2016 ANNUAL REPORT

Upper Cache la Poudre Watershed

Collaborative Water Quality Monitoring Program

June 22, 2017

PREPARED FOR
Fort Collins Utilities
City of Greeley
Soldier Canyon Water Authority

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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 Soldier Canyon Water Treatment Authority (previously 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.

SCOPE OF2016 ANNUAL REPORT

This annual report summarizes the hydrologic and water quality data collected in 2016 and provides a comparison of water quality from the years 2013 – 2015. The report also summarizes significant events, issues of concern, results from special studies, and data quality control.

STATE OF UPPER CACHE LA POUDRE WATERSHED WATER QUALITY

The Upper CLP remains a high quality drinking water supply for Fort Collins, City of Greeley and surrounding communities served by the Soldier Canyon Water Treatment Authority. 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.

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 their expected ranges and followed normal seasonal, temporal, and spatial trends.

Both the Mainstem and North Fork CLP continued to see detectable levels of emerging contaminants closely linked to recreation and herbicide use in the watershed. The timing of these detections (August) indicates the increase in recreational use within the Poudre Canyon during the summer season. The concentrations at which these compounds were detected were several orders of magnitude lower than the pure compound's concentration and considered a low risk to the Poudre drinking water supply.

Wildfire impacts in the Upper CLP watershed were still apparent in 2016. The most notable impacts to water quality associated with the wildfire continued to be elevated nutrients, specifically nitrate. Despite the elevated nitrate, levels were still low and appear to be returning to pre-fire conditions.

A basin-wide increasing trend in orth-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. Geosmin, a naturally occurring organic compound that can impart an earthy odor to water, remained below the taste and odor threshold (4 ng/L). There were no reported geosmin-related customer odor complaints in 2016.

Program Performance

Review of the 2016 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 with some opportunities for improvement.

Monitoring Efforts in 2017

The Upper CLP Collaborative Monitoring Program will continue water quality monitoring efforts in 2017. The 2017 efforts are listed below:

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

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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
SCWTA	Soldier Canyon Water Treatment Authority
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 Soldier Canyon Water Treatment Authority's (SCWTA) Soldier Canyon Filter Plant (SCFP). In the shared interest of sustaining this high quality water supply, the City of Fort Collins, the City of Greeley, and the SCWTA 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 CLP 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)

Seasonal updates, annual water quality reports, 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 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). The second five-year report will be prepared in 2018 and will evaluate trends for the period 2013-2017. 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 2016 monitoring network consisted of 18 sampling locations selected to characterize the headwaters, major tributaries and downstream locations of the Upper CLP River near the City of Fort Collins, SCWTA, and City of Greeley raw water intake structures (Figure 1.1). 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 2016 sampling schedule is provided in Attachment 4 of this report.

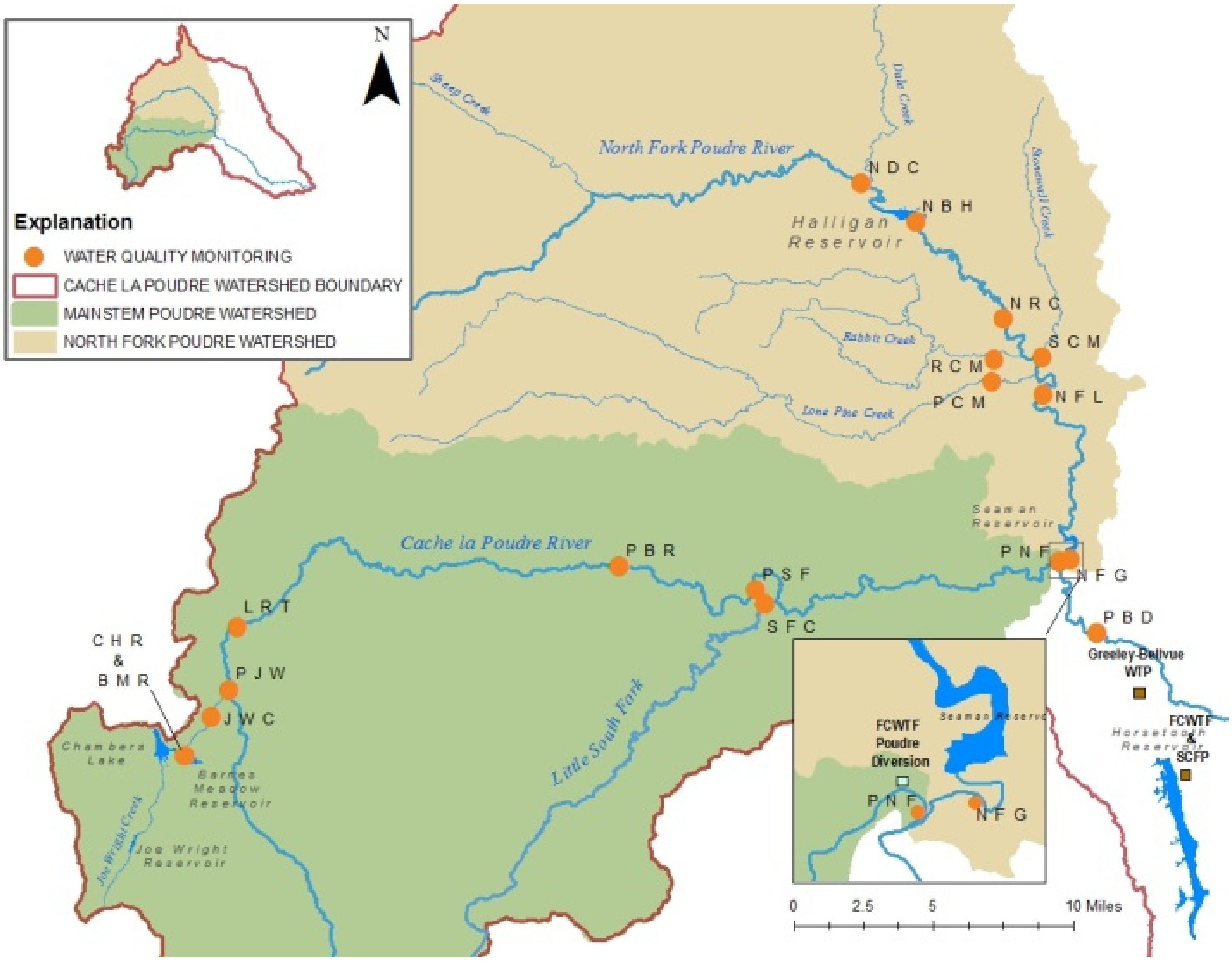

Figure 1.1 – Map of the Upper CLP collaborative water quality monitoring network.

1.4 SAMPLE COLLECTION AND ANALYSIS

In 2016, field sampling was conducted by staff members from the City of Fort Collins. Sampling methods, including those for the collection of physical 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. 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), at least 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 2016 ANNUAL REPORT

The 2016 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 2016 with the previous three years, 2013-2015.

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 CLP raw water supply is monitored monthly for geosmin. This 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.

The results of previous monitoring efforts suggest that concentrations at downstream sites are not well-predicted by upstream concentrations (Oropeza, 2012; Oropeza and Heath, 2013; 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 conditions may be favorable for geosmin production elsewhere. The second location, PNF, is located downstream near water supply intakes and is intended to estimate concentrations that could be observed in raw water at the treatment facilities.

In 2016, samples were collected monthly from May through November at PBR and PNF. Geosmin concentrations remained below the 4 ng/L threshold at both sampling locations (Table 1). Concentrations fluctuated slightly above and below the reporting limit (1 ppt or ng/L) at both monitoring sites. There were no notable temporal or spatial trends in geosmin concentrations. Nine out of the 14 samples (64%) were measured below the reporting limit. A maximum concentration of 2.2 ng/L was measured at PNF on August 15th, but concentrations were observed below the reporting limit for the remainder of the season. Geosmin at PNF decreased 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 2016 at Poudre above the North Fork (PNF) and Poudre below Rustic (PBR) monitoring locations. BDL = below detection limit.

Date	Poudre below Rustic (PBR)	Poudre above North Fork (PNF)
5/9/2016	1.21	BDL
6/6/2016	BDL	BDL
7/18/2016	1.18	1.08
8/15/2016	BDL	2.2
9/12/2016	BDL	BDL
10/17/2016	BDL	BDL
11/7/2016	1.15	BDL

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 that are sampled under this monitoring program and are 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

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; and
- 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 Colorado Big Thompson (CBT) system. In 2009, the program was opened up as a regional collaboration with the cities of Boulder, Broomfield, Fort Collins, Greeley, Longmont, and Loveland, and the Town of Estes Park. 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 for these two sites. 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 is reviewed by the collaborators and additions and/or deletions are made as needed. A full list of analytes can be found in the *2016 Emerging Contaminants Program Annual Report* (Northern Water, 2016).

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 2016, 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 2016, 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 introduce pharmaceuticals, personal care products, and endocrine disrupting compounds to 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, sucralose and triclosan, which are connected to recreation and/or weed management along canals and roadways.

In 2016, monitoring for emerging contaminants was conducted in February, June, and August on the Poudre River at PNF and NFG. No compounds were detected in February and June. In August, the herbicide 2,4-D was detected at very low concentrations at NFG and caffeine, DEET, and sucralose were detected on the Mainstem at PNF (Northern Water, 2015). The presence of these compounds in August indicates the increase in recreational use within the Poudre Canyon during the summer season.

3.0 UPPER CACHE LA POUDRE WATERSHED RESULTS

For the 2016 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
  NFG – North Fork at Gage

- 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. Boxplots presented in this report display summary statistics (maximum, median, and minimum). Boxplots and any summary statistics discussed in this report were calculated using all monitoring locations for each watershed (Mainstem and North Fork). A full list of monitoring sites, abbreviations and descriptions is available in Attachment 2. All data summary graphs are located in Attachment 6; 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 streamflow, spatial and temporal trends in snowpack, specifically snow water equivalent 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.

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 analyzed 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 2016, peak SWE across the entire Cache la Poudre Watershed was 110% of the expected peak SWE based on the long-term median. The North Fork basin was 127% of median, while the South Fork and Mainstem Poudre basins were near the long-term median reporting basin indices of 93% and 105%, 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 long-term median and the previous three years (Figure 3.2).

The start of the 2016 snow accumulation season was dry and below normal. The first measureable snowfall was observed towards the end of October followed by slight accumulations of snow, but mostly dry conditions persisted through early December. Snow water equivalent on December 10th was 48% of normal. Steady snowfall was observed from mid-December through February when snow water equivalent was measured at 87% of normal. The remainder of February and early March were very dry with little snow accumulation and by March 1st, snow water equivalent had dropped to 70% of normal.

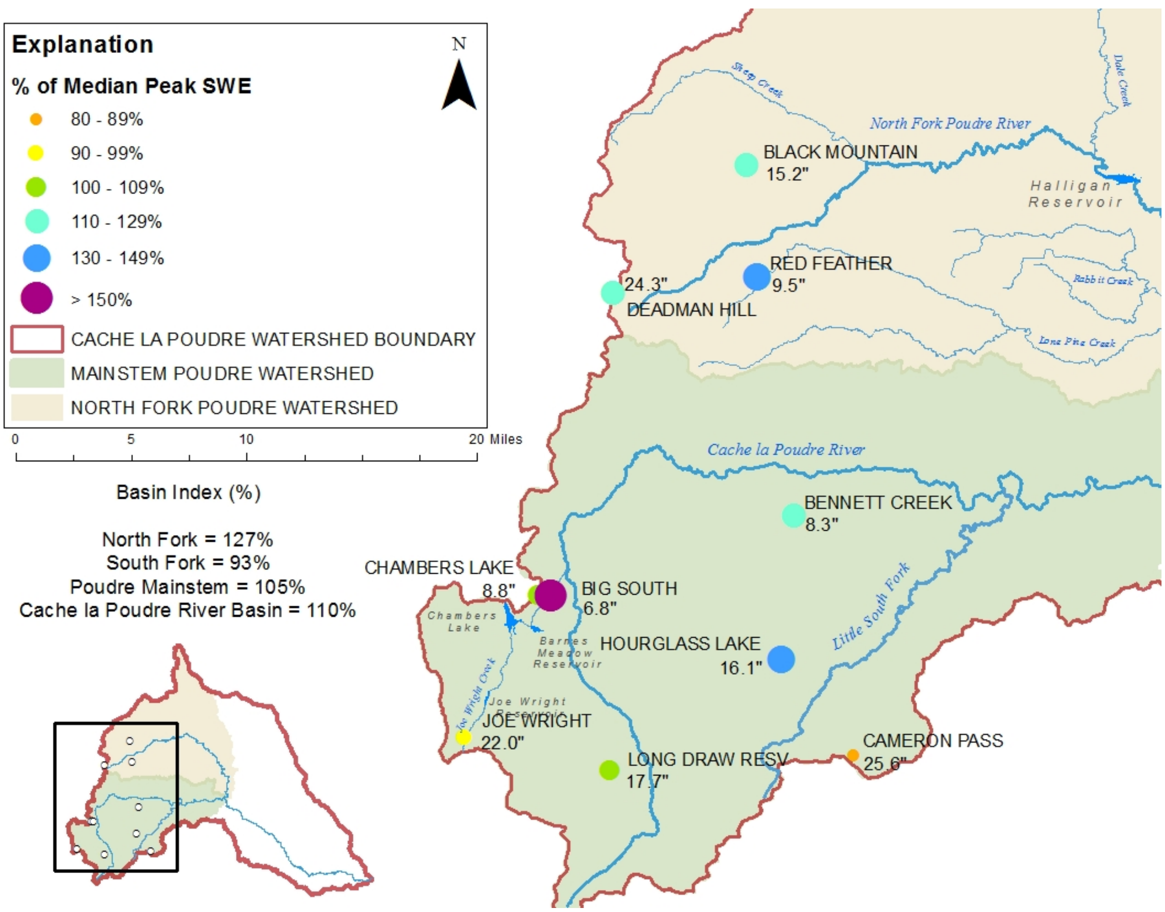

Figure 3.1 – Locations of SNOTEL and snow course monitoring sites in the UCLP and percent of median peak snow water equivalent (SWE) in for the 2016 water year.

A steady increase in SWE was observed throughout the month of March and into early April before the snowpack began to show signs of snowmelt. Several large storms in May continued to increase SWE. Peak SWE was measured at 22.0 inches on May 12th compared to the historical median peak SWE of 23.7 inches measured on April 27th (Figure 3.2). The snowpack began to melt following peak and the melt rate was similar to normal. By mid-June the 2016 snowpack was completely melted at Joe Wright, which was later in the year than normal (Figure 3.2).

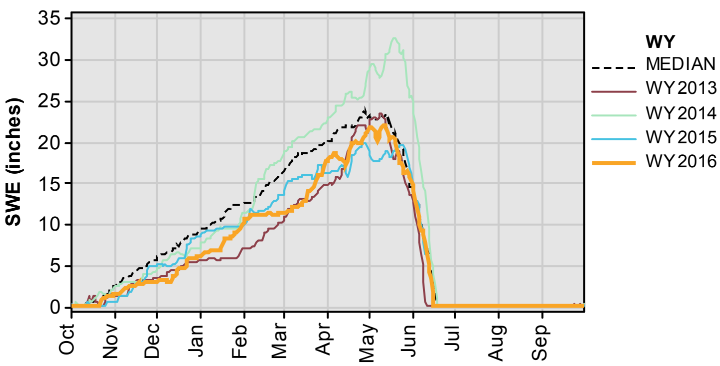

Figure 3.2 – Snow water equivalent measured at Joe Wright SNOTEL site near Cameron Pass over the 2013-2016 water years (October 1, 2015 – September 31, 2016).

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 as snow melts.

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 base flow 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, 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, as well as elevated base flows following the 2013 flood (Figure 3.3). The impacts of the 2012 wildfires, including debris flows and flooding, were less common on the Mainstem during the 2016 monsoon season due to limited number of high intensity, precipitation events over burn scar areas in the Upper CLP watershed.

In 2016, winter base flow conditions remained near average. Streamflow on the Mainstem began to exhibit signs of snowmelt runoff in mid-March steadily increasing through late-April. Colder temperatures and spring snow storms beginning in mid-April slowed snowmelt runoff as can be seen in the slight drop in streamflow from late-April through early-May. Streamflow increased rapidly from 600 cfs to over 2,000 cfs in only seven days following this freeze cycle. The rate of streamflow slowed following this initial peak and multiple spikes in streamflow continued through late May due to extended melt freeze cycles. Streamflow decreased below 2,000 cfs during the final weeks of May before rapidly increasing to its annual peak. In 2016, peak streamflow reached 3,440 cubic feet per second (cfs) on June 12th. The 2016 peak streamflow was 177% of the long-term average. However, streamflow

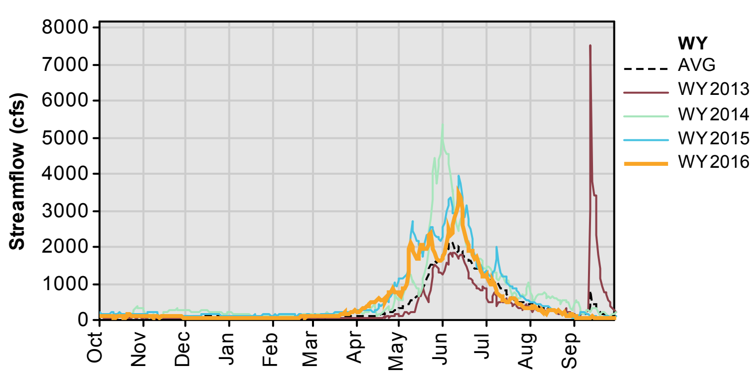

Figure 3.3 – Streamflow measured over the 2012-2015 water years at the CLP at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station.

began to rapidly recede following peak and dropped below average by early July and remained near or below average through the rest of the monitoring season. Base flow conditions beginning in mid to late August were below average for the remainder of the 2016 water year.

Mainstem Streamflow Contributions

An estimated 256,291 acre-feet of water flowed down the Poudre River above the Munroe Tunnel and North Fork in 2016. This is an underestimate of total water because streamflow records from PBD are not yet available for all months of the year (January, February, and December). The stream gage was taken offline on December 1st, 2015 and was placed back online on February 19th, 2016. Streamflow data for these winter months are estimated by the operating agency and will not be available until May 2017.

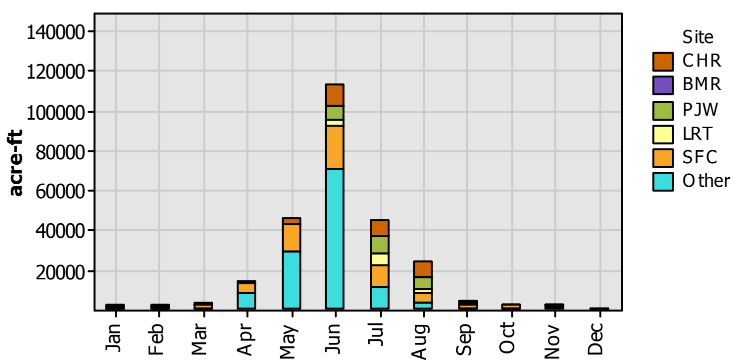

Figure 3.4 – Bar graph of tributary contributions by month to the Mainstem CLP above the Munroe Tunnel in 2016. Note that continuous flow measurements were not available for calculating "other" flow in January, February, and December.

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 import water from the Upper North Platte basin to Joe Wright Reservoir and the Grand Ditch, which imports water from the Upper Colorado River basin into Long Draw Reservoir. The contributions of these diversions are not discussed in the report, but contributions released from the reservoirs in which these waters are stored are addressed. A summary of tributary contributions to the Mainstem Cache la Poudre River above the Munroe Tunnel in 2016 is present in Table 3 and Figure 3.4.

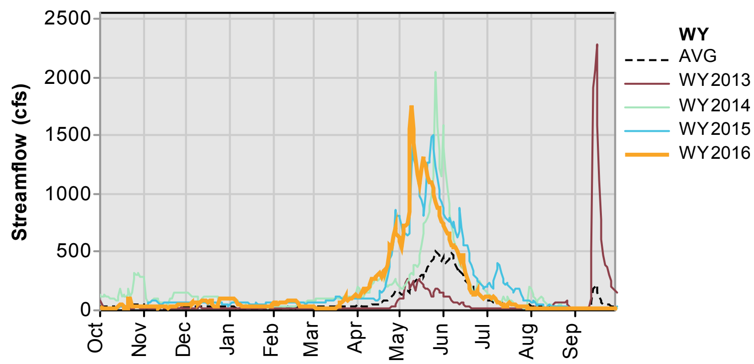

Figure 3.5 – Streamflow measured over the 2012-2015 water years at the North Fork CLP River below Seaman Reservoir (CLANSECO) streamflow monitoring station.

North Fork Cache la Poudre Watershed Streamflow

The North Fork follows a similar streamflow pattern to the Mainstem (Figure 3.5). Runoff and peak streamflow on the North Fork normally occur earlier than on 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).

The snowmelt hydrographs for NFL and NFG are typically very similar. During snowmelt runoff, if Seaman and Halligan Reservoirs are at capacity, the majority of flow going into these Reservoirs spills over the emergency spillways. When reservoir storage capacity is available, inflowing water may be stored in the Reservoirs or bypassed through the outlet structure depending on the river call priority regime at the time of available capacity. Water releases from both Halligan and Seaman Reservoirs increase streamflow later in the season following snowmelt runoff.

In an average year, peak streamflow on the North Fork is observed from late-May to early-June (Figure 3.5). In 2016, snowmelt runoff began in late March, reaching peak runoff earlier than normal on May 9th at a streamflow of 1,760 cfs at NFG. Peak streamflow in 2016 was more than three times the average peak flow (492 cfs) at NFG (2005-2014). The melt-freeze cycles observed on the Mainstem throughout May were not observed on the North Fork, which led to an early peak. Streamflow steadily decreased following peak streamflow and returned to

Table 3 – Tributary contributions by month to the Mainstem Cache la Poudre River above the Munroe Tunnel in 2016. 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	138		922		-		0		1,642		-	-	-	
Feb	178	22%	833	102%	-		-		1,453		(1,648)	-	817	
Mar	179	5%	922	27%	-		-		1,564	46%	744	22%	3,408	------
Apr	81	1%	1,031	7%	-		-		5,243	36%	8,008	56%	14,364	------
May	-		3,041	7%	-		-		14,238	31%	28,891	63%	46,169	------
Jun	-		11,556	10%	2,517	2%	7,026	6%	21,892	19%	70,576	62%	113,567	------
Jul	-		7,162	16%	6,041	14%	9,487	21%	10,266	23%	11,780	26%	44,736	------
Aug	-		7,035	30%	1,779	7%	6,139	26%	5,209	22%	3,663	15%	23,826	------
Sep	-		761	17%	714	16%	583	13%	1,534	34%	955	21%	4,548	------
Oct	-		615	22%	141	5%	-		1,261	45%	799	28%	2,816	------
Nov	-		-		-		-		1,041	51%	1,000	49%	2,041	------
Dec	-		-		-		-		-		-		-	
Total	**576**		**33,879**		**11,192**		**23,236**		**65,342**		**124,768**		**256,291**	

normal conditions by mid-June. Streamflow fluctuated near normal for the rest of the monitoring season (Figure 3.5).

In 2016, the combined volume of water on the Mainstem at PBD was 314,230 acre-feet over the months of May through June. The North Fork contributed 37% of total acre-feet to the Mainstem, which was the greatest percentage of water contributed from the North Fork over the four year period, but was less total water compared to 2015 (Figure 3.6).

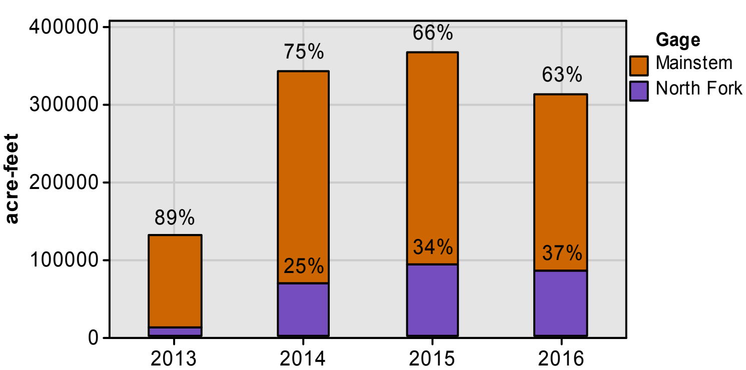

Figure 3.6 – Proportion of average Mainstem and North Fork contributions at PBD during May and June from 2013 through 2016.

3.2 WATER TEMPERATURE

Water temperature increases with decreasing elevation throughout the Upper CLP watershed (Figure 3.7a). In general, water temperatures are at a minimum during winter base flow conditions when air temperatures are the lowest and at a maximum in July and August when air temperatures are the highest 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.

In 2016, water temperatures in the Upper CLP watershed followed similar temporal and spatial patterns to the three previous years (Figure 3.7a). Median water temperatures on the Mainstem was slightly cooler than 2015, but warmer than 2013 and 2014. The median water temperature for the Mainstem watershed was 8.1°C. Water temperatures ranged from 0.10°C to 17.3°C (Figure 3.7b). The lowest temperature was measured at PJW on April 18th at and the highest temperature was measured at PBD on August 15th

The median water temperature for the North Fork watershed was similar to 2015, but slightly warmer water temperatures were measured at NFG. The median water temperature throughout the North Fork watershed was 10.9°C (Figure 3.7a). Water temperatures ranged from 2.0°C to 22.4°C (Figure 3.7b). The lowest temperature was measured at NDC on April 19th at and the highest temperature was measured at NFG on August 16th.

Water temperatures decreased at all sites through the remainder of the monitoring season, but remained warmer than previous years (Figure 3.7a).

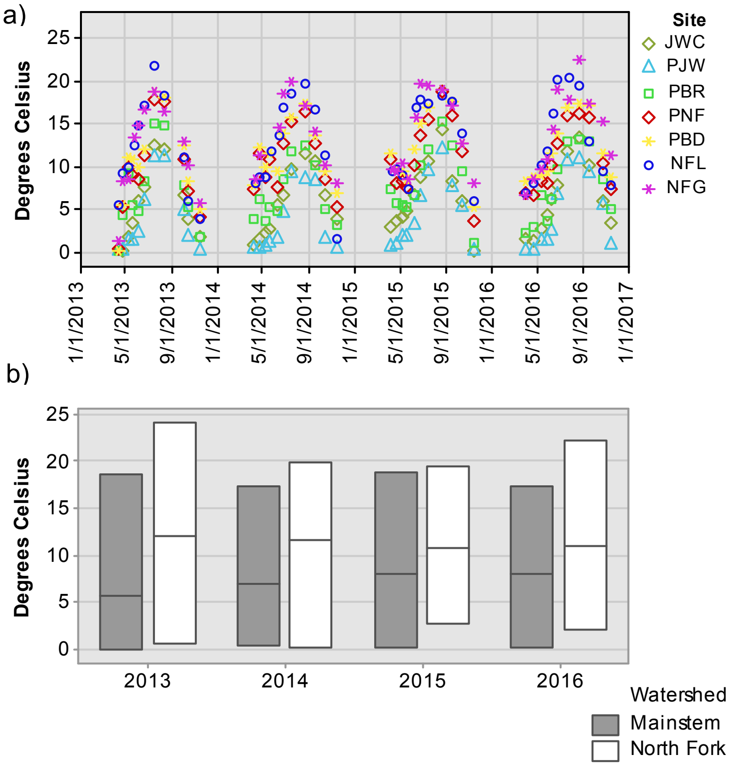

Figure 3.7 – a) Water temperature at key Upper CLP monitoring sites and b) boxplots displaying the distribution of data measured throughout the Mainstem and North Fork watersheds from 2013 through 2016.

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 influenced by the magnitude and timing of streamflow and by the size of 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 2016 to the previous three years, with the exception of 2013. The 2013 flood event and the subsequent increase in streamflows illustrate the dilution effect of high flows on dissolved constituents. Specific conductivity (Figure 3.8a), hardness (Figure 3.8b), and alkalinity (Figure 3.8c) concentrations were within the range of expected values throughout the 2016 monitoring season on the Mainstem (21.3 µS/cm – 201.3 µS/cm; 8.2 mg/L – 90.3 mg/L; and 7.2 mg/L – 82.2 mg/L, respectively). The lowest concentrations on the Mainstem were measured on June 20th at PJW. The highest concentrations were observed at PBD in early spring and late fall when streamflow was low.

North Fork watershed concentrations were higher and more variable across monitoring locations as compared to Mainstem sites. The highest concentrations were monitored on Stonewall Creek (SCM) where concentrations remained constant through the monitoring season. The lowest concentrations were observed at NDC. Concentrations on the North Fork generally increased moving downstream (see Attachment 6, pp. 48, 49, and 50). Specific conductivity, hardness, and alkalinity concentrations measured on the North Fork range from 50.5 µS/cm – 510.0 µS/cm, 21.9 mg/L – 271.8 mg/L, and 21.2 mg/L – 226.2 mg/L, respectively. The greatest factors likely driving higher concentrations throughout the North Fork watershed are land use, hydrology, and geology.

pH

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

In 2016, the pH in the Upper CLP watershed followed similar temporal and spatial patterns as was observed over the previous three years (Figure 3.9a). All sites showed a decrease in pH during spring runoff and then increased following snowmelt runoff.

The median pH on the Mainstem was similar to the previous three years with the exception of 2014. Median pH for the Mainstem watershed was 7.66. pH ranged from 6.34 at BMR on May 9th to 8.62 at PBD on September 12th. This was the highest pH value measured over the four year record (Figure 3.9b).

pH values on the North Fork were generally higher (more alkaline) than the Mainstem. The median pH for the North Fork watershed was 8.06 and all values were within the range of pH values observed in the previous three years. pH ranged from 7.40 to 8.95 over the 2016 monitoring period (Figure 3.9b). The maximum value was measured at NRC on July 19th and the minimum value was observed at NBH on April 19th (Figure 3.9a).

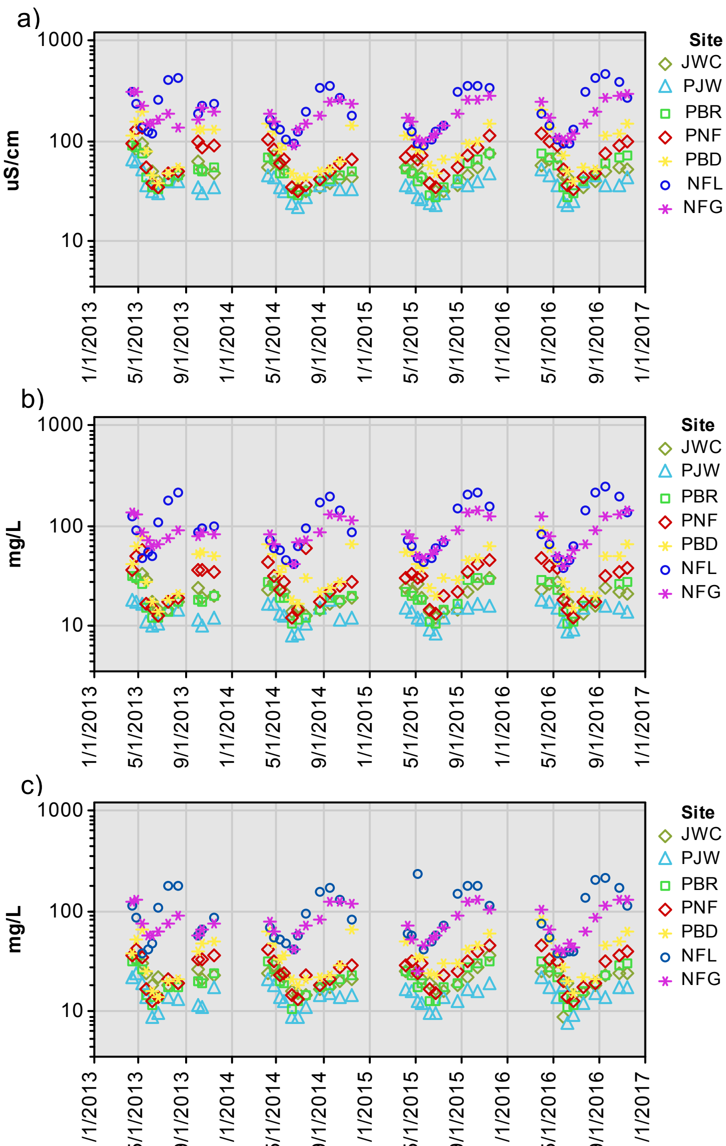

Figure 3.8 – Physical water quality parameters a) specific conductance, b) hardness, and c) alkalinity measured at key Upper CLP monitoring sites.

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 increases during 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 and most North Fork sites. Turbidity measurements later in the monitoring season are generally higher below reservoirs on the North Fork than other sites.

Turbidity values in 2016 followed expected seasonal patterns on the Mainstem. Turbidity was measured below 3 NTU at all sites at the start of the monitoring season, except a BMR. Turbidity values at this site generally do not show seasonal trends and are usually higher than river sites since this water is being released from the bottom of the reservoir. Turbidity increased at all river sites during snowmelt runoff reaching a seasonal maximum value of 21.1 NTU on May 5th at PJW (Figure 3.10a). Peak turbidity values were similar to the previous year, but slightly lower than 2013 and 2014. Turbidity gradually decreased through the summer and fall at most sites. The median turbidity value for the Mainstem watershed was 1.6 NTU, which was the lowest recorded over the four year period.

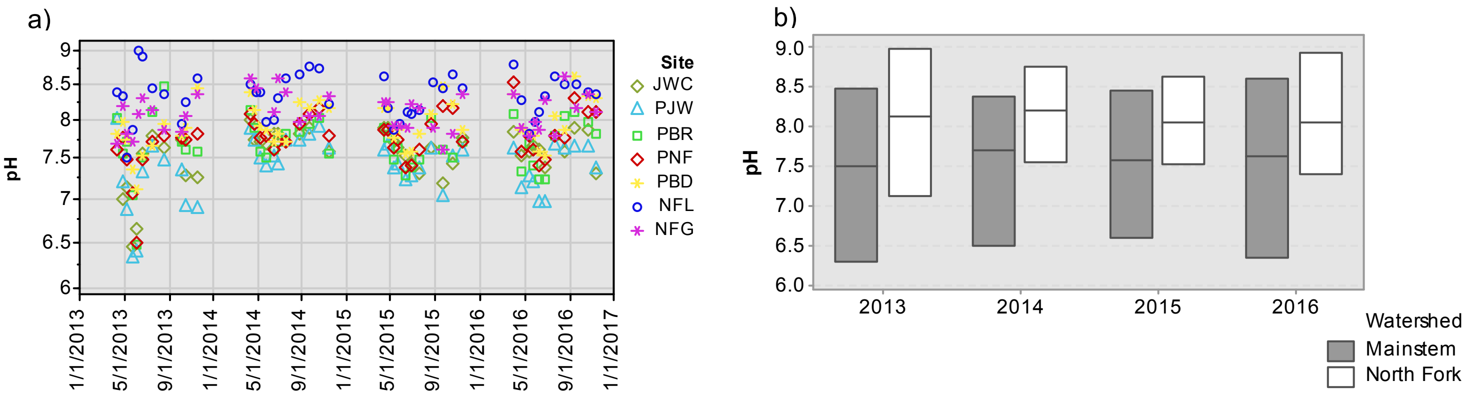

Figure 3.9 – pH levels measured at a) key Upper CLP monitoring locations and b) boxplots displaying the distribution of data measured throughout the Mainstem and North Fork watersheds from 2013 through 2016

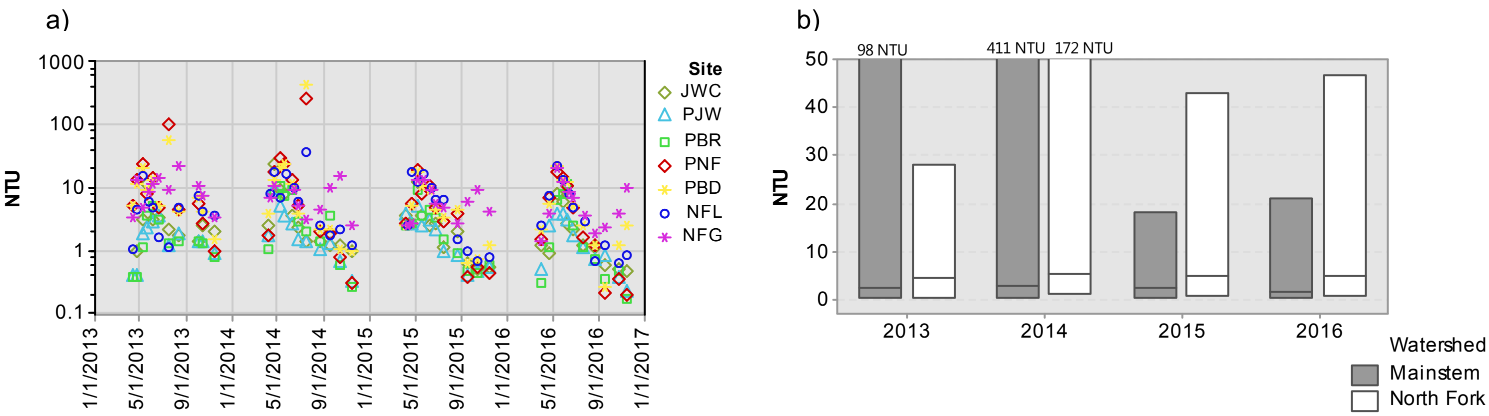

Figure 3.10 –Turbidity levels measured at a) key Upper CLP monitoring locations and b) boxplots displaying the distribution of data measured throughout the Mainstem and North Fork watersheds from 2013 through 2016.

Similar seasonal trends were observed on the North Fork, but turbidity on the North Fork was slightly higher with a median value of 4.7 NTU (Figure 3.10b). North Fork values ranged from 0.6 NTU at NFL to 47.01 NTU at RCM. The 47.01 NTU measured occurred during snowmelt runoff on May 10th and was the highest turbidity recorded over the four year period (Figure 3.10b).

Turbidity was elevated at most North Fork sites on this date. Turbidity decreased following snowmelt runoff, but increased from 1.7 NTU on August 16th to 9.5 NTU on November 8th at NFG. A similar trend was observed at PBD, but the magnitude of change was less from dilution with less turbid Mainstem water. This observation has been detected in most years.

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 peak concentrations are highly dependent on the timing and magnitude of snowmelt runoff and the availability and mobilization of carbon.

In most years, the highest TOC concentrations are observed at BMR (Barnes Meadow Reservoir outflow) and LRT (Laramie River Tunnel). However, the overall TOC loads delivered to the Mainstem from these sites are generally low due to the timing, magnitude, and duration of water releases from these sources.

In 2016, TOC concentrations on the Mainstem followed expected seasonal trends and were within the range of values observed over the previous three years (Figure 3.11a). Concentrations were low and relatively stable in April, but increased rapidly during snowmelt runoff to annual maximum concentrations on May 23rd. Peak concentrations at key sites range from 9.9 mg/L at PBD to 12.1 mg/L at JWC (Figure 3.11a), and higher concentrations up to 18.1 mg/L were measured at LRT (Laramie River Tunnel) (see Attachment 6, pg. 54). TOC concentrations steadily decreased during the summer months to baseflow concentrations of less than 5 mg/L at all sites by July 18th. An increase in TOC was observed at PJW on September 12th corresponding to a water release from Long Draw Reservoir. At this time, concentrations were twice the previous month's concentration, but the elevated TOC levels were not observed at the nearest downstream site, PBR.

The median TOC concentration in 2016 on the Mainstem was 3.8 mg/L, which was the lowest recorded over the four year period. TOC values on the Mainstem ranged from 1.5 mg/L to 18.1 mg/L (Figure 3.11b)

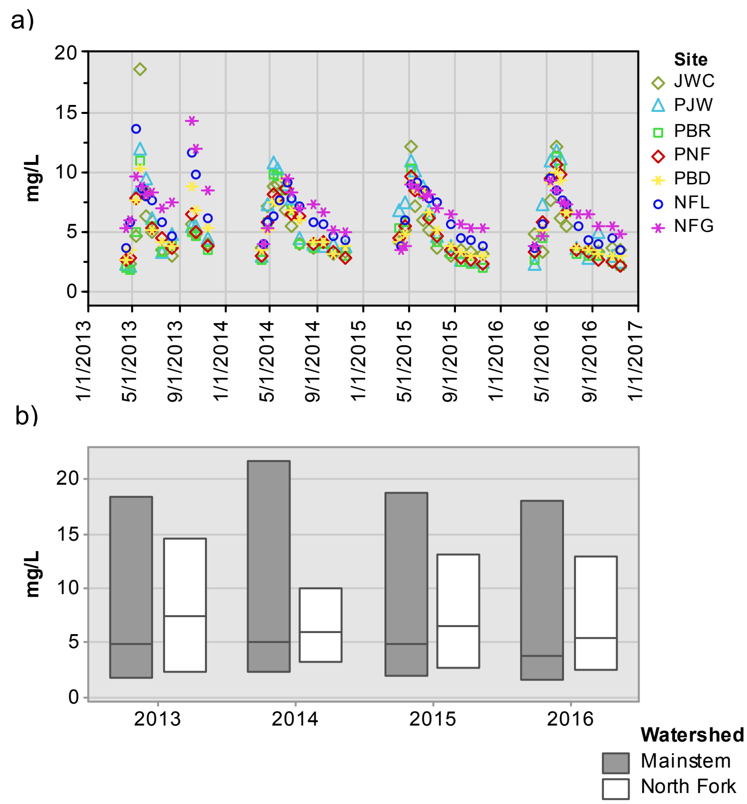

Figure 3.11 – Total organic carbon (TOC) concentrations measured at a) key Upper CLP monitoring locations and b) boxplots displaying the distribution of data measured throughout the Mainstem and North Fork watersheds from 2013 through 2016.

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. In contrast, the lowest TOC concentrations are observed at Stonewall Creek (SCM) (see Attachment 6, pg. 54). 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.

Similar to the Mainstem, 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 coming from the reservoirs. Elevated TOC concentrations are frequently observed on the North Fork at NFG during late summer and early fall and can often translate to elevated concentrations downstream at the Greeley-Bellvue diversion sampling site, or PBD.

In 2016, TOC dynamics on the North Fork were similar to the Mainstem (Figure 3.11a). In early April, TOC concentrations were 3.7 mg/L at NFL and 3.8 mg/L at NFG before increasing during snowmelt runoff to peak concentrations of 9.3 mg/L on May 9th at both sites. Peak concentrations on the North Fork were observed earlier than on the Mainstem. Following runoff, concentrations at NFL and NFG steadily decreased through the remainder of the year. Concentrations below Seaman Reservoir at NFG were slightly higher than NFL from July to November. TOC concentrations were below 5 mg/L at both sites by the end of the monitoring season in November (Figure 3.11a).

The median TOC concentration in 2016 for the North Fork watershed was 5.5 mg/L, which was marginally higher than the Mainstem (Figure 3.11b). However, this was the lowest median concentration recorded over the four year period. TOC values on the North Fork ranged from 2.4 mg/L to 12.9 mg/L (Figure 3.11b). The lowest concentration was measured SCM on March 29th and the highest concentrations was measured at RCM on May 10th.

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-N), nitrate (NO_3-N), nitrite (NO_2-N), 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 (Helsel and Hirsch, 2002).

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 2016, total nitrogen (TN) concentrations on the Mainstem Poudre River were similar across sites, but were generally lower than the previous three years (Figure 3.12a). In general, TN concentrations increased with decreasing elevation prior to and during snowmelt runoff. The highest concentrations were observed during the onset of snowmelt runoff. Peak concentrations at lower elevation monitoring sites (PNF and PBD) were measured on May 9th, while peak concentrations at higher elevation sites (PJW and PBR) were observed on June 6th with the exception of JWC, which was observed on May 23rd (see Appendix 6, pg. 63) Concentrations steadily decreased following the annual maximum TN concentrations (Figure 3.12a). The median TN concentration in 2016 for the Mainstem watershed was 279 µg/L, which was the lowest recorded over the four year period. Concentrations were within the range of values observed over the previous years with concentrations ranging from below the reporting limit (100 µg/L) to 770 µg/L in 2016 (Figure 3.12b). The highest concentration was measured at PBD on May 9th (Figure 3.12a).

In general, concentrations of inorganic species of nitrogen were low throughout the Mainstem watershed. Nitrite (NO_2-N) concentrations were measured below the reporting limit at all sites, which was consistent with previous years. Ammonia (NH_3-N) concentrations were similar to previous years with concentrations reporting slightly above the reporting limit (10 ug/L) at all sites, except BMR. The median concentration at BMR was greater than 50 µg/L, which is consistent with previous years. These elevated concentrations did not appear to impact concentrations downstream. One notable event occurred on August 15th when NH_3-N concentrations were elevated compared to the previous month. Higher concentrations were measured higher in the watershed, but were lower at downstream monitoring sites (see Appendix 6, pg. 56).

Nitrate (NO_3-N) concentrations continued to decrease at all sites in 2016. The median concentration for the Mainstem watershed was 52.3 µg/L (Figure 3.13). The decreasing trend was most notable at the fire impacted site PNF where median concentrations were nearly 50% lower than 2013 when the median concentration was greater than 100 ug/L. The median organic nitrogen (TKN minus NH3) concentration for the Mainstem watershed was measured at 188 µg/L (Figure 3.13). This was the lowest concentration observed over the four year period. Together, with NO_3-N, organic nitrogen comprised the largest fraction of total nitrogen throughout the Mainstem watershed.

Phosphorus

Total phosphorus (TP) concentrations on the Mainstem typically increase during snowmelt and decrease through the summer months into the fall. In contrast, PO_4 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 2016, TP concentrations were within the range of values observed over the previous three years. The median TP concentration for the Mainstem watershed was 15 µg/L with concentrations ranging from below the reporting limit (5 µg/L) to 86 µg/L (Figure 3.14a). The maximum concentration was measured at BMR, which was different than previous years when annual maximum concentrations were observed at PNF and PBD. The elevated concentrations at BMR in 2016 did not appear to impact downstream concentrations. Peak concentrations on the Poudre River, were observed during the onset of snowmelt runoff in May. Concentrations decreased

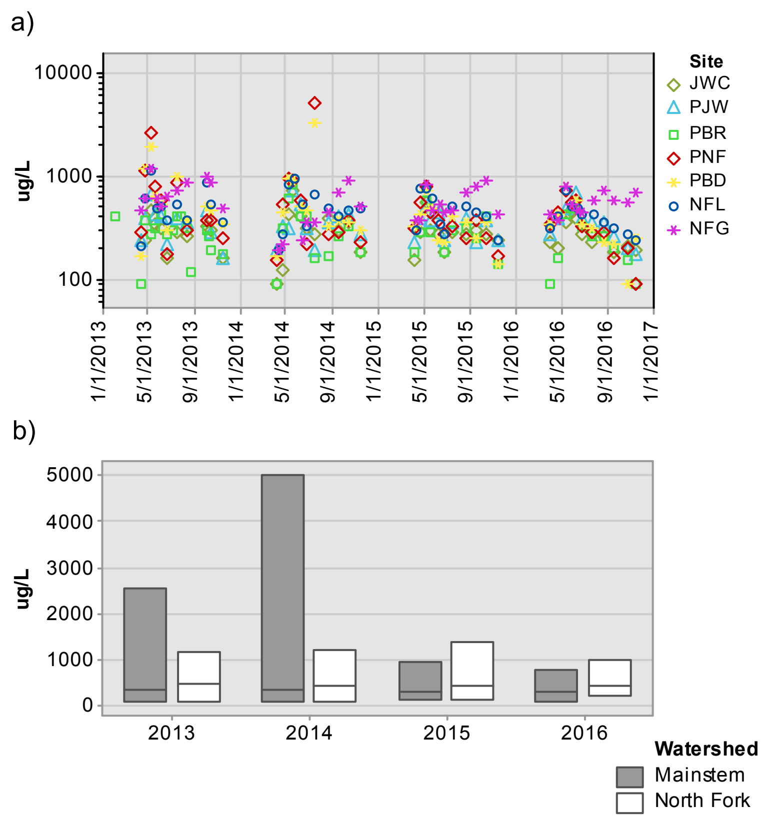

Figure 3.12 – Total nitrogen concentrations at key Upper CLP monitoring locations and b) boxplots displaying the distribution of data measured throughout the Mainstem and North Fork watersheds from 2013 through 2016..

following the snowmelt pulse to near or slightly above the reporting limit (Figure 3.14a).

Ortho-phosphate (PO_4) concentrations measured in 2016 were within the range of values observed over the previous three years; however, the median PO_4 concentration (9 µg/L), although only slightly above the reporting limit, was higher than the previous three years (Figure 3.14b). Ortho-phosphate concentrations ranged from below the reporting limit (5 µg/L) to 39 µg/L. Similar to TP, the maximum concentration was measured at BMR. In contrast to previous years when concentrations decrease rapidly to near or below the reporting limit, concentrations at most sites remained above the reporting limit for longer in the monitoring season. By the end of the monitoring season concentrations at all sites, except PNF and PBR, were measured below the reporting limit.

An increasing trend in PO_4 continued to persist throughout the Mainstem watershed over the short-term record. Median PO_4 concentrations in 2016 were two times greater than the median concentration in 2013 (Figure 3.15). Although, concentrations remained low (slightly above the reporting limit), median concentrations at all sites throughout the Mainstem watershed were the highest documented over the four year record (Figure 3.15).

North Fork Poudre River

In general, nutrient concentrations are higher on the North Fork compared to the Mainstem (Figure 3.13 and 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. The highest concentrations were observed in early May during the onset of snowmelt runoff, and steadily decrease during the early summer months with the exception of TN concentrations at NFG and NBH. Concentrations at these sites remained fairly consistent throughout the season with a slight increasing

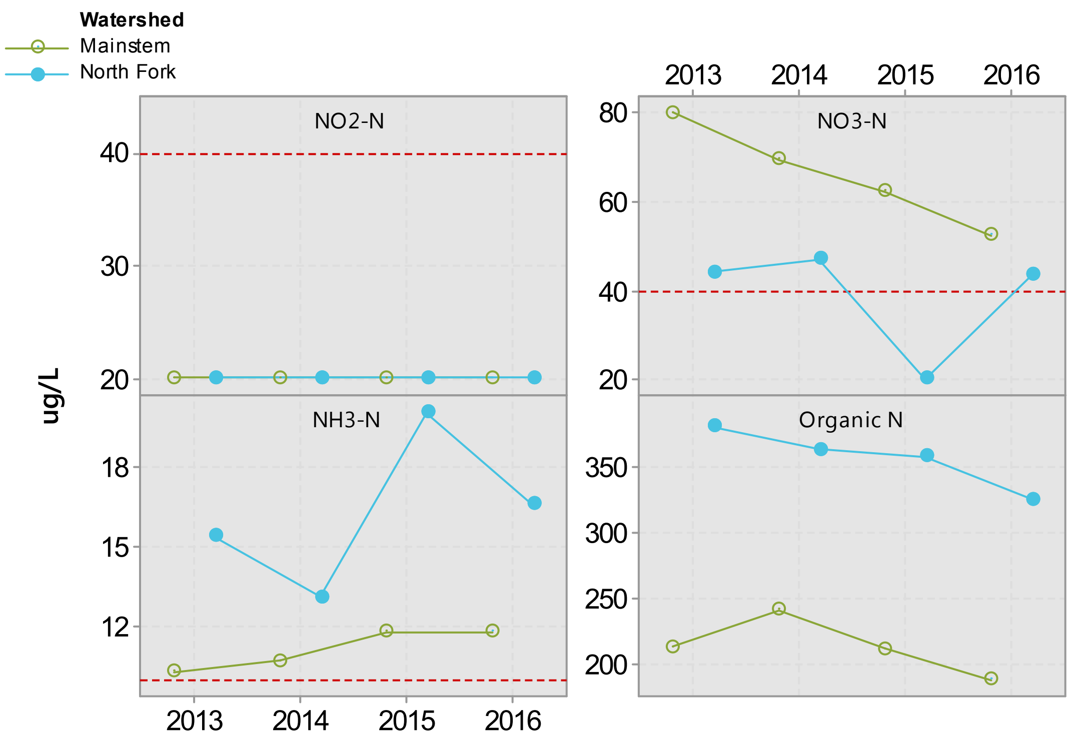

Figure 3.13 – Distribution of total nitrogen concentrations on the Mainstem and North Fork.

trend at NFG (Figure 3.12a)

The median TN concentration in 2016 on the North Fork was 424 µg/L, which was comparable to previous three years. Concentrations were within the range of values observed over the previous years. Total nitrogen concentrations throughout the North Fork ranged from 201 µg/L to 977 µg/L at in 2016 (Figure 3.12b). The highest concentrations were observed in the North Fork tributaries at RCM and PCM during snowmelt runoff.

In general, concentrations of inorganic species of nitrogen were similarly low throughout the North Fork watershed. Nitrite concentrations were measured below the reporting limit at all sites, which is consistent with previous years. The median NH_3-N concentration in 2016 for the North Fork watershed was greater than the Mainstem, which was consistent with previous years (Figure 3.13). The higher median NH_3-N is driven by elevated concentrations at NBH and NFG, which are situated below reservoirs. Concentrations at these sites steadily increased through the monitoring season to peak concentrations in July and August, respectively. This trend was consistent with previous years.

In contrast to the Mainstem watershed, median NO_3-N concentrations fluctuated around the reporting limit over the four year period and no notable trend was evident (Figure 3.13). In 2016, median NO_3-N measured slightly above the reporting (40 µg/L). There was a noticeable trend in median organic nitrogen. Median organic nitrogen decreased annually to 326 µg/L in 2016 (Figure 3.13).

This was the lowest concentration observed over the four year period. Like the Mainstem, NO_3-N and organic nitrogen comprised the largest fraction of total nitrogen, but organic nitrogen concentrations are generally greater than the Mainstem.

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. Concentrations were also elevated at NBH during this time of the season.

In 2016, TP concentrations were within the range of values observed over the previous three years and exhibited similar variability in concentrations across the watershed. The North Fork watershed had a median TP concentration of 34 µg/L with concentrations ranging from 5 µg/L to 213 µg/L. The maximum concentration was observed below Seaman Reservoir, at NFG on August 18th. The elevated concentrations at NFG in 2016 appeared to influence downstream concentrations at PBD (Figure 3.14b).

Ortho-phosphate (PO_4) concentrations measured in 2016 were within the range of values observed over the previous three years. The median PO_4 concentration, like the Mainstem, continued to exhibit an increasing trend and was measured at 19 µg/L, which was the highest median value observed over the previous three years (Figure 3.15). Ortho-phosphate concentrations ranged from below the reporting limit (5 µg/L) to 76 µg/L (Figure 3.14b). The maximum concentration was measured at NFG on August 16th. High concentrations persist at RCM, but do not appear to impact concentrations downstream at NFL. By the end of the monitoring season, PO_4 concentrations were measured below the reporting limit at all sites except NDC and NBH, which were slightly above the reporting limit.

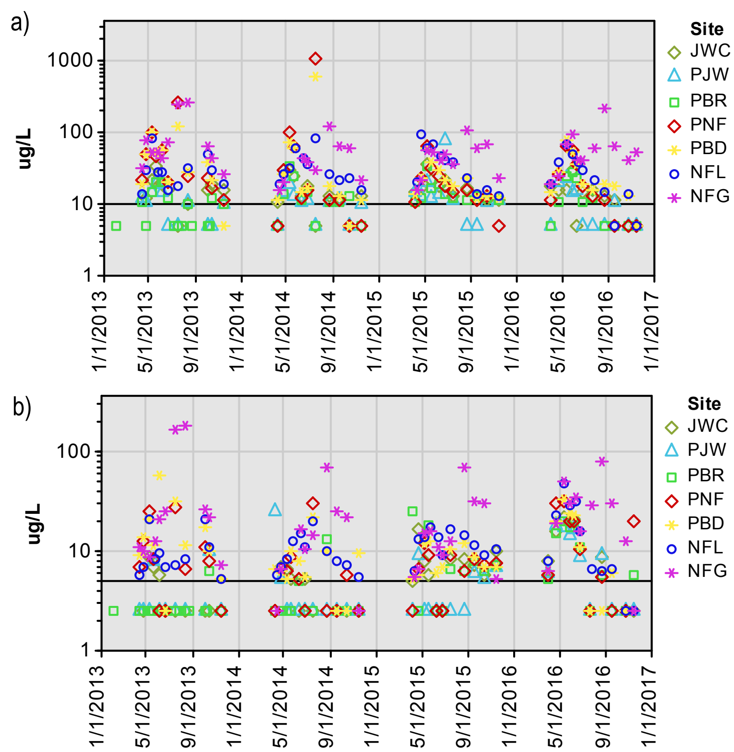

Figure 3.14 – Nutrient concentrations for a) total phosphorus and b) ortho-phosphate phosphorus at key Upper CLP monitoring locations.

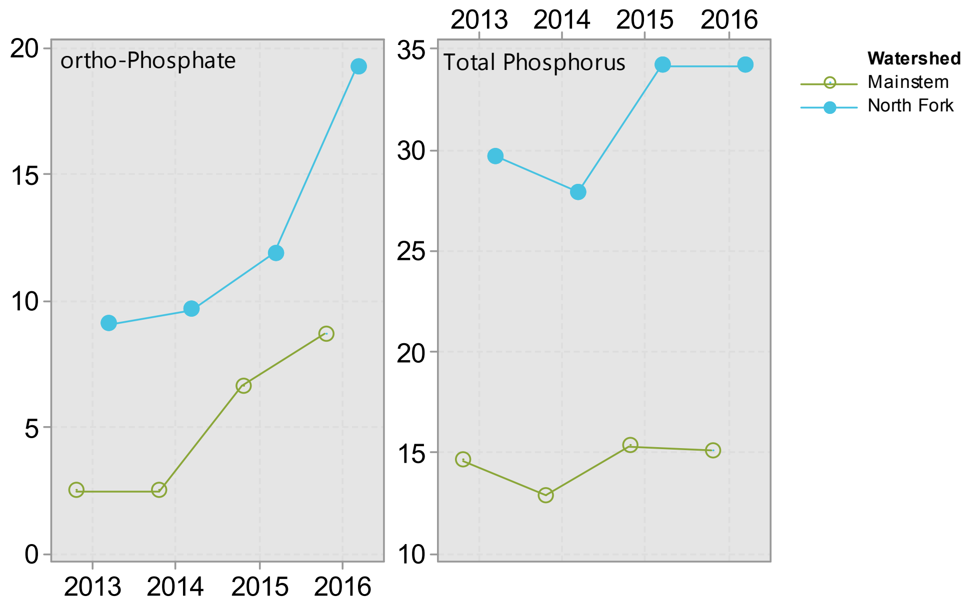

Figure 3.15 – Annual median concentrations for ortho-Phosphate and total phosphorus for the Mainstem and North Fork watersheds.

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. Snowmelt runoff generally results in elevated metal concentrations, as does storm events.

In 2016, metals were sampled 2 times on the Mainstem at PNF and on the North Fork at NFG on May 23rd and 24th and October 17th and 18th. Most metals were analyzed for both dissolved and total fractions.

As was expected, the most commonly detected metals in 2016 were aluminum (Al), iron (Fe), and manganese (Mn). These metals had higher concentrations in May compared to October. There were also detections of arsenic (As) in October at NFG and copper (Cu) at both PNF and NFG in May. Concentrations for these detections were slightly greater than the reporting limit. Mercury (Hg), silver (Ag), cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), selenium (Se), and zinc (Zn) were not detected in 2016.

Dissolved iron concentrations exceeded the secondary drinking water quality standard of 300 µg/L at NFG on May 23th when concentrations were measured at 404 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.

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.

		Site	PNF		NFG	
		Month	*5/23/2016*	*10/17/2016*	*5/24/2016*	*10/18/2016*
Hg	ug/L	Soluble	<0.2	<0.2	<0.2	<0.2
		Total				
Ag	ug/L	Soluble	<1	<1	<1	<1
		Total	ND	ND	ND	ND
Al	ug/L	Soluble	423	<10	559	<10
		Total	1079	14	1105	181
As	ug/L	Soluble	<1	<1	<1	1.25
		Total	<1	<1	<1	1.36
Cd	ug/L	Soluble	<1	<1	<1	<1
		Total	<1	<1	<1	<1
Cr	ug/L	Soluble	<1	<1	<1	<1
		Total	ND	ND	ND	ND
Cu	ug/L	Soluble	3.07	<1	1.61	<1
		Total	2.36	<1	1.38	<1
Fe	ug/L	Soluble	291	20	404	19
		Total	1207	40	1042	310
Mn	ug/L	Soluble	6	2	10	44
		Total	37	4	38	106
Ni	ug/L	Soluble	<1	<1	<1	<1
		Total	ND	ND	ND	ND
Pb	ug/L	Soluble	<1	<1	<1	<1
		Total	<1	<1	<1	<1
Se	ug/L	Soluble	<5	<5	<5	<5
		Total	<5	<5	<5	<5
Zn	ug/L	Soluble	<10	<10	<10	<10
		Total	<10	<10	<10	<10

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 2016 – 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 3.16). 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 3.16a). Total coliforms measured on the Mainstem in 2016 were within the range of values observed over the previous three years (3.1 – 19,863 colony forming units (cfu) per 100 mL). In 2016, total coliforms ranged from 9.6 to 1,844 cfu/100 mL with a median value of 336 cfu/100 mL, which was comparable to previous years. A similar seasonal trend was observed at all sites on the Mainstem. Total coliforms increased throughout the monitoring season to an annual maximum on July 18th at PBR and August 15th at PNF and PBD.

Total coliforms were higher and more variable at NFG compared to sites on the Mainstem, but did not appear to influence cell counts at PBD. In 2016, 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 35 to 6,212 cfu/100 mL. The annual median value of 613 cfu/100 mL was similar to 2014 and lower than 2013 and 2015. Total coliforms followed a similar seasonal trend to the Mainstem.

E. coli counts on the Mainstem in 2016 were within the range of concentrations observed over the previous three years (0 – 1,918 cfu/100 mL). In 2016, *E. coli* counts on the Mainstem ranged from 0 to 384 cfu/100 mL with an annual median value of 15.8 cfu/100 mL, which was the highest median observed over the four year monitoring period (Figure 3.16b). In comparison, *E. coli* counts at NFG were lower than the Mainstem. In 2016, *E. coli* counts at NFG ranged from 0 to 346 cfu/100 mL with an annual median value of 4 cfu/100 mL.

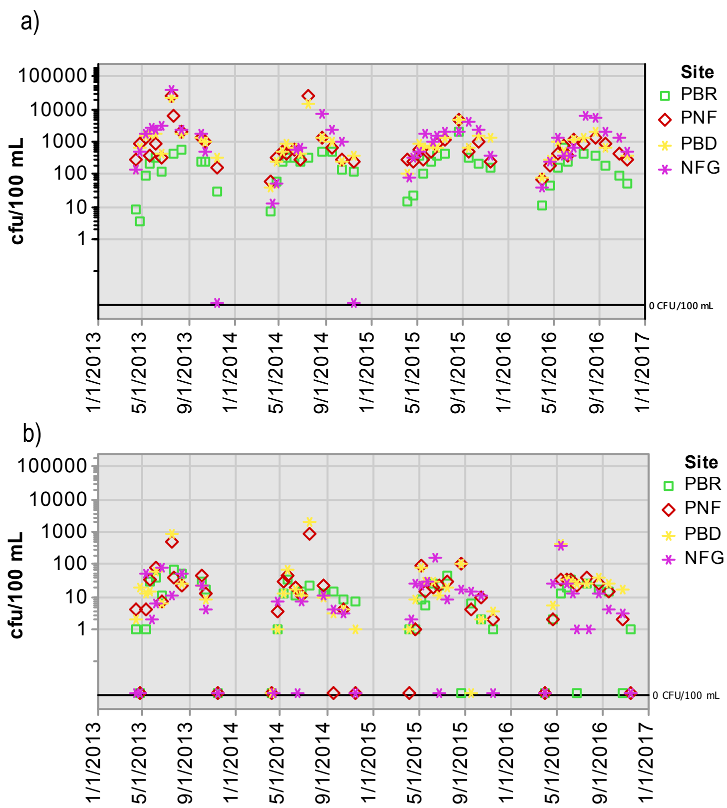

Figure 3.16 – Counts of a) total coliforms and b) E. coli on the Mainstem and North Fork CLP.

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 2013 through 2016. *Giardia* was more abundant than *Cryptosporidium* (Figure 3.17). *Giardia* concentrations were low at PNF and within the range of values observed over the previous three years (<1 – 14 cells/L) (Figure 3.17a). In 2016, giardia concentrations ranged from <1 to 11 cells/L with a median value of 5 cells/L, which was greater than 2013 and 2014 and comparable to 2015. Giardia concentrations decreased from April through July before increasing to the peak concentration of 11.1 cells/L on October 5th. Concentrations decreased in October and November to levels observed in the spring.

Giardia concentrations on the North Fork were similar to concentrations on the Mainstem with the exception of NCD on April 19th. *Giardia* concentrations measured in 2016 were within the range of values observed over the previous three years (<1 – 35 cells/L) at North Fork sites. In 2016, *giardia* concentrations ranged from <1 cell/L to 27 cells/L with an annual median value of 2 cells/L. The highest concentration was measured at NDC at 27 cells/L on April 19th. Giardia concentrations decreased moving downstream to NFG below Seaman Reservoir where the highest *giardia* count was 3 cells/L.

Cryptosporidium concentrations are generally low on both the North Fork and Mainstem. Cell counts are usually below the detection limit of 0.10 cell/L on the Mainstem, while detections occur more often on the North Fork. In 2016, *Cryptosporidium* was not detected on the Mainstem. *Cryptosporidium* was detected on the North Fork, but detections were relatively low. Concentrations were within the range of values observed over the previous three years (<0.10 – 1.32 cells/L). In 2016, cell counts ranged from less than 0.10 to 1.06 cells/L with the maximum cell count measured at NDC on May 24th. Annual maximum cell counts at NBH and NFG were also observed on this date. *Cryptosporidium* decreased following this date to below 0.5 cells/L and remained low for the remainder of the season.

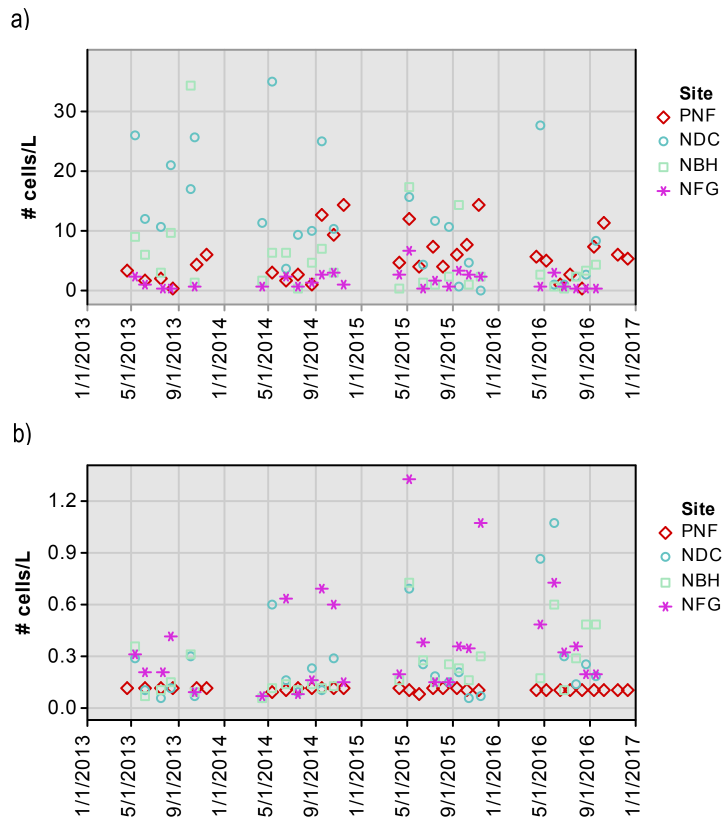

Figure 3.17 – Concentrations of a) giardia and b) Cryptosporidium on the Mainstem and North Fork CLP.

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 (22 blanks in total) were collected at different monitoring locations on both the Mainstem and North Fork, to identify potential for sample contamination. The field data quality sampling schedule is outlined in the 2016 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 7.

Field Duplicates

In 2016, twelve percent (33 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 2016 and illustrates that UCLP water quality data are of high precision. All duplicate samples were within 10% agreement at the 50th percentile. Ammonia, orthophosphate, and TKN were slightly outside of the 10% agreement at the 75th 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.

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		
	min	*max*			*25th*	*50th*	*75th*
Alkalinity (mg/L)	12.8	44.4	2	0.55	0.3	1.0	1.4
Hardness (mg/L)	12.0	46.8	5	0.7	0.1	0.2	2.3
Ammonia (ug/L)	3.5	16.9	10	3.0	3.7	7.4	21.4
Turbidity (NTU)	0.33	18.10	0.05	0.17	1.6	2.6	4.1
ortho-Phosphate (ug/L)	1	30	5	3	0.4	3.0	10.9
TDS (mg/L)	29	263	10	22	0.8	2.3	5.1
TKN (ug/L)	91	552	100	38	3.3	6.7	14.2
TOC (mg/L)	2.14	10.6	0.5	0.1	0.3	0.5	0.8
Total P (ug/L)	1.9	63.2	10	2.1	2.5	4.5	8.7

Field Blanks

Ninety-five percent of field blank samples reported below the constituent's respective reporting limits in 2016. The 5% of field blank samples that were detected above the reporting limits included Cu, NH_4-N, NTU, and TDS (Table 6). Concentrations were reported only slightly above the reporting limit for these samples and concentrations were minimal compared to concentrations of environmental samples. Potential causes of these contaminants may be from the atmosphere/particulates in the air slightly increasing Cu, NTU and TDS. NH_4-N contamination may be introduced by the field sampler by accidentally breathing on the sample. It is suggested to limit the amount of time the sample is exposed to the environment by immediately capping the sample bottle following sample collection.

Table 6 – Blank samples detected above their respective detection limit in 2016.

Constituent	Samples above DL	Total samples	% exceedance
Cu	1	8	13%
NH3-N	12	23	52%
NTU	13	22	59%
TDS	8	22	36%

Instrument Accuracy

Accuracy is a measure of the degree of closeness a measurement is to the true measurement. Equipment calibrations were conducted prior to field monitoring exhibitions using certified standards to assure the accuracy of sensors on the multi-parameter water quality sonde.

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 2016 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 and flood 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 2016, peak snow water equivalent (SWE) in the Upper CLP was 110% of the expected peak SWE based on the long-term median. Peak SWE near Cameron Pass was measured two weeks later than expected due to several winter storms from mid-April through early-May extending the snow accumulation season. The winter snowpack began to melt and by mid-June the 2016 snowpack was completely melted near Cameron Pass.

Winter base flows (low flow) at the canyon mouth dropped to near average in 2016 after three years of above average flows following the 2013 flood. Streamflow at the canyon mouth began to exhibit signs of snowmelt runoff in mid-March steadily increasing through late-April. Peak streamflow was measured on June 12^{th} at 177% of the long-term average. Baseflow conditions beginning in mid- to late-August were below average for the remainder of the 2016 water year, as drought conditions throughout the watershed started to emerge following several months of below average precipitation.

Wildfire impacts on streamflow, including debris flows and flooding, were less common on the Mainstem during the 2016 monsoon season following high intensity, short duration precipitation events localized over burn scar areas in the Upper CLP watershed.

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.

Both the Mainstem and North Fork CLP continued to see detectable levels of emerging contaminants that are closely linked to recreation and herbicide use in the watershed. The timing of these detections (August) indicates the increase in recreational use within the Poudre Canyon during the summer season. The detected compounds, which include 2,4-D, caffeine, DEET, and sucralose, are ubiquitous to the environment. The levels at which these compounds were detected was several orders of magnitude lower than their pure compound levels and considered a very low concern in the Upper CLP watershed. In fact, the Upper CLP is considered the reference site for Northern Water's Emerging Contaminant Monitoring Program due the absence of land use practices within the watershed that introduce these contaminants to surface waters.

Nutrient concentrations were higher on the North Fork compared to the Mainstem, but temporal patterns were consistent between the two watersheds. Nitrogen displayed a decreasing trend in the Mainstem watershed with concentrations of inorganic and organic nitrogen species measured at the lowest levels over the four year period. In the North Fork watershed, nitrogen was within the range of values observed over the previous three years. There was no trend observed in inorganic nitrogen species, but organic nitrogen (TKN minus NH_3-N) displayed a decreasing trend. NO_3-N and organic nitrogen comprised the largest fraction of total nitrogen on both the Mainstem and North Fork, but organic nitrogen concentrations were generally greater on the North Fork.

Total phosphorus concentrations were within the range of values observed over the previous three years and exhibited similar variability in concentrations across both the Upper CLP watershed. An increasing trend in PO_4 continued to persist throughout the Upper CLP watershed over the short-term record. Median PO_4 concentrations in 2016 were two times greater than the median concentration in 2013. Although concentrations remained low, median concentrations for the Mainstem and North Fork watershed were the highest documented over the four year monitoring period.

Wildfire impacts in the Upper CLP watershed were still apparent in 2016. The most notable impacts to water quality associated with the wildfire continued to be elevated NO3-N at wildfire impacted monitoring site (PNF and PBD). Despite the elevated NO3-N, these concentrations are still low and it appears that post-fire nutrient levels are returning to pre-fire conditions. Geosmin concentrations remained below the 4 ng/L odor threshold and excessive algal growth and/or associated taste and odor issues were not reported.

Naturally occurring metals are routinely detected at low concentrations in the North Fork and Mainstem. The most commonly detected metals in 2016 were aluminum (Al), iron (Fe), and manganese (Mn). All of these metals were detected during snowmelt runoff in May. Concentrations of these metals were notably lower or measured below the reporting limit in October. There were also slight detections of copper (Cu) at PNF and NFG in May and arsenic (As) at NFG in October. Dissolved iron concentrations exceeded the secondary drinking water quality standard of 300 µg/L at NFG on May 24th (404 µg/L). The elevated iron concentrations did not cause any aesthetic changes in water quality, nor were any taste and odor issues reported.

Total coliforms and *E. coli* exhibited a great degree of seasonal and annual variability. Total coliforms were higher and more variable at NFG compared to sites on the Mainstem, but did not appear to have a big impact downstream on the Mainstem at PBD. *E. coli* counts were generally lower at NFG compared to the Mainstem.

5.4 MONITORING AND PROTECTION EFFORTS IN 2017

Planned water quality monitoring and other related Upper CLP activities for 2017 are summarized below:

- **Routine Monitoring Program:** Samples will continue to be analyzed for all parameters in 2017.

- **Emerging Contaminant Monitoring:** The Cities of Fort Collins and Greeley will continue to participate in Northern Water's Emerging Contaminants Program in 2017. Samples will be collected at PNF and NFG in February, June, and August.

- **Geosmin:** Geosmin monitoring will continue on the Mainstem CLP in 2017 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 4). 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 2016. 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.

6.0 REFERENCES

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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. ***Discontinued in 2015***	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 ***Discontinued in 2015***	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

2016 UPPER CLP MONITORING PARAMETER LIST

	Rationale	Notes
Field Parameters		
Conductance	Indicator of total dissolved solids.	All sites with water quality sonde.
Dissolved Oxygen	Profile indicates stratification, importance for aquatic life and chemical processes.	All sites with water quality sonde.
Temperature	Reflects seasonality; affects biological and chemical processes; water quality standard.	All sites with water quality sonde.
pH	Measure of acidity.	All sites with water quality sonde.
General & Miscellaneous Parameters		
Alkalinity	Indicator of carbonate species concentrations; Acid neutralizing capacity of water; treatment implications.	
Discharge	Necessary for flow dependent analysis and load estimation.	Measured during sampling at NRC, RCM, SCM, PCM, PJW, SFC when conditions allow
Geosmin	Taste and odor compound	Measured monthly at PBR and PNF
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 and atmospheric deposition; water quality standard.	
Nitrate	Primary source of nitrogen to algae; indicator of pollution by sewage, septic tanks, agriculture, and atmospheric deposition; 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 and atmospheric deposition.	
Total Phosphorus	Includes dissolved and adsorbed, organic and inorganic forms of phosphorus, indicator of pollution by sewage, septic tanks, agriculture and atmospheric deposition.	

Major Ions		
Calcium	Major ion.	6x/yr
Chloride	Major ion.	6x/yr
Magnesium	Major ion.	6x/yr
Potassium	Major ion, minor importance as a nutrient.	6x/yr
Sodium	Major ion.	6x/yr
Sulfate	Major ion.	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.	Monthly above and below Halligan Reservoir, and below Seaman Reservoir
Giardia	Pathogen, Indicator of human or animal waste contamination.	Monthly above and below Halligan Reservoir, and below Seaman Res
Metals		
Aluminum, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; Aesthetic effects to drinking water	Only PNF & NFG
Arsenic, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG
Cadmium, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG
Chromium, dissolved	Natural occurs in rocks and soil. Water quality standard.	Only PNF & NFG
Copper, dissolved	Natural occurs in rocks and soil. Water quality standard.	Only PNF & NFG
Iron, total & dissolved	Natural occurs in rocks and soil. Affects aesthetic quality of treated water.	Only PNF & NFG
Lead, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG
Manganese, total & dissolved	Natural occurs in rocks and soil. Aesthetic effects to drinking water; water quality standard	Only PNF & NFG
Nickel, dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG
Silver, dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels.	Only PNF & NFG
Zinc, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels.	Only PNF & NFG
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 2016 SAMPLING PLAN

	2016 Sampling Dates										
	Mar 28-29	**Apr 18-19**	**May 9-10**	**May 23-24**	**Jun 6-7**	**Jun 20-21**	**Jul 18-19**	**Aug 15-16**	**Sep 12-13**	**Oct 10-11**	**Nov 7-8**
Station											
North Fork CLP											
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 CLP											
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**
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

[1] Grab samples taken at two depths (Top & Bottom); depth profiles at 1-m intervals.
[2] Call River 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 NH_3, NO_3, 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_4 pH <2	28 days
Analysis conducted by City of Fort Collins Water Quality Lab (FCWQL), unless otherwise noted.					
Reporting Limit = lowest reportable number based on the lowest calibration standard routinely used.					

ATTACHMENT 6

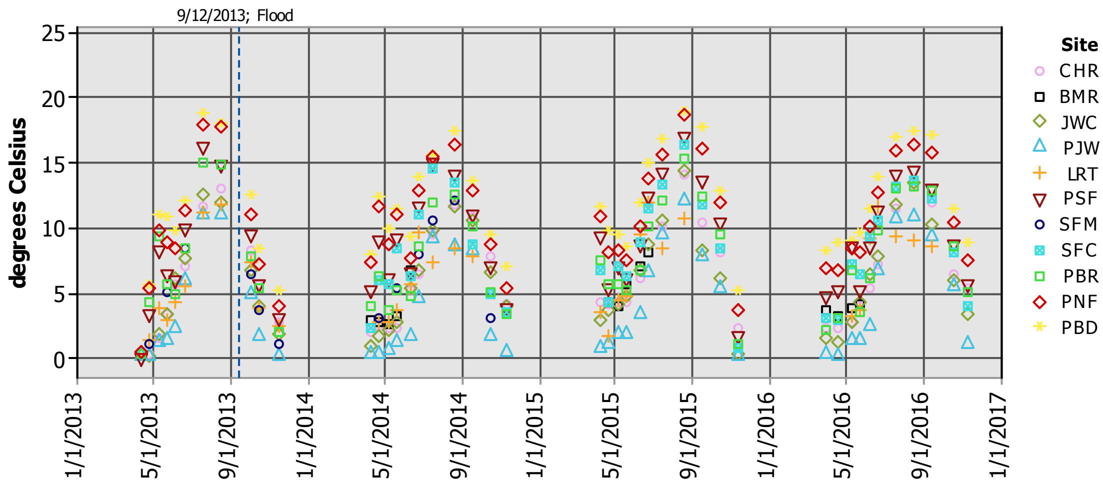
2016 UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM

GRAPHICAL SUMMARY

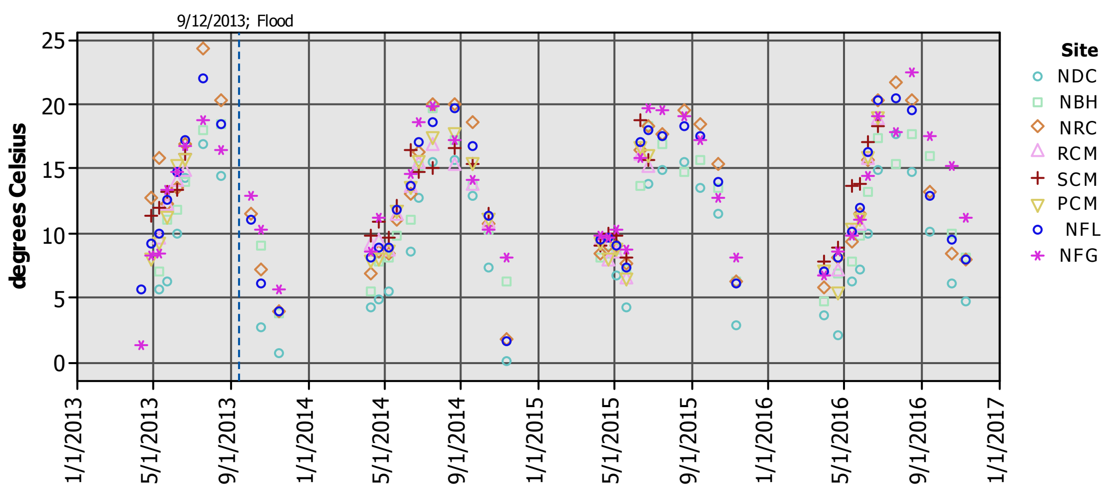
MAINSTEM & NORTH FORK CLP WATERSHEDS

GENERAL PARAMETERS

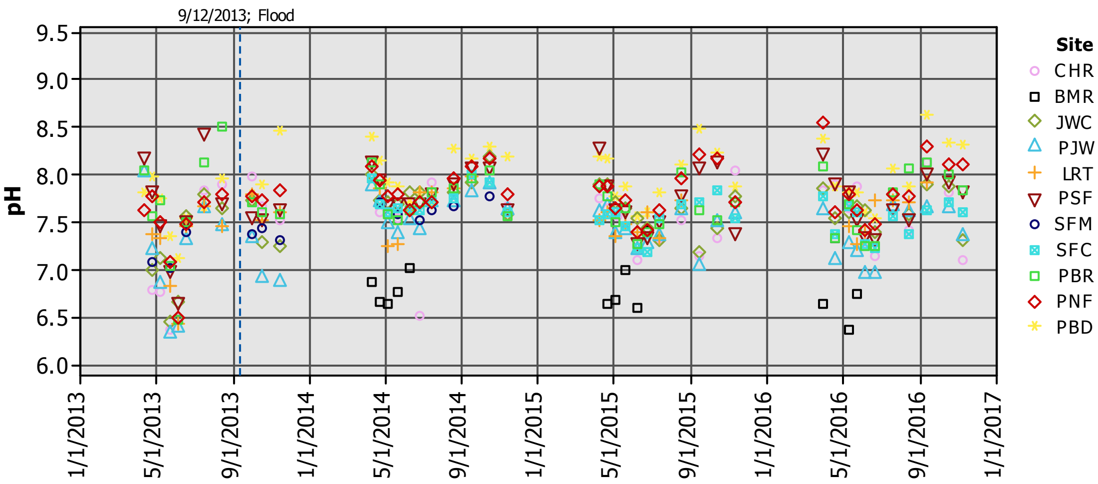
a) Temperature on the Mainstem CLP



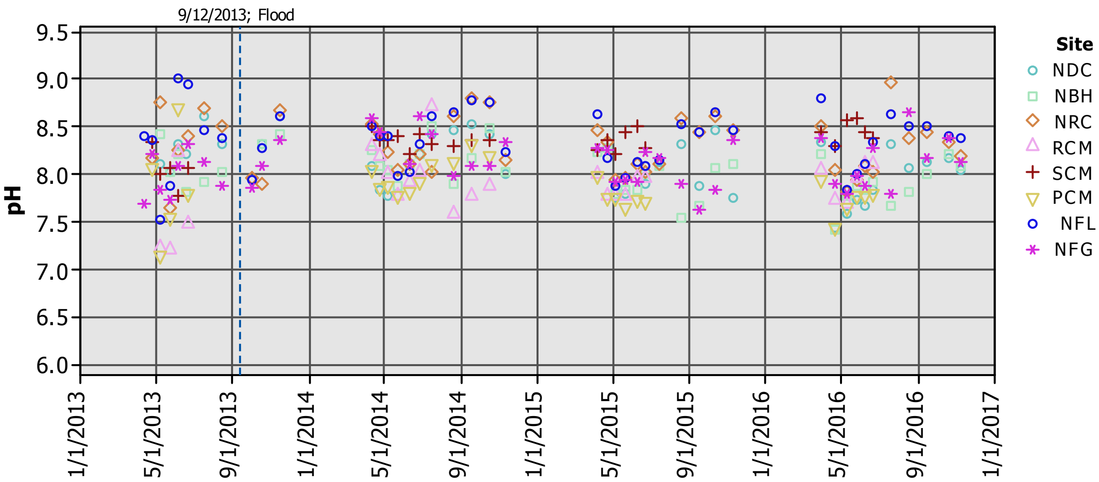
b) Temperature on the North Fork CLP



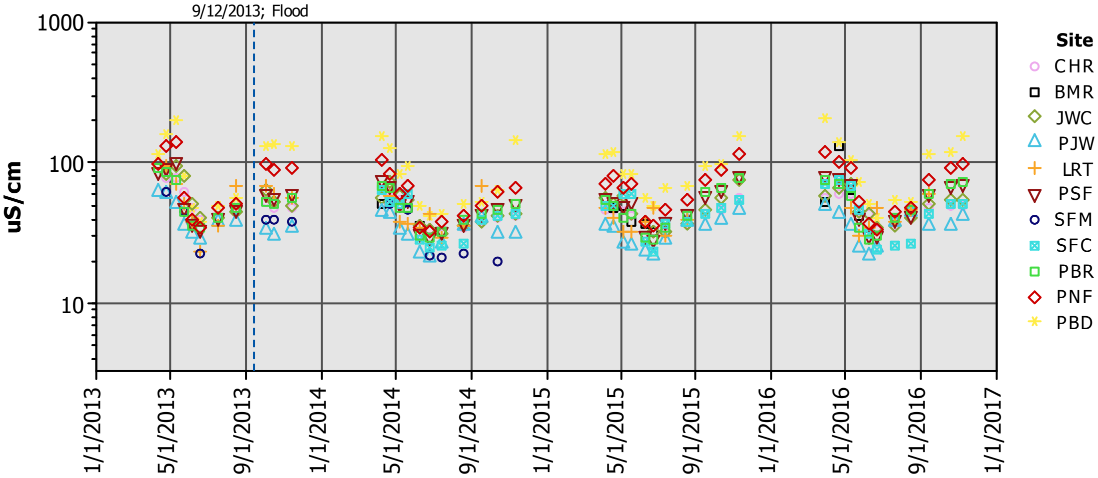
a) pH on the Mainstem CLP



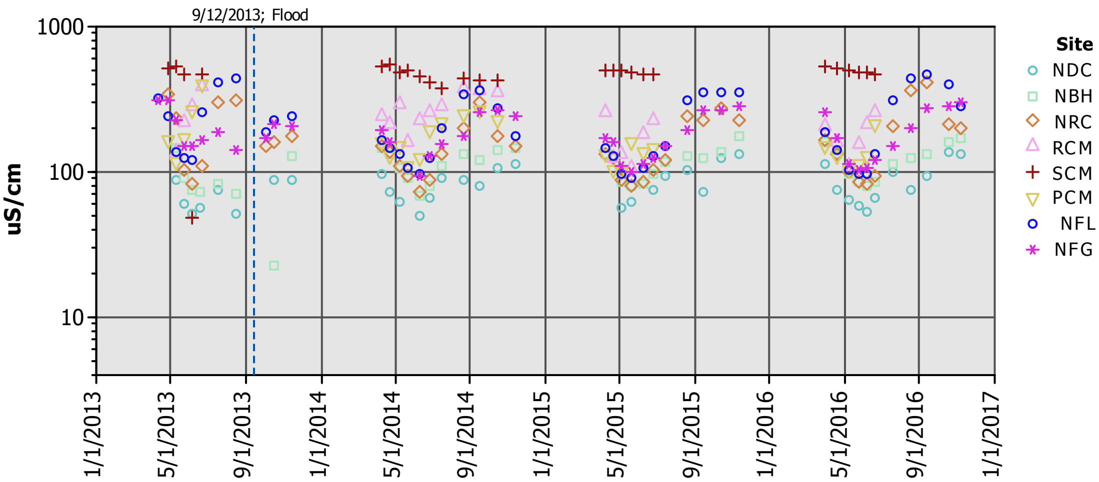
b) pH on the North Fork CLP



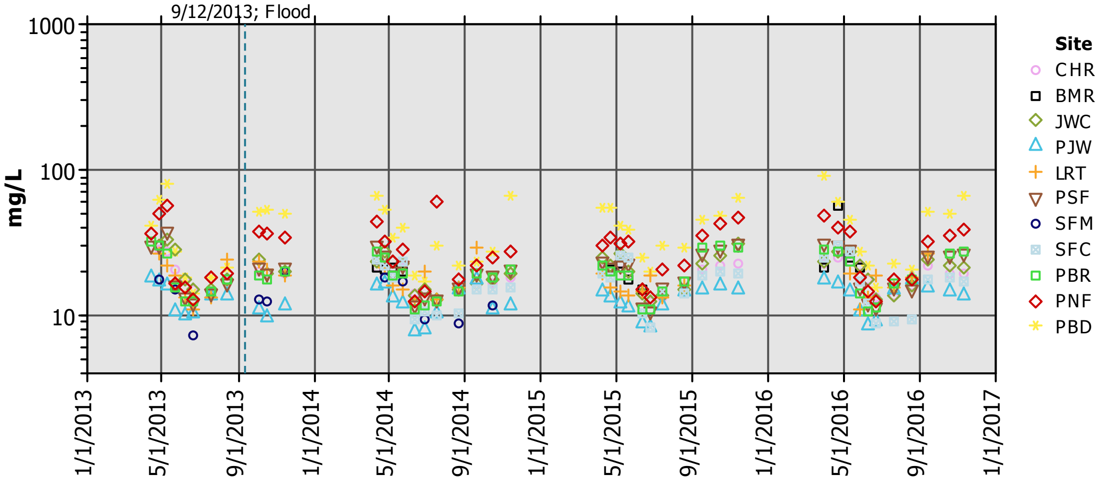
a) Specific Conductance on the Mainstem CLP



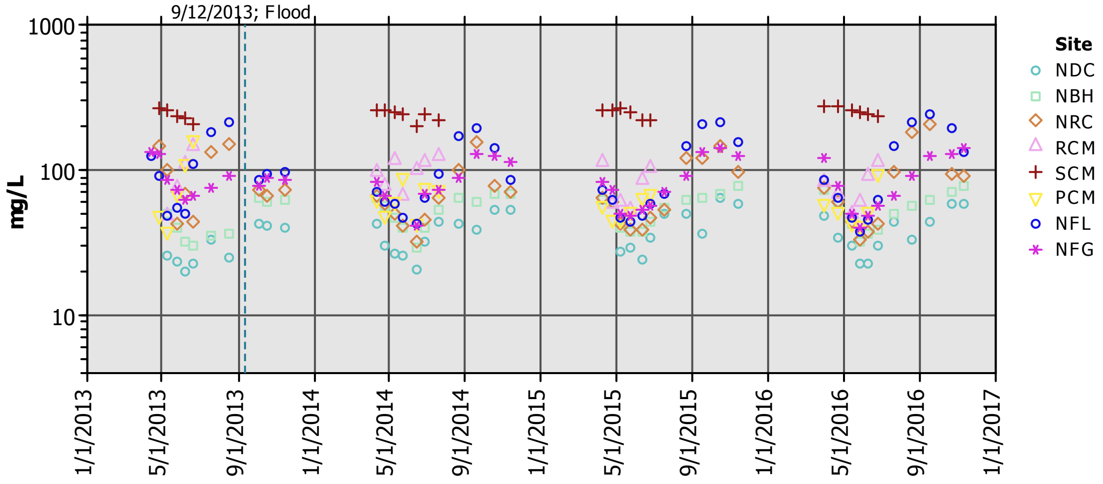
b) Specific Conductance on the North Fork CLP



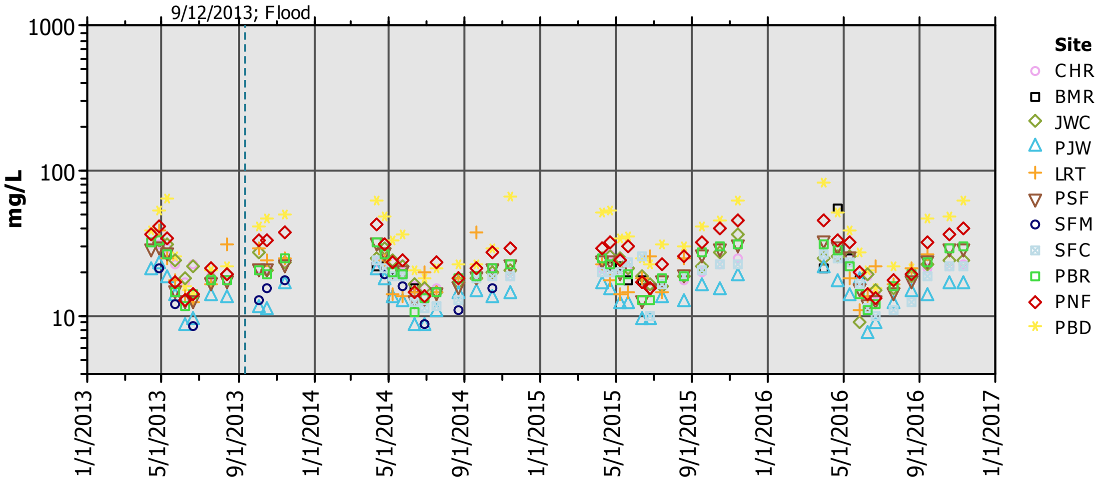
a) Hardness on the Mainstem CLP



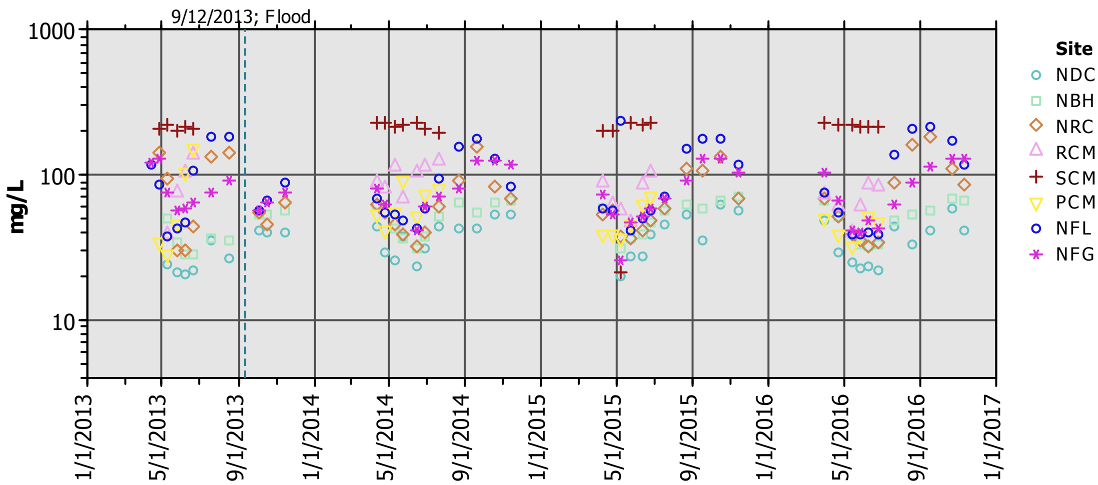
b) Hardness on the North Fork CLP



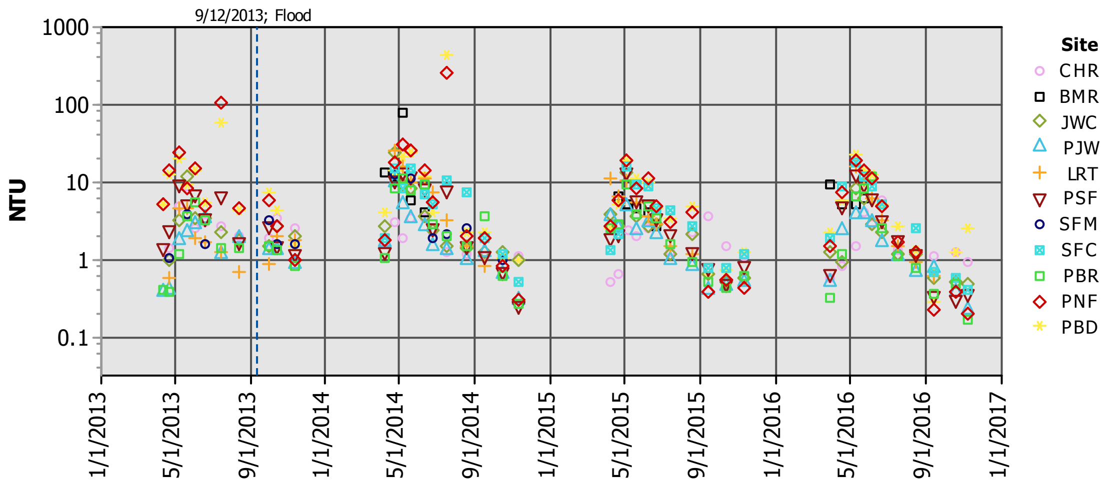
a) Alkalinity on the Mainstem CLP



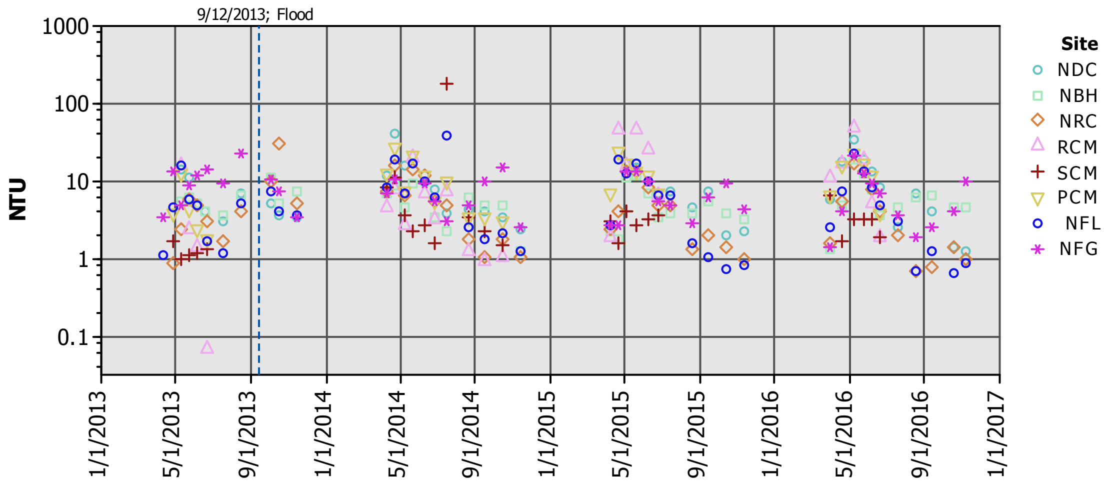
b) Alkalinity on the North Fork CLP



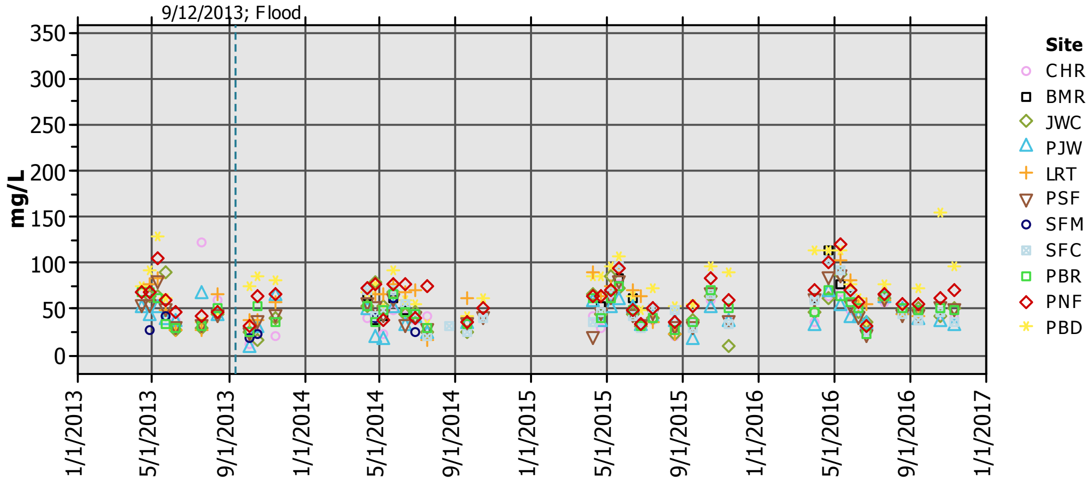
a) Turbidity on the Mainstem CLP



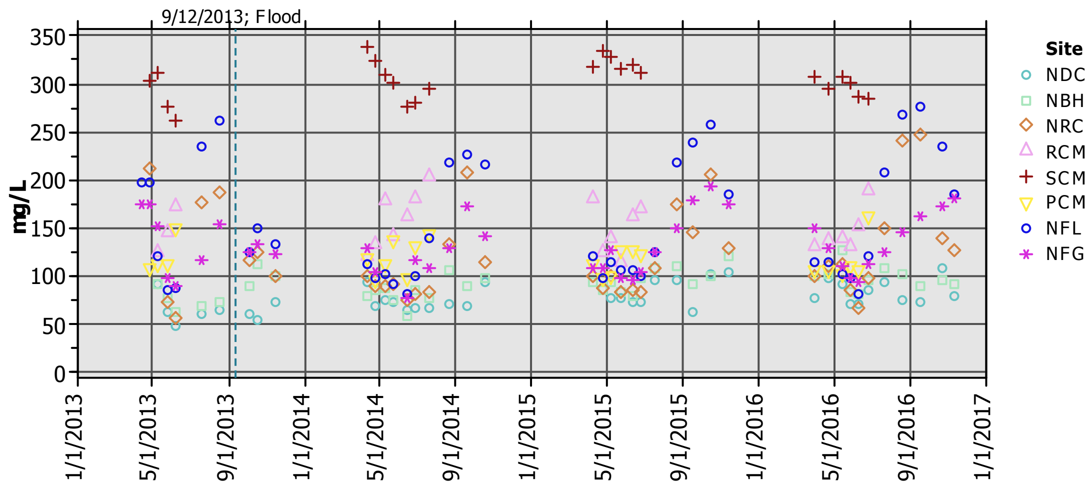
b) Turbidity on the North Fork CLP



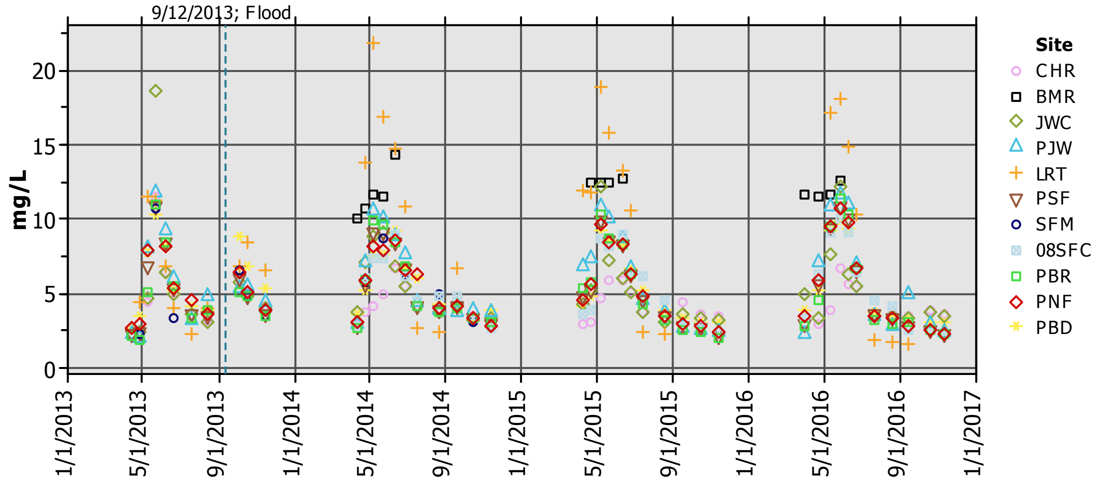
a) Total Dissolved Solids (TDS) on the Mainstem CLP



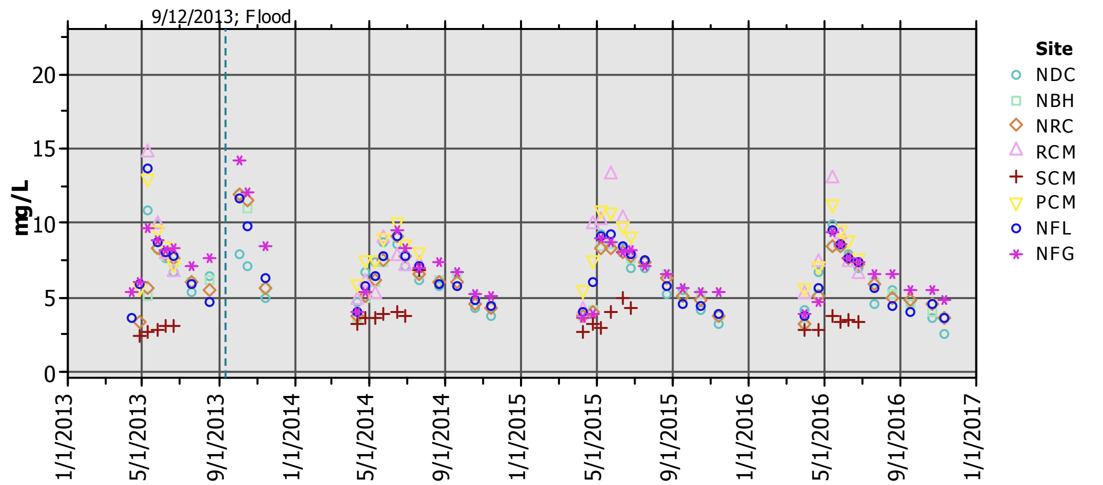
b) Total Dissolved Solids (TDS) on the North Fork CLP



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



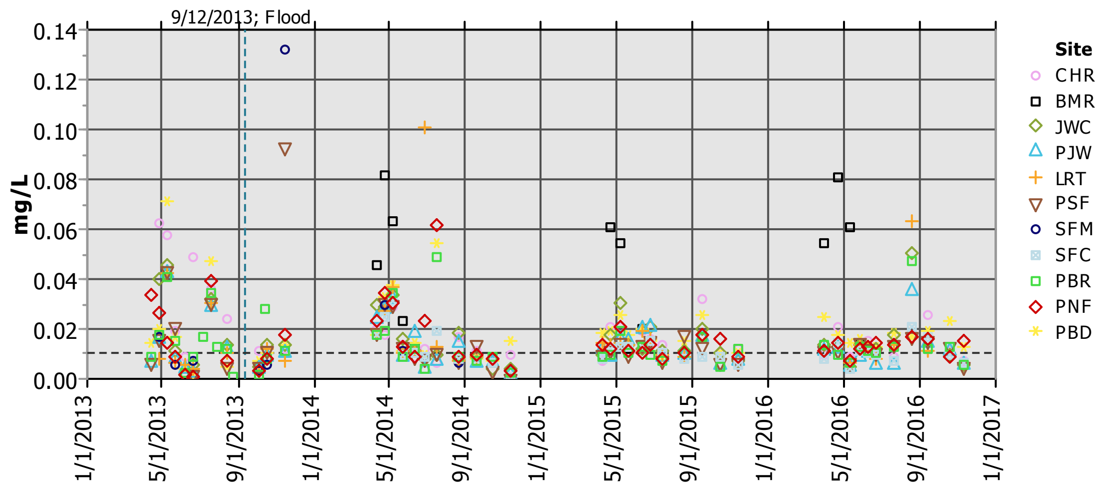
b) Total Organic Carbon (TOC) on the North Fork CLP



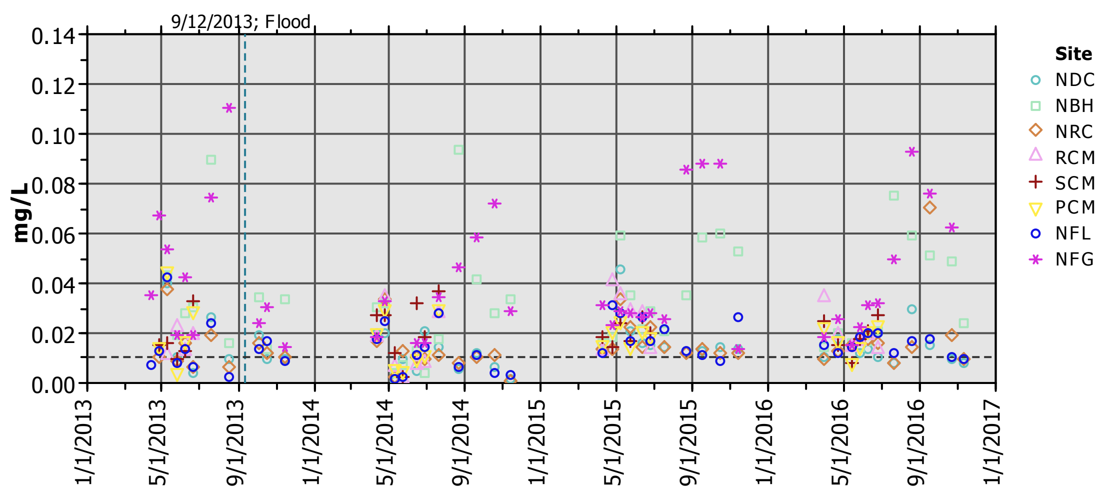
MAINSTEM & NORTH FORK CLP WATERSHEDS

NUTRIENTS

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

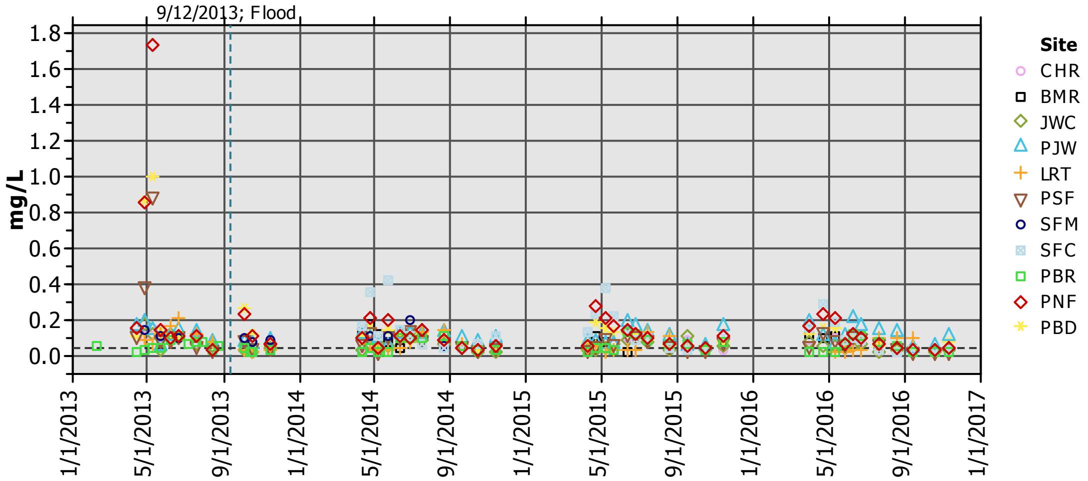


b) Ammonia as Nitrogen (NH3-N) on the North Fork CLP

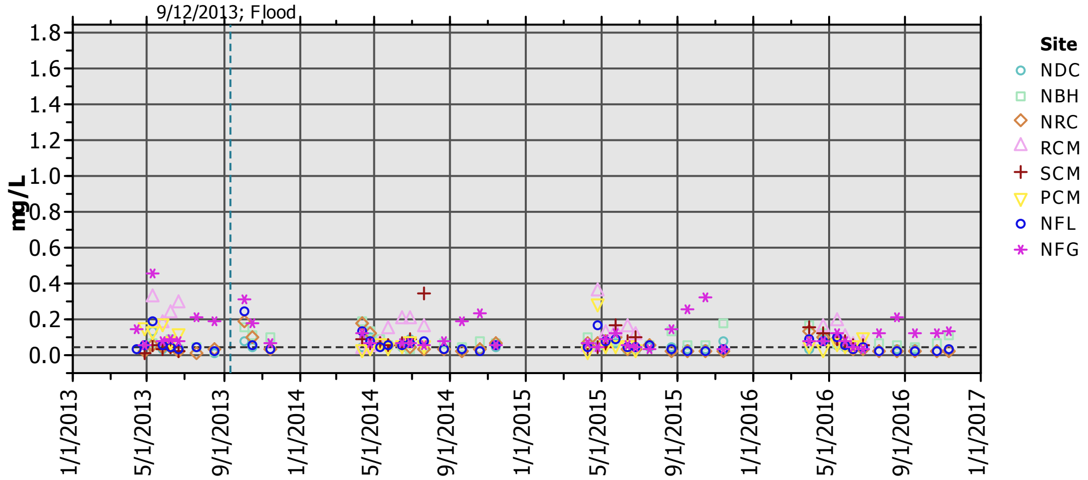


(- - - - FCWQL Reporting Limit; 0.010 mg/L)

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

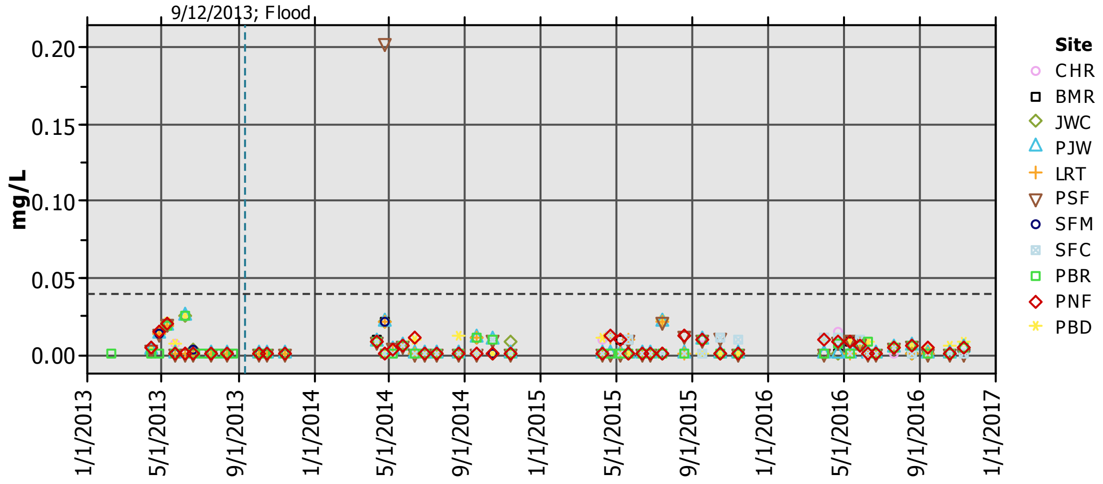


b) Nitrate as Nitrogen (NO3-N) on the North Fork CLP

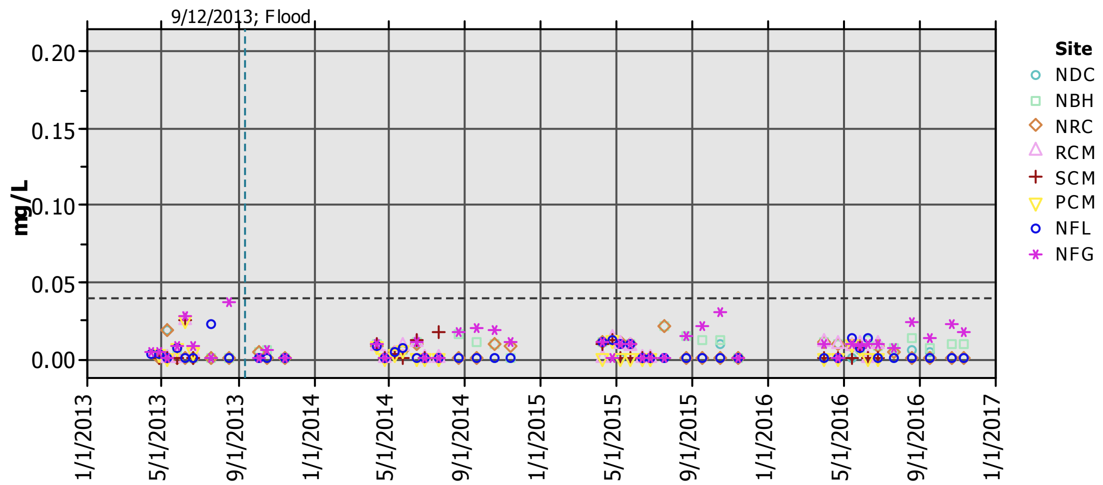


(- - - - FCWQL Reporting Limit; 0.04 mg/L)

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

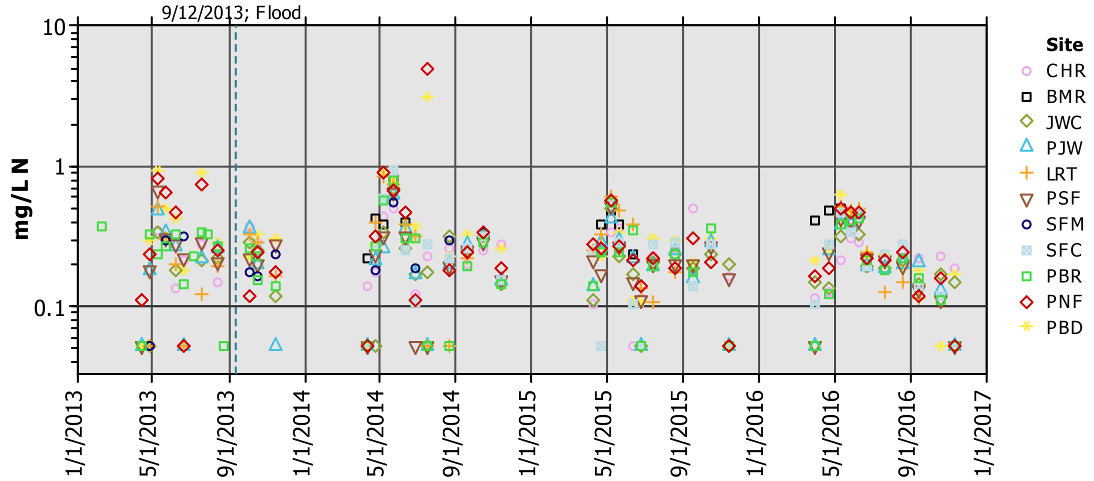


b) Nitrite as Nitrogen (NO2-N) on the North Fork CLP

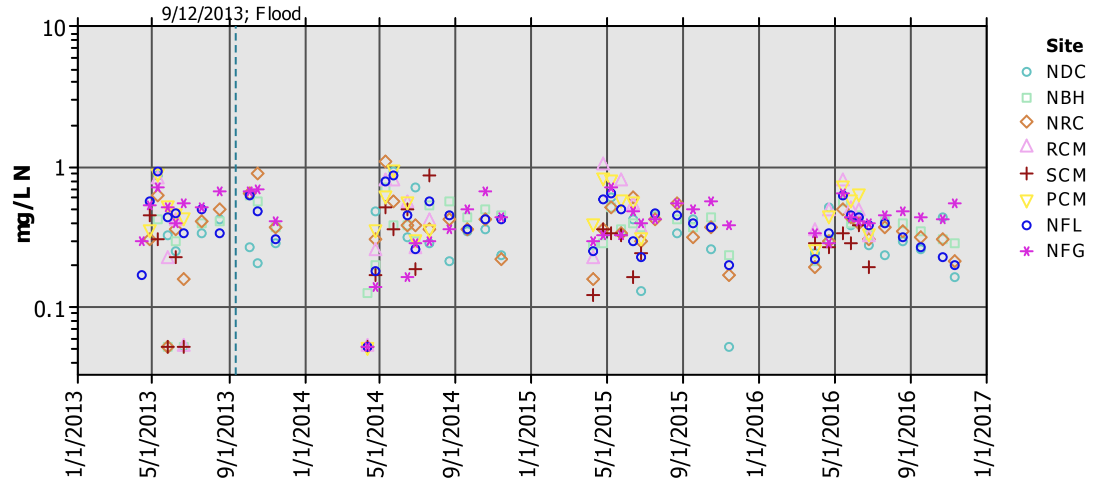


(- - - - FCWQL Reporting Limit; 0.04 mg/L)

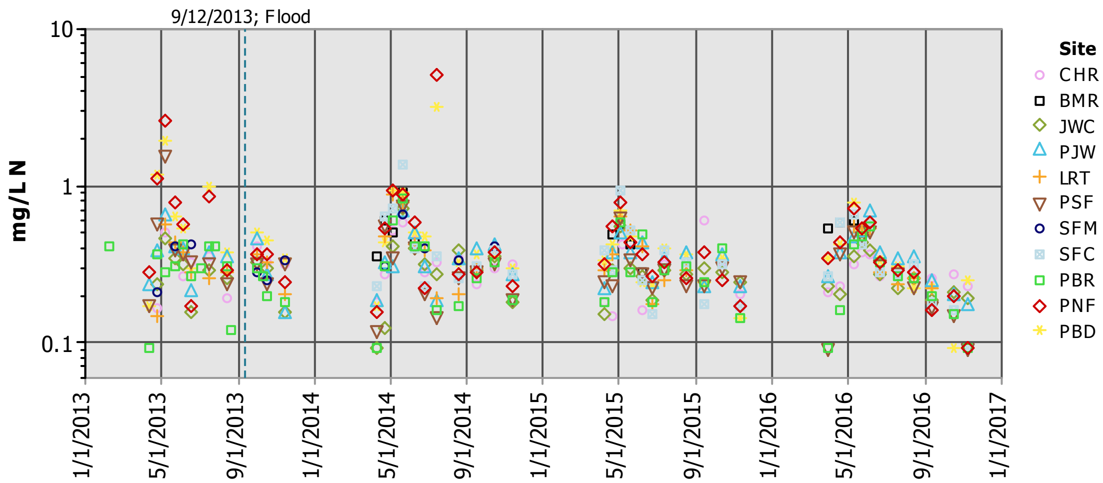
a) Total Kjeldahl Nitrogen (TKN) on the Mainstem CLP



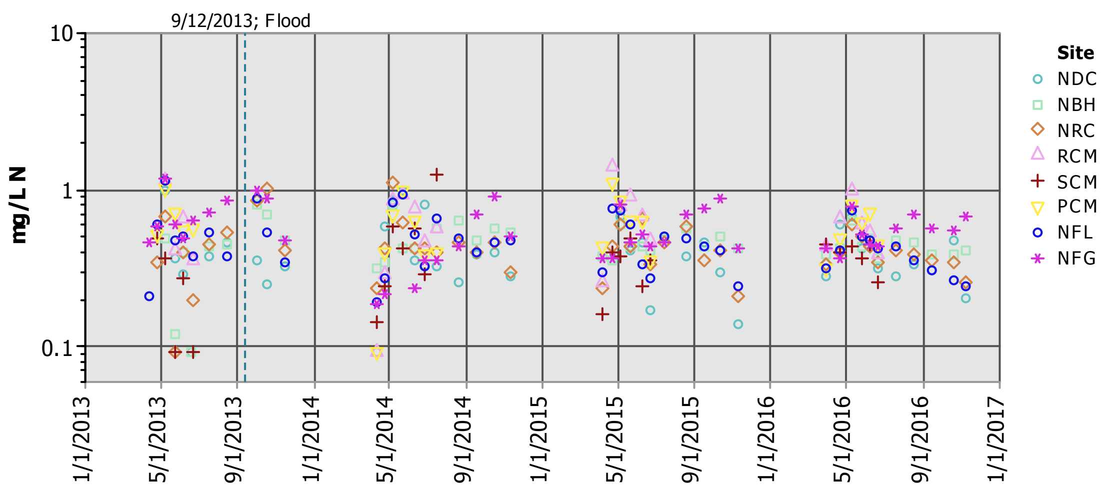
b) Total Kjeldahl Nitrogen (TKN) on the North Fork CLP



a) Total nitrogen (TN) on the Mainstem CLP

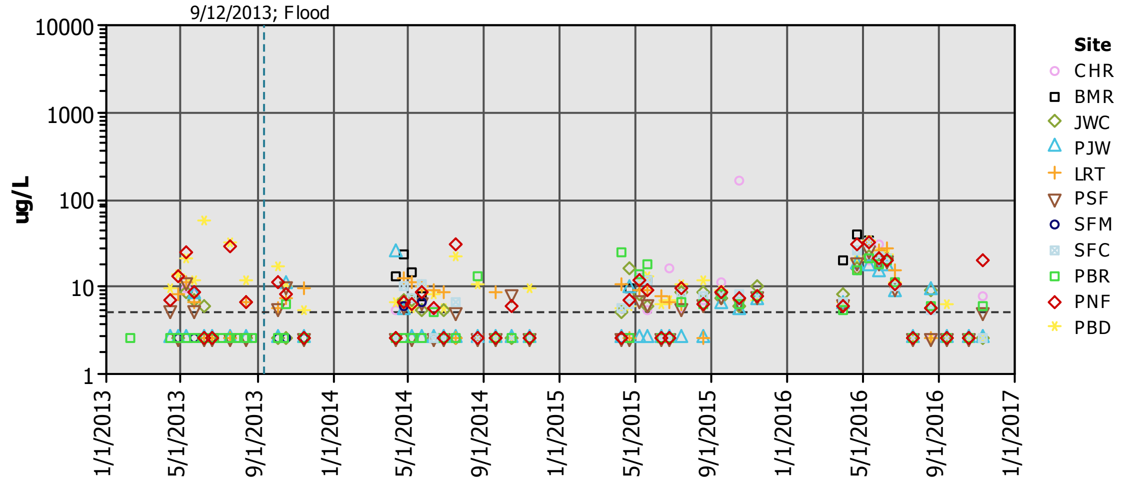


b) Total nitrogen (TN) on the North Fork CLP

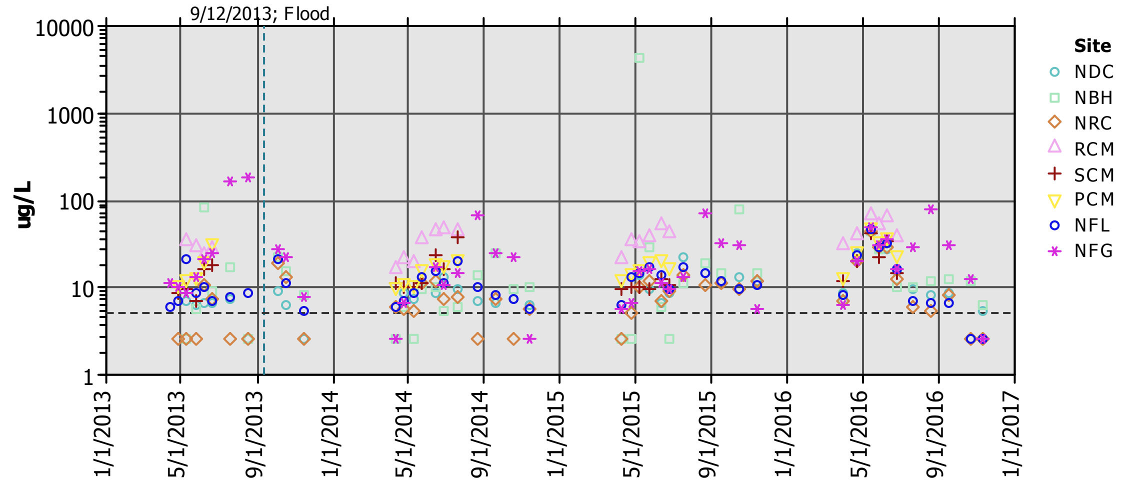


(- - - - FCWQL Reporting Limit; 0.10 mg/L)

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

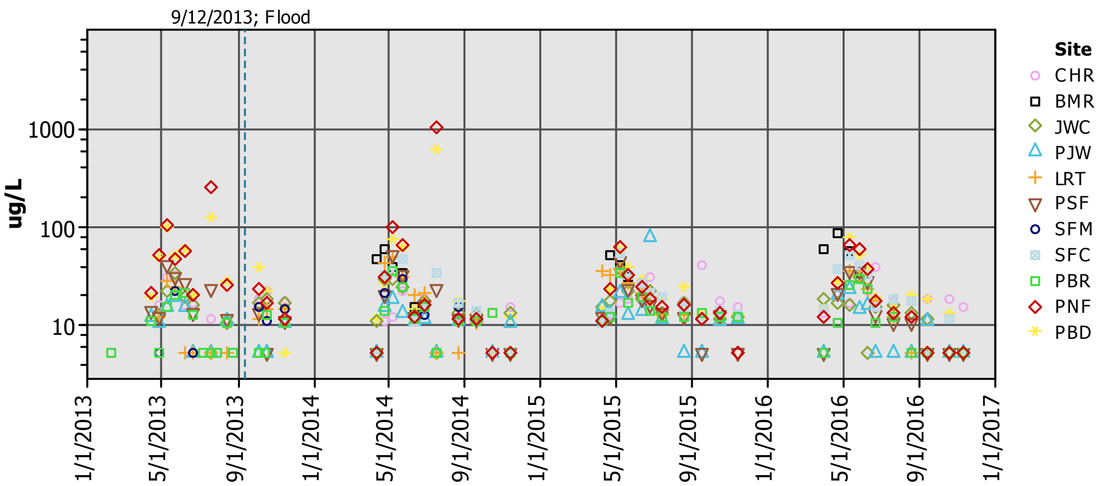


b) Ortho-phosphate (PO4) on the North Fork CLP

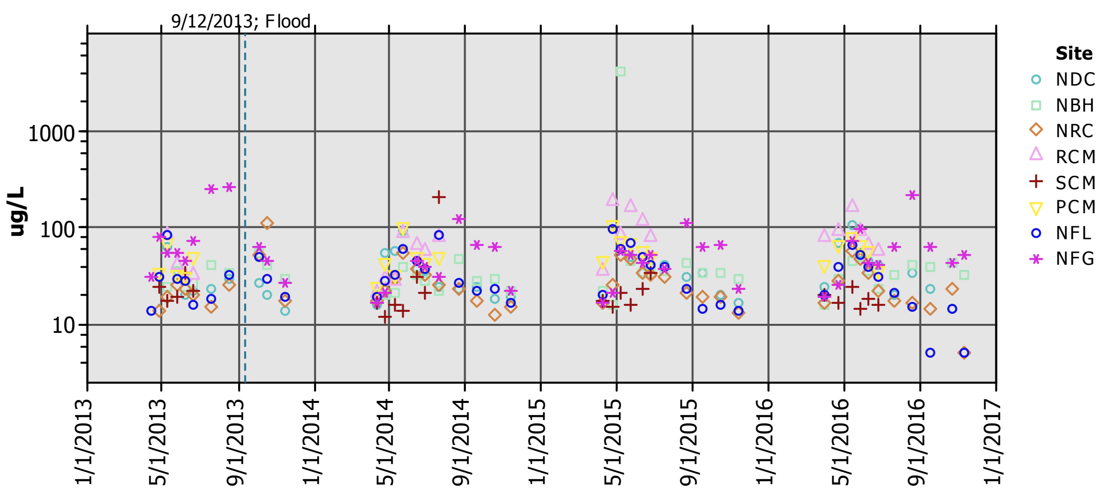


(- - - - FCWQL Reporting Limit; 5 µg/L)

a) Total Phosphorus (TP) on the Mainstem CLP



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

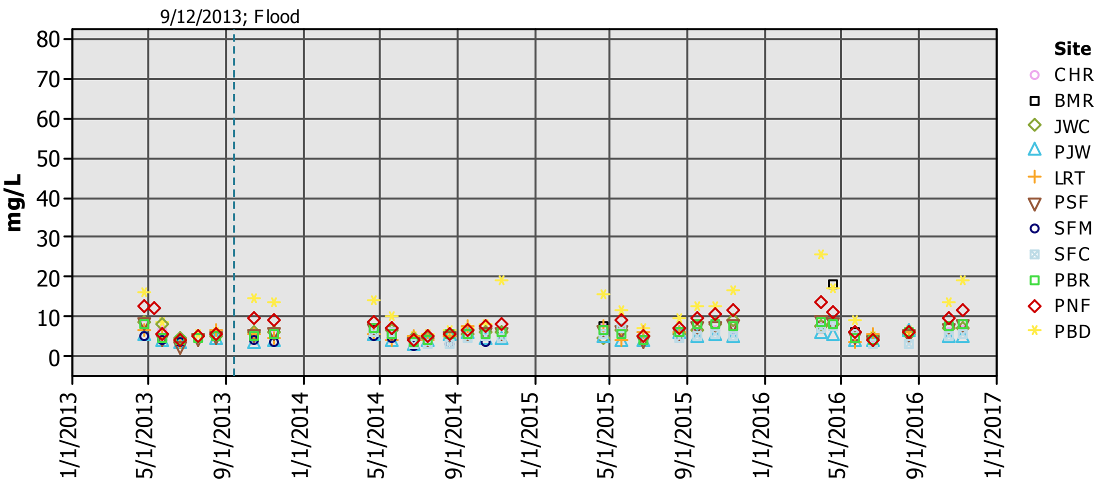


(- - - - FCWQL Reporting Limit; 10 µg/L)

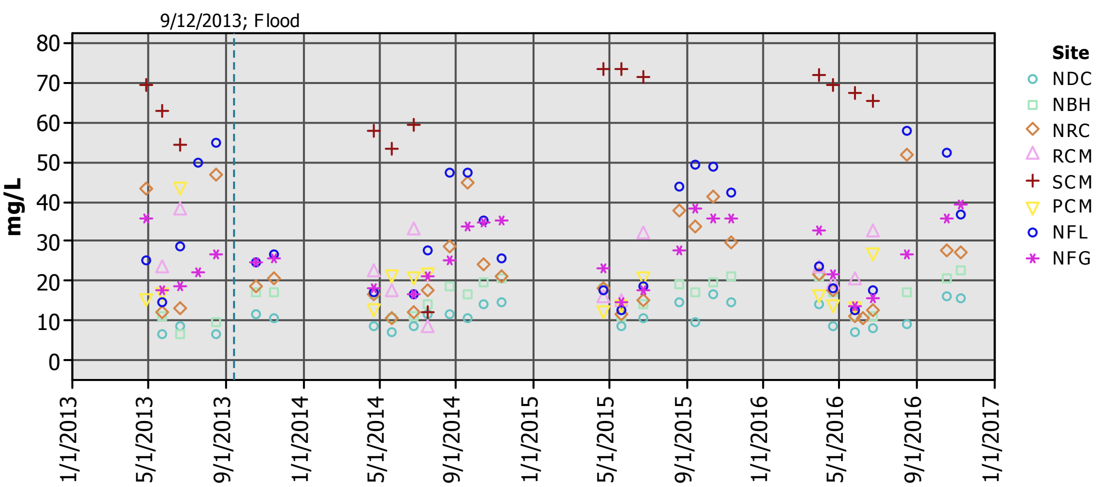
MAINSTEM & NORTH FORK CLP WATERSHEDS

MAJOR IONS

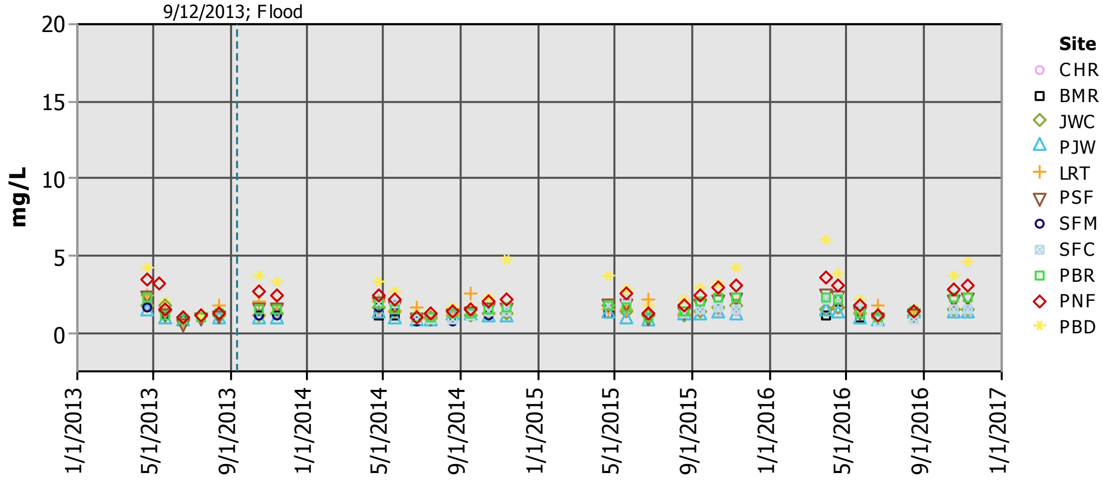
a) Calcium (Ca) on the Mainstem CLP



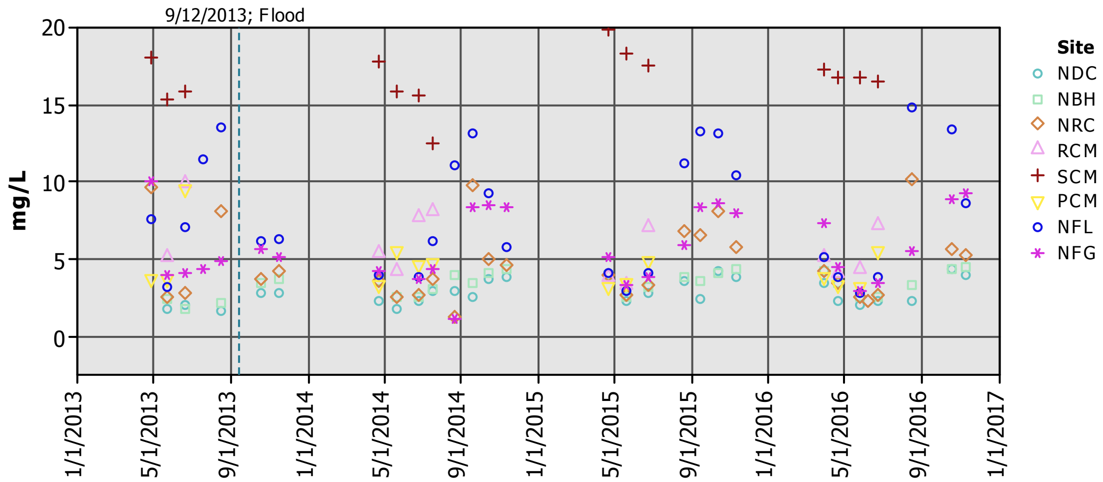
b) Calcium (Ca) on the North Fork CLP



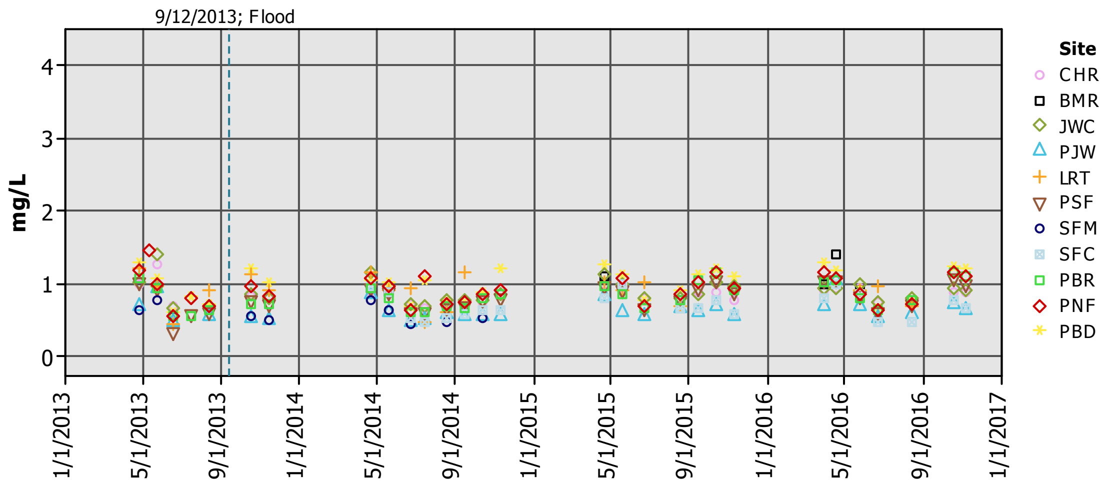
a) Magnesium (Mg) on the Mainstem CLP



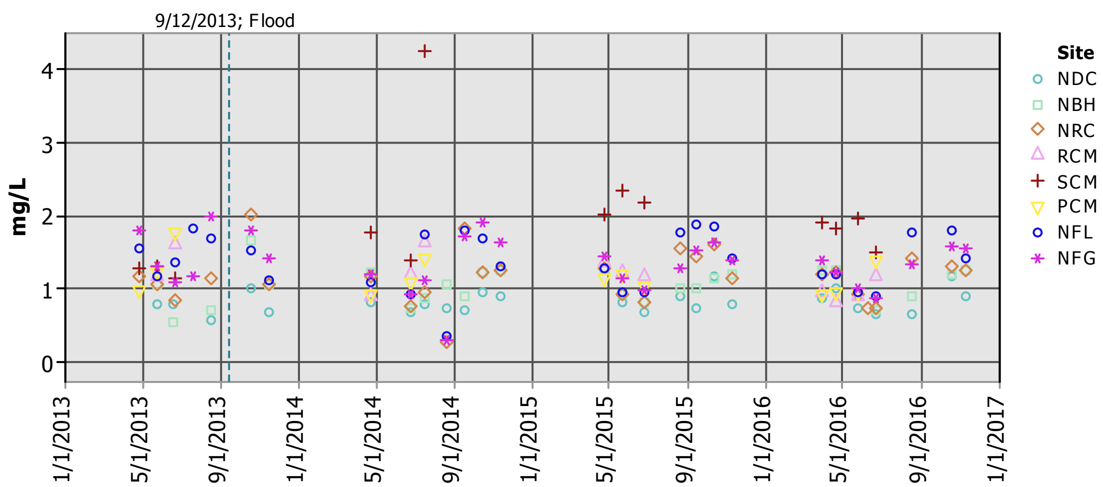
b) Magnesium (Mg) on the North Fork CLP



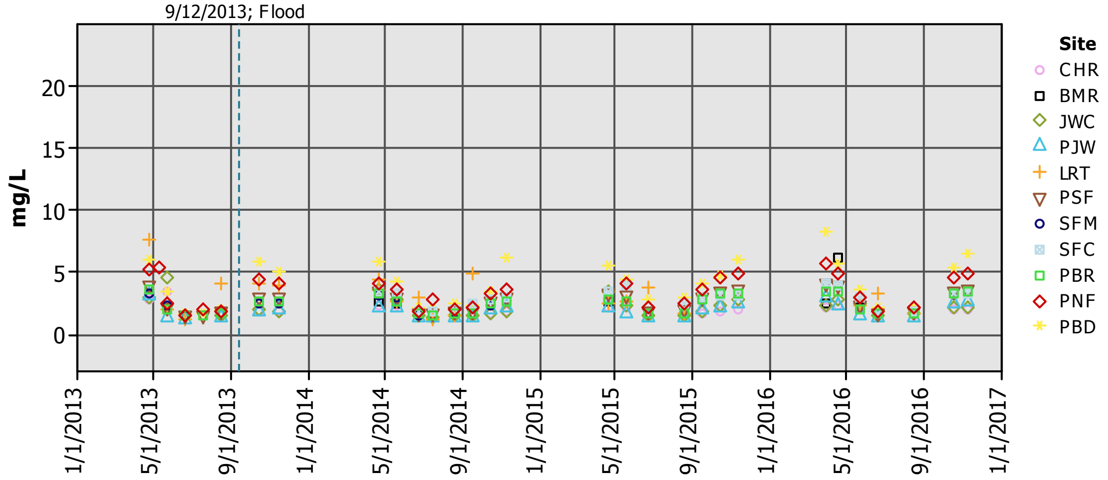
a) Potassium (K) on the Mainstem CLP



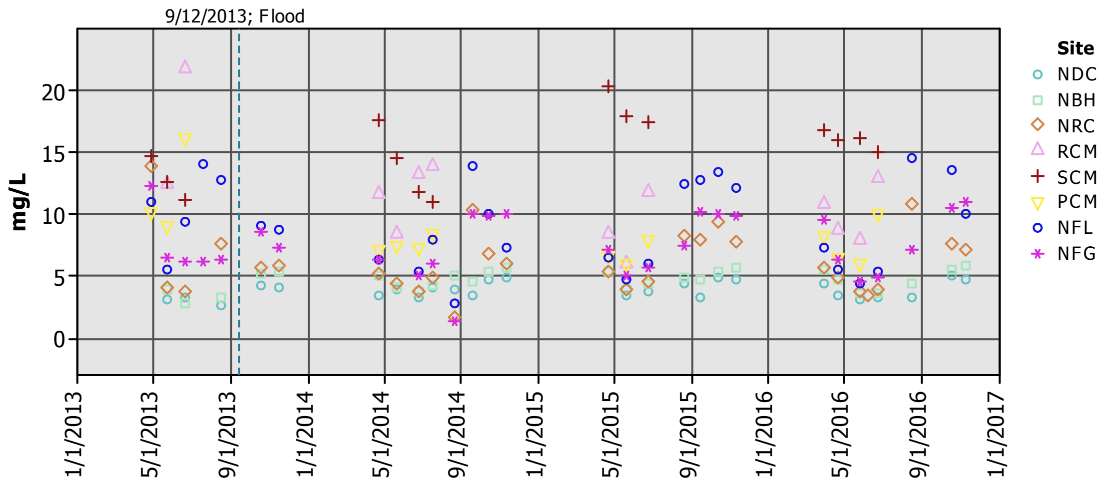
b) Potassium (K) on the North Fork CLP



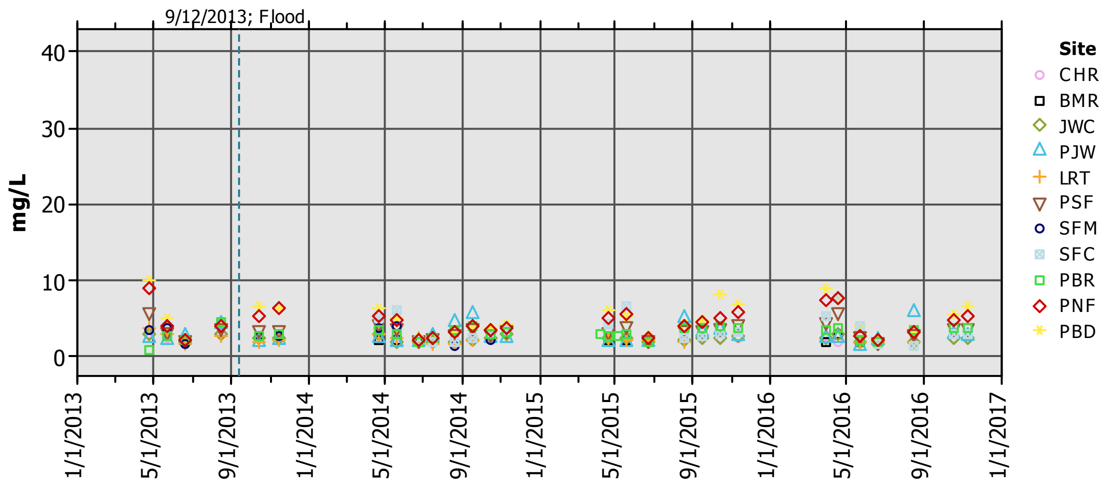
a) Sodium (Na) on the Mainstem CLP



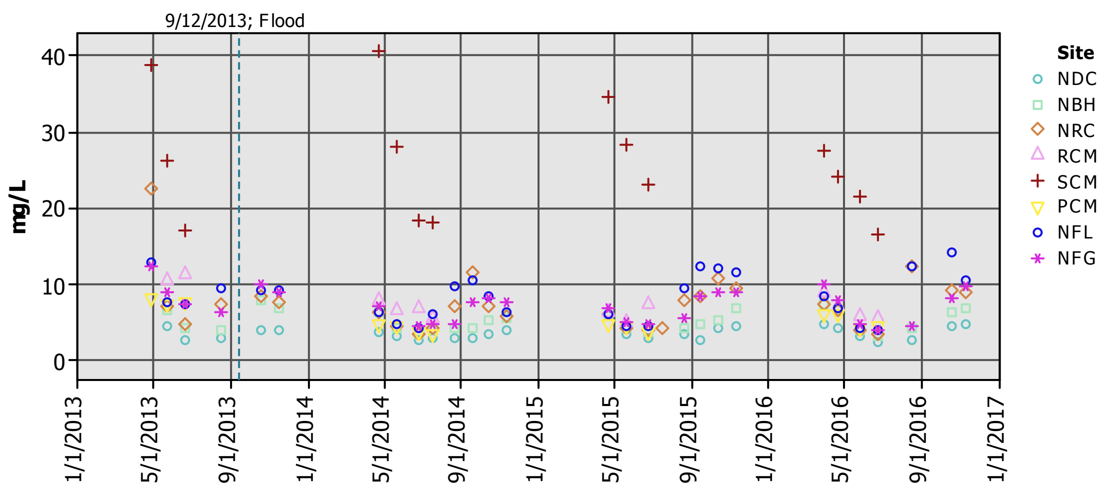
b) Sodium (Na) on the North Fork CLP



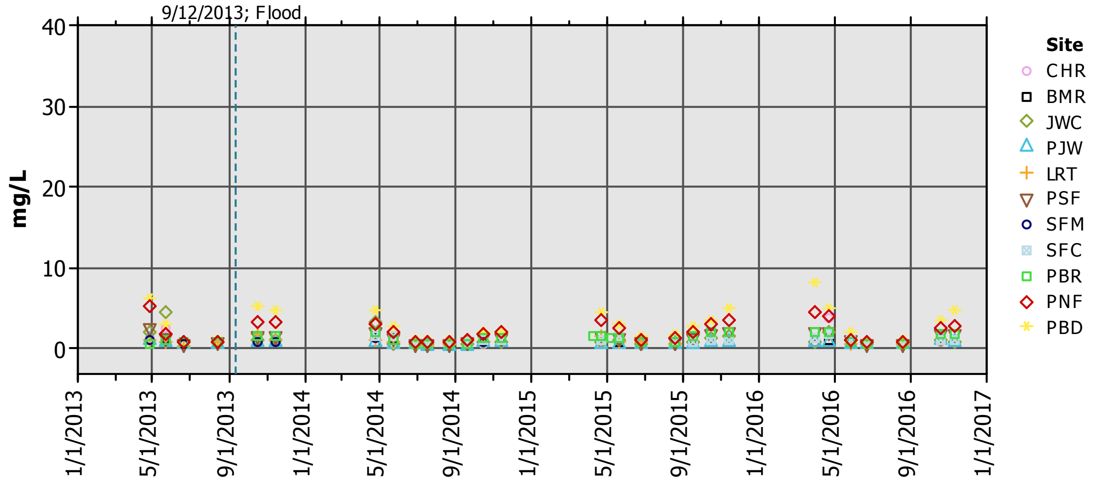
a) Sulfate (SO4) on the Mainstem CLP



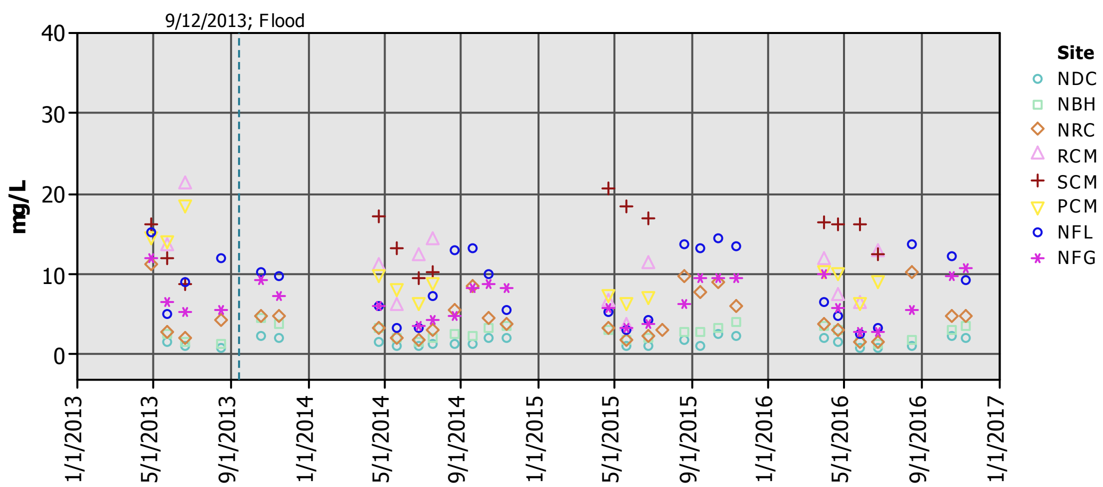
b) Sulfate (SO4) on the North Fork CLP



a) Chloride (Cl) on the Mainstem CLP



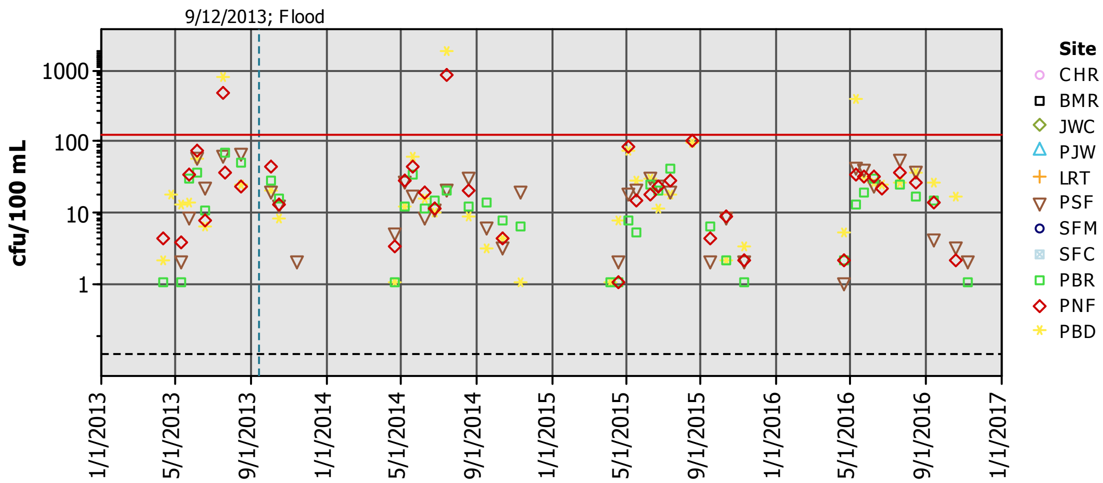
b) Chloride (Cl) on the North Fork CLP



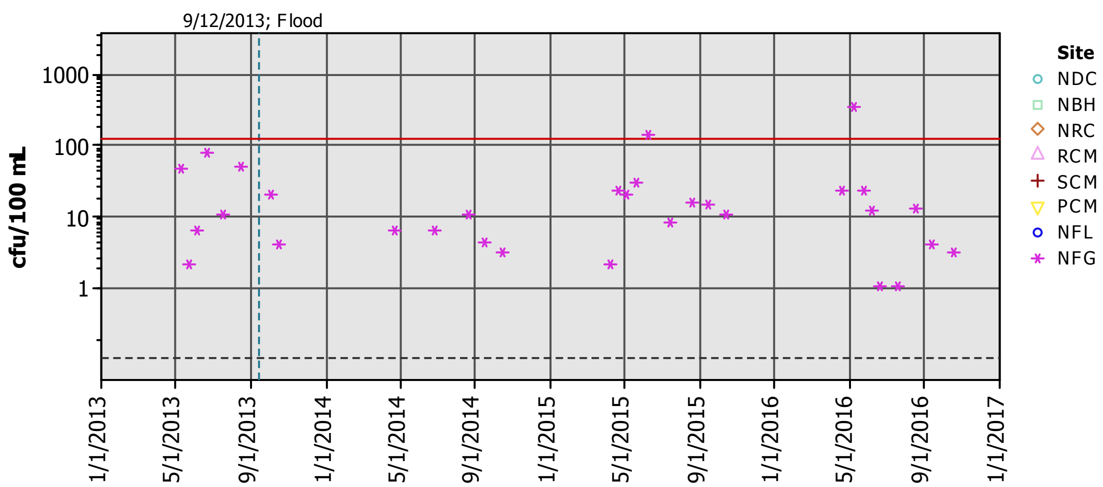
MAINSTEM & NORTH FORK CLP WATERSHEDS

MICROBIOLOGICAL

a) E. coli on the Mainstem CLP



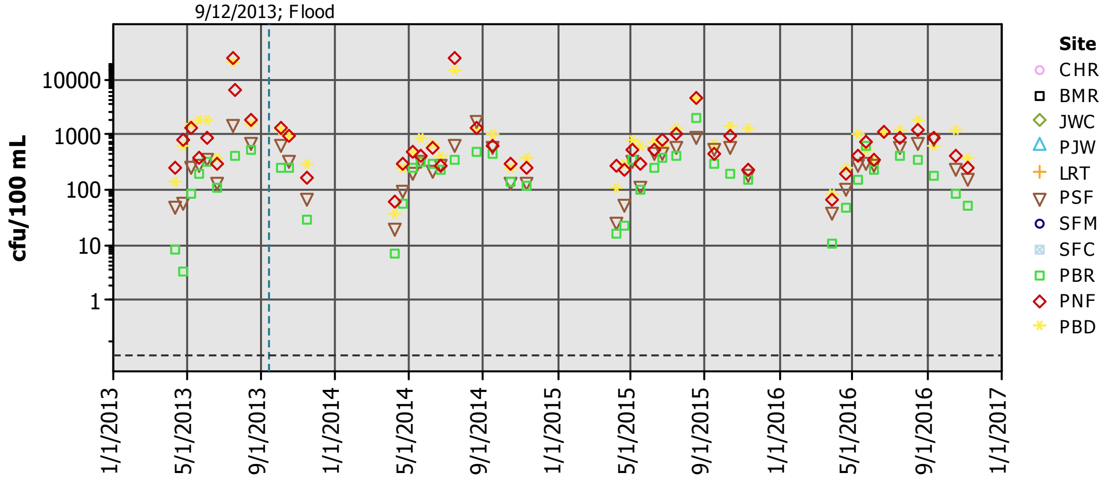
b) E. coli on the North Fork CLP



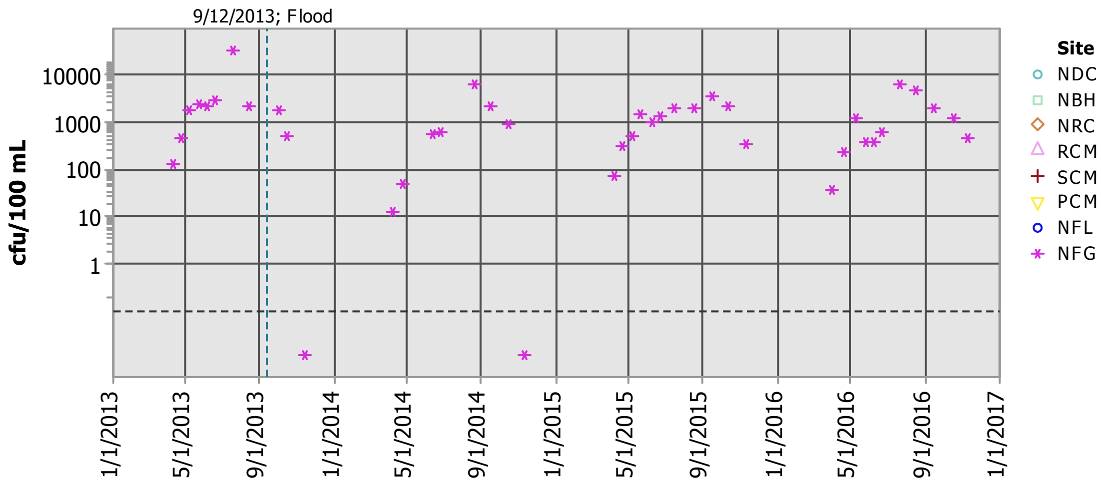
(- - - - FCWQL Reporting Limit; 0 cfu/100 ml)

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

a) Total coliforms on the Mainstem CLP



b) Total coliforms on the North Fork CLP



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

ATTACHMENT 7

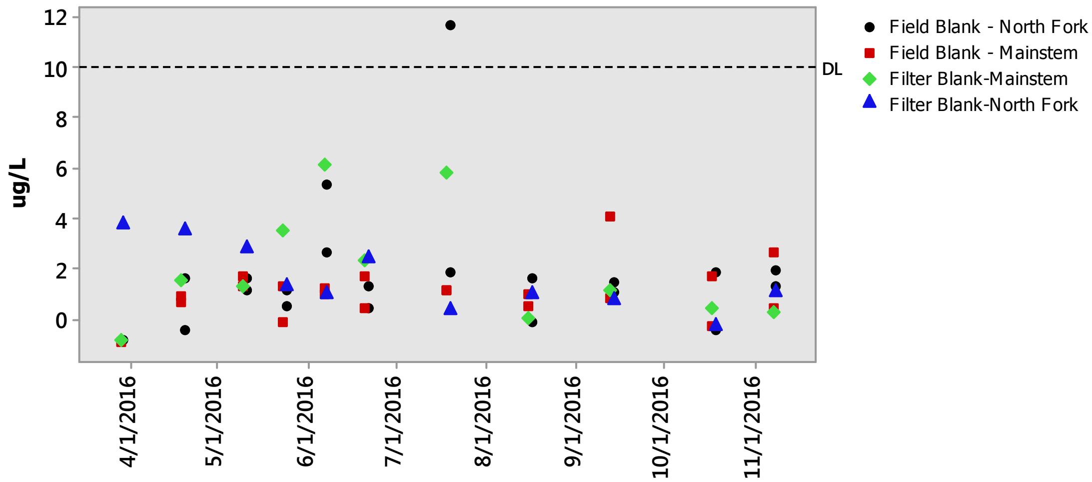
2016 UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM

QUALITY ASSURANCE QUALITY CONTROL

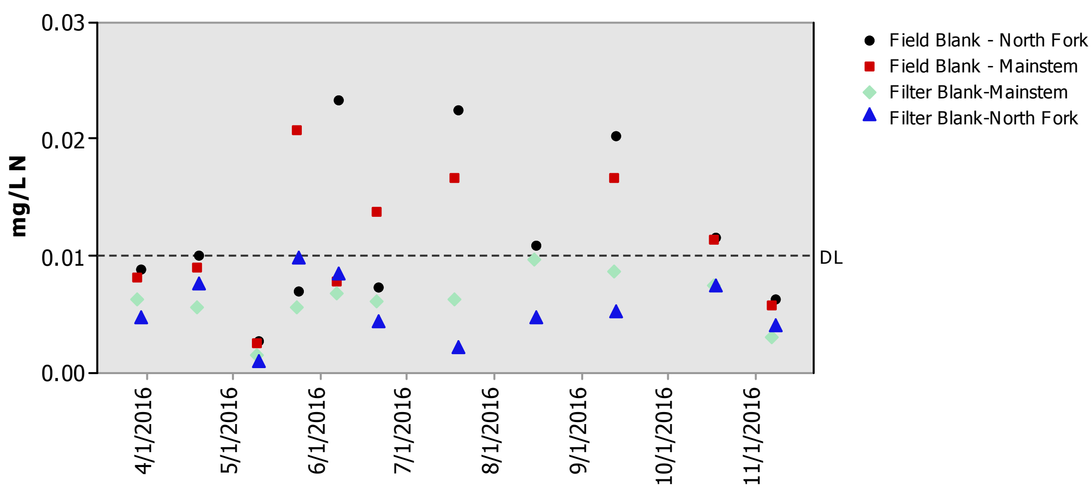
UCLP MAINSTEM AND NORTH FORK

FIELD BLANKS AND LAB FILTER BLANKS

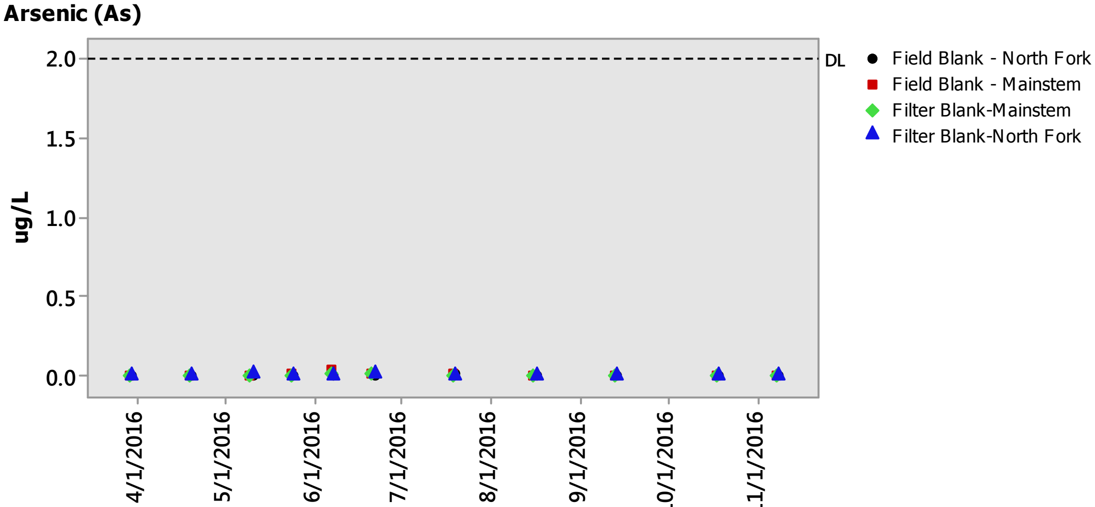
Aluminum (Al)



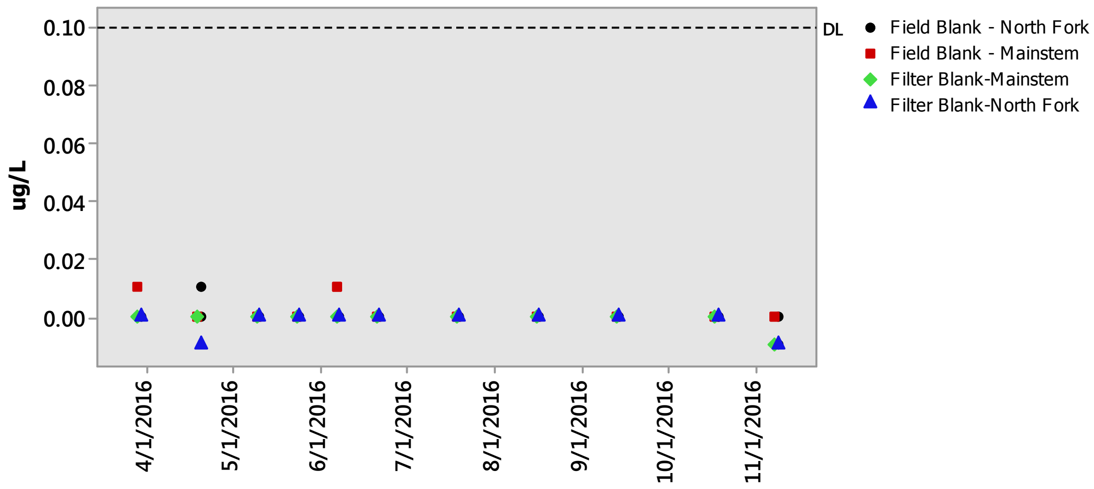
Ammonia as Nitrogen (NH3-N)



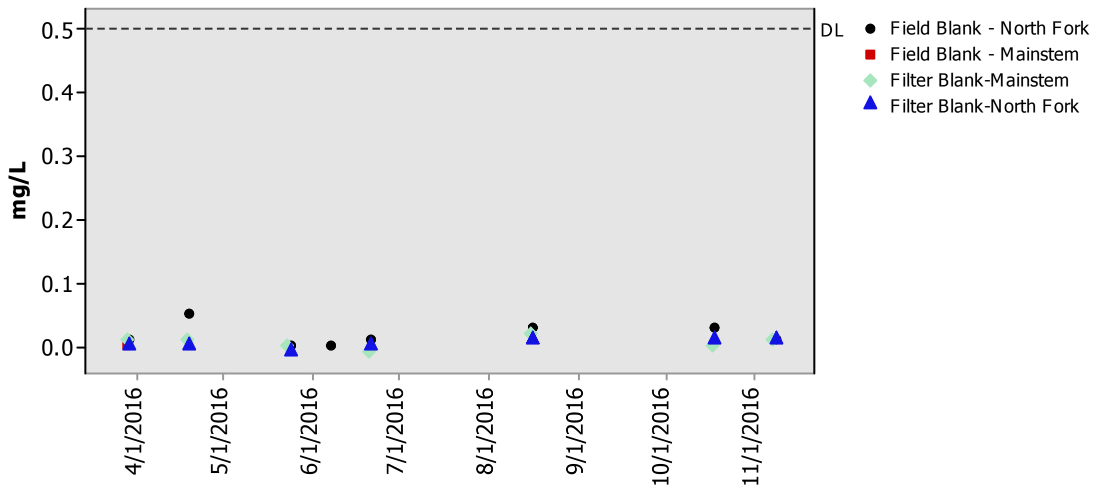
Arsenic (As)



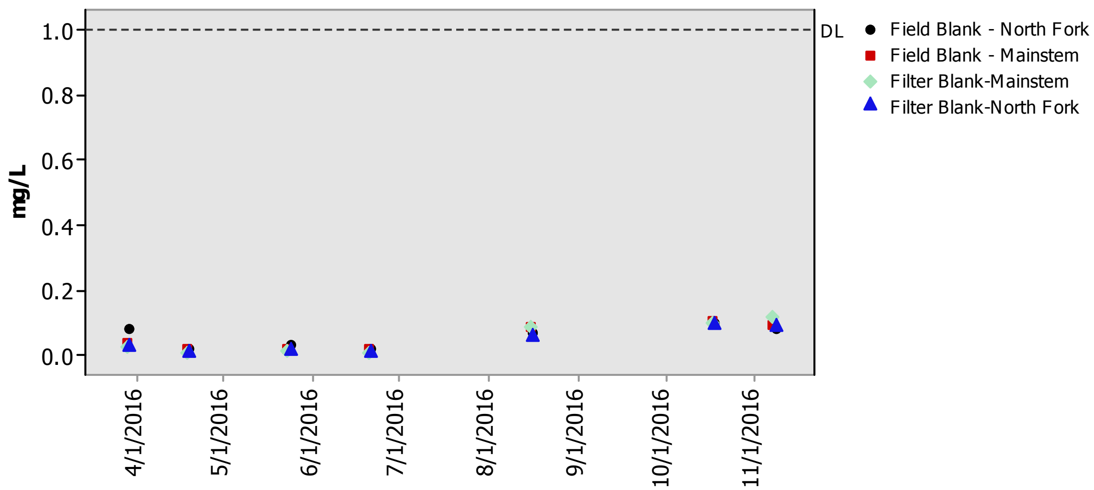
Cadmium (Cd)



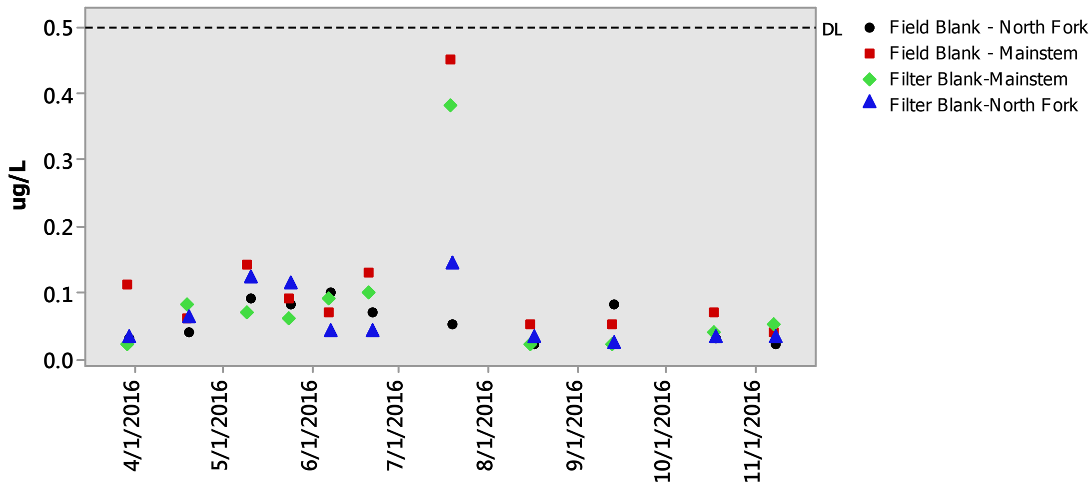
Calcium (Ca)



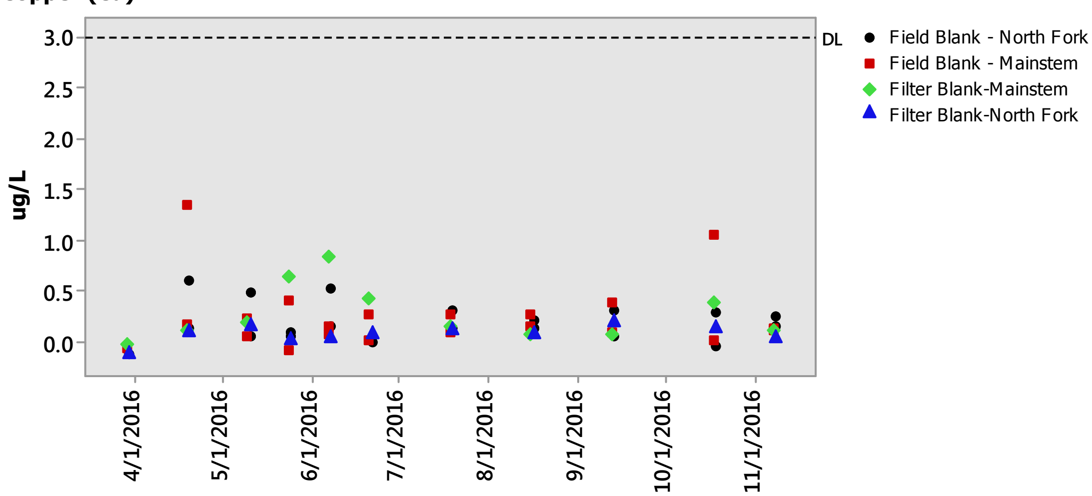
Chloride (Cl)



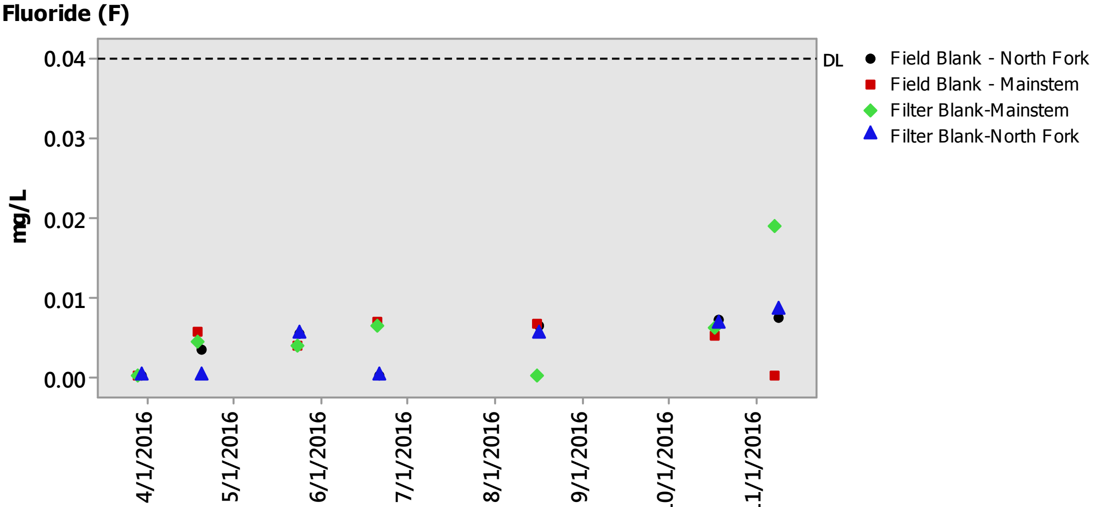
Chromium (Cr)



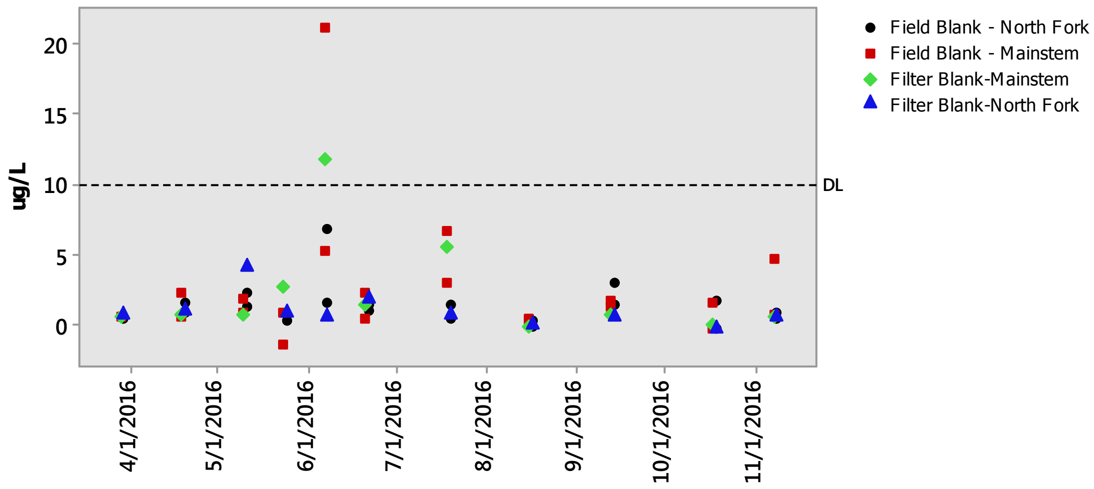
Copper (Cu)



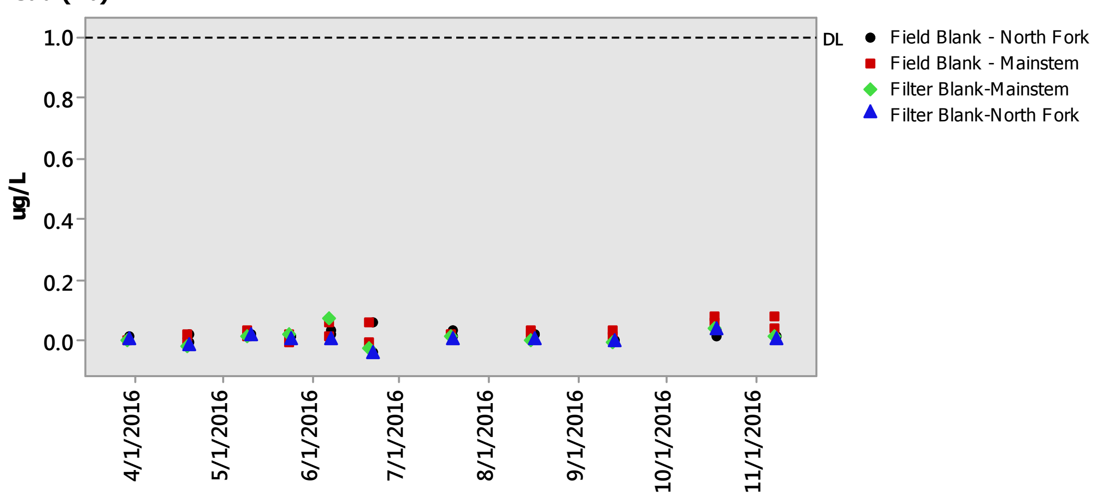
Fluoride (F)



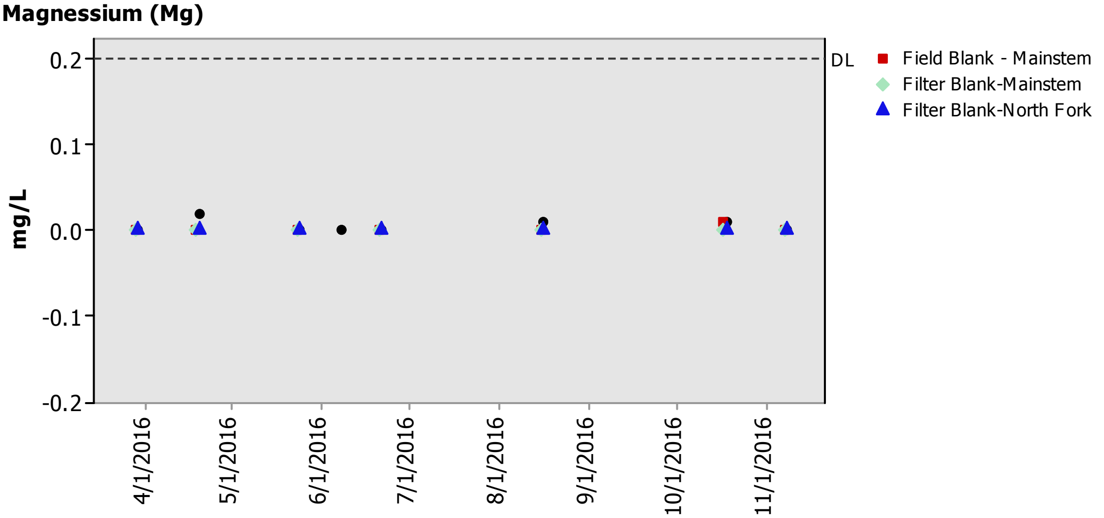
Iron (Fe)



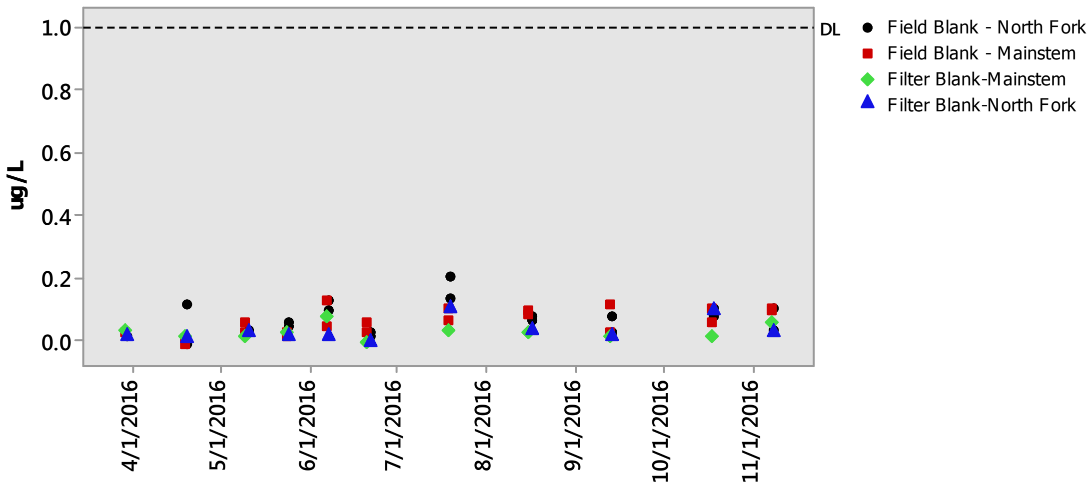
Lead (Pb)



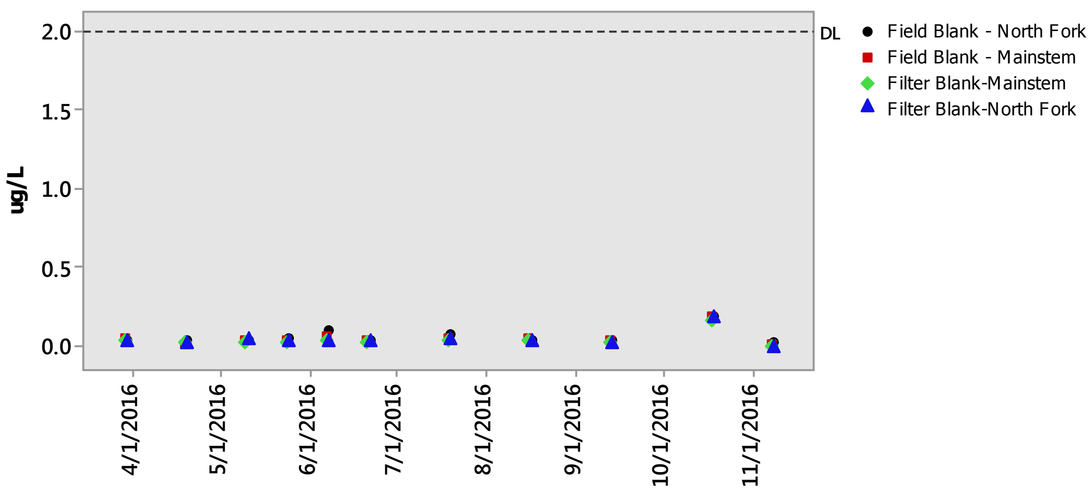
Magnessium (Mg)



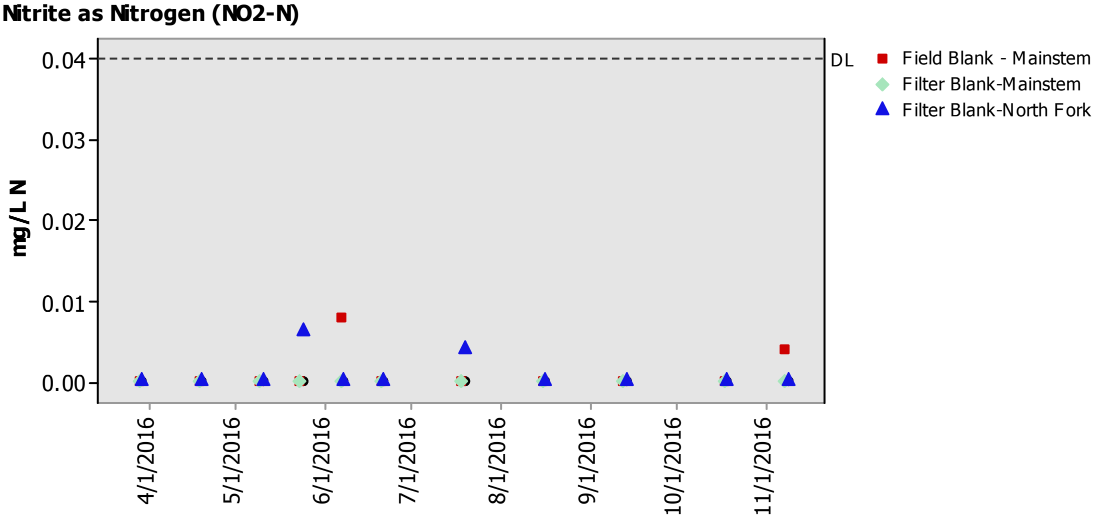
Manganese (Mn)



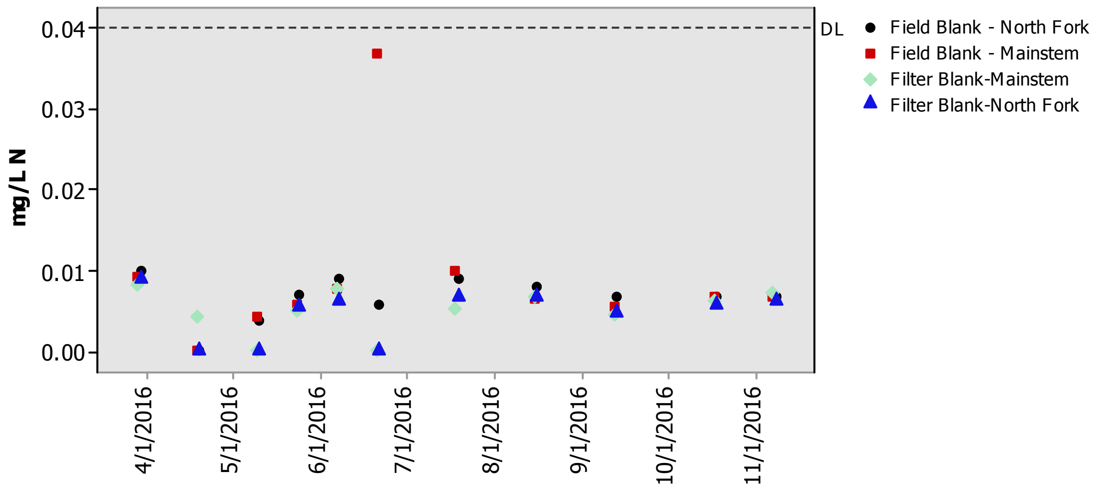
Nickel (Ni)



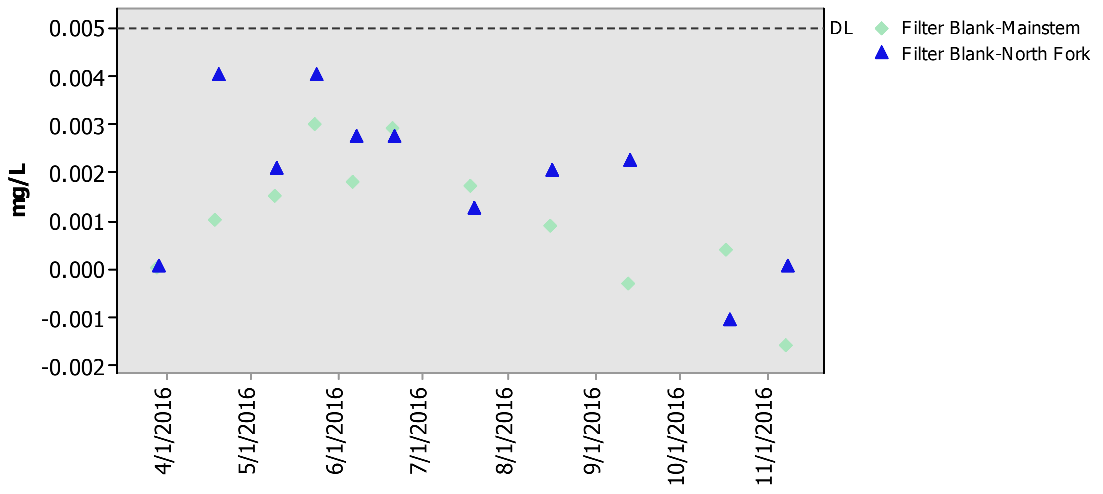
Nitrite as Nitrogen (NO2-N)



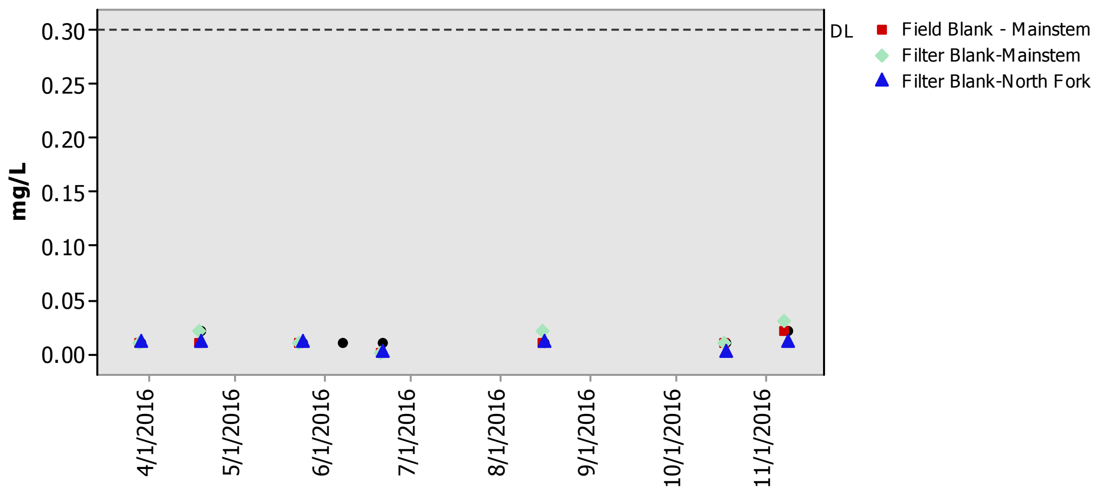
Nitrate as Nitrogen (NO3-N)



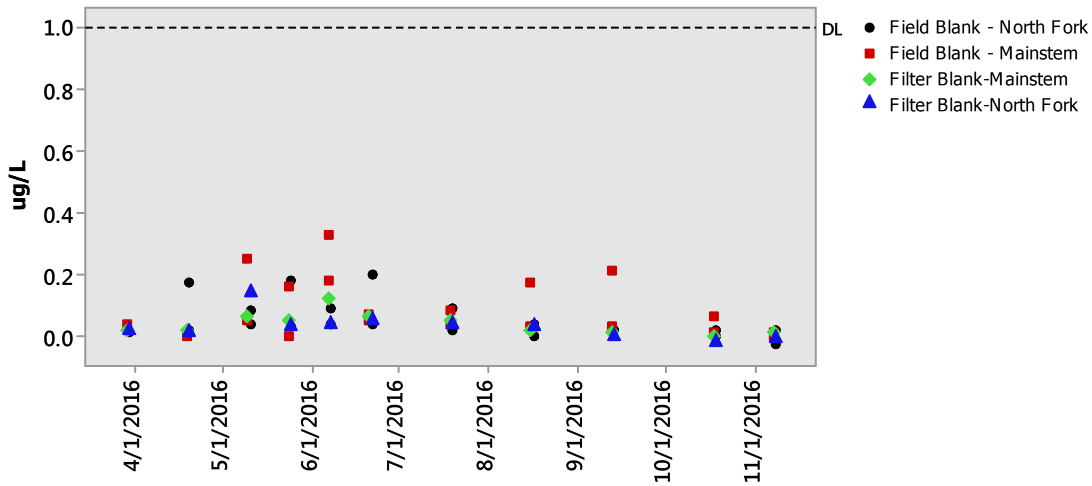
Ortho-phosphate (PO4)



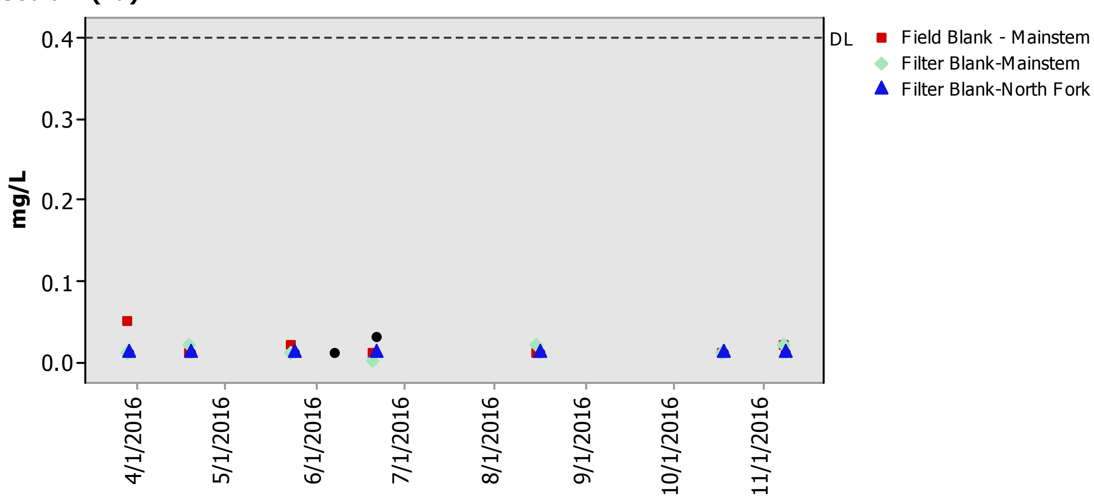
Potassium (K)



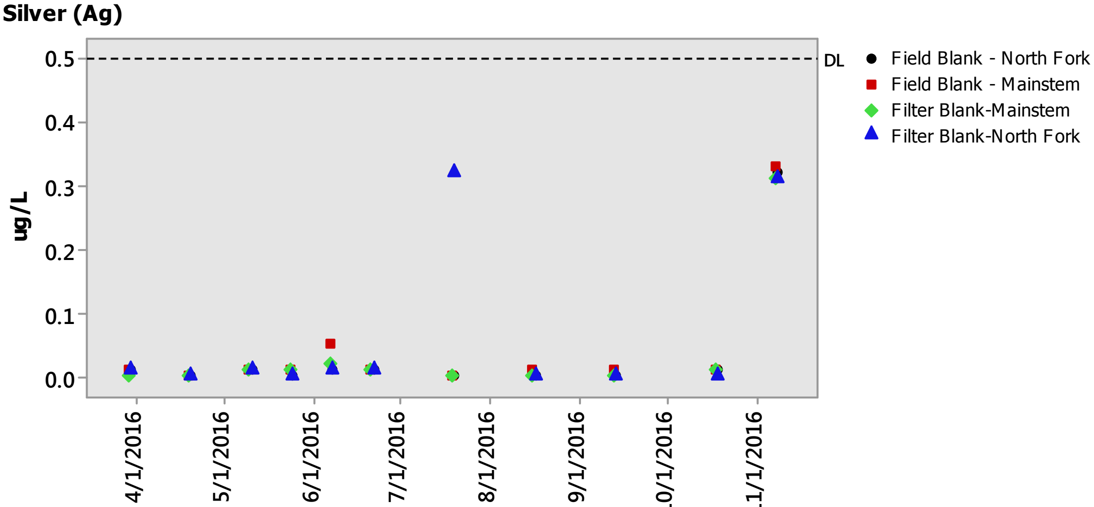
Selenium (Se)



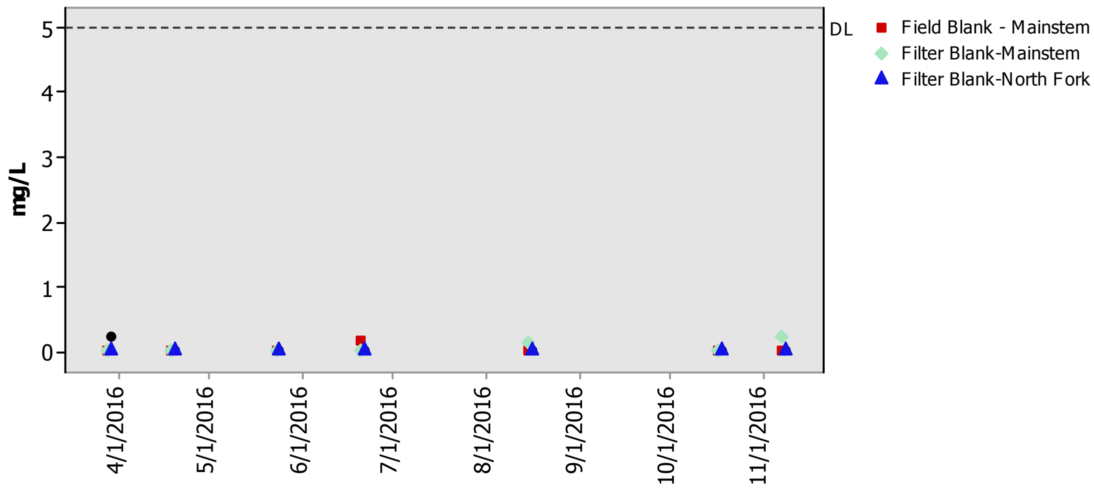
Sodium (Na)



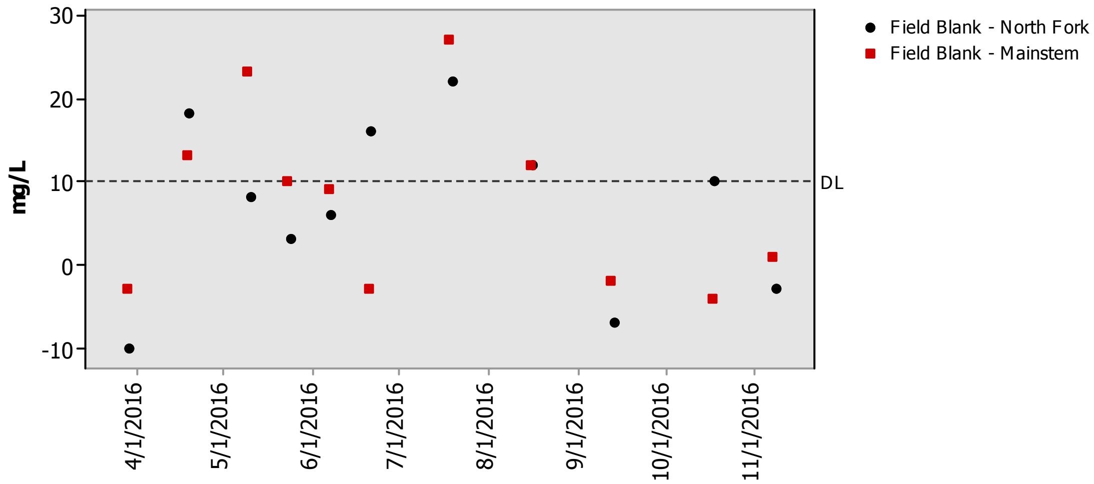
Silver (Ag)



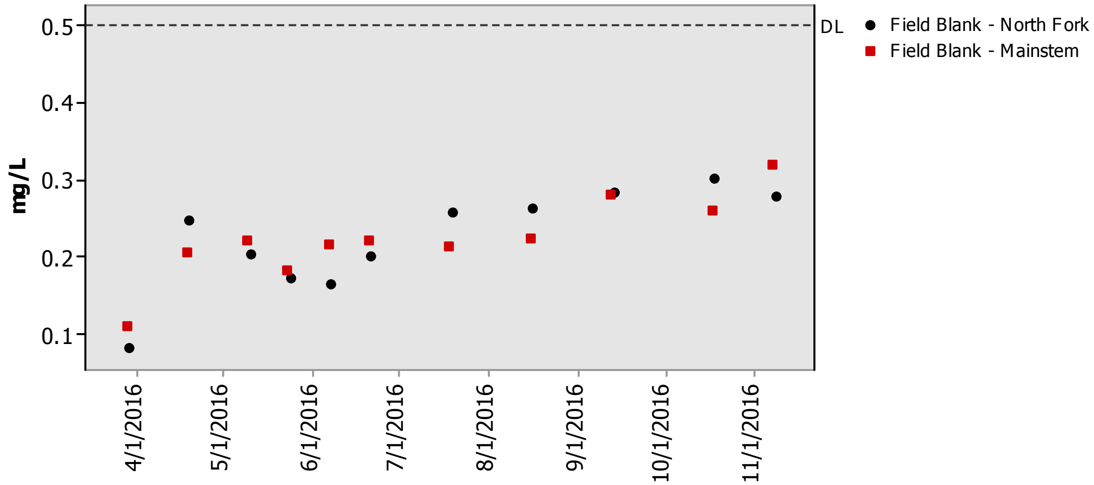
Sulfate (SO4)



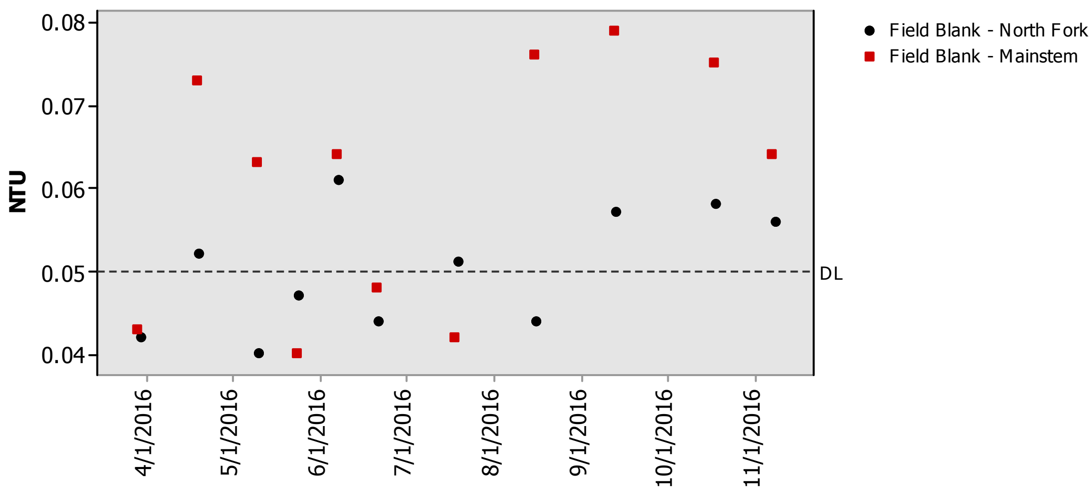
Total Dissolved Solids (TDS)



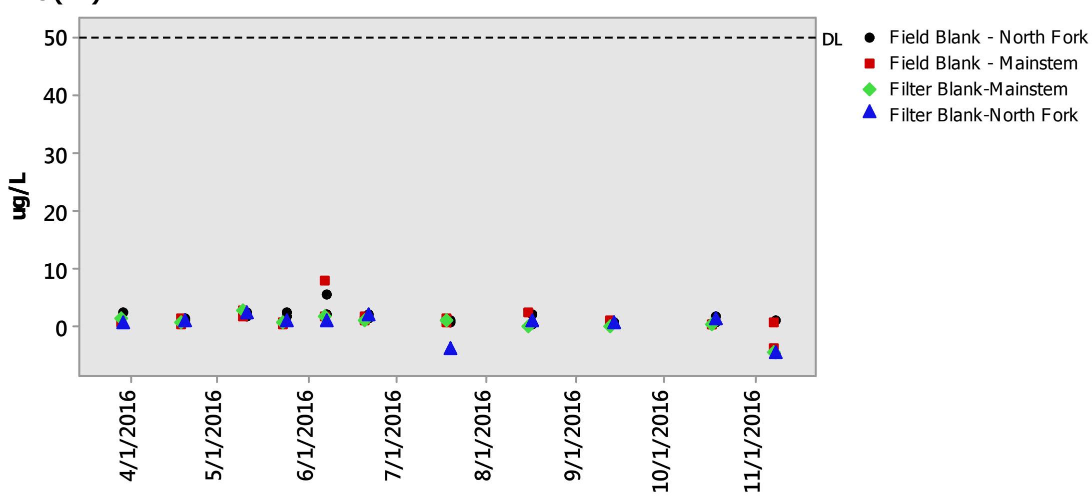
Total Organic Carbon (TOC)



Turbidity

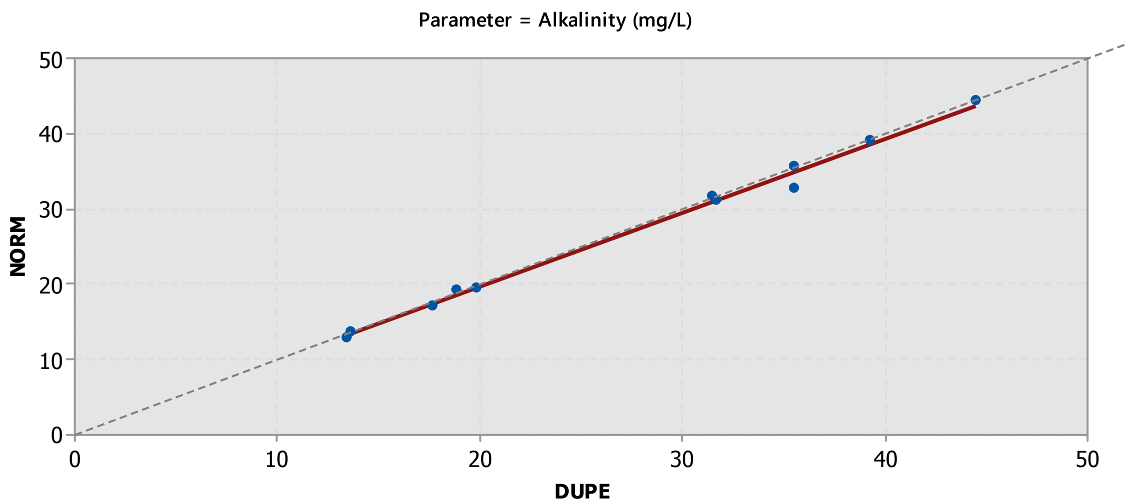


Zinc (Zn)

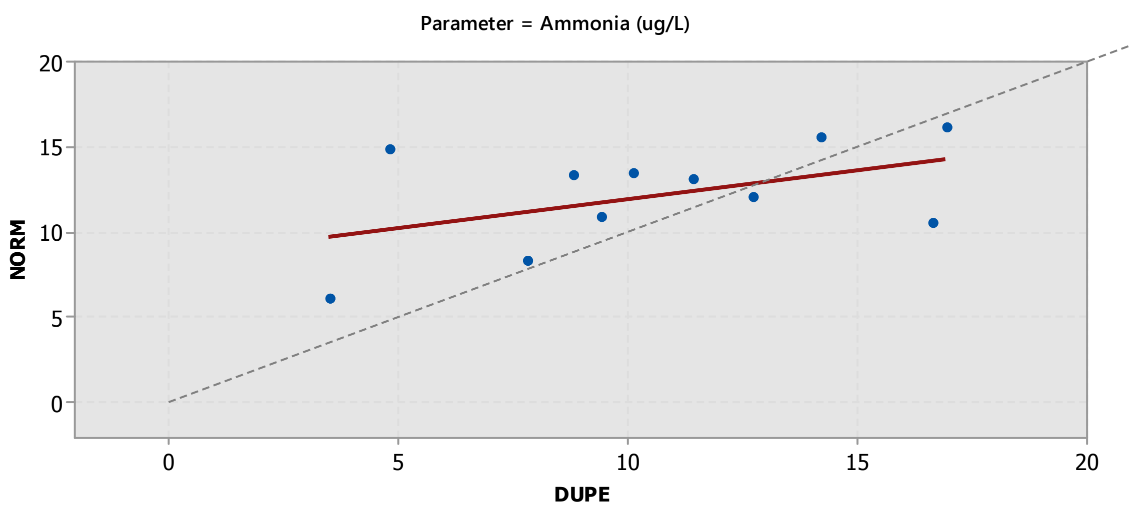


UCLP MAINSTEM

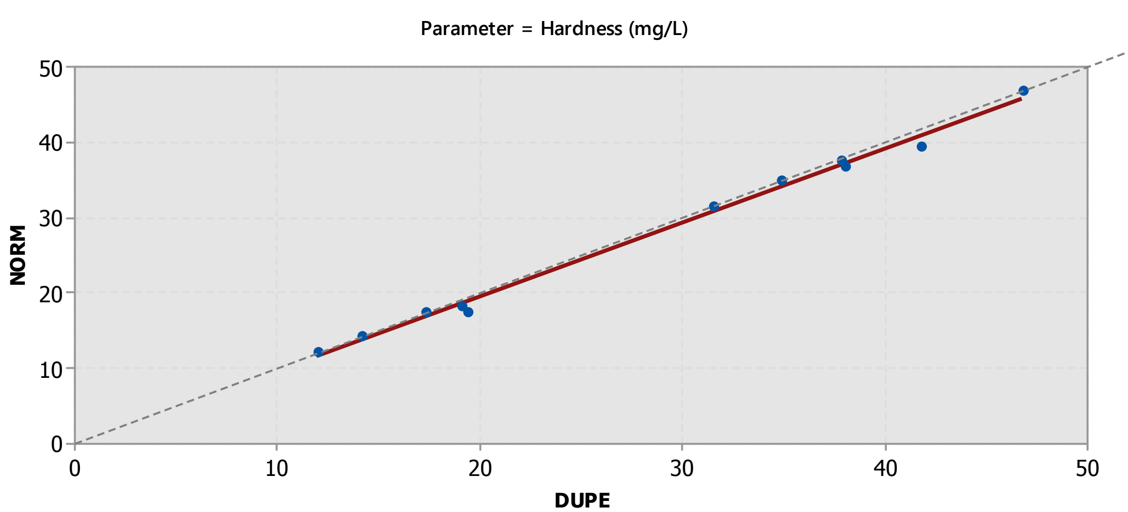
PNF DUPLICATES



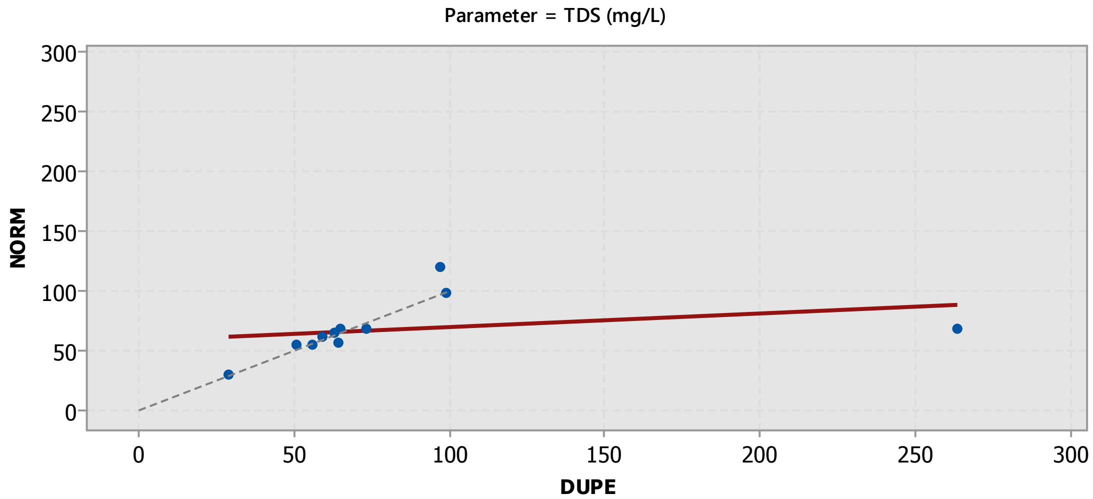
abs mean diff. = 0.55 mg/L



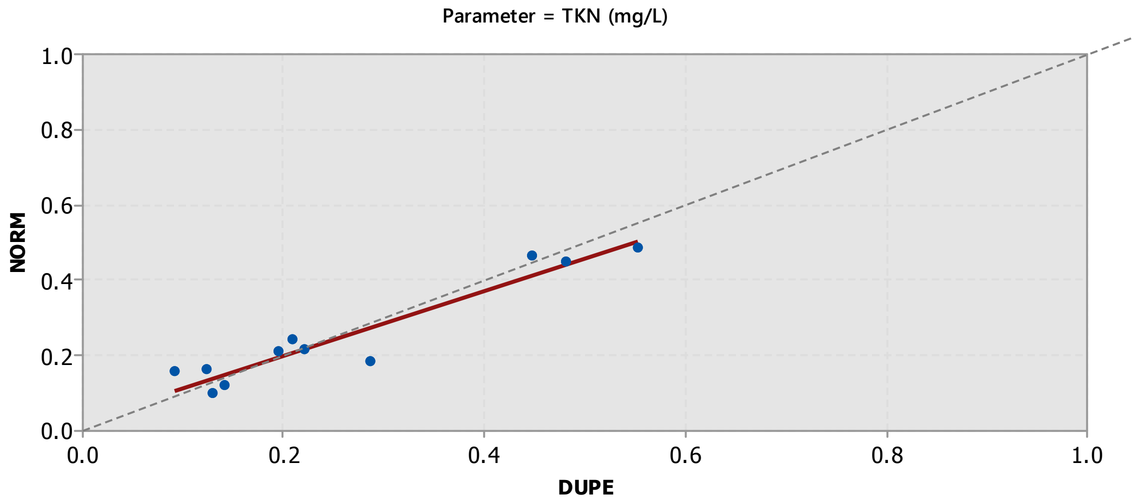
abs mean diff. = 3 ug/L



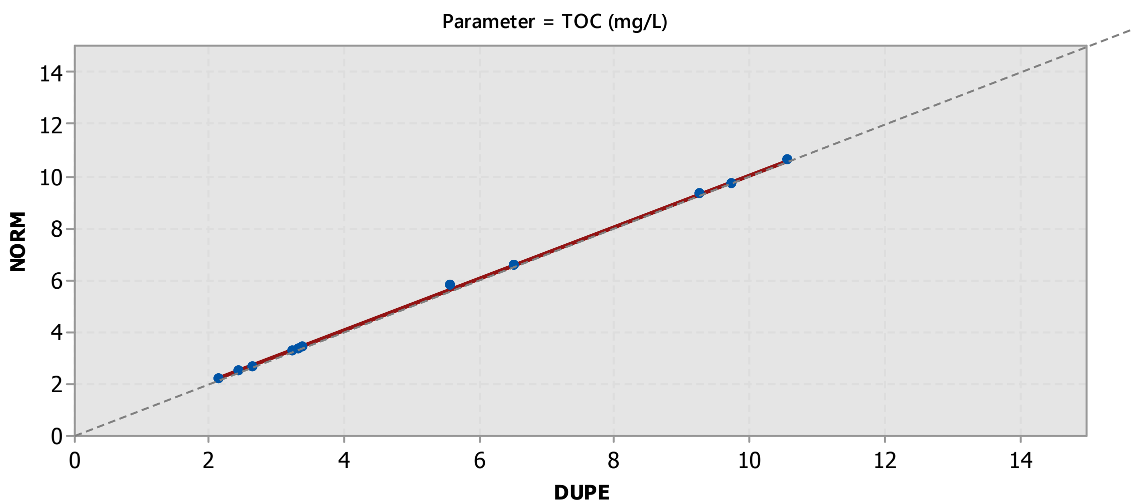
abs mean diff. = 0.7 mg/L



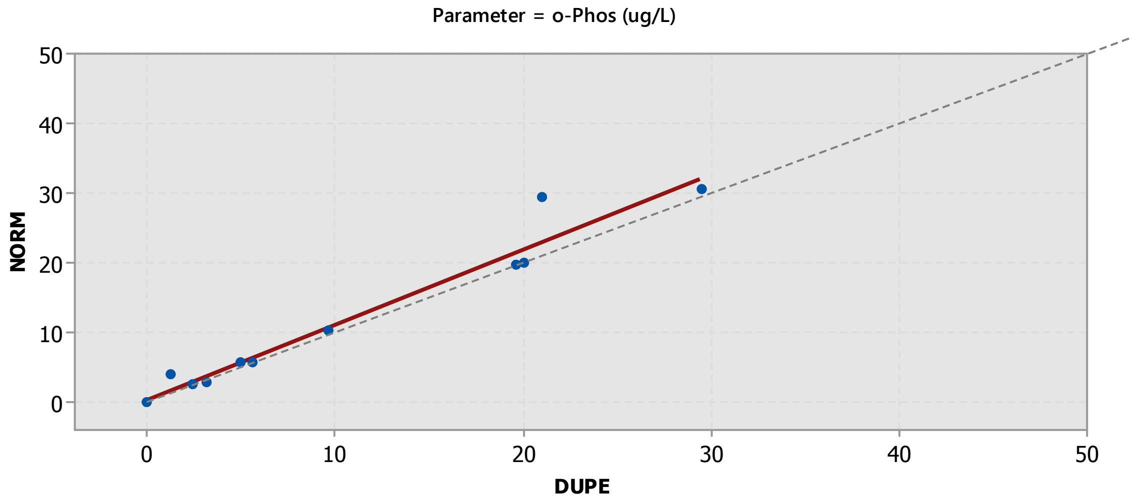
abs mean diff. = 22 mg/L



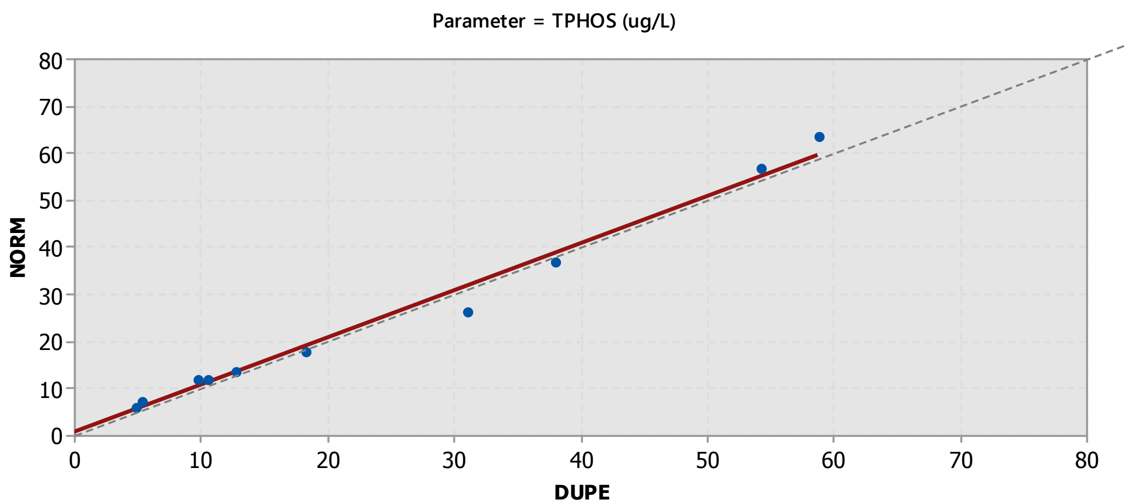
abs mean diff. = 38 ug/L



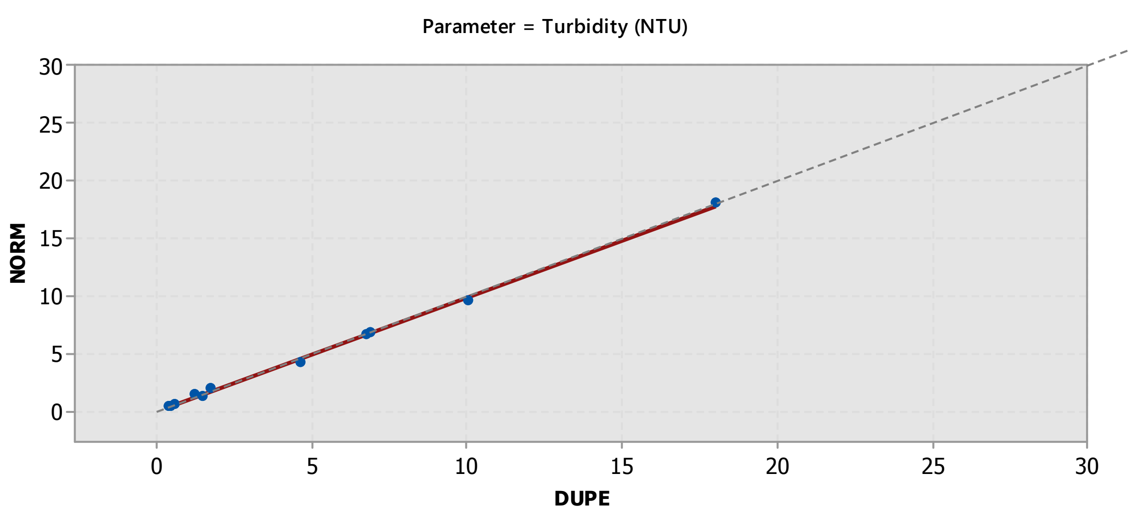
abs mean diff. = 0.1 mg/L



abs mean diff. = 3 ug/L



abs mean diff. = 2.1 ug/L



abs mean diff. = 0.17 NTU