The Use of Biostimulation to Safely Treat a Chlorinated VOC Plume in a Residential Community

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Project Summary

- Discovery of complete vapor intrusion (VI) pathway in new residential development required immediate mitigation
- Sub-slab Depressurization Systems effectively deployed to address VI mitigation
- In-situ biostimulation was implemented to address groundwater CVOC plume with TCE concentrations as high as 50,000 – 120,000 ug/l
- Adaptive approach to reagent injection was implemented
- Successful plume reduction of 2 – 4 orders of magnitude over 3 year period

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Site Location

Former Manufacturing Facility

- Historical badge manufacturer, operated at site from mid 1800s to mid 1980s
- Discharges of VOCs, metals to stream and to sludge pits (permitted discharges)
- Bought by developer in early 2000s

Development Proceeded Along with Environmental Assessment

- Chlorinated Volatile Organic Compounds (VOCs) and metals identified in soil and groundwater
- Impacted soils were either removed off-Site or treated and reused on-Site as fill material
- Site “closed” under state environmental regulations
- Total of 38 units built

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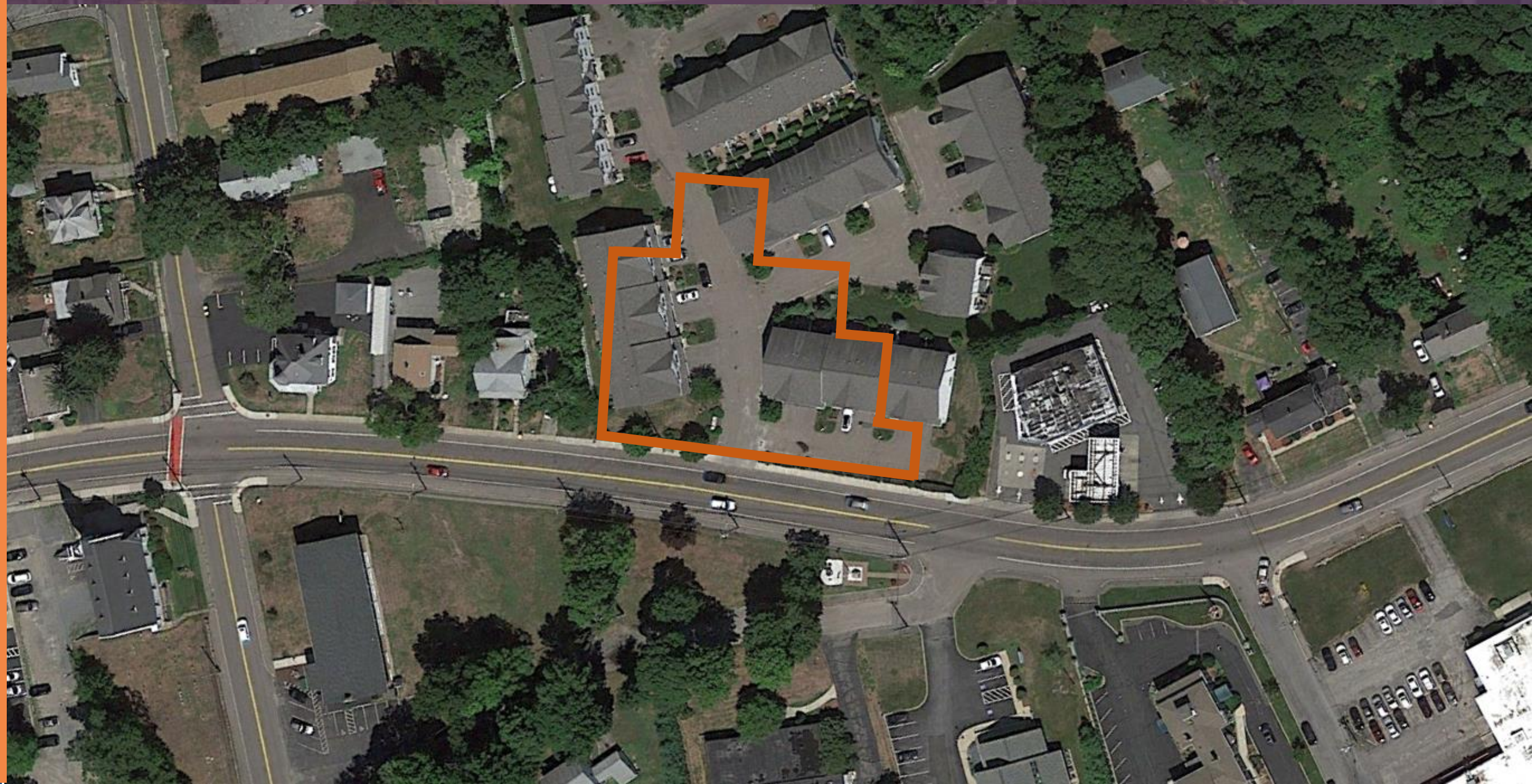
Original Industrial Site

Current Residential Site



Identification of the Problem

- MassDEP audit identifies complete vapor intrusion (VI) pathway for TCE
- Indoor air impacts found in multiple units
- Primary VI source was determined to be shallow soil that had been relocated during construction
- Groundwater CVOC concentrations >50,000 ug/L and quite variable
- Immediate Response Actions required
  - To address vapor intrusion pathway
  - To eliminate or reduce concentrated CVOC plume

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Site Conditions

- Subsurface Conditions
  - 4 – 8 feet of fill overlying coarse sand and gravel (20 – 25 ft thick)
  - Up to 4 feet thick peat layer in some areas

- Groundwater
  - About 7 – 8 feet below grade
  - Estimated hydraulic conductivity about 10 ft/day
  - Flow to south- southeast
  - Estimated seepage velocity through treatment zone is 180 ft/year

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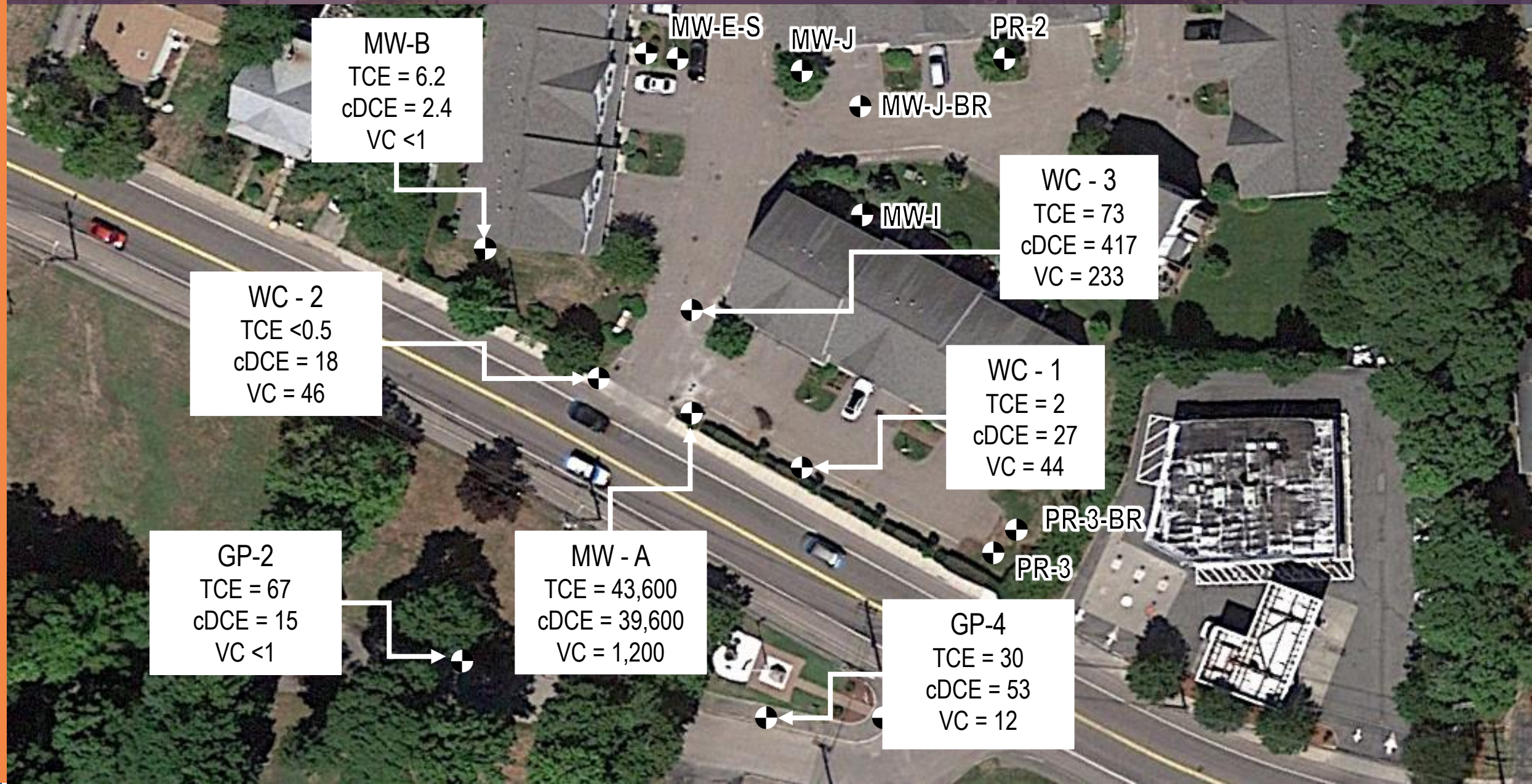
Groundwater Concentrations May 2013 (ug/L)



Remedial Approach Overview

- Sub-slab depressurization systems installed to address TCE VI issue
- Source Area Remedial Objectives were defined
  - Reduce GW concentrations to < UCLs in 2 – 3 years
  - Sufficient mass flux reduction to achieve stable plume & allow MNA for long term
- Alternatives evaluated to address elevated source groundwater concentrations
- In-situ bioremediation selected
  - Good indicators of ongoing biodegradation
  - Cost-effective
  - Safe

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Biostimulation Approach

- Small area did not warrant pilot approach
- Prepare for multiple injection approach
- Initial reagent selected to stimulate either biotic or abiotic reactions
- Perform quarterly groundwater monitoring after injections
- 3 Separate Injections
  - 8 to 12 temporary injection points
  - 1.5 inch diameter GeoProbe® rods
  - Injection from 15 to 30 feet below grade, focused on 15 to 20 foot interval
- Varied injection solution and locations based on groundwater monitoring results

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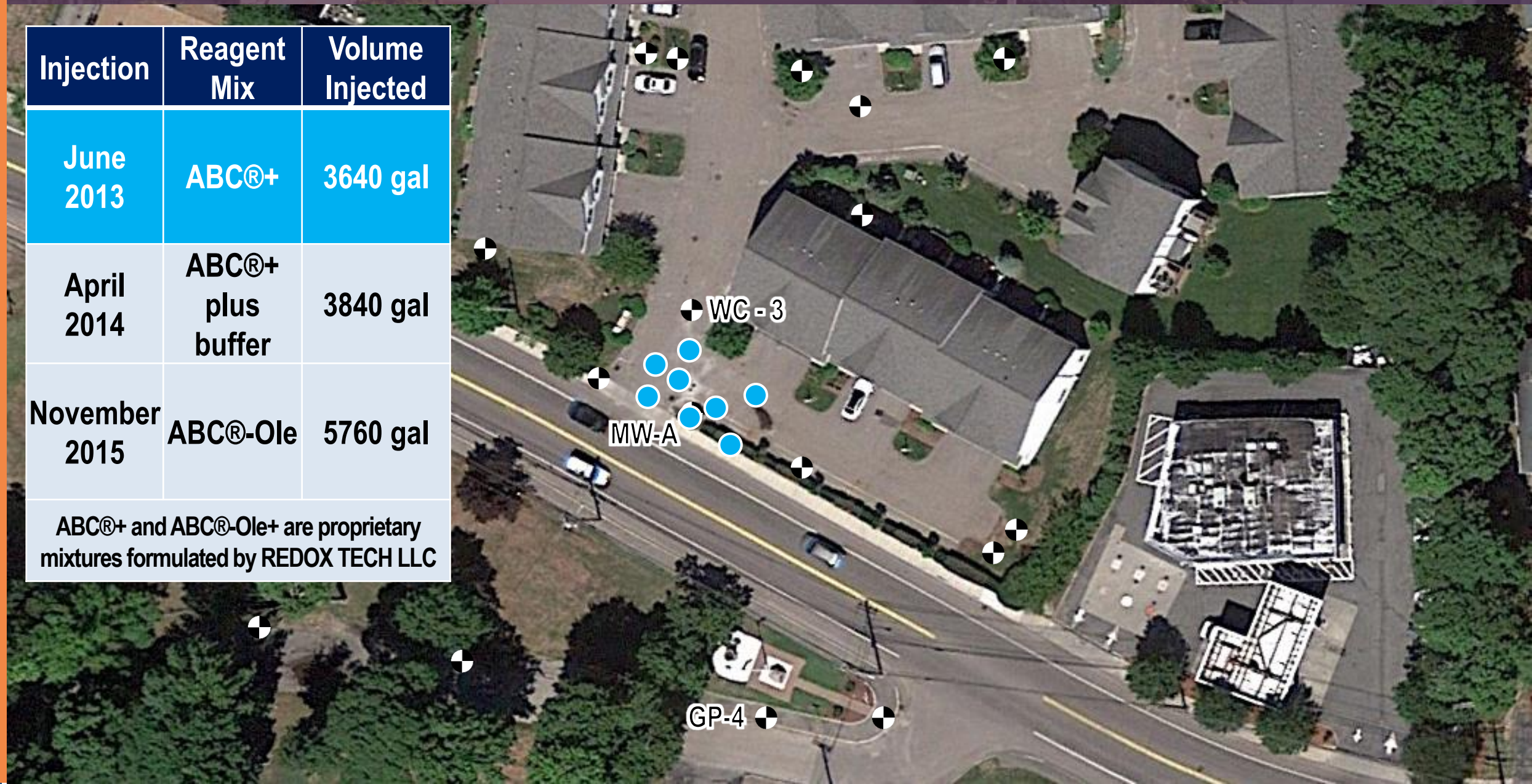
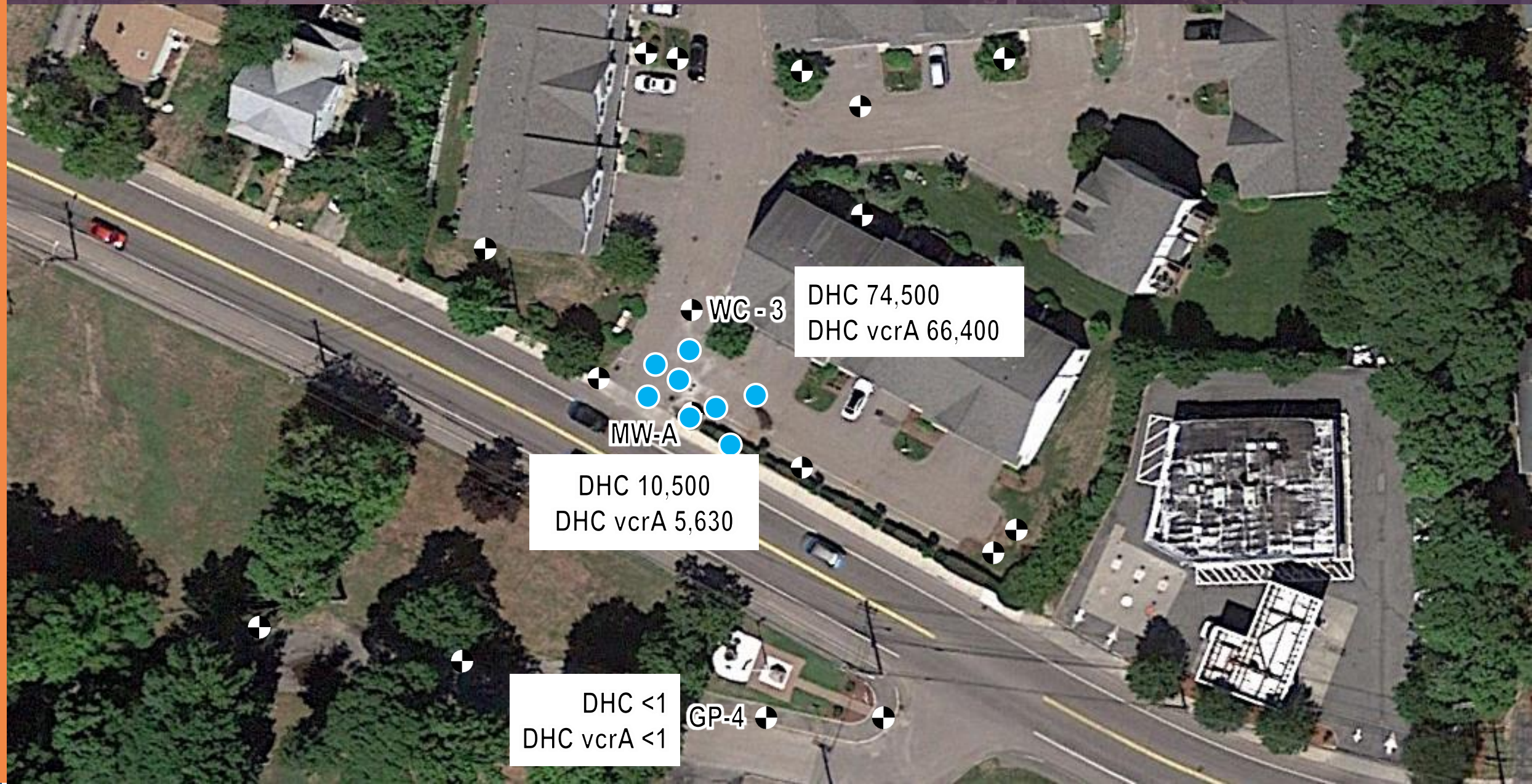
Injection Locations – June 2013

Injection	Reagent Mix	Volume Injected
June 2013	ABC®+	3640 gal
April 2014	ABC®+ plus buffer	3840 gal
November 2015	ABC®-Ole	5760 gal

ABC®+ and ABC®-Ole+ are proprietary mixtures formulated by REDOX TECH LLC



Colony Counts – December 2013 (CEQ/mL)



Injection Locations – April 2014

Injection	Reagent Mix	Volume Injected
June 2013	ABC®+	3640 gal
April 2014	ABC®+ plus buffer	3840 gal
November 2015	ABC®-Ole	5760 gal

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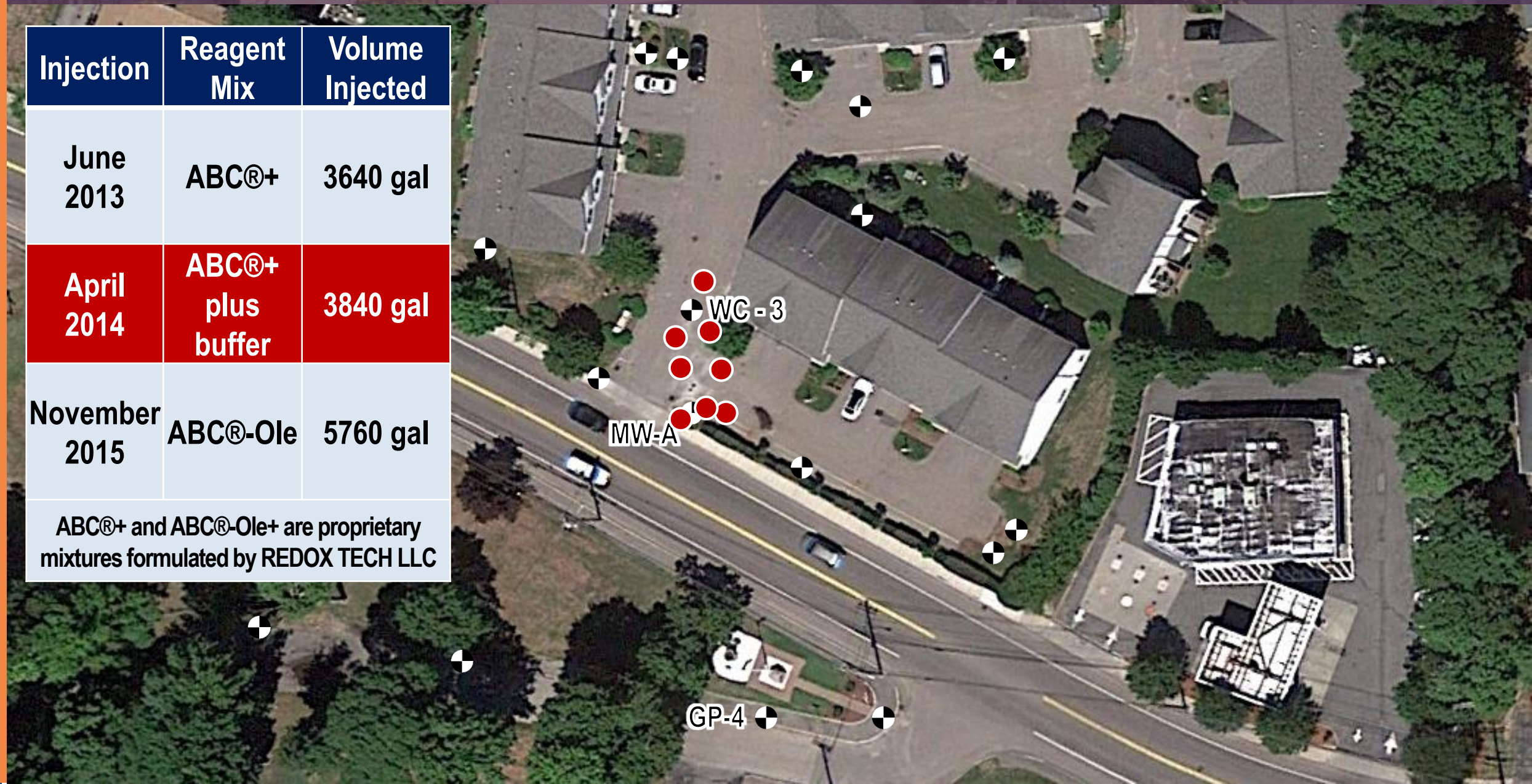

Injection Locations – November 2015

Injection	Reagent Mix	Volume Injected
June 2013	ABC®+	3640 gal
April 2014	ABC®+ plus buffer	3840 gal
November 2015	ABC®-Ole	5760 gal

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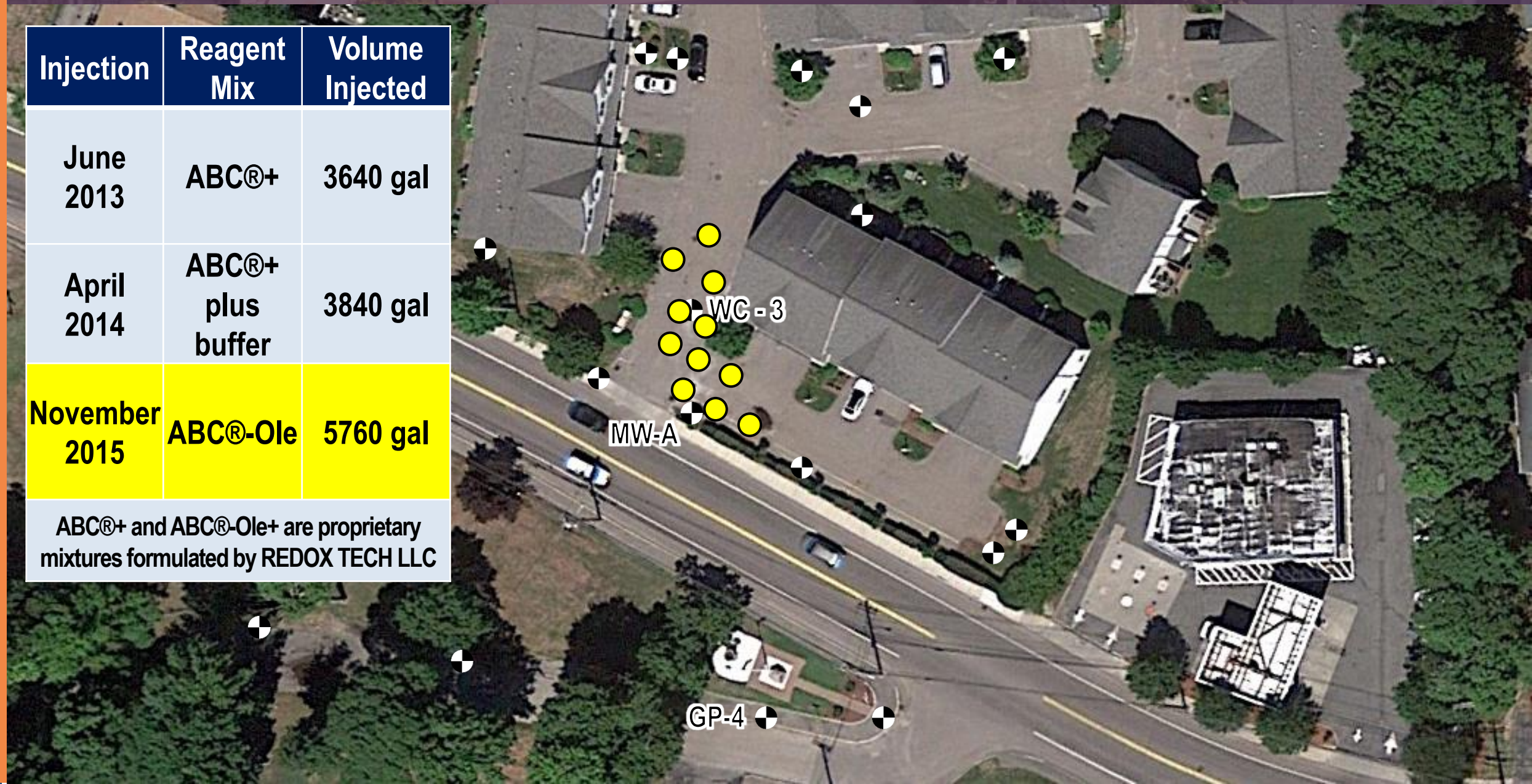

All Injection Locations

Injection	Reagent Mix	Volume Injected
June 2013	ABC®+	3640 gal
April 2014	ABC®+ plus buffer	3840 gal
November 2015	ABC®-Ole	5760 gal

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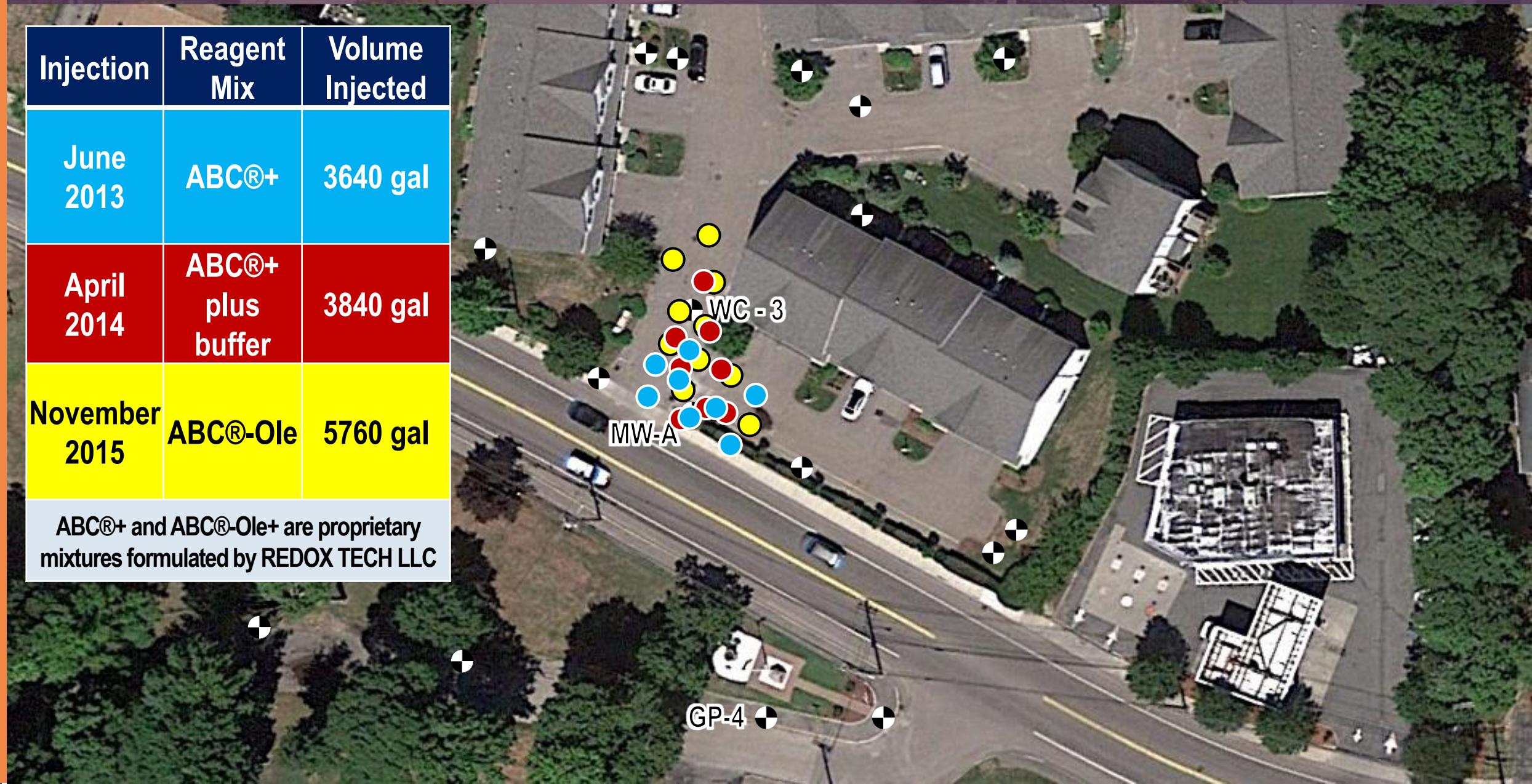

Summary of Adjustments to Injections

OBSERVATION	ACTIONS
After Injection 1	
Decline in pH at MW-A	Add bicarbonate buffer
Increase in cDCE and VC at WC-3 (upgradient)	Reconfigure injection locations
After Injection 2	
Stall of cDCE and VC degradation at MW-A	Maintain buffer
Increased DOC and dissolved iron at GP-4 (across street)	Shift to esterified fatty acids
	-Faster acting, more stable, longer lasting
	Additional wells in upgradient area

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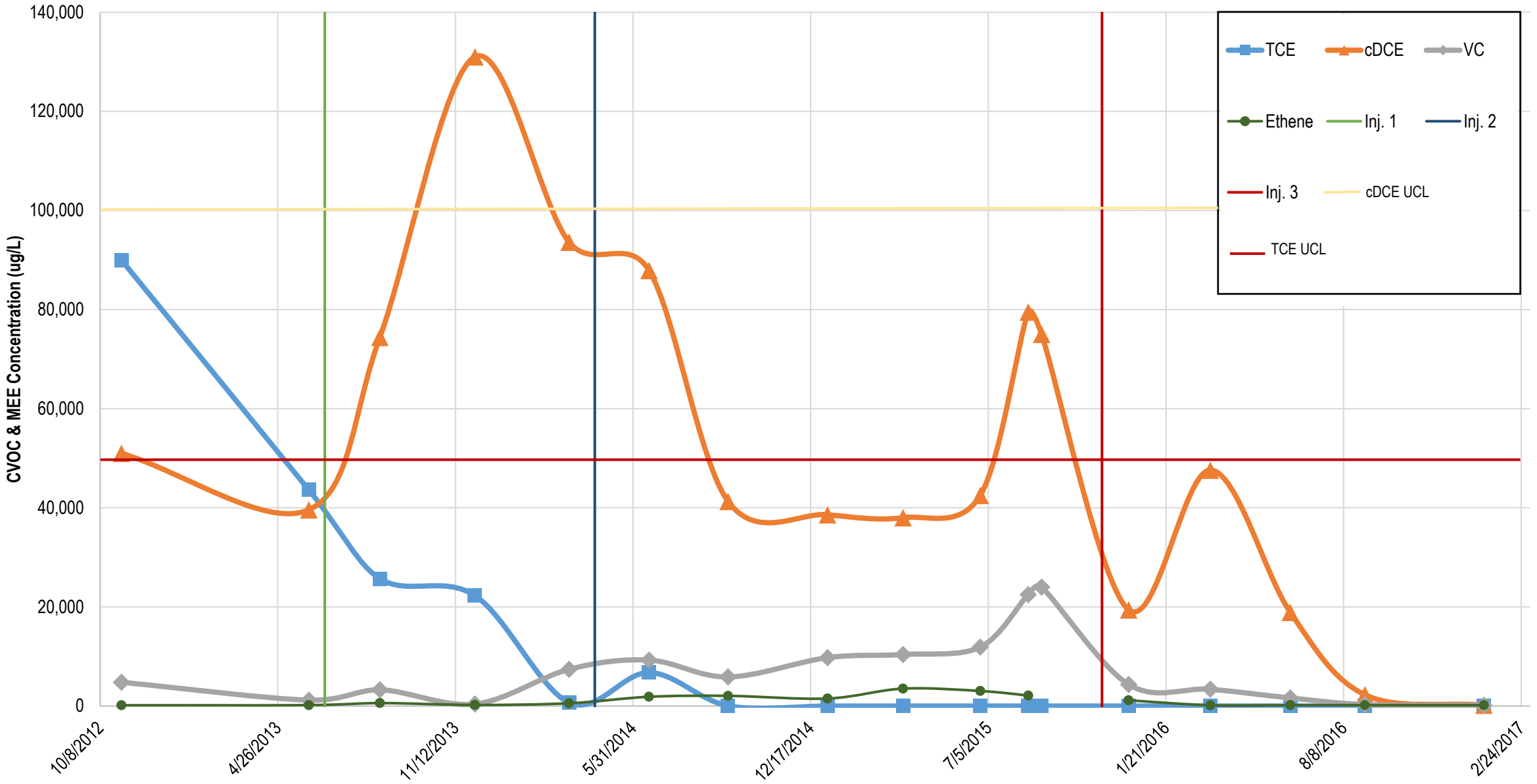
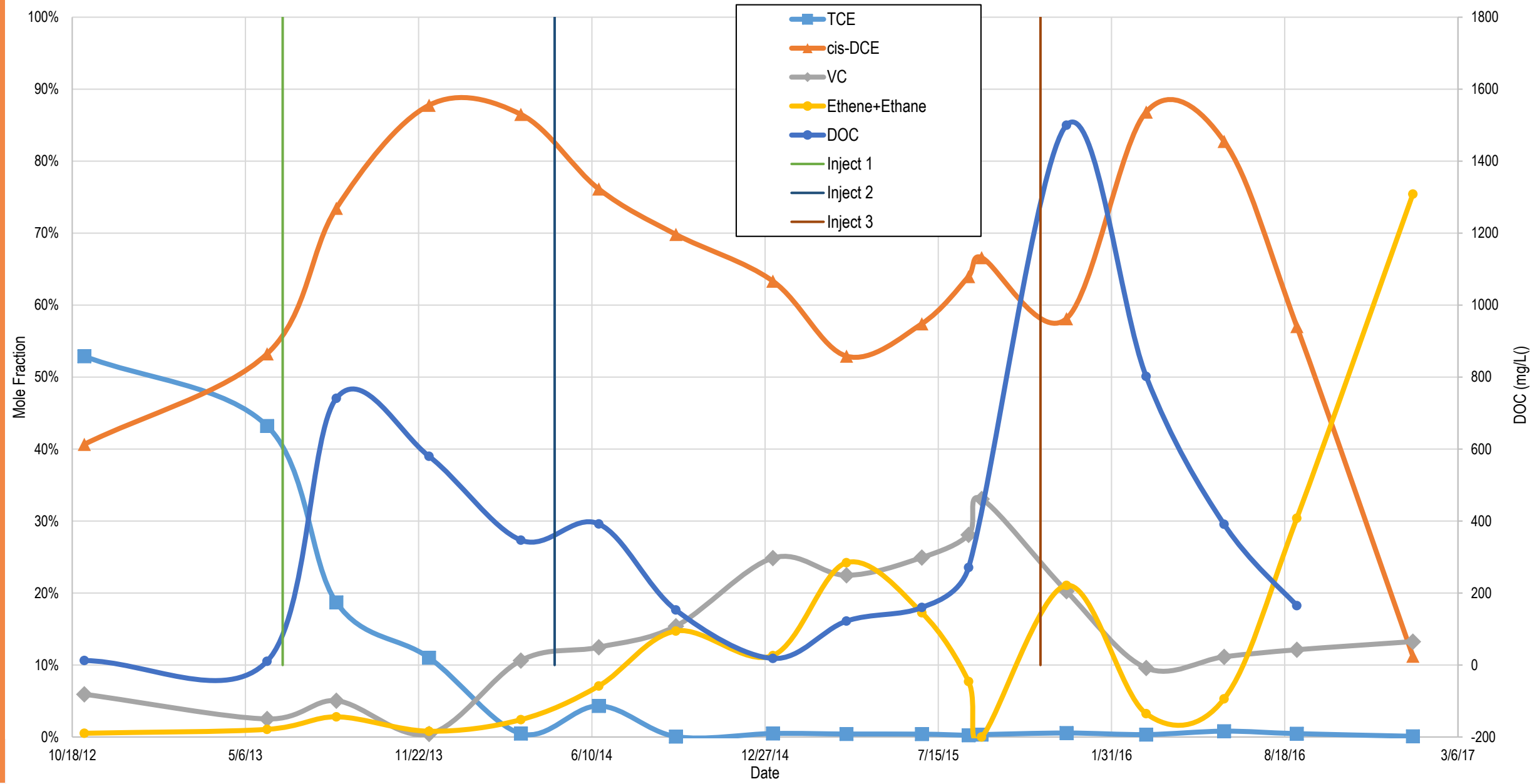
MW-A: CVOC Concentrations



MW-A: Mole Fraction Plot



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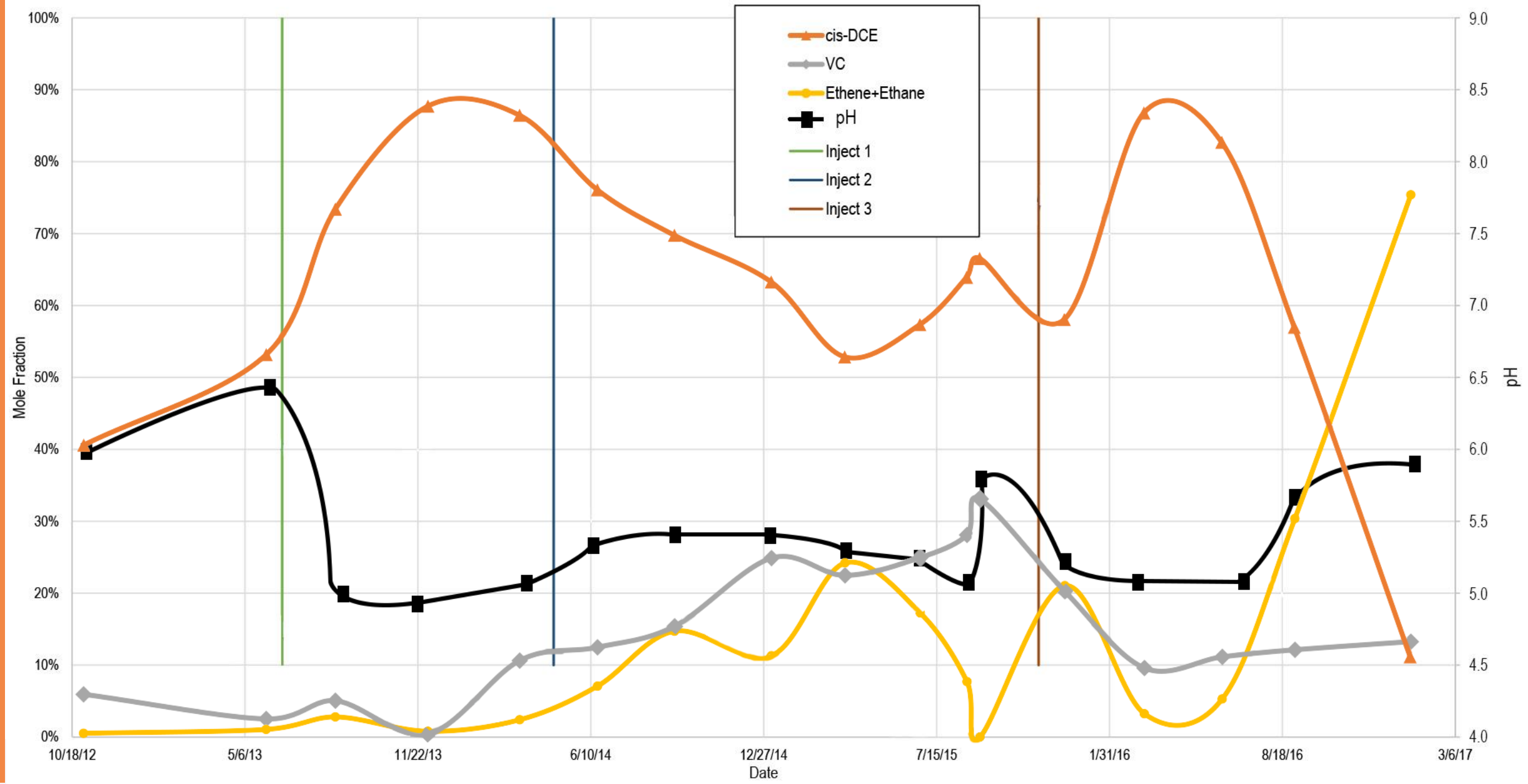
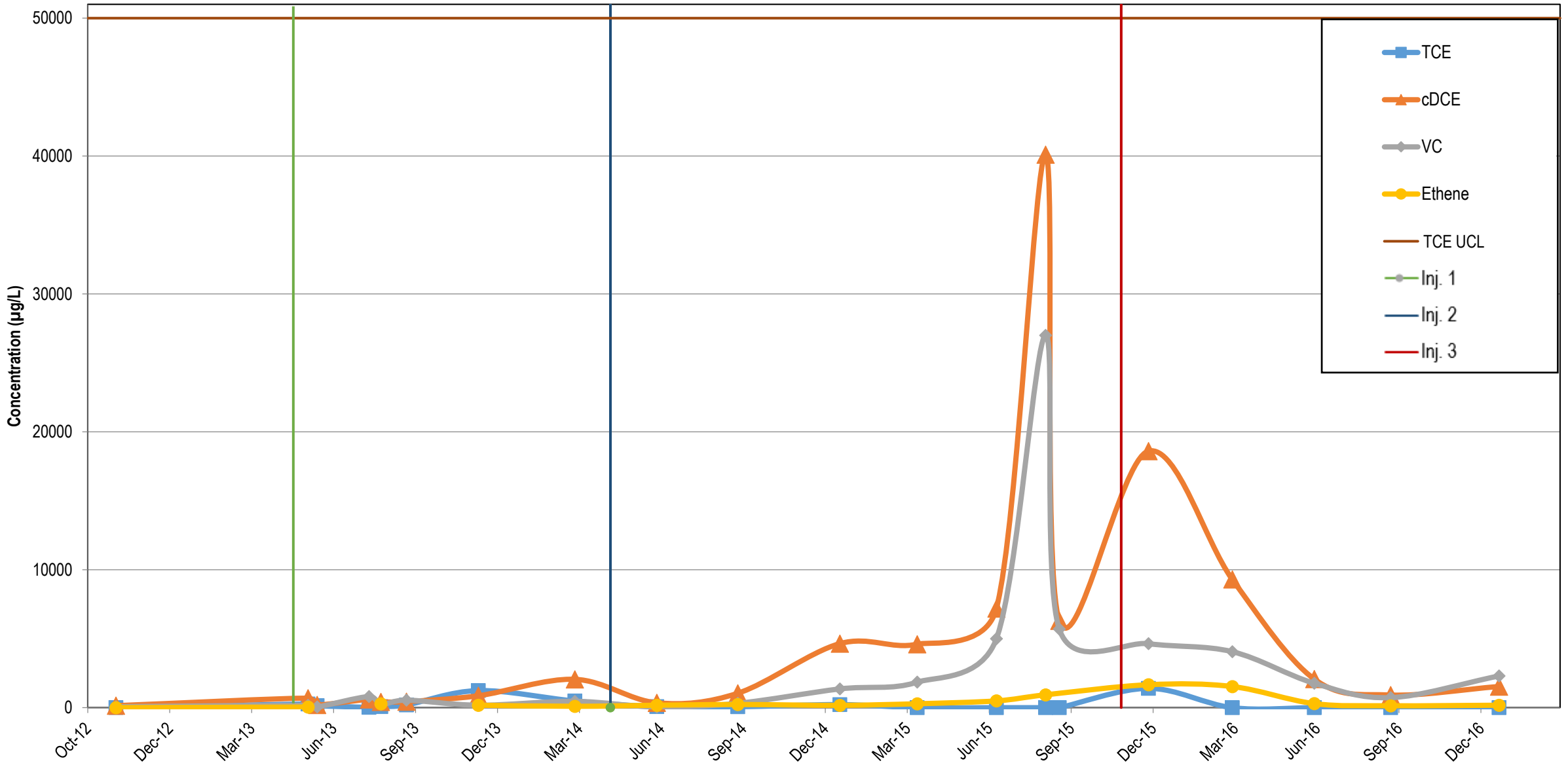


WC-3: CVOC Concentrations



Take-Aways

- Biostimulation can be effective at reducing relatively high CVOC concentrations
- Successfully and cost-effectively reduced CVOC concentrations by 2 – 4 orders of magnitude
- Adaptive implementation approach is critical
  - Plan for flexible, iterative program
  - Collect sufficient data to allow informed decisions
  - Modify injection strategy as appropriate
- Appears that biotic processes were predominant at this site

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Questions?

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