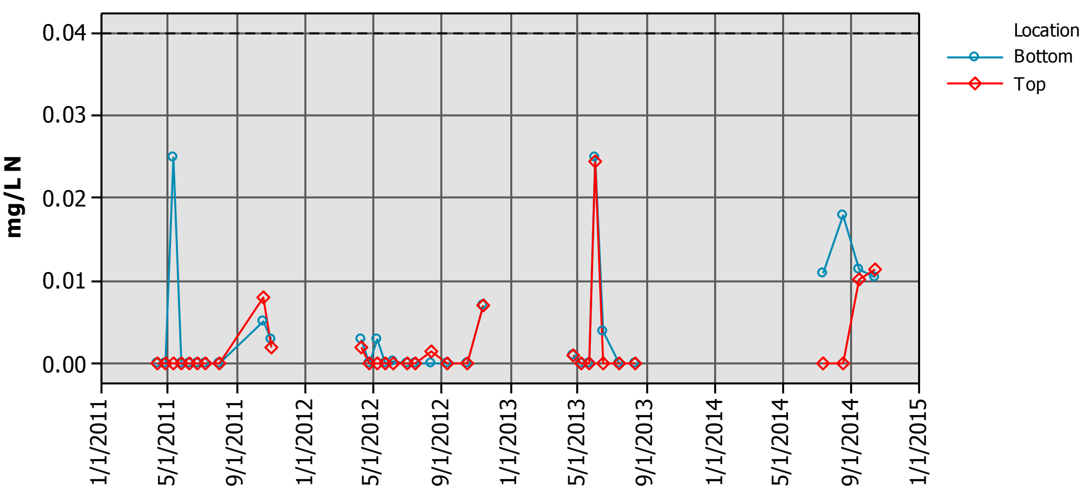
(- - - - FCWQL Reporting Limit; 0.01 mg/L)

Nitrate as nitrogen (NO3-N) in Seaman Reservoir (SER)



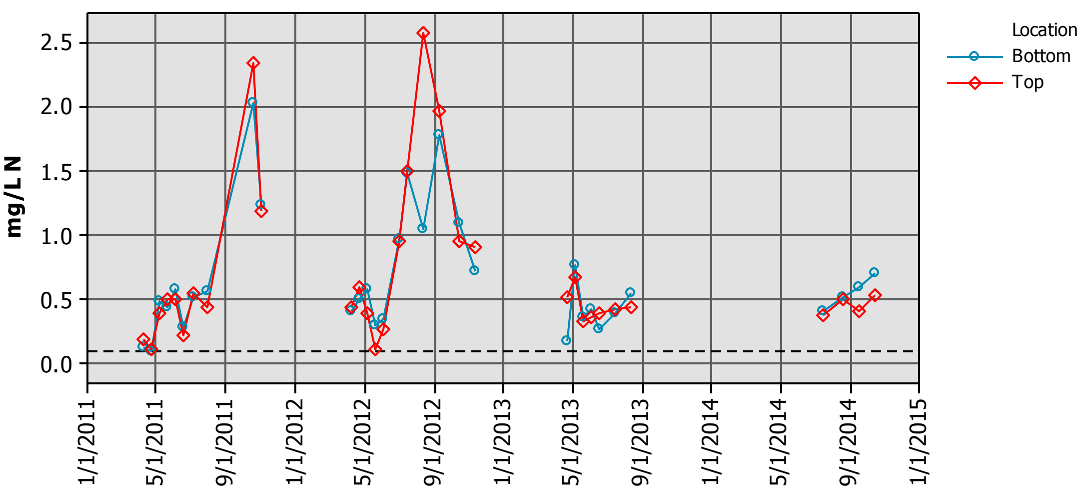
(- - - - FCWQL Reporting Limit; 0.04 mg/L)

Nitrite as nitrogen (NO2-N) in Seaman Reservoir (SER)



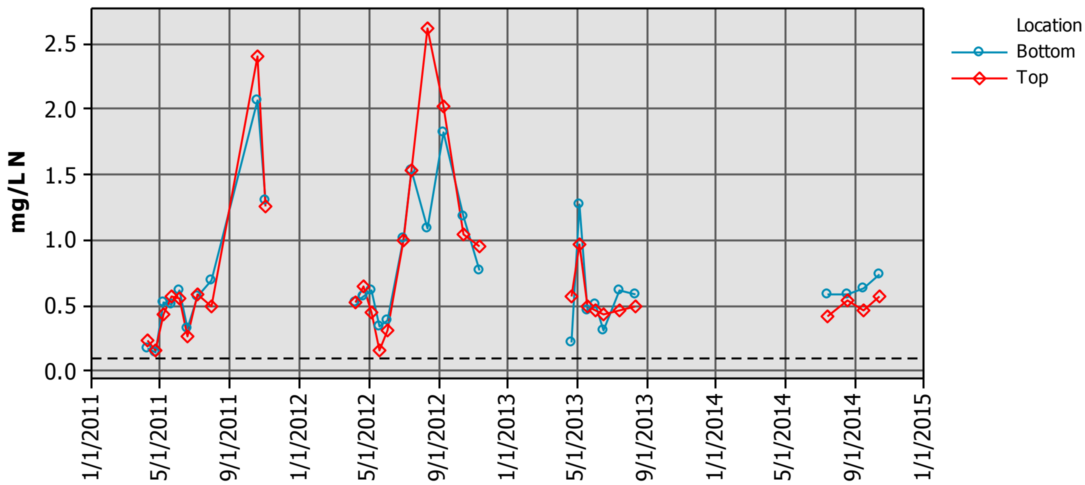
(- - - - FCWQL Reporting Limit; 0.04 mg/L)

Total Kjeldahl Nitrogen (TKN) in Seaman Reservoir (SER)

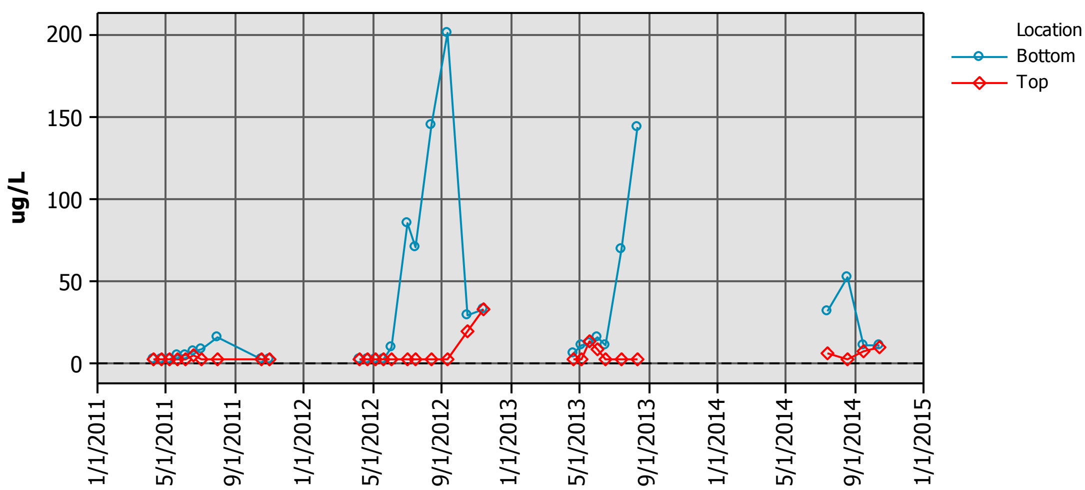


(- - - - FCWQL Reporting Limit; 0.100 mg/L)

Total Nitrogen (TKN + NO3-N + NO2-N) in Seaman Reservoir (SER)

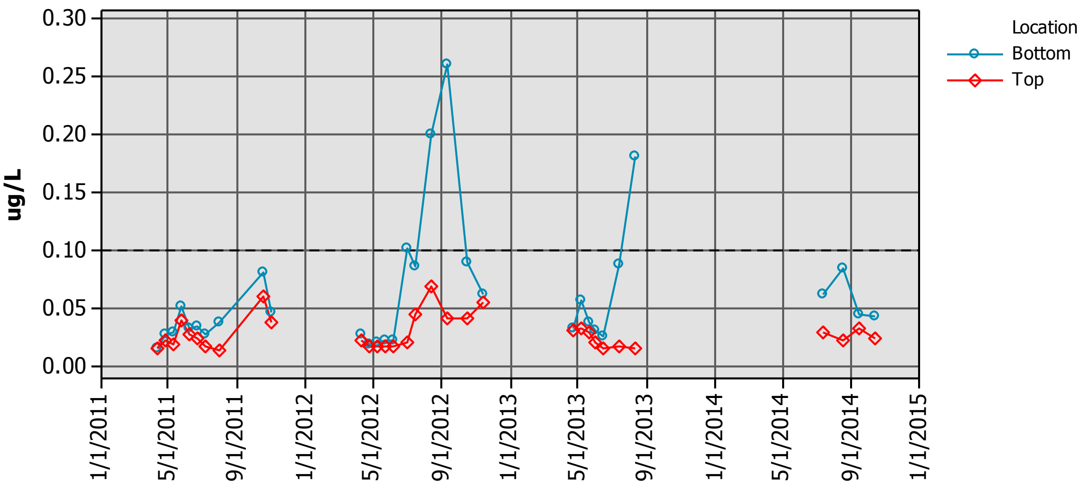


Ortho-phosphate (PO4) in Seaman Reservoir (SER)



(- - - - FCWQL Reporting Limit; 0.005 mg/L)

Total Phosphorus (TP) in Seaman Reservoir (SER)

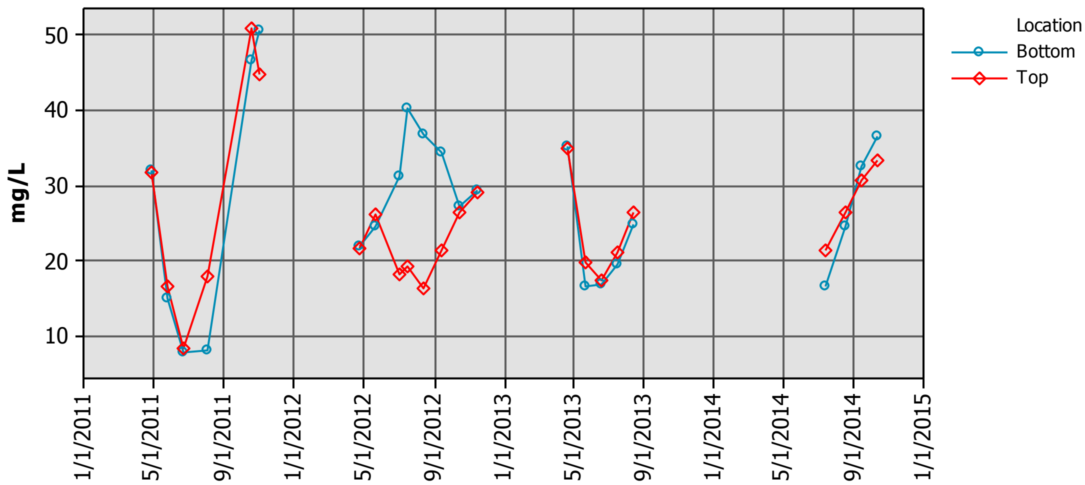


(- - - - FCWQL Reporting Limit; 0.010 mg/L)

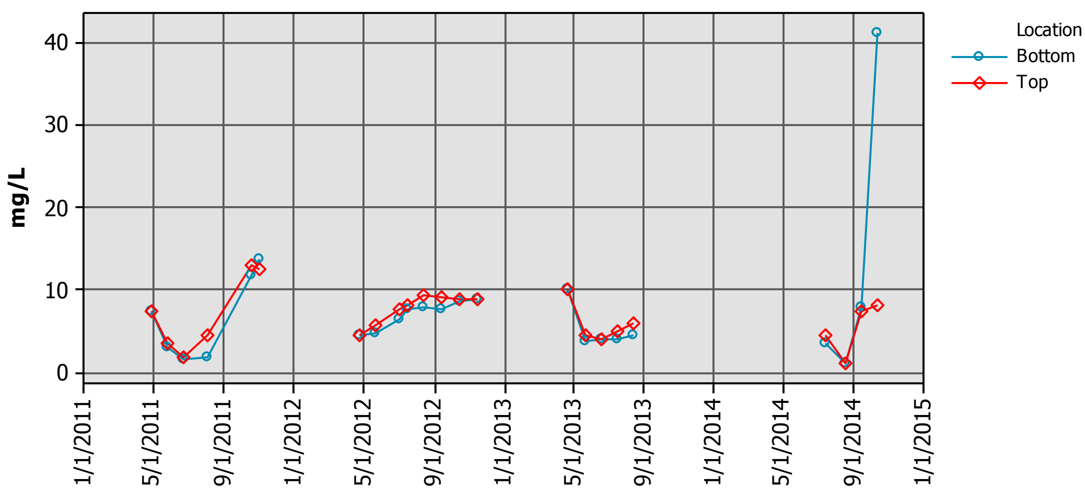
SEAMAN RESERVOIR

MAJOR IONS

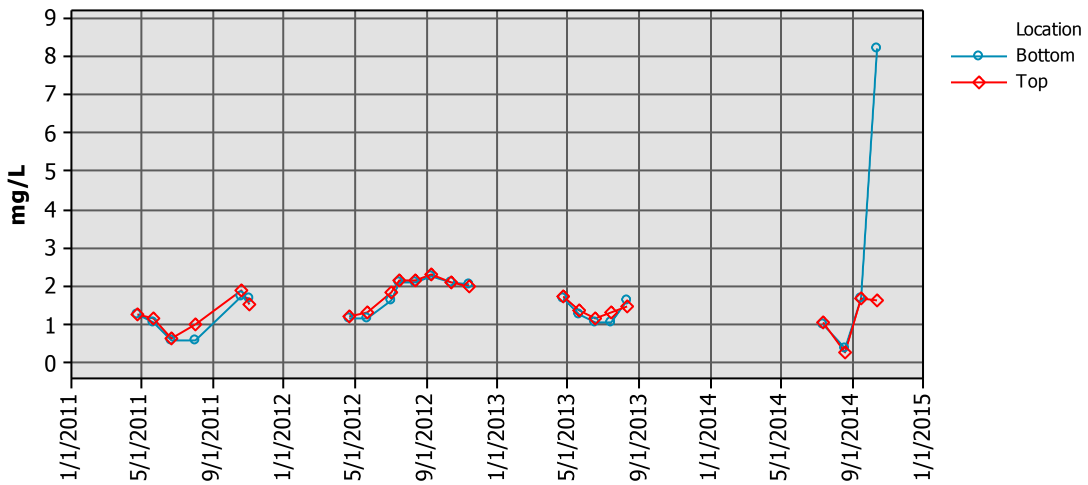
Calcium (Ca) in Seaman Reservoir (SER)



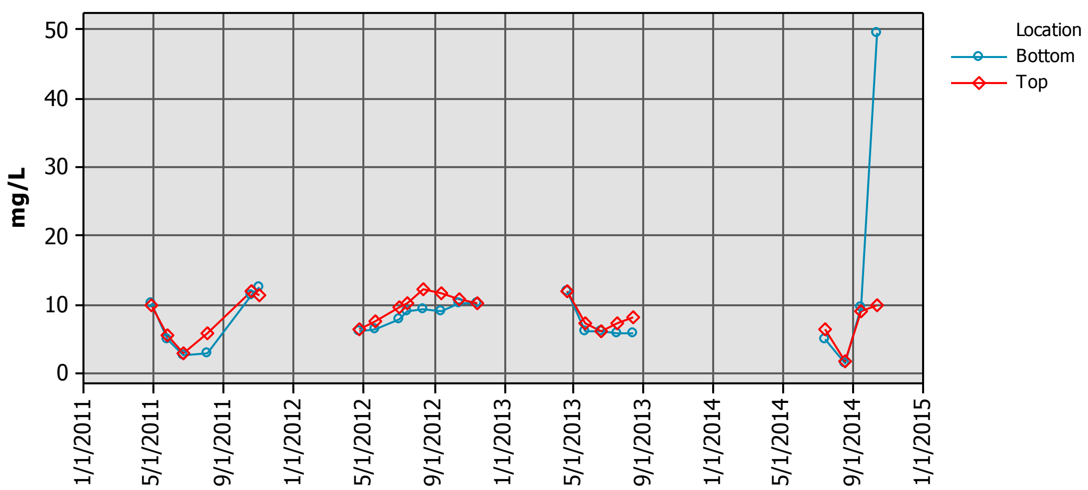
Magnesium (Mg) in Seaman Reservoir (SER)

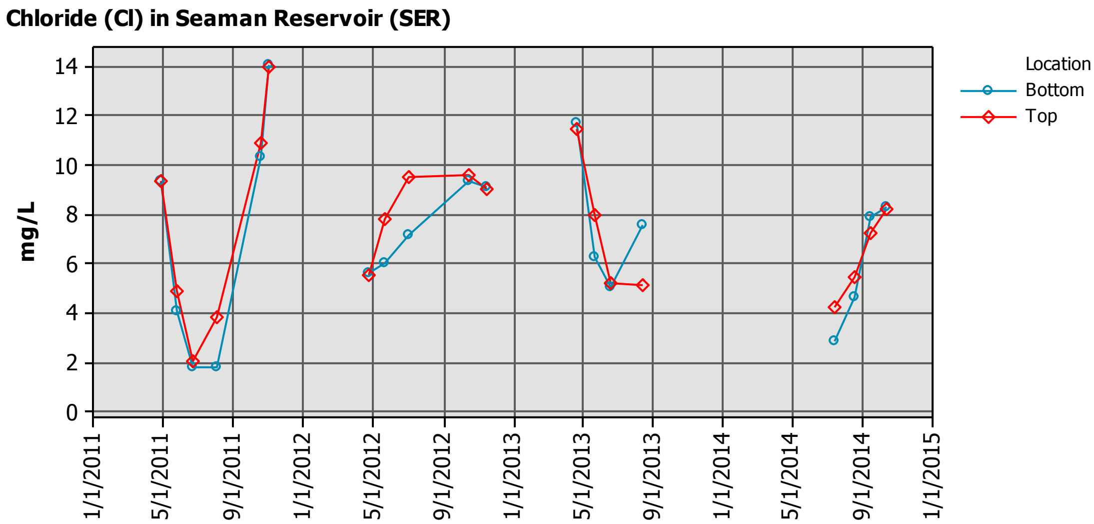


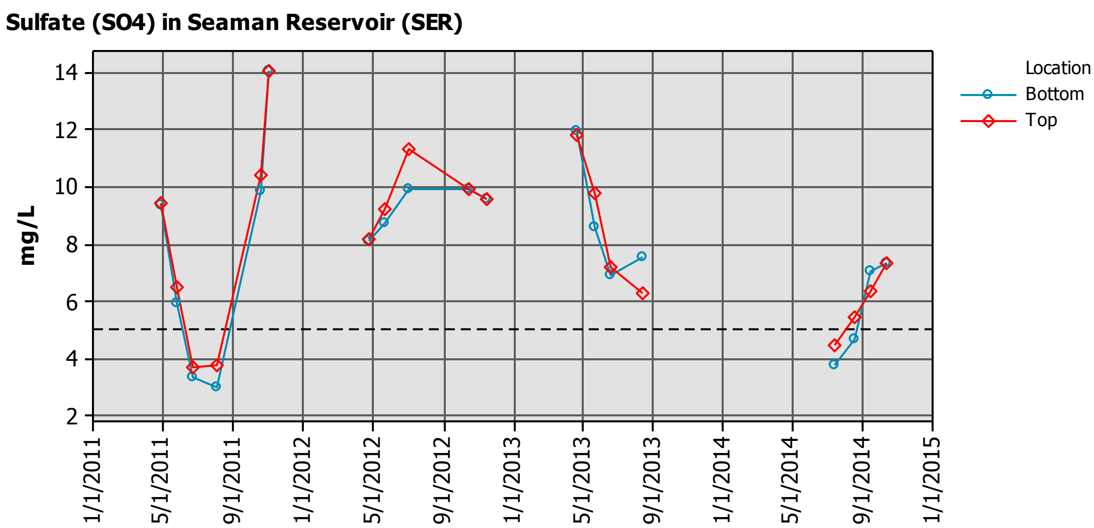
Potassium (K) in Seaman Reservoir (SER)



Sodium (Na) in Seaman Reservoir (SER)



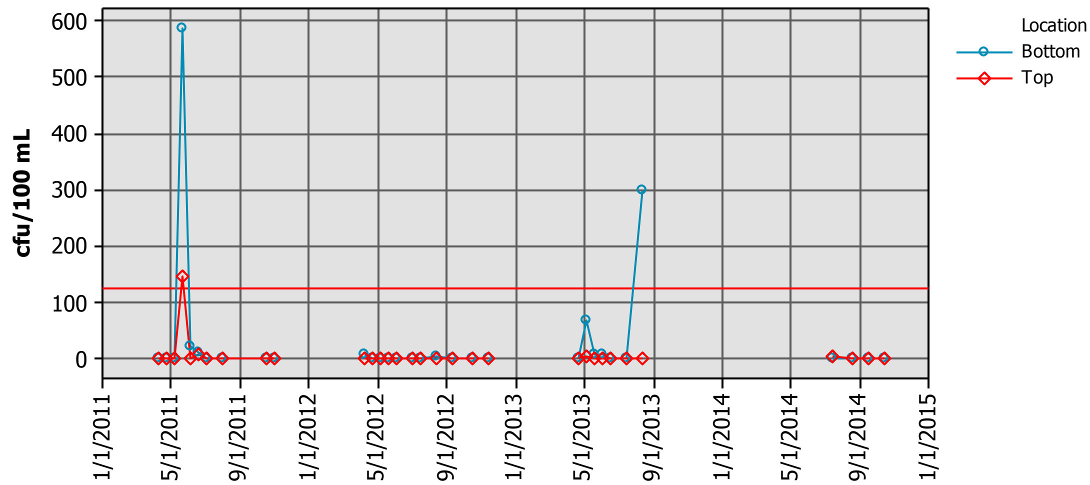

Chloride (Cl) in Seaman Reservoir (SER)
mg/L
14
12
10
8
6
4
2
0
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015
Location
Bottom
Top


Sulfate (SO4) in Seaman Reservoir (SER)
mg/L
14
12
10
8
6
4
2
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015
Location
Bottom
Top

MAINSTEM & NORTH FORK CLP WATERSHEDS

MICROBIOLOGICAL

E. coli in Seaman Reservoir (SER)



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

Total coliforms in Seaman Reservoir (SER)