

DIRECTIONAL
Technologies, Inc
Horizontal Directional Drilling Services

Horizontal Remediation Wells

Horizontal Remediation Technologies • Installation • Design • Engineered Well Screens • Services



*Diversified Horizontal Injection Methods Effectively Deliver
Amendments for Large Plume Coverage or Precise Target Areas*

Presented at the 5th International Symposium on Bioremediation and Sustainable
Environmental Technologies – Baltimore, MD, April 2019

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Brief Company Introduction



- Directional Technologies, Inc. is Celebrating 26th Anniversary.
- Environmental Directional Drilling and Horizontal Well Technology Company Specializing in:
 - Horizontal Remediation Well (HRW) System Design.
 - HRW Screen Engineering.
 - HRW Construction and Installation with Horizontal Directional Drilling.
 - HRW Development, and O&M Support.
- Installed over 1,000 HRWs for the Environmental Industry.
- International Experience and Recognition.

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Presentation Outline

- Part 1: Horizontal Remediation Overview
 - Horizontal Directional Drilling.
 - Horizontal Remediation Well (HRW) Design.
- Part 2: Horizontal Injection Case Studies/Example Projects.
 - 1) Horizontal Injection of Potassium Permanganate – Active Brownfield Redevelopment, Maryland.
 - 2) Horizontal ISCO Injection – Manufacturing Facility, New South Wales, Australia.
 - 3) Horizontal Bio-amendment Injection – Perchlorate Site Near River, Massachusetts.



Installing first ever horizontal remediation wells (HRWs) in South Korea



Horizontal Directional Drilling (HDD) Technology



HDD Rigs

- Angled for near horizontal entry.
- Capable of depths ranging from 1 feet BGS to >100 feet BGS.
- Horizontal Bore lengths of over 1,000 feet.
- Steerable drill bits for horizontal and vertical adjustments during drilling.
- Track mounted for off-road mobility.
- Safety built into the design (hands free drilling).



Horizontal Well Screen Design

- Why is Screen Design Necessary?
 - 1) Critical to the success of a horizontal well.
 - 2) Horizontal wells must be properly designed for the application.
 - 3) Proper design ensures desired fluid flow through the entirety of the horizontal well.



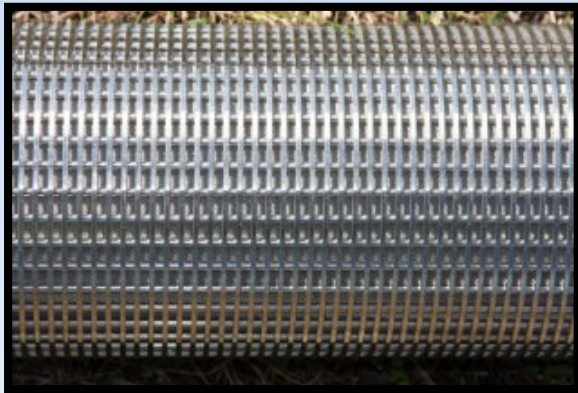
Water being pumped through horizontal remediation well to demonstrate uniform flow through well screen



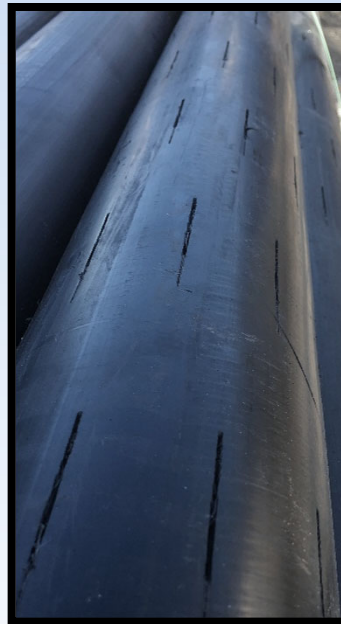
Horizontal Well Screen Design

Design Considerations: Well Screen Engineering:

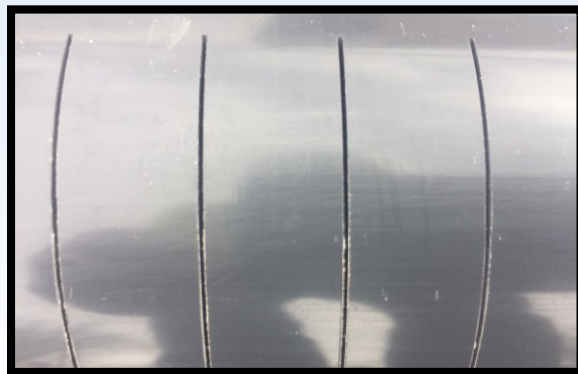
- Directional Technologies owns proprietary wells screen design software.
- Multiple types of well materials: HDPE, Schedule 80 PVC, Stainless Steel.
- Custom slot lengths, widths, and spacing for the desired application.



Stainless steel well screen



HDPE Custom Slotted Well Screen



PVC Slotted Horizontal Well Screen

Horizontal Air-Sparge Well and Porous Media Parameters

Well Flow | Well Screen | Porous Medium |

Well Screen Properties

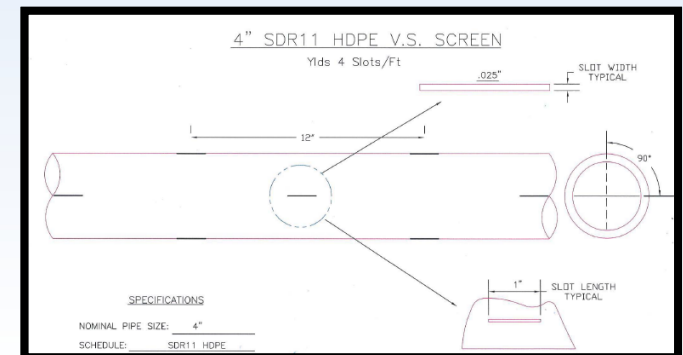
Inner Diameter [inches]: 3.00
 Outer Diameter [inches]: 3.50
 Well Roughness [inches]: 0.000050
 Distance below Water Table [feet]: 6.00 (Constant) Help

Screen Sections

Section	Length [feet]	Open Area (%)	Slot Width [inches]	Slot Length on Inside Wall [inches]	Soil Type	No. Slots per 10 ft
1	120.00	0.0571	0.120	1.50	Fine Sand	53
2	120.00	0.0269	0.120	1.50	Fine Sand	51
3	0.00	0.6342	0.012	1.50	Fine Sand	390
4	0.00	0.6446	0.012	1.50	Fine Sand	404
5	0.00	0.5467	0.012	1.50	Fine Sand	406

Section 1 = Closest to the Blower

Screen Shot of Directional Technologies' Well Screen Design Software



Part 2: Horizontal Remediation



Example Projects

- **Example Site 1: Large Site – Expansive ISCO Injection Coverage During Brownfield Redevelopment, Maryland**
- **Example Site 2: Mid-sized Site – ISCO Injection Beneath Multiple Structures, Manufacturing Facility – Australia**
- **Example Site 3: Small Site – Low Energy, Cost Effective Solution, Bio-amendment Injection, Industrial Complex, Massachusetts**

Example Site: ISCO Injection – PCE Brownfield Site - Maryland

Acknowledgements:

Stewart Abrams Now @ Langan Engineering Moran, William et al. 2008. The Shaw Group. Enhanced Delivery of Potassium Permanganate Using Horizontal Remediation Wells. Proceedings of the Sixth International Conference on Remediation of Chlorinated and Recalcitrant Compounds. Monterey, CA. May 2008)

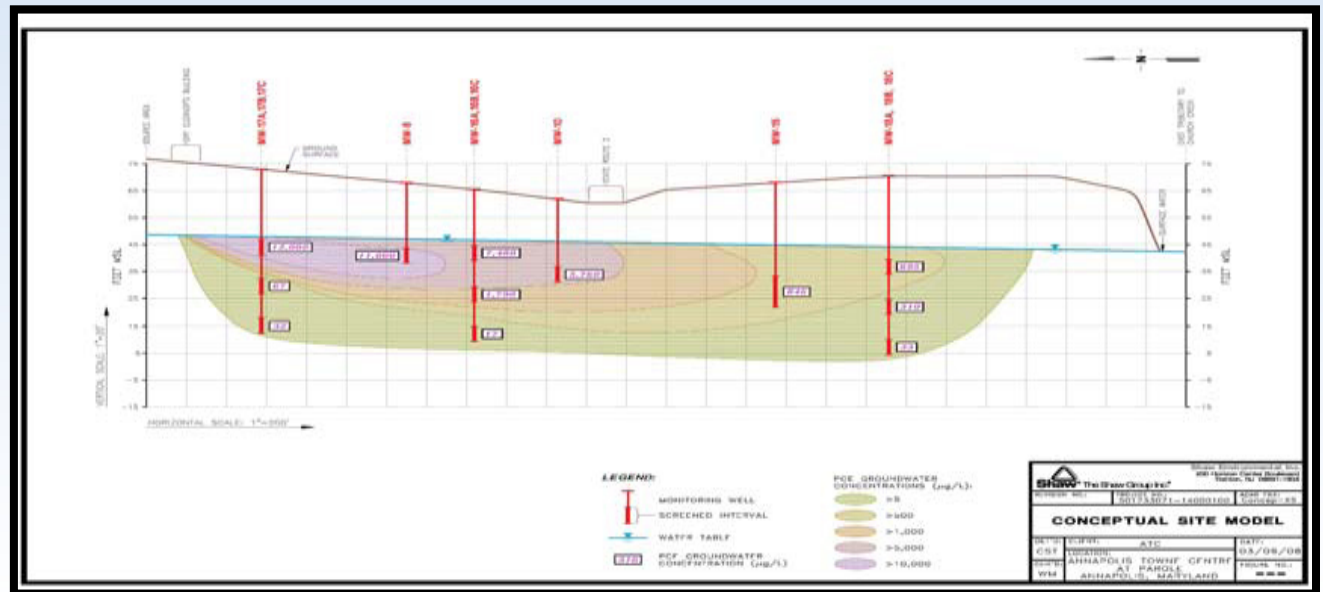
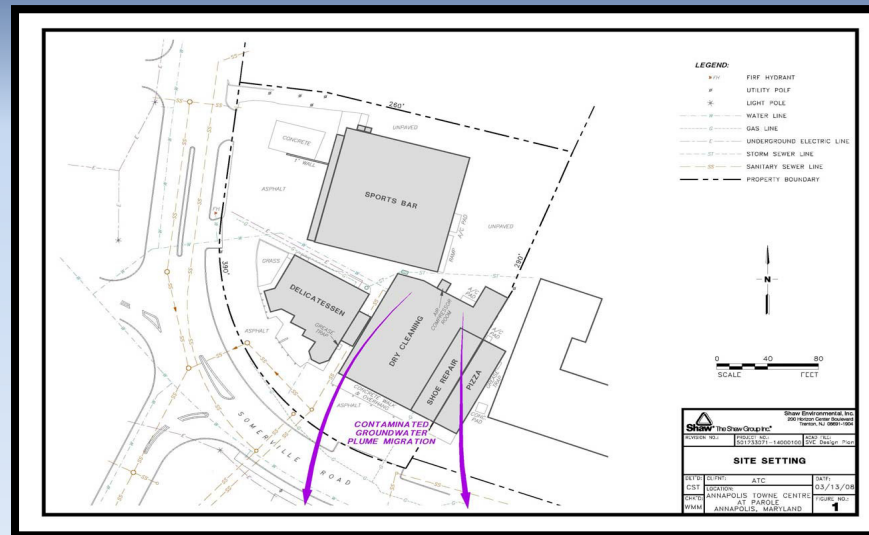
Maryland Department of the Environment (MDE). 2010. Facts About Annapolis Towne Center at Parole Main Parcel & Annex Properties. October 2010.

Example Site 1: Chlorinated Solvent Site, Maryland



Background:

- Major redevelopment project in suburban Baltimore.
- Chlorinated solvent plume extended 1,600 feet in groundwater.
- Impacted GW 25' – 55' BGS
- An In-situ chemical injection method needed to be installed while redevelopment continued.



Example Site 1: Chlorinated Solvent Site, Maryland



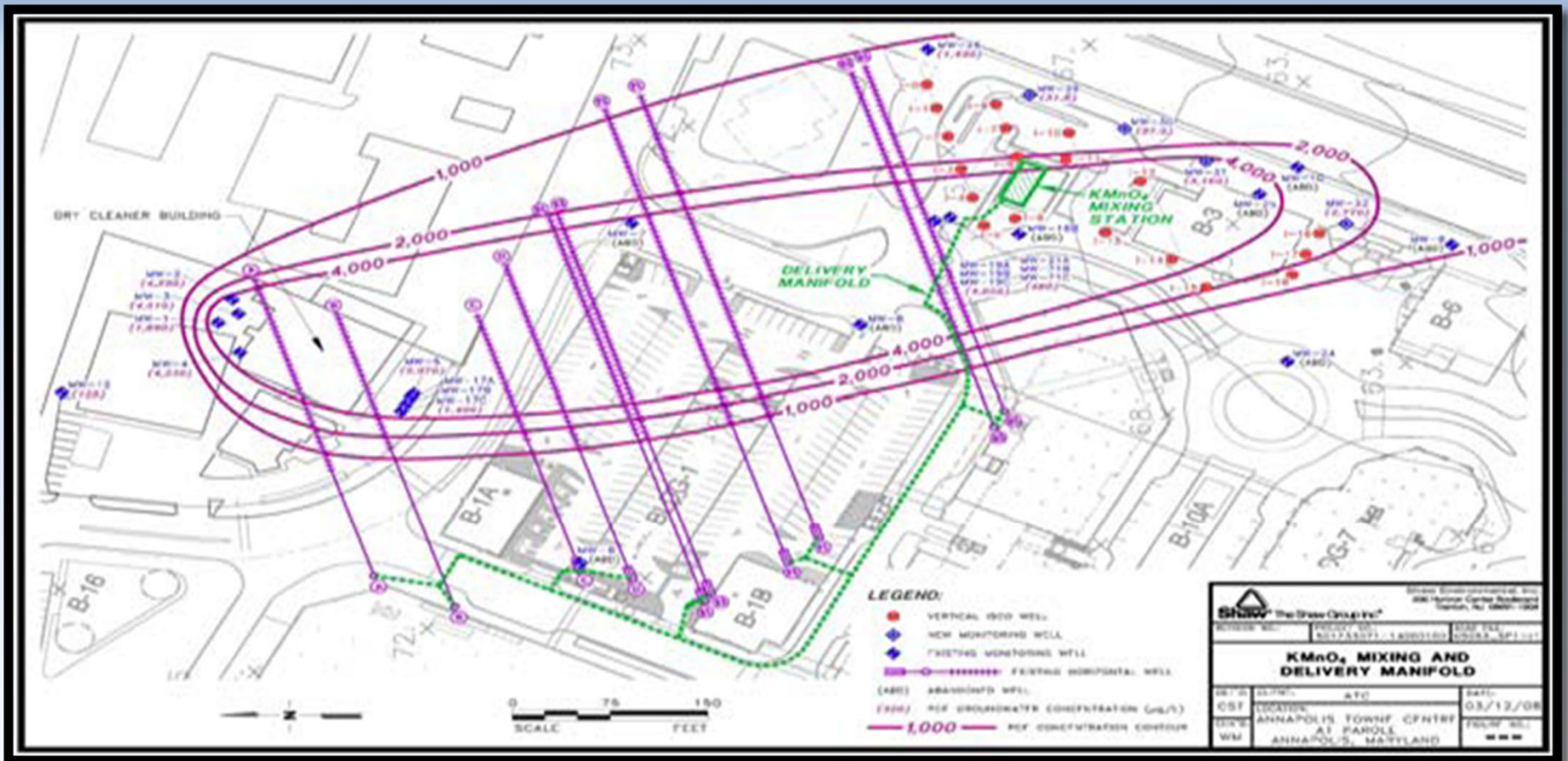
Remedial Strategy:

- Install 10 Potassium permanganate (KMNO₄) Horizontal Injection Wells,
- Perpendicular to groundwater flow.
- Several pairs of “Stacked” HIWs for vertical coverage.
- 5 horizontal SVE wells beneath former dry-cleaner.
- Blind method installation.
- 2,300 total linear feet of well screen.

Example Site 1: Chlorinated Solvent Site, Maryland



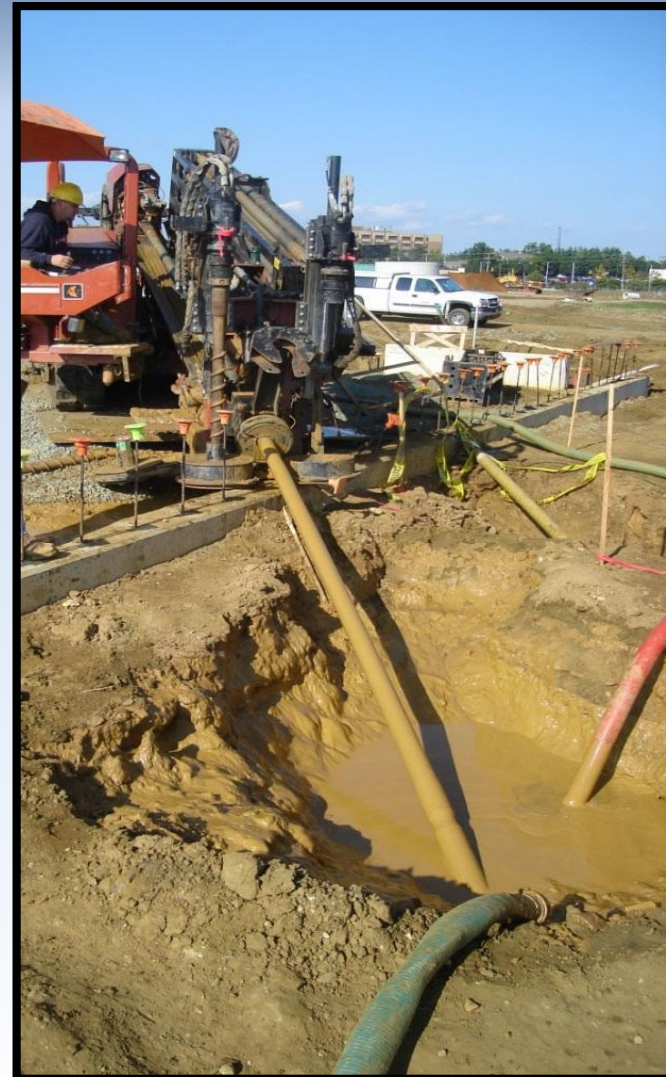
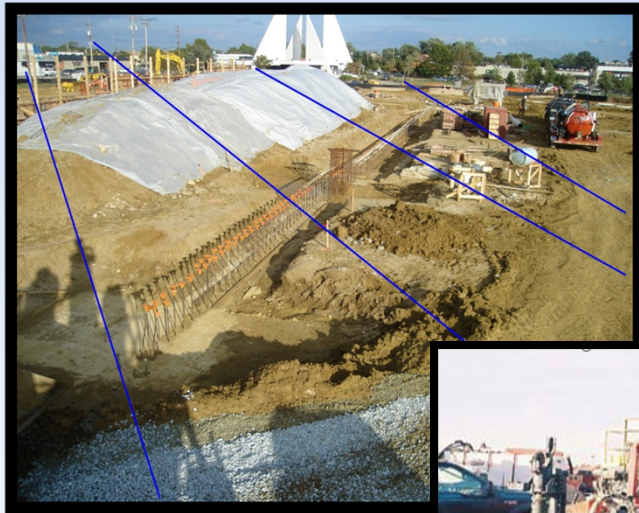
Remedial Strategy: Horizontal Injection Well Layout



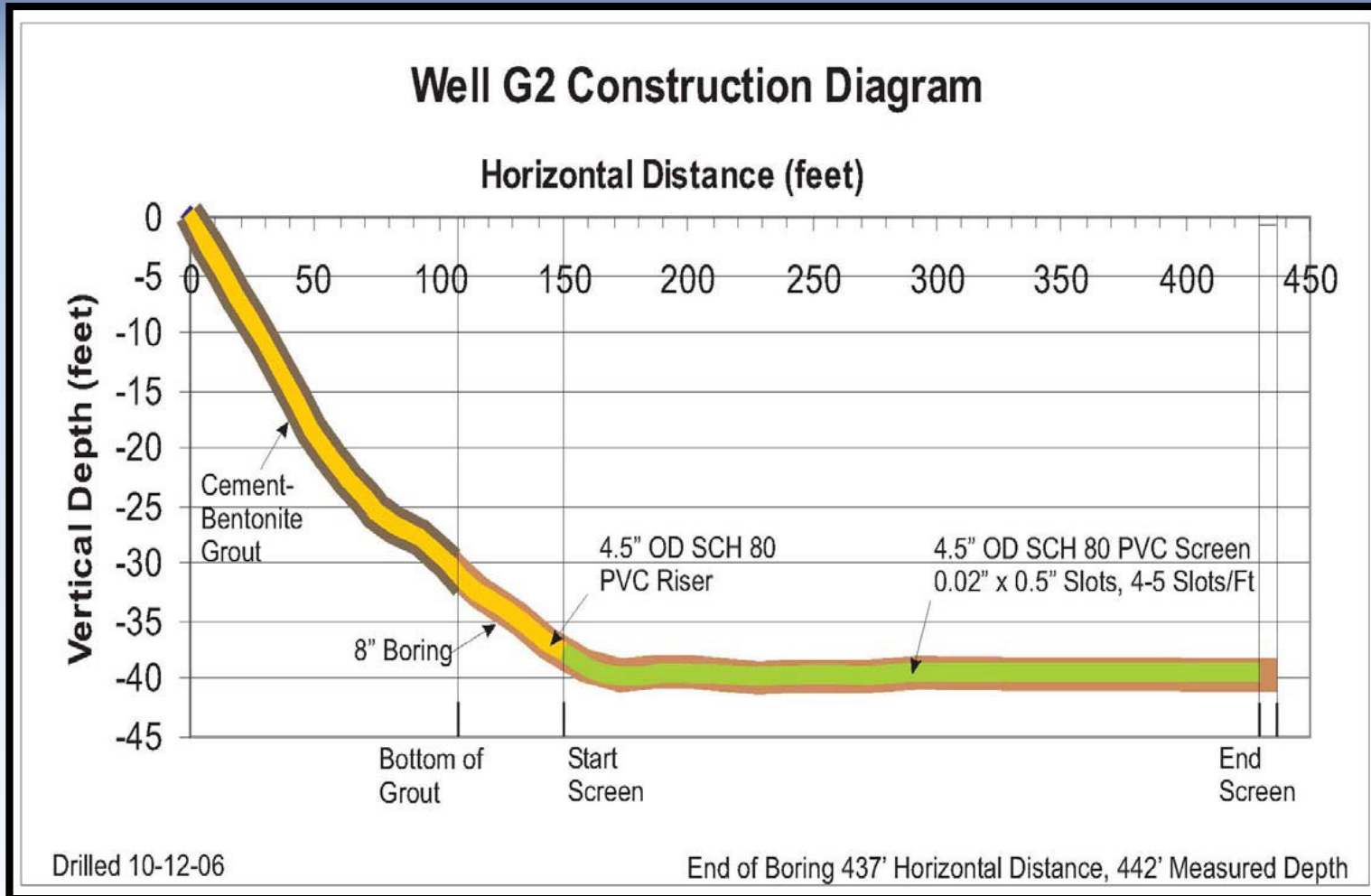
Example Site 1: Chlorinated Solvent Site, Maryland



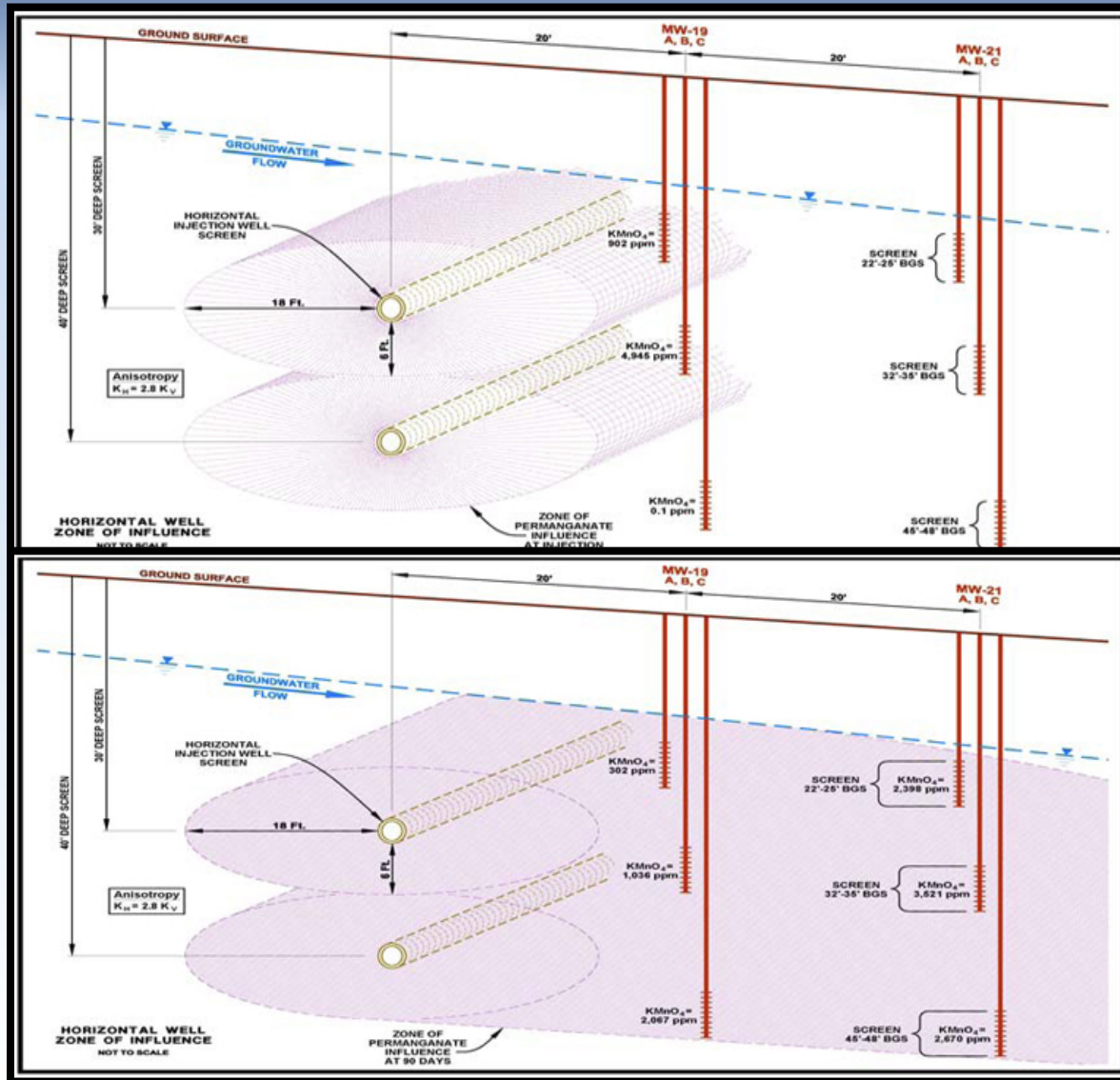
Horizontal Injection Well Installation
during site redevelopment construction.



Example Site 1: Chlorinated Solvent Site, Maryland



Example Site 1: Chlorinated Solvent Site, Maryland



Example Site 1: Chlorinated Solvent Site, Maryland



Injection Results:

- 1.4 million gallons of KMNO₄ solution injected over two major events
- TCE Concentrations reduced from 12 mg/L to non-detect.
- PCE concentrations significantly reduced.
- Maryland Department of the Environment touted project as a major success through the Land Restoration Program

KMNO ₄ Concentrations (mg/L) in MWs Downgradient of Horizontal Wells G1 & 2						
2nd Injection	Monitor Well Depth (ft)	Well ID Distance	Day 19 8/29/2007	Day 83 11/1/2007	Day 159 1/16/2008	Day 207 3/4/2008
ISCO-2 Injected Volume = 1,412,333 gal.	25	MW-19a 20 ft	68.9	302	20.8	<10
	35	MW-19b 20 ft	1036	2067	30	<10
	45	MW-19c 20 ft	2607	564	23.9	<10
	25	MW-21a 40 ft	247	2398	1351	595
	35	MW-21b 40 ft	10	3521	1986	84.4
	45	MW-21c 40 ft	10	2670	996	11.8

PCE Concentrations In Wells Downgradient Of The Dry Cleaner's Building (ppb)				
Time	Well MW-5 Screen -20-40 ft	Well MW-17a Screen 25-30 ft	Well MW-17b Screen 40-45 ft	Well MW-17c Screen 55-60 ft
Prior to First ISCO	6,270	16,600	960	532
6 Months After 1 st ISCO	3,970	6,400	555	212
3 Months After 2 nd ISCO	2,970	1,410	ND (Purple)	66.8
5 Months After 2 nd ISCO	ND (Purple)	757	ND (Purple)	95.9

Example Site # 2: ISCO Injection – Resin Manufacturing Facility with ASTs & USTs, Australia

Acknowledgements:

Balbatchevsky, Pedro (AECOM) and Sequino, Mike (Directional Technologies, Inc.)
Horizontal Wells Down Under: Horizontal Wells Tasked to Target Source Area Under
Industrial Complex. Presented at the Battelle Bioremediation Symposium 2018.

Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia



Project Background:

- An active resin manufacturing facility in Botany Bay, New South Wales, Australia.
- Source area under manufacturing facilities and above and underground storage tanks.
- Horizontal wells were selected as the best choice to target the source.

Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia



Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia



APPROACH: Three (3) horizontal injection wells

- The HRWs were installed via blind method.
- The starting angles of the well paths were adjusted in the field resulting in fan shaped horizontal well pattern allowing for better coverage of the plume.
- The horizontal well screens were designed for site specific remedial goals and engineered to ensure even flow distribution.

Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia



Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia

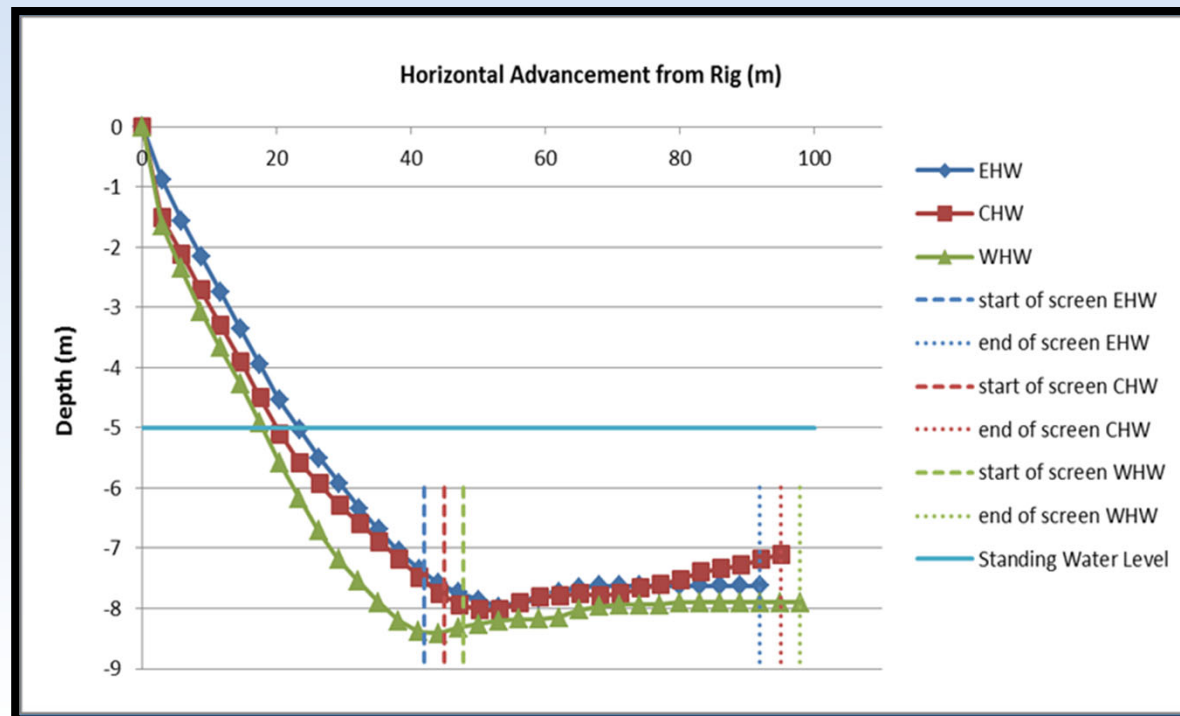


Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia



Horizontal Well Design Details:

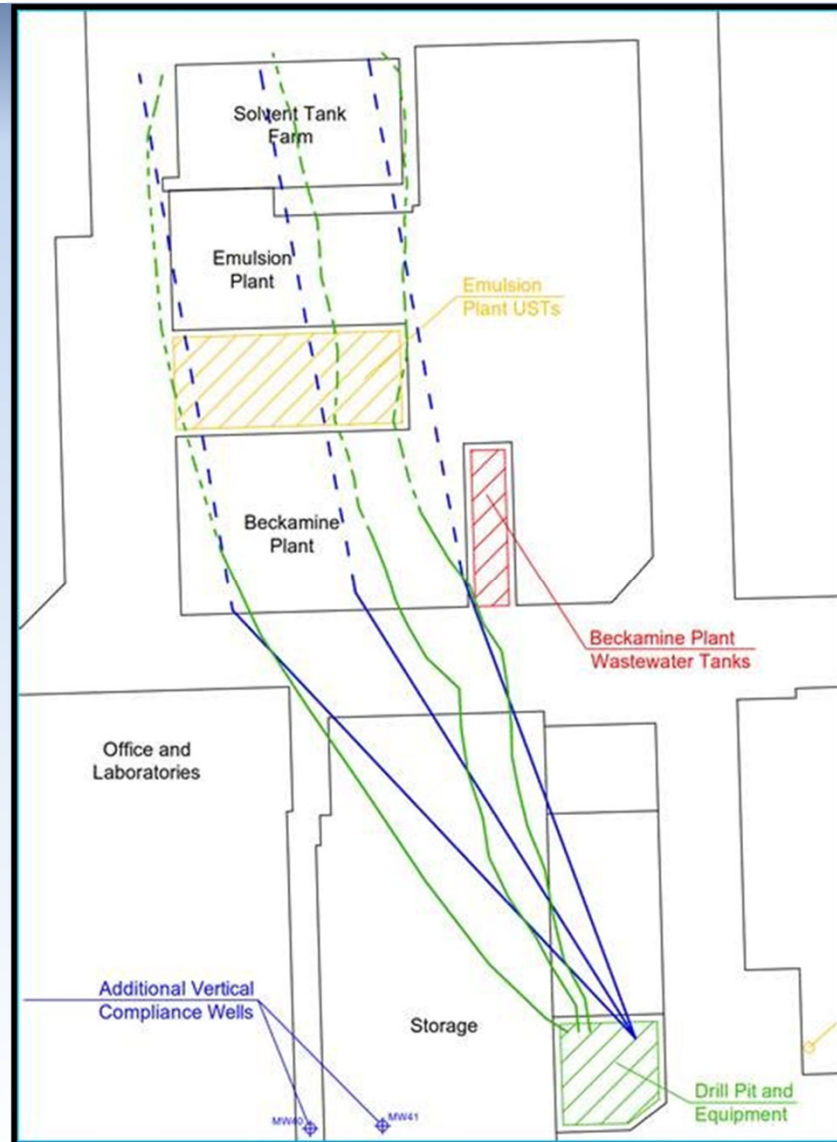
- Screen sections were at depths of approximately 8 meters (26 feet) below ground surface (bgs).
- Ensured successful injection below the groundwater table at 4.8 to 5.2 meters (15.7 feet to 17.0 feet) bgs.



Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia



Horizontal Injection Well Paths Beneath the Facility



Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia

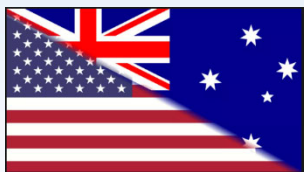


- The three (3) HRWs were utilized for injection of Modified Fenton Reagents (MRRs): **stabilized hydrogen peroxide and chelated ferrous sulphate combination.**
- The remediation system consists of two progressive cavity pumps connected to 34,000 liter (9,000 gallon) tanks.
- First 3 Injection Events: August 2017, November 2017, and February 2018: >130,000 gallons injected.

Example Site #2: ISCO Injection, Manufacturing Facility, NSW Australia



- Initial injection successfully influenced the groundwater by creating groundwater mounding of 40 centimeters (16 inches) and temperature increases observed at nearby groundwater monitoring wells.
- After only 6 months of operation, an estimated 36% of the mass in the target zone has been remediated.



2018 Outstanding Innovation Advancing the Land & Groundwater Industry from the Australasian Land & Groundwater Association (ALGA) for Australia's 1st Installation of Horizontal Wells for ISCO.

Example Site # 3: Bio-amendment Injection - Perchlorate Site, Massachusetts

Acknowledgements:

Irwin, J. Andrew, PE, LSP (IRWIN Engineers) and Sequino, Mike (Directional Technologies, Inc.) Horizontal Remediation Injection Wells (HRIW) Solution to Slow Uptake via Vertical Injection Wells. Presented at the Battelle Bioremediation Symposium 2015.

Example Site #3: Perchlorate Site, Massachusetts



Background:

- Perchlorate in groundwater from a leaking wastewater line undetected for 8 to 10 years.
- Perchlorate plume extended 900 feet toward a river.



Aerial Photograph of Industrial Park:

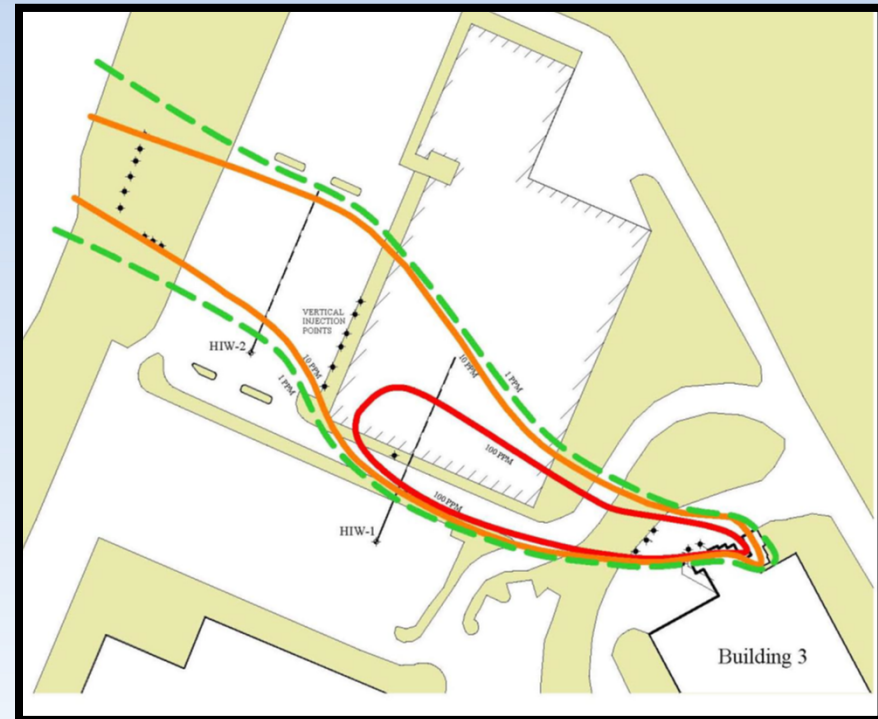


Example Site #3: Perchlorate Site, Massachusetts



Background (continued):

- The formation permeability was calculated to 3.5 ft/day.
- Concentrations were between 10 mg/L to 500 mg/L.
- Total calculated mass of 1,500 pounds of perchlorate.
- Challenging geology: heterogeneous alluvium with overlying glacially deposited sand, gravel, and till.



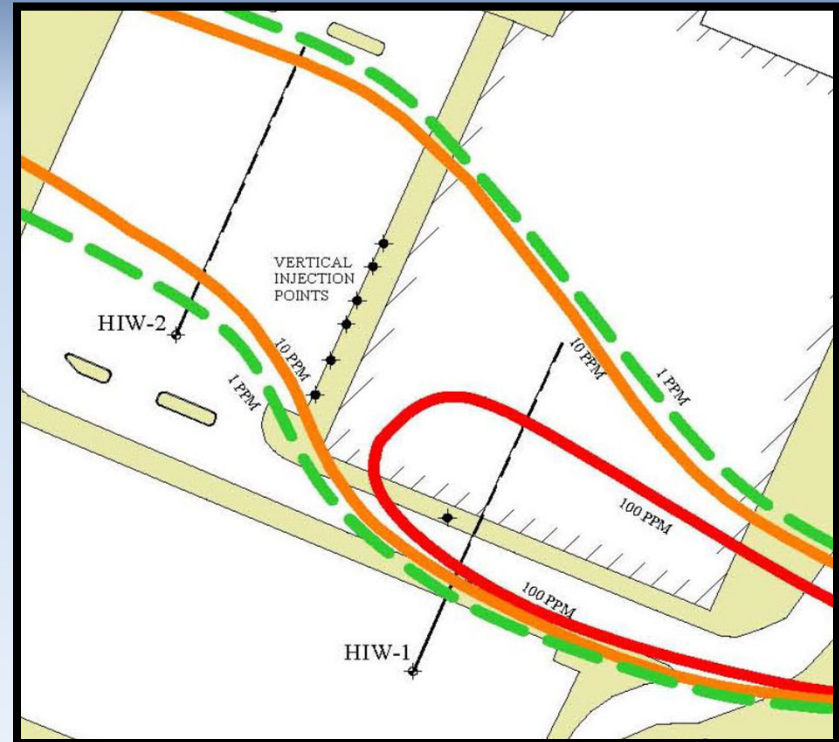
**Groundwater Contaminate Plume
Before Bioremediation:**

Example Site #3: Perchlorate Site, Massachusetts



Remedial Strategy:

- Installed 2 horizontal injection wells for bacterial culture Clout® gravity injection.
 - 3-inch diameter well screen
 - Blind well installation method (no exit point required)
 - Wells were installed above the till layer for injection deeper into the saturated zone

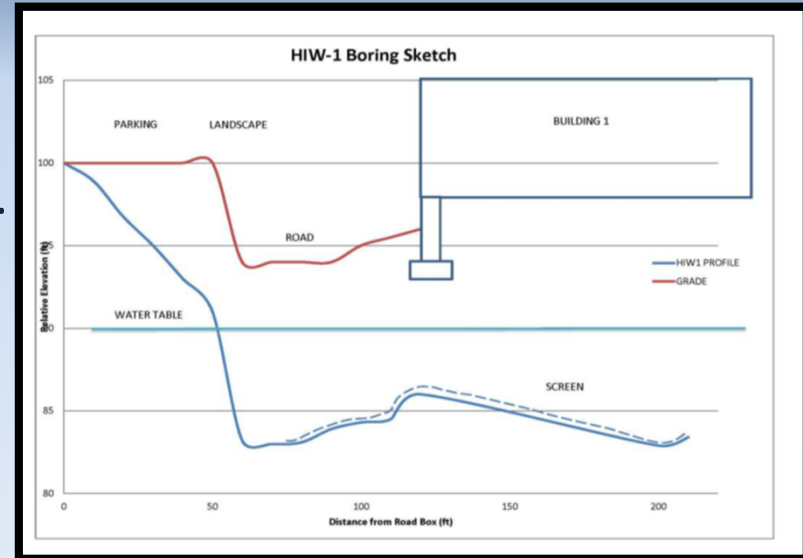


Example Site #3: Perchlorate Site, Massachusetts



Remedial Strategy (cont'd):

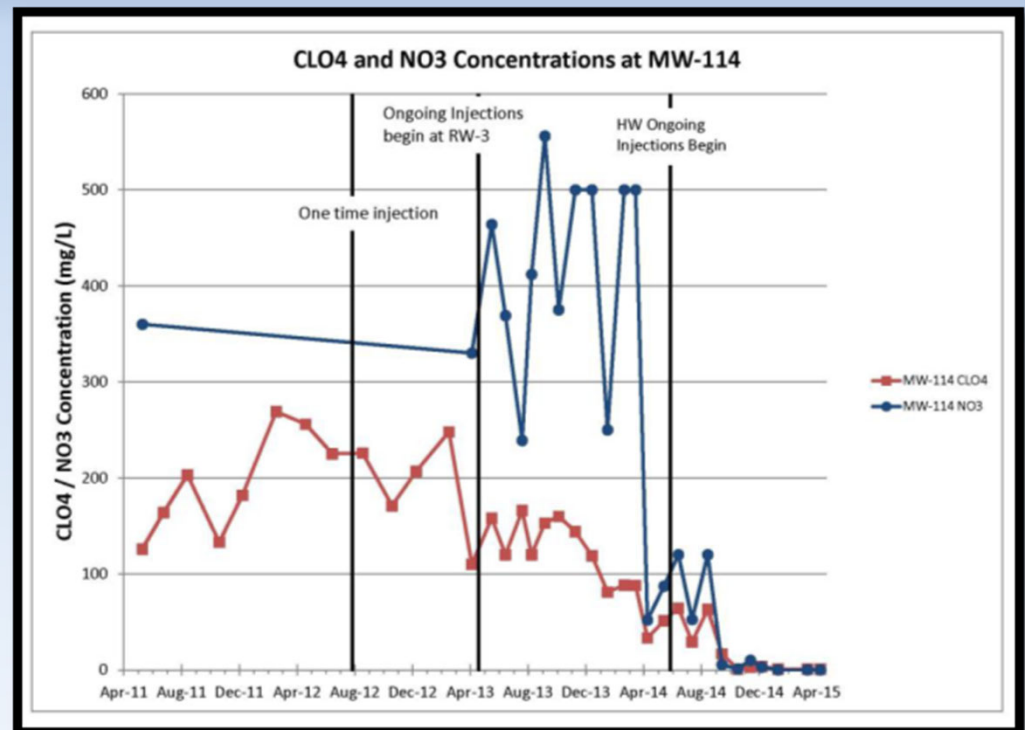
- Twice as much submerged well screen vs vertical injection well row.
 - 160 linear feet of submerged screen per well.
 - Distribution of additive across width of plume without gaps.
- Limited site disturbance.
- Single gravity-feed injection point for simplified operation and maintenance.



Example Site #3: Perchlorate Site, Massachusetts

Gravity Injection Flow Rates:

- 2,000 Gallons per day horizontal injection compared to 2,000 gallons per week vertical injection.
- Achieved injection rates of up to ~83 gallons per hour.
- Increased injection due to total submerged screen increasing from 45 ft to 320 ft

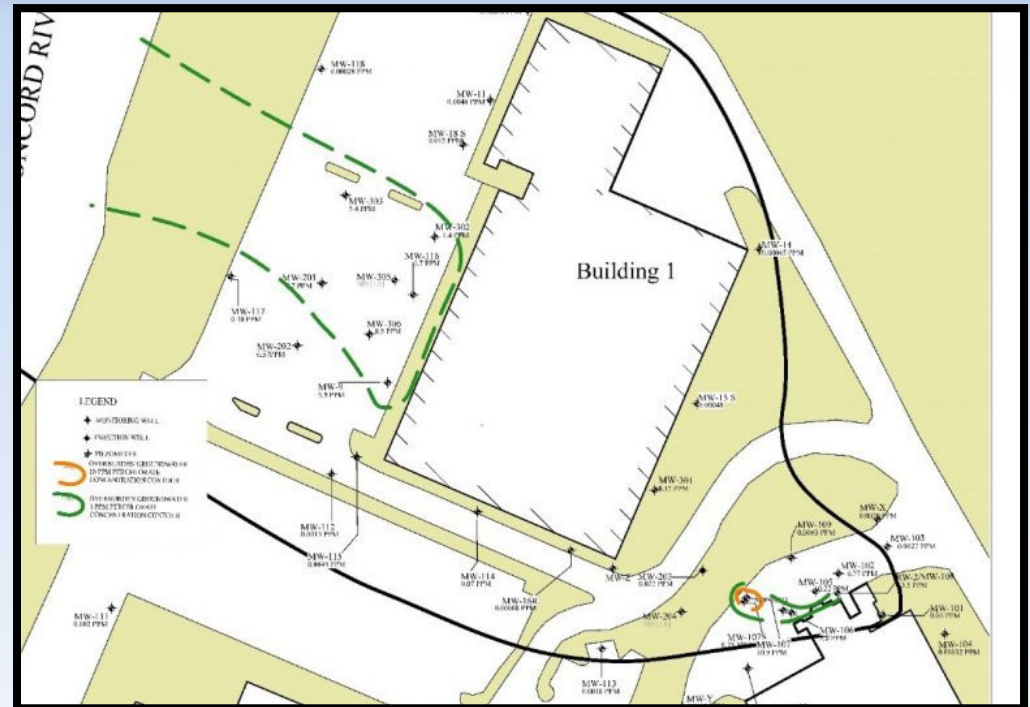


Example Site #3: Perchlorate Site, Massachusetts



Remedial Results:

- 98 percent reduction of perchlorate mass within a 3-year period, with NFA status from the Mass DEP.
- The site was recognized by Mass DEP with a **Greener Cleanup Leadership Award** in 2016.
- Closed without Activity and Use Limitation.
- Completed the treatment phase in 3 years and reduced the overall project cost by more than 60%
- Saved the responsible party over \$5 million and at least 5 years of additional O&M compared to continuing with pump and treat.



Plume Two Years after Horizontal Injection Well Installation

Summary



- Horizontal injection strategies vary widely on scale, target compounds, site conditions, and delivery methodology.
- Horizontal Remediation Well systems are mature technology with 25+ years of case studies, site closures, and regulatory acceptance.
- Numerous remedial applications: AS/SVE, Biosparge, DPE, GW Extraction, Vapor Mitigation, Thermal remediation.
- HRWs allow for a creative placement to avoid surface obstructions and minimize disruptions to site activities.
- HRW can lower project costs when compared to multiple vertical wells.

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Questions?

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