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March 14, 2011

Mr. Chris Countie
Water Supply Manager
Pennichuck Water Works
200 Concord Street
Nashua, NH 03064

RE: PENNICHUCK WATER WORKS
2007 – 2010 TRIBUTARY SAMPLING DATA

Dear Mr. Countie:

The purpose of this letter report is to present the results of the tributary sampling program performed May 2007 through December 2010 as well as any recommendations for changes to the program. The program began in conjunction with the preparation of a Watershed Restoration Plan for the Pennichuck Brook Water Supply Watershed and included dry and wet weather sampling of nine tributaries and recording of continuous tributary flows through the use of data loggers. No sampling was performed in 2009 due to a “freeze” on projects during ownership negotiations between Pennichuck Water Works and the City of Nashua. Figure 1 shows the nine sampling locations.

Background

Pennichuck Water Works, in coordination with NRPC, has been collecting data from the watershed since 1991. Over this time, sampling locations and parameters varied until around 2005, at which time a sampling program using a specific set of water quality parameters was developed for nine tributaries within the watershed. This program was further refined in 2007 to include continuous flow monitoring and the collection of winter samples, beginning a more complete data set. This letter report focuses on the full data set collected beginning in 2007.

Monitoring Locations

The nine tributary sampling locations are shown on Figure 1 with descriptions provided in the following table.

Station	Description	Station	Description
01-BRB	Boire Field Brook, Tinker Road	01-WCH	South Merrimack Road Bridge
09-PEN	Holt Pond Dam	01-XWB	Unnamed Trib to Witches Brook
09T-PEN	Route 101A Bridge	02-WCH	Ames Road Bridge off Route 122
09-XPB	Unnamed Trib to Pennichuck Brook	12-PEN	Nevins Road Bridge
		01-MUD	Farley Road Bridge

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Data Collection

Monitoring activities presented in this report include those beginning in May of 2007 through December 2010 and excluding 2009 as previously described. During this time, CEI collected water quality and flow data to aid in determining the health of each tributary. In 2010, dry weather samples were collected on May 25th, July 13th, September 22nd, October 20th and November 30th and analyzed for Total Coliform, E.coli, Nitrate-N, Ammonia-N, TKN, Total Phosphorus and Total Suspended Solids. CEI also performed field analysis of pH, Conductivity, Dissolved Oxygen (some dates) and Temperature during these dates. Note that dry weather samples could not be collected from 01-XWB during the May and September sampling rounds due to inaccessibility of the site associated with excessive overgrowth of vegetation. Also, a dry weather sample was not collected from 01-BFB on November 30th as there was no water in the stream during that time. All data was tabulated and input into a water quality database.

Electronic data loggers were installed at all locations on May 21, 2007 to determine the relative contribution of each stream to Pennichuck Brook and to track long-term trends in flow. The surface water data loggers read and record water levels every 30 minutes. During previous monitoring efforts in 2005 and 2006, staff gauges were installed at the nine locations and stage-discharge relations were created based on field measurements. Using the stage-discharge equations, the water levels recorded by the data loggers can convert to an approximate flow for the river at each point in time. Data loggers were downloaded to a field laptop for analysis approximately every four to six weeks each year.

Due to changes in stream profiles, new stage-discharge equations were developed for stations 01-WCH and 02-WCH during the 2007 and 2008 monitoring period. The original stage-discharge curves developed using the 2005 and 2006 data are still valid for all other streams. Periodic adjustments to flow equations may also be made when a data logger is taken out for repairs and/or replaced. In these cases, the original stage-discharge curves still apply and the adjustment is only made to reflect a change in elevation in the setting of the data logger. These adjustments are noted in the database table where all data is recorded.

Data Results

The sampling data results were analyzed for trends and correlations, as well as any unexpected data outliers. Overall, stations 09-XPB, 09T-PEN, 01-BFB and 01-XWB continue to show the highest concentrations for each parameter analyzed. These stations also have the largest flows recorded.

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Seasonal

Samples taken during the summer months in 2007, 2008 and 2010 roughly correlate to one another. As expected, temperature rises during summer months along with ammonia, phosphorus and bacteria levels. Turbidity data was not collected during all 2010 rounds. Turbidity is not part of the ongoing sampling program, however, is collected periodically depending on the field equipment used during sampling. Turbidity levels should not exceed naturally occurring concentration. A limit of 5 NTU is often used for drinking water standards.

Dissolved oxygen is inversely proportional to the above parameters as it tends to fall during warmer months and recover during colder periods. Dissolved oxygen surface water quality standards specify a minimum concentration of 5.0 mg/L. Samples from stations 09T-PEN and 01-WCH continue to violate standards in 2010 consistent with 2007 and 2008 data. Stations 01-XWB and 09-XPB also violated standards in 2010, while 01-MUD DO levels improved and all others are generally above 6.0 mg/L. Readings below 4.0 mg/L would be considered dangerous to aquatic organisms.

Winter sampling was not performed during the 2010 calendar year as the sampling program was not authorized to begin until April 2010. Winter samples collected in 2011 will be used to evaluate the full spectrum of seasonal trends and whether there is a trend associated with the higher than average levels observed for many parameters in January 2008.

Wet and Dry Weather

An analysis of dry and wet weather data for ammonia and TKN revealed that concentrations during dry weather were higher than wet weather in almost every occasion. Wet weather phosphorus levels were also generally lower than dry weather levels, with some dry and wet weather showing similar concentration ranges. This is possible as wet weather has larger volumes of water which would dilute concentrations, particularly in data collected after the first flush. An analysis of wet weather data shows a spike for ammonia and TKN and phosphorus during the same 2007 and 2008 June through August period as exhibited during dry weather. Only one wet weather sample was collected in 2010 due to the relatively dry year. A wet weather sample could not be collected from all stations, as there was not enough precipitation to trigger sampling at all locations. While it is difficult to draw conclusions from the limited wet weather data (e.g., one or two samples a year), it does allow comparison of sites to one another to evaluate impacts of development on water quality.

Stream Flow

Flow results measured at all stations are roughly correlated to each other, as seen by similar rise and fall trends. Available data for the year varied by location. Data loggers for locations 01-BFB, 09-WPB, 01-XWB and 12-PEN were repaired/replaced in



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October 2010, with data collection beginning at that time. Periodic data gaps were also noted at several other locations including 09-PEN, 09T-PEN, 01-WCH and 01-MUD, sometimes with missing data and sometimes with negative data logger readings. Data gaps are shown on the "Tributary Flow Data" figures for any missing or negative data. Negative readings are often associated with battery issues, particularly in the cold weather, requiring battery replacement. The data logger manufacturer has incorporated the use of two batteries in newer data logger models, one for normal use and the second for backup, triggered when the first battery life is exhausted. CEI will replace the alkaline batteries currently used with longer life lithium batteries to help address this problem in the future.

Note that negative flows were estimated at location 01-WCH even though the data logger was reading positive water elevations. This is because the data logger readings were outside the data used to develop the stage-discharge curve. An additional point for the flow discharge curve should be collected to avoid this in the future.

Total Suspended Solids (TSS)

TSS represents suspended material in the water. It can smother benthic macroinvertebrates as it settles to river bottoms and also result in decreased dissolved oxygen. TSS can also hide other pollutants, such as bacteria, complicating disinfection. High TSS levels may result from erosion of disturbed areas (e.g., construction sites) and of natural stream banks.

TSS spikes were most notable at 01-XWB during July and November 2010 sampling rounds, which also corresponded with phosphorus spikes during the same period. Historically, elevated levels of TSS have been associated with increased flows, which is to be expected as runoff washed sediments into the streams from surfaces and stream bank erosion. TSS does not have a numeric standard specified in the New Hampshire surface water quality standards. Some states set a TSS standard of 30 mg/L.

Total Phosphorus

Phosphorus is a nutrient essential to plants and in excess amounts can cause algal blooms, particularly in fresh water systems. Algal blooms in turn can in turn decrease oxygen levels and make water less attractive. Phosphorus can indicate the presence of sewage, animal waste, lawn fertilizer, erosion and may also come from atmospheric deposition and natural wetlands.

Stations 09-XPB and 09T-PEN continue to show higher phosphorus readings than the other locations, however did not spike as high as in previous years. As expected, spikes in phosphorus correspond to high TSS readings and higher than normal flow. This is logical as phosphorus is largely contained in sediments flushed into the tributaries



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during storm events. Unlike nitrogen in the nitrate form which flush quickly, TSS and the attached particulate phosphorus take longer to enter the waterbody.

While there is no numeric standard for phosphorus, the NHDES level of concern is 0.05 mg/L. In 1976, the EPA also recommended phosphorus limits of 0.05 mg/L for streams. Only naturally occurring phosphorus should be present, typically from 0.014 to 0.017 mg/L under natural conditions. Levels of 0.015 mg/L in lakes and ponds are often set as a goal to support recreational uses of the water and decrease algae blooms.

Total Kjeldahl Nitrogen (TKN)

Nitrogen is a nutrient essential for algae and other plant growth and excess amounts can lead to nuisance algae blooms. TKN represents organic nitrogen and ammonia nitrogen, which can indicate the presence of sewage, animal waste, fertilizer, erosion, or other types of pollution. As with previous years, TKN readings at all stations in 2010 were relatively consistent with the exception of 09-XPB during May of 2010. This same trend was noted in January of 2008 with elevated TKN levels at 09-XPB and 09T-PEN compared to other stations. The 2008 TKN spikes correlated with TSS spikes, which was not the case in 2010. TKN does not have a numeric standard specified in the New Hampshire surface water quality standards.

Nitrate and Ammonia

As with TKN, nitrate and ammonia are nutrients that contribute to plant growth.

There are no numeric standards for nitrate levels in streams; however, the drinking water limit is 10 mg/L. Both dry and wet weather nitrates remained below the detection limit of 1.0 mg/L. Only naturally occurring concentrations should be present.

Ammonia toxicity is dependent on pH levels. When the pH is below 8.75, NH_4^+ dominates. Basic pHs above 9.75 can cause NH_3 to dominate, which is more toxic to aquatic species. Measurement of TKN and ammonia allows for estimation of organic nitrogen by subtracting the concentration of ammonia nitrogen from TKN. Ammonia should be less than 0.64 mg/L as per New Hampshire water quality standards. All samples continue to meet water quality standards for ammonia.

Escherichia Coliform Bacteria (*E.coli*)

E. coli represents bacteria associated with the fecal matter of warm-blooded animals. It is often used to determine whether water is safe for swimming and requires treatment for use as drinking water. It may indicate the presence of sewage or wildlife.

E. coli readings are fairly consistent during the sampling period, with levels generally rising during Summer and Fall months and declining during winter periods. The elevated *E. coli* levels seen in 02-WCH in May of 2008 did not repeat itself in 2010. The

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highest E.coli levels of 325 mpn/100 ml and 416 mpn/100 ml were seen in 09-XPB in the summer of 2010, which is consistent with historic data and levels of other sampling parameters at this location. E.coli should not exceed 153 cts/100 mL for any single sample, based on numeric standards for Class A waters.

pH

pH measures the acidity of water and can affect biological processes in water important to aquatic life. It can also affect the treatment process for drinking water.

pH appears relatively constant during the 2010 period, generally ranging between 6 and 9 with a slight dip below 6 in November. Based on this new data, the extreme dips in pH identified in August of 2007 and October of 2008 appear to be anomalies associated with equipment malfunctions. The Class A NH Surface Water Quality Standard for pH is between 6.5 and 8.0 unless naturally occurring.

Conductivity

Conductivity measures the free ion (charged particles) content in water and can indicate the presence of chlorides, nitrates, sulfates, phosphates, and sodium, magnesium, calcium, iron, and aluminum ions. Possible sources include road salt, septic systems, wastewater treatment plants, urban/agricultural runoff or naturally occurring from surrounding geology. Polluted water usually has a higher conductivity than unpolluted water.

Conductivity levels were relatively consistent between sampling stations in 2010 with a rise in the summer and fall and decline in spring and winter. Levels were higher in 2010 compared with previous years. New Hampshire water quality standards do not specify a numeric standard for conductivity, however, a waterbody with conductivity greater than 2000 umhos/cm would be considered high in dissolved solids.

Recommended Changes to the Monitoring Program

In order to make the most efficient use of time and funding, CEI recommends that the sampling of nitrates be discontinued at all stations. Data obtained between 2007 and 2010 showed nitrate levels at less than 1 mg/L at all stations during all sampling events with the exception of the single abnormality in July 2008. Nitrate readings have consistently been below laboratory detection limits and are not thought to be cause for concern in the watershed. The TKN and ammonia samples can serve as nitrogen indicators in the watershed.

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Sampling should continue as follows:

Proposed Sampling Schedule
February
March
April
July
August
September
November

In addition to the monitoring program, CEI recommends collecting one or two additional rounds of flow and staff gage data at 01-WCH to generate another data point for the stage discharge curve. This will refine the existing equation and help avoid the calculation of negative flows outside of the existing curve data range.

If you have any questions or require any additional information, please do not hesitate to contact me at (800) 725-2550, ext. 308.

Sincerely,

COMPREHENSIVE ENVIRONMENTAL INC.

Rebecca Balke, P.E.
Project Manager

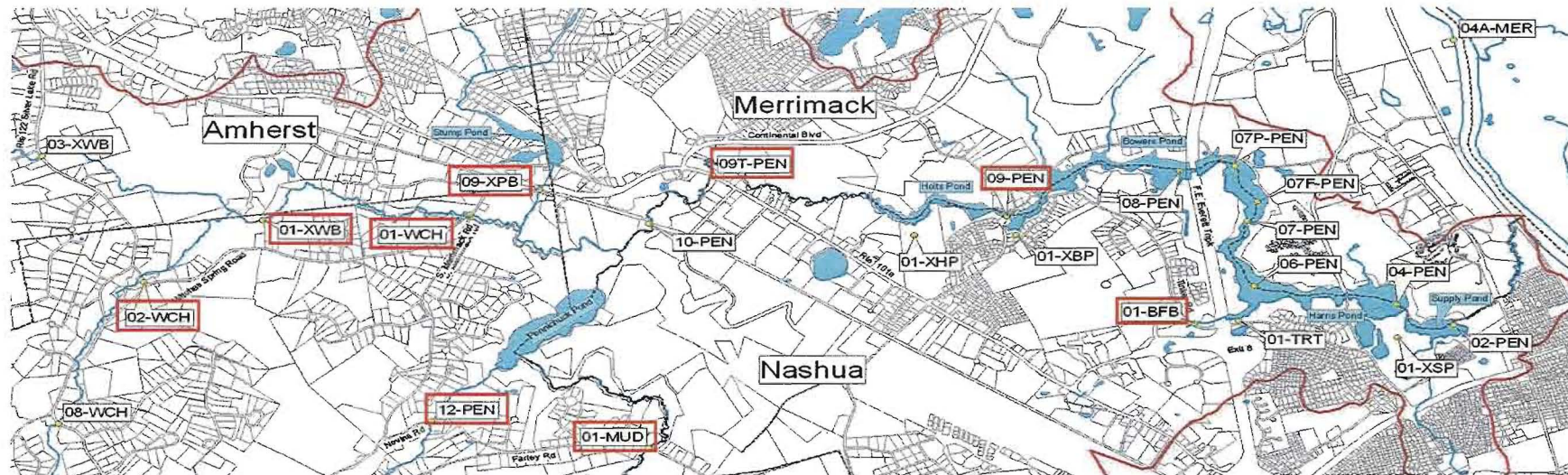
Attachments:

- Figure 1. Site Locations and Names
- 2007-2010 Trendline Graphs for: tributary flow data; DO; temperature; TSS; phosphorus; TKN; ammonia-nitrogen; E.coli; total coliform; pH; and conductivity.

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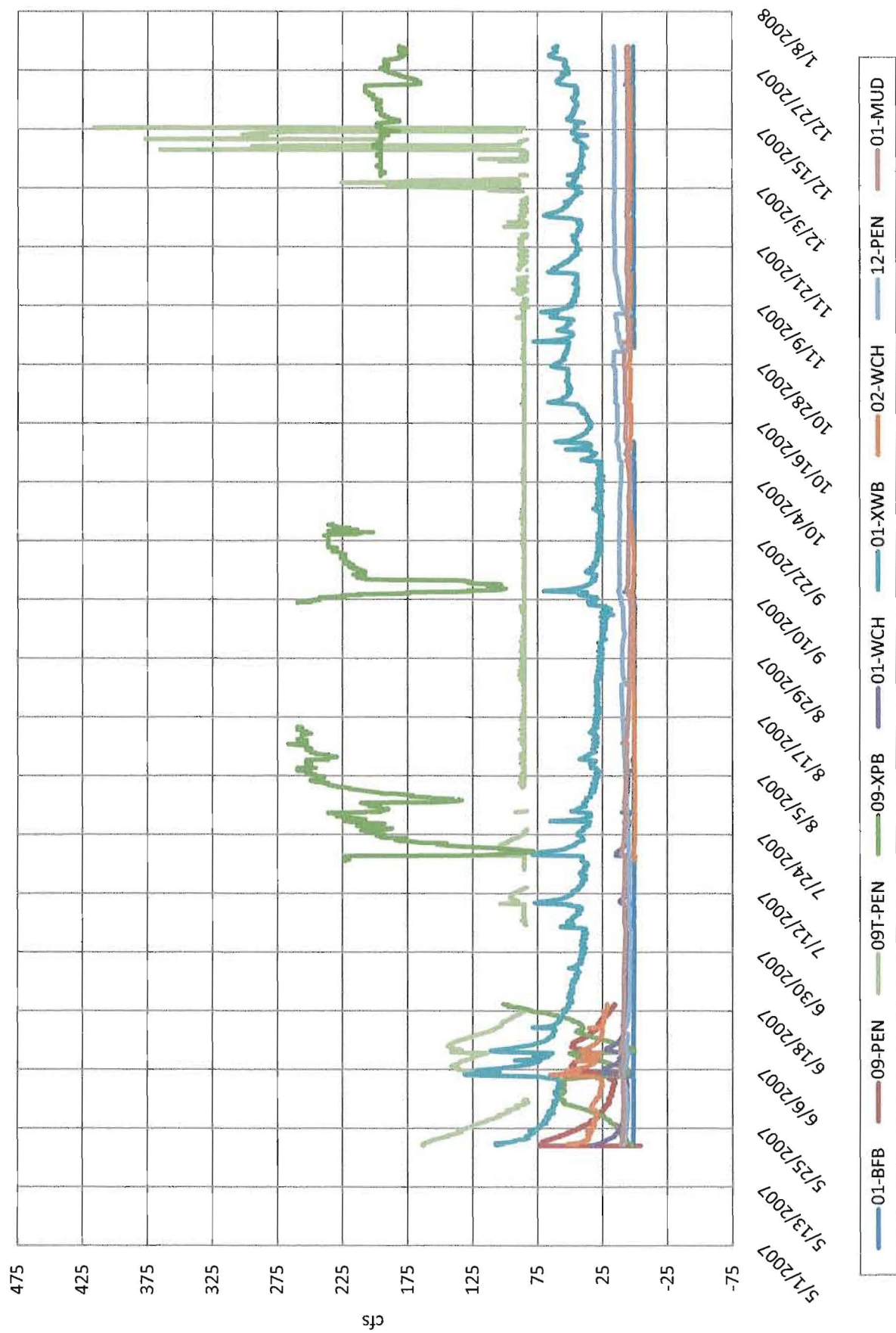
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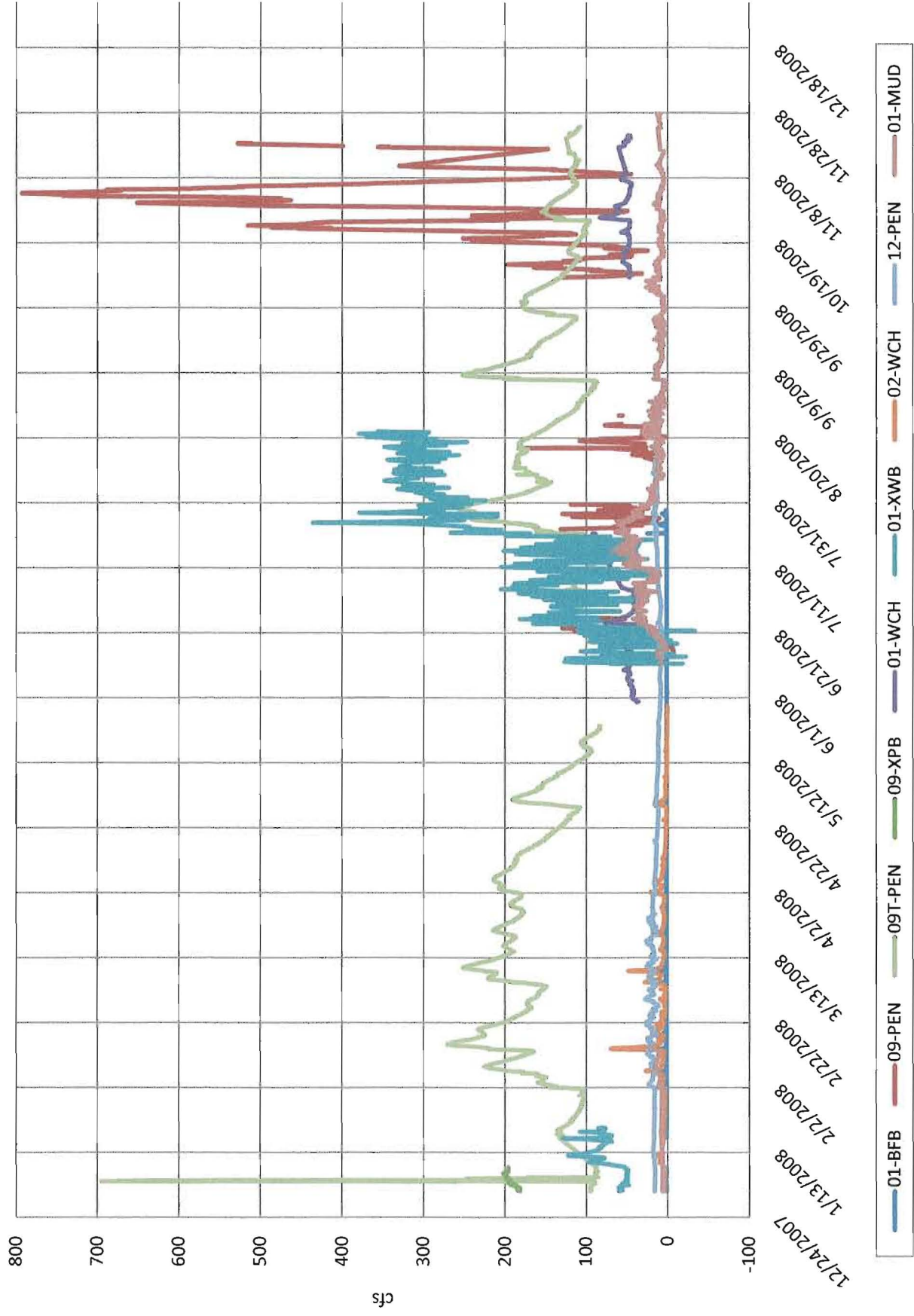
Old Name	New DES Name	Descriptions	Old Name	New DES Name	Descriptions
T-1	01-BFB	Boire Field Brook - Tinker Road	B1	07F-PEN	Bowers Pond - 700' US of Bowers
T-2	09-PEN	Holt Pond Dam	B2	08-PEN	Bowers Pond - Middle
T-3	09T-PEN	Route 101A Bridge	H1	04-PEN	Harris Pond - 100' US of Harris
T-4	09-XPB	Unnamed Trib to Pennichuck Brook	H2	06-PEN	Harris Pond - Middle
T-5	01-WCH	South Merrimack Road Bridge	R1	07P-PEN	Bowers Pond - 1/4 mile DS of E
T-6	01-XWB	Unnamed Trib to Witches Brook	R2	04A-MER	Merrimack River - Boat Launch
T-7	02-WCH	Ames Road Bridge off Route 122	S1	02-PEN	Supply Pond - 25' Upstream of
T-8	12-PEN	Nevins Road Bridge			
T-9	01-MUD	Farley Road Bridge			

FIGURE 1: Site Locations and Names

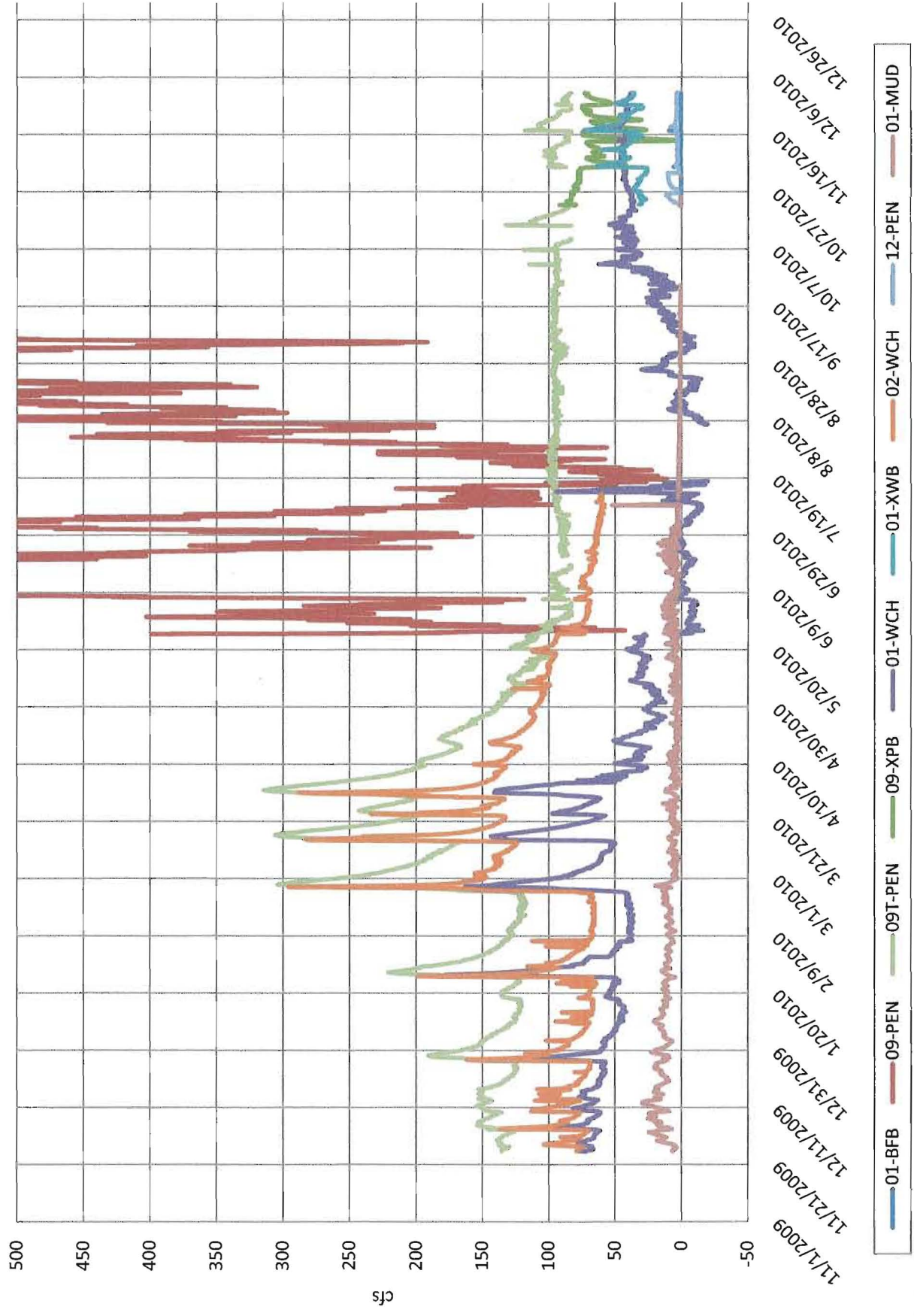
Tributary Flow Data for 2007

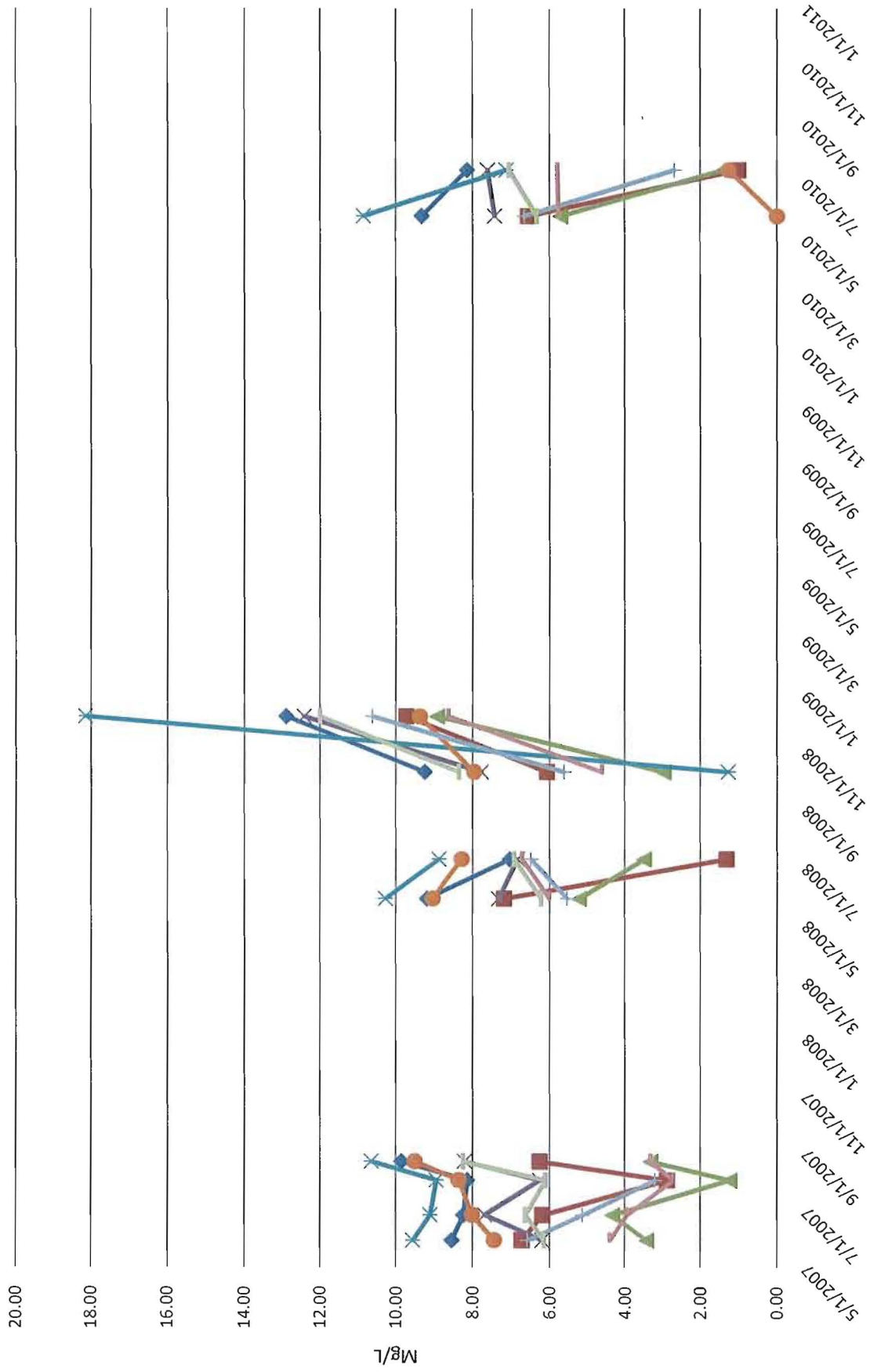


Tributary Flow Data for 2008

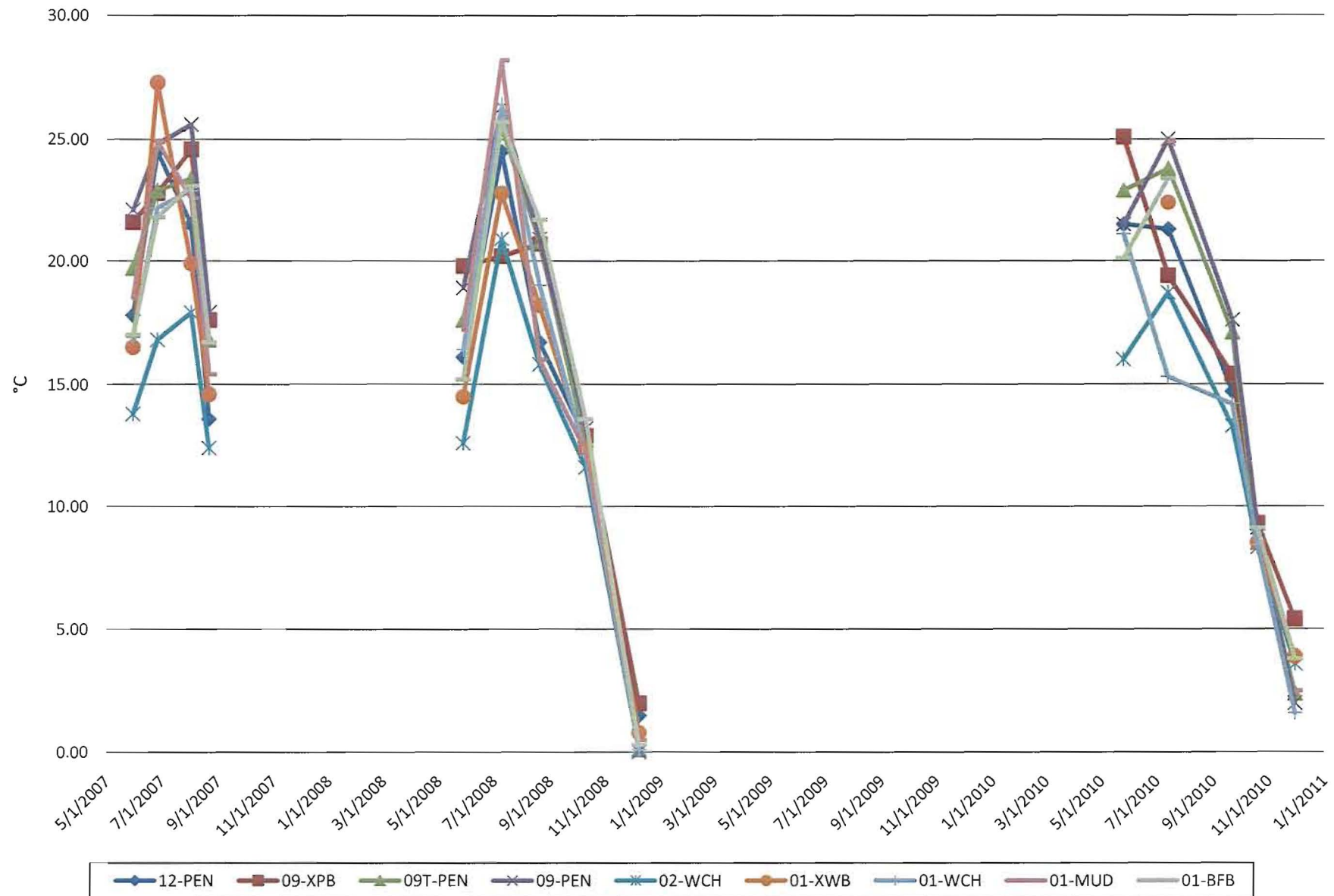


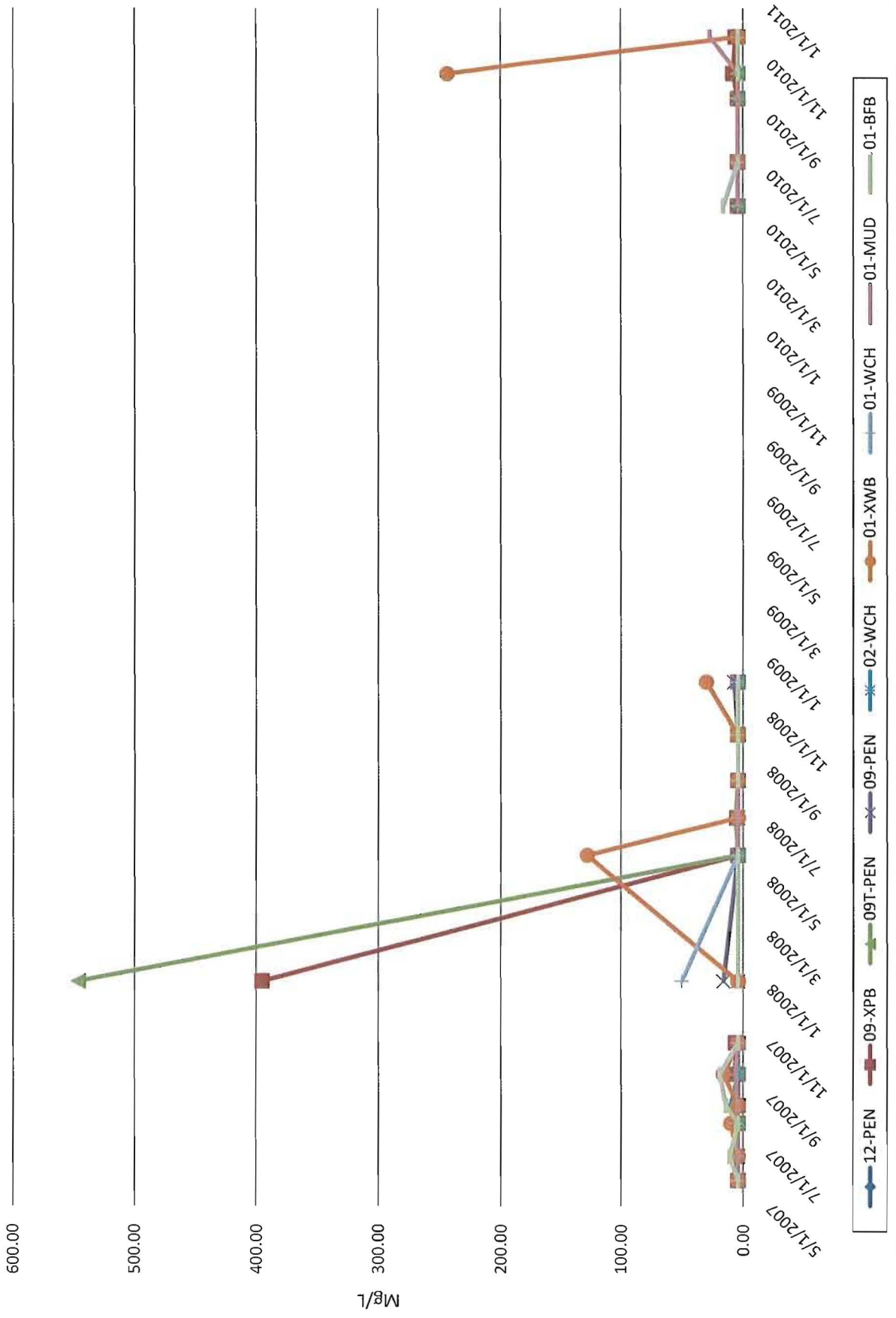
Tributary Flow Data for 2009-2010



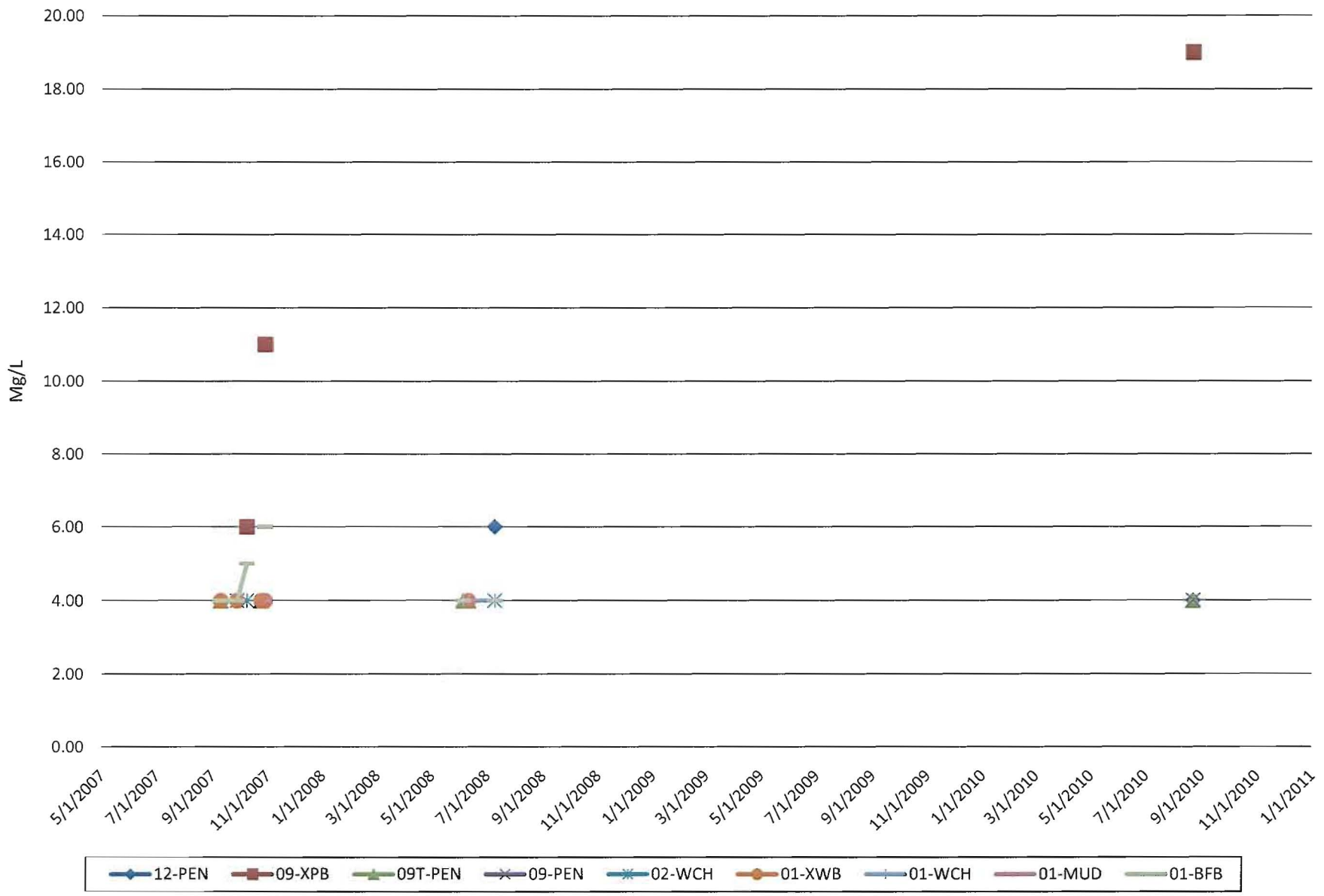


Dry Weather Sampling - Temperature 2007-2011

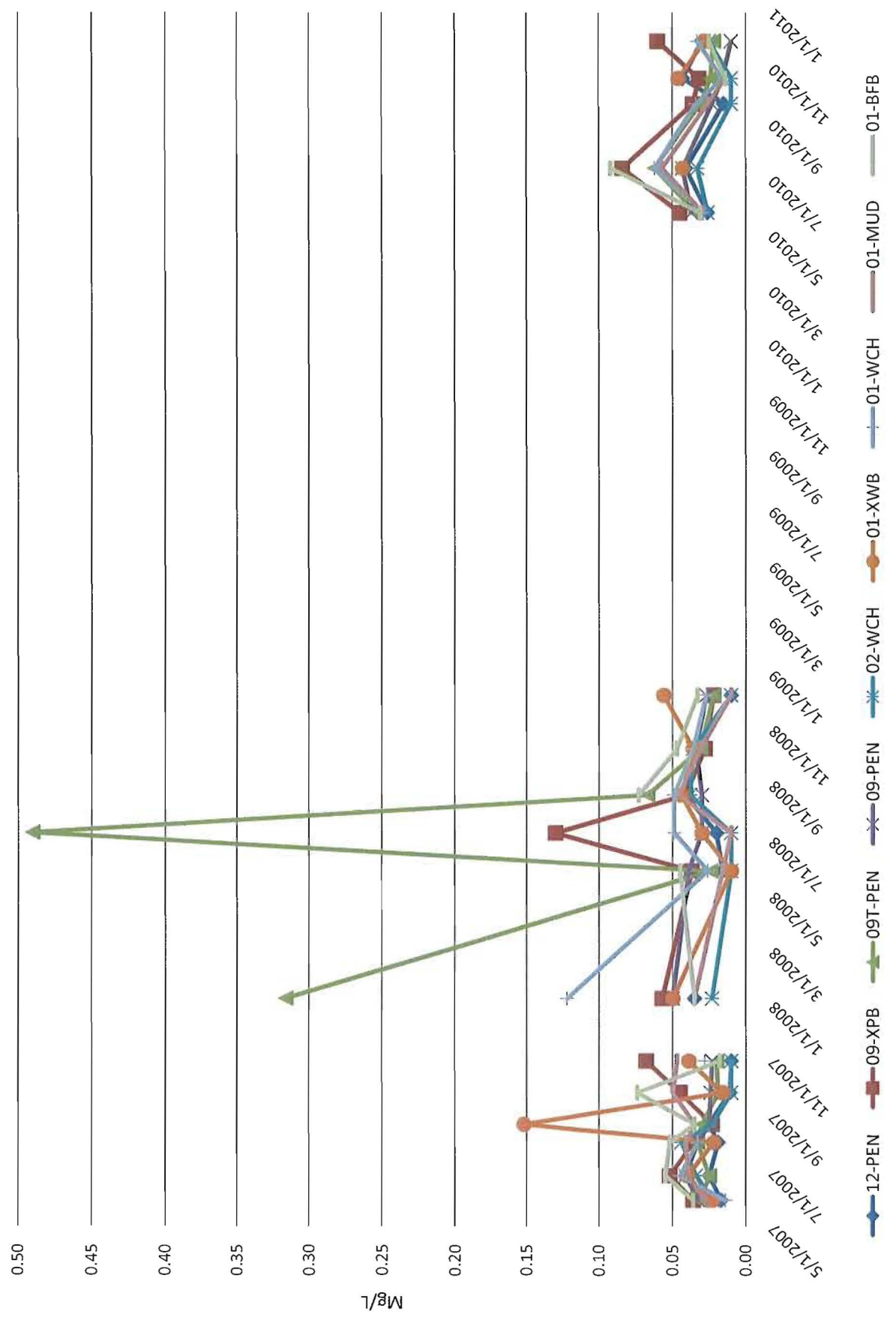


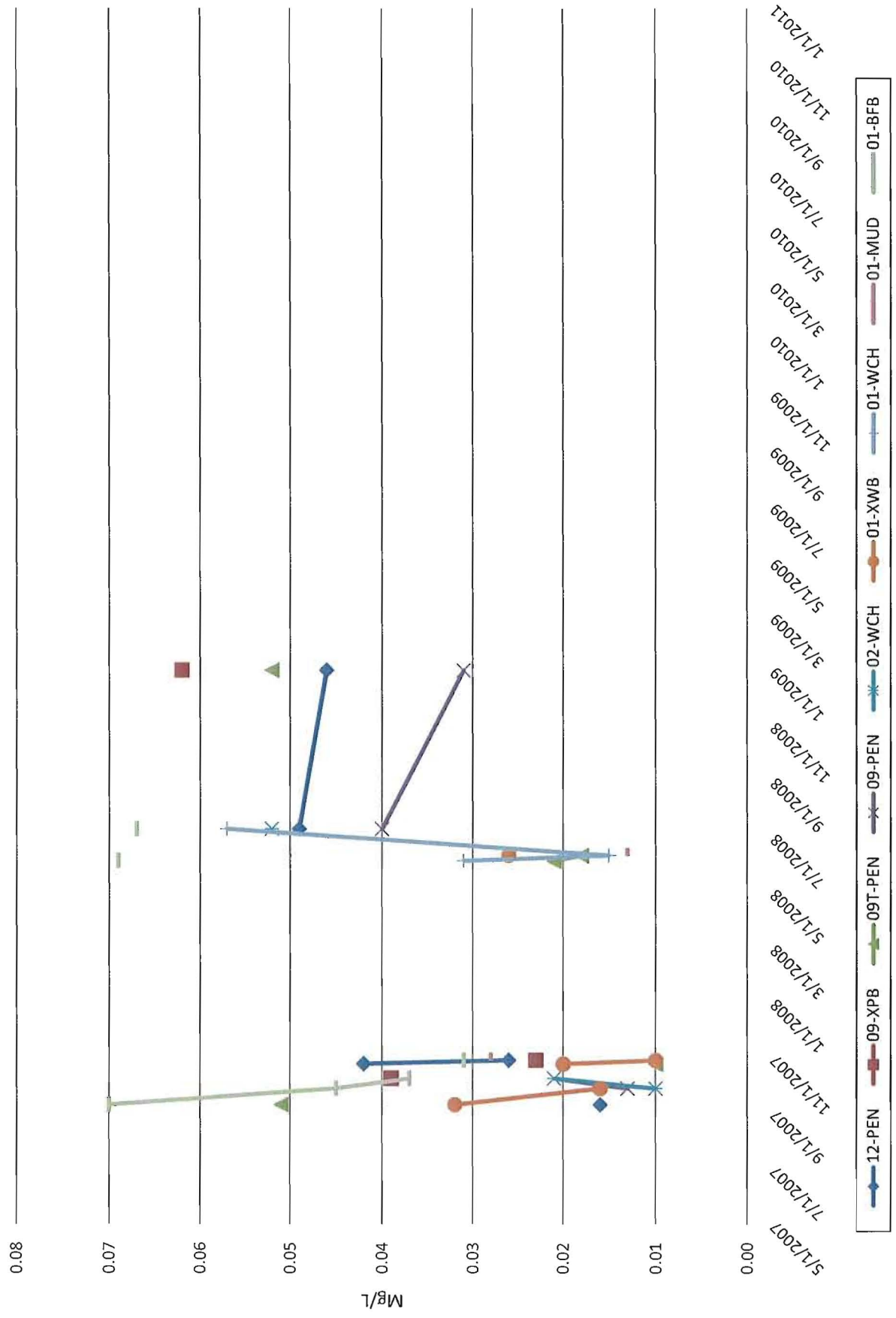


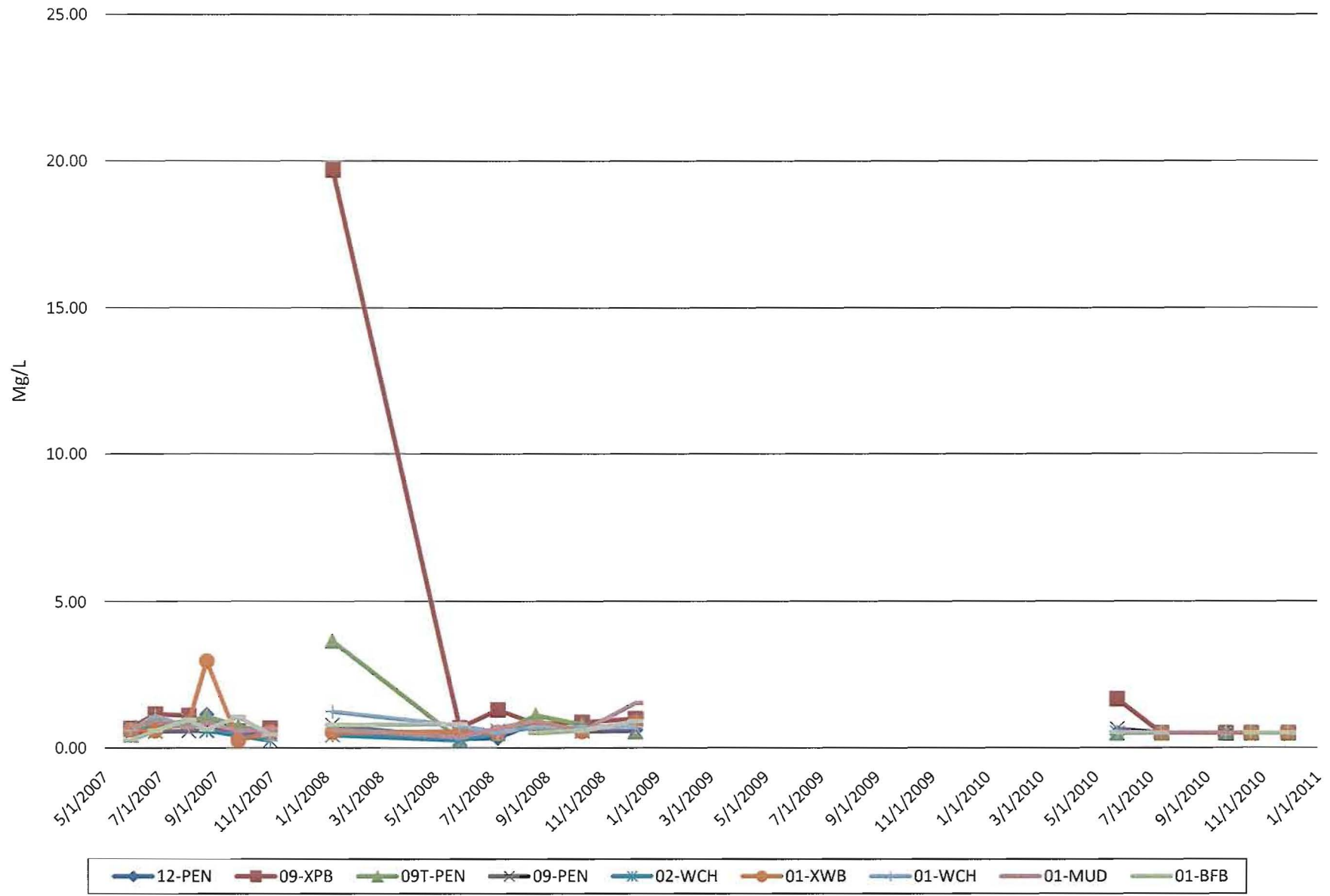
Wet Weather Sampling - TSS Levels 2007-2010



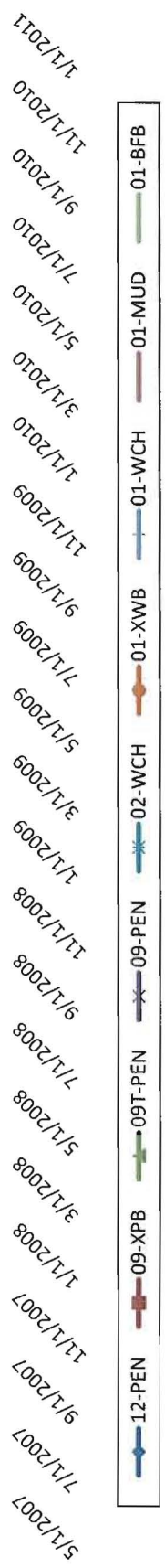
Dry Weather Sampling - Phosphorus Levels 2007-2010

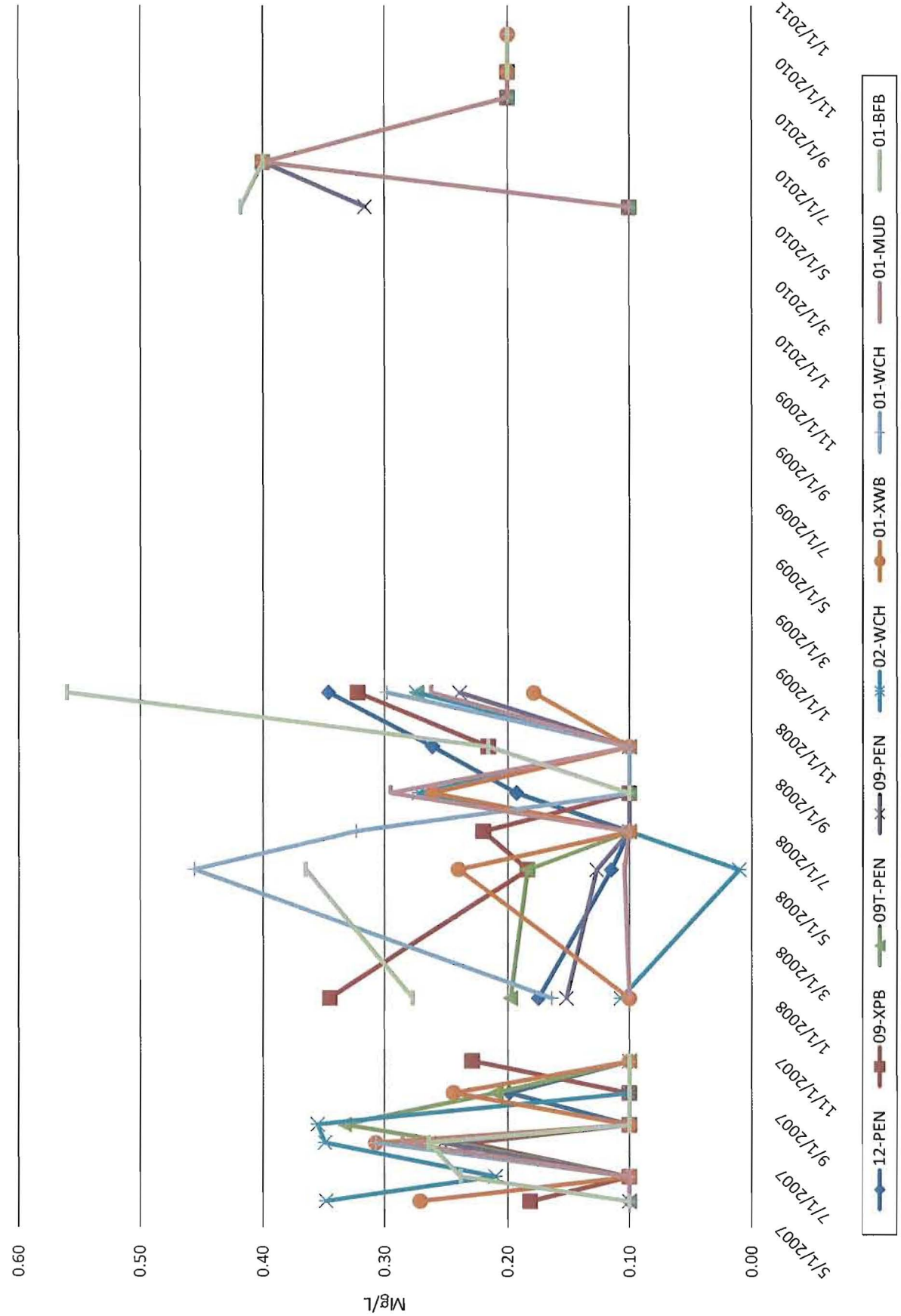


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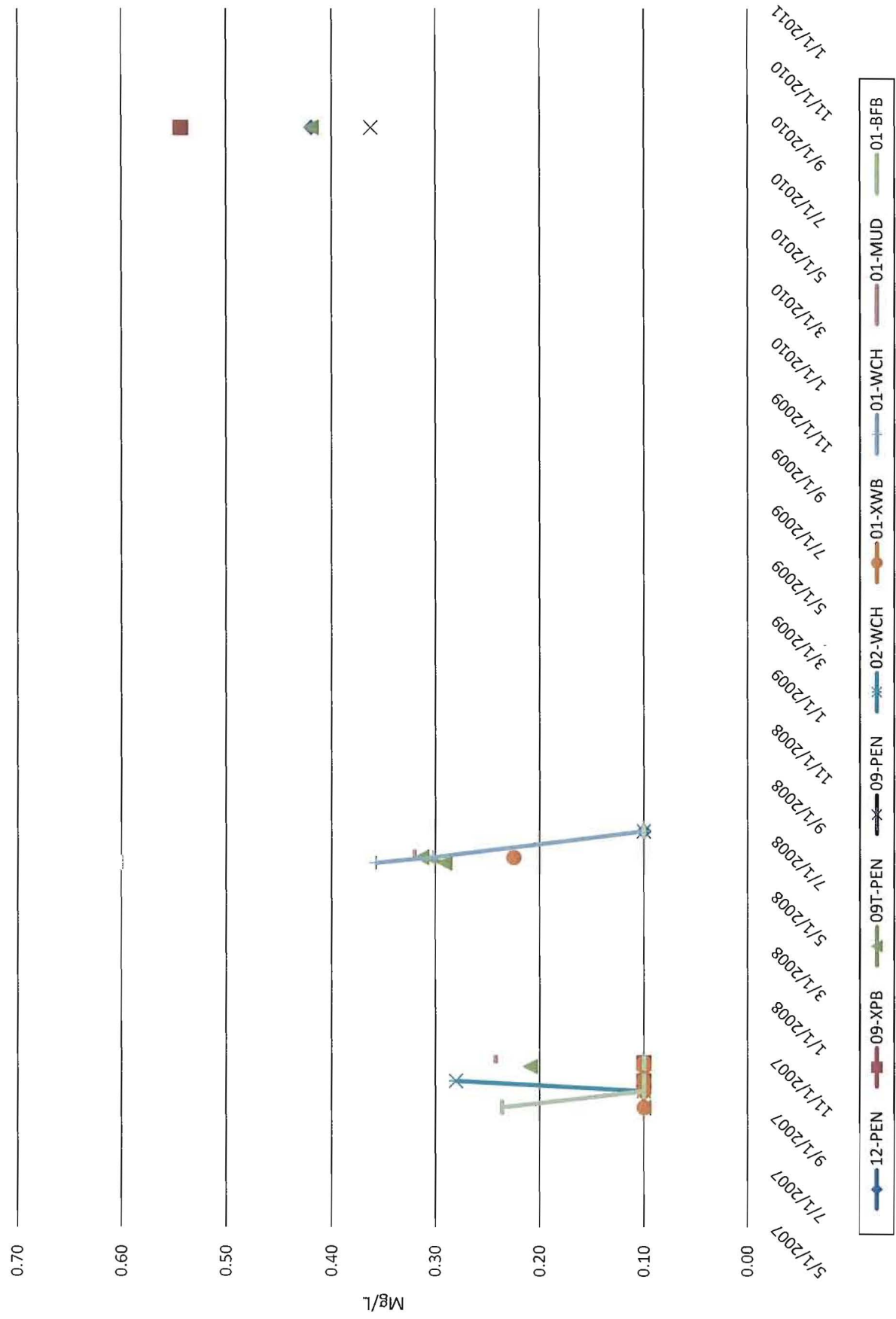
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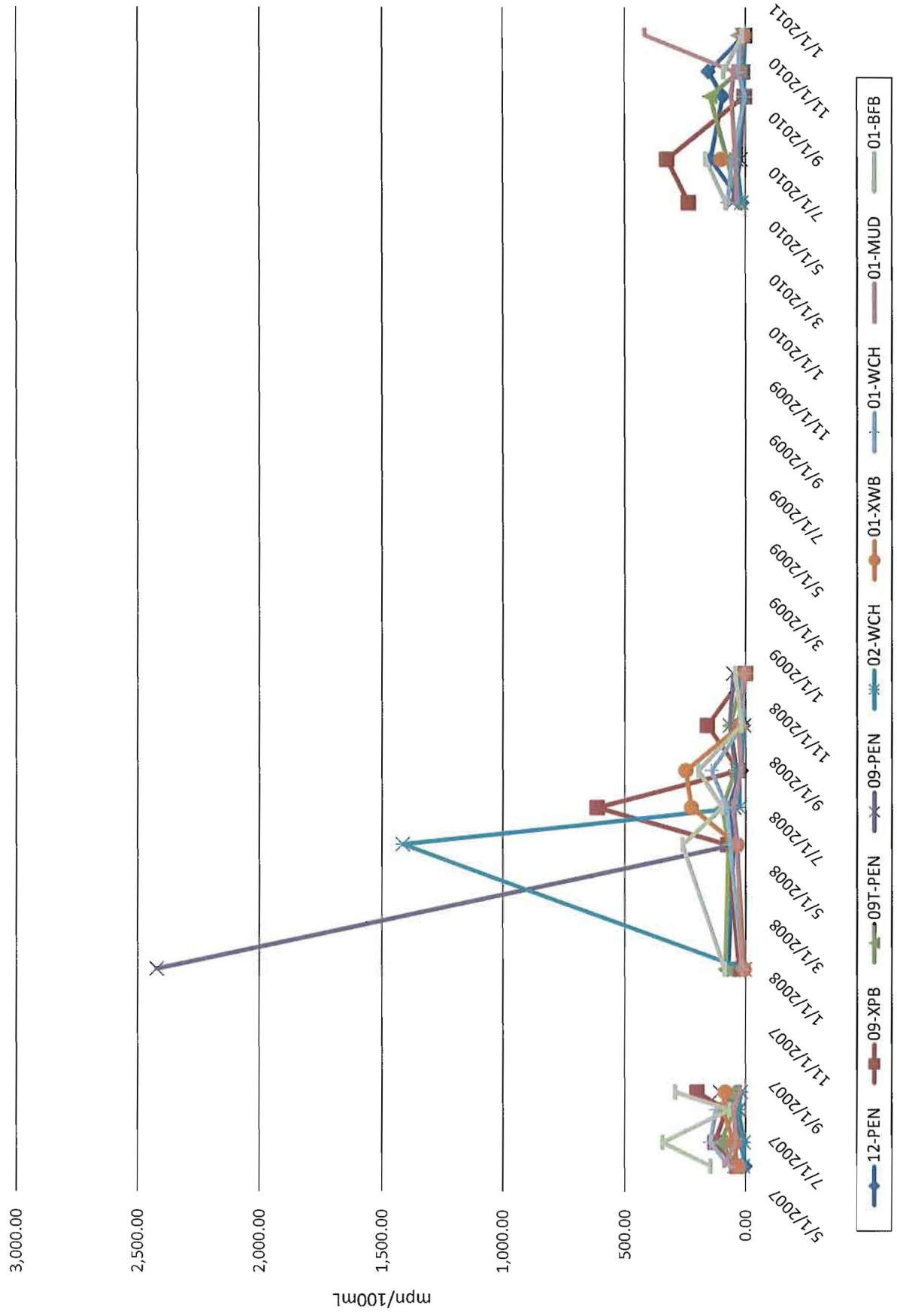
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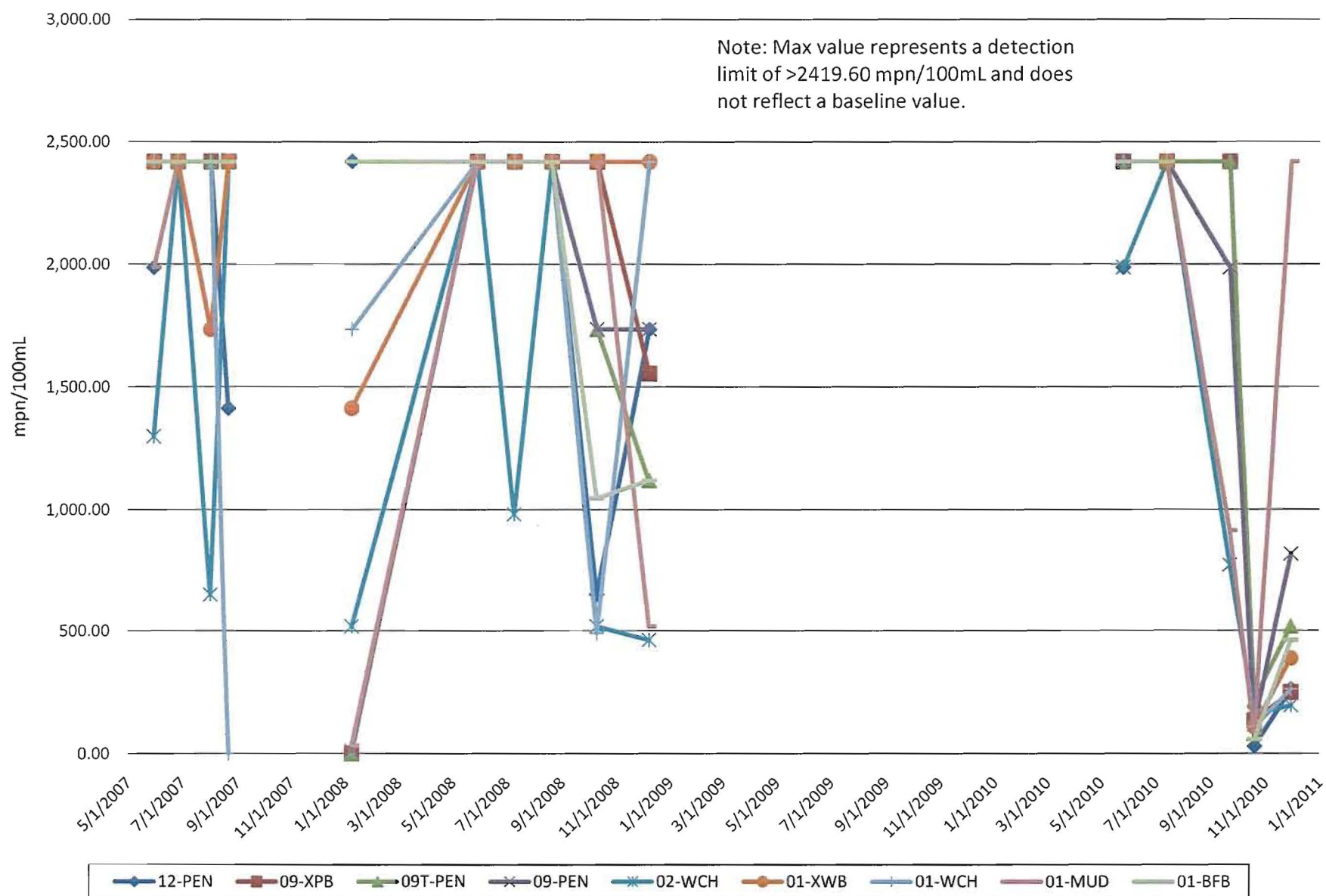
Wet Weather Sampling - Ammonia-N 2007-2010



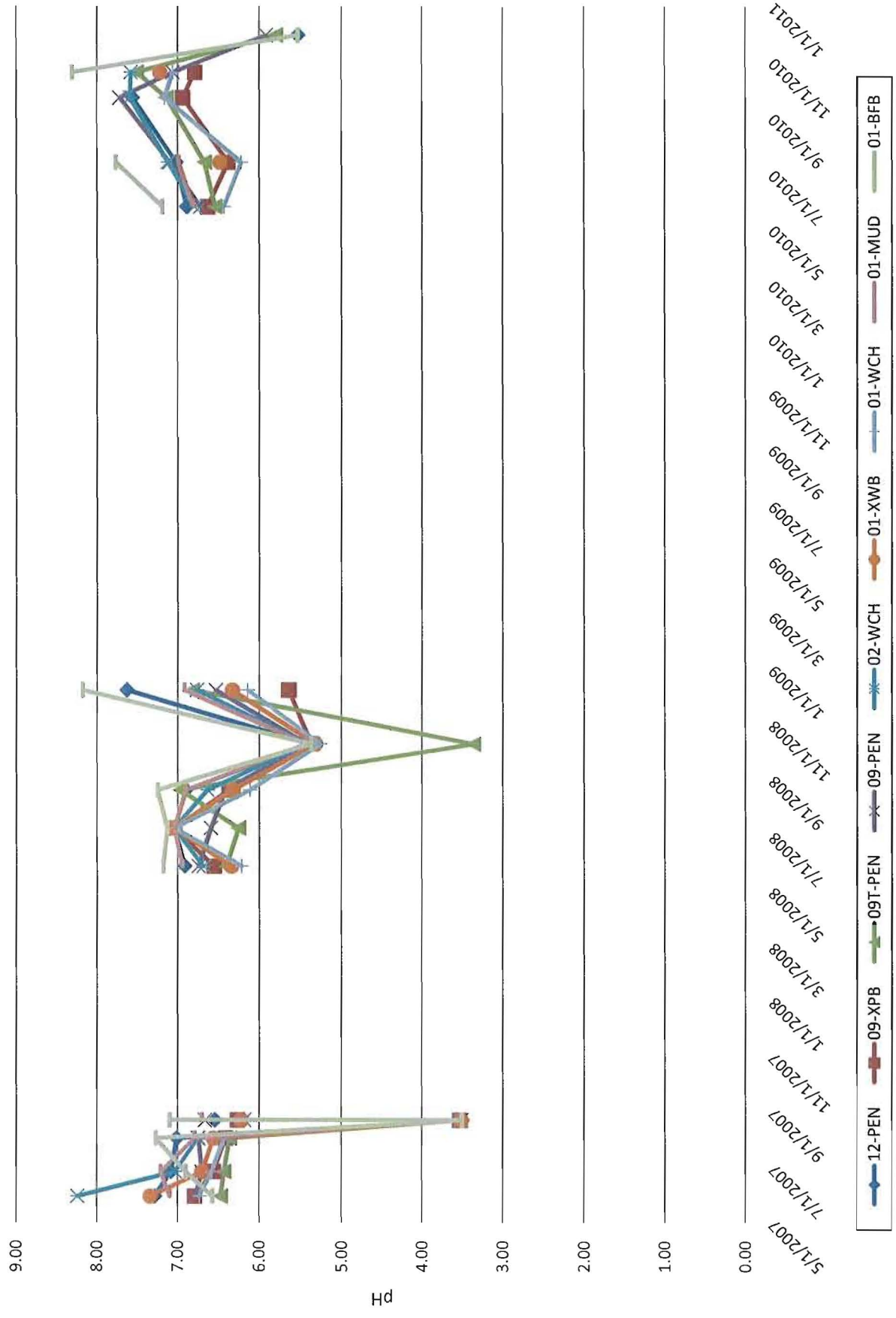


Dry Weather Sampling - Total Coliform Levels 2007-2010

Note: Max value represents a detection limit of >2419.60 mpn/100mL and does not reflect a baseline value.



Dry Weather Sampling - pH 2007-2010



Dry Weather Sampling - Conductivity Levels 2007-2010

