NAVFAC
Naval Facilities Engineering Command
WASHINGTON

Adaptive DNAPL Treatment in Groundwater Using an ISCO Recirculation System

Gunarti Coghlan, P.E.
NAVFAC Headquarters, Washington, D.C., USA

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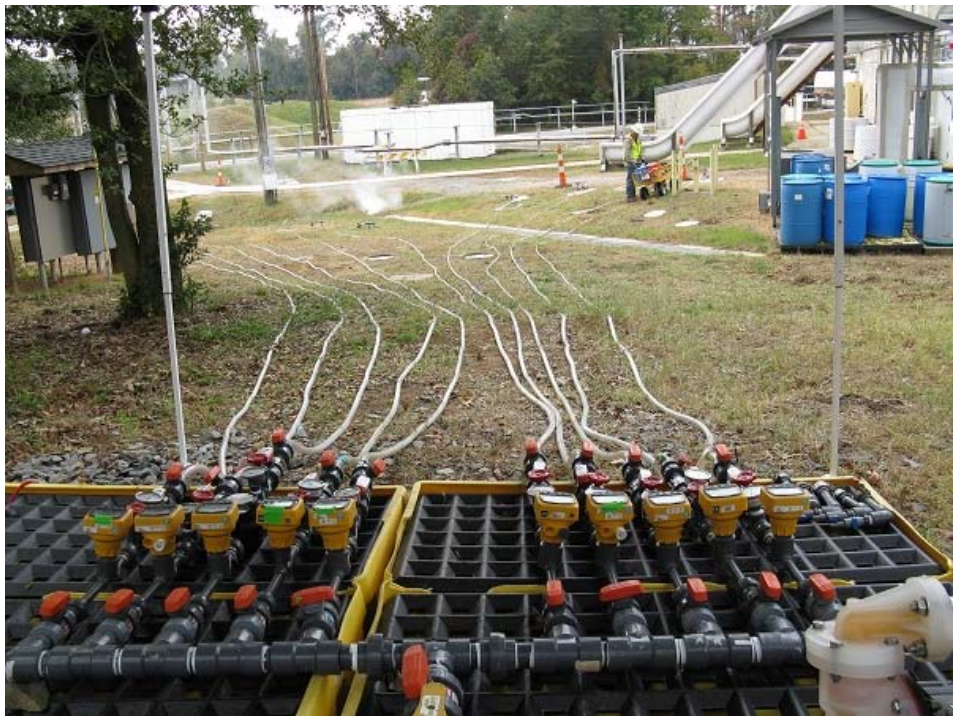
Project Team

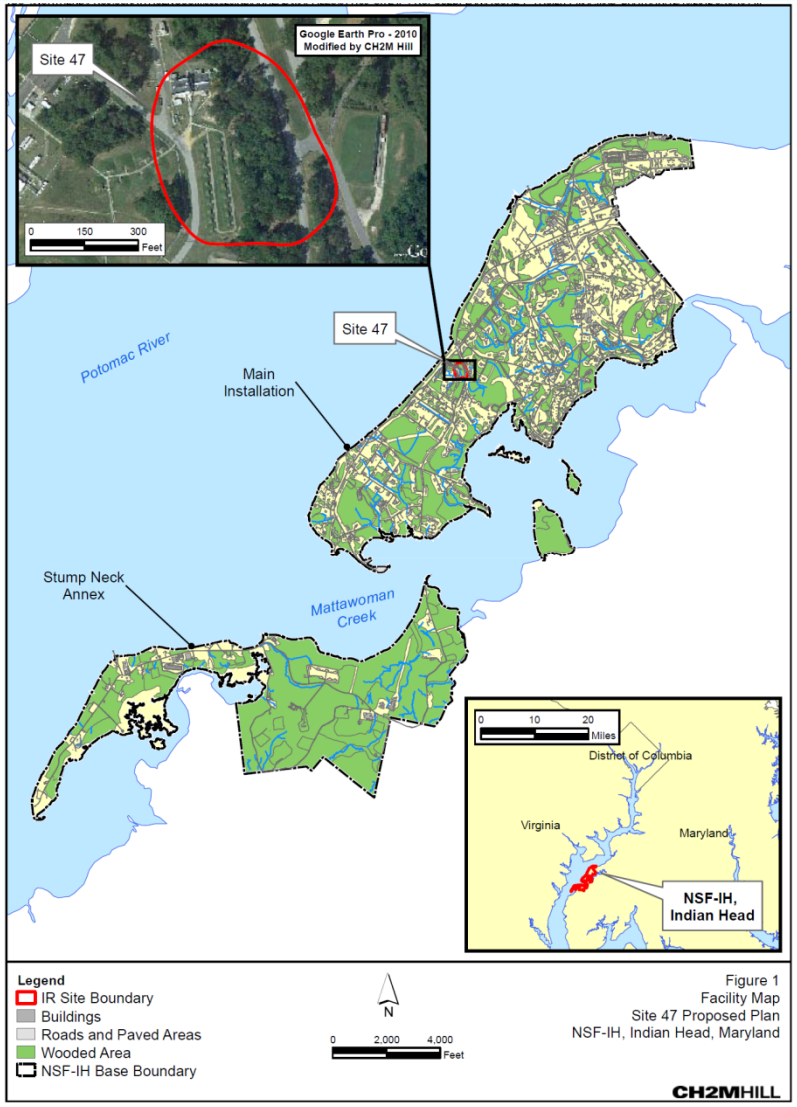
- **NAVFAC Washington**
  - –Joe Rail
  - –Nick Carros
- **XDD, LLC**
  - –Brant Smith
  - –Karen O'Shaughnessy
- **CB&I Federal Services**
  - –Steve Carriere
- **CH2M HILL**
  - –Mark Strong



Presentation Overview

Site Overview

- Contamination Characteristics
- Selected Remedy
- Bench and Pilot Studies
- Full-Scale Remedy
- Challenges and Lessons Learned



Site Overview - Setting

Active explosive research and storage areas with multiple and overlapping explosives arches

Site Overview - Geology

- **Shallow confined aquifer**
- **Silty sand lithology: 0 and 18- 20 feet bgs**
- **Clay layer starting at 18 – 20 feet bgs; thickness > 30 feet**
- **Water table – between 5 and 6 feet bgs**

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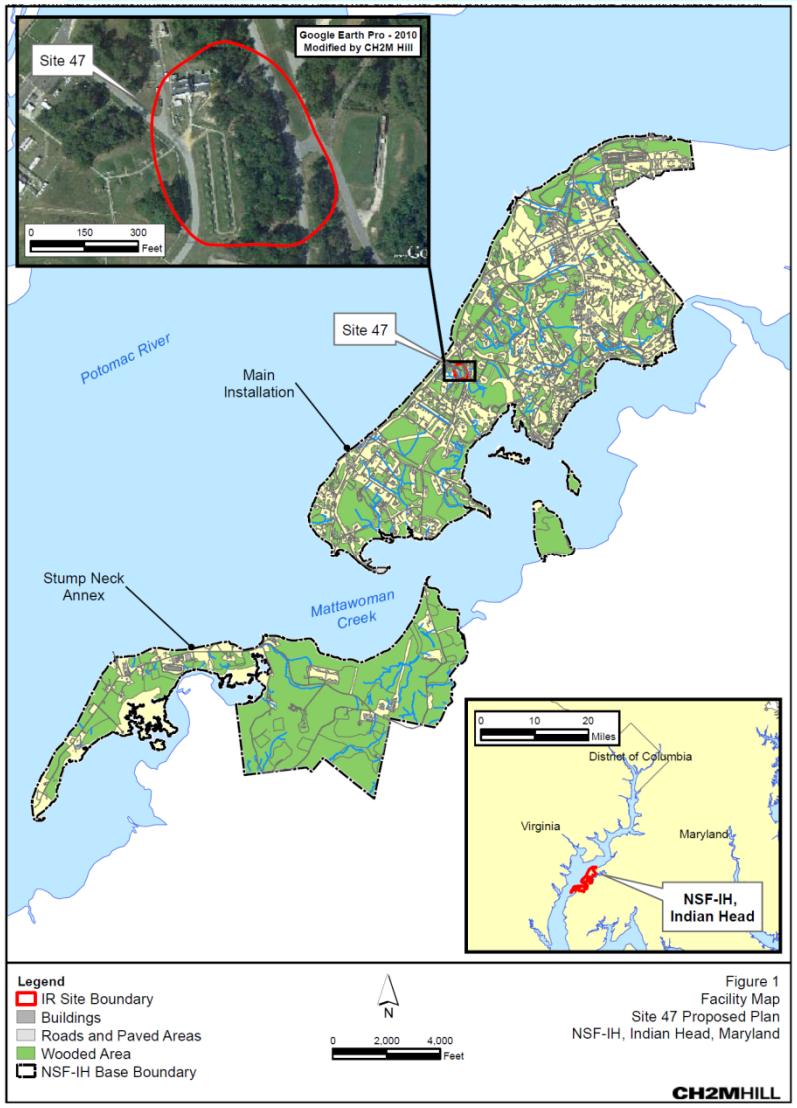


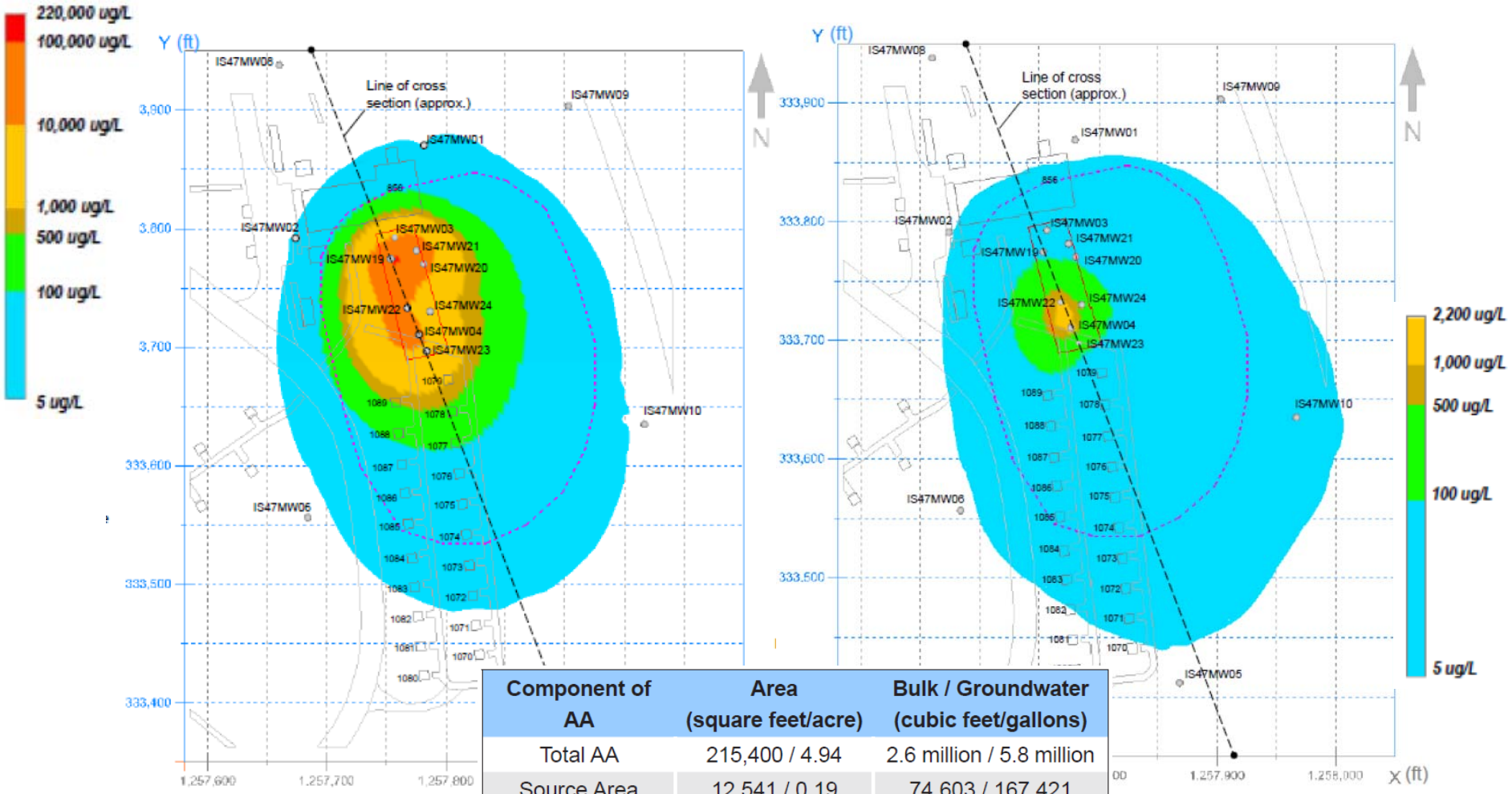
Past Release and COCs

- **Past releases – disposal of spent catalyst and inerting agent from 1957 – 1965**
- **Constituents of concern (COCs)**
  - **Chlorinated solvents**

Contaminants	Max. Concentration (µg/L)
CT	150,000
CF	61,000
PCE	2,200
TCE	420
Cis-1,2-DCE	480
Carbon disulfide	11,000

  - **Inorganics**
    - Arsenic, iron, thallium, and vanadium

CT and PCE Plumes



CT

Component of AA	Area (square feet/acre)	Bulk / Groundwater (cubic feet/gallons)
Total AA	215,400 / 4.94	2.6 million / 5.8 million
Source Area	12,541 / 0.19	74,603 / 167,421
Inferred Residual DNAPL Area	2,075 / 0.05	6,350 / 14,250

PCE

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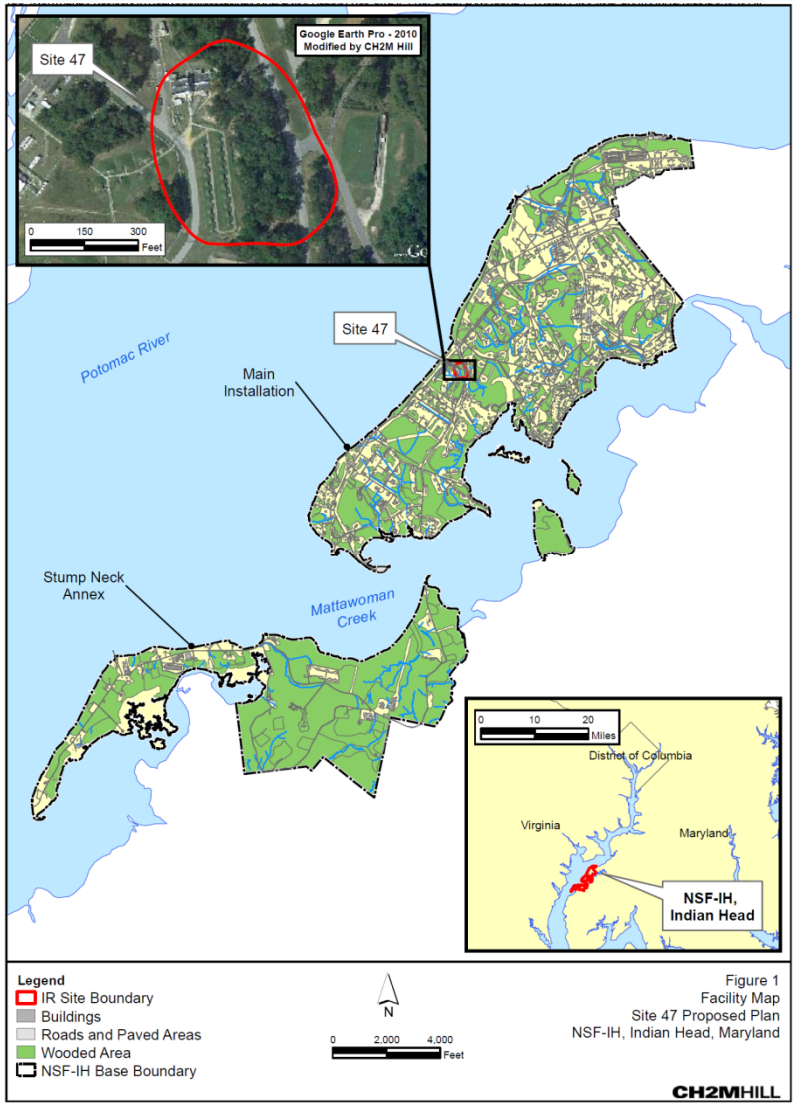
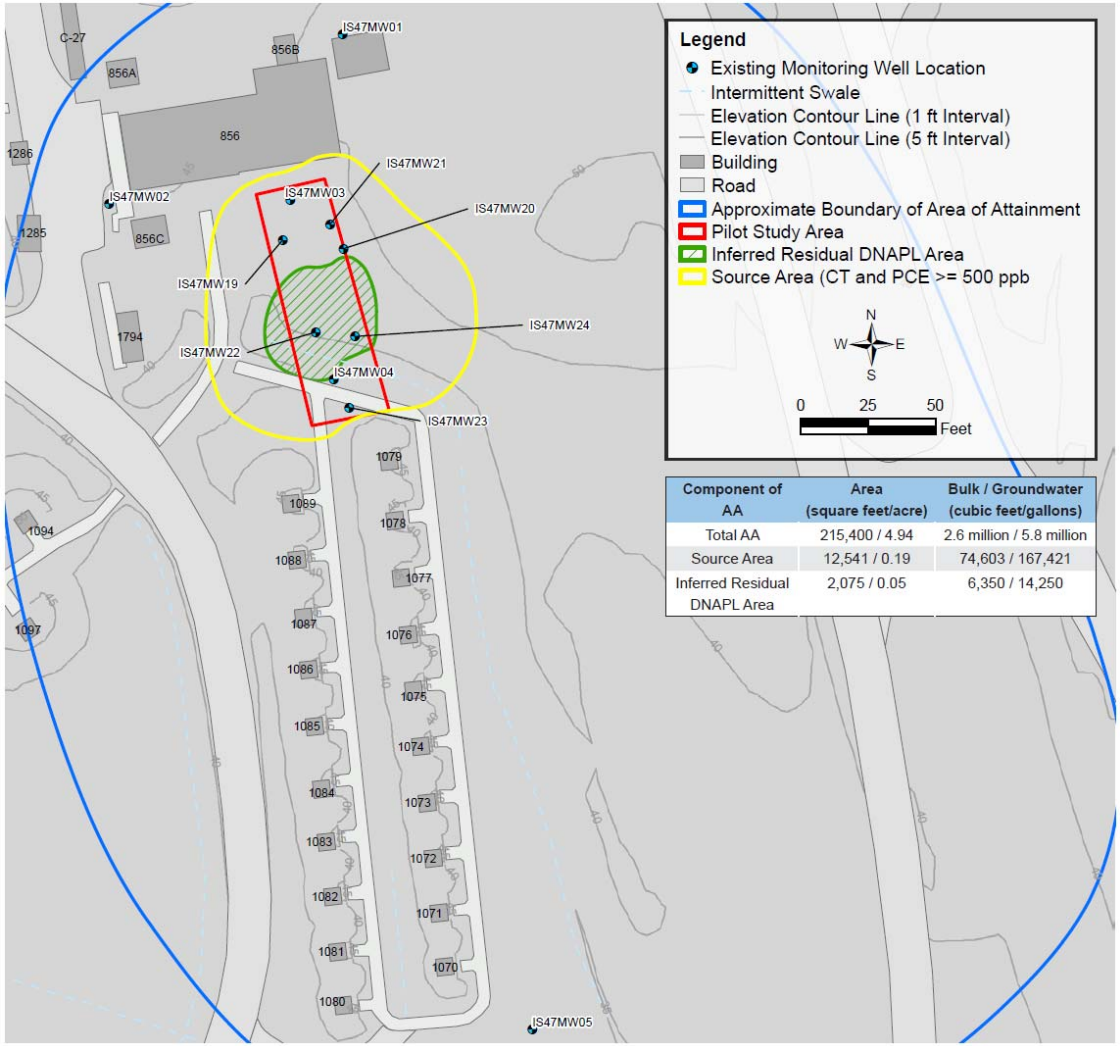


Selected Remedy

- **Treatment of Source Zone (CT ≥ 500 µg/L area) with ISCO**
- **Followed by MNA within the rest of Area of Attainment (AA)**
- **Implementing LUCs until the cleanup goals are met within the AA**



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- **Bench and Pilot Studies**
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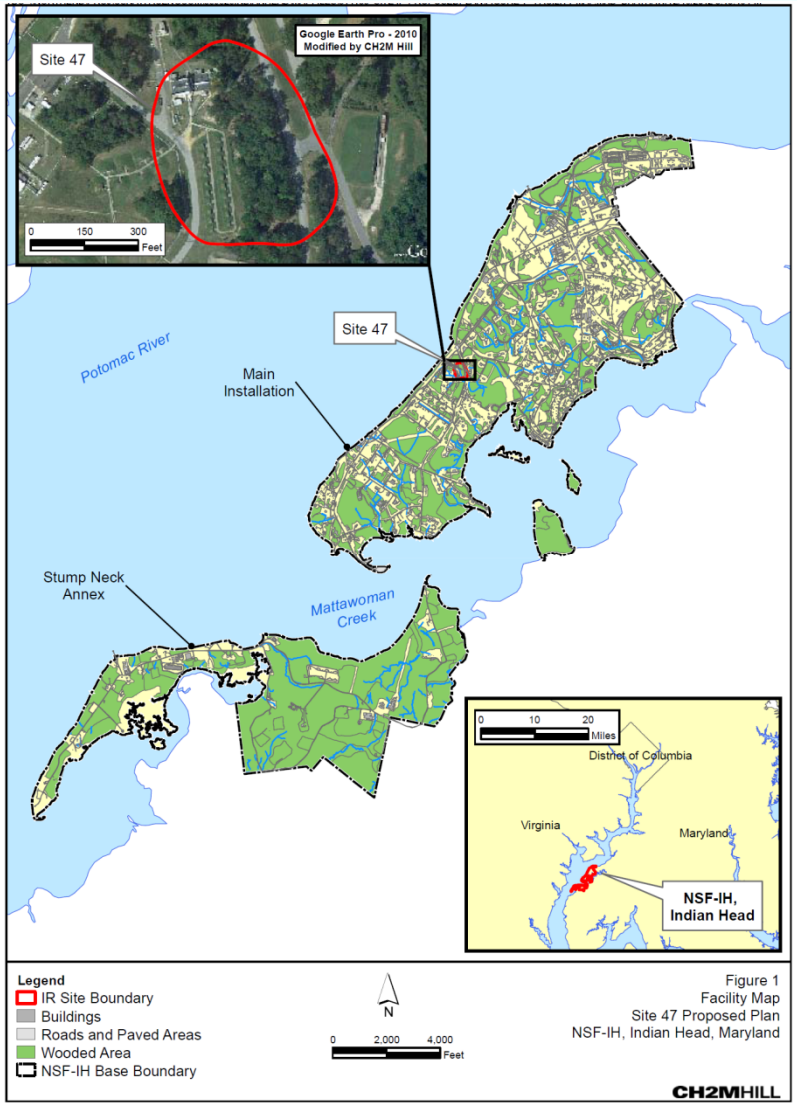


Bench Study

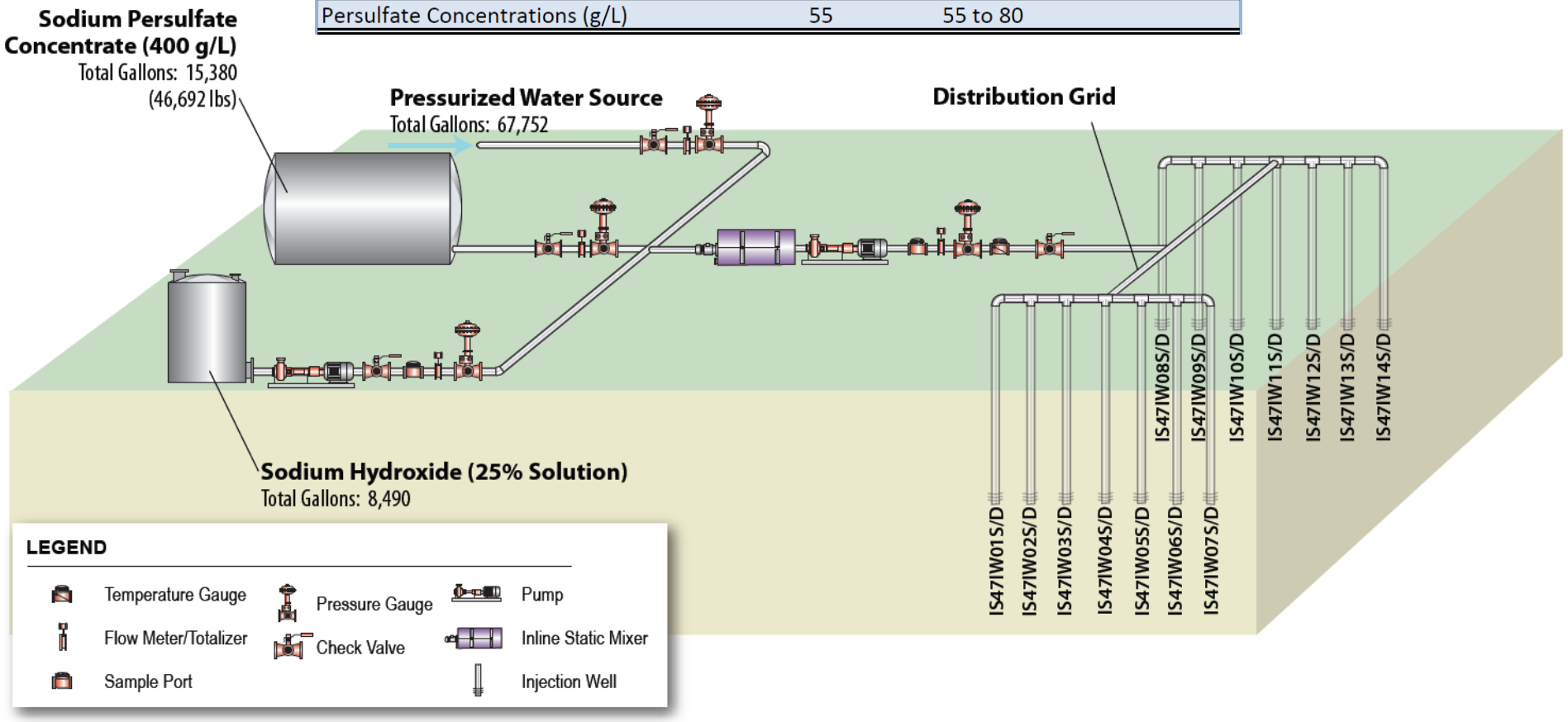
- **Evaluated**
  - **Catalyzed Hydrogen Peroxide**
  - **Alkaline Activated Persulfate (AAP)**
  - **Micron scale**
    - ZVI
    - Nickel catalyzed ZVI
  - **Nano-scale ZVI**
- **AAP**
  - **50 g/L**
    - 75 percent CT in 1 application
    - >98 percent in 3 applications
  - **200 g/L**
    - >99 percent after 1 and 3 applications
- **CHP**
  - **Effective but concerned about gas evolution**
- **ZVI**
  - **Effective in treating CT, but persistent daughter products observed (chloroform and methylene chloride)**

Pilot Study

- **Conducted Fall 2009**
- **Injected:**
  - **46,700 lbs of sodium persulfate**
  - **91,600 gals (55 g/L to 80 g/L)**
  - **14 clusters of shallow/deep injection wells**

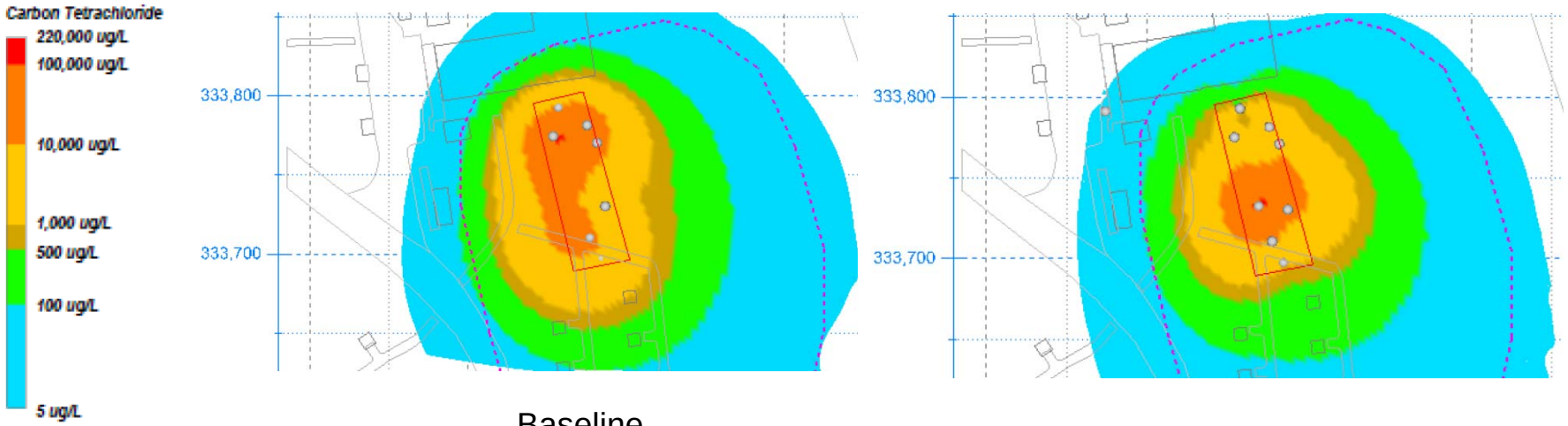
Actual vs. Design

Parameter	Design	Actual	% Actual/Design
Mass of Persulfate (lbs)	46,200	46,692	101%
Volume of Persulfate (gallons)	102,004	91,622	90%
Mass Ratio in Shallow to Deep Wells	50% : 50%	42% : 58%	
Flow Rate/Well (GPM)	5	1.3 to 3.9	
Persulfate Concentrations (g/L)	55	55 to 80	



Pilot Study Results – Concentration Reduction

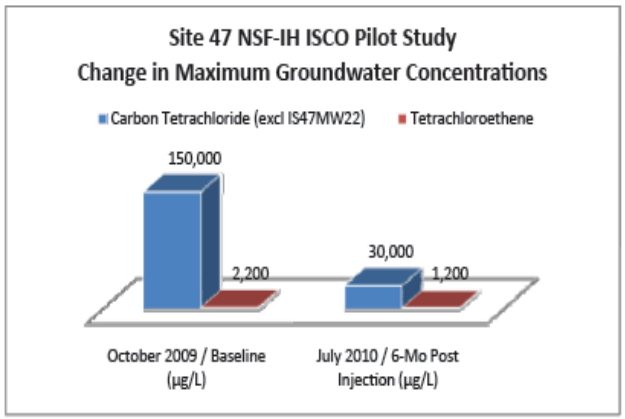
CT

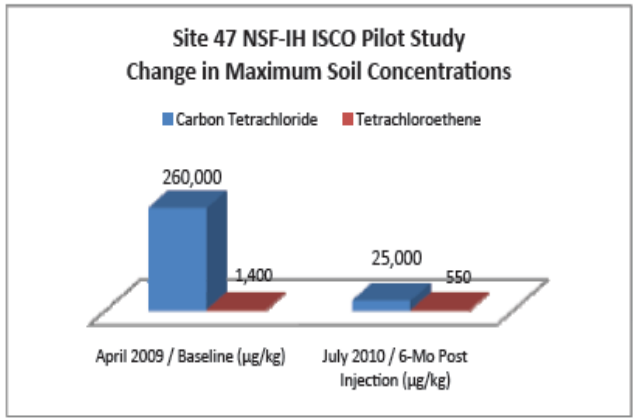


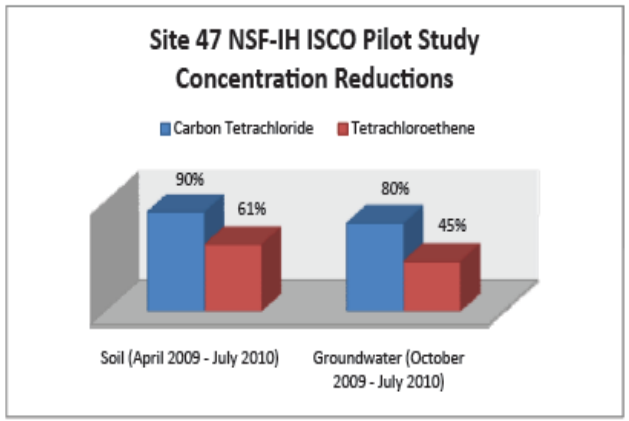
Baseline

6-Month Post-Injection

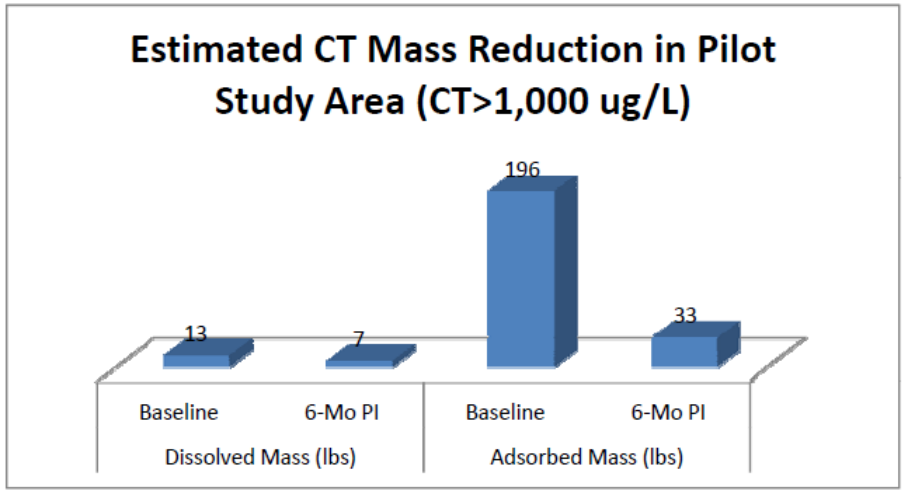
CT and PCE

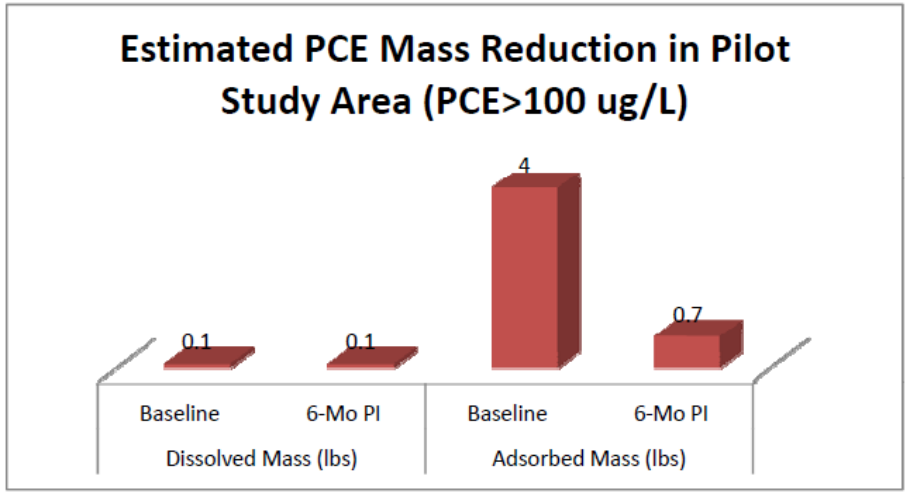


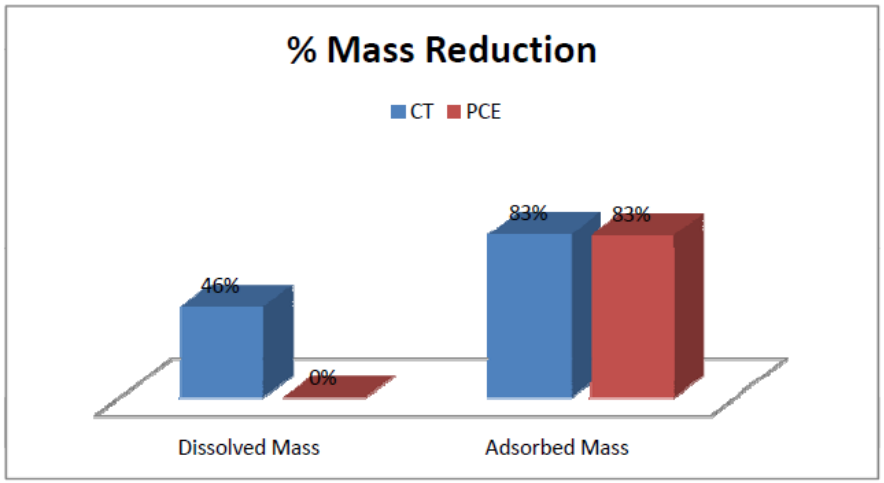




Pilot Study Results – Mass Reduction







Assumptions:

- Using actual groundwater and soil concentrations
- Does not consider the mass of free phase DNAPL

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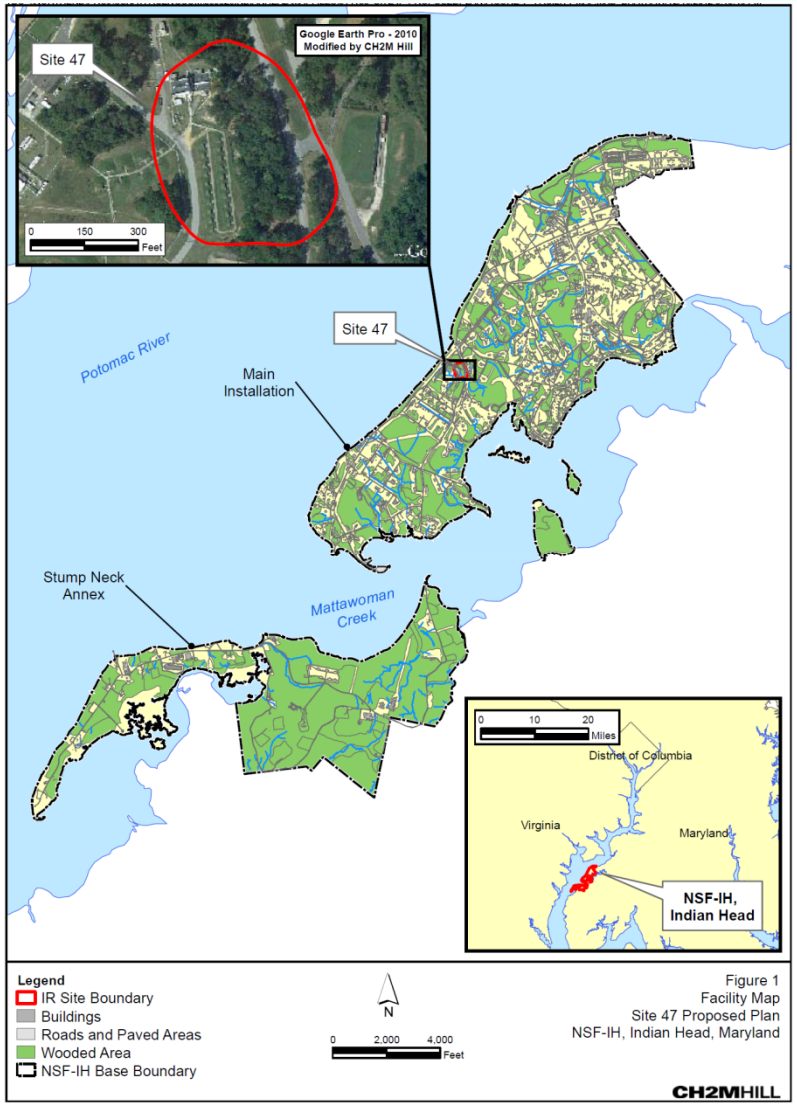
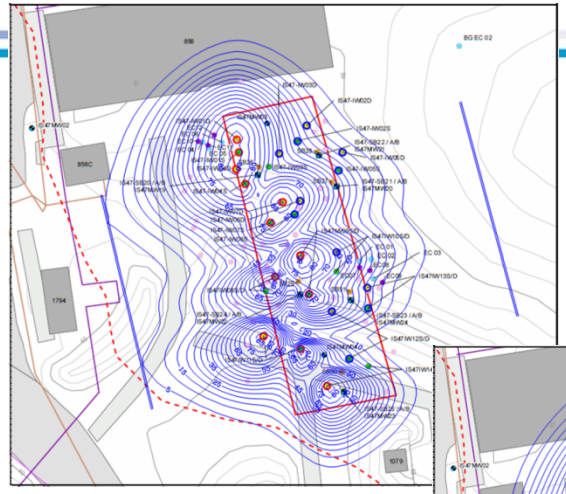


Lessons Learned from Pilot Study

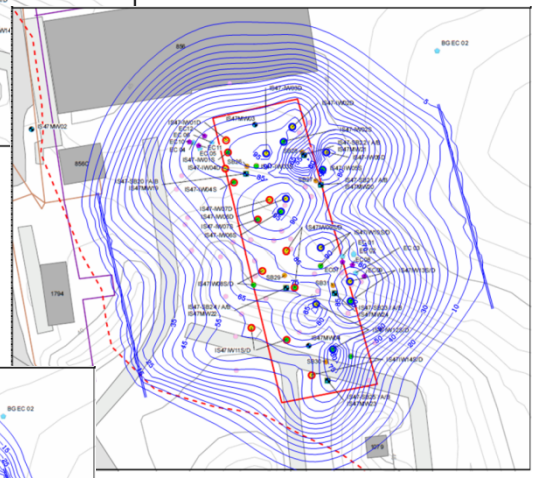
- The ISCO delivery using uniform injection grid where accessible is not feasible due to the site constraints and must be revised.
- The new ISCO delivery approach:
  - Must minimize intrusive activities, particularly within the K-18 arc of Building 856
  - Has the ability to maintain a maximum of 2-foot groundwater mounding and deliver a high volume/mass of treatment reagent

Full-Scale Pre-Design Activities

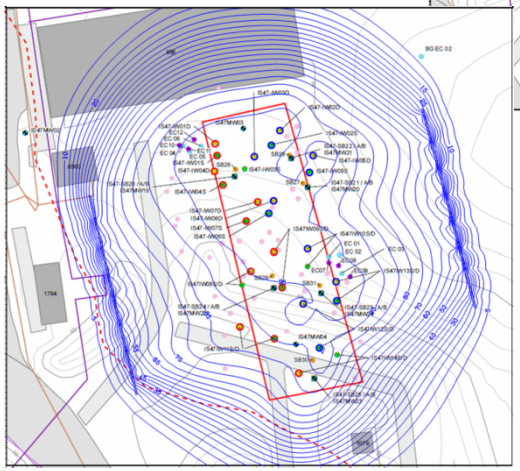
- **Aquifer Performance Test**
  - **Refine hydraulic conductivity in anticipation of a recirculation system**
- **Flow and Transport Model**
  - **Assessed flow paths, areas of influence, and particle transit times for recirculation system**
- **Data Gap Investigation**
  - **Refined target area (CT + PCE > 500 ug/L)**



3 Days



6 Days



24 Days

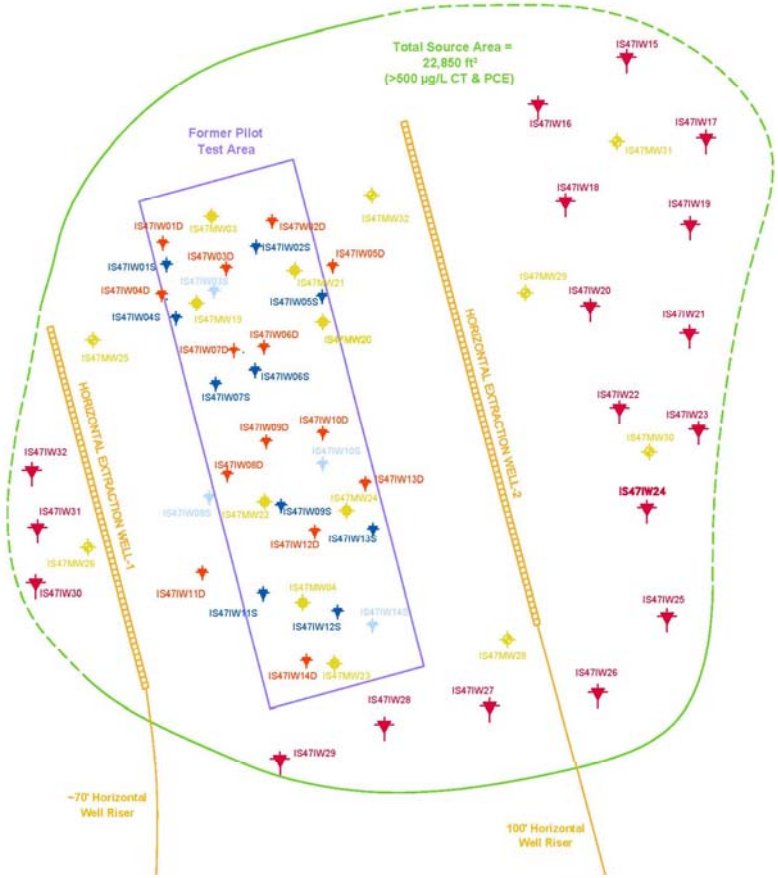
Full-Scale Remedy

ISCO Recirculation Strategy

- Target area 22,850 ft^2
- 42 Injection wells
- 2 Horizontal extraction wells
- Rotation between 3 sets of 18 injection wells simultaneously

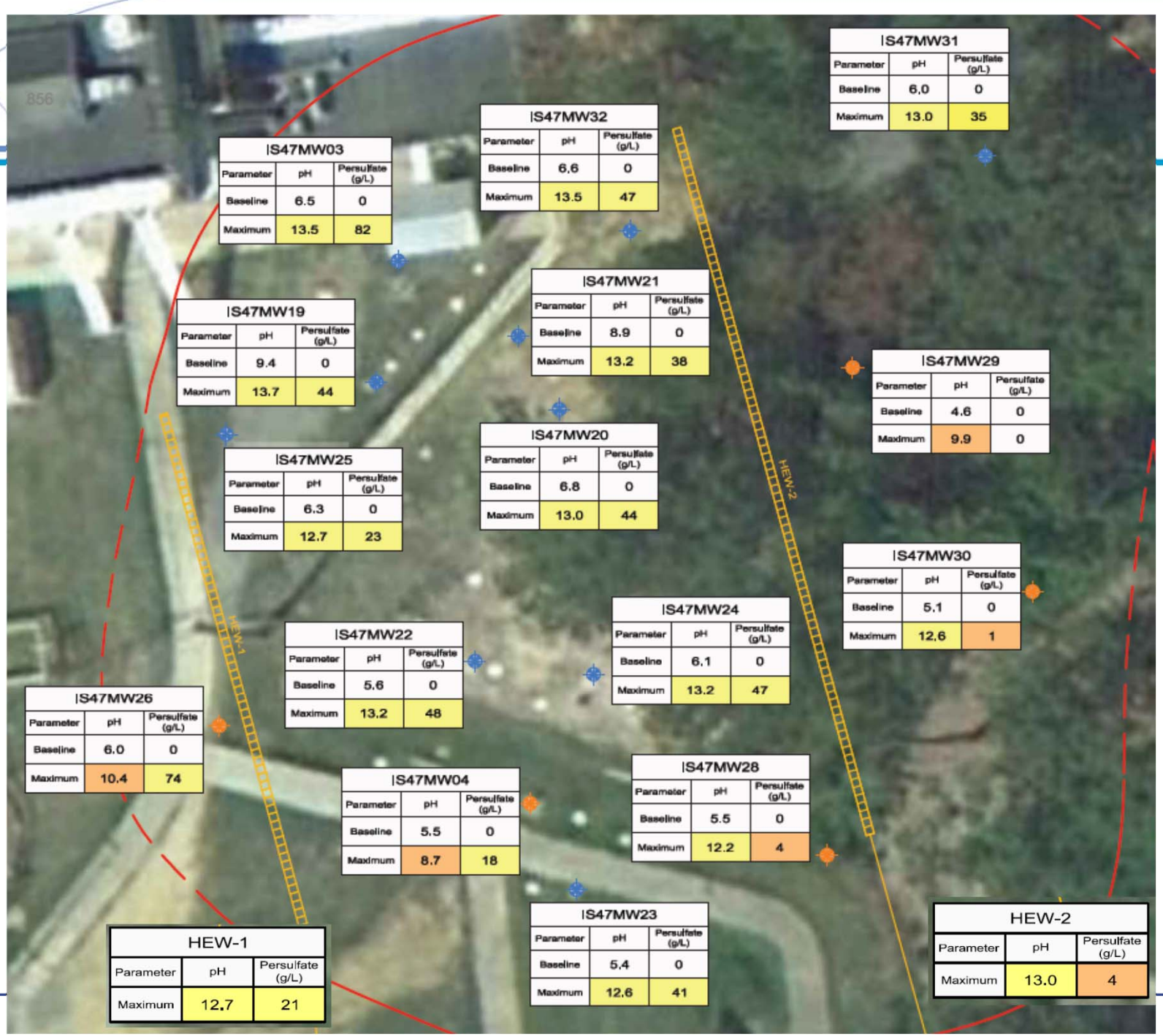
Performance Objectives

- Injection of at least 75 percent of the total design mass of persulfate
- A minimum of 10 grams per liter (g/L) sodium persulfate and pH> 10.5 is observed in each horizontal extraction well.
- A minimum of 10 g/L sodium persulfate and pH > 10.5 is observed in at least 75 percent of the monitoring wells located within the target area.

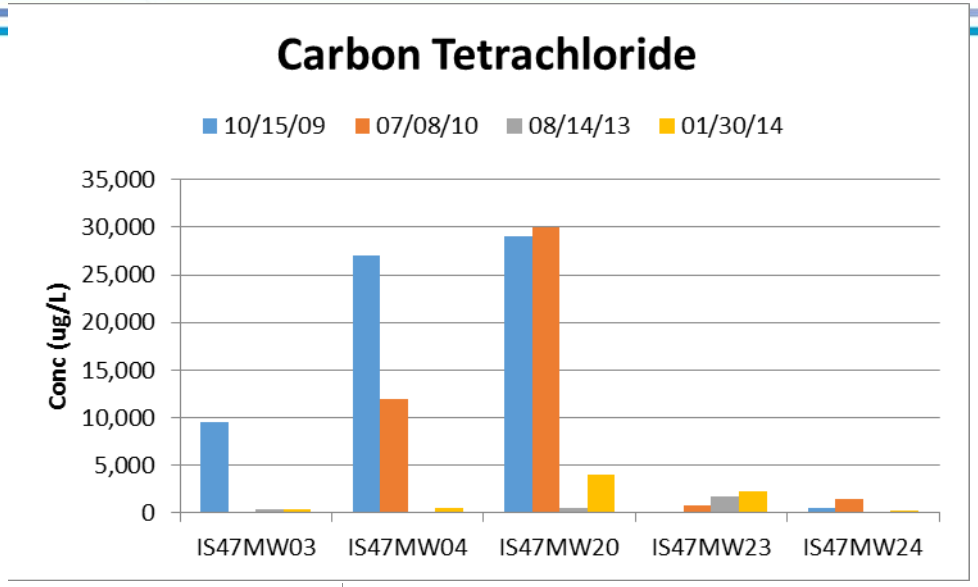


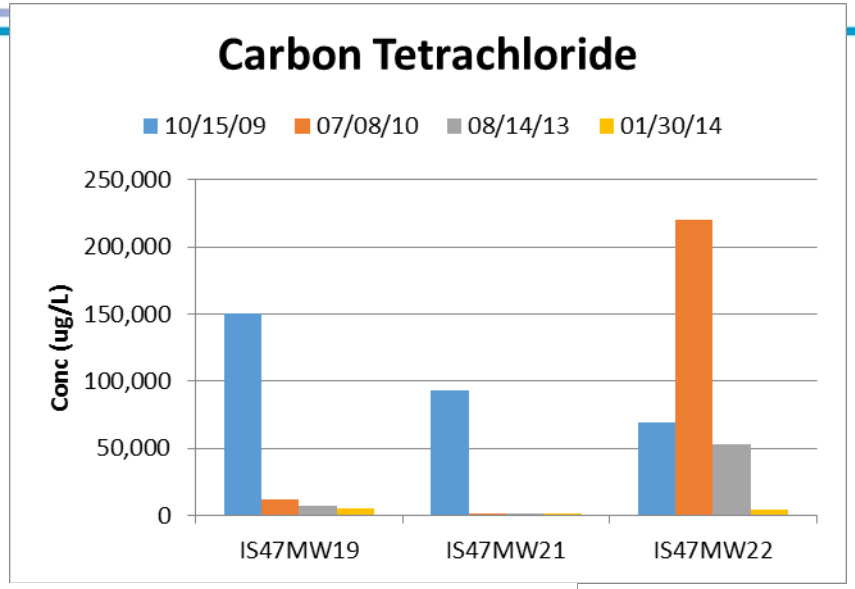
Full-Scale Application

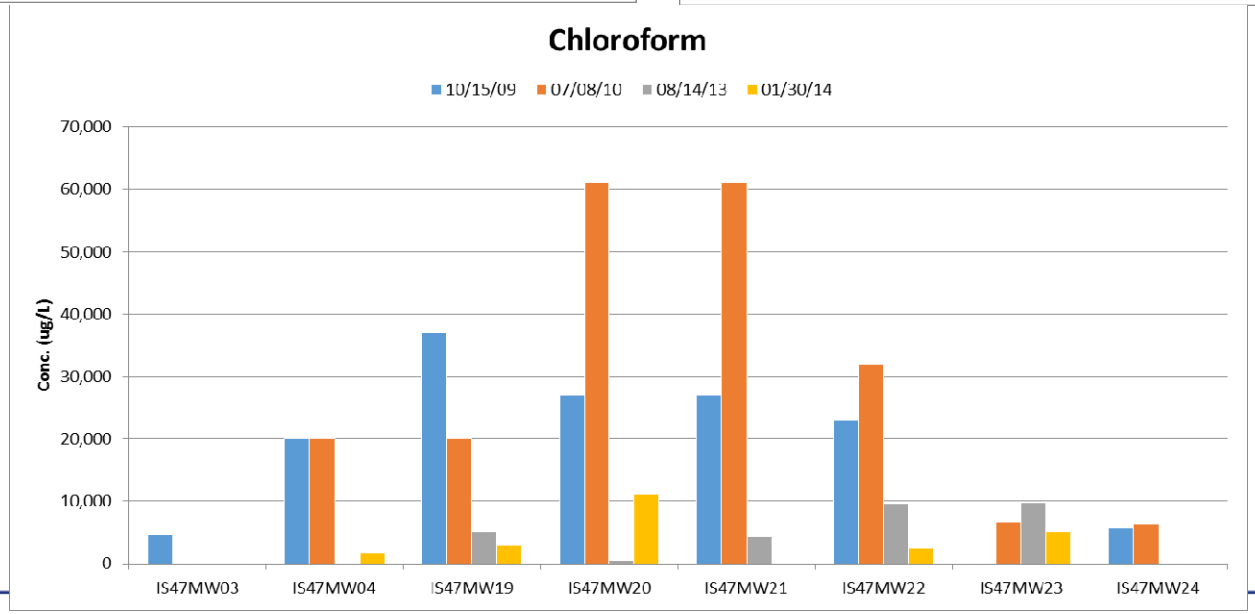
Parameter	Designed	Actual
Target persulfate concentration (g/L)	50	178
Sodium persulfate / NaOH-25%wt (lbs)	204,600 / 351,151	204,972 / 351,400
Injection volume (gals)	477,800	139,200
Total extraction rate (gpm)	38	5


IS47MW31
Parameter | pH | Persulfate (g/L)
Baseline | 6,0 | 0
Maximum | 13.0 | 35
IS47MW32
Parameter | pH | Persulfate (g/L)
Baseline | 6,6 | 0
Maximum | 13.5 | 47
IS47MW03
Parameter | pH | Persulfate (g/L)
Baseline | 6.5 | 0
Maximum | 13.5 | 82
IS47MW21
Parameter | pH | Persulfate (g/L)
Baseline | 8.9 | 0
Maximum | 13.2 | 38
IS47MW19
Parameter | pH | Persulfate (g/L)
Baseline | 9.4 | 0
Maximum | 13.7 | 44
IS47MW29
Parameter | pH | Persulfate (g/L)
Baseline | 4.6 | 0
Maximum | 9.9 | 0
IS47MW20
Parameter | pH | Persulfate (g/L)
Baseline | 6.8 | 0
Maximum | 13.0 | 44
IS47MW25
Parameter | pH | Persulfate (g/L)
Baseline | 6.3 | 0
Maximum | 12.7 | 23
IS47MW30
Parameter | pH | Persulfate (g/L)
Baseline | 5.1 | 0
Maximum | 12.6 | 1
IS47MW24
Parameter | pH | Persulfate (g/L)
Baseline | 6.1 | 0
Maximum | 13.2 | 47
IS47MW22
Parameter | pH | Persulfate (g/L)
Baseline | 5.6 | 0
Maximum | 13.2 | 48
IS47MW26
Parameter | pH | Persulfate (g/L)
Baseline | 6.0 | 0
Maximum | 10.4 | 74
IS47MW28
Parameter | pH | Persulfate (g/L)
Baseline | 5.5 | 0
Maximum | 12.2 | 4
IS47MW04
Parameter | pH | Persulfate (g/L)
Baseline | 5.5 | 0
Maximum | 8.7 | 18
IS47MW23
Parameter | pH | Persulfate (g/L)
Baseline | 5,4 | 0
Maximum | 12.6 | 41
HEW-1
Parameter | pH | Persulfate (g/L)
Maximum | 12.7 | 21
HEW-2
Parameter | pH | Persulfate (g/L)
Maximum | 13.0 | 4
HEW-1
HEW-2

Full-Scale Remedy: Results







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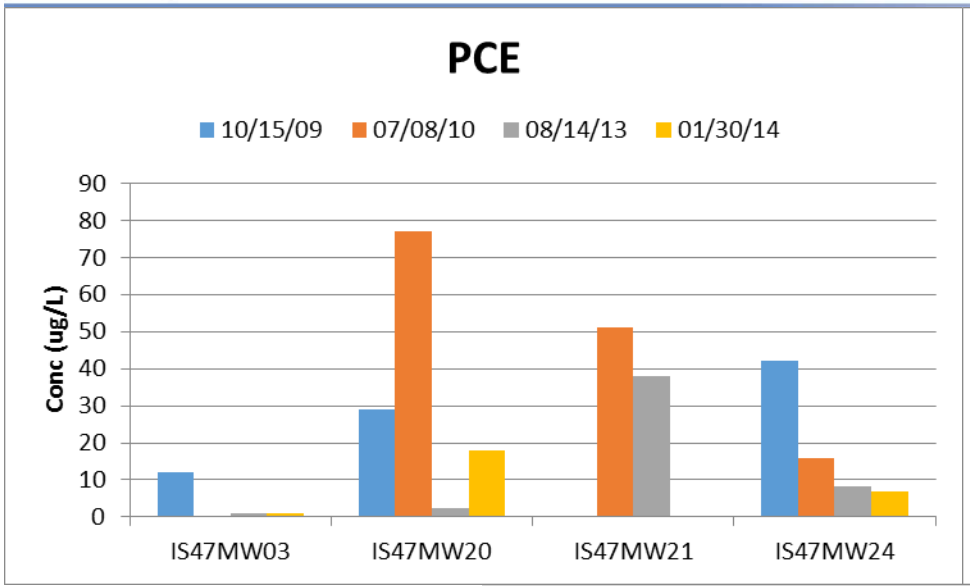

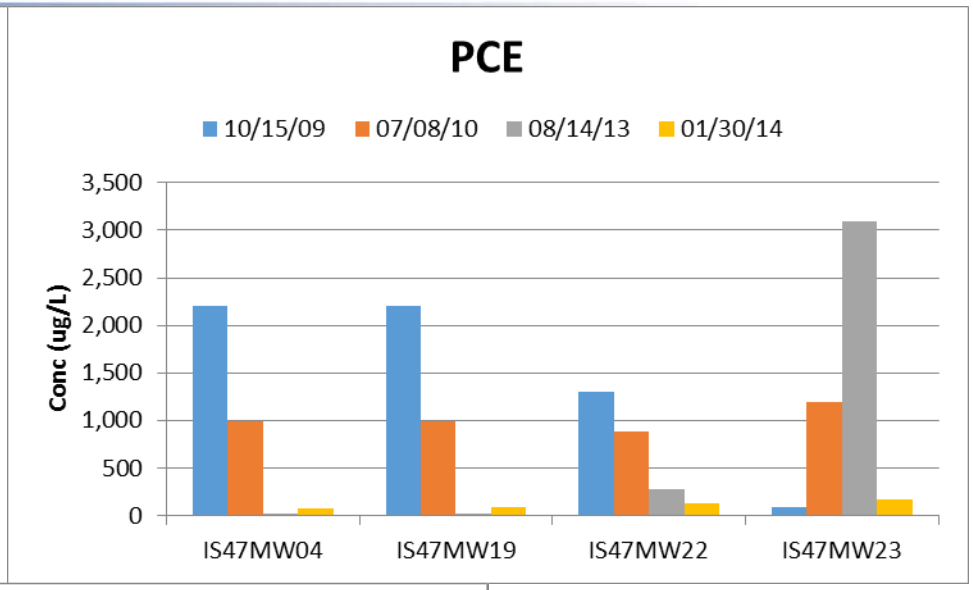

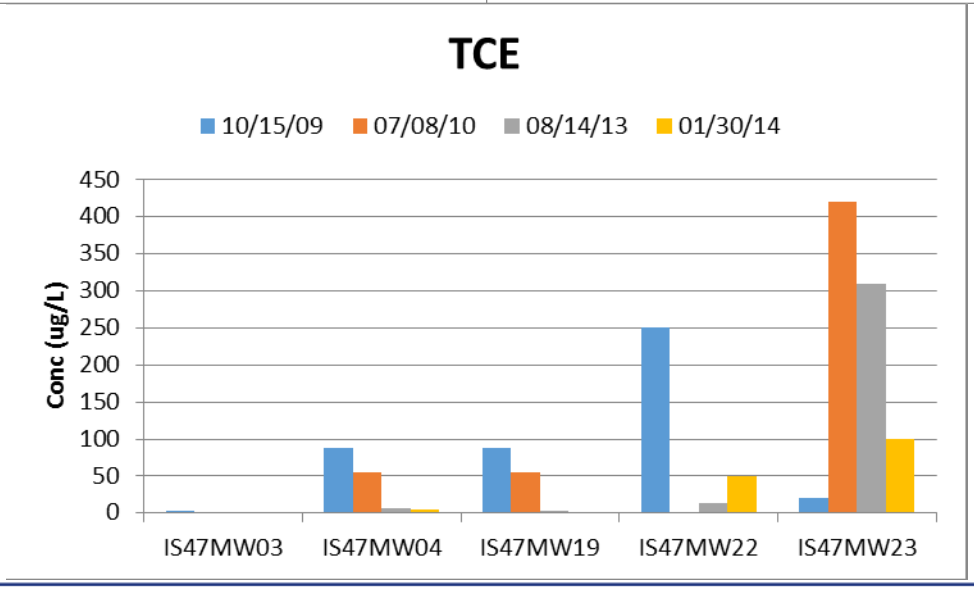

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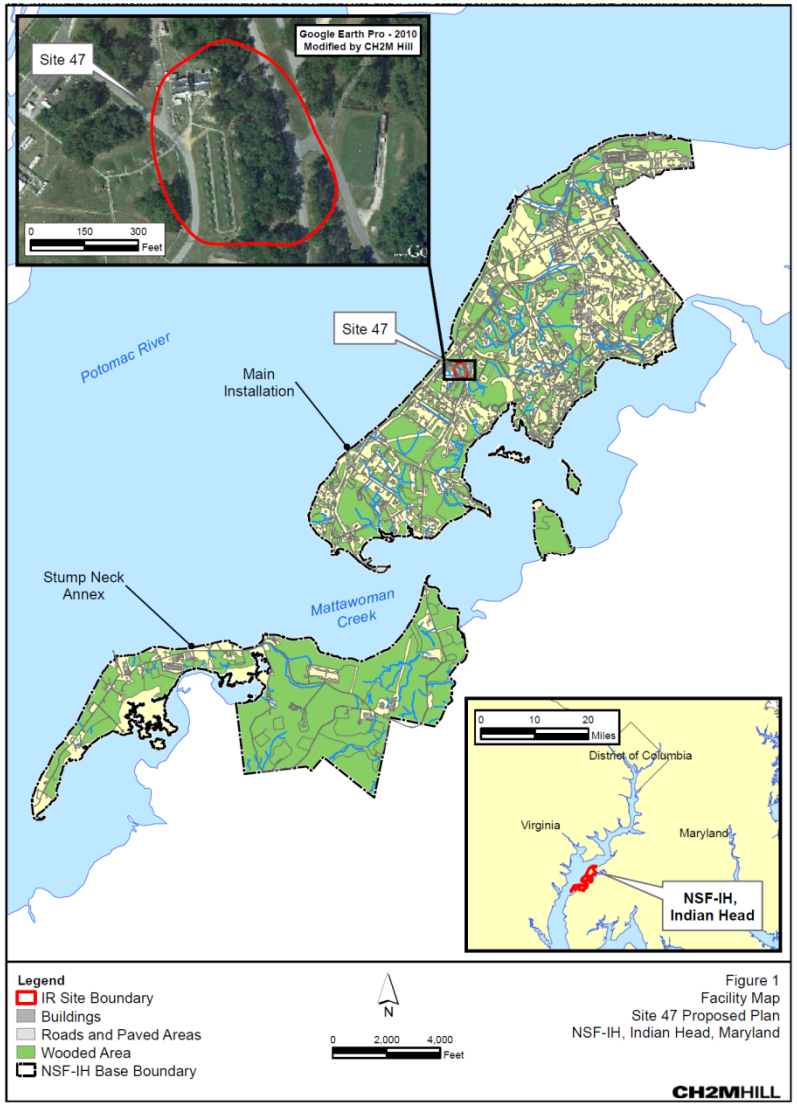

Challenges and Lessons Learned

- **Non optimal extraction rate from horizontal wells**
  - **Operation modifications:**
    - Pulsed extraction
    - Well head seals
    - Adjustment of inlet placement/level
    - Optimizing pump performance
    - Foot valve variation (with/without and stainless steel/PVC)
- **Preferential reagent distribution in the eastern portion of target area**
  - **Operation modification:**
    - Using HEW-2 for injecting reagent

Questions ?