Hazardous Waste Section

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17

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Memorandum

To	Larry Stanley, NCDENR Division of Waste Management	Page 1
CC	Eric G. Smith, P.G., NCDENR Division of Water Resources Jim Schenker, Parker Hannifin Corporation	
Subject	Former Parker Hannifin Site: Wake Forest – ERD Pilot Test Update NCDENR Site NCD-002-591-014	
Project Number	60285550	

From	Matt Allen, Bob Wyrick – AECOM
Date	July 10, 2015

This memorandum summarizes work performed by AECOM North Carolina, Inc. to date for an Enhanced Reductive Dechlorination (ERD) field pilot test at the former Parker Hannifin Site in Wake Forest, North Carolina. **Figure 1** illustrates the site location and a site plan has been included as **Figure 2**. The field pilot test was performed under a Notification of Intent to Construct or Operate Injection Wells, "*permitted-by-rule"* notification under Title 15A North Carolina Administrative Code 02C .0200. This notification was received by the North Carolina Department of Environment and Natural Resources on April 4, 2014 and approval was issued on April 24, 2014.

The ERD field pilot test consisted of injecting approximately 3,000 gallons of a solution of High Fructose Corn Syrup (HFCS) and sodium bicarbonate into one shallow (overburden) injection well (SIW-1) and one deep (bedrock) injection well (DIW-1) on August 11 and 12, 2014. Approximately 1,500 gallons of a 10 percent solution by volume of HFCS and bicarbonate were injected into each injection well at low pressure with a double diaphragm pump. Water (Asheboro municipal water) for the injection solution was delivered to the site by Garco in a 10,000 gallon tanker. The injection solution was mixed on site by adding 5 gallon pails of corn syrup and 40 pound bags of sodium bicarbonate to the water.

Prior to injection activities, baseline groundwater sampling was completed on August 9, 2014 at monitoring wells PMW-1s, PMW-2s, PMW-2s, PMW-2d, POC-2A, POC-2B, recovery well RW-4, and injection well DIW-1. The remnant cone of depression from pumping of RW-4 prevented the sampling of MW-4 and SIW-1. Post injection groundwater sampling has been conducted monthly since the injection with sampling events in September, October, November, December 2014, and March 2015. The next proposed groundwater sampling event will be in June 2015.

In general, injection results currently appear favorable with groundwater analytical data indicating significant reductions in trichloroethylene (TCE) and increases in cis-1,2-dichloroethene (DCE) and several detections of vinyl chloride. A brief summary of analytical data and concentration trends is provided below. Trend graphs are provided as **Attachment A**.

Total organic carbon (TOC) concentrations have decreased significantly since injection however still remain at relatively high concentrations (>100 mg/L) more than 203 days after injection. Dissolved oxygen concentrations have remained at low levels (generally below 1.0 milligrams per liter [mg/L]) since injection; which is supportive of anaerobic biodegradation. Sodium bicarbonate buffering has generally kept pH ranges in the favorable zone (5.5 to 7.5) for reductive dechlorination. *Dehalococcoides ethenogenes* (DHC) sampling at multiple wells indicates that these bacteria are present in the aquifer, however these data indicate that the population is not yet significant (maximum density of 1,440 cells per milliliter [cells/mL]). Dehalobacter (DHB) data indicate that the microbial density of these bacteria has increased by up to three orders of magnitude during testing, and are significantly higher than the DHC density (maximum density of 62,700 cells/mL). This observation is expected, as DHB are more pH tolerant than DHC. Carbon dioxide (CO_2), methane, ethane, and ethene have increased relative to baseline sampling in several of the groundwater monitoring wells indicating increased microbial activity and complete mineralization of parent chlorinated volatile organic compounds (CVOCs) is occurring.

Elevated concentrations of TOC at recovery well RW-4 indicate that the radius of influence for the injection is relatively large (approximately 40 feet). Continued monitoring of volatile organic compound (VOC) concentrations and geochemical parameters is recommended until TOC concentrations have reached background levels. A summary of groundwater data can be found in the attached **Table 1**. A summary of pilot injection monitoring results by well is included below.

Shallow Zone Injection

SIW-1:

- No baseline samples were collected at this location because the well was dry prior to injection (due to groundwater extraction from recovery well RW-4).

POC-2A (~7 feet downgradient of SIW-1):

- TCE concentrations have decreased significantly since injection (22,000 to 3,200 micrograms per liter [µg/L]).
- Daughter product cis-1,2-DCE has increased (160 to 1,900 µg/L). No vinyl chloride has been detected to date.
- Dissolved oxygen remains low (below 1.0 mg/L), supportive of anaerobic biodegradation.
- pH remains above 5.5 which are moderate/acceptable conditions for reductive dechlorination.
- TOC has decreased significantly to 82 mg/L, from its high at 56,300 mg/L.
- DHC and functional genes have been detected, but at low concentrations.
- DHB has been detected at 10^4 cells/mL concentrations.
- CO_2 and methane have been detected at increased concentrations indicating stimulation of microbial activity.

PMW-1s (~12 feet downgradient of SIW-1):

- TCE concentrations have decreased significantly since injection (16,000 to 1,400 µg/L).
- Daughter product cis-1,2-DCE has increased (150 to 1,500 µg/L). Vinyl chloride was detected at 1 µg/L during the most recent sampling event (March 3, 2015).

- Dissolved oxygen remains low (below 1.0 mg/L).
- pH remains above 5.5 which are moderate/acceptable conditions for reductive dechlorination.
- TOC has decreased (35 mg/L) significantly from a high of 1,200 mg/L.
- DHC and functional genes have been detected, but at low concentrations.
- DHB has been detected at 10^4 cells/mL concentrations.
- Additionally, CO_2, methane, ethane, and ethene have been detected at increased concentrations indicating stimulation of microbial activity and complete mineralization of parent CVOCs is occurring.

PMW-2s (~22 feet downgradient of SIW-1):

- TCE concentrations have decreased significantly since injection (19,000 to 440 µg/L).
- Daughter product cis-1,2-DCE has increased (230 to 7,100 µg/L). No vinyl chloride has been detected to date.
- Dissolved oxygen remains low (below 1.0 mg/L).
- pH remains in the range of 5.5 which is moderately favorable for reductive dechlorination.
- TOC has decreased (320 mg/L) significantly from a high of 1,800 mg/L.
- Additionally, CO_2, ethane, and ethene have increased concentrations, indicating stimulation of microbial activity and complete mineralization of CVOC compounds is occurring.

<u>Deep Zone Injection</u>

DIW-1:

- TCE concentrations have decreased significantly since injection (18,000 to 2,200 µg/L)
- Daughter product cis-1,2-DCE has increased (non-detect to 320 µg/L). No vinyl chloride has been detected to date.
- Dissolved oxygen remains low (below 1.0 mg/L).
- pH remains above 7.5 which is favorable for reductive dechlorination.
- TOC remains very high (140,000 mg/L).
- DHC has been detected at 10^3 cells/mL concentrations.

POC-2B (~7 feet downgradient of DIW-1):

- TCE concentrations have decreased significantly since injection (40,000 to 6,400 µg/L).
- Daughter product cis-1,2-DCE has increased (1,100 µg/L). No vinyl chloride has been detected to date.
- Dissolved oxygen remains low (below 0.5 mg/L).
- pH remains in optimal range (~6.6) for reductive dechlorination.
- TOC remains at high levels (26,000 mg/L).

- DHC has been detected, but at low concentrations.
- DHB has been detected at 10^3 cells/mL concentrations.
- Additionally, CO_2, ethane, and ethene have increased concentrations, indicating stimulation of microbial activity and complete mineralization of CVOC compounds is occurring.

MW-4 (~17 feet cross-gradient of DIW-1):

- TCE concentrations have decreased significantly since injection (29,000 to 650 µg/L).
- Daughter product cis-1,2-DCE has increased (82 to 12,000 µg/L). No vinyl chloride has been detected to date.
- Dissolved oxygen remains low (below 0.5 mg/L).
- pH remains above 6.5 which is favorable for reductive dechlorination.
- No TOC, microbial, or dissolved gas data have been collected for this well.

PMW-1d (~12 feet downgradient of DIW-1):

- TCE concentrations have decreased significantly since injection (17,000 to 30 µg/L).
- Daughter product cis-1,2-DCE has increased (83 to 16,000 µg/L).
- Vinyl chloride was detected at 4.8 µg/L during the most recent sampling event (March 3, 2015).
- Dissolved oxygen remains low (below 1.0 mg/L).
- pH remains in the range (~5.83) that is suitable for reductive dechlorination.
- TOC has remains relatively stable (380 mg/L).
- DHC has been detected at 10^2 cells/mL in recent sampling events. This is a significant increase since monitoring began.
- DHB has been detected at 10^3 cells/mL concentrations.
- CO_2, methane, ethane, and ethene have been detected indicating stimulation of microbial activity and complete mineralization of parent CVOCs is occurring.

PMW-2d (~22 feet downgradient of DIW-1):

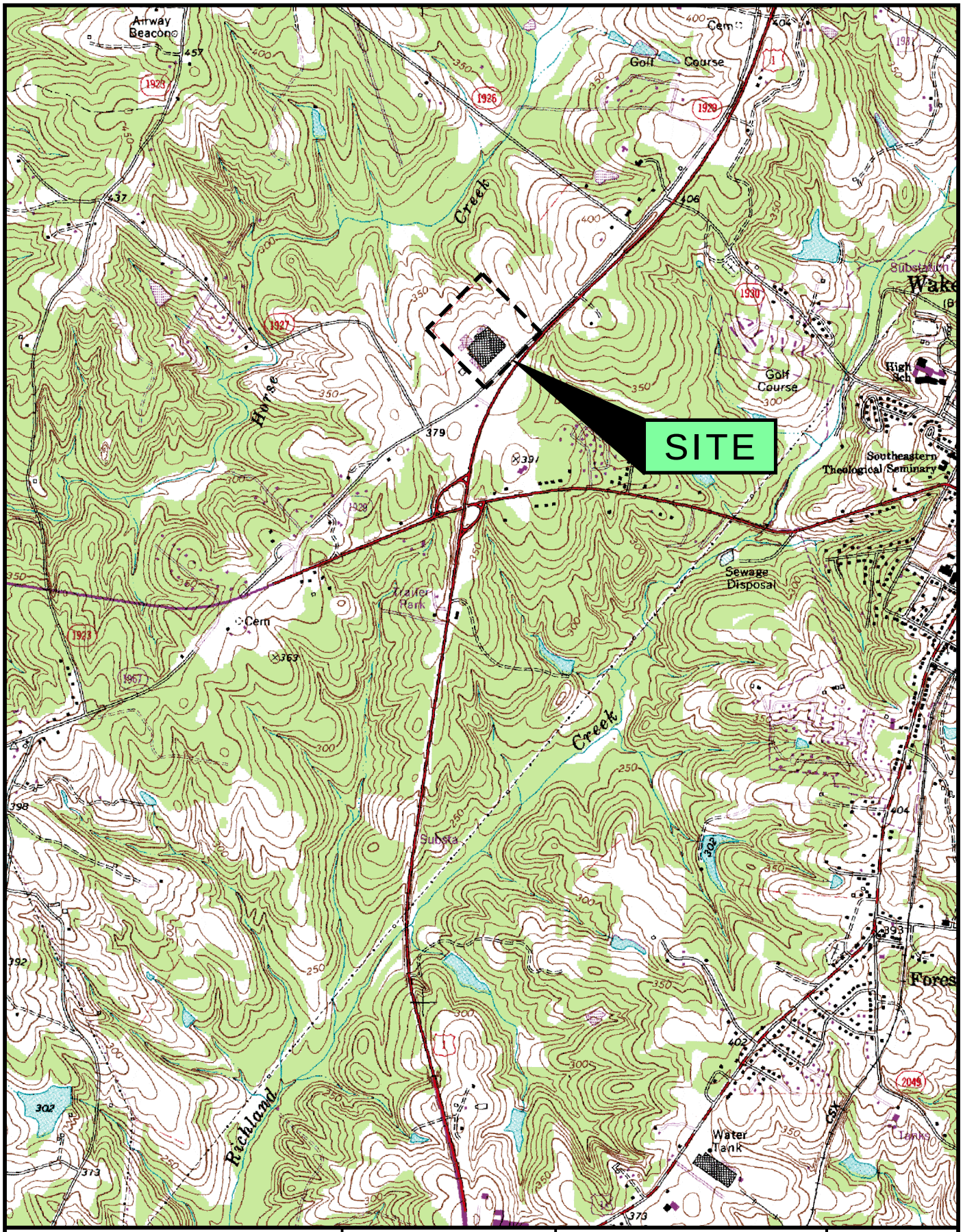
- TCE concentrations have decreased significantly since injection (28,000 to 3,400 µg/L).
- Daughter product cis-1,2-DCE has increased (150 to 7,400 µg/L). Vinyl chloride has not been detected to date.
- Dissolved oxygen remains low (below 0.5 mg/L).
- pH remains in the low range (~5.35) that is suitable for reductive dechlorination.
- TOC has decreased (2,700 mg/L) significantly from its high at 23,000 mg/L, but remains high.
- CO_2, methane, and ethane have increased, indicating stimulation of microbial activity and complete mineralization of parent CVOCs is occurring.

RW-4 (40 feet downgradient of DIW-1):

- TCE concentrations have decreased significantly since injection (29,000 to 190 µg/L).
- Daughter product cis-1,2-DCE has increased (220 to 8,400 µg/L).
- Vinyl chloride was detected at 1.9 µg/L during the most recent sampling event (March 3, 2015).
- Dissolved oxygen remains low (below 0.5 mg/L).
- pH remains in the range (~5.6) that is suitable for reductive dechlorination.
- TOC remains at 440 mg/L.
- CO_2 has been detected indicating stimulation of microbial activity and complete mineralization of parent CVOCs is occurring.

TOC concentrations in groundwater have remained relatively high (>100 mg/L) longer than anticipated. Based on the available TOC, continued groundwater monitoring is recommended to evaluate the long-term TOC trends and potential rebound of VOCs following depletion of the TOC.

Continued groundwater monitoring is planned for June 2015. If VOC concentrations stabilize and/or TOC results return to background concentrations, the post injection monitoring will be considered complete; otherwise, additional monitoring will be performed.



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WEB: HTTP://WWW.AECOM.COM

USGS 7-1/2 MINUTE SERIES MAP
Wake Forest, NC
1987
TOPOGRAPHIC QUADRANGLE

SCALE 1:24000

SITE LOCATION MAP

Former Parker Hannifin Corp. Facility
Wake Forest, North Carolina

FIGURE NUMBER: 1

DRAWN BY:	DATE:	PROJECT NUMBER:	DRAWING NUMBER:
KLR	03/27/13	60285550	A130070A

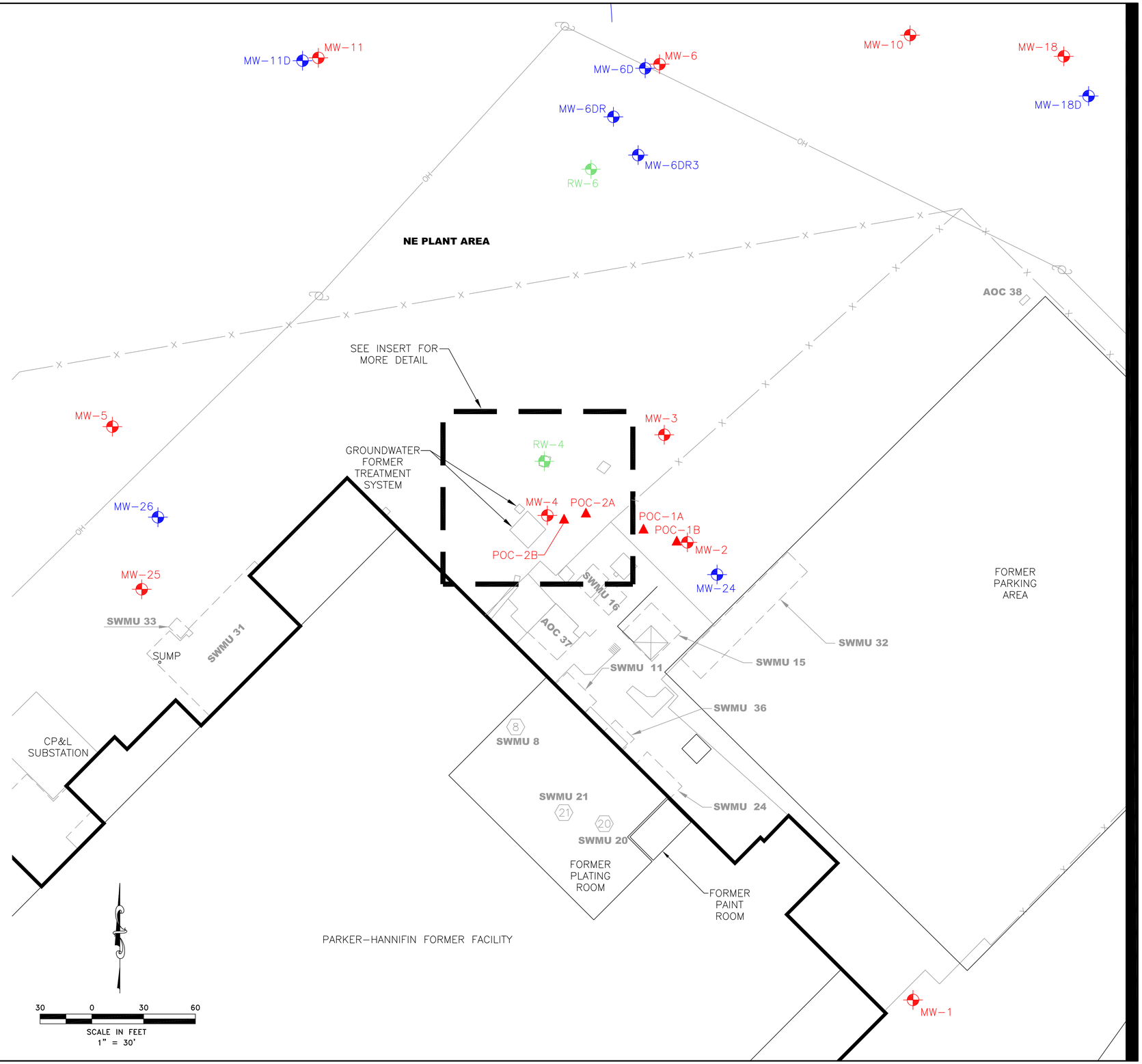
LEGEND

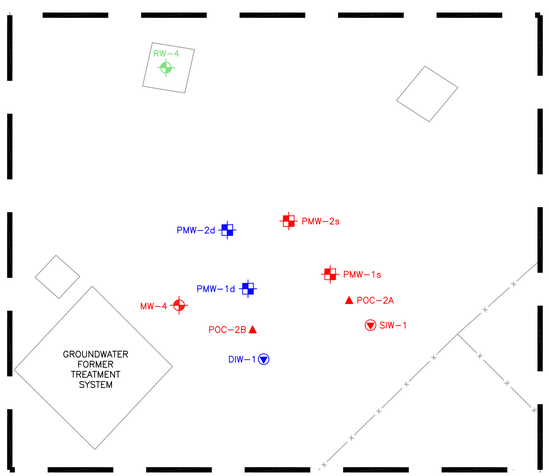
- CREEK WITH FLOW DIRECTION
- FORMER LOCATION OF FENCE
- OH — FORMER LOCATION OF OVERHEAD POWER LINES
- MW-14 — MONITORING WELL COMPLETED IN SAPROLITE OR PWR
- MW-11D — MONITORING WELL COMPLETED IN BEDROCK
- RW-4 — RECOVERY WELL
- POC-2A — POINT OF COMPLIANCE MONITORING WELL COMPLETED IN SAPROLITE OR PWR
- SIW-1 — SHALLOW INJECTION WELL
- DIW-1 — DEEP INJECTION WELL
- PMW-2s — SHALLOW PILOT MONITORING WELL
- PMW-2d — DEEP PILOT MONITORING WELL
- SWMU 32 — SOLID WASTE MANAGEMENT UNIT

NOTES:

1. GROUNDWATER SAMPLES COLLECTED THE WEEK OF FEBRUARY 20, 2012.
2. ALL RESULTS REPORTED IN MICROGRAMS PER LITER (ug/L).
3. DATA FROM DEEP BEDROCK WELLS NOT USED IN MAP INTERPRETATION.
4. NS = NOT SAMPLED DURING THIS SAMPLING EVENT.

SOURCE:
BASE MAP CREATED FROM "BOUNDARY RETRACEMENT" DONE BY MURPHY & SACKS, PROFESSIONAL LAND SURVEYORS, 6308 J. RICHARD DR., RALEIGH, NORTH CAROLINA, DATED OCTOBER 2002. WELL LOCATIONS WERE NOT INCLUDED IN SURVEY, AND ARE APPROXIMATE.





INSET – INJECTION AREA
SCALE: 1" = 10'

AECOM

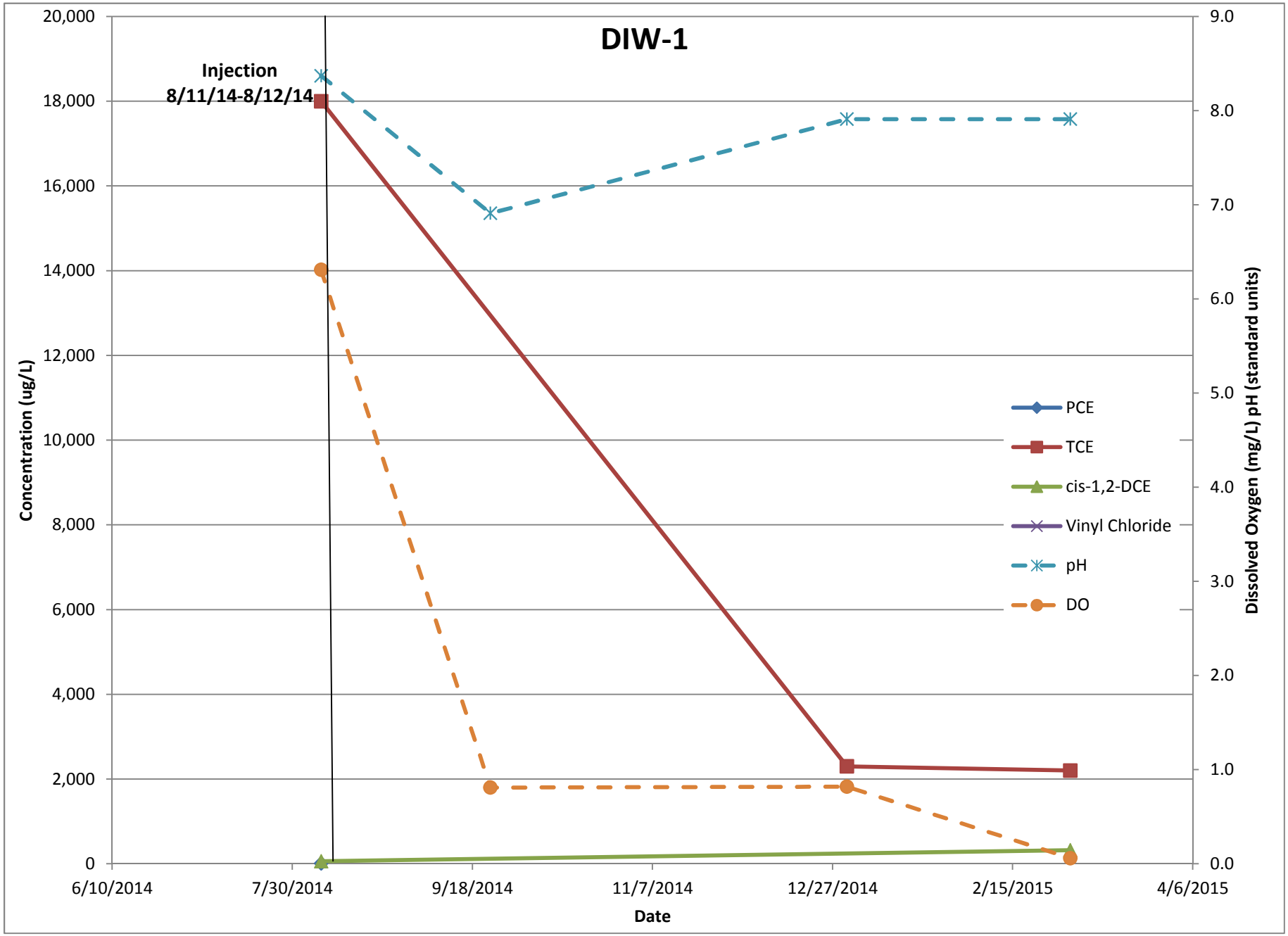
Figure: 2

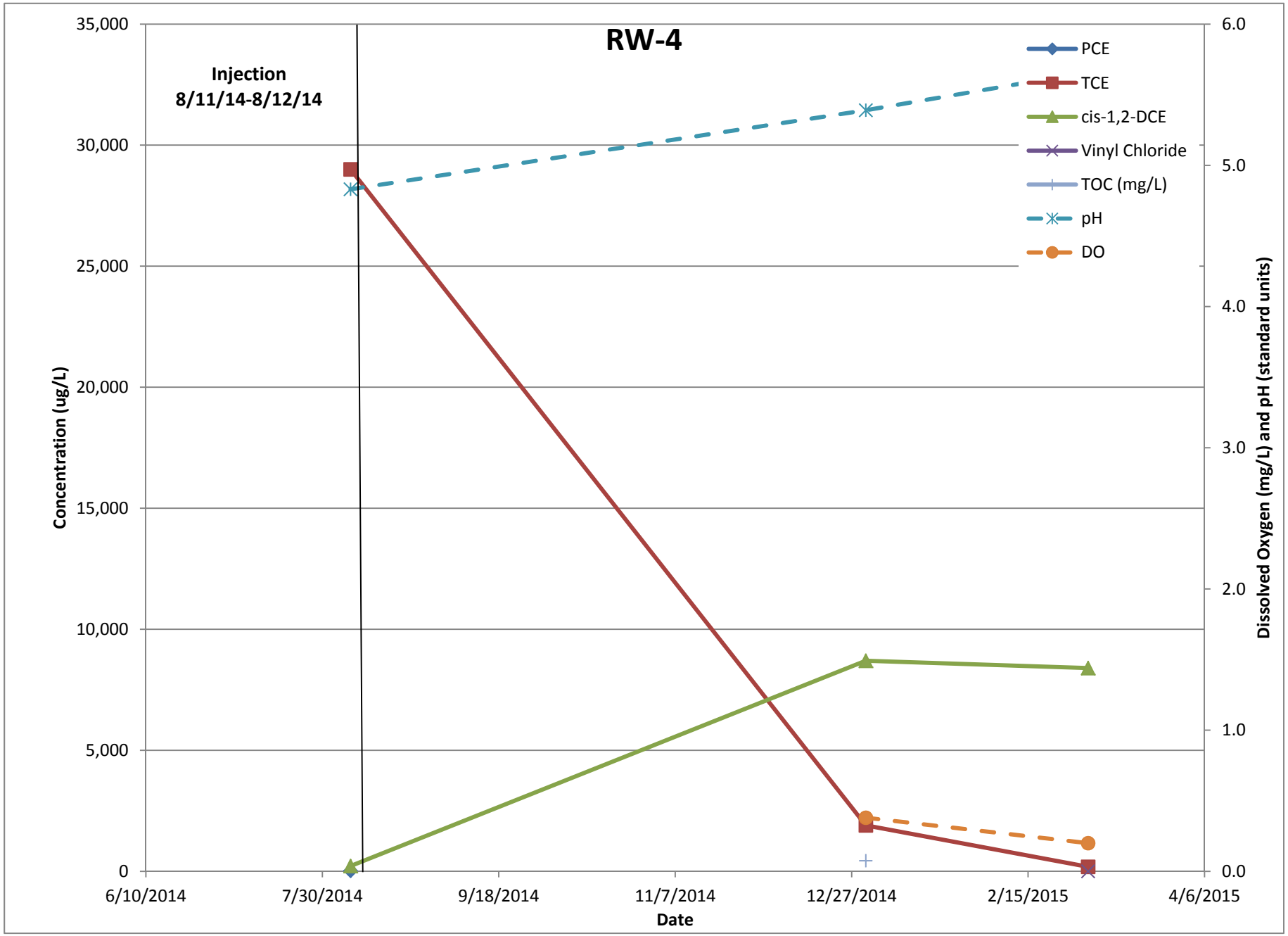
INJECTION PLAN

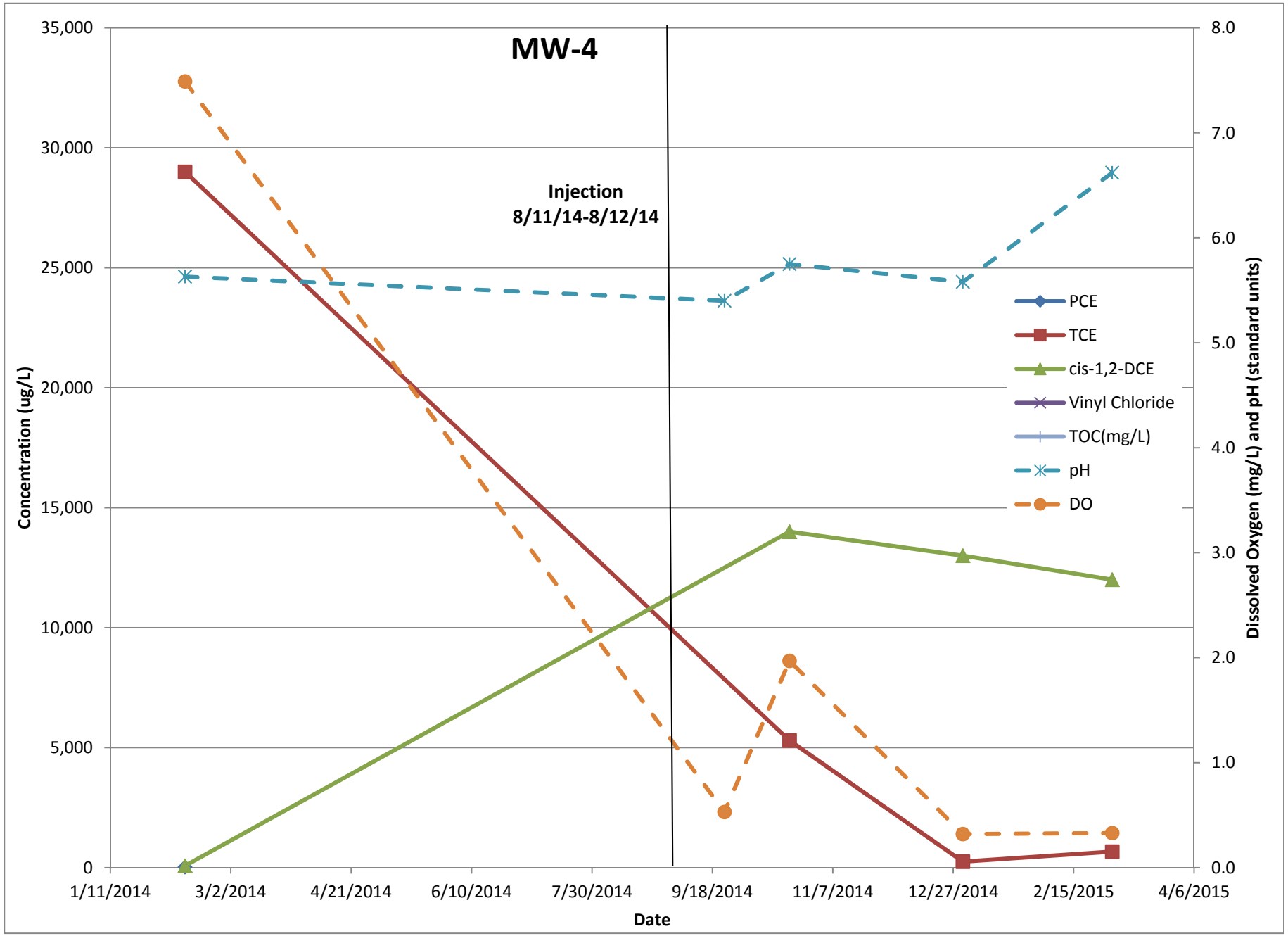
PARKER HANNIFIN CORPORATION
Former Parker Hannifin Corporation Facility
Wake Forest, North Carolina
Project No.: 60285550.2 Date: 2015-05-26

ANSI D 22" x 34"
Approved:
Checked:
Designer: C.C.
Project Management Initials:

Last saved by: CAMPBELLC(2015-05-26) Last Plotted: 2015-06-01
Filename: Z:\CAD\PROJECTS\PIP\PARKER_HANNIFIN\WAKE_FOREST_NC\2015\60285550.2\DWG\FIGURE 2_INJECTION PLAN_5.2015.DWG


DIW-1
Injection
8/11/14-8/12/14
Concentration (ug/L)
Dissolved Oxygen (mg/L) pH (standard units)
Date
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
6/10/2014
7/30/2014
9/18/2014
11/7/2014
12/27/2014
2/15/2015
4/6/2015
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
pH
DO


RW-4
Injection
8/11/14-8/12/14
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
TOC (mg/L)
pH
DO
Concentration (ug/L)
Dissolved Oxygen (mg/L) and pH (standard units)
Date
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
6/10/2014
7/30/2014
9/18/2014
11/7/2014
12/27/2014
2/15/2015
4/6/2015


MW-4
Injection
8/11/14-8/12/14
Concentration (ug/L)
Dissolved Oxygen (mg/L) and pH (standard units)
Date
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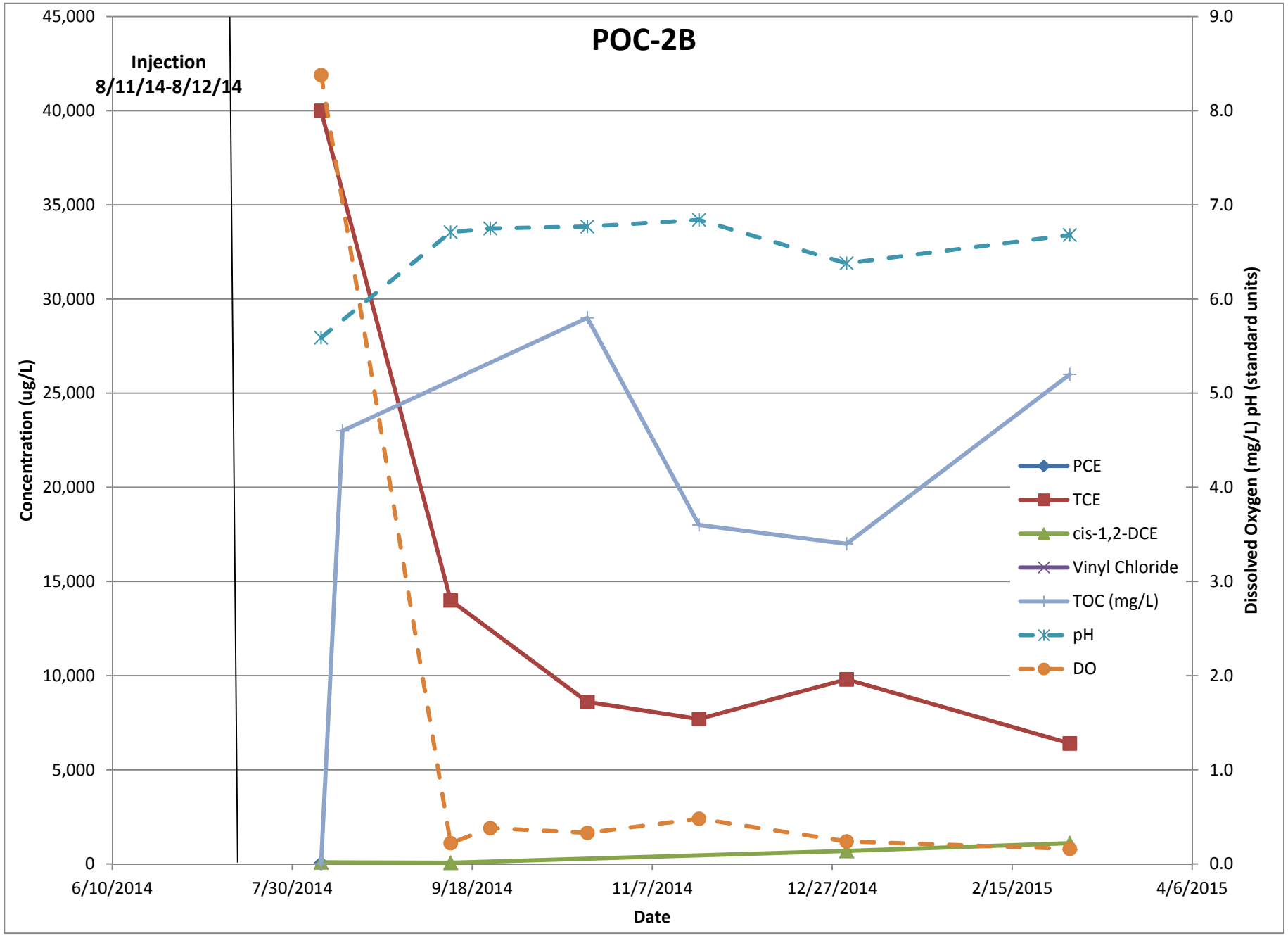
30,000
25,000
20,000
15,000
10,000
5,000
0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1/11/2014
3/2/2014
4/21/2014
6/10/2014
7/30/2014
9/18/2014
11/7/2014
12/27/2014
2/15/2015
4/6/2015
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
TOC(mg/L)
pH
DO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Injection
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Concentration (ug/L)
Dissolved Oxygen (mg/L) pH (standard units)
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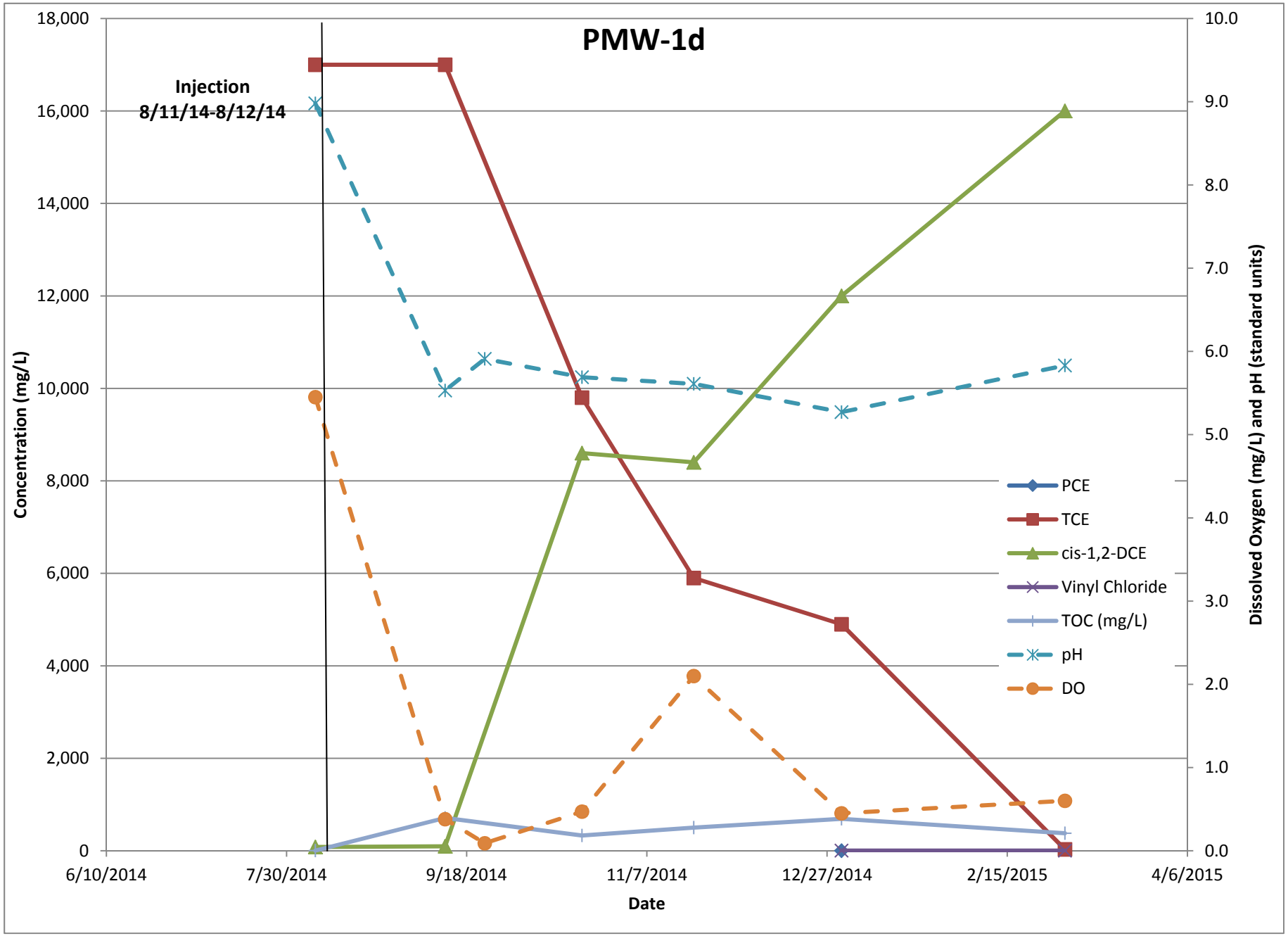
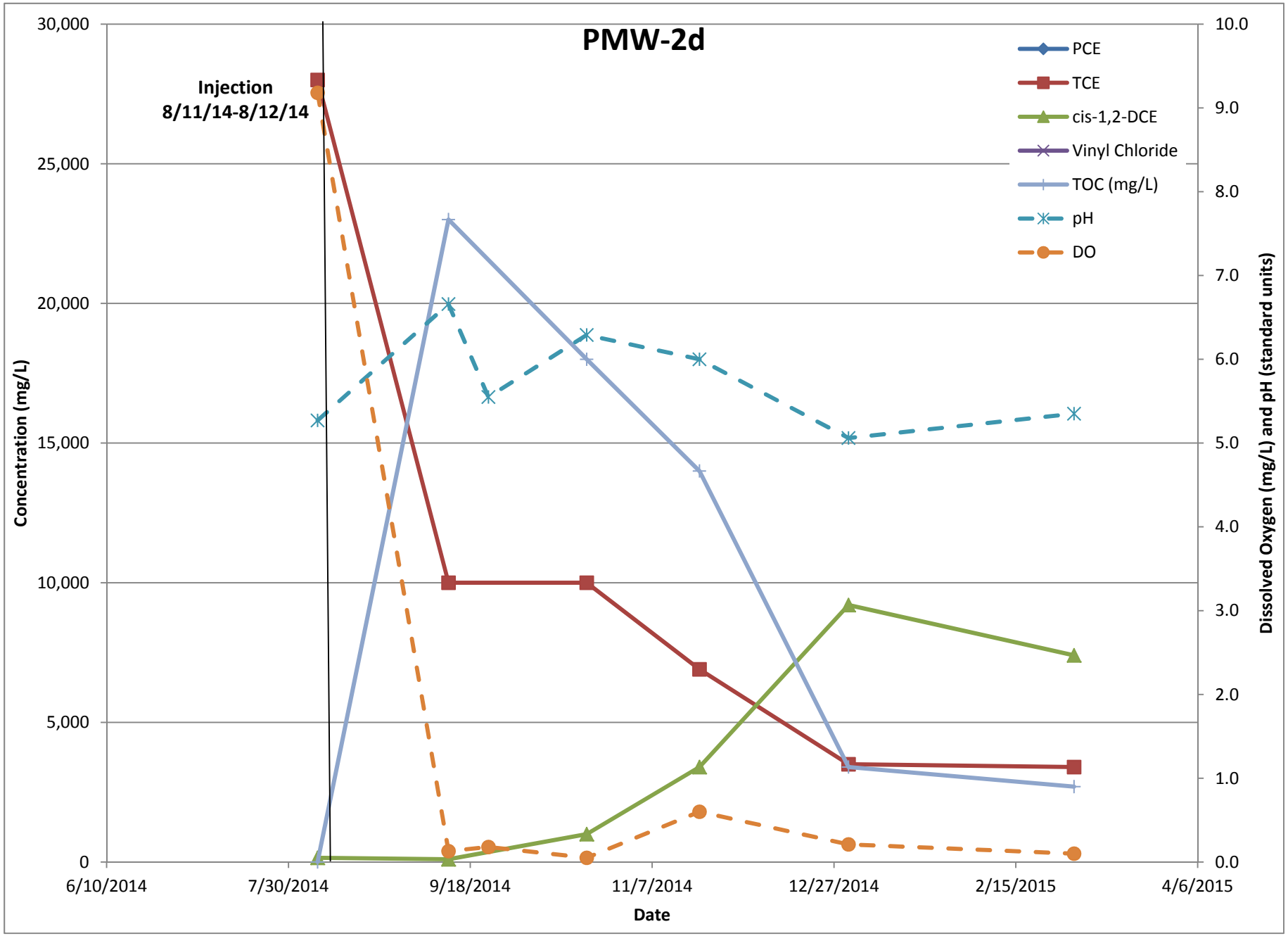
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
6/10/2014
7/30/2014
9/18/2014
11/7/2014
12/27/2014
2/15/2015
4/6/2015
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
TOC (mg/L)
pH
DO


PMW-1d
Injection
8/11/14-8/12/14
Concentration (mg/L)
Dissolved Oxygen (mg/L) and pH (standard units)
Date
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
6/10/2014
7/30/2014
9/18/2014
11/7/2014
12/27/2014
2/15/2015
4/6/2015
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
TOC (mg/L)
pH
DO


PMW-2d
Injection
8/11/14-8/12/14
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
TOC (mg/L)
pH
DO
Concentration (mg/L)
Dissolved Oxygen (mg/L) and pH (standard units)
Date
30,000
25,000
20,000
15,000
10,000
5,000
0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
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6/10/2014
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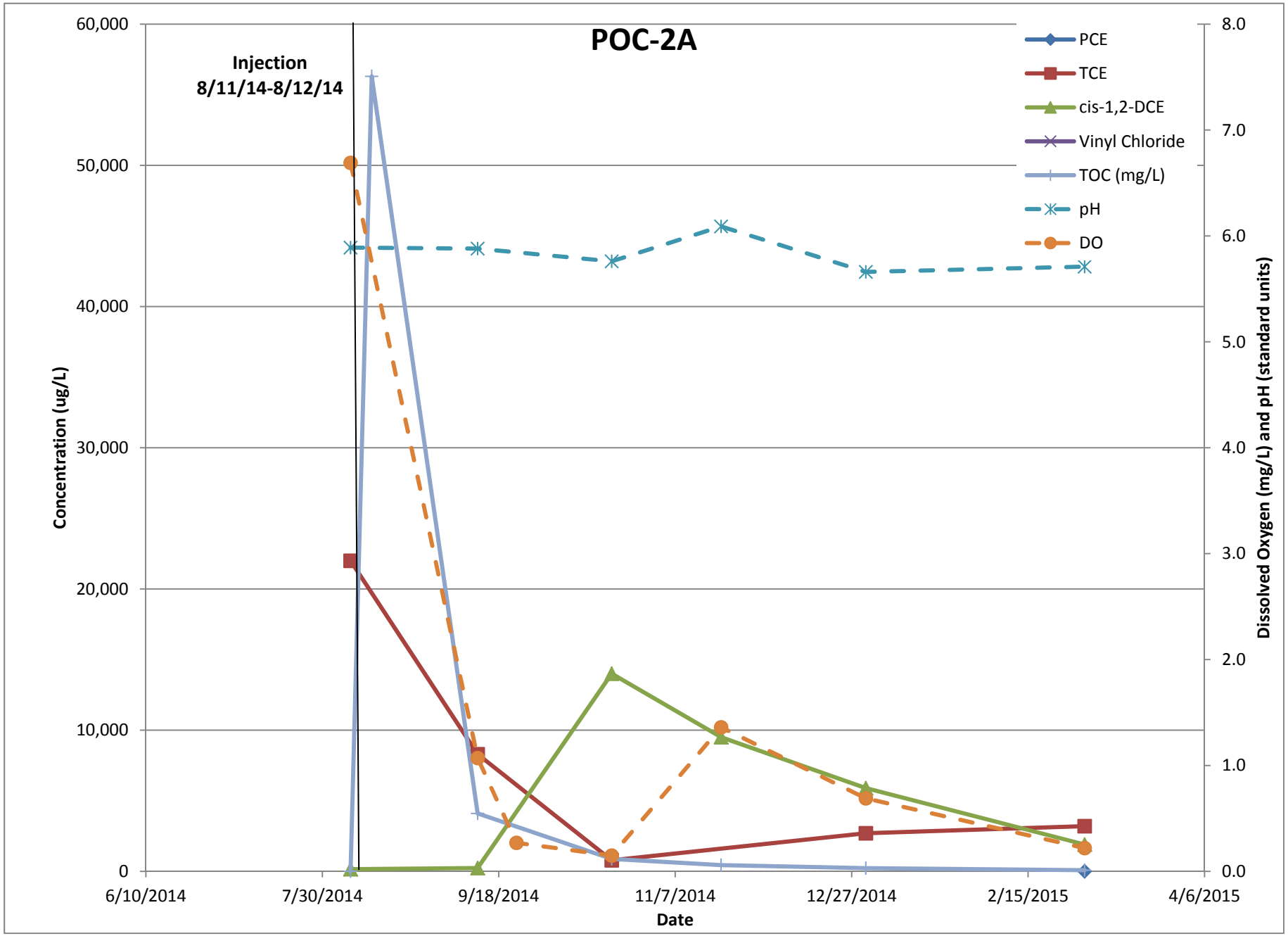
2/15/2015
4/6/2015


POC-2A
Injection
8/11/14-8/12/14
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
TOC (mg/L)
pH
DO
Concentration (ug/L)
Dissolved Oxygen (mg/L) and pH (standard units)
Date
60,000
50,000
40,000
30,000
20,000
10,000
0
8.0
7.0
6.0
5.0
4.0
3.0
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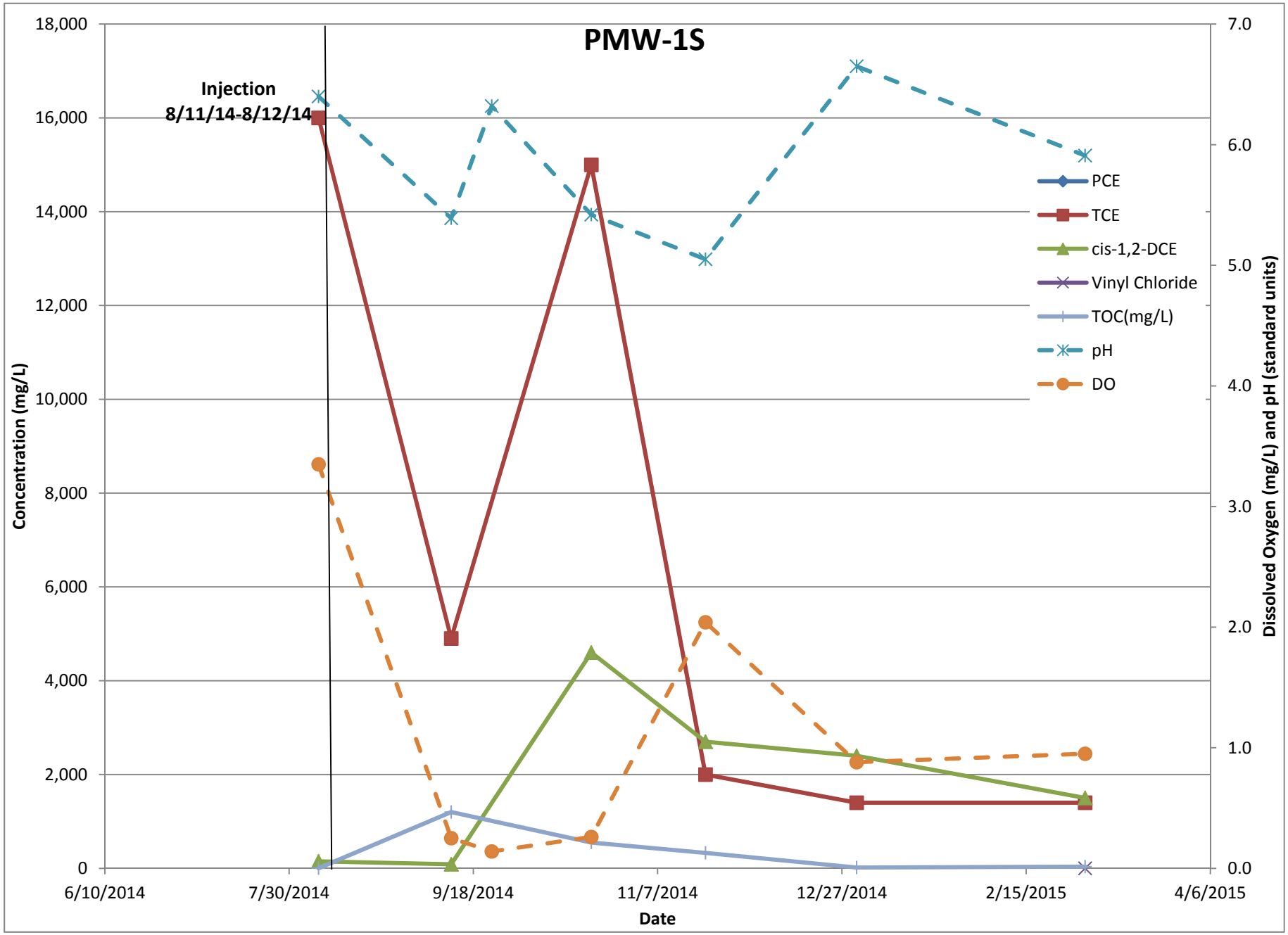
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Dissolved Oxygen (mg/L) and pH (standard units)
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4,000
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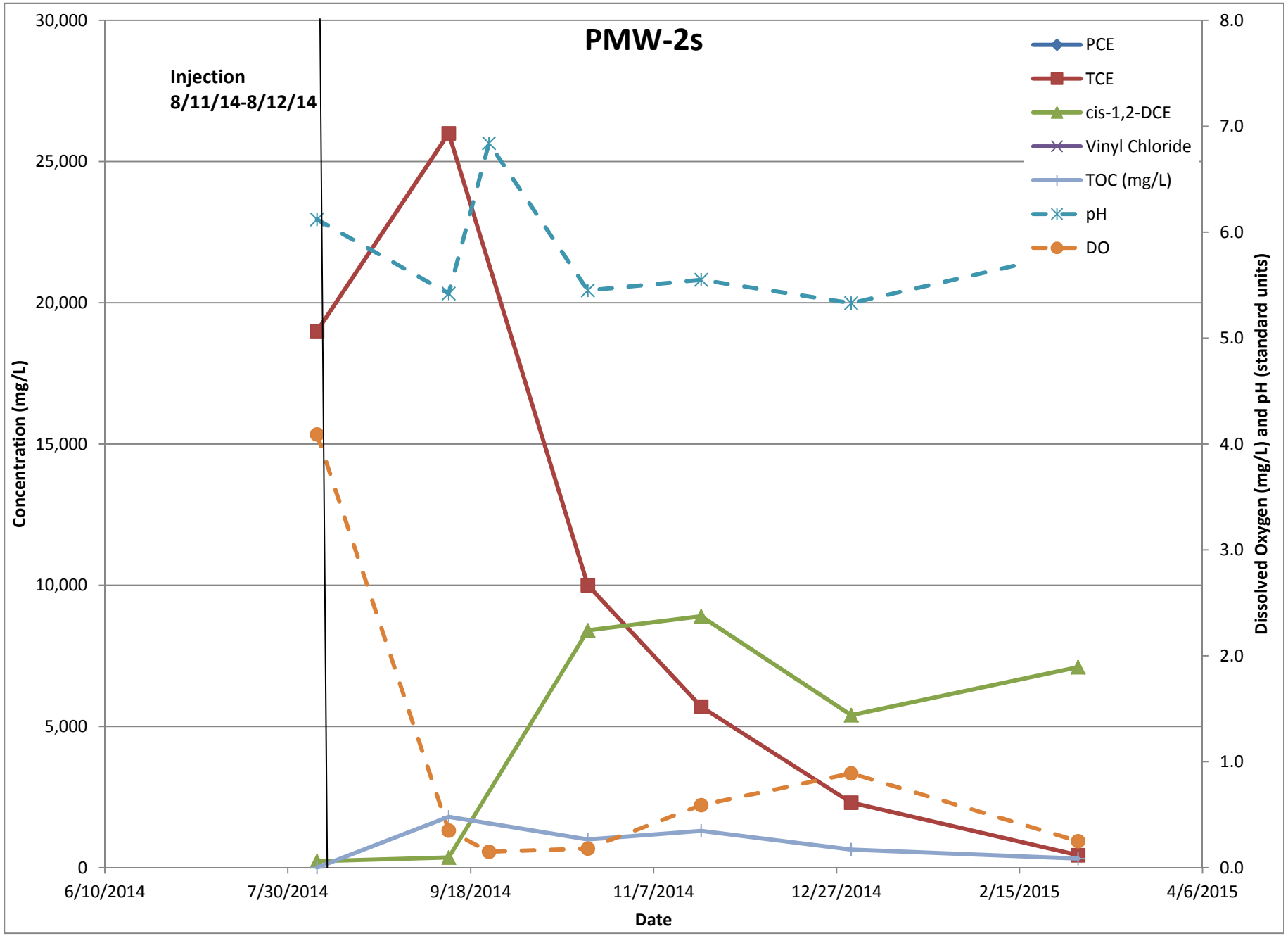
6.0
5.0
4.0
3.0
2.0
1.0
0.0
6/10/2014
7/30/2014
9/18/2014
11/7/2014
12/27/2014
2/15/2015
4/6/2015
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
TOC(mg/L)
pH
DO


PMW-2s
Injection
8/11/14-8/12/14
PCE
TCE
cis-1,2-DCE
Vinyl Chloride
TOC (mg/L)
pH
DO
Concentration (mg/L)
Dissolved Oxygen (mg/L) and pH (standard units)
Date
30,000
25,000
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6.0
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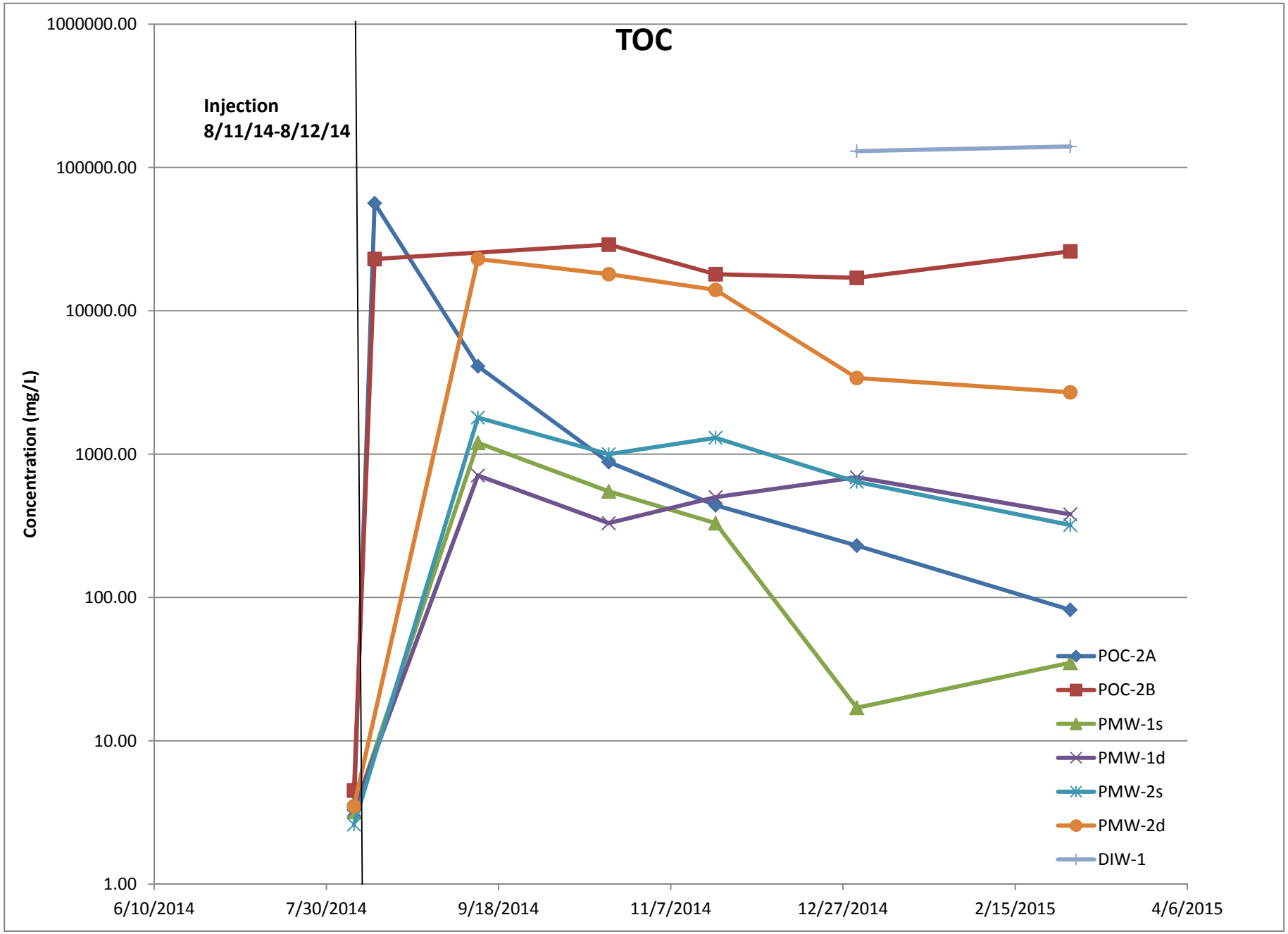
4/6/2015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Injection
8/11/14-8/12/14
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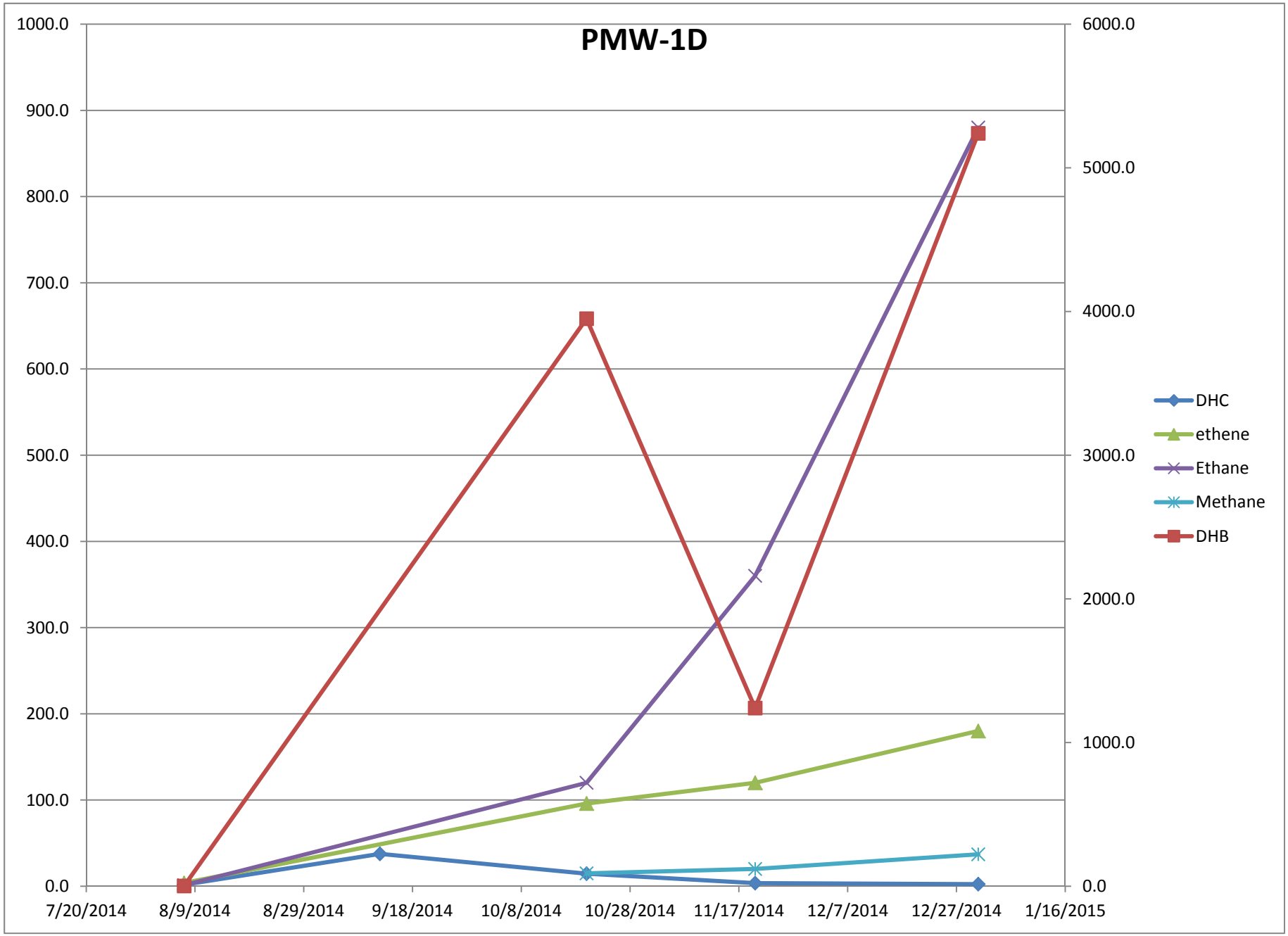
6/10/2014
7/30/2014
9/18/2014
11/7/2014
12/27/2014
2/15/2015
4/6/2015
POC-2A
POC-2B
PMW-1s
PMW-1d
PMW-2s
PMW-2d
DIW-1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12/7/2014
12/27/2014
1/16/2015
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Ethane
Methane
DHB