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December 27, 2013

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

**RE: PENNICHUCK WATER WORKS
2007 – 2013 TRIBUTARY AND IN-POND 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 2013. This report also presents the results of the groundwater piezometer sampling program performed in 2013 and briefly presents the results of the in-pond sampling program conducted by Pennichuck Water Works. Recommendations for changes to the monitoring program are also provided.

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 tributary sampling locations.

1.0 Background

Pennichuck Water Works, in coordination with the Nashua Regional Planning Commission (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 tributary and five pond sampling locations within the watershed. This program was further refined in 2007 to include continuous flow monitoring and the collection of winter samples at tributary locations, beginning a more complete data set. Since then, water quality sampling and flow measurements at tributary locations have been ongoing, with modifications and adjustments made as needed.

In 2013, Pennichuck initiated a groundwater sampling program to evaluate phosphorus concentrations in the groundwater and how this compares with phosphorus concentrations used in the restoration plan model and those found in the tributaries. The model used a phosphorus groundwater concentration of 20 ppb as estimated from dry

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COMPREHENSIVE
ENVIRONMENTAL
INCORPORATED

Mr. Chris Countie
December 27, 2013
Page 2 of 14

weather flow concentrations in the tributaries, which attributed about 20% of the watershed phosphorus load to groundwater inputs. The purpose of the groundwater evaluation is to allow for future adjustments of the watershed model and to determine whether additional recommendations to address this load are warranted.

This letter report focuses on the full data set collected from 2007 through 2013.

2.0 Monitoring Locations

Groundwater monitoring locations were selected to correspond with tributary sampling locations where possible (this was impractical in some cases due to property ownership). The nine groundwater and tributary sampling locations are shown on Figure 1 with descriptions provided in **Table 1**.

Table 1 – Groundwater and Tributary Sampling Locations

Groundwater Station ID	Tributary Station ID	Location / Description
01-BFB-MW	01-BFB-T	Boire Field Brook, Tinker Road, adjacent to tributary sampling location
09-PEN-MW	09-PEN-T	Holt Pond Dam, adjacent to tributary sampling location
09T-PEN-MW	09T-PEN-T	Route 101A Bridge, adjacent to tributary sampling location
09-XPB-MW ¹ (01-CML)	09-XPB-T ¹	Unnamed Trib to Pennichuck Brook on 101A. (Craftsman Lane, Merrimack Valley Baptist Church, Merrimack)
01-WCH-MW	01-WCH-T	South Merrimack Road Bridge, adjacent to tributary sampling location
01-XWB-MW	01-XWB-T	Unnamed Trib to Witches Brook, adjacent to tributary sampling location
02-WCH-MW ¹ (01-HAY)	02-WCH-T ¹	Ames Road Bridge on Route 122. (Hayden Road, Hollis, in PSNH electrical line easement)
12-PEN-MW	12-PEN-T	Nevins Road Bridge, adjacent to tributary sampling location
01-MUD-MW	01-MUD-T	Farley Road Bridge, adjacent to tributary sampling location

¹Groundwater monitoring wells not installed adjacent to tributary sampling locations.

In addition, Pennichuck Water Works has been collecting in-pond data at five locations since 2007. In-pond stations and locations are shown on Figure 1 with descriptions provided in **Table 2**.

Table 2 – In-Pond Sampling Locations

Station	Description	Sample Locations
07F-PEN	Bowers Pond - 700' US of Bower	Surface and Bottom
08-PEN	Bowers Pond - Middle	Surface and Bottom
04-PEN	Harris Pond - 100' US of Harris	Surface and Bottom
06-PEN	Harris Pond - Middle	Surface and Bottom
07P-PEN	Bowers Pond - 1/4 mile DS of E	Surface Only

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3.0 Data Collection

Monitoring activities presented in this report include those beginning in May of 2007 through December 2013 and excluding 2009 as previously described. During this time, Comprehensive Environmental Inc. (CEI) collected groundwater and tributary samples, while Pennichuck Water Works collected data from in-pond sampling locations.

Laboratory and Field Data

Tributary and groundwater samples were analyzed by assorted laboratories during the sampling program, most recently Granite State Analytical and Chemserve. Pennichuck Water Works also collected samples from in-pond locations for laboratory analysis of select parameters. The parameters analyzed for tributaries, groundwater and the ponds are summarized in **Table 3**.

Table 3 – Sampling Parameters

Field Analysis	Laboratory Analysis		
Tributaries and Groundwater	Tributaries	Groundwater	Ponds
• Dissolved Oxygen • Conductivity • pH • Temperature	• Total Phosphorus • TSS • E. Coli • Fecal Coliform • Ammonia-N • Nitrate/Nitrite-N • TKN • Total Nitrogen • Chloride • Sodium	• Total Phosphorus • Chloride • Nitrate/nitrite-N • TKN • Total Nitrogen • Sodium	• Total Phosphorus • Orthophosphate • TSS • E. Coli • Total Coliform • Ammonia-N • Nitrate-N • TKN • Alkalinity • Chloride • Chlorophyll • Color • Iron • Manganese
Ponds			
• Dissolved Oxygen • Conductivity • pH • Temperature • Turbidity			

TSS = Total Suspended Solids

N = Nitrogen

TKN = Total Kjeldahl Nitrogen

Though all parameters are not analyzed as part of this report, all data was tabulated and input into a water quality database, continuously updated since 2007.

In 2013, dry weather samples were collected on the following dates:

- Tributaries – April 4th, May 6th, June 6th, July 17th, August 16th, September 10th, and October 28th. Sampling rounds scheduled for February and March were pushed to later in the year due to snow melt that could skew results.
- Groundwater – April 4th, July 17th, August 16th, September 10th, & October 28th.
- Ponds – June 5th, June 26th, July 25th, August 14th, September 5th, & October 9th.

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COMPREHENSIVE
ENVIRONMENTAL
INCORPORATED

Mr. Chris Countie
December 27, 2013
Page 4 of 14

Staff Gauges, Data Loggers and Stage/Discharge Relationships

During previous monitoring efforts in 2005 and 2006, staff gauges were installed at the nine tributary locations and stage-discharge relationship equations were developed based on field measurements.

Electronic data loggers were installed at all tributary locations on May 21, 2007 to collect continuous, year-round stream elevations and to track long-term trends in flow. Data loggers collect and record stream elevations once per hour. The stage-discharge relationships are used to convert these elevations to an approximate flow for the river. No major problems were encountered with data loggers in 2013.

4.0 Summary of Data Results

The sampling data results were analyzed for trends and correlations, as well as any unexpected data outliers. This section summarizes the overall results and trends of the multiple sampling programs, with more detailed discussion regarding specific parameters provided in Section 5.

Tributaries

Overall, the water quality in tributaries is similar to the last few years, with the exception of phosphorus, which generally increased since 2010, both in concentration and as a mass loading. An increase in phosphorus was also observed in the ponds in 2013 compared with data since 2011. There is no clear explanation for the increase in tributaries as streamflows were fairly consistent with previous years and flow-weighting, which removes the influence flow has on the concentrations (e.g., dilution), still showed a general increase in phosphorus.

Despite these recent increases in phosphorus, the overall water quality trend for phosphorus since 2007 still shows an improvement. However, longer-term data is needed to draw any conclusions as to whether water quality is generally improving over time, as variability is expected to occur from year to year with changing weather conditions (e.g., temperature, rainfall volume, rainfall intensity, etc.).

In-Pond

In general, water quality in the ponds in 2013 was similar to previous years for most parameters. A decline in DO levels and increase in phosphorus levels was generally noted, specifically at 06-PEN and 08-PEN, which appear to be the least influenced by the pond weir-baffle and aeration system installed to promote cooler, oxygenated waters to the deeper layer. These locations are more removed from system components than other locations. The lower DO levels can promote the release of phosphorus from the pond sediments and may have some influence on these higher concentrations. However, phosphorus loads from tributaries were also generally higher in 2013 than previous

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COMPREHENSIVE
ENVIRONMENTAL
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Mr. Chris Countie
December 27, 2013
Page 5 of 14

years. Despite these recent increases, the overall trend since data collection in 2007 is still slightly improving, however, variability in concentrations is expected from year to year and longer-term data is needed to draw any conclusions as to whether water quality is improving.

Groundwater

Elevated phosphorus concentrations were observed in groundwater, with site-wide averages ranging between 33 ug/l and 120 ug/l on a given date, and an overall average of 49 for all sampling rounds. Averages by location ranged from 21 ug/L to 88 ug/L. While there is no apparent trend between the groundwater and tributary concentrations, the high concentrations in groundwater suggest groundwater is contributing a higher phosphorus load to the tributaries and ponds than predicted in the Watershed Restoration Plan model.

Chloride and conductivity levels in groundwater suggest that locations 01-BFB-MW, 09-PEN, 09-XPB and 01-MUD are most influenced by road salting practices.

5.0 Discussion of Sampling Parameters

Stream Flow

Stream flow is measured to assess trends including baseflow, to evaluate its influence on water quality parameters and to allow for conversion of pollutant concentrations to a mass loading.

Flow results measured at all tributary stations are roughly correlated to each other, as seen by similar rise and fall trends. Data available for the year is substantially complete with the exception of 12-PEN, which due to mechanical issues is missing approximately 15 weeks of data during the winter months (December through mid-March). Data gaps are shown on the "Tributary Flow Data" figures for any missing or negative data, however, these data gap issues have been substantially reduced with the installation of new data loggers with larger or more efficient batteries.

Flow data for 09-XPB is only provided from September 2012 to the present. Previous data was deemed to be unreliable due to mechanical issues, and the datalogger has since been replaced. There is still some discrepancy between flow data and stage-discharge relationships established earlier in the sampling program. Additional velocity and flow readings will be collected during 2014 to more closely establish stage-discharge relationships. This information will be used to determine actual historic flow rates as much as practical.

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COMPREHENSIVE
ENVIRONMENTAL
INCORPORATED

Mr. Chris Countie
December 27, 2013
Page 6 of 14

- Engineering
- Design
- Construction
- Inspection

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Dissolved Oxygen

Dissolved oxygen (DO) is inversely proportional to temperature 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. Readings below 4.0 mg/L would be considered dangerous to aquatic organisms. DO in tributaries ranged between 0.91 mg/L and 14.40 mg/L. Similar, but slightly lower levels were observed in groundwater samples. Several groundwater samples exhibited artificially high DO readings at locations 09-PEN, 09T-PEN, and 01-WCH, likely introduced during sampling with Waterra piping and foot valves which require a pumping action.

Samples from tributary stations 09T-PEN, 09-XPB, 01-WCH, 09-PEN and 01-MUD fell below standards multiple times in 2013, consistent with previous years. However, there was an overall improvement in dissolved oxygen (DO) levels at all tributary stations except for stations 09-PEN and 01-XWB from 2007 through 2013. Tributary and groundwater DO trends are shown in **Figure 2**.

In-pond surface samples are above 4 mg/L. Bottom samples dipped below 4 mg/L and in some cases below 2 mg/L, similar to observations in 2011. This dip in DO levels occurs over the summer, when there is a rise in water temperatures and is likely associated with stratification in the ponds. It is more apparent at locations 06-PEN and 08-PEN, which are more removed from the weir-baffle and aeration system components installed in the ponds to promote cooler, oxygenated waters to the deeper layers. Low DO concentrations in the pond bottom can contribute to the release of phosphorus to the water column from bottom sediments when mixing occurs.

Total Suspended Solids (TSS)

TSS represents suspended material in the water. It can smother benthic macroinvertebrates as it settles to river bottoms, carry pollutants such as phosphorus, and contribute to declines in 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.

Dry weather TSS levels were low throughout the 2013 sampling period with small spikes noted in 12-PEN and 09-XPB in September. Historically, elevated levels of TSS have been associated with increased flows, which is to be expected as runoff washes 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, and all 2012 samples recorded from both tributary and in-pond locations were below this threshold. Overall, TSS levels in tributaries are declining (improving) since the start of the 2007 sampling program as shown on **Figure 3**, with some slight fluctuations from one location to another.



COMPREHENSIVE
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INCORPORATED

Mr. Chris Countie
December 27, 2013
Page 7 of 14

- Engineering
- Design
- Construction
- Inspection

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Total Phosphorus

Phosphorus is a nutrient essential to plants and in excess amounts can cause algal blooms, particularly in fresh water systems. Algal blooms increase oxygen during the day in turn decreasing oxygen at night, resulting in a net loss, and make water less attractive. Phosphorus can indicate the presence of sewage, animal waste, lawn fertilizer, erosion and may also come from natural wetlands.

The majority of both in-pond and tributary sampling results ranged from 10 ug/L to 60 ug/L in 2013, and is higher overall than levels detected during the last few years. Tributary stations 09-XPB and 01-MUD showed the highest phosphorus concentrations in 2013. Data consistently show increased phosphorus concentrations during dry summer sampling events in comparison to other seasons. Station 09-XPB continues to show an occasional spike. With the exception of 2011, tributary station 09-XPB typically shows the highest concentrations throughout the sampling period, with this trend continuing into 2013.

Groundwater samples are filtered using a 45-micron filter to remove sediment particles before analysis, thus, phosphorus concentrations represent dissolved phosphorus. Dissolved phosphorus concentrations in the filtered groundwater samples ranged from less than 10 ug/L to as high as 2,970 ug/L (09T-PEN-MW). Average phosphorus concentrations over all locations ranged from 33 ug/L (09-PEN-MW) to 566 ug/L (09T-PEN-MW) with an overall average concentration of 125 ug/L. All averages exceed the 20 ug/L assumed phosphorus groundwater concentration in the 2012 Restoration Plan model. Average filtered groundwater concentrations were highest during summer (July) at 531 ug/L, compared to 29 ug/L during the fall (September). Average tributary phosphorus concentrations (average of all locations) compared well with average groundwater concentrations on most dates, with the exception of July and August 2013, which included extremely high concentrations at select locations in comparison to the rest of the data. Refer to **Table 4** for average phosphorus concentrations in groundwater and tributaries for each sampling round.

Table 4 – Comparison of Average Phosphorus Concentrations by Date (ug/L)

Date	Groundwater	Tributaries
11/26/2012	33	15
4/4/2013	50	50
7/17/2013	120	57
8/16/2013	28	21
9/10/2013	29	29
10/28/2013	33	38
Total Average	49	35

Note: Excludes outliers with concentrations greater than 250 ug/l.



COMPREHENSIVE
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INCORPORATED

Mr. Chris Countie
December 27, 2013
Page 8 of 14

Generally, spring through summer have higher phosphorus concentrations compared to fall and winter, but this varies by location.

The results show all sampling locations have phosphorus concentration of 20 ug/L or higher during two or more of the sampling rounds. Groundwater locations 01-BFB-MW, 09-XPB-MW, 01-WCH-MW and 12-PEN-MW exhibited the highest average phosphorus concentrations, indicating these may be potential hot spot areas. Average concentrations in tributaries are more consistent between stations. Refer to **Table 5** for a comparison of average phosphorus concentrations by location.

Table 5 – Comparison of Average Phosphorus Concentrations by Location (ug/L)

Station ID	Groundwater	Tributaries
01-BFB	88	37
09-PEN	33	35
09T-PEN	25	40
09-XPB (01-CML)	58	35
01-WCH	57	38
09-XWB	21	34
02-WCH (01-HAY)	34	30
12-PEN	51	32
01-MUD	24	39

Note: Excludes outliers with concentrations greater than 250 ug/l.

While there is no apparent trend between the groundwater and tributary concentrations, the high concentrations in groundwater suggest groundwater is contributing a higher phosphorus load to the tributaries and ponds than predicted in the Watershed Restoration Plan model.

While phosphorus concentrations have increased in tributaries since 2010, the overall phosphorus concentration trend is still slightly improving since 2007 and the start of the watershed restoration program as shown on **Figure 4**. Since precipitation events and tributary flows can influence these concentrations, the data was flow weighted to determine the mass load of phosphorus during each sampling event. This represents the amount of they phosphorus in pounds in the stream on a given day (**Figure 5**). The data show increasing phosphorus load trends in four of the nine sampling locations, with decreasing or flat trend lines at the remaining locations.

In-pond phosphorus concentrations also generally increased in 2013 with increasing concentration trends noted in 06-PEN TOP and 08-PEN-TOP and in most bottom samples. A decrease in DO was also noted at the corresponding bottom locations and 07F-PEN BOT during July, August and September, which can result in the release of phosphorus from bottom sediments. These three stations appear to be the least

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INCORPORATED

Mr. Chris Countie
December 27, 2013
Page 9 of 14

- Engineering
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influenced by the baffle-weir and aeration system installed in the ponds to promote cooler, oxygenated waters at greater depths, therefore may be subject to greater variability in water quality. While the overall average water quality trend for all data is still improving (declining trend) as shown in **Figure 6**, there continues to be some variability from year to year and longer-term data is needed to determine whether there is an actual improvement.

While there is no numeric standard for phosphorus, the NHDES level of concern is 50 ug/L. In 1976, the EPA also recommended phosphorus limits of 50 ug/L for streams. Ideally, only naturally occurring phosphorus should be present, typically from 14 ug/L to 17 ug/L under natural conditions. Levels of 15 ug/L in lakes and ponds are often set as a goal to support recreational uses of the water and decrease algae blooms. Several in-pond and tributary samples collected during 2013 exceed 50 ug/L and several groundwater samples exceed 15 ug/L.

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 levels were generally higher during summer and fall months and lower during winter periods, consistent with historical data. Tributary results are consistent with previous sampling years. The overall trend of *E.coli* is slightly improving (four locations) or straight (three locations) at all stations with the exception of 01-XWB and 12-PEN, which showed a slight upward trend or increase in concentration.

In-pond *E.coli* levels were typically highest at bottom locations, particularly 08-PEN, which increased slightly since 2011. The overall water quality trend is slightly improving since 2007, with typical variability from year to year.

Refer to **Figure 7** for data results between 2007 and 2013. *E.coli* data was not analyzed for groundwater samples.

E.coli should not exceed 153 cts/100 mL for any single sample, based on numeric standards for Class A waters. With the exception of six tributary samples, the remainder of samples (tributary and pond) met the numeric threshold for Class A waters.

Nitrogen

Nitrogen is also a nutrient essential for algae and other plant growth and excess amounts can lead to nuisance algae blooms, however, phosphorus is typically the limiting nutrient in fresh water systems.



COMPREHENSIVE
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Mr. Chris Countie
December 27, 2013
Page 10 of 14

- Engineering
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Nitrates/Nitrites

Nitrates and nitrites are nitrogen-oxygen chemical units that combine with various organic and inorganic compounds. Nitrates are highly mobile and can leach into groundwater. Common sources of nitrate/nitrite include fertilizers and manure, animal feedlots, municipal wastewater and sludge, septic systems and nitrogen fixation from atmosphere.

Total nitrate/nitrite-N tributary results were low in 2013, typically non-detect or below 1 mg/L. Nitrate/nitrite-N levels in groundwater varied considerably ranging from non-detect levels (>0.05 mg/L) to 5.05 mg/L at station 01-MUD-MW during August 2013. 01-MUD-MW also had some of the highest phosphorus concentrations. All groundwater stations exhibited detectable nitrate/nitrite-N levels during the sampling period. Refer to Attachment A for water quality graphs of nitrates/nitrites.

The EPA has established a Maximum Contaminant Level Goal (MCLG) for nitrates and nitrites in public drinking water systems of 10 mg/L and 1 mg/L, respectively.¹ Nitrates and nitrites during this sampling program were measured in a combined reading, with a maximum value of 5.05 mg/L obtained at 01-MUD-MW. Remaining values ranged between non-detect and 2.41 mg/L. This combined with the phosphorus data suggest contributions from fertilizers, manure or wastewater.

Total Kjeldahl Nitrogen (TKN)

TKN represents organic nitrogen and ammonia nitrogen, which can indicate the presence of sewage, animal waste, fertilizer, erosion, or other types of pollution. TKN levels were non-detect at all tributary and in-pond locations in 2013. This mimics the 2011 TKN results.

TKN in groundwater ranged from non-detect to as high as 26 mg/L in December 2012, likely due to the fact that these samples were not filtered to remove sediment. Filtered TKN samples taken between April and October 2013 were much lower, all <0.5 mg/L (detection limit) with the exception of sample 09T-PEN-MW (July and August), 01-HAY (July) and 09-PEN (August), which had results between 2 and 8 mg/L. Refer to Attachment A for water quality graphs of TKN.

TKN does not have a numeric standard specified in the New Hampshire surface water quality standards. However, NHDES in conjunction with the Volunteer River Assessment Program (VRAP) has suggested that TKN concentrations <0.25 mg/L are ideal, and <0.40 mg/L are average.² Many filtered groundwater samples were above 0.5 mg/L; however, TKN has historically been below 1 mg/L in the tributaries.

¹ NHDES Fact Sheet, Nitrate and Nitrite: Health Information Summary (ARD-EHP-16)

² NHDES Interpreting VRAP Water Quality Monitoring Parameters



COMPREHENSIVE
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INCORPORATED

Mr. Chris Countie
December 27, 2013
Page 11 of 14

- Engineering
- Design
- Construction
- Inspection

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Ammonia-Nitrogen

As with TKN, ammonia is a nutrient that contributes to plant growth. Ammonia-nitrogen toxicity is dependent on pH levels. When the pH is below 8.75, NH_4^+ dominates. Basic pH above 9.75 can cause NH_3 to dominate, which is more toxic to aquatic species. Measurement of TKN and ammonia-nitrogen allows for estimation of organic nitrogen by subtracting the concentration of ammonia-nitrogen from TKN. Ammonia-nitrogen should be less than 0.64 mg/L as per New Hampshire water quality standards. All tributary and in-pond samples continue to meet water quality standards for ammonia. Refer to Attachment A for water quality graphs of ammonia-nitrogen.

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 consistent during the 2012 period, generally ranging between 6 and 7.5, further confirming that the extreme dips in pH identified at tributary locations in August of 2007 and October of 2008 are likely anomalies associated with equipment malfunctions. Groundwater pH is slightly lower, generally ranging between 5.5 and 7 as expected due to the generally acidic nature of soil in the area. pH levels in the ponds are generally between 6 and 7.5, similar to pH levels in tributaries, however, a wider range of values was noted compared with previous years. A dip in pH was observed in tributaries, groundwater and ponds in the late summer. The Class A NH Surface Water Quality Standard for pH is between 6.5 and 8.0 unless naturally occurring, and no groundwater standards are available. Refer to Attachment A for water quality graphs of pH.

Conductivity

Conductivity measures the total dissolved solids including free ion (charged particles) content in water and can indicate the presence of chlorides, and total dissolved solids including 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.

Tributary conductivity levels were relatively consistent between sampling stations in 2013 with a general rise in the spring (May) and summer (July), and decline in fall and winter. Levels are similar to those observed in 2007, 2008, 2011, and 2012 and less than 2010 results.

Conductivity in groundwater and ponds was also highest in the summer with a notable decline in the fall.



COMPREHENSIVE
ENVIRONMENTAL
INCORPORATED

Mr. Chris Countie
December 27, 2013
Page 12 of 14

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- Design
- Construction
- Inspection

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New Hampshire water quality standards do not specify a numeric standard for conductivity, however, a waterbody with conductivity greater than 2,000 umhos/cm would be considered high in dissolved solids. All samples from 2013 are substantially less than 2,000 umhos/cm. Refer to Attachment A for water quality graphs of conductivity.

Sodium/Chloride

Sodium and chlorides represent salt content in the water, typically associated with salting of roadways.

Sodium and chloride levels were highest in September and October in the tributaries and in July through October in the groundwater. The highest tributary concentrations were at 01-BFB and the highest groundwater concentrations were at 01-MUD-MW and 09-PEN-MW. This indicates that salting practices in these areas are likely contributing to concentrations in the groundwater and surface water.

In order to protect freshwater aquatic life, New Hampshire has adopted acute and chronic chloride water quality standards of 860 and 230 mg/L, respectively for surface waters. Chloride levels in the tributaries fell below the water quality standards in all but one sample (01-WCH).

There are no standards for sodium and chloride in groundwater, however, typical background levels for pristine locations in New Hampshire are less than 20 mg/L and 30 mg/L, respectively.³ Observed sodium and chloride levels in groundwater are above background concentrations at most locations. Refer to Attachment A for water quality graphs of sodium and chloride.

6.0 Conclusions

Overall water quality is consistent or improving since the start of the 2007 watershed restoration program as shown by select water quality parameters in figures 2 through 7. Despite a slight increase in phosphorus in 2013, overall trends of total phosphorus, total suspended solids, E.coli and DO since 2007 are still generally improving, despite some variability from year to year. However, considering year to year variability, longer-term trends are needed to draw any conclusions as to whether the water quality is actually improving with time.

7.0 Recommended Changes to the Monitoring Program

Pennichuck has been collecting streamflow data since 2007. The data was originally collected to help calibrate the model used in the 2008 Watershed Restoration Plan and

³ NHDES Fact Sheet, Sodium and Chloride in Drinking Water, 2010 (WD-DWGB-3-17)



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Mr. Chris Countie
December 27, 2013
Page 13 of 14

continues to be collected to provide overall trend data and information for future modeling efforts. Sampling in 2012 was largely successful on all fronts. Data loggers performed largely as expected, and dry weather sampling was performed as scheduled.

It is recommended that CEI continue to download data from field data loggers approximately every six weeks. Dry weather tributary sampling should continue as follows:

Table 6 – Proposed Dry Weather Sampling Schedule

2014 Month			
March	April	May	July
August	September	November	

We recommend the elimination of sodium since chloride provides similar results. We also recommend minimizing the nitrogen sampling to include only total nitrogen in the tributaries and ponds and total nitrogen and nitrates in groundwater. Future sampling programs should include analysis of the parameters included in Table 7.

Table 7 – Proposed Sampling Parameters

Field Analysis	Laboratory Analysis		
Tributaries and Groundwater	Tributaries	Groundwater	Ponds
• Dissolved Oxygen • Conductivity • pH • Temperature	• Total Phosphorus • TSS • E. Coli • Fecal Coliform • Total Nitrogen • Chloride	• Total Phosphorus • Chloride • Nitrate-Nitrogen • Total Nitrogen	• Total Phosphorus • Orthophosphate • TSS • E. Coli • Total Coliform • Total Nitrogen • Alkalinity • Chloride • Chlorophyll • Color • Iron • Manganese
Ponds			
• DO • Conductivity • pH • Temperature • Turbidity			

TSS = Total Suspended Solids

Additionally, it is recommended that CEI conduct up to 3 velocity-flow readings every 6-inches for station 09-XPB to confirm or reestablish the stage-discharge curve for this location.

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- Hazardous Waste
- Permitting & NEPA
- Stormwater & LID
- Transportation
- Water & Wastewater
- Watershed Restoration



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December 27, 2013
Page 14 of 14

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

Figures:

- Figure 1: Site Locations and Names
- Figure 2: Dissolved Oxygen Trends in Tributaries, 2007-2013
Dissolved Oxygen in Groundwater, 2012-2013
- Figure 3: TSS Trends in Tributaries, 2007-2013
- Figure 4: Phosphorus Trends in Tributaries, 2007-2013
Phosphorus in Groundwater, 2012-2013
- Figure 5: Phosphorus Load Trends in Tributaries, 2007-2013
- Figure 6: Phosphorus Trends for In-Pond Locations, 2007-2013
- Figure 7: E.coli Trends in Tributaries, 2007-2013
E.coli Trends in Ponds, 2007-2013

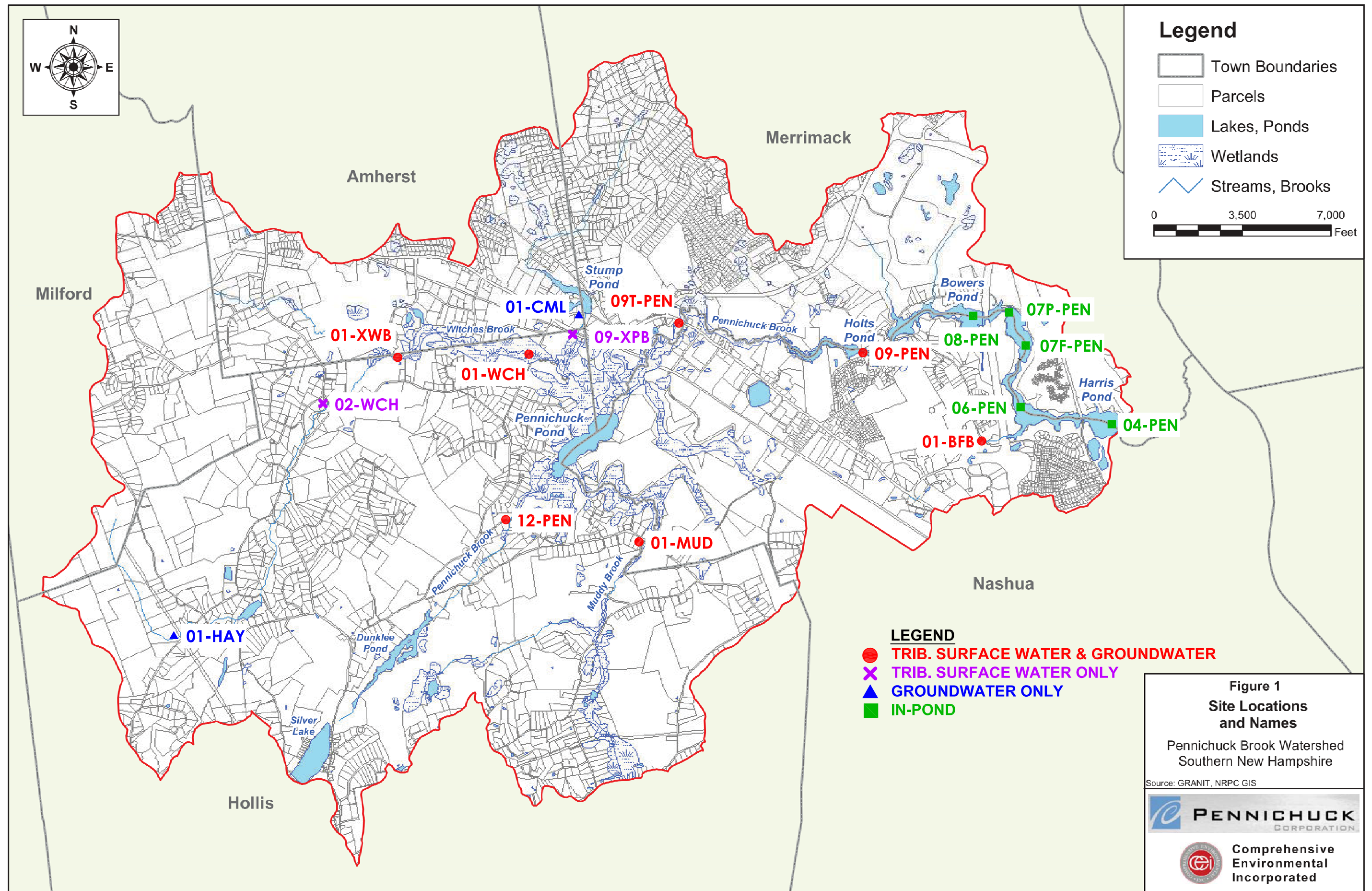
Attachment A – Supporting Graphs

- Tributary Flow Data Graphs
- 2007-2013 Tributary, Groundwater and In-Pond Trendline Graphs
 - Dissolved Oxygen
 - Temperature
 - Total Suspended Solids
 - Total Phosphorus
 - E.coli
 - Fecal Coliform
 - Nitrates/Nitrites
 - TKN
 - Ammonia-N
 - Sodium
 - Chloride
 - pH
 - Conductivity

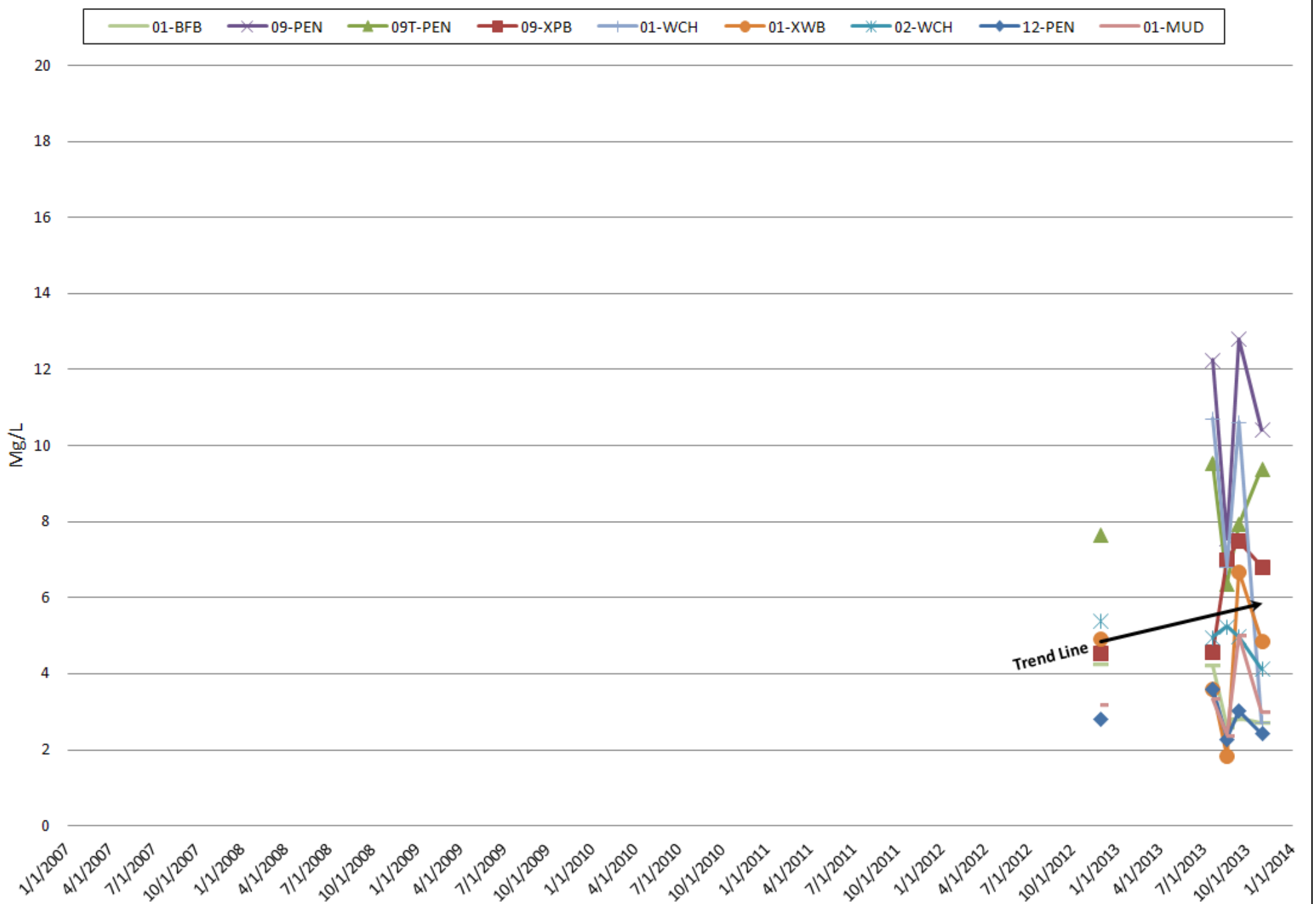
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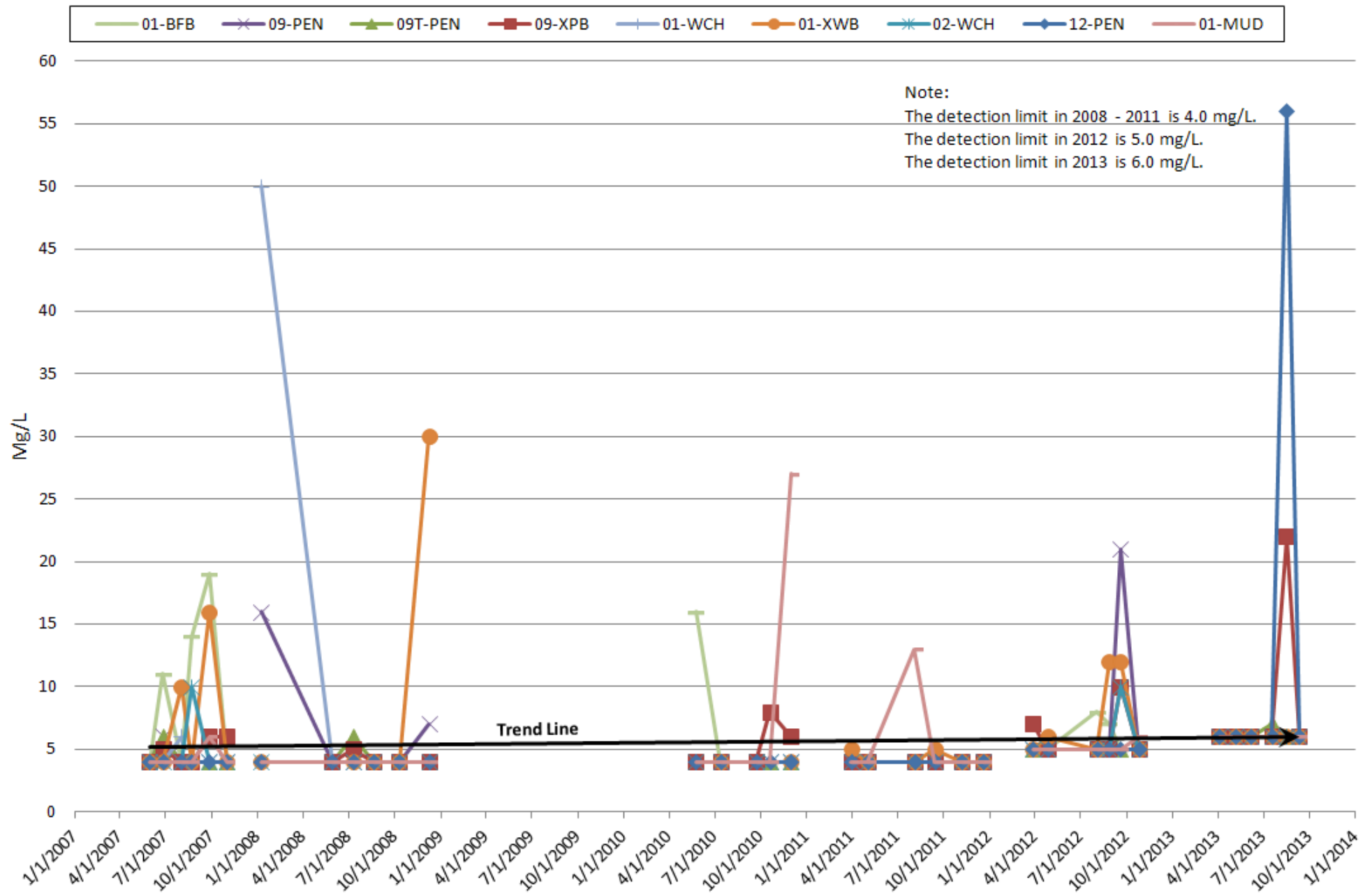
- Drainage &
Flooding
- Energy &
Sustainability
- Hazardous Waste
- Permitting & NEPA
- Stormwater & LID
- Transportation
- Water &
Wastewater
- Watershed
Restoration



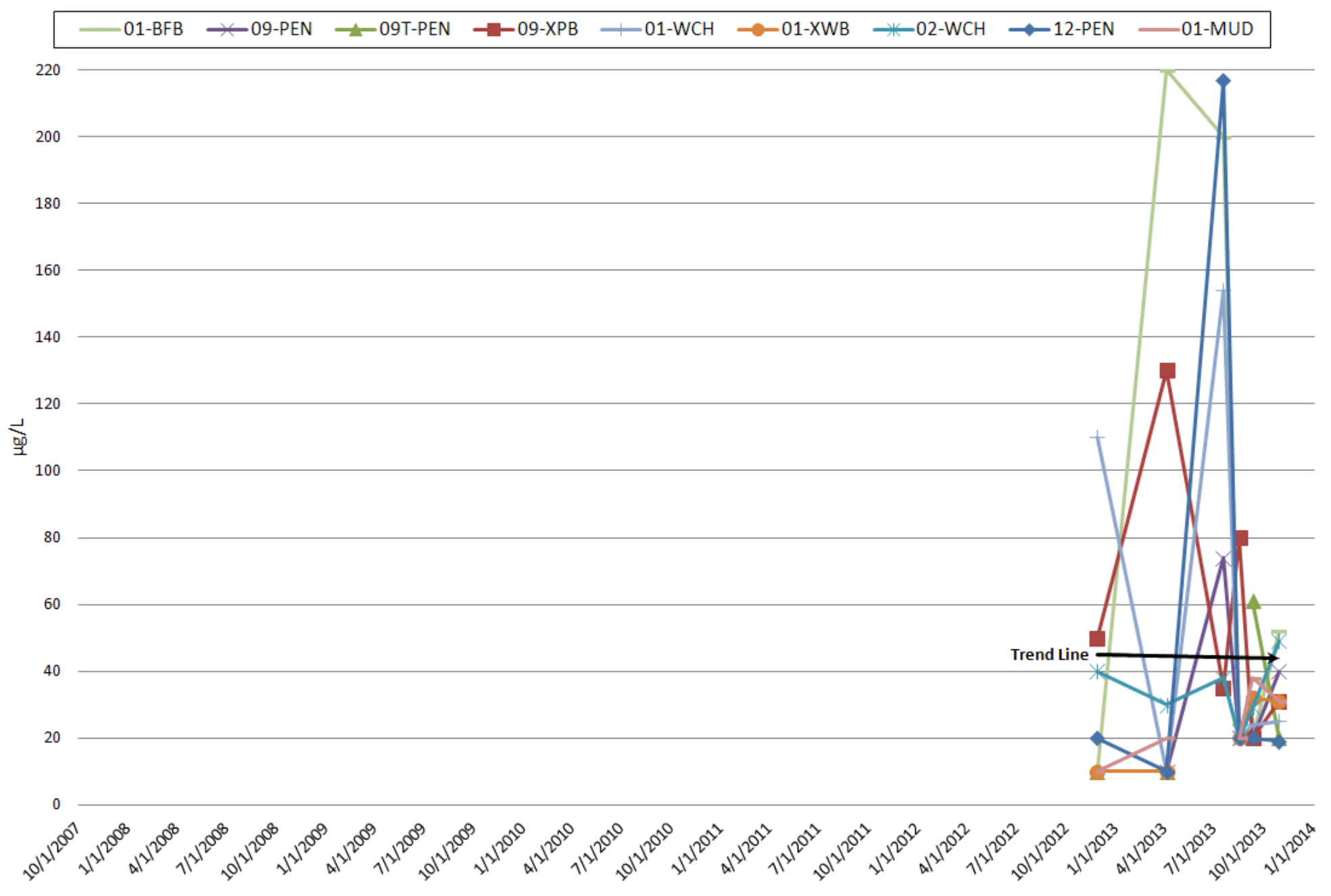
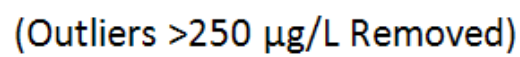
Dissolved Oxygen Trends in Tributaries, 2007-2013



(Outliers >100 mg/L Not Shown)



(Outliers >250 µg/L Not Shown)



(Outliers >250 µg/L Removed)

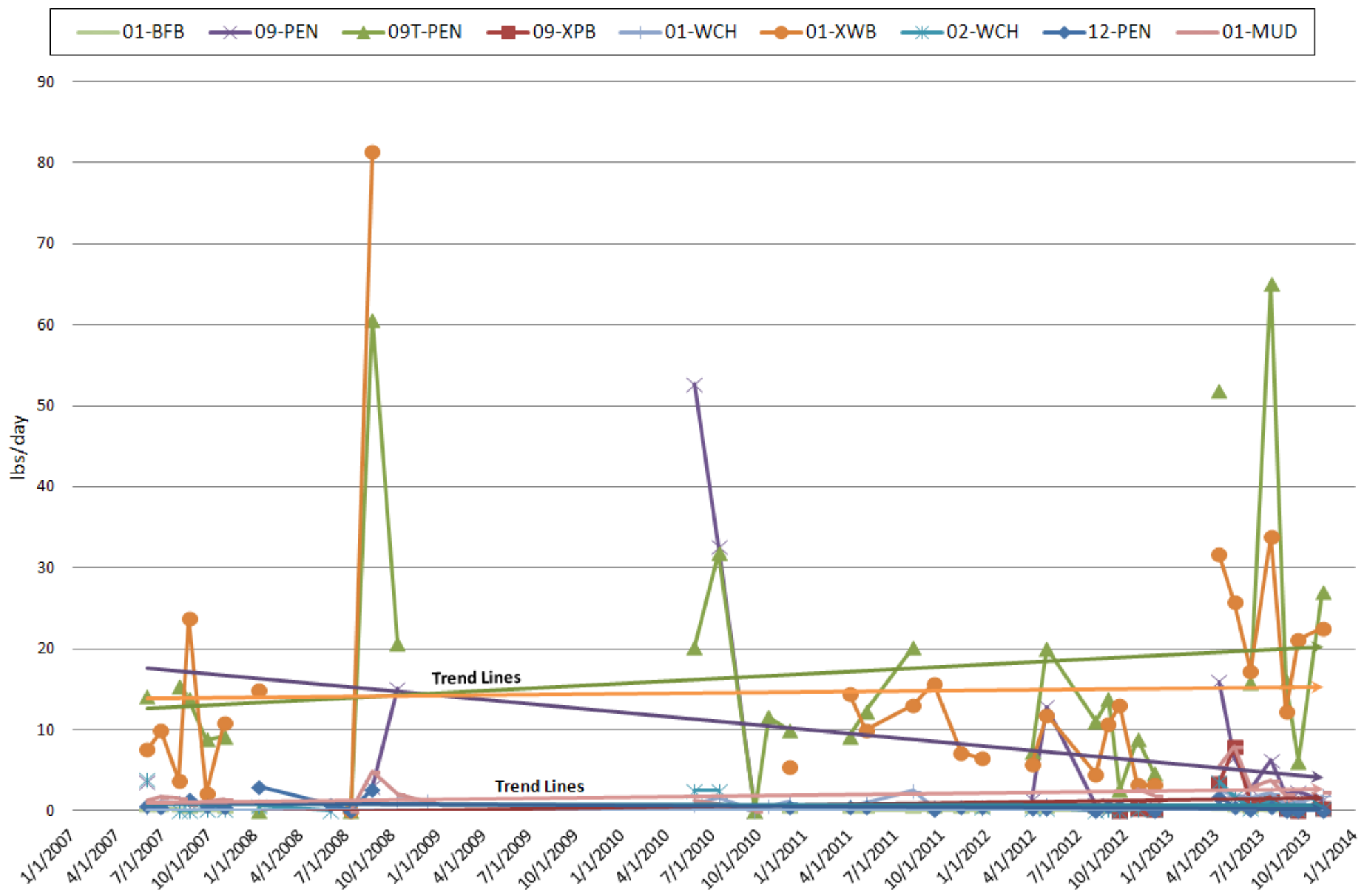


Figure 6: Phosphorus Trends for In-Pond Locations 2010-2013

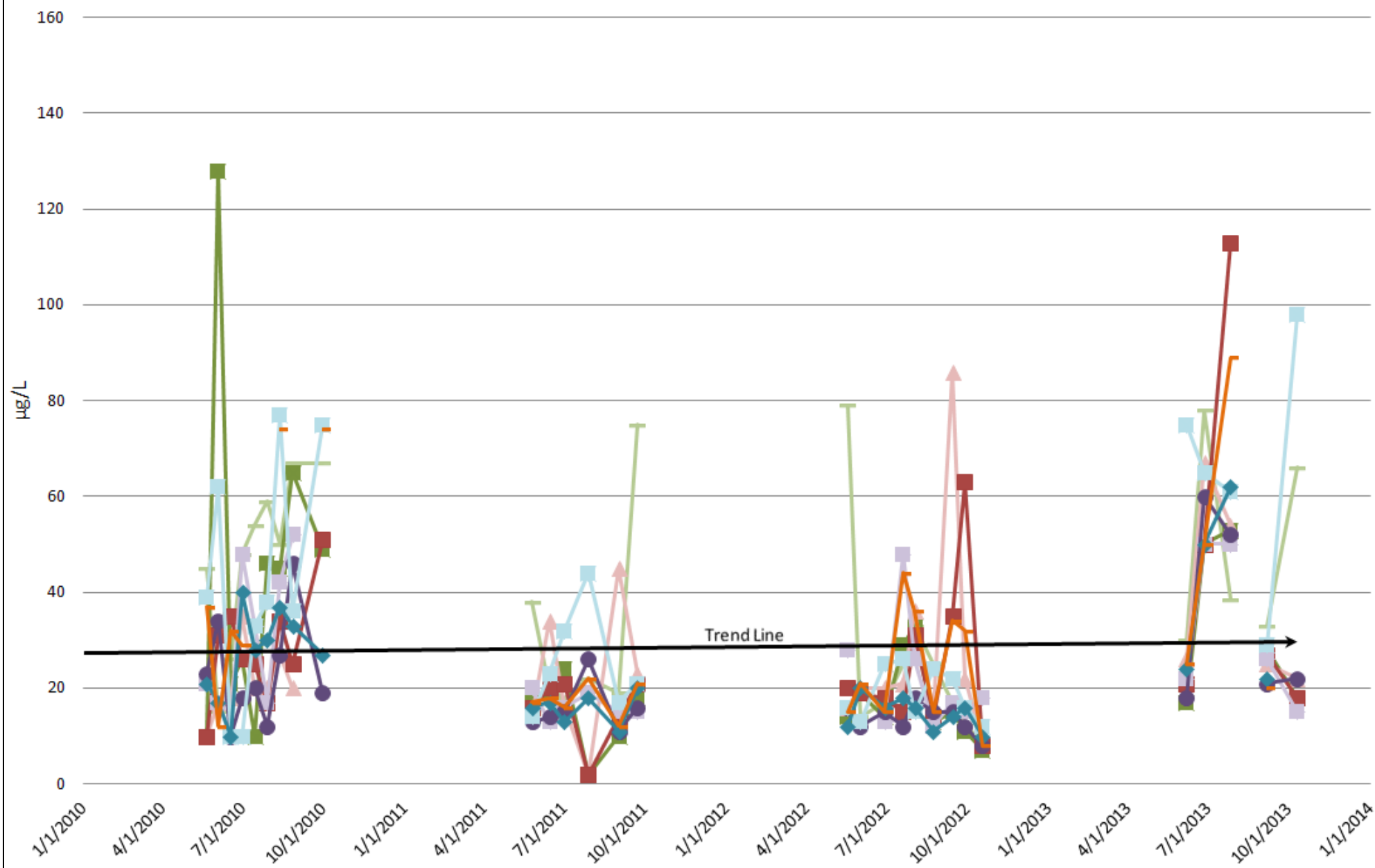
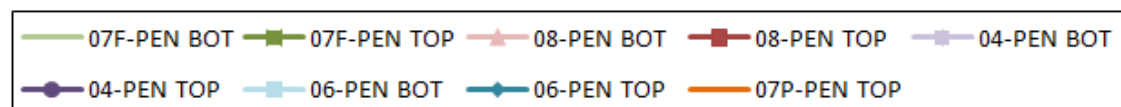
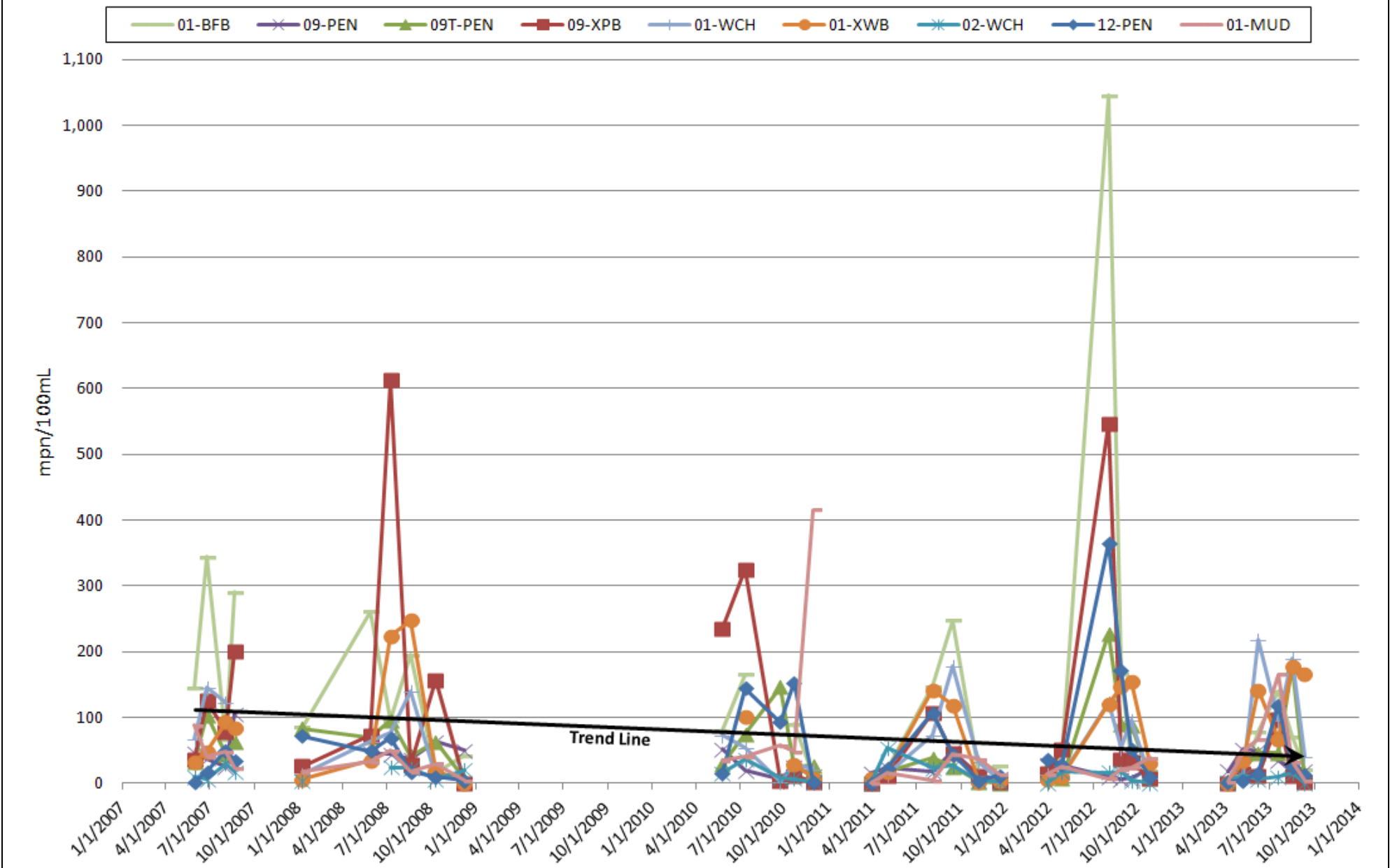
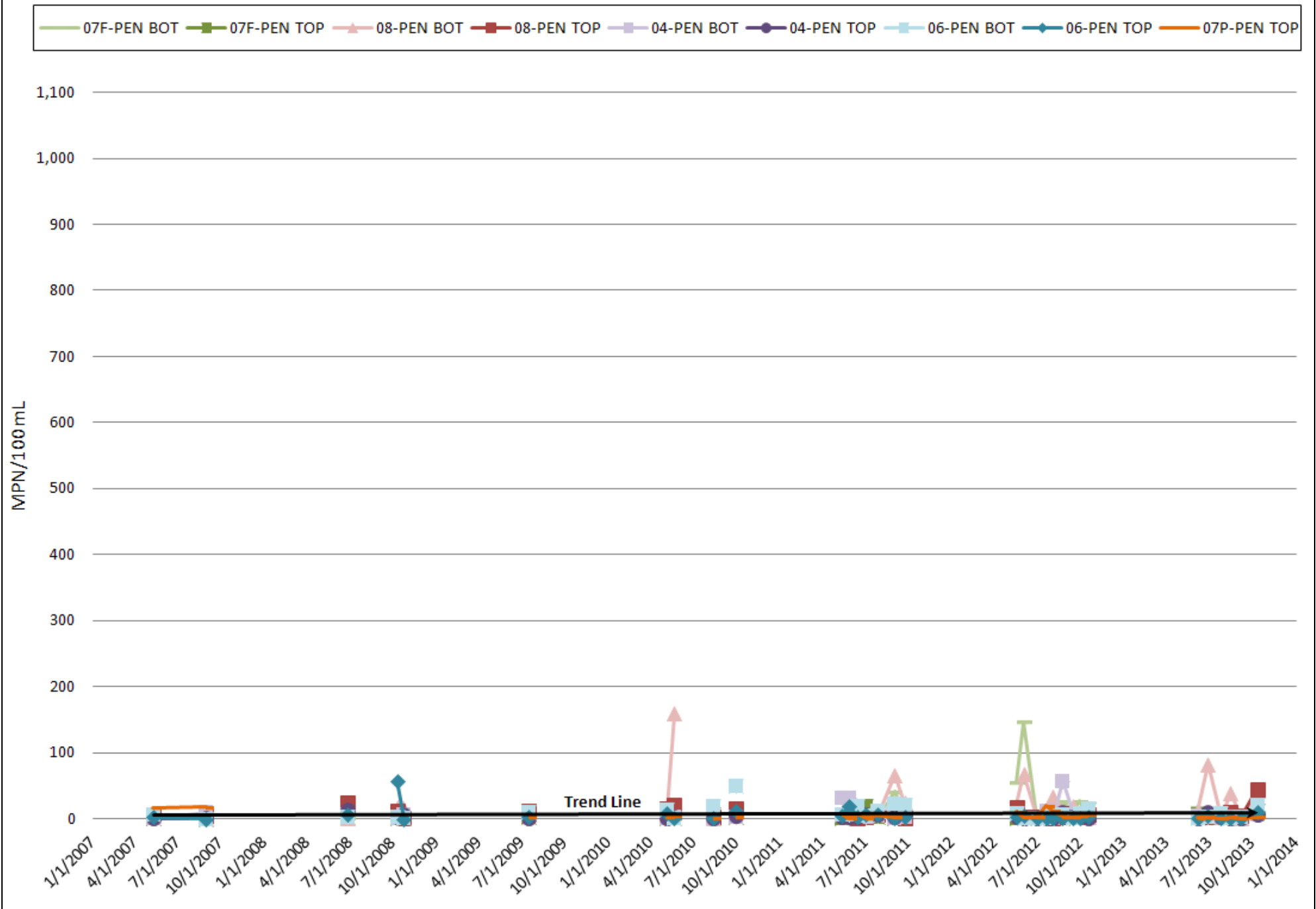


Figure 7: E.coli

E.coli Trends in Tributaries, 2007-2013
(Outliers >1,400 MPN/100 mL Not Shown)



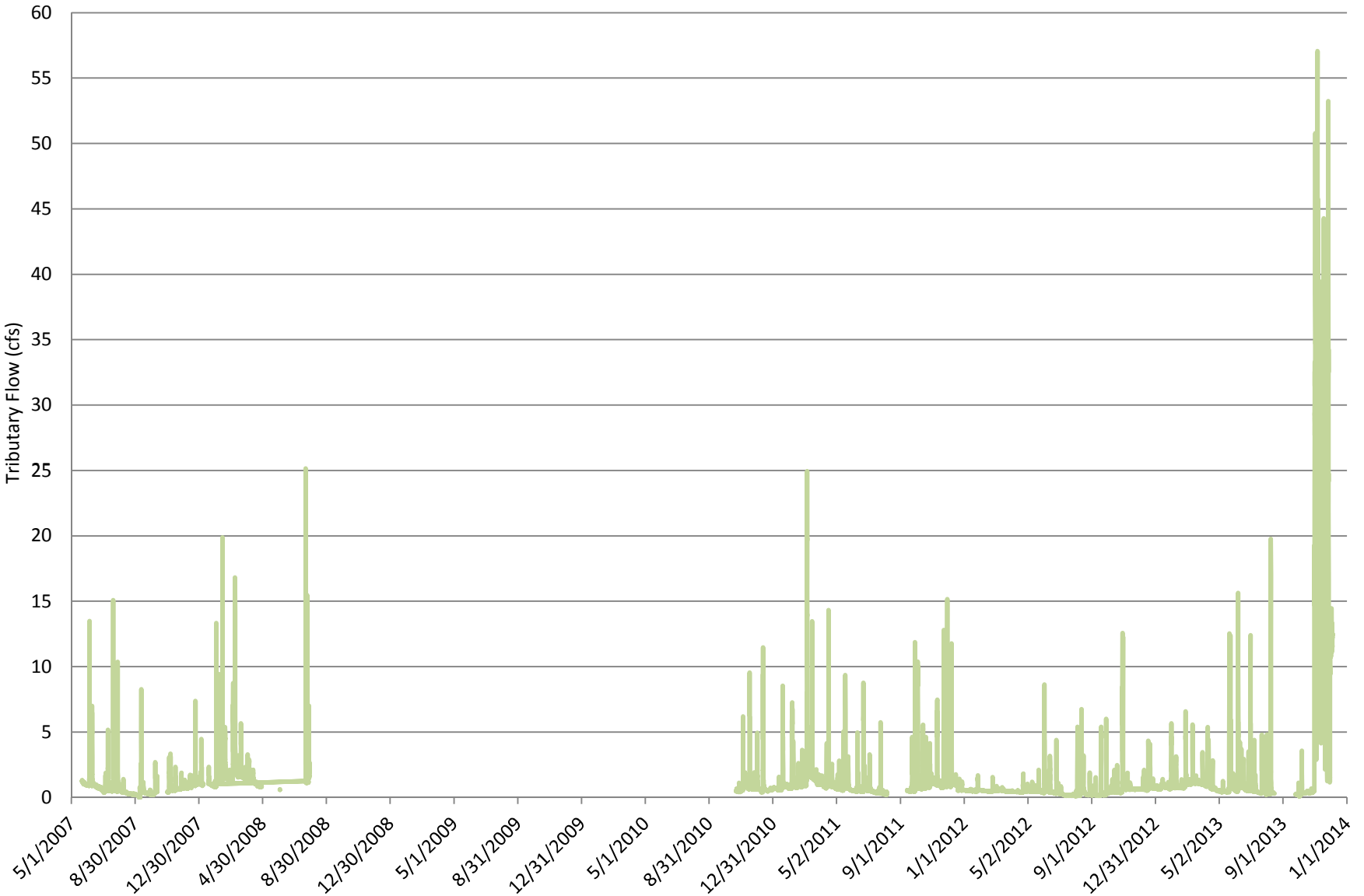
E.coli Trends in Ponds, 2007-2013



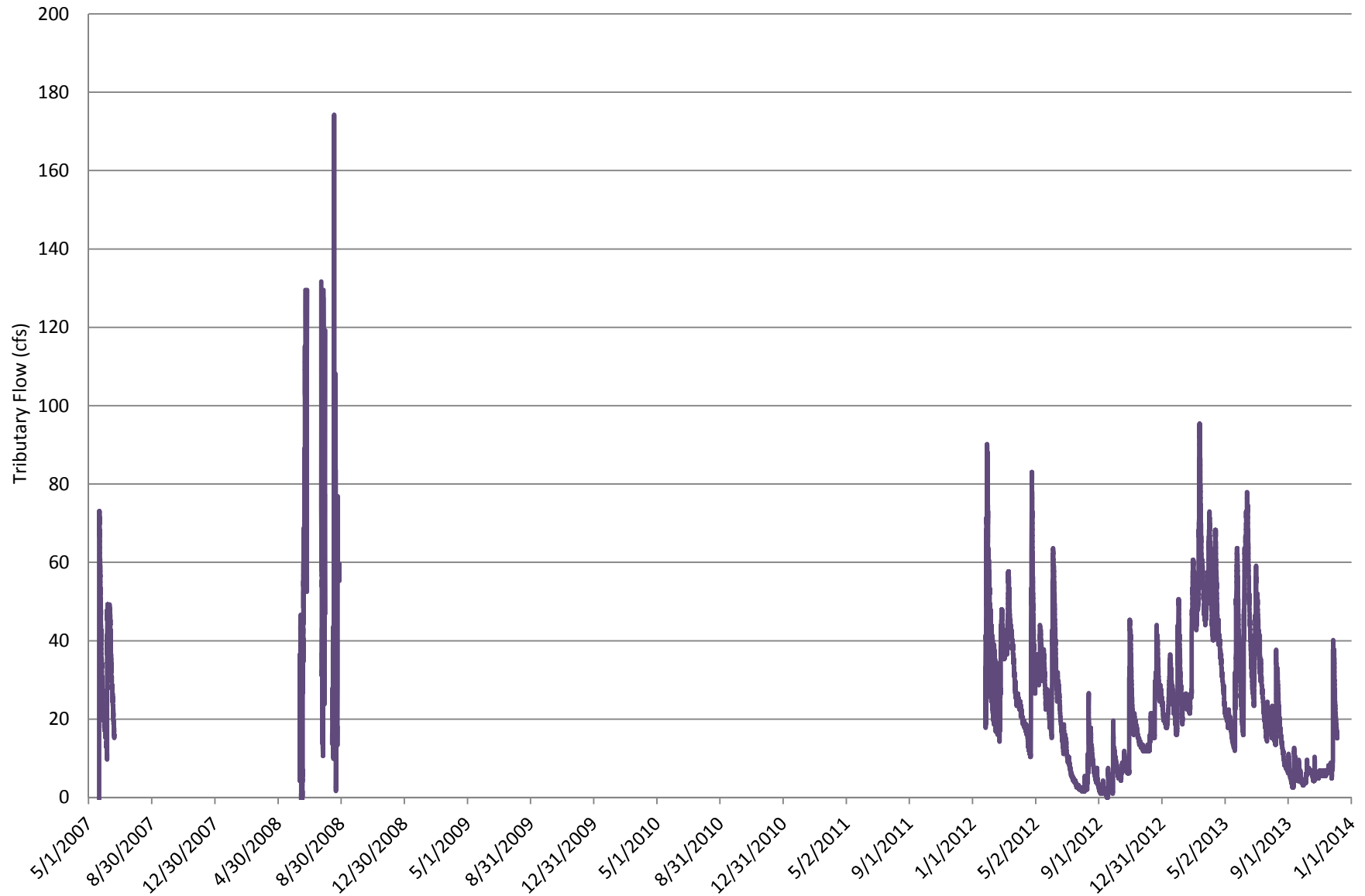
Attachment A – Supporting Graphs

Tributary Flow Data Graphs

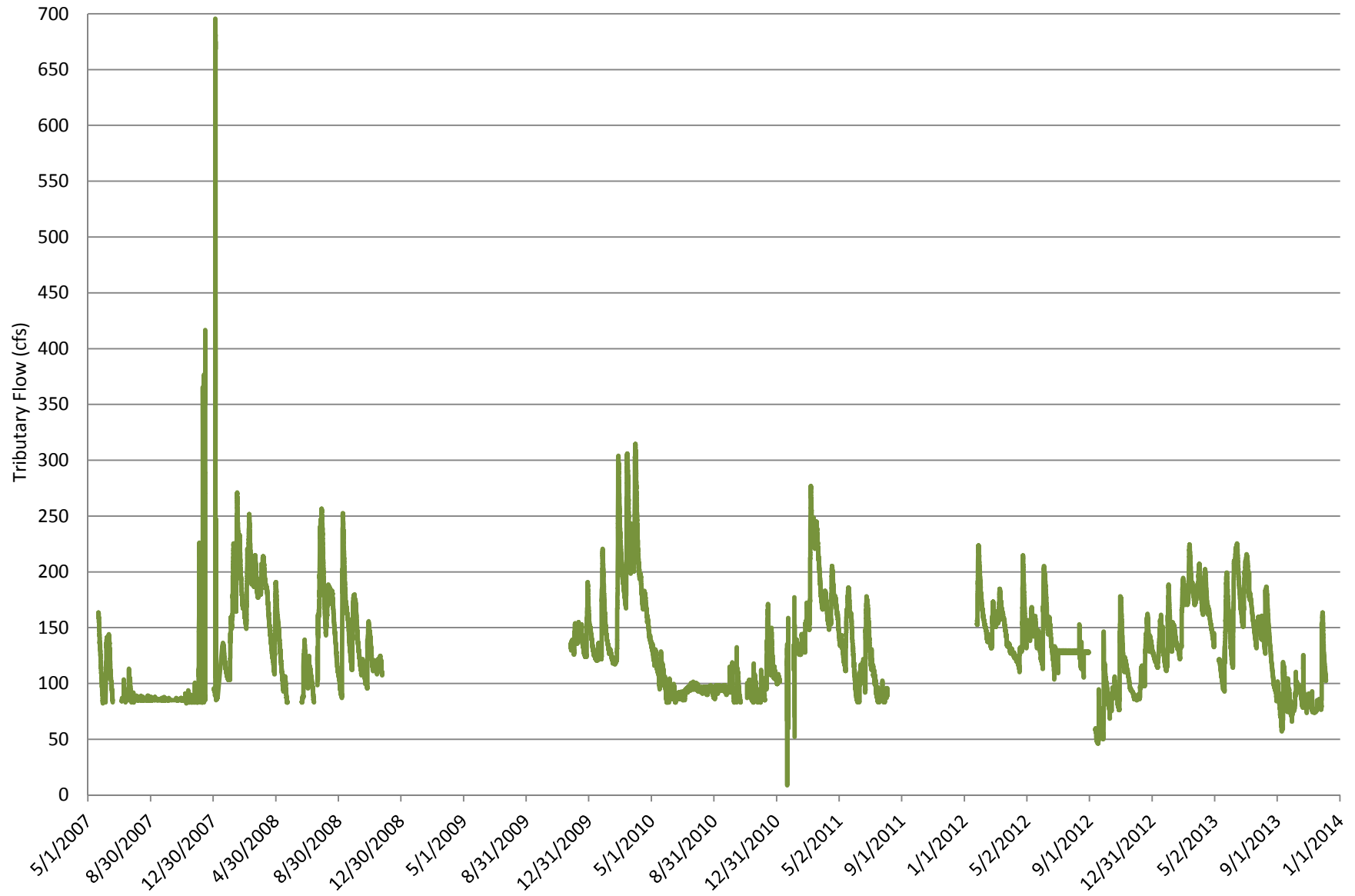
**Tributary Flow Data for 01-BFB
2007-2013**



Tributary Flow Data for 09-PEN 2007-2013

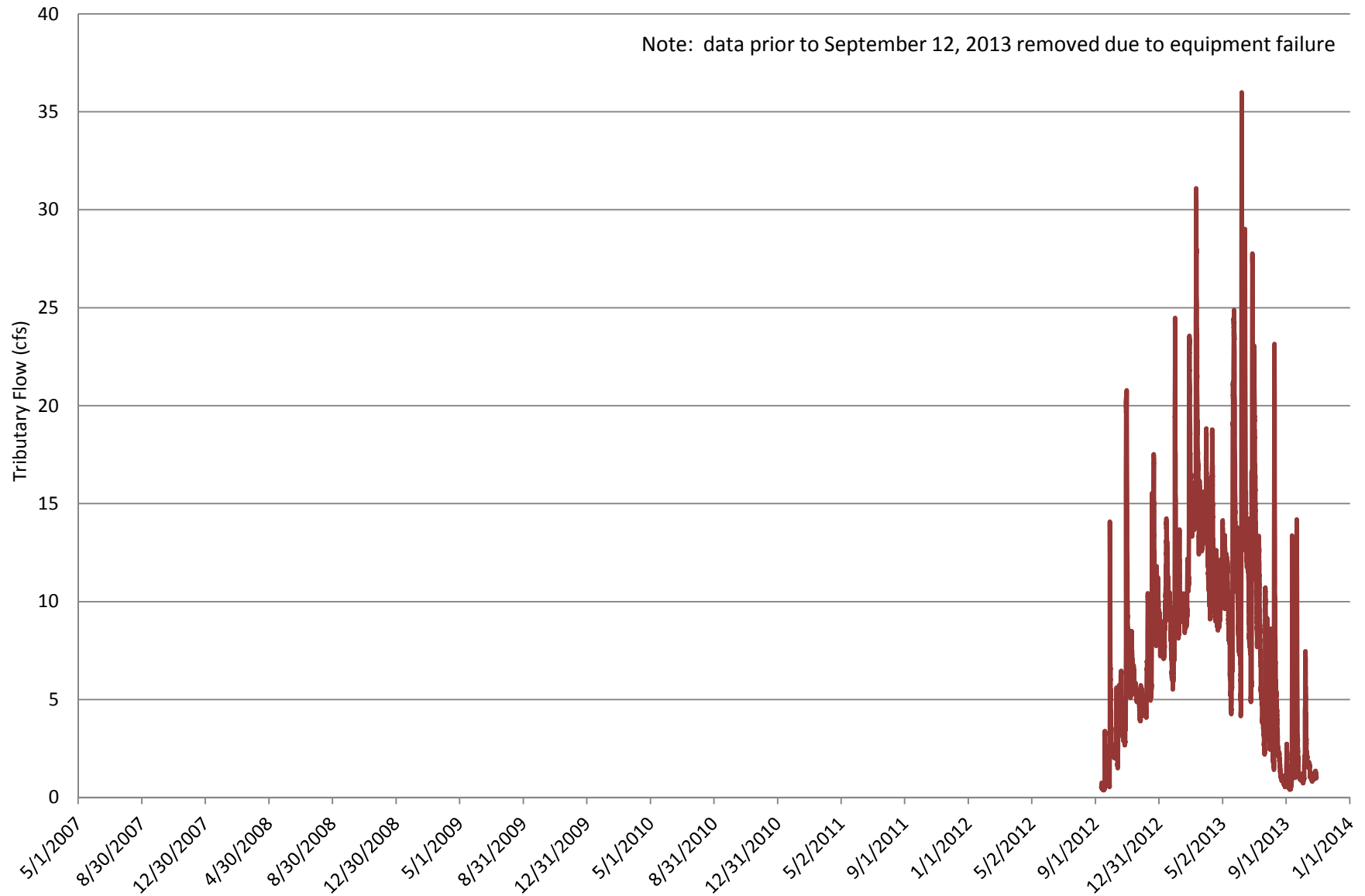


Tributary Flow Data for 09T-PEN 2007-2013

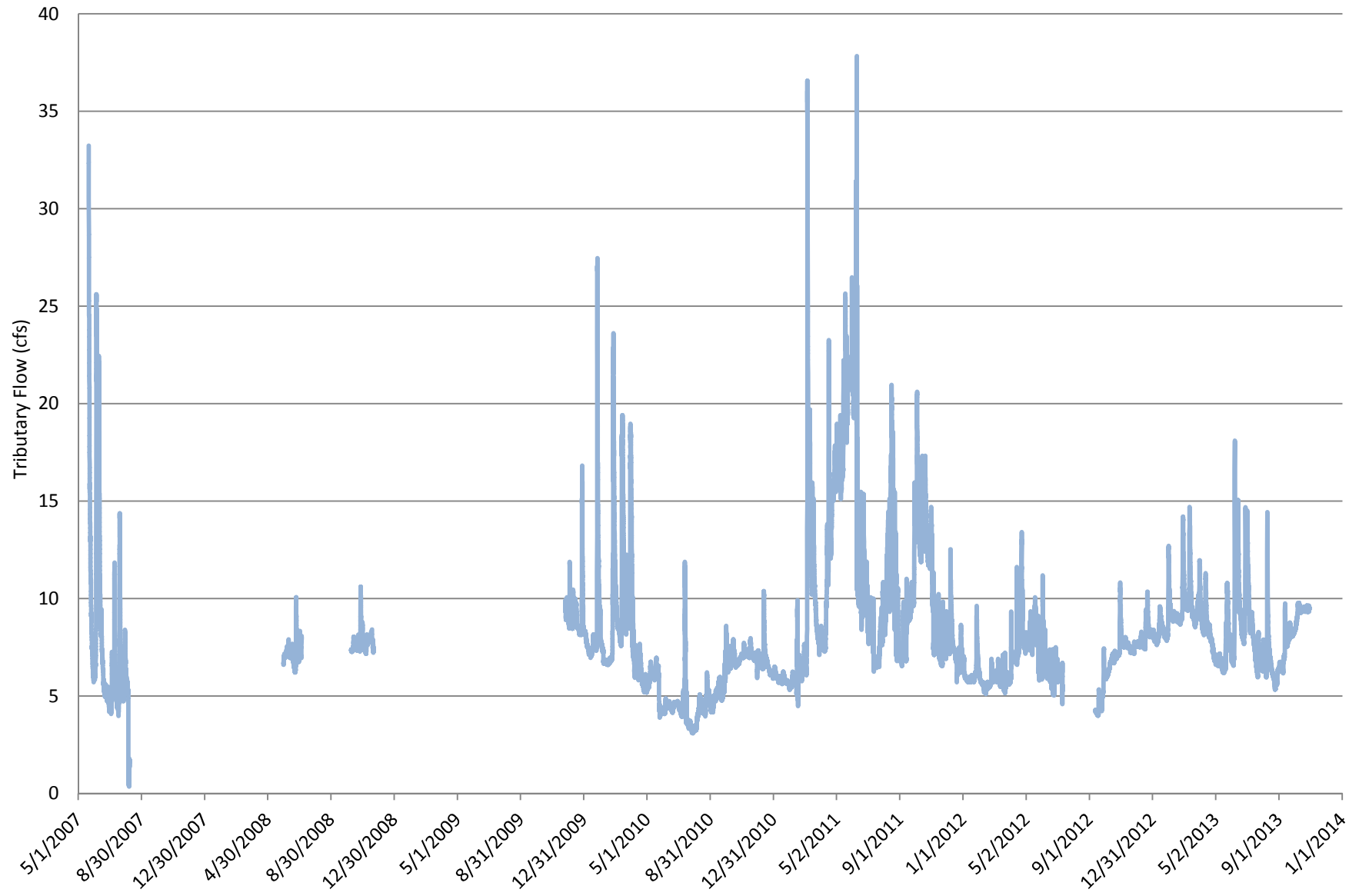


Tributary Flow Data for 09-XPB 2007-2013

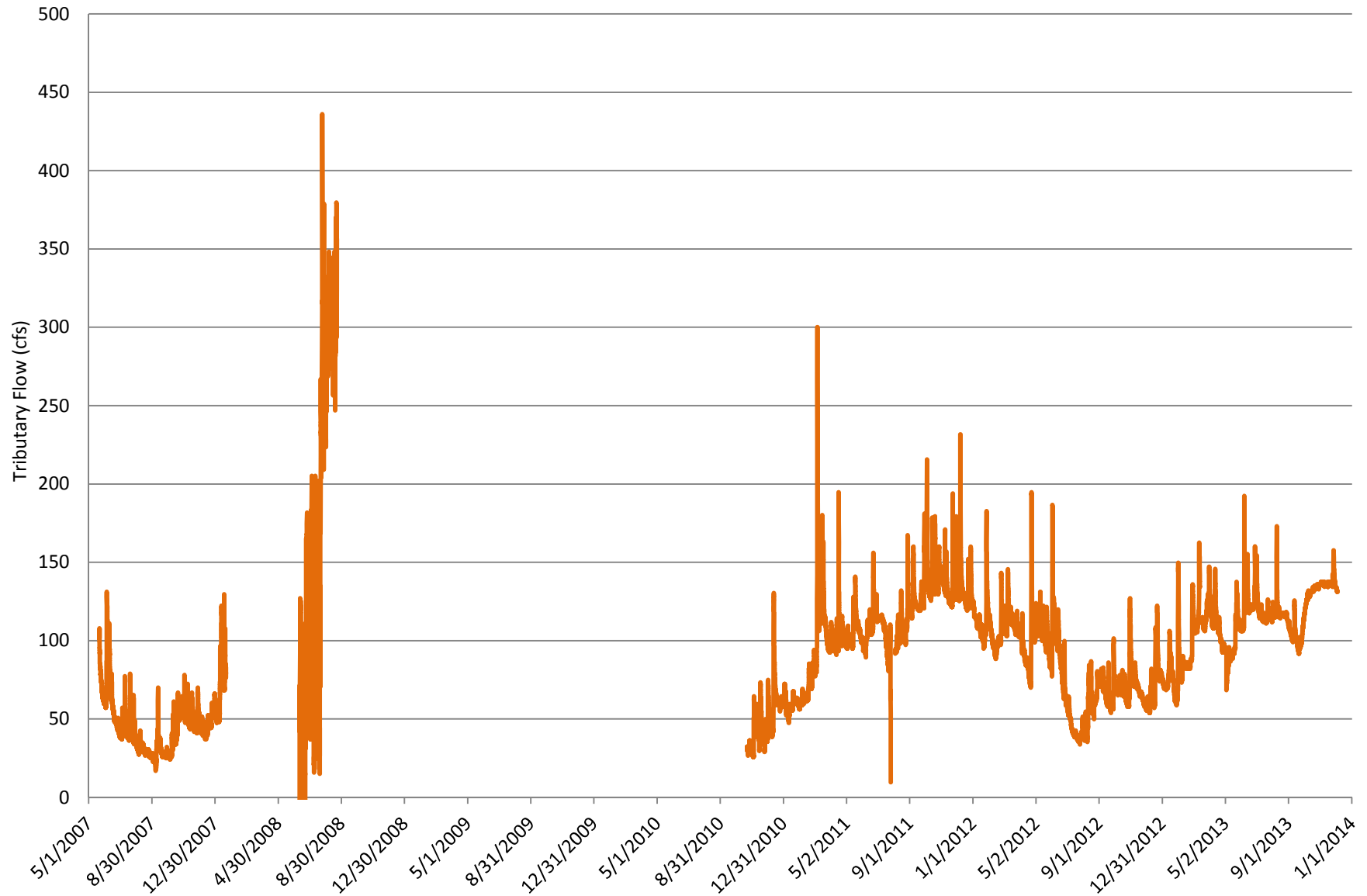
Note: data prior to September 12, 2013 removed due to equipment failure



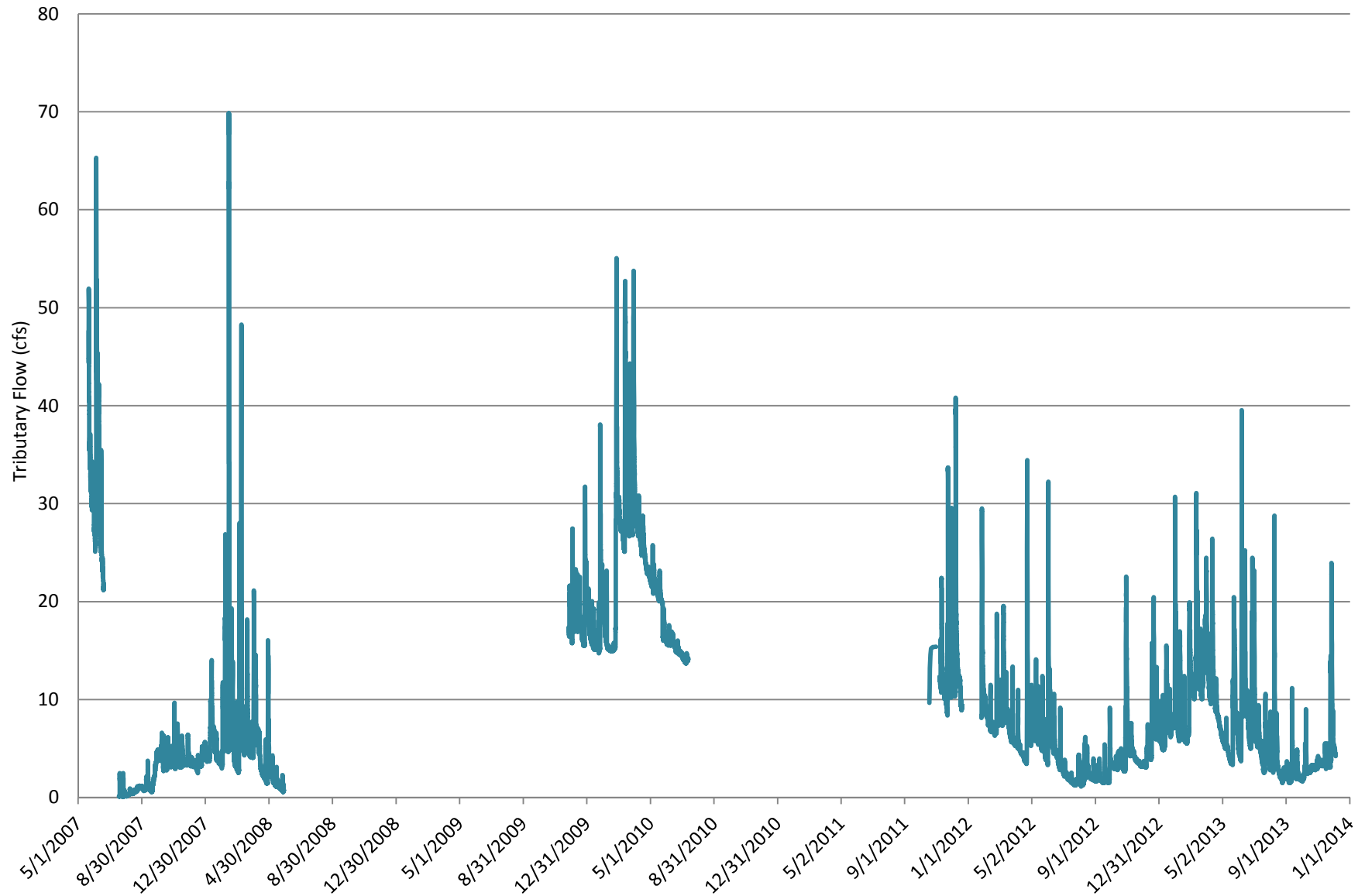
Tributary Flow Data for 01-WCH 2007-2013



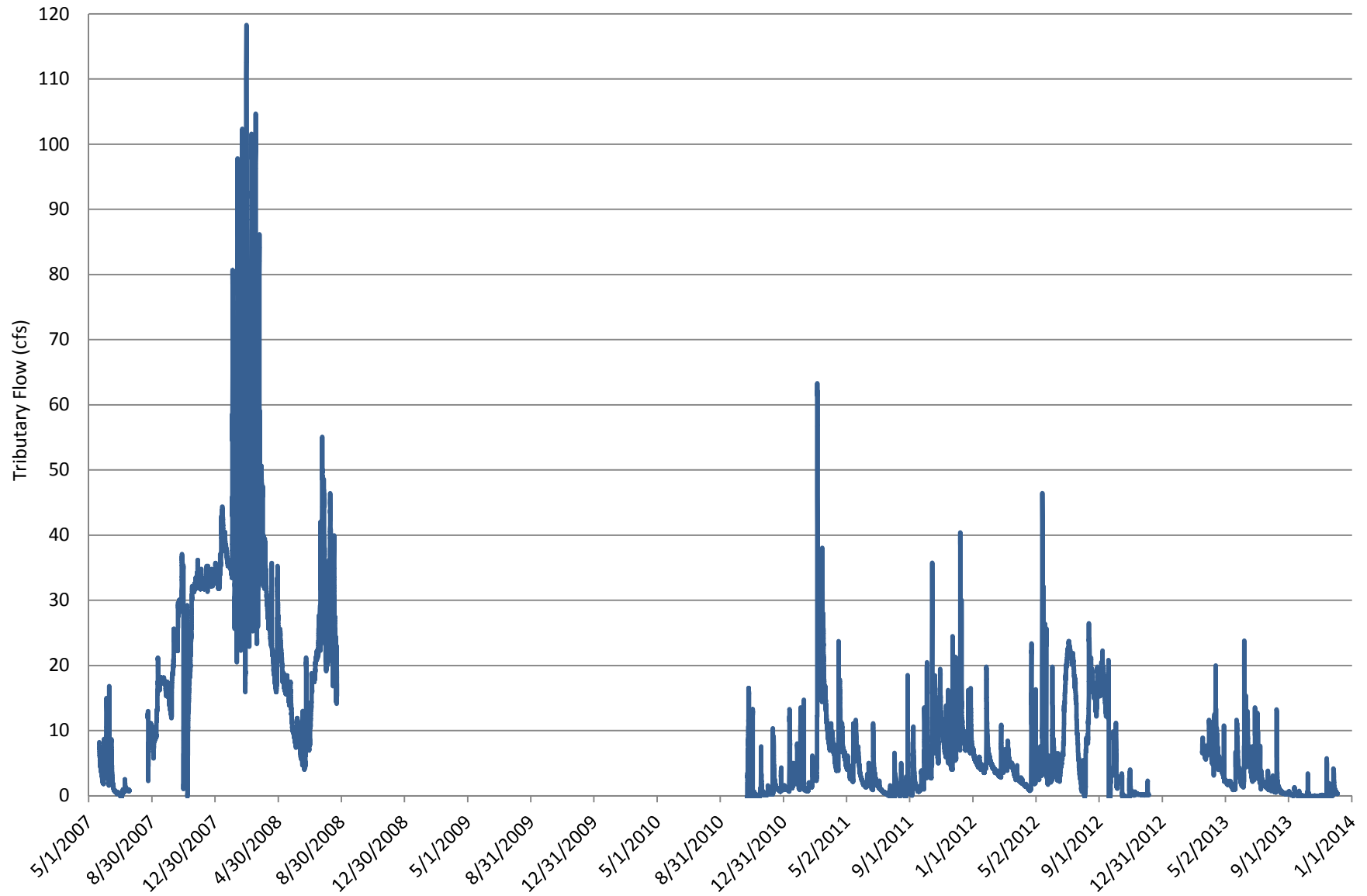
Tributary Flow Data for 01-XWB 2007-2013



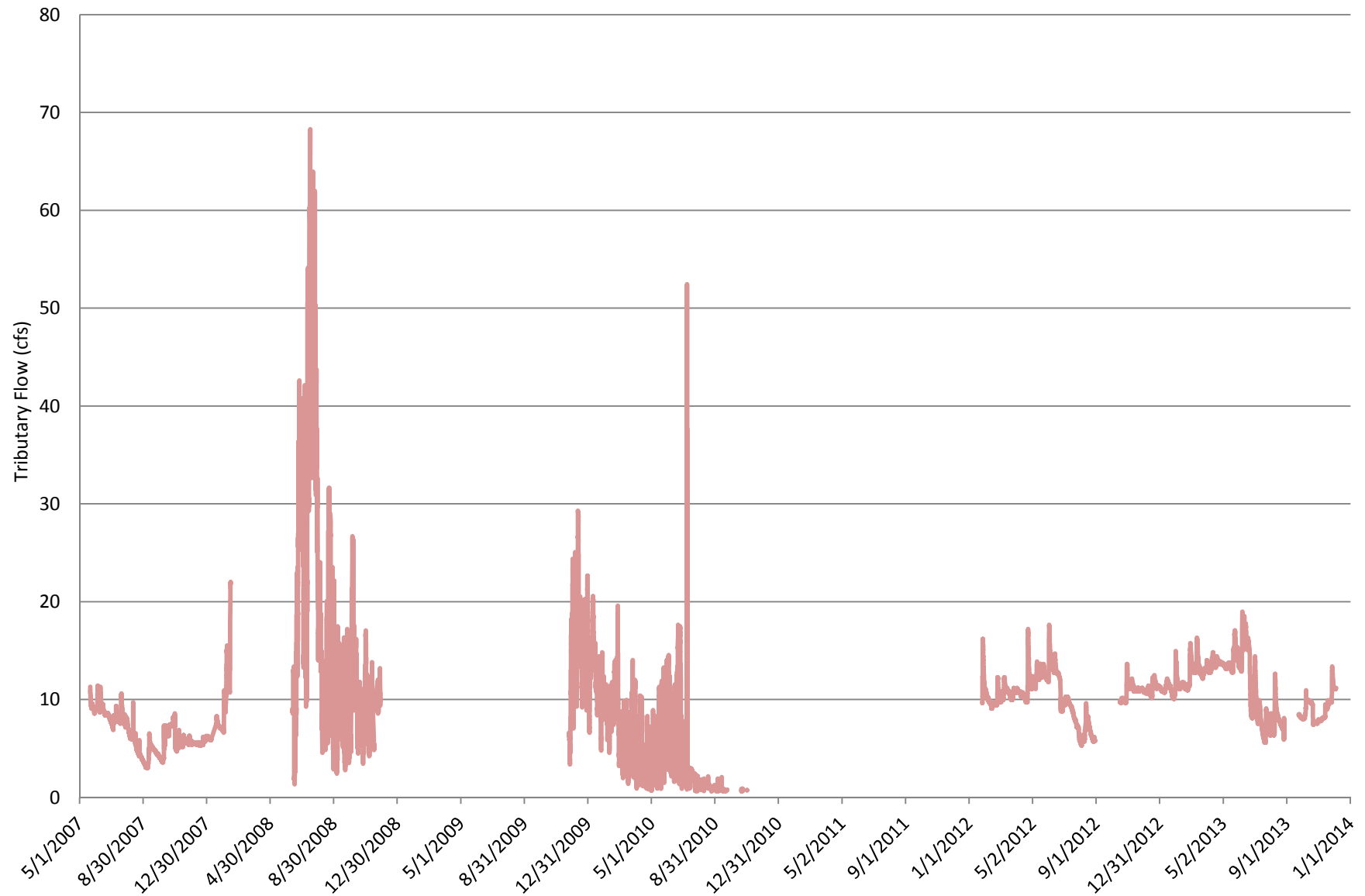
Tributary Flow Data for 02-WCH 2007-2013



Tributary Flow Data for 12-PEN 2007-2013

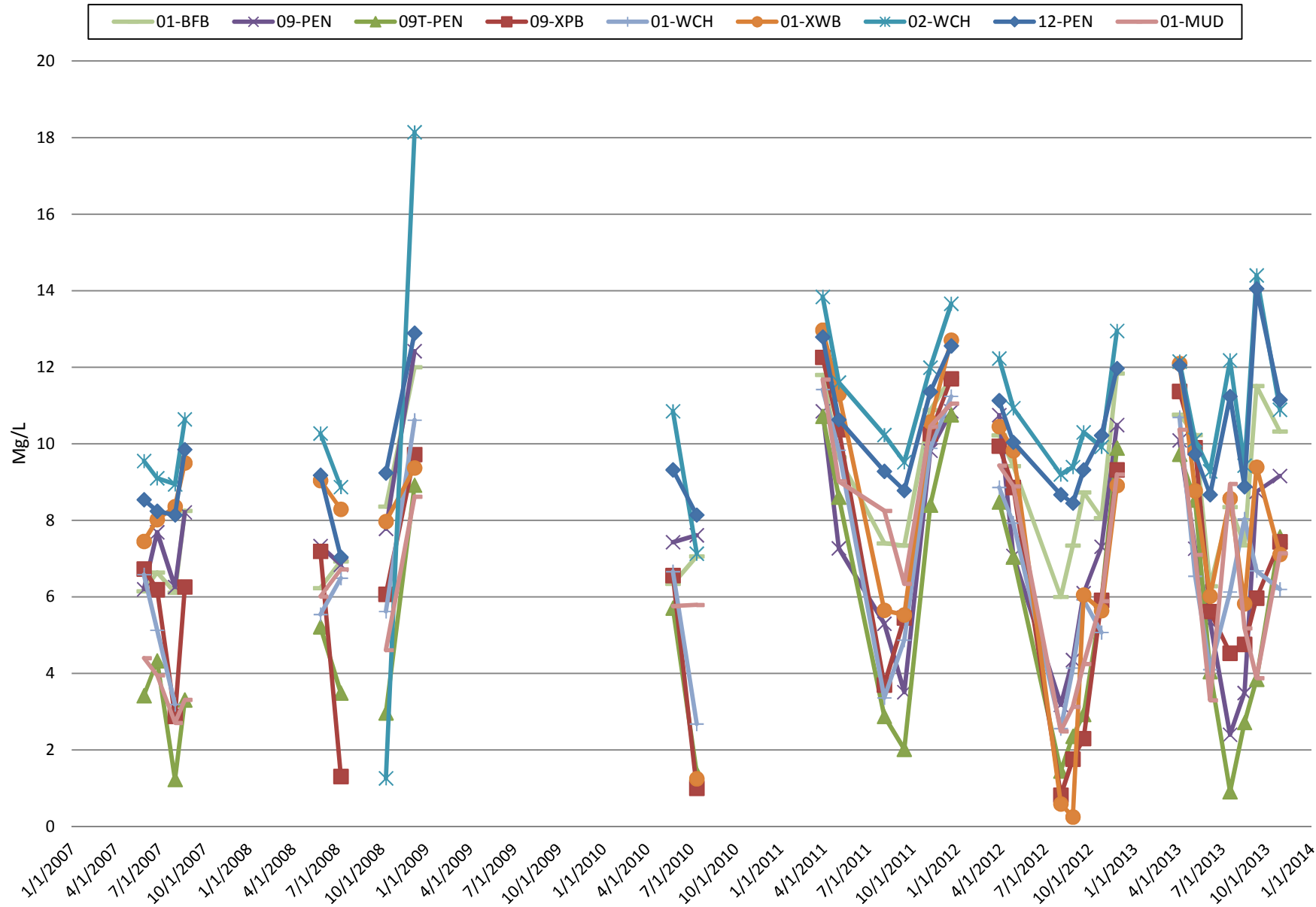


Tributary Flow Data for 01-MUD 2007-2013

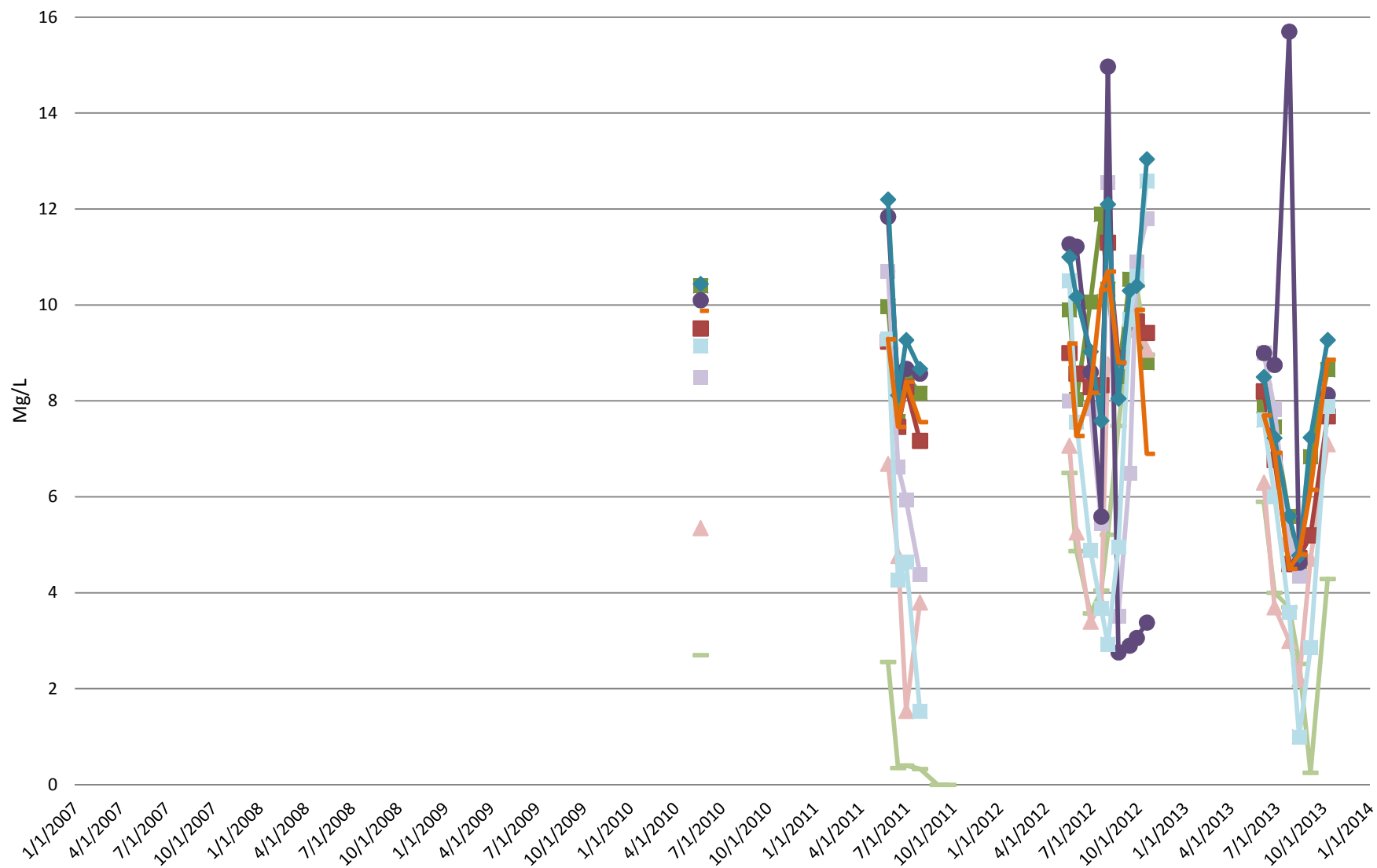


2007-2013 Tributary, Groundwater and In-Pond Trendline Graphs

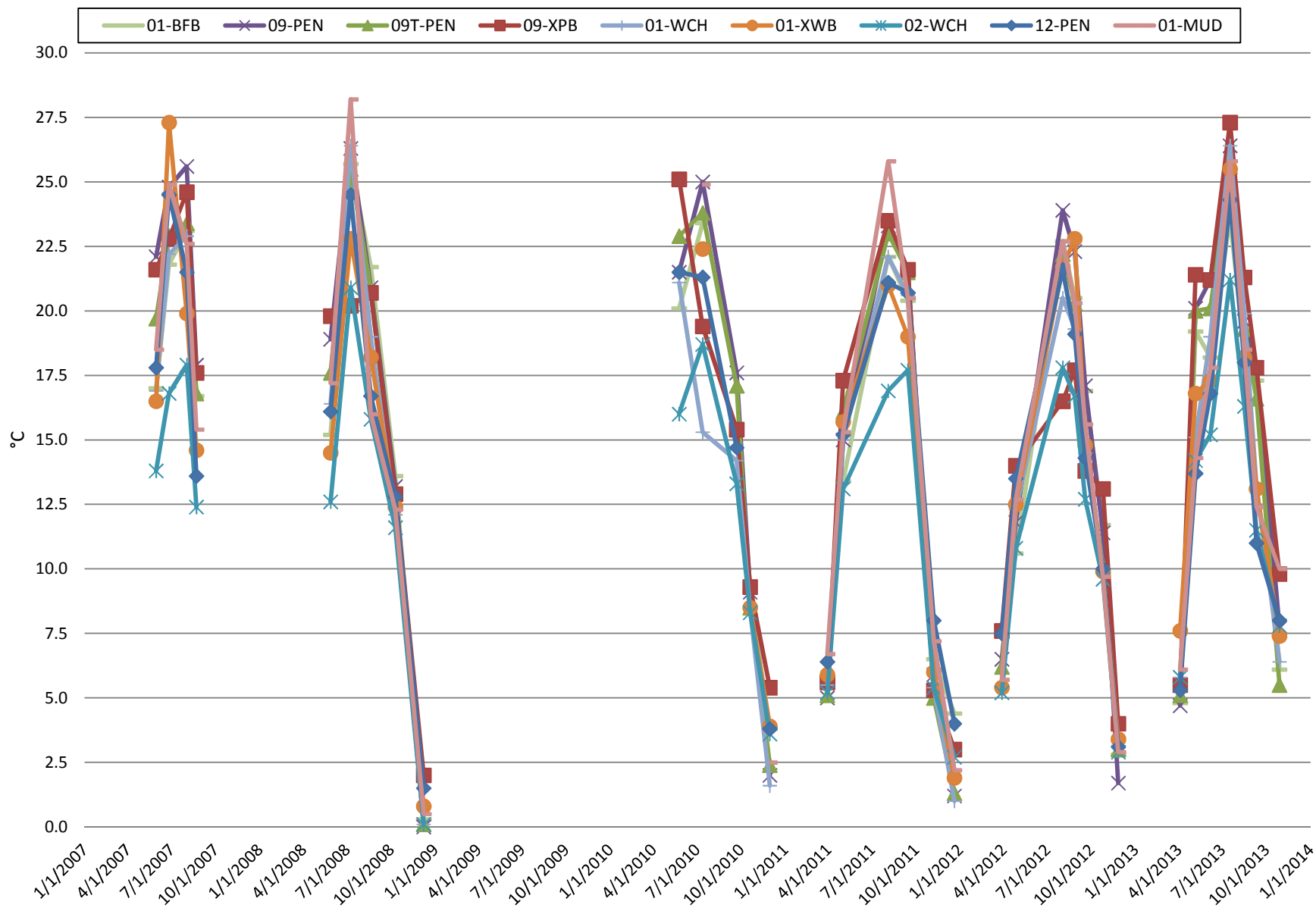
Tributary Dry Weather Sampling - Dissolved Oxygen 2007-2013



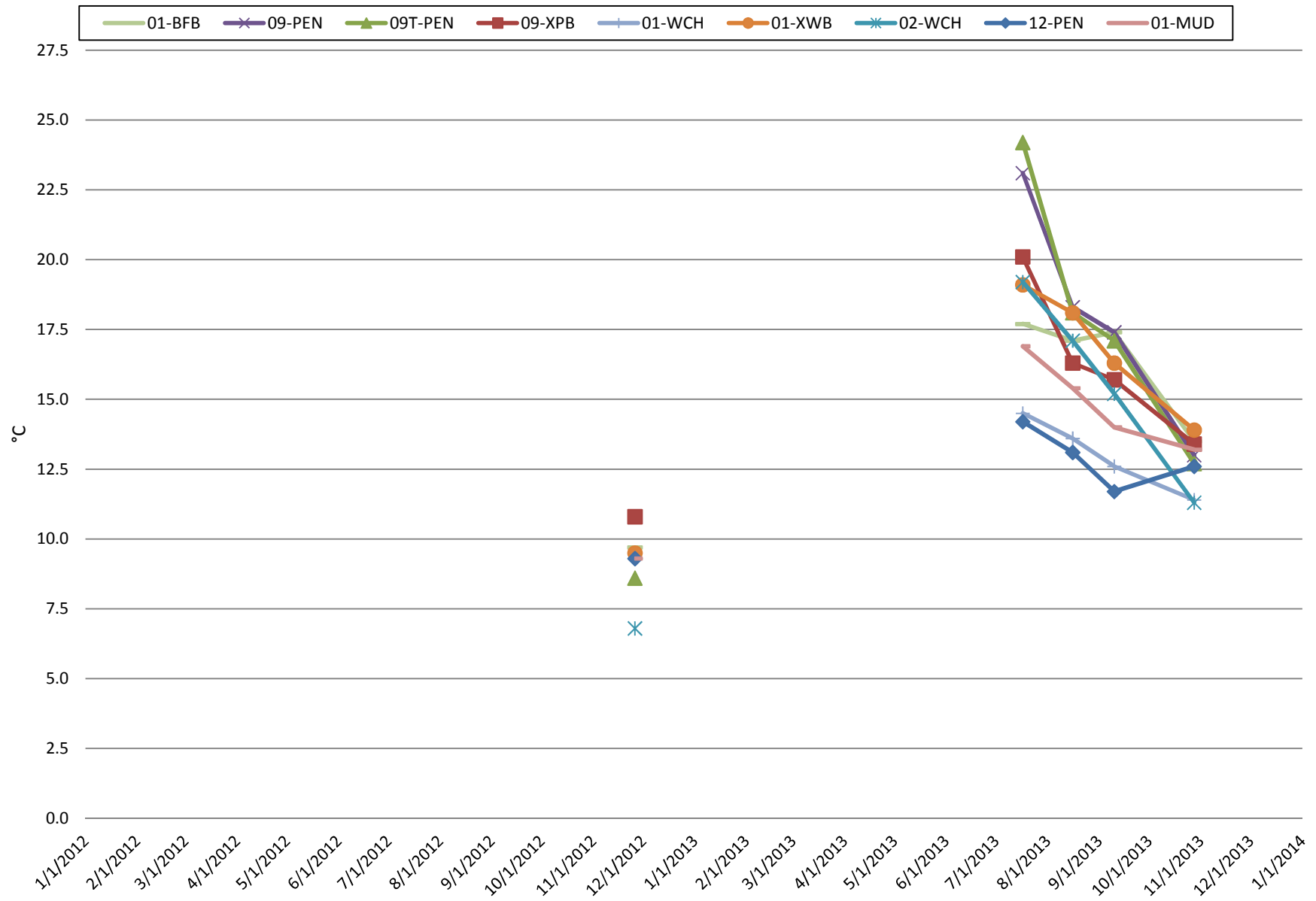
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 07P-PEN TOP



Tributary Dry Weather Sampling - Temperature 2007-2013

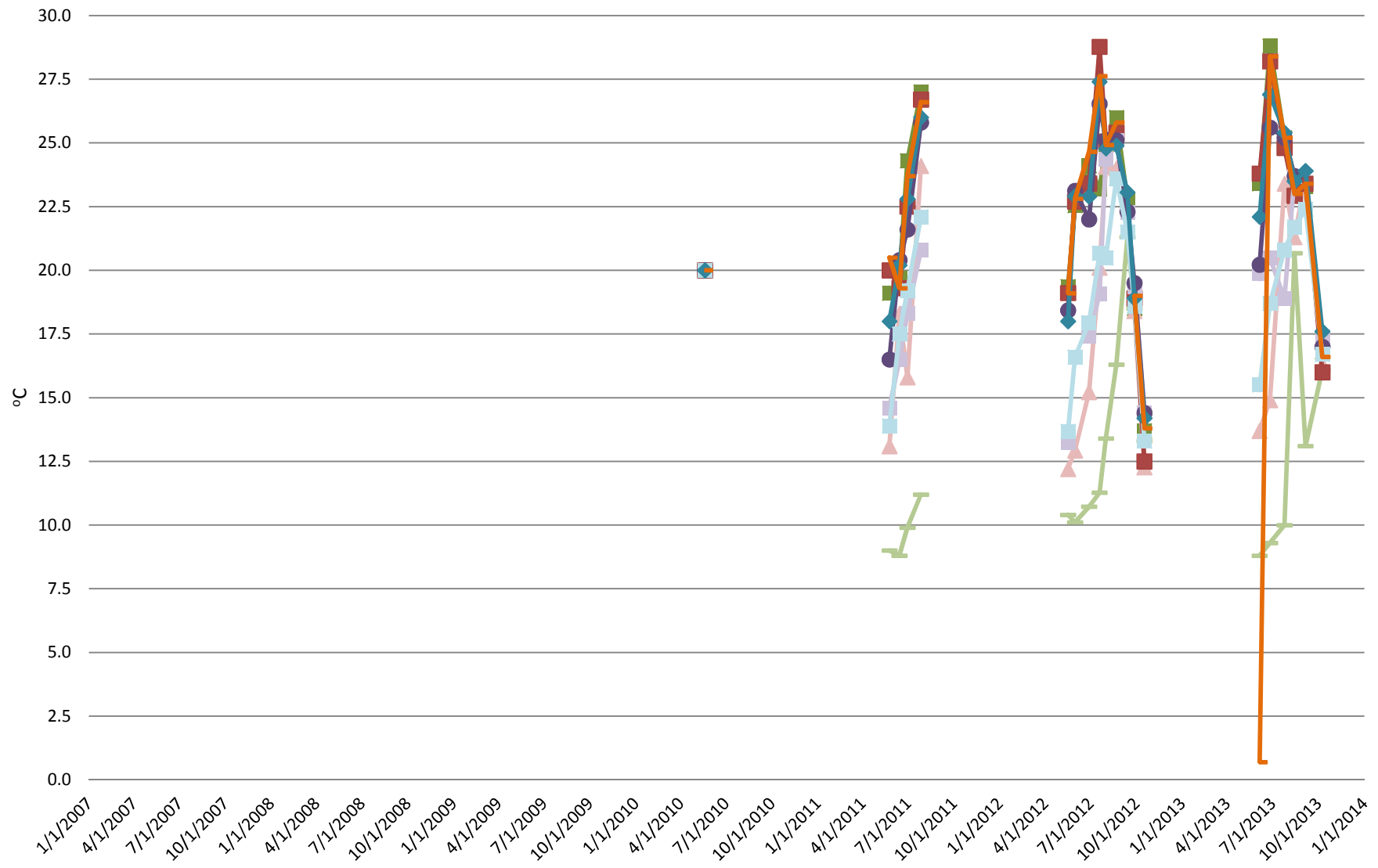


Groundwater Dry Weather Sampling - Temperature 2012-2013

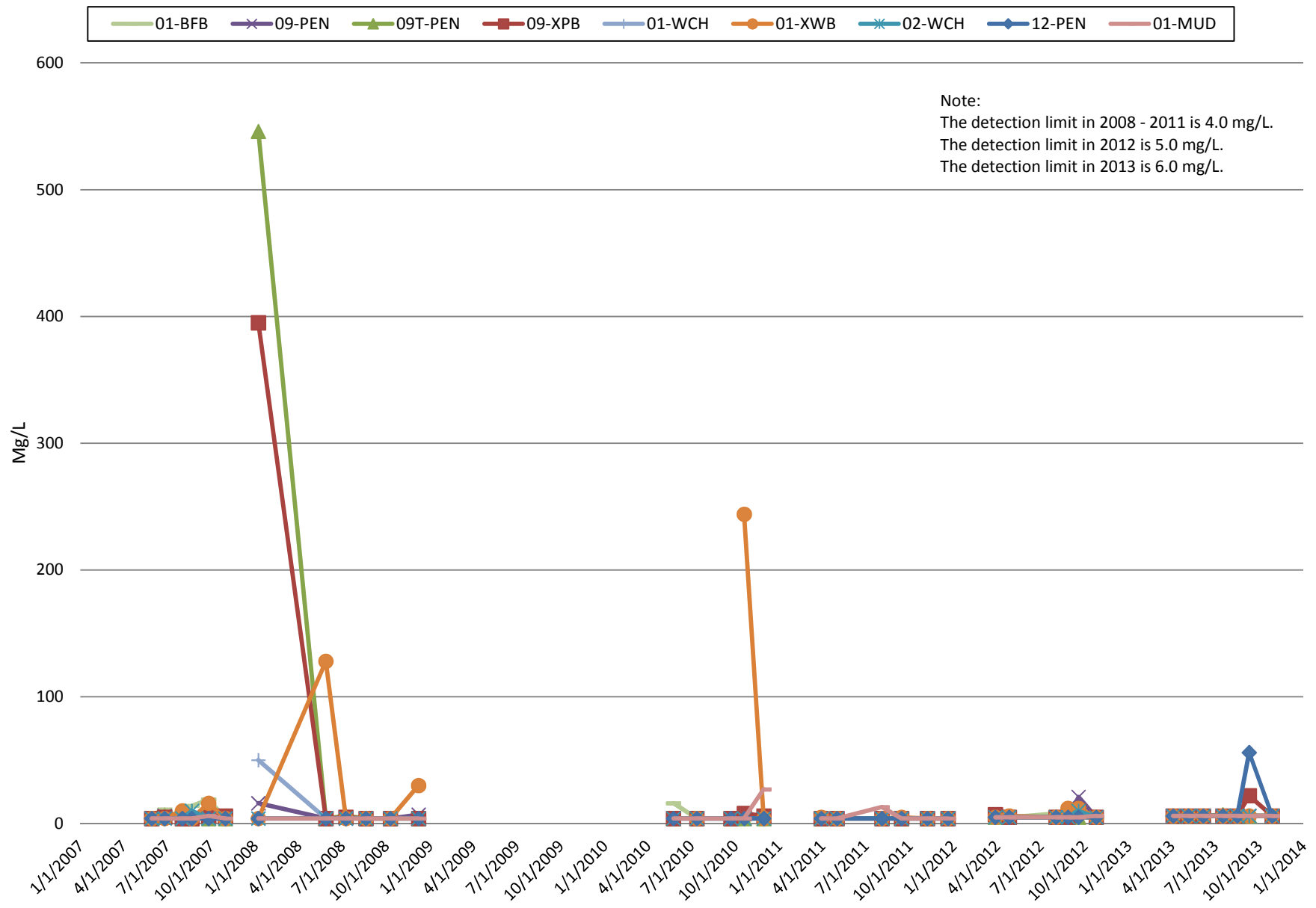


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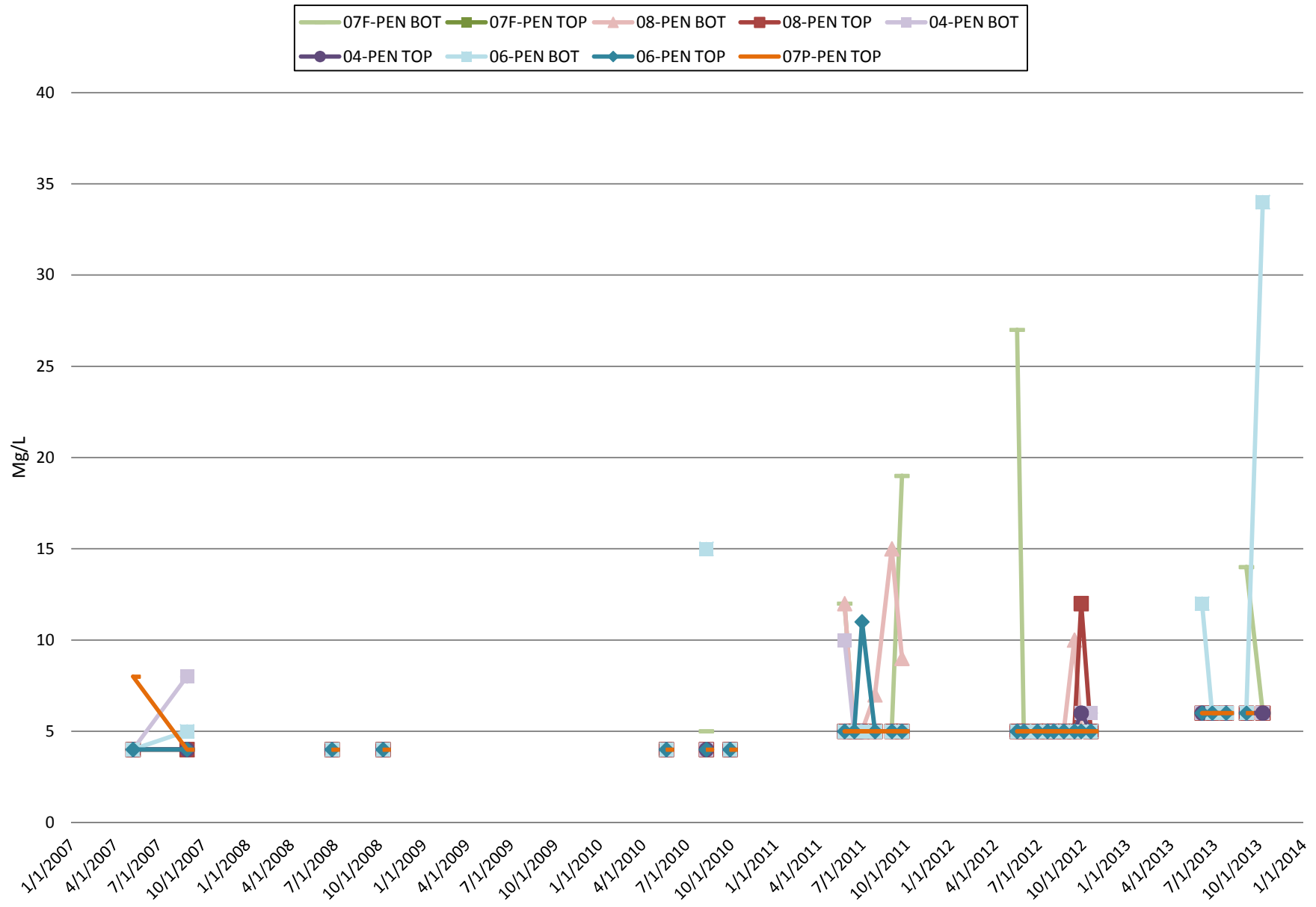
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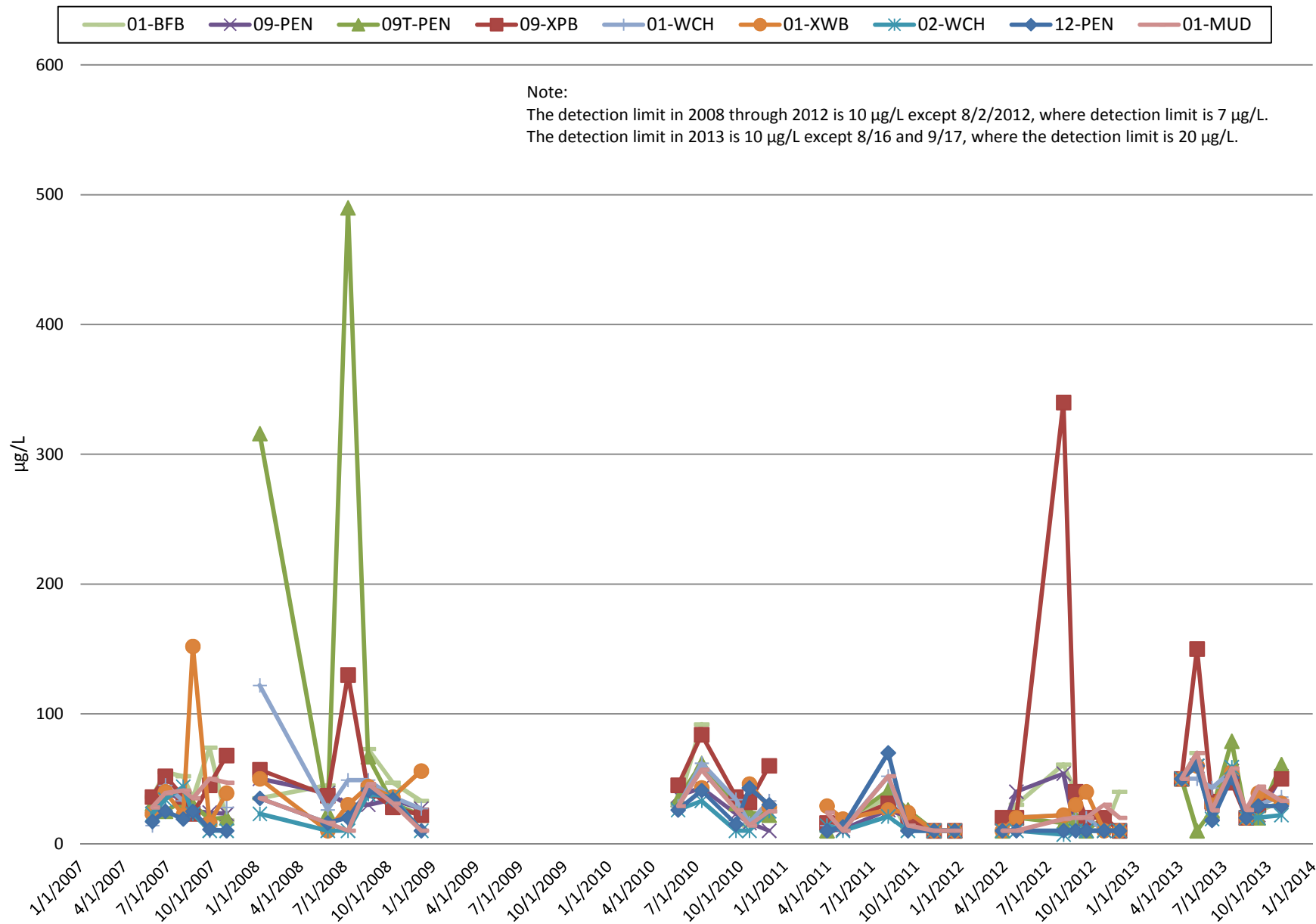
Tributary Dry Weather Sampling - TSS Levels 2007-2013



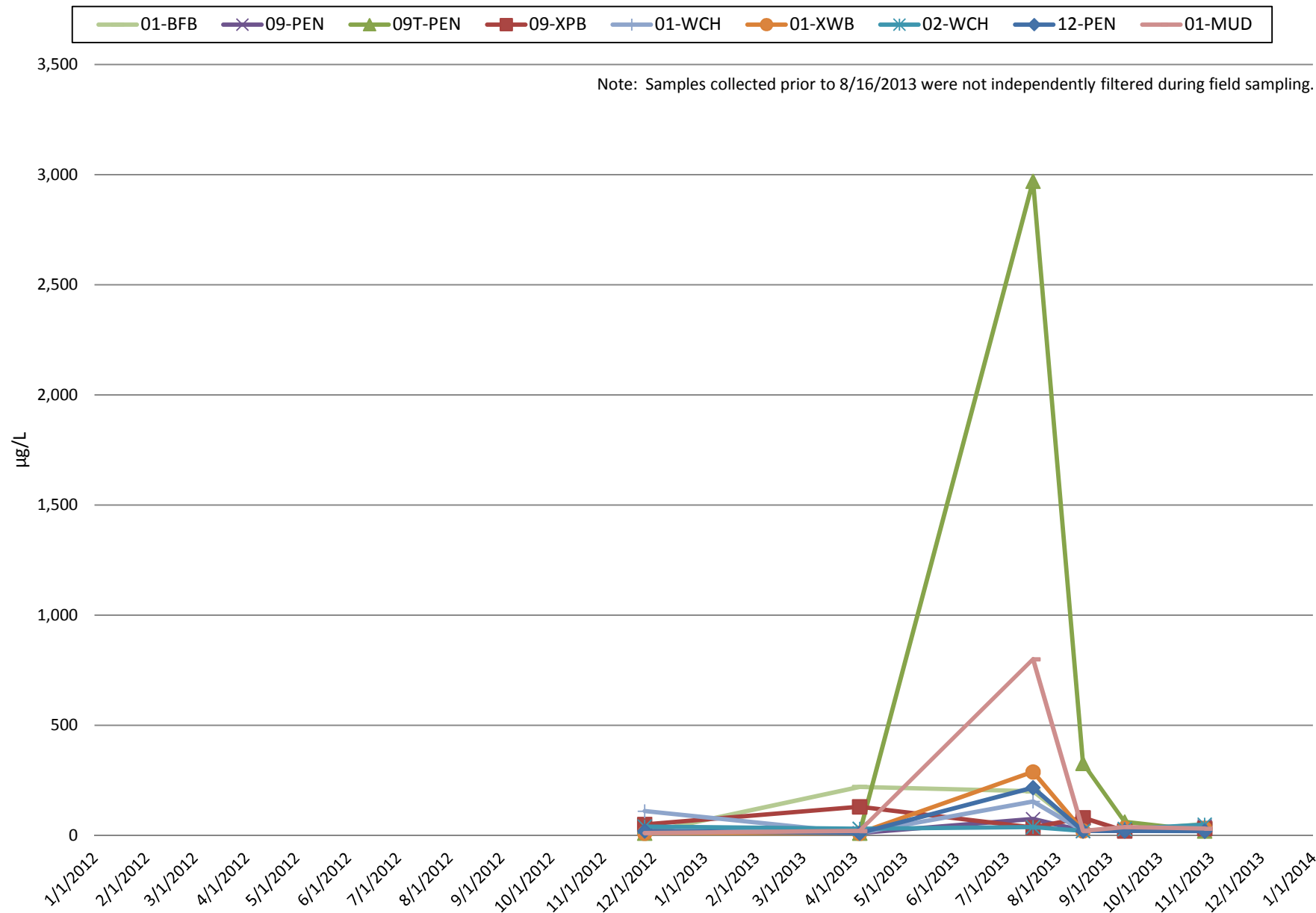
In-Pond Sampling, Total Suspended Solids (TSS) 2007-2013



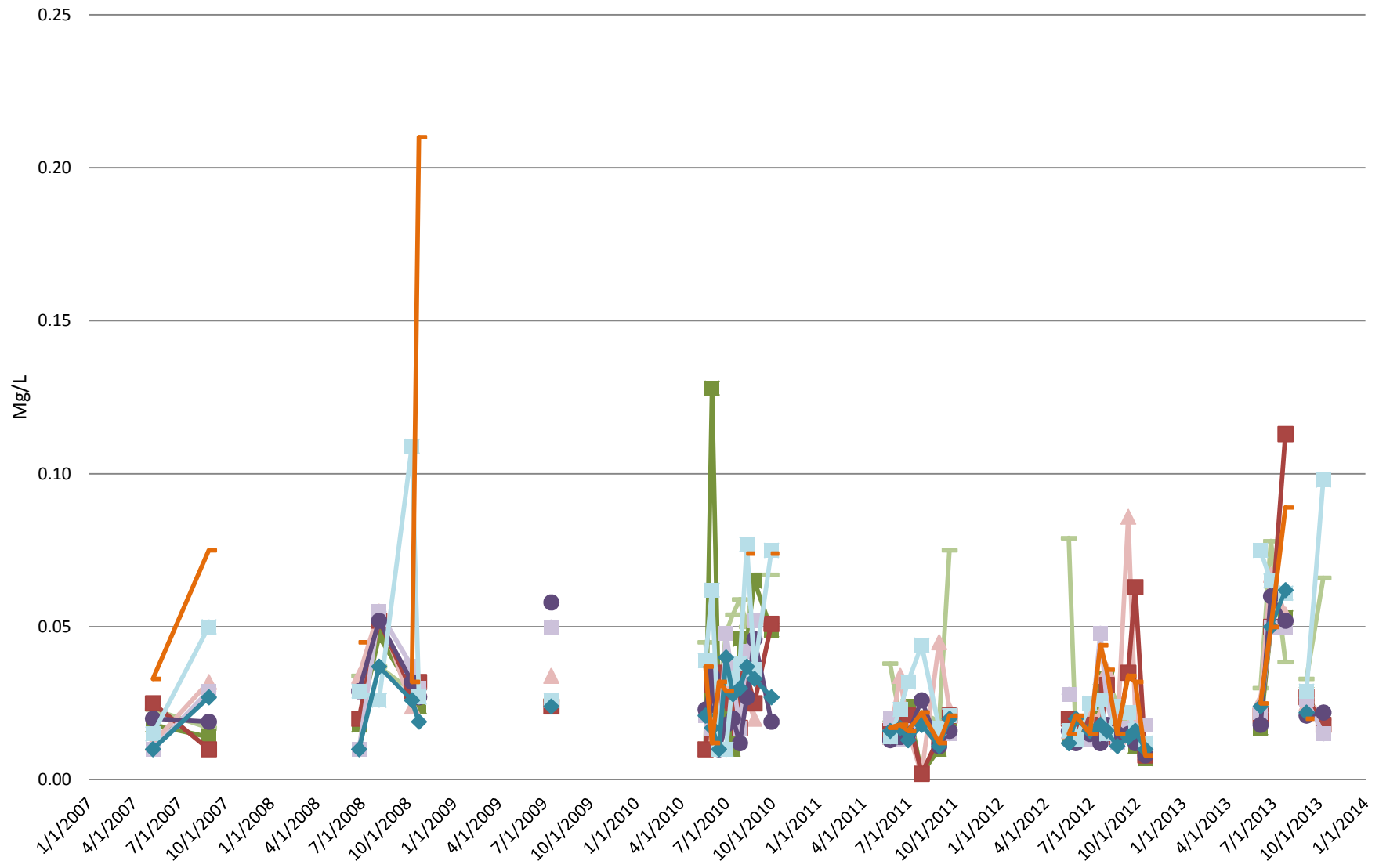
Tributary Dry Weather Sampling - Phosphorus Levels 2007-2013



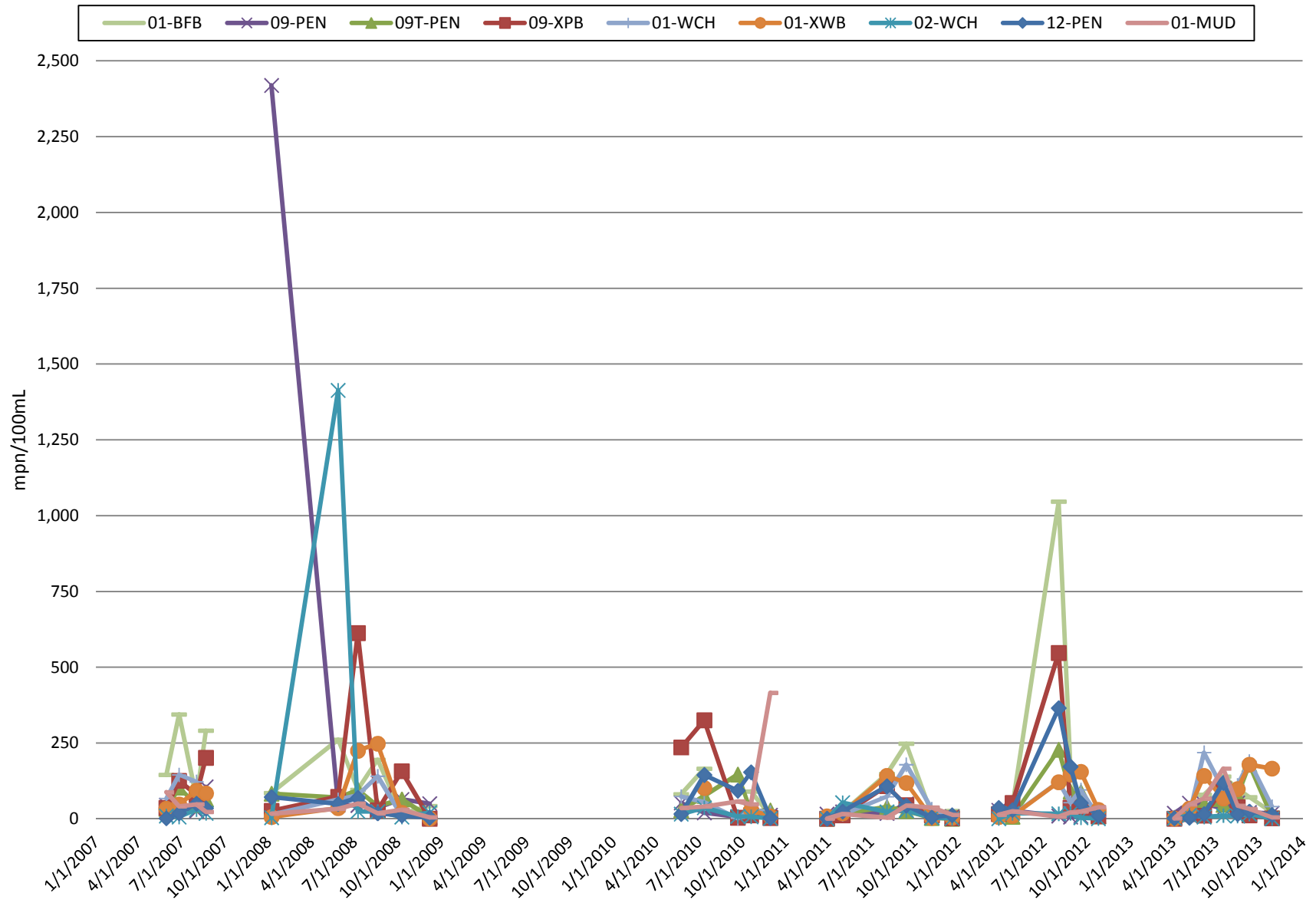
Groundwater Dry Weather Sampling - Phosphorus Levels 2012-2013



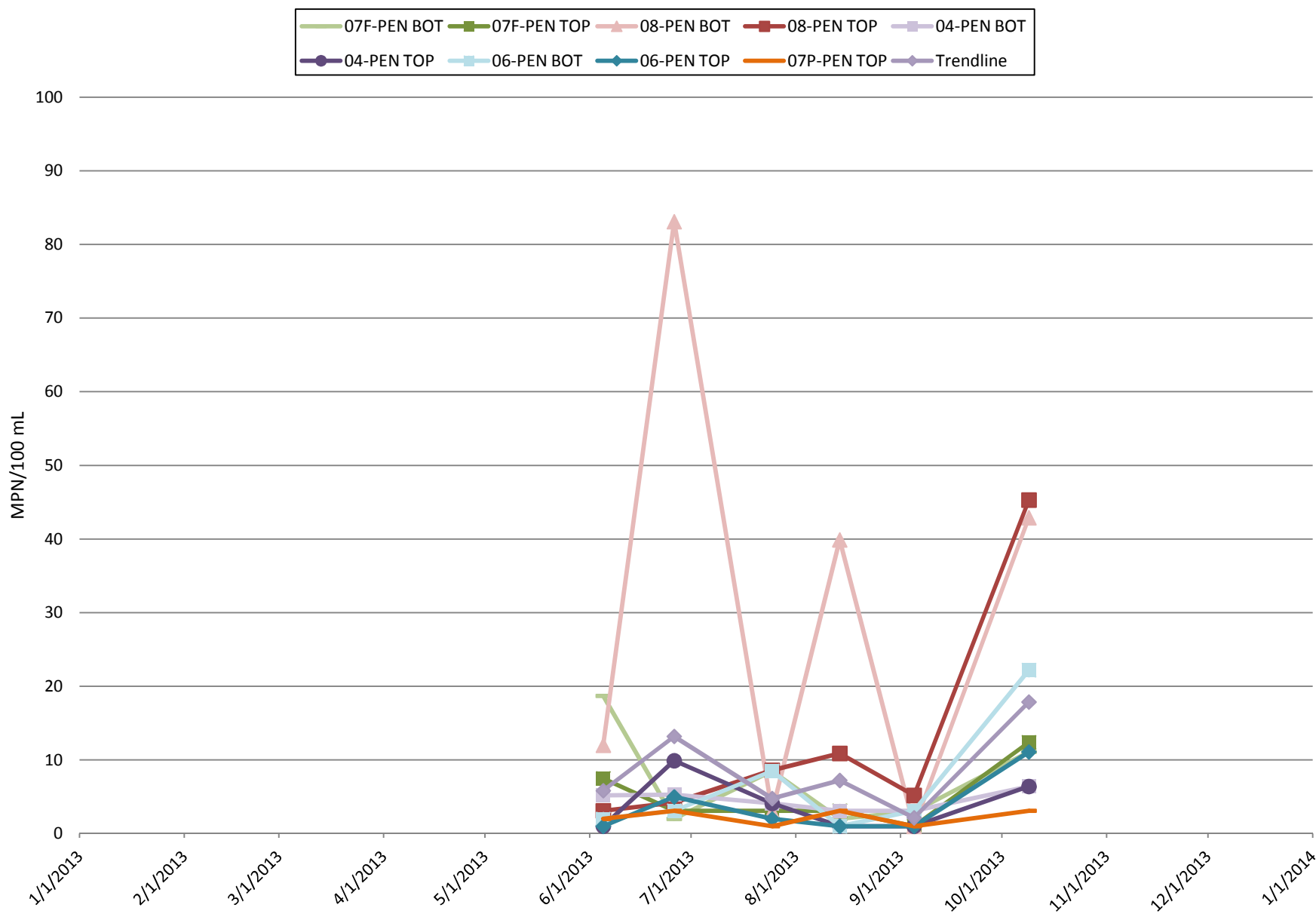
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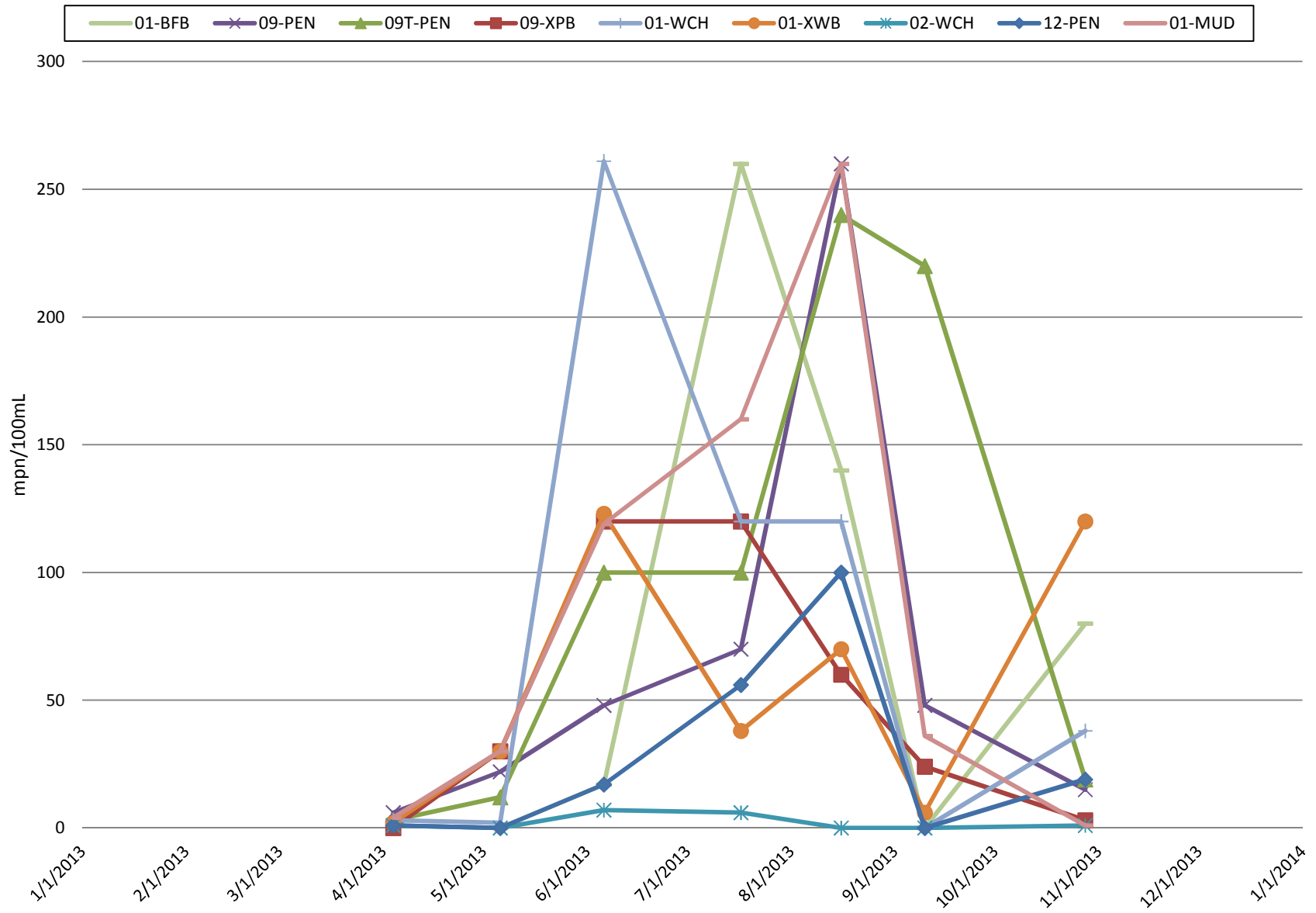
Tributary Dry Weather Sampling - E.Coli Levels 2007-2013



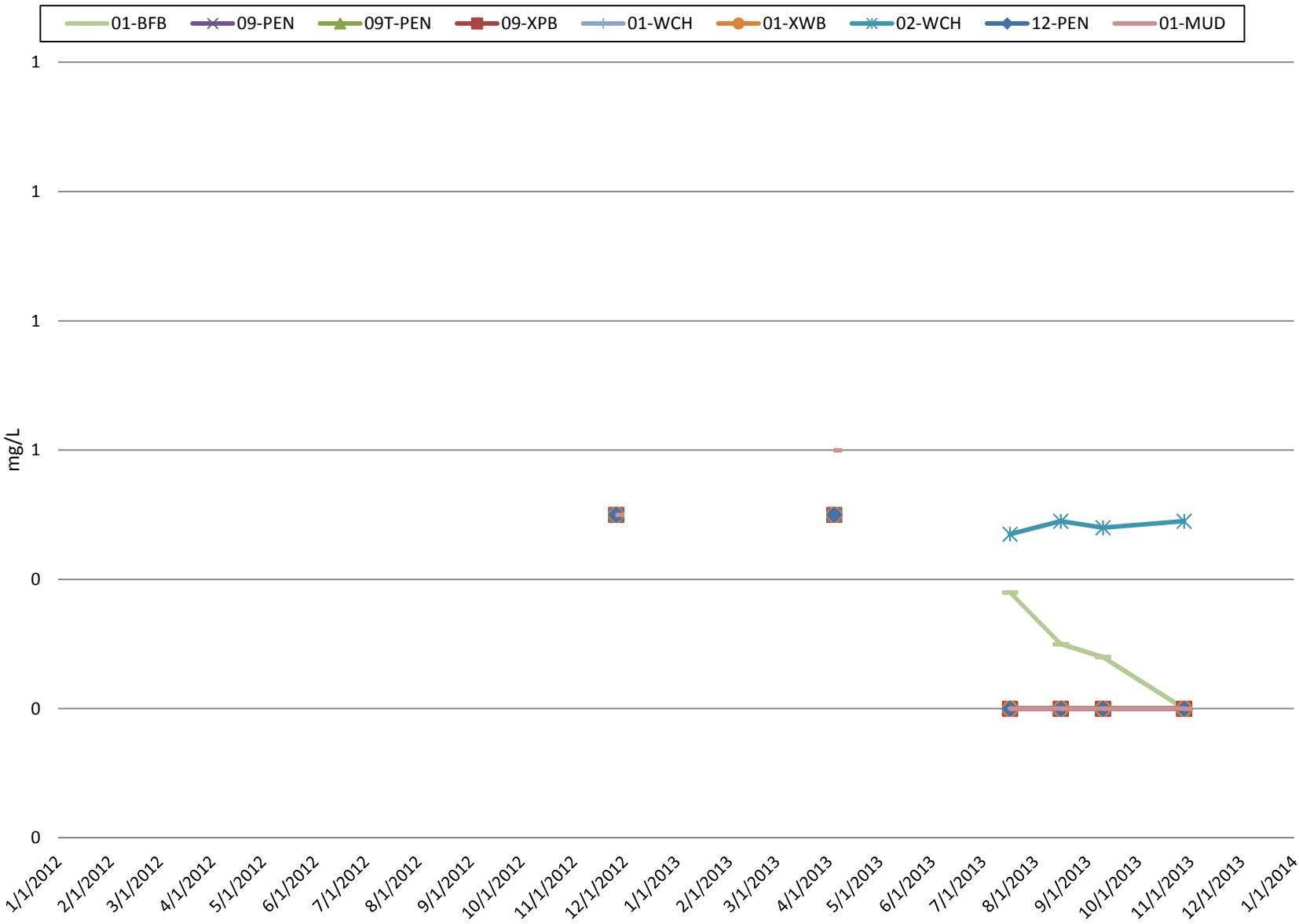
In-Pond Sampling, E.coli, 2013



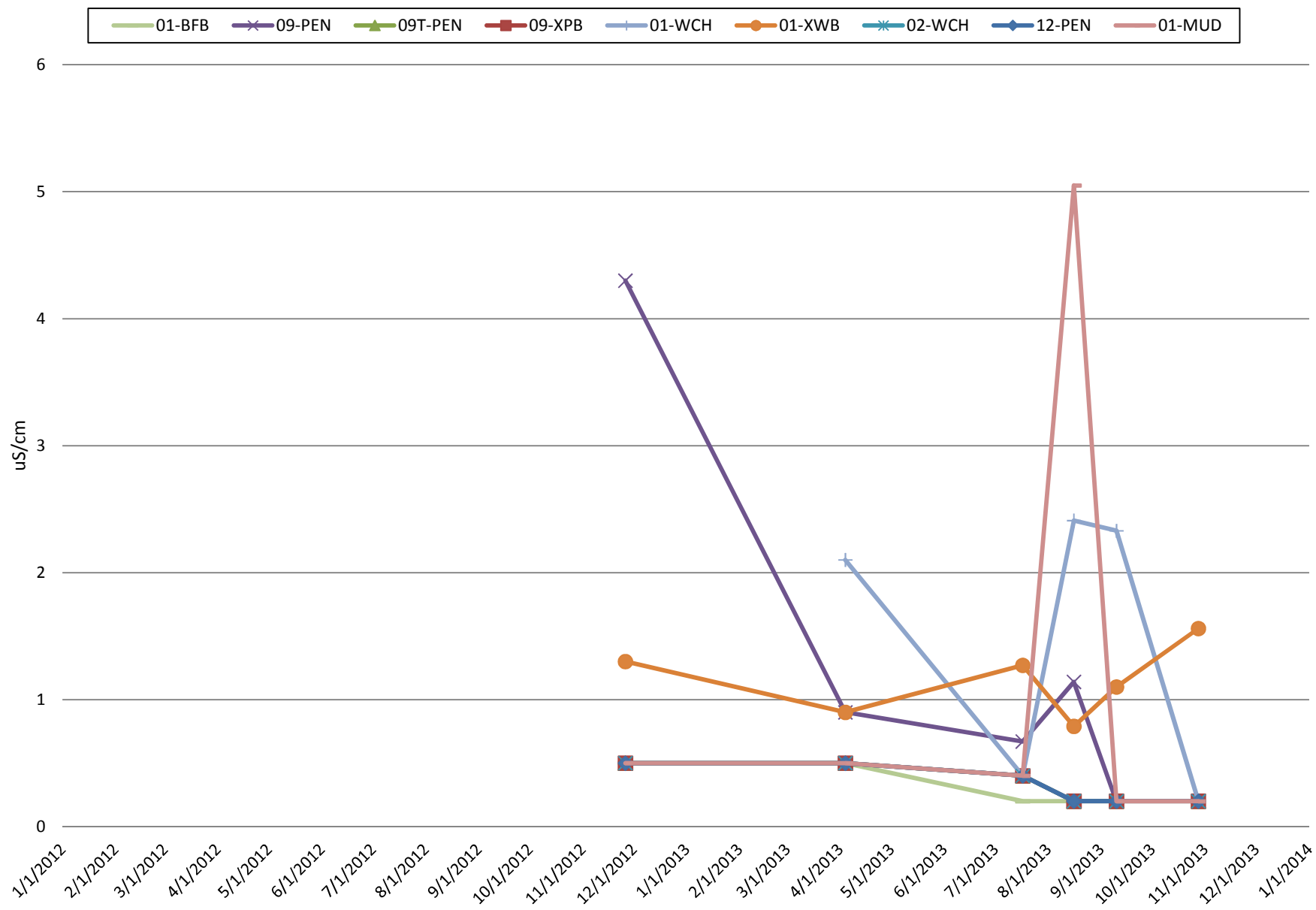
Tributary Dry Weather Sampling - Fecal Coliform Levels 2013



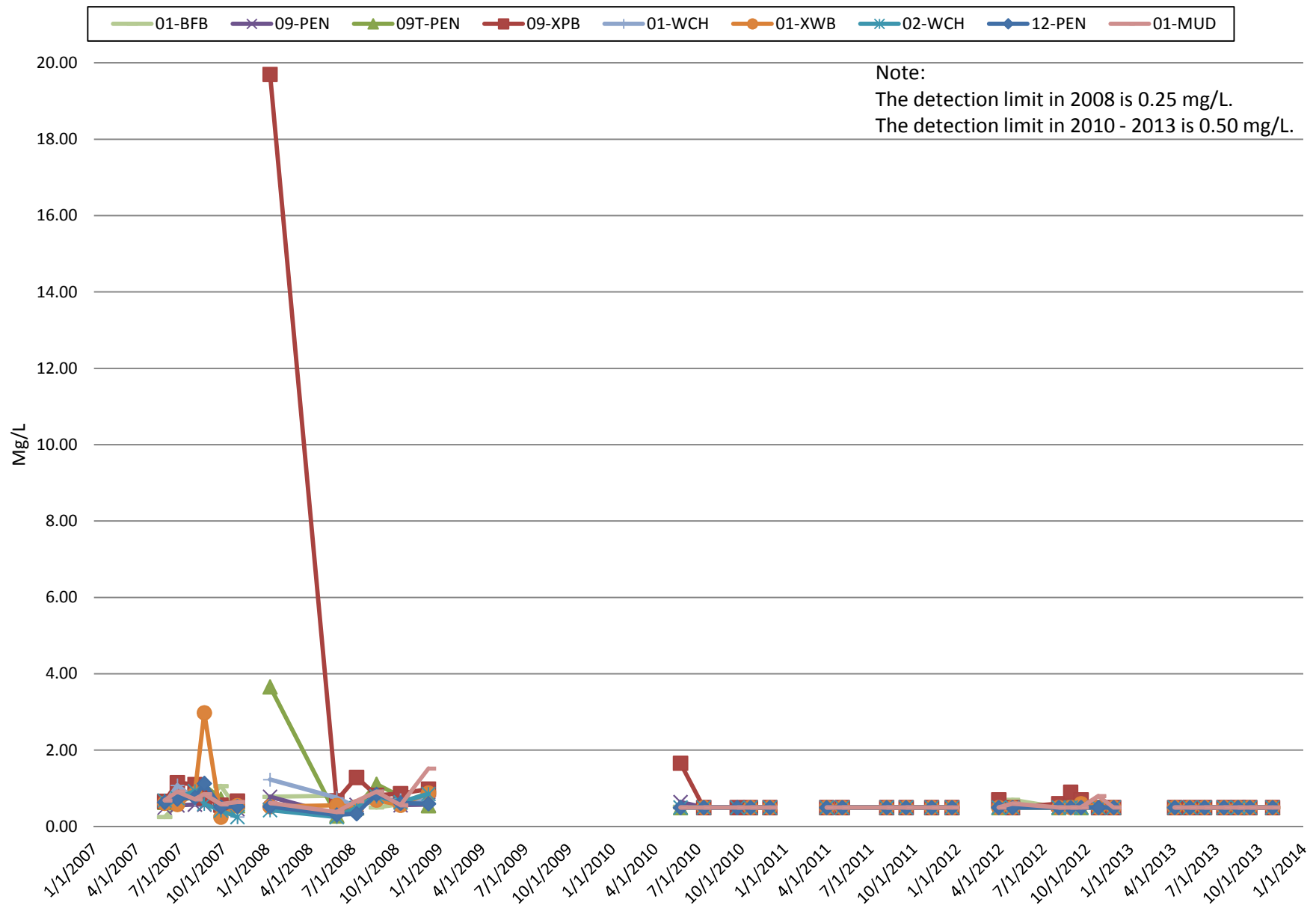
Tributary Dry Weather Sampling - Nitrate/Nitrite Levels 2012-2013



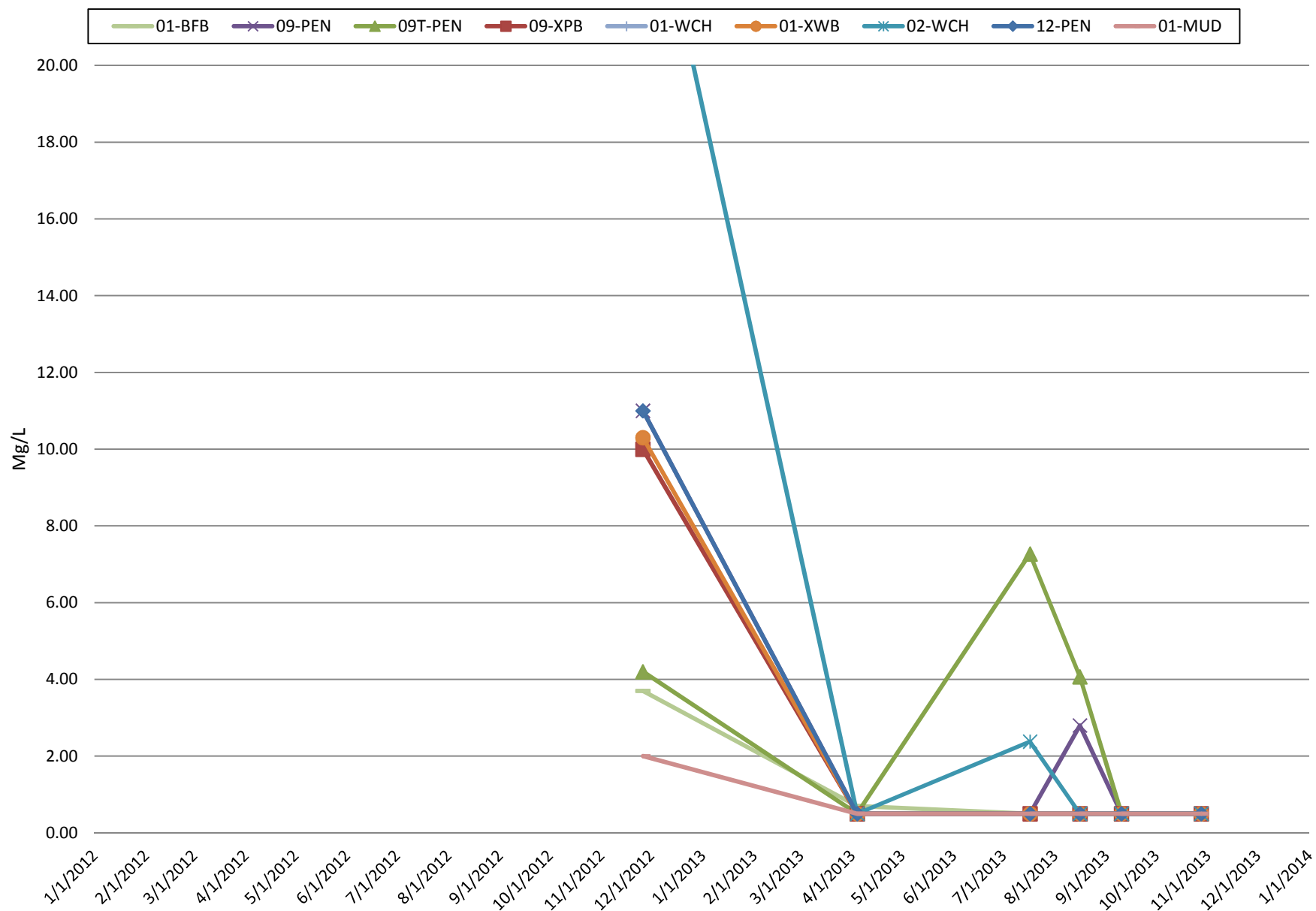
Groundwater Dry Weather Sampling - Nitrate/Nitrite Levels 2012-2013



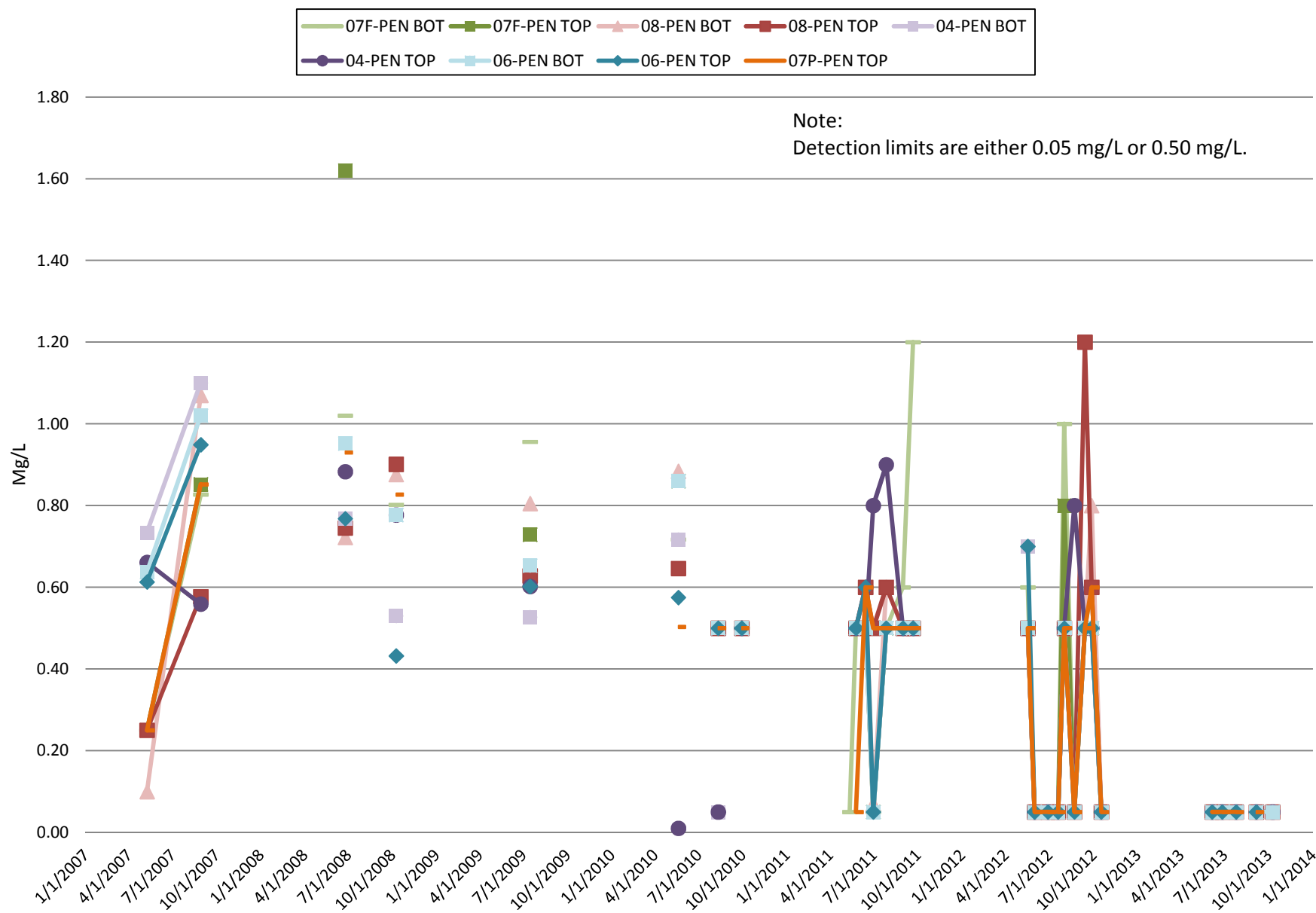
Tributary Dry Weather Sampling - TKN Levels 2007-2013



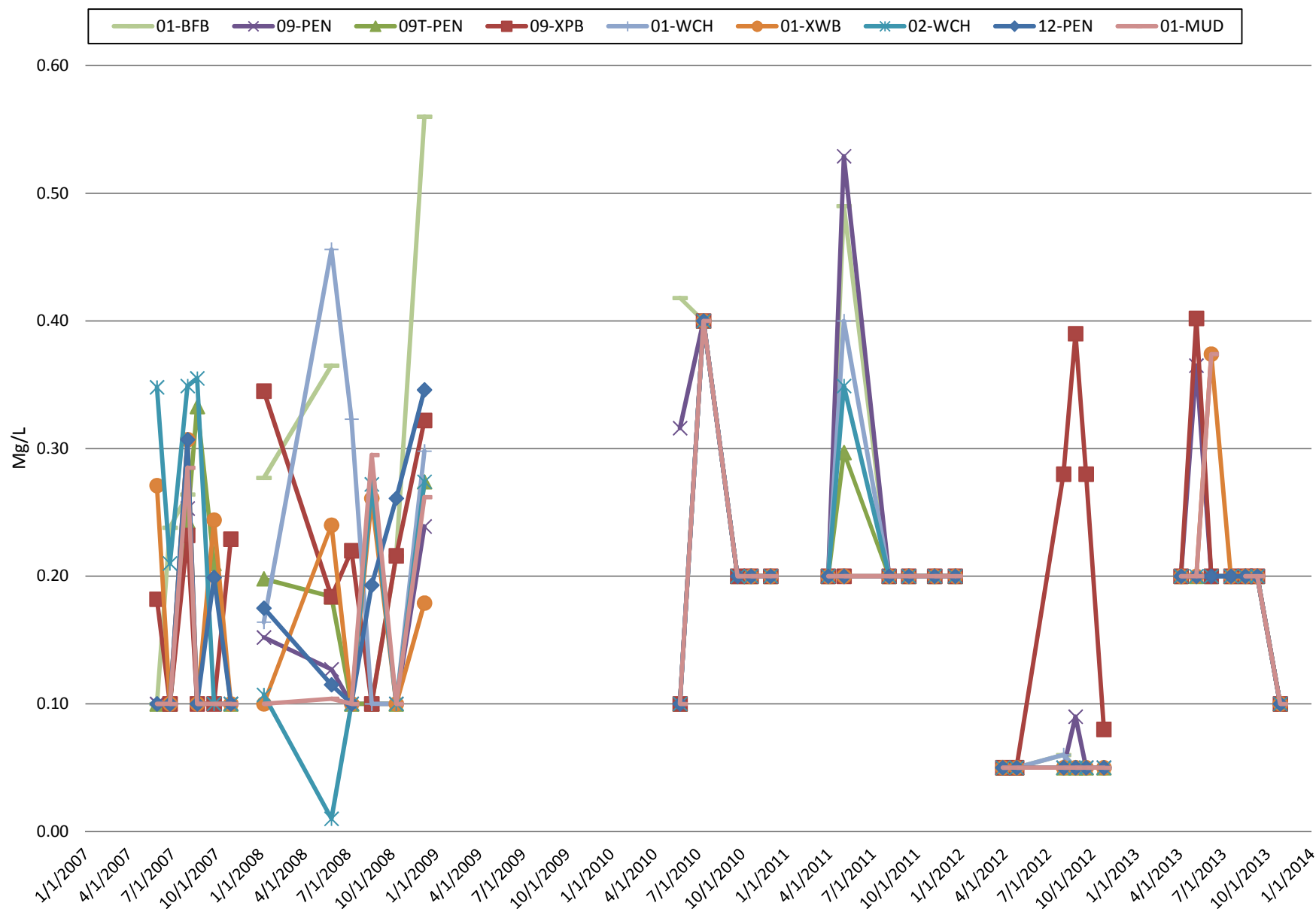
Groundwater Dry Weather Sampling - TKN Levels 2012-2013



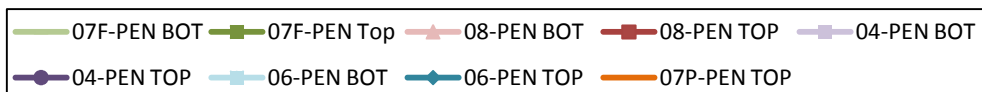
In-Pond Sampling, TKN 2007-2013



Tributary Dry Weather Sampling - Ammonia-N 2007-2013



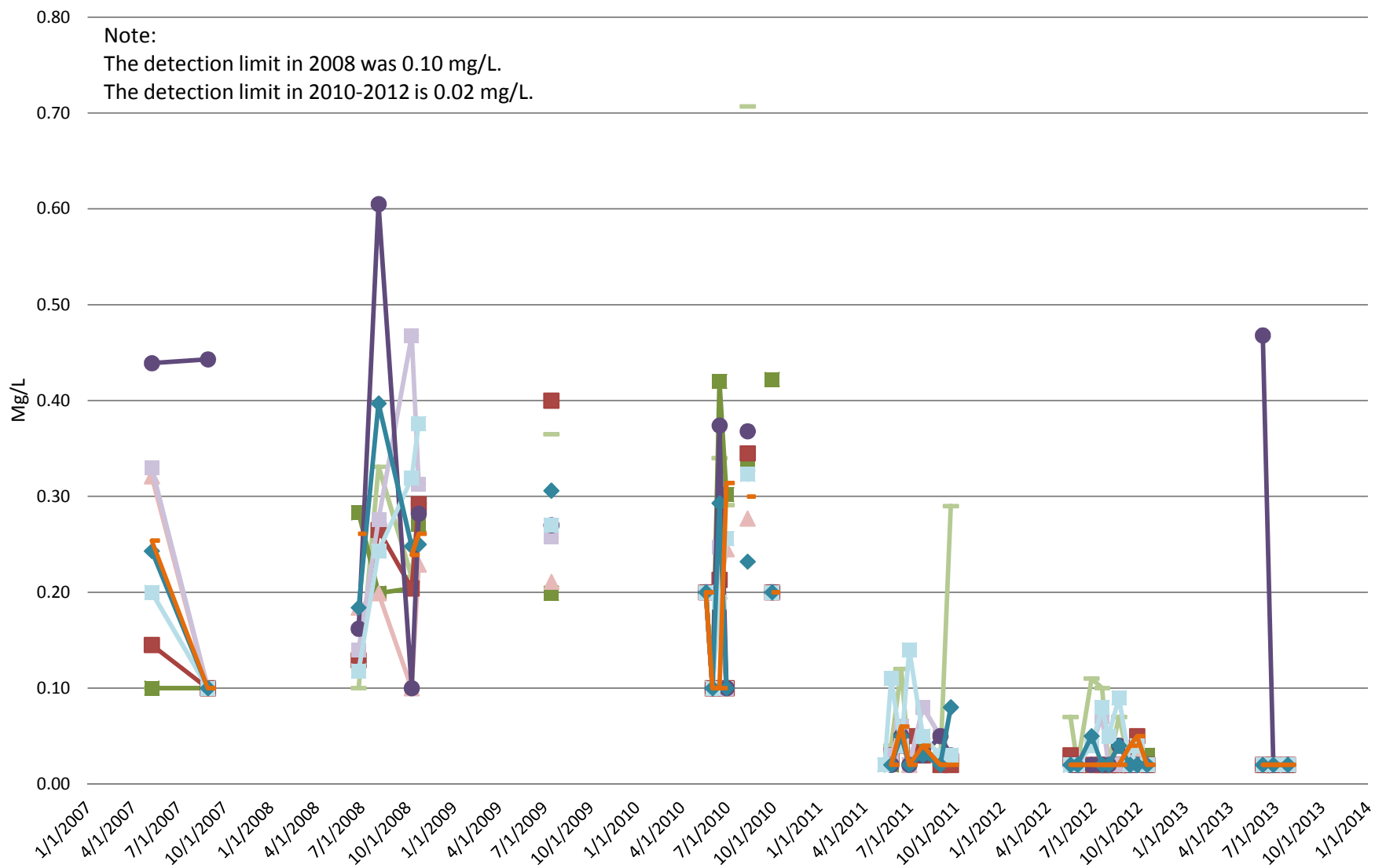
In-Pond Sampling, Ammonia 2007-2013



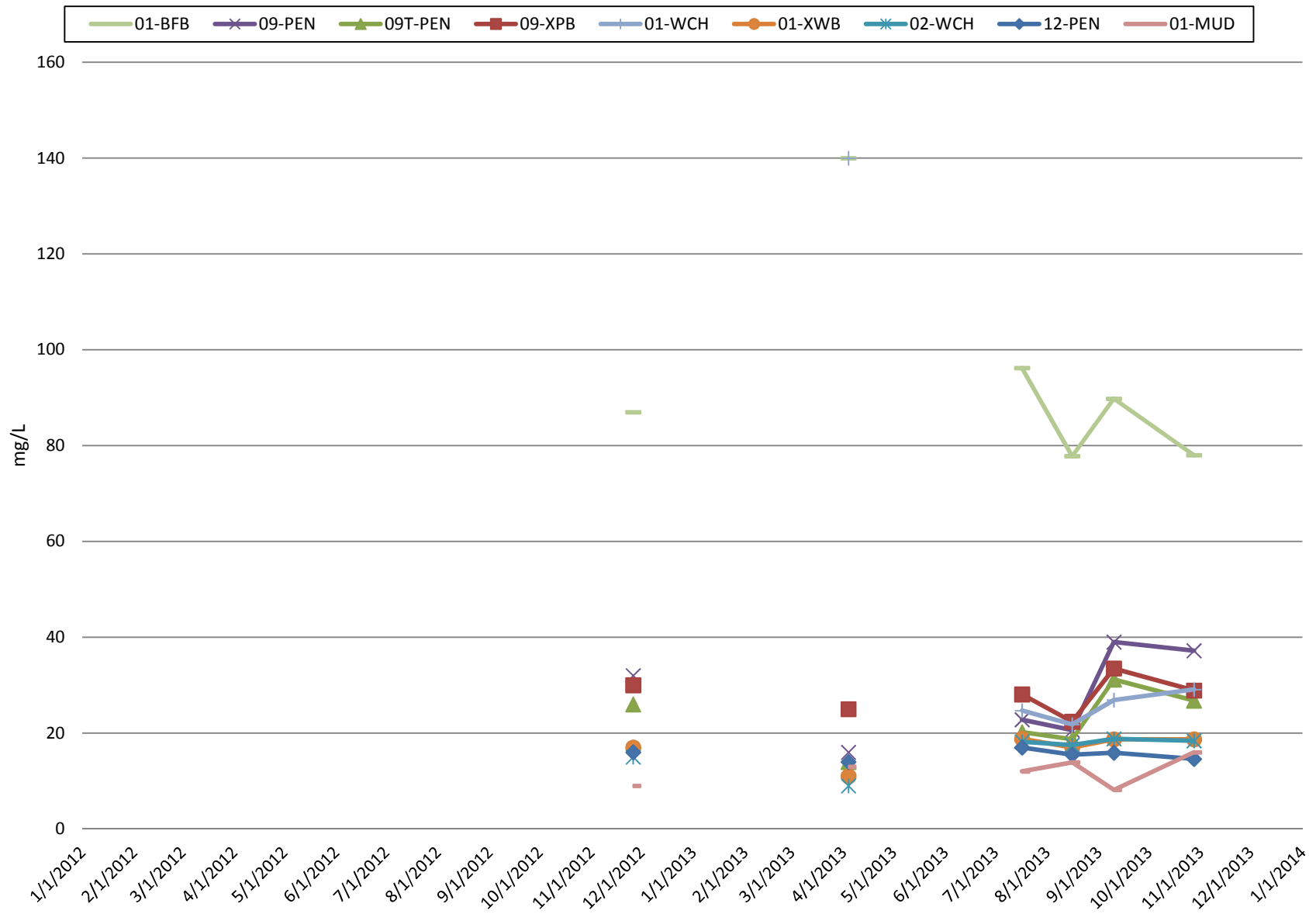
Note:

The detection limit in 2008 was 0.10 mg/L.

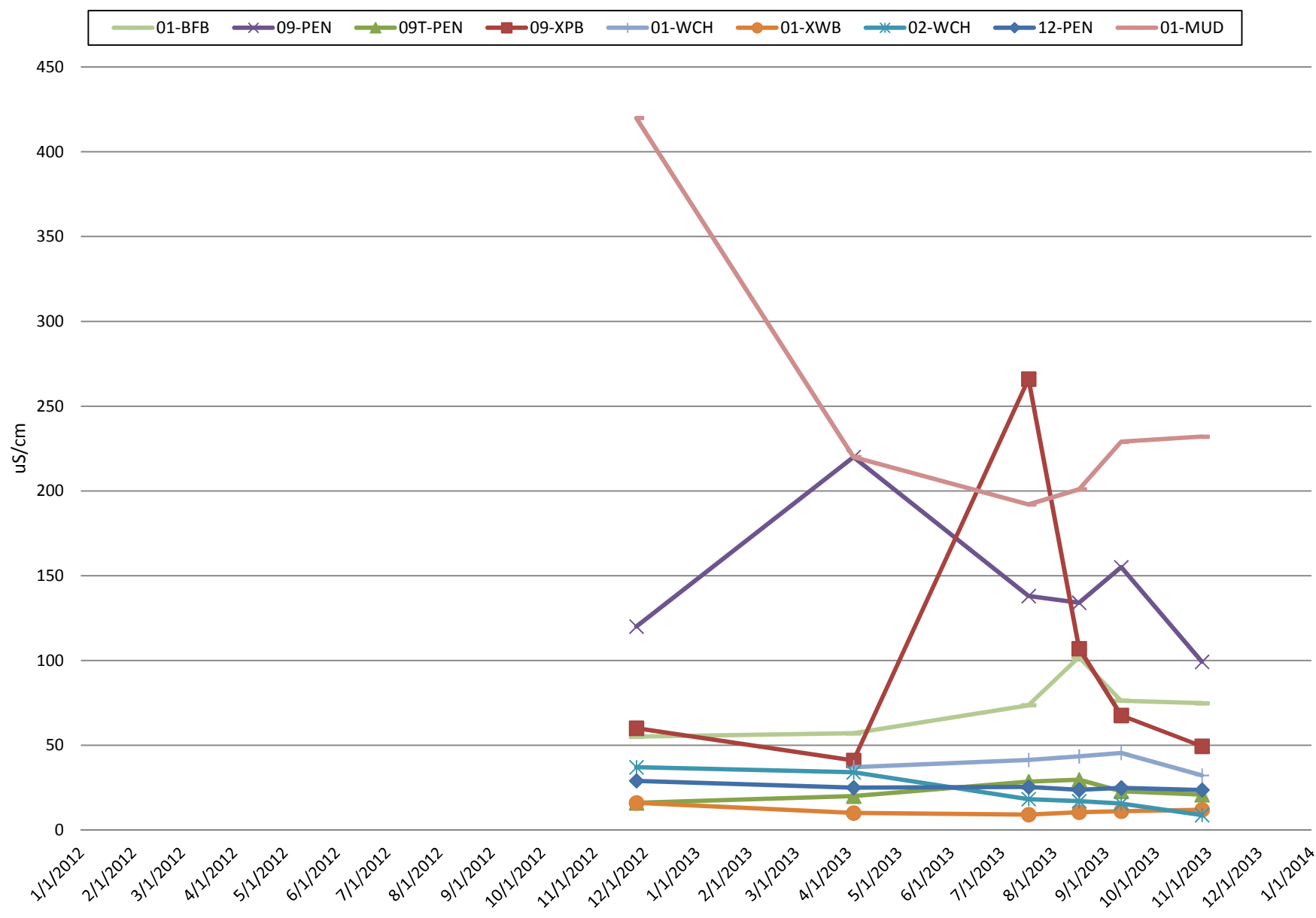
The detection limit in 2010-2012 is 0.02 mg/L.



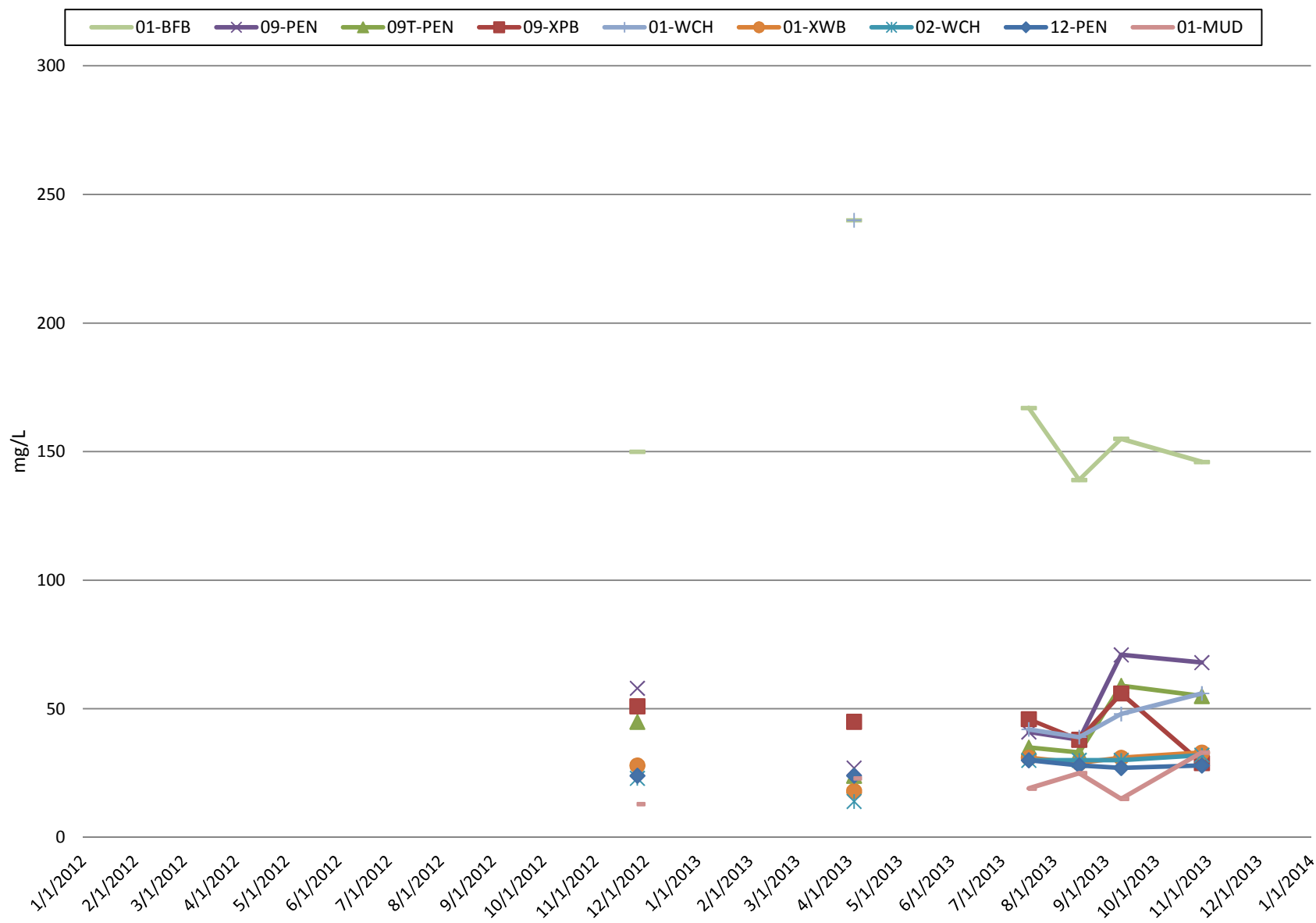
Tributary Dry Weather Sampling - Sodium Levels 2012-2013



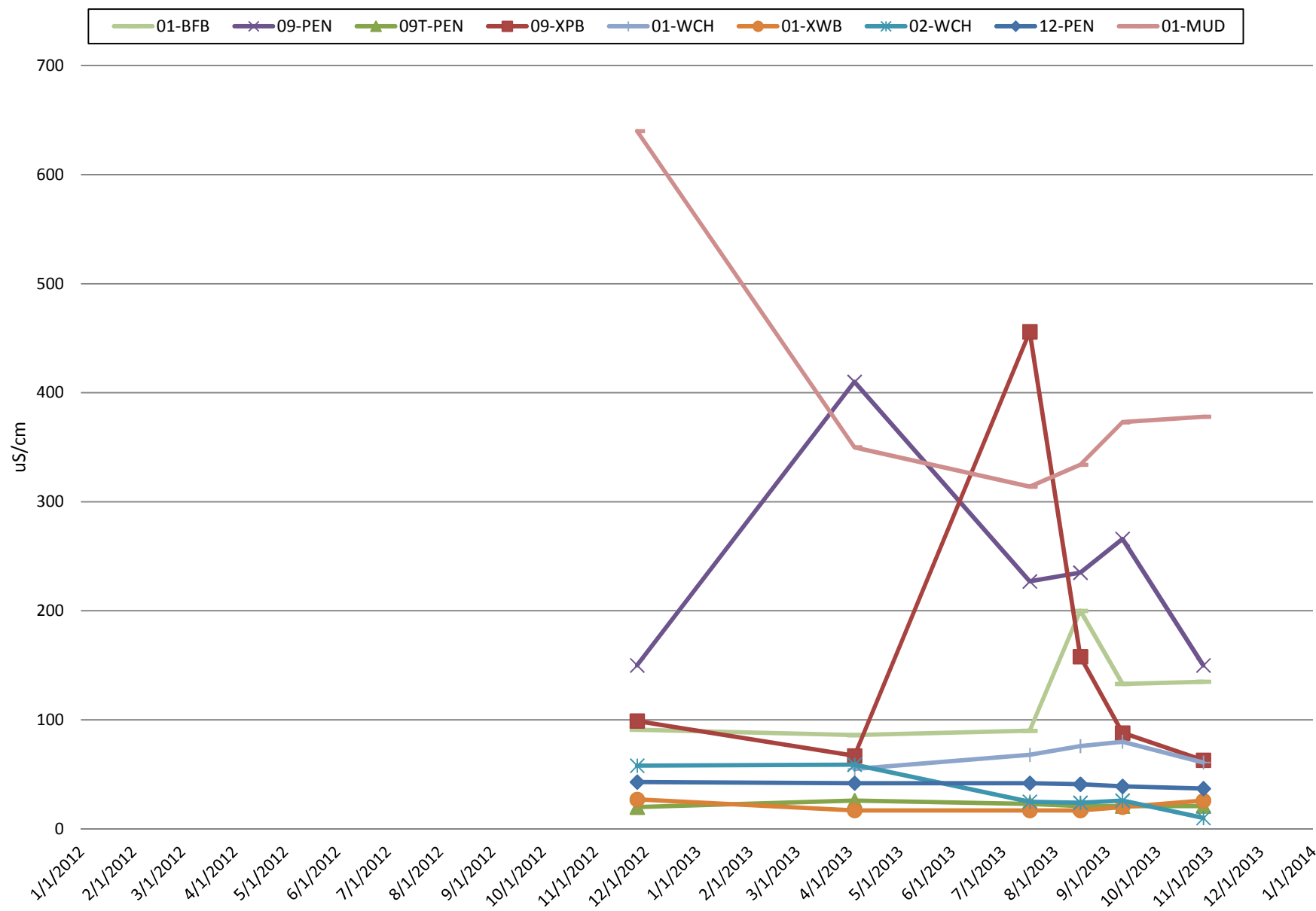
Groundwater Dry Weather Sampling - Sodium Levels 2012-2013



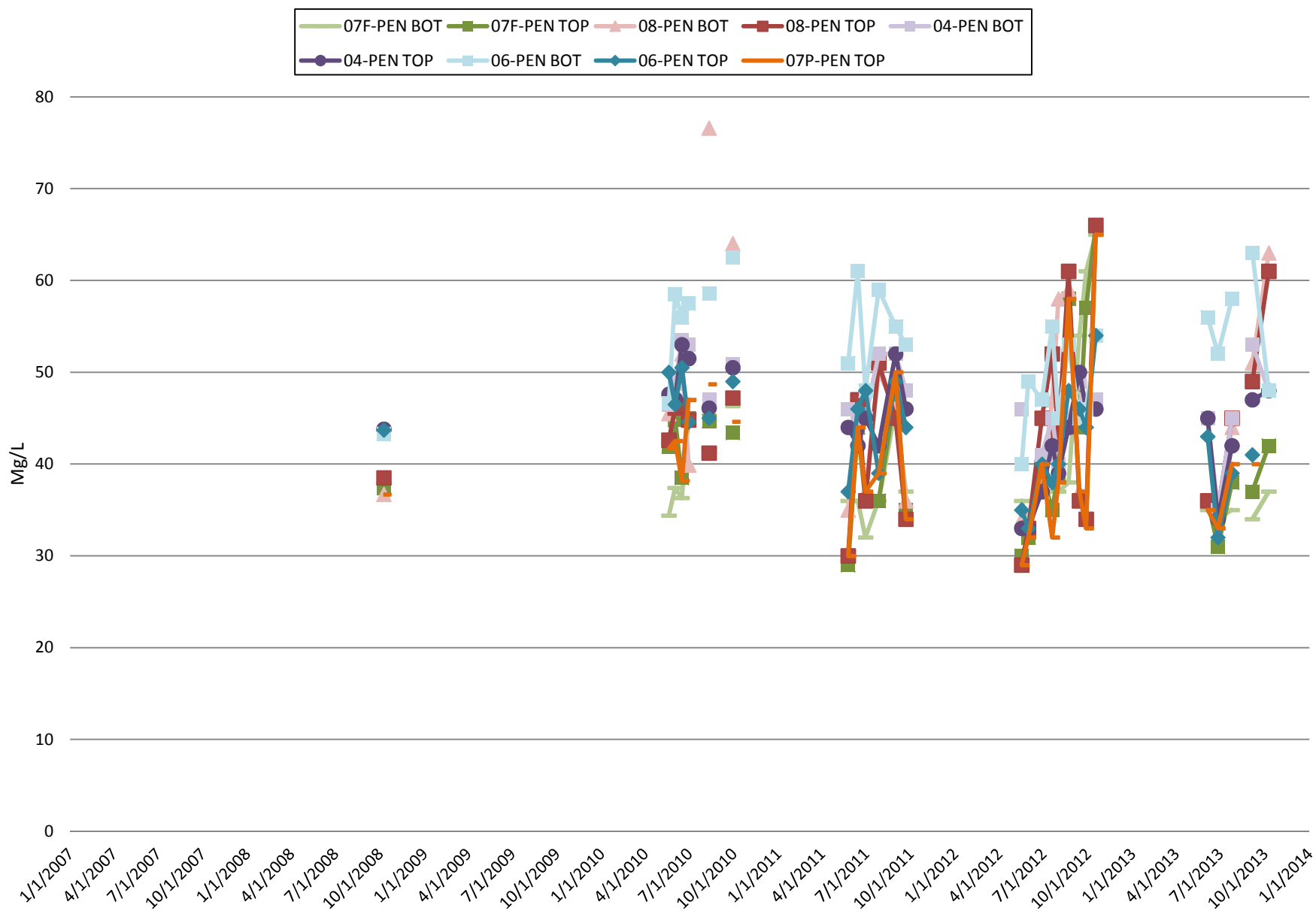
Tributary Dry Weather Sampling - Chloride Levels 2012-2013



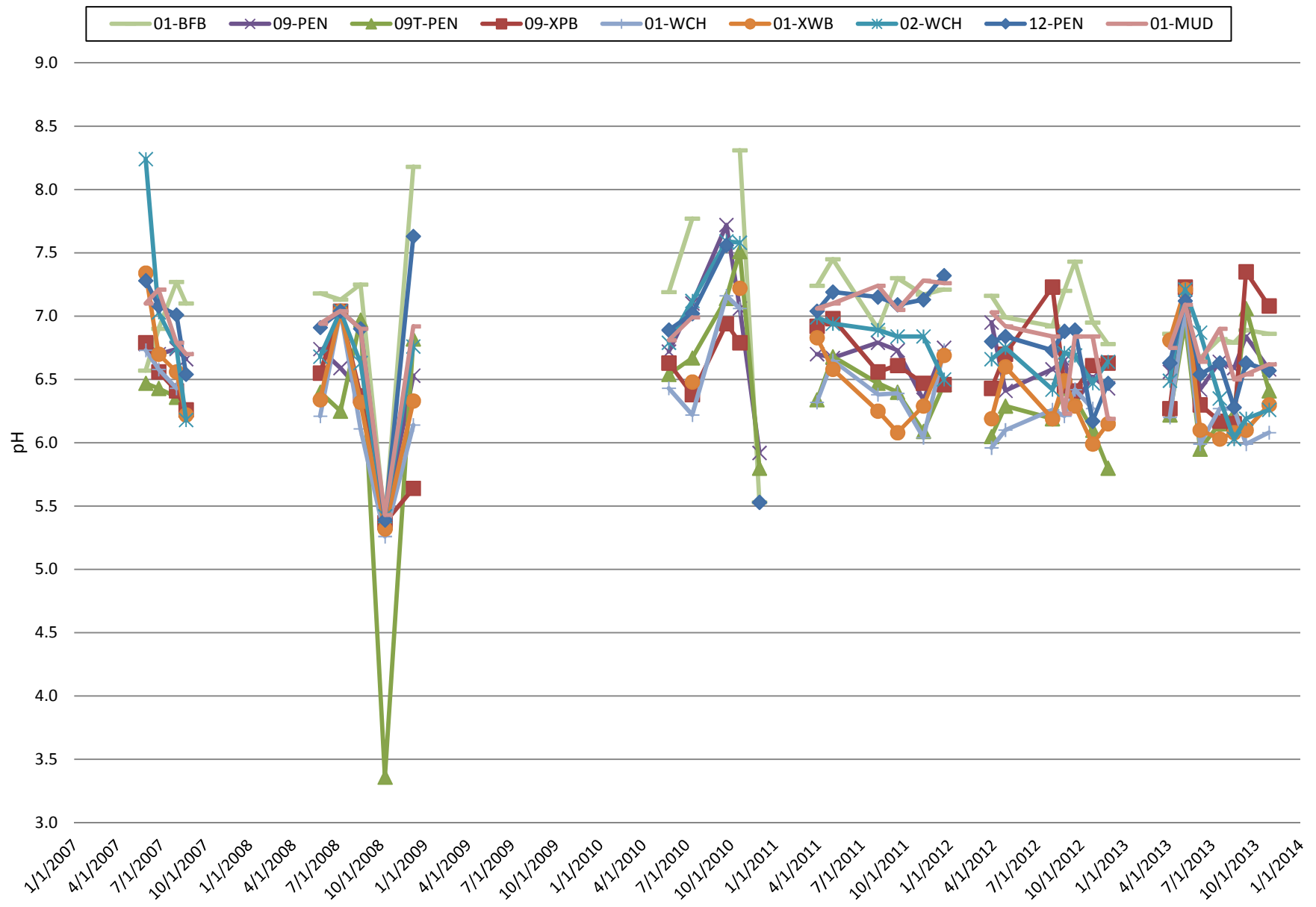
Groundwater Dry Weather Sampling - Chloride Levels 2012-2013



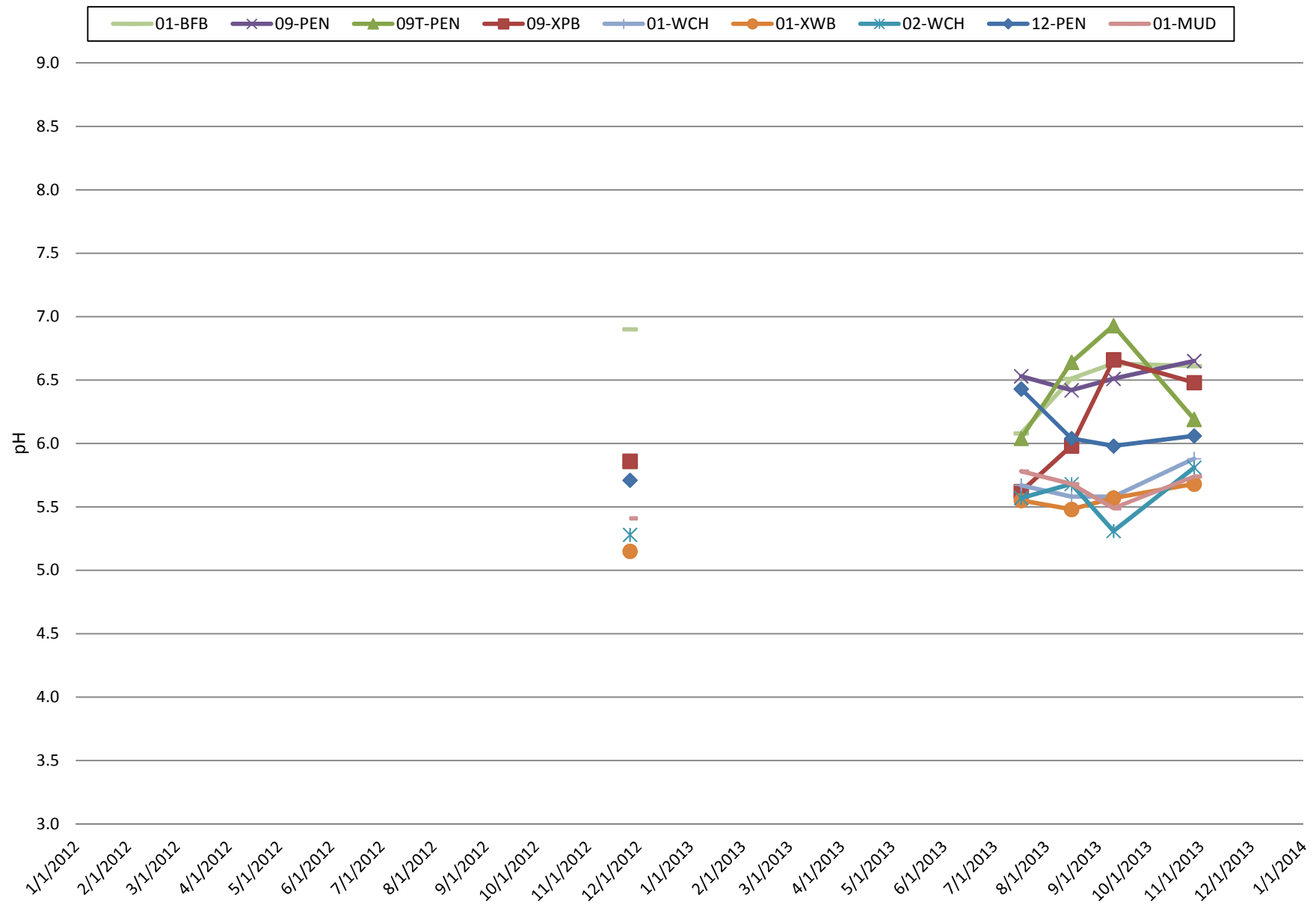
In-Pond Sampling, Chloride 2007-2013



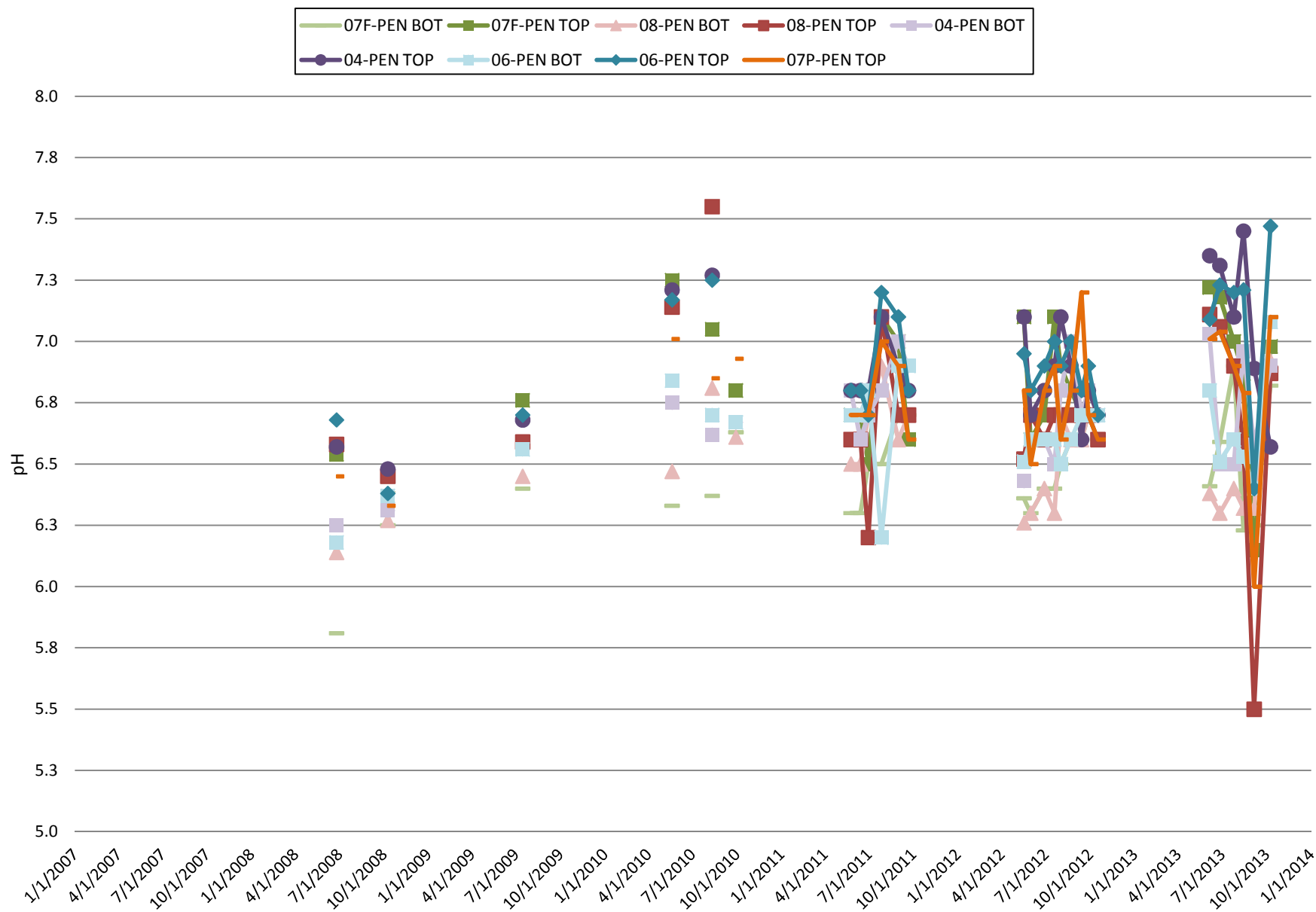
Tributary Dry Weather Sampling - pH 2007-2013



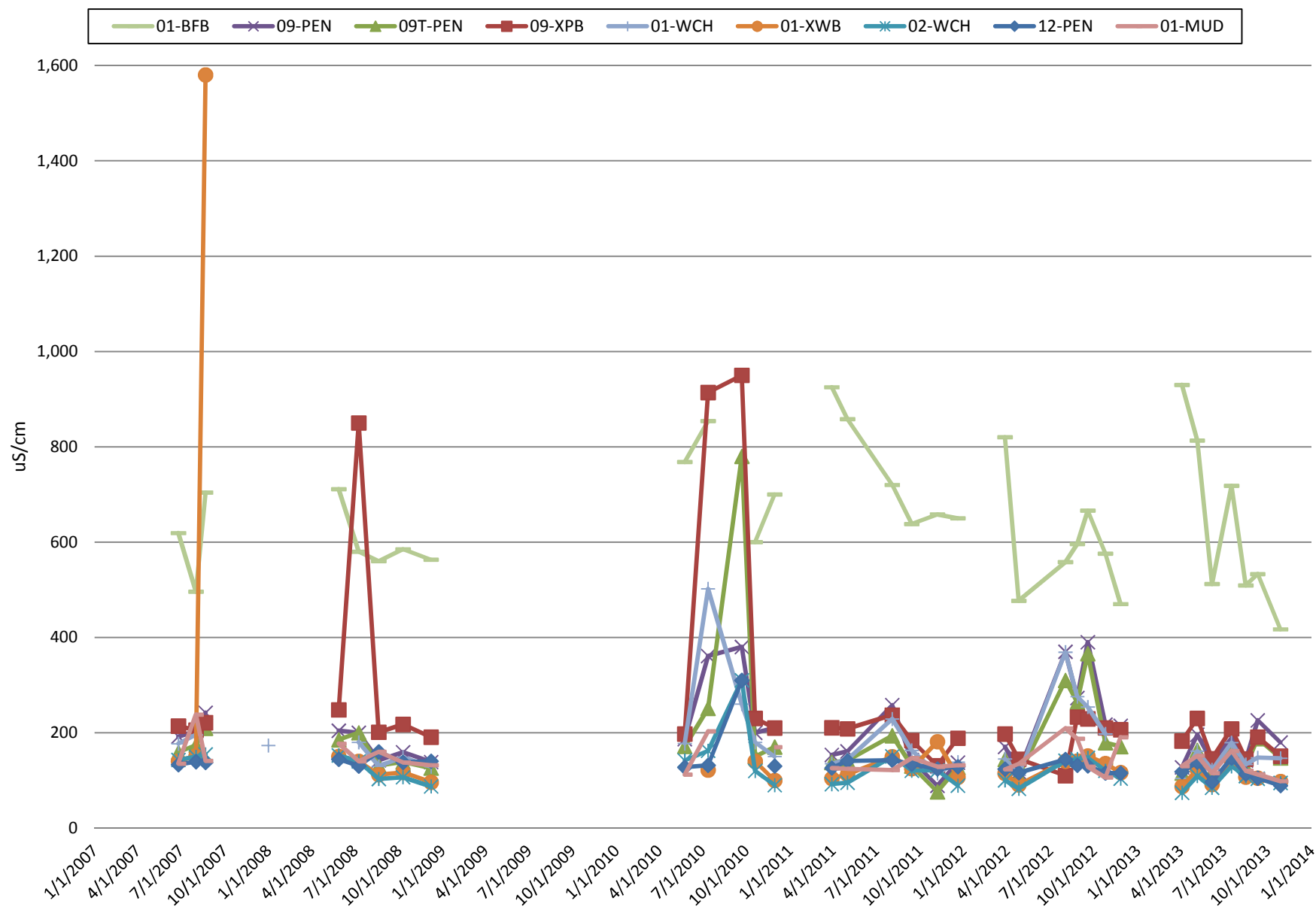
Groundwater Dry Weather Sampling - pH 2012-2013



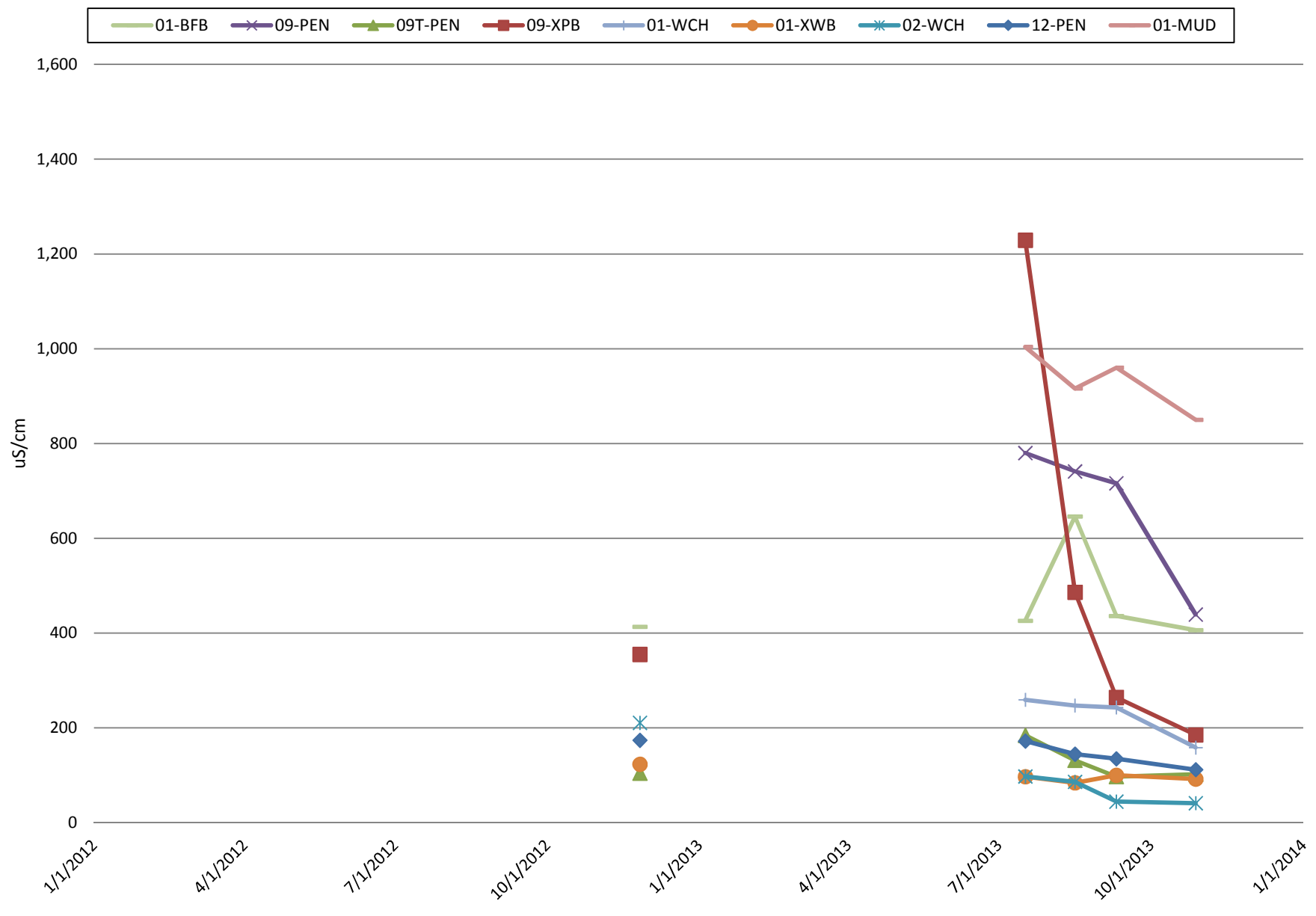
In-Pond Sampling, pH 2007-2013



Tributary Dry Weather Sampling - Conductivity Levels 2007-2013



Groundwater Dry Weather Sampling - Conductivity Levels 2012-2013



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