Combined In Situ Biogeochemical Reduction Solution Rapidly Mitigates Threat to River and Saves Client $380,000

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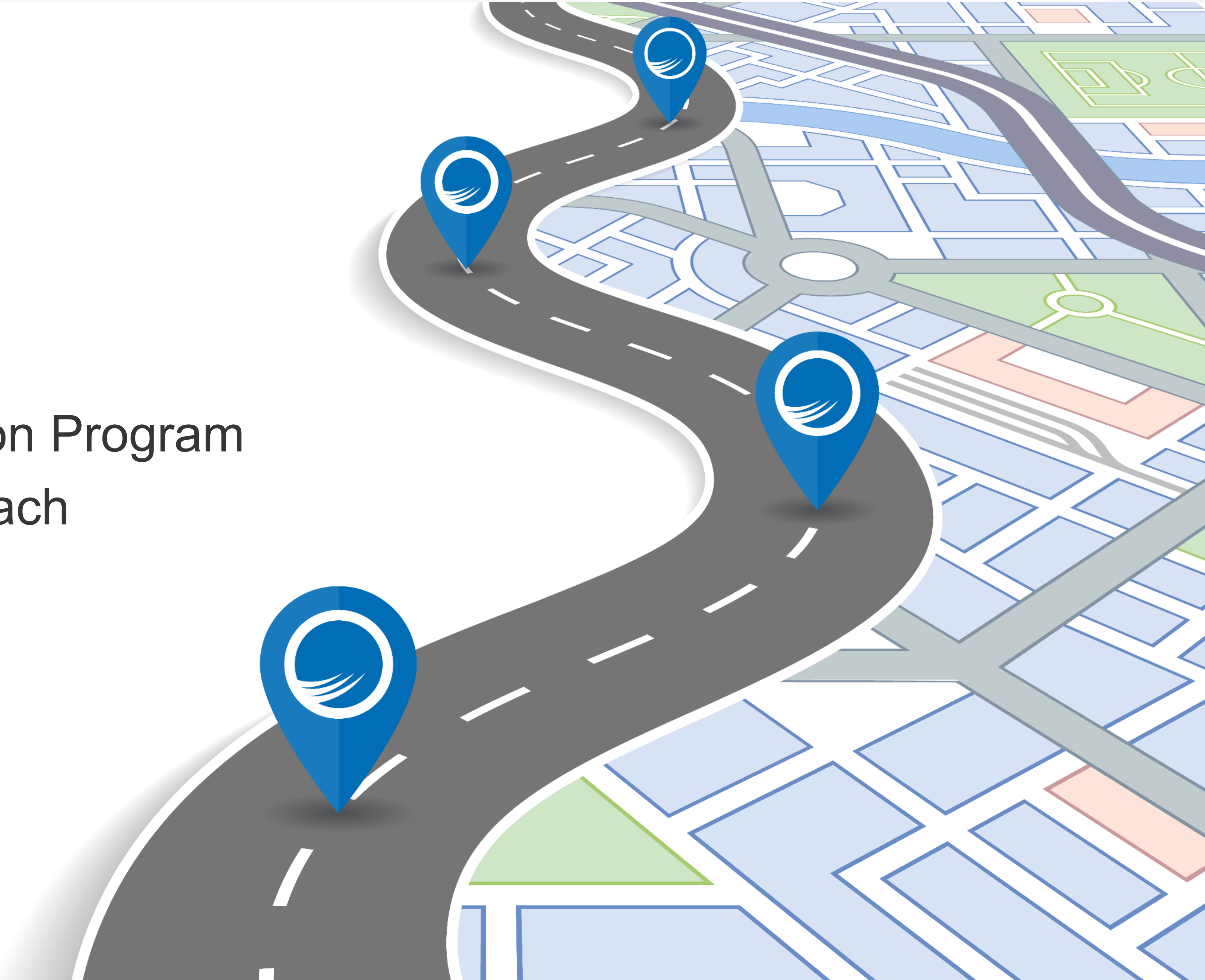
Introduction

Roadmap

- Introduction
- Site Background
- Design Verification Program
- Full-Scale Approach
- Results
- Questions



Site Background

- Former chemical manufacturing and photo engraving processes from 1950s-2004
- 1500'+ TCE plume
- Plume moving through shallow and deep aquifer zones
- Plume migrating towards a large surface water body

Site Background

Innovative Remediation of TCE Plume in Indianapolis

Ideal Solution:

- Flexible Approach For a Logistically Challenged Urban Location
- Halt Plume Migration To River
- Minimize Toxic Daughter Product Generation
- Cost Effective
- Rapid Treatment

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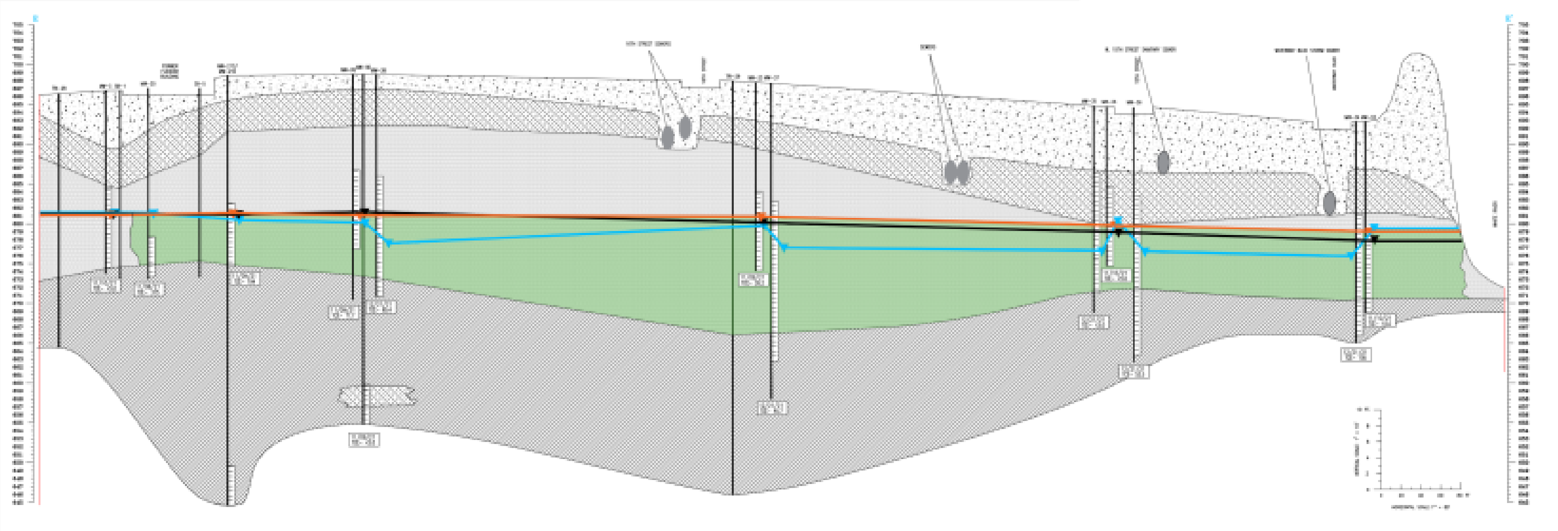
Site Background

The Challenge

- Plume features known, but lacking granularity
- Potential contamination of surface water body
- Migration through shallow and deep aquifer
- Roadways, buildings, and other infrastructure was restricted the placement of *in situ* Permeable Reactive Barriers (PRBs)



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Design Verification Program

The In-Situ Process

FluxTracer®
Flux Mapping Tool

DVT
Design Verification Testing

FluxTracer
Mass Flux Vertical Profiling

Design Revision
Placement Validation

Injection
Distribution Verification

Technical Review of Performance

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Design Verification

What is DVT?

- A process of data collection and analysis to verify design assumptions of a sites chemical and geological conditions and the viability of *in situ* injection
- Localized, high-density identification of COC transport zones
- Flux Zone verification

Why is it necessary?

- Site investigations typically focus on liability and risk
  - Define nature and extend

Focus on efficient reagent-contaminant contact

- Ensure accurate, efficient placement of reagents for maximum flux interception
- Field verification of remedial design parameters
- Identification of contaminant transport strata

Design Verification Program

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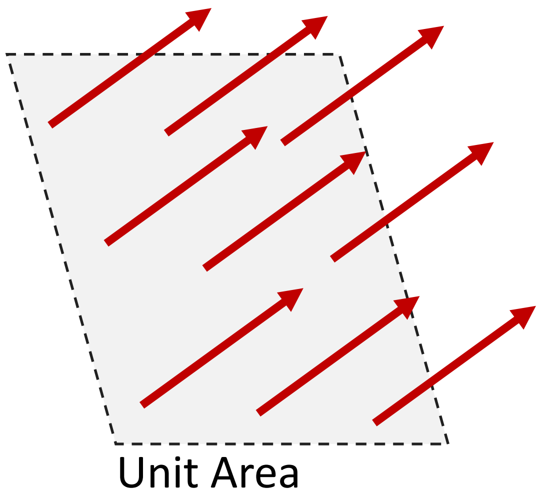
What is Mass Flux?

Flux ≈ Flow

Quantity of (contaminant, groundwater, etc.) moving



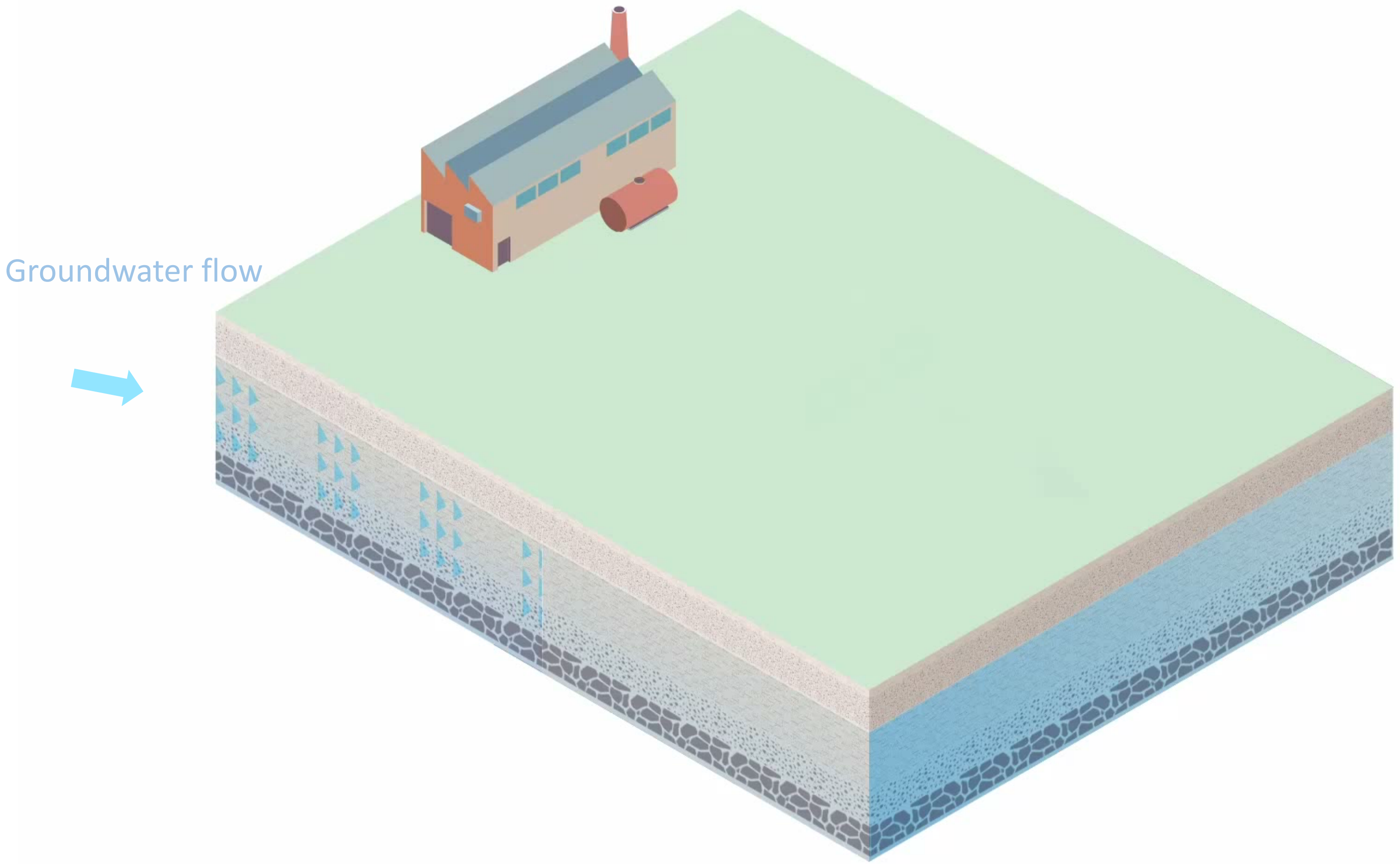
Amount of (…) passing through unit area with time

Can be:

- Groundwater (Darcy Flux)
- Contaminant molecules (Contaminant Mass Flux)

Design Verification Program

What is Mass Flux?



Flux is rate of flow through a plane of compliance

Units

Darcy flux

(cm/d)

Mass flux

($mg/m^2/d$)

Darcy velocity (cm/d)	Seepage* (ft/yr)	Mass flux** ($mg/m^2/d$)
2	96	100
4	192	200
6	287	300
8	383	400
10	479	500
20	958	1000

*Porosity = 0.25

**GW concentration = 5 mg/L

Graphic adapted from ITRC "Use and Measurement of Mass Flux and Mass Discharge" August 2010

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Design Verification Program

Why is Measuring Mass Flux Important?

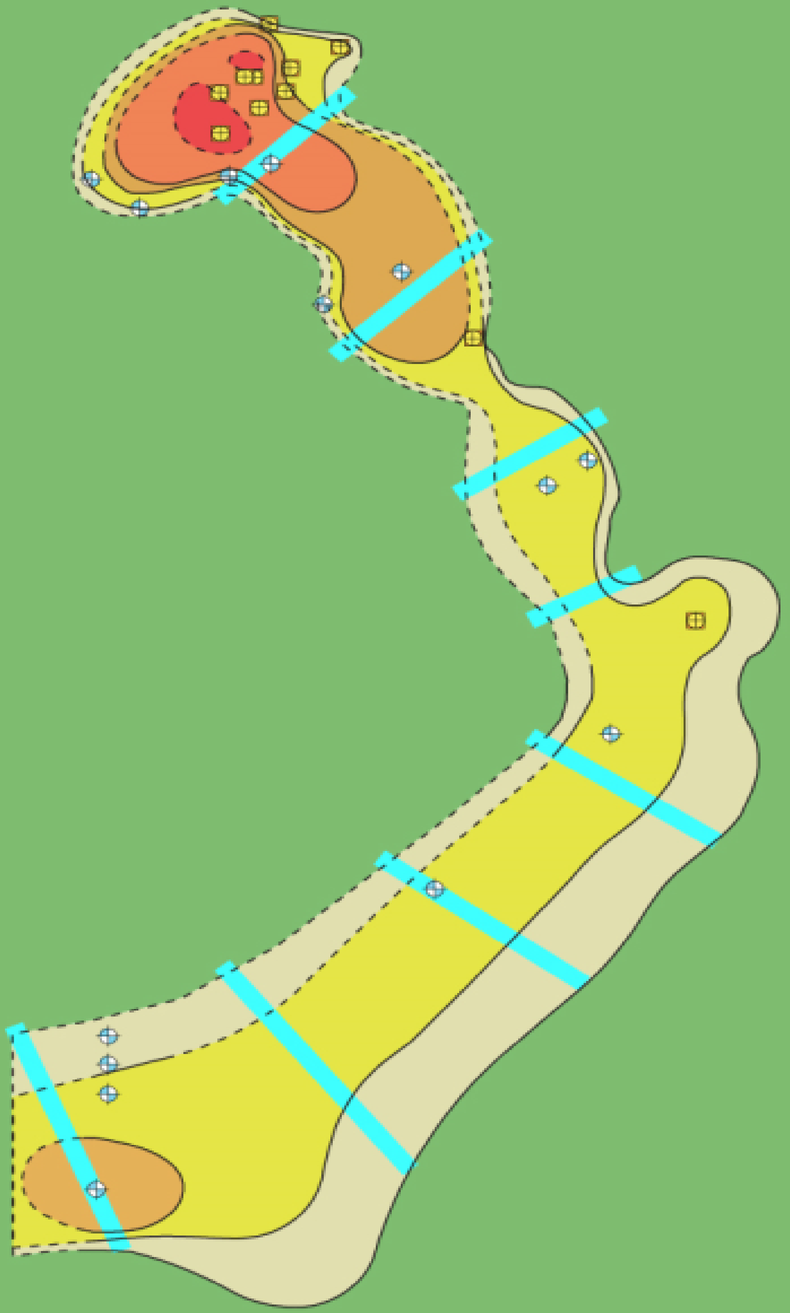
Most flux occurs in a small fraction of the aquifer

- 80% of the mass flows through 20% of the aquifer
- Identifies and quantifies the “mass that moves”
- Delineates vertical zones controlling size and shape of plumes

Permeable Reactive Barriers (PRBs) are highly *sensitive* to contaminant mass flux

- Short and long-term performance

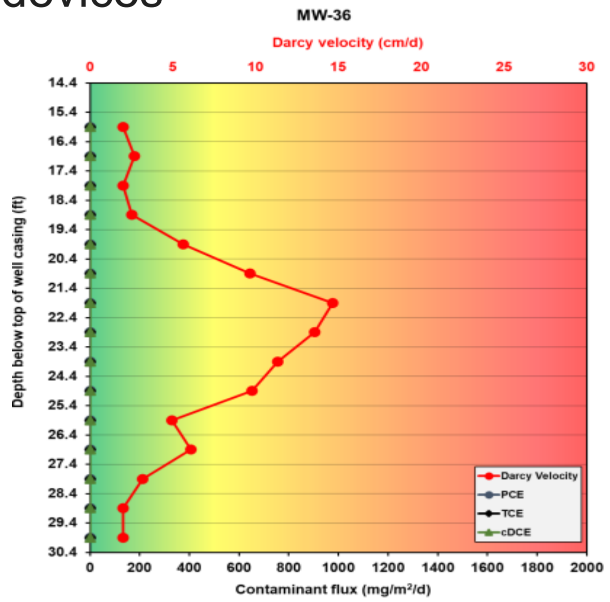
Results are directly used in remediation designs

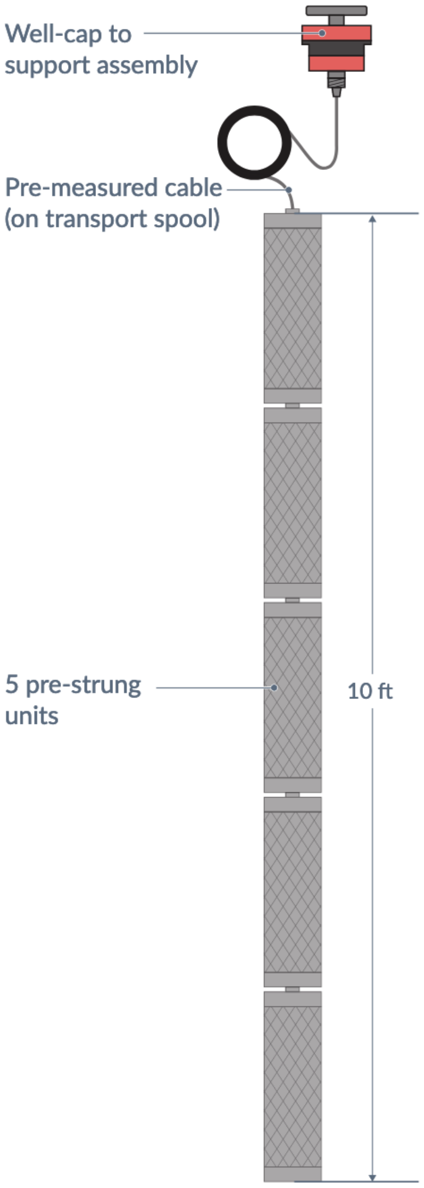


Design Verification Program

Identify Flow Channels and Injection Hydrology by performing initial Design Verification Study

- Baseline groundwater geochemistry sampling
- Soil cores to confirm lithology changes
  - Interval fluctuations as we move toward river
- FluxTracer devices in plume monitoring wells (5)-15' devices





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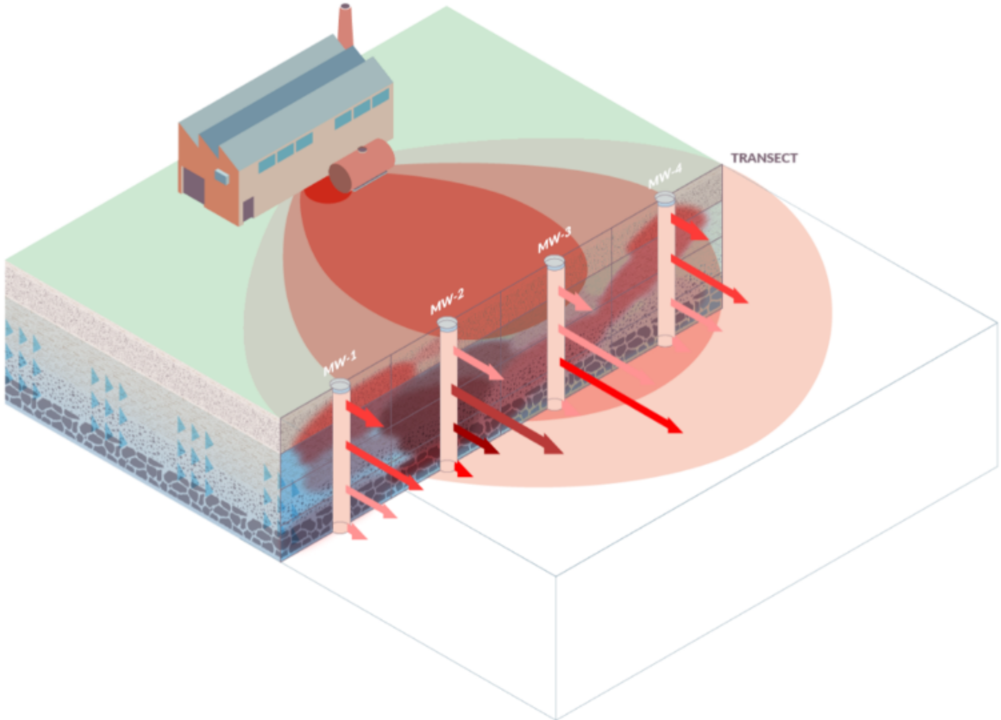
Design Verification Program

Design Verification (DVT) Results

- 5-15’ FluxTracer Devices
  - Identified mass flux zones
  - Firmed up GW velocity assumption
    - 1200ft/yr est. Vs. 300’yr calculated
  - Optimized vertical dosing
  - Horizontal plume sampling
    - Decreased barrier length 44%



“We were able to save the Client about $380,000 in injectant material. It was time and effort well spent”

- Senior Geologist Scott Brown-Connors, Wilcox

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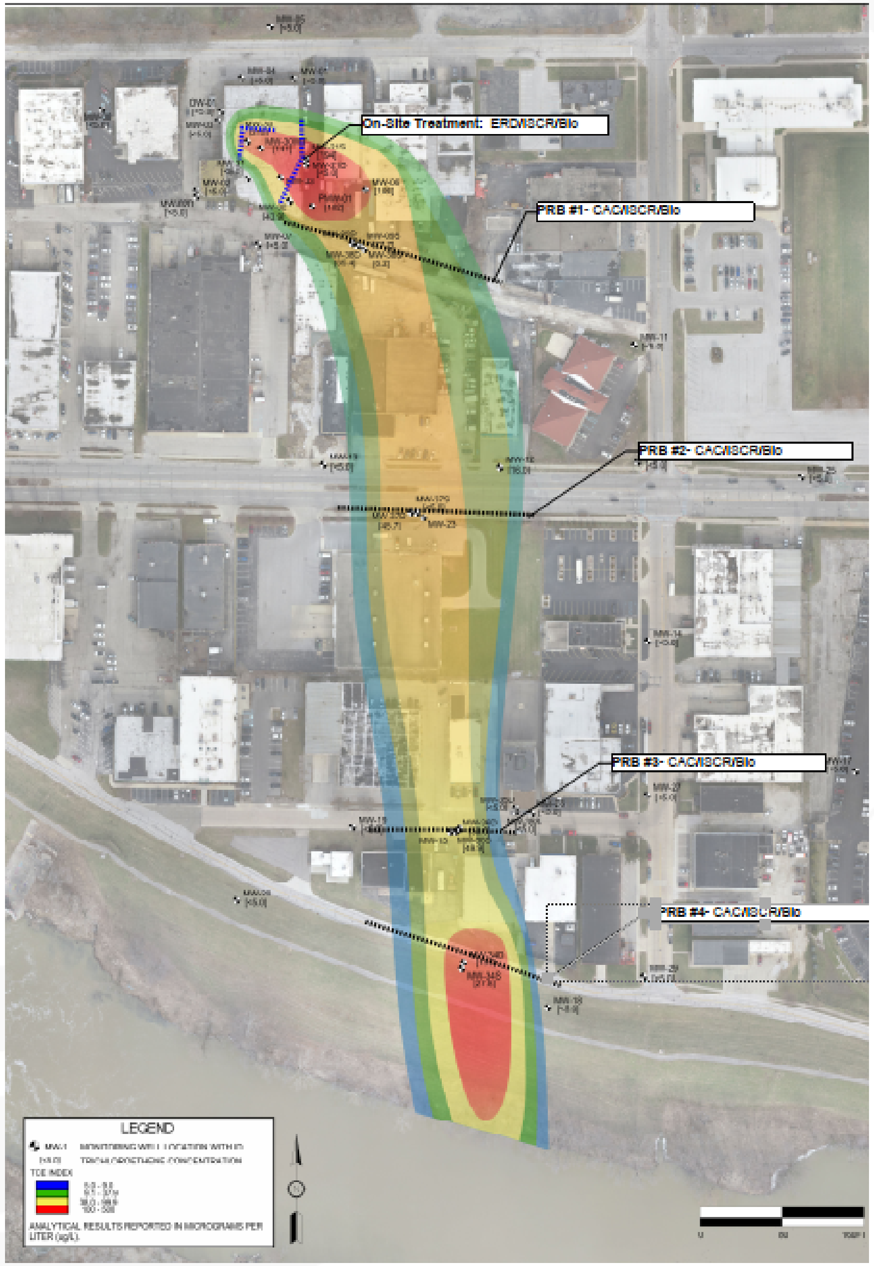
Full-Scale Approach

Full-Scale iPRB Approach

Reinforce Remedial Conceptual Model By:

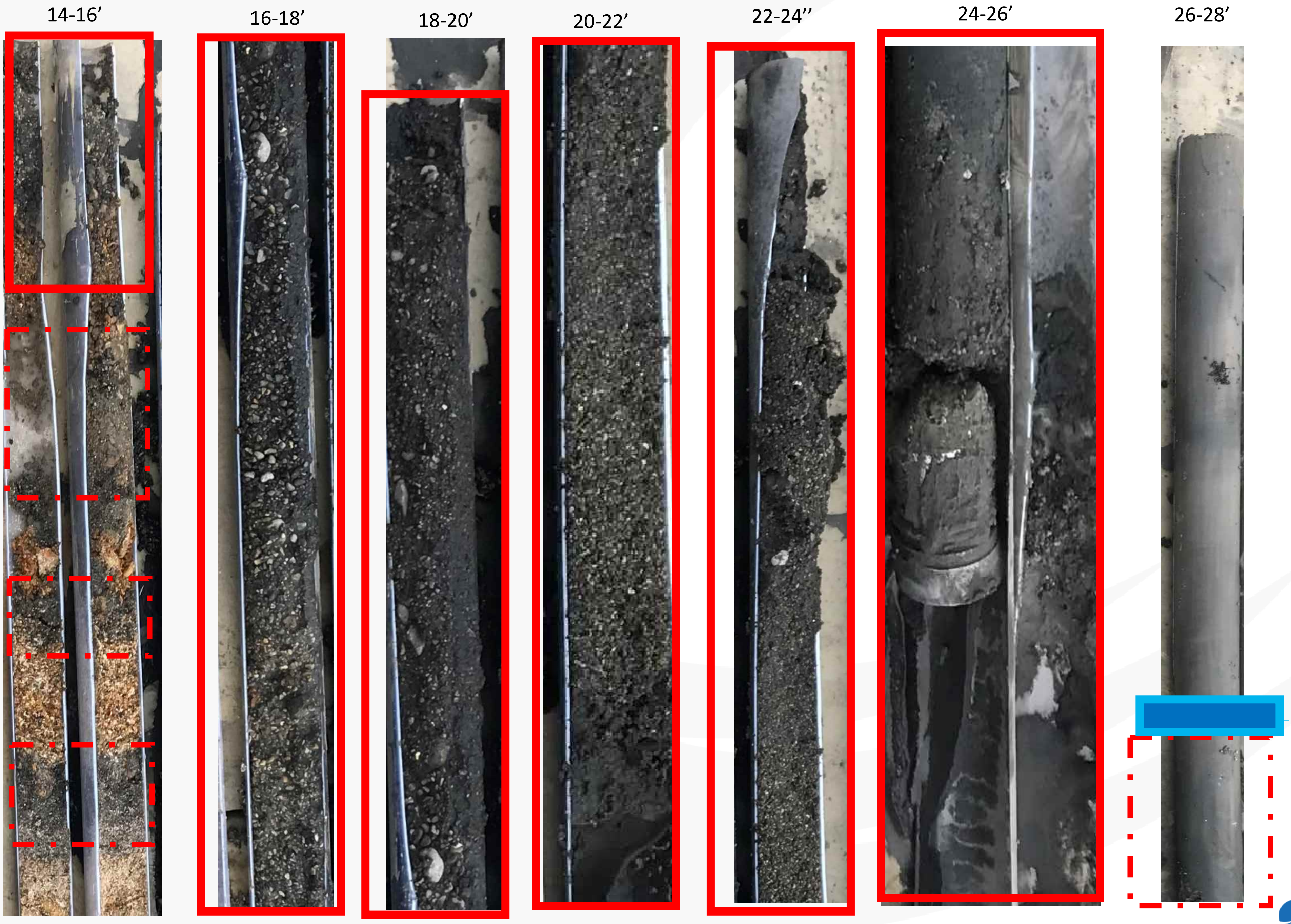
- On-site PRBs to control source
  - ERD – slow-release colloidal electron donor
  - ISCR – soluble ferrous iron
  - Bio-Augmentation
- Off-Site PRBs to truncate and stop plume
  - Sorption – colloidal activated carbon
  - ISCR – sulfidated micron scale ZVI
  - Bio-Augmentation



Full-Scale Approach

Confirm and Adjust in Field

- **Pre-Injection Soil Core Collection and Piezometer Placement**
  - Each SC collected equidistant (2ft) between two injections point from a depth of 13 ft bgs to 30 ft bgs.
- **Real Time Groundwater Monitoring**
  - Actively collect and monitor ground water geochemical response within temporary piezometers.
- **Confirmation Core Collection**
  - Black staining is visible from 15' bgs to 26' bgs where confining layers starts and injection interval thoroughly covered.
- **Team Review**
  - Once completed project team update provided via Microsoft Teams.



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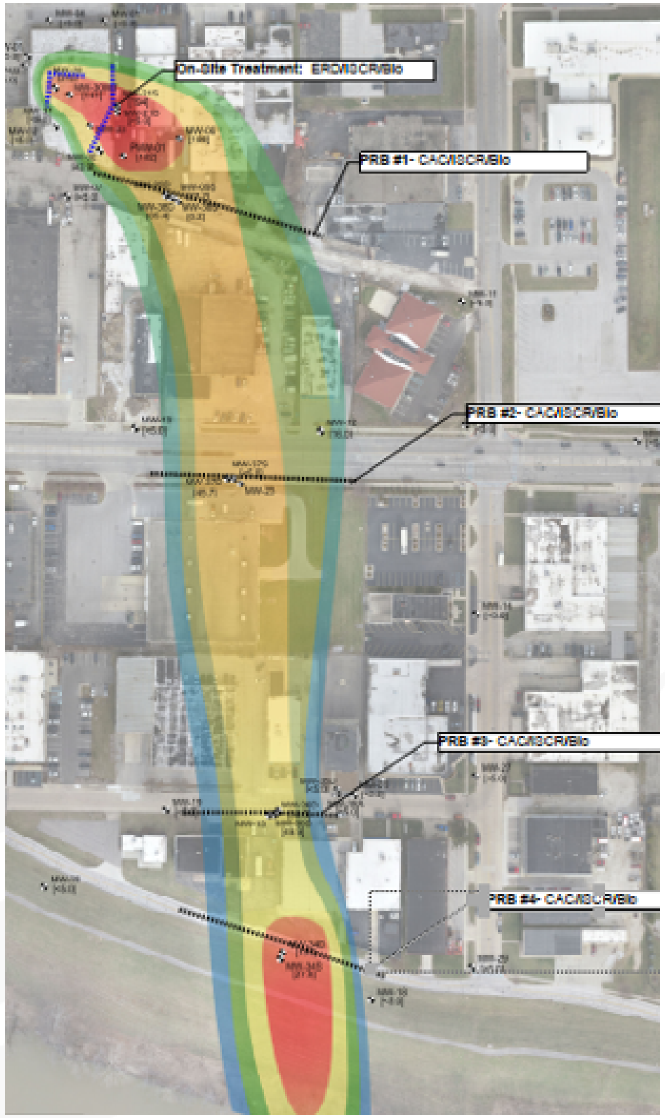
Full Scale PRB Approach

- Onsite iPRBs to control source –
    - ERD – slow-release colloidal electron donor
    - ISCR – soluble ferrous iron
    - Bio-Augmentation
- Off-Site iPRBs to truncate and stop plume
    - Sorption – colloidal activated carbon
    - ISCR – sulfidated micro scale ZVI
    - Bio-Augmentation
- 56 days of injections from October to January 2023
- 110,000 gallons of remediation amendments were applied

Off-Site PRB Summary

PRB #	Total Length (ft)	Treatment Interval (ft bgs)	Injection Points	Application Volume (gal)	PlumeStop (lbs)	S-MicroZVI (lbs)	BDI (L)
1	280	18-28	56	22,811	18,400	6,800	8.5
2	245	18-35	49	33,560	16,000	5,900	7.5
3	180	15-28	36	18,711	12,000	4,400	11
4	255	16-27	51	24,693	16,800	6,200	8



Results

- 3 months post injection
  - 80-100% reduction in total cVOCs
  - Sustained for 3 quarters and counting
- Drastic reduction of overall plume length
- The threat of TCE and other cVOC impacts on river has been diminished

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In Summary

Ideal Solution: Achieved

- ✓ Flexible Approach For a Logistically Challenged Urban Location
- ✓ Halt Plume Migration To River
- ✓ Minimize Toxic Daughter Product Generation
- ✓ Cost Effective
- ✓ Rapid Treatment

Questions?

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