2015 ANNUAL REPORT

Upper Cache la Poudre Watershed

Collaborative Water Quality Monitoring Program

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PREPARED FOR
Fort Collins Utilities
City of Greeley
Tri-Districts

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EXECUTIVE SUMMARY

BACKGROUND

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 summarizing 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). Water samples are analyzed for a total of up to 39 parameters.

SCOPE OF 2015 ANNUAL REPORT

This annual report summarizes the hydrologic and water quality data collected in 2015 and provides a comparison of water quality from the years 2012 – 2015. The report also summarizes significant events, issues of concern, results from special studies, and data quality control.

The main body of the report focuses on seven key sites that are considered representative of conditions throughout the Mainstem and North Fork CLP watersheds. Time-series 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 continues to provide a high quality drinking water supply for the City of Fort Collins, the City of Greeley, and the Tri-Districts. 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 water quality concerns were identified for the Mainstem or North Fork CLP that immediately impact drinking water quality or treatment operations.

Several river segments in the upper CLP are listed on Colorado's Section 303(d) List and Monitoring and Evaluation (M&E) List (Regulation #93) identifying impaired however, water quality data collected and analyzed as part of the upper CLP watershed collaborative monitoring program were measured below the WQCC's standards with the exception of short-lived exceedances in naturally occurring metals.

Elevated baseline nutrient levels continue to persist at wildfire-impacted monitoring locations lower in the watershed, and a basin-wide increasing trend in phosphate continues following the 2013 flood event. Despite these increases, nutrient concentrations remain low (near the reporting limit). Neither excess algal growth nor potentially associated taste and odor issues have been observed. Program staff will continue to monitor these trends in subsequent years.

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 2015, geosmin concentrations remained below the odor threshold at both sampling locations on the Poudre River. There were no reported geosmin-related customer odor complaints in 2015.

Emerging Contaminants

The Upper CLP watershed is largely free of land use practices that cause pharmaceuticals, personal care products, and endocrine disrupting compounds to enter surface waters. Emerging contaminants that have been detected in the Upper CLP since 2009 include 2,4-D, atrazine, caffeine, DEET and triclosan, which are associated with recreation and/or weed management along roadways near the river. The only compound detected during the 2015 monitoring season was 2,4-D on the North Fork.

Post-wildfire Watershed Recovery

Observable changes in water quality continued to occur during and following storm events at wildfire impacted monitoring sites. These events were limited in 2015 due to a dry summer monsoon season. Changes from baseline water quality conditions were short-lived and water quality conditions recovered within 24 hours. Storm event sampling will continue in 2016 as the watershed progresses towards recovery.

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 2012 through 2015.

The Colorado Department of Public Health and Environment's (CDPHE) secondary drinking water quality standards for dissolved iron and manganese were exceeded on the Mainstem and North Fork, respectively, but exceedances were short-lived. Compounds regulated under the secondary drinking water standards are not a threat to public health, but may impact the aesthetics of the finished water. The observed elevated iron and manganese concentrations did not affect the aesthetic quality of finished water supplies at any of the three water treatment facilities.

The Upper Cache La Poudre Watershed continues to provide a high quality drinking water supply for the City of Fort Collins, the City of Greeley, and the Tri-Districts.

Program Performance

Review of the 2015 Upper CLP Collaborative Water Quality Monitoring Program data indicate the program continues to adequately capture seasonal and annual trends and characteristics in water quality, while providing a spatial context for examining notable events and impacts to the watershed. Field quality assurance and control sampling indicated that data precision and accuracy were acceptable.

Monitoring and Protection Efforts in 2015

The Upper CLP Collaborative Monitoring Program will continue water quality monitoring and protection efforts in 2016. The 2016 efforts are listed below:

- Routine Water Quality Monitoring Program
- Emerging Contaminant Monitoring
- Geosmin Monitoring
- Storm Water & Watershed Recovery Monitoring
- Little South Fork Streamflow Monitoring

Joe Wright Creek on May 4th, 2015

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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
µg/L	micrograms per liter
µS/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 (CLP) River 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 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*),
- taste and odor (T&O) compound (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.

Seasonal updates and annual and five-year reports for the collaborative program are prepared by City of Fort Collins' Source Watershed Program staff to keep participants informed of current issues and trends in water quality of the Upper CLP. Seasonal updates are provided throughout the monitoring season in the Spring, Summer, and Fall. These updates include a seasonal summary of the Upper CLP watershed by highlighting seasonal precipitation, streamflow, and water quality conditions. The purpose of annual reports is to summarize hydrologic and water quality information for the current 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. The first five-year report was completed for the years 2008-2012 (Oropeza & Heath, 2013). Upper CLP updates and reports are available on the City of Fort Collins Utilities Source Water Monitoring website:

(www.fcgov.com/ source-water-monitoring).

1.2 WATERSHED DESCRIPTION AND SAMPLING LOCATIONS

Sampling efforts are divided between the Mainstem (including the Little South Fork Cache la Poudre River) 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 2015 monitoring network consists of 19 sampling locations selected to characterize the headwaters, major tributaries and downstream locations of the Upper CLP River 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.

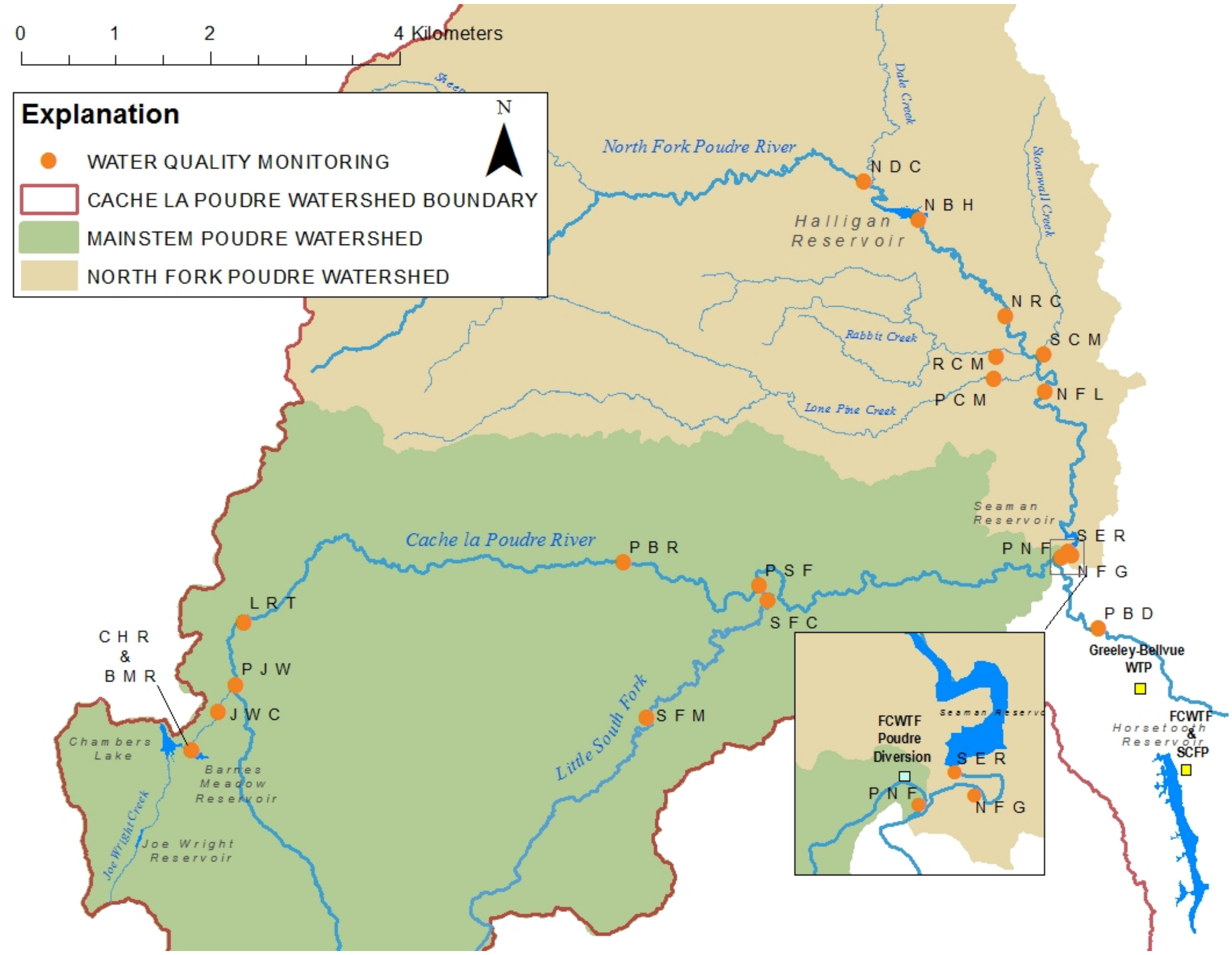

Figure 1.1 – Map of the Upper CLP collaborative water quality monitoring network.

In 2015, the South Fork above Mainstem (SFM) site was discontinued because data collected in 2014 at the new downstream location, South Fork above Mainstem Confluence (SFC) and SFM revealed comparable water quality conditions. A description and rationale for each site is provided in Attachment 2.

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 program design document by Billica, Loftis and Moore (2008). The 2015 sampling schedule is provided in 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 monthly from April through November at the top and bottom of Seaman

Reservoir in 2015. 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 environmental samples consist of field blanks and field duplicate samples, which are identified in the sampling plan (Attachment 4). Quality assurance and quality control of field blanks and field duplicates is discussed further in Section 4 of this document.

1.5 SCOPE OF 2015 ANNUAL REPORT

The 2015 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 2015 with the previous three years, 2012-2014.

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 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 Mainstem Poudre River raw water supply is monitored monthly for geosmin. The Upper 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.

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 in the CLP watershed focus on the following objectives:

- Identify areas on the Poudre River with high geosmin concentrations;
- 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).

The results of previous monitoring efforts suggest that concentrations at downstream sites are not well-predicted by upstream concentrations (Heath and Oropeza, 2014). In 2014, the number of sampling locations was reduced to two sites, PBR and PNF (Figure 1.1). PBR is an upstream site near Rustic that has historically seen relatively high geosmin concentrations and provides early-indication that conditions may be favorable for geosmin production elsewhere. The second location, PNF, is located near downstream water supply intakes and is intended to estimate concentrations that could be observed in raw water at the treatment facilities.

In 2015, samples were collected June through November at both sites. Geosmin concentrations remained below the 4 ng/L threshold at both sampling locations (Table1). Concentrations were reported slightly above the reporting limit (1 ppt or ng/L) at Poudre below Rustic (PBR) monitoring site from April through June, and then dropped below the reporting limit through the remainder of the sampling season. In contrast, geosmin concentrations were below the reporting limit at Poudre above the North Fork (PNF) monitoring site from April through July before increasing to a maximum concentration of 2.47 ppt on August 17th. Geosmin decreased at PNF following this date to near the reporting limit. There were no reported geosmin-related customer odor complaints.

Table 1 – Poudre River geosmin concentrations (ppt or ng/L) in 2015 at Poudre above the North Fork (PNF) and Poudre below Rustic (PBR) monitoring locations.

Date	Poudre below Rustic (PBR)	Poudre above North Fork (PNF)
4/6/2015	1.94	BDL
5/4/2015	1.05	1.06
6/8/2015	1.04	BDL
7/13/2015	BDL	BDL
8/17/2015	BDL	2.47
9/14/2015	BDL	2.4
10/12/2015	BDL	1.62
11/9/2015	BDL	1.13

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 suspected of water quality problems. Colorado's Section 303(d) List and M&E List for the 2016 listing cycle were adopted on January 11, 2016 and became effective on March 1, 2016. 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.

The Section 303(d) Listing Methodology and Colorado's Section 303(d) List is scheduled for review every two years. Segments of the Mainstem and North Fork Cache la Poudre River on the State of Colorado's Section 303(d) List of impaired water and M&E List, as of March 1, 2016 are listed in Table 2. Segments with 303(d) impairment require total maximum daily loads (TMDLs) and are prioritized with respect to TMDL development from low (L) to high (H) priority.

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
COSPCP02a	Cache la Poudre River including all tributaries from the boundaries of RMNP, and the Rawah, Neota, Comanche Peak, and Cache la Poudre Wilderness Areas to the South Fork Cache la Poudre River	all		As, Aquatic Life (provisional)	H/L
COSPCP06	Mainstem of the North Fork of the Cache la Poudre River, including all tribs from source to Halligan Reservoir	all		As	L
COSPCP07	North Fork of the Cache la Poudre from Halligan Reservoir to the Cache la Poudre	all	As, Ag, Fe(Dis)	Pb, Cd, Mn	M L
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	pH	As	L
COSPCP10a	Mainstem of the Cache la Poudre River from the Munroe Gravity Canal Headgate to the Larimer County Ditch diversion	all		Temperature, As	M/L
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) are becoming more widely recognized as a water quality concern. 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 2015, 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 *2015 Emerging Contaminants Program Annual Report* (Northern Water, 2015).

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 2015, 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. In 2015, 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).

The Poudre River is largely free of land use practices that cause pharmaceuticals, personal care products, and endocrine disrupting compounds to enter surface waters. These compounds are typically linked to wastewater effluent. Emerging contaminants that have been detected in the Upper CLP since 2009 include 2,4-D, atrazine, caffeine, DEET and triclosan, which are connected to recreation and/or weed management along canals and roadways. The only compound detected during the 2015 monitoring season was 2,4-D (<10 ng/L) in August at NFG (Northern Water, 2015).

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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.

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. The burned area includes numerous sub-drainages that are tributary to the Mainstem and the South Fork.

The 2012 wildfires caused dramatic changes to land cover within the Upper CLP watershed that had an immediate effect on watershed hydrology and water quality within and downstream of the burn scars. The disturbance has caused an increase in streamflow and sediment erosion into streams draining burned sub-basins specifically during and following high-intensity storm events. The loss of vegetative cover altered the cycling of water, carbon, nutrients and other elements directly influencing water quality in the Poudre River.

Upper CLP monitoring sites that were impacted by the wildfires were limited to the middle to lower elevations of the watershed and included South Fork above the Mainstem Confluence, SFC, the Poudre below the South Fork (PSF), PNF, the North Fork below Seaman Reservoir (NFG), and the Poudre at the Bellvue Diversion (PBD) (Figure 1.1). Routine data collected from these monitoring locations (pre- (2008 to 2012) and post-wildfire (2012-present)) are valuable for evaluating the impacts of wildfire on CLP water quality (non-event based) and watershed recovery.

In addition, early warning instrumentation was installed in 2013 to provide warning alerts of impacted river water quality to water treatment plant staff and trigger event-based stormwater monitoring. Event-based stormwater monitoring has been conducted since 2013 to evaluate storm impacts to water quality. In 2015, an automated stormwater sampler was installed at the City of Fort Collins raw water intake structure to increase event-based stormwater sampling efficiency due to uncertainty in the timing of storm events and availability and safety of staff during storm events.

Wildfire impacts on background (non-storm event) water quality were still evident in 2015. Background nutrient concentrations, specifically nitrate as nitrogen (NO_3-N), ammonia as nitrogen (NH_3-N), and ortho-phosphate (PO_4), remained elevated in 2015 compared to pre-fire conditions.

Storm events over the Upper CLP watershed, causing short term impairments to water quality, were limited in 2015 due to a relatively inactive monsoon season. There were only two storm events in 2015 that caused short term water quality impairment. One notable event was recorded on August 16th from early warning instrumentation upstream of the City's raw water intake structure. Prior to the event, river turbidity was 2 NTU. Over a two hour period, turbidity increased to a peak value of 805 NTU. Turbidity values returned to pre-storm values within 24 hours of the observed peak. Unfortunately, the automated stormwater sampler failed to collect samples during this event.

The elevated background nutrient concentrations and stormflow response on August 16th demonstrate that after-effects of the 2012 wildfires are still occurring. The Upper CLP Collaborative Monitoring Program will continue to sample event-based storm water quality in 2016 to track watershed recovery.

Storm events over the Upper CLP watershed, causing short term impairments to water quality, were limited in 2015 due to a relatively inactive monsoon season.

3.0 UPPER CACHE LA POUDRE WATERSHED RESULTS

For the 2015 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

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; finalized 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 two key sites on the Mainstem: Poudre above Joe Wright Creek (PJW) and South Fork of the Poudre above the Confluence (SFC). Discharge values for PJW represent instantaneous discharge measurements collected on the specified sampling dates, while SFC represents continuous streamflow data throughout the monitoring season.

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. Continuous streamflow data from the South Fork at SFC was collected and managed by the City of Fort Collins. 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 the timing and magnitude in discharge, spatial and temporal trends in snowpack, snow water equivalent, and temperature need to be considered, as snowmelt is the dominant driver of 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. 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.

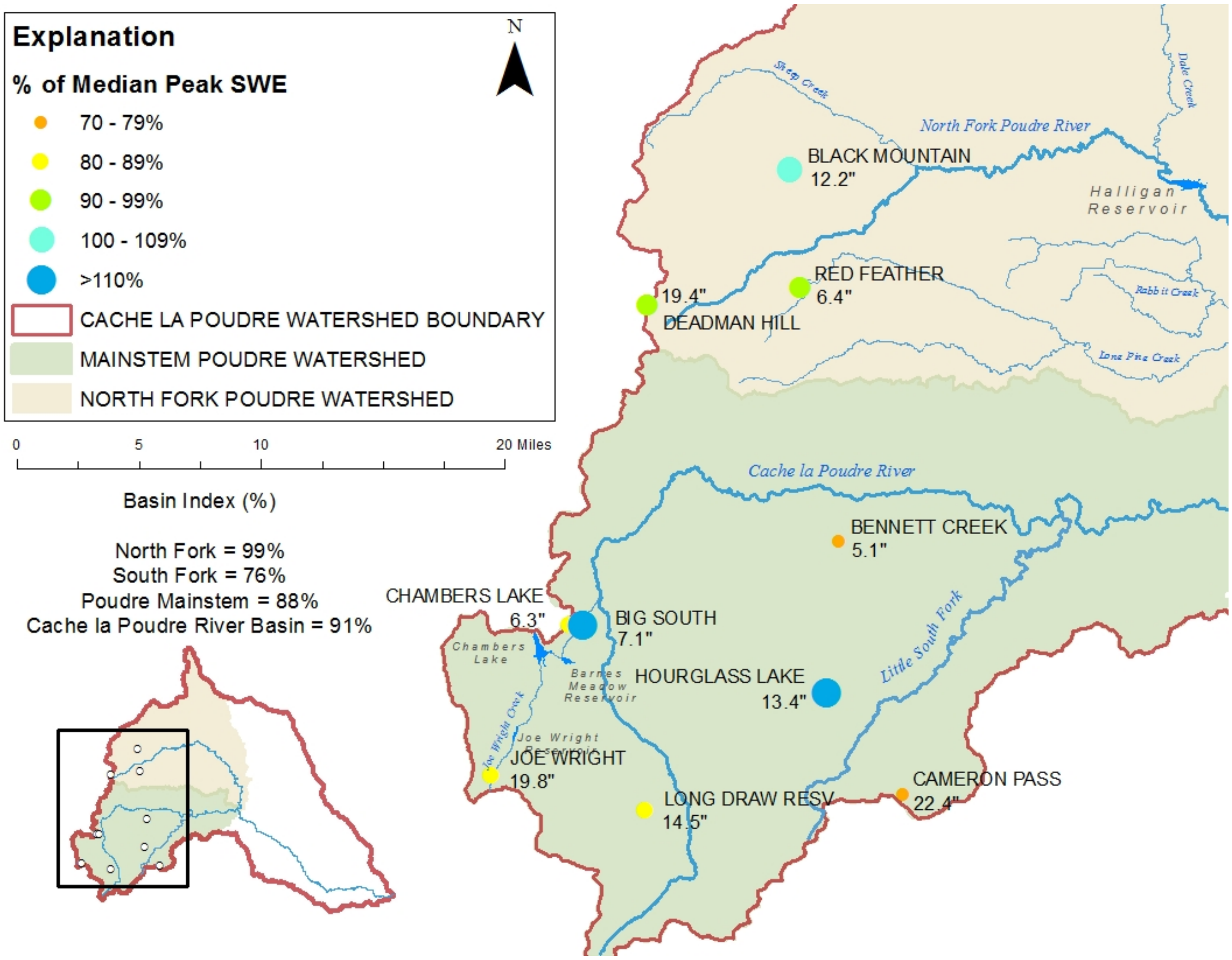

Figure 3.1 – Locations of SNOTEL and snow course monitoring sites in the UCLP and percent of median peak snow water equivalent (SWE) in for the 2015 water year.

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 stations and 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 Poudre basin (Figure 3.1).

On an annual basis, higher elevation sites receive 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 2015, peak SWE across the entire Cache la Poudre Watershed was 91% of the expected peak SWE based on the long term average. The North Fork basin was 99% of average, while the South Fork and Mainstem Poudre basins were below average reporting basin indices of 76% and 88%, respectively (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 evolution of the snowpack, in terms of accumulated water and snowmelt, compared to the historical average and previous three years (Figure 3.2).

The start of the 2015 snow accumulation season was dry and below normal. The first measureable snowfall was observed towards the end of October followed by steady snowfall through the end of November. Snow water equivalent was recorded near the long-term median in early December, but conditions became quite dry with no measured precipitation until mid-December. A large winter storm in the later part of the month brought several inches of water, but was followed by a dry January with below normal SWE through early 2015.

A steady increase in SWE was observed beginning in February through the first week of March, but conditions were dry through mid-April when the snowpack began to show signs of an early snowmelt. Significant snowfall increased SWE at Joe Wright by nearly 5 inches beginning in mid-April. Peak SWE was measured at 19.8 inches on April 27th compared to the historical median peak SWE of 23.8 inches measured on April 29th (Figure 3.2). The snowpack began to melt following peak, but steady late season snow storms continued to impact the Northern Colorado Mountains and Upper CLP through May extending the snow accumulation season by nearly one month. Snowmelt runoff began in late May and the by mid-June the 2015 snowpack was completely melted at Joe Wright (Figure 3.2).

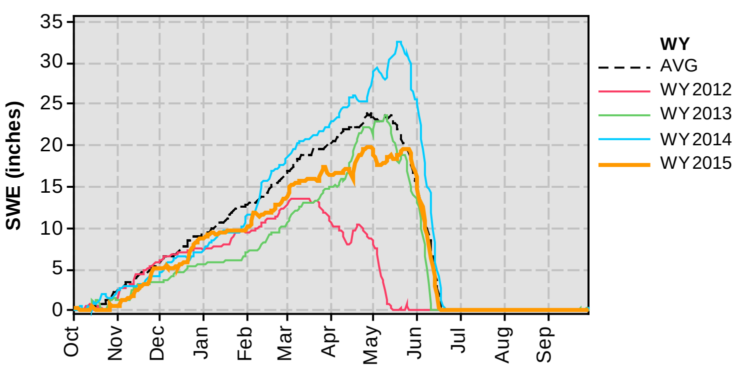

Figure 3.2 – Snow water equivalent measured at Joe Wright SNOTEL site near Cameron Pass over the 2012-2015 water years (October 1, 2014 – September 31, 2015).

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 subsequent

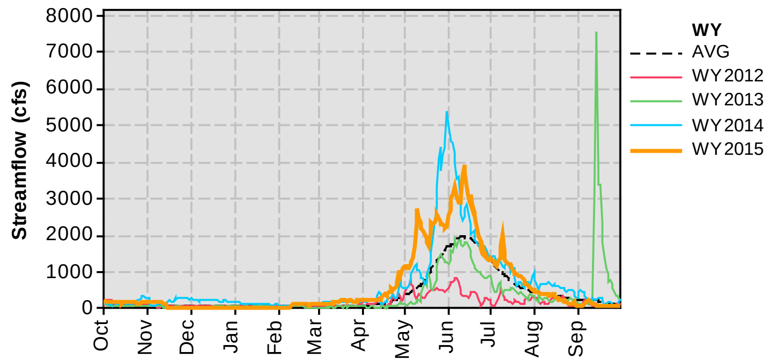

Figure 3.3 – Streamflow measured over the 2012-2015 water years at the CLP at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station.

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 contributions 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).

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 2015, winter baseflow conditions remained above average. A significant spring snow storm in mid-April brought several feet of snow to the lower elevations of the watershed, which resulted in a rapid rise in the snowmelt hydrograph through mid-May. Streamflow receded after another late spring snowstorm slowed the snowmelt cycle higher in the watershed. Multiple spikes in streamflow continued through May due to extended melt freeze cycles lengthening the duration of the 2015 snowmelt runoff. A peak streamflow of 3,910 cubic feet per second (cfs) was measured on June 12th, which was six days later and 182% of the long-term average. Streamflow began to rapidly recede following peak and remained near average through the remainder of the season with the exception of two notable storm events, which were observed on July 5th and August 16th. Baseflow conditions beginning in mid to late August were below average for the remainder of the 2015 water year.

Wildfire impacts on streamflow, including debris flows and flooding, were less common on the Mainstem during the 2015 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 315,379 acre-feet of water flowed down the Poudre River above the Munroe Tunnel and North Fork in 2015. This is 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 February 9th 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 2016. In addition, the streamflow gage on the Little South Fork was not online until late March 9th, 2015 and was taken offline for the season on November 19th.

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.

In 2015, releases from Long Draw Reservoir contributed 27,453 acre-feet (5%) of water to the Poudre River, which was 94% of 2014 water volumes. Most of this contribution occurred in July (10,999 acre-feet) with the highest percentage contribution (24%) in August (Table 2 and Figure 3.4).

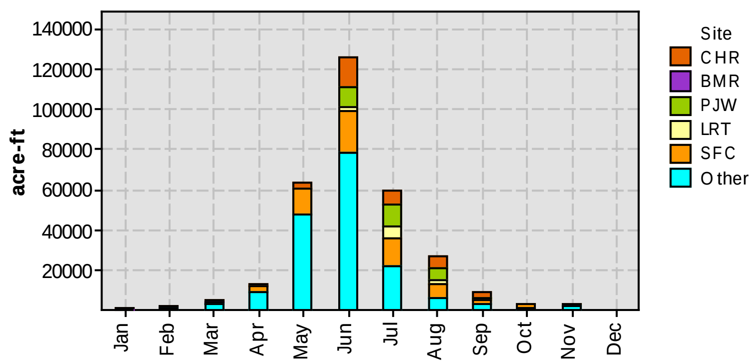

Figure 3.4 – Bar graph of tributary contributions by month to the Mainstem CLP above the Munroe Tunnel in 2015. Note that continuous flow measurements were not available for calculating "other" flow in January, February, and December.

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 Poudre River. Water releases from Chambers Lake contributed 39,894 acre-feet of water in 2015 accounting for 8% of the total water in the Poudre River basin (Table 3 and Figure 3.4), and 85% of 2014 contributions. 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 the winter months. Water is released from Barnes Meadow into Joe Wright Creek, below Chambers Lake, before entering the Poudre River downstream. In 2015, Barnes Meadow Reservoir contributed 384 acre-feet of water, which represents less than 1% of annual Poudre River volume, compared to 20% in 2014. The greatest monthly contribution occurred in March (Table 3 and Figure 3.4).

Table 3 – Tributary contributions by month to the Mainstem Cache la Poudre River above the Munroe Tunnel in 2015. 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	103		1,230		-		-		-		-	-	-	
Feb	137	7%	1,111	57%	-		-		-		697	36%	**1,945**	
Mar	144	3%	1,230	26%	-		-		744	15%	2,697	56%	4,814	------
Apr	-	0%	726	6%	-		-		3,091	24%	8,985	70%	12,802	------
May	-	0%	3,798	6%	-		-		12,527	20%	47,377	74%	63,702	------
Jun	-		15,356	12%	1,317	1%	10,303	8%	21,256	17%	77,871	62%	126,104	------
Jul	-		7,607	13%	5,574	9%	10,399	17%	13,894	23%	22,079	37%	59,553	------
Aug	-		5,320	20%	1,955	7%	6,228	24%	7,292	28%	5,704	22%	26,499	------
Sep	-		3,056	36%	321	4%	477	6%	1,927	22%	2,784	33%	8,564	------
Oct	-		461	14%	-		46	1%	1,671	50%	1,187	35%	3,365	------
Nov	-		-		-		-		984	36%	1,719	64%	2,703	------
Dec	-		-		-		-		-		-		-	
Total	384		39,894		9,167		27,453		63,386		171,100		310,051	

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 Poudre River. In general, the LRT diverts water beginning in late April through early September. In 2015, water diversions from the Laramie River began in late June. The LRT contributed 9,167 acre-feet (3%) of water to the CLP in 2015, which was 73% of 2014 contributions. Water delivery from the LRT ended on September 10th.

The largest tributary in the Upper CLP (above the confluence with the North Fork Poudre) is the 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 2015, the South Fork contributed 63,386 acre-feet (20%) of water to the Poudre River (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 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 the North Fork to Mainstem flows (measured at PBD). Although, streamflow at NFG is regulated by reservoir operations, the snowmelt hydrographs for NFL and NFG are typically very similar. During snowmelt runoff, if Seaman Reservoir is at capacity, the majority of flow going into Seaman Reservoir spills over the emergency spillway. When reservoir storage capacity is available, inflowing water may be stored in the reservoir or bypassed through the outlet structure depending on the river call priority regime at the time of available capacity. Reservoir operations generally influence streamflow later in the season following snowmelt runoff, as a result of water releases from both Halligan and Seaman Reservoirs.

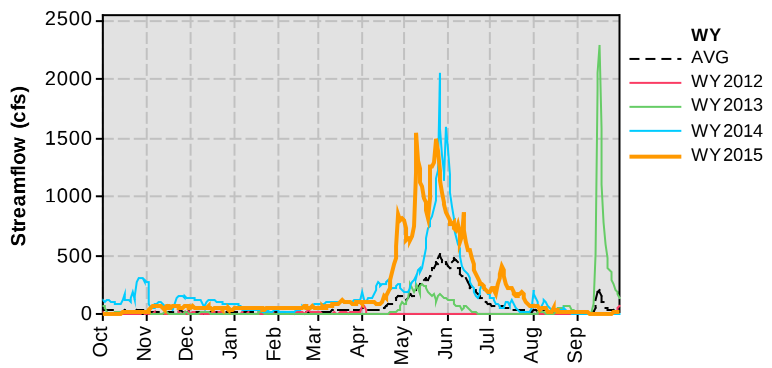

Figure 3.5 – Streamflow measured over the 2012-2015 water years at the North Fork CLP River below Seaman Reservoir (CLANSECO) streamflow monitoring station.

In an average year, peak streamflow on the North Fork is observed from late-May to early-June (Figure 3.5). In 2015, snowmelt runoff began in mid-April, reaching peak runoff earlier than normal on May 10th at a discharge of 1,550 cfs at NFG. Peak streamflow in 2015 was three times the average peak flow (435 cfs) at NFG (2005-2014). A late spring snowstorm slowed the snowmelt cycle higher in the watershed lessening the magnitude of peak streamflow, but also lengthened the duration of streamflow runoff. In mid-May snowmelt runoff resulted in second peak of 1,480 cfs on May 23rd. Streamflow steadily decreased to near baseflow conditions following the second peak (Figure 3.5). Water was released periodically from reservoirs throughout the rest of the season.

In 2015, the combined volume of water on the Mainstem at PBD was 368,991 acre-feet during averaged over the months of May through June from 2012 through 2015. The North Fork contributed 34% of total acre-feet to the Mainstem, which was the highest water contribution from the North Fork over the four year period (Figure 3.6).

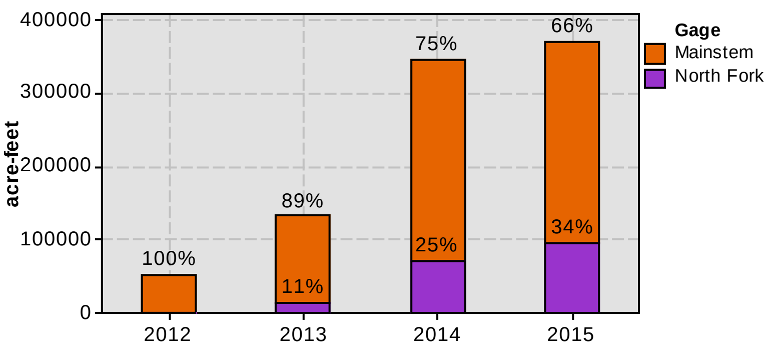

Figure 3.6 – Proportion of average Mainstem and North Fork contributions at PBD during May and June from 2012 through 2015.

3.2 WATER TEMPERATURE

Water temperature increases with decreasing elevation throughout the watershed (Figure 3.7a). 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 August when air temperatures are the greatest and streamflow is low. The highest stream temperatures typically occur on the lower North Fork (NFL and NFG) presumably due to relatively low flows and differences in elevation between the Mainstem and North Fork watersheds.

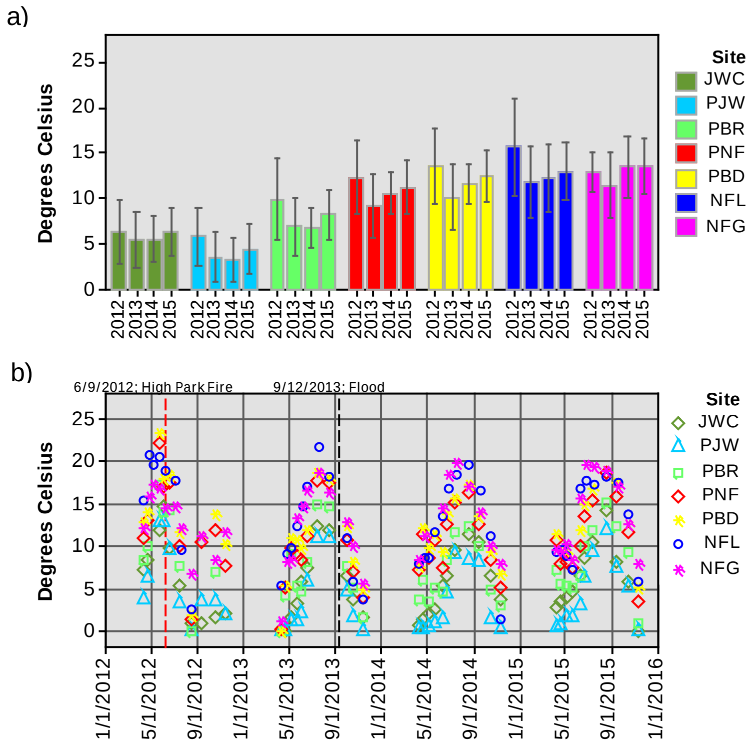

Figure 3.7 – a) Average water temperature at key sites in the Upper CLP watershed from 2012 through 2015 and b) water temperature at key Upper CLP monitoring sites from 2012 through 2015.

In 2015, water temperatures in the Upper CLP watershed followed similar temporal and spatial patterns to the three previous years. Mean water temperatures were slightly greater than 2013 and 2014, but lower than the drought year 2012 with the exception of NFG which exhibited warmer temperatures in 2014 and 2015 (Figure 3.7a). Water temperature throughout the Upper CLP watershed ranged from 0.05°C at PJW on November 9th to a maximum temperature of 19.5°C at NFG on June 23rd. Maximum temperatures at sites along the Mainstem and NFL were observed in August (Figure 3.7b). Temperatures at PJW and NFG were likely influenced by Long Draw and Seaman Reservoir, respectively, which can result in colder stream temperatures due to cold water being released from the bottom of these reservoirs. Following the annual maximum, water temperatures decreased at all sites through the remainder of the monitoring season to the lowest temperatures observed over the 2015 monitoring season (Figure 3.7).

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 in late-fall and winter, while minimum concentrations are observed during snowmelt runoff. In general, concentrations increase with decreasing elevation and increasing contributing watershed area.

Spatial and temporal patterns were similar in 2015 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 range of expected values throughout the 2015 monitoring season on the Mainstem (21.4 µS/cm – 114.4 µS/cm; 8.0 mg/L – 60.3 mg/L; and 9.0 mg/L – 60.4 mg/L, respectively). The lowest concentrations on the Mainstem were measured on June 22nd. The highest concentrations were observed in late summer and fall, which were greater than the previous three years, except at PJW.

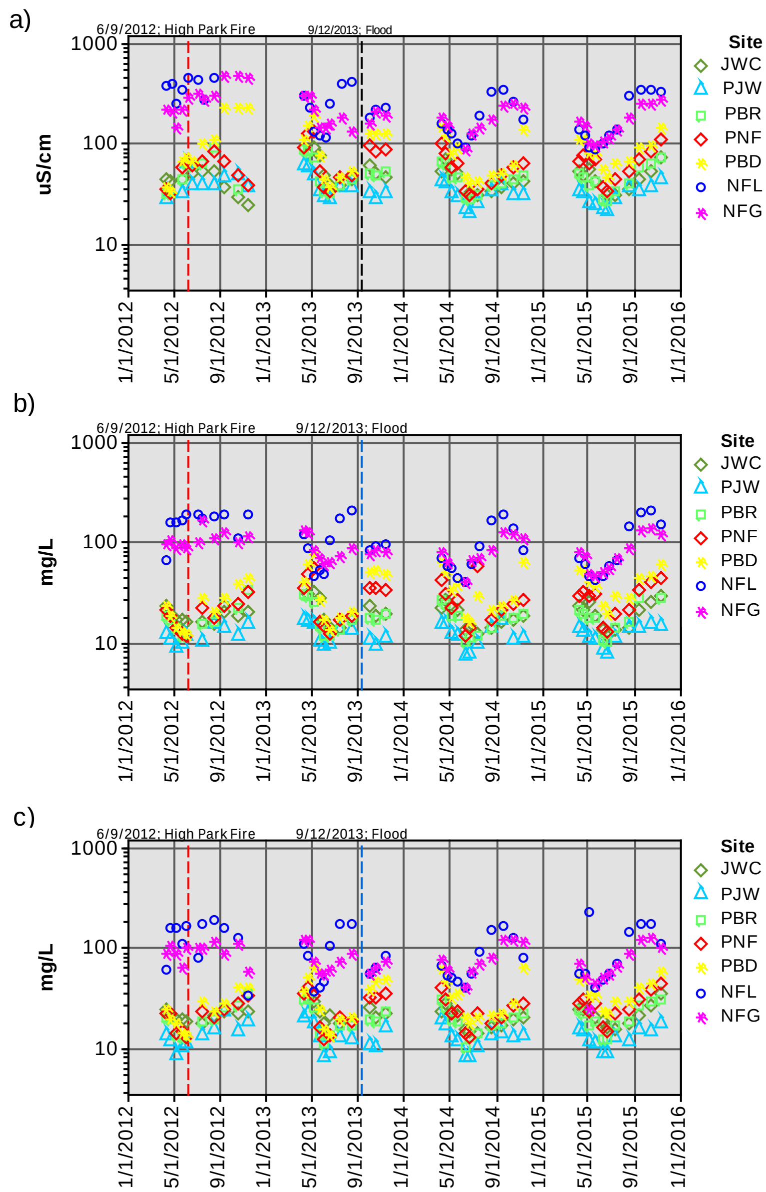

Figure 3.8 – General water quality parameters a) specific conductance, b) hardness, and c) alkalinity measured at key Upper CLP monitoring sites.

North Fork watershed concentrations were higher and more variable across monitoring locations as compared to Mainstem sites. The highest concentrations were monitored on tributary sites (Rabbit Creek (RCM), Stonewall Creek (SCM), and Lone Pine Creek (PCM)) (see Attachment 7, pp. 61, 62, and 63). Specific conductivity, hardness, and alkalinity concentrations measured at NFL and NFG range from 81.4 µS/cm – 346.3 µS/cm, 40.2 mg/L – 229.4 mg/L, and 43.0 mg/L – 208.8 mg/L, respectively. The greatest factors likely driving higher concentrations throughout the North Fork watershed are land use, changes in streamflow, 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.

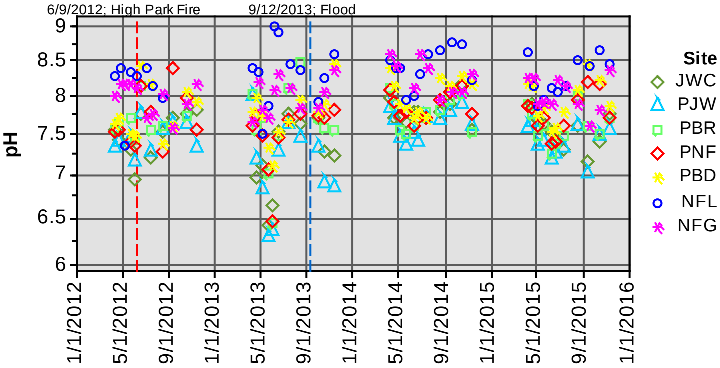

Figure 3.9 – pH levels measured at key Upper CLP monitoring locations from 2011 through 2014.

In 2015, 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 (6.30 – 9.00), but did not experience as much variability as 2013. All sites showed a decrease in pH during spring runoff and then increased following snowmelt runoff. Summer and fall pH trends varied between Mainstem and North Fork sites as well as between years. In 2015, pH on the Mainstem ranged from 7.01 at PJW on September 14th to 8.21 at PBD on October 12th. Values on the North Fork were greater than the Mainstem and ranged from 7.61 to 8.64.

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. Following peak snowmelt runoff, turbidity values steadily decrease to values near 1 NTU on the Mainstem with values approaching 10 NTU on the North Fork. The highest turbidity values in the fall are observed at NBH and NFG (see Attachment 7, p. 64).

Turbidity values in 2015 followed seasonal patterns similar to pre-fire and pre-flood conditions. Snowmelt peak turbidity values on May 4th ranged from 5 NTU at PJW to 18 NTU at PNF and were nearly two times greater than observed in 2012 (Figure 3.10). The lower snowmelt peak turbidity values in 2012 were related to drought conditions and the river's decreased capacity to move sediment due to lower than normal streamflow.

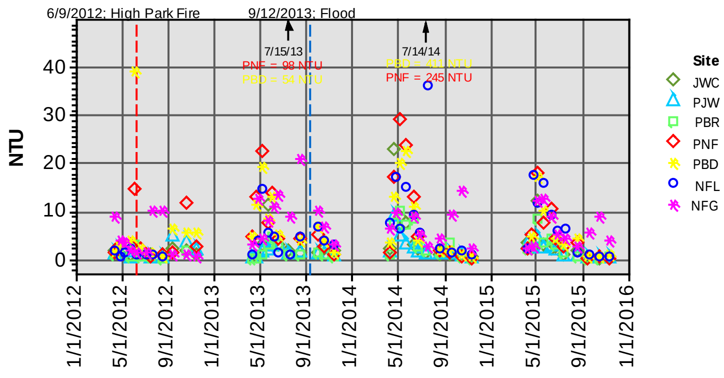

Figure 3.10 –Turbidity levels measured at key Upper CLP monitoring locations from 2012 through 2015.

A greater degree of variability was observed following the High Park wildfire (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 impact of the wildfires was still evident in 2015 when storm event on August 16th caused turbidity values to spike from 2 NTU to a peak value of 805 NTU in less than 2 hours. Turbidity values recovered within 24 hours of the event (Figure 3.11). The watershed response to the high intensity precipitation event in August indicates the 2012 wildfires continue to impact Cache la Poudre water quality, but the events are typically short-lived.

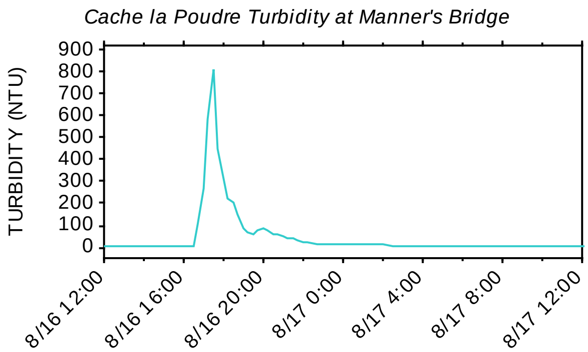

Figure 3.11 – Turbidity spike measured at the early warning turbidity sensor above the City of Fort Collins intake on August 16th.

The maximum values observed during snowmelt runoff in 2015 were 18.2 NTU on the Mainstem at PNF and 17.7 NTU on the North Fork at NFL. Overall, values ranged from 0.36 to 18.2 NTU, excluding the August 16th sampling event (Figure 3.10). As seen in previous years, a late season spike in turbidity (10 NTU) was observed in 2015 at NFG downstream of Seaman Reservoir. This spike in turbidity at NFG was not of sufficient magnitude or load to impact downstream turbidity at Greeley's water supply intake (<1 NTU at PBD) when mixed with Mainstem water.

3.4 TOTAL ORGANIC CARBON

Total organic carbon (TOC) is a measure of the total concentration of dissolved and particulate organic matter in water. TOC 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. Unlike most water quality constituents, there is a direct relationship between streamflow and TOC meaning that as streamflow increases TOC concentrations increase and vice versa. Concentrations are highly variable during the spring and summer, but begin to stabilize in the fall and early winter when streamflow is low. TOC concentrations at most sites are normally low (<5 mg/L) during baseflow conditions and then begin to increase during snowmelt. In a normal year, annual maximum TOC values occur in early May after the onset of spring snowmelt and before peak streamflow. The timing and magnitude of concentrations are highly dependent on the timing and magnitude of snowmelt runoff and the availability and mobilization of carbon.

Concentrations are less variable between monitoring locations throughout the watershed. The highest TOC concentrations are observed at BMR and LRT. Maximum concentrations measured at LRT have been measured at nearly 1.5 times the maximum concentration measured on the Mainstem (see Attachment 7, pg. 66). The highest concentration measured over the past four years was 21.75 mg/L. The overall load to the Mainstem is generally low due to the timing, magnitude, and duration of water releases from these sources. In recent years, following the High Park Fire, debris flows and flooding from burned hillslopes caused temporary increases in TOC concentrations in July and August at wildfire impacted sites (PNF and PBD).

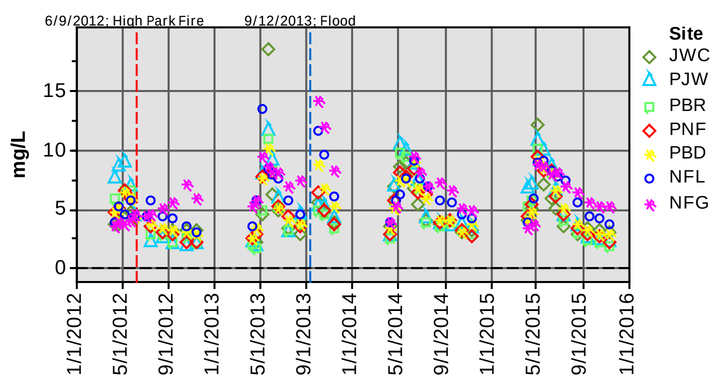

Figure 3.12 – Total organic carbon (TOC) concentrations measured at key Upper CLP monitoring locations from 2012 through 2015.

In 2015, TOC concentrations on the Mainstem followed expected seasonal trends and were within the range of values observed over the previous three years. Concentrations were low and relatively stable in April, but increased rapidly during snowmelt runoff to annual maximum concentrations on May 6th. Peak concentrations at key sites range from 9.12 mg/L at PBD to 12.1 mg/L at JWC (Table 3.12), and higher concentrations up to 23 mg/L were measured at LRT (see Attachment 7, pg. 66). TOC concentrations steadily decreased during the summer months to baseflow concentrations of less than 5 mg/L at all sites by August 17th and continued to remain low through the remainder of the monitoring season.

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. In the North Fork watershed, TOC is normally highest at Rabbit Creek (RCM) and Lone Pine Creek (PCM) during snowmelt runoff from April through May or June, but the magnitude of concentrations at these sites is variable from year to year. In contrast, the lowest TOC concentrations are observed at Stonewall Creek (SCM) (see Attachment 7, pg. 66). Concentrations at this site remain low throughout the monitoring season and do not vary greatly throughout the year because Stonewall Creek is primarily fed by ground water as opposed to snowmelt.

The North Fork Cache la Poudre River experiences snowmelt driven changes in TOC concentrations. Concentrations on the North Fork are typically below 5 mg/L prior to spring snowmelt and then increase rapidly following the onset of snowmelt runoff. Peak TOC concentrations are characteristically observed in early to mid-May. TOC concentrations slowly decrease throughout the remainder of the season to baseflow concentrations following peak.

The two monitoring locations situated below Seaman and Halligan Reservoir (NFG and NBH, respectively) remain slightly elevated in the late summer and fall relative to other sites in the upper CLP watershed. The elevated TOC levels at these sites suggest additional sources of TOC, which may be caused by reservoir hydrochemical processes. Elevated TOC concentrations on the North Fork at NFG can influence downstream concentrations at PBD. This is especially evident in the late summer and fall when comparing concentrations between PBD and PNF.

In 2015, TOC dynamics on the North Fork were similar to the Mainstem (Figure 3.12). In early April, TOC concentrations were 3.9 mg/L at NFL and 3.5 mg/L at NFG before increasing during snowmelt runoff to peak concentrations of 9.1 mg/L and 8.8 mg/L on May 20th and May 5th, respectively. Concentrations at NFL and NFG steadily decreased through the remainder of the year following peak. TOC concentrations were near 5 mg/L at NFG by September and remained at this concentration through November. The slightly elevated TOC concentrations in September and October at NFG were diluted by flows in the Mainstem, as suggested by TOC comparisons between PNF and PBD during those months. TOC concentrations were slightly elevated at PBD compared to PNF in November suggesting some influence from the North, however, concentrations still remained low.

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 cause abundant growth 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, erosion, and atmospheric deposition.

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.

Total nitrogen (TN) is the sum of TKN and inorganic nitrogen (NO_3-N and NO_2-N). TKN is a measure of ammonia plus organic nitrogen and comprises the largest fraction of TN, with inorganic nitrogen representing lesser fractions. 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

Nitrogen

Seasonal and spatial patterns of nitrogen on the Mainstem are generally consistent from year-to-year. The highest nitrogen concentrations are typically observed early in the snowmelt period due to the flushing of finite pools of inorganic and organic nitrogen from soils, in combination with the release of atmospherically derived nitrogen contained within the snowpack. Nitrogen concentrations steadily decrease on the Mainstem following snowmelt runoff into the summer months with the exception of storm-driven nutrient spikes in recent years at monitoring locations located within the burn scar.

In 2015, total nitrogen (TN) concentrations on the Mainstem Poudre River were similar across sites, but were generally lower than the previous three years (<10 – 5,018 µg/L N, from 2012 – 2014) (Figure 3.13). Total nitrogen concentrations ranged from 138 µg/L to 770 µg/L at key sites in 2015 with a median value of 288 µg/L. The highest concentrations were observed during snowmelt at wildfire impacted sites. The nitrogen pulse during snowmelt is an expected seasonal response in river water quality especially in areas affected by wildfires of high and moderate burn severity (Rhoades, 2011; Smith, 2011). This water quality response was most pronounced in 2015, especially in NO_3-N at PNF (Figure 3.14), because of significant late-season snow accumulation over the burn scar and subsequent snowmelt and delivery of nitrogen to the Mainstem.

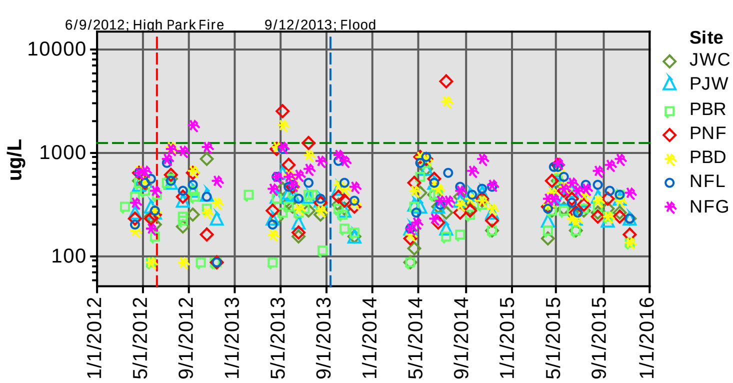

Figure 3.13 – Total nitrogen concentrations at key Upper CLP monitoring locations.

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

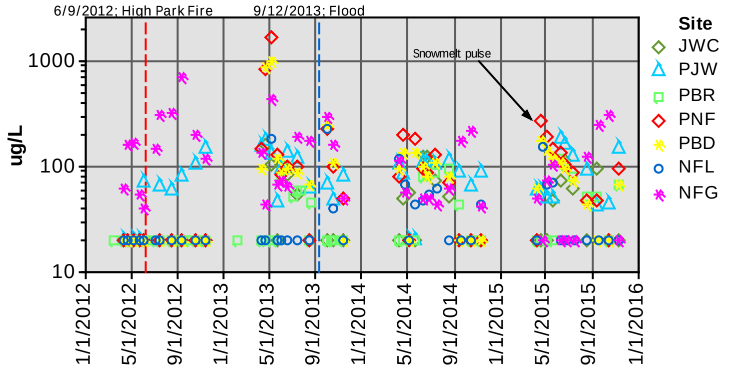

Figure 3.14 – Nitrate as nitrogen concentrations at key Upper CLP monitoring locations.

In contrast to previous years, the variability of total nitrogen on the Mainstem was lower (Figure 3.15). Temporal and spatial variability is usually quite low throughout the watershed, but monitoring locations located within the burn area (PNF and PBD) have experienced infrequent, yet significant, spikes in nitrogen, primarily during snowmelt runoff and rainstorm events.

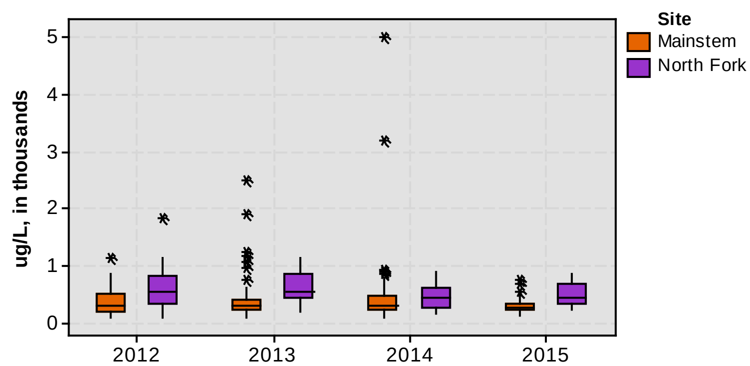

Figure 3.15 – Distribution of total nitrogen concentrations on the Mainstem and North Fork.

Post-fire background (non-storm event) nitrogen concentrations were elevated at fire impacted monitoring locations in 2012 through 2014, but concentrations were lower in 2015. TKN concentrations were notably lower in 2015, but NO_3-N and NH_3-N concentrations remained elevated. The monsoon season was dry in 2015 compared to previous years, which limited erosion from the burn scar and delivery of organic nitrogen to Mainstem surface waters.

Phosphorus

Total phosphorus (TP) concentrations on the Mainstem typically increase during snowmelt and decrease through the summer months into the fall. In contrast, ortho-phosphate generally does not follow temporal or spatial trends. In recent years, phosphorus concentrations at lower elevations in the watershed (PNF and PBD) have experience infrequent spikes as a result of impacts from the High Park Fire.

In 2015, TP concentrations were within the range of values observed over the previous three years (10 µg/L – 1000 µg/L). The Mainstem Poudre had a median TP concentration of 14 µg/L with concentrations between 5 µg/L and 75 µg/L in 2015. The peak concentration was observed during snowmelt at PJW on June 22nd. Annual maximum TP concentrations at lower elevation sites were observed earlier in 2015 on May 4th. Concentrations decreased following the snowmelt pulse to near the reporting limit (Figure 3.16b).

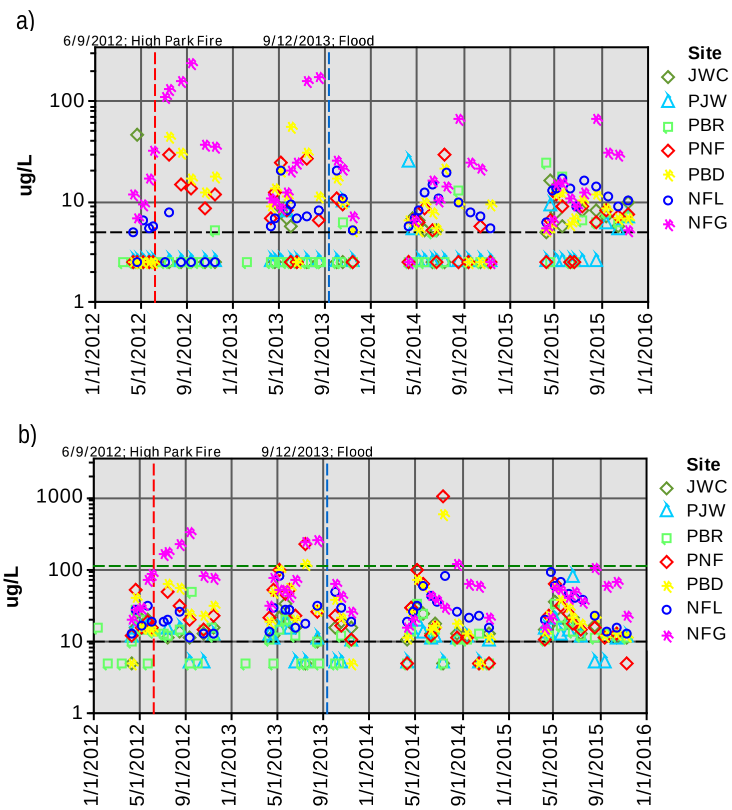

Figure 3.16 – Nutrient concentrations for a) ortho-phosphate and b) total phosphorus at key Upper CLP monitoring locations.

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

Ortho-phosphate (PO_4) concentrations measured in 2015 were within the range of values observed over the previous three years (<5 µg/L – 56 µg/L); however the median PO_4 concentration (7 µg/L), although only slightly above the reporting limit, was higher than the previous three years (Figure 3.16a). Historically, concentrations have been low with reportable levels measured at BMR and LRT. Beginning in 2012, PO_4 concentrations were measured above the reporting limit more often and at more monitoring locations. This basin wide observation may be a combination of drought conditions and wildfire in 2012 further exacerbated by the flood event in 2013.

Soil erosion is a major source of phosphorus to surface waters. Large flood events not only deliver large amounts of soil from the surrounding watershed into surface waters, but also cause severe bank and channel erosion. The flood event may be responsible for increasing PO4 concentrations throughout the watershed. Elevated PO_4 concentrations persisted through 2015 at wildfire impacted monitoring locations.

North Fork Poudre River

In general, nutrient concentrations are higher on the North Fork compared to the Mainstem (Figure 3.15). Elevated nutrient concentrations are generally observed at upstream North Fork tributary sites during snowmelt runoff. These higher concentrations likely occur 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 streamflow, especially during the summer months, and represent small contributions to overall streamflow and nutrient loads to NFL. Most nutrients on the North Fork River increase slightly with decreasing elevation. Halligan and Seaman Reservoirs appear to be both a source and sink for nutrients in the North Fork watershed.

Nitrogen

TN on the North Fork followed a similar seasonal pattern and was within the range of values observed over the previous three years (<10 µg/L – 1,857 µg/L). The highest concentrations were observed in late-April 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 2015 at NFL were slightly lower than previous years and ranged from 236 µg/L to a peak concentration of 753 µg/L on May 21st (Figure 3.13). In comparison, TN at NFG ranged from 358 µg/L to a peak concentration of 876 µg/L measured on October 12th. The peak concentration at NFG observed in the fall is likely related to reservoir dynamics. Higher peak concentrations were observed in the North Fork tributaries at RCM and PCM (1,400 µg/L and 1,110 µg/L, respectively) during snowmelt runoff. Concentrations at NRC were slightly higher than concentrations downstream at NFL suggesting the tributaries may be sources of nitrogen (see Attachment 7, pg.73).

A slight increase in NH_3-N has been observed throughout the North Fork watershed with more sites reporting values above the reporting limit throughout the monitoring season in recent years (2012-2015). Similar to Mainstem, this increase is likely associated with the impacts of the 2013 flood event.

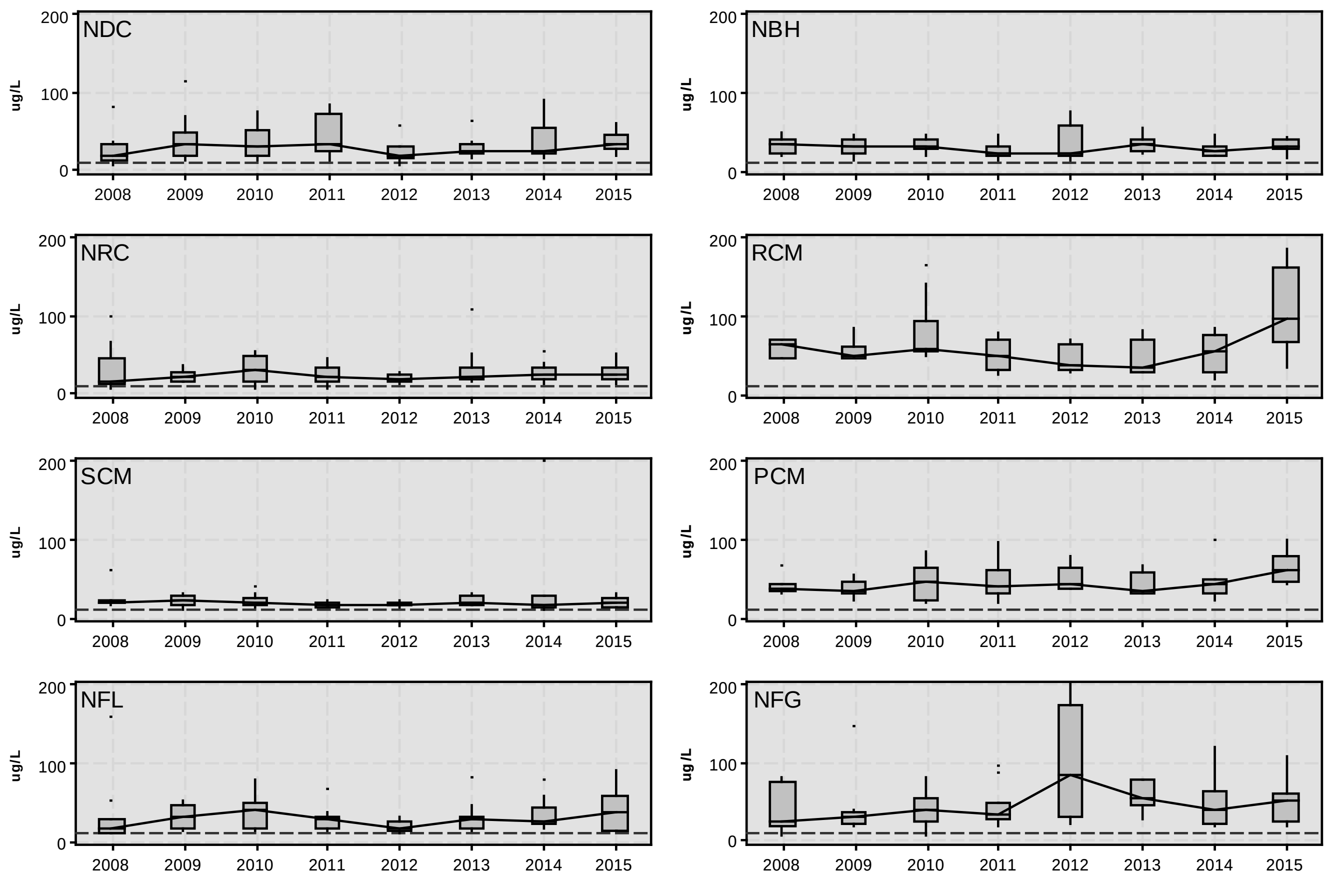

Figure 3.17 – Distribution of total phosphorus concentrations at monitoring locations throughout the North Fork watershed.

In most years during the late summer and fall, reservoir thermal stratification leads to depletion of dissolved oxygen concentrations in the lower levels of the reservoir (see Attachment 7, p.89 for Seaman Reservoir water quality profiles). These conditions may facilitate the release of nutrients stored in reservoir sediments into the water column. This may explain the seasonal occurrences often observed at NDC and NFG, respectively. The extent and magnitude of these events varies from year to year.

Phosphorus

Total phosphorus dynamics on the North Fork followed a similar seasonal pattern to previous years. Concentrations increased during snowmelt and then steadily decreased through the summer and fall. Phosphorus concentrations increased at NFG beginning in August and remained elevated through November. Concentrations during these months were the highest levels observed throughout the monitoring season.

Total phosphorus concentrations throughout the North Fork watershed in 2015 were within the range of values observed over the previous three years (<10 µg/L – 336 µg/L); however, annual median concentrations were higher in 2015 at all sites with the exception of monitoring locations situated below Halligan and Seaman Reservoirs (Figure 3.17). It should be noted, however, that one value was observed on May 5th, 2015 at NBH when concentrations exceeded 4,000 µg/L. While the cause of this high concentration is unknown, it may be a result of winter thermal stratification of Halligan Reservoir.

Ortho-phosphate concentrations throughout the North Fork watershed in 2015 were also within the range of values observed over the previous three years (<5 µg/L – 44 µg/L) and followed expected seasonal patterns. Similar to trends in median TP concentrations, annual median PO_4 concentrations continued to increase in 2015, except at monitoring locations located below the Reservoirs.

3.6 METALS

Naturally occurring metals are routinely detected at low concentrations in the North Fork and Mainstem. The presence of metals 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. Additional sources of metals may include atmospheric deposition,

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 and all samples were analyzed for total and dissolved metals. Post-fire analysis of metals indicated that baseline metal concentrations were similar to pre-fire conditions. Snowmelt runoff generally results in elevated metal concentrations, as does storm events.

In 2015, metals were sampled twice annually on the Mainstem at PNF and on the North Fork at NFG, similar to pre-fire routine sampling. Samples were collected on May 18th and May 20th and October 12th and October 13th at PNF and NFG, respectively.

The most commonly detected metals in 2015 were aluminum (Al), iron (Fe), and manganese (Mn). All of these metals were detected during snowmelt runoff and later in the season during baseflow conditions. Both Al and Fe were detected at much lower concentrations in October at PNF and NFG. Mn, however, was measured at 194 µg/L at NFG on October 13th, which exceeded the secondary drinking water quality standard of 50 µg/L. The higher concentration of this metal at this site is associated with low streamflow and the release of Mn from reservoir bottom sediments facilitated by depleted oxygen in the Reservoir hypolimnion.

Dissolved iron concentrations were just below the secondary drinking water quality standard of 300 µg/L during snowmelt (May 19th) at NFG. The standard was exceeded on May 18th at PNF when concentrations measured 330 µg/L (Table 4). Metal concentrations are usually higher during snowmelt. 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.

Copper (Cu), chromium (Cr), and nickel (Ni) were detected slightly above the reporting limit during snowmelt runoff on May 18th. Both the total and dissolved fractions of Cu were detected at PNF and NFG, but only the total fraction of Ni and Cr were detected at PNF. In contrast, arsenic (dissolved) was detected at NFG on October 13th, but was only slightly above the reporting limit at 1.25 µg/L. Silver (Ag), cadmium (Cd), nickel (Ni), lead (Pb), selenium (Se), and zinc (Zn) were not detected in 2015.

Table 4 – Dissolved and total metals concentrations measured in 2015 on the Mainstem and North Fork of the Poudre River. Metals highlighted in red indicated temporary exceedances of the CDPHE secondary drinking water standard.

Metal	Site	May 18[a] - May 20[b]		October 12[a] - October 13[b]	
		Soluble	Total	Soluble	Total
Aluminum (Al)	PNF	484	1,013	6	-----
	NFG	364	480	5	-----
Arsenic (As)	PNF	<1	<1	<1	-----
	NFG	<1	<1	1	-----
Copper (Cu)	PNF	1.41	2.36	<1	-----
	NFG	1.14	1.88	<1	-----
Chromium (Cr)	PNF	<1	3	<1	-----
	NFG	<1	<1	<1	-----
Iron (Fe)	PNF	330	959	31	-----
	NFG	258	375	31	-----
Manganese (Mn)	PNF	4	21	4	-----
	NFG	6	13	194	-----
Nickel (Ni)	PNF	<1	1	<1	-----
	NFG	<1	<1	<1	-----

3.7 MICROORGANISMS

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 four monitoring locations in 2015 – NFG, PBR, PNF, and PBD – along the Mainstem and North Fork Poudre Rivers. Coliforms samples have been collected from these monitoring locations since 2008.

Total coliforms and *E. coli* exhibited a great degree of seasonal and annual variability (Figure 3.18). Total coliforms are generally low at the beginning of the monitoring season at all sites, but increase during runoff and remained elevated until streamflow receded to baseflow levels in the fall (Figure 3.18a). Total coliforms measured on the Mainstem in 2015 were within the range of values observed over the previous three years (3.1 – 24,196 colony forming units (cfu) per 100 mL). The large range in total coliforms observed over the previous three years was largely associated with post-wildfire impacts from debris flows and flooding mobilizing soil and plant material from burned hillslopes into the Poudre River. In 2015, total coliforms ranged from 14.6 to 4,611 cfu/100 mL with a median value of 435 cfu/100 mL, which was greater than the previous three years. A similar seasonal trend was observed at all sites on the Mainstem. Total coliforms increased throughout the monitoring season to an annual maximum concentration at all Mainstem sites on August 18th. Concentrations decreased following this date, but remained elevated (>1000 cfu/100 mL) at PBD through November.

Total coliforms are commonly higher and more variable at NFG compared to sites on the Mainstem, but do not

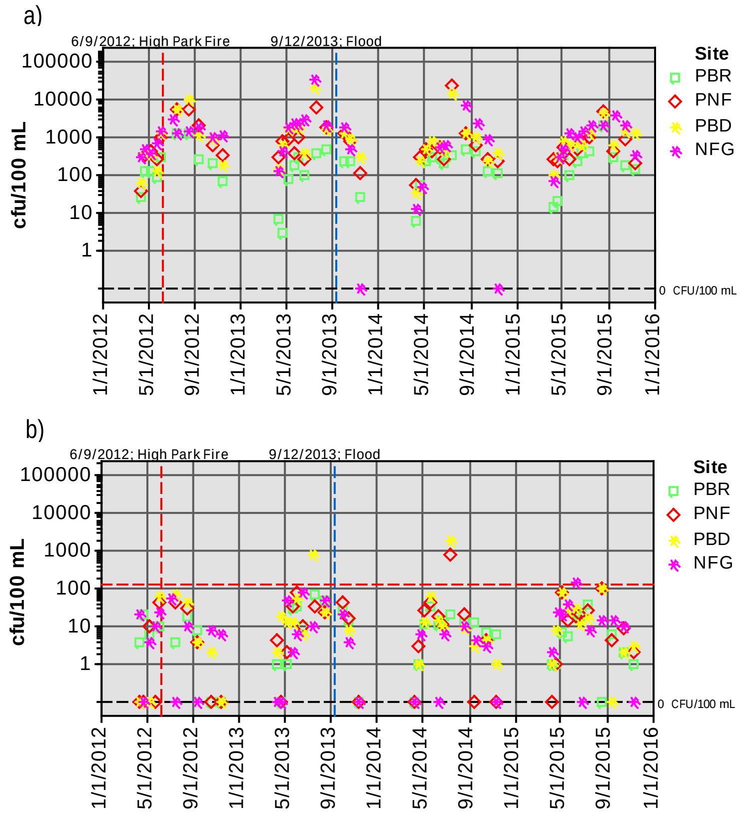

Figure 3.18 – Counts of a) total coliforms and b) E. coli on the Mainstem and North Fork CLP.

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

appear to have a big impact on the Mainstem at PBD. In 2015, total coliforms were within the range of values observed over the previous three years (0 – 34,411 cfu/100 mL). Total coliforms at NFG ranged from 69 to 3,654 cfu/100 mL. The annual median value of 1,270 cfu/100 mL was similar to the previous three years. Total coliforms followed a similar seasonal trend to the Mainstem.

E. coli counts on the Mainstem in 2015 were within the range of concentrations observed over the previous three years (0 – 1,918 cfu/100 mL). Like total coliform, the large range in values over the previous three years is related to wildfire impacts from debris flows and flooding. In 2015, *E. coli* counts on the Mainstem ranged from 0 to 96 cfu/100 mL with an annual median value of 7.5 cfu/100 mL. Cell counts approached, but did not exceed, the CDPHE recreational water quality standard of 126 cfu/100 mL at PNF and PBD during snowmelt runoff on May 4th and later in the monitoring season on August 17th (Figure 3.18b). In comparison, *E. coli* counts at NFG were lower than the Mainstem and range from 0 to 196 cfu/100 mL over the previous three years. In 2015, *E. coli* counts at NFG ranged from 0 to 140 cfu/100 mL with an annual median value of 14.5 cfu/100 mL. *E. coli* exceeded the CDPHE recreational water quality standard at NFG on June 9th when cell counts were 140 cfu/100 mL. The exceedance did not persist and counts were measured well below (~10 cfu/100 mL) the standard through the remainder of the season.

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 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.*

Giardia and *Cryptosporidium* were detected on both the Mainstem and North Fork from 2012 through 2015. *Giardia* was more abundant than *Cryptosporidium* (Figure 3.19). *Giardia* concentrations were low at PNF and within the range of values observed over the previous three years (0.1 – 14 cells/L) (Figure 3.19a). In 2015, giardia concentrations ranged from 4 to 14 cells/L with a median value of 7 cells/L, which was higher than any of the previous three years. In contrast to previous years, giardia concentrations were higher from April through August, but the magnitude and timing of the annual maximum concentration was similar to previous years. An annual maximum concentration of 14 cells/L was observed on November 4th.

Giardia concentrations on the North Fork were similar to concentrations on the Mainstem. *Giardia* concentrations measured in 2015 were within the range of values observed over the previous three years (0.10 – 35 cells/L) at North Fork sites. In 2015, *giardia* concentrations ranged from 0.06 to 17 cells/L with an annual median value of 4 cells/L. The highest concentration was measured at NBH at 17.1 cells/L on May 5th. Concentrations were consistently higher at NDC throughout the year. Giardia concentrations decreased moving downstream to NFG below Seaman Reservoir where *giardia* counts were less than 7 cells/L throughout the entire monitoring season.

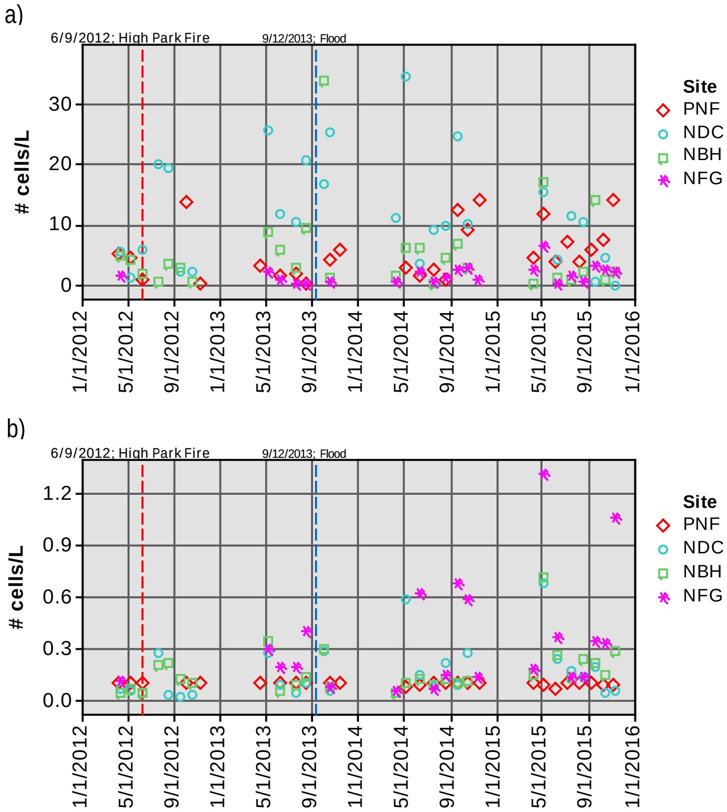

Figure 3.19 – Concentrations of a) giardia and b) Cryptosporidium on the Mainstem and North Fork CLP.

Cryptosporidium concentrations are generally low on both the North Fork and Mainstem. Cell counts are generally below the detection limit of 0.1 cell/L on the Mainstem, while detections occur more often on the North Fork. In 2015, *Cryptosporidium* did not display seasonal or annual trends on the Mainstem, but concentrations were higher, although still low, at North Fork sites. The range in *Cryptosporidium* cell counts on the North Fork in 2015 was greater than the previous three years (<0.1 – 0.68 cells/L). In 2015, cell counts ranged from less than 0.1 to 1.32 cells/L. The maximum cell count was measured at NFG on May 5th. Cell counts at NDC and NBH were also measured at an annual maximum on this date, which were the highest counts observed over the three year period at these sites. *Cryptosporidium* decreased following this date to below 0.5 cells/L and remained low at NDC and NHG for the remainder of the season. In contrasts, *Cryptosporidium* at NFG was observed above 1 cell/L by the end of the season.

4.0 DATA QUALITY ASSURANCE AND CONTROL

The Upper CLP watershed collaborative monitoring program assures comparability and validity of data by complying with monitoring methods and implementing quality assurance and quality control (QAQC) measures. QAQC measures are good practice in environmental monitoring and can be used to determine potential error in data due to contamination of water samples, sampling error, equipment contamination, and/or laboratory error. The Upper CLP monitoring sites are representative of the goals and objectives outline previously and demonstrate the true character of the watershed at the time of sampling.

4.1 FIELD QUALITY CONTROL

A minimum of ten percent of the total samples collected in the field were collected as field duplicate and/or field blank samples. Field duplicates (11 duplicates in total) were obtained at PNF during each monitoring event to determine precision of data, while field blanks (11 blanks in total) were collected at different monitoring locations, alternating between the Mainstem and North Fork, to identify potential for sample contamination. The field data quality sampling schedule is outlined in the 2015 annual sampling plan (Attachment 4). QAQC samples and accuracy of field equipment is reviewed by Source Watershed Program staff. A complete graphical summary of field quality control data is located in Attachment 8.

Field Duplicates

In 2015, twelve percent (22 out of 183) of the environmental samples collected were QAQC samples. Precision is a measure of the deviation from the true value. For most constituents, duplicate determinations should agree within a relative percent difference of 10%. Duplicate samples that differ greater than 10% were flagged for further quality assurance and control measures. Blank samples should not contain analytes above the reporting limit. The results of the field quality assurance and control sampling indicate that precision and accuracy were acceptable.

Table 5 outlines relative percent difference statistics for duplicate samples collected in 2015 and illustrates that UCLP water quality data are of high precision. All duplicate samples, except ammonia, were within 10% agreement at the 50^{th} percentile. Ammonia, PO_4, and TKN were slightly outside of the 10% agreement at the 75^{th} percentile, but these constituents are generally measured at concentrations near or below the reporting limit. There is more uncertainty in the accuracy of concentrations measured below the reporting limit and comparison of duplicate samples at these levels does not allow for a genuine measure of precision.

Nearly all field blank samples reported below the constituent's respective reporting limits in 2015. Constituents that were detected above the reporting limits included NH_4-N, NTU, and TDS. Concentrations were reported only slightly above the reporting limit for these samples and concentrations were minimal compared to concentrations of environmental samples. Out of the 22 field blank samples analyzed, a total of three samples reported between 0.05 and 0.10 NTU, two samples reported above 10 mg/L for TDS, and nine samples

Table 5 – Data quality assurance statistics calculated for duplicate samples collected at PNF monitoring location in 2015.

Constituent	Range in QAQC sample concentration	Reporting Limit	Absolute Mean Difference	Relative Percent Difference (%)		
				Percentile		
				25th	*50th*	*75th*
Hardness (mg/L)	12.61 - 45.48	5	0.42	0.3	0.5	1.4
Ammonia (ug/L)	4 - 20	10	2.1	4.5	10.6	13.0
Turbidity (NTU)	0.36 - 13	0.05	0.37	1.8	3.4	9.3
ortho-Phosphate (ug/L)	2 - 12	5	1.1	3.1	7.8	13.8
TDS (mg/L)	31 - 93	10	7.36	3.4	4.7	9.8
TKN (mg/L)	0.05 - 0.61	0.1	0.04	4.0	8.6	16.5
TOC (mg/L)	2.21 - 9.48	0.5	0.03	0.2	0.2	0.6
Total P (ug/L)	11 - 61	0.01	1.44	1.1	2.8	5.1

reported above 0.01 mg/L N for NH_4-N, but were below 0.02 mg/L. Field and laboratory blanks are easily contaminated by NH_4-N.

Field Instrument Accuracy

Monthly equipment calibrations using certified standards were conducted to assure the accuracy of sensors on the multi-parameter water quality sonde. Accuracy is a measure of the degree of closeness a measurement is to the true measurement. The accuracy of the multi-parameter water quality sonde was checked prior to monitoring events by comparing sonde readings to bench-top instruments to assure sonde readings were within the acceptable margin of error (Table 6). Sensors were re-calibrated and re-checked if the sensors were outside of the QC limits.

The results of monthly calibrations and calibration checks indicated that the multi-parameter water quality sonde sensors were within the acceptable range for instrument accuracy and precision.

Table 6 – Acceptable margin of error for multi-parameter water quality sonde sensors.

Parameter	Units	Range	Accuracy
pH	pH units	0 to 14 units	±0.1 pH units within ±10°C of calibration temperature; ±0.2 pH units for entire temp range
Turbidity	NTU	0 to 4000 NTU	0-999 NTU: 0.3 NTU or ±2% of reading, whichever is greater; 1000-4000 NTU: ±5% of reading
Dissolved Oxygen	mg/L	0 to 50 mg/L	0-20 mg/L: ±1% of reading or 0.1 mg/L
Conductivity	uS/cm	0 to 200,000	0 – 100,000 uS/cm: ±0.5% of reading or
Temperature	°Celsius	-5 to +50°C	-5 to 35°C; ±0.01°C 35 to 50°C: ±0.05°C

4.2 LABORATORY QUALITY CONTROL

Upper CLP water quality samples analyzed by the Fort Collins Water Quality Laboratory are reviewed by the Quality Assurance Coordinator to ensure data are free of sample contamination, analytical, and/or data entry errors.

The City of Fort Collins Water Quality Laboratory implements analytical QAQC measures by conducting laboratory blank, duplicate, replicate, and spiked samples. The City of Fort Collins WQL conducts a majority of analyses for the Source Water Quality Monitoring Program, and is a U.S. EPA Certified Drinking Water Laboratory with an established QA plan that is applied to all samples received by the laboratory (Elmund et al, 2013). The primary features of their QA protocol include:

- Precision: one duplicate sample is analyzed for every 10 samples; relative deviation should be less than 10%.
- Accuracy: one external QCS sample is analyzed with each set of samples analyzed. Methods may specify an acceptable recovery range. In general, Standard Methods limits are ± 5% and EPA methods are ± 10%.
- Recovery: one sample is spiked for every 10 samples; if there are different matrices, at least one sample per matrix is spiked. Limits for most methods are ± 15%. If one type of matrix spike fails and all other QC passes, those samples may be flagged.

A complete description of laboratory personnel, equipment, and analytical QA methods is outside of the scope of this report and is not addressed in detail here. As part of the City's Environmental Services Division the WQL operates under the guidance of a general QA plan (Elmund et al., 2013).

5.0 SUMMARY

5.1 PROGRAM PERFORMANCE

Review of the 2015 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 recent years, the spatial distribution of monitoring locations and the long-term dataset have provide a valuable tool for evaluating wildfire impacts on both baseline and event-based water quality by comparing pre- and post-wildfire water quality conditions at burn impacted monitoring locations. The results of the field quality assurance and control sampling indicate that data precision and accuracy were acceptable.

5.2 HYDROLOGY

In 2015, peak snow water equivalent (SWE) in the Upper CLP watershed was slightly below average at 91% of normal. Peak SWE was observed on April 27th, which is similar to the long-term data record. Steady late season snow storms continued through May extending the snow accumulation season by nearly one month.

Winter baseflow conditions remained above average in 2015. A significant spring snow storm in mid-April brought several feet of snow to the lower elevations of the watershed, which resulted in a rapid rise in streamflow through mid-May. Peak streamflow was measured on June 12th at 182% of the long-term average. Baseflow conditions beginning in mid- to late-August were below average for the remainder of the 2015 water year. Two notable storm events were observed on July 5th and August 16th, which caused an increase in streamflow.

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. Raw water from these two sources exhibited high TOC and turbidity levels, low alkalinity and hardness concentrations, and decreased pH during spring runoff, but concentrations were within the expected range of variability and followed normal seasonal, temporal, and spatial trends.

North Fork watershed concentrations for these water quality constituents were higher and more variable across monitoring locations as compared to Mainstem sites, but followed similar seasonal trends with the exception of monitoring sites located below reservoirs. These sites experienced similar early season trends during snowmelt runoff, but reservoir processes later in the monitoring season appeared to influence water quality at monitoring locations situated below the reservoirs. In most instances, notable events or trends in water quality observed on the North Fork at NFG were not detectable downstream at PBD near Greeley's water intake. The data collected through this program suggest that the greatest factors influencing water quality throughout the North Fork watershed are land use changes in streamflow, and watershed geology.

In general, nutrient concentrations were higher on the North Fork compared to the Mainstem. Increasing trends in background (non-storm event) NH_3-N, PO_4, and Total P have been observed watershed wide on the Mainstem and North Fork with more sites reporting values above the reporting limit throughout the monitoring season in recent years (2012-2015). The watershed-wide increases in these nutrients may be related to the flood event of 2013, and the increase is even more distinguished at sites impacted by the Hewlett Gulch and High Park Fires. The exception to this observation is at monitoring locations situated below Halligan and Seaman Reservoirs (NBH and NFG), suggesting that reservoirs can act as both a sink and source for nutrients within the watershed depending on the time of year.

Storm events over the Upper CLP watershed that caused short-term impairments to water quality in previous years were limited in 2015 due to a relatively dry monsoon season. There were only two storm events in 2015 that caused short term water quality impairment. One notable event caused a rapid spike in turbidity, but the event was short-lived and river water quality returned to normal within 24 hours. Unfortunately, the automated sampler located at the City of Fort Collins raw water intake failed to collect samples during these events, but the significant increase in river turbidity indicates ongoing wildfire impacts.

In addition, routine, non-storm event water quality data from wildfire impacted sites continues to show impacts of the 2012 wildfires continue in the Upper CLP watershed. The most notable impacts to water quality associated with the wildfire are increases in nutrients (nitrogen and phosphorus). Nutrients on the Mainstem continued to be relatively low in 2015, but inorganic nitrogen (NO_3-N and NH_3-N) and PO_4 remained elevated at wildfire impacted monitoring sites (PNF and PBD) compared to pre-fire conditions. Elevated nutrient concentrations have been observed in many studies that examined the impact of wildfires on water quality (Hibbert, 1974; Tiedemann, 1979; Neary, 2005; Rhoades et al., 2011). Despite the elevated concentrations in 2015, nutrient levels remained low and have not resulted in excessive algal growth and/or associated taste and odor issues. Data collected from the Upper CLP monitoring program suggest that the Upper Poudre watershed remains on a path toward recovery.

Naturally occurring metals are routinely detected at low concentrations in the North Fork and Mainstem. The most commonly detected metals in 2015 were aluminum (Al), iron (Fe), and manganese (Mn). All of these metals were detected during snowmelt runoff and later in the season during baseflow conditions. Dissolved iron concentrations exceeded the secondary drinking water quality standard during snowmelt at PNF. The secondary drinking water quality standard for dissolved Mn was exceeded at NFG on October 13th. These exceedances did not cause any issues for water treatment.

Total coliforms and *E. coli* exhibited a great degree of seasonal and annual variability. Total coliforms are commonly higher and more variable at NFG compared to sites on the Mainstem, but do not appear to have a big impact downstream on the Mainstem at PBD. *E. coli* counts at NFG were lower than the Mainstem. *E. coli* counts at NFG exceeded the CDPHE recreational water quality standard on June 9th. The exceedance was short-lived.

5.4 MONITORING AND PROTECTION EFFORTS IN 2016

Planned water quality monitoring and other related Upper CLP activities for 2016 are summarized below:

- **Routine Monitoring Program:** Samples will continue to be analyzed for all parameters in 2016. The South Fork above Mainstem (SFM) site was not sampled in 2015 and has been 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 Cities of Fort Collins and Greeley will continue to participate in Northern Water's Emerging Contaminants Program in 2016. Samples will be collected at PNF and NFG in February, June, and August.

- **Geosmin:** Geosmin monitoring will continue on the Mainstem CLP in 2016 at two key sites (PBR and PNF) during routine sampling events. Sampling will also be conducted monthly through the winter at these locations

- **Event-based Stormwater & Watershed Recovery Monitoring:** Event-based stormwater monitoring will continue through the summer of 2016. An automated sampler located at the City of Fort Collin's Intake Facility will 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 (year 3). 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 2015. 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.

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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

2015 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 2015 SAMPLING PLAN

2015 Sampling Dates											
	Apr 6-7	Apr 20-21	May 4-5	May 18-19	Jun 8-9	Jun 22-23	Jul 13-14	Aug 17-18	Sep 14-15	Oct 12-13	Nov 9-10
Station											
North Fork											
NDC	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
NBH	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,B
NRC	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D,B	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,I,D
RCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	----------	----------	----------	----------	----------
SCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	----------	----------	----------	----------	----------
PCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	----------	----------	----------	----------	----------
NFL	F,G	F,G,I	F,G	F,G,I,B	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	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,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	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, 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
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	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, B	F,G,I,E	F,G,E,T	F,G,I,E	F,G,E,T	F,G,I,E,T	F,G,E,T	F,G,I,E,T	F,G,I,E,T
SFM	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
SFC[3]	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D,B	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,I,D
PSF	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
PNF	F,G,E,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,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	F,G,E	F,G,I,E	F,G,E,B	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
Reservoir											
SER[1]	F,G,A,C,E	----------	F,G,A,C,E	----------	F,G,A,C,E	----------	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E,B	F,G,I,A,C,E	F,G,I,A,C,E

[1] Grab samples taken at two depths (Top & Bottom); meter samples at 1-m intervals.
[2] Call commissioner to find out if water is flowing. If not flowing, skip sample.
[3]SFC = South Fork above Confluence w/ Mainstem, new site in 2014 to capture fire impacts.
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 sample for 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_4pH <2	28 days
Analysis conducted by City of Fort Collins Water Quality Lab (FCWQL), unless otherwise noted.					
Reporting Limit = lowest reportable number based on the lowest calibration standard routinely used.					

ATTACHMENT 6

2015 SEAMAN RESERVOIR PHYTOPLANKTON DATA

Phytoplankton Densities (cells/mL)	SAMPLING DATE												
= geosmin producing species	4/21/2015		6/9/2015	7/14/2015		8/18/2015		9/15/2015		10/13/2015		11/10/2015	
CYANOPHYTA (blue-green algae)	***top***	***bottom***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Anabaena inaequalis													
Anabaena sp.													
Aphanizomenon flos-aquae								9480.0	34.4	324.4	12.0	126.8	80.0
Aphanocapsa conferta	375.0							9375.0					
Aphanocapsa delicatissima								1500.0				750.0	
Aphanocapsa holsatica	20.0												
Aphanocapsa sp.													
Aphanothece clathrata													
Aphanothece smithii	2625.0		750.0	16250.0	3000.0				2500.0	800.0		1000.0	
Coelosphaerium aerugineum										10.4			
Cuspidothrix issatschenkoi													
Cyanobium sp.				500.0			250.0						
Dactylococcopsis acicularis													
Dactylococcopsis sp.				40.0									
Dolichospermum (Anabaena) flos-aquae								1050.0					
Dolichospermum (Anabaena crassa) crassum						689.6		160.0		8.8		3.2	
Dolichospermum (Anabaena) lemmermannii													
Dolichospermum (Anabaena planctonica) planctonicum								84.0			10.4		
Geitlerinema sp.													
Gloeotrichia echinulata													
Jaaginema sp.													
Limnothrix sp.													
Lyngbya birgei											10.4		
Merismopedia sp.													
Merismopedia tenuissima													
Microcystis flos-aquae													
Microcystis wesenbergii													
Myxobaktron hirudiforme													
Oscillatoria tenuis													
Planktolyngbya limnetica							20640.0		2100.0				2140.0
Planktothrix agardhii													
Pseudanabaena limnetica											10.0		
Pseudanabaena mucicola													
Pseudanabaena sp.											3.2		
Rhabdogloea smithii													
Romeria leopoliensis													
Romeria sp.													

CYANOPHYTA (blue-green algae) continued	top	bottom	bottom	top	bottom	top	bottom	top	bottom	top	bottom	top	bottom
Snowella litoralis													
Synechococcus capitatus													
Synechococcus nidulans	125.0												
Synechocystis sp.													
Woronichinia naegeliana								628.0	80.0	343.2		1760.0	600.0
TOTAL CYANOPHYTA	**45,260**	**0**	**42,914**	**58,989**	**3,000**	**42,924**	**20,890**	**64,539**	**4,714**	**43,777**	**46**	**45,958**	**2,820**

CHRYSOPHYTA (golden-brown algae)	top	bottom	bottom	top	bottom	top	bottom	top	bottom	top	bottom	top	bottom
Chromulina parvula	875.0	2500.0	62.5			250.0							
Chrysococcus sp.													
Dinobryon bavaricum		0.8											
Dinobryon cylindricum var. *alpinum*	4.0	0.8											
Dinobryon cylindricum													
Dinobryon cylindricum var. *palustre*													
Dinobryon divergens	158.4	59.2		1.2						0.2			
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	**1,037**	**2,561**	**63**	**1**	**0**	**250**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

XANTHOPHYTA													
Gloeobotrys limneticus													

Phytoplankton Densities (cells/mL)	SAMPLING DATE												
	4/21/2015		6/9/2015	7/14/2015		8/18/2015		9/15/2015		10/13/2015		11/10/2015	
BACILLARIOPHYTA (diatoms)	***top***	***bottom***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Amphora sp.													
Asterionella formosa	332.0	124.8		124.4		14.4		62.0		40.0	2.4	170.8	600.0
Aulacoseira ambigua		3.2		383.6									
Aulacoseira granulata var. *angustissima*					65.6	16.0	4.4	478.0	130.4	76.0	120.0	292.4	263.6
Aulacoseira granulata													
Aulacoseira italica	18.4	8.8	18.4		4.0		2.4		8.0				
Aulacoseira italica var. *tenuissima*	84.8	137.6	21.6										
Aulacoseira subarctica													
Cyclostephanos sp.													
Cymatopleura solea													
Diatoma anceps													
Diatoma moniliformis													
Diatoma tenuis													
Discostella glomerata													
Discostella pseudostelligera													
Discostella stelligera				60.0									
Fragilaria crotonensis	70.4	14.4		38.4		324.4	10.4	615.0	58.0	113.6	42.8	1021	604.0
Fragilaria sp.													
Gomphonema sphaerophorum													
Gyrosigma acuminatum													
Melosira varians			0.8										
Navicula capitatoradiata			0.2										
Navicula lanceolata													
Navicula rhynchocephala													
Navicula tripunctata													
Nitzschia archibaldii													
Nitzschia draveillensis				0.4									
Nitzschia fonticola													
Nitzschia gracilis													
Nitzschia linearis													
Nitzschia nana													
Nitzschia sigma													
Nitzschia sp.													
Nitzschia supralitorea													
Punticulata bodanica	0.8	1.6									0.4		
Stephanocyclus meneghiniana													

Phytoplankton Densities (cells/mL)	SAMPLING DATE												
	4/21/2015		6/9/2015	7/14/2015		8/18/2015		9/15/2015		10/13/2015		11/10/2015	
BACILLARIOPHYTA (diatoms) continued	***top***	***bottom***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Stephanodiscus medius													1.2
Stephanodiscus niagarae	0.4							2.0		27.6	4.0	462.5	437.5
Stephanodiscus parvus				2800.0				120.0		20.0		20.0	
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*		0.4	1.2										
Synedra ulna													
Tabellaria fenestrata			1.6										
Urosolenia eriensis													
TOTAL BACILLARIOPHYTA	**507**	**291**	**44**	**3,407**	**70**	**355**	**17**	**1,277**	**196**	**277**	**170**	**1,967**	**1,906**
HAPTOPHYTA													
Chrysochromulina parva	850.0	30.0		380.0				280.0					
CRYPTOPHYTA													
Chroomonas coerulea										2.4			
Chroomonas nordstedtii						6.0							
Cryptomonas borealis	21.2			93.2		9.2		15.0					
Cryptomonas curvata	6.8			20.4		5.2		3.0	0.2				
Cryptomonas erosa													
Cryptomonas marsonii						0.4				2.0			
Goniomonas truncata													
Hemiselmis sp.													
Komma caudata	50.0												
Plagioselmis nannoplanctica				1600.0		440.0		2240.0		110.0		80.0	
cyst of *Cryptomonas*													
TOTAL CRYPTOPHYTA	**78**	**0**	**0**	**1713.6**	**0**	**460.8**	**0**	**2258**	**0.2**	**114.4**	**0**	**80**	**0**

Phytoplankton Densities (cells/mL)	SAMPLING DATE												
	4/21/2015		6/9/2015	7/14/2015		8/18/2015		9/15/2015		10/13/2015		11/10/2015	
DINOPHYTA	*top*	*bottom*	*bottom*	*top*	*bottom*	*top*	*bottom*	*top*	*bottom*	*top*	*bottom*	*top*	*bottom*
Ceratium hirundinella				0.4				3.0		16.4	0.4		
Gymnodinium aeruginosum													
Gymnodinium fuscum													
Peridinium lomnickii													
Peridinium willei													
Tovellia (Woloszynskia) coronata				0.8									
TOTAL DINOPHYTA	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**3**	**0**	**16**	**0**	**0**	**0**
EUGLENOPHYTA													
Euglena sp.													
Euglena viridis													
Lepocinclis acus													
Lepocinclis oxyuris													
Trachelomonas dybowskii													
Trachelomonas hispida													
Trachelomonas volvocina													
TOTAL EUGLENOPHYTA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
PRASINOPHYTA													
Monomastrix sp.													
Pyramimonas sp.													
Scourfieldia sp.													
Tetraselmis cordiformis													
TOTAL PRASINOPHYTA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
CHLOROPHYTA (green algae)													
Acutodesmus acuminatus													
Acutodesmus dimorphus													
Ankistrodesmus falcatus													
Ankyra judayi				20.0		140.0		800.0	8.0			20.0	2.0
Botryococcus braunii													
Chlamydomonas dinobryonis													
Chlamydomonas globosa												10.0	
Chlamydomonas snowiae													
Chlamydomonas sp. 1													
Chlamydomonas sp. 2				60.0									

Phytoplankton Densities (cells/mL)	SAMPLING DATE												
	4/21/2015		6/9/2015	7/14/2015		8/18/2015		9/15/2015		10/13/2015		11/10/2015	
CHLOROPHYTA (green algae) continued	***top***	***bottom***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Chlamydomonas tetragama													
Chlorella minutissima	625.0	1750.0				125.0							
Chlorella sp.													
Chloromonas sp.													
Choricystis minor					250.0	750.0	7875.0		8375.0	1625.0	10000.0	2250.0	6250.0
Closterium aciculare										0.2	0.2		
Closterium acutum var. *variabile*												0.4	0.4
Closterium dianae													
Closterium moniliferum			0.8										
Coelastrum indicum													
Coelastrum pseudomicroporum													
Coelastrum pulchrum									6.4		5.6	12.8	
Coenochloris fottii						5.6				152.0		8.8	
Cosmarium bioculatum													
Cosmarium candianum													
Cosmarium depressum var. *achondrum*													
Desmodesmus armatus													
Desmodesmus bicaudatus													
Desmodesmus communis													
Desmodesmus intermedius var. *balatonicus*													
Dictyosphaerium pulchellum var. *minutum*													
Elakatothrix viridis	5.6	0.4											
Eudorina elegans								12.0				19.2	
Gonatozygon kinahanii													
Heimansia pusilla													
Keratococcus sp.													
Kirchneriella obesa													
Micractinium pusillum													
Monoraphidium contortum													
Monoraphidium minutum													
Monoraphidium sp.													
Mougeotia sp.													
Nephrocytium limneticum													
Oocystis apiculata													
Oocystis borgei								8.0		1.6			
Oocystis parva													

Phytoplankton Densities (cells/mL)	SAMPLING DATE												
	4/21/2015		6/9/2015	7/14/2015		8/18/2015		9/15/2015		10/13/2015		11/10/2015	
CHLOROPHYTA (green algae) continued	***top***	***bottom***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***	***top***	***bottom***
Oocystis pusilla													
Pandorina charkowiensis													
Pandorina smithii						7.2							
Pediastrum boryanum						3.6							
Pediastrum duplex													
Pediastrum tetras													
Pseudodictyosphaerium elegans													
Pseudodictyosphaerium sp.													
Pseudodidymocystis planctonica													
Quadrigula sp.													
Raphidocelis contorta													
Raphidocelis sp.													
Scenedesmus arcuatus													
Scenedesmus ellipticus													
Schroederia setigera								120.0		20.0			
Staurastrum planctonicum						1.2		2.0	0.2	3.2	1.2	3.6	1.2
Tetraedron minimum													
Tetraspora lemmermannii													
Volvox sp.													
TOTAL CHLOROPHYTA	**631**	**1,750**	**1**	**80**	**250**	**1,033**	**7,875**	**942**	**8,390**	**1,802**	**10,007**	**2,325**	**6,254**

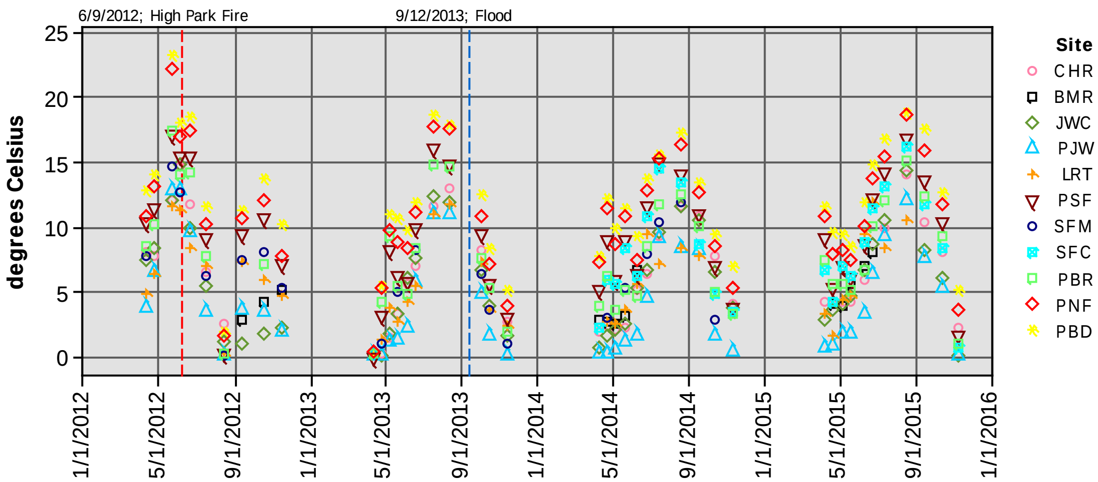
ATTACHMENT 7

2015 UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM GRAPHICAL SUMMARY

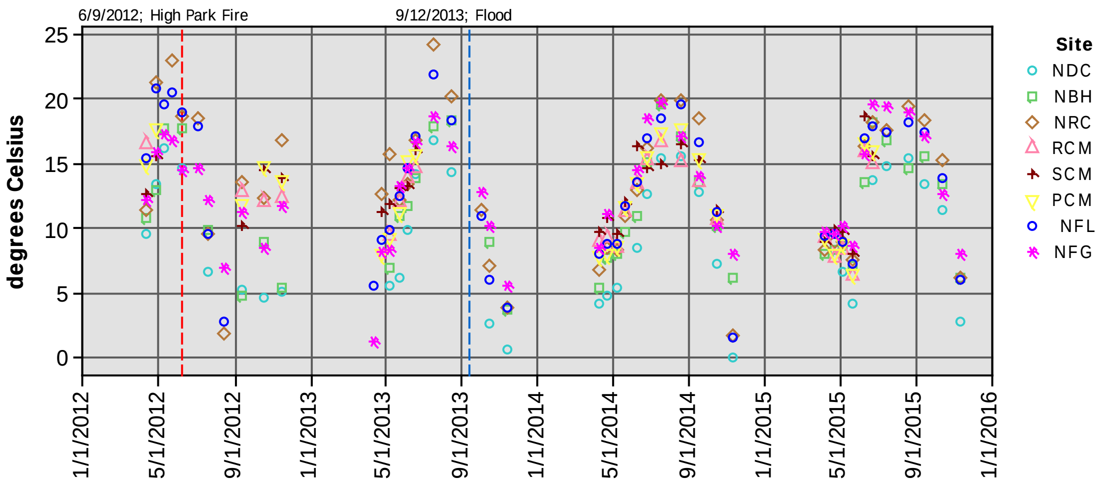
MAINSTEM & NORTH FORK CLP WATERSHEDS

GENERAL PARAMETERS

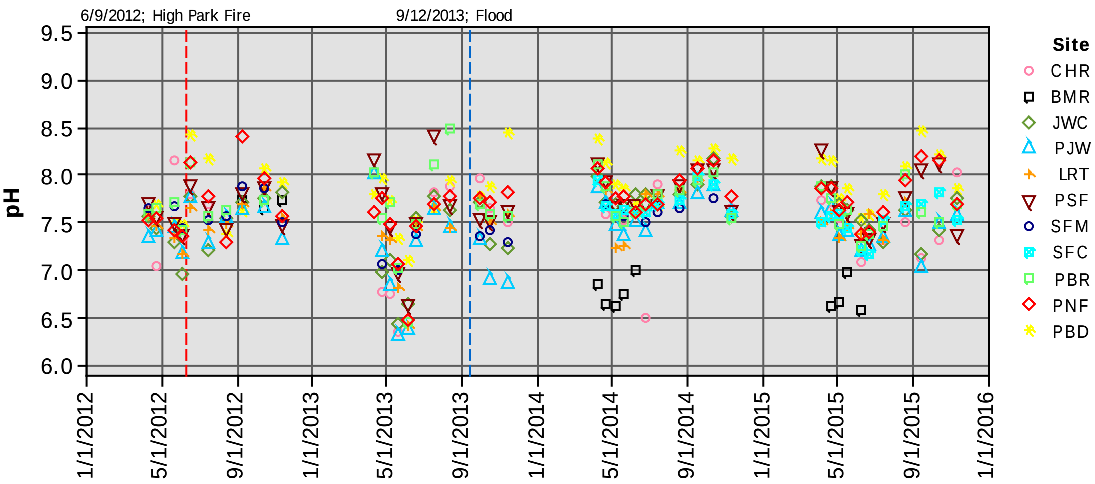
a) Temperature on the Mainstem CLP



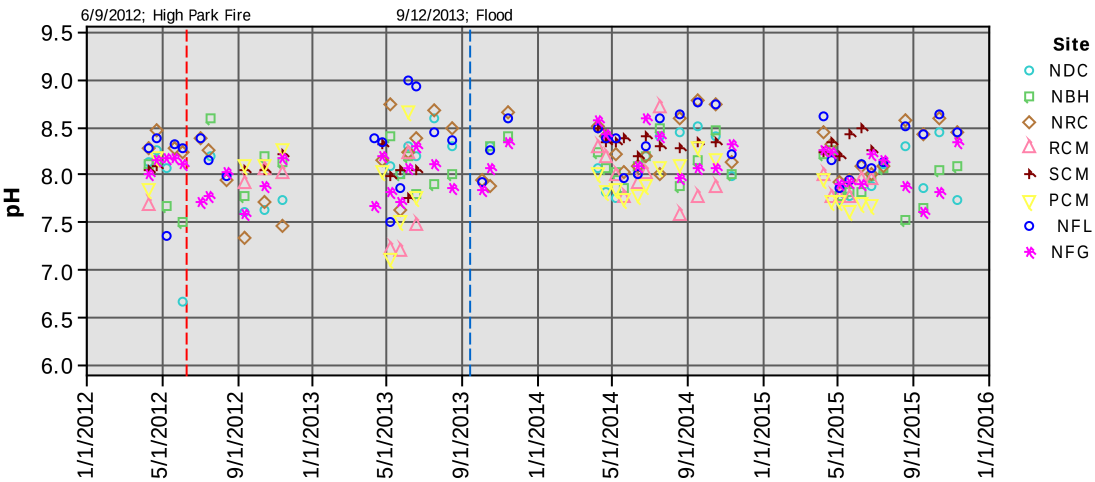
b) Temperature on the North Fork CLP



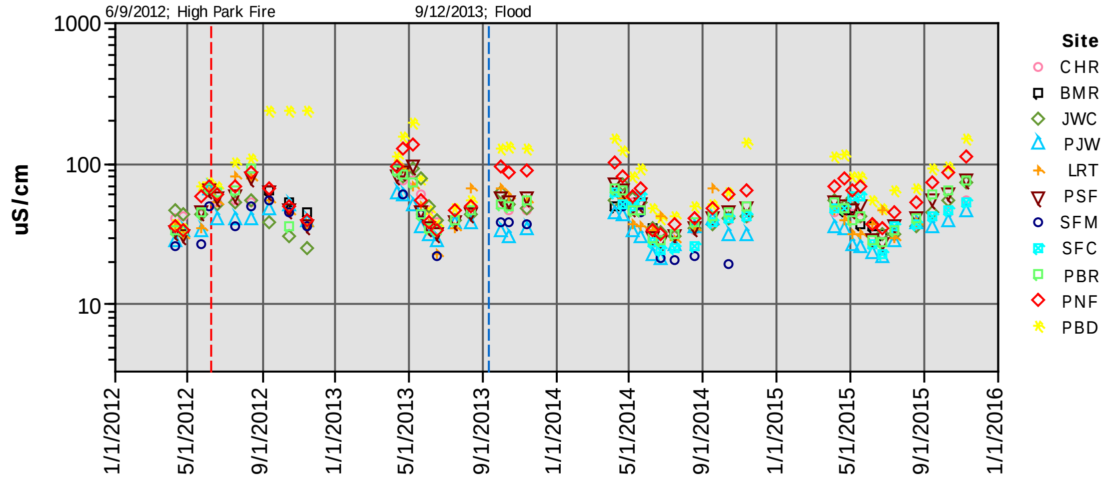
a) pH on the Mainstem CLP



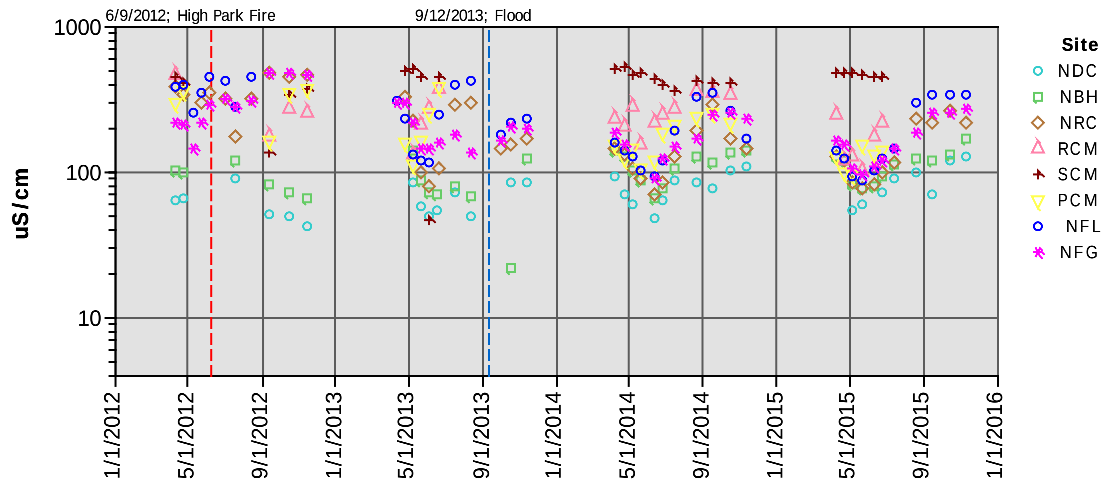
b) pH on the North Fork CLP



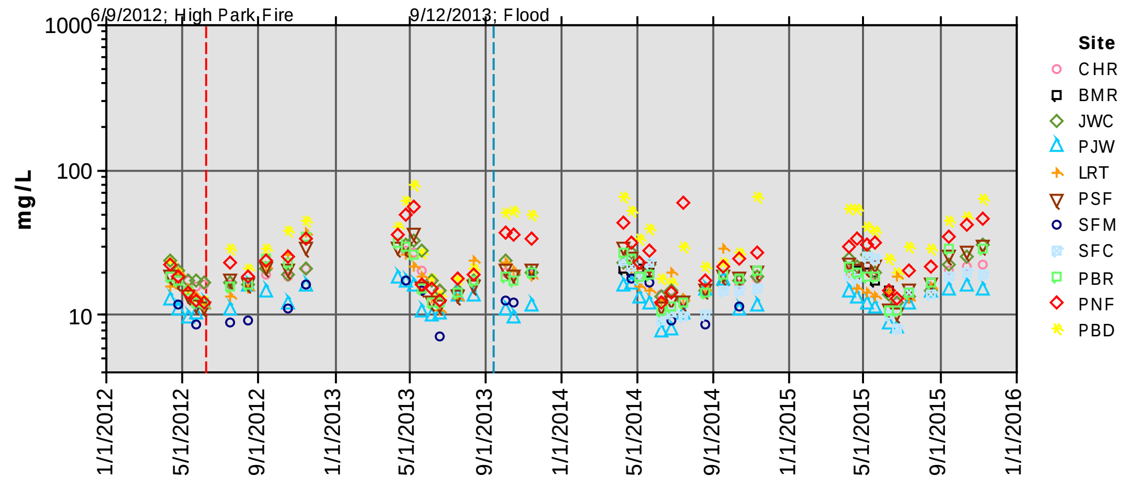
a) Specific Conductance on the Mainstem CLP



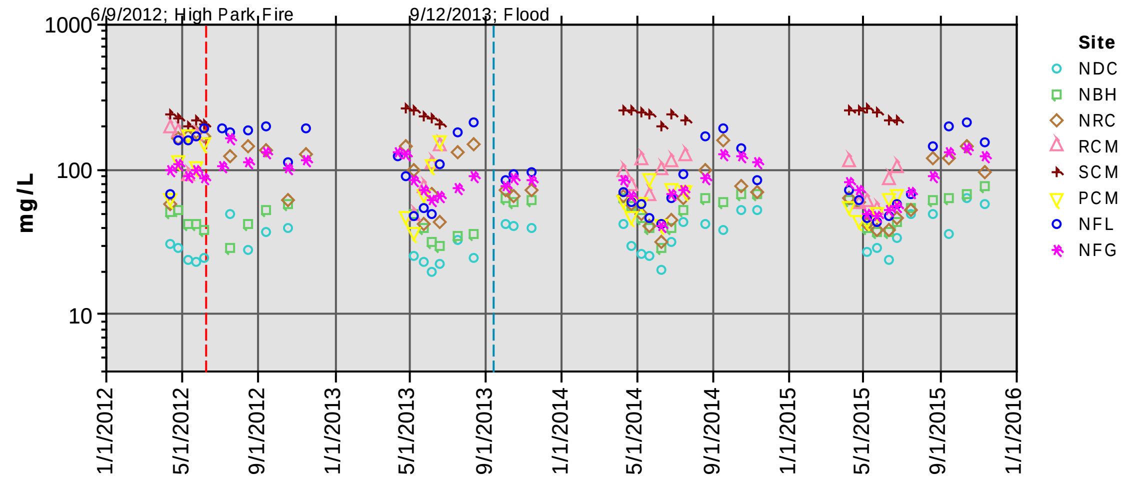
b) Specific Conductance on the North Fork CLP



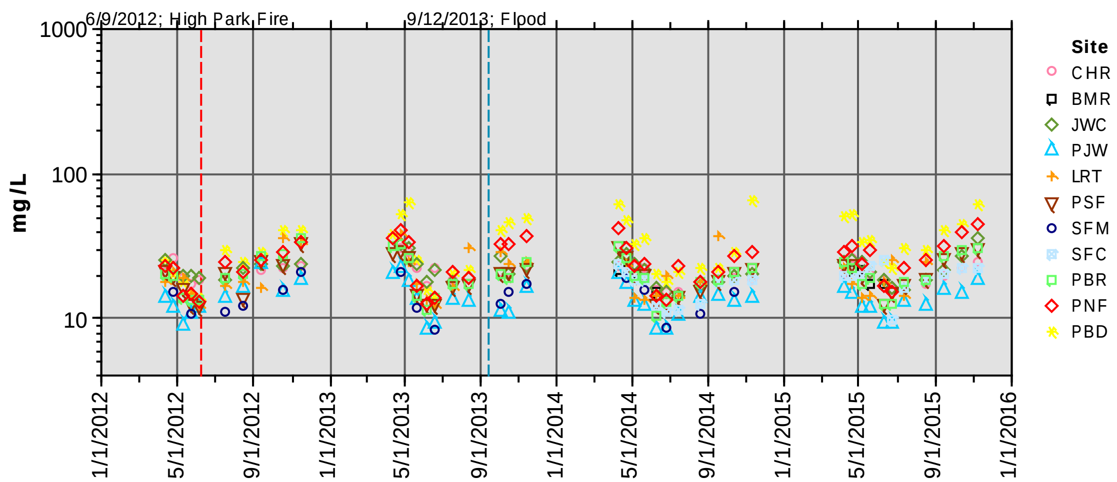
a) Hardness on the Mainstem CLP



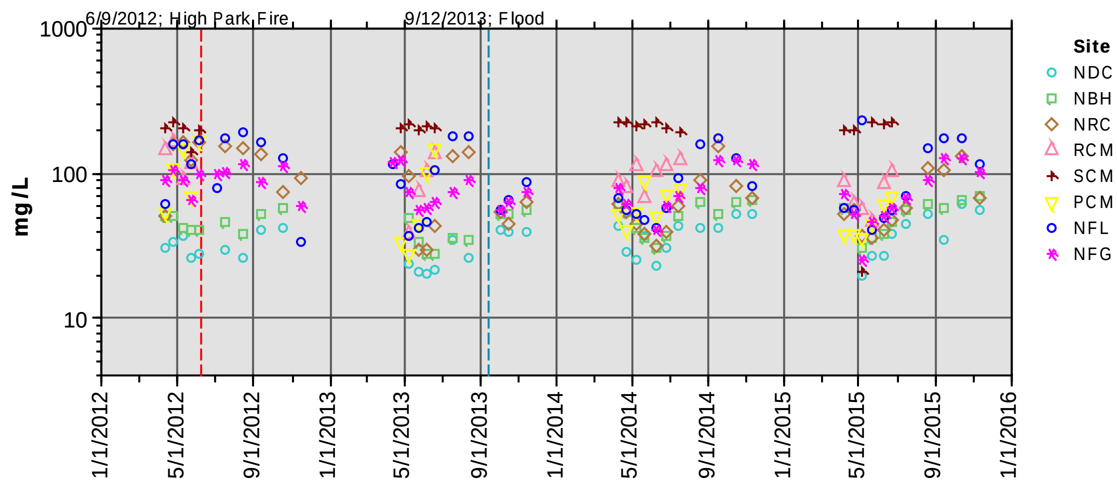
b) Hardness on the North Fork CLP



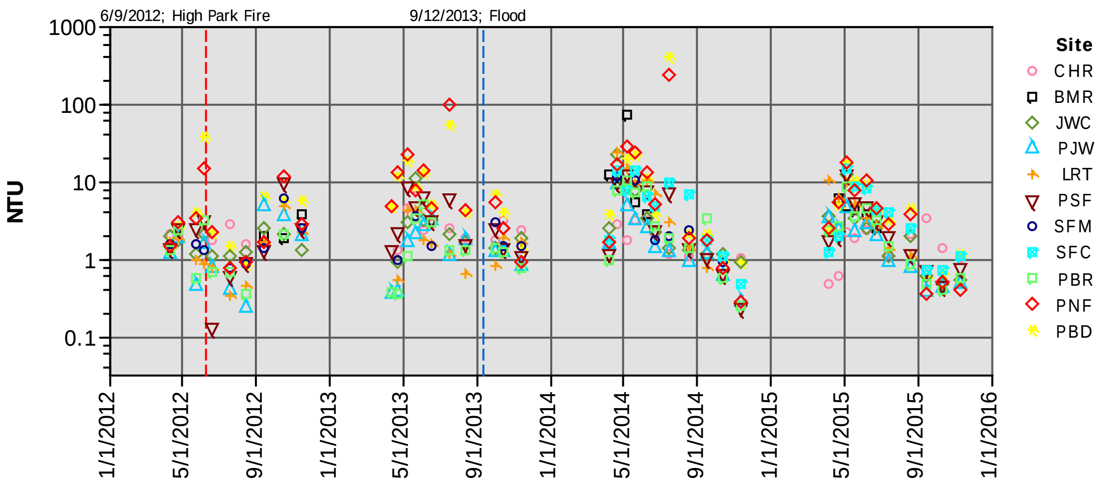
a) Alkalinity on the Mainstem CLP



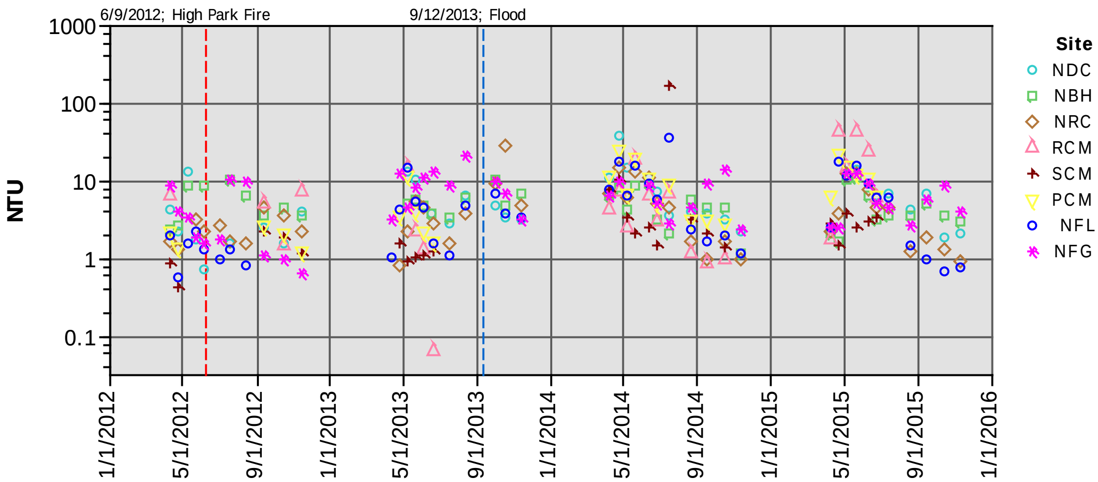
b) Alkalinity on the North Fork CLP



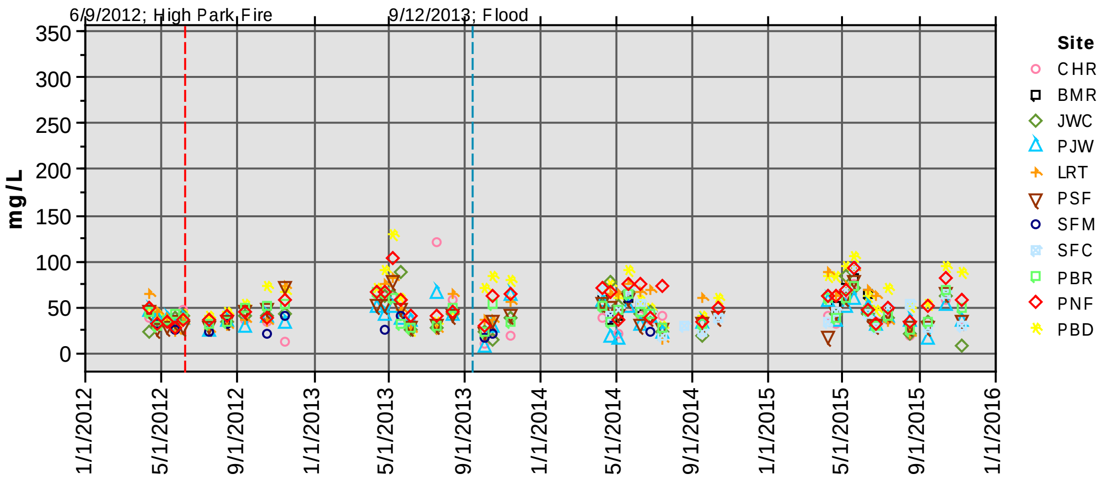
a) Turbidity on the Mainstem CLP



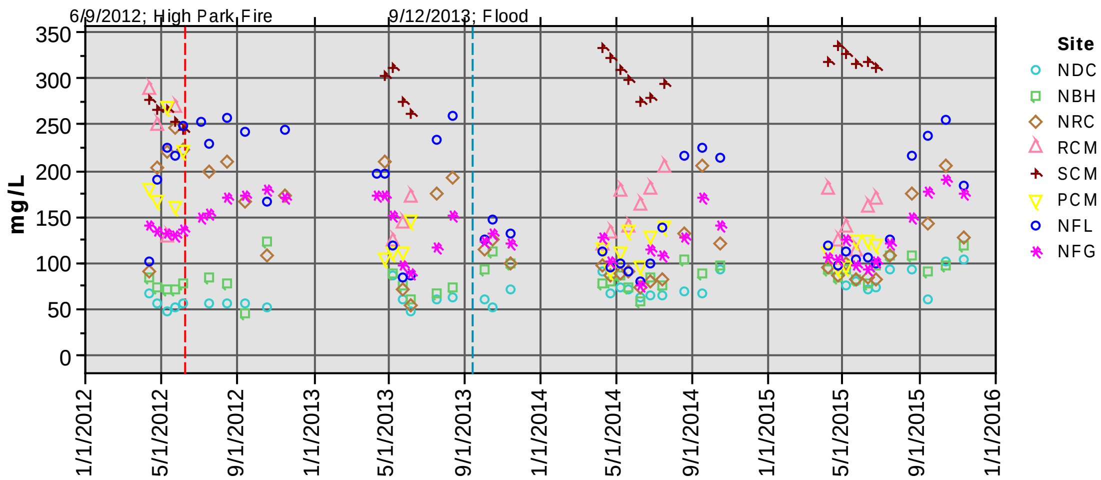
b) Turbidity on the North Fork CLP



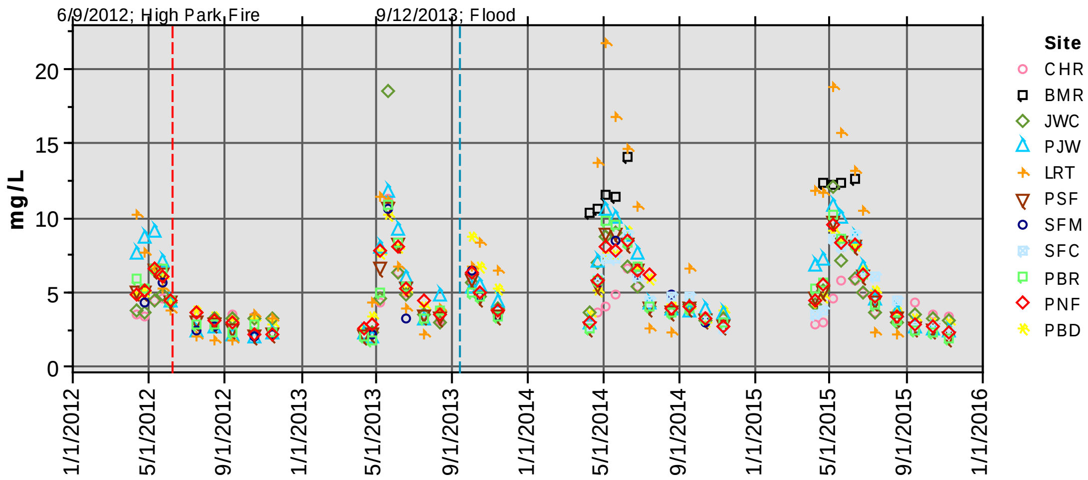
a) Total Dissolved Solids (TDS) on the Mainstem CLP



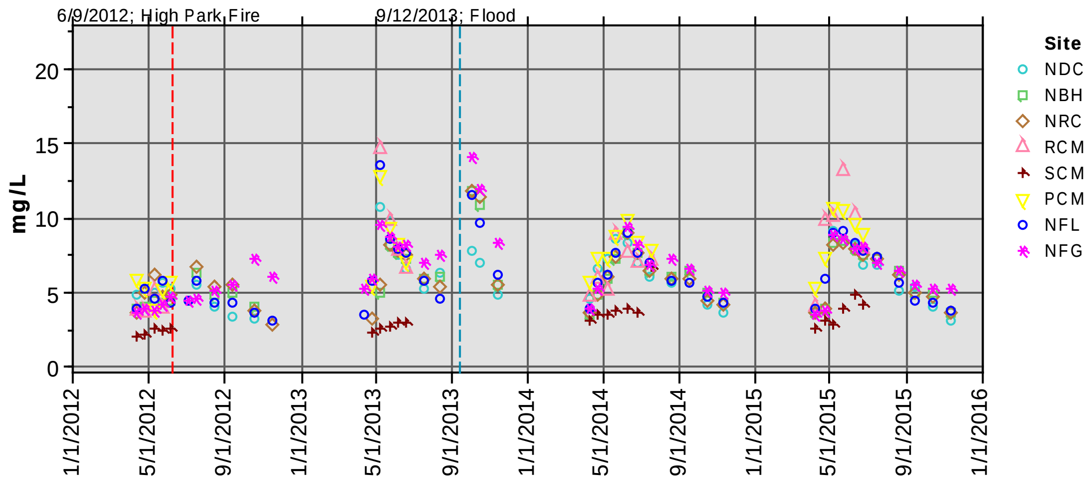
b) Total Dissolved Solids (TDS) on the North Fork CLP



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



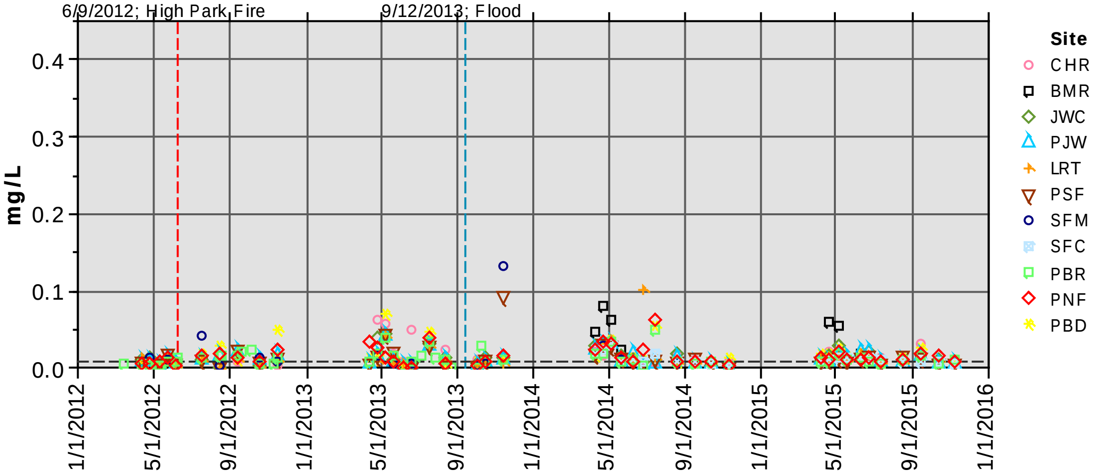
b) Total Organic Carbon (TOC) on the North Fork CLP



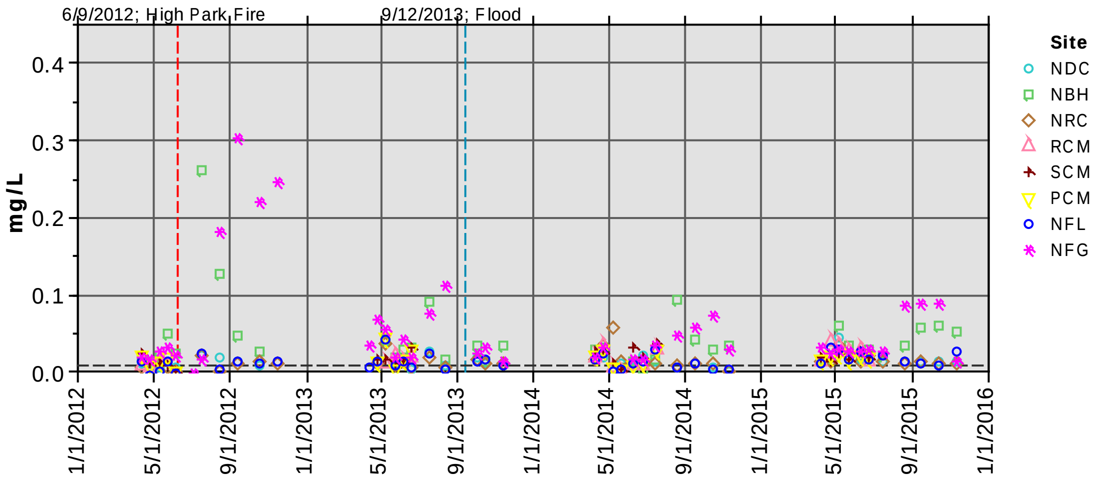
MAINSTEM & NORTH FORK CLP WATERSHEDS

NUTRIENTS

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

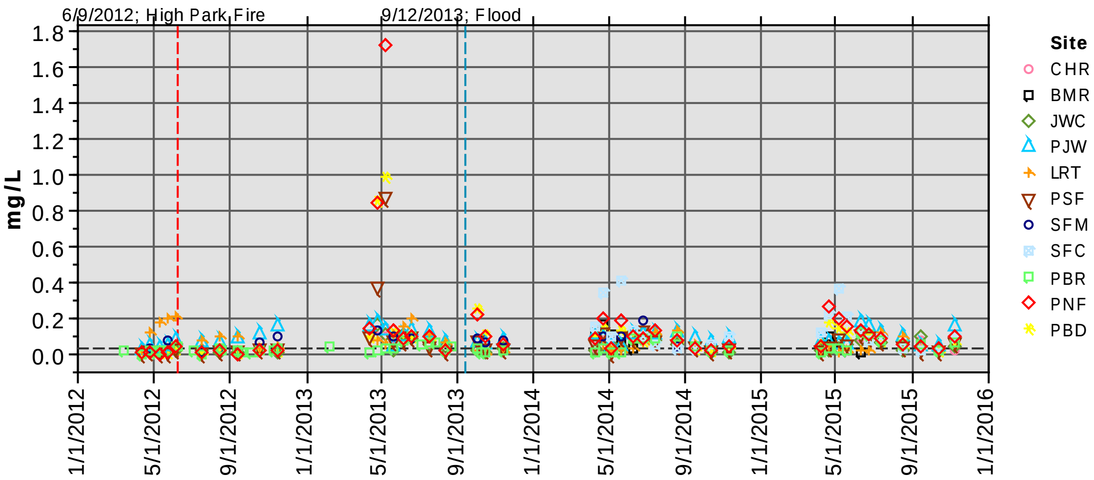


b) Ammonia as Nitrogen (NH3-N) on the North Fork CLP

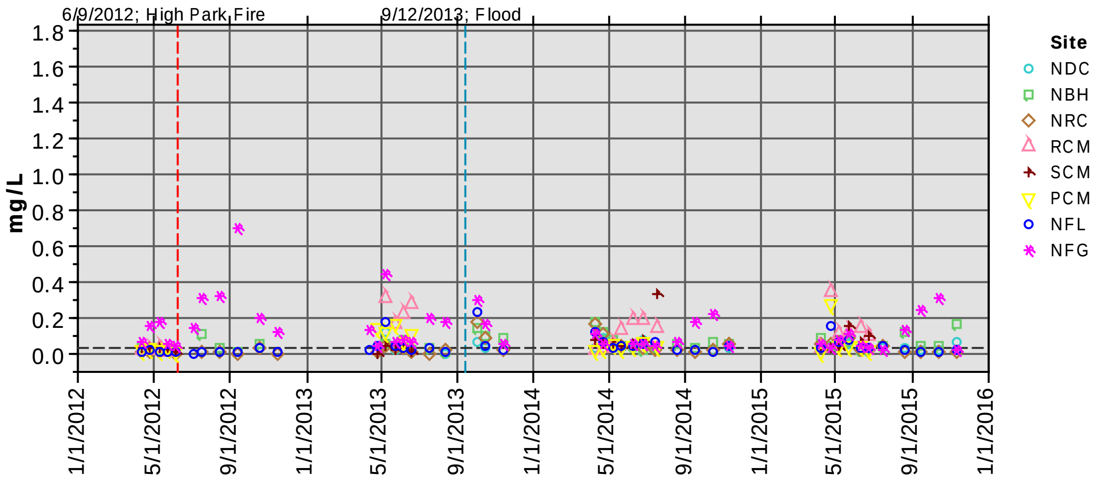


(- - - - FCWQL Reporting Limit; 0.010 mg/L)

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

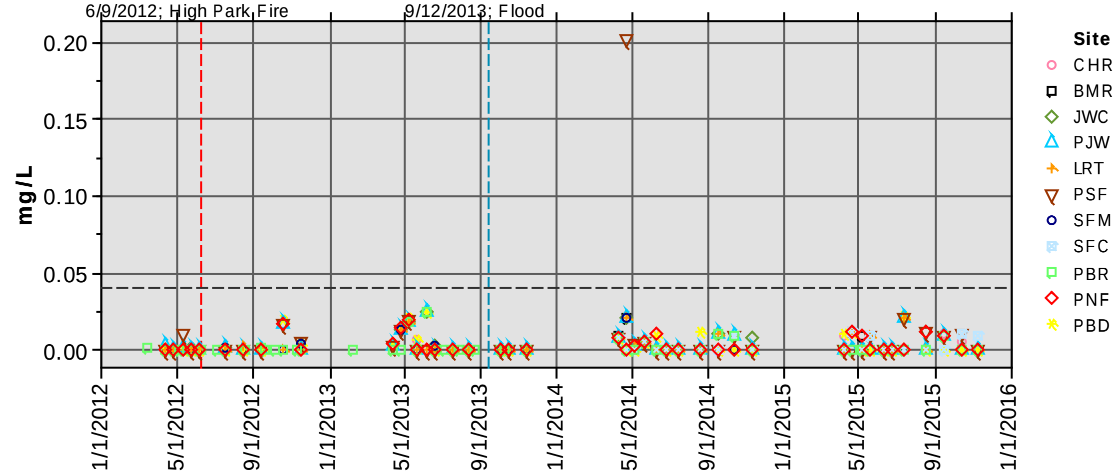


b) Nitrate as Nitrogen (NO3-N) on the North Fork CLP

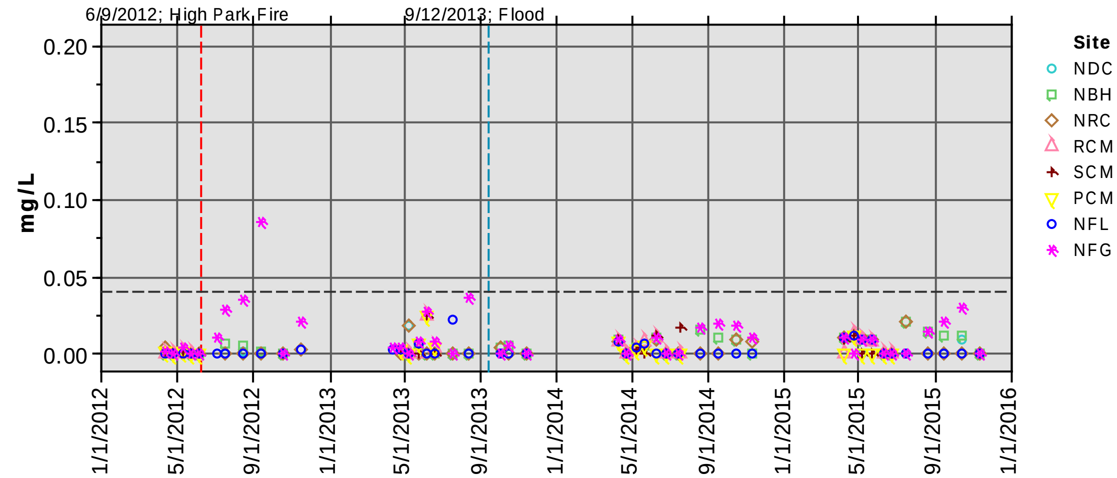


(- - - - FCWQL Reporting Limit; 0.04 mg/L)

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

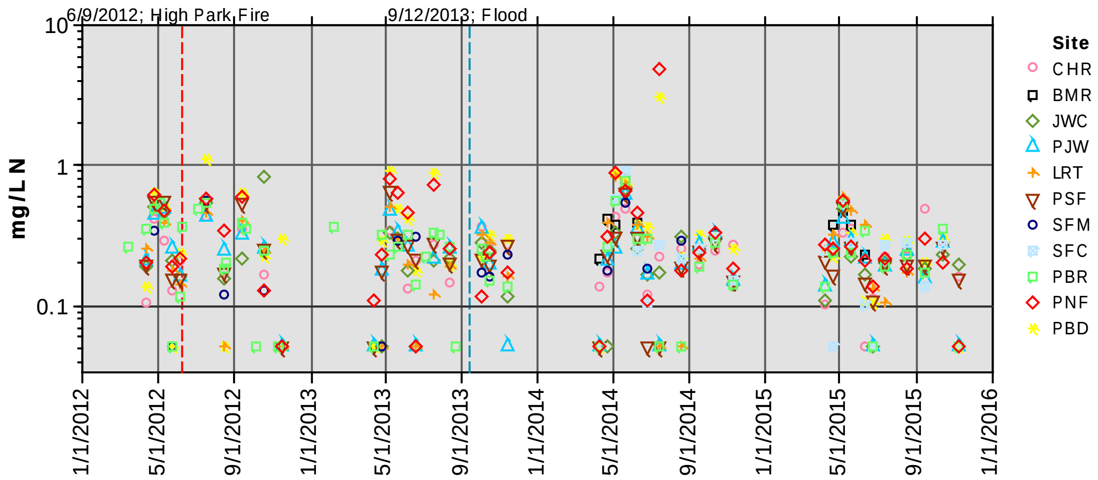


b) Nitrite as Nitrogen (NO2-N) on the North Fork CLP

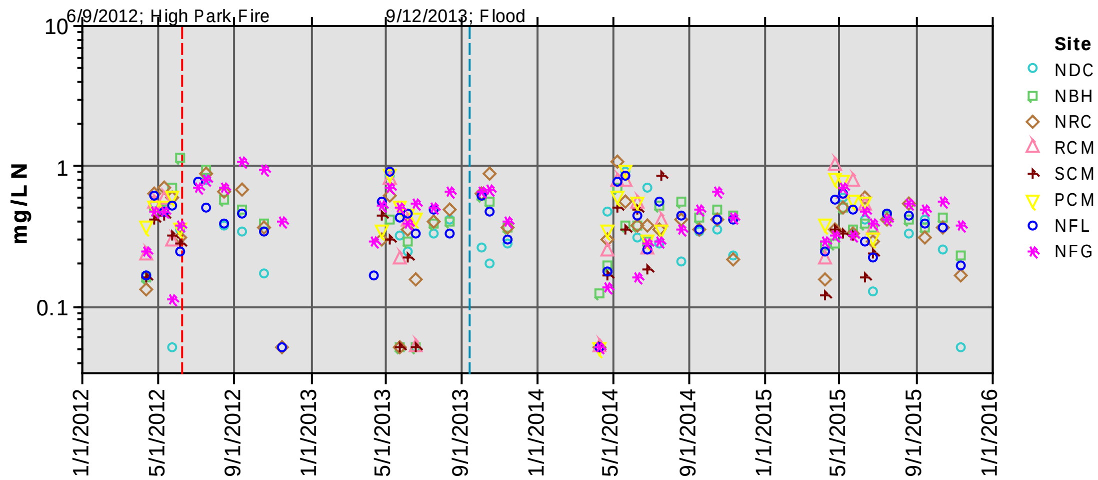


(- - - - FCWQL Reporting Limit; 0.04 mg/L)

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

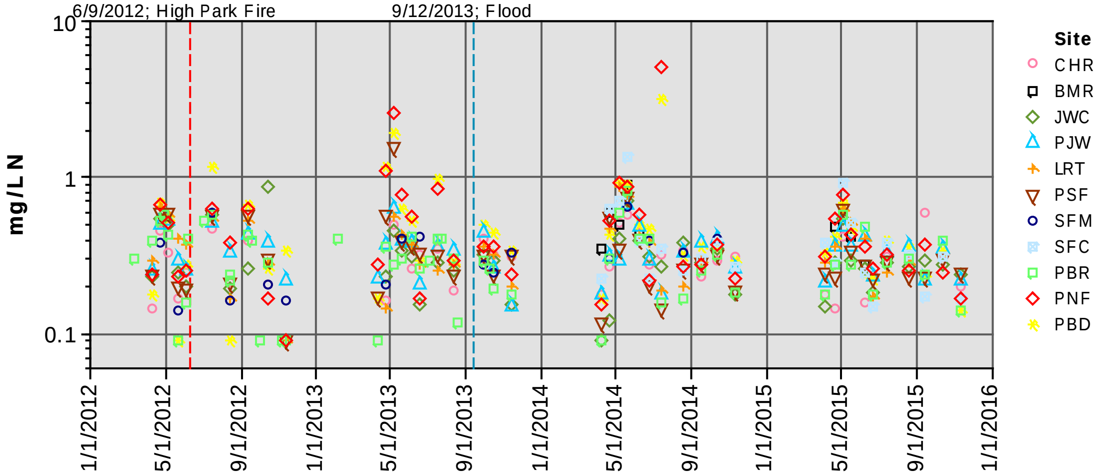


b) Total Kjeldahl Nitrogen (TKN) on the North Fork CLP

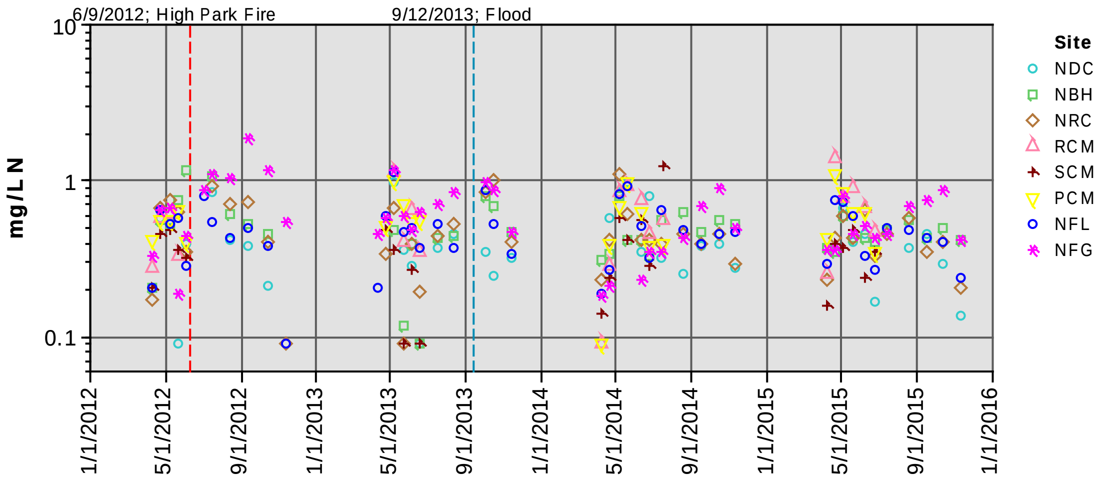


(- - - - FCWQL Reporting Limit; 0.100 mg/L)

a) Total nitrogen (TN) on the Mainstem CLP

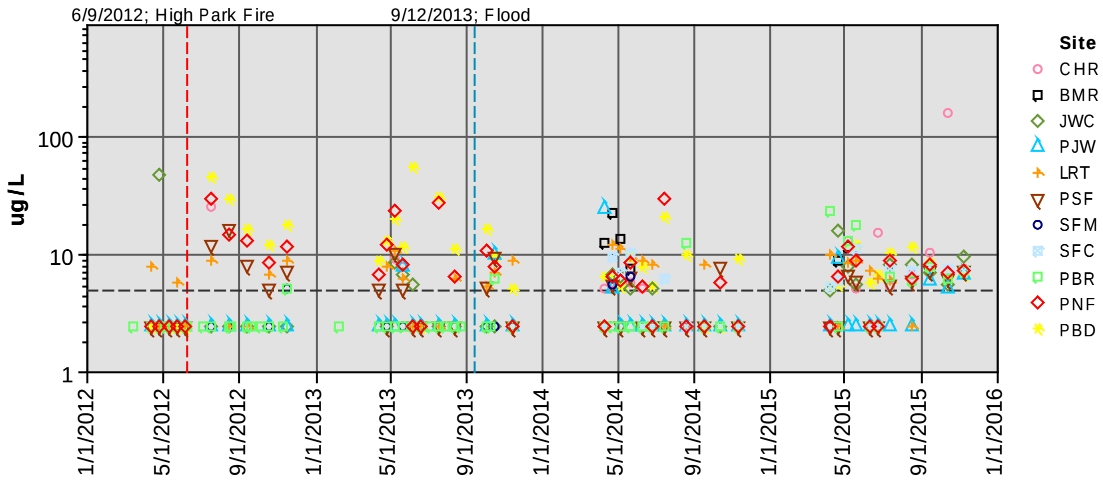


b) Total nitrogen (TN) on the North Fork CLP

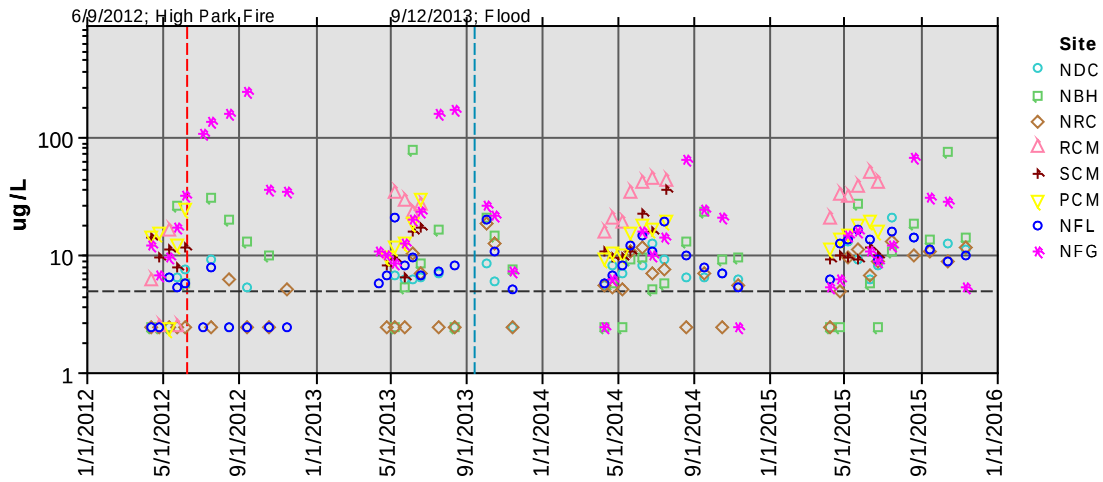


(- - - - FCWQL Reporting Limit; 0.10 mg/L)

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

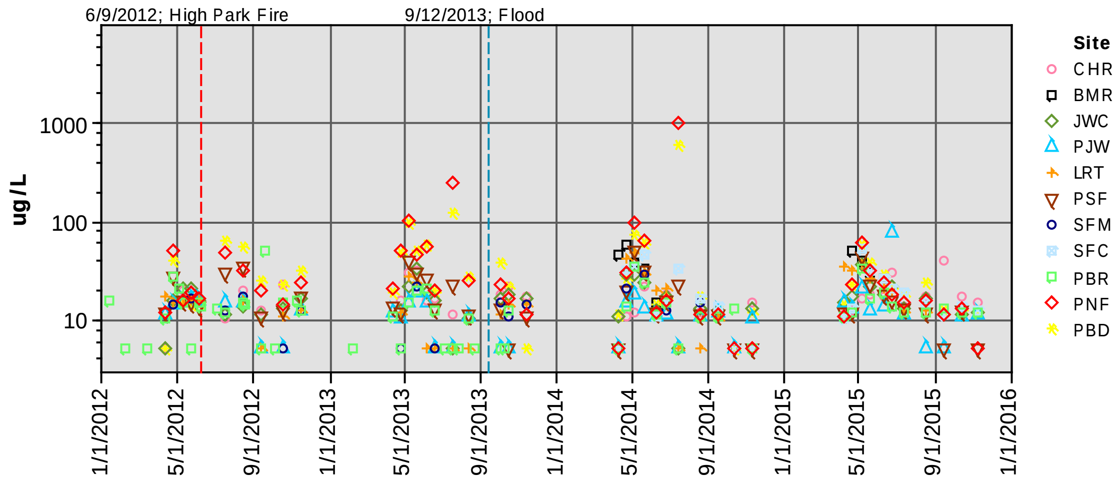


b) Ortho-phosphate (PO4) on the North Fork CLP

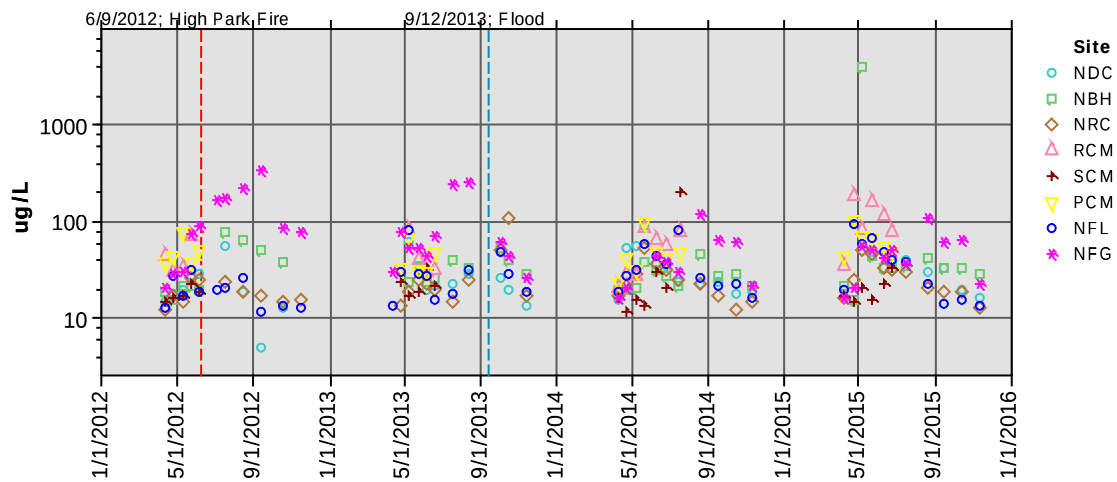


(- - - - FCWQL Reporting Limit; 5 µg/L)

a) Total Phosphorus (TP) on the Mainstem CLP



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

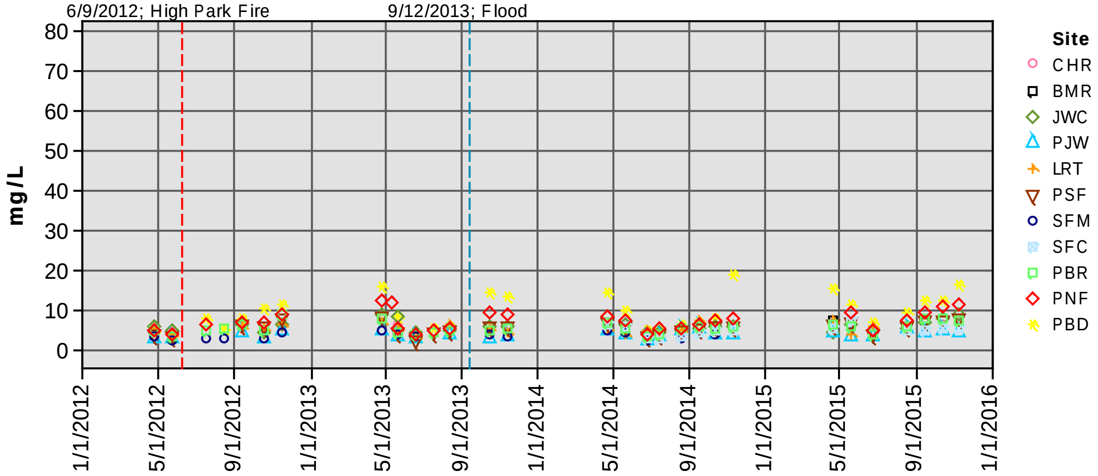


(- - - - FCWQL Reporting Limit; 10 µg/L)

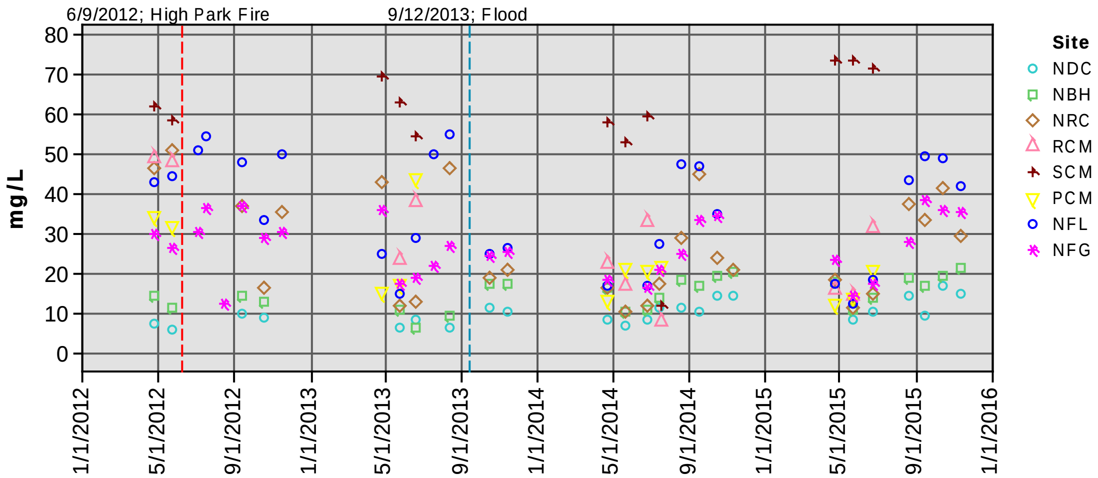
MAINSTEM & NORTH FORK CLP WATERSHEDS

MAJOR IONS

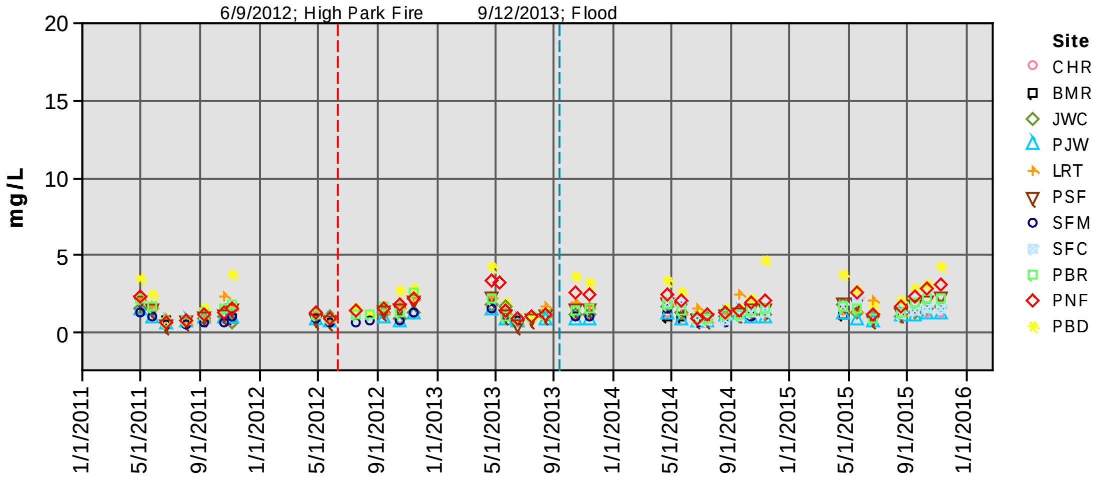
a) Calcium (Ca) on the Mainstem CLP



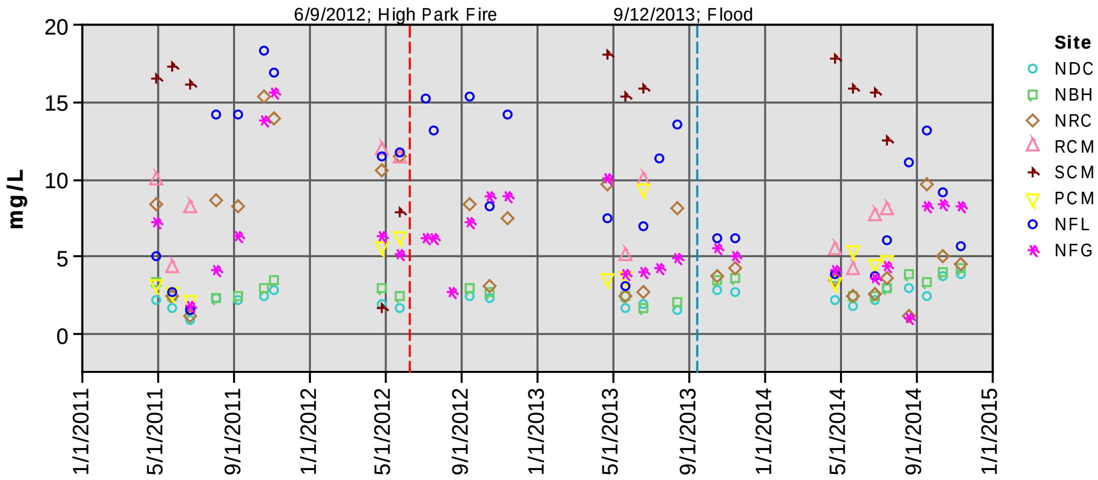
b) Calcium (Ca) on the North Fork CLP



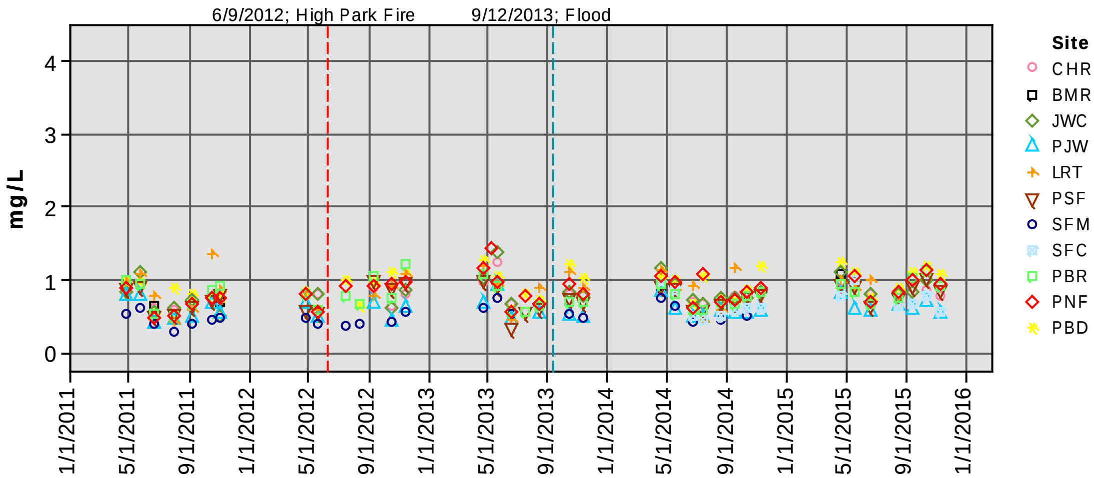
a) Magnesium (Mg) on the Mainstem CLP



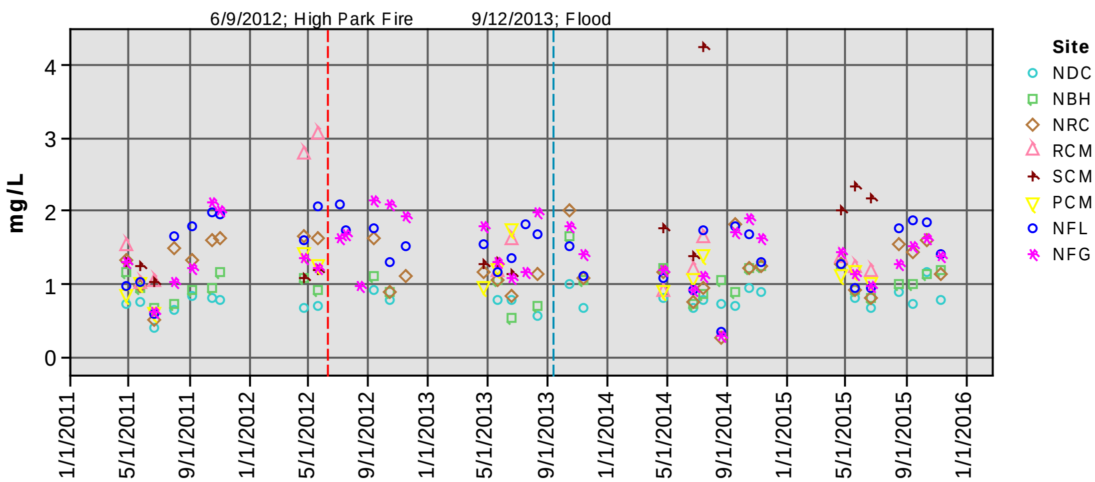
b) Magnesium (Mg) on the North Fork CLP



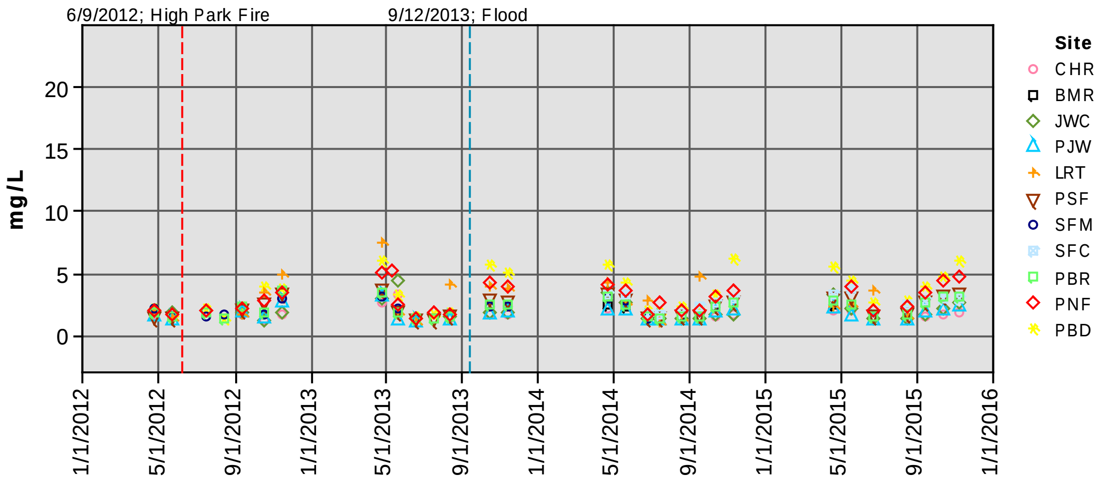
a) Potassium (K) on the Mainstem CLP



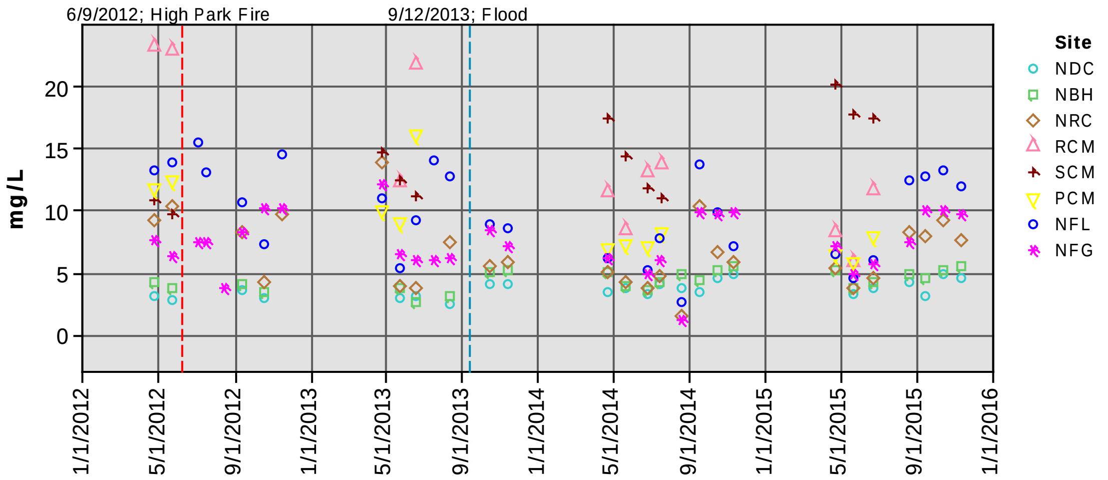
b) Potassium (K) on the North Fork CLP



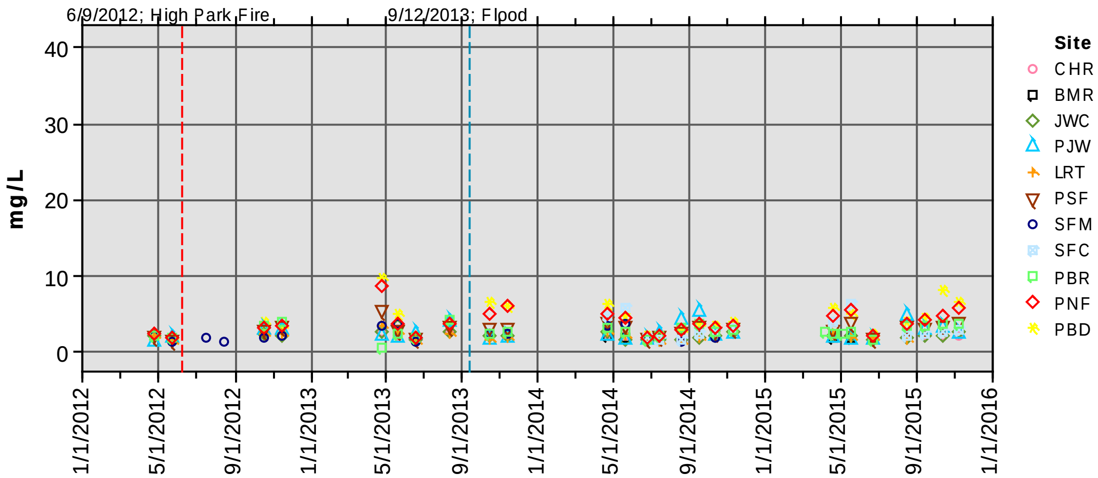
a) Sodium (Na) on the Mainstem CLP



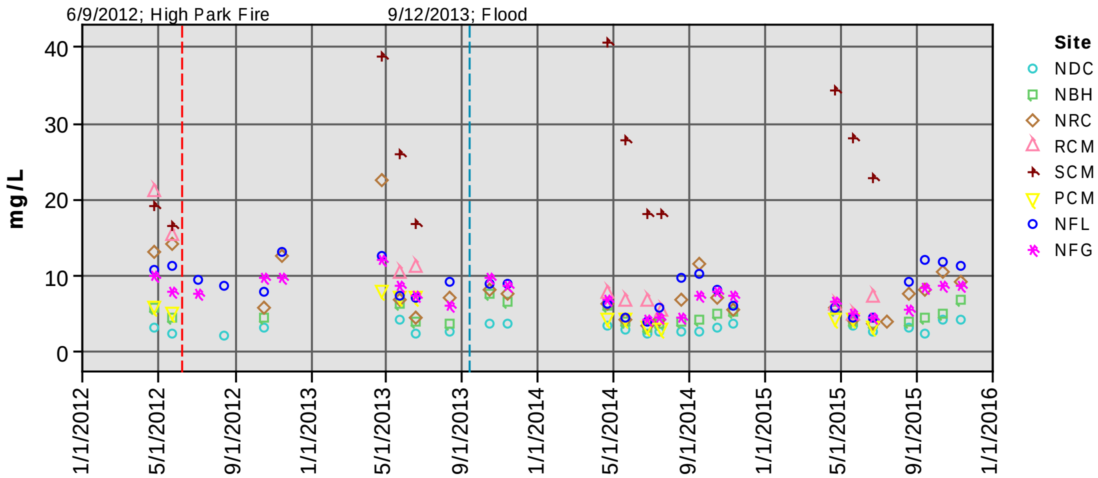
b) Sodium (Na) on the North Fork CLP



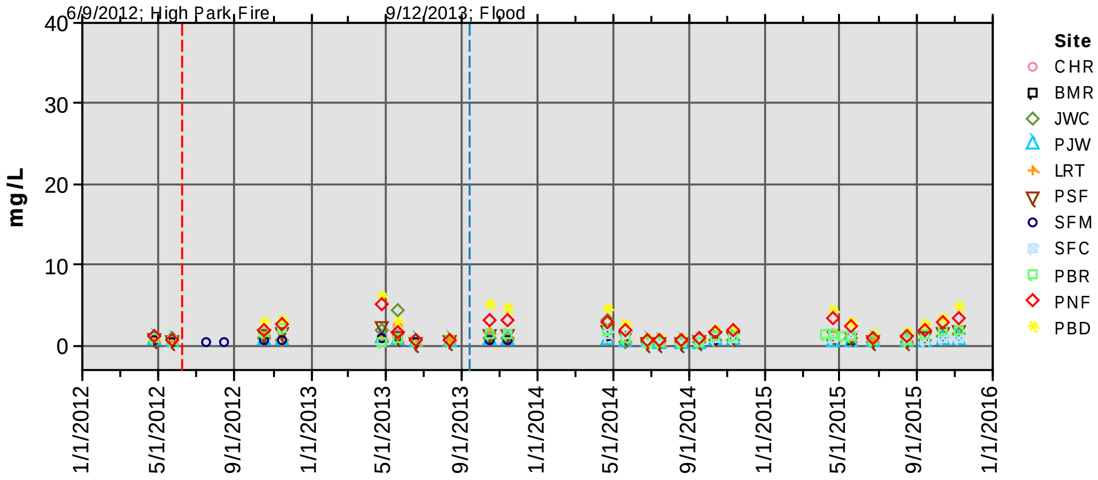
a) Sulfate (SO4) on the Mainstem CLP



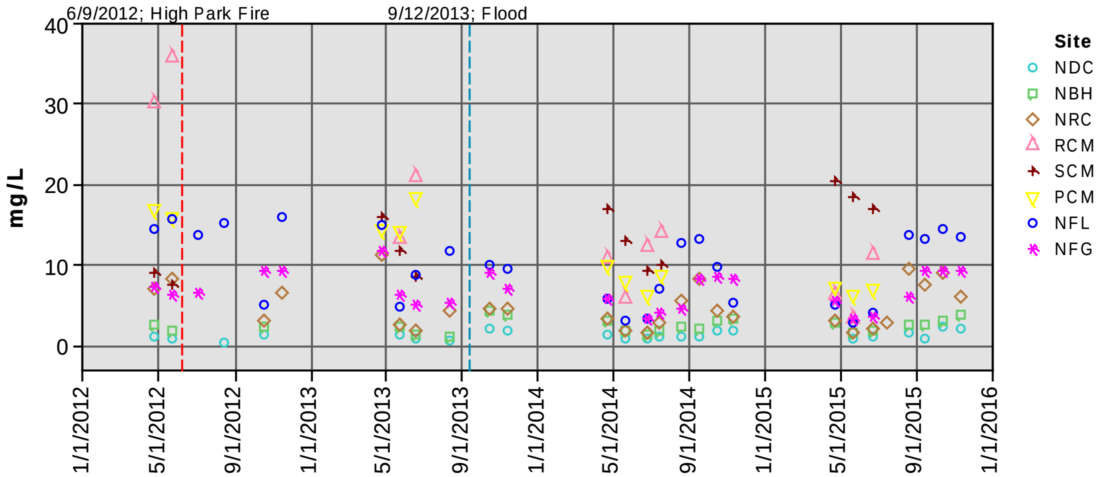
b) Sulfate (SO4) on the North Fork CLP



a) Chloride (Cl) on the Mainstem CLP



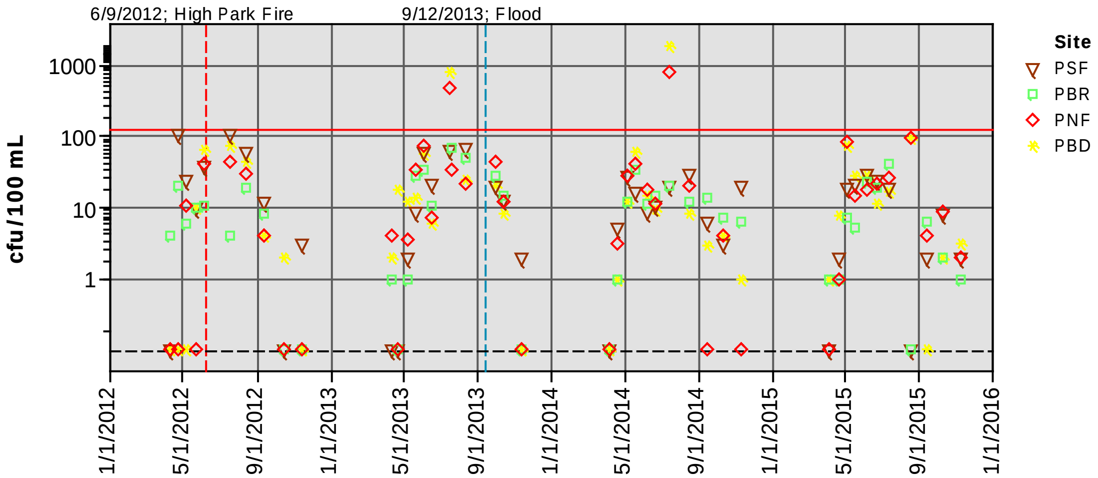
b) Chloride (Cl) on the North Fork CLP



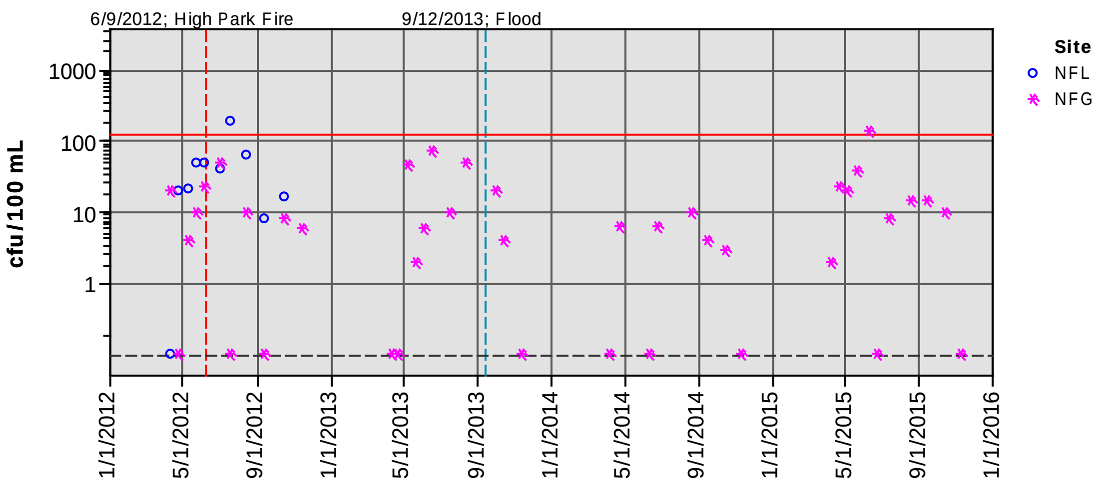
MAINSTEM & NORTH FORK CLP WATERSHEDS

MICROBIOLOGICAL

a) E. coli on the Mainstem CLP



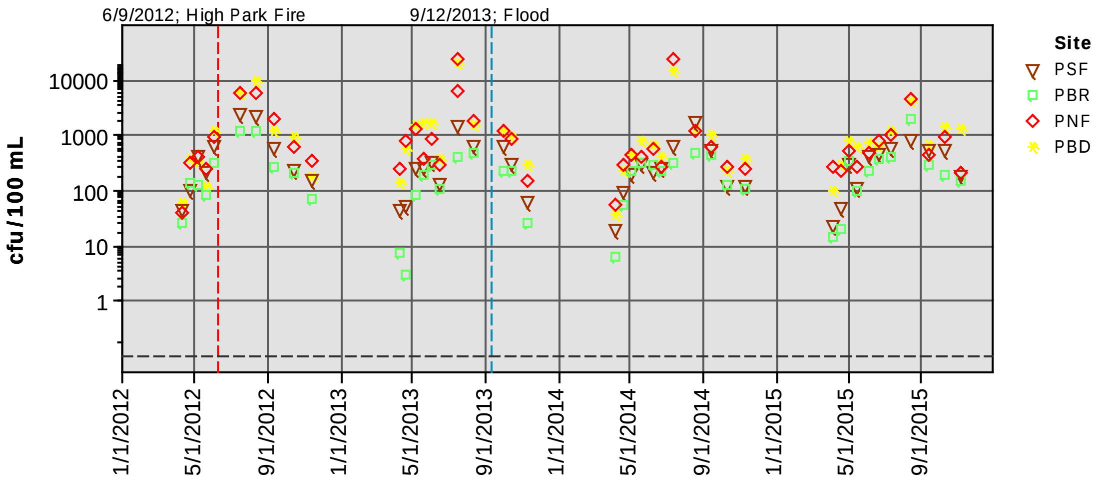
b) E. coli on the North Fork CLP



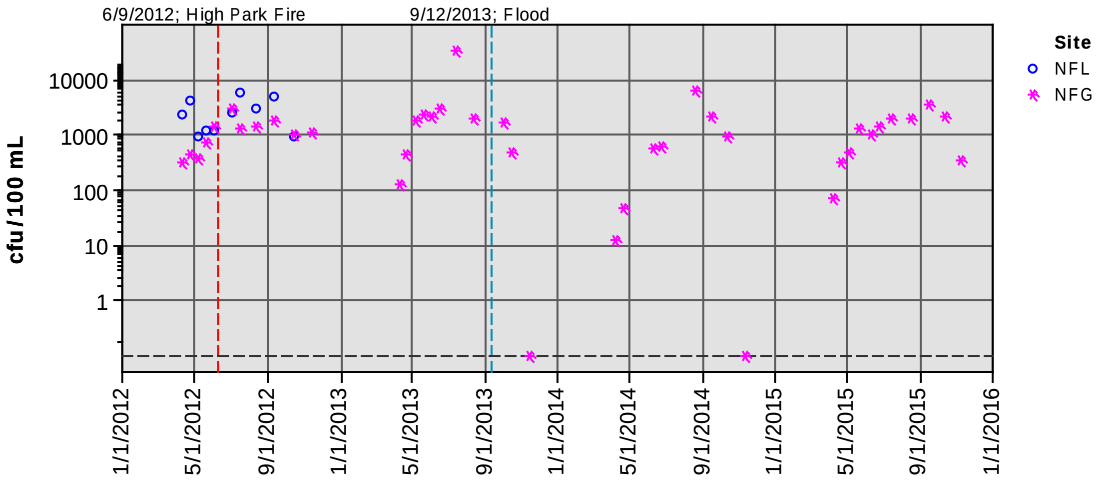
(- - - - FCWQL Reporting Limit; 0 cfu/100 ml)

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

a) Total coliforms on the Mainstem CLP



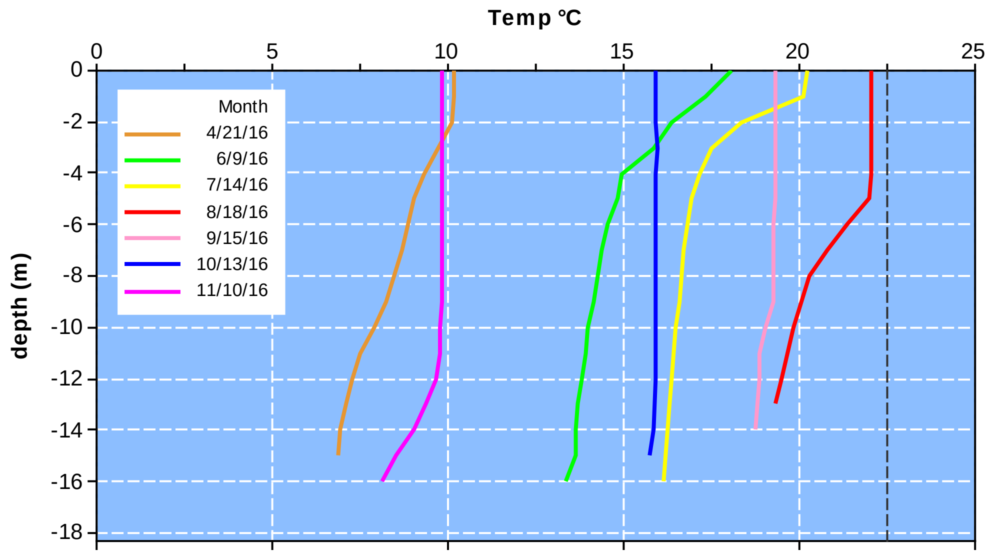
b) Total coliforms on the North Fork CLP



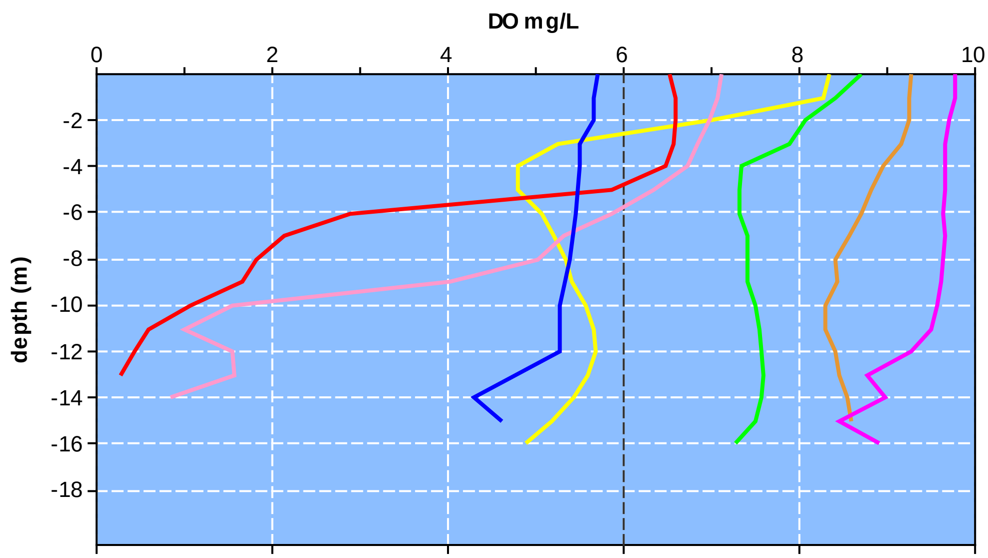
(- - - - FCWQL Reporting Limit; 0 cfu/100 ml)

SEAMAN RESERVOIR

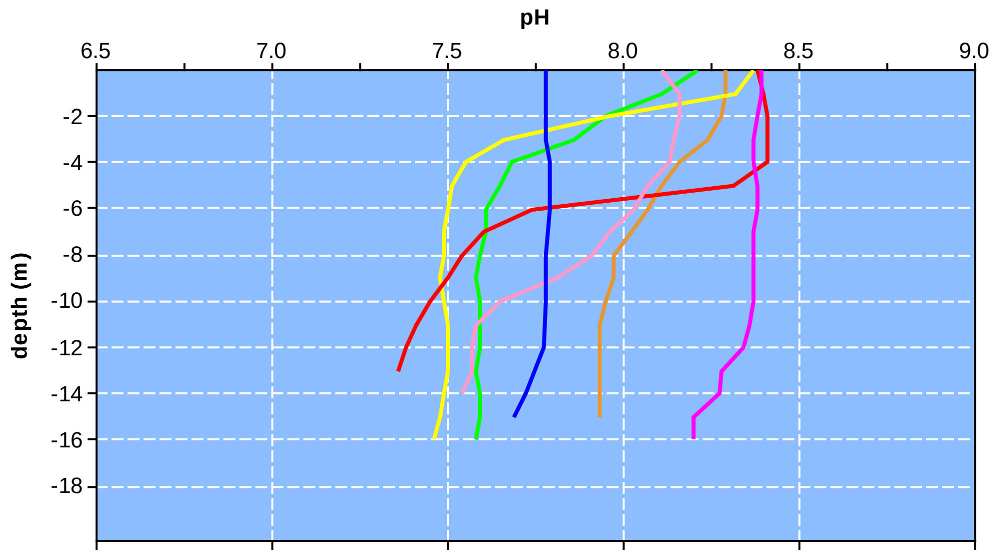
DEPTH PROFILES

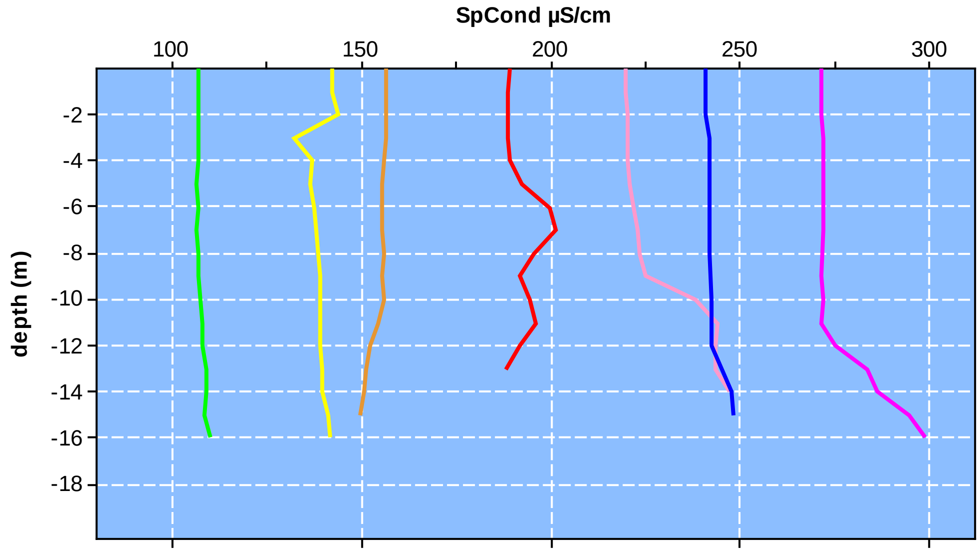


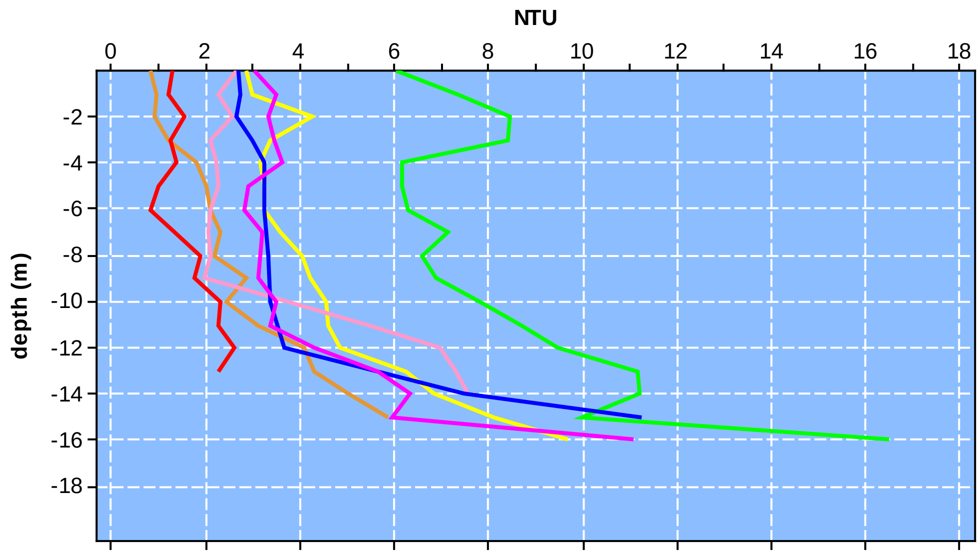
----- Water quality standard for cold water aquatic life: 22.5 degrees C



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


pH
6.5
7.0
7.5
8.0
8.5
9.0
depth (m)
-2
-4
-6
-8
-10
-12
-14
-16
-18

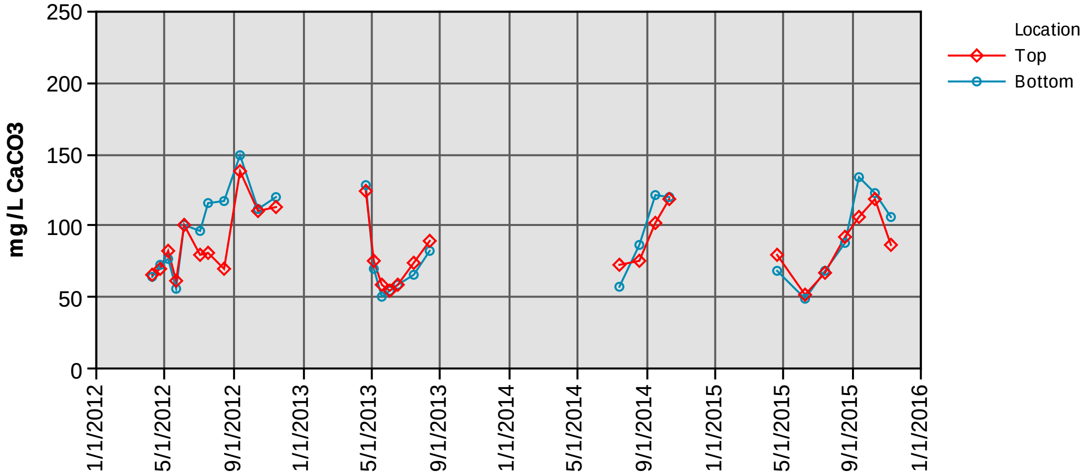

SpCond µS/cm
100
150
200
250
300
depth (m)
-2
-4
-6
-8
-10
-12
-14
-16
-18


NTU
0
2
4
6
8
10
12
14
16
18
depth (m)
-2
-4
-6
-8
-10
-12
-14
-16
-18

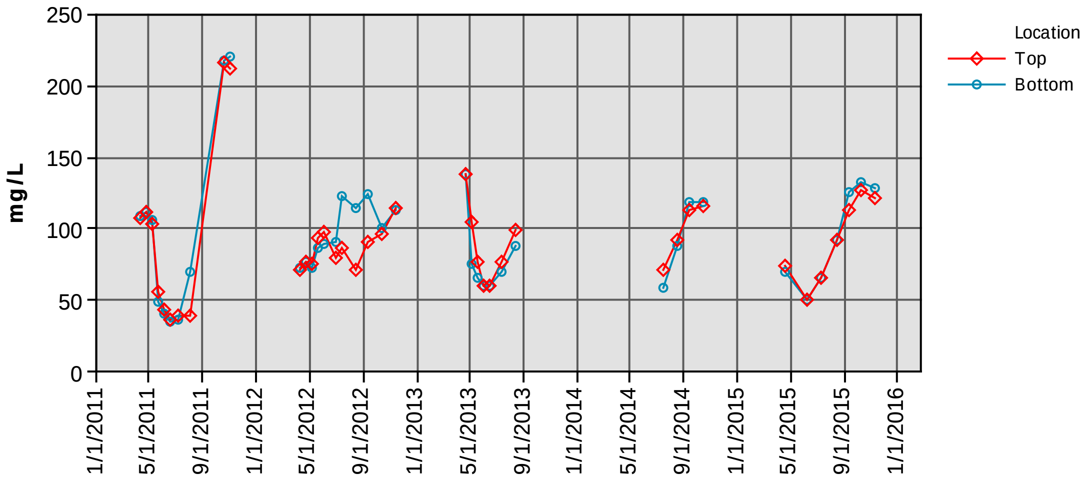
SEAMAN RESERVOIR

GENERAL PARAMETERS

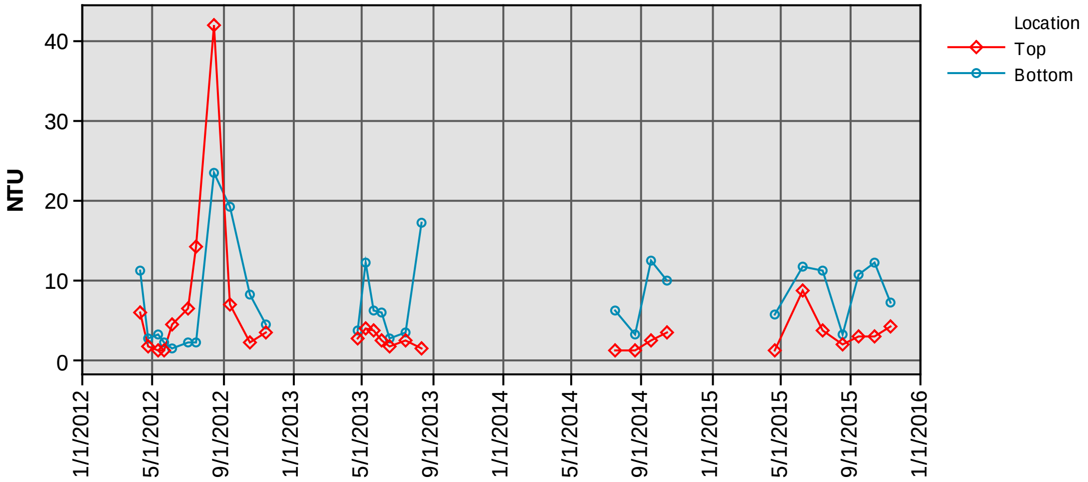
Alkalinity in Seaman Reservoir (SER)



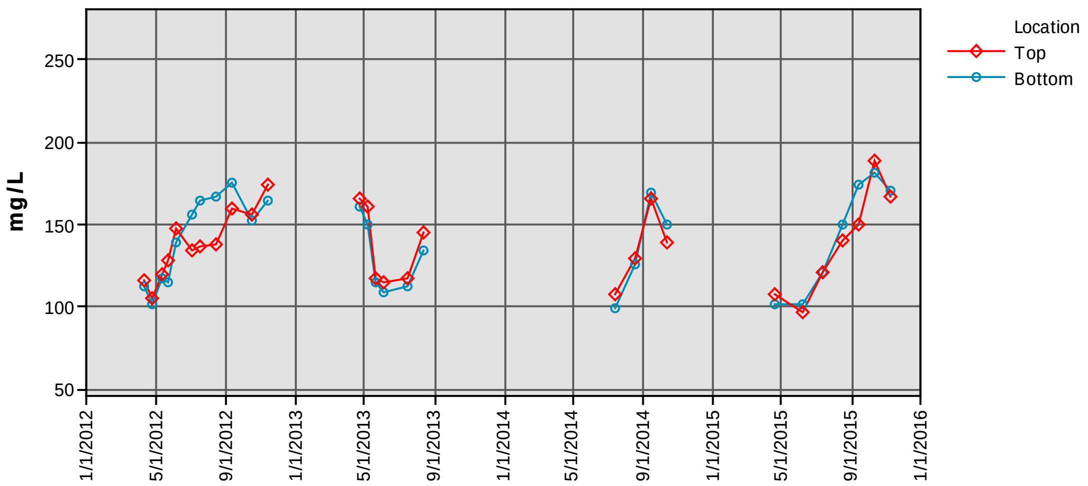
Hardness in Seaman Reservoir (SER)

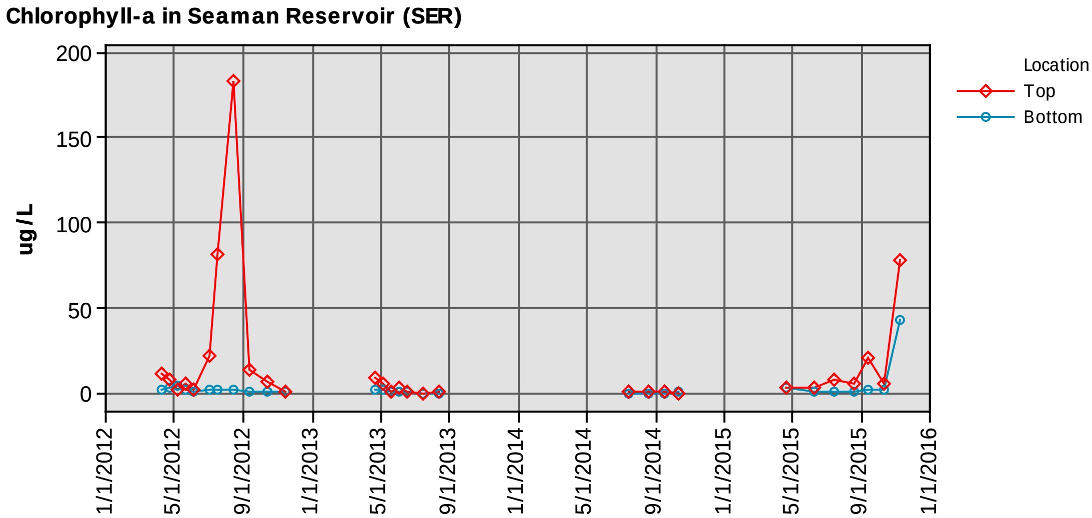


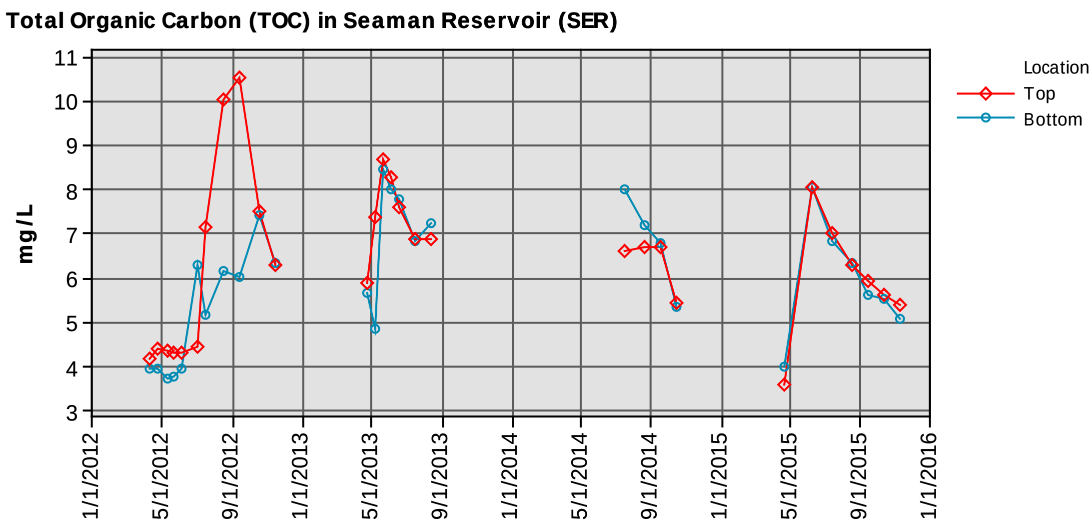
Turbidity in Seaman Reservoir (SER)



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

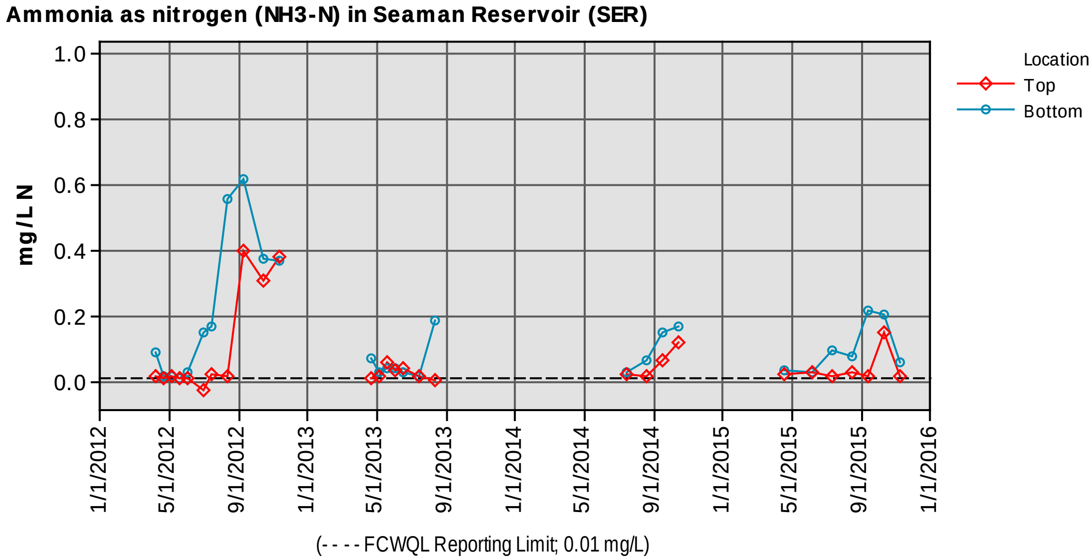



Chlorophyll-a in Seaman Reservoir (SER)
ug/L
200
150
100
50
0
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015
5/1/2015
9/1/2015
1/1/2016
Location
Top
Bottom

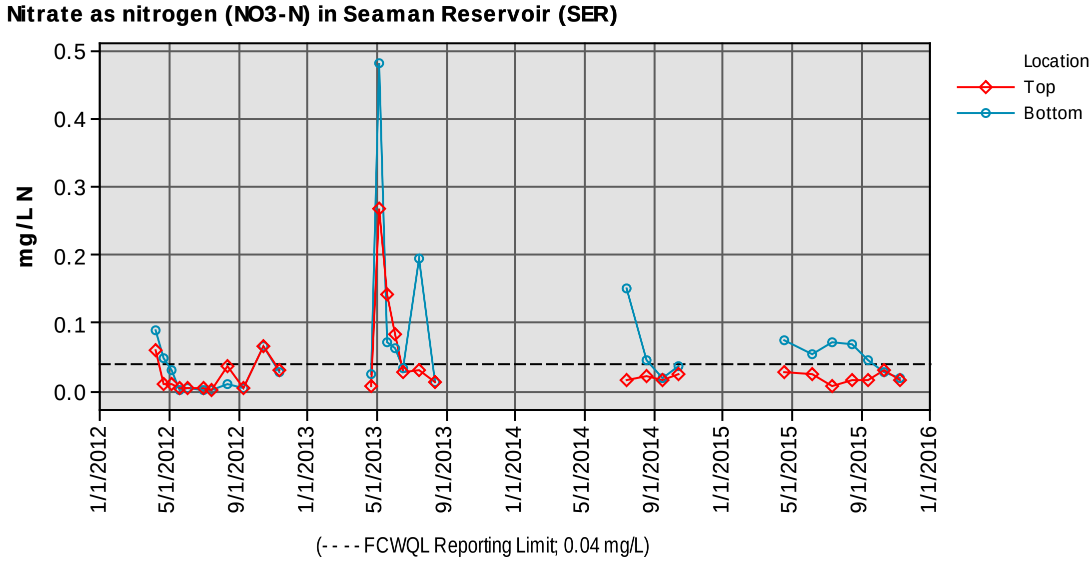

Total Organic Carbon (TOC) in Seaman Reservoir (SER)
mg/L
11
10
9
8
7
6
5
4
3
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015
5/1/2015
9/1/2015
1/1/2016
Location
Top
Bottom

SEAMAN RESERVOIR

NUTRIENTS

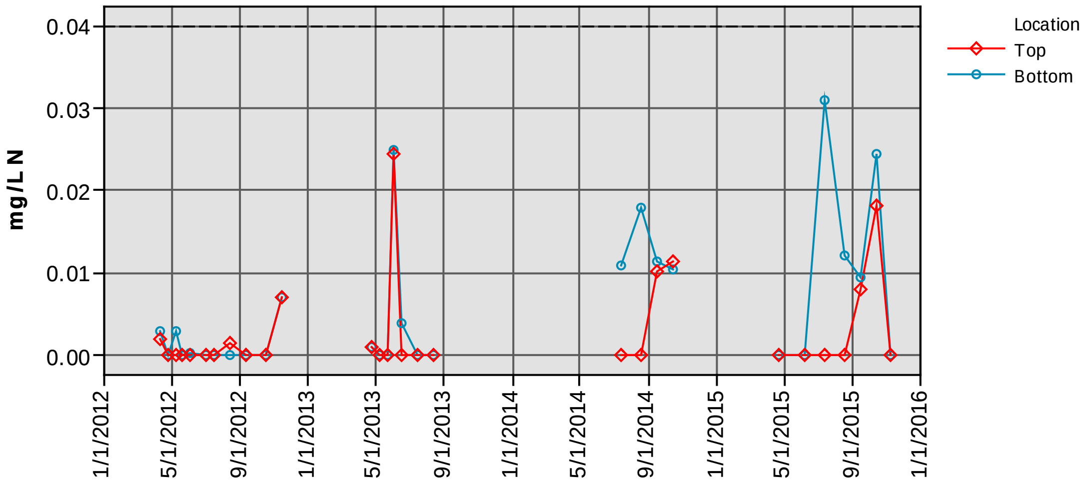


Ammonia as nitrogen (NH3-N) in Seaman Reservoir (SER)
mg/L N
1.0
0.8
0.6
0.4
0.2
0.0
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015
5/1/2015
9/1/2015
1/1/2016
Location
Top
Bottom
(- - - - FCWQL Reporting Limit; 0.01 mg/L)



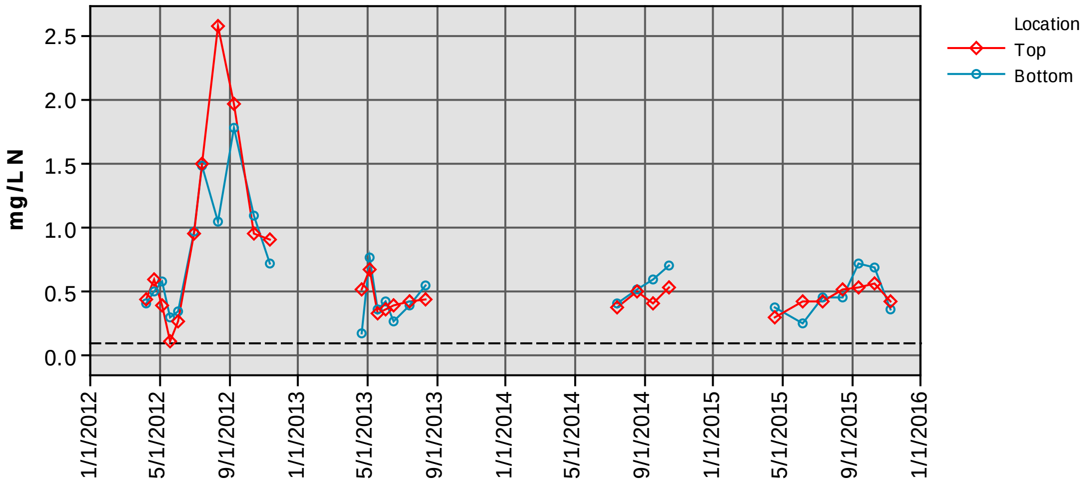
Nitrate as nitrogen (NO3-N) in Seaman Reservoir (SER)
mg/L N
0.5
0.4
0.3
0.2
0.1
0.0
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015
5/1/2015
9/1/2015
1/1/2016
Location
Top
Bottom
(- - - - FCWQL Reporting Limit; 0.04 mg/L)

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



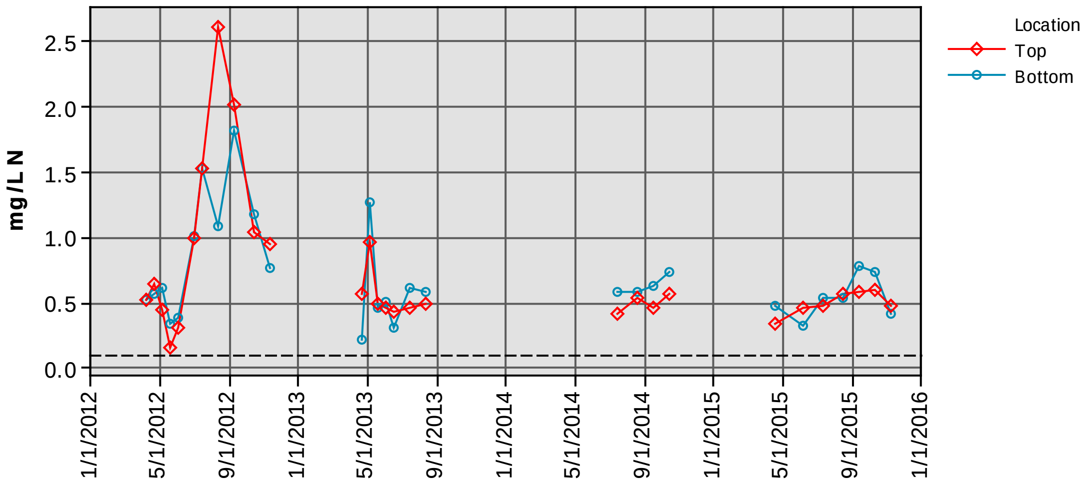
(- - - - FCWQL Reporting Limit; 0.04 mg/L)

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

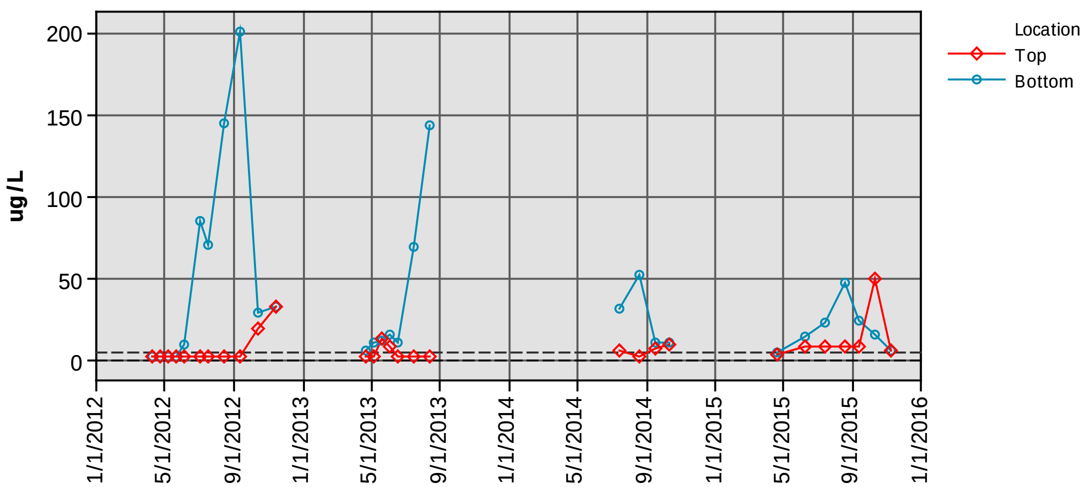


(- - - - FCWQL Reporting Limit; 0.100 mg/L)

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

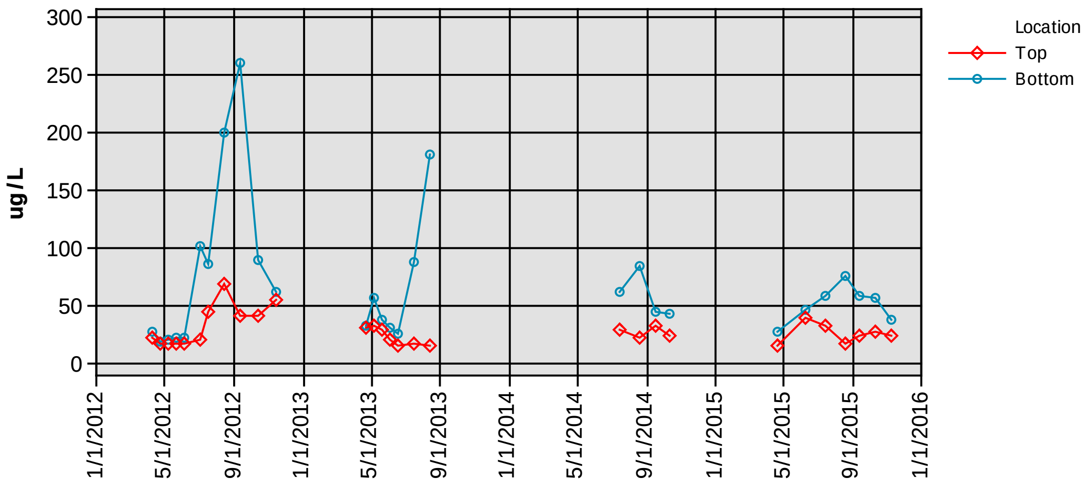


Ortho-phosphate (PO4) in Seaman Reservoir (SER)



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

Total Phosphorus (TP) in Seaman Reservoir (SER)

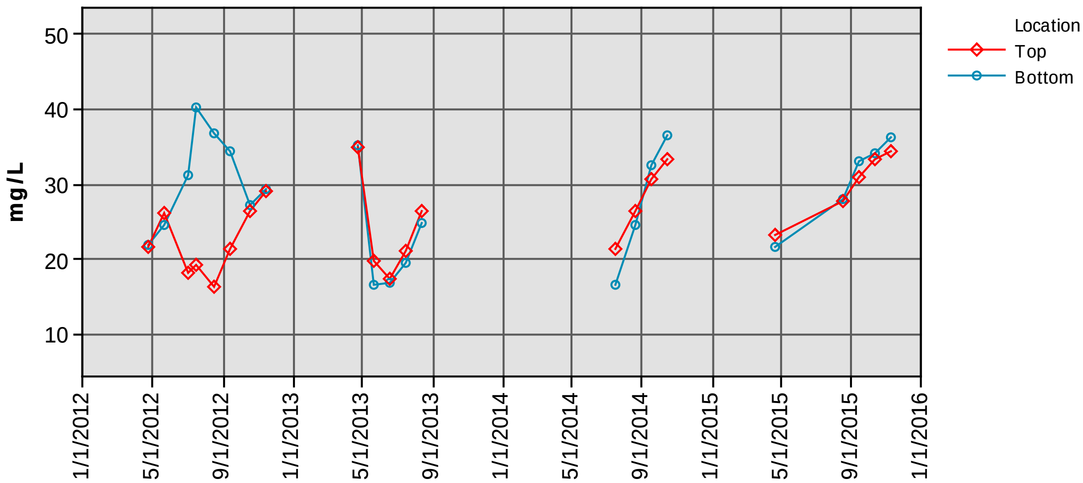


(- - - - FCWQL Reporting Limit; 0.010 mg/L)

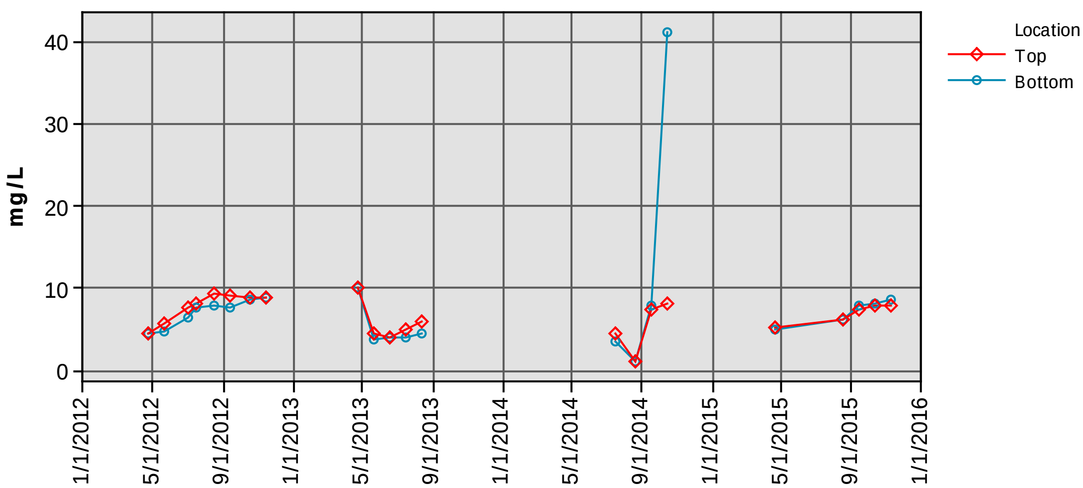
SEAMAN RESERVOIR

MAJOR IONS

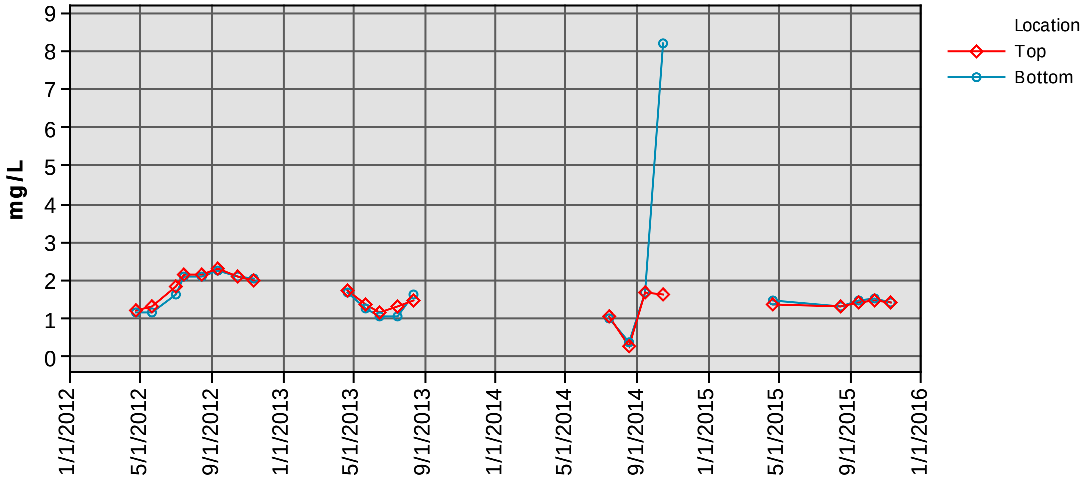
Calcium (Ca) in Seaman Reservoir (SER)



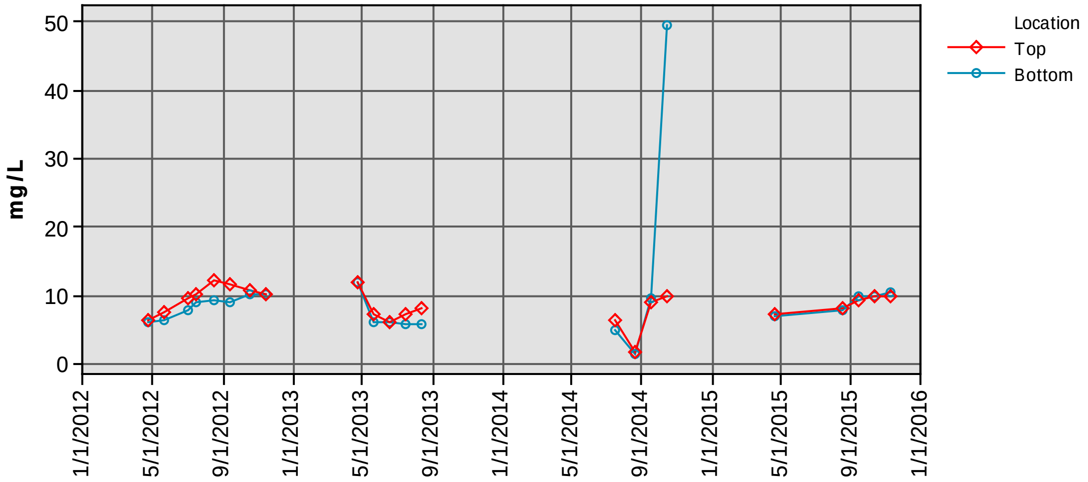
Magnesium (Mg) in Seaman Reservoir (SER)



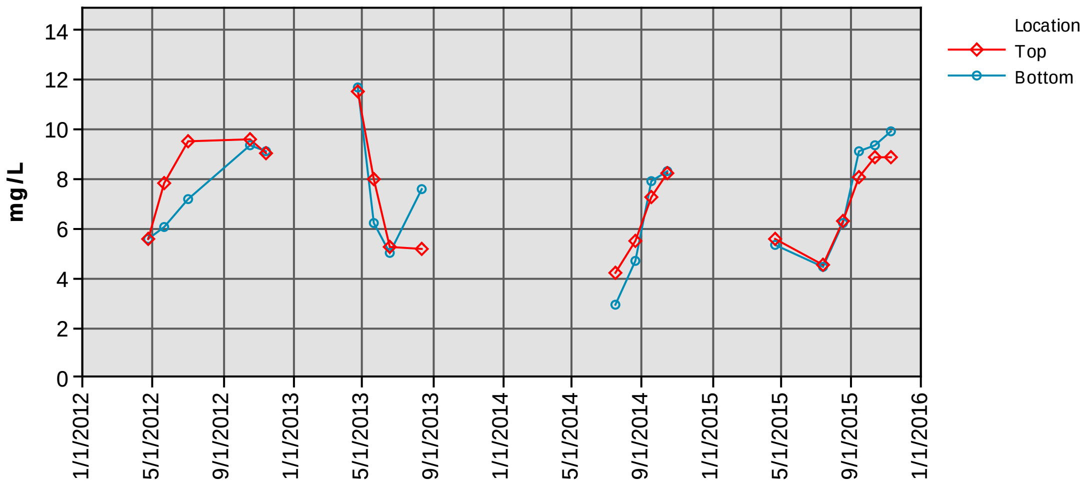
Potassium (K) in Seaman Reservoir (SER)



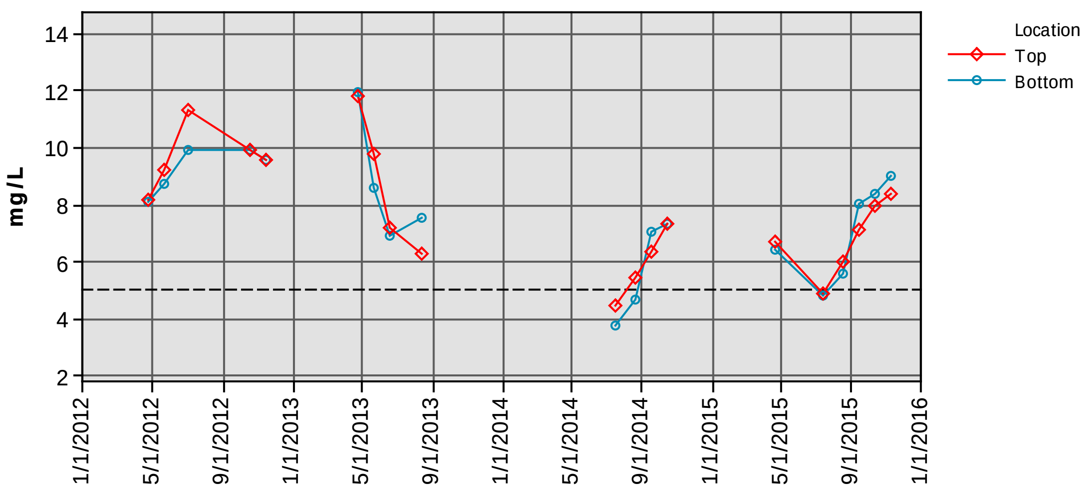
Sodium (Na) in Seaman Reservoir (SER)



Chloride (Cl) in Seaman Reservoir (SER)



Sulfate (SO4) in Seaman Reservoir (SER)

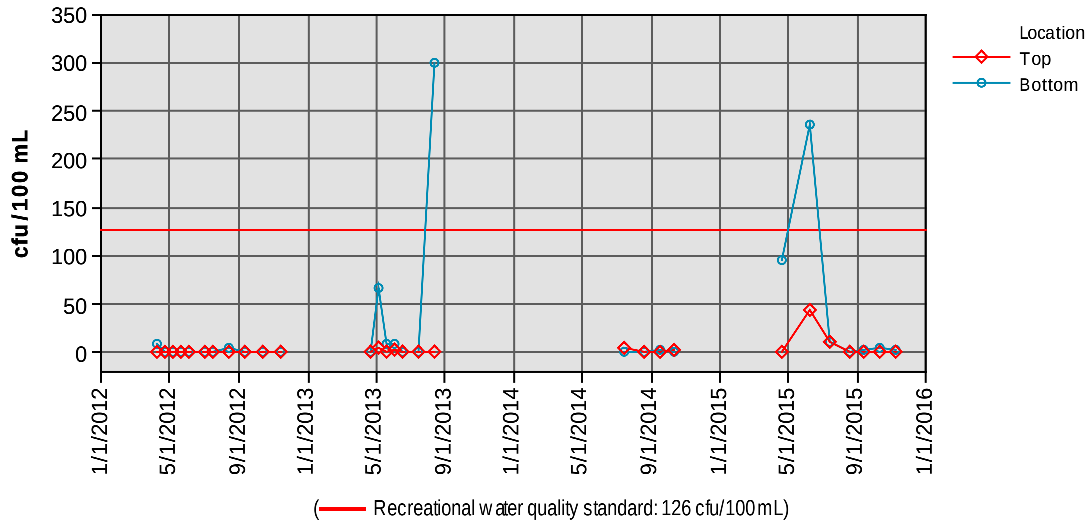


(- - - - FCWQL Reporting Limit; 5 mg/L)

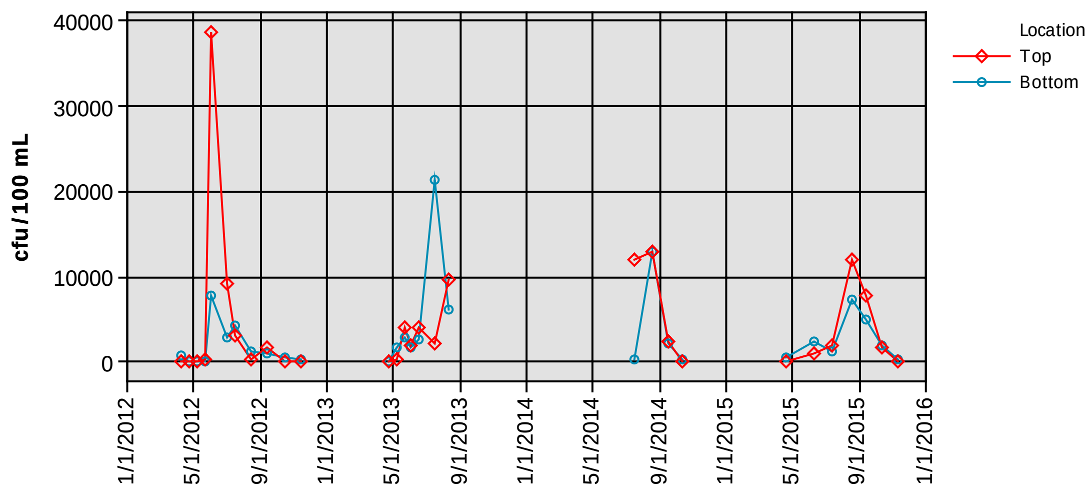
MAINSTEM & NORTH FORK CLP WATERSHEDS

MICROBIOLOGICAL

E. coli in Seaman Reservoir (SER)



Total coliforms in Seaman Reservoir (SER)



ATTACHMENT 8

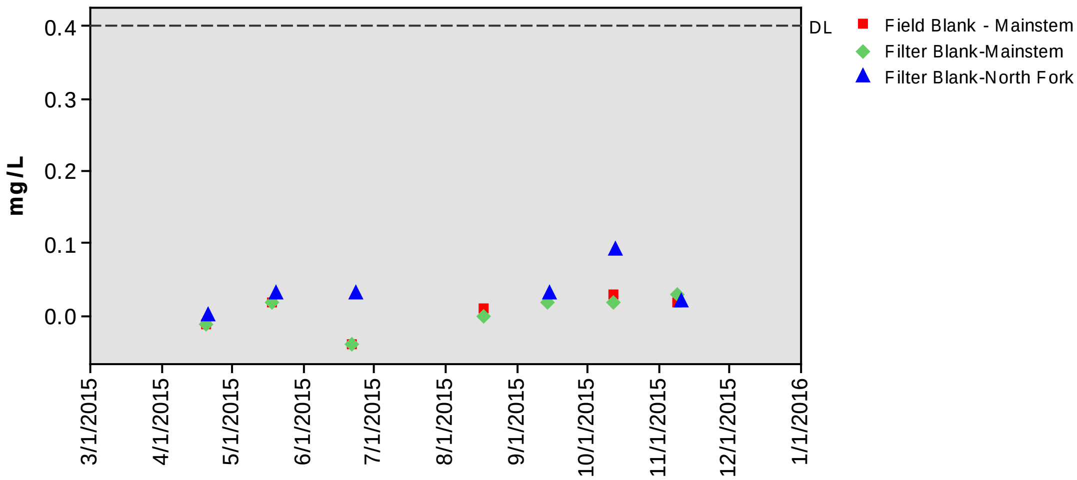
2015 UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM

QUALITY ASSURANCE QUALITY CONTROL

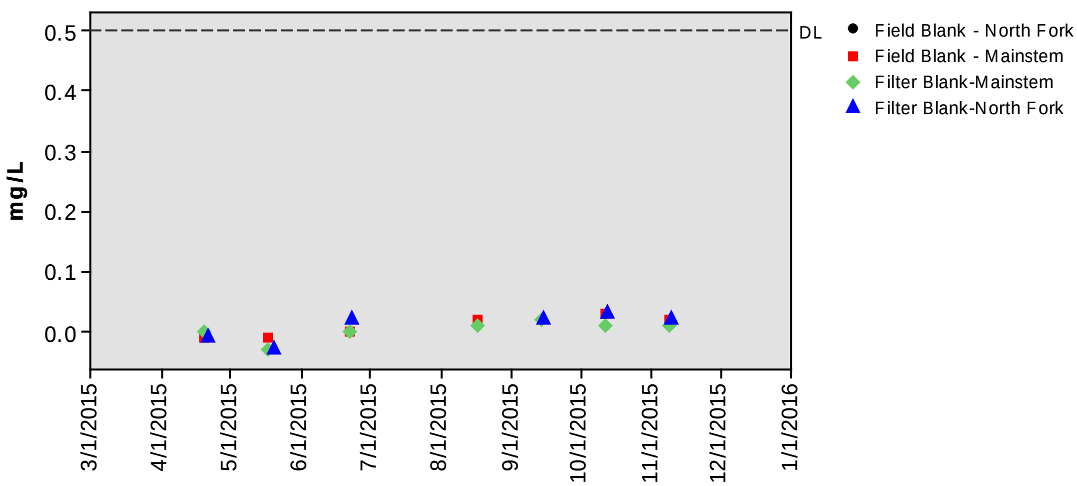
UCLP MAINSTEM AND NORTH FORK

FIELD BLANKS AND LAB FILTER BLANKS

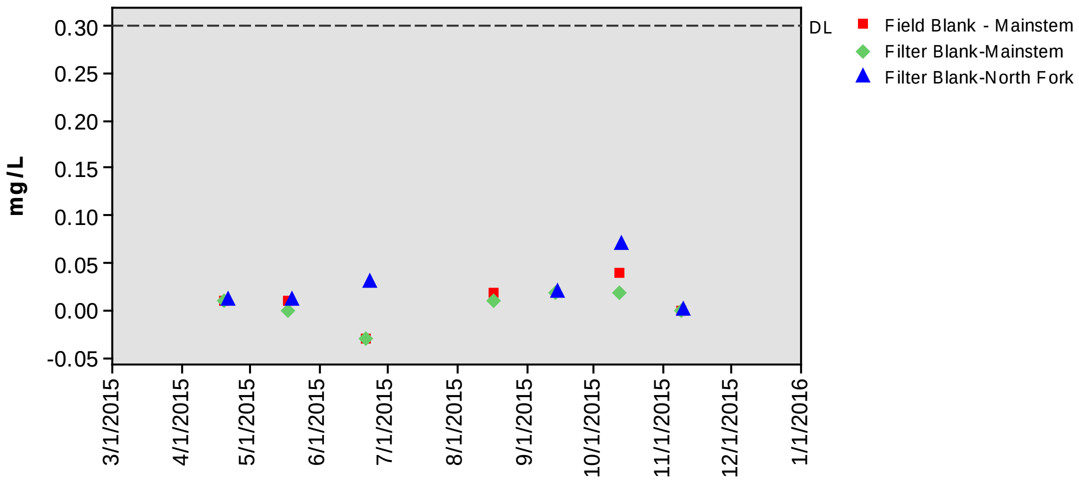
Sodium (Na)



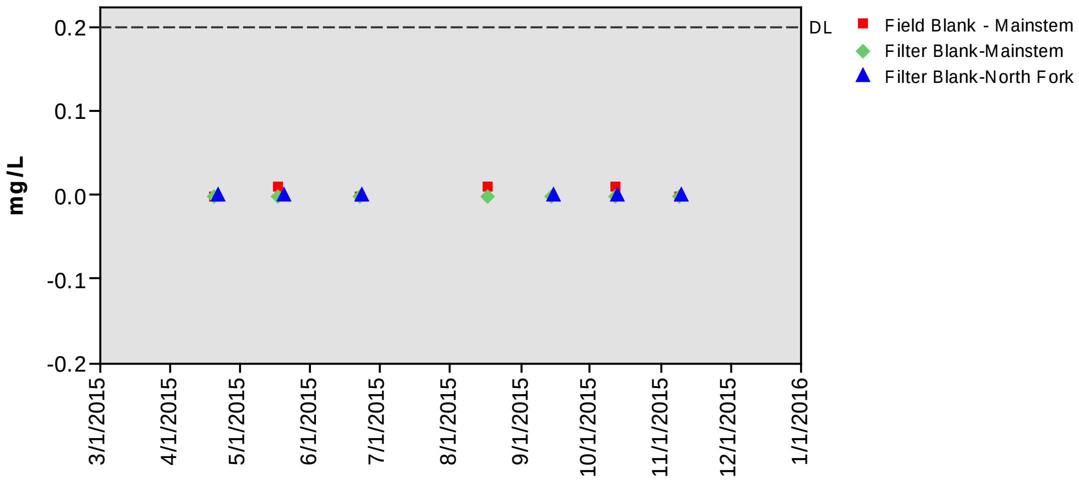
Calcium (Ca)



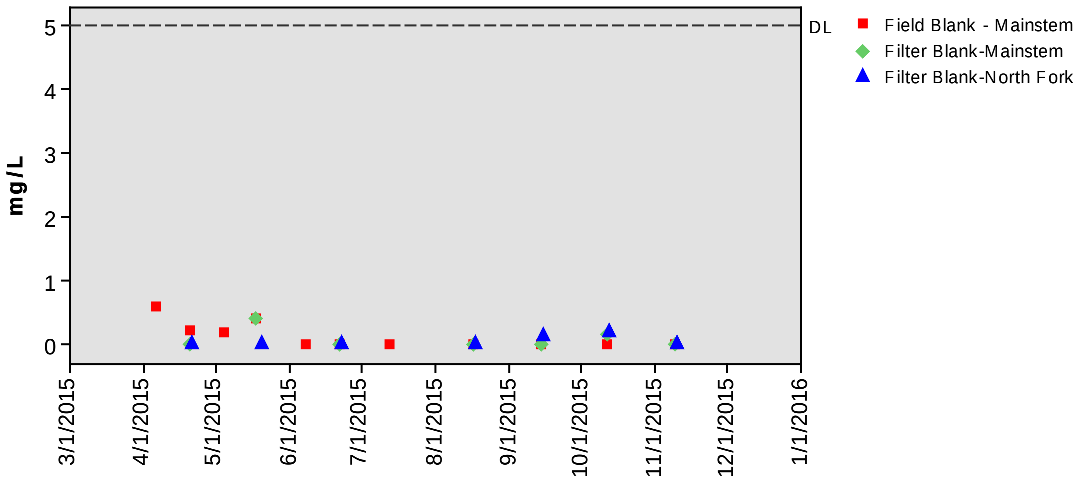
Potassium (K)



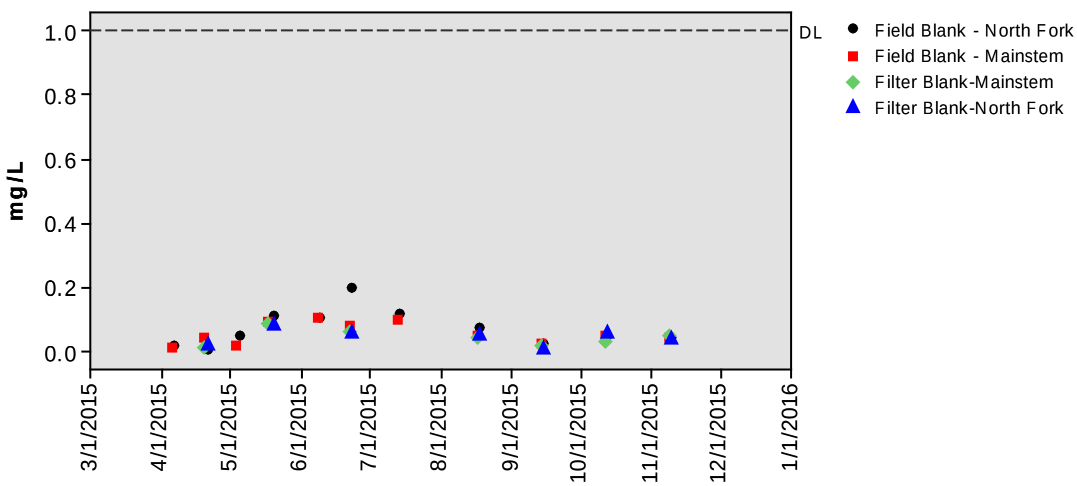
Magnessium (Mg)



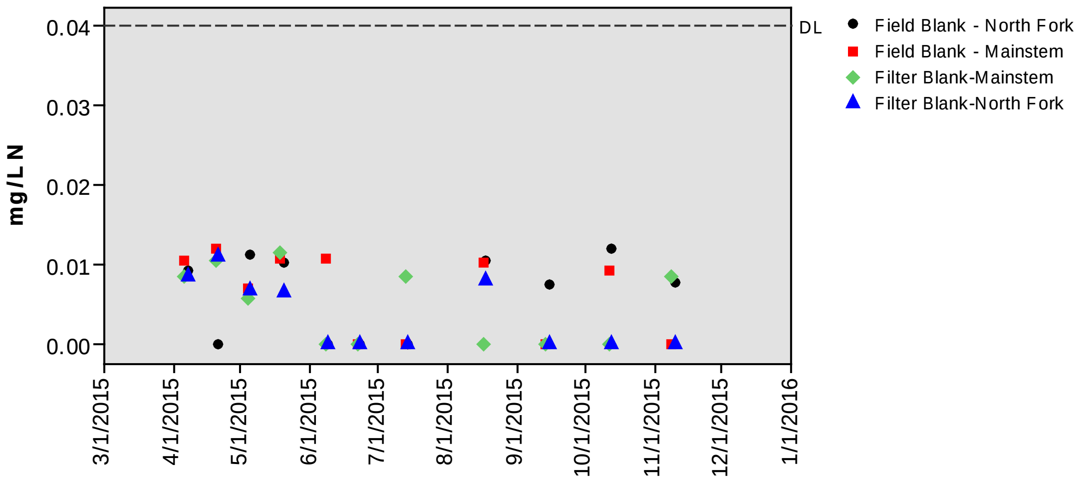
Sulfate (SO4)



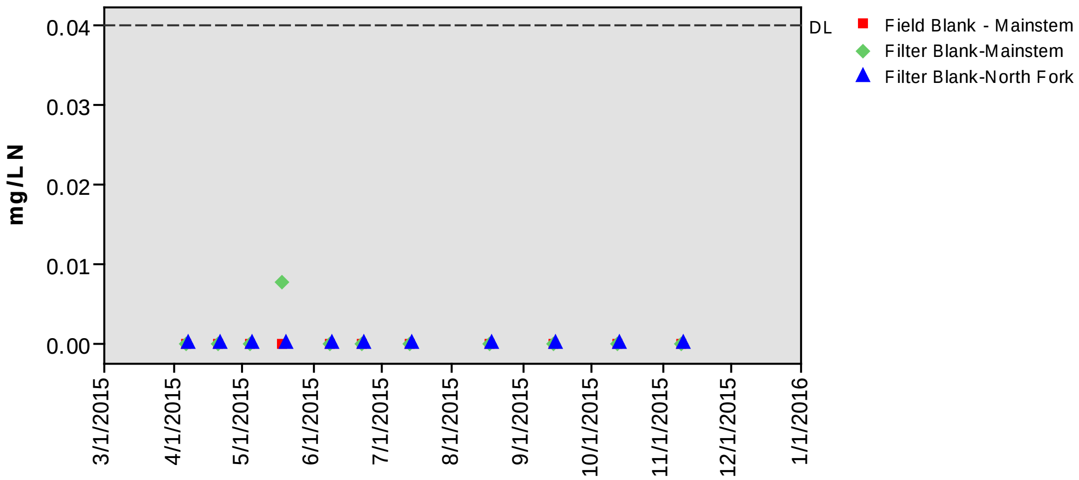
Chloride (Cl)

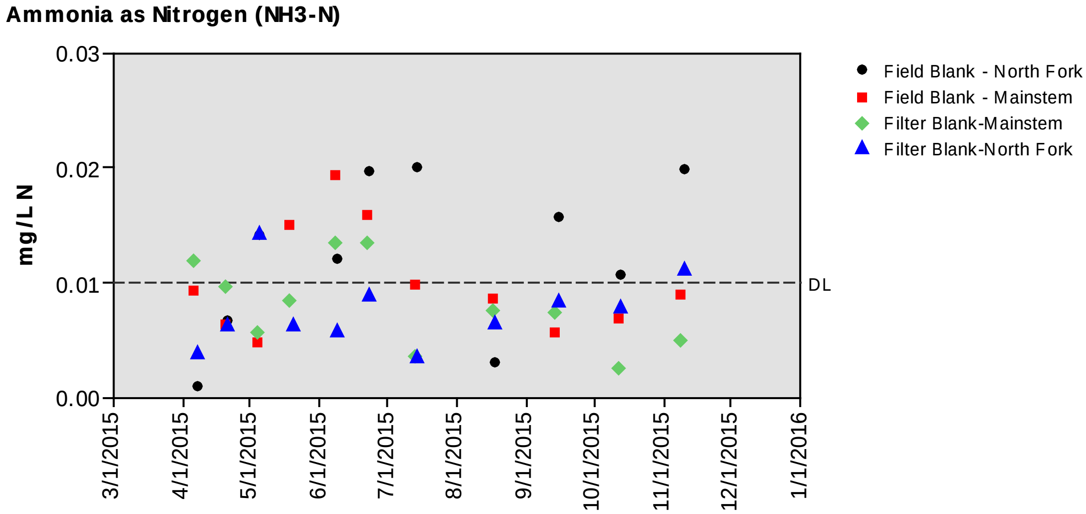


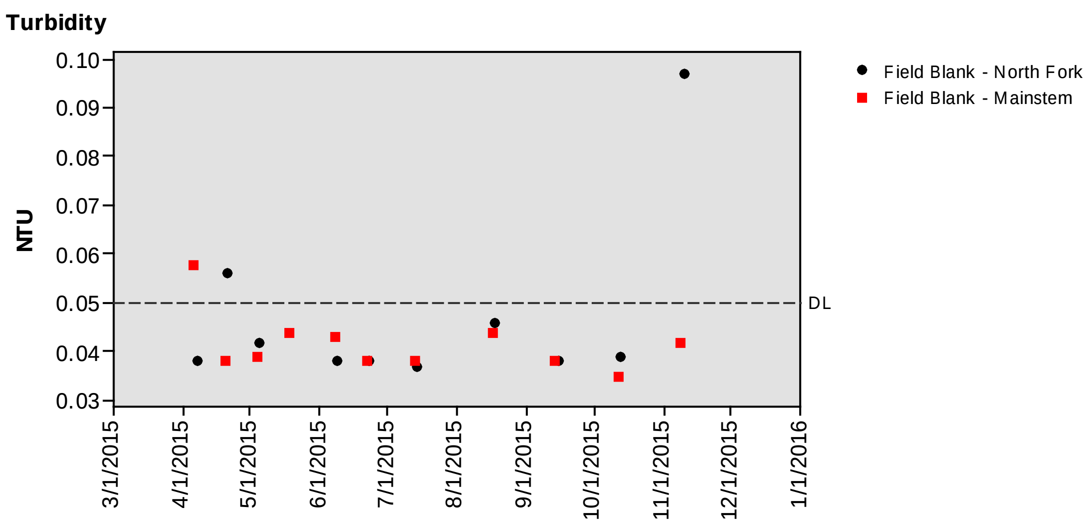
Nitrate as Nitrogen (NO3-N)



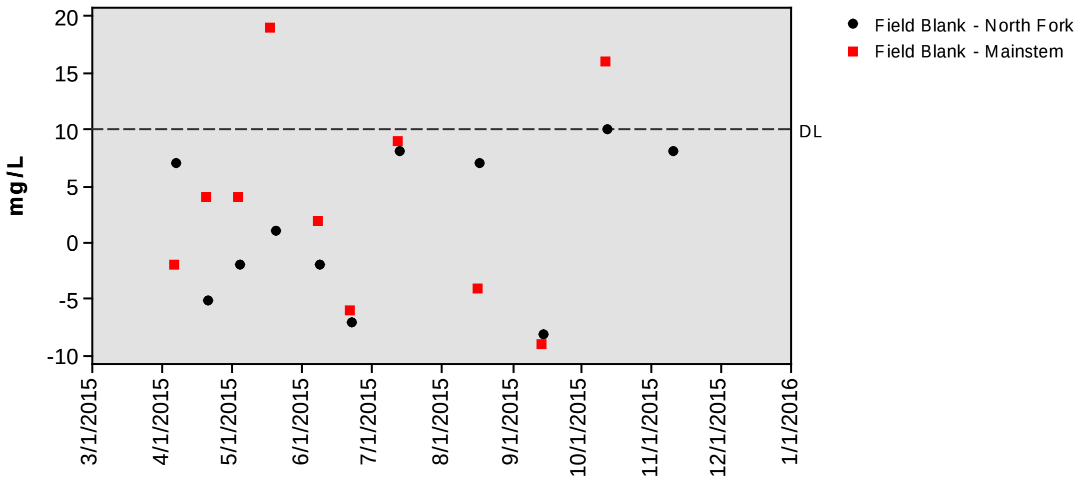
Nitrite as Nitrogen (NO2-N)



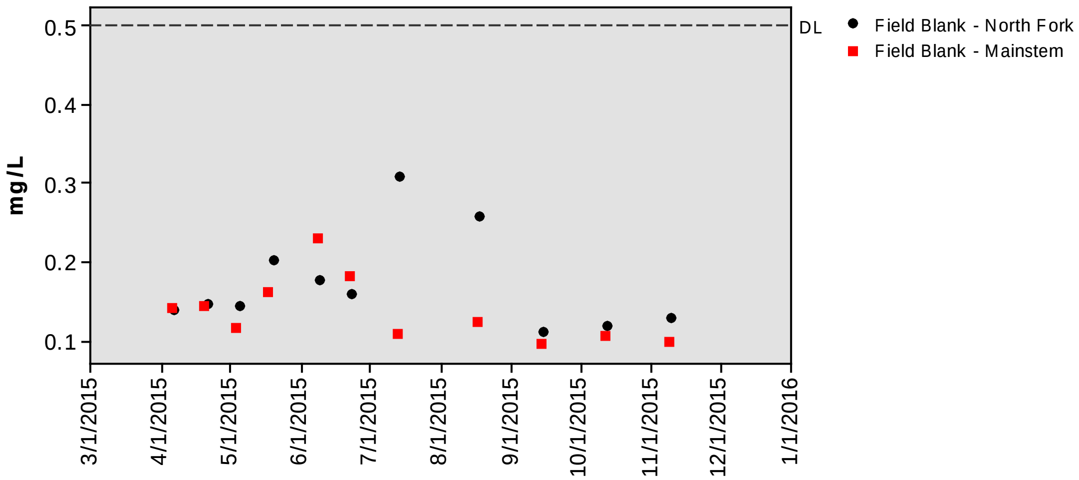

Ammonia as Nitrogen (NH3-N)
mg/L N
0.03
0.02
0.01
0.00
DL
3/1/2015
4/1/2015
5/1/2015
6/1/2015
7/1/2015
8/1/2015
9/1/2015
10/1/2015
11/1/2015
12/1/2015
1/1/2016
Field Blank - North Fork
Field Blank - Mainstem
Filter Blank-Mainstem
Filter Blank-North Fork


Turbidity
NTU
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
DL
3/1/2015
4/1/2015
5/1/2015
6/1/2015
7/1/2015
8/1/2015
9/1/2015
10/1/2015
11/1/2015
12/1/2015
1/1/2016
Field Blank - North Fork
Field Blank - Mainstem

Total Dissolved Solids (TDS)



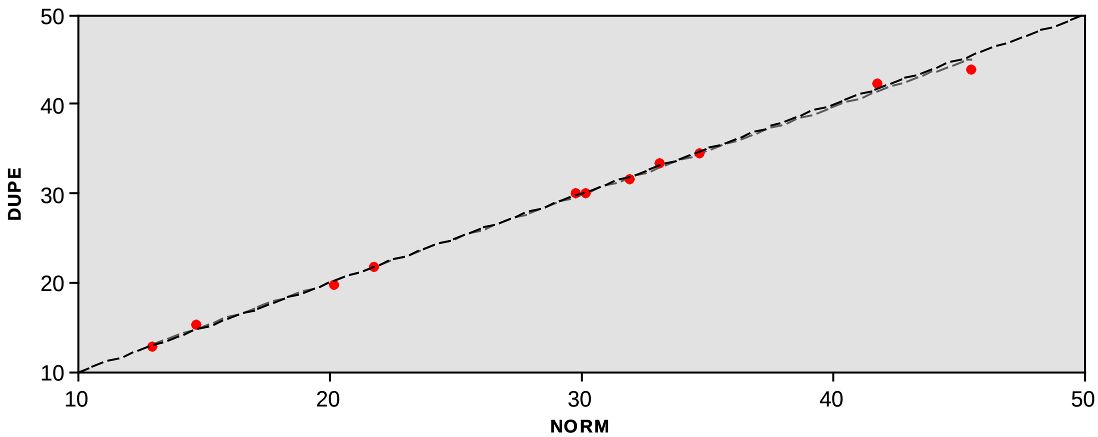
Total Organic Carbon (TOC)



UCLP MAINSTEM

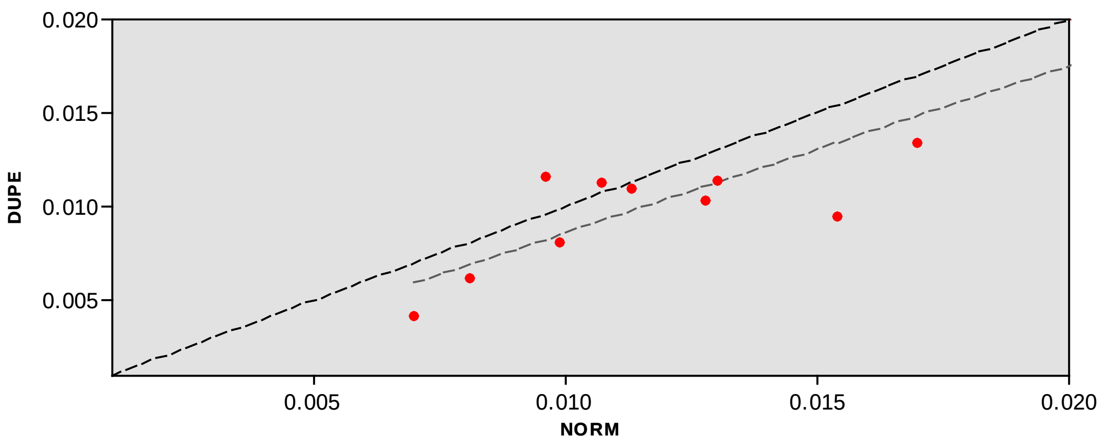
PNF DUPLICATES

Hardness

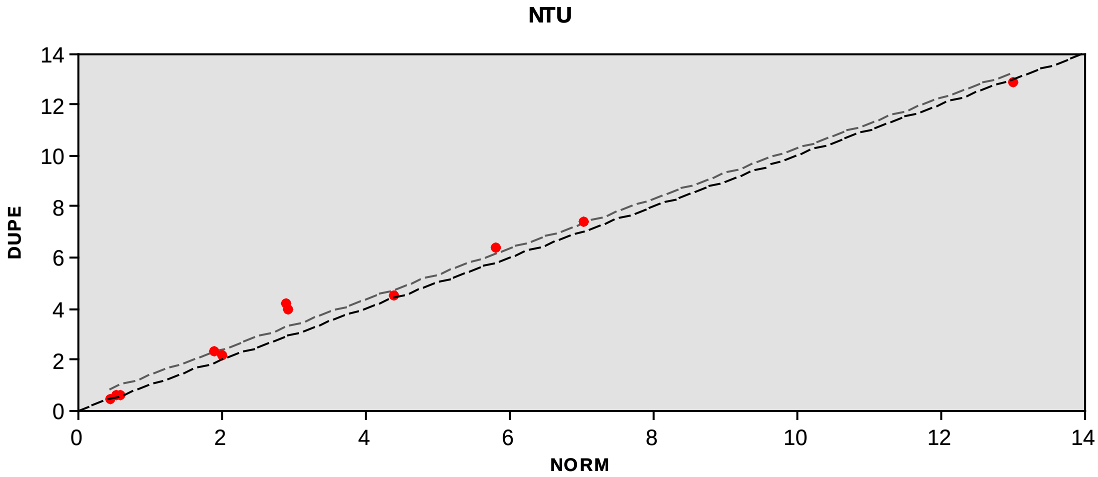


abs mean = 0.42 mg/L
p = 0.97

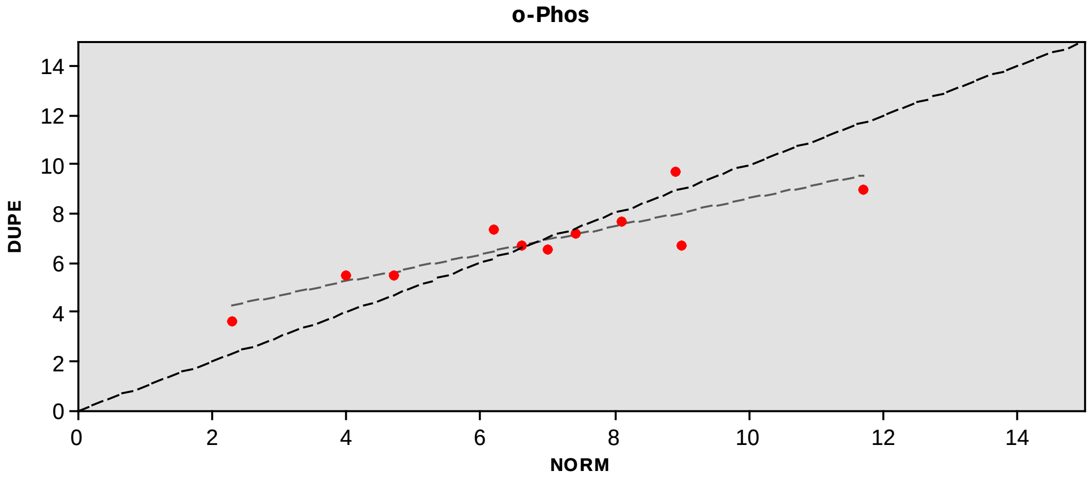
NH3



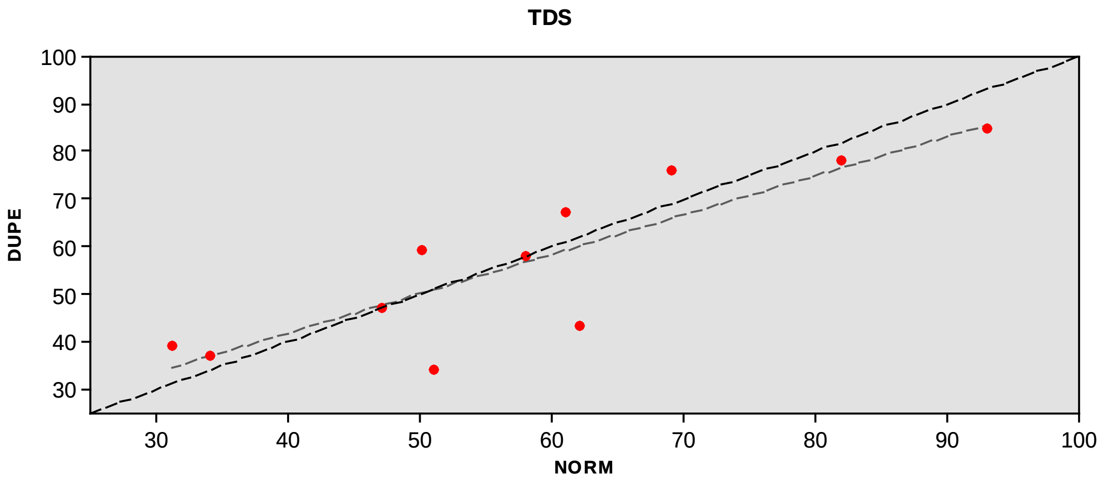
abs mean = 0.002 mg/L
p = 0.35



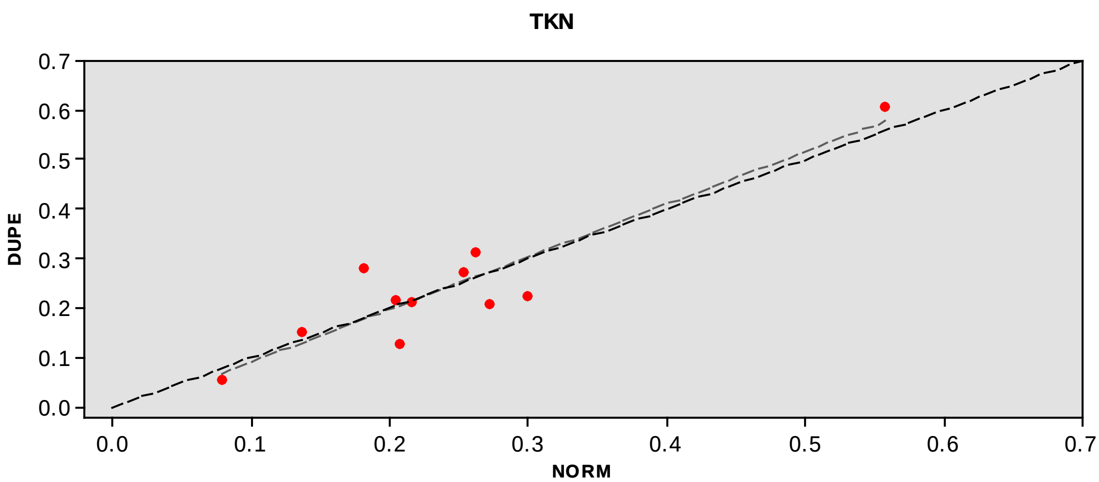
abs mean = 0.37 NTU
p = 0.84



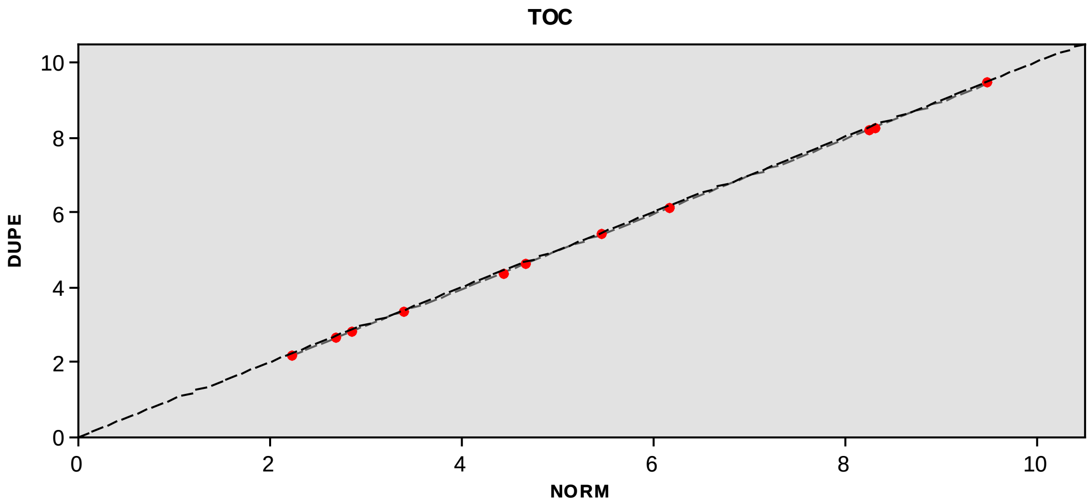
abs mean = 1.06 ug/L
p = 0.80



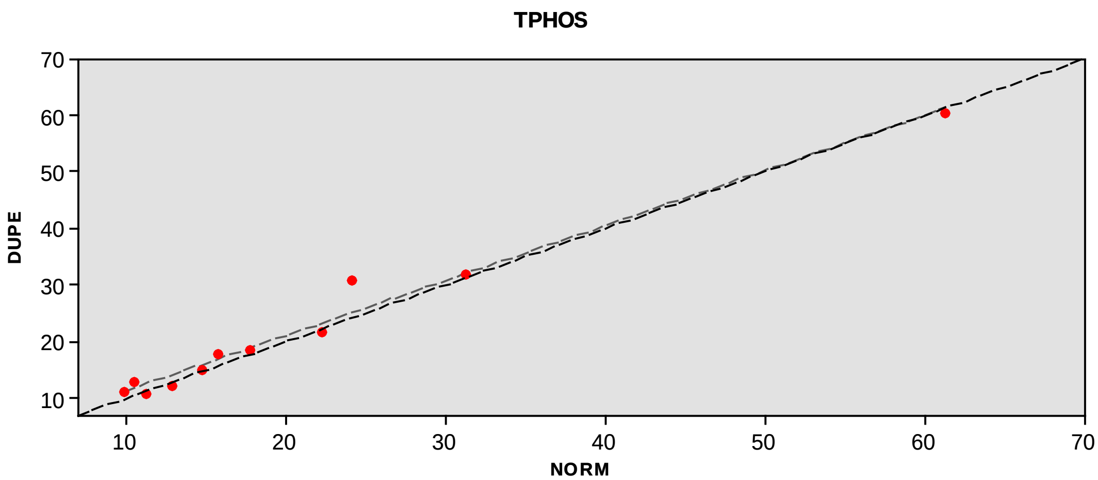
abs mean = 7.36 mg/L
p = 0.86



abs mean = 0.04 mg/L
p = 0.84

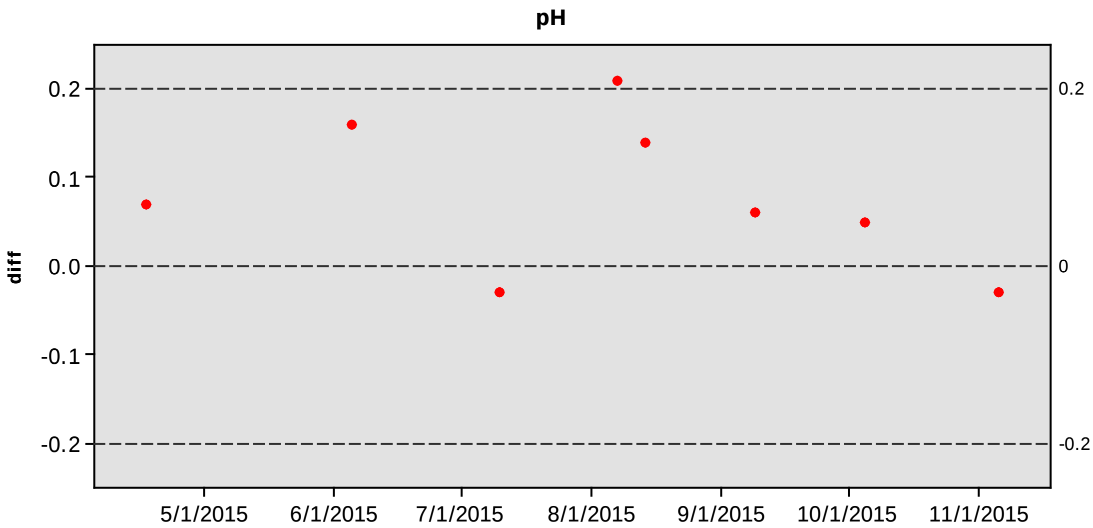


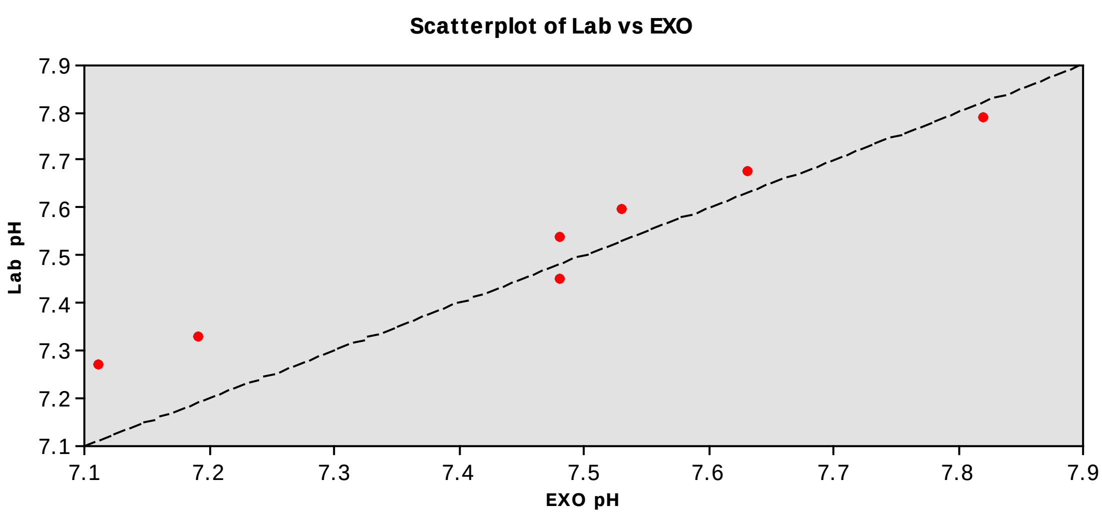
abs mean = 0.03 mg/L



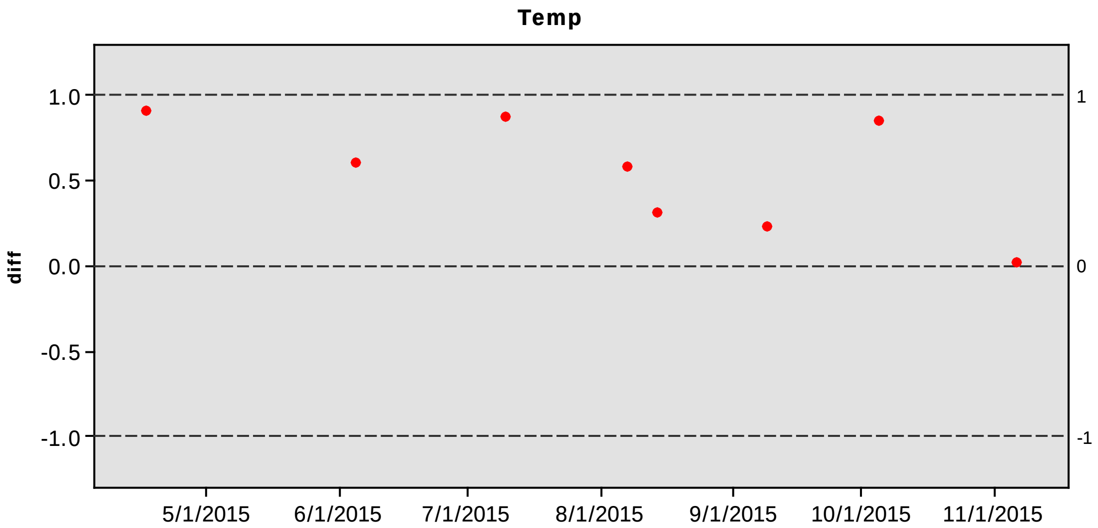
abs mean = 1.43 ug/L
p = 0.84

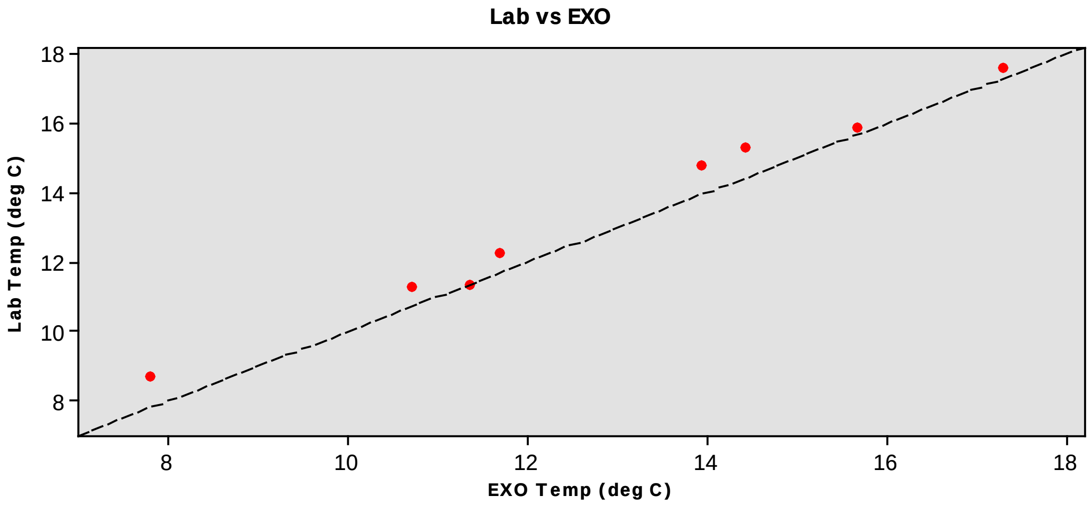
UCLP EXO MULTI-PARAMETER SONDE


pH
0.2
0.1
0.0
-0.1
-0.2
diff
0.2
0
-0.2
5/1/2015
6/1/2015
7/1/2015
8/1/2015
9/1/2015
10/1/2015
11/1/2015

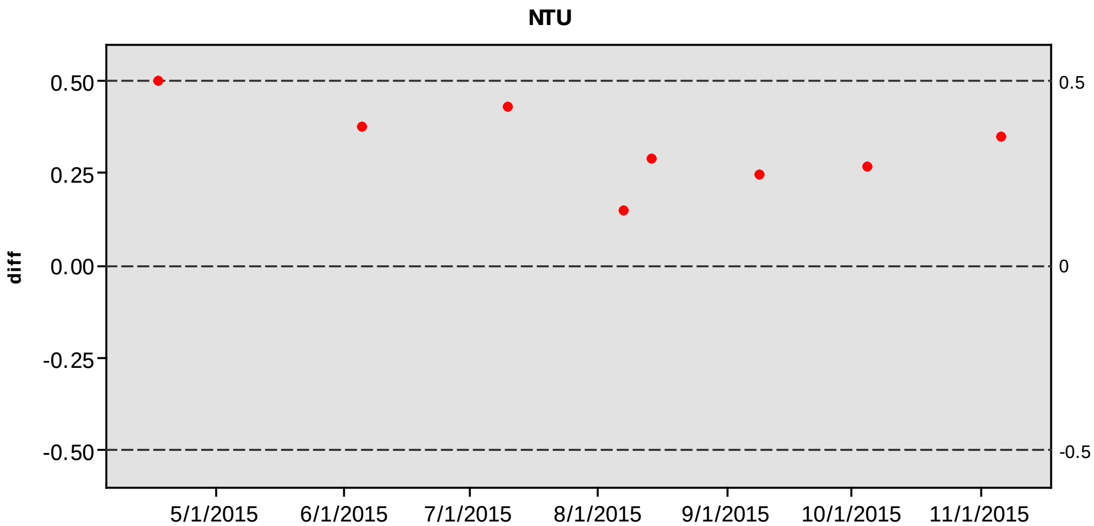

Scatterplot of Lab vs EXO
Lab pH
7.1
7.2
7.3
7.4
7.5
7.6
7.7
7.8
7.9
EXO pH

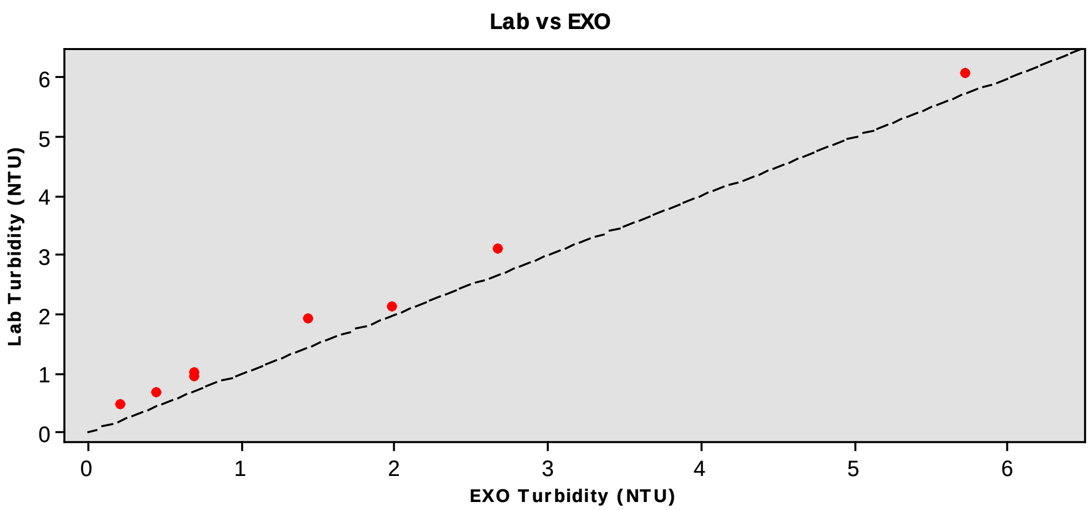
abs mean = 0.09



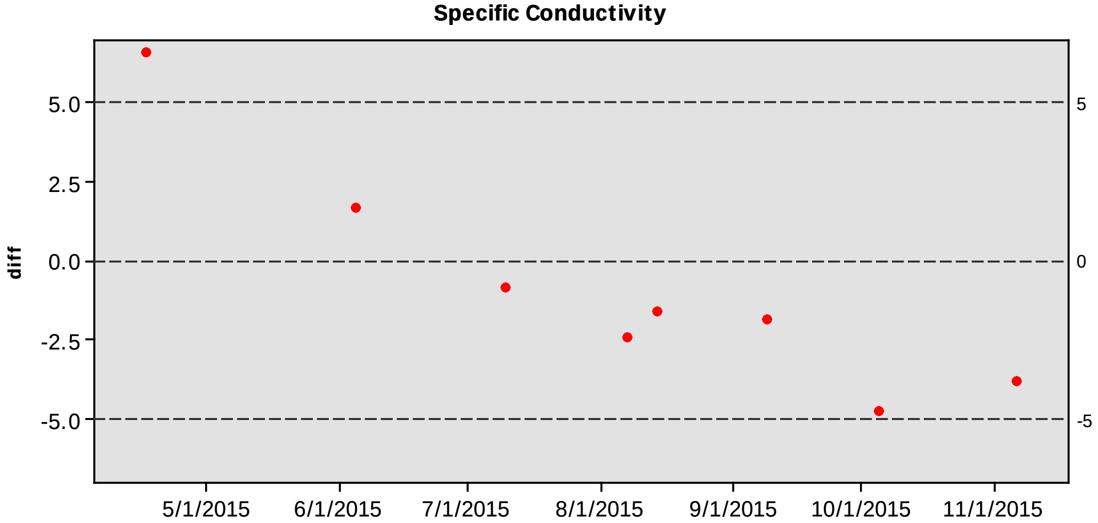


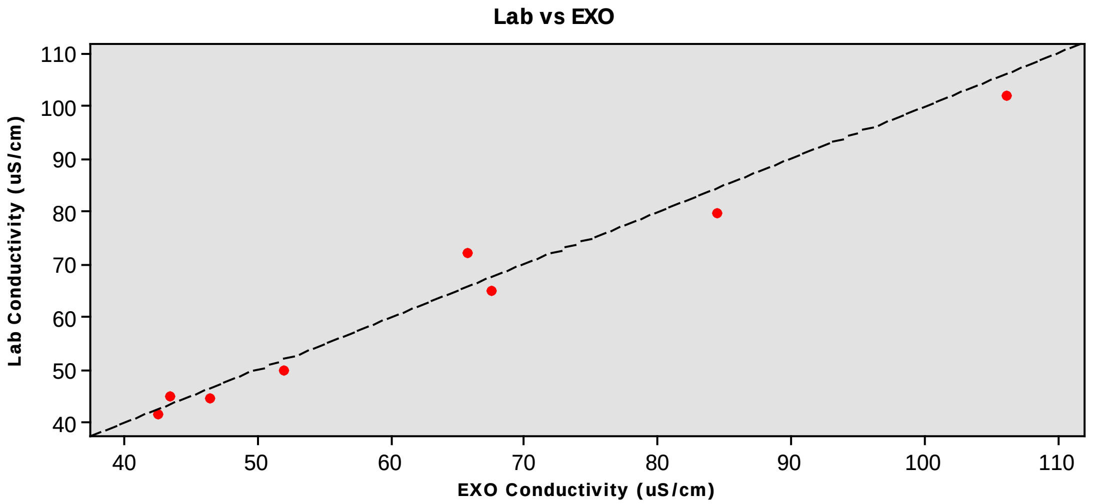
abs mean = 0.55 deg C



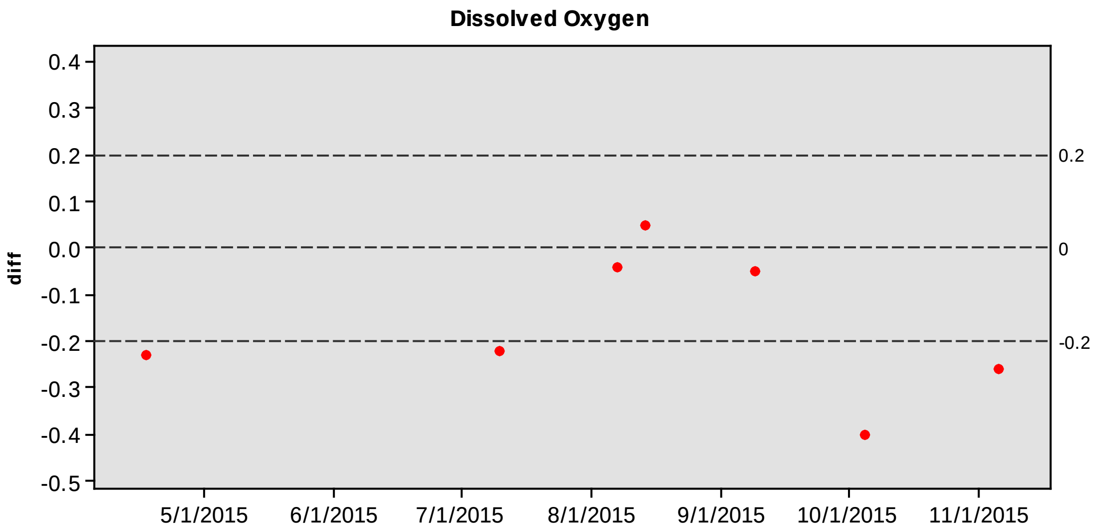


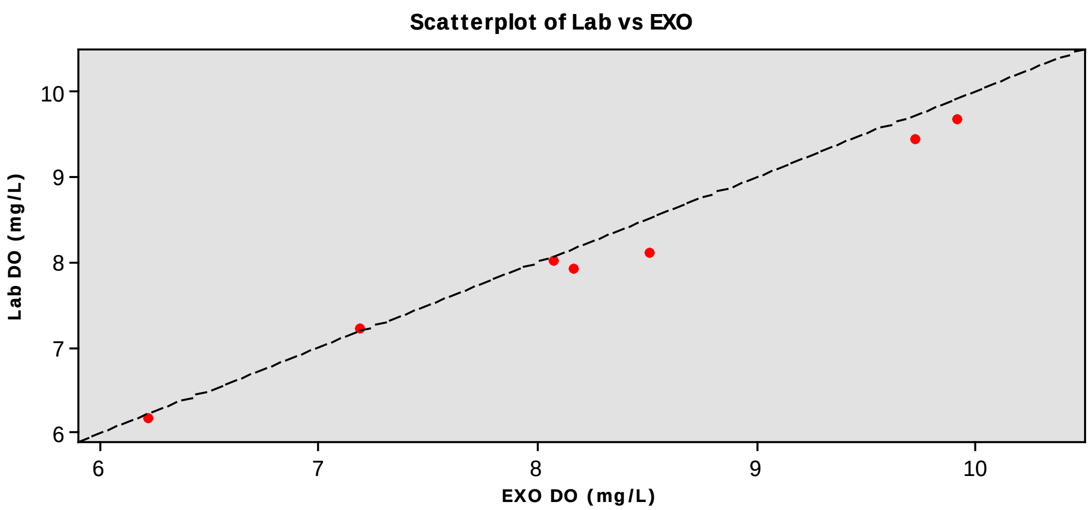
abs mean = 0.33 NTU





abs mean = 2.93 uS/cm





abs mean = 0.16 mg/L