Vertex Environmental Inc.

Optimizing Oxidant Delivery for In-Situ Remediation

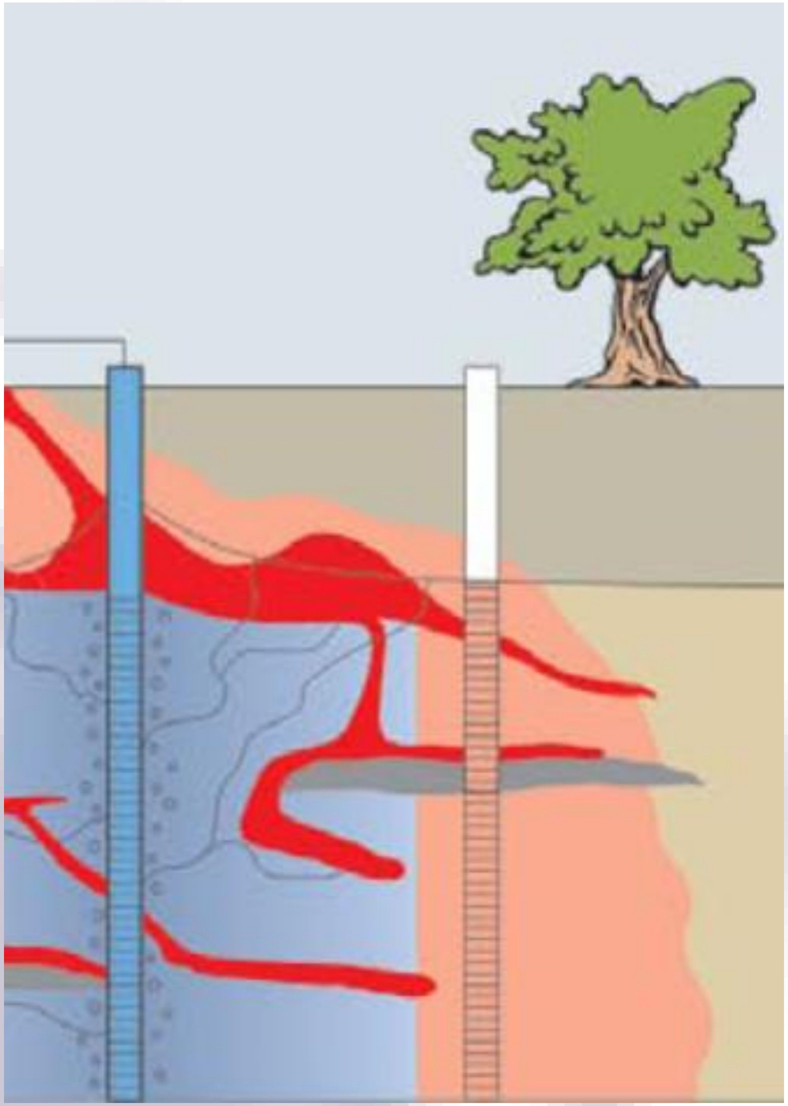
Remediation Technologies Symposium 2012

Banff, Alberta

October 19, 2012

Bruce Tunnicliffe

Overview



- Background
  - Purpose of Talk
  - Vertex
  - What is In-Situ? Key Factors
- Contaminant Distribution
  - Free Phase Product
  - Dissolved Phase Plume
- Oxidant Delivery
  - Delivery Method
  - Delivery Experiment
- Questions

Purpose of Talk

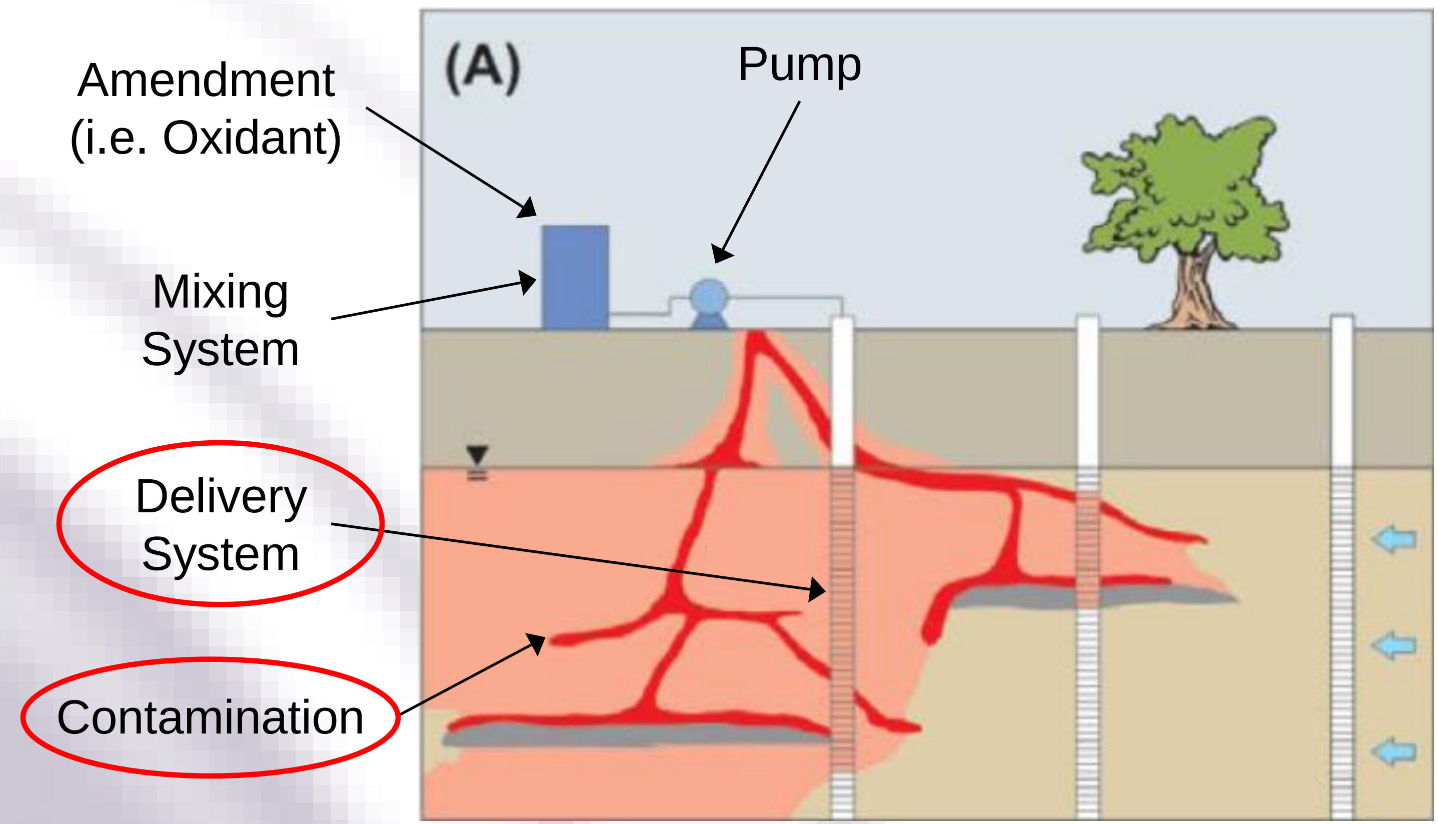
- In-situ remediation is now commonly considered and applied
- Currently: pre-remediation data & design for an in-situ project is similar to excavation

- Purpose: Explore what we need to consider to better deliver a remediation liquid (i.e oxidant) to the subsurface to improve remedial success.

Vertex Background

- Environmental Contracting
- Remediation and injection services
- Clients are consultants
  - ➢ Consultant: Phase II ESA
  - ➢ Vertex: Remedial Design, Remediation (bench, pilot, full-scale)

What Is In-Situ?

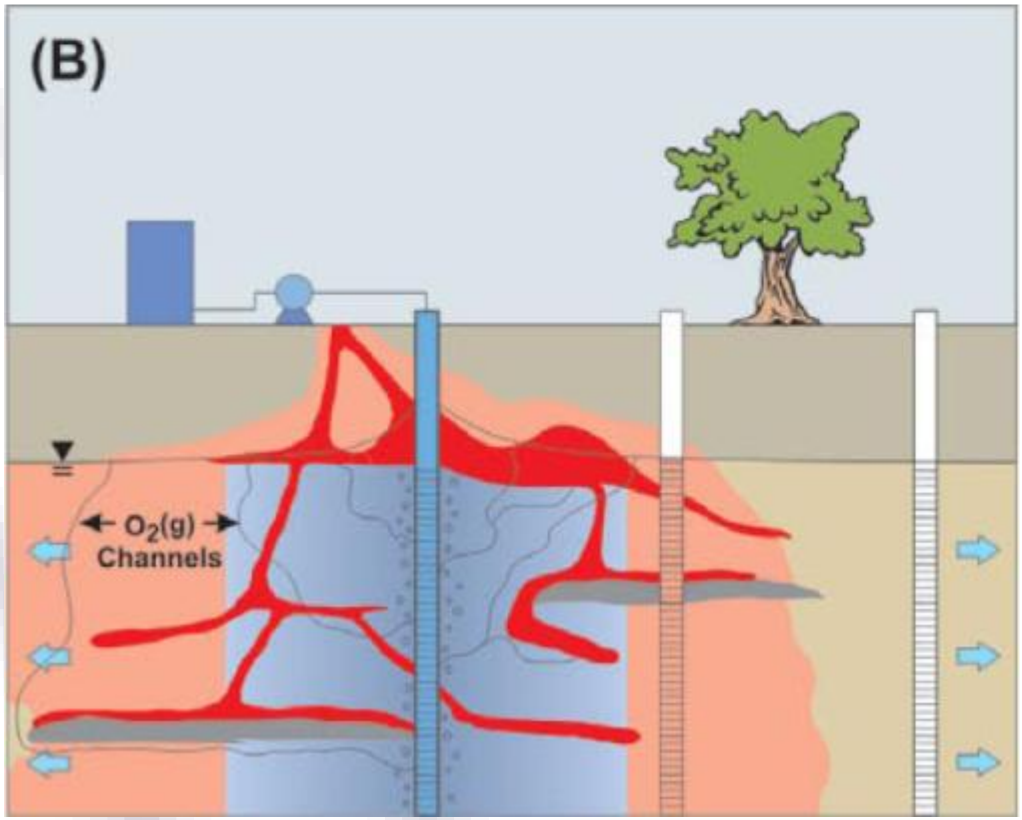


- In-Situ is a Latin phrase meaning “in its place”
- Remediation completed in the ground

Source: EPA, 2010

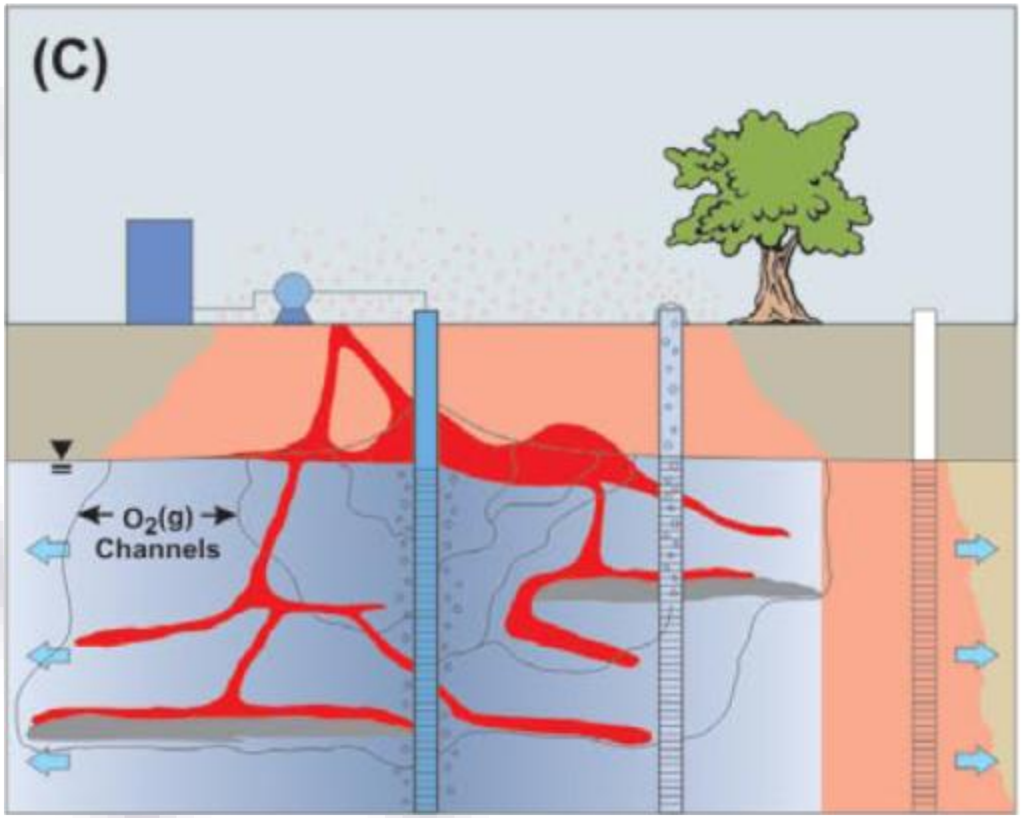
VERTEX

What Is In-Situ?



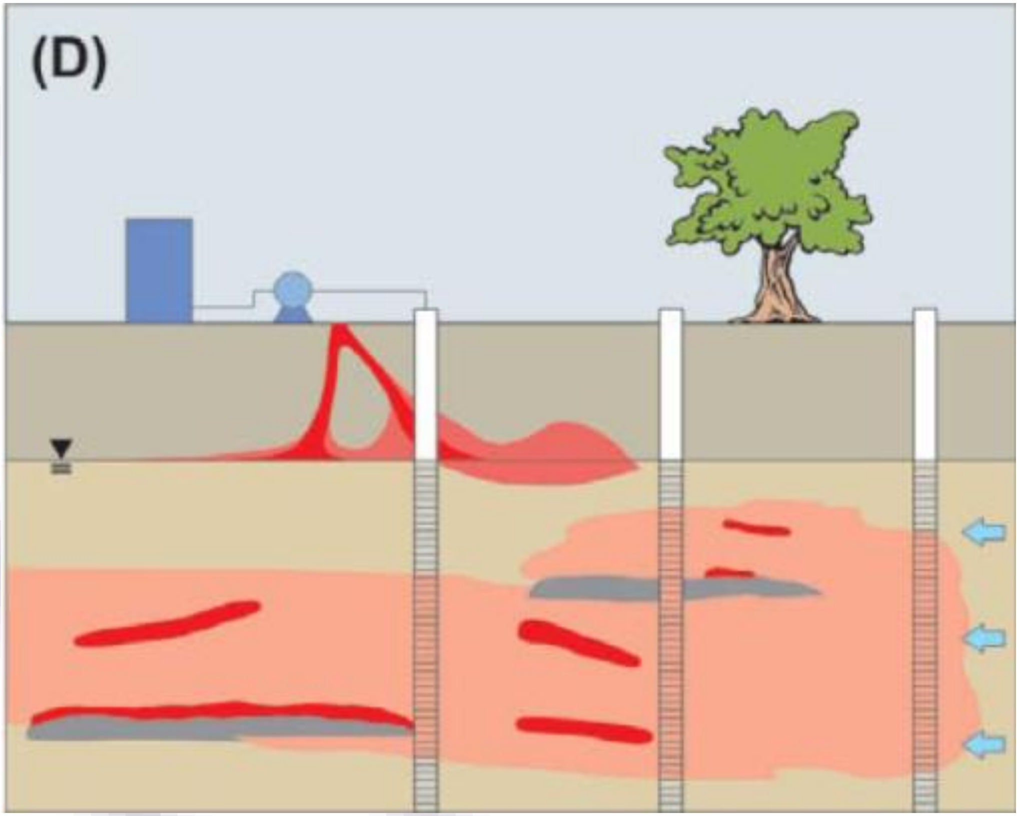
Source: EPA, 2010

What Is In-Situ?



Source: EPA, 2010

What Is In-Situ?



Source: EPA, 2010

Contaminant Characterization

Advanced Characterization Tools:

- Laser Induced Fluorescence
  - LIF
  - Free Product (LNAPL)
- Membrane Interface Probe
  - MIP
  - Dissolved Phase (Plume)

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Contaminant Characterization

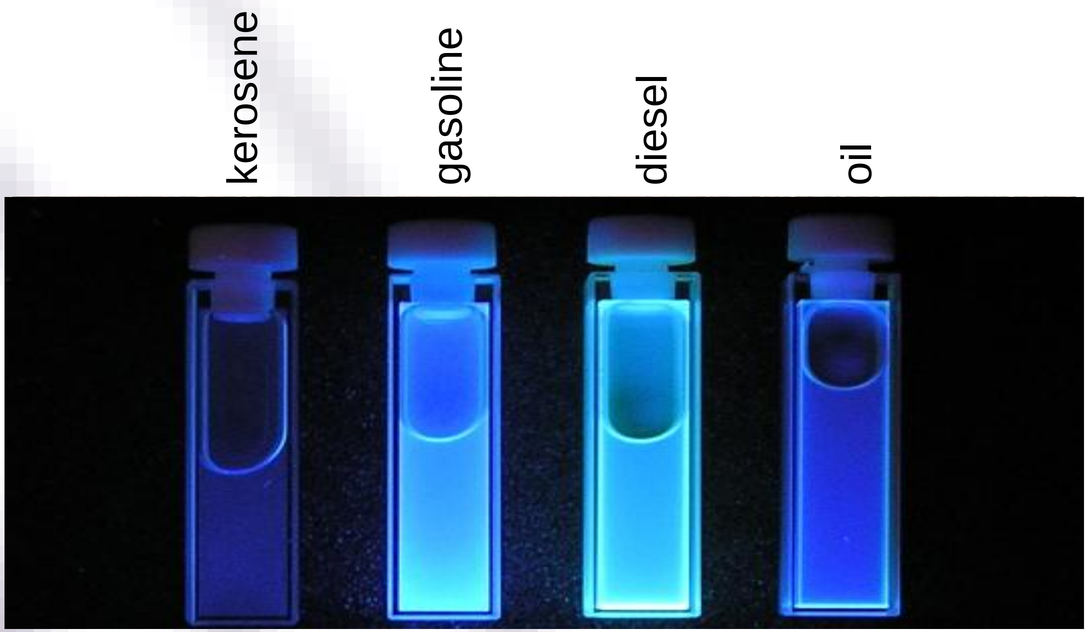
- Laser Induced Fluorescence

Laser Induced Fluorescence

- Developed in early 1990s
  - US Army Corps of Engineers
- UVOST (Ultra Violet Optical Screening Tool)
- Light-based
- Equipment
  - Geoprobe (direct push)
  - Fibre optic cable
  - Sapphire window

Laser Induced Fluorescence

- Spectroscopy – molecules absorb light (gain energy) and then emit light (lose energy = fluoresce)
- Aromatic molecules (PAHs) readily absorb and emit light



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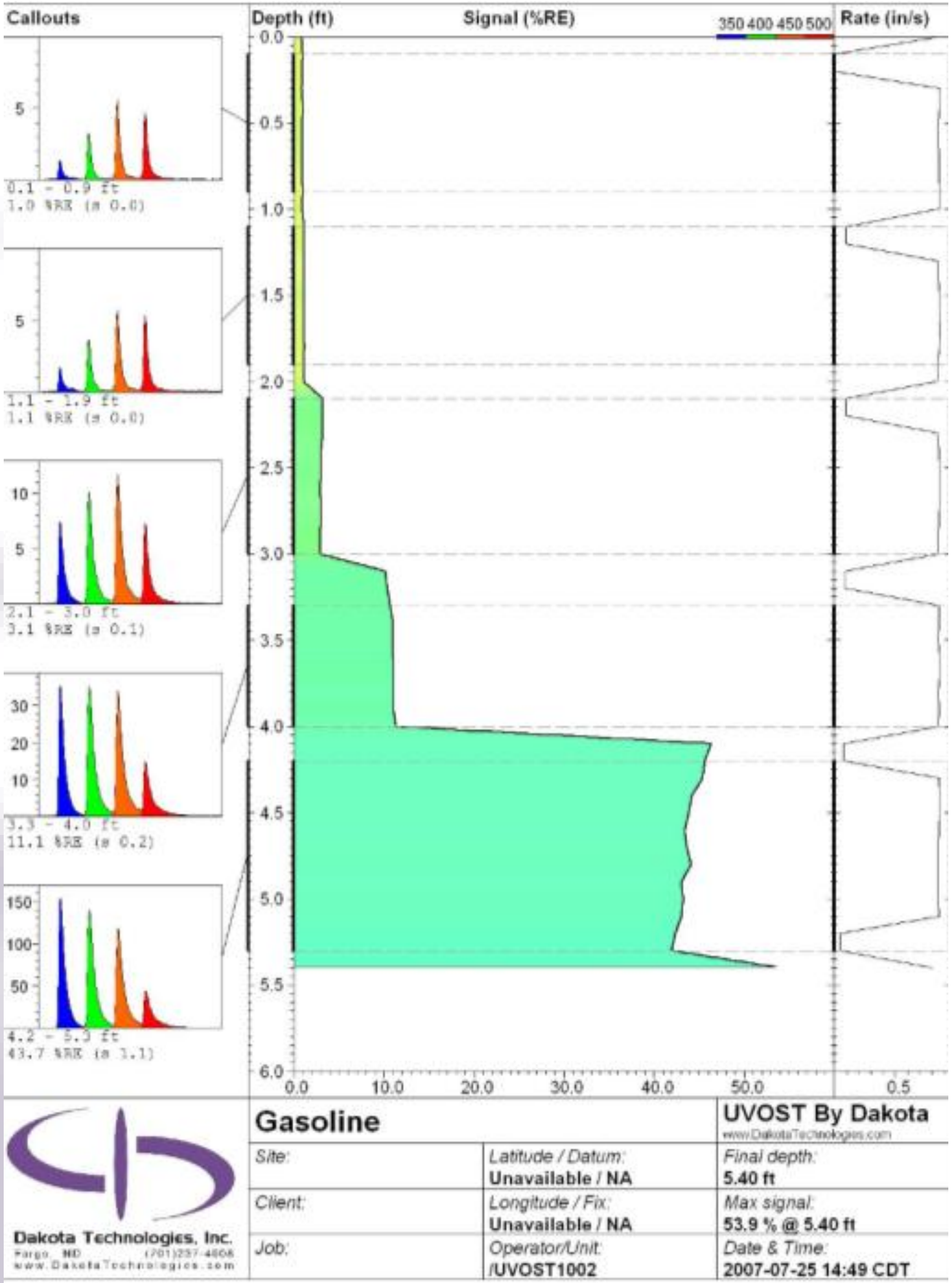
Laser Induced Fluorescence



Clean Sand

350 ppm

1,100 ppm

10,000 ppm

84,000 ppm

Gasoline

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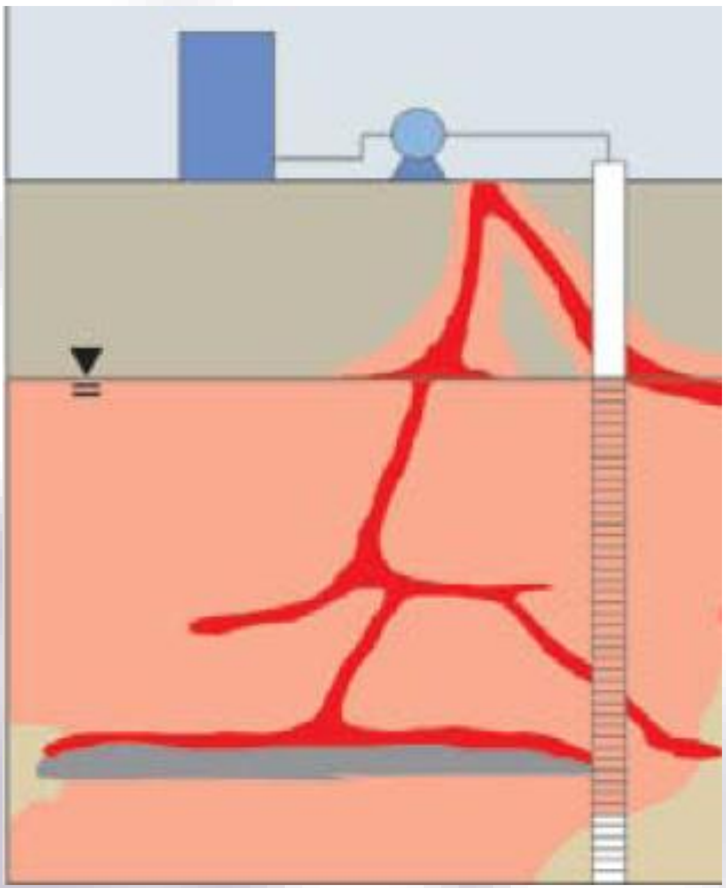
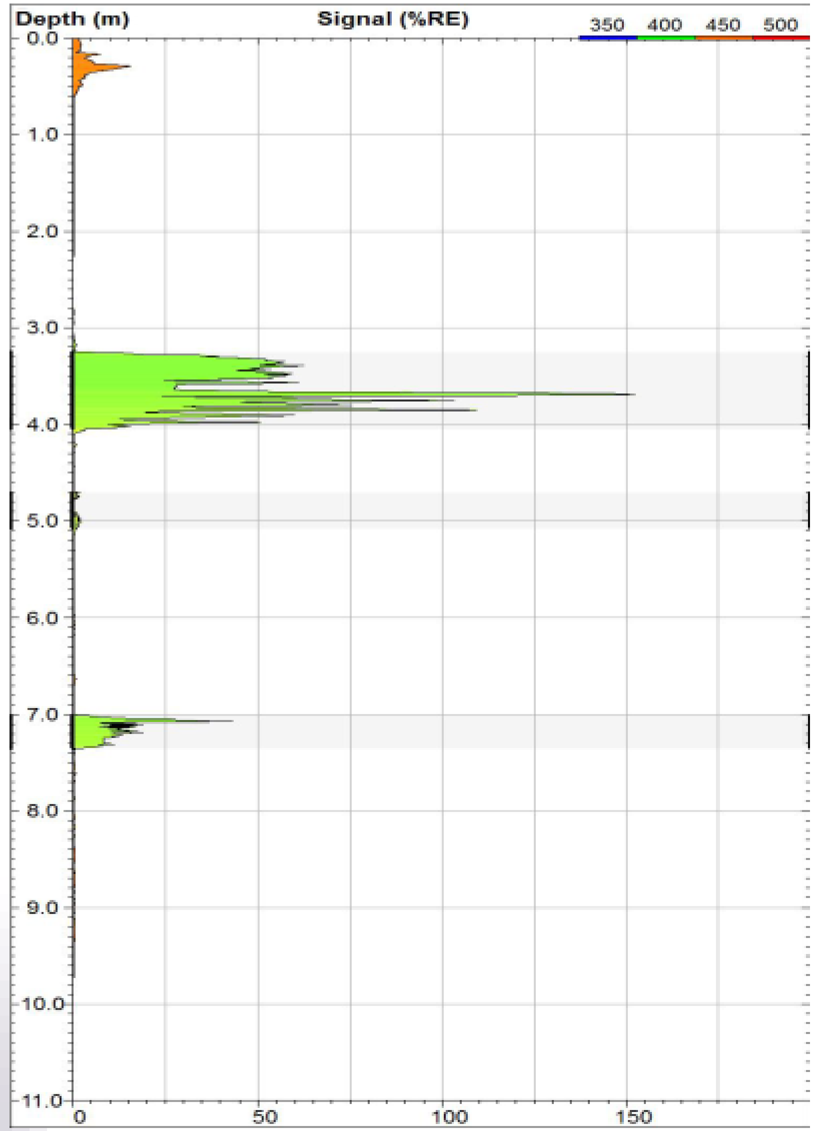
Laser Induced Fluorescence

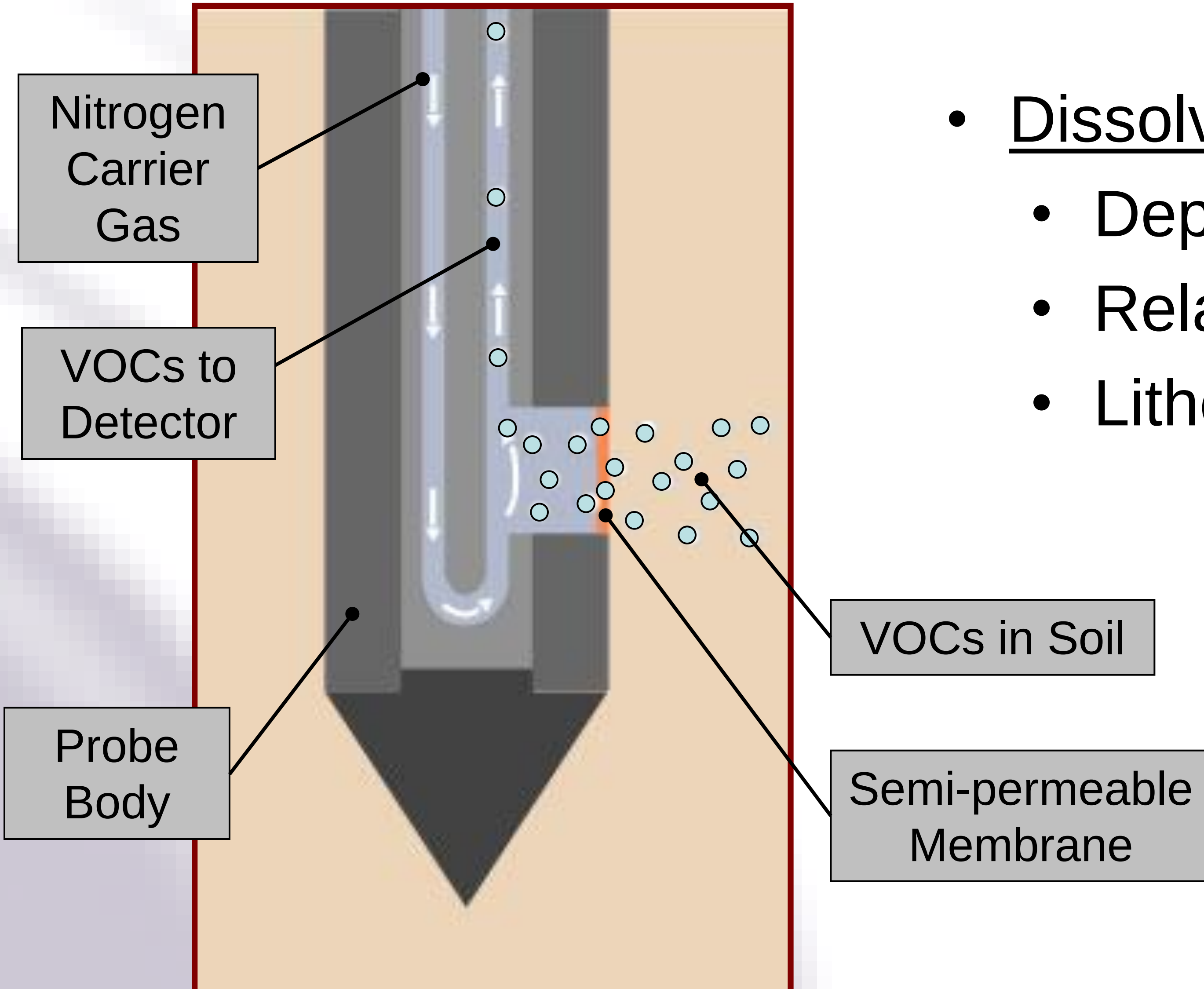




Contaminant Characterization

- Membrane Interface Probe

Membrane Interface Probe



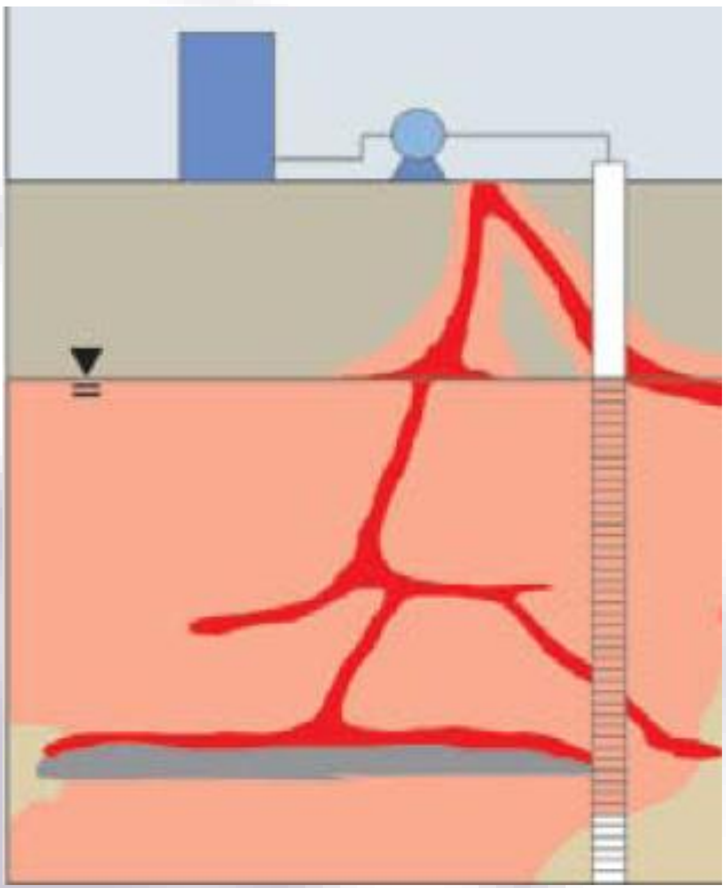
- Dissolved phase:
  - Depth
  - Relative conc.
  - Lithology

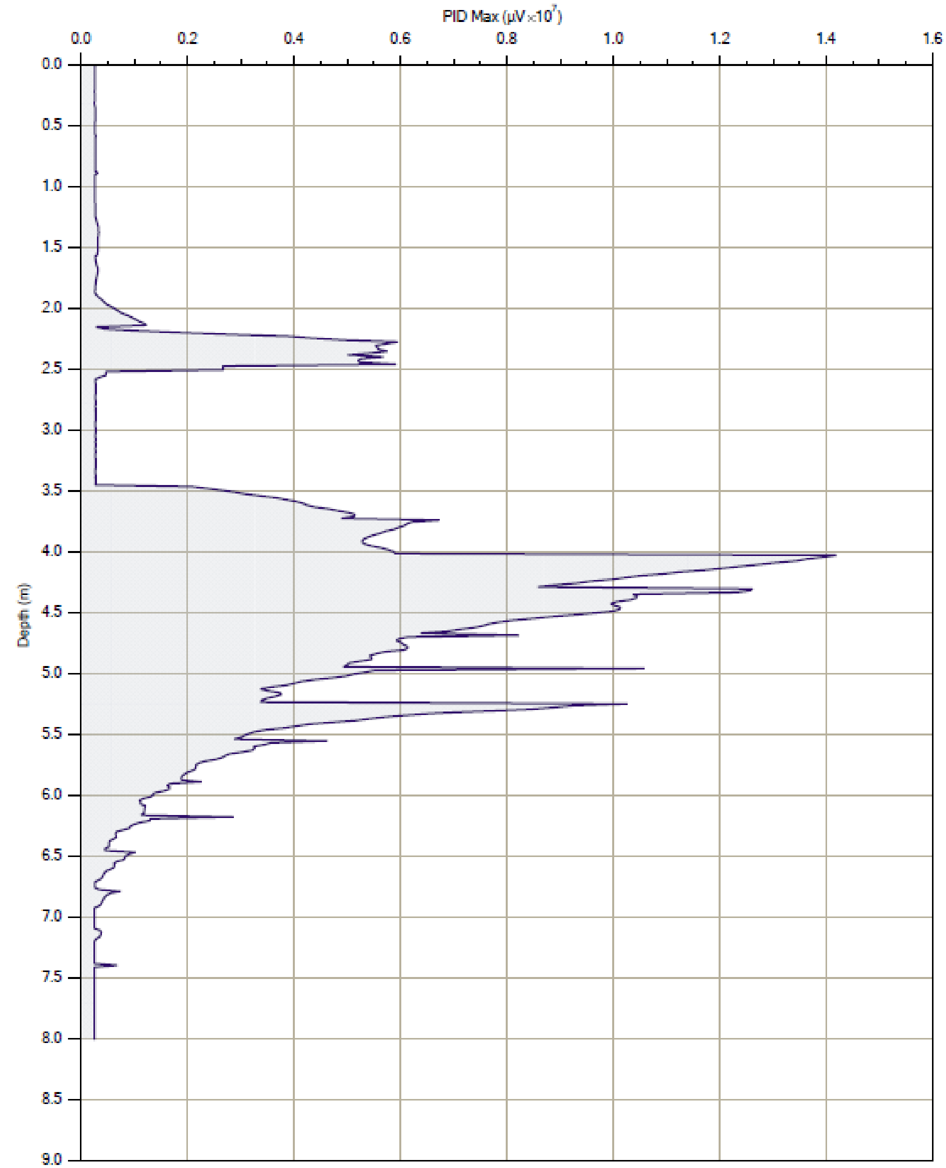
Membrane Interface Probe

Membrane

Heater Block

MIP Example




PID Max (µV×10^7)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0

Characterization – In Sights

Standard Characterization

- Monitoring Wells and Sampling (3 m)

Advanced Characterization Tools

- Laser Induced Fluorescence (0.01 m)
  - Free Product (LNAPL)
- Membrane Interface Probe (0.3 m)
  - Dissolved Phase (Plume)
- 3-D view: superior understanding of aquifer
- Remedial design: Target discrete zones

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Oxidant Delivery

- Oxidant Delivery Method
  - Injection Wells
  - Injection Points
- Delivery Experiment
  - Injection Well
  - Injection Points

Oxidant Delivery Method

- Article published in fall 2010
  - Ground Water Monitoring & Remediation
- 5 authors (Krembs et al. 2010):
  - Created a database
  - Examined 242 in-situ projects (‘96 to ‘07)
  - All oxidation projects:

    Permanganate, catalyzed hydrogen peroxide (H_2O_2), ozone, persulfate, peroxone (ozone and H_2O_2), percarbonate
  - Oxidants = liquids or gases

Delivery Method

Gas Injection

Oxidant Delivery Method	Percent of Sites
Injection wells	47
Direct push	23
Sparge points	14
Trenches, Galleries	10
Recirculation	7
Fracturing	6
Mechanical mixing	2
Horizontal wells	1

Percentages greater than 100% because multiple delivery techniques were used at some sites.

Source: Krembs et al. 2010

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Delivery Method

Liquid Injection only

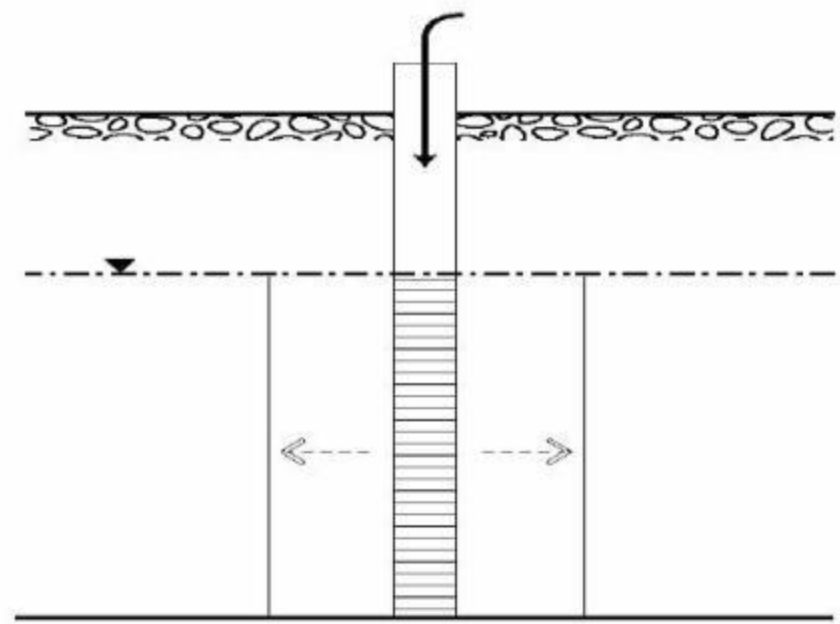
Oxidant Delivery Method	Percent of Sites
Injection wells	54
Direct push	26
Sparge points	
Trenches, Galleries	11
Recirculation	8
Fracturing	7
Mechanical mixing	2
Horizontal wells	1

Percentages greater than 100% because multiple delivery techniques were used at some sites.

Source: Krembs et al. 2010

Delivery Method

Injection Well

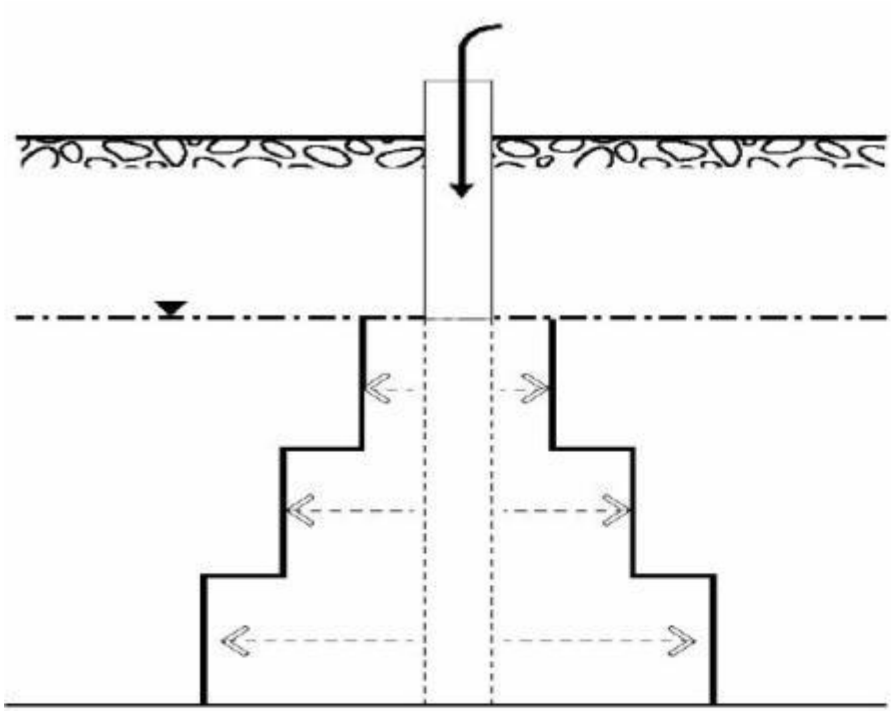


Source: ITRC, 2005

Delivery Methods

Direct Push

Bottom Up



Source: ITRC, 2005

Delivery Methods

Injection Point

Delivery Laboratory Experiment

<u>Overview</u>

- Purpose:
  - Assessment of Dye Distribution
- Experiments:
  - Distribution from Injection Well
    - Coarse Sand
  - Distribution from Injection Point
    - Coarse Sand
    - Sand with Clay Layer

Delivery Laboratory Experiment

Glass Container

- 51 by 26 by 31 cm
- 41 L

Coarse Sand

- Filter Sand (#3)
- Bentonite Clay

Water and Dye

- Food grade dye

Injection

- Gravity Feed (0 psi)
- Hydraulic Head=1.5 m
- Flow = 1.0 to 4.5 lpm

Delivery Laboratory Experiment

Experiment #1

Injection into Injection Well

Delivery Laboratory Experiment

Injection Well, Experiment #1
2” diameter PVC Slot 10 Well, screened to bottom of tank
Flow = 4.5 lpm

Delivery Laboratory Experiment

Experiment #2

Injection into Temporary Point

Delivery Laboratory Experiment

Pulling Injection Rod to remove Injection Tip

Delivery Laboratory Experiment

Injection into Injection Point, Experiment #1
Injection rod located 9 cm from bottom of tank
Flow = 4.0 lpm

Delivery Laboratory Experiment

Injection into Injection Point, Experiment #2
Injection rod located 9 cm from bottom of tank
Flow = 2.8 lpm

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Delivery Laboratory Experiment

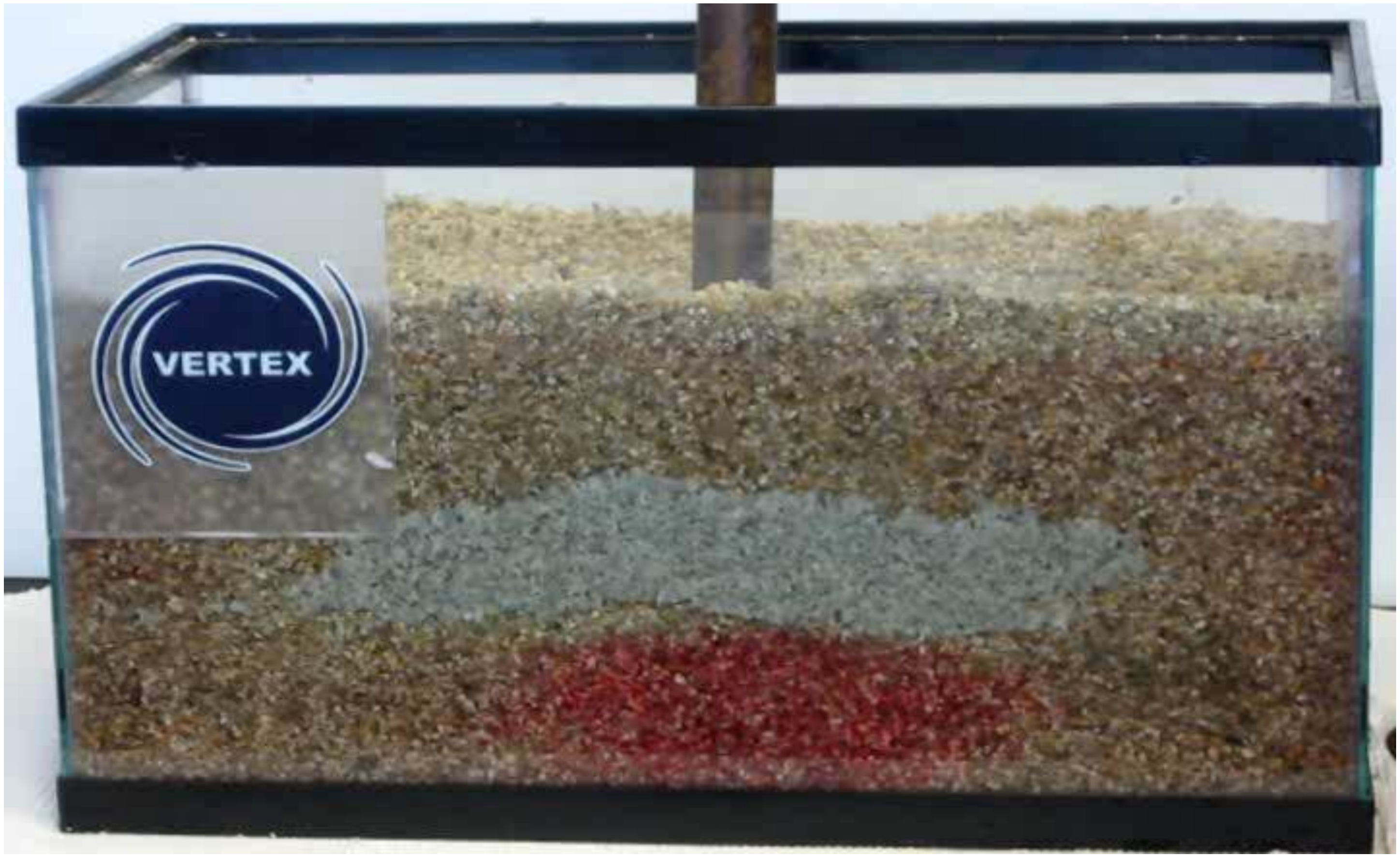
Experiment #3

Injection into Temporary Point

Clay Aquitard

Delivery Laboratory Experiment

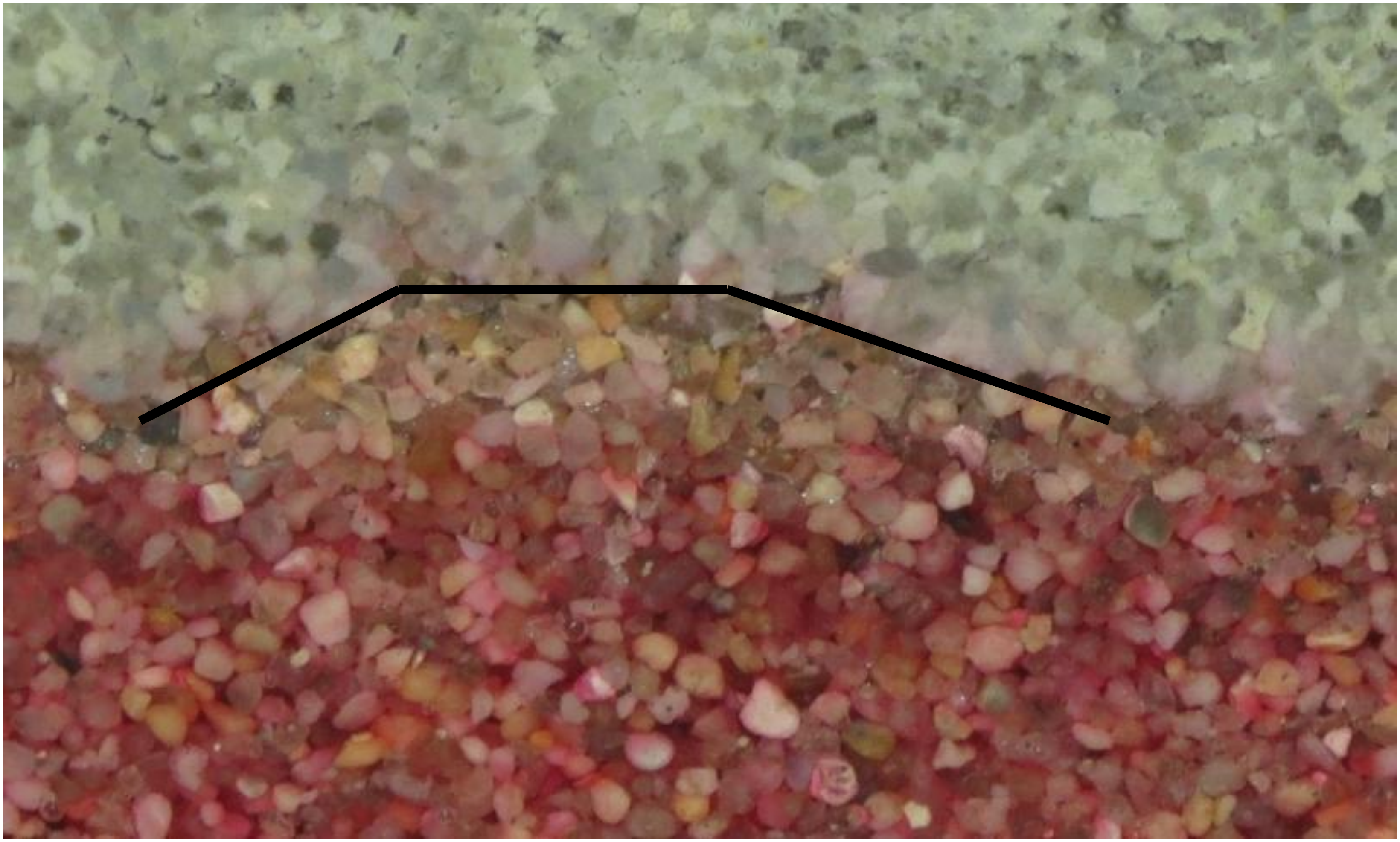
Delivery Laboratory Experiment



Injection into Injection Point, Experiment #3
Injection rod located 5 cm from bottom of tank
Flow = 1.0 lpm

Delivery Laboratory Experiment

Delivery Laboratory Experiment



Delivery Laboratory Experiment

Injection into Injection Point, Experiment #3
Time = 0 min

Delivery Laboratory Experiment

Injection into Injection Point, Experiment #3
Time = 2 min

Delivery Laboratory Experiment

Injection into Injection Point, Experiment #3
Time = 4 min

Delivery Laboratory Experiment

Injection into Injection Point, Experiment #3
Time = 5 min

Delivery Laboratory Experiment

Injection into Injection Point, Experiment #3
Time = 15 min

Delivery – In Sights

- Homogenous sand:
  - Well = Horizontal distribution
  - Point = Radial distribution
- Clay aquitard:
  - Significant influence on dye distribution
  - Tight soil will control distribution of liquid
  - No dye migration into clay
  - Idea: Injection point could be placed into clay to deliver directly to the clay unit

Conclusions / In Sights

- Oxidant chemistry works
- Better oxidant delivery = better remediation
- Two important factors:
  - Understanding contaminant distribution
  - Designing delivery system
- Contaminant Distribution
  - Monitoring well (300 cm resolution)
  - LIF – free phase (1 cm resolution)
  - MIP – dissolved phase (30 cm resolution)
  - Detailed data – produce 3D plots, and design remediation approach accordingly

Conclusions / In Sights

- Oxidant Delivery System
  - 2 most common methods: Wells and Points
  - Wells:
    - Good for homogeneous aquifers and evenly distributed contamination
    - If multiple injections, lower cost option
    - Limited ability to deliver into tighter soils, due to preferential flow into coarse soils
      - Major problem, considering most historical contamination is located within tight soils

Conclusions / In Sights

- <u>Injection Points:</u>
  - Pin point delivery – flow from end of injection rod allows accurate vertical placement of oxidant
  - Vertical distribution – rods can be advanced to specific depths to target impacted seams
  - Targeting tight soil layer = distribution into clays
  - Higher injection pressure with steel injection rod construction
  - Multiple injections, different locations
- Overall: When designing an in-situ remediation program, consider advanced characterization techniques and delivery method

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Questions?

Thank You for Your Time

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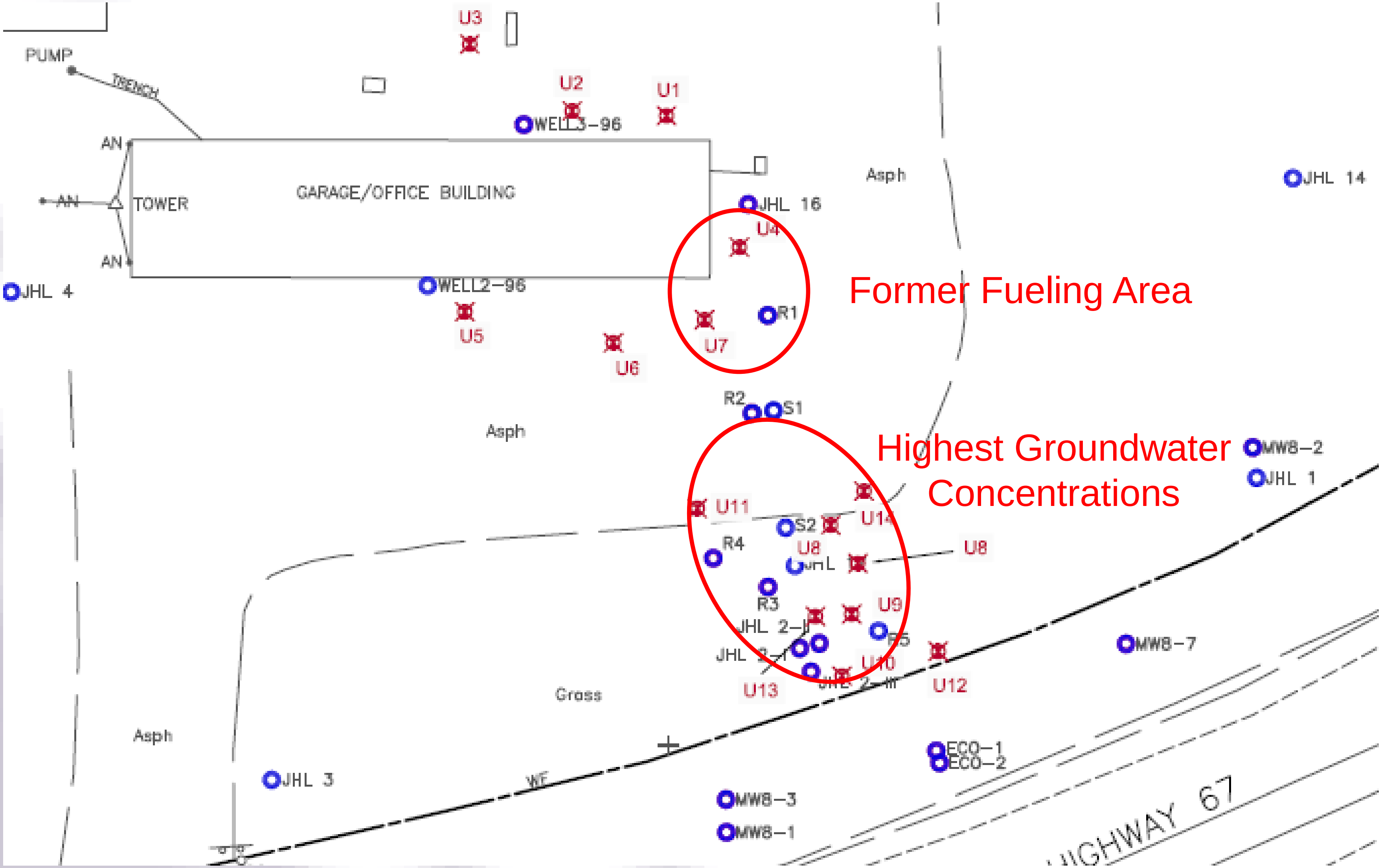
Case Study

Advanced Characterization and Oxidant Delivery

- Laser Induce Fluorescence
  - Free Product (LNAPL)
- Membrane Interface Probe
  - Dissolved Phase (Plume)
- Injection Points
  - Oxidant Delivery

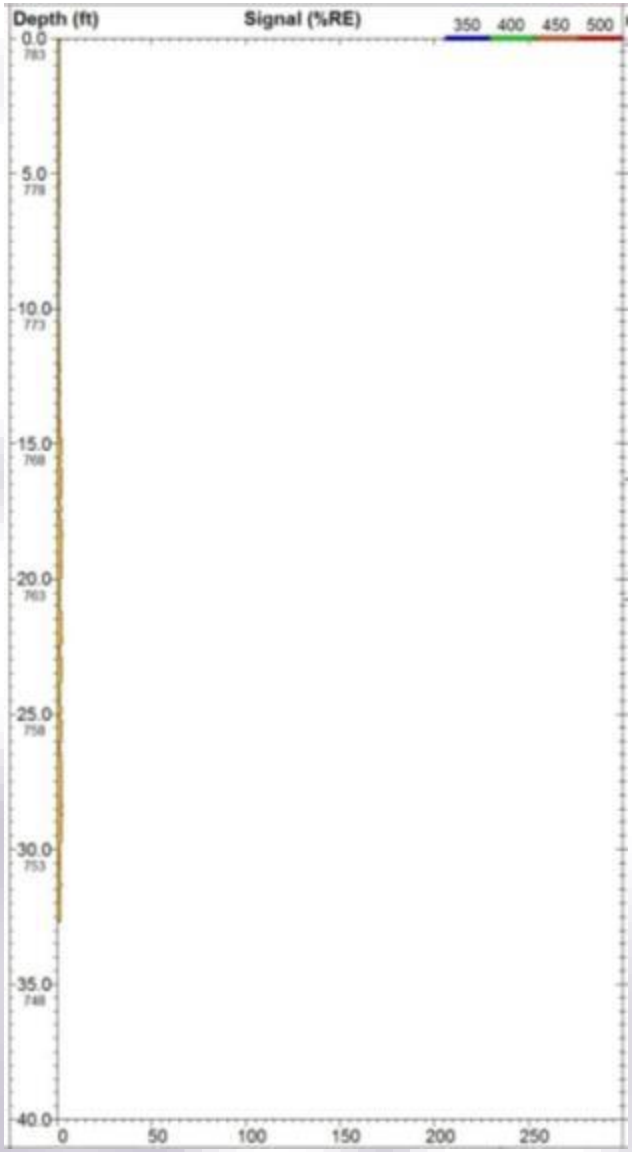
VERTEX

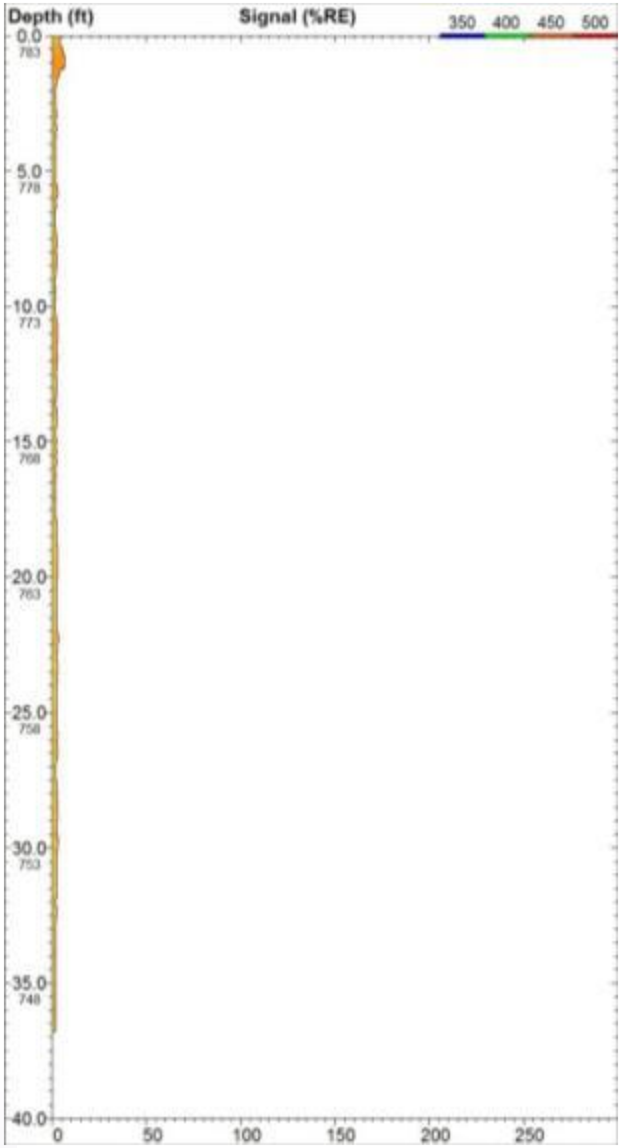
Case Study



U3
PUMP
TRENCH
U2
U1
WELL3-96
AN
TOWER
GARAGE/OFFICE BUILDING
Asph
JHL 14
JHL 16
U4
Former Fueling Area
JHL 4
WELL2-96
R1
U5
U7
U6
R2
S1
Asph
Highest Groundwater Concentrations
MW8-2
JHL 1
U11
U14
S2
R4
U8
U8
R3
U9
R5
MW8-7
U10
U12
U13
Grass
Asph
ECO-1
ECO-2
JHL 3
WF
MW8-3
MW8-1
HIGHWAY 67

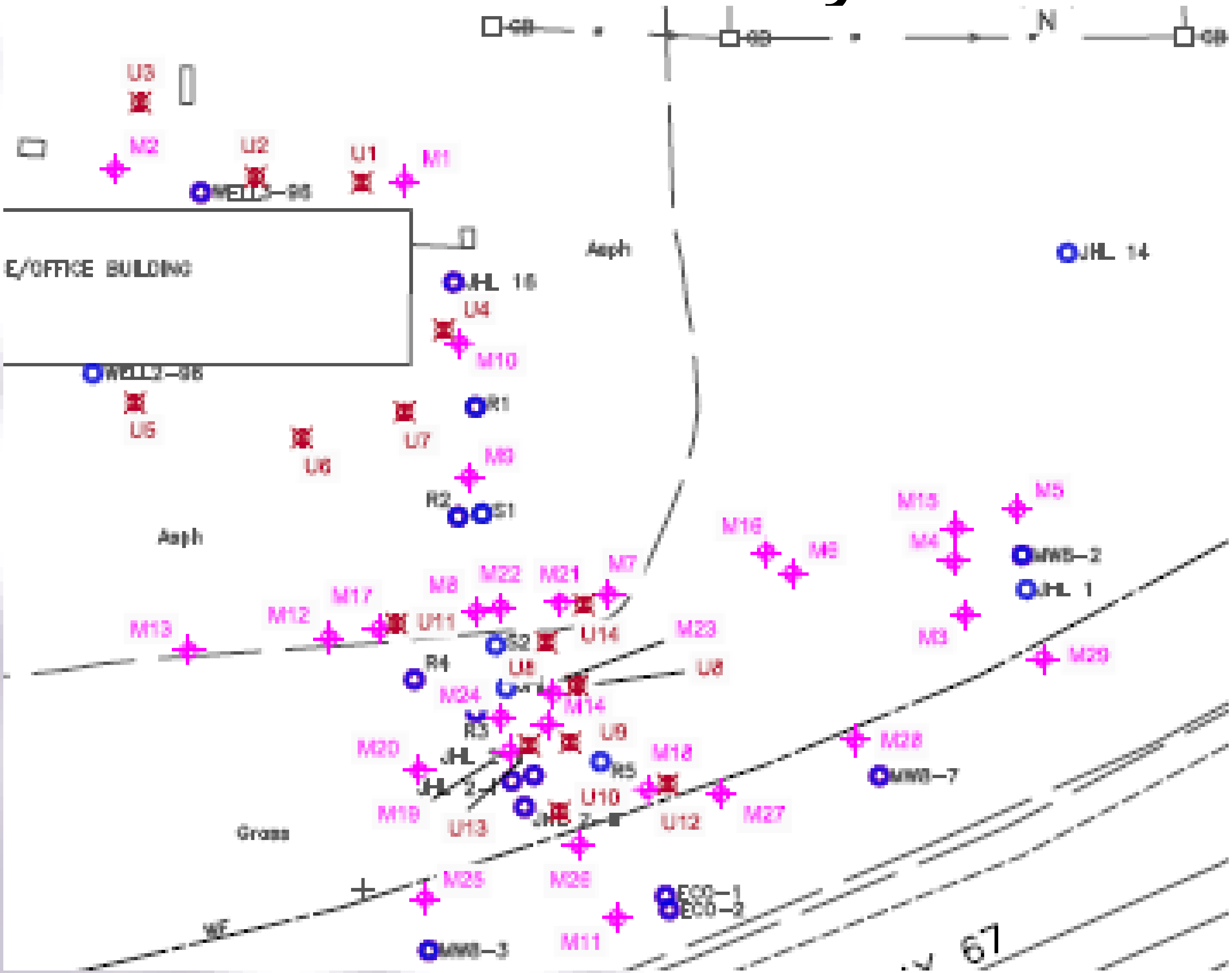
Case Study – LIF Results





No NAPL detected

Case Study



E/OFFICE BUILDING
Asph
Grass
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
U12
U13
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M1
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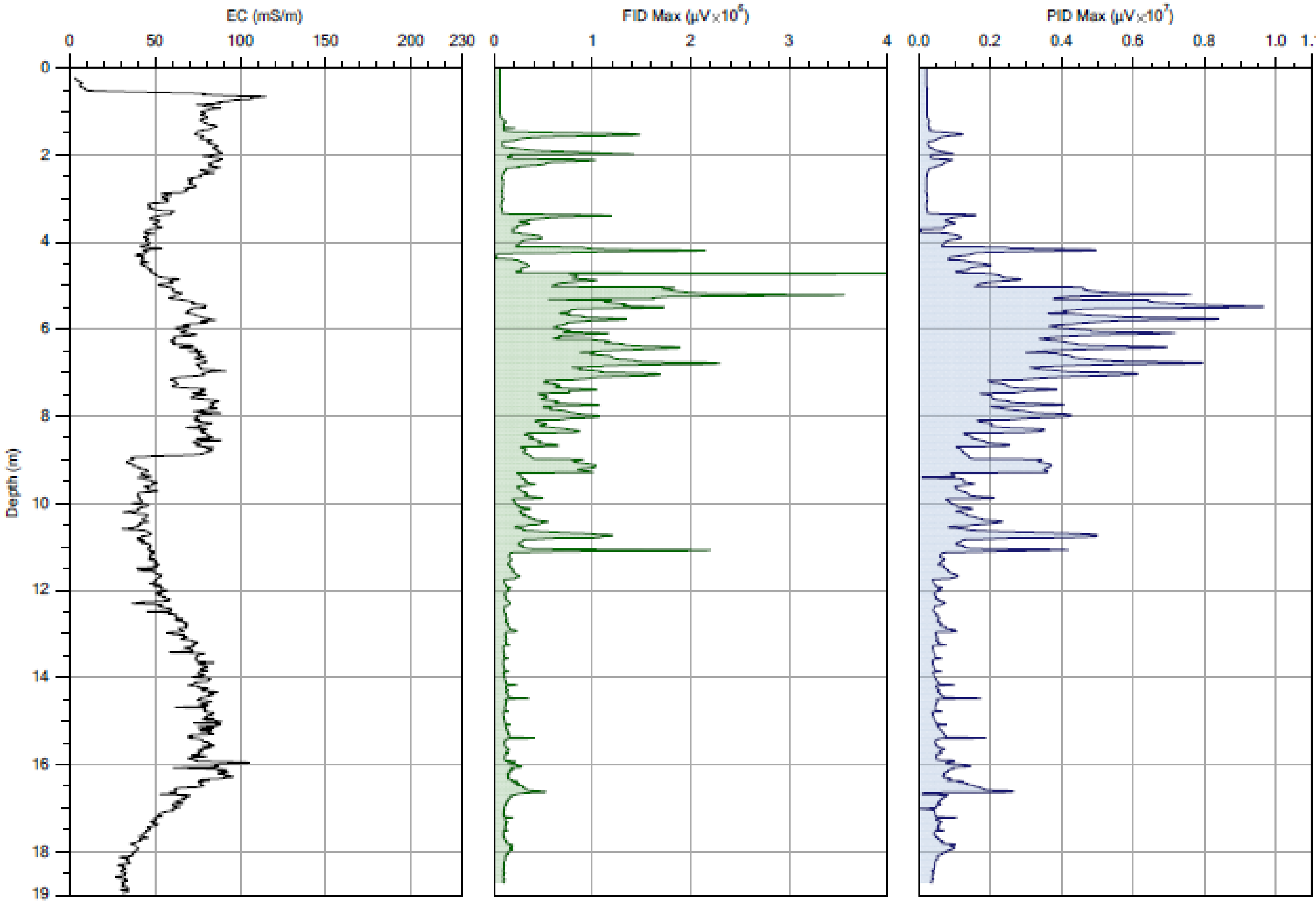
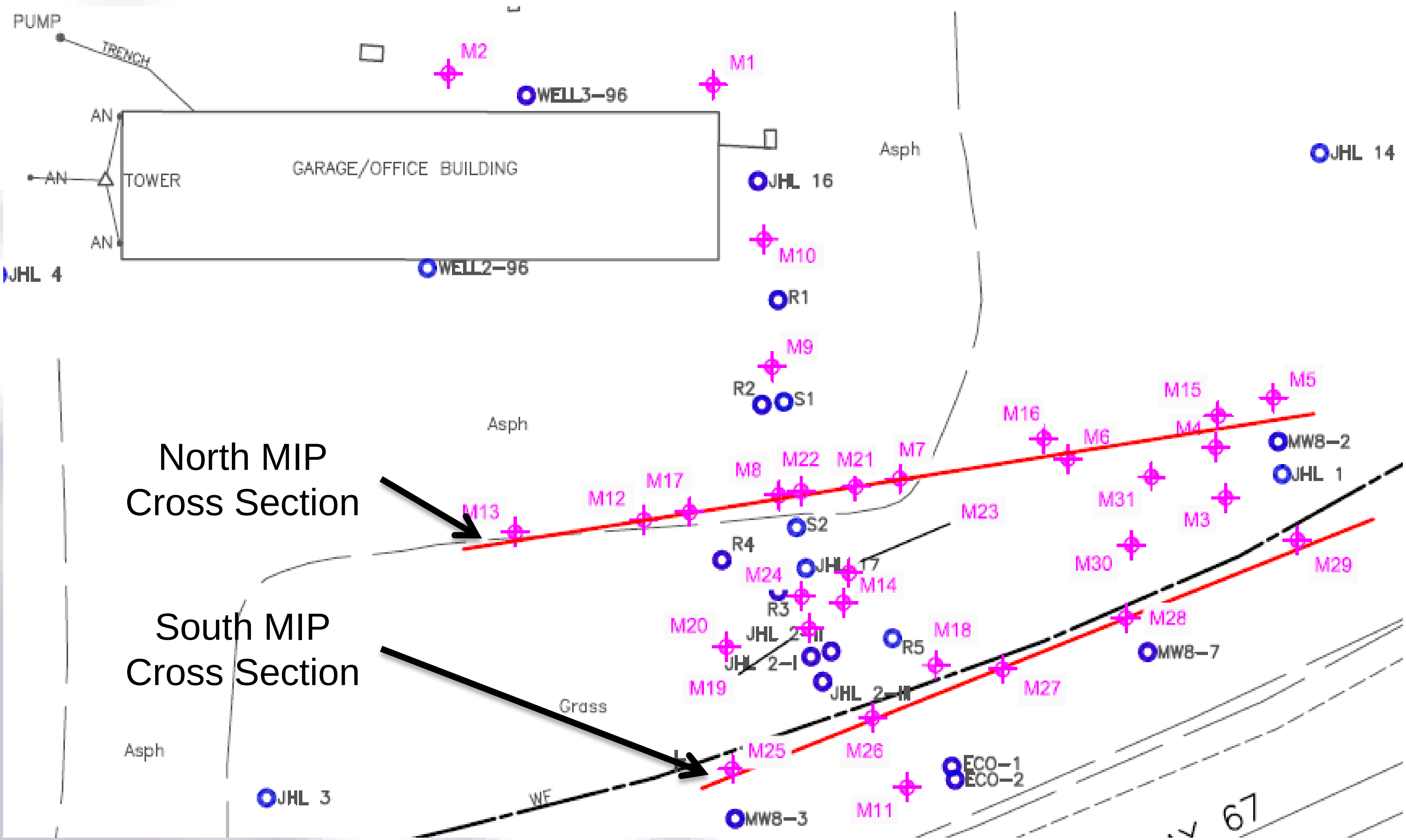
M17
M18
M19
M20
M21
M22
M23
M24
M25
M26
M27
M28
M29
JHL 14
JHL 16
JHL 1
R1
R2
R3
R4
R5
S1
S2
MW6-2
MW6-7
MW6-3
ECO-1
ECO-2
N
67

Case Site – MIP Results



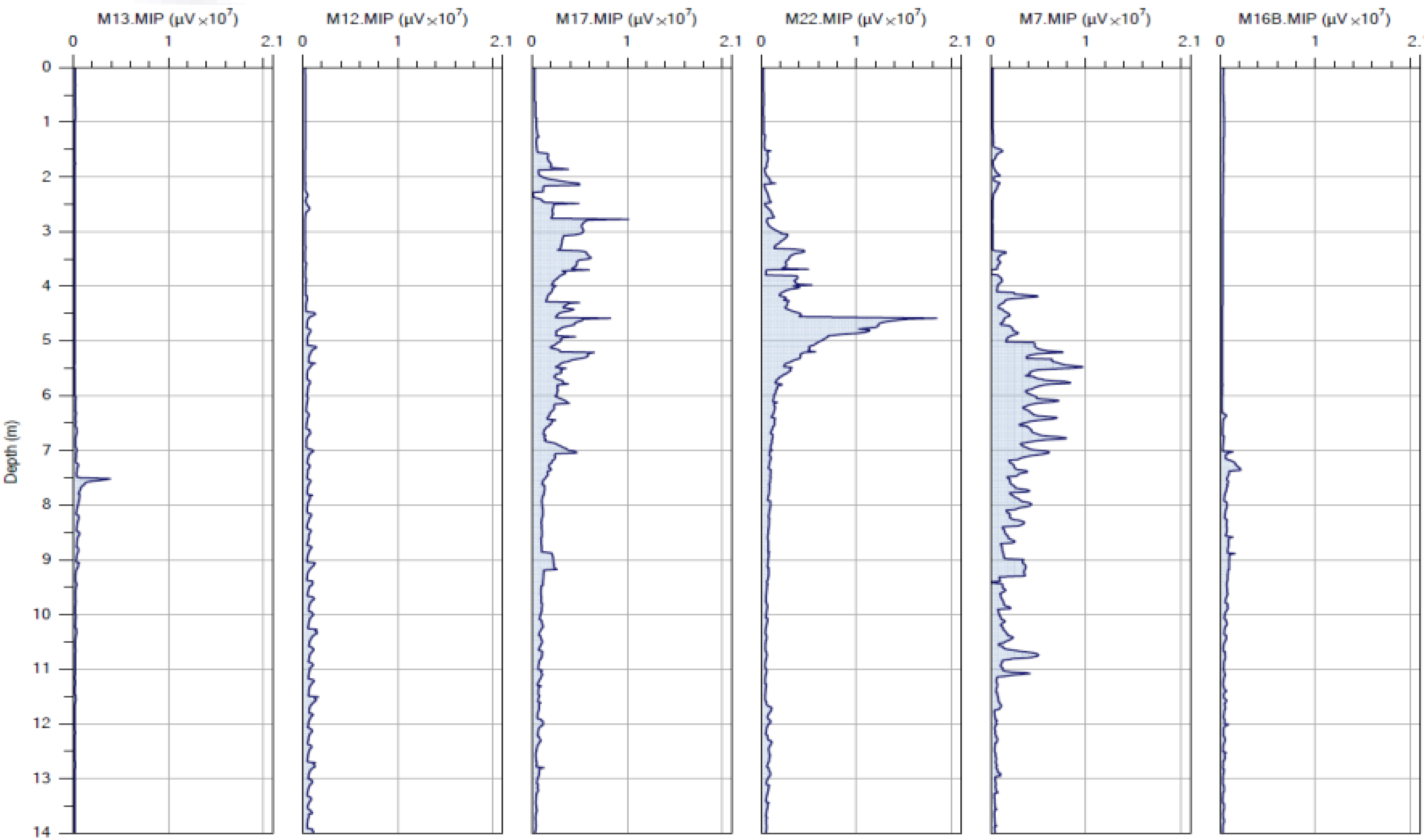
Dissolved phase plume 2 m to 11 m below ground

Case Site – Results



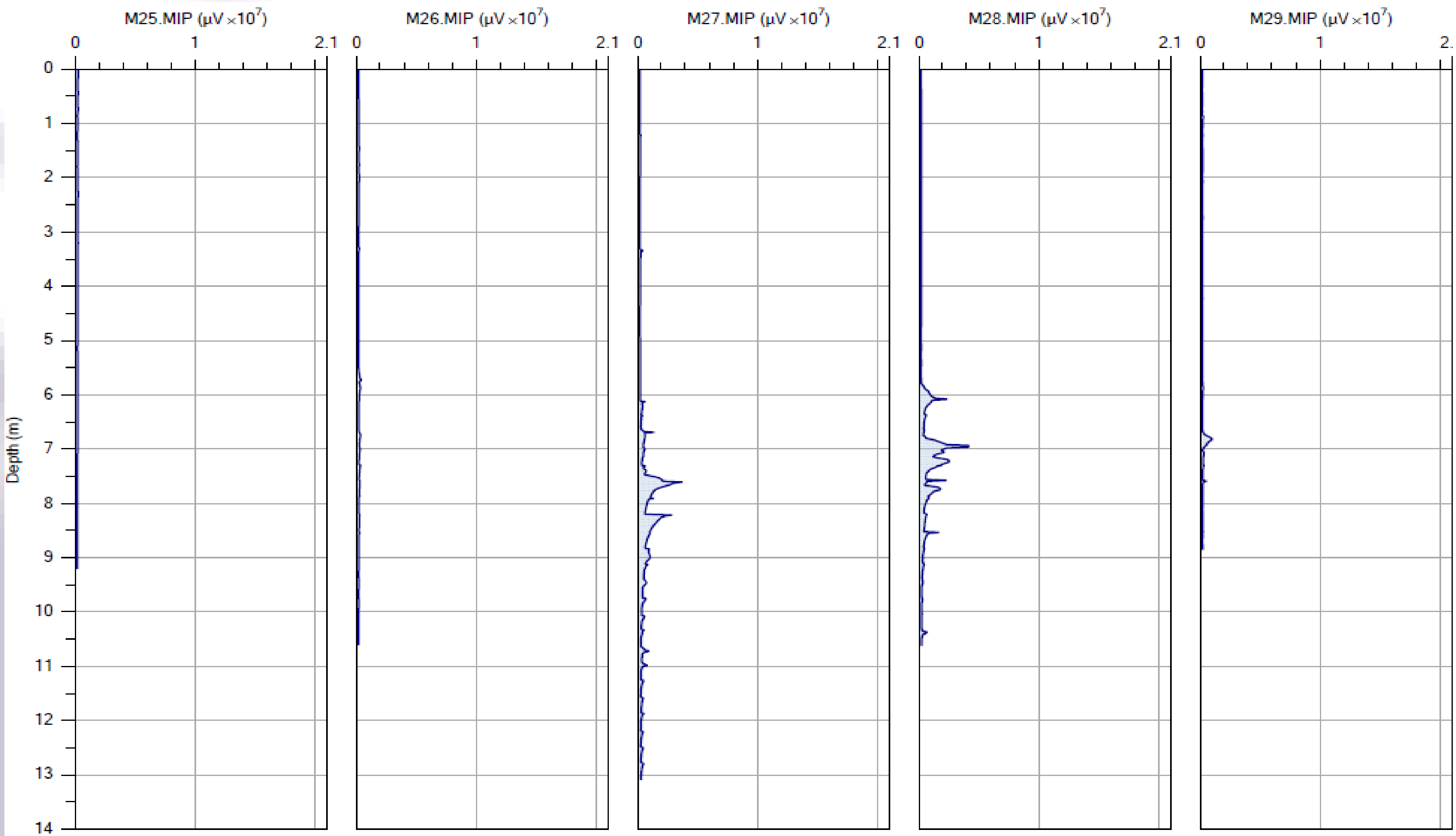
Case Site – Results

North MIP Cross Section



Case Site – Results

South MIP Cross Section



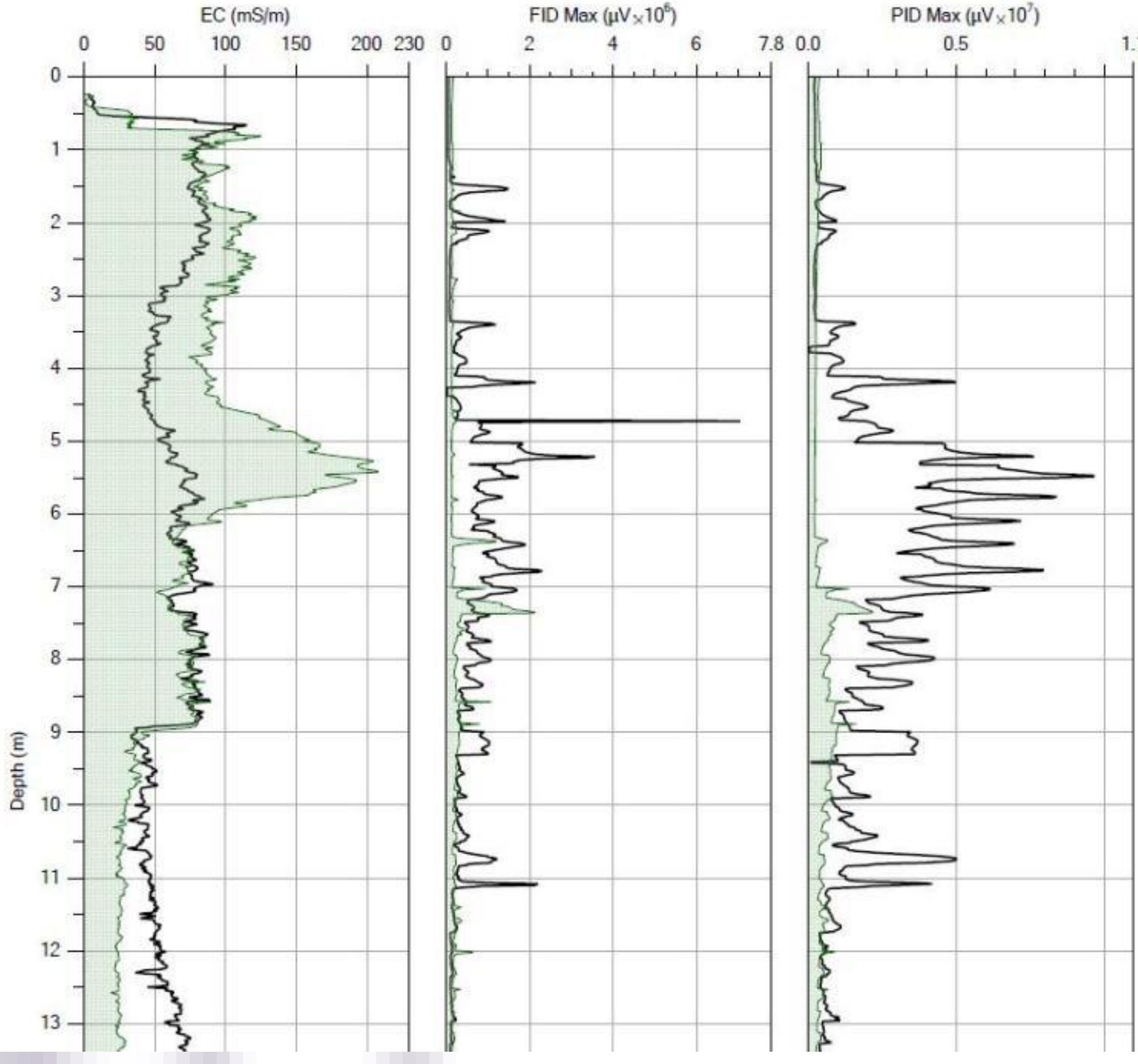
MIP Results

<u>Before ISCO</u>

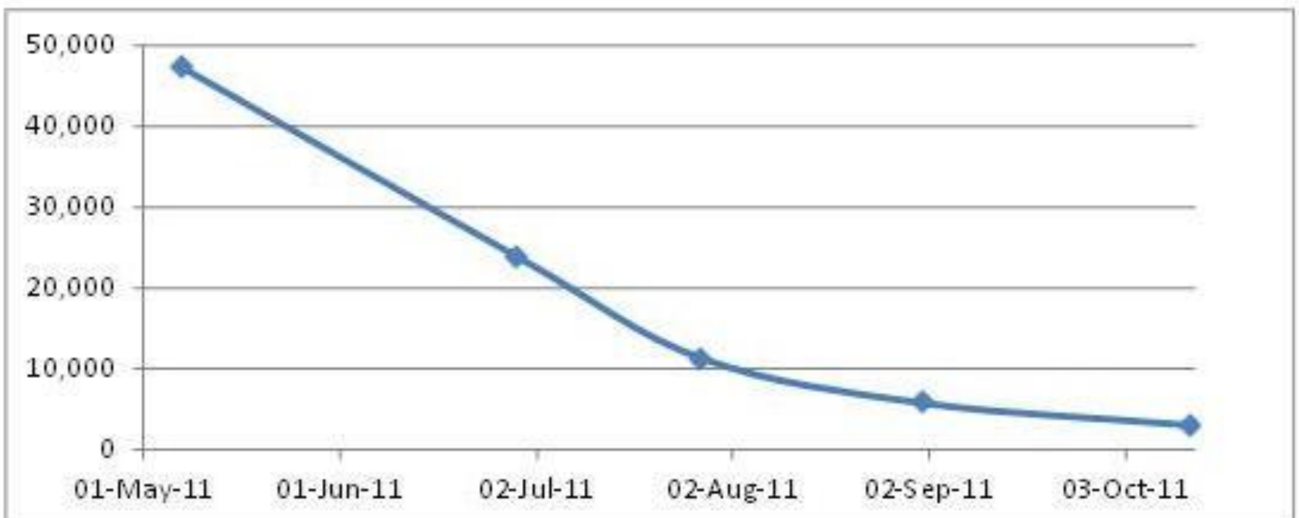
Black Line
May 13/2011

<u>After ISCO</u>

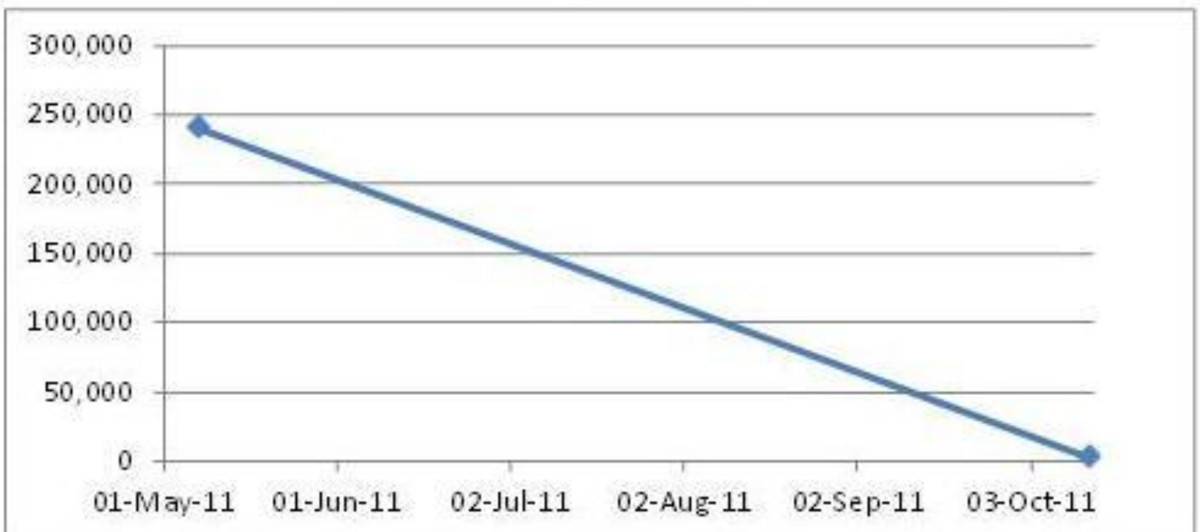
Green Line
Sept 27/2011



PARAMETER	MOE Groundwater Standards (ug/L)	JHL2-II (11 m, 35 ft)					
		MMM	Vertex	Vertex	Vertex	MMM	% Reduction
		07-May-11	29-Jun-11	28-Jul-11	01-Sep-11	13-Oct-11	
Benzene	5.0	9,500	4,400	1,100	800	1,100	88
Toluene	24	9,100	4,500	2,200	540	780	91
Ethylbenzene	2.4	690	160	85	-	46	93
Xylenes (total)	300	2,900	2,740	2,000	1,100	1,100	62
PH(F1-C6 to C10)	750	25,000	12,000	5,900	3,300	ND	99.7
PH(F2-C10 to C16)	150	ND	-	-	ND	ND	-
PH(F3-C16 to C34)	500	ND	-	-	ND	ND	-
PH(F4-C34 to C50)	500	ND	-	-	ND	ND	-
Total BTEX/PHCs	-	47,190	23,800	11,285	5,740	3,026	94



PARAMETER	MOE Groundwater Standards (ug/L)	R3		
		MMM	MMM	% Reduction
		07-May-11	13-Oct-11	
Benzene	5.0	2,100	170	92
Toluene	24	15,000	370	98
Ethylbenzene	2.4	2,300	ND	99.98
Xylenes (total)	300	15,000	1,100	93
PH(F1-C6 to C10)	750	140,000	1,100	99.2
PH(F2-C10 to C16)	150	61,000	160	99.7
PH(F3-C16 to C34)	500	4,300	ND	98.8
PH(F4-C34 to C50)	500	790	ND	94
Total BTEX/PHCs	-	240,490	2,900	98.8



Case Study

- Average PHC groundwater reduction across Site = 96%
- LIF: safe commencement of ISCO
- MIP: ISCO re-design
- Zones of high impacts targeted, resulting in excellent treatment