



In-situ LNAPL Treatment Following Pipeline Transmission Rupture

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Site Background

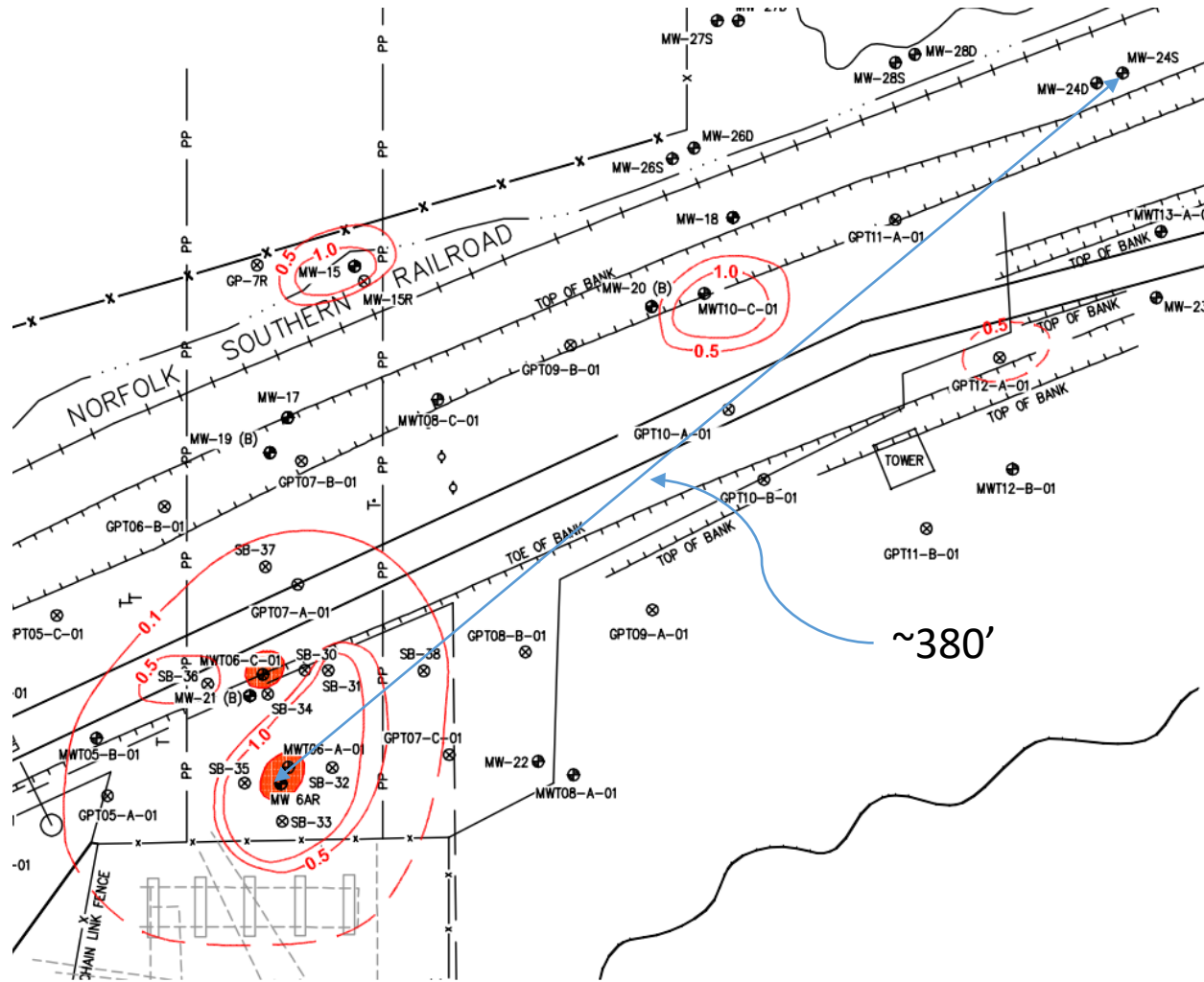
- Pipeline Transmission Facility in Southern Michigan
 - ~1,700 barrels of gasoline fuel released in June 2000 following failure of a 16” stopple fitting
 - ~1,400 barrels were recovered during initial response
 - 30,000 tons of impacted soil removed and disposed
 - Groundwater extraction system capable of up to 25,000 gallons per month operated until 2012
 - Quarterly groundwater monitoring conducted to present

Site Background (cont.)

- **Geology**

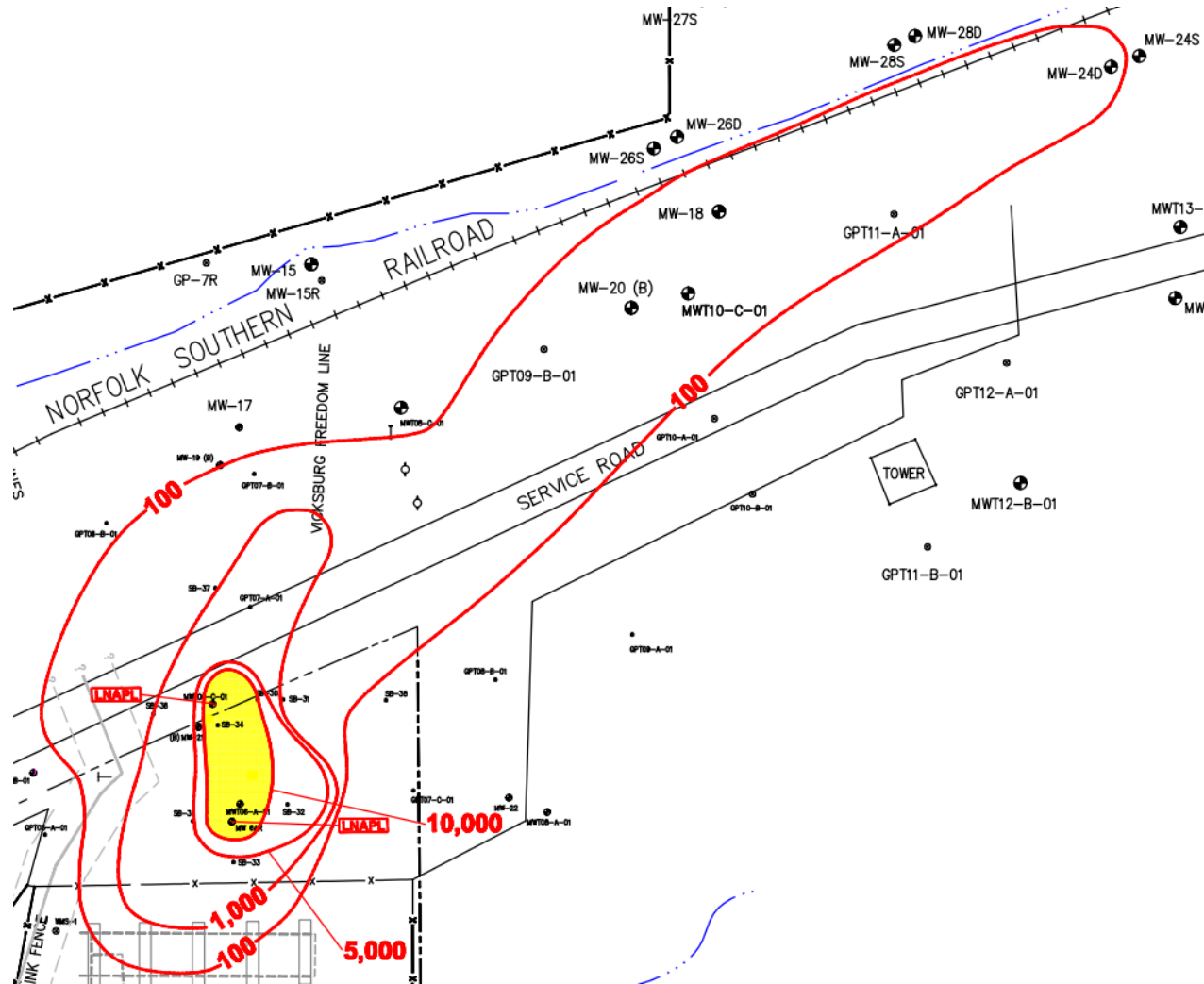
- Thumb Upland Physiographic Region of Michigan's Lower Peninsula
- Predominantly sand and gravel varying 8' to 22' thick
- Saginaw Formation: sandstone and shale
- Groundwater 9' to 14' bgs
 - Unconsolidated sediment aquifer
 - Bedrock aquifer
 - Groundwater analytical indicated hydraulic connection between the 2 aquifers

Site Background (cont.) – CSM 1Q2013



- Soil sampling indicated sorbed mass begins at ~4' to 5' bgs and extends below groundwater
 - Elevated PID readings in saturated soil, but soil not delineated below WT

Site Background (cont.) – CSM 1Q2013

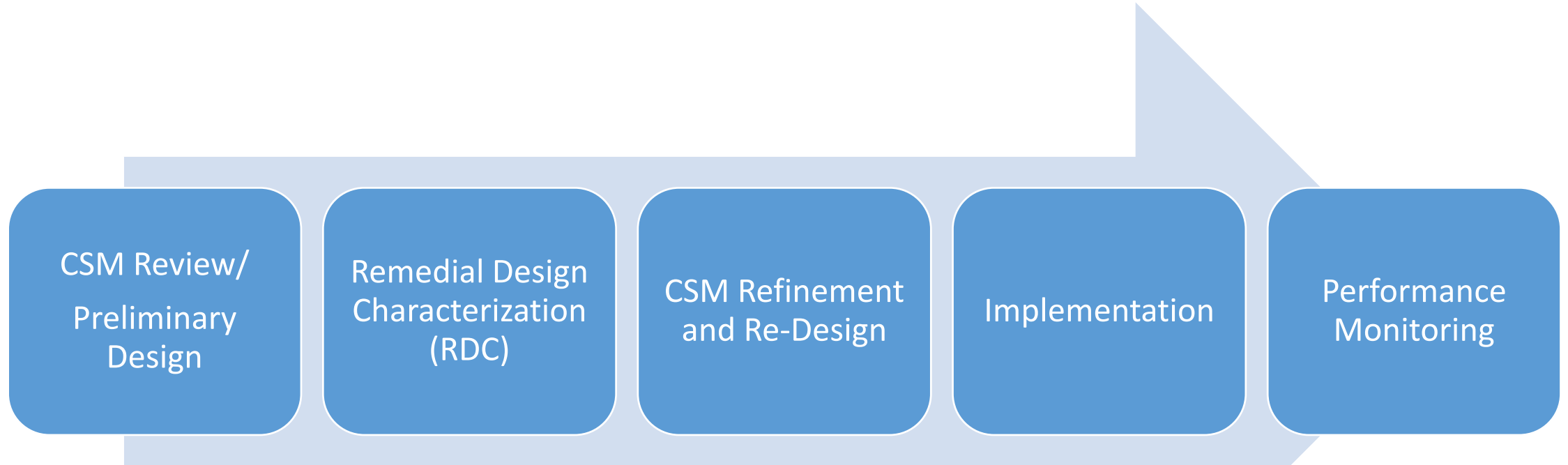


- Groundwater primarily impacted in unconsolidated sediments
 - LNAPL present as a film in on-site monitoring wells
 - Low-level dissolved constituents detected in distal shallow bedrock aquifer

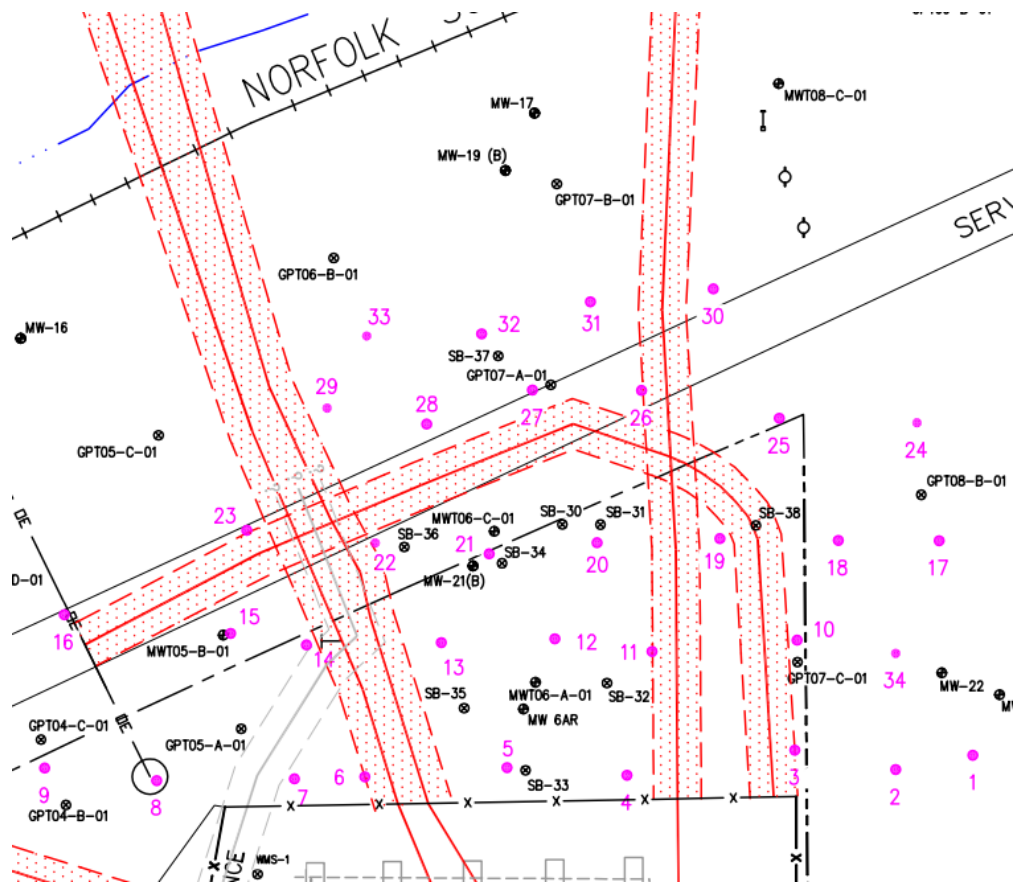
Remedial Objectives

- MDEQ requested an updated Remedial Action Plan
 - No specified soil remediation goal
 - Significant reduction in groundwater COC concentrations
 - Elimination of measurable LNAPL in site monitoring wells
- AST contacted in early 2013 to provide a remedial option
 - Preliminary Design based on existing CSM for budgeting
 - Remedial Design Characterization
 - Pilot Scale Injection – Trap & Treat[®] BOS 200[®]
 - Full Scale Injection – Trap & Treat[®] BOS 200[®]

“The Approach”



Remedial Design Characterization



Thirty-four (34) soil borings to bedrock

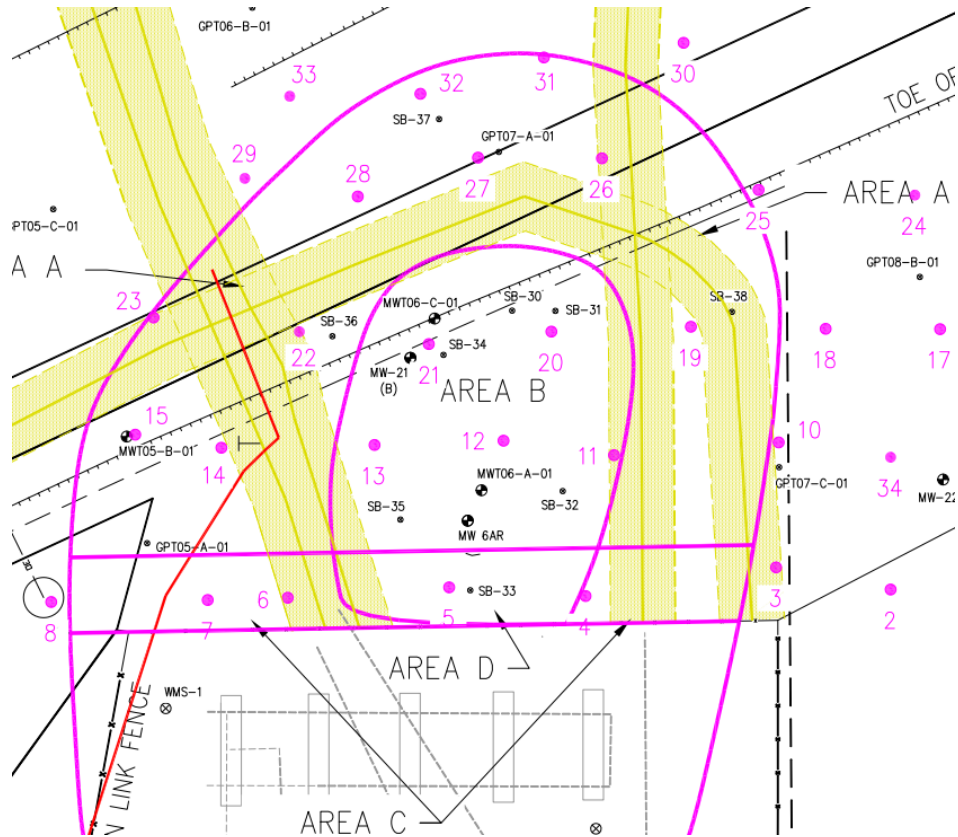
- Continuous sampling every 2-feet and submitted for analysis
- VOCs 8260B: Speciated VOCs constituents, total volatile hydrocarbons (TVPH)

Thirty-four (34) nested well pairs in completed boreholes

- Discrete intervals for vertical delineation
- Deep interval screened from bedrock +4'
- Shallow interval separated by bentonite seal
- VOCs 8260B, Anions 300.1

Laboratory analysis performed at no cost to project

Remedial Design Characterization (cont.)



Original Design based on Pre-RDC CSM

Soil and Groundwater Standards Defined

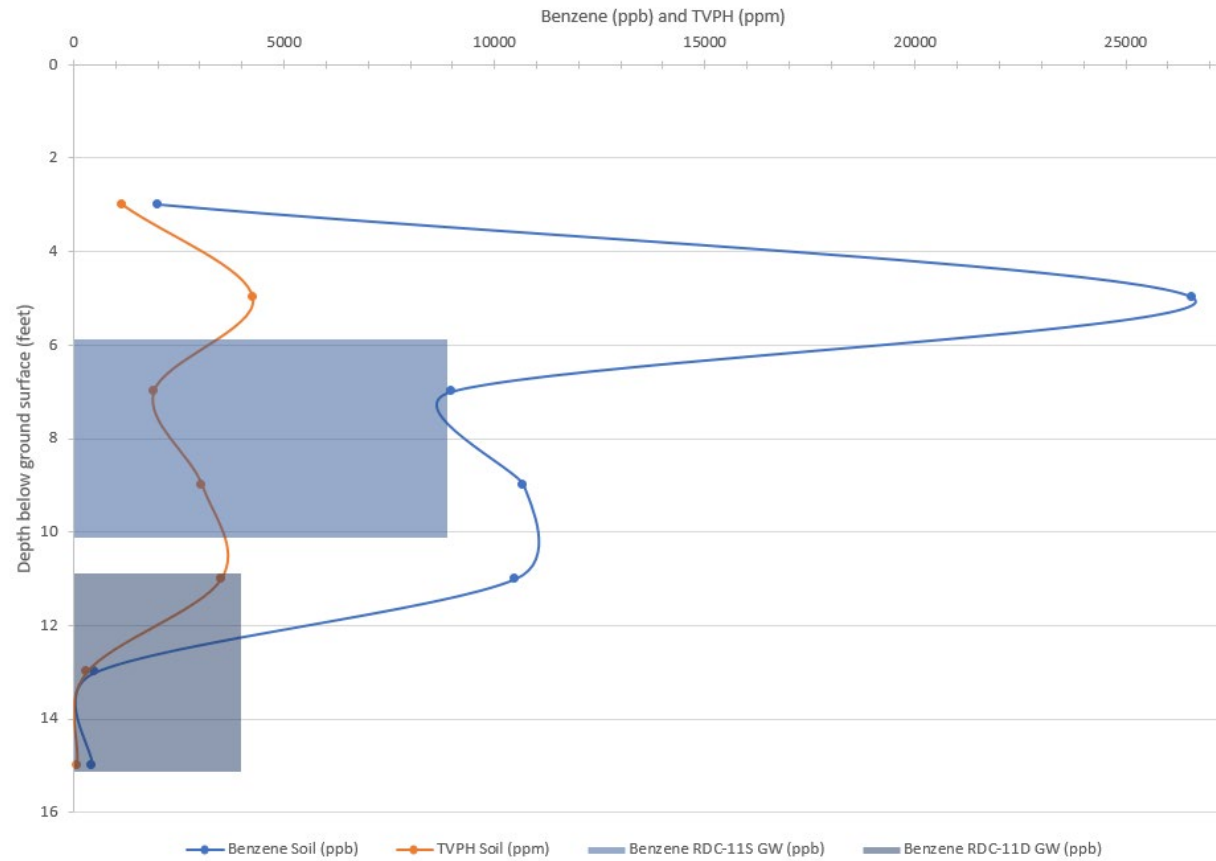
- Soil: 0.01 mg/kg benzene
- Groundwater: 0.005 mg/L benzene

Benefits from RDC

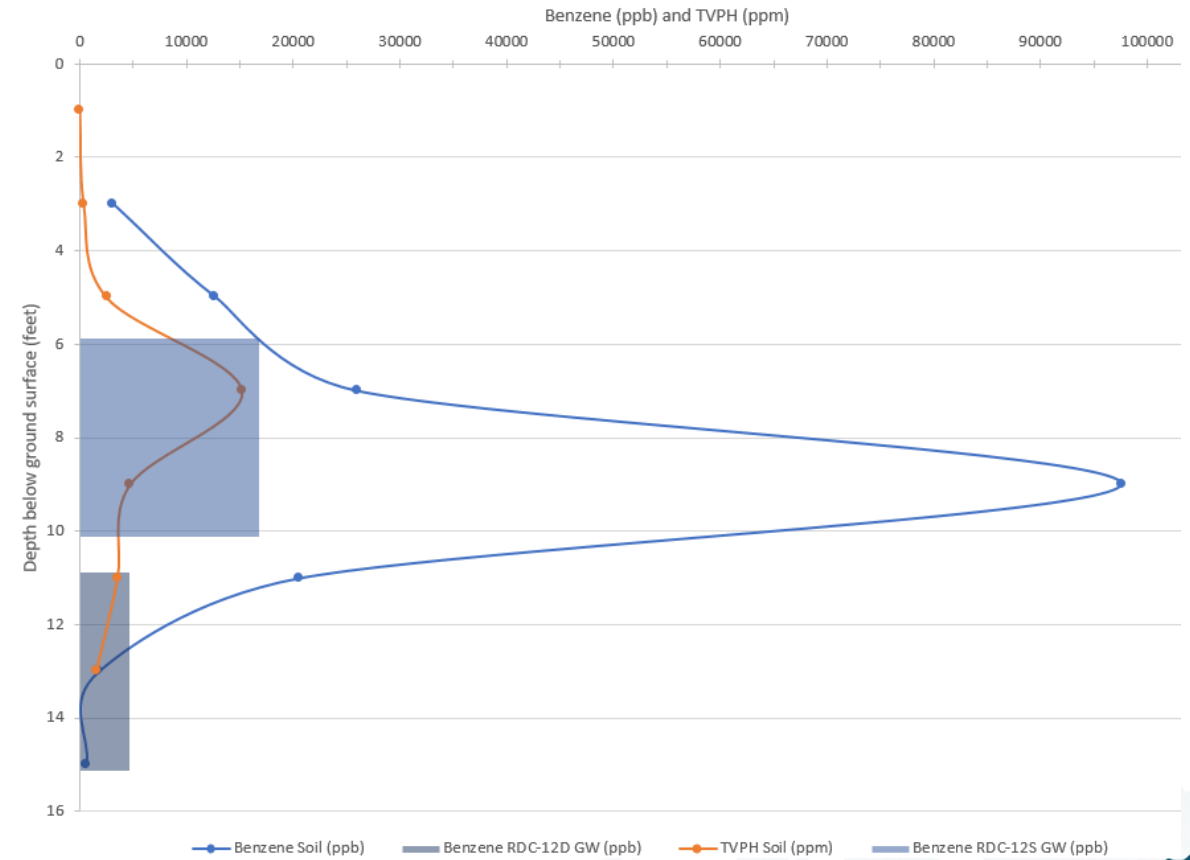
- Preliminary CSM: Under designed 1st Event ~20%
- Preliminary CSM: Under designed 2nd Event ~100%
- Significant sorbed mass present across unsaturated and saturated intervals
- Surgical Approach based on each RDC sample location
 - Injection loadings varied with depth based on actual mass present and its distribution

CSM Refinement and Revised Design (cont.)

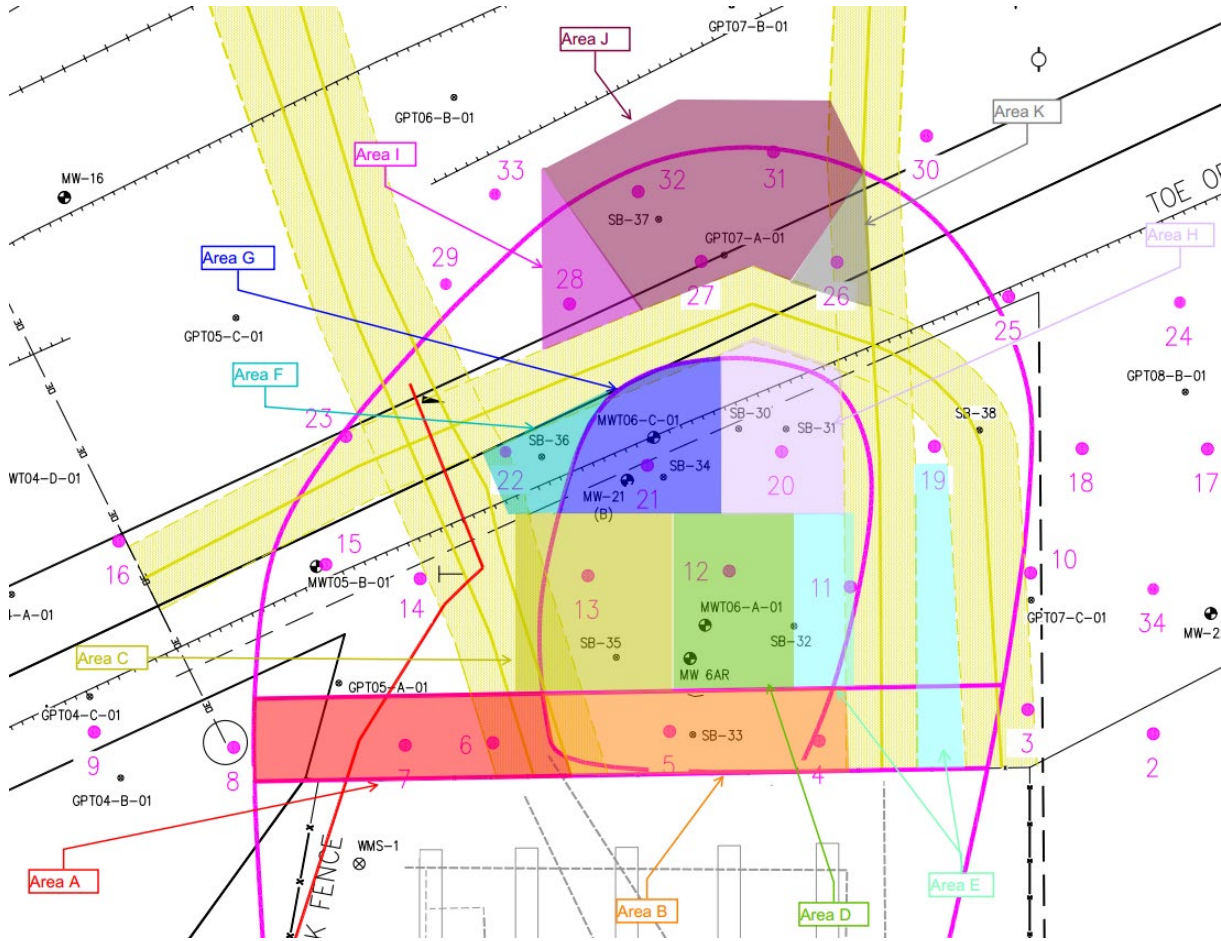
RDC-11 - Concentration Versus Depth



RDC-12 - Concentration Versus Depth



Revised Design – A More Surgical Approach



1st Injection Event

Treatment Area	Injection Interval - Pounds Per Injection											Total BOS 200®	
	4	5	6	7	8	9	10	11	12	13	14	15	For Area
Area A - 28 points	10	10	25	25	25	25	25	25	25	25	10	10	3,360
Area B - 28 points	10	10	10	10	30	30	30	30	30	30	30	10	3,780
Area C - 30 points	30	30	30	30	30	30	30	30	15	15	15	15	4,500
Area D - 25 points	30	30	30	30	30	30	30	30	30	30	30	30	4,500
Area E - 24 points	30	30	30	30	30	30	30	30	30	30	20	20	4,080
Area F - 11 points	10	10	10	25	25	25	25	10	10	10	10	10	990
Area G - 22 points	25	25	25	25	25	25	15	15	15	15	15	15	2,530
Area H - 25 points	25	25	25	25	25	25	25	10	10	10	10	10	3,000
Area I - 4 points	35	35	35	35	35	35	35	35	n/a	n/a	n/a	n/a	630
Area J - 21 points	n/a	n/a	15	15	20	20	20	20	20	20	20	20	1,995
Area K - 3 points	n/a	10	10	10	10	10	10	10	10	10	n/a	n/a	150
													29,515

2nd Injection Event

Treatment Area	Injection Interval - Pounds Per Injection											Total BOS 200®	
	4	5	6	7	8	9	10	11	12	13	14	15	For Area
Area B - 28 points	n/a	n/a	n/a	n/a	30	30	30	30	30	30	30	n/a	2,940
Area C - 30 points	30	30	30	30	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1,800
Area D - 25 points	30	30	30	30	30	30	30	30	30	30	n/a	n/a	3,750
Area E - 24 points	30	30	30	30	30	30	30	30	30	30	n/a	n/a	3,600
													12,090

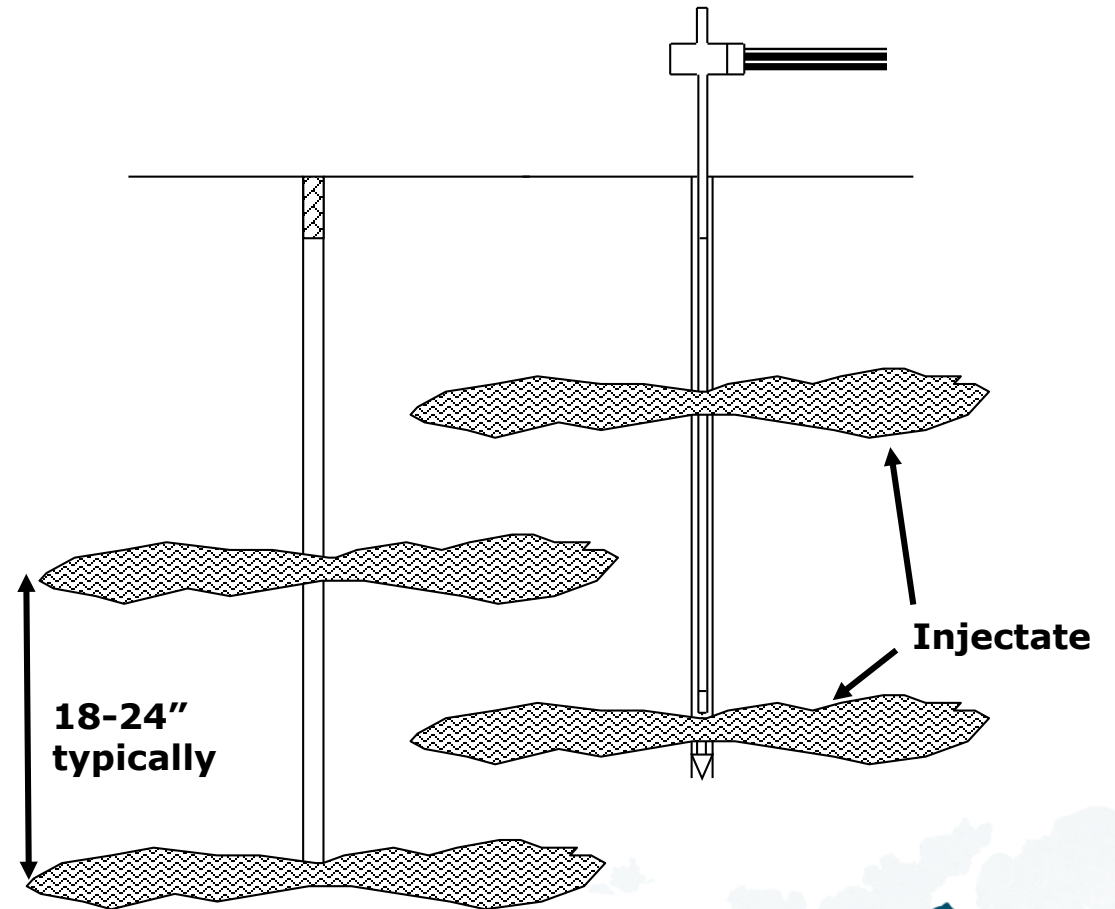
BOS 200® Implementation – 1st Event April 2014



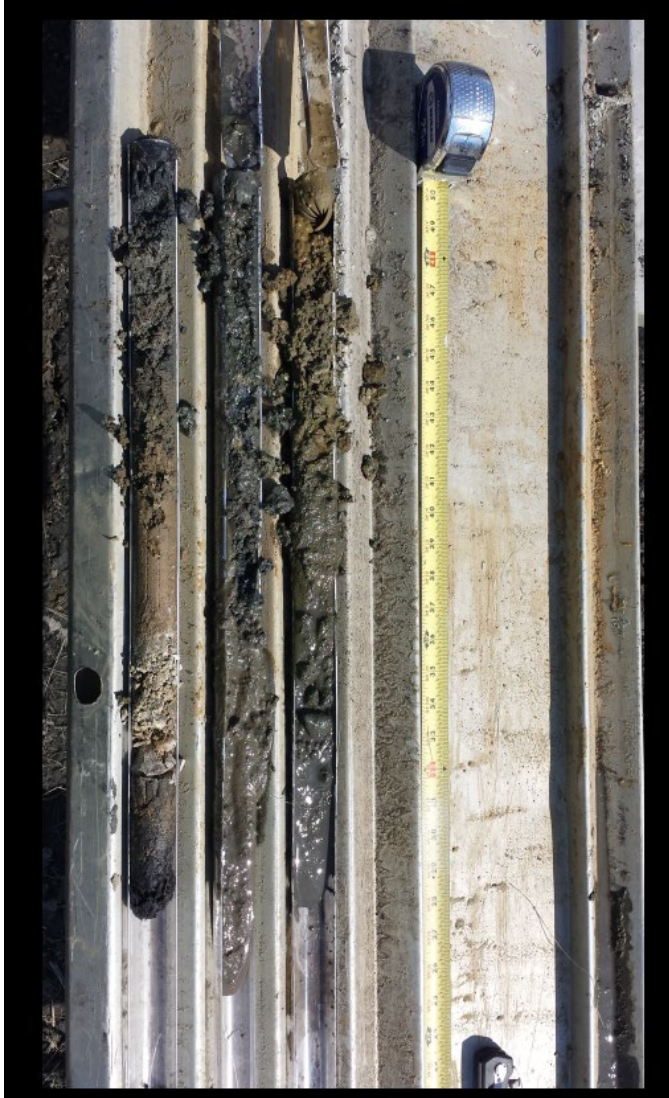
View Looking North

BOS 200[®] Slurry Application Best Practices

- Proper equipment
- Top-down critical to success
- Alternate vertical injection intervals
- Proper injection point spacing



1-year Post-Injection – 2nd RDC



Twelve (12) soil borings to bedrock

- Completed adjacent to key locations from 2013 RDC in the treatment area
- GW samples from resample borehole locations for adjacent comparison
- Visual inspection for the presence of BOS 200®

Laboratory analysis performed to:

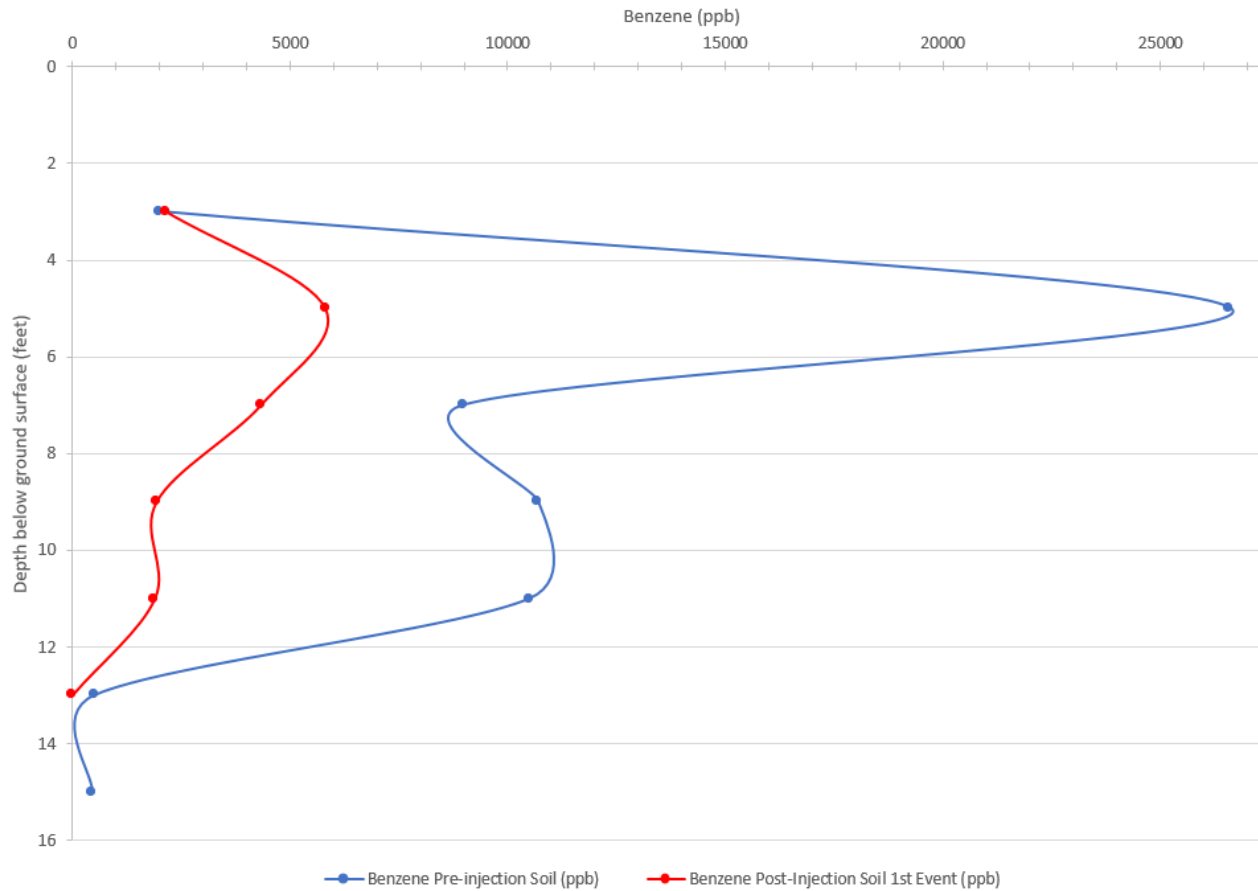
- Establish new baseline for 2nd injection design update
- Estimate total mass removed to date following the 1st injection event

2nd RDC Results

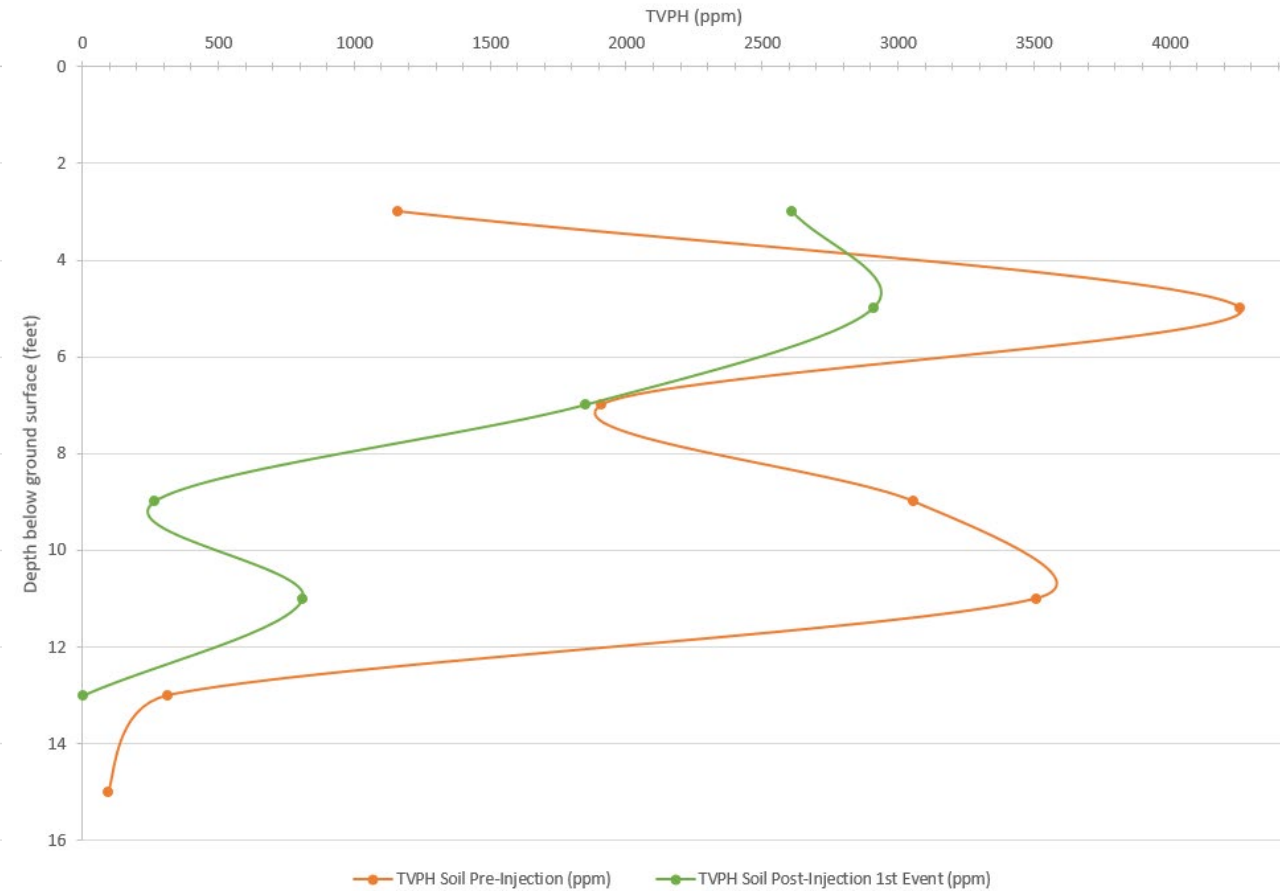
- Soil Mass Reductions
 - ~85% reduction in benzene
 - ~68% reduction in TVPH (total contaminant mass)
- Groundwater Mass Reductions
 - ~73% reduction in benzene
 - ~88% reduction in TVPH
- Full Scale 2nd BOS 200[®] Event Approved and Implemented in April 2016

2nd RDC Results – RDC-11

RDC-11 - Concentration Versus Depth

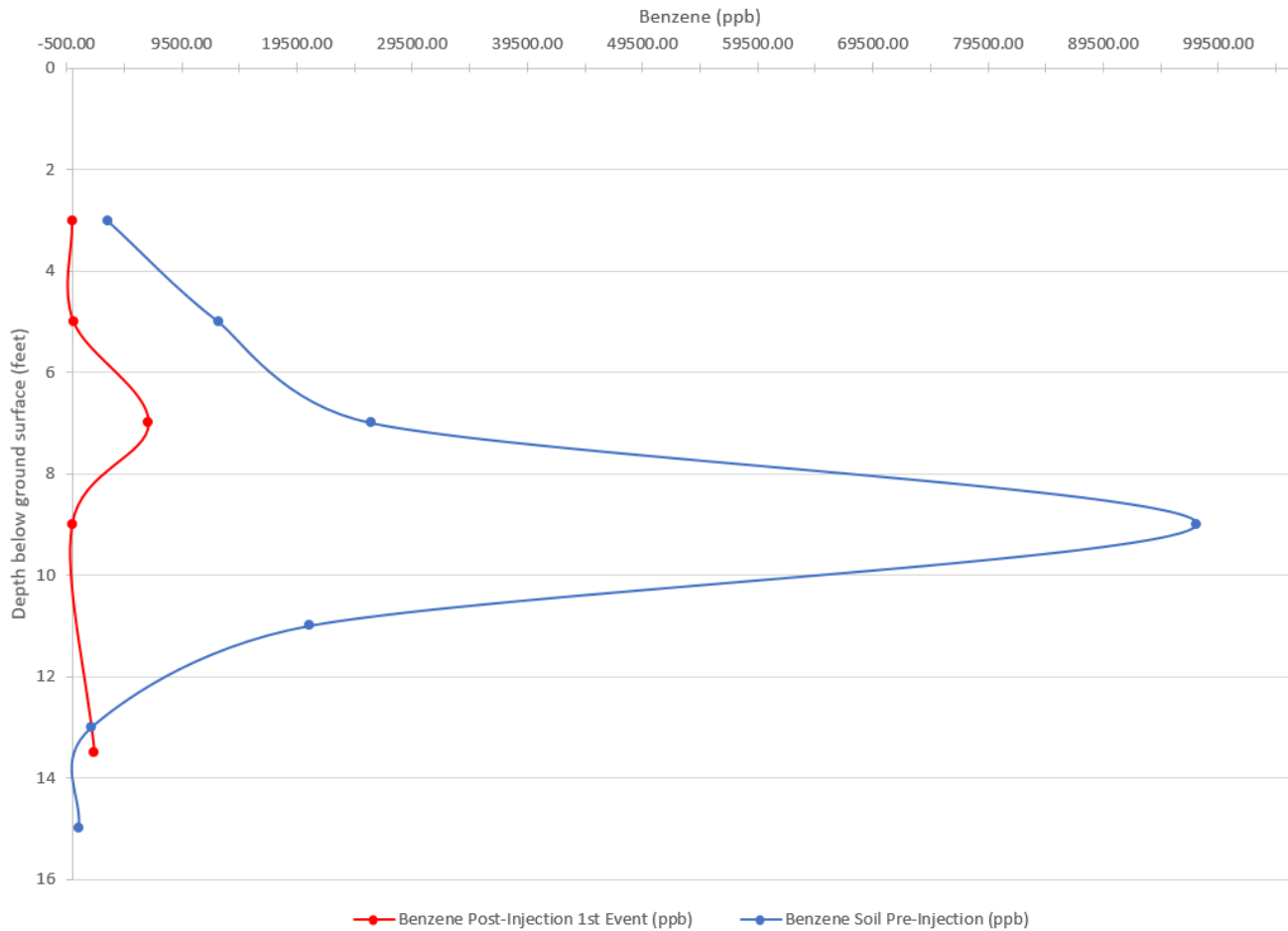


RDC-11 - Concentration Versus Depth



2nd RDC Results – RDC-12

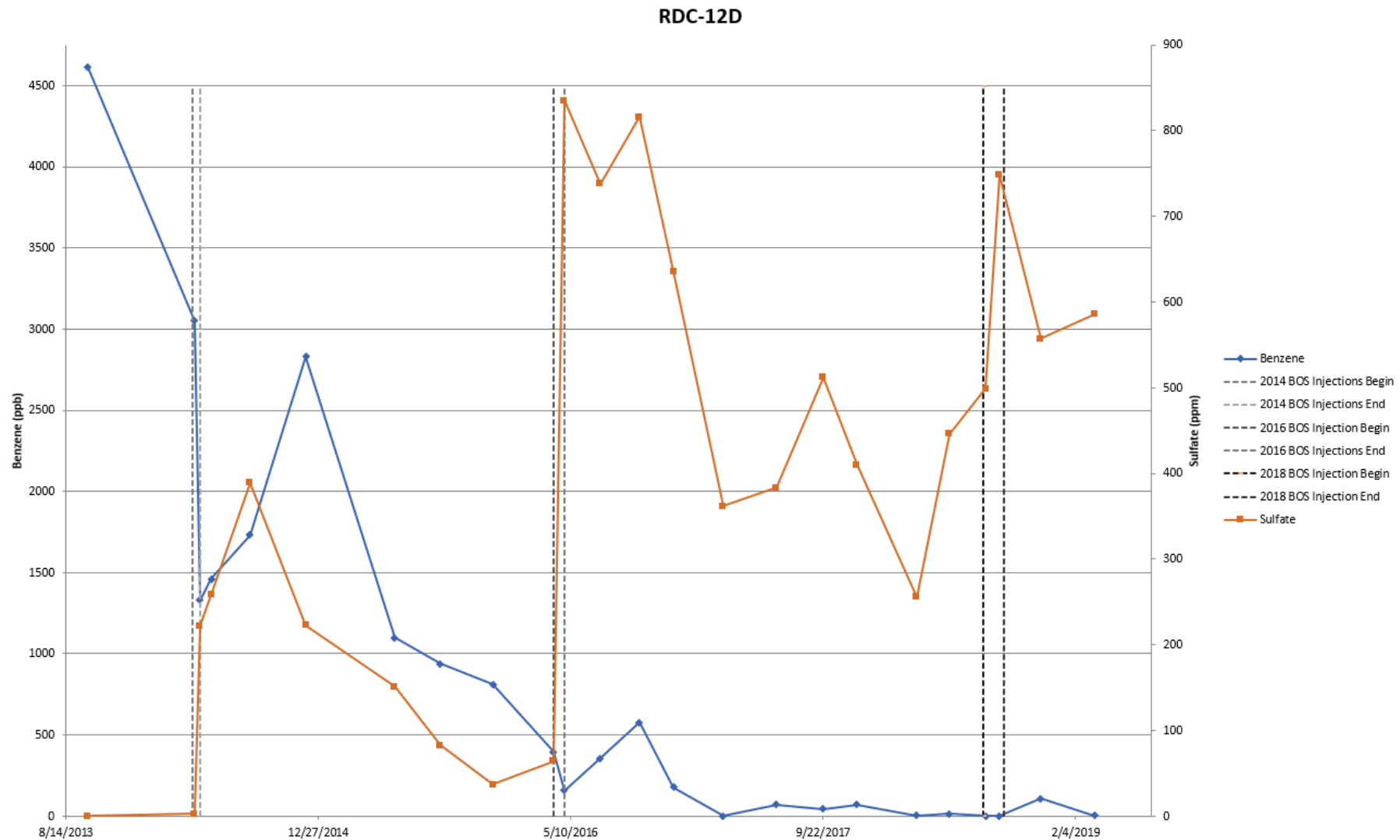
RDC-12 - Concentration Versus Depth



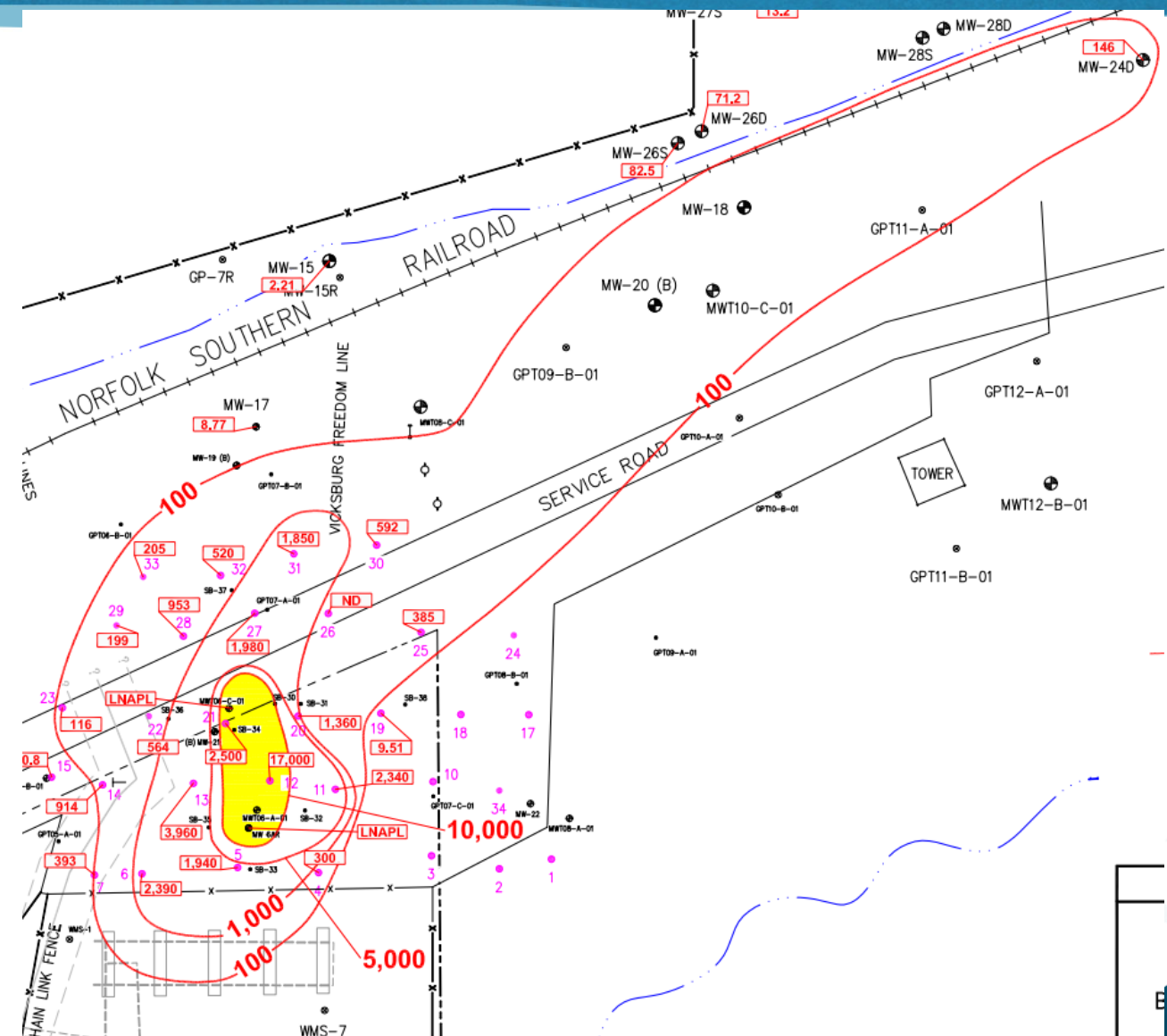
RDC-12 - Concentration Versus Depth



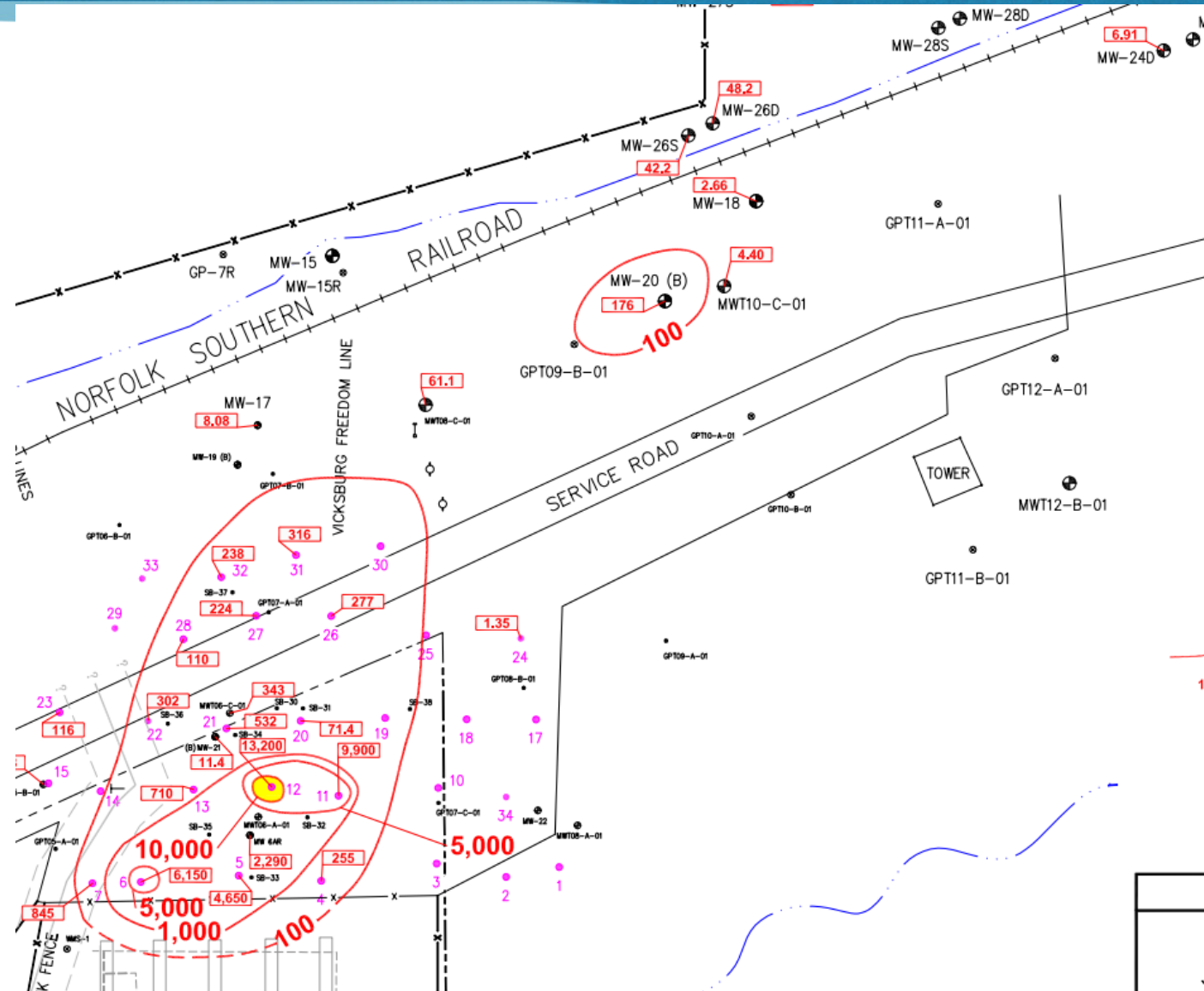
Full-Scale BOS 200[®] Results



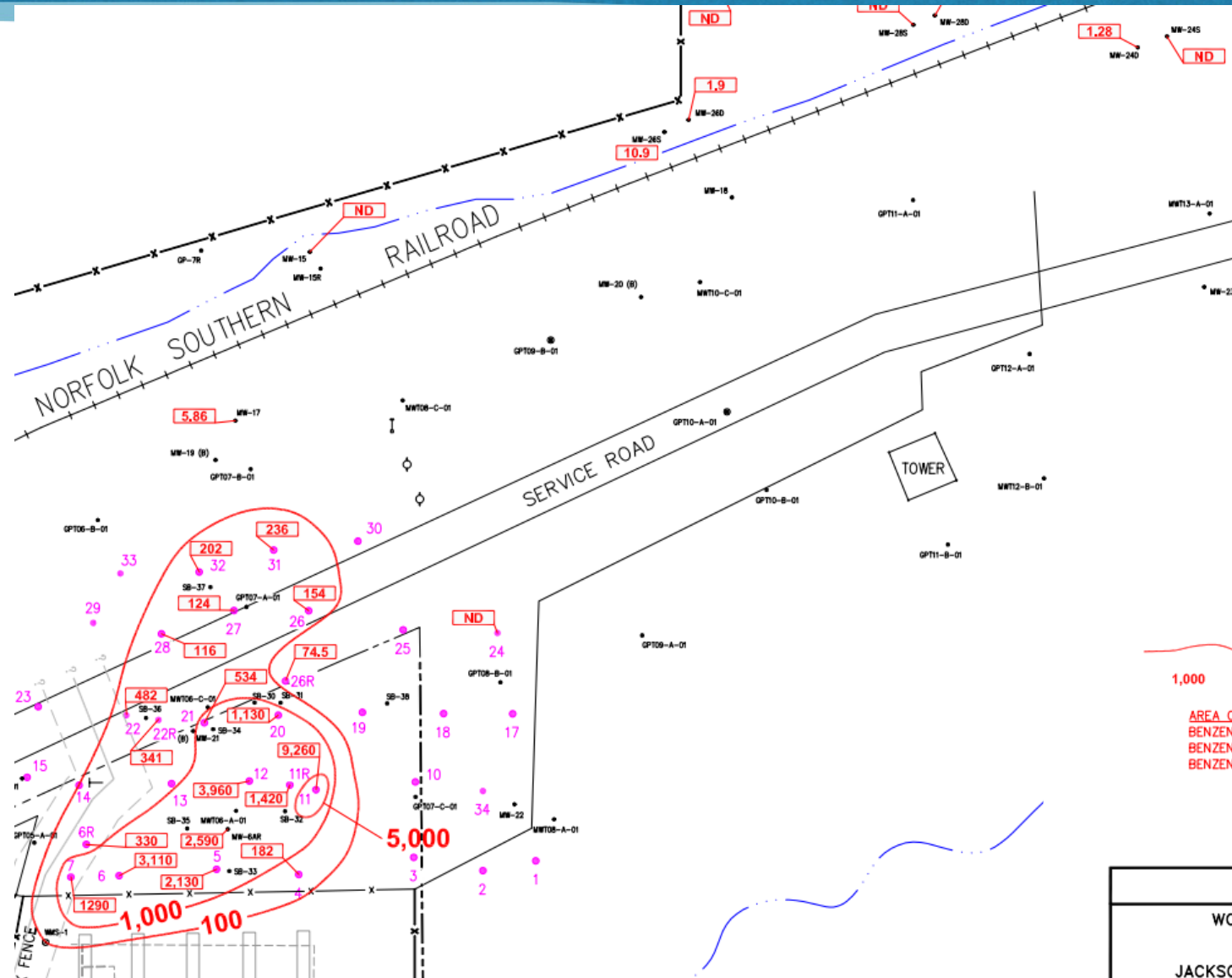
T=0 GW Sampling Prior to 1st Injection April 2014



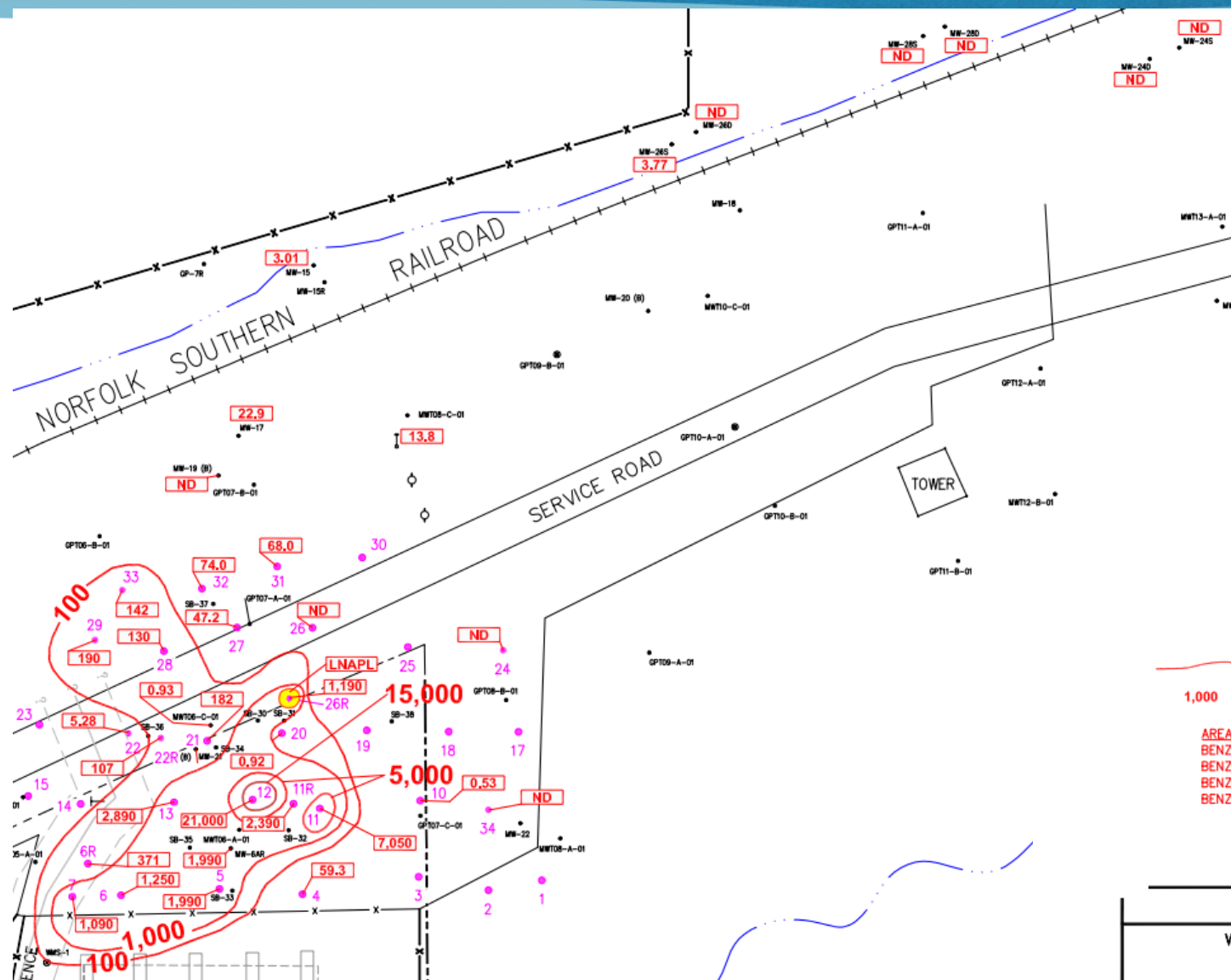
December 2014



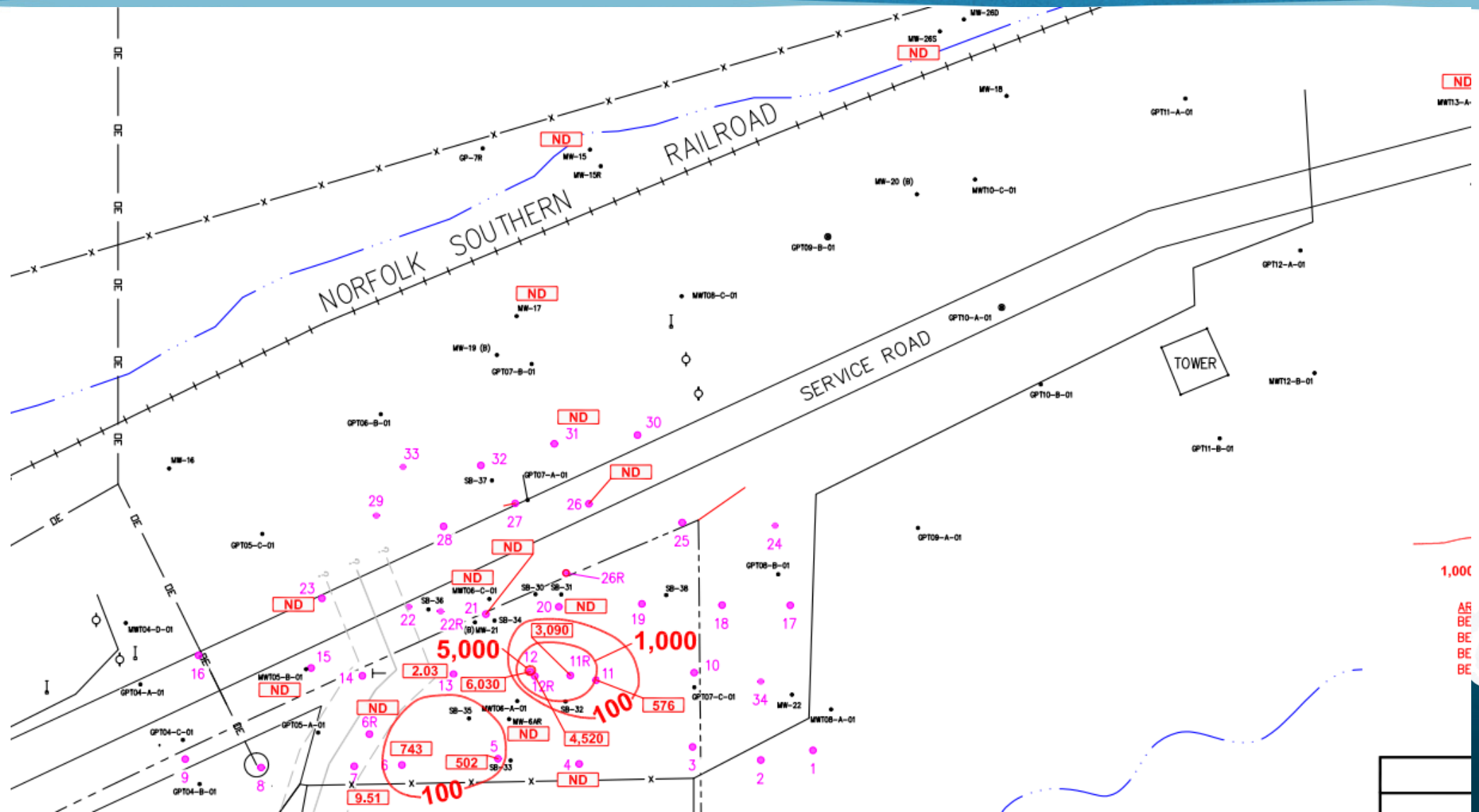
2nd RDC Event May/June 2015



T=0 GW Sampling Prior to 2nd Injection April 2016



September 2018 – T=0 Post-Injection 3rd Event



Closing Thoughts...

- Risk-Based SSTLs Approved for the Facility and Closure Under Evaluation
- Groundwater Plume Reduced to w/in Extents of the Facility
- LNAPL Eliminated From All Monitoring Wells

Questions?

