Remedy Optimization via Correlation of Hydraulic Profile Tooling and Membrane Interface Probe Studies

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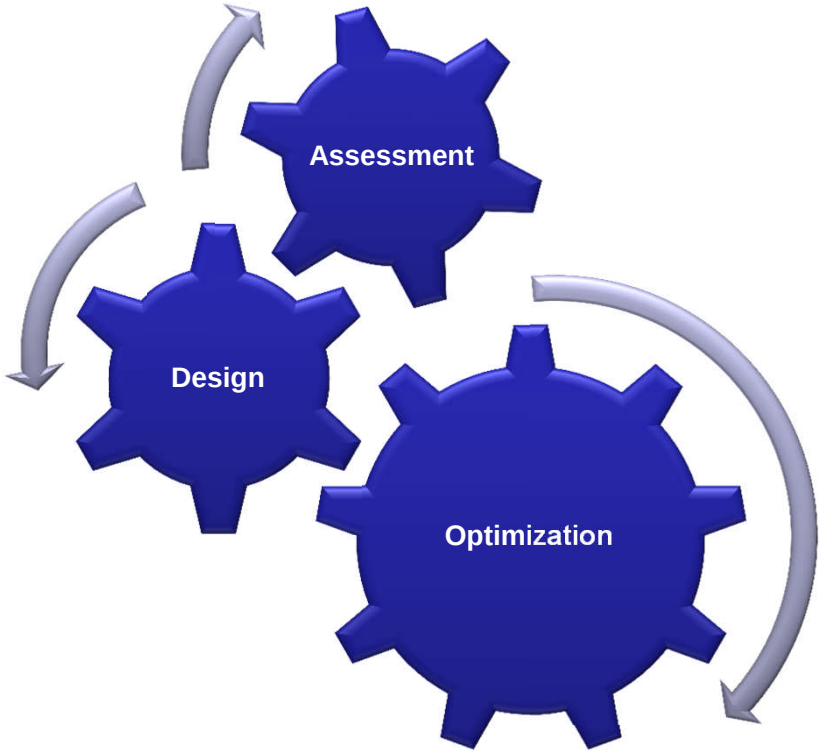
Goals / Overview

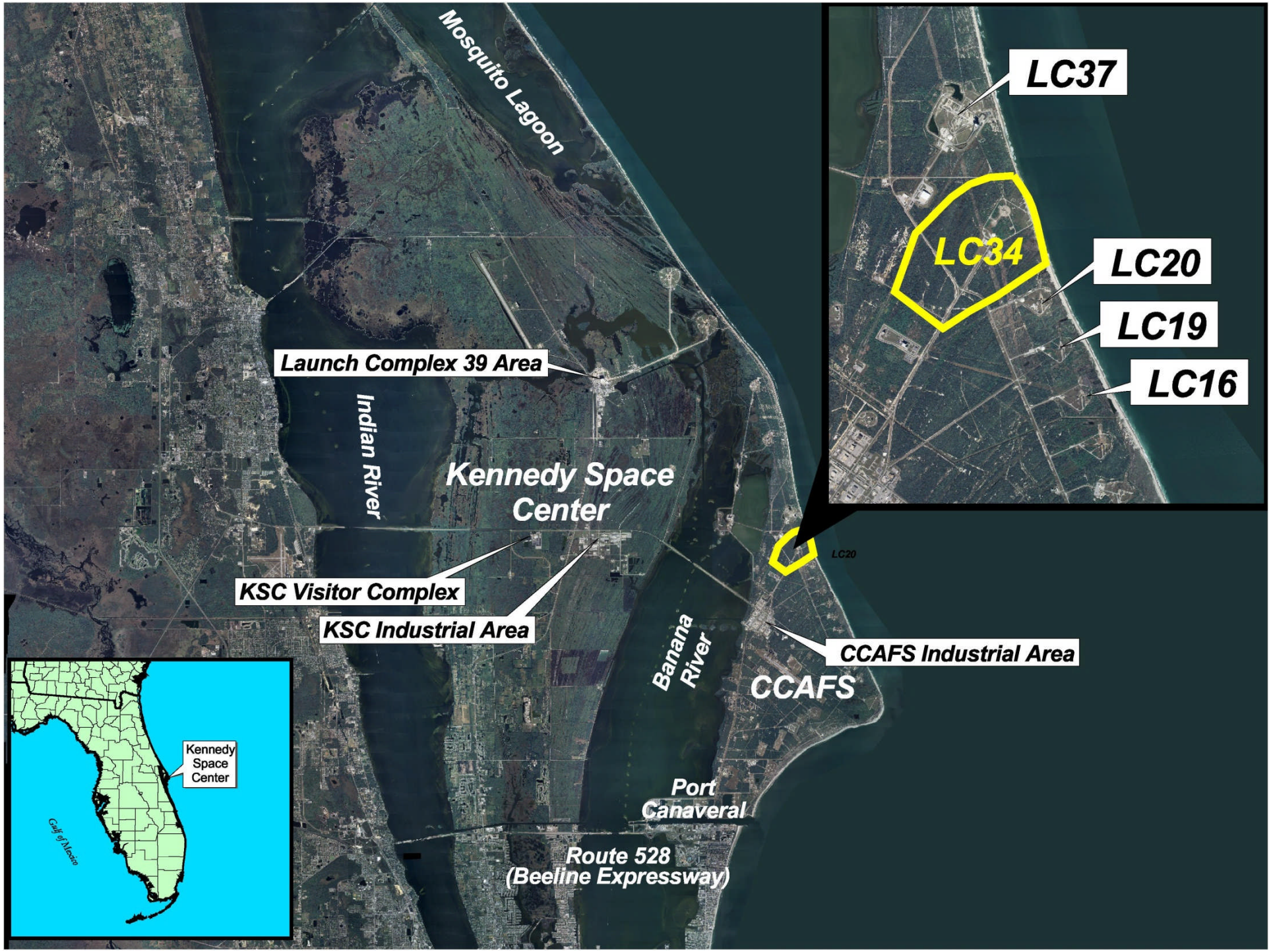
TETRA TECH

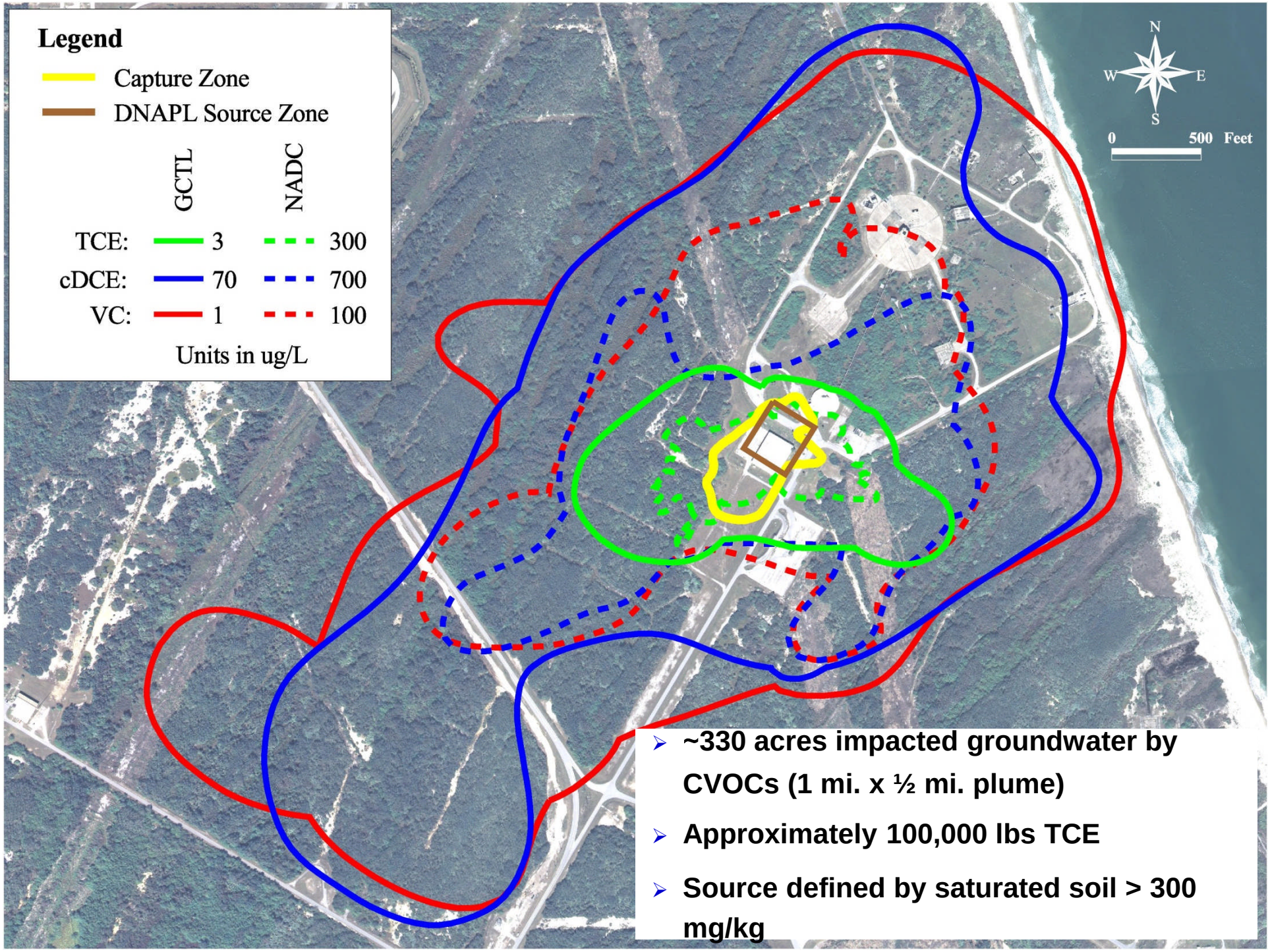
- Site Background
- Interim Measure (IM) Results
- Hydraulic Profiling Tool (HPT)/ Membrane Interface Probe (MIP) Study Goals
- Study Data
  - Pre-IM/Interim IM MIP data
  - MIP/HPT Data Correlation
- Refined Conceptual Model
- Optimizations

Adaptive Management Perspective

- LC34 Adaptive Site management Practices (Battelle 2012):
  - Assessment (*DOES NOT END WITH DESIGN*)
  - Design (*DOES NOT END WITH IMPLEMENTATION*)
  - Optimization Evaluations (*THROUGHOUT*)




Mosquito Lagoon
LC37
LC34
LC20
LC19
LC16
Launch Complex 39 Area
Indian River
Kennedy Space Center
LC20
KSC Visitor Complex
KSC Industrial Area
Banana River
CCAFS Industrial Area
CCAFS
Kennedy Space Center
Gulf of Mexico
Port Canaveral
Route 528 (Beeline Expressway)



- **~330 acres impacted groundwater by CVOCs (1 mi. x ½ mi. plume)**
- **Approximately 100,000 lbs TCE**
- **Source defined by saturated soil > 300 mg/kg**

Pre-IM Site Conceptual Model

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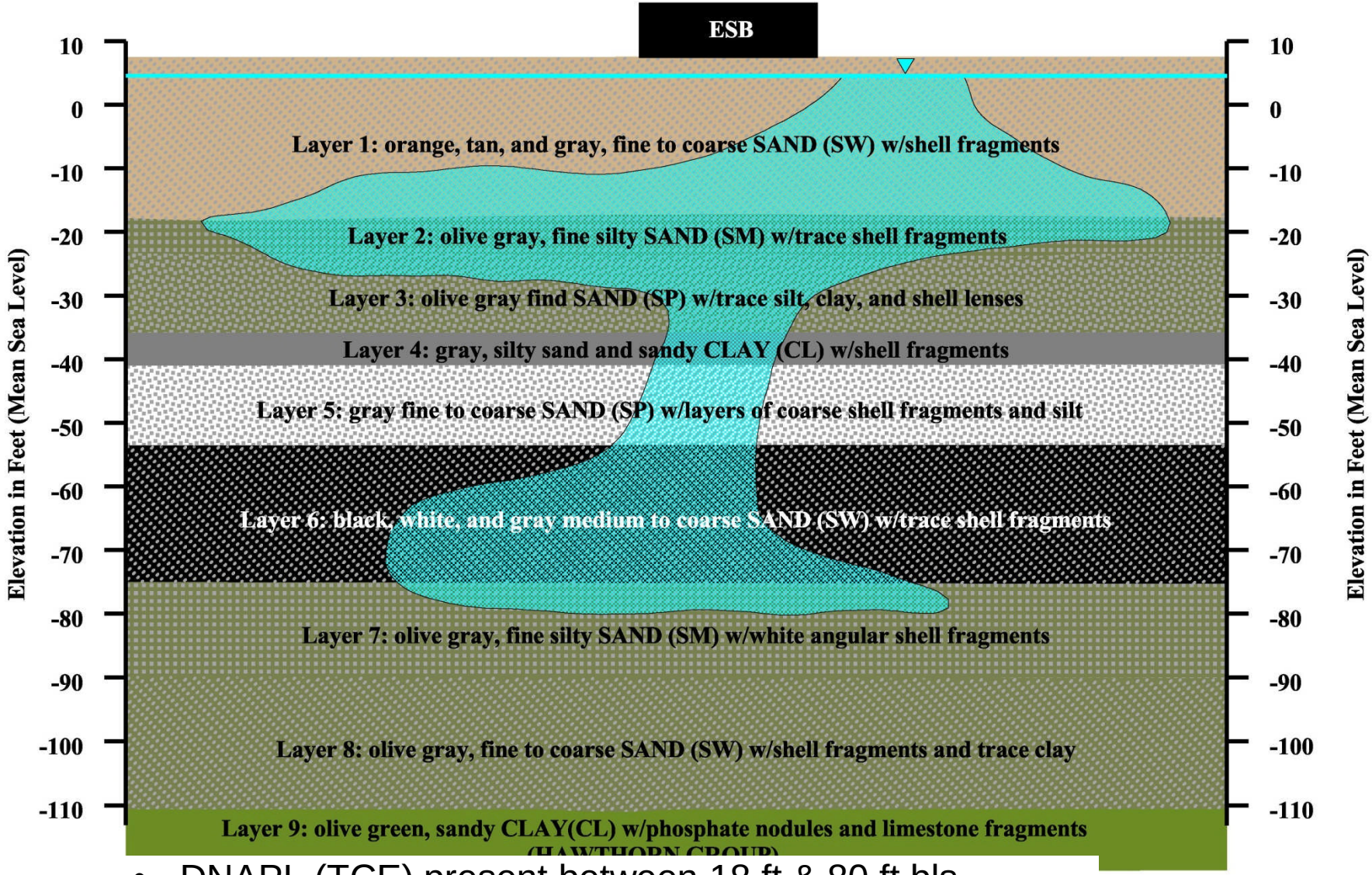

- DNAPL (TCE) present between 18 ft & 80 ft bls

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Interim Measure Overview

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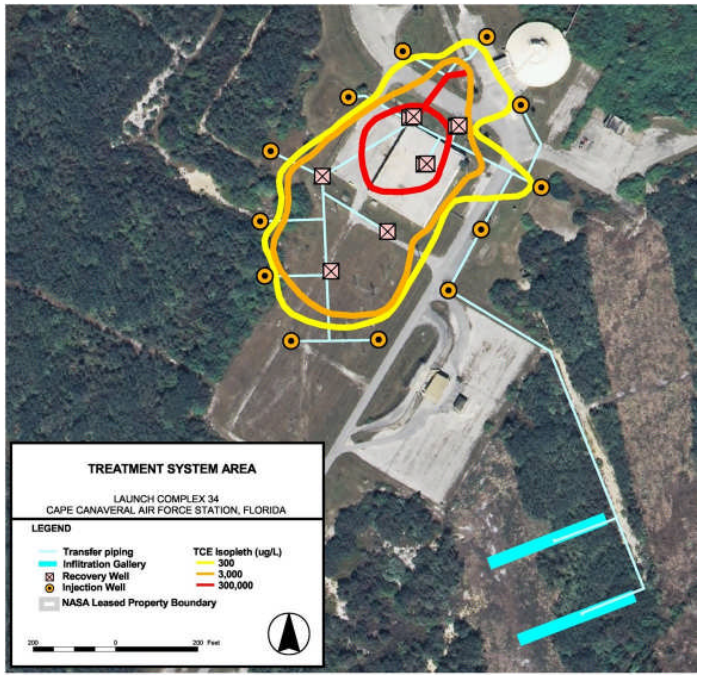
- Hydraulic control of the DNAPL source zone and deep groundwater TCE plume >300 µg/l
- Treat extracted groundwater to GCTLs
- Design peak flow of 50 gpm and normal flow of 39 gpm
- Primary components include:
  - 3 shallow recovery wells
  - 6 deep recovery wells
  - Primary treatment via air stripping
  - Liquid Phase GAC polishing
  - Catalytic oxidation off gas treatment
  - Discharge treated groundwater to 12 deep injection wells and infiltration gallery



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Interim Measure Results

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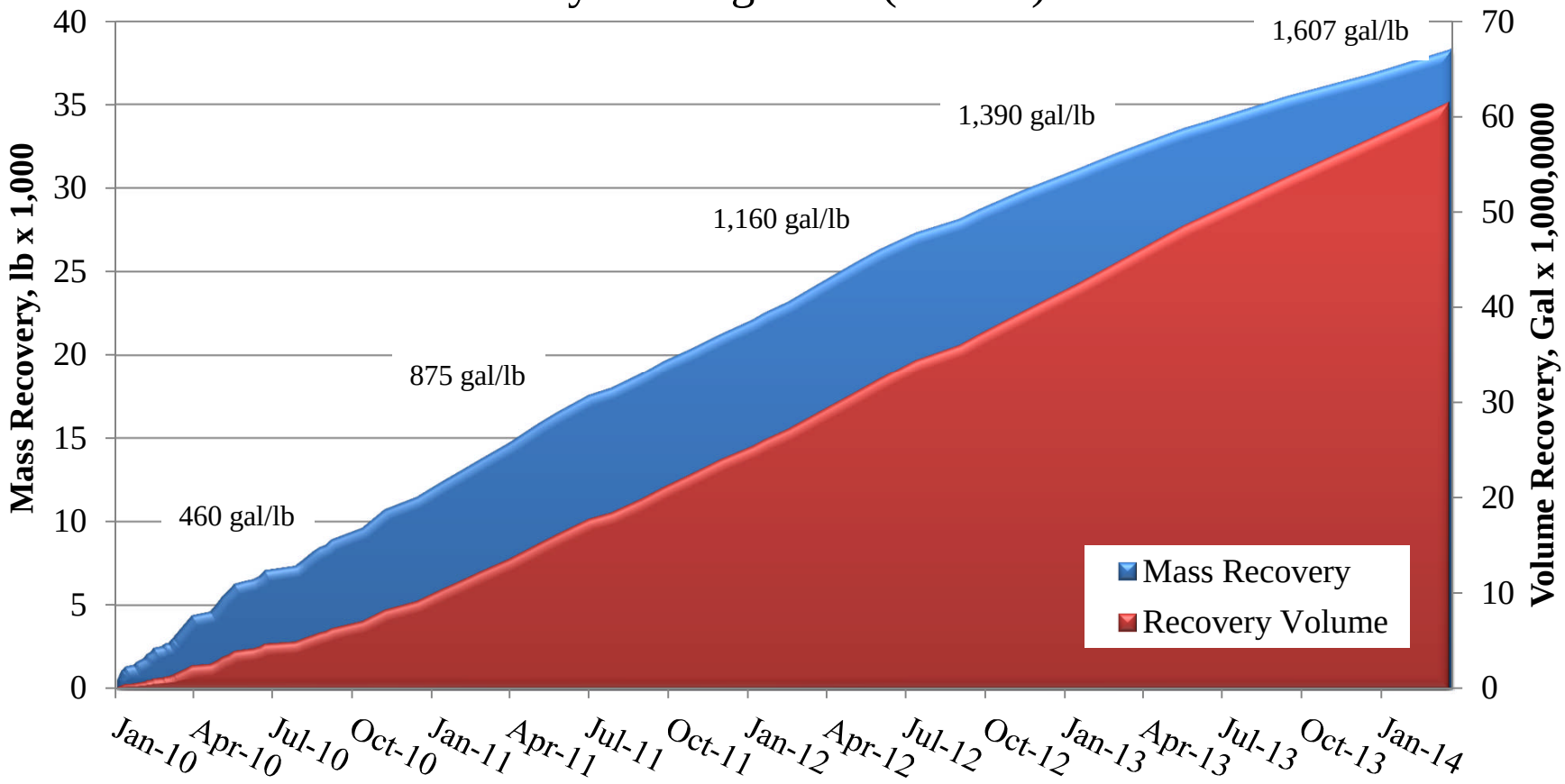
- CVOC Mass recovery: 38,294 lb (4/2014); 16 lb/d average (Year 4)
- Cost per pound of CVOC mass recovered: $83/lb (Previous Year: $94/lb)
  - Capital cost driven, figure continues to decrease as operation continues
- Groundwater recovery: 61M gallons (4/2014)



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MIP/HPT Study Goals

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- Identify depth intervals where contamination persists
- Obtain knowledge of hydraulic conductivity variations
- Correlate conductivity and contamination magnitude
- Distinguish mass storage and transport zones
- Optimize existing operations and IM expansion efforts

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HPT Overview

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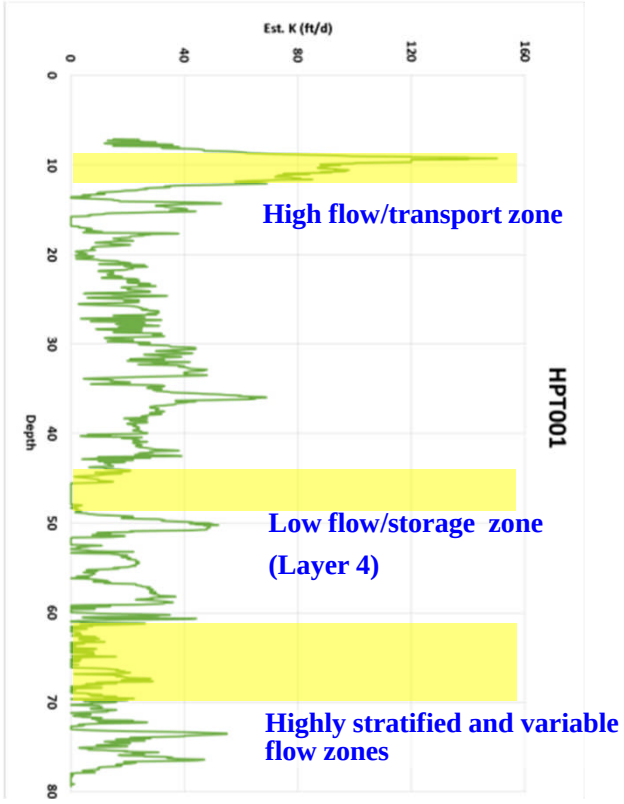
- Technology use: Real-time vertical hydraulic conductivity profiling
- Equipment: DPT Rig, HPT Tooling (pressure/conductivity sensor & water injector)
  - Water injected as tool is advanced
  - Pressure sensor measures response of soil to water injection
    - Identifies ability of soil to transmit water
- Measured data output: Electrical conductivity, injection flow and pressure
- K value calculated by HPT software
  - Peaks indicate high K/flow zones
  - Valleys indicate low K/flow zones



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MIP/HPT Locations

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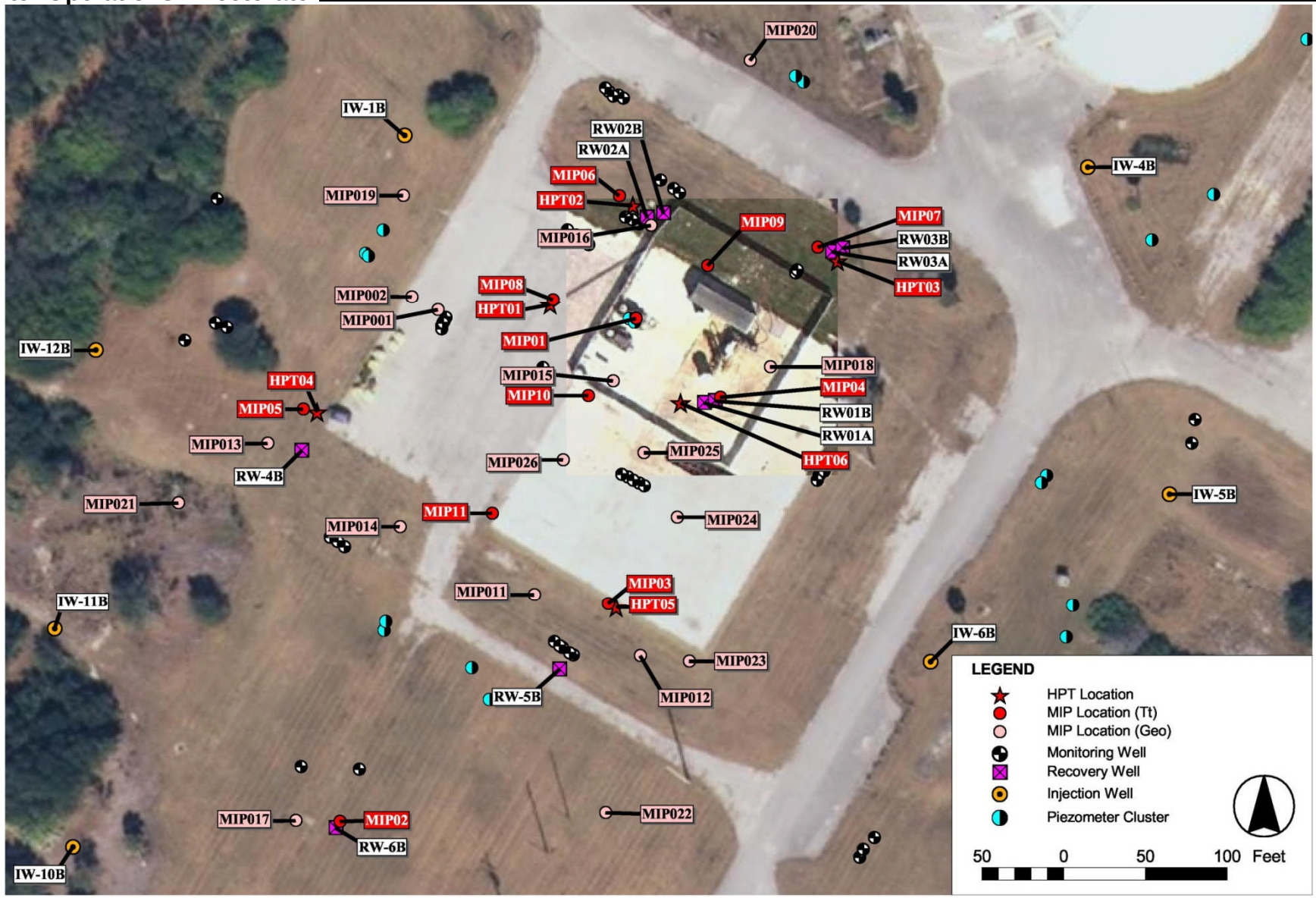

RW1A/1B Optimization:

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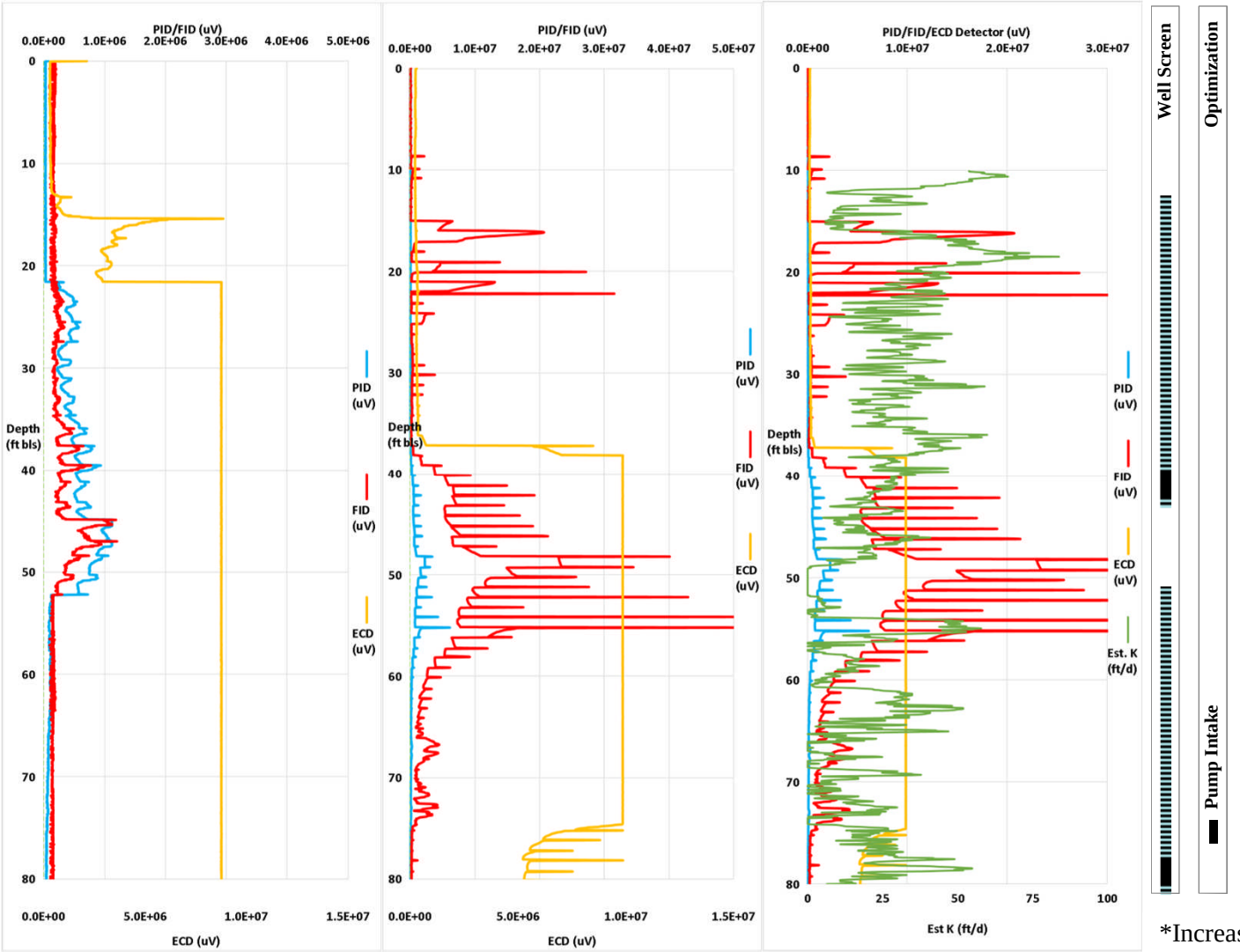
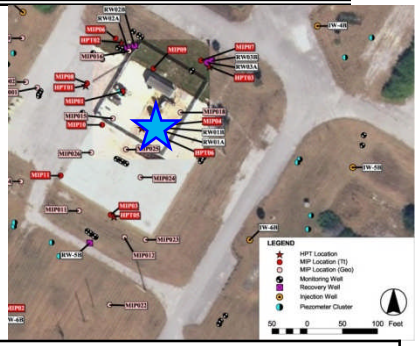
TETRA TECH

Pre-IM MIP: Jan 2013 MIP: Jan 2013 HPT/MIP





RW-1A Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	240,000	20.9
2/21/2011	35,700	6.2
2/2/2012	85,000	7.0
3/11/2013	91,900	6.8
4/3/2014	91,800	6.7

RW-1B Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	130,000	5.4
2/21/2011	198,000	7.4
2/2/2012	176,000	13.2
3/11/2013	73,800	4.8
4/3/2014	62,400	6.1

*Increase RW1B from 5 to 7.5 gpm

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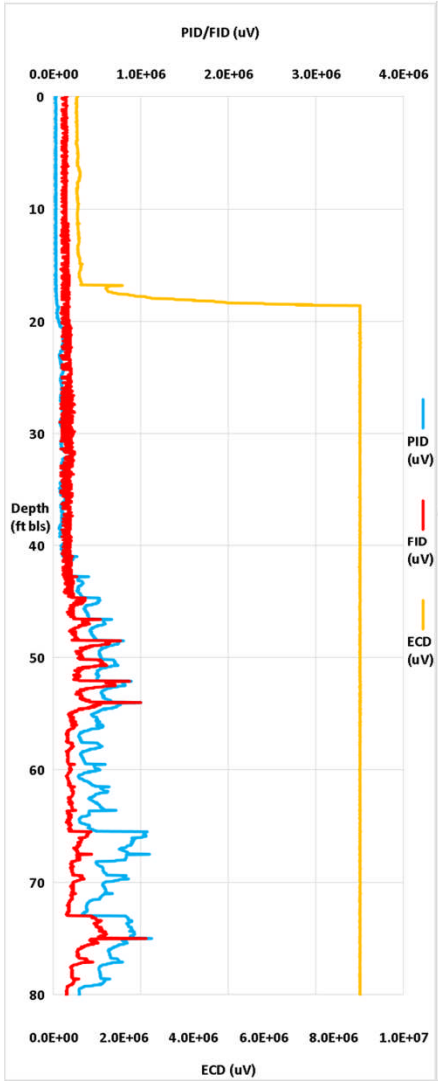
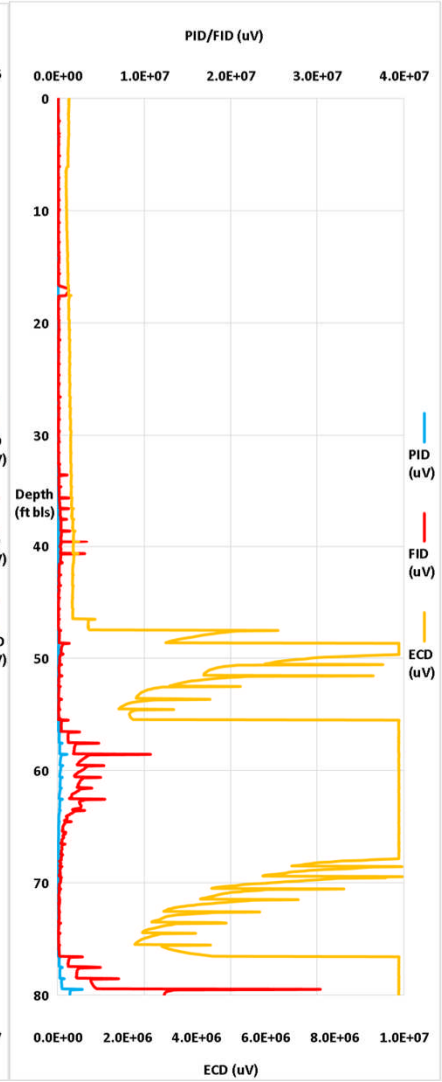
RW2A/2B Optimization

TETRA TECH

Pre-IM MIP:



Jan 2013 MIP:



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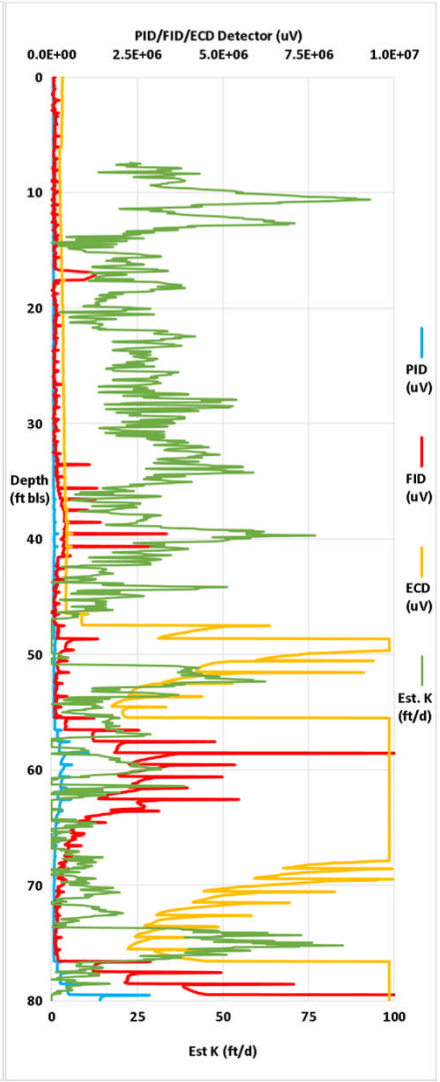

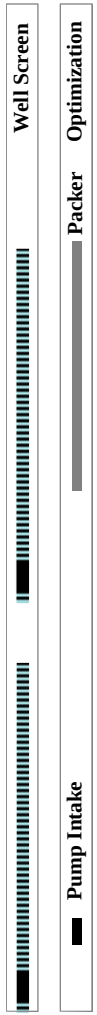

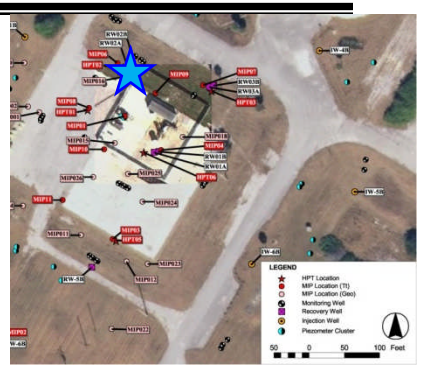

RW-2A Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	280,000	28.5
2/21/2011	3,630	4.4
2/2/2012	42,500	3.8
3/11/2013	39,000	3.2
4/3/2014	33,600	2.6

RW-2B Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	940,000	34.7
2/21/2011	203,000	7.4
2/2/2012	126,000	9.3
3/11/2013	66,300	4.2
4/3/2014	59,900	5.6

*Increase RW2B from 5 to 7.5 gpm

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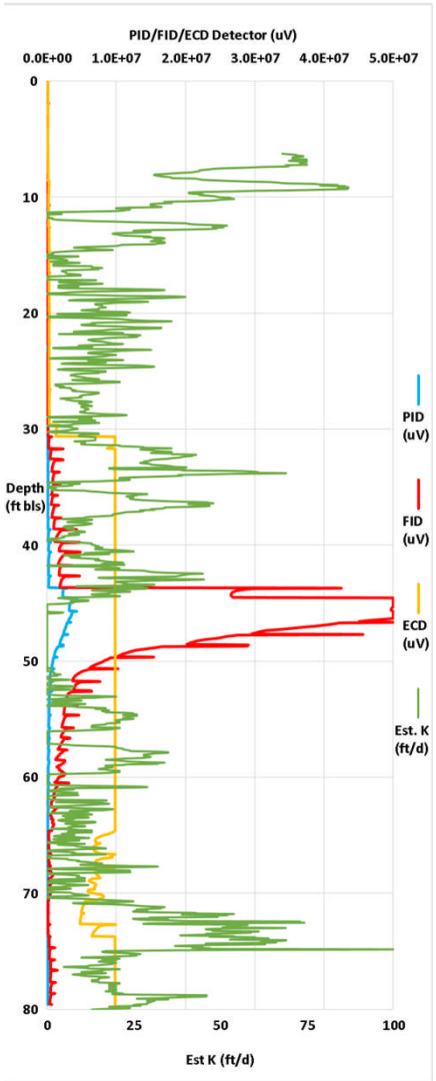
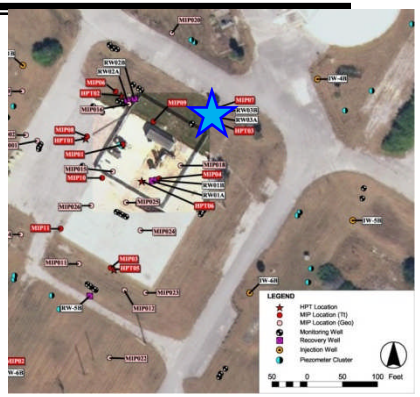
RW3A/3B Optimization

TETRA TECH

Jan 2013 HPT/MIP:





RW3A

- Mobile mass at 30-46' bls
- Immobile mass at 43-52' bls (within screen)
- Isolate screen from 30-46' bls

RW3B

- Immobile mass at 43-52' bls
- Mobile mass at 52-65' bls
- Move pump intake to 65'bls; pump at 3 gpm

*Rehab (surge/chemical) if no signif. changes

*Layer 4 mass storage

RW-3A Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	41,000	3.8
2/21/2011	3,520	2.9
2/2/2012	427	1.8
3/11/2013	80	0.5
4/3/2014	<60	0.4

RW-3B Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	16,000	1.0
2/21/2011	6,540	0.3
2/2/2012	3,210	0.1
3/11/2013	2,200	0.1
4/3/2014	2,200	0.1

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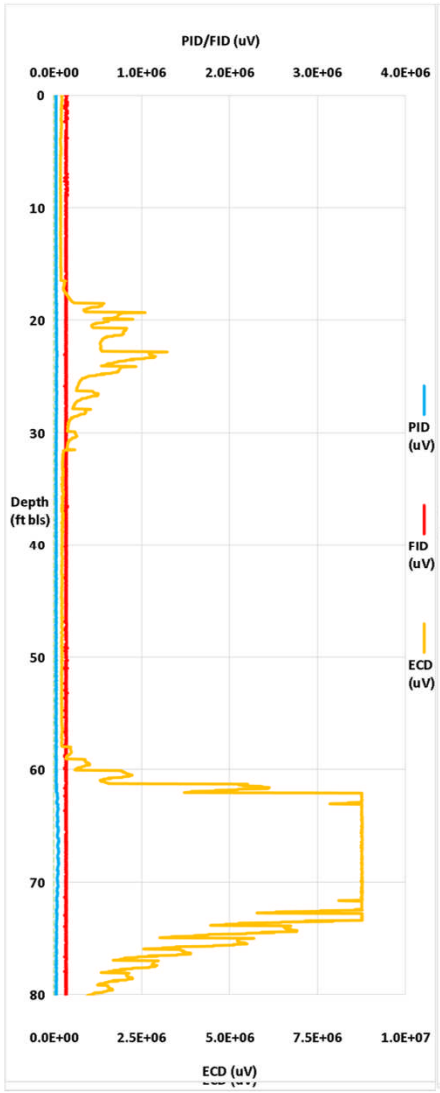
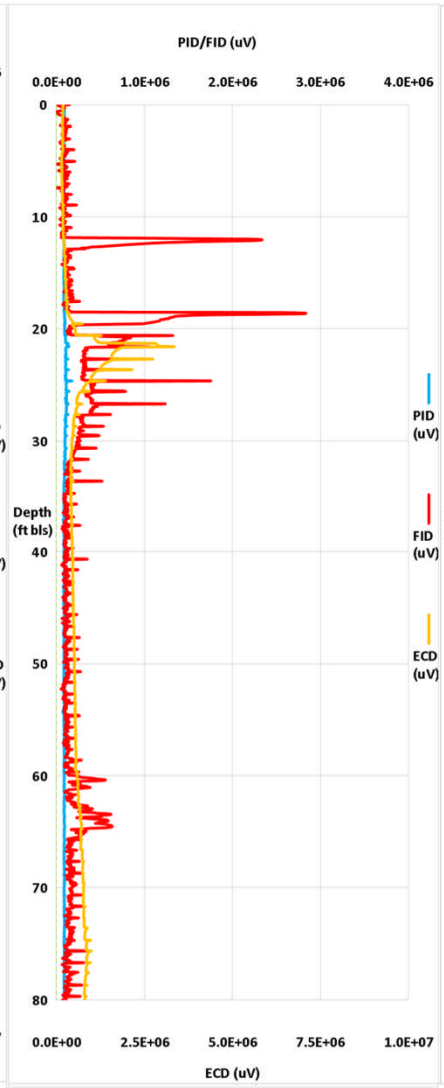
RW4B Optimization

TETRA TECH

Pre-IM MIP:



Jan 2013 MIP:



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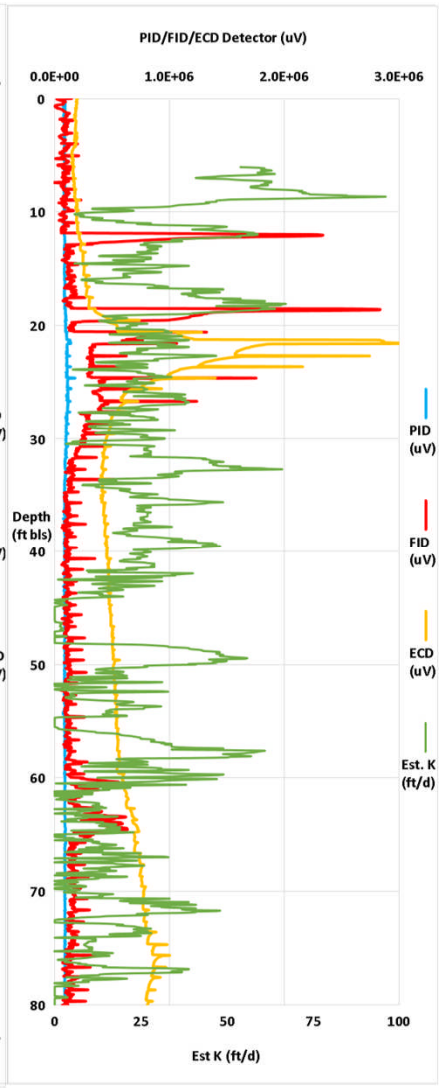

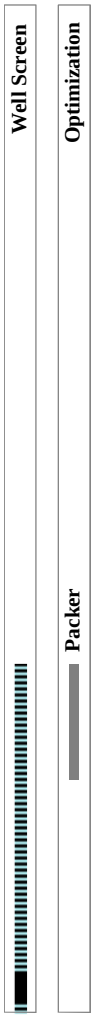

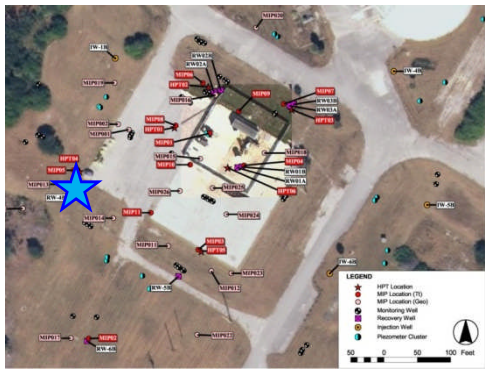

RW-4B Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	250,000	17.0
2/21/2011	54,100	3.5
2/2/2012	16,100	1.0
3/11/2013	2,640	0.2
4/3/2014	517	<0.1

*Reduce flow rate from 4 to 3 gpm (expansion flow budget variable)

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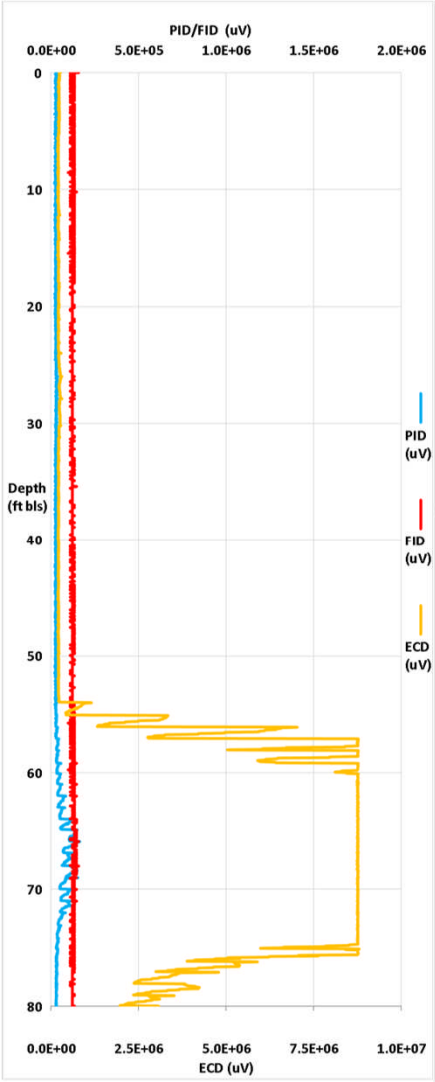
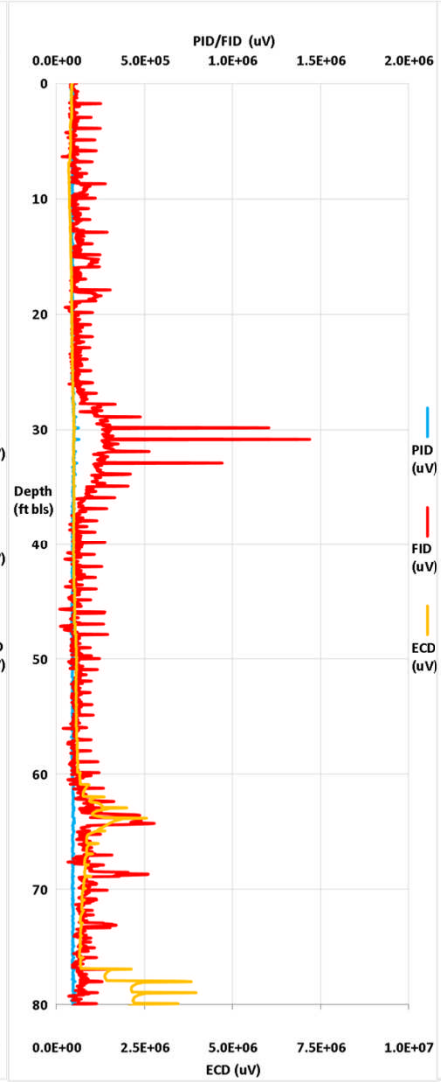
RW5B Optimization

TETRA TECH

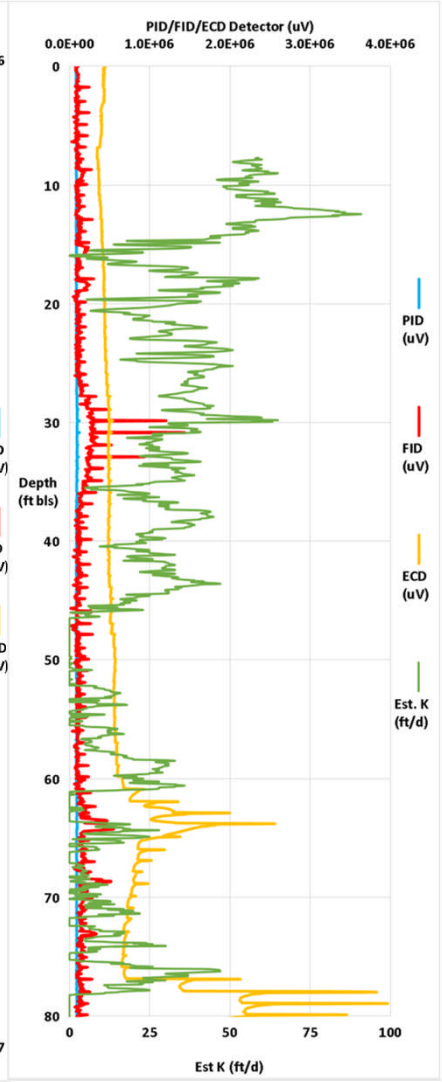
Pre-IM MIP:

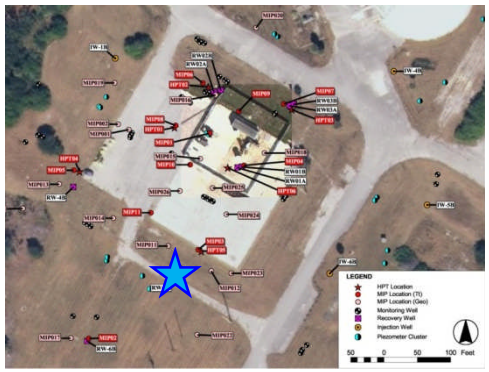


Jan 2013 MIP:



Jan 2013 HPT/MIP:





RW-5B Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	250,000	16.9
2/21/2011	86,400	5.6
5/18/2011	77,700	5.0
2/2/2012	57,000	3.7
3/11/2013	47,300	3.1
4/3/2014	9,050	0.6

*Reduce flow rate from 4 to 2 gpm (expansion flow budget variable)

RW6B Optimization

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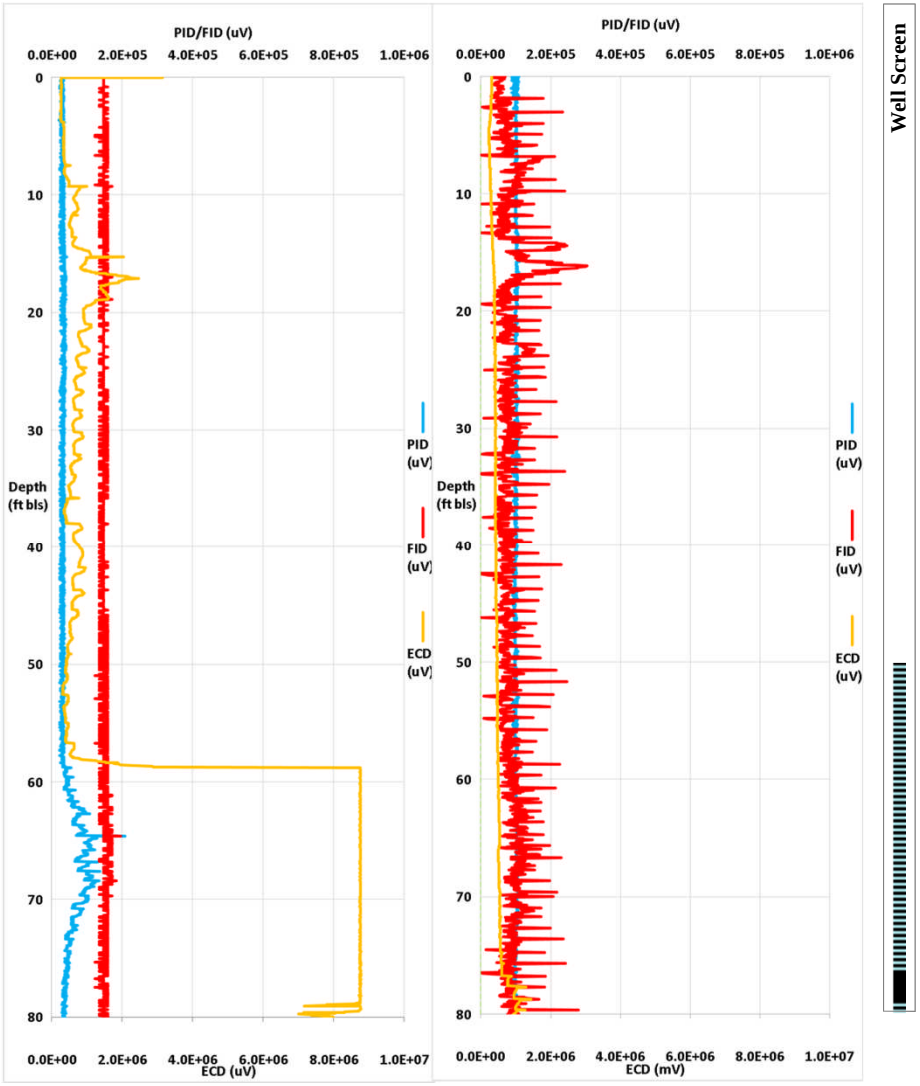
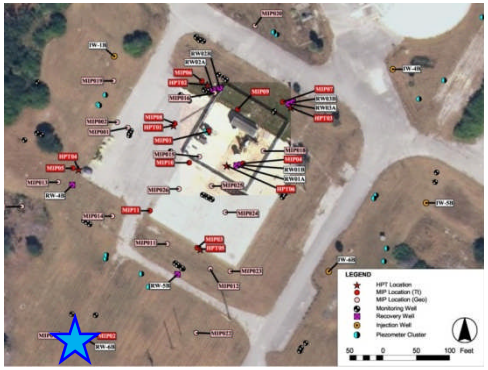
TETRA TECH

Pre-IM MIP: Jan 2013 MIP:





RW-6B Influent		
Date	**TCE (ppb)**	**Mass Recovery (lbs/d)**
1/20/2010	270,000	18.5
2/21/2011	43,400	3.0
2/2/2012	9,320	0.6
3/11/2013	1,360	0.1
11/20/2013	<0.21	<0.1

*Based on influent and MIP data, shutoff of well approved; pumping capacity offset to other wells

Conceptual Model Refinement

- Additional TCE mass identified between DPT sampling intervals +/- 18 feet bls in lower portion of Layer 1
- MIPS/HPTs confirmed Layer 4 mass storage extent
- MIPs improved understanding of flux and remaining source zones
- MIPs verified source zone model assumptions
- HPTs identified that Layer 6 (60-80 feet bls) is more heterogeneous than identified via soil coring
- MIP/HPT pairings narrowed the intervals capable of mass transport and storage within Layer 6
- MIP/HPT pairings hint at mass storage/back diffusion in upper portion of Layer 7 (>80 ft bls)

Conceptual Model Refinement

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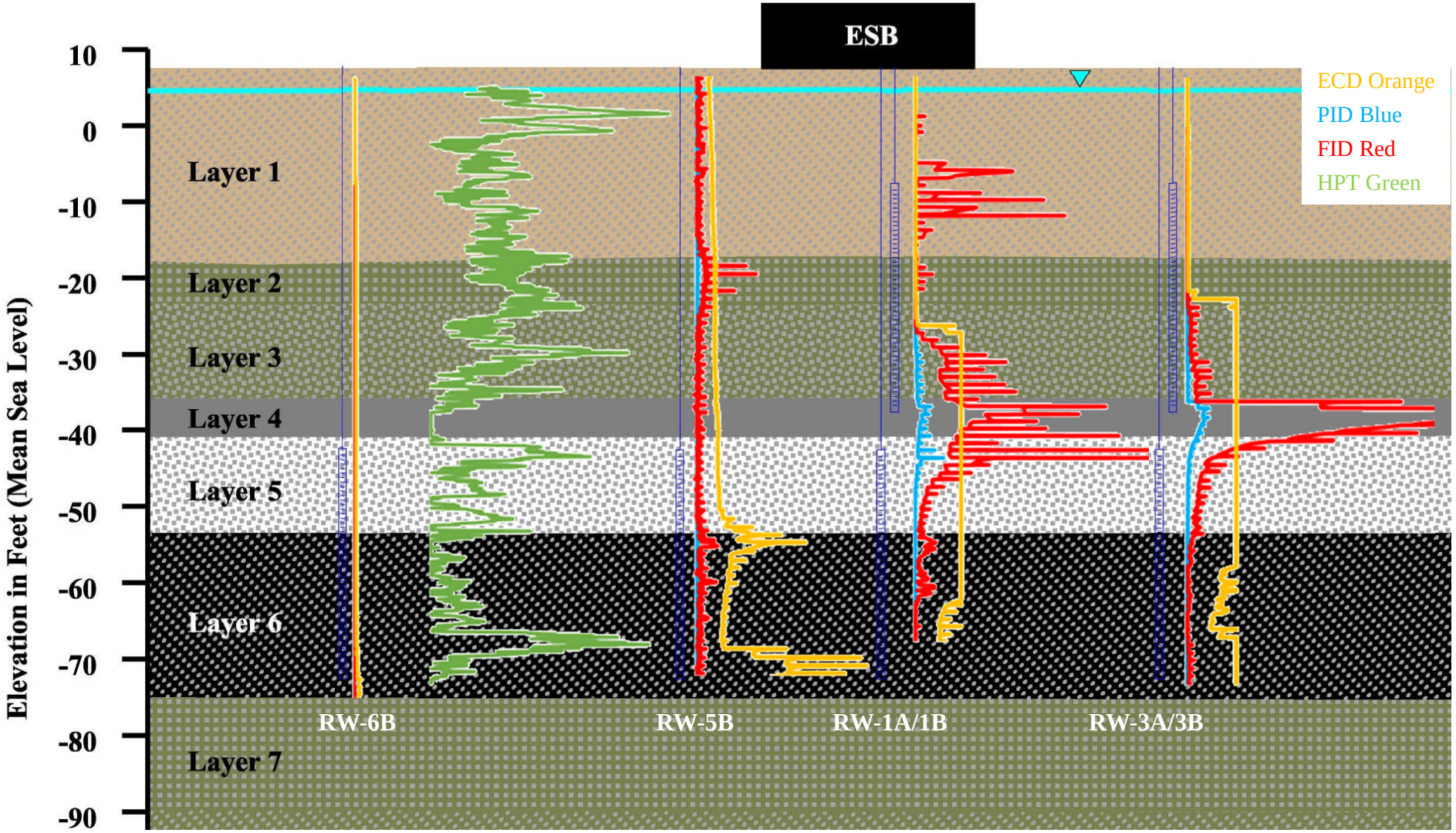

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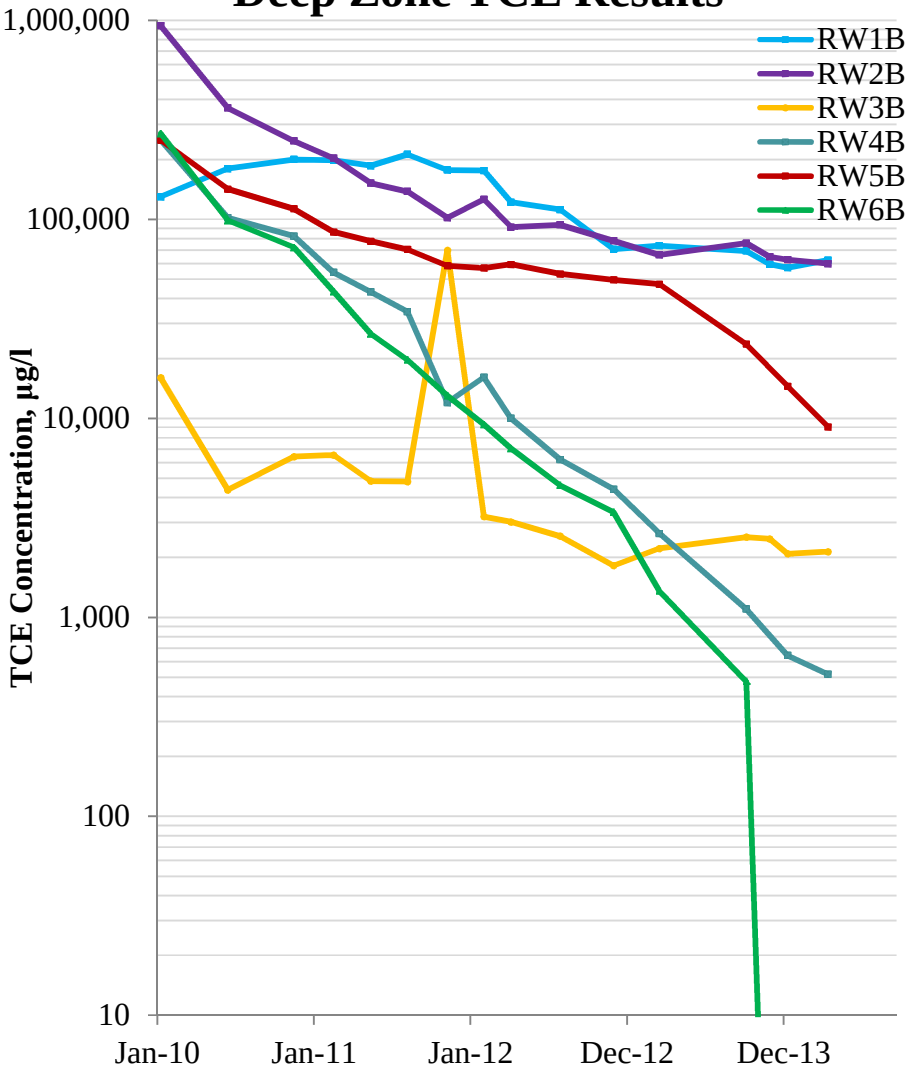
Recovery Well Influent

TETRA TECH

Shallow Zone TCE Results

Deep Zone TCE Results



Remedial Strategy Refinement

- MIP/HPT pairings provided additional lines of evidence for capture/flow manipulation
- Recovery well screens selectively packered
- Pump intakes adjusted based on contaminant magnitude and conductivity characteristics
- RW-6B deactivated based on multiple criteria, supported by Pre-IM and Interim MIP data
- Identified need for additional deep extraction well (via MIP)
- Upcoming expansion of shallow recovery well network enhanced with increased site knowledge

Applying to Your Site

- Enhance site conceptual model/remedy approach
- Verify sampling intervals relative to conductivity zones
- Does the remedy address mobile/immobile mass?
- Does hydraulic conductivity constrain the effectiveness?
- HPT/MIP assessment is not technology specific. Examples:
  - Surgical treatment interval optimization
  - Substrate distribution prediction
  - Injection pressure requirements
  - Remedy progress/optimization
  - Mobile/immobile mass assessment
  - Changes in permeability from remedy (e.g., mixing, ZVI, etc.)

Questions