2009 Annual Report

Upper Cache la Poudre River

Collaborative Water Quality Monitoring Program

Prepared for:

City of Fort Collins Utilities

City of Greeley

Tri-Districts

Prepared by:

Jill Oropeza, Watershed Specialist
City of Fort Collins Utilities

Judith A. Billica, P.E., Ph.D., Senior Process Engineer
City of Fort Collins Utilities

May 20, 2010

EXECUTIVE SUMMARY

Scope of Upper Cache la Poudre Collaborative Water Quality Monitoring Program

Sample collection for the Upper Cache la Poudre (CLP) Collaborative Water Quality Monitoring Program consisted of 11 sampling events between April and November, 2009 at ten sites on the Mainstem CLP and nine sites on the North Fork, including Seaman Reservoir. Water samples were analyzed for a total of up to 39 parameters.

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

Scope of 2009 Annual Report

The 2009 annual report summarizes the hydrologic and water quality data collected as part of the Upper CLP Collaborative Water Quality Monitoring Program and provides a comparison with water quality information from the years 2006 – 2009. Data for 2006 and 2007 were obtained from the historic City of Fort Collins and City of Greeley sampling program records.

Six key sites were identified that are considered representative of conditions on the Mainstem and North Fork CLP. The discussion of results focuses primarily on these six key sites as well as Seaman Reservoir, although data for all sites were analyzed and significant events and trends are also included in the discussion. Summary graphs for all parameters and locations are presented in a separate attachment (Attachment 5).

Significant Events

- On 8/25/09, a Malpaso Asphalt tanker truck carrying 5,700 gallons of liquid asphalt crashed into the Poudre River, approximately 2 miles above the City of Fort Collins Poudre intake and 6.5 miles above the City of Greeley Poudre intake, spilling approximately 5,200 gallons of asphalt on the bank and directly into the river. Both City of Greeley and City of Fort Collins intakes were closed shortly after the accident was reported. Containment and clean-up activities were conducted with oversight by the EPA.
- On 9/3/09, just prior to the EPA's final inspection of the Malpaso spill site, a second tanker, owned by J & J Asphalt, crashed into the Poudre River approximately three miles below the Malpaso crash site, dumping 5,000 gallons of liquid asphalt and approximately 100 gallons of diesel fuel from a ruptured fuel tank into the river. The second crash occurred below the City of Fort Collins raw Poudre water intake, but above the City of Greeley's intake; both intakes were still closed at the time of the 9/3/09 crash, awaiting final inspection from the first spill. As with the first spill, the containment and clean-up activities were conducted with oversight by the EPA and

prevented contamination from the spill from reaching the drinking water treatment facilities.

- An attached algae bloom occurred during the summer of 2009 in the middle reaches of the Mainstem Poudre River. Dense mats of dried and live filamentous green algae (*Ulothrix* sp.) were observed in the area. Nutrient data did not indicate elevated nutrient levels and no taste and odor (T&O) complaints were received by the FCWQL during this time, indicating that any potential off-taste or odors associated with the algae bloom were adequately eliminated during the treatment process.

Significant Results

Mainstem and North Fork

- 2009 stream flows on the Mainstem were similar to the previous three years. North Fork stream flows were lower than in 2008, but were still considerably higher than in 2006 or 2007.
- In general, water from the North Fork basin was warmer with higher levels of dissolved constituents than the Mainstem, which was reflected by higher levels of hardness, conductivity, alkalinity, and major ions. In both drainages, these characteristics increased with decreasing elevation. Across all sites, minimum values occurred during periods of high flow due to the diluting effect of snowmelt runoff.
- Turbidity peaked at all sites during spring run-off. North Fork sites experienced much higher peak turbidity values than Mainstem sites.
- Peak TOC concentrations occurred during peak run-off across the watershed. As seen in previous years, Mainstem TOC decreased to low levels following runoff, while the North Fork exhibited persistently elevated TOC concentrations during periods of low flows.
- Nutrient concentrations on the Mainstem were generally lower than on the North Fork. The influence of Seaman Reservoir on downstream water quality was particularly evident during the summer months, as reflected by large spikes in total phosphorus and ortho-phosphate concentrations at NFG.
- Mainstem nutrient concentrations were generally low, as in previous years. The Poudre above Joe Wright Creek, (PJW) consistently experienced higher nitrate concentrations than lower-elevation sites on the Mainstem.
- *Giardia* was more abundant than *Cryptosporidium* on both the Mainstem and the North Fork. Following a three year increase at North Fork above Dale Creek (NDC), *Giardia* concentrations in 2009 were similar to 2008.
- *E.coli* and total coliform concentrations were similar to previous years on the Mainstem (PNF). The North Fork consistently experienced higher concentrations of both pathogens than did the Mainstem. There were no consistent relationships observed between *E.coli* or total coliform concentrations at NFL, NFG and in Seaman Reservoir.

- Geosmin concentrations on the Mainstem, as measured in samples of raw Poudre River water collected at the FCWTF, were consistently below the taste and odor threshold of 5 parts per trillion (ppt).

Seaman Reservoir

- Seaman Reservoir was strongly stratified during the summer of 2009. As seen in years prior to 2008, the hypolimnion experienced a prolonged period of near-zero dissolved oxygen (D.O.) concentrations.
- Spikes in turbidity and nutrients (except nitrite) also occurred in Seaman Reservoir during the late summer, and were similar to late season spikes observed in the previous three years.
- Blue-green algae are prevalent in Seaman Reservoir during the late summer.
- Geosmin concentrations in Seaman Reservoir were consistently at or above the taste and odor threshold, as in previous years. The maximum geosmin concentration at the top of the reservoir was 36 ppt on 8/25/09.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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, the City of Greeley-Bellvue Water Treatment Plant, and the Tri-Districts Soldier Canyon Filter Plant. In the shared interest of sustaining this pristine water supply, the City of Fort Collins, the City of Greeley and the Tri-Districts partnered in 2007 to design the Upper Cache la Poudre River Collaborative Water Quality Monitoring Program. The over-arching goal of this monitoring partnership is to assist the participants in meeting current and future drinking water treatment goals by providing up-to-date information about water quality and trends within the Upper CLP watershed.

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

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

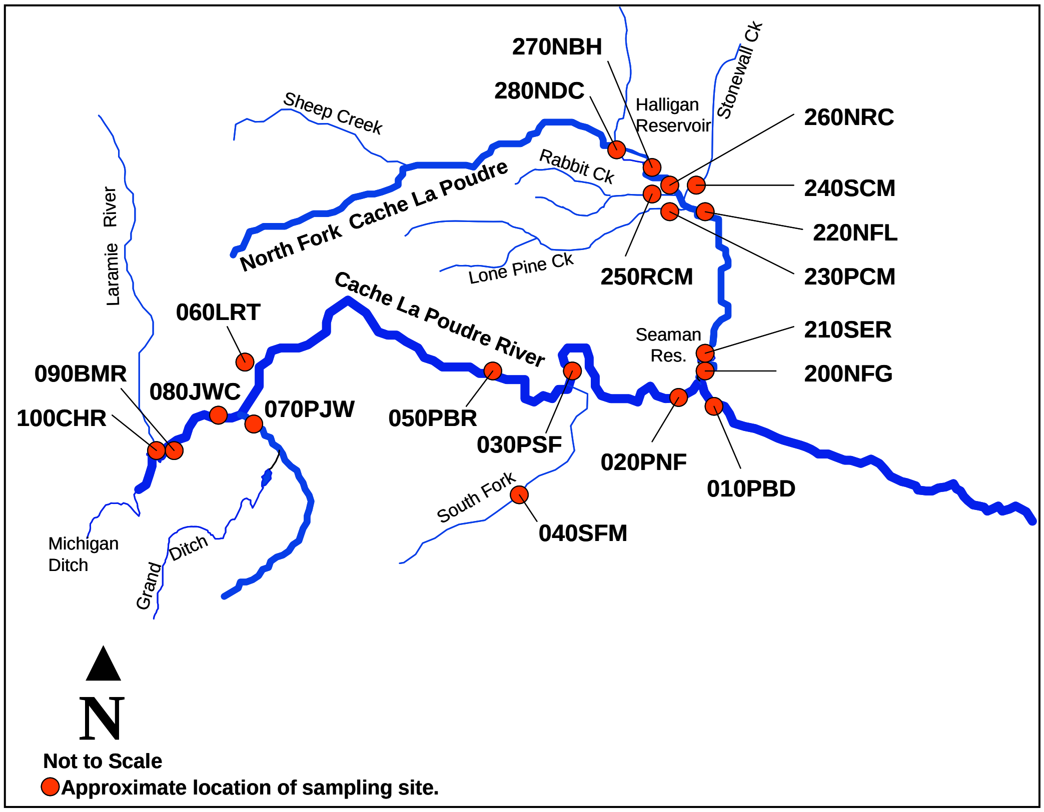
Annual and five-year reports for the collaborative program are prepared by City of Fort Collins staff to keep participants abreast of current issues and trends in water quality of the Upper CLP. The purpose of annual reports is to summarize hydrologic and water quality information for the current water year, describe notable events, and provide a comparison with water quality from the preceding three years. The five-year reports will provide a more in-depth analysis of both spatial and temporal trends in watershed hydrology and water quality, including concentrations and loads.

1.2 Watershed Description and Sampling Locations

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

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

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



1.3 Sampling Schedule and Parameters

Sampling frequency was determined based on both statistical performance and cost considerations. Parameters included in the monitoring program were selected based on analysis of historical data and aim to provide the best information possible within current budgetary constraints. A list of parameters is included in Attachment 3. Complete discussions of parameter selection and sampling frequency are provided in Sections 5.3 and 5.4, respectively, of the original design document by Billica, Loftis and Moore (2008). The 2009 sampling schedule is provided as Attachment 4 of this report.

1.4 Sample Collection and Analysis

Dr. William Lewis was contracted by the City of Greeley in agreement with the City of Fort Collins and the Tri-Districts to perform sampling activities for the Upper CLP monitoring program at 17 of the 19 Mainstem and North Fork CLP sites. Staff from the City of Fort Collins, City of Greeley, and Tri-Districts collected samples at the remaining two locations: North Fork Poudre above confluence with Dale Creek (NDC) and North Fork Poudre below Halligan Reservoir (NBH). Sampling methods, including those for the collection of field measurements for temperature, pH, conductivity, and dissolved oxygen are documented in Section 5.5 of Billica, Loftis and Moore (2008). All bulk water samples were analyzed by the City of Fort Collins Water Quality Lab (FCWQL), except for *Cryptosporidium* and *Giardia* filter samples, which were delivered to CH Diagnostic and Consulting, Inc., in Berthoud, CO for analysis. In addition, plytoplankton samples were collected from April through November at the top and bottom of Seaman Reservoir in 2009. April and May samples were analyzed by PhytoFinders of Berthoud, CO. Samples were identified and enumerated at the genus level, for a pre-determined set of genera. However, beginning in June 2009, phytoplankton analysis was contracted to Dick Dufford (private consultant) of Fort Collins, CO, for enumeration and identification to the species level. Changes in phytoplankton sample collection and preservation methods were also made at this time and are detailed in Section 4.7 of this report. The analytical methods and detection limits for the FCWQL parameters are included in Attachment 5.

1.5 Scope of 2009 Annual Report

The 2009 annual report summarizes the hydrologic and water quality data collected for the Upper CLP collaborative monitoring program and highlights the significant events and issues of concern. This report provides a comparison with water quality information from the years 2006-2009. Data for 2006 and 2007 were obtained from the historic City of Fort Collins and City of Greeley sampling program records.

2.0 SIGNIFICANT EVENTS AND ISSUES OF CONCERN

2.1 2009 Significant Events

August 25 Asphalt Spill. At 10:30am on August 21st, a Malpaso Asphalt tanker truck carrying 5,700 gallons of liquid asphalt crashed into the Poudre River, approximately 2 miles above the City of Fort Collins intake and 6.5 miles above the City of Greeley intake, spilling approximately 5,200 gallons of asphalt on the bank and directly into the river. The City of Fort Collins initiated shutdown of their intake at 10:45 am with shutdown complete by 11:16 am. The City of Greeley shut off their intake supply of Poudre River water at 11:00am. Shortly thereafter, booms were deployed to contain the spill.

Both the City of Fort Collins and City of Greeley collected water quality samples which were analyzed for diesel-related hydrocarbons (VOCs) at several locations downstream of the accident site by EPA and City of Fort Collins staff. Samples were also collected at the respective raw Poudre River intakes during clean-up operations. Results for both intakes were non-detects or well below drinking water standards. The CDOW collected sediment samples and macroinvertebrate and fish tissue samples to determine the biological impact of the spill. CDOW reported no evidence of any acute effects on wildlife outside the immediate spill area, with the exception of three ducks that became stuck in the soft asphalt. The ducks were taken by CDOW to a rehabilitation center. Due to difficult terrain and distance to the river, the clean up operations were performed using hand tools to remove the asphalt from the river. Most of the spill was contained within 500 feet of the crash site. The EPA declared inspection complete on September 4th, two weeks after the spill occurred.

September 3 Asphalt Spill. On September 3rd, just prior to the EPA's final inspection of the Malpaso spill site, a second tanker, owned by J & J Asphalt, crashed into the Poudre River approximately three miles below the Malpaso crash site, dumping 5,000 gallons of liquid asphalt and approximately 100 gallons of diesel fuel from a ruptured fuel tank into the river. The second crash occurred below the City of Fort Collins raw Poudre water intake, but above the City of Greeley's intake; both intakes were still closed at the time of the September 3rd crash, awaiting final inspection from the August 25th spill. Again booms were deployed to contain the spill and water samples were collected to test for hydrocarbons (VOCs). All samples were non-detects or well below drinking water standards. The tanker was hoisted from the river, and because the crash location allowed, heavy equipment as well as hand tools were used to remove the asphalt. CDOW instituted a temporary recommended "catch and release" policy for fish caught below the spill sites until follow-up testing was complete. The final EPA clean-up inspection occurred on September 16, 2009.

Attached algae bloom in Poudre River. During the summer of 2009, an attached algae bloom occurred along the middle reaches of the Mainstem Poudre River, from areas near Big Bend Campground and the State fish hatchery to downstream around Indian Meadows, which corresponds to the Upper CLP monitoring site, Poudre below Rustic (PBR). In September, FCWTF staff collected and identified samples collected in this general area. Dense mats of dried filamentous algae covered rocks along the river banks in areas where high flows had receded, and live green algae was observed in areas of flowing and standing water (Figures 2.a.& 2.b). The dominant form of algae was identified as the green algae, *Ulothrix* (sp) (Fig. 3). Although algal blooms typically occur in response to increased nutrient availability, no general increases or spikes in nutrients were observed for PBR or upstream locations from June through September. Furthermore, FCWTF did not receive any taste and odor (T&O) complaints during this time, indicating that any potential off-taste or odors associated with the algae bloom were adequately eliminated during the treatment process.

Figures 2.a. and 2.b. Attached algae on Mainstem of the Poudre, September, 2009.

Figure 2.a.

Figure 2.b.

Figure 3. Green algae (*Ulothrix* sp.) from the Mainstem of the Poudre, September 2009.

A large abundance of aquatic plants as well as some attached algal growth was also observed on the North Fork CLP below Halligan Reservoir Dam at NBH (See Figure 4). Dense mats of attached aquatic plants as well as attached algae were observed in mid- to late-summer, as seen in the previous year. Samples were not collected for identification. Nutrient releases from Halligan Reservoir during times of low flow likely contribute to the favorable conditions for this abundant aquatic growth.

Figure 4. Aquatic plant and algae growth at NBH, Summer 2009.

2.2 Issues of Concern

Proposed Revisions to Colorado's Monitoring and Evaluation (M&E) List and Section 303(d) List. In 2009, the Water Quality Control Division (WQCD) of the Colorado Department of Public Health and Environment (CDPHE) proposed to combine Colorado's Monitoring and Evaluation List (Regulation #94) into Regulation #93 (Colorado's List of Water Quality Limited Segments requiring Total Maximum Daily Loads, also referred to as the Section 303(d) List). At the same time, revisions were proposed to the M&E List and the Section 303(d) List. The public rulemaking hearing before the Colorado Water Quality Control Commission for these revisions was Feb. 8, 2010. The Commission adopted the final action documents pertaining to these revisions on March 9, 2010 and they became effective on April 30, 2010. The outcome was the approval of the proposed 2010 Section 303(d) List and the M&E List as rules (revised Regulation #93) and the repeal of Regulation #94. The listing methodology used by the WQCD for the 2010 listing cycle was documented in May 2009.

The 2010 revisions to the M&E List and the Section 303(d) List include several segments in the Upper CLP (see Table 1). Seaman Reservoir was placed on the Section 303(d) List for dissolved oxygen (D.O.) using profile data obtained from the City of Greeley's monitoring program for the period of 04/03 – 09/06. The WQCD's attainment analysis for Seaman Reservoir concluded the following:

> *"The DO was below the standard in the epilimnion for 3 of the 50 profiles examined. DO was also below the standard in the metalimnion for 22 of the profiles examined. Temperature exceeded in the epilimnion for 2 profiles and adequate DO refuge was not present on these dates. For these reasons, the Division recommends Seaman Reservoir for the 303(d) list for DO."*

Hypolimnetic D.O. concentrations in Seaman Reservoir did not influence the proposed 303 (d) listing, as the listing criteria for dissolved oxygen pertain to zones of potential aquatic refugia, and in general, do not apply to bottom waters. The exception would occur when a lake or reservoir exceeds both temperature and dissolved oxygen standards in the hypolimnion, which is not applicable in this situation. The dissolved oxygen standard is scheduled to be revised by the 2010 Basic Standards and Methodology, Regulation No.31, rule-making hearing in June 2010.

The North Fork of the Poudre from the inlet of Halligan Reservoir to the Mainstem Poudre River (Segment 7) was placed on the 2010 Section 303(d) list for lead (Pb) and cadmium (Cd) exceedances. The data used for this determination were collected by the WQCD.

When water quality standard exceedances are suspected, but uncertainty exists regarding one or more factors, such as the representative nature of the data used in the evaluation, a site is added to the M&E List. The following segments of the North Fork Cache la Poudre River were placed on the 2010 M&E List:

- Segment 6: The Mainstem of the North Fork of the Poudre River, including all tributaries, from the source to the inlet of Halligan Reservoir for exceedances of copper (Cu).
- Segment 8: All tributaries to the North Fork of the Poudre from the inlet of Halligan Reservoir to the Mainstem Poudre, except for Segment 9 tributaries, for *E. coli*. The recreational standard for *E.coli* is 126 individuals/100ml. Note that data from the Upper CLP watershed monitoring program show exceedances of the standard in 2009, although these data were not used in the WQCD attainment assessment.
- Segment 9: Rabbit Creek and Lone Pine Creek for exceedances of cadmium (Cd) and lead (Pb).

Table 1. Summary of Standards Attainment Assessment for Upper CLP Segments conducted by the CDPHE WQCD in 2009 in preparation for the February 2010 WQCC Hearing related to revisions to Colorado's Monitoring and Evaluation (M&E) List and Section 303(d) List.

Segment	Segment Description	Data Source	Non-attainment Parameter	No. of data	Standard	Ambient water quality statistics (1)	Proposed Listing (2)
COSPCP 06	Mainstem of the North Fork, including all tributaries & wetlands, from the source to inlet of Halligan Res.	WQCD (POR 3/08 - 6/08)	Copper	2	Aquatic Life: Acute = 2.53 ug/L Chronic = 2.65 ug/L	6.80 ug/L	M&E
COSPCP 07	Mainstem of the North Fork from inlet of Halligan Res to confluence with CLP River.	WQCD (POR 10/03 - 6/08)	Cadmium	17	Aquatic Life: Chronic = 0.47 ug/L	0.48 ug/L	303(d)
			Lead	17	Aquatic Life: Chronic = 2.94 ug/L	6.00 ug/L	
COSPCP 08	All North Fork tribs from inlet of Halligan Res to confluence with CLP River, except for listings in Segment 9.	WQCD (POR 7/03 - 6/08)	*E. coli*	5	Recreation: 126 per 100 mL	229.26 per 100 mL	M&E (3)
COSPCP 09	Mainstem of Rabbit Creek & Lone Pine Creek from the source to the confluence with the North Fork	WQCD (POR 10/03 - 6/08)	Cadmium	3	Aquatic Life: Chronic = 0.46 ug/L	0.56 ug/L	M&E
			Lead	3	Aquatic Life: Chronic = 2.83 ug/L	7.00 ug/L	
COSPCP 20	All lakes and res. tributary to North Fork from inlet of Halligan to confluence with CLP River. This segment includes Halligan Res and Seaman Res.	City of Greeley (POR 4/03 - 9/06) Seaman Reservoir only	Dissolved Oxygen and Temp.	50 profiles	Aquatic Life: DO = 6.0 mg/L Temp = 22.5 C	DO < 6.0 mg/L in epilimnion for 3 of 50 profiles; DO < 6.0 mg/L in metalimnion for 22 of 50 profiles; temp exceeded in epilimnion for 2 profiles.	303(d) for Seaman Reservoir only

1. Attainment of the dissolved metals chronic standards is assessed against the 85th percentile. Attainment of the *E.coli* standard is assessed using the geometric mean of the representative stream samples (pages 14-15, WQCD Section 303(d) Listing Methodology, 2010 Listing Cycle, May 2009).
2. Data sets comprised of three or fewer samples that indicate impairment of the chronic standard results in placement on the M&E List (page 28, WQCD Section 303(d) Listing Methodology, 2010 Listing Cycle, May 2009).
3. CDPH&E stated that this segment may not be in attainment of the recreational standard but more data needs to be gathered.

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

According to information provided by the US Forest Service (USFS) website (http://www.fs.fed.us/r2/news/press-kits/2010/index.shtml), 3.6 million acres in Colorado and southern Wyoming have been affected since 1996. Results of the 2009 USFS Forest Health Aerial Survey show that the area affected by mountain pine beetles in Larimer County, Colorado grew from 280,000 to 500,000 acres from 2008 through 2009, an area which includes much of the Upper Cache la Poudre watershed.

One of the major risks associated with the increasing number of dead and dying trees is the short-term elevated risk of high severity wildfires. Research continues on forest management options to improve post-outbreak forest health (McDonald and Stednick, 2003; Uunila et. al, 2006; LeMaster et al., 2007), as well as options for protecting communities and critical water supplies against the effects of wildfire (LeMaster et al., 2007; FRWWPP, 2009). However, potentially widespread changes in the vegetative cover that occur either as a result of extensive forest die-back or from severe wildfire, have the potential to affect water quality in the Upper CLP watershed, including potential changes in stream flow and temperatures, sediment loads, as well as in-stream nutrient and TOC levels.

TOC Studies. A comprehensive TOC characterization study was conducted in 2008 by Dr. Mel Suffet (Professor at UCLA) and was jointly funded by the City of Fort Collins, City of Greeley, Tri-Districts, and Northern Water. The study area included the Upper CLP as well as Horsetooth Reservoir and associated components of the CBT Project. Laboratory analyses for this study included UV, fluorescence, ultrafiltration for size characterization, polarity rapid assessment method for polarity characterization, and trihalomethane formation potential. The final report for this study is expected to be completed in 2010.

A new study that builds on the 2008 UCLA study was funded in 2009 by the City of Fort Collins and the Water Research Foundation as a Tailored Collaboration Project with Dr. Scott Summers and other researchers at the University of Colorado at Boulder (Water Research Foundation Project 04282 "Watershed Analysis of Dissolved Organic Matter and the Control of Disinfection By-Products (DBPs))." This project will include the same study area as the UCLA project, but will focus on the use of fluorescence to develop relationships between TOC in the watershed and DBP formation at the FCWTF. The project will also include: 1) an evaluation of the impact of photodegradation (solar radiation) on TOC characteristics, 2) an evaluation of the impact of pine beetle kill on TOC characteristics, and 3) treatability studies whereby watershed samples are coagulated and/or chlorinated to evaluate DBP formation and characterize the DBP precursors that are not removed during conventional treatment. The final report for this study is expected to be completed in 2011.

Emerging Contaminants. Emerging contaminants and their presence in water have recently received national attention. Emerging contaminants are trace concentrations (at the nanogram/L or parts per trillion level, or less) of the following types of chemicals:

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

- Pharmaceuticals: prescription and non-prescription human drugs (including pain medications, antibiotics, β-blockers, anti-convulsants, etc) and veterinary medications
- Endocrine disruption chemicals (EDCs): chemicals that interfere with the functioning of natural hormones in humans and other animals; includes steroid hormones (estrogens, testosterone, and progesterone), alkylphenols, and phthalates
- Pesticides and herbicides

Snyder et al (2008) recently completed a document for the Water Research Foundation on the "State of Knowledge of Endocrine Disruptors and Pharmaceuticals in Drinking Water." Effluent from wastewater treatment plants is considered to be the major source of PCPs, pharmaceuticals, and EDCs to surface waters. Other sources can include septic systems, leaky sewers, urban runoff, agricultural runoff, and direct release from humans during recreational activities.

Human development and agricultural activities in the Mainstem and North Fork CLP watersheds is limited, although there is a relatively high level of summer recreation on the Mainstem. A U.S.G.S. study conducted on the Mainstem Cache la Poudre in 2002 and 2003 identified the presence of several compounds related to recreation, automobile emissions, and the use of various household and personal-care products in the watershed (Collins and Sprague, 2005). Of the 271 organic compounds monitored, only 14 were detected, including three VOCs (acetone, benzene, and toluene), one pesticide (the herbicide Siduron), and 10 wastewater compounds (including caffeine and the insect repellant DEET). Most compounds were detected at concentrations well below 1 μg/L, and no water quality standards were exceeded. Furthermore, the USGS concluded that the Upper CLP provides a high quality drinking water source. However, due to the recent national media attention focused on emerging contaminants, there is interest in gaining more information about the occurrence of emerging contaminants in waters of the Upper CLP.

Northern Water collaborative emerging contaminant study. In 2008, Northern Water initiated a collaborative emerging contaminant study to determine the presence of these compounds in waters of the Colorado- Big Thompson system. In 2009, two sites on the Upper Cache la Poudre were added with funding assistance provided by the City of Fort Collins and the City of Greeley. In the spring of 2009, samples for emerging contaminants were collected from the Upper CLP monitoring sites, PNF and NFG. Samples were analyzed for 51 pharmaceuticals and 103 pesticides by the Center for Environmental Mass Spectrometry Laboratory. In addition, samples were submitted to Underwriters Laboratories, Inc. which provided analysis for estrogens and other hormones (9 compounds), and phenolic endocrine disrupting chemicals (8 compounds). The only compound detected in the samples was progesterone, detected at 0.1 ng/L at PNF. However, 0.1 ng/L is the method reporting limit for progesterone and caution must be exercised in terms of assigning importance to results at this extremely low value.

The Northern Water collaborative emerging contaminant study will continue through 2010 with sampling in June (at PNF and NFG) and August (PNF). The August sampling date was added because of the possibility of seasonal variability in some of the emerging contaminants such as pesticides and the personal care products related to recreational activities.

3.0 UPPER CACHE LA POUDRE RIVER RESULTS

For this annual report, six key sites were identified that are considered representative of conditions on the Mainstem and North Fork CLP River. The selected sites are:

- Mainstem above North Fork
  - JWC – Joe Wright Creek above Mainstem
  - PJW – Poudre above Joe Wright Creek
  - PNF – Poudre above North Fork
- North Fork above Mainstem
  - NFL – North Fork at Livermore (above Seaman Reservoir)
  - NFG – North Fork at Gage below Seaman Reservoir
- Mainstem below North Fork Confluence
  - PBD – Poudre at Bellvue Diversion

Discussion of the results will focus primarily on these 6 sites; however, data from all sites were reviewed and analyzed and any notable events and trends are included in the discussion. A full set of data summary graphs is contained in Attachment 7; raw data are available upon request from the City of Fort Collins.

3.1 Hydrology

Discharge was measured as part of the routine Upper CLP monitoring activities at two key sites on the Mainstem: Poudre above Joe Wright Creek (PJW) and South Fork Poudre (SFM). Discharge values presented for these sites represent instantaneous discharge measurements collected on the specified sampling dates.

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

Both the Mainstem and North Fork sites show snowmelt-dominated hydrographs (Fig. 5). The 2009 spring runoff began in mid-May. For the years 2006 - 2009, the hydrographs for the lower Mainstem sites PNF and PBD are characterized by two peaks in stream flow during the spring run-off season. This fluctuation of river levels is largely a result of rainfall events and/or snowmelt in the lower elevations plus repeated freezing and thawing that is characteristic of early spring conditions in the Upper CLP watershed (Fig. 6).

Figure 5. 2006 – 2009 Daily average stream flow at key Upper CLP monitoring sites.

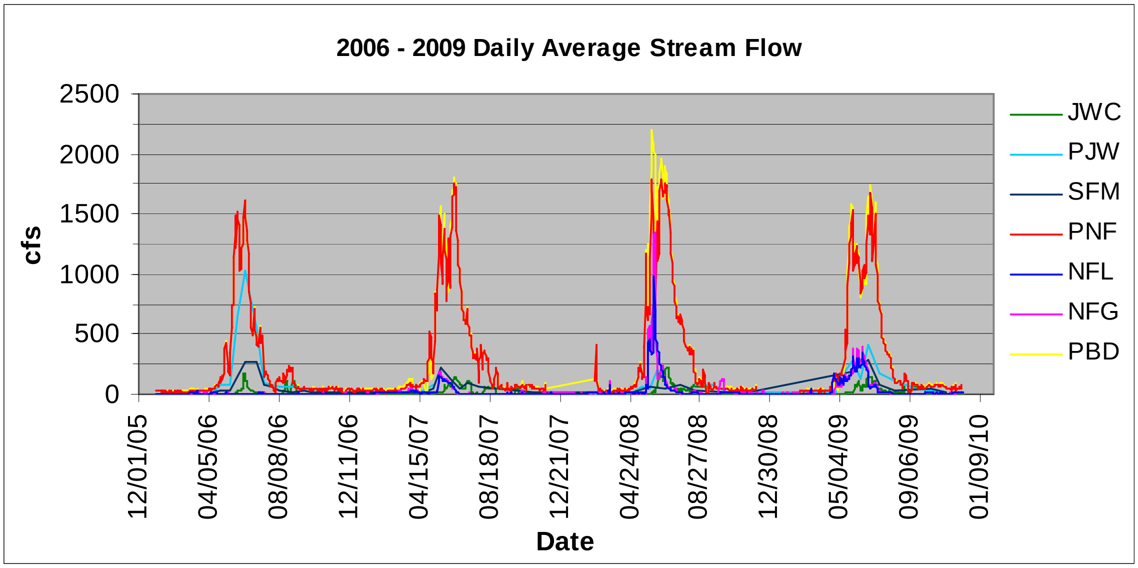
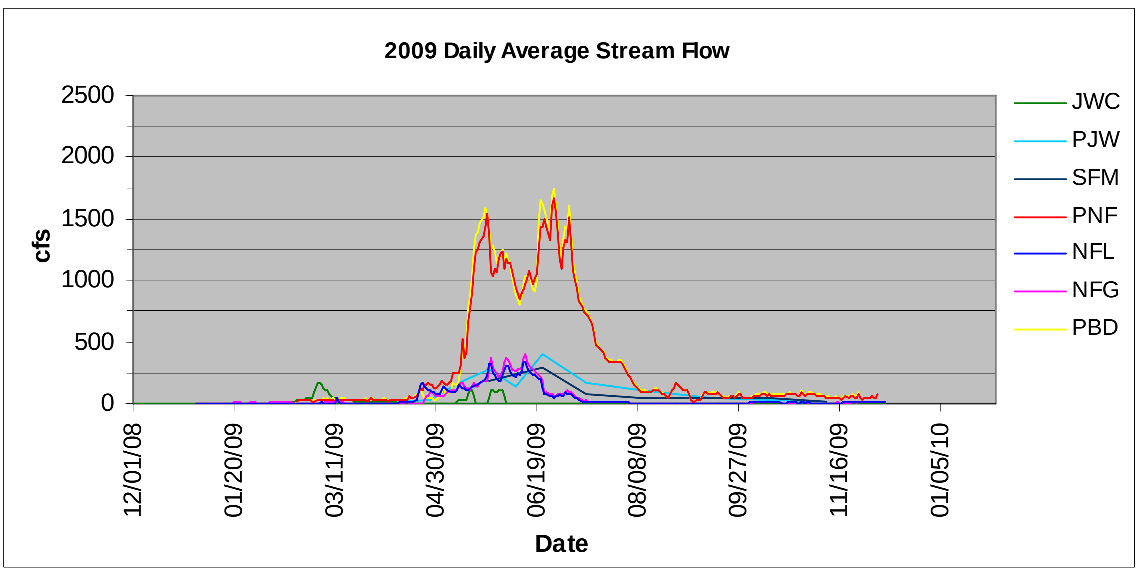


Figure 6. **2009 Daily Average Stream Flow at key Upper CLP monitoring sites.**

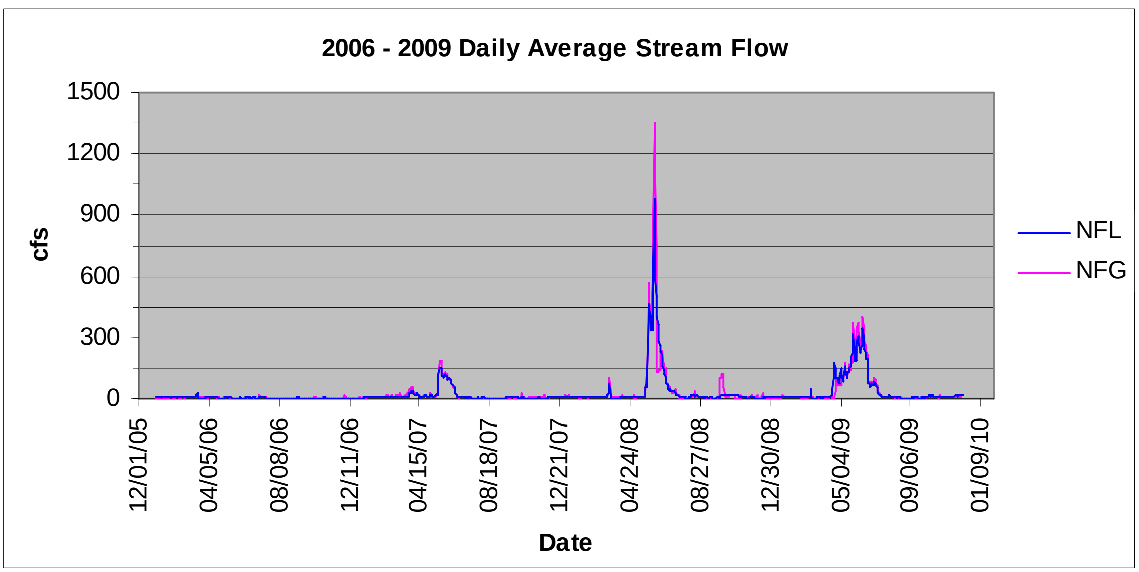


Mainstem CLP. Headwater sources, PJW, SFM and JWC experienced peak flows of 405 cfs, 289 cfs, and 156 cfs, respectively. PJW and SFM experienced greater peak flows than were observed in 2008, although the magnitudes of peak flows was not outside the range of flows observed in 2006 and 2007. The somewhat higher peak flows on the Mainstem headwater sources in 2009 were not sufficient to produce higher peak flows downstream at PNF. The timing and magnitude of spring run-off were similar to all previous years at PNF. An initial peak flow of 1,537 cfs occurred on 5/25/09, followed by a second, slightly larger peak of 1,671 cfs nearly a month later, on 6/27/09.

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

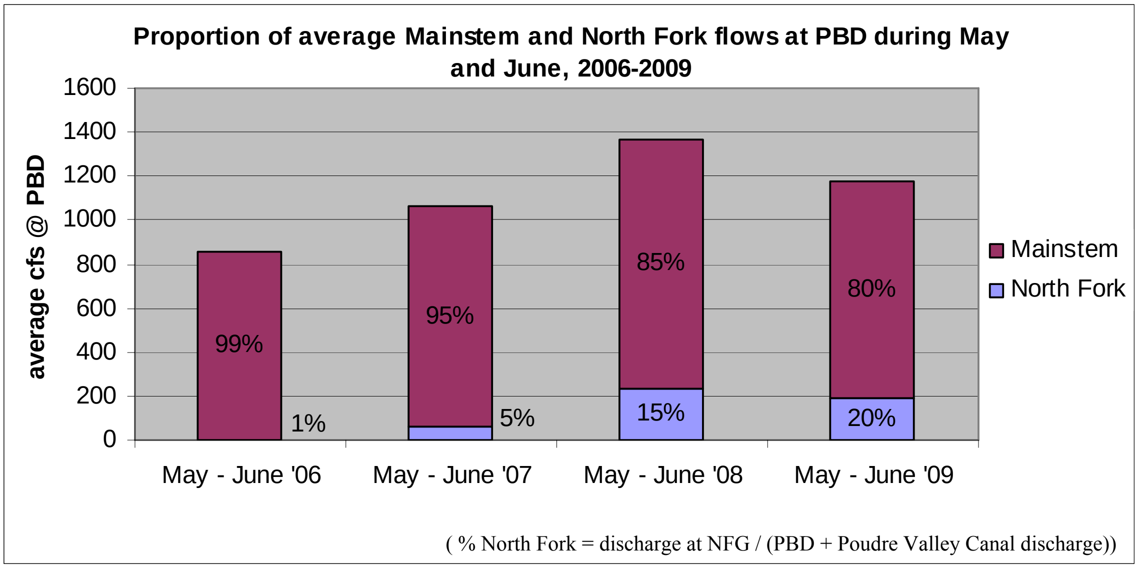
North Fork CLP. Stream flows measured at NFL represent cumulative flows of the North Fork CLP above Seaman Reservoir and provide information about the timing and relative magnitude of spring run-off in the upper North Fork drainage. Stream flow measurements at NFG include contributions from both the North Fork and Seaman Reservoir and represent the total North Fork contributions to Mainstem flows (measured at PBD). Although stream flow at NFG is influenced by reservoir operations, the hydrographs for NFL and NFG are typically very similar (Fig.7) because during the period of highest flow (spring runoff) the majority of flow going into Seaman Reservoir is flowing over the spillway and not being stored.

Figure 7. 2006 - 2009 Daily Average Stream Flow at NFL and NFG



In 2009, stream flows at NFL and NFG tracked closely, with only slightly higher flows recorded at NFG. Stream flows peaked on 6/13/09 at NFL and NFG, and were 347 and 402 cfs, respectively. Peak flows at NFG were substantially smaller than in 2008 (1,350 cfs), but greater than in 2006 and 2007. From May through June, the North Fork comprised, on average, 1% to 20% of Mainstem stream flow at PBD (Fig. 8).

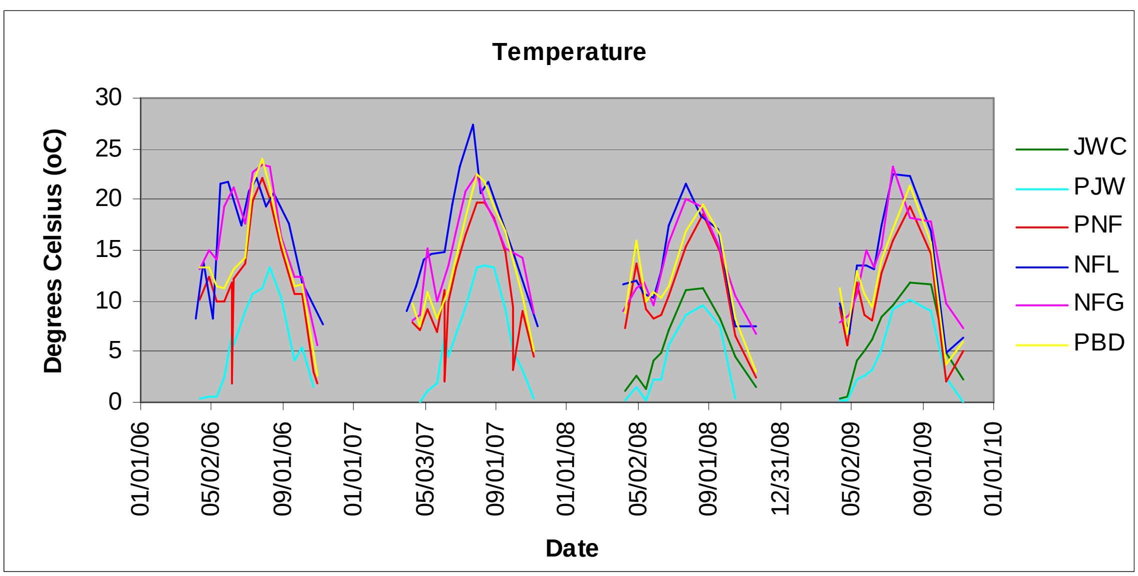
Figure 8. Proportion of average Mainstem and North Fork CLP flows at PBD during May and June from 2006 to 2009.



3.2 Water Temperature

Water temperature increases with decreasing elevation throughout the watershed (Fig. 9). Peak temperatures occurred mid-summer, with North Fork sites peaking a few days earlier than the Mainstem sites due to the influence of the warmer temperatures within this lower elevation drainage. Seaman Reservoir did not have any discernible influence on North Fork water temperature.

Figure 9. Water temperature at key Upper CLP monitoring sites.



3.3 General Parameters: Conductivity, Hardness, Alkalinity, pH, and Turbidity

Conductivity, Hardness and Alkalinity. Conductivity is an index of dissolved ionic solids in the water and hardness is an index of the total calcium and magnesium in the water. Alkalinity is a measure of the effective acid buffering capacity of the water, and is derived, in large part, from the dissociation of mineral carbonates (CO_3^-), bicarbonates (HCO_3^-) and hydroxides (OH^-). Conductivity, hardness and alkalinity are influenced by the local geology as well as the dissolved constituents derived from other watershed activities. Across the watershed, these three parameters track closely, with minimum values occurring during peak run-off when the concentrations of all dissolved constituents are diluted by large volume flows, and high values occurring at times of low flow (Figures 10.a – 10.c).

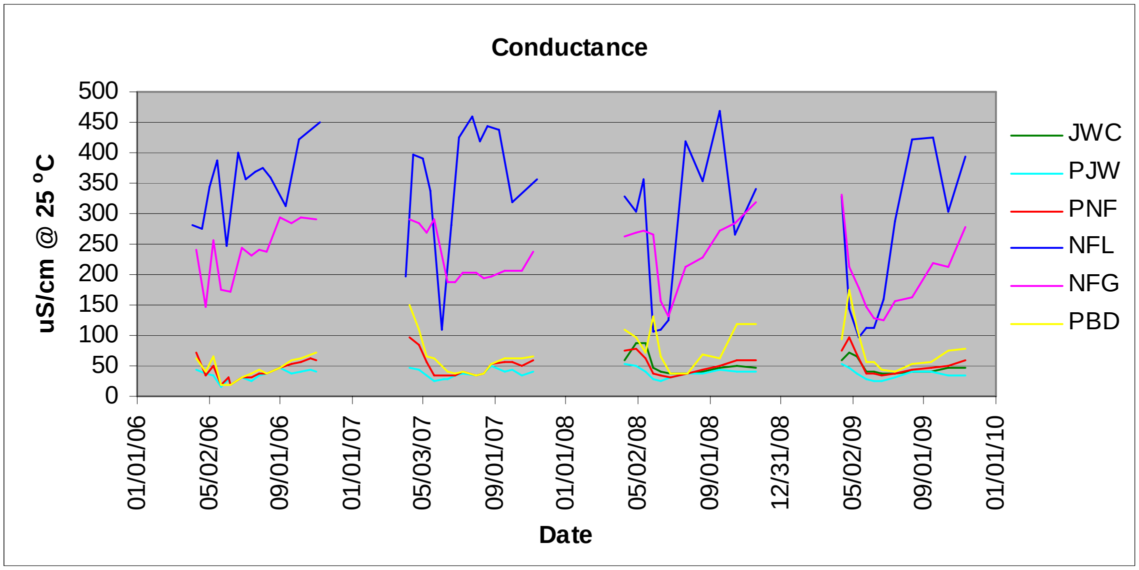
In general, conductivity, hardness and alkalinity increased with decreasing elevation. Accordingly, North Fork sites showed consistently higher values and greater variability for these parameters than Mainstem sites, which reflect the combined influences of differing geology and elevation. With the exception of 2008 spikes in hardness and alkalinity at NFG, observed values at each site remained consistent between years.

pH. In 2009, the pH of the Upper CLP waters followed similar patterns related to season and elevation as alkalinity, conductivity and hardness (Fig. 10.d). In general, the North Fork exhibited higher pH than the Mainstem, with the exception of higher pH at PBD on 5/11/09 (pH 8.6). 2009 pH values ranged from 6.5 – 8.6 on the Mainstem and from 7.0 – 8.5 on the North Fork. All values were within the ranges observed in previous years. However, unlike previous years, 2009 spring run-off on the Mainstem produced only modest decreases in pH, which were followed by continuous declines through mid-summer. Minimum values were recorded in the month period from mid-July through mid-August. On the North Fork, spring run-off also resulted in smaller decreases in pH (0.4 – 0.5 units) than in previous years, when pH decreased as much as 1.2 units in response to snowmelt runoff. In contrast to the summer decreases observed on the Mainstem, North Fork pH values increased consistently from June through November.

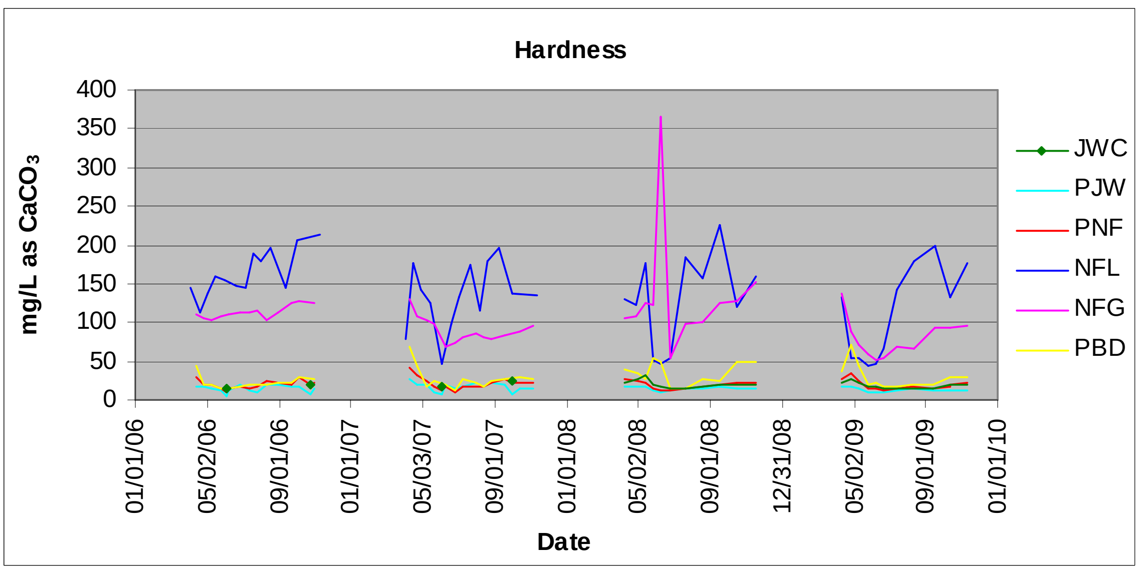
Turbidity. In general, turbidity at all Mainstem and North Fork sites peaks during spring run-off, when higher volume and velocity flows increase the amount of sediment and organic material transported from the surrounding landscapes. 2009 peak turbidity values on the North Fork (NFL and NFG) and the lower Mainstem (PBD) were considerably lower than in 2008 (Fig. 10.e.) On the North Fork, peak turbidity values at NFL and NFG were 12.2 NTU and 8.0 NTU, respectively. In comparison, the maximum observed turbidity value on the Mainstem at PNF was 6.5 NTU. In periods of lower flow, turbidity decreased considerably and values on the Mainstem and North Fork decreased below 1.0 NTU.

Figure 10 (a –e). General water quality parameters at key Upper CLP monitoring sites: Conductance, Hardness, Alkalinity, pH and Turbidity

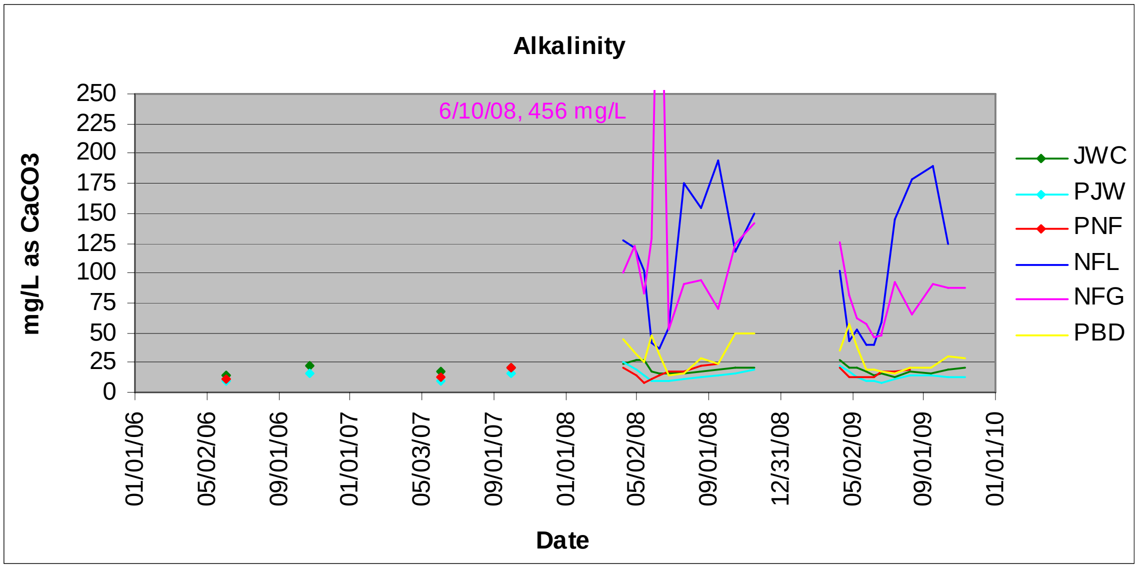
10.a. Conductance



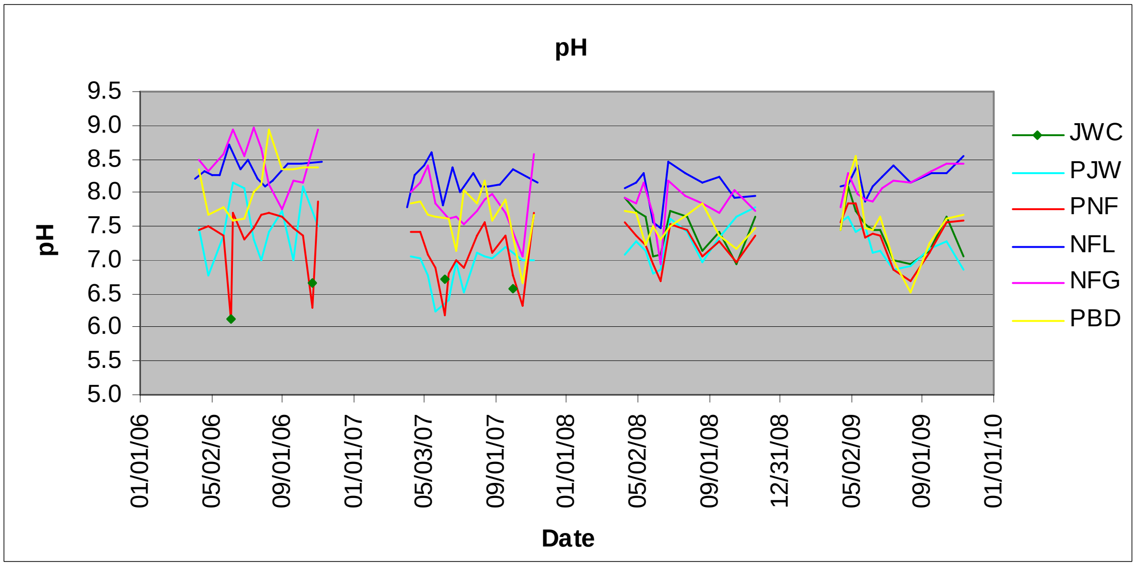
10.b. Hardness



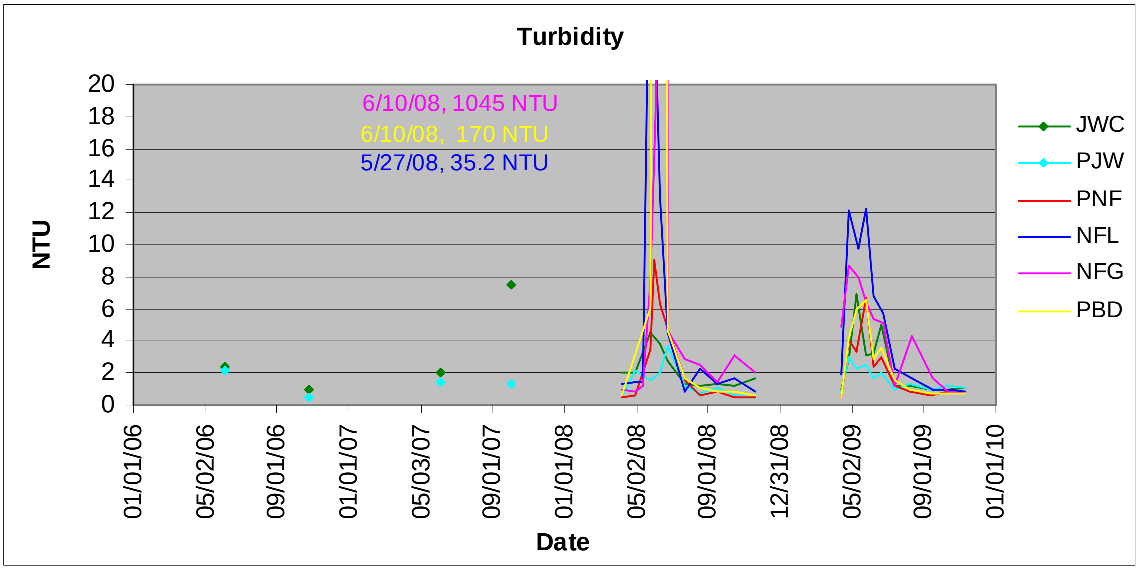
10.c. Alkalinity



10.d. pH



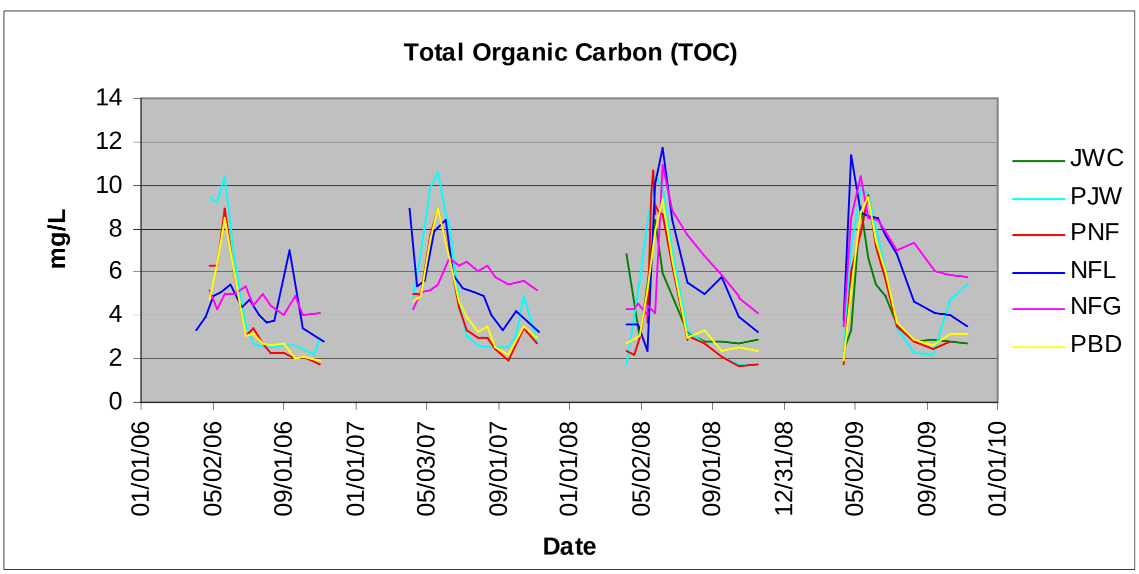
10.e. Turbidity



3.4 Total Organic Carbon (TOC)

Seasonal patterns of TOC concentrations in the upper CLP watershed are generally consistent year-to-year, with annual maximum TOC values occurring during the onset of spring snowmelt. This trend was evident in years 2006 through 2009. In previous years, Mainstem TOC concentrations at PNF have peaked approximately two weeks to a month earlier than North Fork concentrations at NFL and NFG. However, in 2009, an early-April increase in stream flow on the North Fork caused TOC concentrations to peak nearly a month earlier than on the Mainstem (Fig. 11).

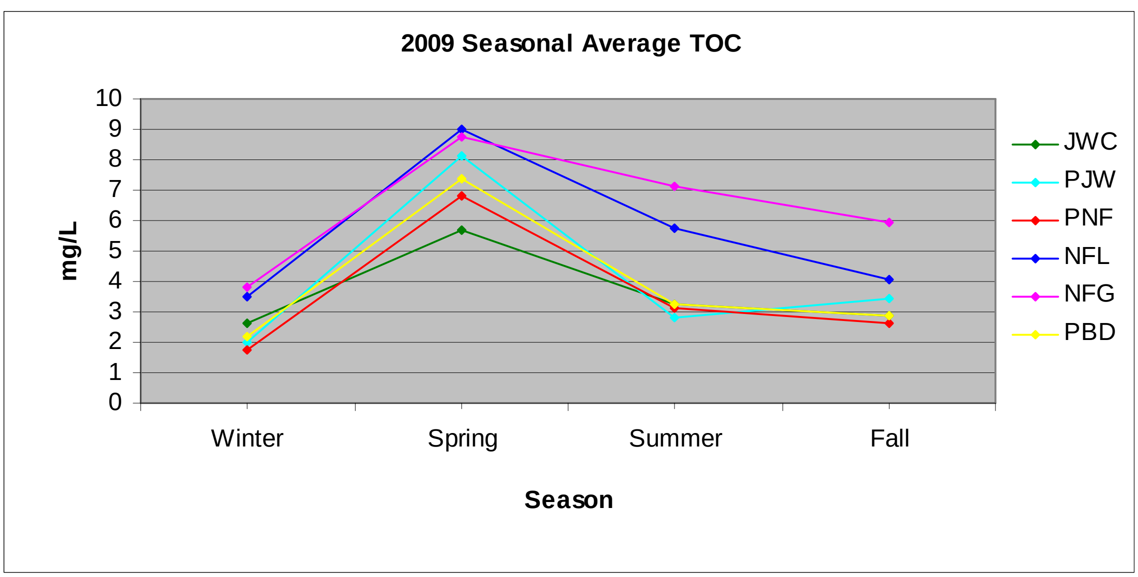
Figure 11. TOC concentrations at key Upper CLP monitoring sites.



The Mainstem typically experiences lower TOC concentrations than are observed on the North Fork at NFL and NFG. In general, the highest Mainstem TOC concentrations were observed at the high-elevation site, PJW, an occurrence that is likely related to the high proportion of runoff occurring as snowmelt near the Mainstem headwaters. Water released from Barnes Meadow Reservoir (BMR) during spring runoff serves as an exception to this pattern. Flows from BMR have historically resulted in exceptionally high concentrations of TOC entering into Mainstem flows due to boggy conditions within this sub drainage (Billica, Loftis and Moore, 2008). From 2006 – 2009, peak TOC concentrations at BMR were between 10-14 mg/l and often exceeded TOC concentrations at PJW. Releases from BMR were, however, infrequent and of short duration, thereby minimizing their impact on source water supplies at PNF and PBD. Large spikes in TOC were also observed in 2008 and 2009 in the incoming waters diverted through the Laramie River Tunnel (LRT). Peak TOC concentrations at LRT for 2008 and 2009 were approximately 15 mg/L, and represented a large increase over peak values recorded for 2006 and 2007, which were slightly less than 9 mg/L. Like BMR, the impact of elevated TOC concentrations at LRT on lower Mainstem sites is minimal due to the relatively small volume of flow from this source.

Peak TOC concentrations on the lower North Fork (NFL and NFG) in 2009 were similar to those observed in 2008, but considerably higher than in 2006 and 2007. The North Fork tributaries experienced lower 2009 peak TOC concentrations than in the previous year. As usual, seasonal differences in TOC concentrations were also observed between Mainstem and North Fork sites. The North Fork TOC levels remained relatively high throughout the late summer season, after levels at Mainstem sites had decreased dramatically. This longer period of elevated TOC is reflected by the higher late-summer and fall average TOC values at NFL and NFG (Fig. 12). While TOC concentrations on the North Fork are consistently higher than those observed on the Mainstem, the TOC load carried by the Mainstem is greater due to substantially higher flow volume.

Figure 12. 2009 Seasonal Average TOC concentrations at key Upper CLP monitoring sites.



The persistence of elevated TOC levels on the North Fork, and to a lesser degree, the Mainstem site PJW, during periods of low flow suggests the presence of an additional source or sources of TOC other than that mobilized during spring snowmelt. Possible sources of this additional TOC in the North Fork include water released from Halligan and Seaman Reservoirs, and runoff from agricultural land within the North Fork basin. Water released from Long Draw Reservoir on the Mainstem is a potential contributor to the elevated fall average TOC values at PJW. This pattern was not observed in previous years at this site.

3.5 Nutrients

A complete comparison of 2009 data with years 2006 - 2008 was not possible for nutrients due to differences in reporting limits between the former monitoring programs. Those parameters include ammonia (NH_4), nitrite (NO_2), nitrate (NO_3), total phosphorus (TP) and ortho-phosphate (PO_4). For the purpose of this report, the discussion of results only pertains to values above the reporting limits currently used by the FCWQL for 2008 data and beyond.

Current reporting limits are 5 ug/L for ortho-phosphate, 10 ug/L for ammonia and total phosphorus, and 40 ug/L for nitrate and nitrite, and are considerably higher than those used by Dr. Lewis in years 2006 - 2007. Analysis of Total Kjeldahl Nitrogen (TKN) began in 2008.

Ammonia, nitrate, nitrite, and ortho-phosphate are dissolved forms of nitrogen and phosphorus that are readily available for plant and animal uptake. Both TKN and total P serve as aggregate measures of potential nitrogen and phosphorus availability to the system. TKN is a measure of ammonia plus organic nitrogen. Likewise, total P is a measure of dissolved phosphorus as well as phosphorus bound to sediments and organic matter. In aquatic systems, sources of nutrients include animal waste, leaking septic systems, fertilizer run-off and sediment loading.

North Fork. In general, higher concentrations of nutrients were observed on the North Fork than at Mainstem sites, as reflected by values at NFL and NFG (Figures 13.a. - 13.f.). Although frequent spikes of ammonia, nitrate, ortho-phosphate and total phosphorus from 2006 – 2009 were observed at both sites, nutrient spikes at NFG were larger and more frequent because of the influence of Seaman Reservoir, especially in non-runoff times of the year. There were no exceedances of the EPA drinking water quality standard for nitrate (10,000 ug/L) or nitrite (1,000 ug/L).

Elevated concentrations of nitrate, total P and TKN were observed at NFL during spring run-off. These higher concentrations likely occurred in response to flushing of sediment and dissolved nutrients during snowmelt. The 2009 spring concentrations of TKN and total P at NFL were lower than those observed in 2008, a year in which spring run-off was unusually high.

The effects of reservoir releases on downstream nutrient concentrations can be seen at NFG below Seaman Reservoir and NBH below Halligan Reservoir. At NFG, late-summer peaks in total P and ortho-phosphate and elevated ammonia concentrations were observed, and are indicative of low dissolved oxygen concentrations in Seaman Reservoir (See section 4.1). Similarly, spikes in ammonia were observed on the North Fork below Halligan Reservoir (NBH) in all years. The observed spikes in nutrient concentrations at NBH and NFG were not sufficient in size or duration to produce observable nutrient spikes at downstream locations. Nitrite was non-detectable throughout the watershed in 2009.

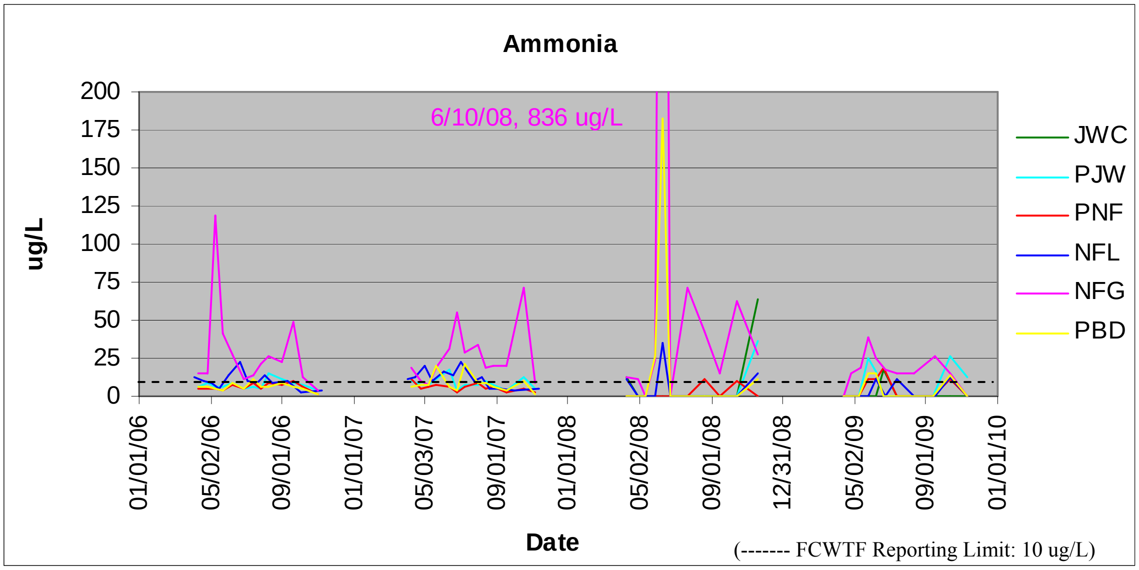
Mainstem. Nitrite and ortho-phosphate were generally not detected above reporting limits on the Mainstem, with the exception of JWC, which occasionally has reportable levels of ortho-phosphate. Ammonia concentrations were generally below 30 ug/L on the Mainstem, with the exception of BMR, which had relatively high ammonia values. For example, on 4/27/09, the concentration of ammonia in waters released from BMR was 289 ug/L, while at the nearest downstream site JWC, concentrations were below 10 ug/L.

Nitrate concentrations were low at all Mainstem sites in 2009. In fact, at the lower Mainstem sites PNF and PBD, nitrate was non-detect until 11/9/09 when it was detected at low concentrations (42 and 40 ug/L, respectively). These results were in contrast the previous three years which displayed a seasonal pattern of highest concentrations prior to spring runoff followed by a decrease during the high flow period and a return to higher values in the late summer. From 2006 – 2009, the highest peak nitrate concentrations were generally observed at the high-elevation site, PJW, where concentrations ranged between 116 – 157 ug/L. However, higher nitrate concentrations were occasionally seen at BMR, JWC and LRT. Potential factors contributing to the high nitrate concentrations at the high-elevation site, PJW, include nitrate accumulation in the snowpack in response to over-winter soil microbial activity (Brooks et. al, 1996) and atmospheric nitrogen deposition, a well-documented source of nitrate in high-elevation watersheds of the Colorado Front Range (Campbell et. al, 1995).

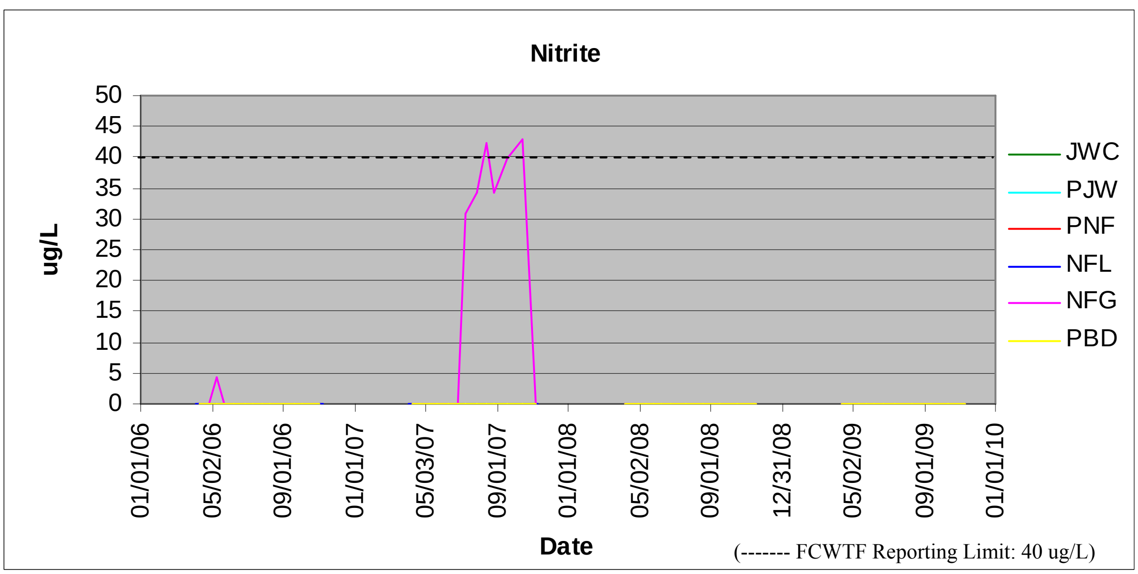
Similar to the North Fork, the highest concentrations of TKN and Total P on the Mainstem typically occur during spring runoff, followed by sharp declines during the summer months. Total P concentrations at PNF were similar to the previous three years, with a 2009 peak concentration of 25 ug/L. The 2009 peak TKN concentration at PNF was 421 ug/L.

Figure 13 (a-f). Nutrient concentrations at key Upper CLP monitoring sites.

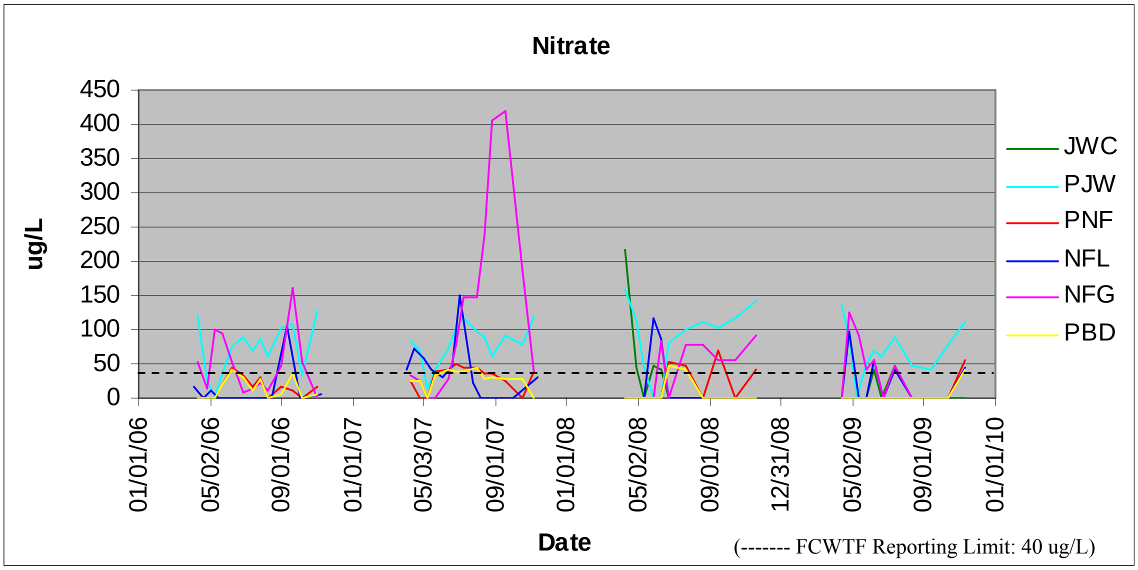
13.a. Ammonia (NH_3)



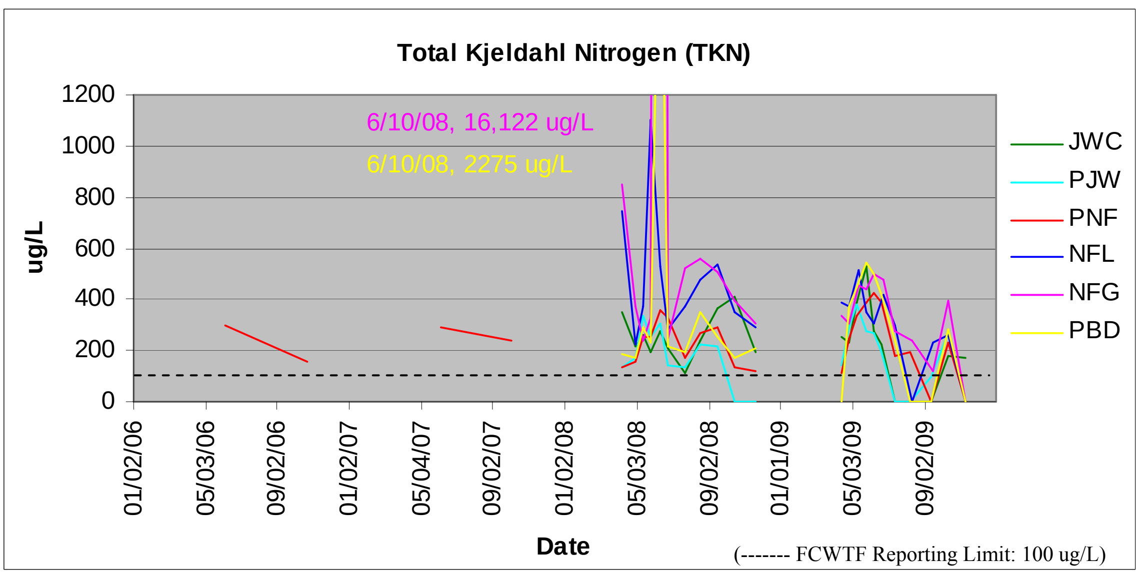
13.b. Nitrite (NO_2)



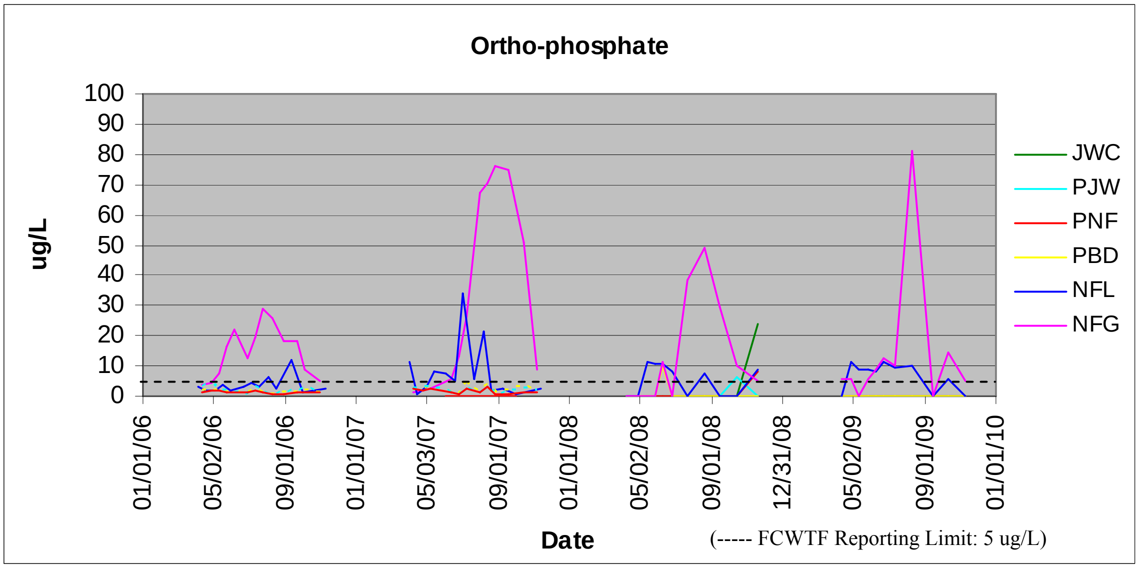
13.c. Nitrate (NO_3)



13.d. Total Kjeldahl Nitrogen (TKN)

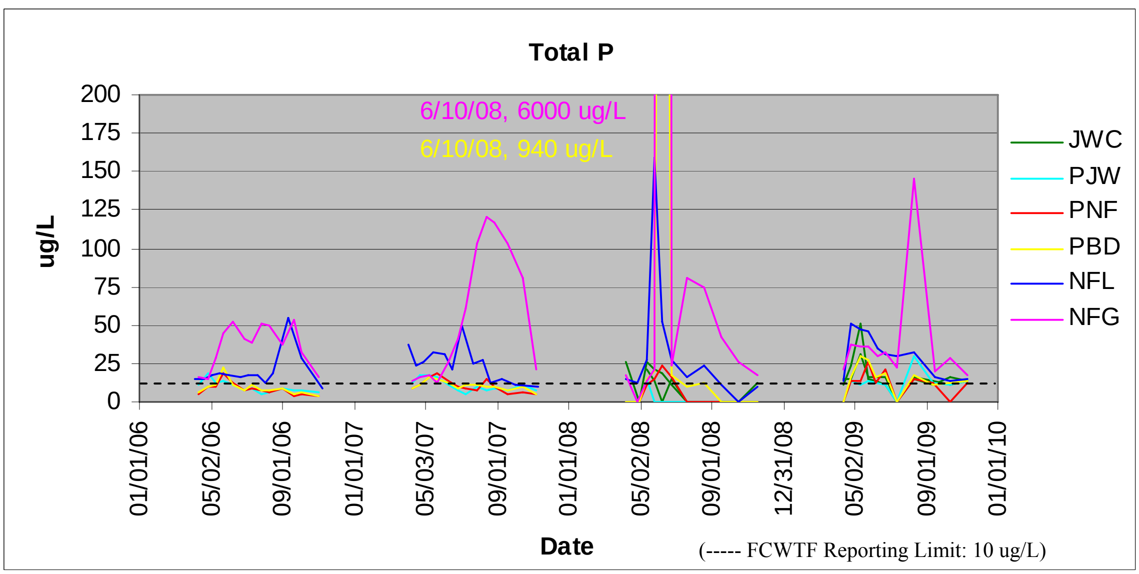


13.e. Ortho-phosphate (PO_4)



* Values in 2006 – 2007 reported as Soluble Reactive Phosphorus (SRP)

13.f. Total Phosphorus (P)



3.6 Metals

Metals are sampled twice annually at two sites, PNF and NFG. A spring sample was collected on 5/26/09 and a fall sample was collected on 11/09/09. All metals are analyzed for dissolved fractions except iron (Fe), which is analyzed for both total and dissolved fractions. In 2009, dissolved concentrations of silver (Ag), cadmium (Cd), nickel (Ni), lead (Pb) and zinc (Zn) were not detected at concentrations above reporting limits.

Dissolved iron concentrations at PNF were 155 and 53 ug/L on the spring and fall sampling dates, respectively. NFG had similar values for dissolved iron, of 128 and 44 ug/L. As expected, dissolved iron constituted only a small fraction of the total iron at both NFG and PNF. Total iron concentrations at PNF were 620 ug/L and 82 ug/L for the spring and fall dates, respectively. NFG concentrations of total iron were similar at 615 and 54 ug/L. Total concentrations at both sites on 5/26/09 exceeded the EPA secondary drinking water maximum contaminant level (MCL) for iron of 300 ug/L. Secondary drinking water MCLs are guidelines for constituents that may cause aesthetic effects such as discoloration, but do not pose a threat to public health. Because water treatment processes remove much of the iron in raw water supplies, the iron concentrations reported for the Upper CLP are not expected to have adverse effects on finished water supplies.

Reportable concentrations of copper (Cu) and chromium (Cr) were also observed at PNF during the spring sampling event. Copper was detected at 6.28 ug/L and chromium was detected at 0.83 ug/L. Neither of the observed concentrations exceeded the EPA drinking water standards.

3.7 Pathogens: *Cryptosporidium* and *Giardia*

Cryptosporidium and *Giardia* testing on the North Fork sites above and below Halligan Reservoir began in 2006. In 2008, the NDC sampling site was moved upstream of the confluence with Dale Creek to accommodate potential future expansion of Halligan Reservoir. This site represents the water quality of the North Fork flows, above Dale Creek, as source waters to Halligan Reservoir. Samples on the Mainstem Poudre are collected from the raw Poudre water supply at the FCWTF, but are considered representative of values at PNF since there are no additional inflows to the water supply between the intake structure at PNF and the FCWTF.

Giardia is more abundant than *Cryptosporidium* on both Mainstem and North Fork (Fig. 14 and 15). From 2006 - 2009, *Giardia* was present at levels ranging from 0 to 35 cysts/L, whereas *Cryptosporidium* was frequently not detected, with no observed values exceeding 0.8 cysts/L.

The Mainstem had higher concentrations of both pathogens than the North Fork in 2006 and 2007; however, beginning in 2008, this trend was reversed due to an increase in concentrations at NDC and a decrease at PNF. The outflows from Halligan and Seaman Reservoirs (NBH and NFG, respectively) consistently had the lowest *Giardia* concentrations. *Cryptosporidium* was similar above and below Halligan Reservoir (at NDC and NBH, respectively). *Cryptosporidium* and *Giardia* both show an increase from

2006 through 2008 at NDC, although no change was observed from 2008 to 2009. Because of the change in sampling site location, it is not possible to know whether the observed increase from 2006 -2008 is due to changes that occurred within the watershed, or is a response to site-specific conditions. A general seasonal trend of increasing *Giardia* concentrations did, however, occur throughout the spring and summer months at NDC. In 2009, concentrations peaked on 9/15/09 at 24 cysts/L.

Testing for pathogens below Seaman Reservoir at NFG began in 2008. In 2008 and 2009, *Giardia* was generally not detected. In contrast, relatively strong spikes of *Cryptosporidium* were observed in both years, and on 4/14/09, NFG reported the highest concentration on record (0.78 cysts/L) for all sites.

Figure 14. Concentrations of *Giardia* on Mainstem and North Fork CLP.

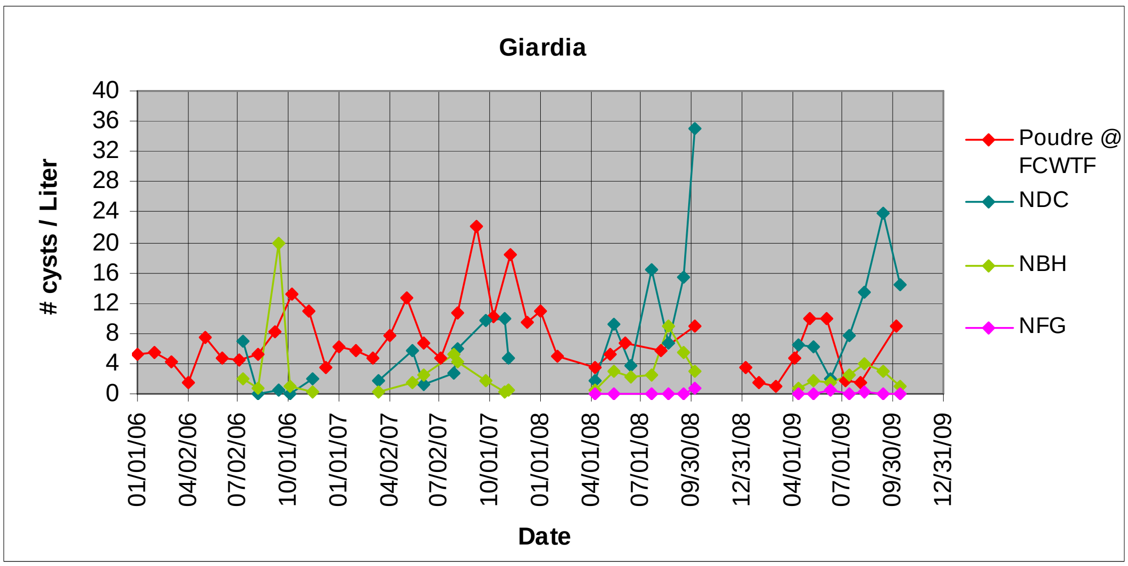
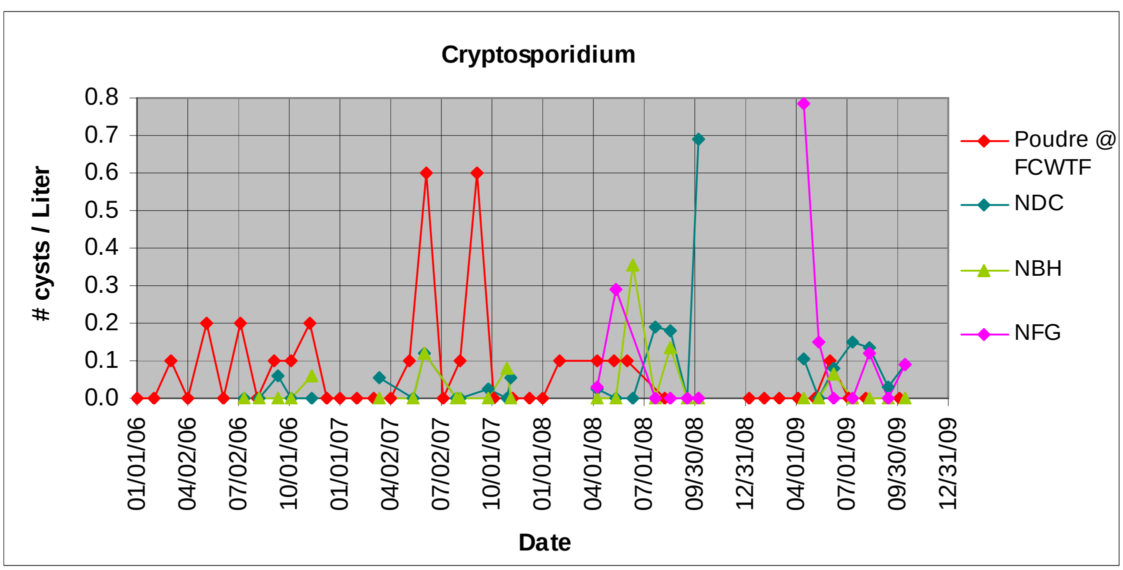


Figure 15. Concentrations of *Cryptosporidium* on Mainstem and North Fork CLP.



3.8 Total Coliforms and *E. coli*

Total coliforms and *E. coli* samples were collected from 2005 - 2007 as part of the City of Greeley's water quality monitoring program as well as by the City of Fort Collins. A comparison of all available data suggests that differences in the concentrations reported by the two programs are larger than what would be expected by inter-annual variation and are not supported by similar trends in nutrients, other water quality parameters or reported events within the watershed. Therefore, the data are not considered comparable and only results from the FCWQL are presented in this report.

PNF was the only site for which a complete data set from the FCWQL was available for 2006 – 2009. In 2009, values for *E. coli* and total coliforms were within the range of values observed from the previous three years at PNF (Fig. 16 & 17). In general, PBD had similar concentrations of total coliforms as PNF and *E. coli* concentrations. The major exception was a spike on 6/10/08 during the unusually high spring run-off on the North Fork.

Consistent with 2008 results, the North Fork showed higher concentrations of both total coliforms and *E. coli* than the Mainstem in 2009, although there were some notable differences in North Fork concentrations between the two years. For example, in 2009, peak total coliform concentration at NFG was nearly three times greater (14,136 colonies/100 mL) than in 2008 (4352 colonies/100 mL). NFL was added as a sample site in 2009 to gain a better understanding of the sources of total coliforms and *E. coli* within the North Fork watershed. Results showed that although peak total coliform concentrations above and below the reservoir (at NFL and NFG, respectively) coincided, the concentration of total coliforms at NFL was considerably less (2851 colonies/100 mL) than at NFG (14,136 colonies/100 mL). Concentrations of *E.coli* exceeded the CDPHE recreational standard of 126 colonies/100mL at both NFL and NFG.

Unlike total coliforms, the timing of peak *E. coli* concentrations at NFL and NFG did not coincide. At NFG, *E. coli* peaked during spring run-off, followed by a sharp decrease. In contrast, *E. coli* concentrations at NFL continued to increase after spring runoff and remained elevated throughout the year at levels higher than at NFG. These results suggest that while the North Fork drainage is an important source of *E.coli* and total coliforms to Seaman Reservoir, there is no clear relationship between concentrations above (at NFL) and below the reservoir (at NFG). The lack of direct relationship is likely due to a complex set of interacting factors, some of which may include the timing and magnitude of stream flow at NFL, reservoir holding time and release rates. The relationships between total coliforms and *E.coli* concentrations on the North Fork and in Seaman Reservoir are explored in more detail in Section 4.6.

Figure 16. Concentrations of total coliforms at key Upper CLP monitoring sites

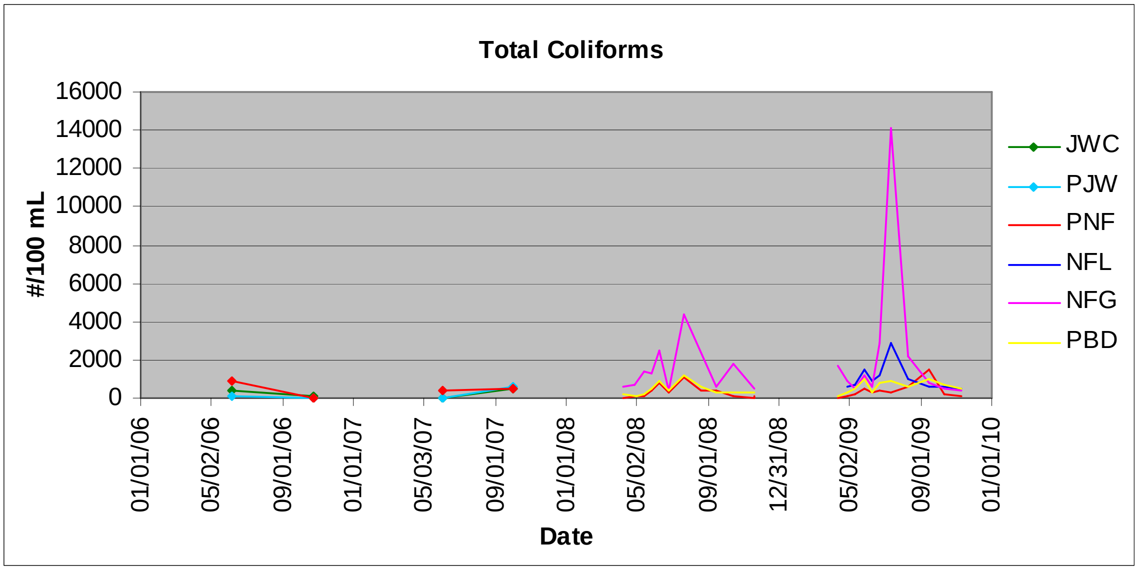
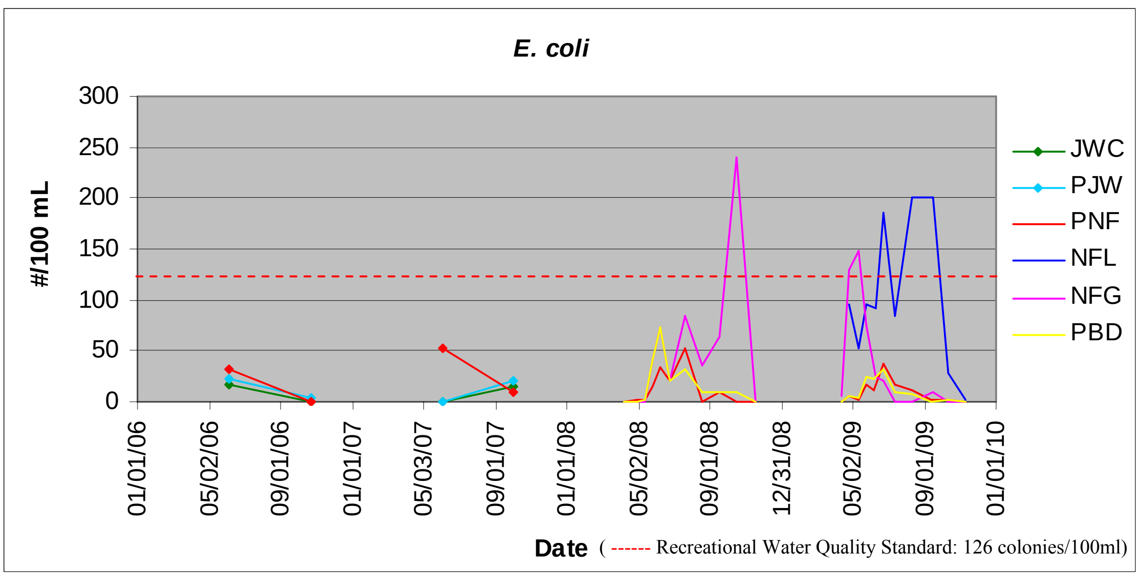


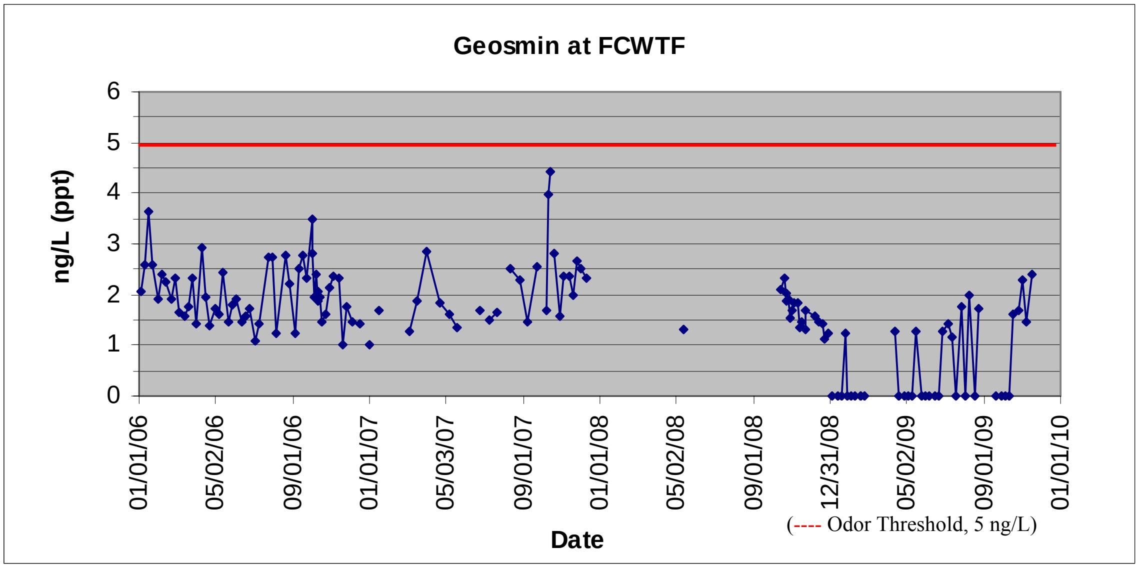
Figure 17. Concentrations of *E. coli* at key Upper CLP monitoring sites.



3.9 Geosmin

Geosmin samples for the Upper CLP Mainstem were collected from January through December at the FCWTF raw Poudre sample station. Concentrations of all samples were below the 5 parts per trillion (ppt) odor threshold; values ranged from below detection to 2.4 ppt. The 2009 values were similar to 2006 – 2007 concentrations, but there were considerably more sample dates on which geosmin was not detected (Fig. 18).

Figure 18. Geosmin concentration of the Mainstem CLP, sampled at the FCWTF.



4.0 SEAMAN RESERVOIR RESULTS

4.1 Temperature, Dissolved Oxygen, pH, and Conductivity Profiles

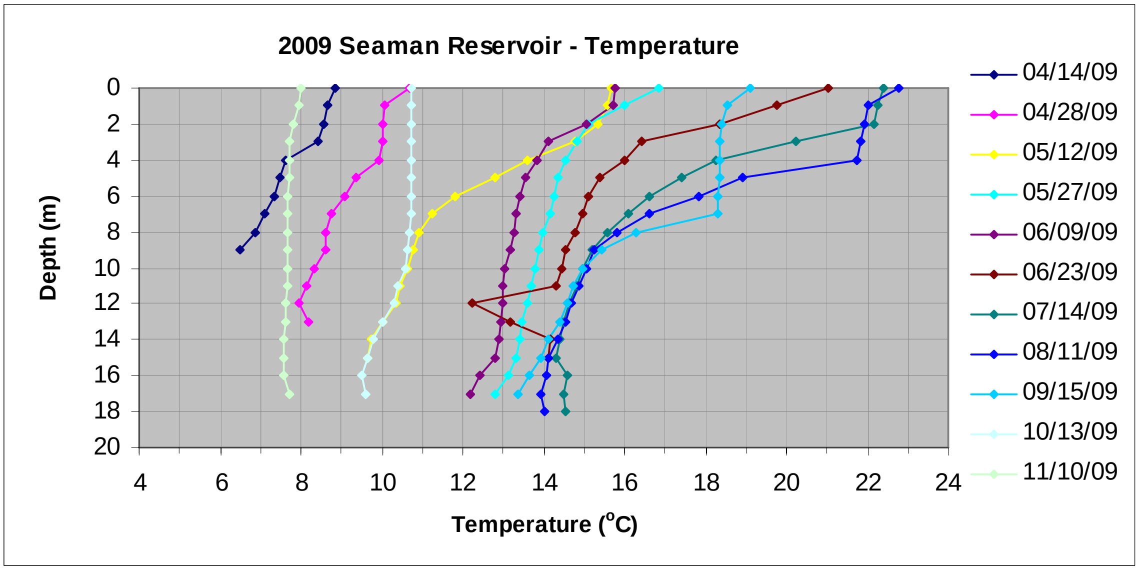
In 2009, the onset of thermal stratification in Seaman Reservoir began in April, with a strong thermocline becoming established by early May (Fig.19.a). Stratification persisted throughout the late-summer months. Reservoir turnover, which occurs as surface water cools and begins to mix with the bottom water, is characterized by an increasingly uniform temperature profile from top to the bottom of the reservoir. In 2009, turnover in Seaman Reservoir was evident by the mid-October sampling date (10/13/09). The timing of thermal stratification and turnover were similar to previous years (Lewis 2007). Reservoir dynamics in 2008 differed from other years due to the reservoir operations related to the draw-down and subsequent refilling as detailed in the 2008 annual report (Oropeza and Billica, 2009).

As observed in previous years, the concentration of dissolved oxygen (D.O.) in the lower waters decreased progressively from the onset of thermal stratification until fall turnover (Fig 19.b). At depth, D.O. concentrations decreased to below 4 mg/L in July and reached anoxic conditions (0 mg/L) during the months of August and September. The duration of low bottom D.O. concentrations in 2009 was similar to the previous year, although complete D.O. depletion did not occur in 2008 (Fig. 20). Prolonged periods of low D.O. concentrations are of concern because they can mobilize trace metals (e.g. manganese) and phosphorus from the bottom sediments.

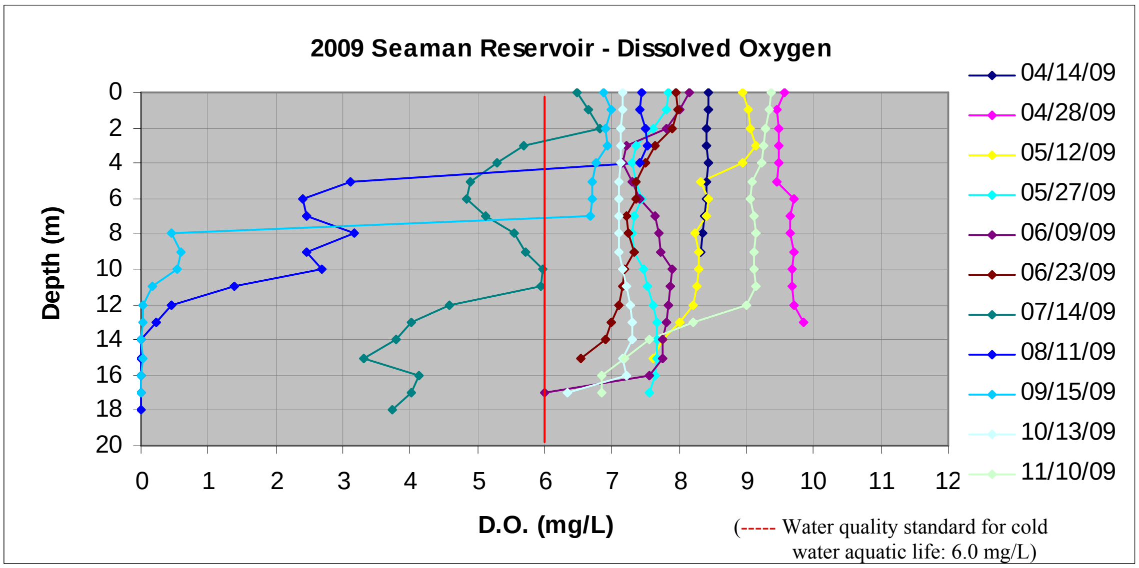
In general, pH decreases with decreasing temperature and D.O. concentrations. As expected, Seaman Reservoir profiles show that pH minima occur at the bottom and during the summer months, when the reservoir is thermally stratified and D.O. is also at a minimum. In 2009, pH values ranged from 7.6 to 8.4 at the surface and 6.8 to 8.3 at the bottom (Fig.19c). Conductivity values were higher under well-mixed conditions, and did not vary substantially with depth. In contrast, conductivity was lower when the reservoir was stratified and values varied substantially between the epilimnion and the hypolimnion especially in the months of July through September (Fig. 19d).

Figure 19 (a-d). 2009 Seaman Reservoir Profiles

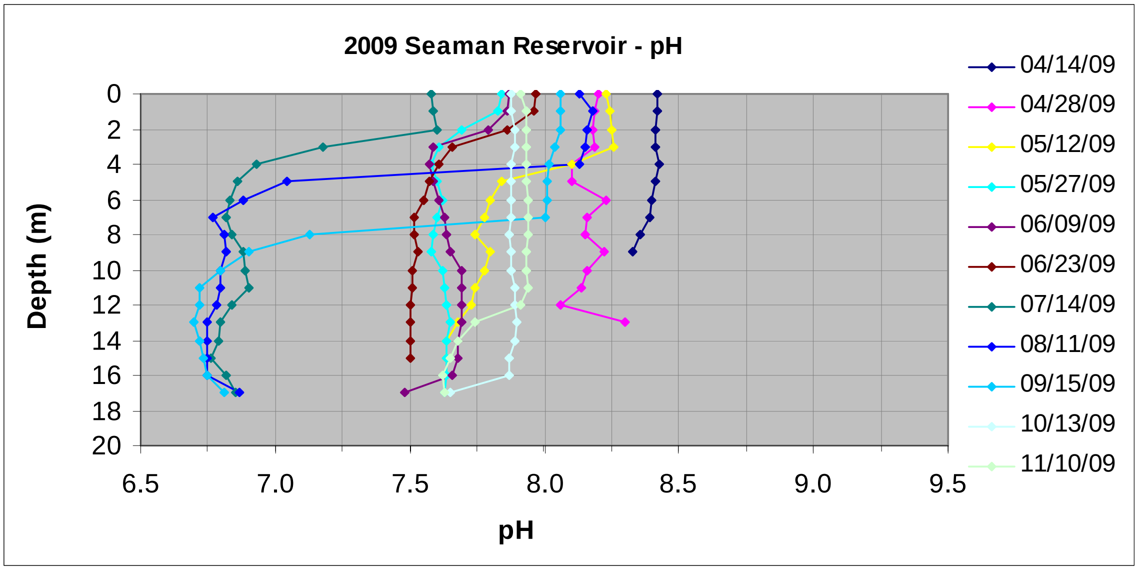
19.a Temperature



19.b. Dissolved Oxygen



19.c. pH



19.d. Conductance

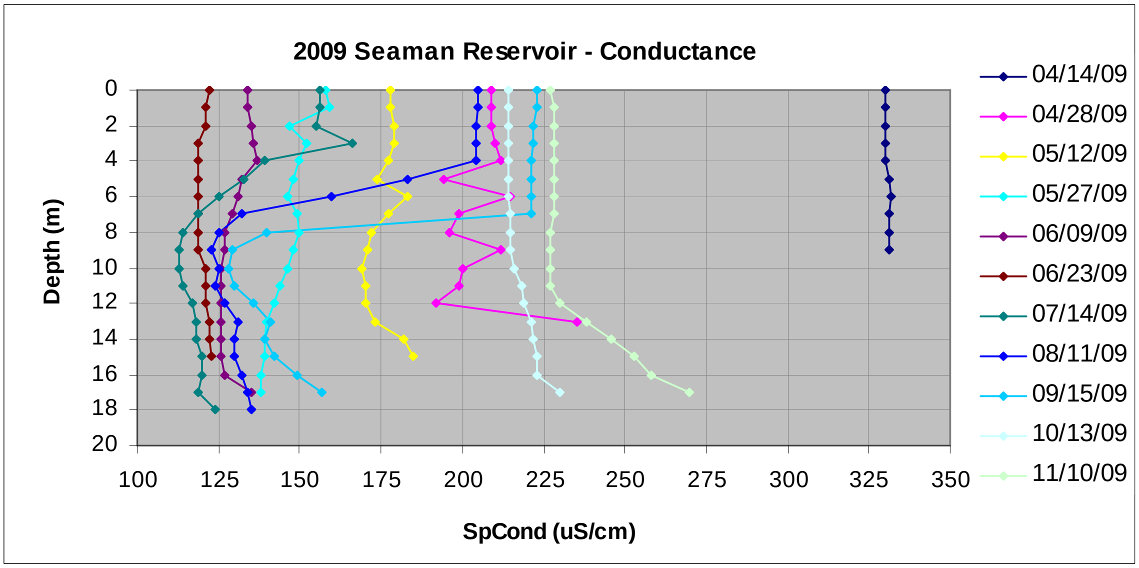
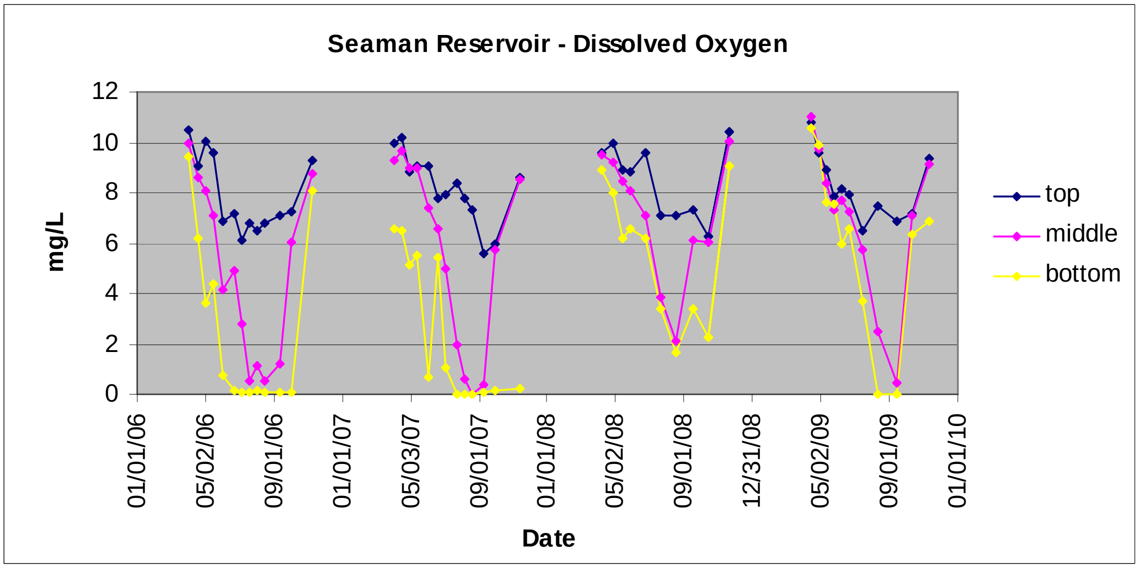


Figure 20. Dissolved oxygen concentrations at the top, middle and bottom of Seaman Reservoir.



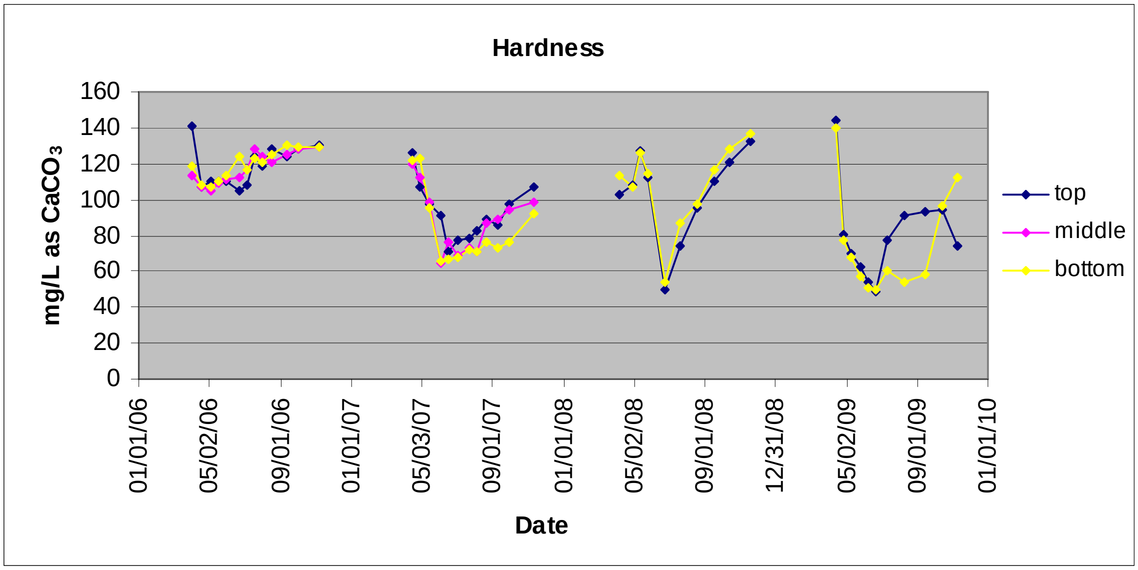
4.2 General Parameters: Hardness and Alkalinity

Hardness and alkalinity both track closely on top and bottom (Fig. 21.a and 21.b). In 2009, the seasonal trend in hardness was similar to 2007 and 2008 during which a strong spring decrease in hardness was observed, followed by a steady return to early spring values. 2006 hardness values decreased less during spring runoff than in other years, although early- and late-season values were similar.

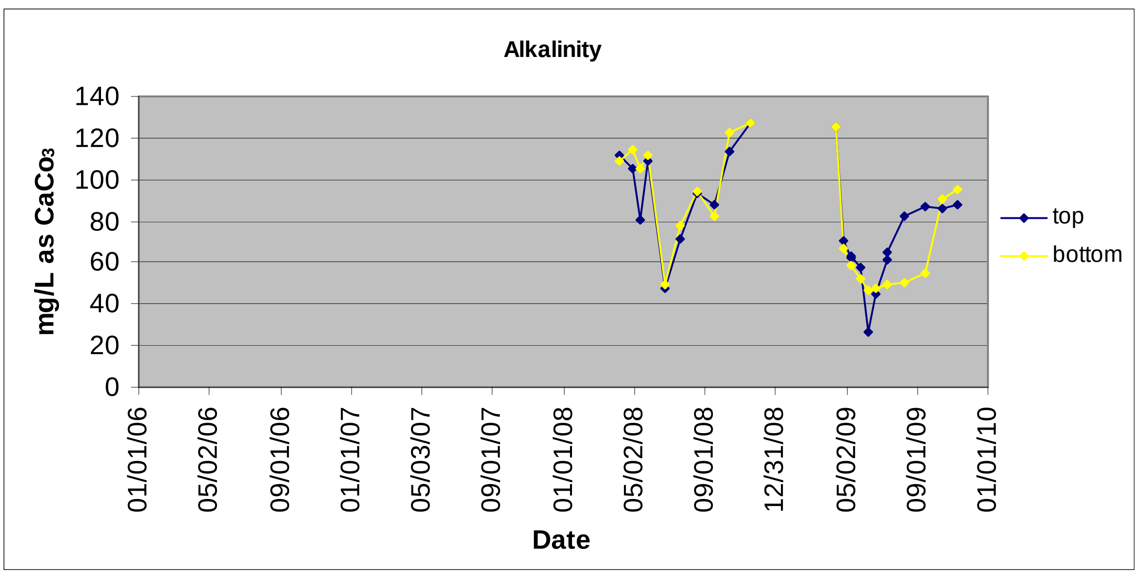
The 2008 and 2009 alkalinity data followed a similar seasonal pattern as hardness, with an exception on 6/9/09 where alkalinity decreased to a minimum of 20.4 mg/L compared to 50.2 mg/L for hardness. Alkalinity data were not available for 2006 or 2007. For both parameters, minima occurred during spring runoff.

Figure 21 (a-b). General water quality parameters at Seaman Reservoir: Hardness and Alkalinity.

21.a. Hardness



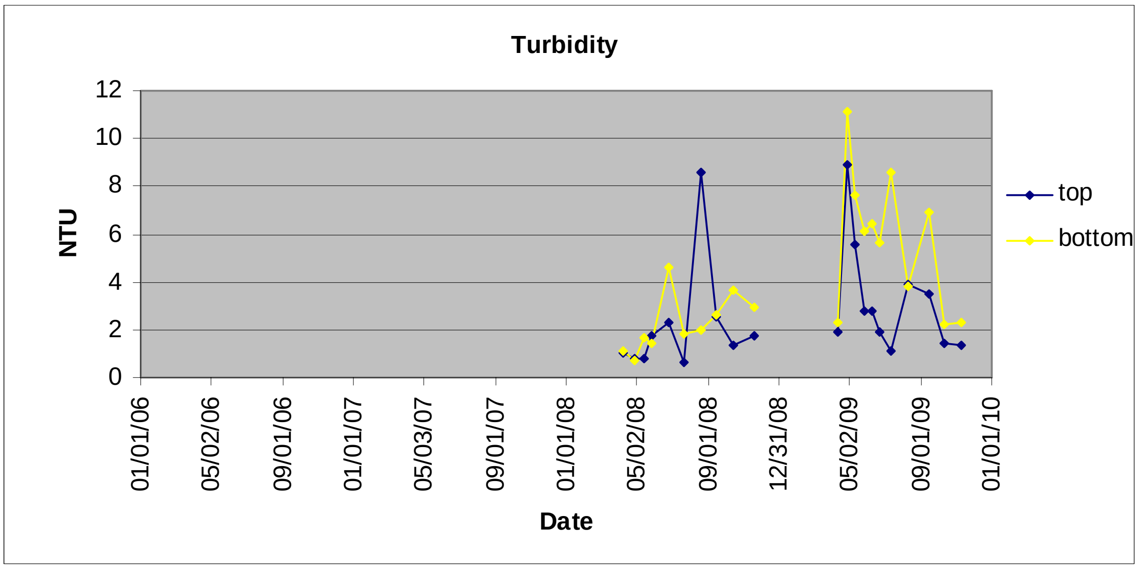
21.b. Alkalinity



4.3 Turbidity, Chlorophyll-a and Secchi Depth

Turbidity values at the top of Seaman Reservoir were similar to values observed in 2008. The samples from the reservoir bottom were, in general, more turbid than the previous year (Fig. 22). In 2009, turbidity values on the top ranged from 1.1 to a peak value of 8.9 NTU, which coincided with the initial spike in upstream flow at NFL on 4/27/09 and the flush of sediments transported by the snowmelt run-off (Fig. 5). The bottom of the reservoir was more turbid than the surface throughout the year, as reflected by turbidity values that ranged from 2.3 to 11.1 NTU.

Figure 22. Turbidity in Seaman Reservoir.



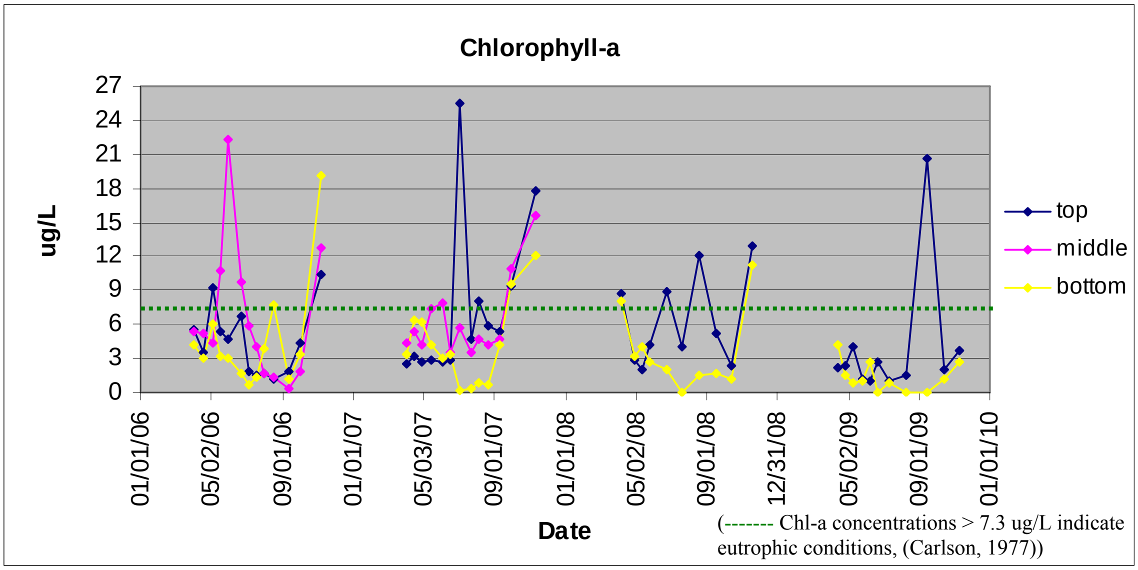
Chlorophyll-a concentrations in Seaman Reservoir were within the range observed for the previous three years (Fig. 23). From 2006 to 2008, chlorophyll-a was consistently higher on the top than on the bottom, with the exception of a late season spike in bottom concentrations which occurred in 2006. 2009 contrasted to previous years in that the top and bottom chlorophyll-a concentrations were similar, except for the peak in top concentrations on 9/15/09.

Epilimnetic (top) chlorophyll-a values greater than 7.3 ug/L may indicate eutrophic conditions, based on Carlson's Trophic State Index (TSI) for a TSI $\geq$ 50 as calculated from (Carlson, 1977):

$$TSI\ (Chl\text{-}a) = 30.6 + 9.81 \times \ln(Chl\text{-}a \text{ in ug/L}).$$

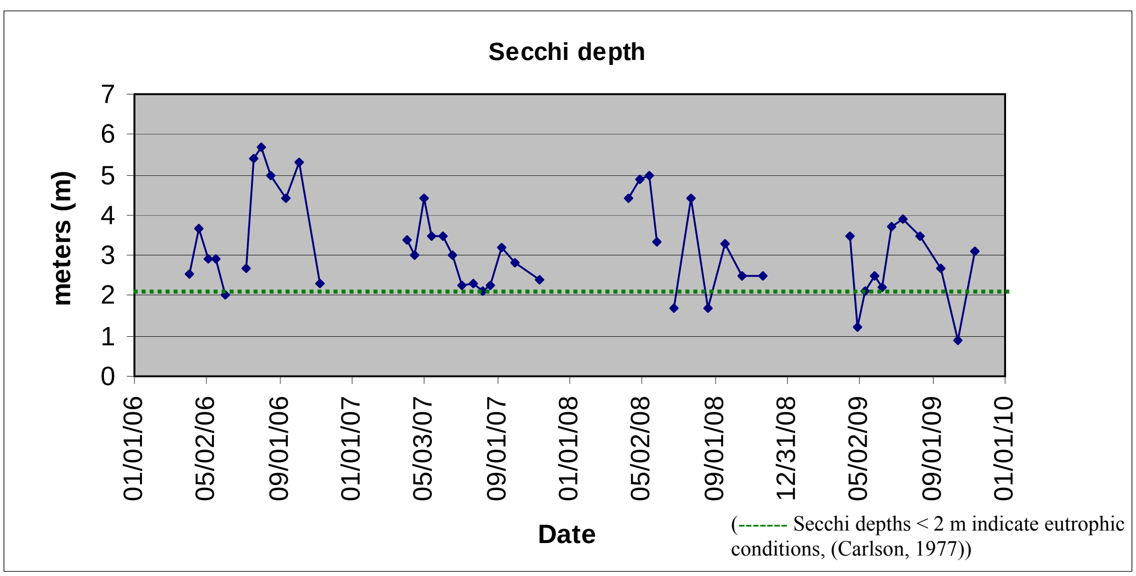
From 2006 through 2009, Seaman Reservoir generally had chlorophyll-a concentrations less than 7.3, although higher concentrations were occasionally observed.

Figure 23. Chlorophyll-a concentrations in Seaman Reservoir.



Secchi depth results indicate that Seaman Reservoir experienced a general decrease in water clarity from 2006 through 2009 (Fig. 24). In 2008 and 2009, secchi depth minima (periods of lowest light penetration) coincided with periods of high turbidity and chlorophyll-a levels, suggesting that algal growth may contribute to turbidity and decreased clarity in the reservoir, especially during the summer months (Fig. 25).

Figure 24. Secchi depth in Seaman Reservoir.

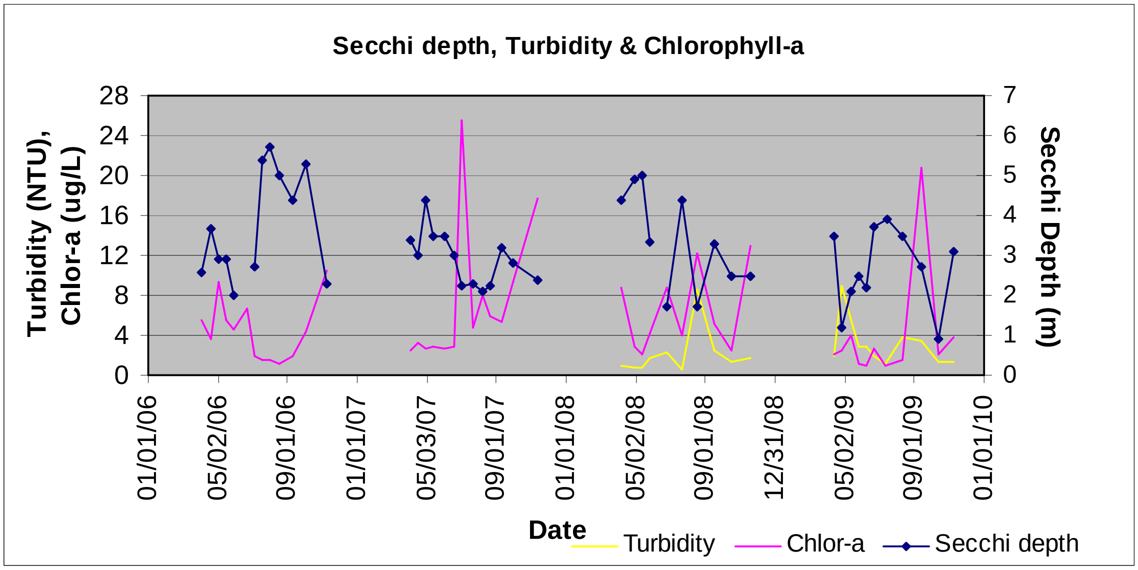


In 2009, the secchi depth ranged from 0.9 to 3.9 m with the maximum depth occurring mid-summer; seasonal trends were not consistent year to year. Note that secchi depth values less than 2.0 m may indicate eutrophic conditions based on Carlson's TSI for a TSI ≥ 50 as calculated from (Carlson, 1977):

$$\text{TSI (secchi depth)} = 60 - 14.41 \times \ln(\text{secchi depth in meters}).$$

From 2006 through 2009, Seaman Reservoir secchi depth values were generally above 2.0 m, although there were several occasions in 2008 and 2009 in which secchi depth was less than 2.0 m.

Figure 25. Comparison of secchi depth, turbidity and chlorophyll-a concentrations in Seaman Reservoir.



4.4 Nutrients

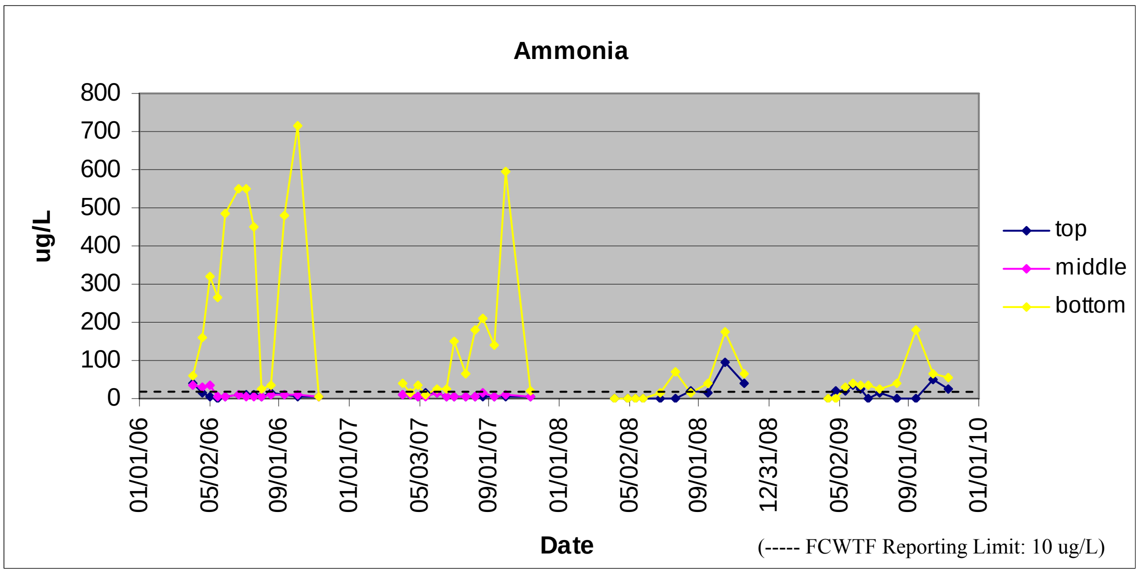
As seen in previous years, concentrations of nitrate, ammonia, ortho-phosphate and total phosphorus at the bottom of Seaman Reservoir peaked during the period of lowest observed pH and D.O. values in the hypolimnion, from August 11th to September 19th, 2009 (Figures 26.a. – 26.f.). The late season peaks in nitrate, ortho-phosphate and total phosphorus (TP) at the reservoir bottom were significantly higher in 2009 than in 2008 because of the expanded period of low dissolved oxygen over the previous year. Peak ammonia concentrations at the reservoir bottom were similar to 2008, but lower than observed in 2006 and 2007. However, in contrast, ammonia concentrations at the surface were higher in 2008 and 2009 than in the earlier years.

During other times of the year, concentrations of dissolved nutrients are generally low at the top and bottom of the reservoir. 2009 was an exception for nitrate; unusually high concentrations observed at the surface during peak runoff (258 ug/L on 4/27/09) were roughly four times higher than the next highest value on record from 2006 - 2009 (60 ug/L on 4/4/06). In addition, top and bottom nitrate values were generally higher and more variable throughout the year than observed in the previous three years. The high 2009 peak nitrate values coincide to the early season peak in snowmelt runoff at NFL and the related peak in reservoir turbidity. These results suggest that either a particularly large load of nutrients was delivered from the upper North Fork drainage, or that the volume of flow associated with the initial early spike in runoff (4/23/09) was not sufficient to dilute the nutrients to concentrations seen in previous years.

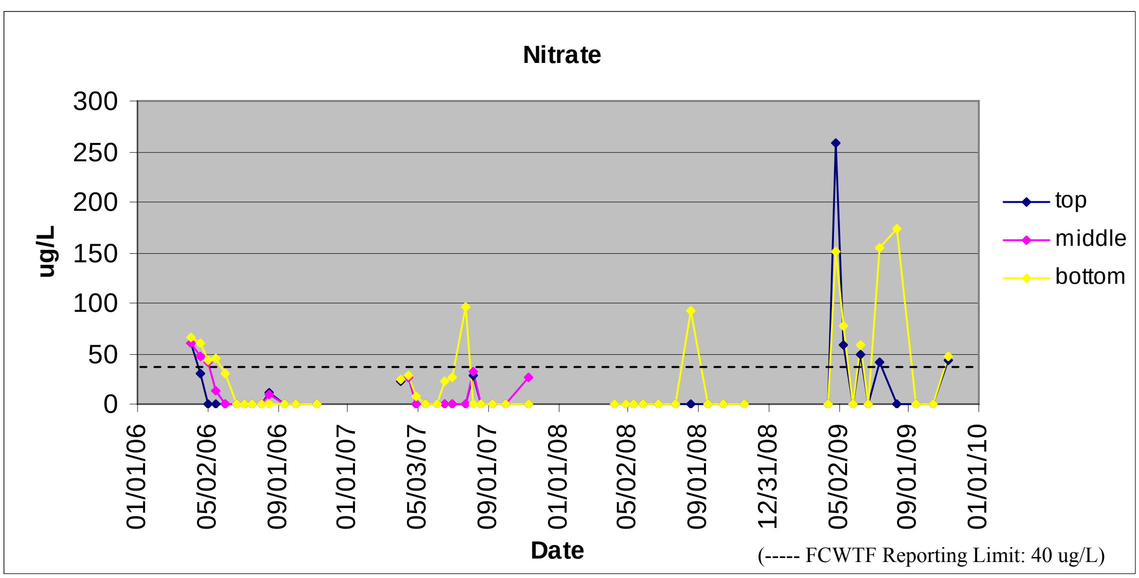
Nitrite is generally not detected in either the top or bottom of the reservoir; the large spike in bottom concentrations that occurred in July 2007 (28.3 ug/L) provided the exception. The cause of the 2007 nitrite spike is unknown. TKN concentrations are similar at the top and bottom of the reservoir and track closely the seasonal patterns of ammonia and nitrate, although overall concentrations are considerably higher (235 – 619 ug/L in 2009). A late-season increase in nutrients at the top of the reservoir (with the exception of nitrite) was observed in 2009, and is likely due to redistribution of bottom nutrients during reservoir turnover.

Figure 26 (a-f). Nutrient concentrations in Seaman Reservoir.

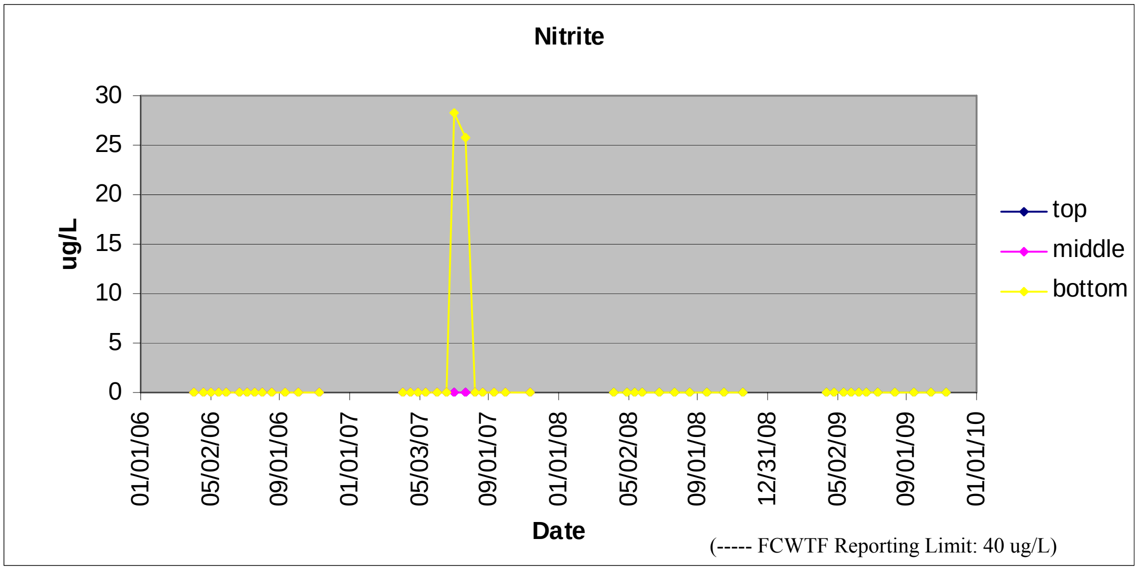
26.a. Ammonia (NH_3)



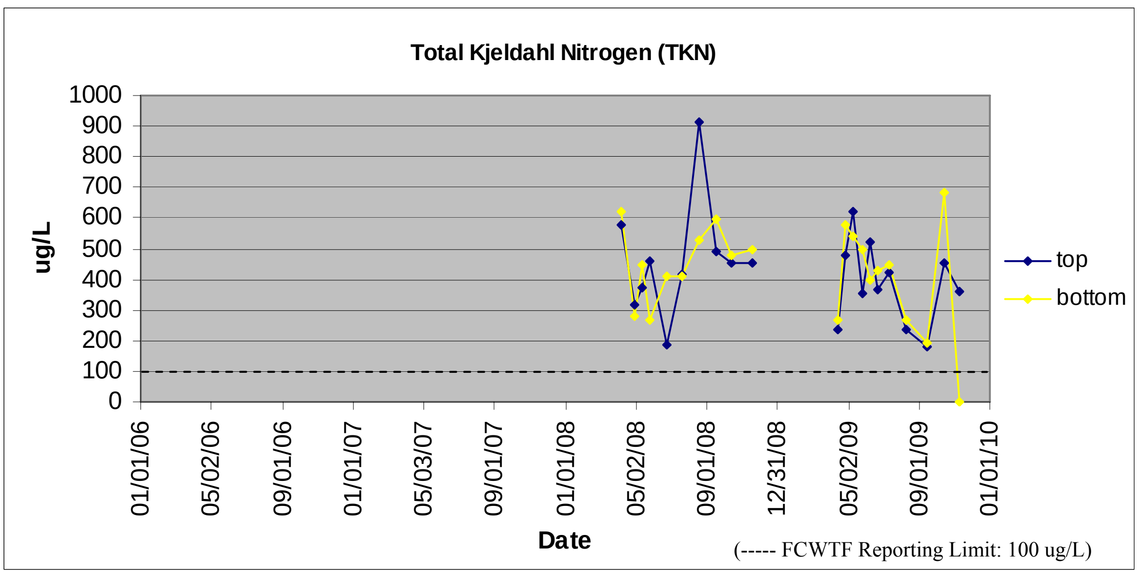
26.b. Nitrate (NO_3)



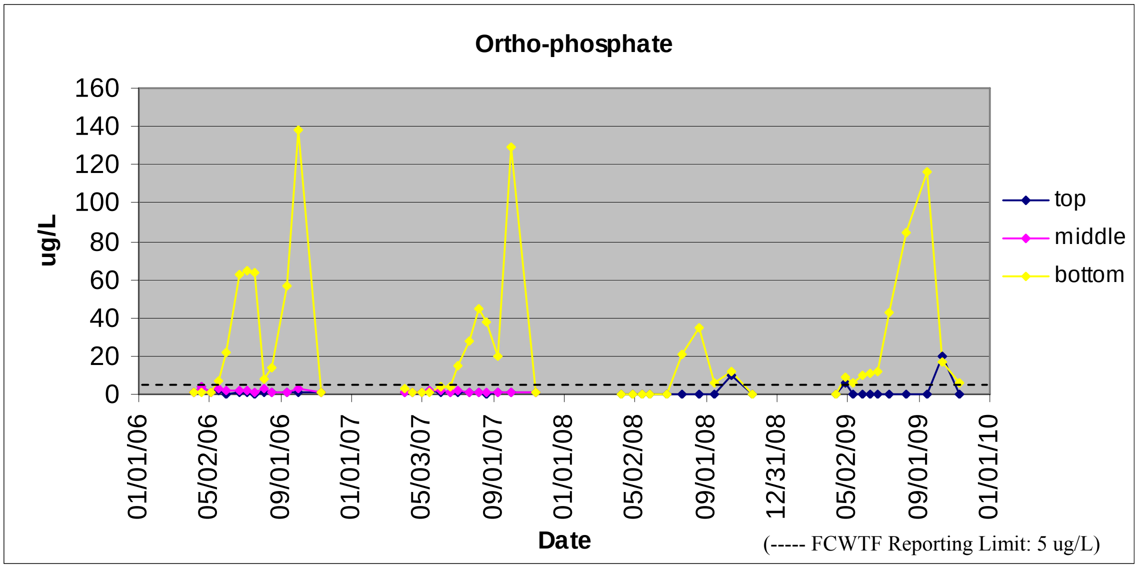
26.c. Nitrite (NO_2)



26.d. Total Kjeldahl Nitrogen (TKN)

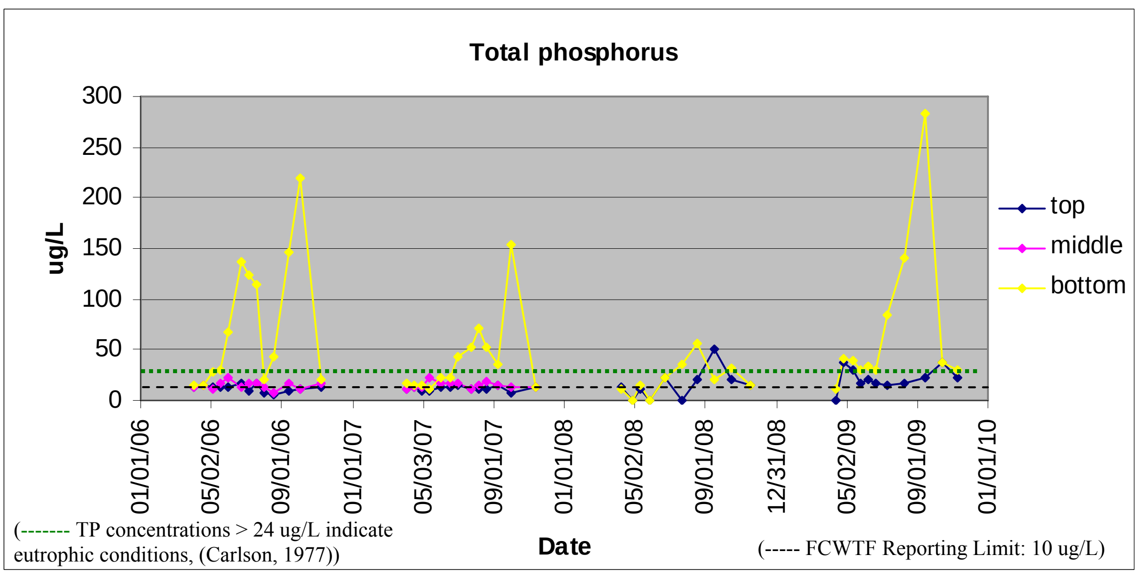


26.e Ortho-phosphate (PO_4)



* Values in 2006 – 2007 reported as Soluble Reactive Phosphorus (SRP)

26.f. Total Phosphorus (P)



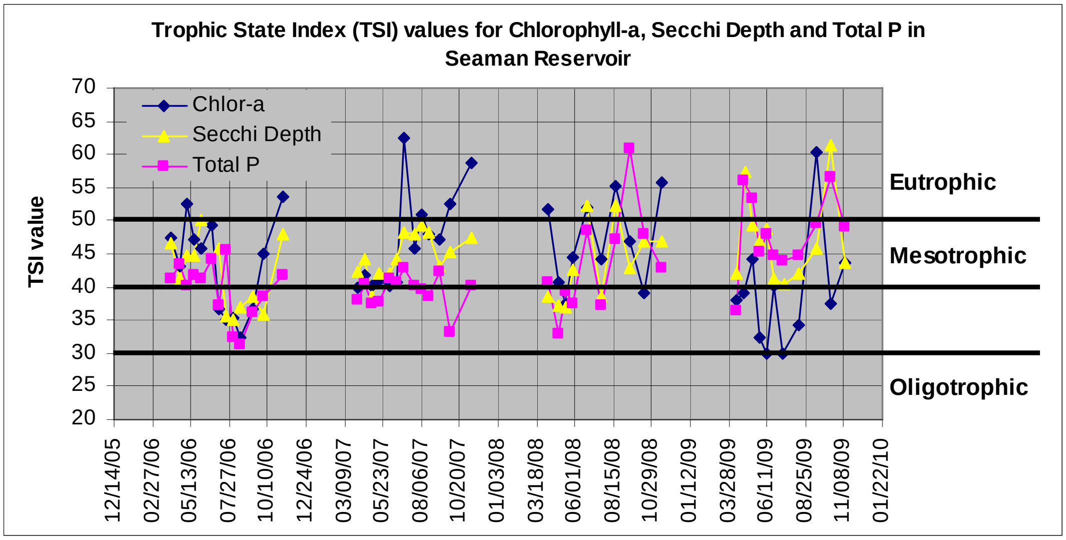
According to Carlson's TSI, epilimnetic (top) total P concentrations above 24 ug/L may indicate eutrophic conditions, corresponding to a TSI ≥ 50 as calculated from (Carlson, 1977):

$$\text{TSI (total P)} = 4.15 + 14.42 \times \ln(\text{total P in mg/L}).$$

In 2006 and 2007, surface total P concentrations in Seaman Reservoir were consistently below 24 ug/L. Concentrations increased slightly in 2008 to 2009 and resulted in four events in which total P concentrations were within the eutrophic range.

For comparison purposes, TSI values for total P, chlorophyll-a and secchi depth were plotted together in Figure 27.

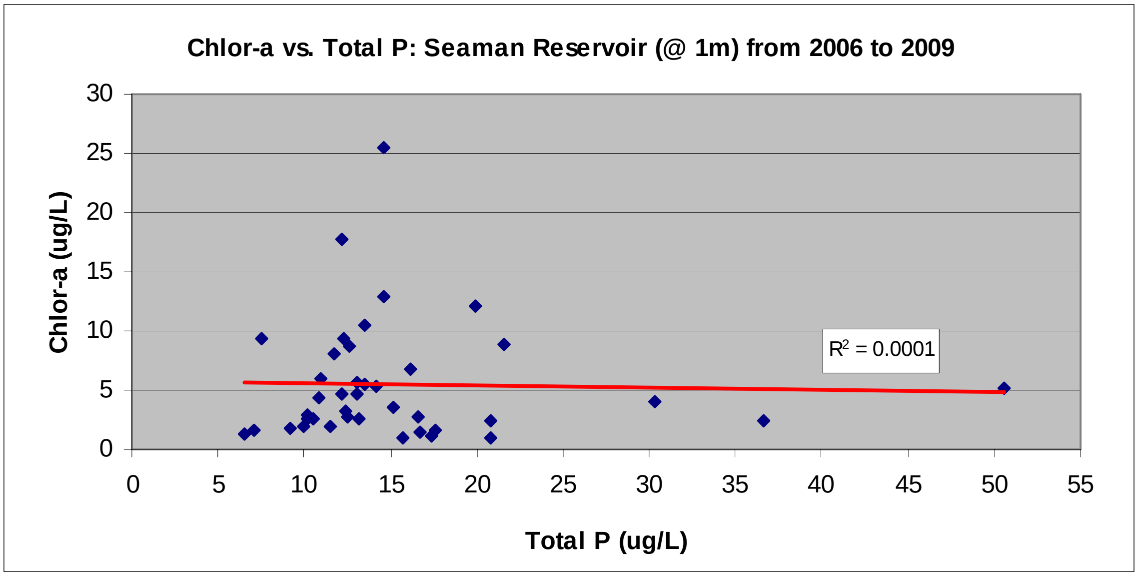
Figure 27. Carlson's Trophic State Index (TSI) values for chlorophyll-a, secchi depth and total P in Seaman Reservoir.



Possible interpretations of the relationships between chlorophyll-a, secchi depth and total phosphorus TSI values is provided by Wetzel (2001, pg. 284). Accordingly, in 2006 and 2007, phosphorus appears to be the limiting nutrient, as indicated by the fact that the total phosphorus TSI is generally lower than the chlorophyll-a TSI. 2008 marks a possible change in the reservoir nutrient status, as demonstrated by an increased similarity between the three indices (note, however, that there was a change in laboratory in 2008, from Dr. Bill Lewis' lab prior to 2008 to the City of Fort Collins WQL beginning in 2008). While algal growth in Seaman Reservoir appears to have been phosphorus limited throughout much of 2008 (TN:TP $\geq$ 33:1), TSI values for total P exceeded chlorophyll-a TSI values during late summer, suggesting a period of N-limitation (TN:TP < 33:1). In 2009, algal growth appears to have been N-limited over much of the growing season, as shown by chlorophyll-a TSI values that were generally much lower than TSI values for total P. Alternatively, algal growth (as indicated by chlorophyll-a) may have been light limited due to the presence of non-algal sources of turbidity, including suspended sediments and dissolved organic matter, as indicated by higher TSI values for secchi depth than for chlorophyll-a.

Chlorophyll-a versus total P is plotted on Figure 28 using data collected at 1 meter depth from Seaman Reservoir. There was no direct relationship observed between chlorophyll-a and total P concentrations, despite the fact that algal growth appears to be limited primarily by phosphorus availability from 2006 through 2008.

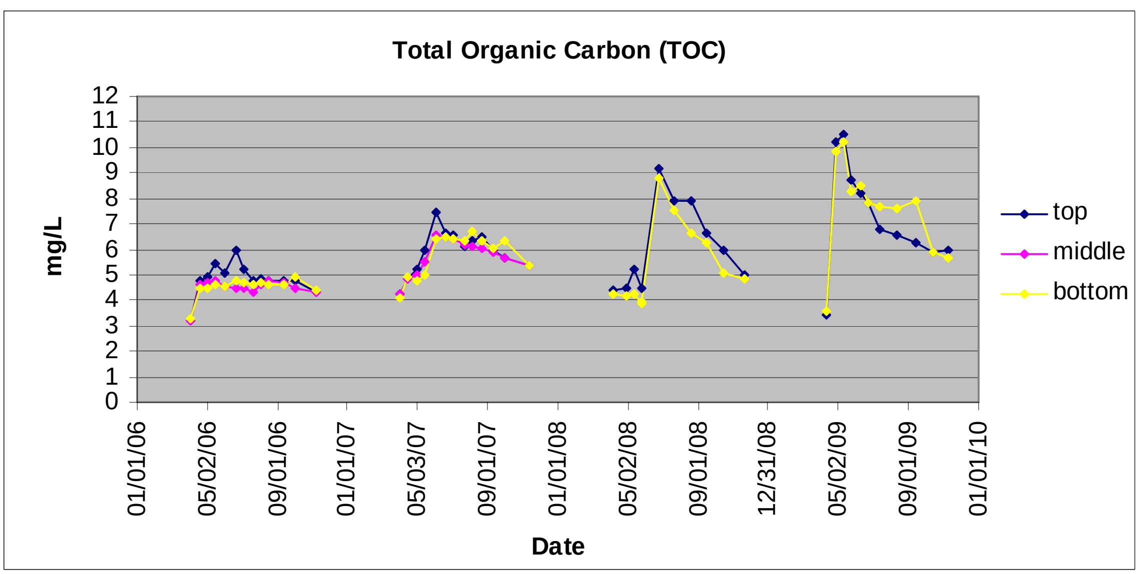
Figure 28. Plot of chlorophyll-a versus total P using data collected at 1m in Seaman Reservoir from 2006 to 2009.



4.5 Total Organic Carbon (TOC)

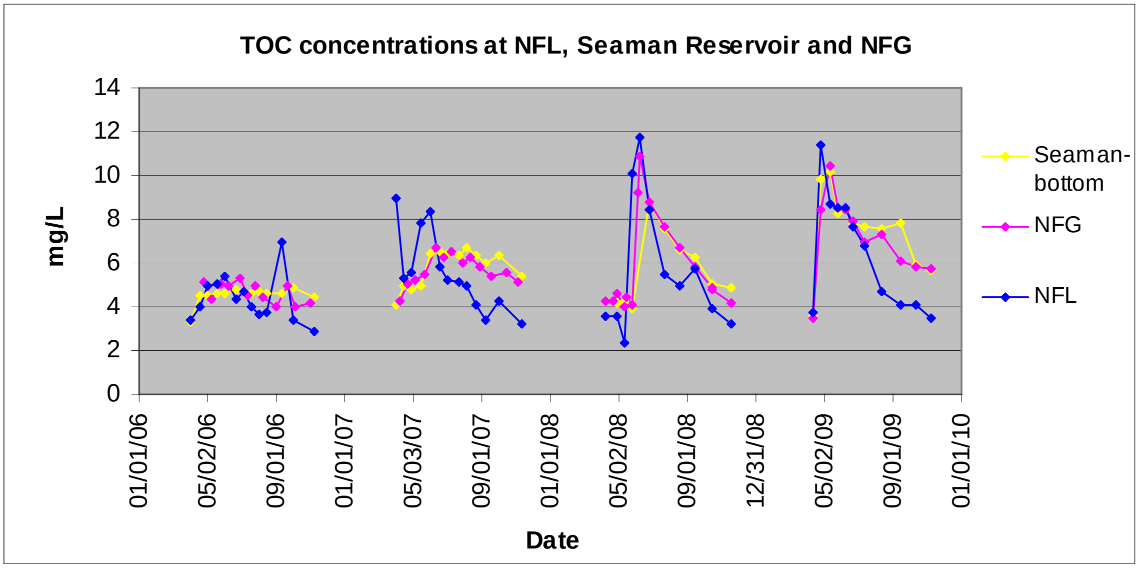
TOC values were comparable to previous years (2006 – 2009) and generally did not differ between the top and bottom of the reservoir (Fig. 29). In 2009, the peak measured TOC value was 10.5 mg/l on 5/12/09, and coincided with peak runoff on the North Fork. A subsequent decline in TOC was observed throughout the summer and fall due to dilution by lower TOC inflows. Peak TOC values showed a consistent and substantial increase (4.6 mg/L) over the four year period.

Figure 29. TOC concentrations in Seaman Reservoir.



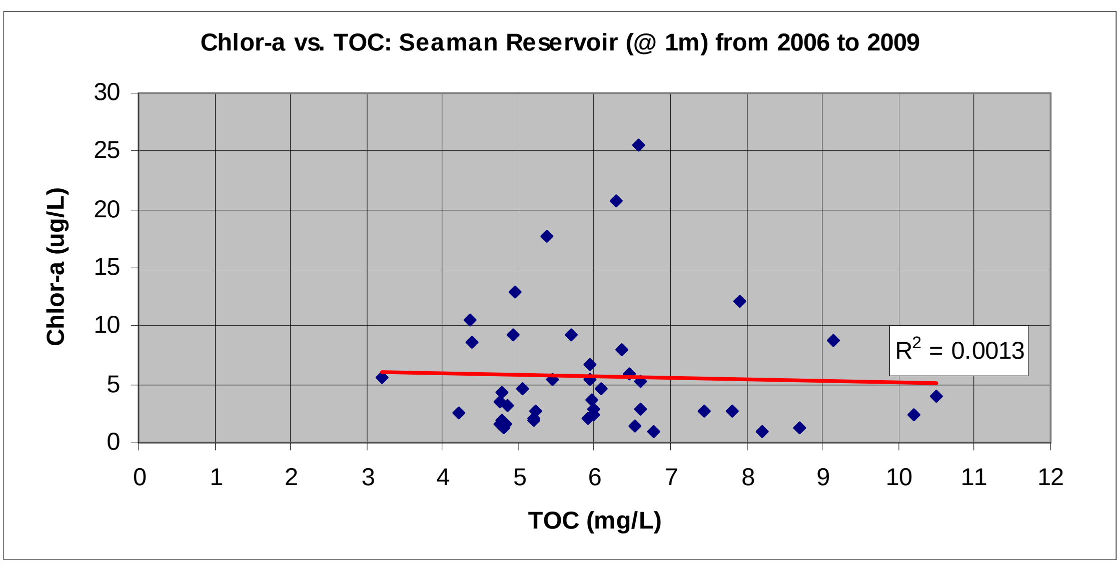
The TOC concentrations on the North Fork below Seaman Reservoir (NFG) were generally similar to the TOC concentrations at the bottom of Seaman Reservoir (Fig. 30). After the spring runoff period, TOC at both of these locations is higher than the TOC in waters entering Seaman Reservoir (NFL).

Figure 30. Comparison of TOC concentrations at NFL, Seaman Reservoir, and NFG.



In-reservoir production of TOC from algal growth provides a possible explanation for the higher TOC concentrations within and below Seaman Reservoir at NFG. However, the lack of relationship between TOC and chlorophyll-a concentrations at 1M, suggests that TOC conecentrations in Seaman Reservoir can not be explained by algal growth alone (Fig. 31). Higher in-reservoir TOC concentrations may also be due to the fact that the reservoir stores high-TOC spring runoff water which is blended with lower TOC inflows and released over the course of the year.

Figure 31. Plot of chlorophyll-a versus TOC using data collected at 1m in Seaman Reservoir from 2006 to 2009.



4.6 Total Coliforms and *E. coli*

Total coliforms peaked in late summer, with top and bottom concentrations of 14,136 and 4,106 colonies/100ml, respectively (Fig. 32). Coincident peaks in total coliform concentrations at all sites on the North Fork and in Seaman Reservoir occurred on 7/13/09. Peak concentrations were very similar in the top of Seaman Reservoir and downstream at NFG, whereas concentrations at the bottom of Seaman Reservoir were, to a lesser degree, similar to the upstream site, NFL.

E. coli concentrations were consistently very low at the top of the reservoir. In contrast, a large spike in bottom concentrations occurred during spring runoff; the concentration of *E. coli* on 5/24/09 was 154 colonies/100ml (Fig. 33). *E. coli* concentrations at the bottom of the reservoir corresponded closely with those at NFG. It cannot, however, be concluded from this close correspondence that bottom releases from Seaman Reservoir are the sole source of *E.coli* downstream at NFG. It should be noted that releases occur over the spillway at times throughout the year, particularly during spring runoff. Furthermore, inspection of the data show that the down stream peak concentration at NFG actually occurred approximately two weeks before the in-reservoir peak concentration, suggesting an additional or alternate source.

Figure 32. Total Coliforms at NFL, in Seaman Reservoir and at NFG

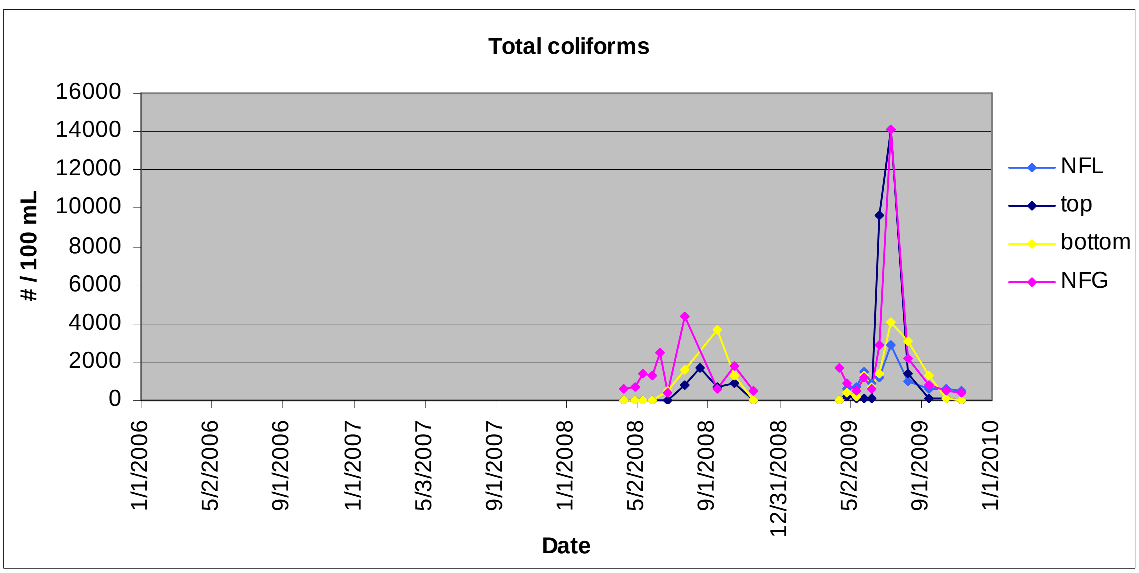
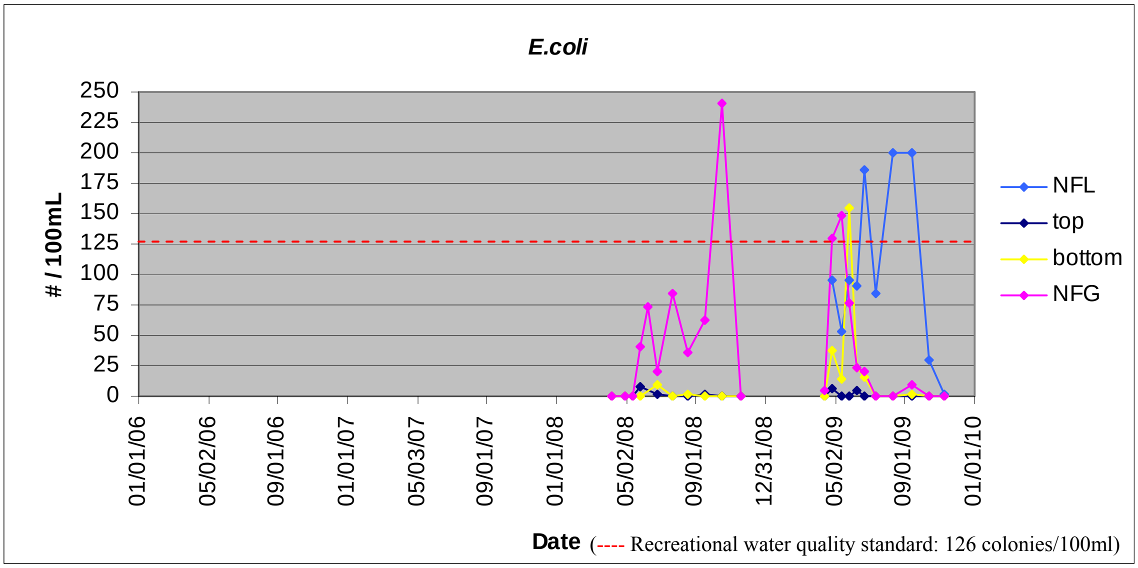


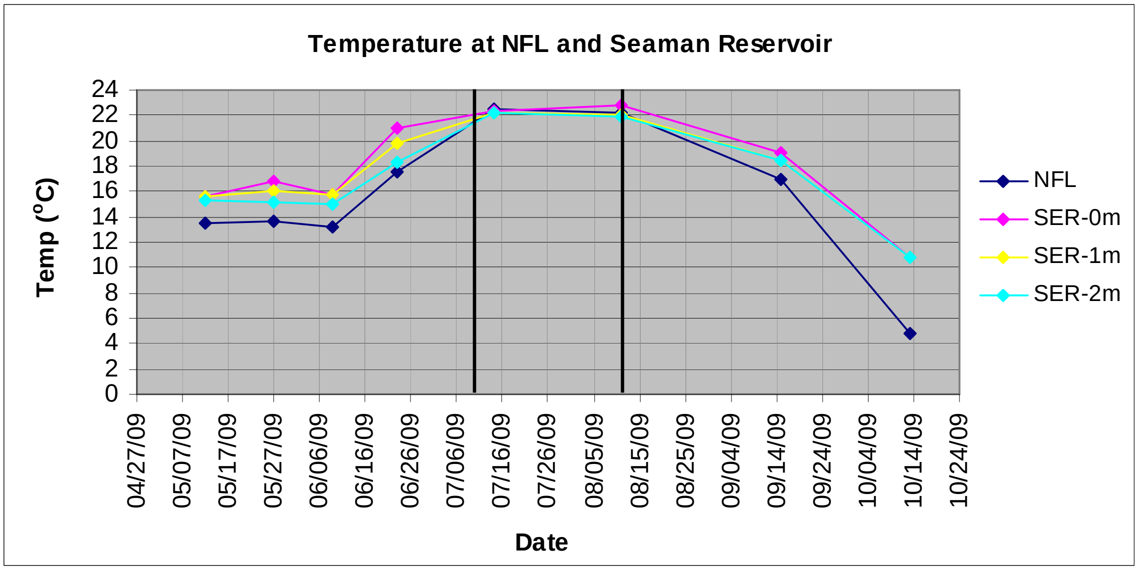
Figure 33. Concentrations of *Escherichia coli* (*E. coli*) at NFL, in Seaman Reservoir and at NFG



Upstream water temperatures at NFL were compared to temperatures within the top 2 meters of Seaman Reservoir to determine whether inflowing waters would remain in the epilimnion or sink below the epilimnion (Fig. 34). Temperatures at NFL and at the reservoir surface were similar for much of the summer season when the reservoir is stratified. It would, therefore, be expected that inflowing waters and the associated coliforms and *E. coli* (measured at NFL) would remain at the surface of the reservoir. Because the volume of flow at NFL is small compared to the total volume of Seaman Reservoir, the concentrations delivered to the reservoir (as observed at NFL) would likely be diluted considerably upon mixing within the epilimnion. The dilution effect may partially account for the observed differences in *E. Coli* concentrations between NFL and the top of Seaman Reservoir. However, for total coliforms, the same relationship does not exist. In fact, the opposite occurred, with high total coliform concentrations in the top of the reservoir and considerably lower concentrations in the inflowing waters from NFL, suggesting an alternate source below NFL or within the reservoir.

While it is known that occurrences of *E.coli* and total coliforms are closely related to agricultural and human activity in the watershed, it is also clear that not enough is known about the seasonal dynamics and relationships between sites to make any conclusions about the sources and fate of these pathogens in Seaman Reservoir. For this reason, it is recommended that *E.coli* and total coliform monitoring continue at all sites in 2010.

Figure 34. A temperature comparison of NFL and the top 2 meters of Seaman Reservoir.



4.7 Phytoplankton and Geosmin

Phytoplankton. Phytoplankton data provided by PhytoFinders for April and May of 2009 were not of sufficient detail to be considered comparable to the results for September through November, which were provided by Dick Dufford (private consultant). The June, July and August samples were collected as scheduled; however, over the one to two month storage period, the dye in the Lugol's preservative solution was absorbed by the plastic sample containers and the samples were unable to be analyzed. Plastic sample containers are no longer used and have been replaced with 60ml amber glass bottles. Therefore, only the results for September, October and November are presented here. A summary of the available 2009 phytoplankton data is provided in Attachment 6.

Blue-green algae (Cyanophytes) were the dominant contributor to total phytoplankton in the top (96%) and bottom (99%) of Seaman Reservoir on 9/14/09, with much smaller contributions from the green-algae (Chlorophytes) and diatoms (Bacillariophytes) (Fig. 35 – Fig. 38). The density of Cyanophytes was substantially lower at the bottom of the reservoir (8,105 cells/ml) compared to the top (24,122 cells/ml), as were Chlorophytes (735 cells/ml and 51 cells/ml for top and bottom, respectively).

The composition and densities of the phytoplankton communities at the top and bottom of the reservoir changed significantly from September to November. Blue-green algae decreased dramatically in both relative abundance and density in the months of October and November to become a very minor contributor to total phytoplankton communities. During the same time, the relative abundance of green algae, golden-brown algae (Chrysophytes) and diatoms increased within the phytoplankton communities.

Figure 35. Relative abundance of phytoplankton in top of Seaman Reservoir in 2009.

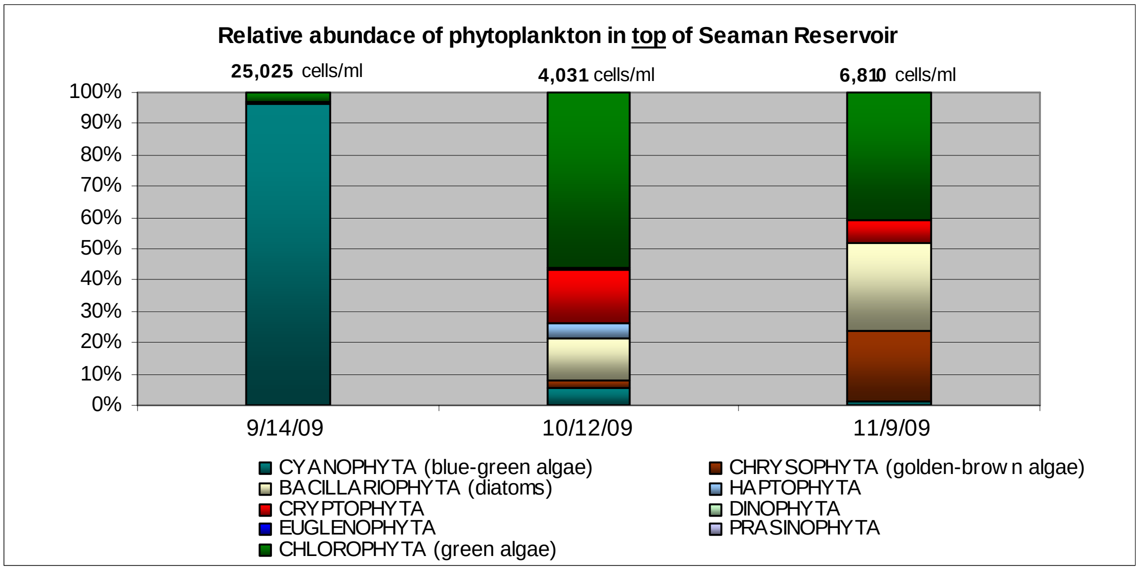


Figure 36. Relative abundance of phytoplankton at the bottom of Seaman Reservoir in 2009.

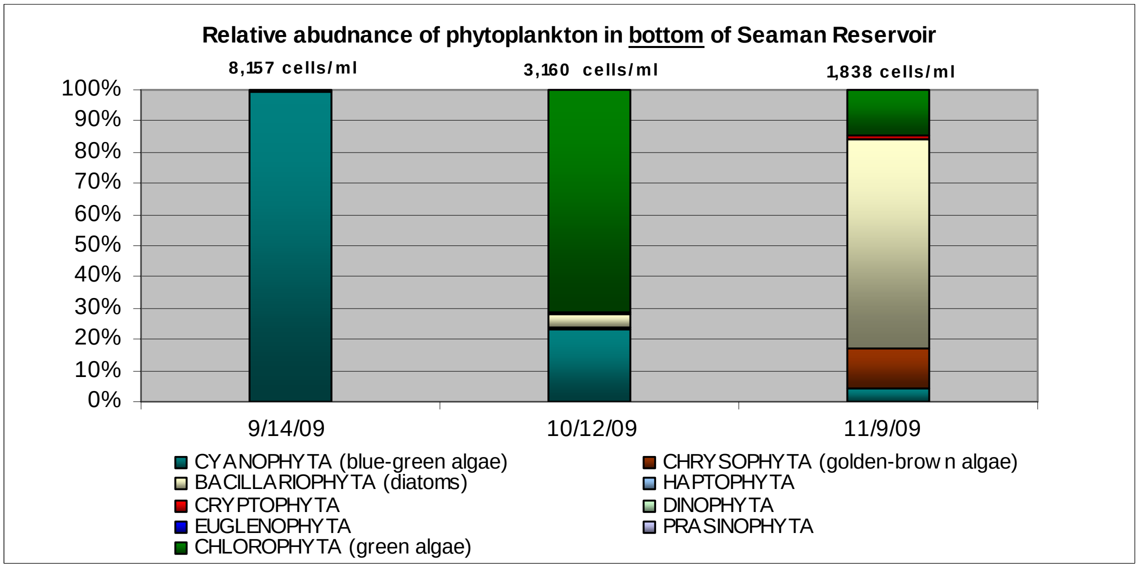


Figure 37. Phytoplankton densities at the top of Seaman Reservoir in 2009.

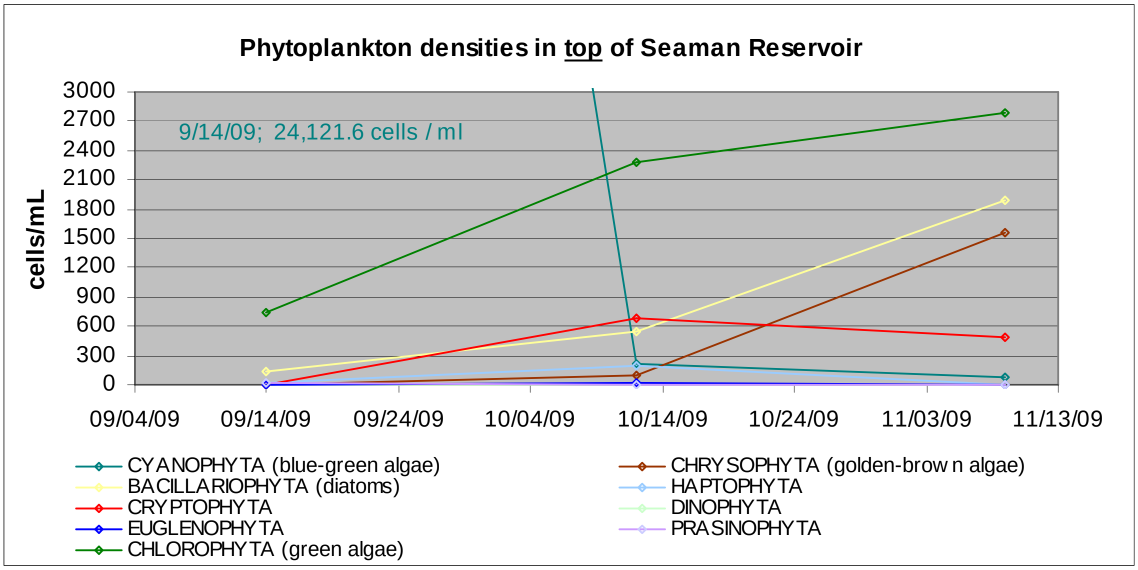
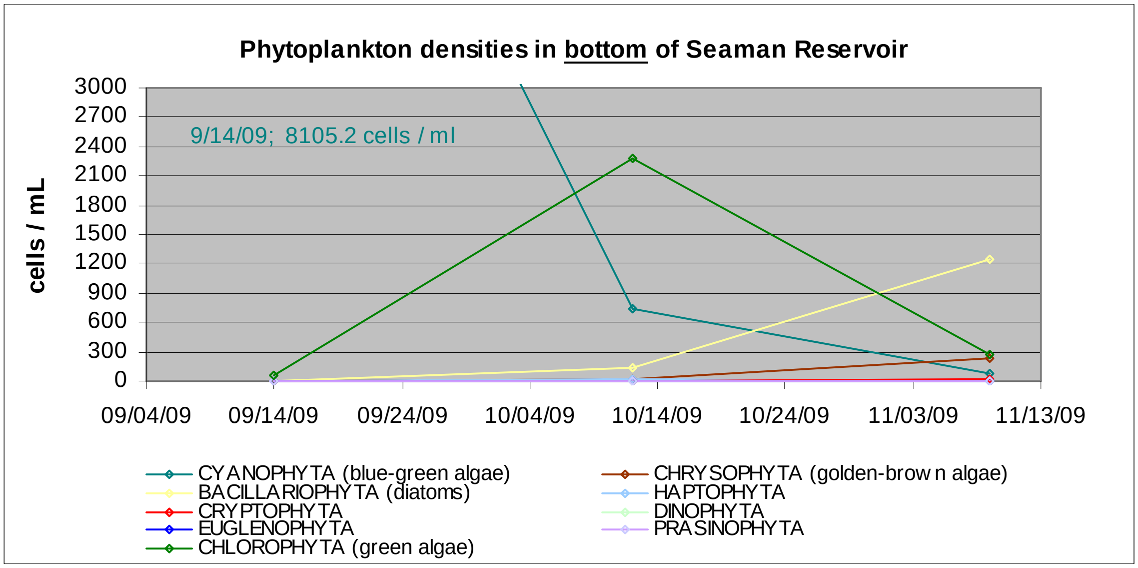
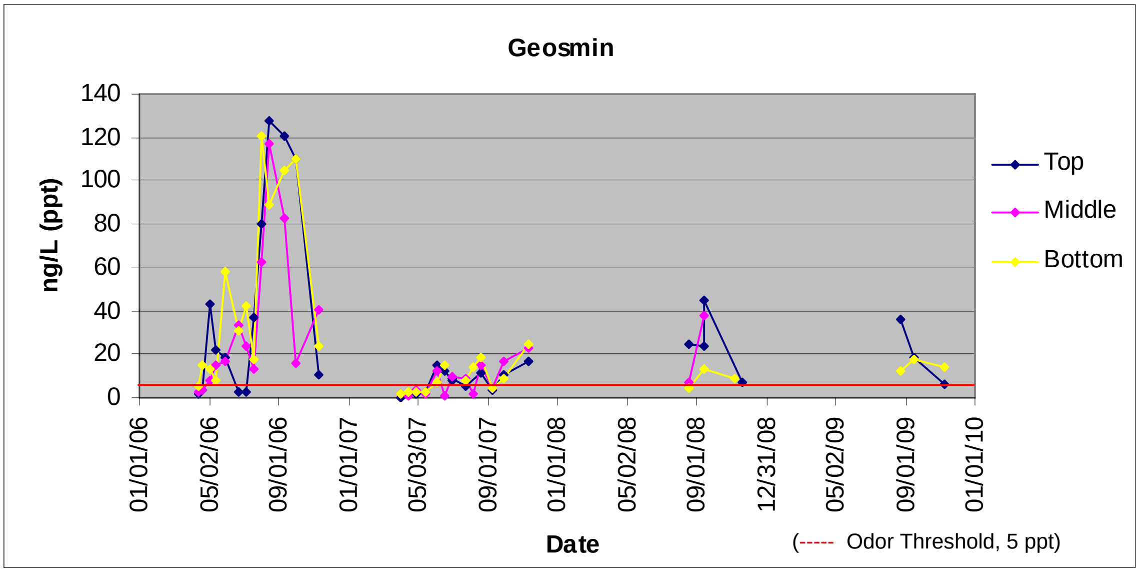


Figure 38. Phytoplankton densities at the bottom of Seaman Reservoir in 2009



Geosmin. In 2009, geosmin samples were collected at the top and bottom of the reservoir profile on three occasions between August and December. All reported values were at or above the odor threshold of 5 nanograms/L, or parts per trillion (ppt) (Fig. 39). The maximum concentration at the top was 36 ppt and occurred on 8/25/09. The peak bottom concentration of 18 ppt occurred on 9/15/09. In the previous three years, peak concentrations ranged from 25 ppt (2007) to 128 ppt (2006).

Figure 39. Geosmin concentrations in Seaman Reservoir.



In September, 96% of the total phytoplankton community in Seaman Reservoir (top) was comprised of cyanophytes, or blue-green algae. This contrasts greatly with conditions in October and November, during which cyanophytes represented only 6% and 1% percent of the total phytoplankton density, respectively. Of the blue-green algae identified in Seaman Reservoir, six of the genera are known to include geosmin producers and include *Anabaena, Aphanizomenon, Synechoccoccus, Lyngbya, Planktothrix, and Pseudanabaena.*

During September, more than half (57%) of the blue-green algal density in the top of reservoir was comprised of known geosmin producing genera. Note, however, that not all species within a genus produce geosmin. The geosmin producing species identified in the 2009 samples include *Aphanizomenon flos-aquae*, *Planktothix agardhii* and *Pseudanabaena limnetica* (Juttner and Watson, 2007). On 9/15/09, the geosmin concentration at the reservoir surface was 18.27 ppt. At this time, the identified geosmin producing species only comprised one percent of the known geosmin-producing genera of blue-green algae. Although their relative abundance was very small, the presence of known geosmin-producing species suggests that one or more are the likely sources of geosmin in Seaman Reservoir at this time.

Other studies have also found little to no correlation between geosmin concentrations and density of geosmin producing algae, as the source of geosmin is often a minor or inconspicuous component of the phytoplankton community (Taylor et al, 2006). Furthermore, some species do not release geosmin until cellular decomposition, thereby creating a time lag between algal abundance and geosmin levels. To verify any particular species as a geosmin producer, a laboratory culture test would be required.

In November, the geosmin concentration at the top of Seaman Reservoir had decreased to 6.17 ppt. and likewise, the densities and relative abundance of known geosmin-producing genera and species also decreased.

5.0 SUMMARY

Review of the 2009 Upper CLP Collaborative Water Quality Monitoring Program data indicates that the program adequately captures the seasonal trends in water quality and provides a spatial context for examining notable events.

The Mainstem and the North Fork, as expected, exhibited different water quality characteristics, resulting from differences in geology, land use, and elevation. In general, no significant concerns were identified for the Mainstem or North Fork CLP that would impact drinking water quality or treatment operations. During spring runoff, the Mainstem and the North Fork both presented the usual challenges to water treatment, including the delivery of waters with high TOC, high turbidity and low alkalinity. The primary differences in water quality between the two drainages include higher alkalinity and nutrient concentrations, as well as persistently elevated TOC concentrations on the North Fork.

The 2008 draw-down of Seaman Reservoir did not appear to affect water quality or reservoir dynamics in 2009. The reservoir became thermally stratified, and as usual, exhibited anoxic conditions in the bottom waters during the summer months. Fall turnover occurred in early October.

Samples will continue to be analyzed for all parameters in 2010. Three additional samples will be collected as part of the Northern Water collaborative study on emerging contaminants at PNF and NFG. In addition, there are several issues that have the potential to affect water quality as well as monitoring activities in 2010 and beyond, including:

Mountain Pine Beetle (MPB) and Wildfire. The continued spread of mountain pine beetle infestation and the related increased risk of high-severity wildfire pose potential threats to water quality in the upper CLP watershed. In 2010, the City of Fort Collins and the City of Greeley will contract Brad Peihl of J.W. Associates in Breckenridge, CO to conduct a vulnerability assessment of source water supplies related to the potential effects of high-severity wildfire in the upper CLP watershed. Results of this initial assessment phase will identify potential Zones of Concern, which are areas within the source watershed above water diversions, intake structures, and classified drinking water supply reservoirs that have a higher potential for contributing significant sediment or debris in the event of a high severity wildfire. In the future, these identified zones of concern can be used by stakeholders to identify issues and mitigation tactics related to protecting the source watershed and water supplies against high severity wildfires. Any mitigation efforts would be led by private property owners as well as federal and state land management agencies that have legal jurisdiction over targeted areas of the watershed.

Halligan Seaman Water Supply Projects (HSWSPs) EIS. In support of studies currently being conducted for the HSWSPs EIS, more intensive sampling may be conducted in 2010 of the North Fork sites. In addition to the routine Upper CLP monitoring, plans are currently being made for the following: 1) increase the sampling frequency at all the North Fork sites to 3 times/month in June, July, and August, 2) collect surface samples from Halligan Reservoir, and 3) analyze all North Fork samples for a suite of metals and additional parameters. The specific details related to the proposed intensive sampling are still being developed.

Water Quality Standards. Certain segments of the North Fork CLP and its tributaries were added to the 2010 Monitoring and Evaluation List and Section 303(d) List for water quality standard exceedances for parameters including cadmium, copper, lead and *E coli*. The metals exceed aquatic life standards while *E. coli* exceeds the recreation use standard. These conditions are not expected to impact water treatment operations or drinking water quality for the City of Greeley at this time.

In addition, Seaman Reservoir was added to the 2010 Section 303 (d) List of impaired waters for low dissolved oxygen (D.O.) concentrations in the epilimnion. This designation applies to water quality as it relates to aquatic refugia for fish populations. Low D.O. concentrations in the epilimnion are not expected to impact drinking water quality.

In 2010, the sampling frequency and parameters on the North Fork may be increased as a result of more intensive sampling being proposed to support the HSWSPs EIS. Because of this, more data may be available to support the CDPHE WQCD's assessment of the listed segments of the North Fork.

Nutrients and Algae. In response to the algae bloom that occurred on the middle reaches of the Mainstem (near PBR - Poudre below Rustic) and other indications that there may be a persistent source of nutrients along this section of the river, a special study may be conducted during the summer of 2010 to help identify potential sources of nutrients. At the same time, a search will be made of Larimer County Department of Health and Environment records to determine locations and characteristics of individual sewage disposal systems (ISDS's).

6.0 REFERENCES

Billica, Loftis and Moore, 2008. Design of a Collaborative Water Quality Monitoring Pogram for the Upper Cache la Poudre River. July 14, 2008.

Brooks, Paul D., Mark W. Williams and Steven K. Schmidt, 1996. Microbial activity under alpine snowpacks, Niwot Ridge, Colorado. *Biogeochemistry,* Vol. 32 (2). pp. 93-113.

Campbell, D. H., Clow, D. W., Ingersoll, G. P., Mast, M.A., Spahr, N. E., Turk, J. T. 1995. Processes controlling the chemistry of two snowmelt-dominated streams in the Rocky Mountains. *Water Resources Research* 31(11): 2811-2821.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.

Collins, Jim A. and L.A. Sprague, 2005. The Cache la Poudre River, Colorado, as a Drinking-Water Source, U.S. Geological Survey Fact Sheet 2005-3037, 4 p.

Front Range Wildfire Watershed Protection Planning (FRWWPP) - Data Refinement Work Group, 2009. Protecting Critical Watersheds in Colorado from Wildfire: A technical approach to watershed assessment and prioritization.

Juttner, F. and S. Watson, 2007. MiniReview: Biochemical and Ecological Control of Geosmin and 2-Methylisoborneol in Source Waters, *Applied and Environmental Microbiology*, Vol. 73, No. 14, July 2007, p. 4395-4406.

Le Master, Dennis C., Guofan Shao, and Jacob Donnay, 2007. Protecting Front Range Forest Watersheds from High-Severity Wildfires. An assessment by the Pinchot Institute for Conservation, funded by the Front Range Fuels Treatment Partnership.

Lewis Jr., W.M., 2007. Studies of Water Quality for the Water Supply to the Bellvue Water Treatment Plant: Presentation and Interpretation of Monitoring Data for Year 2006. City of Greeley, CO, March 1, 2007.

MacDonald, Lee H. and John D. Stednick, 2003. Forests and Water: A State-of-the-Art Review for Colorado. Colorado Water Resources Research Institute Completion Report No. 196. Colorado State University, Fort Collins, CO.

Oropeza, J. and J. Billica, 2009. City of Fort Collins Utilities 2008 Annual Report for the Upper Cache la Poudre River Collaborative Water Quality Monitoring Program, Internal Water Production Report, February 23, 2009, 36 pages plus appendices.

Snyder, A.S., B.J. Vanderford, J.Drewes, E. Dickenson, E.M. Snyder, G.M. Bruce, R.C. Pleus, 2008. *State of Knowledge of Endocrine Disruptors and Pharmaceuticals in Drinking Water*, Awwa Research Foundation, Denver, CO.

Taylor W.D., R.F. Losee, M. Torobin, G. Izaguirre, D. Sass, D. Khiari, and K. Atasi, 2006. Early W*arning and Management of Surface Water Taste-and-Odor Events*, AWWA Research Foundation, Denver, CO.

Uunila, L., B. Guy, and R. Pike. 2006. Hydrologic effects of mountain pine beetle in the interior pine forests of British Columbia: Key questions and current knowledge. Extended Abstract. *BC Journal of Ecosystems and Management.* 7(2):37–39.
URL: *http://www.forrex.org/publications/jem/ISS35/vol7_no2_art4.pdf*

Wetzel, R.G., 2001. *Limnology: Lake and River Ecosystems*, Third Edition. Academic Press, San Diego, California.

ATTACHMENT 1

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

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

ATTACHMENT 2

Upper CLP collaborative water quality monitoring program sampling sites.

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

ATTACHMENT 3

Upper CLP collaborative water quality monitoring program parameter list.

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

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

ATTACHMENT 4

Upper CLP Collaborative Water Quality Monitoring Program 2009 Sampling Plan

	2009 Sampling Date										
	Apr 13–14	Apr 27-28	May 11-12	May 26-27	Jun 8-9	Jun 22-23	Jul 13-14	Aug 10-11	Sep 14-15	Oct 12-15	Nov 9-10
Station											
North Fork											
NDC[3]	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
NBH[3]	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
NRC	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,I,D
RCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D					
SCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D					
PCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D					
NFL	F,G,E	F,G,I,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
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	F,G,E,P	F,G,I,M,E,P	F,G,I,E
Main Stem											
CHR	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
BMR[2]	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
JWC	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
PJW	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,I,D
LRT	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
PBR	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
SFM		F,G,I,D		F,G,I,D		F,G,I,D		F,G,I,D		F,G,I,D	F,G,I,D
PSF	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
PNF	F,G,E	F,G,I,E	F,G,E	F,G,I,E,M	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E,M	F,G,I,E
PBD	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
Reservoir											
SER[1]	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,I,A,C,

[1] Grab samples taken at two depths (Top & Bottom); meter samples at 1-m intervals.
[2] Call commissioner to find out if water is flowing. If not flowing, skip sample.
[3] To be sampled by City of Fort Collins personnel; all other stations to be sampled by Dr. Bill Lewis' Team.
A = Algae (Lugol's); C = Chlorophyll (500 mL sample); D = Flow; F = Field data (Temp, pH, conductance streams + Secchi, DO for lake); G = 1 liter sampleor general, nutrients, TOC; E = *E. coli*, coliform (500 mL sterile bottle); I = Major ions; M = Metals; P = *Giardia/Cryptosporidium* (collected by City of Fort Collins personnel).

ATTACHMENT 5

Analytical methods, reporting limits, sample preservation, and sample 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	none	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		none	28 days
	Total Dissolved Solids	SM 2540 C	10 mg/L	cool, 4C	7 days
	Turbidity (NTU)	SM2130B,EPA180.1	0.01 units	none	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	SM 3111 B	0.05 mg/L	HNO_3 pH <2	6 mos
	Chloride	EPA 300 (IC)	1.0 mg/L	none (eda)	28 days
	Magnesium, flame	SM 3111 B	0.2 mg/L	HNO_3 pH <2	6 mos
	Potassium	SM 3111 B	0.2 mg/L	HNO_3 pH <2	6 mos
	Sodium, flame	SM 3111 B	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	SM 3113 B	0.1 ug/L	HNO_3 pH <2	6 mos
	Chromium	SM 3113 B	0.5 ug/L	HNO_3 pH <2	6 mos
	Copper, GFAA	SM 3113 B	3 ug/L	HNO_3 pH <2	6 mos
	Iron, GFAA (total & dissolved)	SM 3113 B	10 ug/L	HNO_3 pH <2	6 mos
	Lead	SM 3113 B	1 ug/L	HNO_3 pH <2	6 mos
	Nickel	SM 3113 B	2 ug/L	HNO_3 pH <2	6 mos
	Silver	SM 3113 B	0.5 ug/L	HNO_3 pH <2	6 mos
	Zinc, flame	SM 3111 B	50 ug/L	HNO_3 pH <2	6 mos
TOC	TOC	SM 5310 C	0.5 mg/L	HCl 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

Summary of 2009 Seaman Reservoir Phytoplankton Data

ATTACHMENT 6

Summary of 2009 Seaman Reservoir Phytoplankton Data

Phytoplankton biovolumes (ug/L) provided by PhytoFinders of Berthoud, CO for 4/13/09 – 5/11/09.

Seaman Reservoir - Top		**Date**		**Seaman Reservoir - Bottom**		**Date**	
	4/13/2009	**4/27/2009**	**5/11/2009**		**4/13/2009**	**4/27/2009**	**5/11/2009**
Chlorophyta	1.650	14.680	16.356	Chlorophyta	9.721	7.728	6.472
Chrysophyta	1.319	12.924	0.641	Chrysophyta	15.826	4.484	0.264
Cryptophyta	4.004	4.971	50.804	Cryptophyta	8.833	0.085	0.124
Dinophyta	0.188	0.377	0.000	Dinophyta	0.000	0.000	0.000
Euglenophyta	0.000	0.000	0.000	Euglenophyta	0.332	0.000	0.332
Cyanophyta	0.000	0.000	0.031	Cyanophyta	0.000	0.004	0.000
Bacillariophyta	639.836	128.318	125.545	Bacillariophyta	489.813	151.744	144.109
Total Phytoplankton Biovolume (ug/L)	**646.997**	**161.270**	**193.377**	**Total Phytoplankton Biovolume (ug/L)**	**524.525**	**164.045**	**151.301**
Ciliates	0.007	0.035	0.014	Ciliates	0.254	0.021	0.049
Rotifer	0.000	0.000	4.710	Rotifer	14.130	0.000	0.000

Phytoplankton densities (cells/ml) provided by Dick Dufford, private consultant, of Fort Collins, CO for 9/14/09-11/9/09.

Seaman Reservoir – Top	Date		
	9/14/2009	10/12/2009	11/9/2009
CYANOPHYTA (blue-green algae)			
Anabaena flos-aquae	12800.0	2.4	
Anabaena planctonica	178.8	10.0	
Aphanizomenon flos-aquae	156.0		
Aphanocapsa conferta			69.2
Aphanocapsa delicatissima	125.0		
Aphanothece smithii	10000.0	125.0	
Cyanobium (Synechococcus) sp.	375.0		
Jaaginema sp.			
Lyngbya birgei	345.2	6.4	
Myxobaktron hirudiforme			
Planktolyngbya limnetica			
Planktothrix agardhii		3.2	
Pseudanabaena limnetica		11.2	
Snowella litoralis	25.6		
Woronichinia naegeliana	116.0	64.0	
TOTAL	**24121.6**	**222.2**	**69.2**
CHRYSOPHYTA (golden-brown algae)			
Chromulina sp.			500.0
Dinobryon divergens	0.4	62.0	14.0
Mallomonas akrokomos		40.0	
Ochromonas minuscula			1000.0
Synura petersenii		4.8	51.2
TOTAL	**0.4**	**106.8**	**1565.2**

Seaman Reservoir – Bottom	Date		
	9/14/2009	10/12/2009	11/9/2009
CYANOPHYTA (blue-green algae)			
Anabaena flos-aquae		14.4	
Anabaena planctonica	0.4	12.8	
Aphanizomenon flos-aquae		1.0	2.4
Aphanocapsa conferta			
Aphanocapsa delicatissima	1030.0	412.0	
Aphanothece smithii	6180.0		
Cyanobium (Synechococcus) sp.	824.0		
Jaaginema sp.	0.8		
Lyngbya birgei	14.6	2.6	
Myxobaktron hirudiforme			18.0
Planktolyngbya limnetica	54.0	72.0	6.4
Planktothrix agardhii			
Pseudanabaena limnetica	1.4	202.5	
Snowella litoralis			
Woronichinia naegeliana		22.0	53.6
TOTAL	**8105.2**	**739.3**	**80.4**
CHRYSOPHYTA (golden-brown algae)			
Chromulina sp.			12.8
Dinobryon divergens		12.4	0.8
Mallomonas akrokomos			
Ochromonas minuscula			206.0
Synura petersenii		1.8	8.8
TOTAL	**0**	**14.2**	**228.4**

Seaman Reservoir - Top	Date	Seaman Reservoir - Bottom	Date

Seaman Reservoir - Top

	9/14/2009	10/12/2009	11/9/2009
BACILLARIOPHYTA (diatoms)			
Asterionella formosa	2.4	6.4	562.0
Aulacoseira granulata var. *angustissima*		128.8	486.4
Aulacoseira italica			20.0
Discostella pseudostelligera			600.0
Fragilaria crotonensis	124.0	3.2	178.4
Melosira varians		28.8	11.2
Nitzschia fonticola		0.8	
Punticulata bodanica	2.0	8.8	27.2
Stephanodiscus niagarae	0.4		8.8
Stephanodiscus parvus		360.0	
TOTAL	**128.8**	**536.8**	**1894**
HAPTOPHYTA			
Chrysochromulina parva	**20.0**	**200.0**	**0**
CRYPTOPHYTA			
Cryptomonas borealis		2.4	34.0
Cryptomonas curvata		1.6	4.8
Cryptomonas marsonii			3.2
Komma caudata		540.0	120.0
Plagioselmis nannoplanctica		140.0	320.0
TOTAL	**0.0**	**684.0**	**482.0**
DINOPHYTA			
Ceratium hirundinella		0.4	
Peridinium lomnickii			
TOTAL	**0.0**	**0.4**	**0.0**

Date

Seaman Reservoir - Bottom

	9/14/2009	10/12/2009	11/9/2009
BACILLARIOPHYTA (diatoms)			
Asterionella formosa		12.4	246.8
Aulacoseira granulata var. *angustissima*		113.0	784.0
Aulacoseira italica			36.4
Discostella pseudostelligera			45.0
Fragilaria crotonensis		4.0	83.0
Melosira varians			9.2
Nitzschia fonticola			
Punticulata bodanica		2.0	28.4
Stephanodiscus niagarae			6.0
Stephanodiscus parvus			
TOTAL	**0**	**131.4**	**1238.8**
HAPTOPHYTA			
Chrysochromulina parva	**0**	**18.0**	**0**
CRYPTOPHYTA			
Cryptomonas borealis		0.2	2.4
Cryptomonas curvata			0.4
Cryptomonas marsonii			0.8
Komma caudata			9.0
Plagioselmis nannoplanctica			9.0
TOTAL	**0.0**	**0.2**	**21.6**
DINOPHYTA			
Ceratium hirundinella			
Peridinium lomnickii			0.6
TOTAL	**0.0**	**0.0**	**0.6**

Date

	9/14/2009	10/12/2009	11/9/2009		9/14/2009	10/12/2009	11/9/2009
EUGLENOPHYTA				EUGLENOPHYTA			
Euglena acus				*Euglena acus*	0.3		
Trachelomonas dybowskii		10.4	5.6	*Trachelomonas dybowskii*		1.8	1.2
TOTAL	**0.0**	**10.4**	**5.6**	**TOTAL**	**0.3**	**1.8**	**1.2**
PRASINOPHYTA				PRASINOPHYTA			
Tetraselmis cordiformis	**20.0**	**0**	**0**	*Tetraselmis cordiformis*	**0**	**0**	**0**
CHLOROPHYTA (green algae)				CHLOROPHYTA (green algae)			
Ankyra judayi	100.0	140.0	20.0	*Ankyra judayi*		4.5	
Botryococcus braunii	4.8			*Botryococcus braunii*			
Chlorella minutissima	125.0	875.0	750.0	*Chlorella minutissima*	51.5		51.5
Choricystis minor	500.0	1250.0	2000.0	*Choricystis minor*		2266.0	206.0
Closterium acutum var. *variabile*	0.4	0.4	0.4	*Closterium acutum* var. *variabile*		0.4	1.2
Coenochloris fottii		3.2		*Coenochloris fottii*			1.2
Dictyosphaerium pulchellum var. *minutum*			5.6	*Dictyosphaerium pulchellum* var. *minutum*			
Elakatothrix viridis		1.6	0.4	*Elakatothrix viridis*			3.2
Eudorina elegans			5.6	*Eudorina elegans*			
Heimansia pusilla			2.8	*Heimansia pusilla*			3.0
Oocystis apiculata	1.6			*Oocystis apiculata*		2.0	
Oocystis borgei			7.2	*Oocystis borgei*			
Staurastrum planctonicum	2.8	0.8	2.0	*Staurastrum planctonicum*		0.2	0.6
TOTAL	**734.6**	**2271.0**	**2794.0**	**TOTAL**	**51.5**	**2273.1**	**266.7**
TOTAL DENSITY (cells/mL)	**25025.4**	**4031.6**	**6810.0**	TOTAL DENSITY (cells/mL)	**8157**	**3160.0**	**1837.7**

ATTACHMENT 7

2009 Upper CLP Collaborative Water Quality Monitoring Program

Graphical Summary

2009 Upper Cache la Poudre River Cooperative Water Quality Monitoring Program

Graphical Summary

Prepared for:

City of Fort Collins Utilities
City of Greeley
Tri-Districts

Prepared by:

Jill Oropeza, Watershed Specialist
City of Fort Collins Utilities

Judith A. Billica, P.E., Ph.D., Senior Process Engineer
City of Fort Collins Utilities

May 20, 2010

List of Figures

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

Mainstem and North Fork CLP: Daily Average Stream Flow

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

Figure 1.a. 2009 Daily average stream flow on the Mainstem and North Fork CLP.

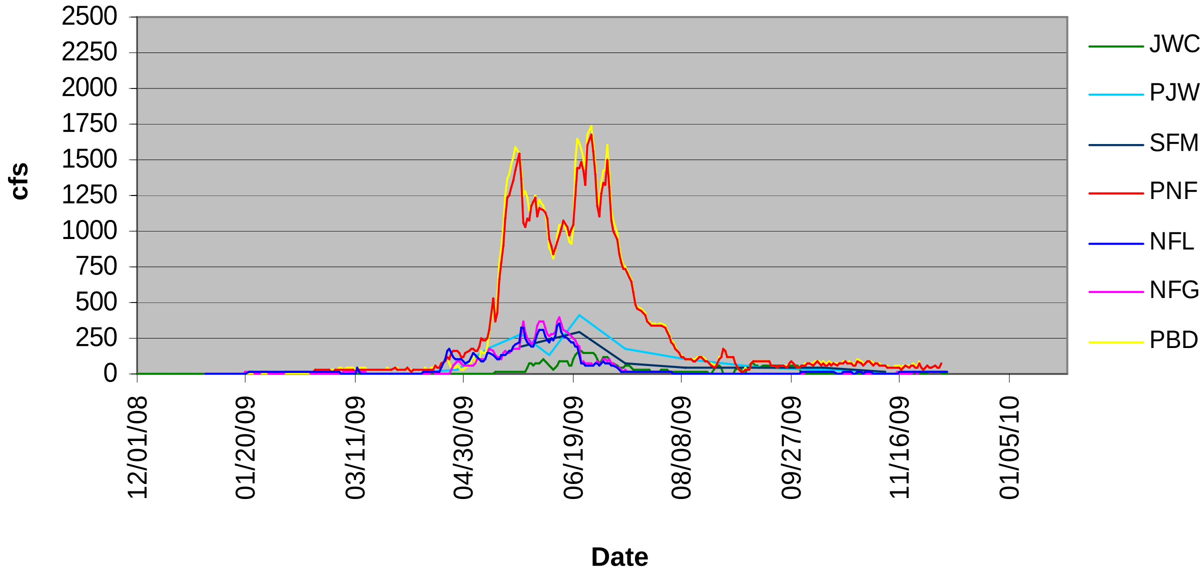


Figure 1.b. 2006 – 2009 Daily average stream flow on the Mainstem and North Fork CLP.

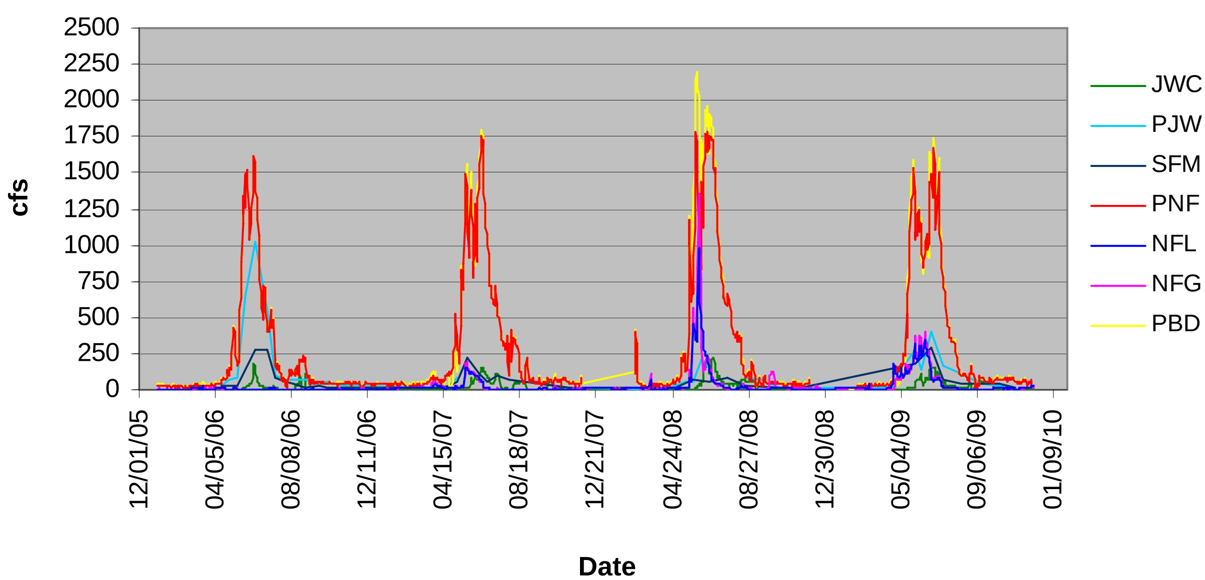


Figure 2 (a & b). Daily average stream flow on the North Fork tributaries.

Figure 2.a. 2009 Daily average stream flow on the North Fork tributaries

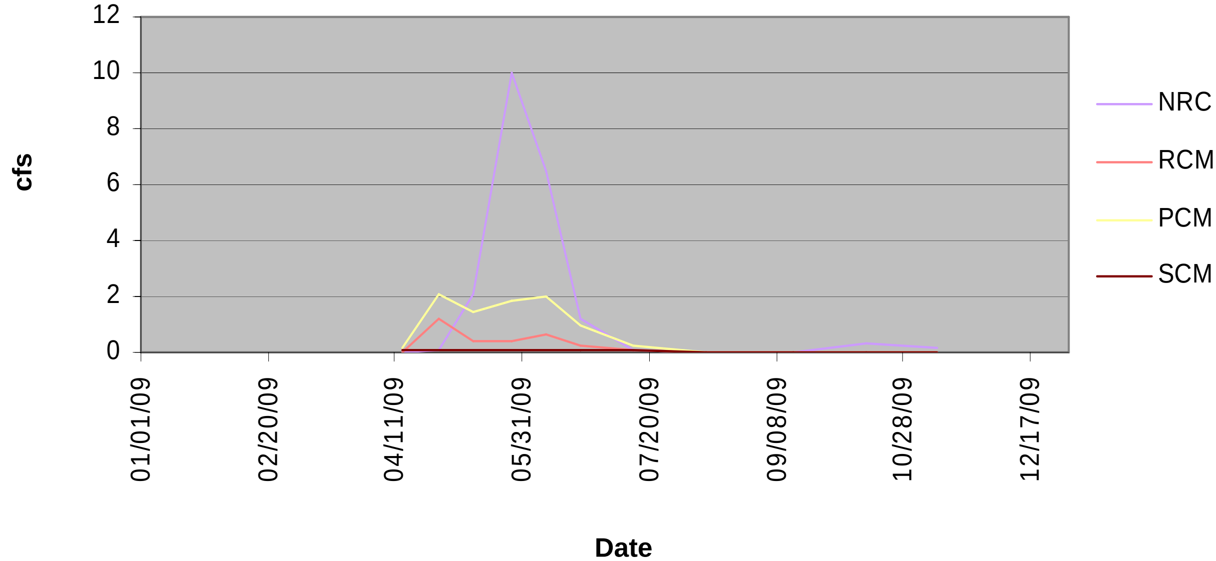
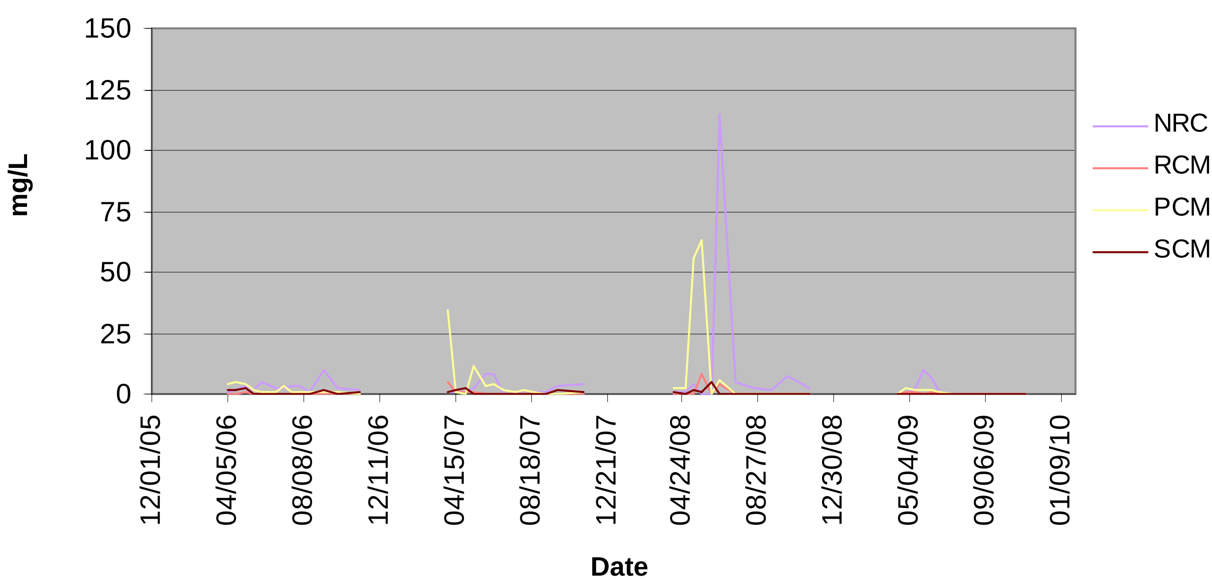


Figure 2.b. 2006-2009 Daily average stream flow on the North Fork tributaries



Mainstem and North Fork CLP: General Parameters

Figure 3 (a & b). Water Temperature

Figure 3.a. Water temperature on the Mainstem CLP.

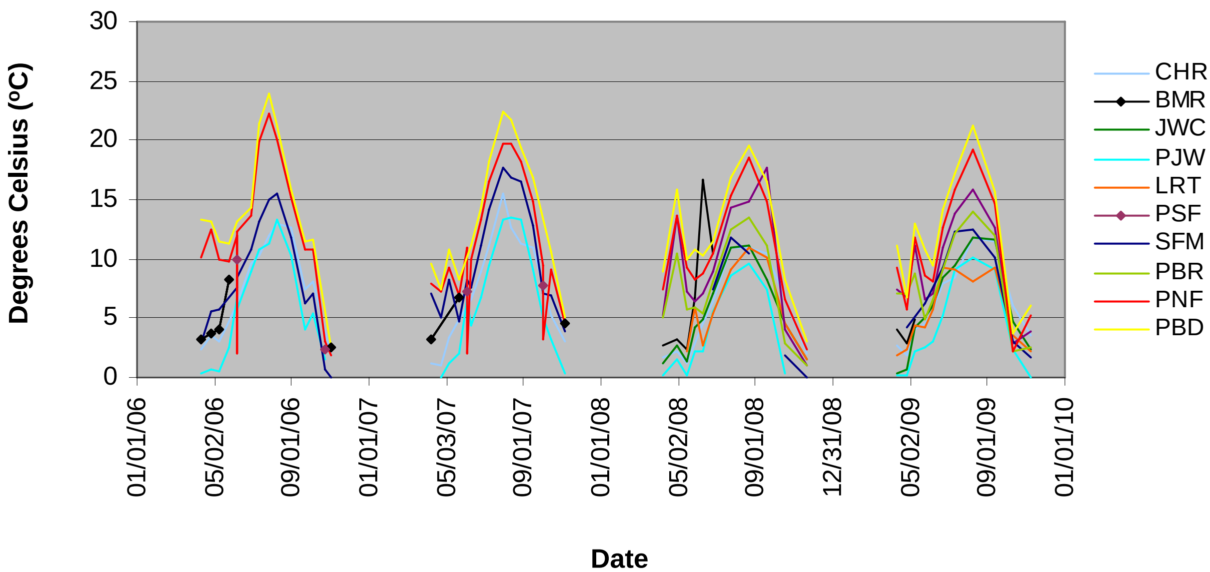


Figure 3.b. Water temperature on the North Fork CLP.

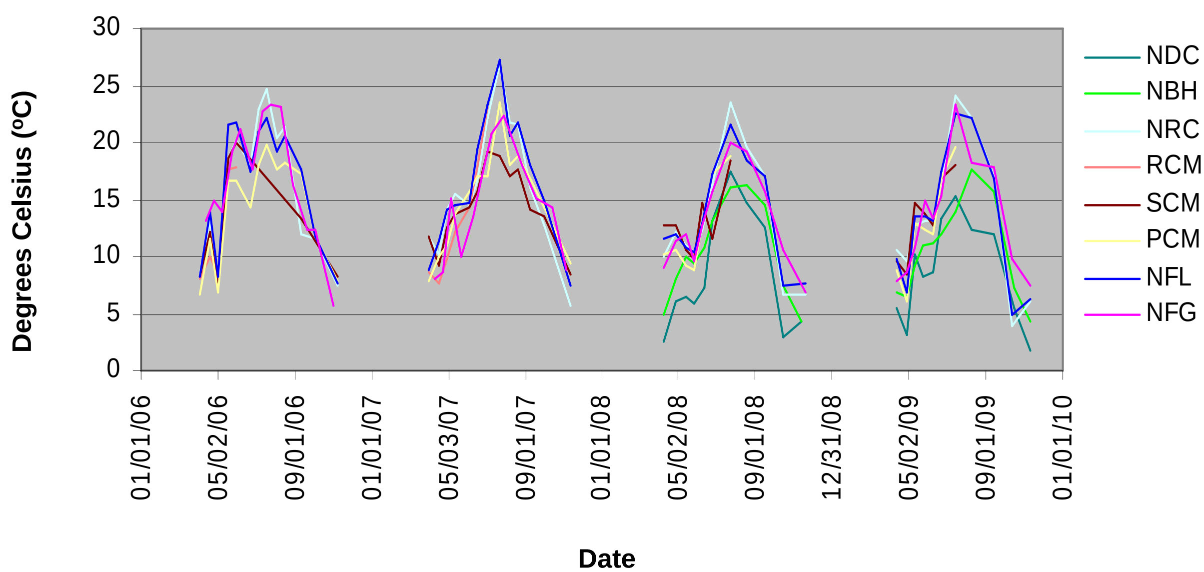


Figure 4 (a & b). pH

Figure 4.a. pH on the Mainstem CLP.

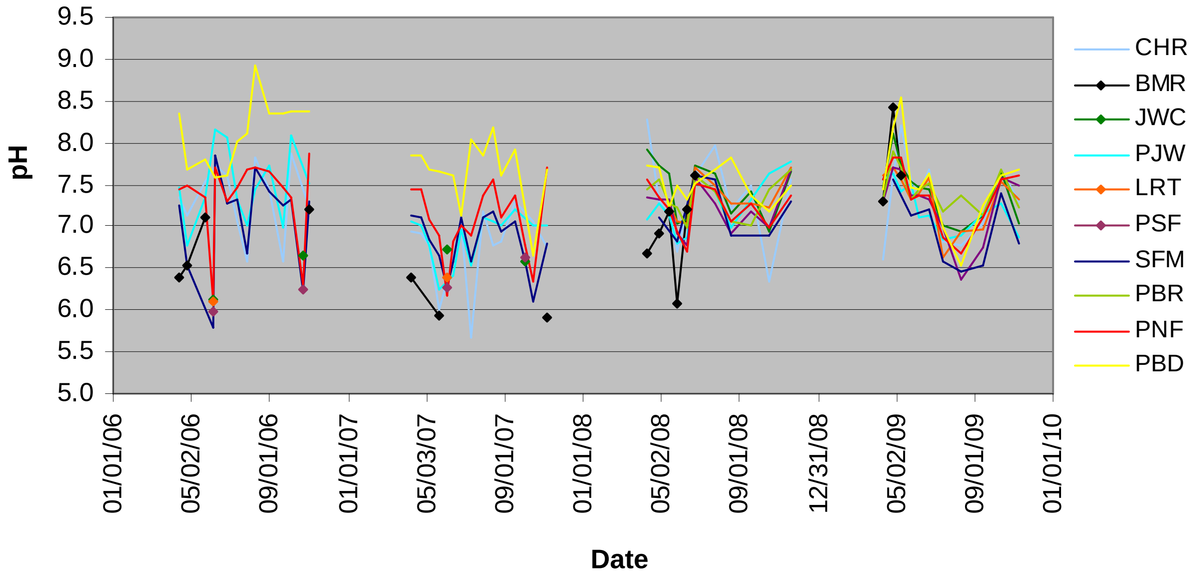


Figure 4.b. pH on the North Fork CLP.

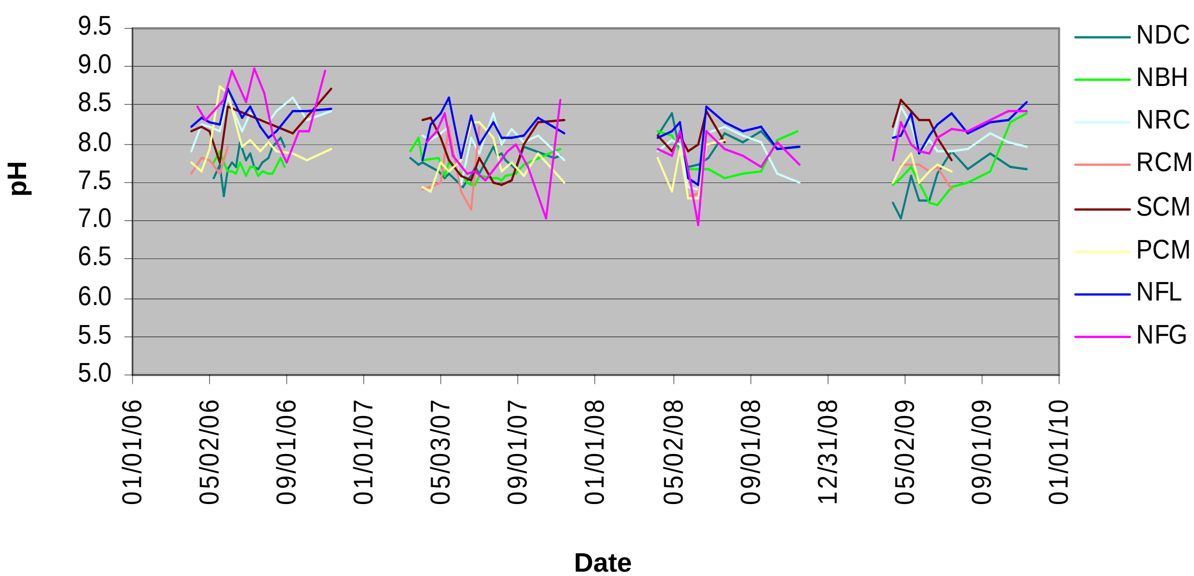


Figure 5 (a & b). Conductance

Figure 5.a. Conductance on the Mainstem CLP.

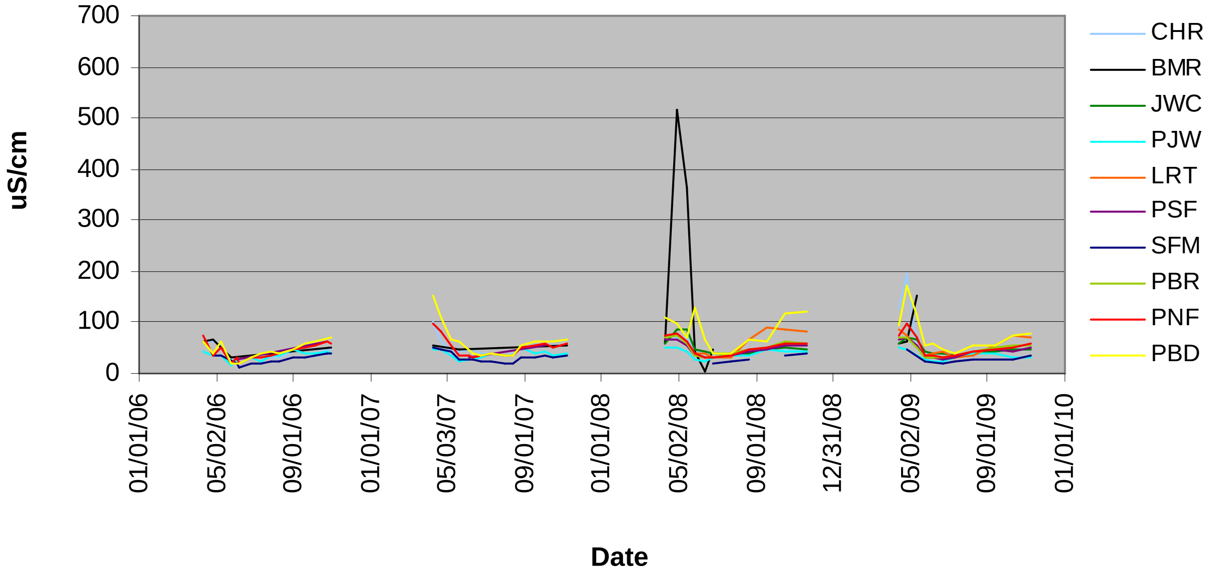


Figure 5.b. Conductance on the North Fork CLP.

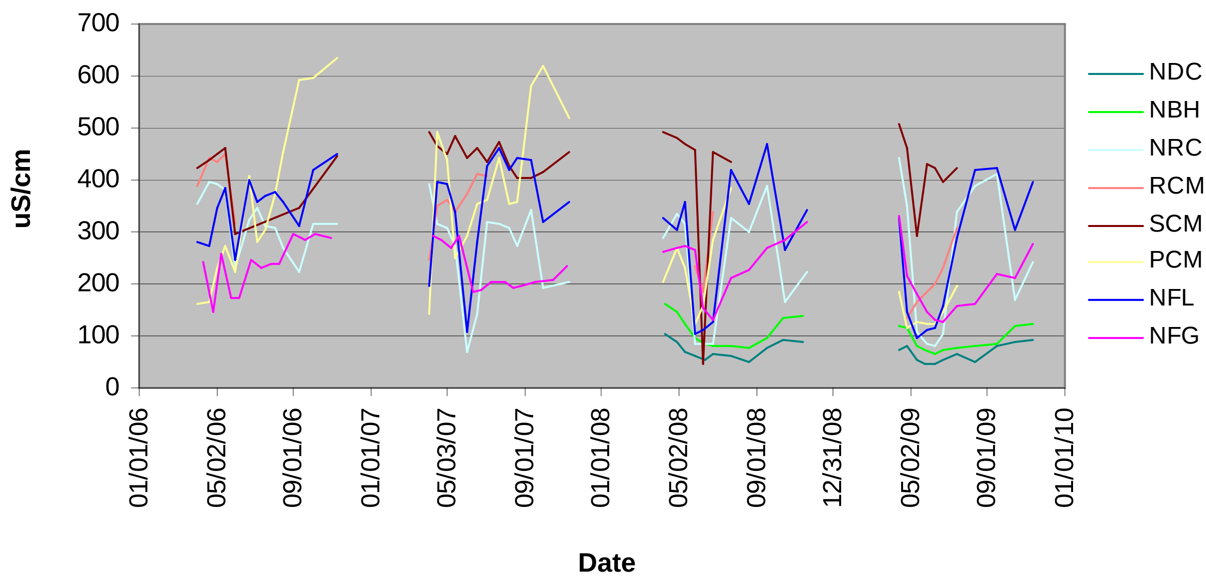


Figure 6 (a & b). Hardness

Figure 6.a. Hardness on the Mainstem CLP.

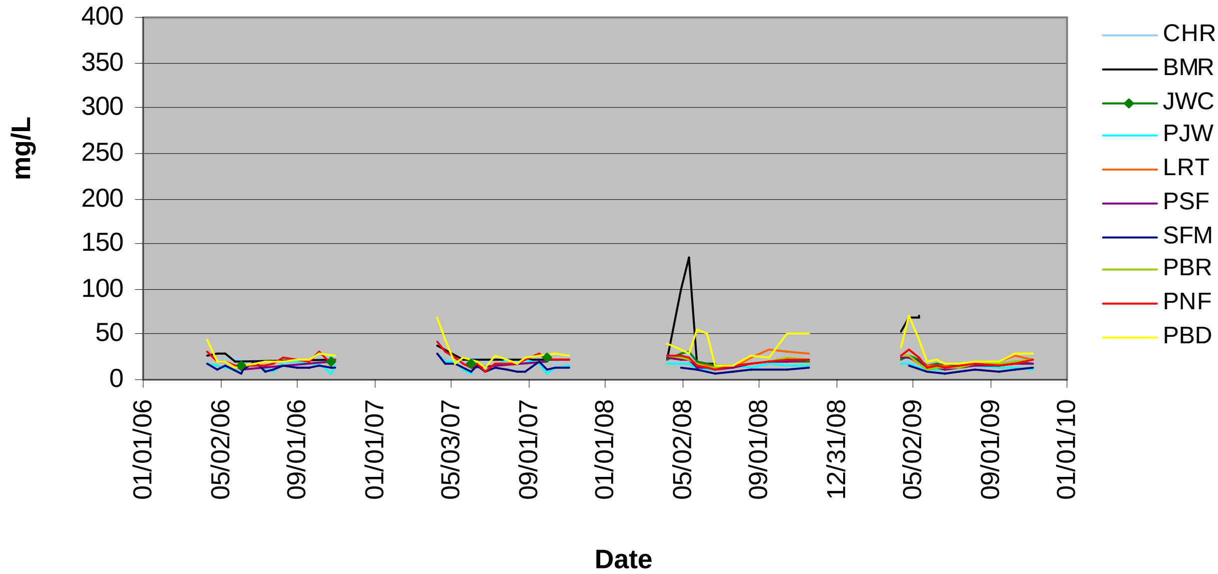


Figure 6.b. Hardness on the North Fork CLP.

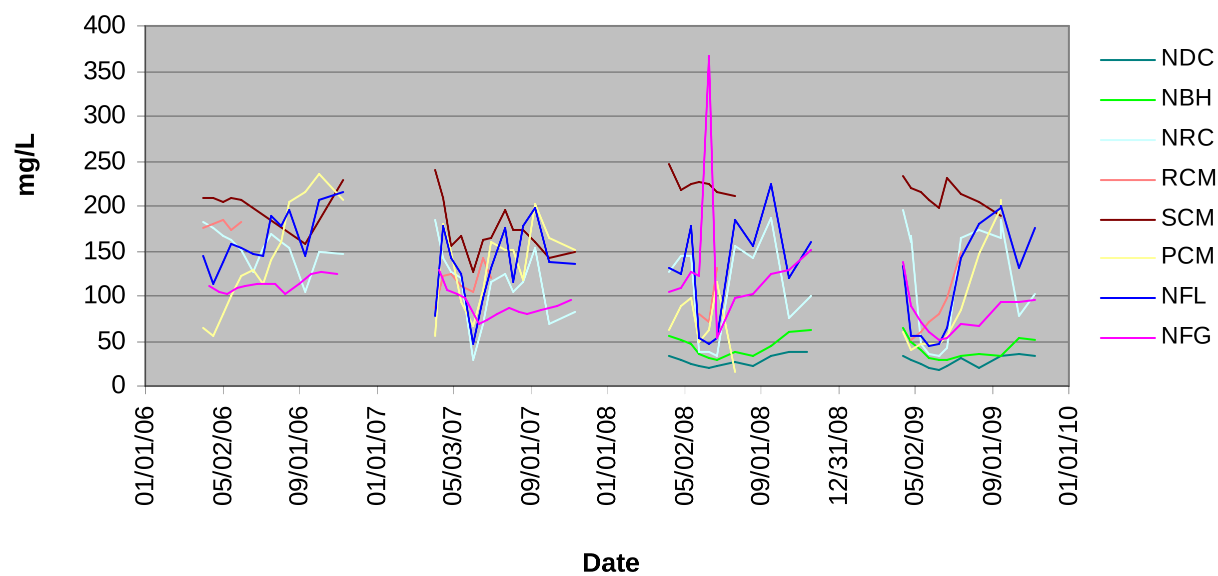


Figure 7 (a & b). Alkalinity

Figure 7.a. Alkalinity on the Mainstem CLP.

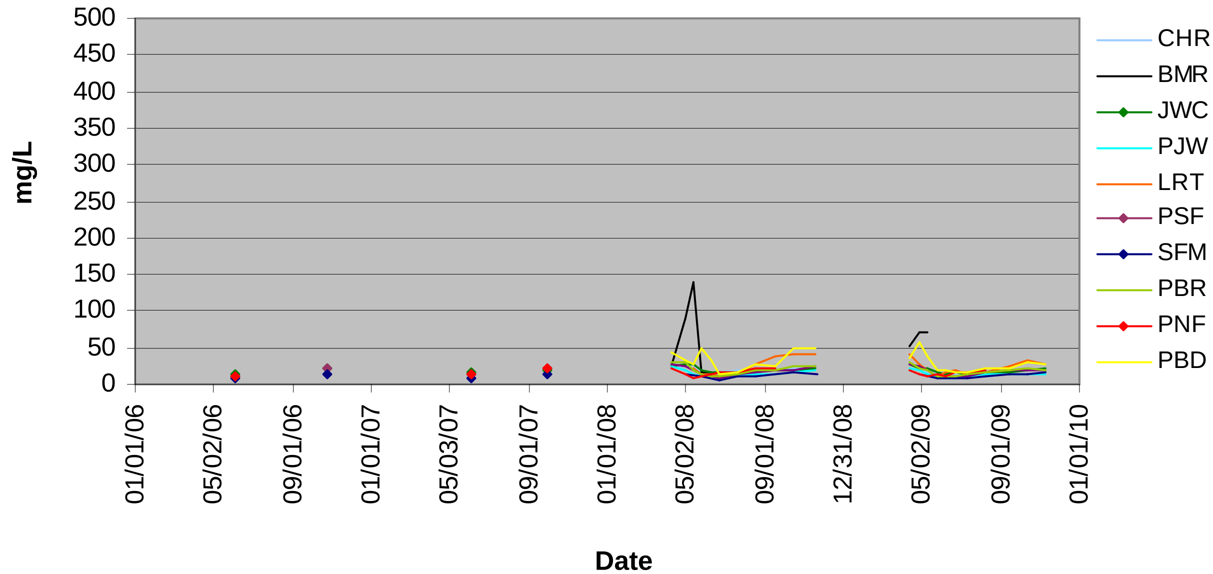


Figure 7.b. Alkalinity on the North Fork CLP.

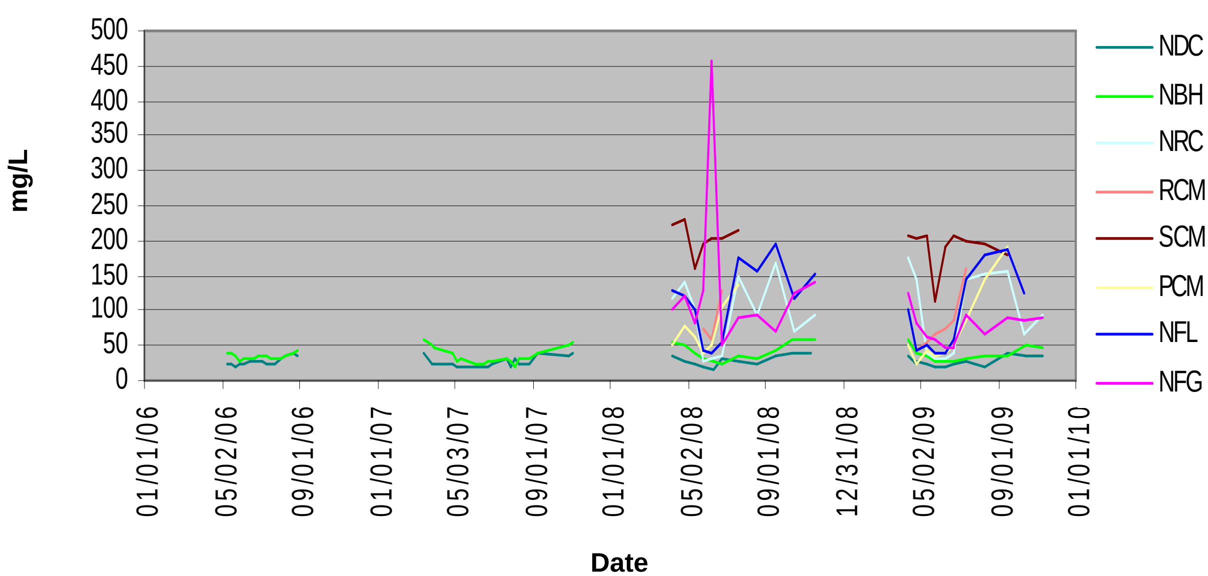


Figure 8 (a & b). Turbidity

Figure 8.a. Turbidity on the Mainstem CLP.

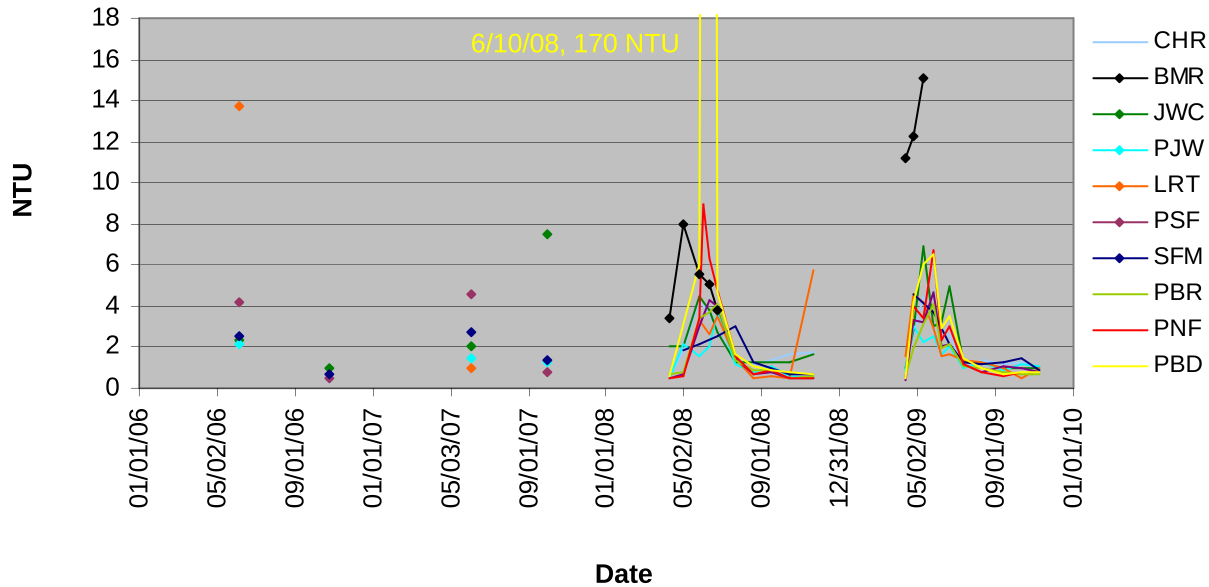


Figure 8.b. Turbidity on the North Fork CLP.

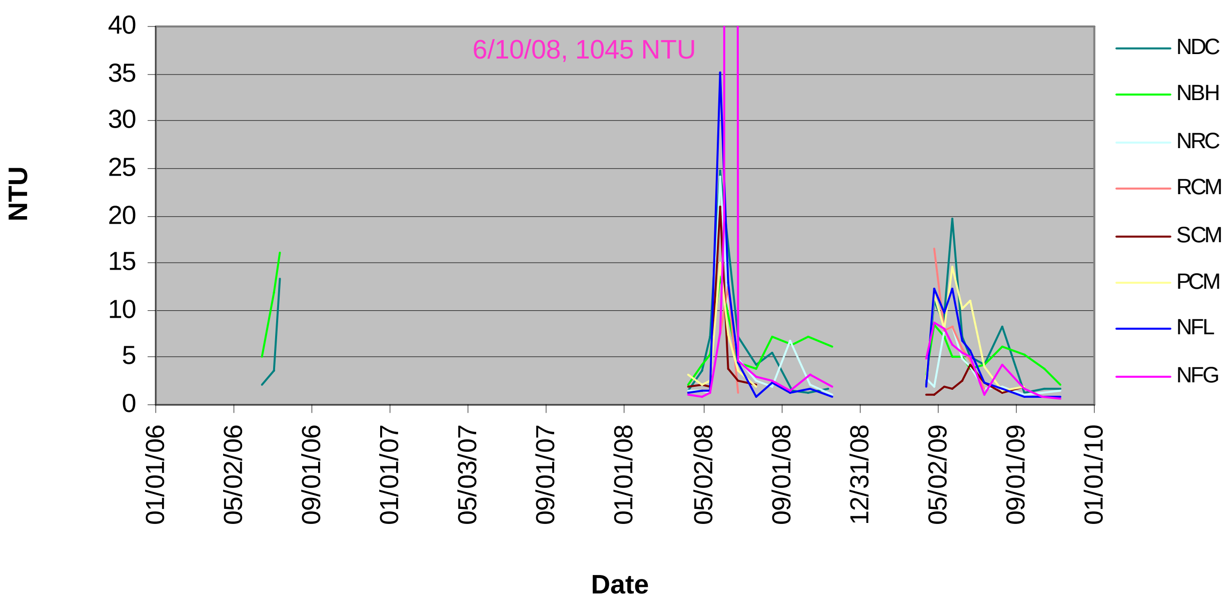
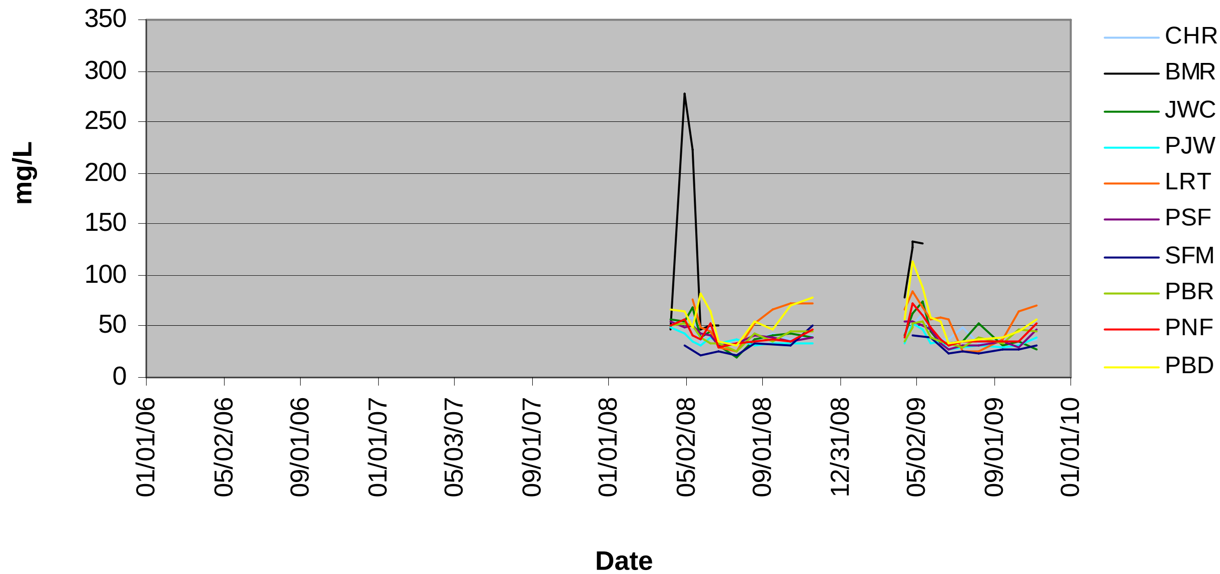


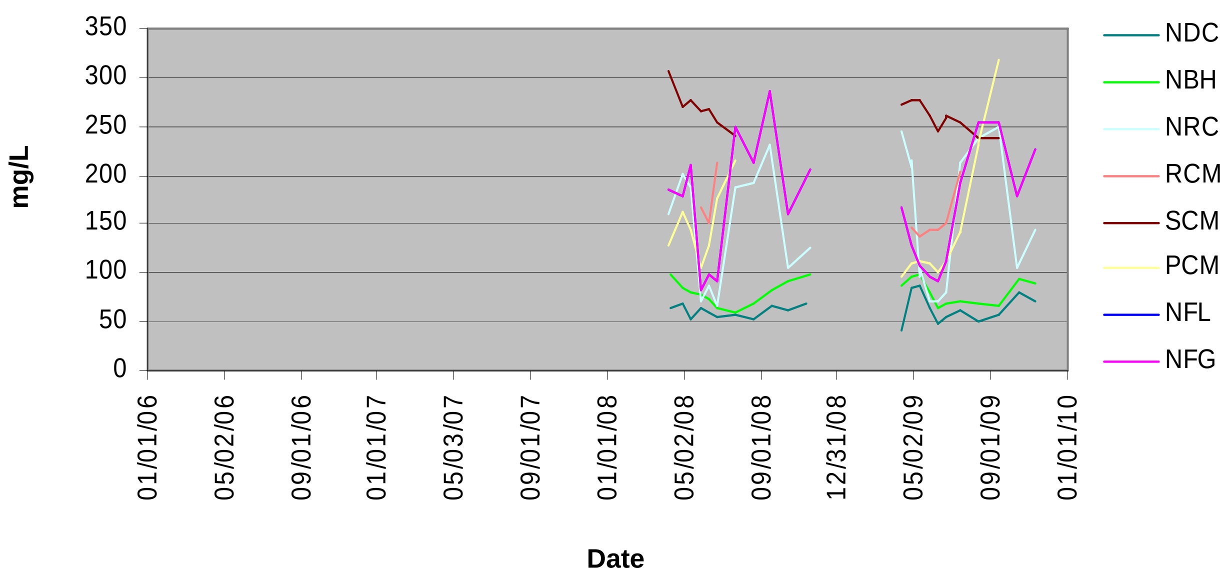
Figure 9 (a & b). Total Dissolved Solids (TDS)

Figure 9.a. TDS on the Mainstem CLP.



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

Figure 9.b. TDS on the North Fork CLP.



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

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

Figure 10.a. TOC on the Mainstem CLP.

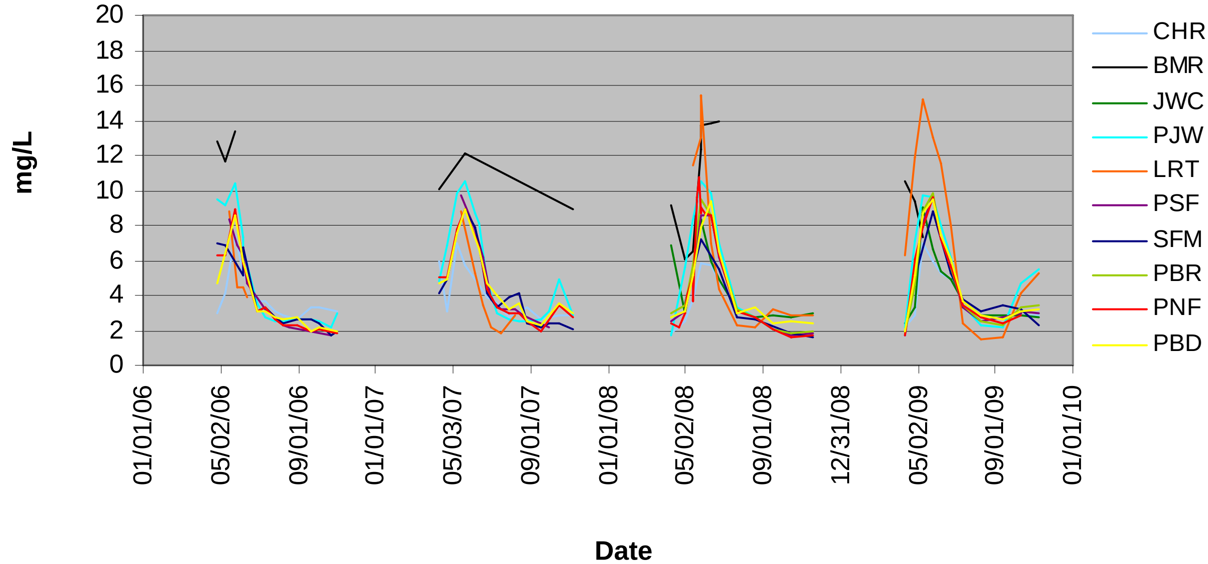
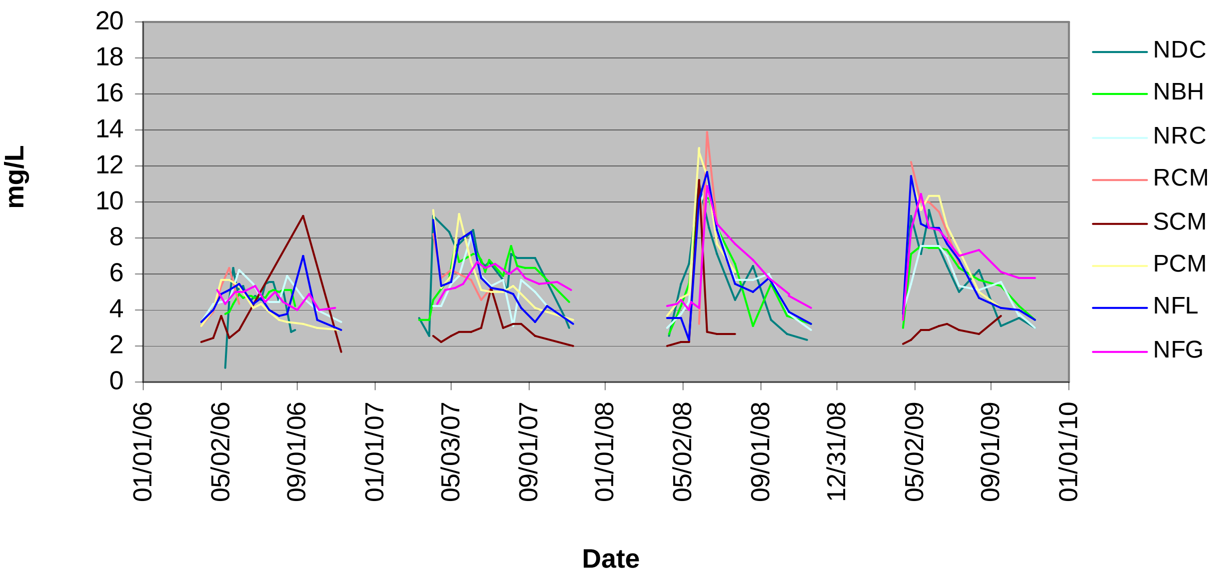


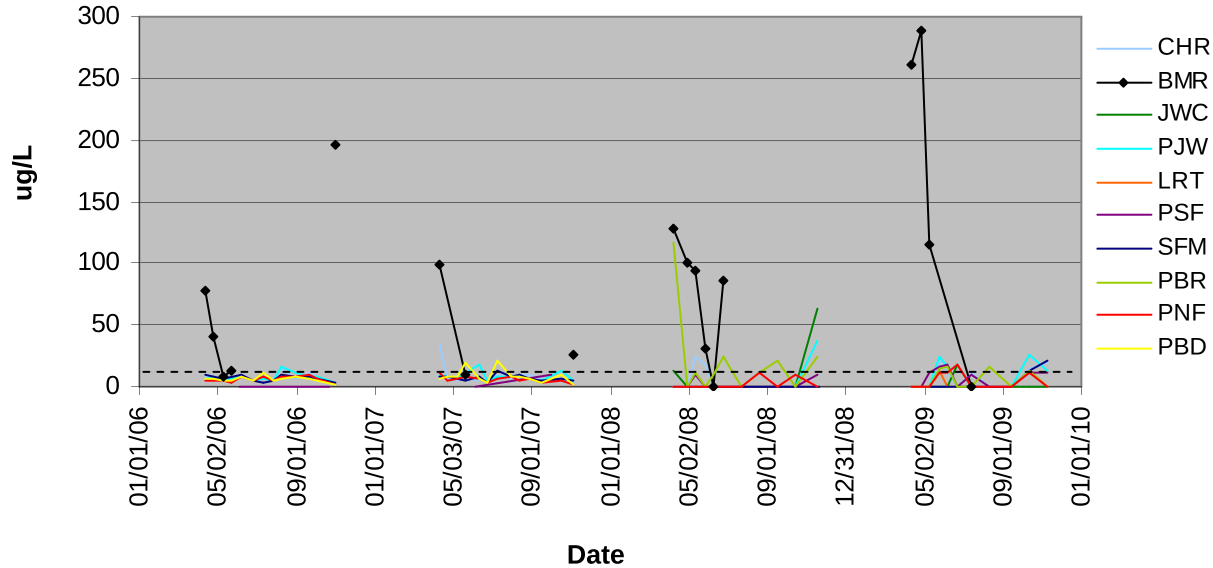
Figure 10.b. TOC on the North Fork CLP.



Mainstem and North Fork CLP: Nutrients

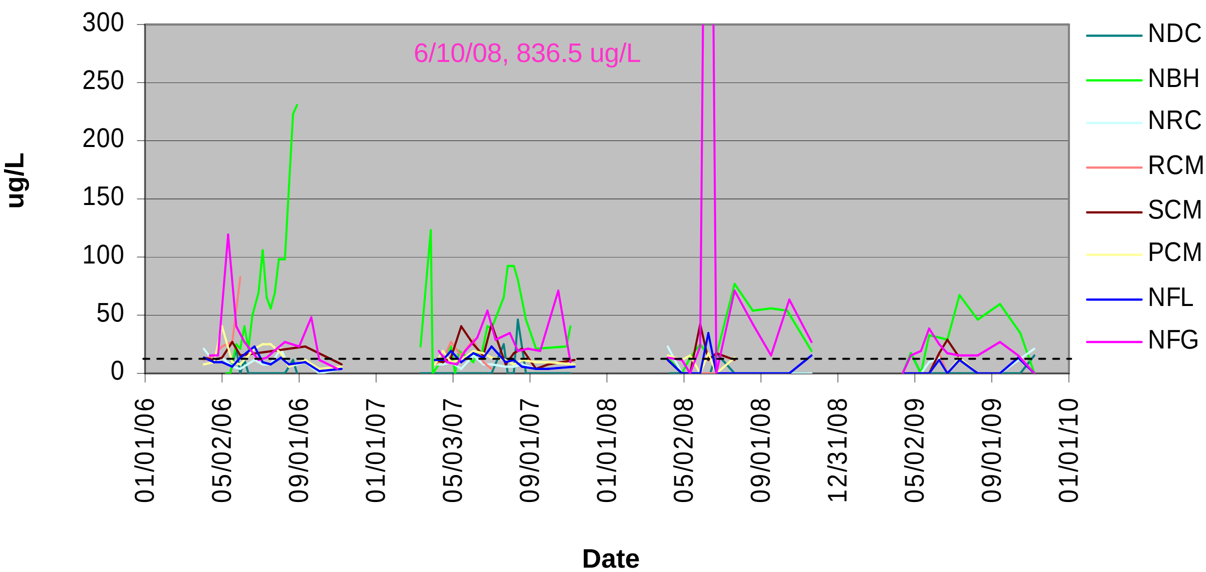
Figure 11 (a & b). Ammonia (NH_3)

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



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

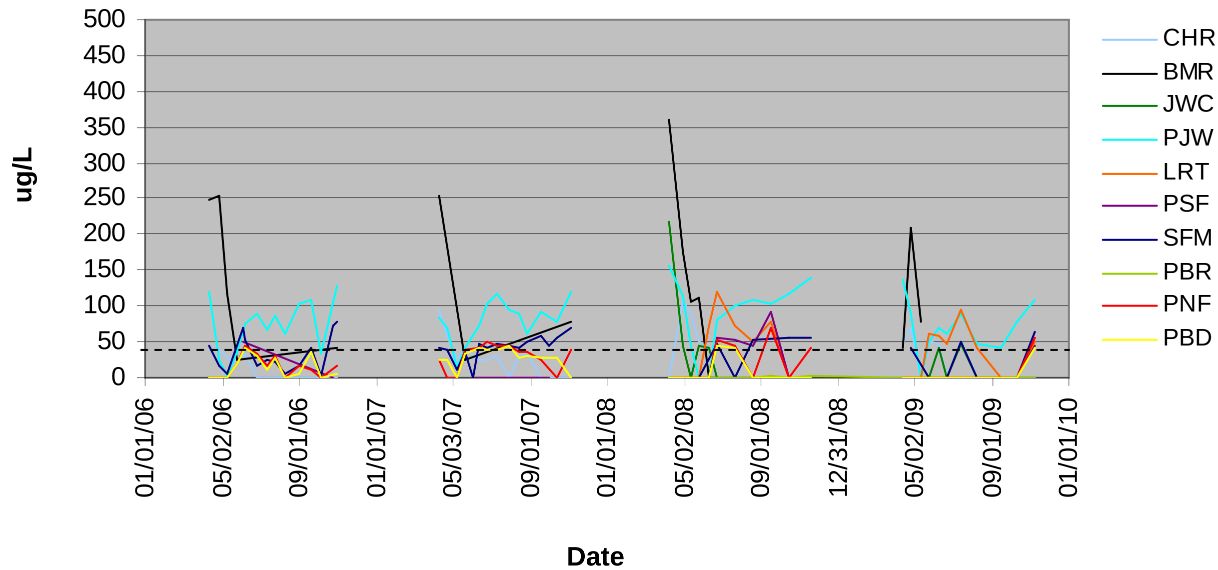
Figure 11.b. Ammonia (NH_3) on the North Fork CLP.



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

Figure 12 (a & b). Nitrate (NO_3)

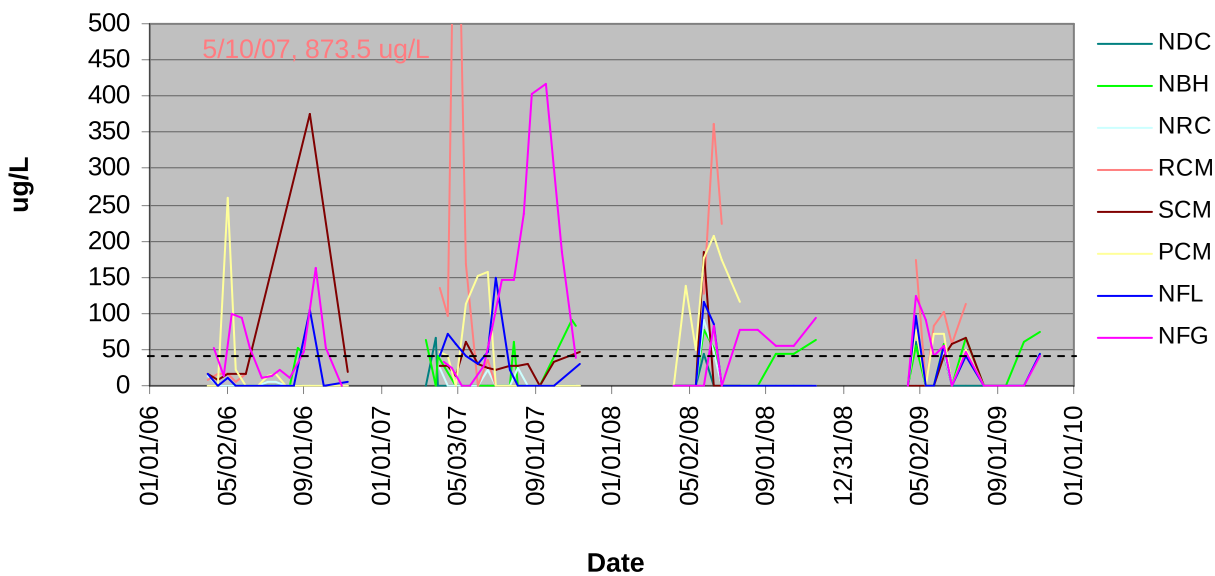
Figure 12.a. Nitrate (NO_3) on the Mainstem CLP.



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

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

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

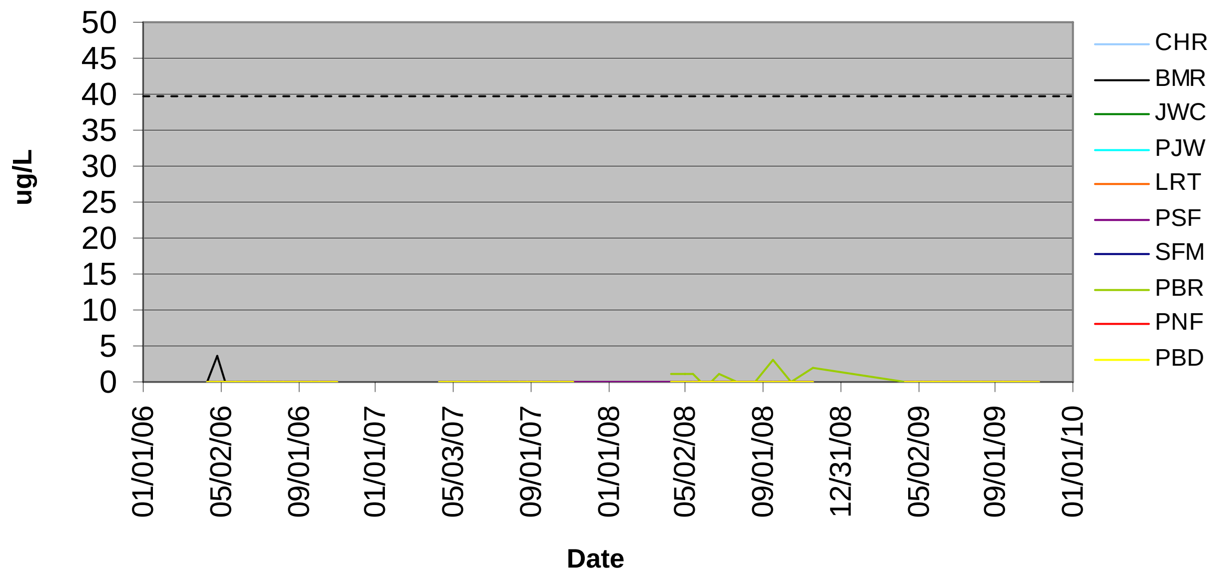


(------ FCWQL Reporting Limit: 40 ug/L)

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

Figure 13 (a & b). Nitrite (NO_2)

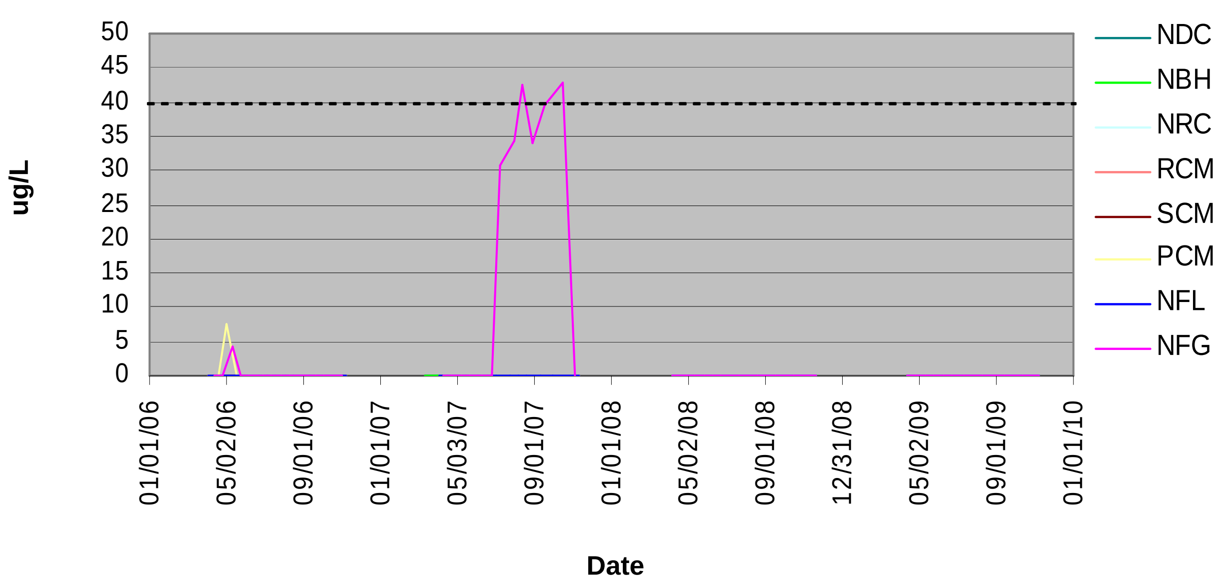
Figure 13.a. Nitrite (NO_2) on the Mainstem CLP.



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

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

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

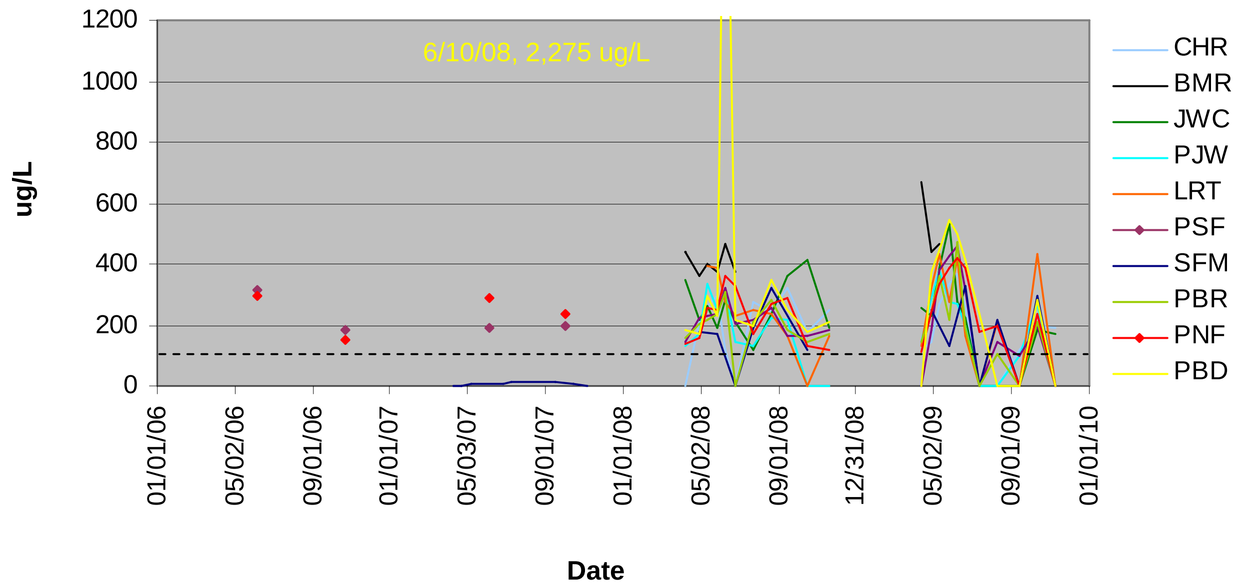


(------ FCWQL Reporting Limit: 40 ug/L)

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

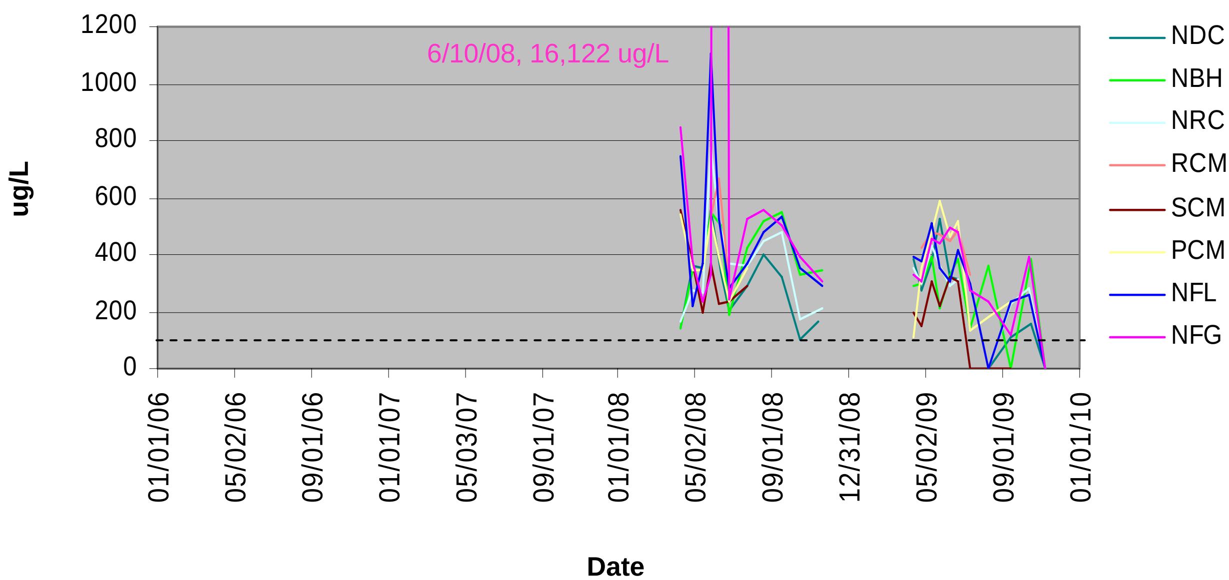
Figure 14 (a & b). Total Kjeldahl Nitrogen (TKN)

Figure 14.a. TKN on the Mainstem CLP.



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

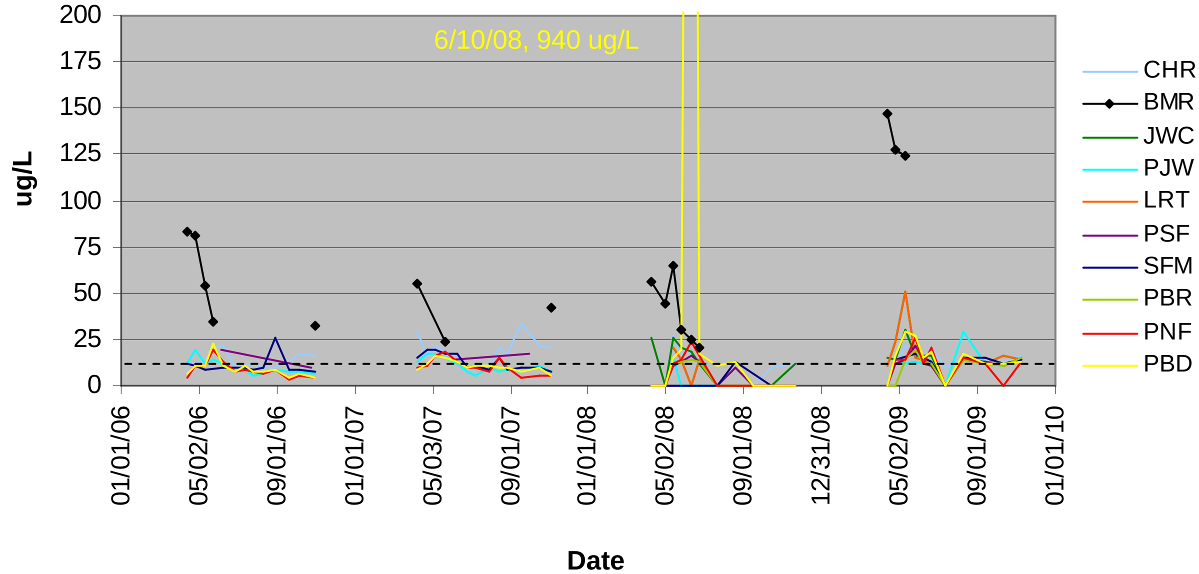
Figure 14.b. TKN on the North Fork CLP.



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

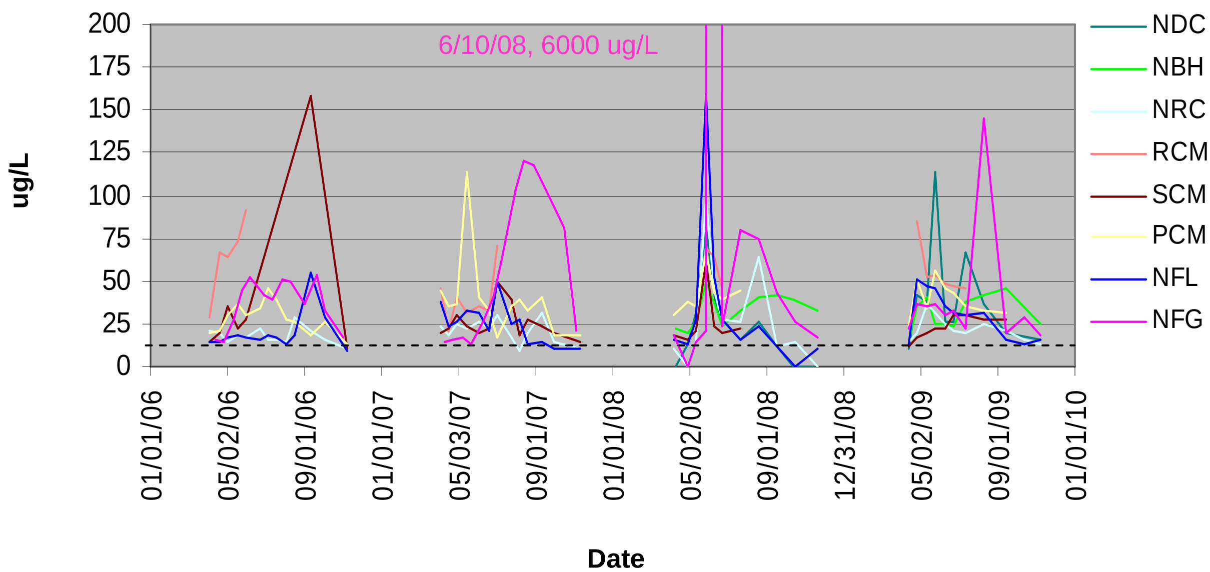
Figure 15 (a & b). Total Phosphorus

Figure 15.a. Total phosphorus on the Mainstem CLP.



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

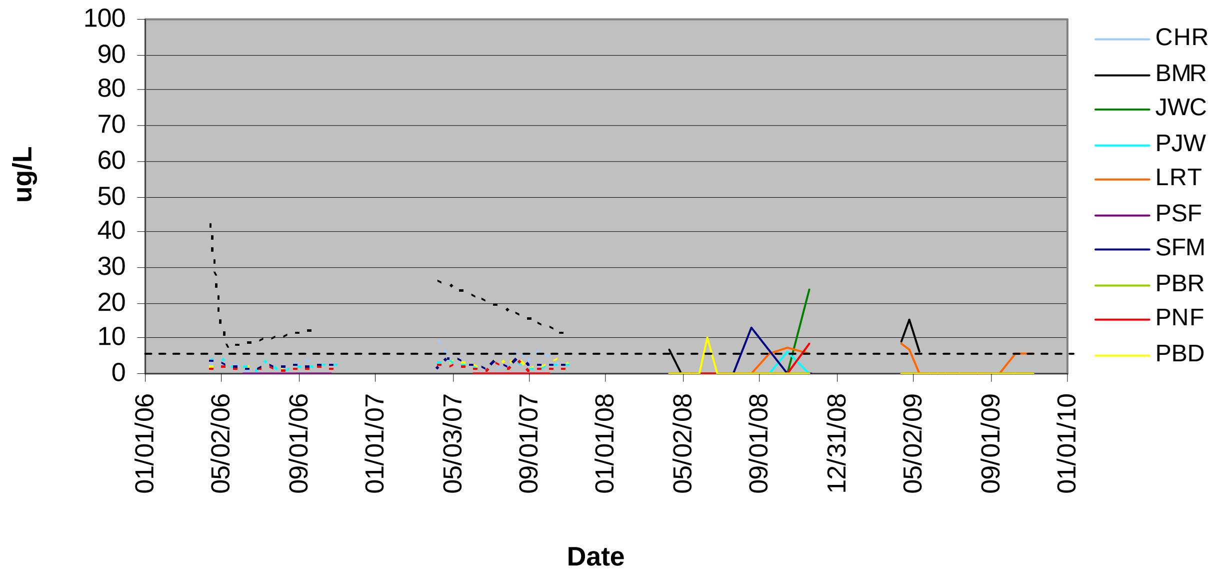
Figure 15.b. Total Phosphorus on the North Fork CLP.



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

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

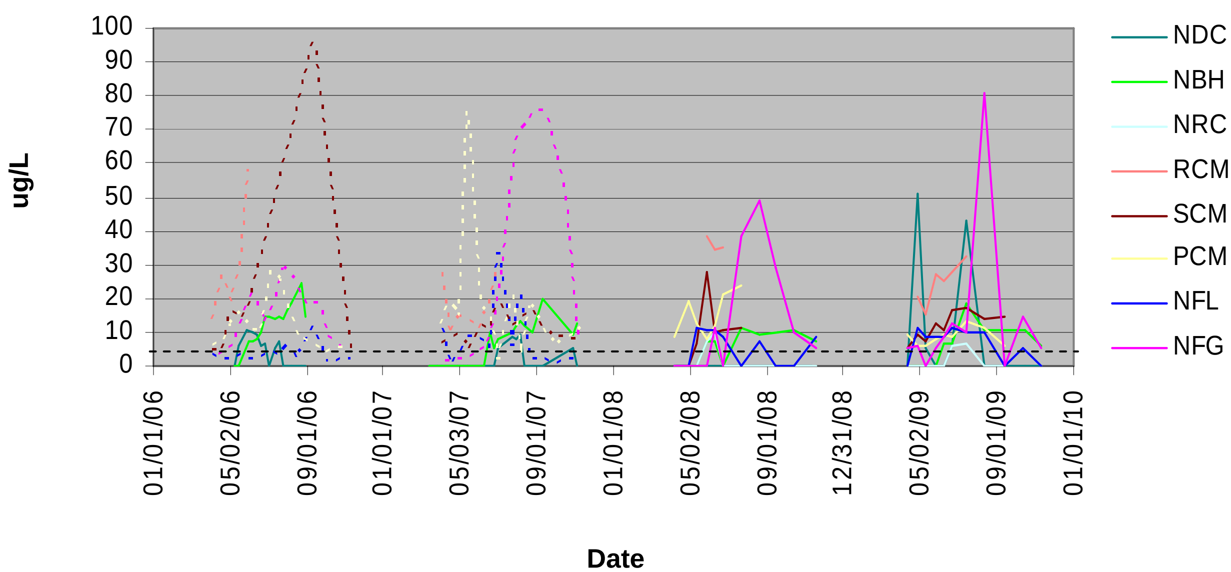
Figure 16.a. Ortho-phosphate (PO_4) on the Mainstem CLP.



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

* Values in 2006 – 2007 reported as Soluble Reactive Phosphorus (SRP)

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

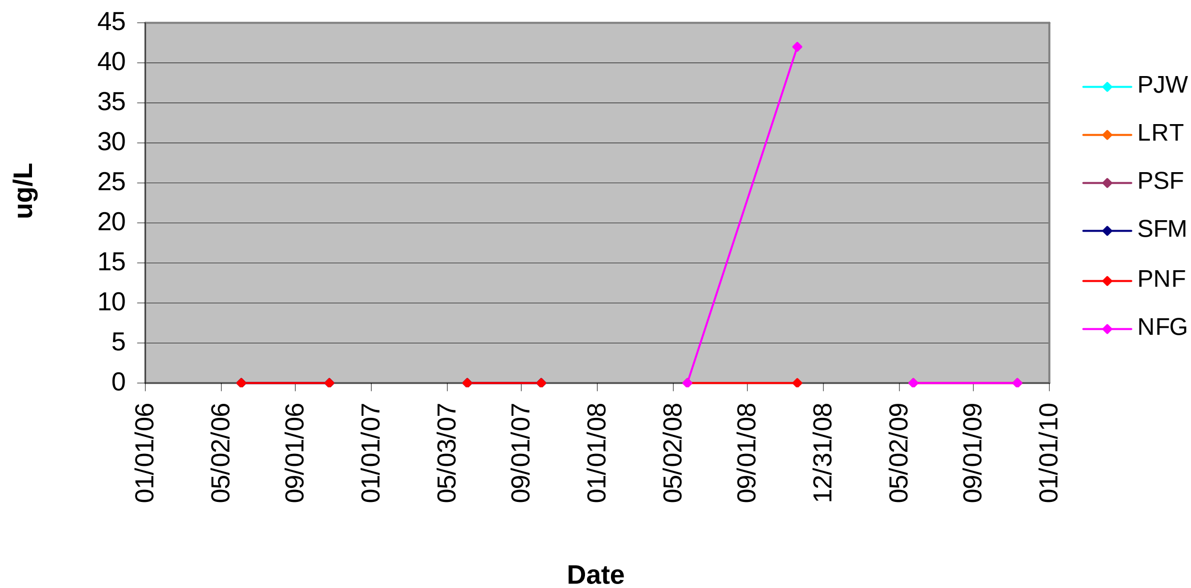


(------ FCWQL Reporting Limit: 5 ug/L)

* Values in 2006 – 2007 reported as Soluble Reactive Phosphorus (SRP)

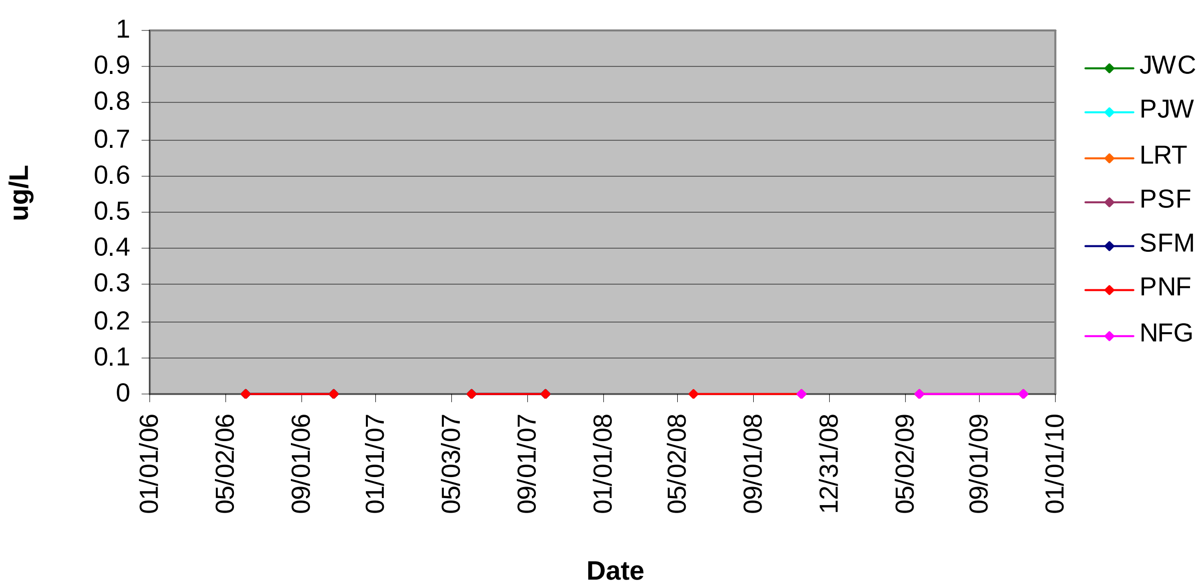
Mainstem and North Fork CLP: Metals

Figure 17. Dissolved silver (Ag) on the Mainstem and North Fork CLP.



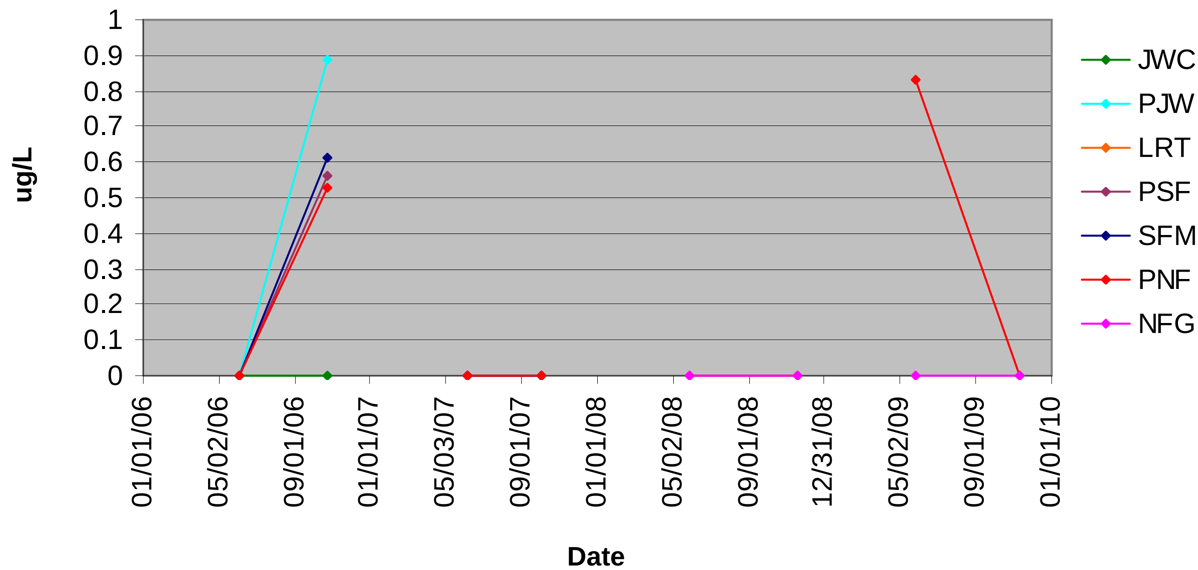
(EPA Secondary Drinking Water Standard: 100 ug/L)

Figure 18. Dissolved cadmium (Cd) on the Mainstem and North Fork CLP North Fork CLP.



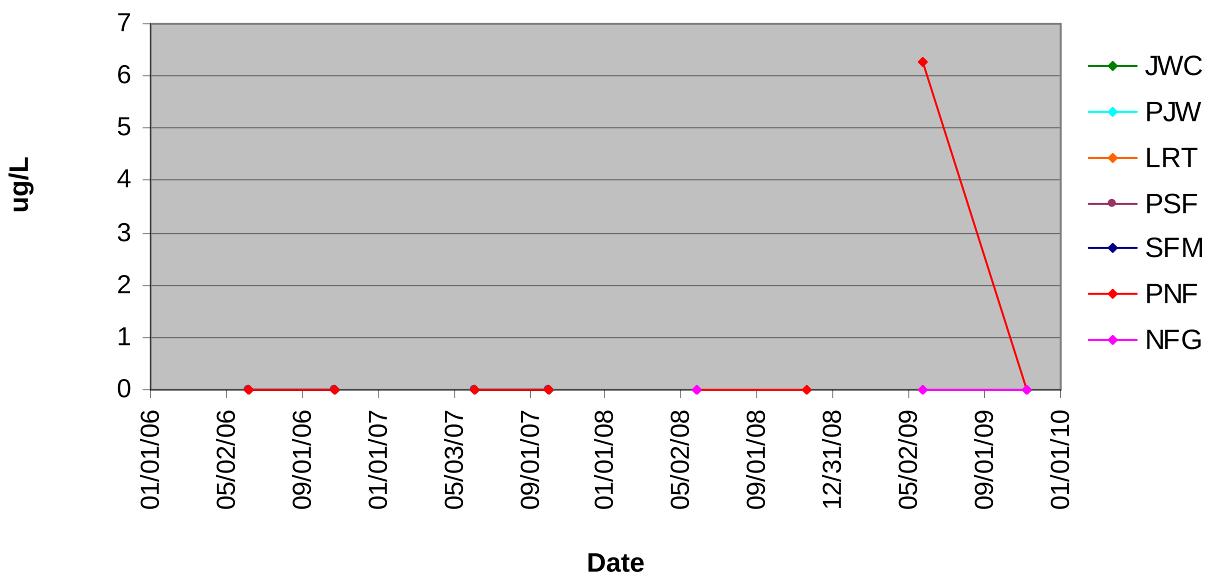
(EPA Maximum Contaminant Level: 5 ug/L)

Figure 19. Dissolved chromium (Cr) on the Mainstem and North Fork CLP.



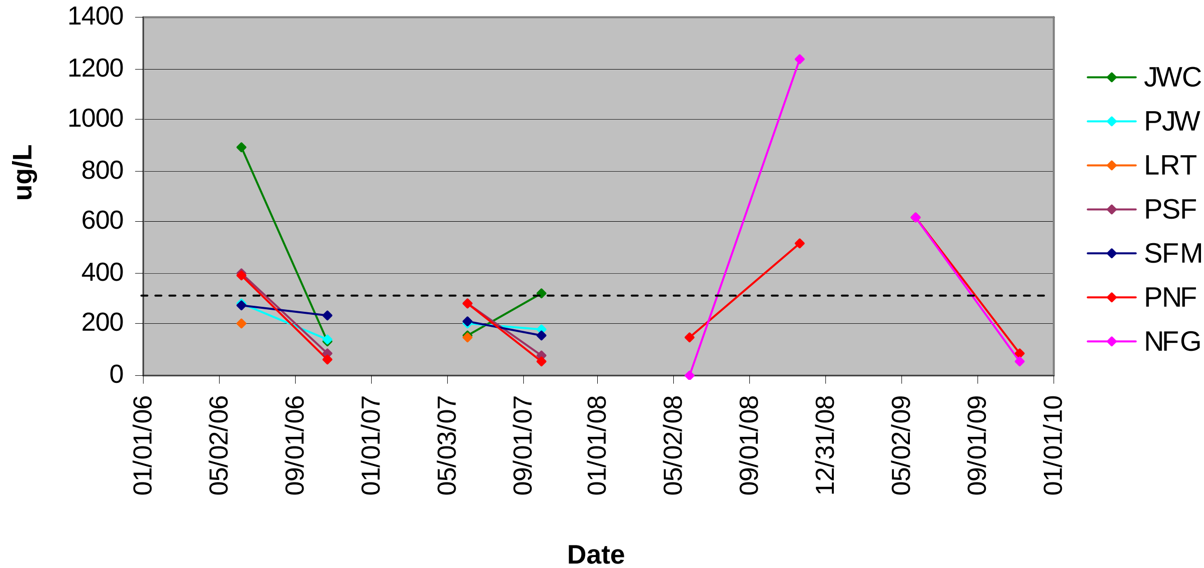
(EPA Maximum Contaminant Level : 100 ug/L)

Figure 20. Dissolved copper (Cu) on the Mainstem and North Fork CLP North Fork CLP.



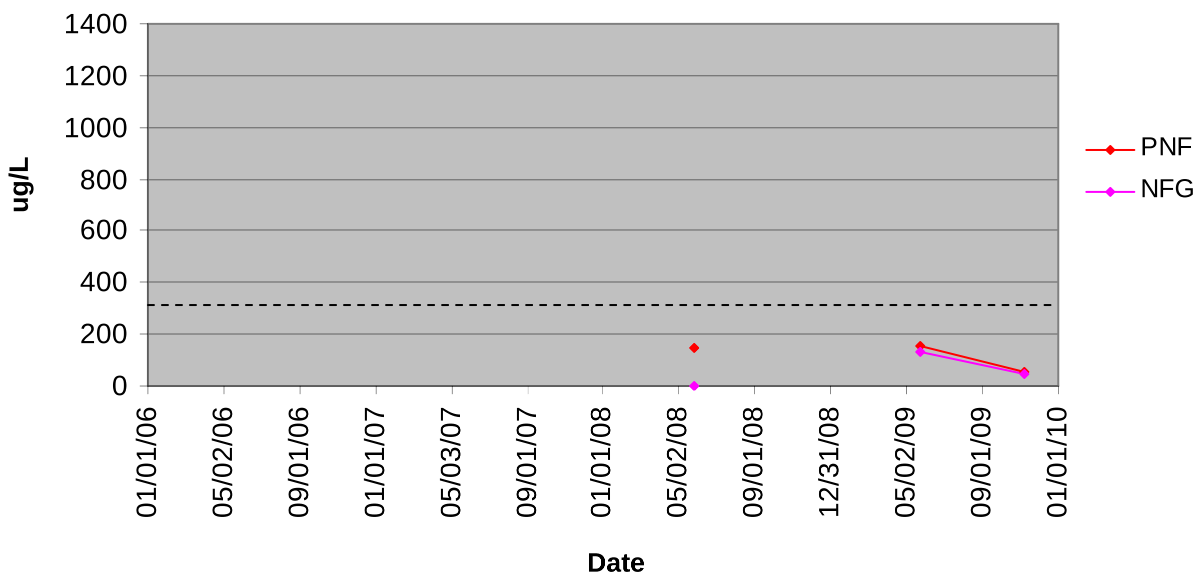
(EPA Maximum Contaminant Level : 1,300 ug/L)

Figure 21. Total iron (Fe) on the Mainstem and North Fork CLP.



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

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



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

Figure 23. Dissolved nickel (Ni) on the Mainstem and North Fork CLP.

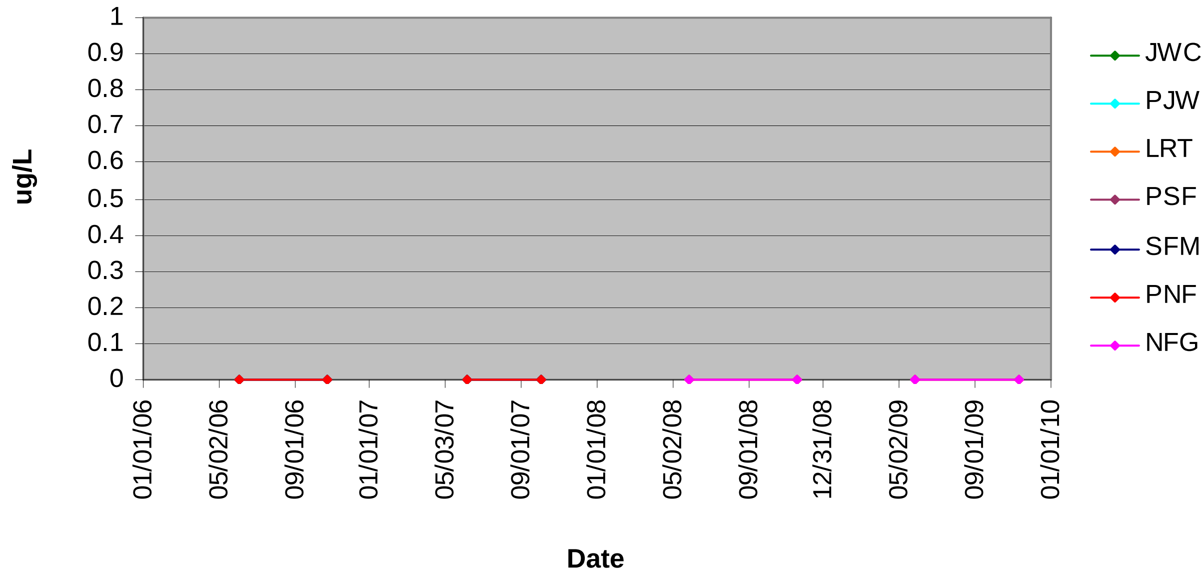
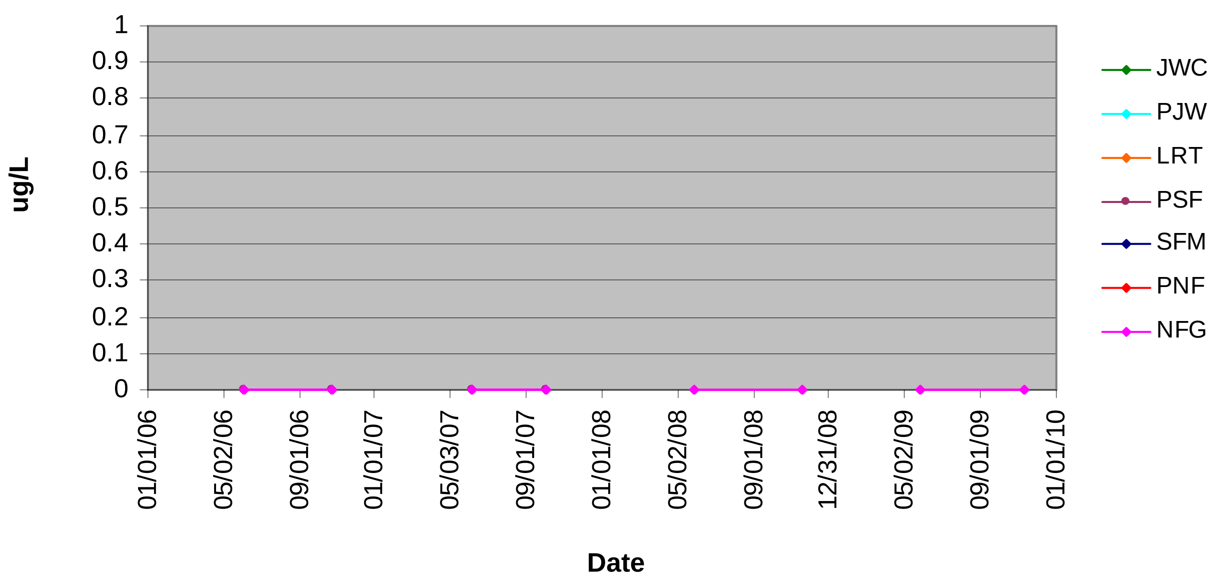
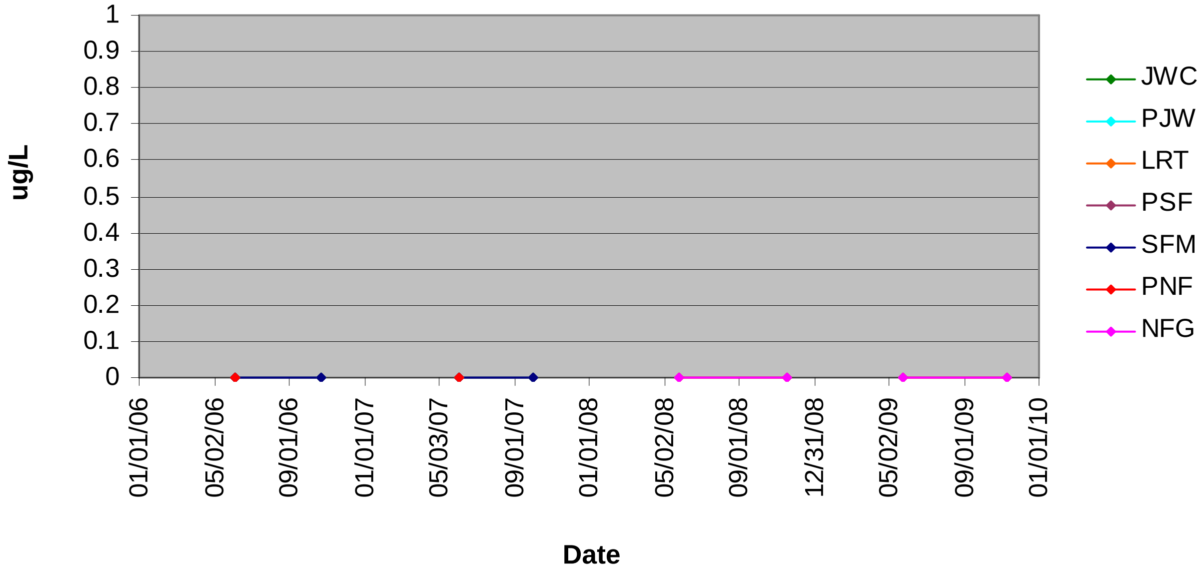


Figure 24. Dissolved lead (Pb) on the Mainstem and North Fork CLP North Fork CLP.



(EPA Maximum Contaminant Level : 15 ug/L)

Figure 25. Dissolved zinc (Zn) on the Mainstem and North Fork CLP.



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

Mainstem and North Fork CLP: Major Ions

Figure 26 (a & b). Calcium

Figure 26.a. Calcium (Ca) on the Mainstem CLP.

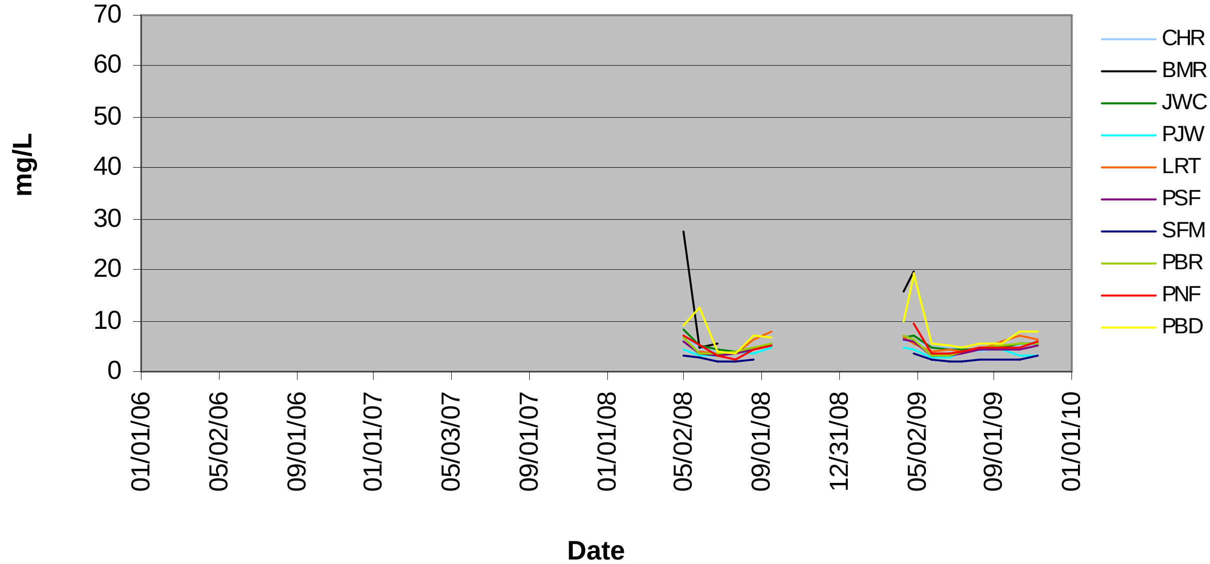


Figure 26.b. Calcium (Ca) on the North Fork CLP.

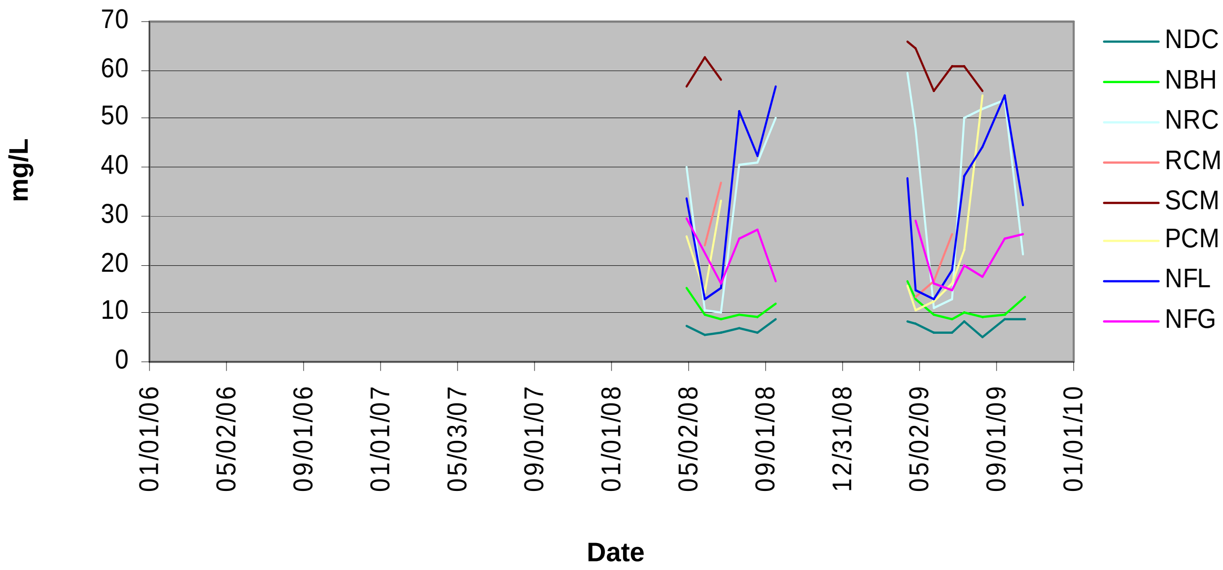


Figure 27 (a & b). Magnesium (Mg)

Figure 27.a. Magnesium (Mn) on the Mainstem CLP.

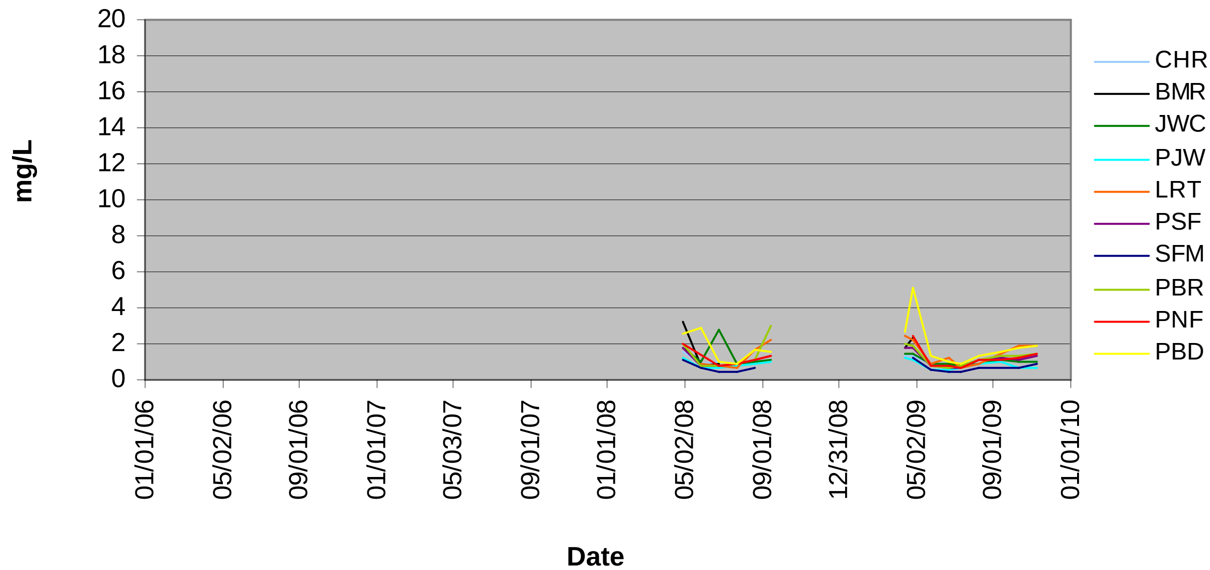


Figure 27.b. Magnesium (Mg) on the North Fork CLP.

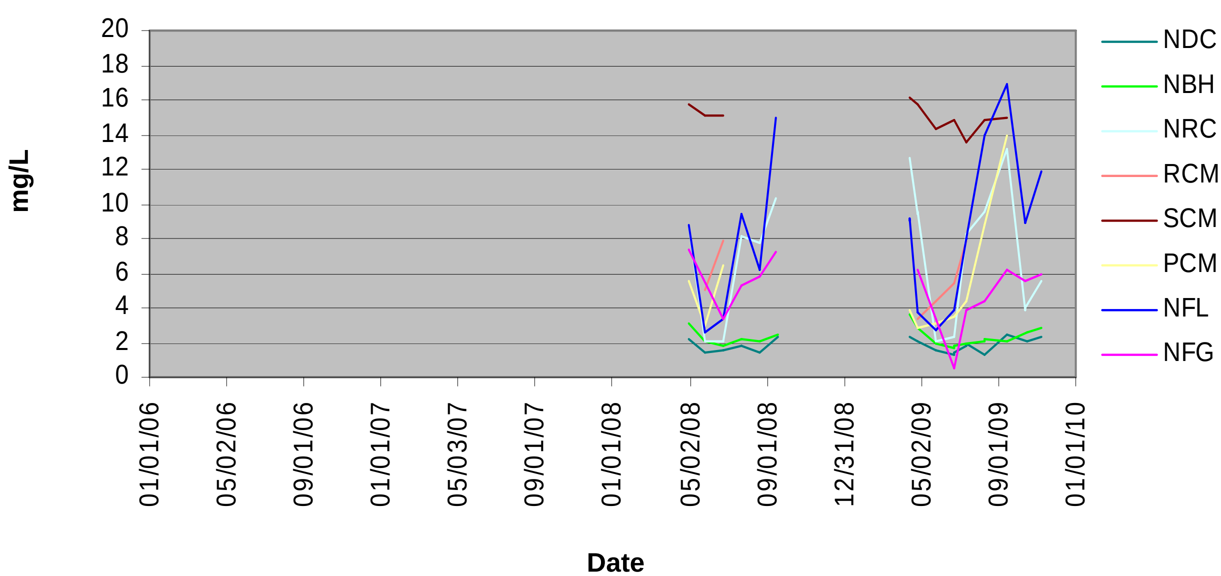


Figure 28 (a & b). Potassium (K)

Figure 28.a. Potassium (K) on the Mainstem CLP.

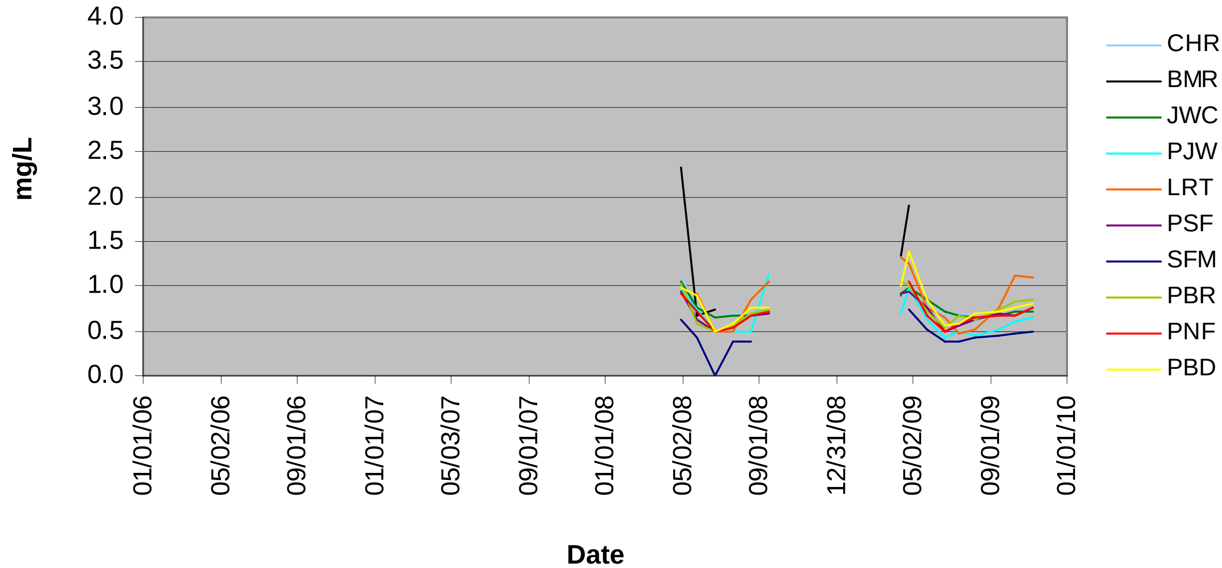


Figure 28.b. Potassium (K) on the North Fork CLP.

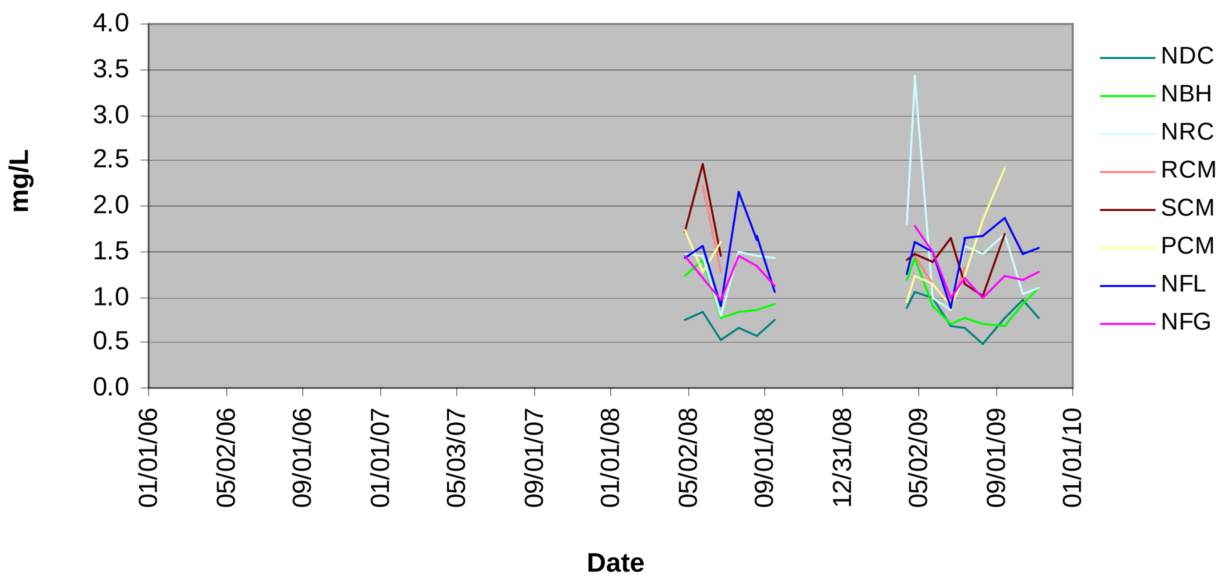


Figure 29 (a & b). Sodium (Na)

Figure 29.a. Sodium (Na) on the Mainstem CLP.

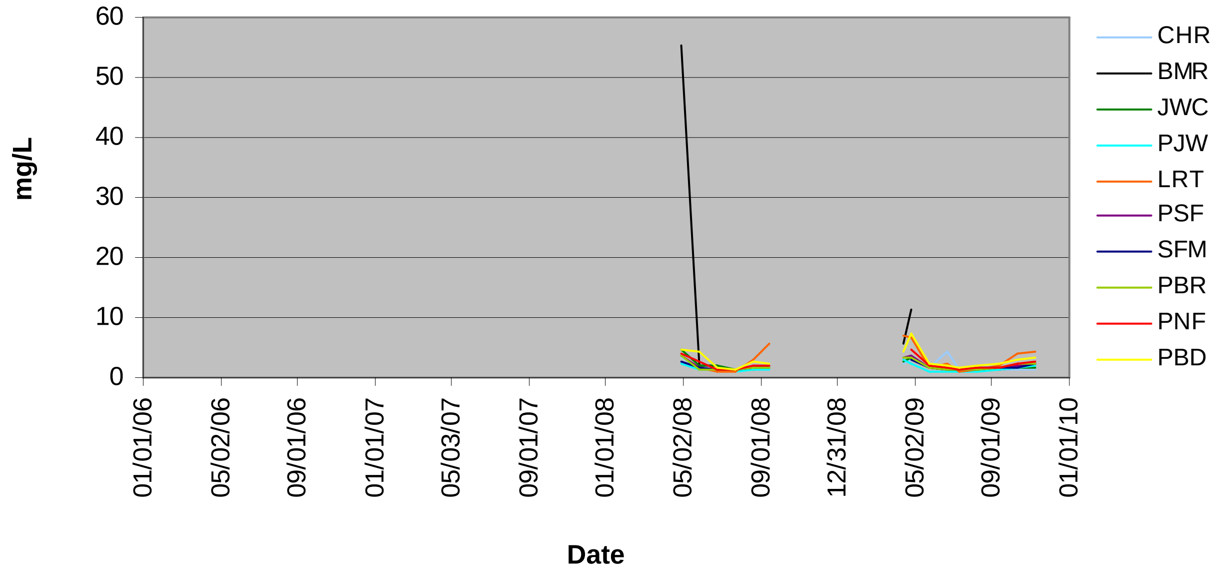


Figure 29.b. Sodium (Na) on the North Fork CLP.

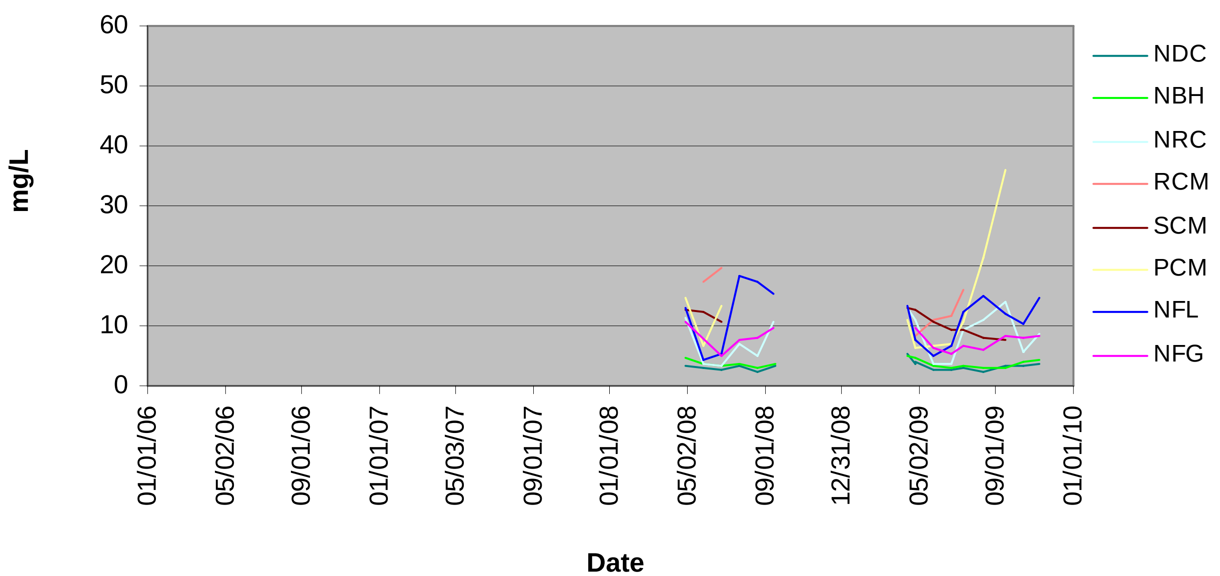


Figure 30 (a & b). Chloride (Cl^-)

Figure 30.a. Chloride (Cl^-) on the Mainstem CLP.

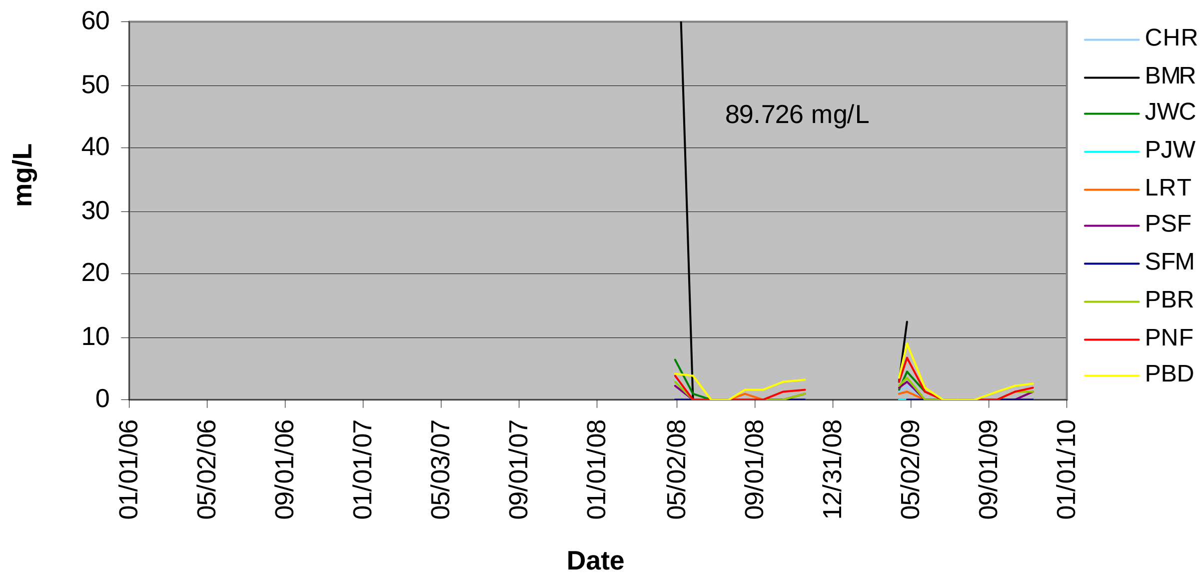


Figure 30.a. Chloride (Cl^-) on the Mainstem CLP.

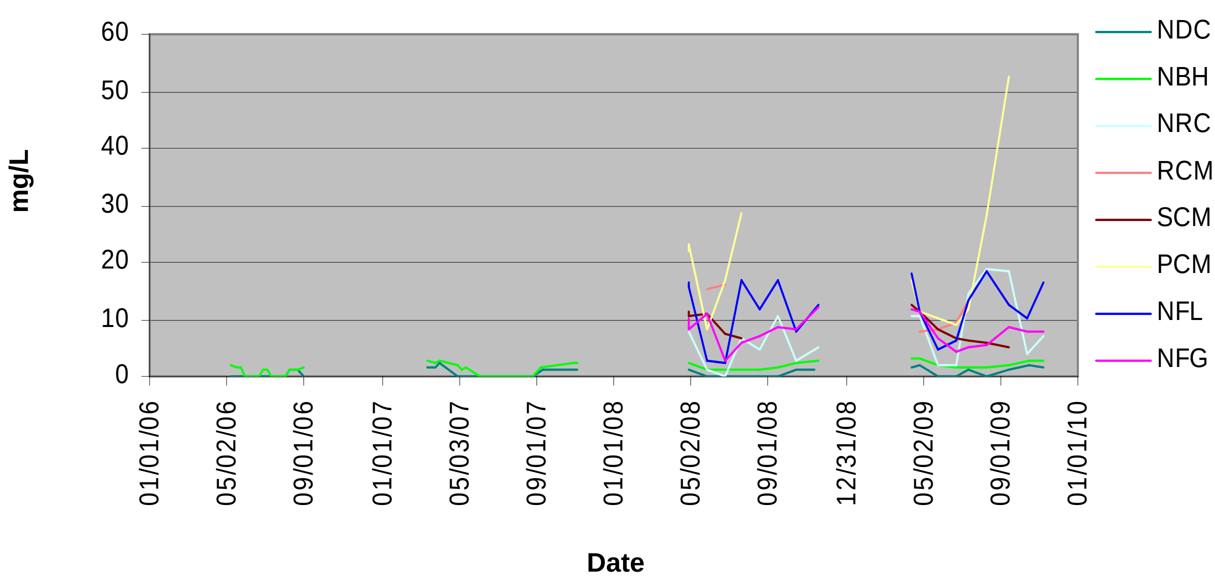
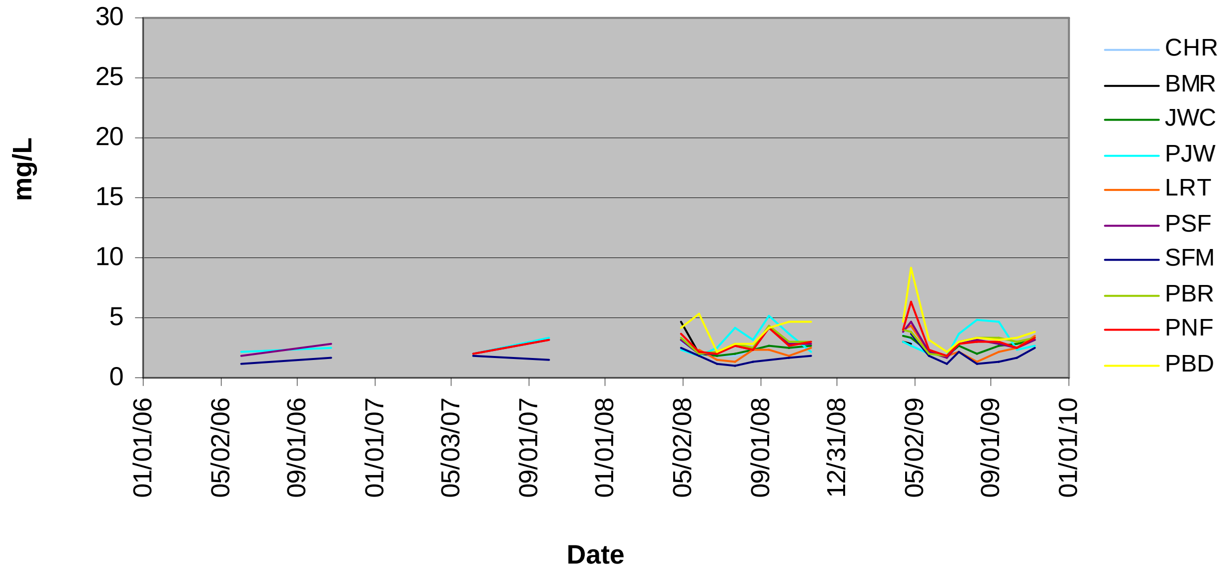


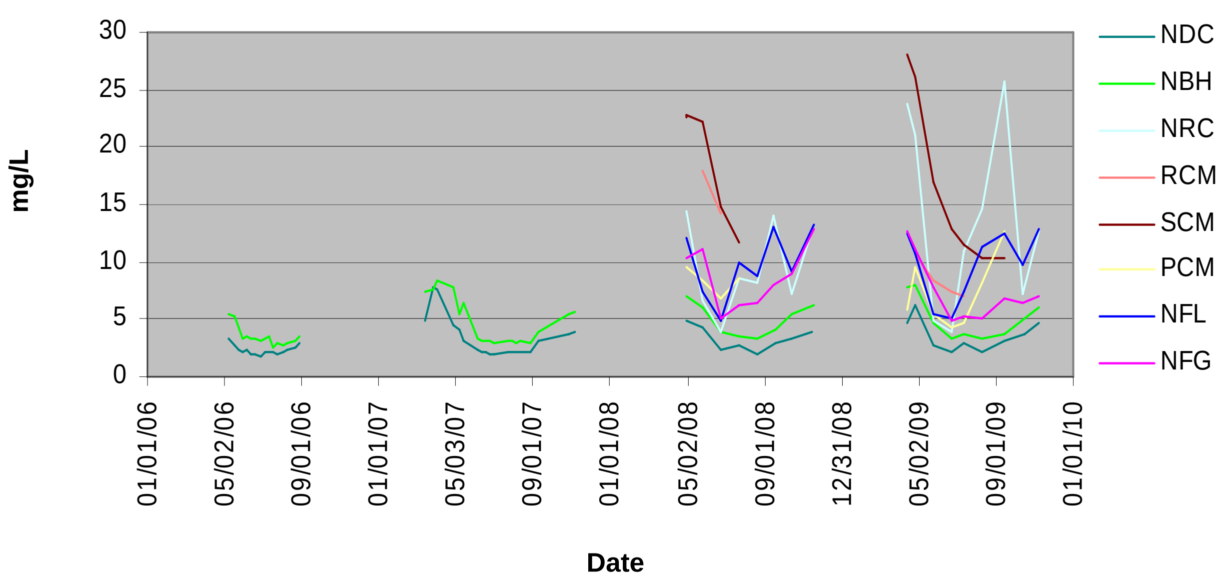
Figure 31 (a & b). Sulfate (SO_4^-)

Figure 31.a. Sulfate (SO_4^-) on the Mainstem CLP.



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

Figure 31.a. Sulfate (SO_4^-) on the North Fork CLP.



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

Mainstem and North Fork CLP: Microbiological Constituents

Figure 32. Total Coliforms on the Mainstem and North Fork CLP.

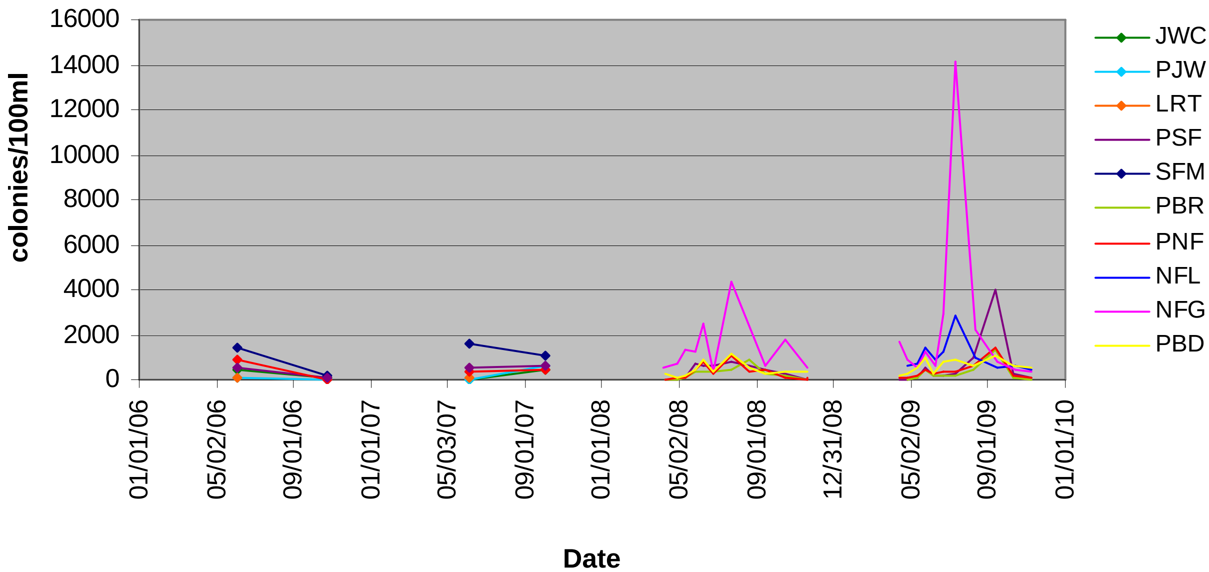


Figure 33. *E. coli* on the Mainstem and North Fork CLP.

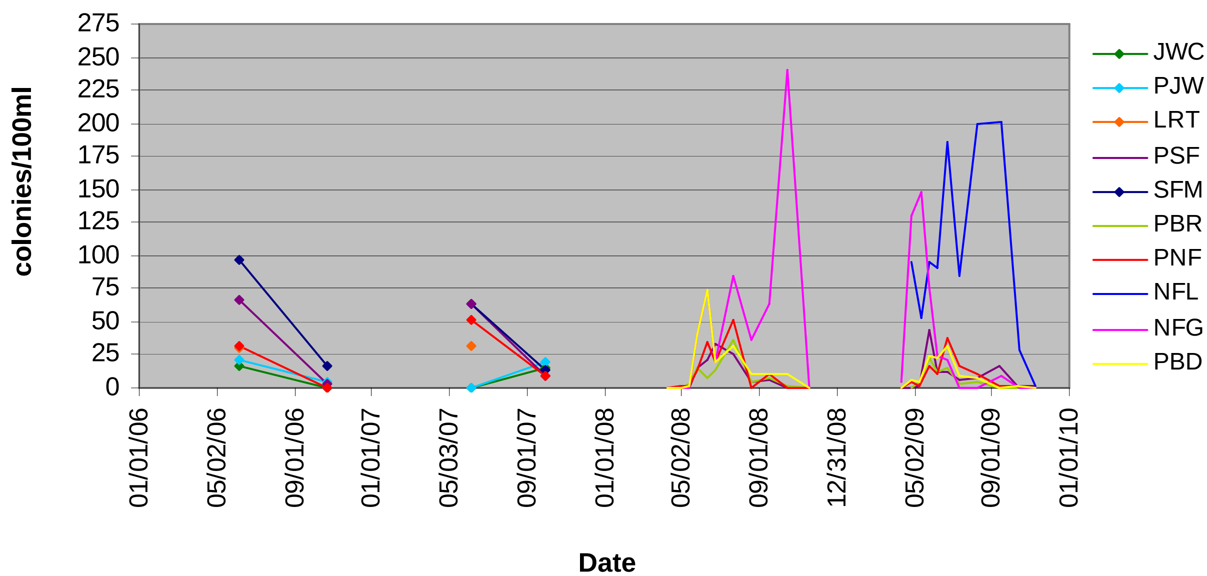


Figure 34. *Giardia* on the Mainstem and North Fork CLP.

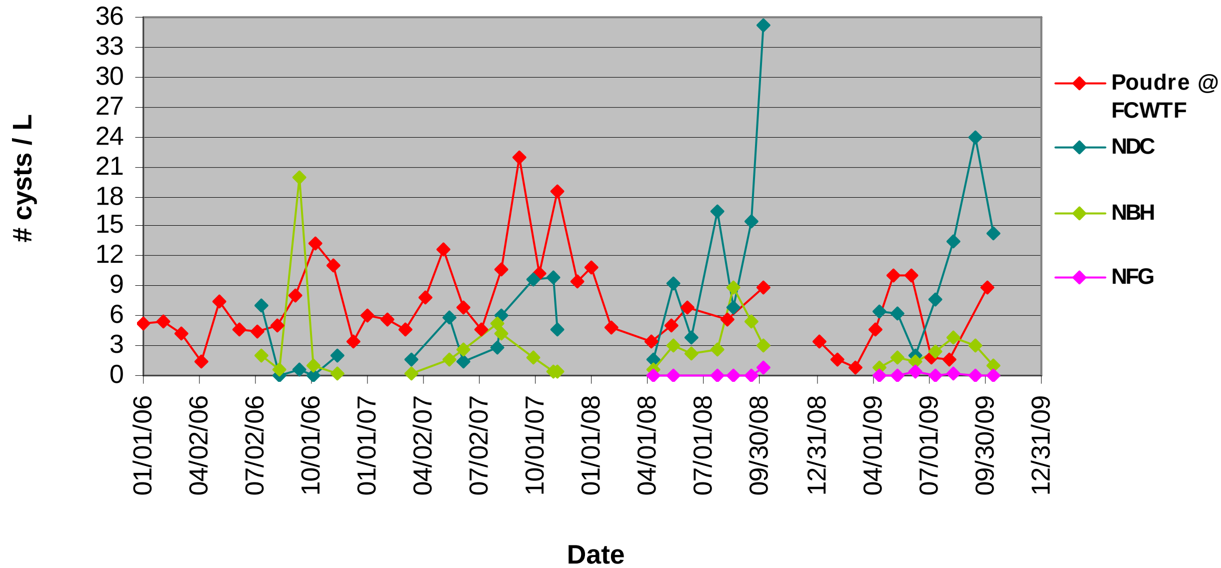
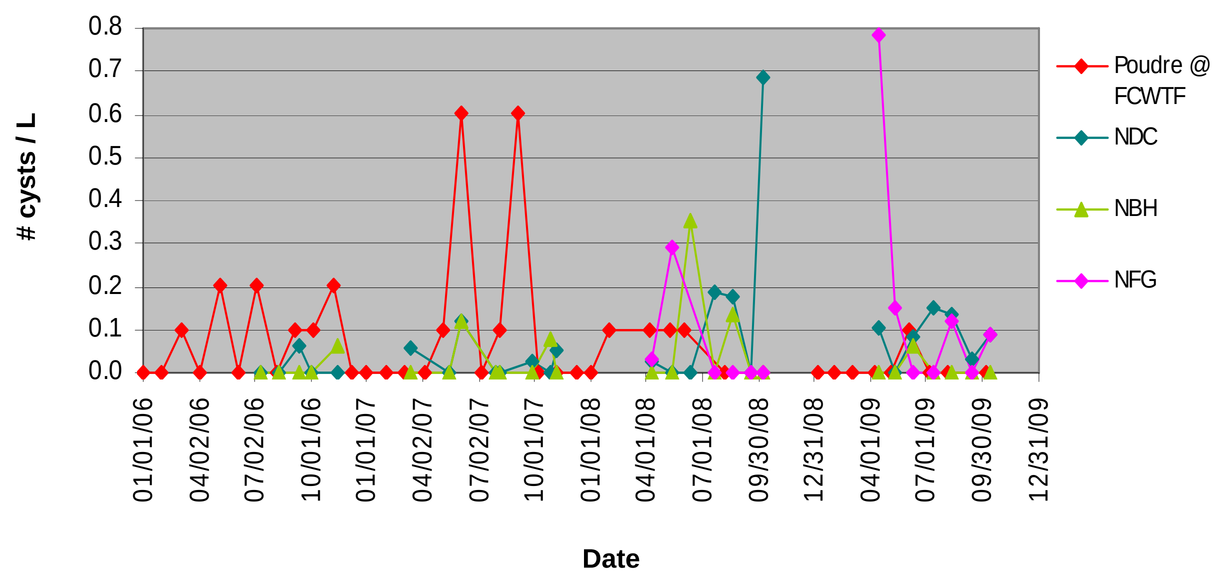
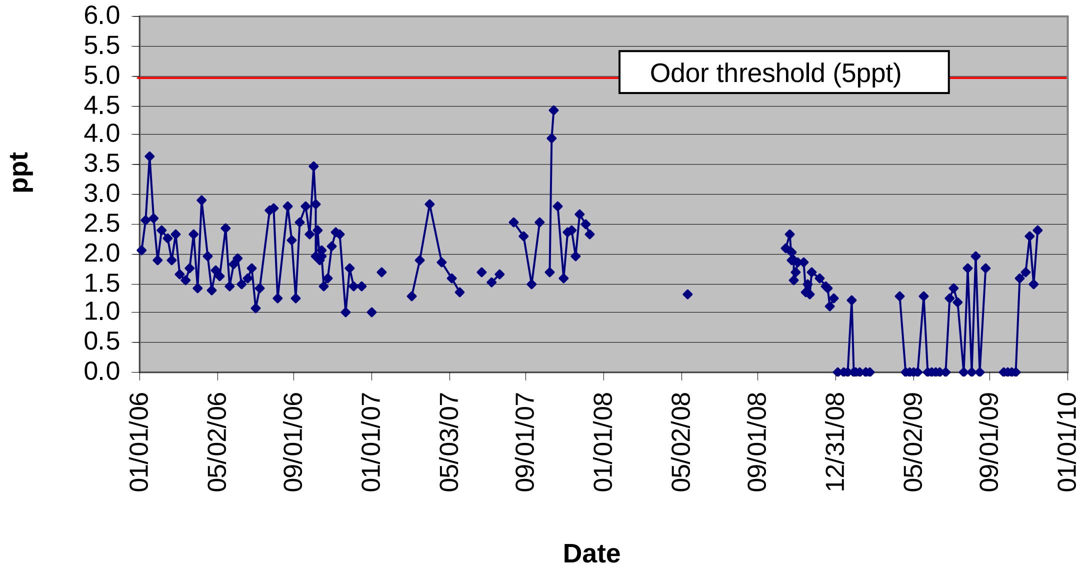


Figure 35. *Cryptosporidium* on the Mainstem and North Fork CLP.



Mainstem and North Fork CLP: Geosmin

Figure 36. Geosmin concentrations of the Mainstem CLP collected at the FCWTF.



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

Figure 37. 2009 Seaman Reservoir temperature profiles.

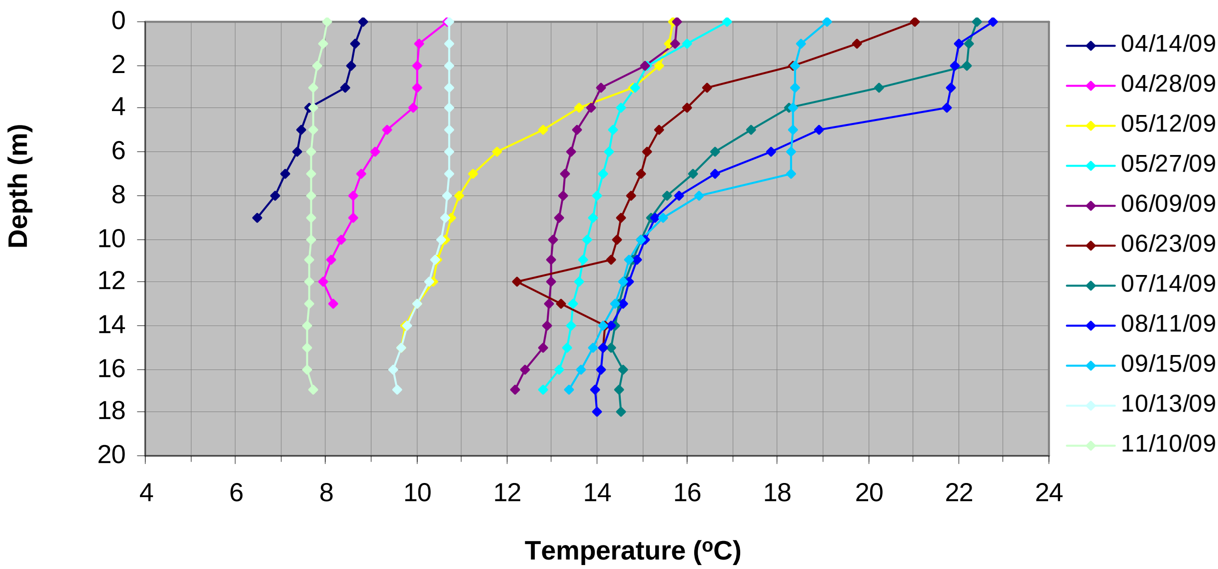


Figure 38. 2009 Seaman Reservoir dissolved oxygen (D.O.) profiles.

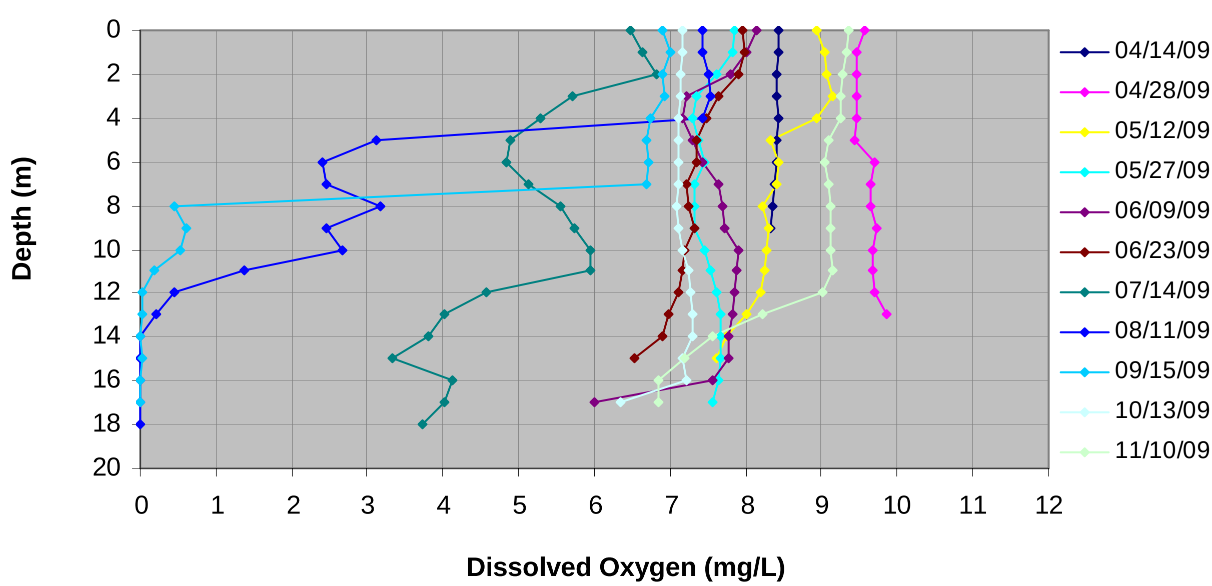


Figure 39. 2009 Seaman Reservoir pH profiles.

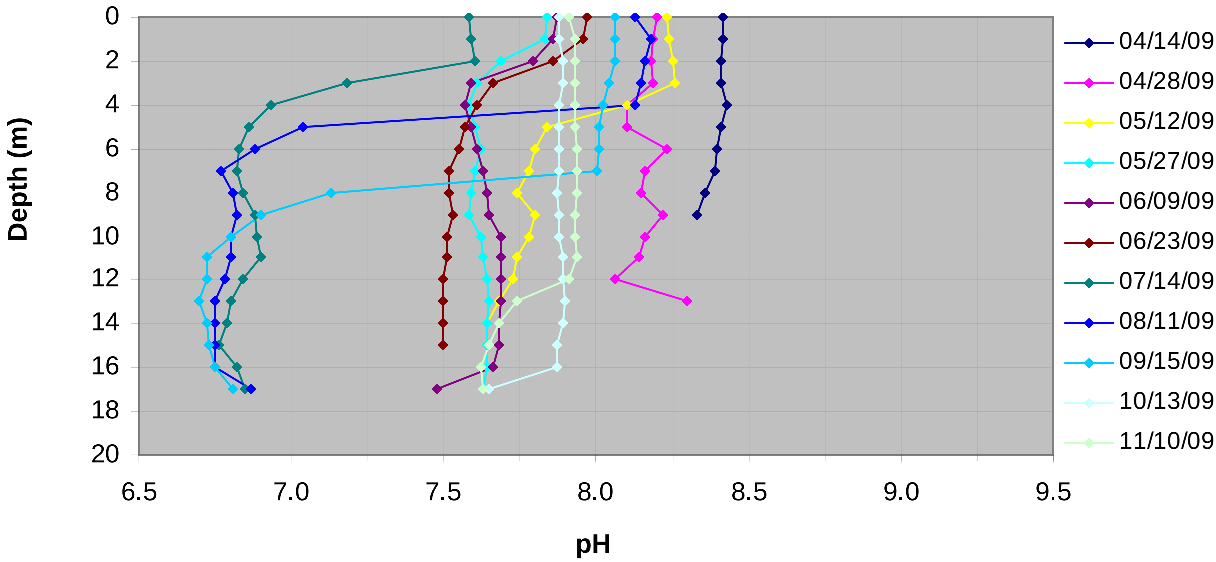
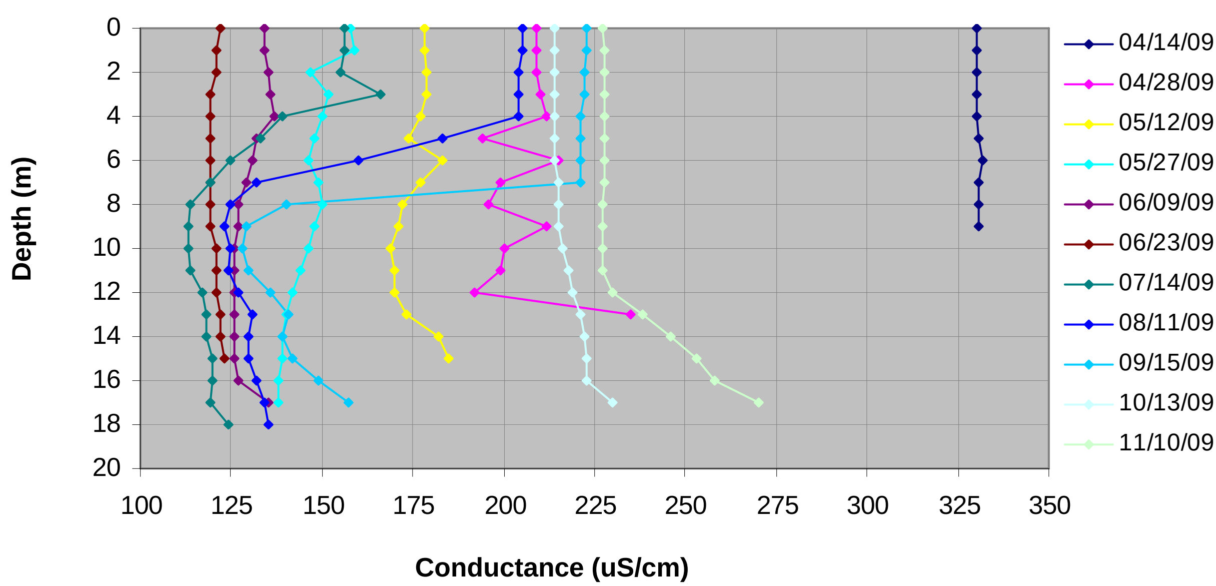


Figure 40. 2009 Seaman Reservoir conductance profiles.



Seaman Reservoir: General Parameters

Figure 41. Alkalinity concentrations in Seaman Reservoir.

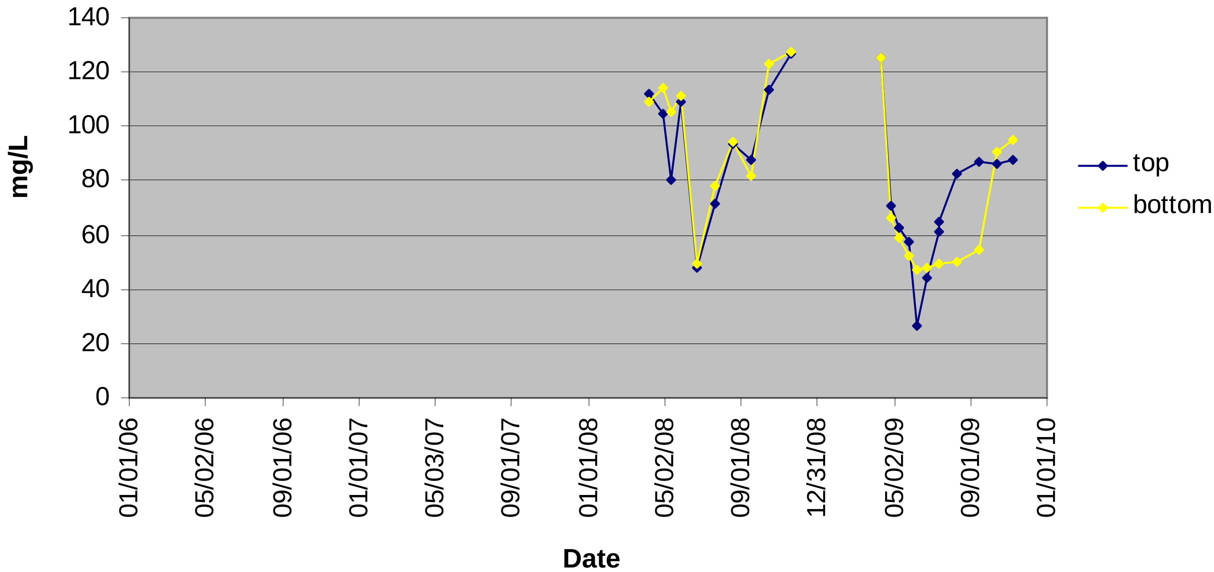


Figure 42. Hardness concentrations in Seaman Reservoir.

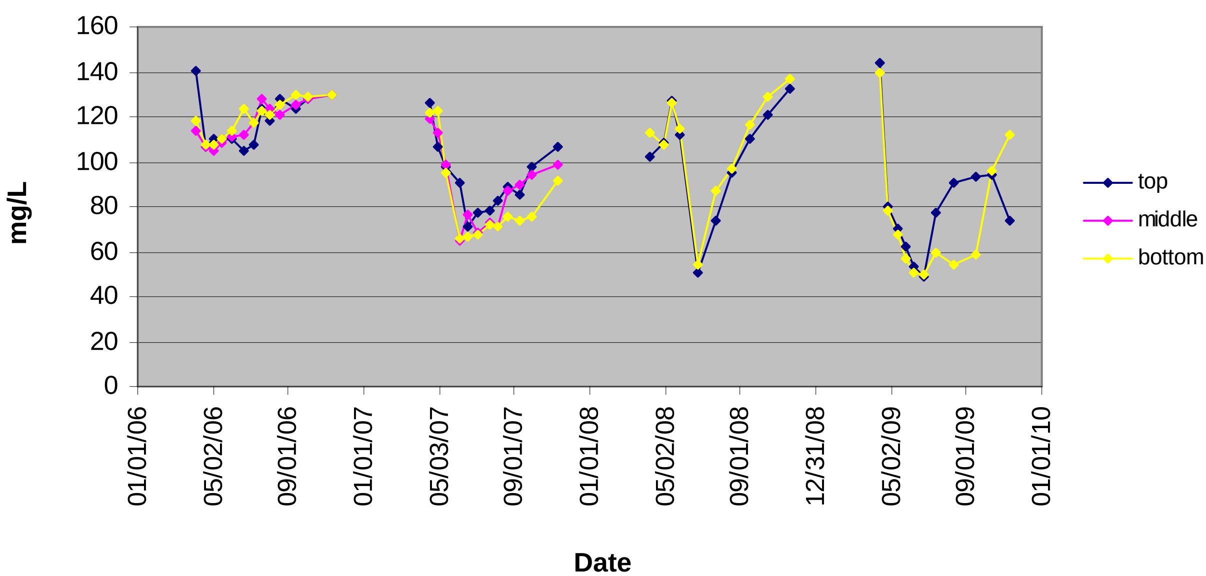


Figure 43. Turbidity in Seaman Reservoir.

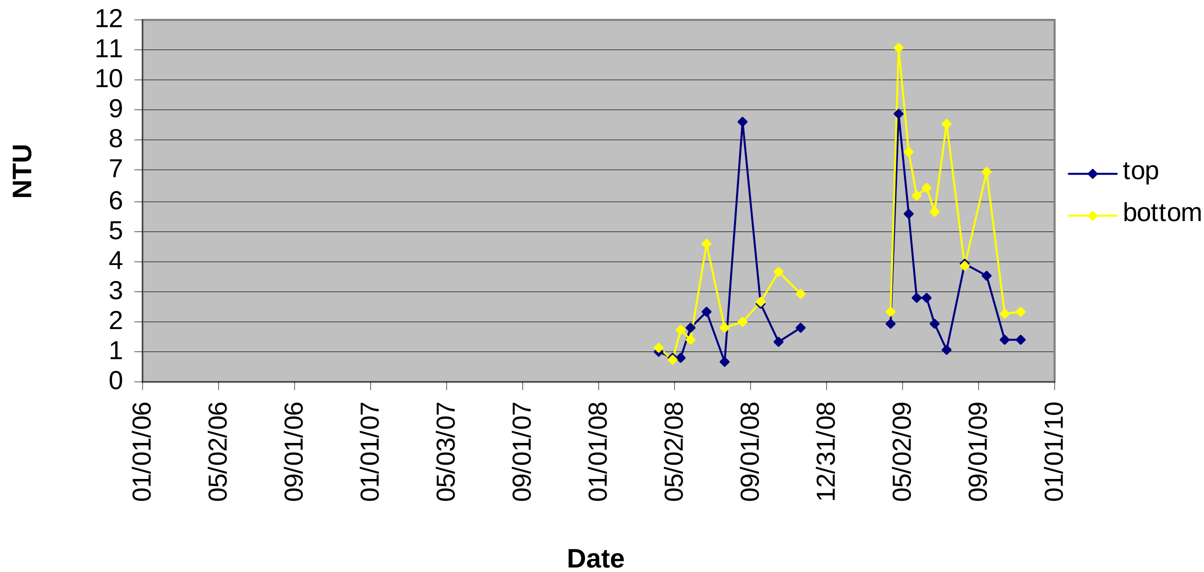


Figure 44. Chlorophyll-a concentrations in Seaman Reservoir.

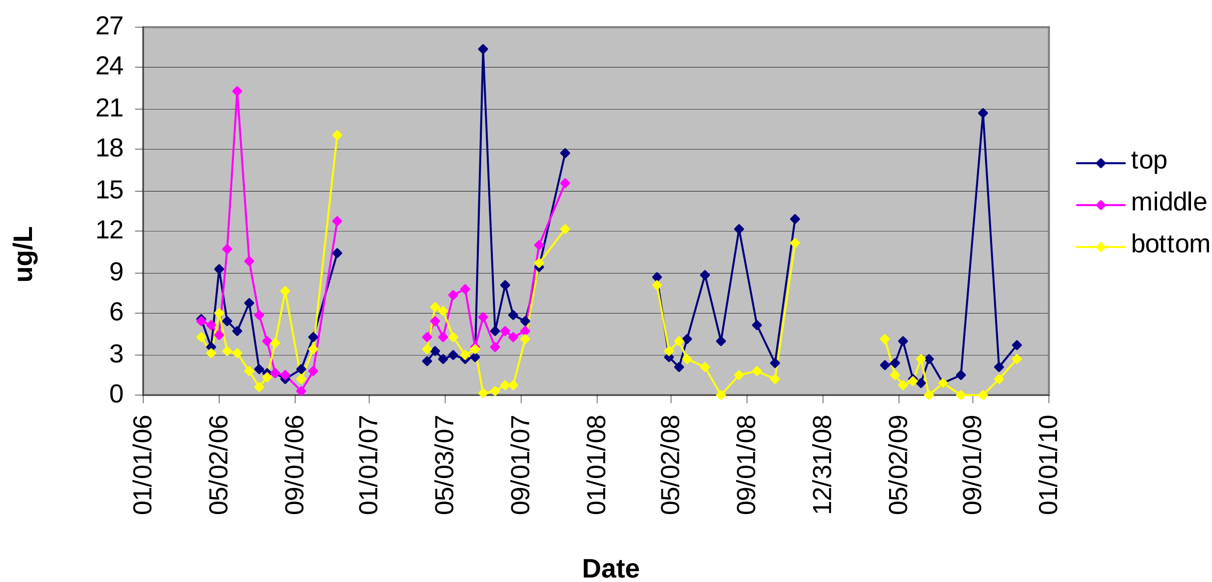
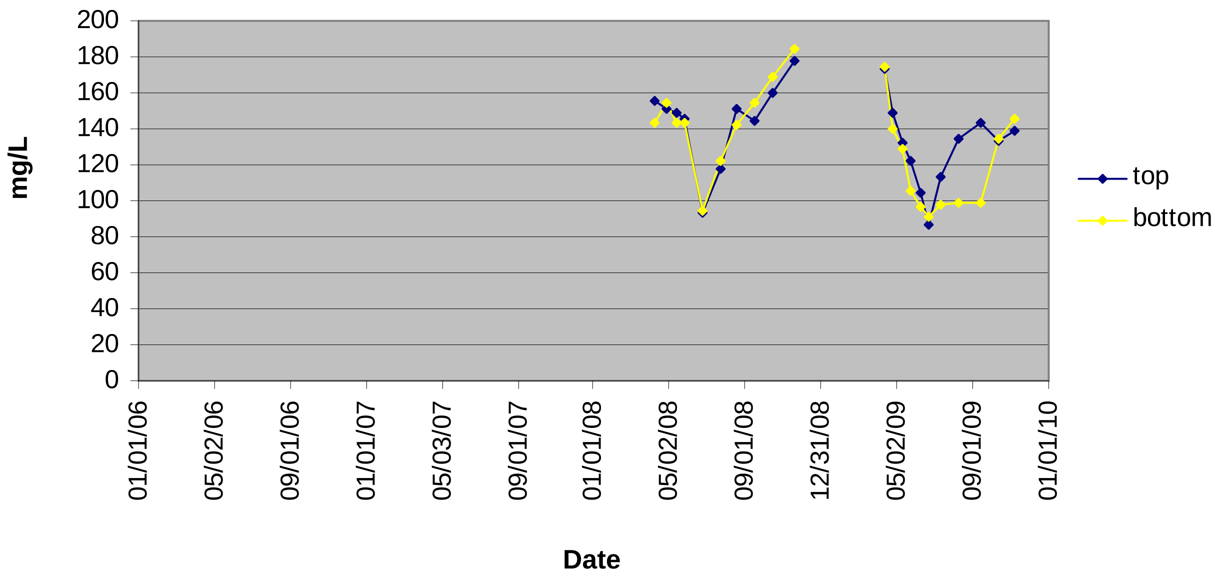


Figure 45. Total Dissolved Solids (TDS) in Seaman Reservoir.



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

Figure 46. Total Organic Carbon (TOC) concentrations in Seaman Reservoir.

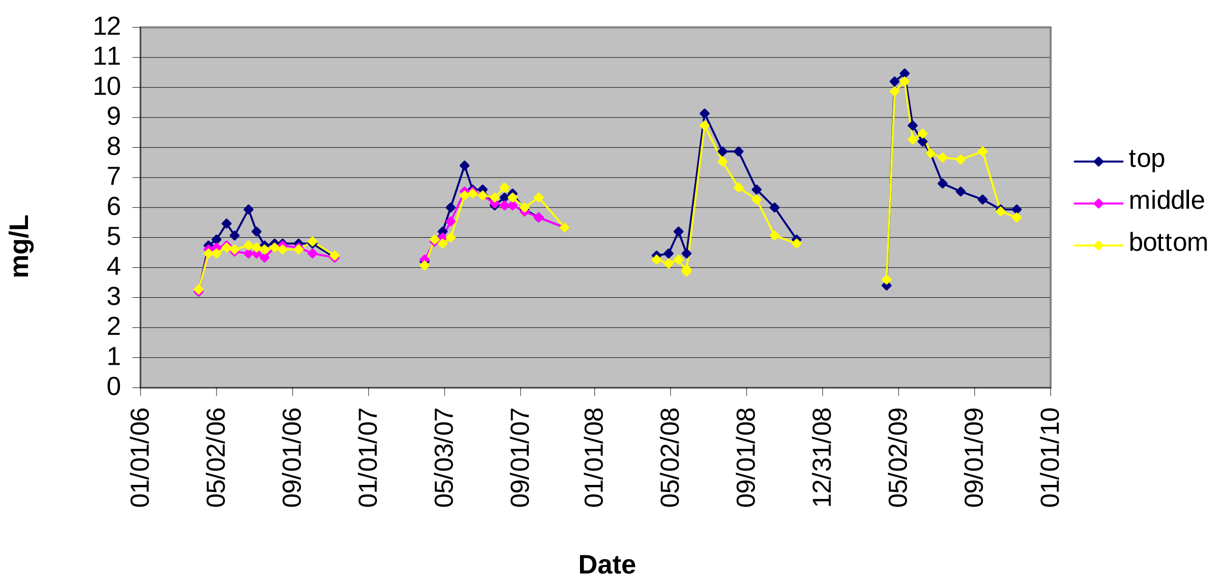
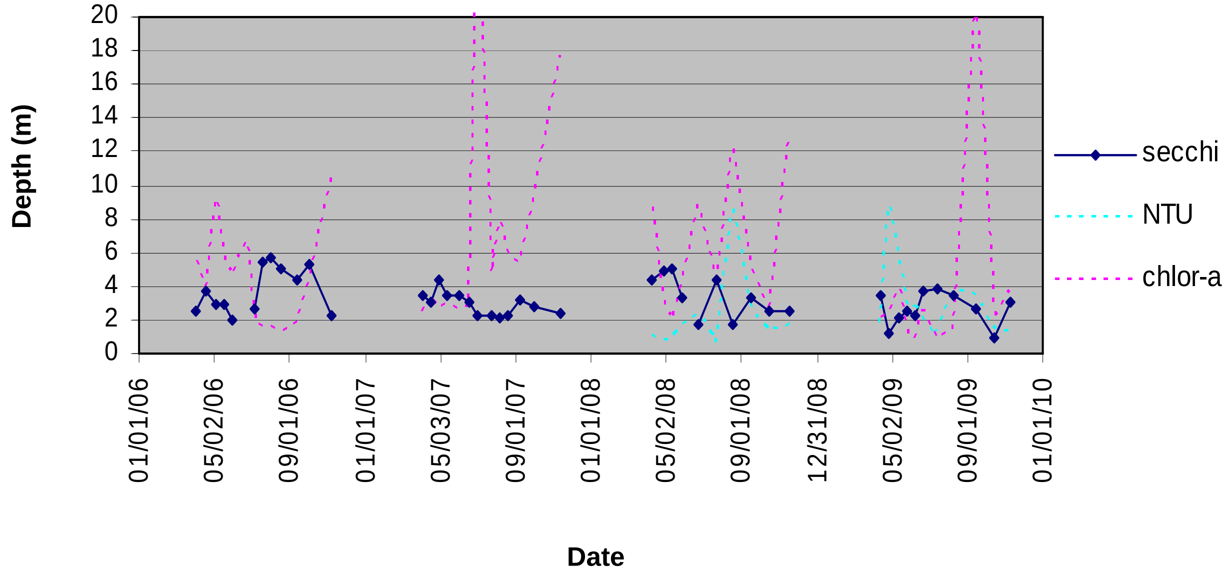
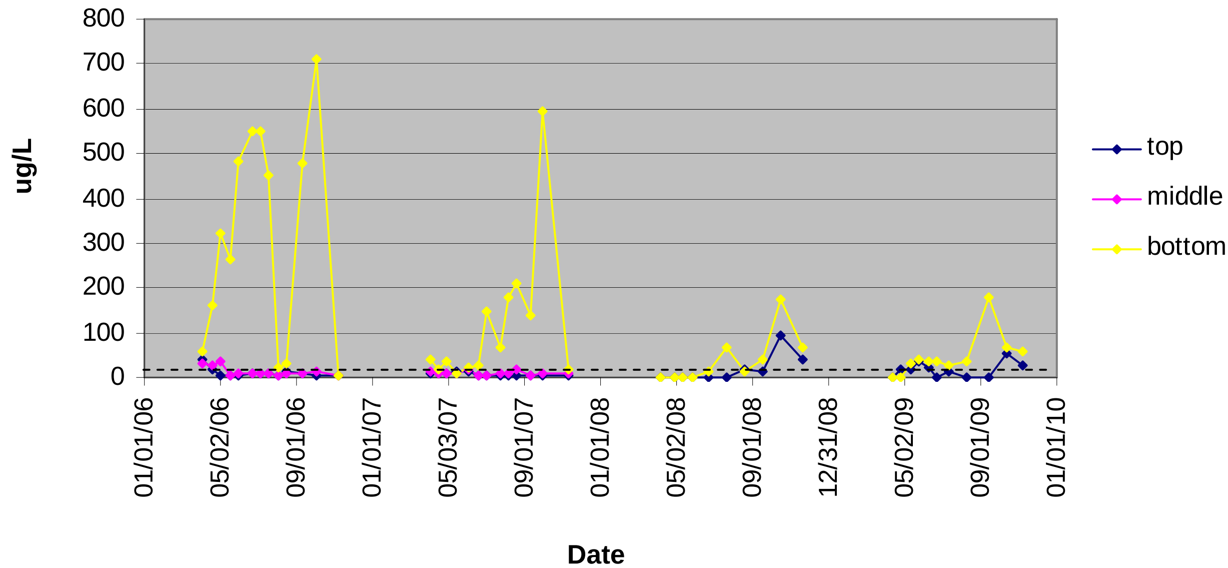


Figure 47. Secchi disk depth in Seaman Reservoir.



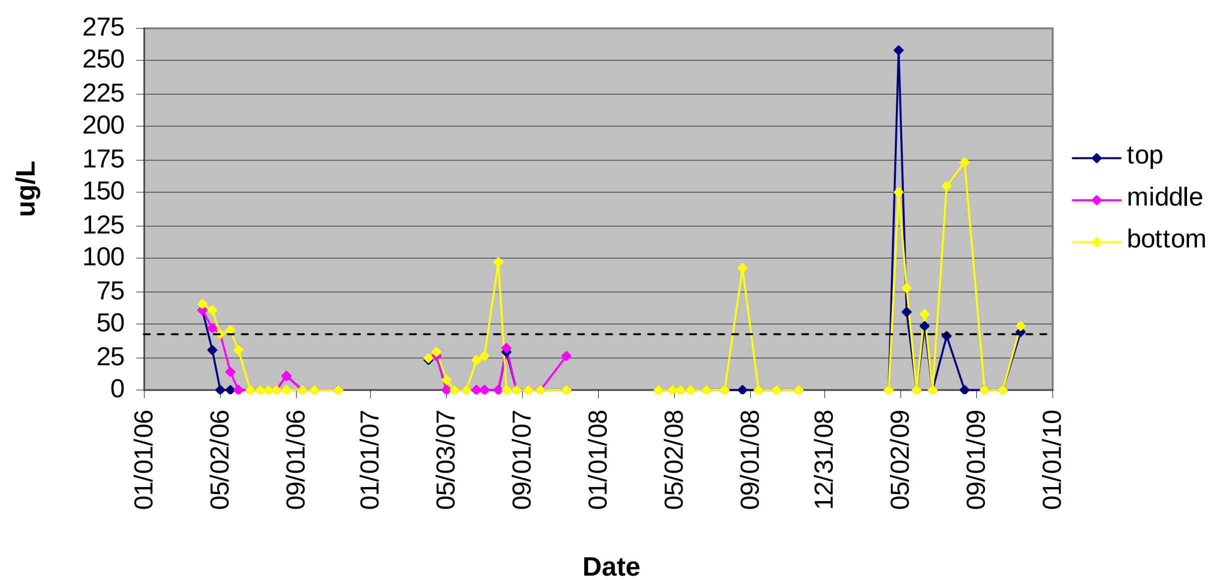
Seaman Reservoir: Nutrients

Figure 48. Ammonia (NH_3) in Seaman Reservoir.



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

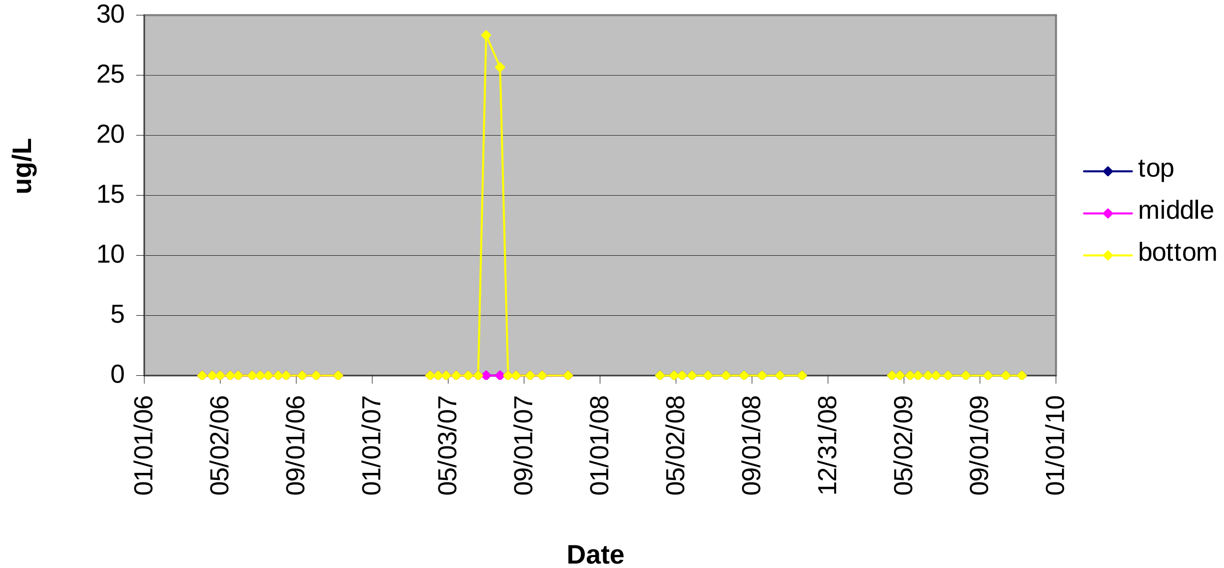
Figure 49. Nitrate(NO_3) concentrations in Seaman Reservoir.



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

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

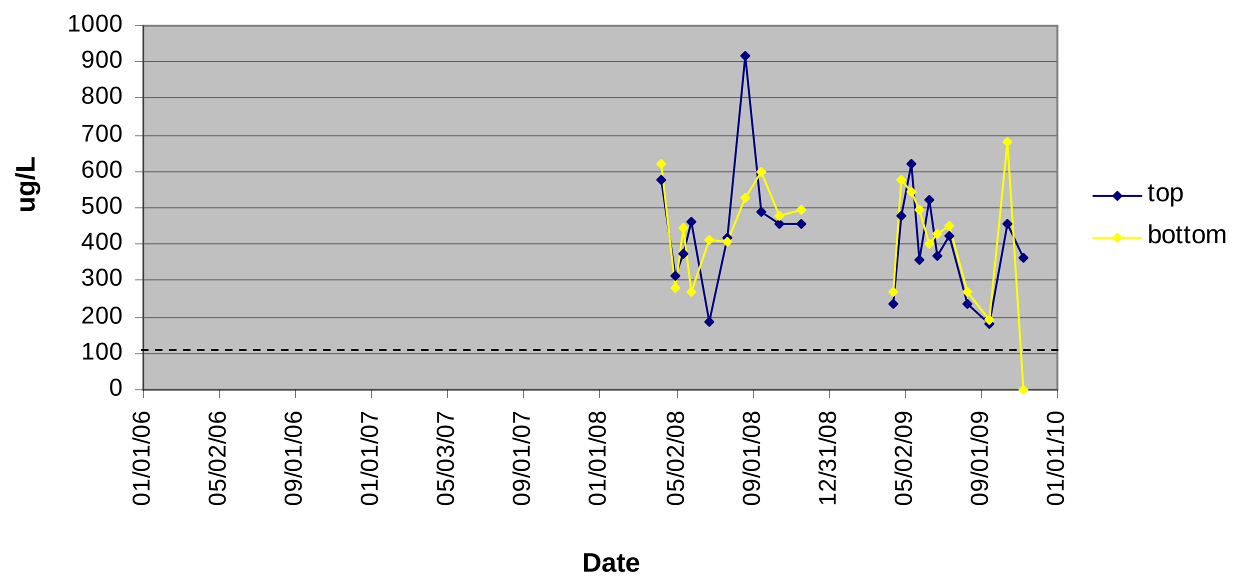
Figure 50. Nitrite (NO_2) in Seaman Reservoir.



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

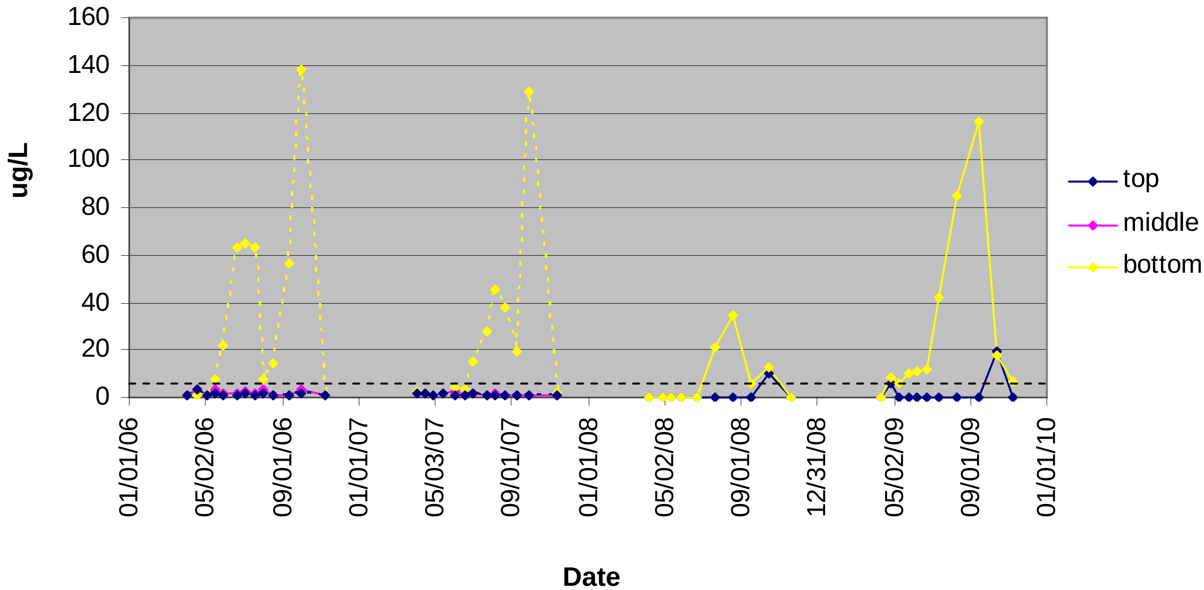
(EPA Maximum Contaminant Level: 1,000 ug/L)

Figure 51. Total Kjeldahl Nitrogen (TKN) concentrations in Seaman Reservoir.



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

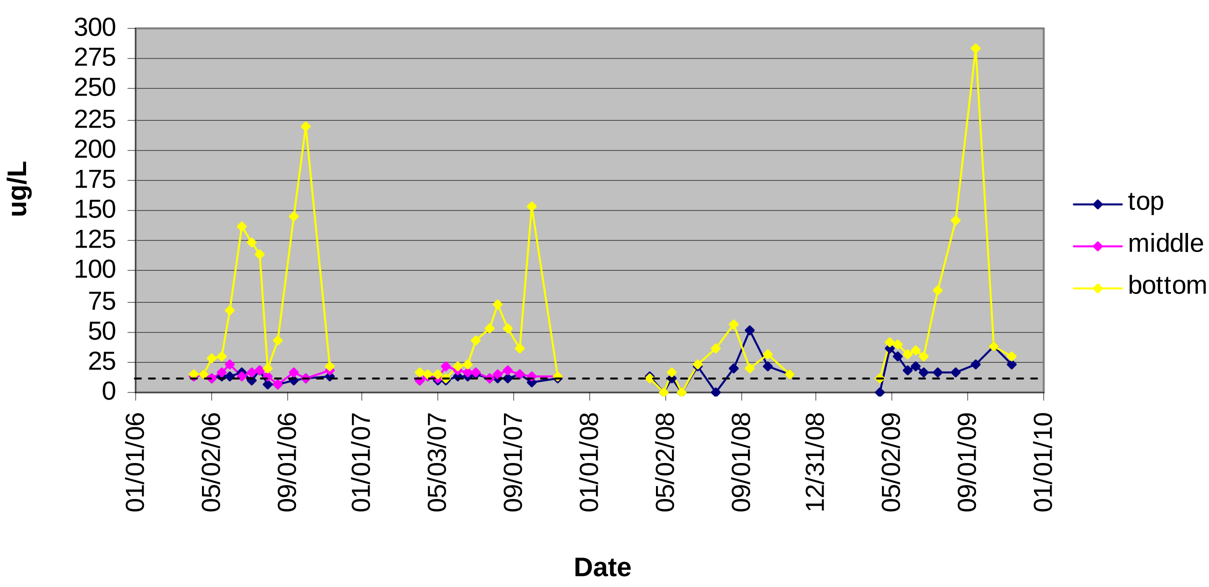
Figure 52. Ortho-phosphate (PO_4) in Seaman Reservoir.



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

* Values in 2006 – 2007 reported as Soluble Reactive Phosphorus (SRP)

Figure 53. Total Phosphorus (P) concentrations in Seaman Reservoir.



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

Seaman Reservoir:
Major Ions

Figure 54. Calcium (Ca) concentrations in Seaman Reservoir.

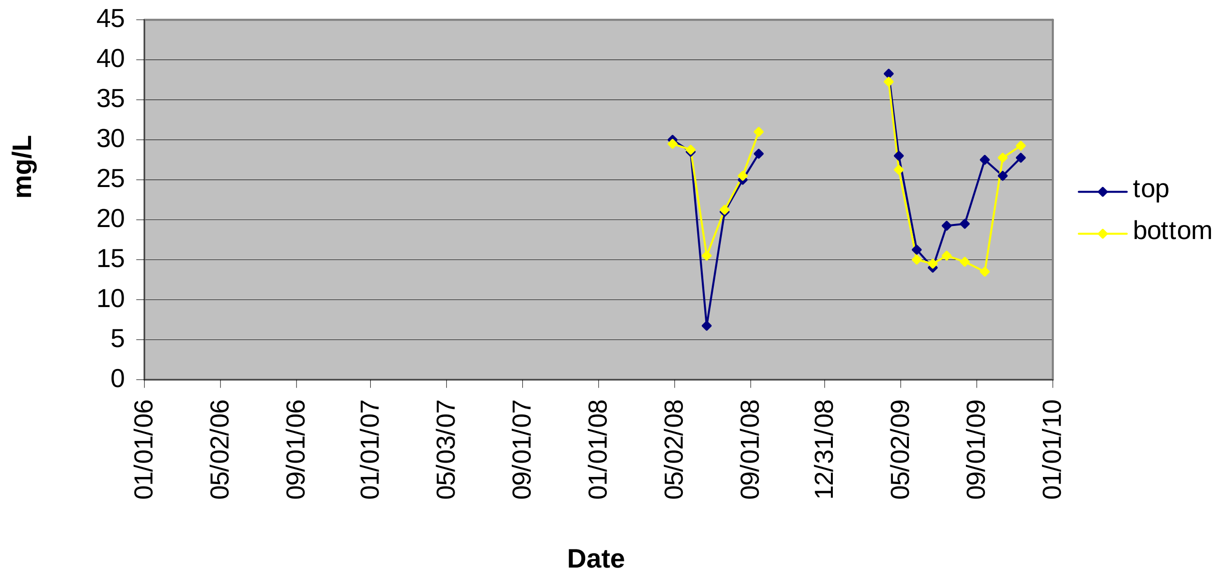


Figure 55. Magnesium (Mg) concentrations in Seaman Reservoir.

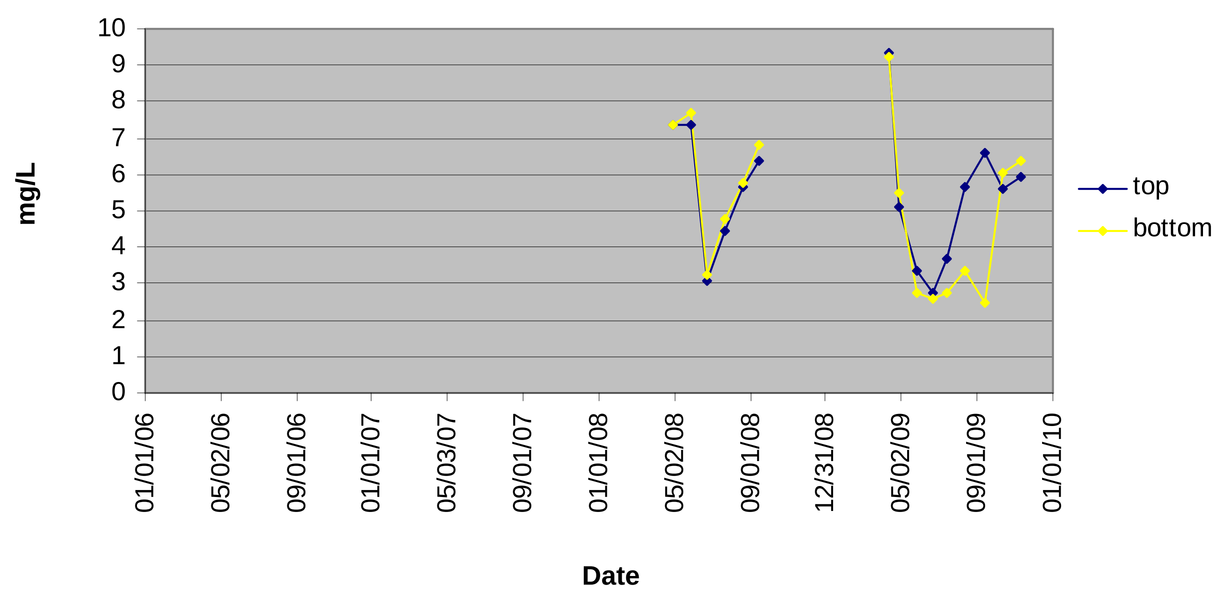


Figure 56. Potassium (K) concentrations in Seaman Reservoir.

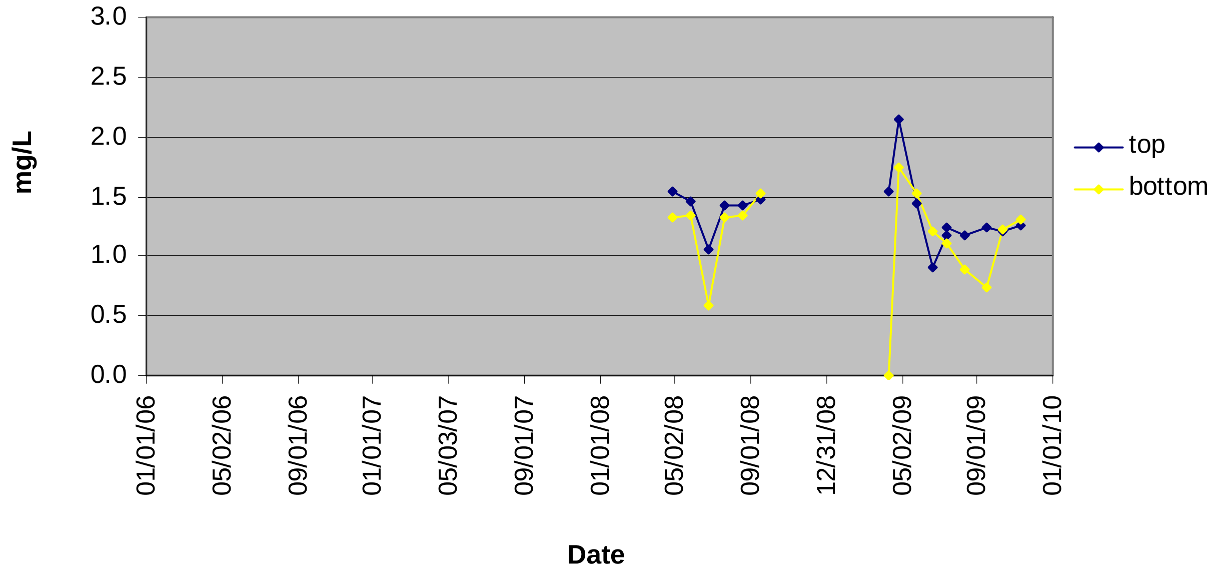


Figure 57. Sodium (Na) concentrations in Seaman Reservoir.

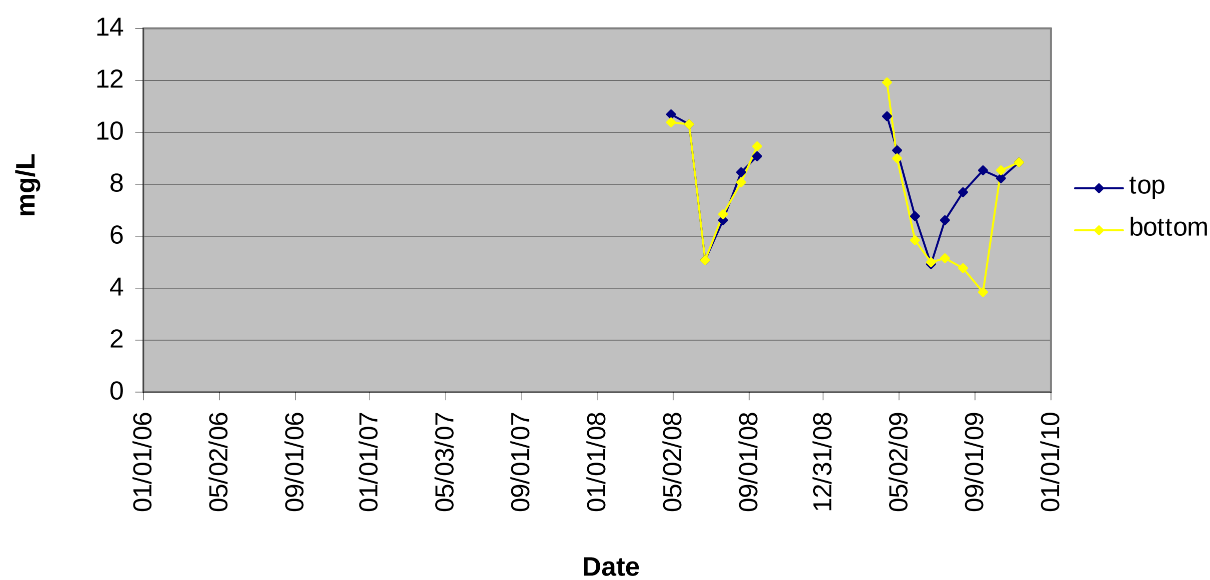


Figure 58. Chloride (Cl^{-}) concentrations in Seaman Reservoir.

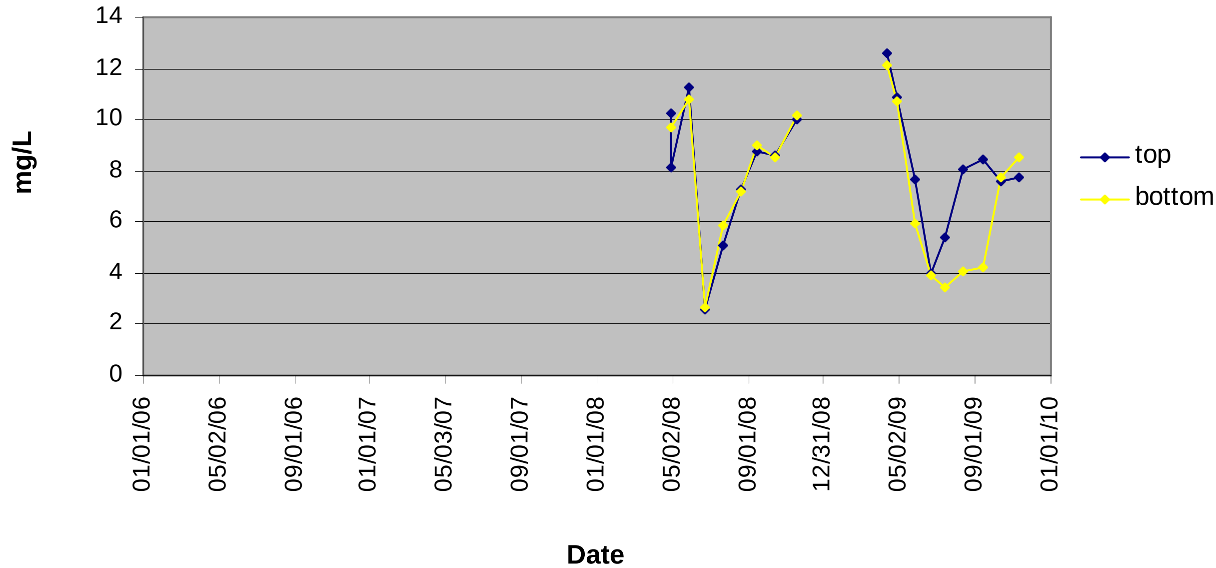
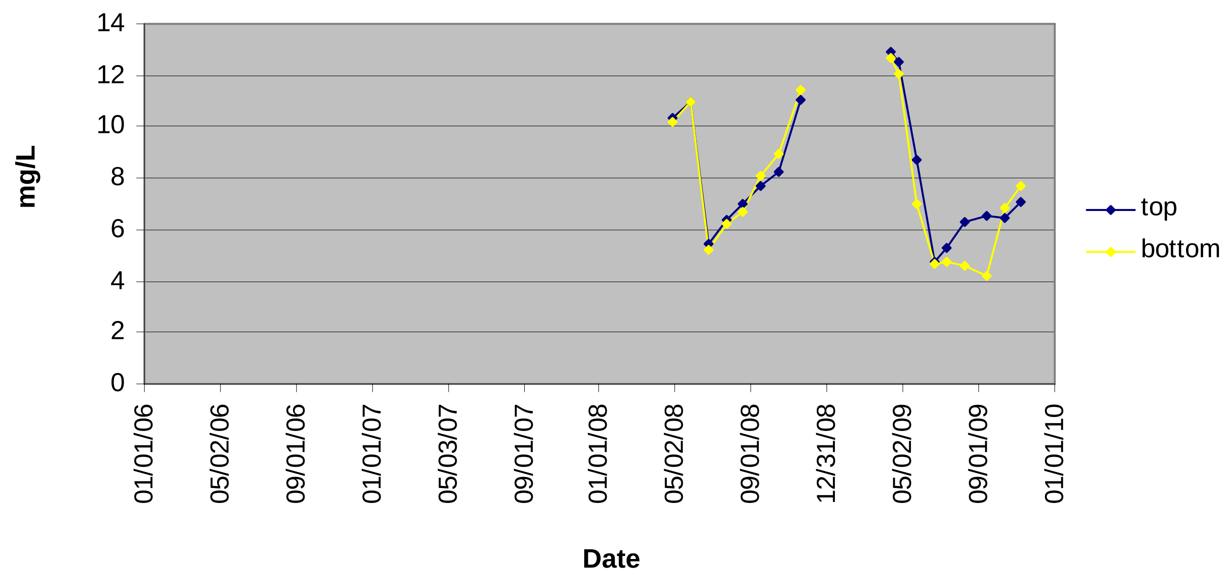


Figure 59. Sulfate (SO_4^{-}) concentrations in Seaman Reservoir.



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

Seaman Reservoir: Microbiological Constituents

Figure 60. *E.coli* concentrations in Seaman Reservoir.

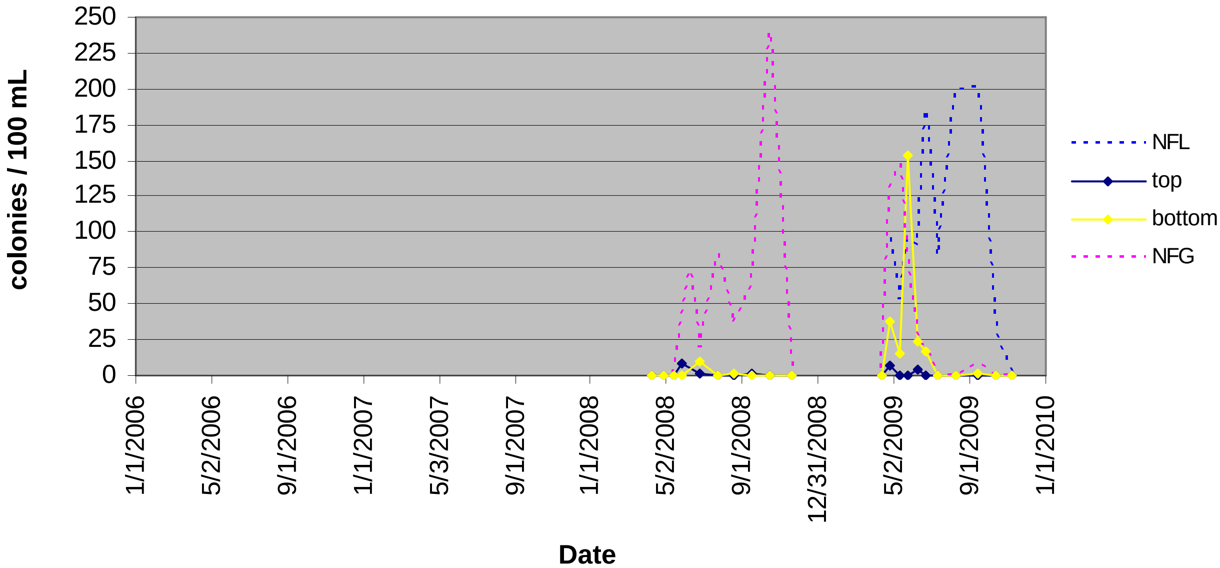
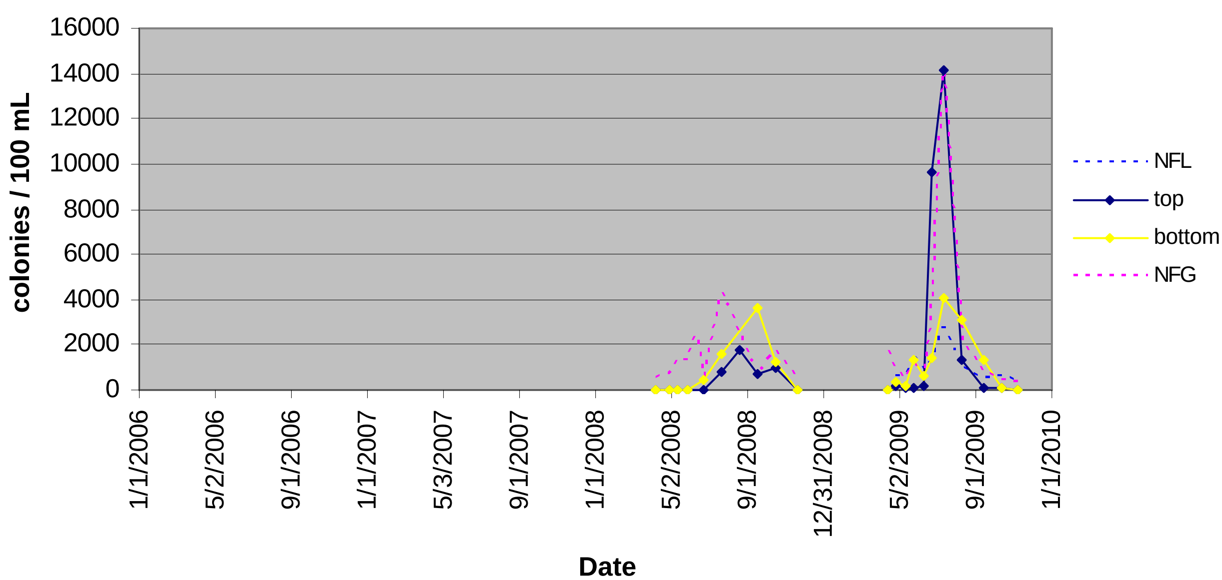


Figure 61. Total coliform concentrations in Seaman Reservoir.



Seaman Reservoir: Geosmin

Figure 62. *Geosmin* concentrations in Seaman Reservoir.