The Horizontal Reactive Treatment Well (HRX Well®) for Long-Term In Situ cVOC and PFAS Mass Discharge Control at Three Sites

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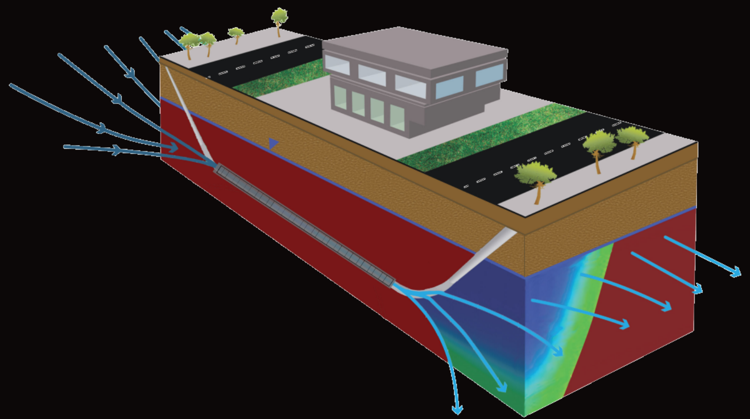
May 2024



Modeling Analyses and Laboratory Evaluation of the Horizontal Treatment Well

A New Sustainable Passive In Situ Remediation Concept

Craig Divine, Gaston Leone, Jeff Gillow, Tracy Roth, Matt Spurlin, Scott Potter (ARCADIS)

Tayler Rigsby (Colorado School of Mines, now at ARCADIS)

The Eighth International Conference on Remediation of Chlorinated and Recalcitrant Compounds
Monterey, California, May 24, 2012

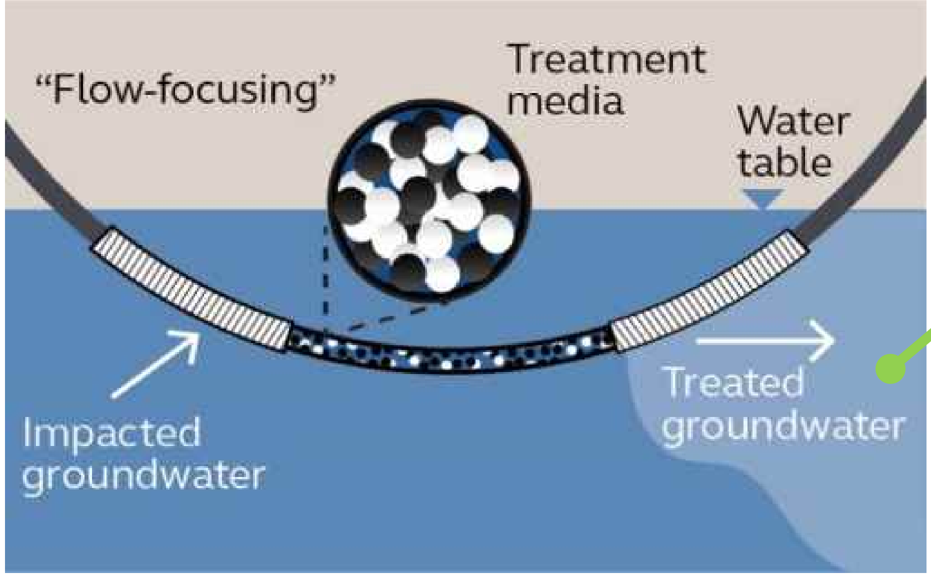
Imagine the result

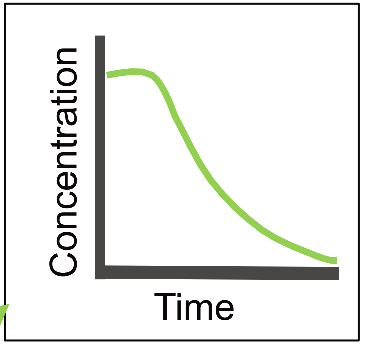
ARCADIS

HRX Well® Description (Passive Configuration)

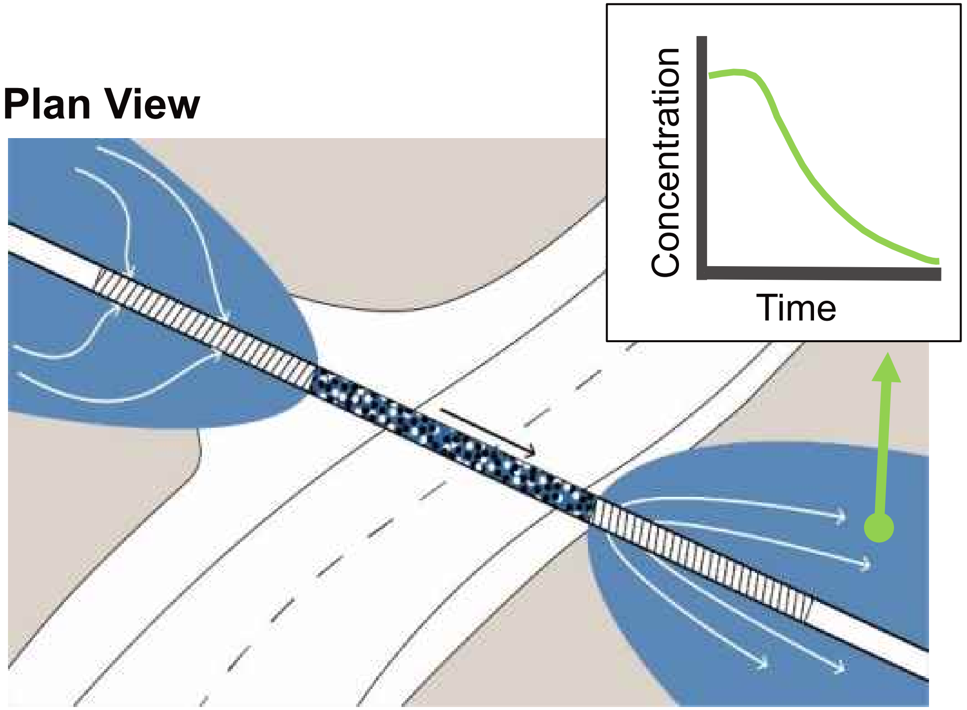
The HRX Well* is a large-diameter horizontal well installed along the groundwater flow path that is filled with treatment media for long-term in situ mass flux/discharge control

Profile View



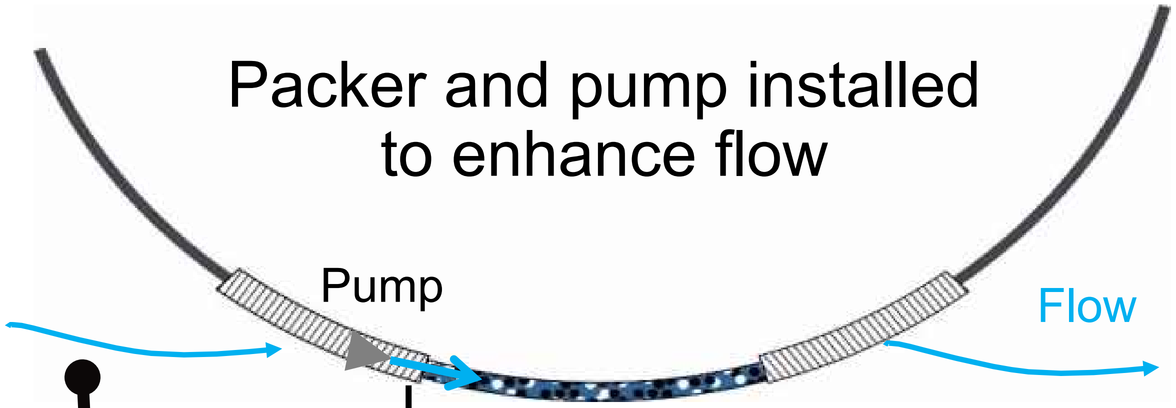


Plan View



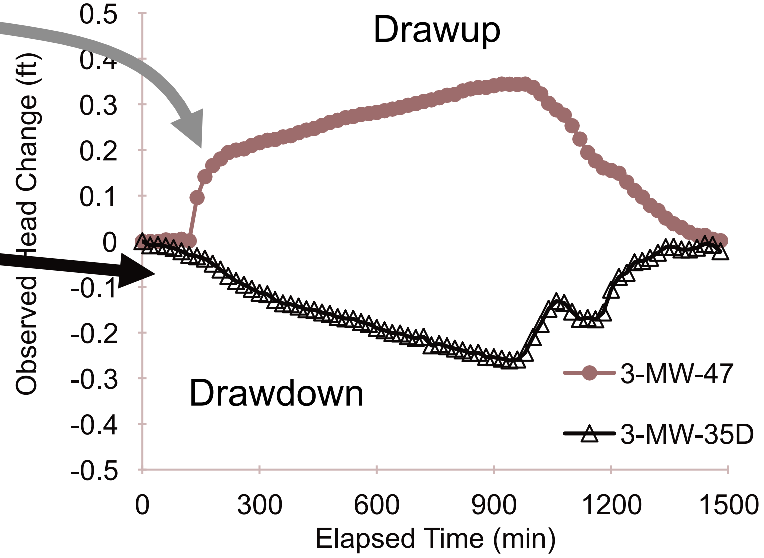
*Patent US20120261125A1

HRX Well Description (Active Configuration)



Appropriate for more permeable aquifer settings

Packer



Treatment Zone Size

Passive Configuration

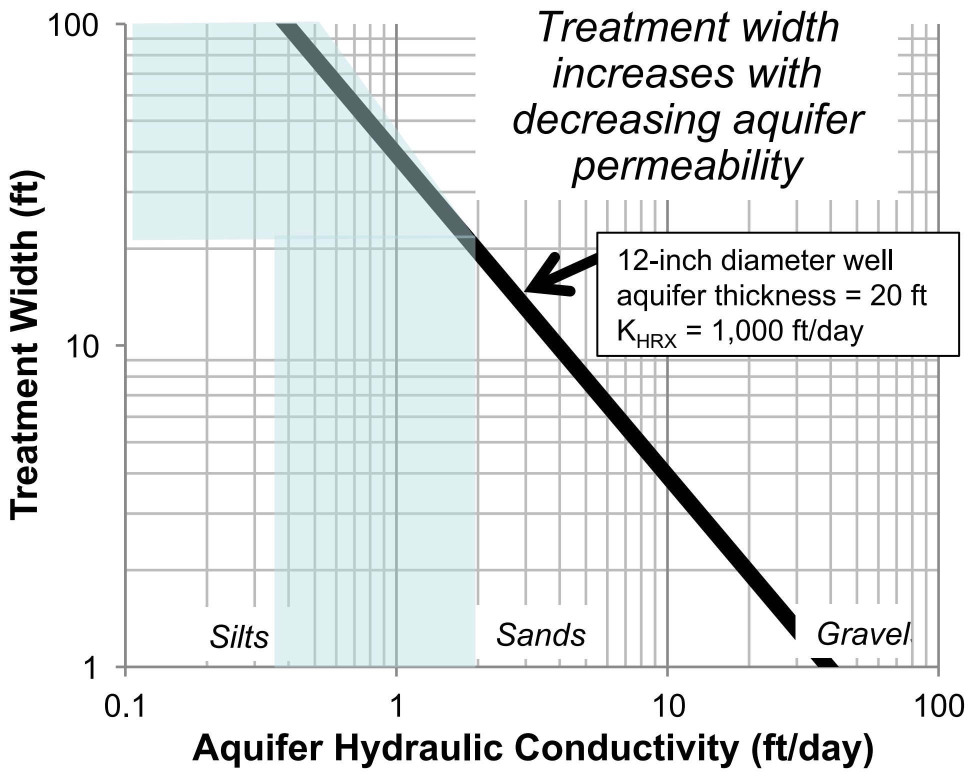
$$w_{treatment} = \frac{K_{HRX} A_{HRX} i_{HRX}}{K_A b_A i_A}$$

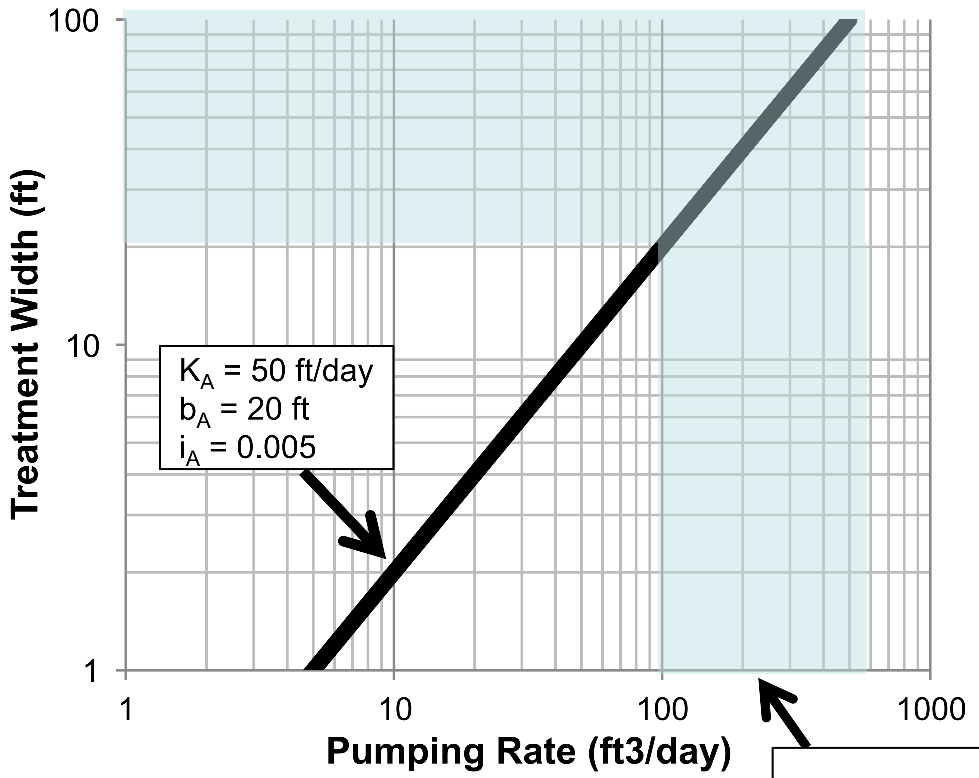
Flow through the well

Flow through the aquifer

Active Configuration

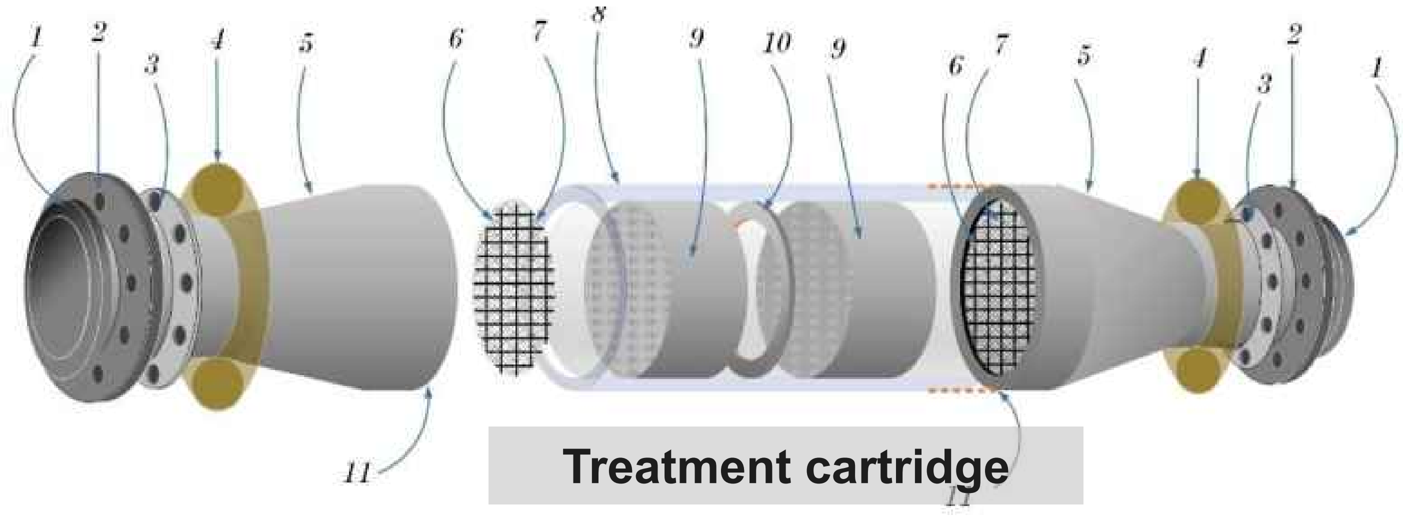
$$w_{treatment} = \frac{Q_{HRX}}{K_A b_A i_A}$$





200 ft^3/day ≈ 1 gpm

Treatment Media Cartridges



Potential Reactive Media and Contaminants

Target Groundwater Contaminant	Reactive Media
Chlorinated solvents (CVOCs), Arsenic, Cobalt, Chromium, Molybdenum, Selenium, Thallium, nitrate, perchlorate, energetics	Zero valent iron (ZVI), Bimetallics (e.g., ZVI + Pd, Pt, or Ni)
PFAS, CVOCs, hydrocarbons, halomethanes	Granulated Activated Carbon (GAC), Organosilicates (e.g., Osorb®)
CVOCs, 1,4-dioxane, hydrocarbons, polyaromatic hydrocarbons (PAHs), phenolic compounds (e.g., pentachlorophenol; PCP), energetics	Sustained Release Oxidants (e.g., RemOxSR+ISCO)
CVOCs, nitrate, perchlorate	Biodegradable particulate organic carbon (e.g., mulch)
Boron, brines, PFAS	Ion exchange resins
Cobalt, Low pH, acid rock drainage	Limestone, lime, magnesium oxide
Chromium, Molybdenum, high pH	Iron sulfide
Antimony, Selenium, Ammonium, radionuclides, PFAS	Zeolites
Radium	Barium sulfate (barite)
Lithium	Hydrotalcite
Boron, Arsenic, Thallium	Activated Alumina

Advantages

Treatment and Contaminants

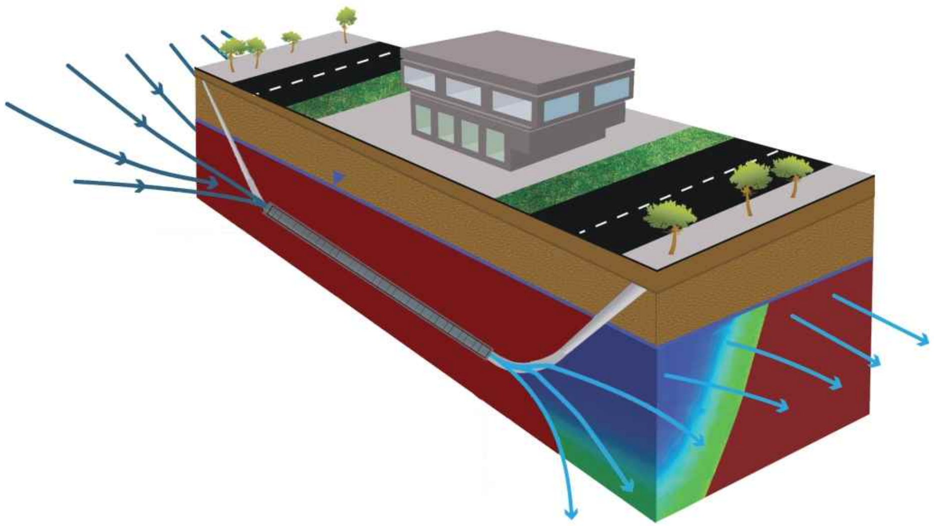
- Many solid-phase reactive media options
- Efficient use of reactive media (replaceable/serviceable)
- Treatment trains for multiple contaminants

Site Conditions

- Works for both low and high-permeability aquifers
- Can be applied in relatively deep settings
- Access under infrastructure
- Limited above-ground footprint

Operation

- Minimal O&M, energy use
- In situ; no above-ground water management
- Pumping can optimize residence time and treatment zone size



HRX Well Field Installation

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A Drill site 1

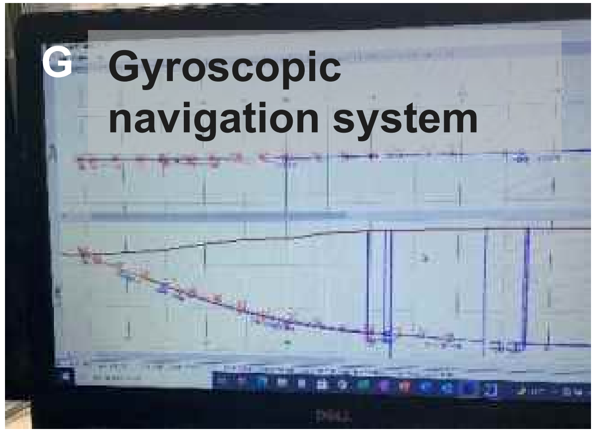
B Drill rig

C Drill rig

D Duckbill bit

E Well pullback

F Walkover tracking



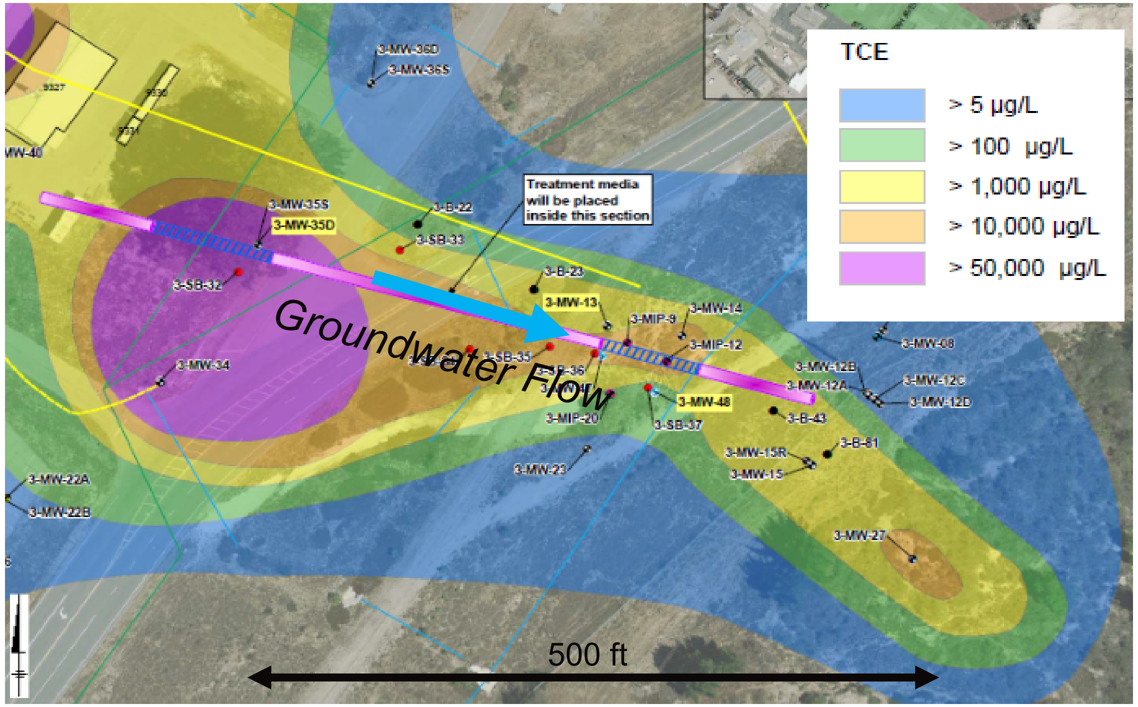
G Gyroscopic navigation system

H Steel well screen shield

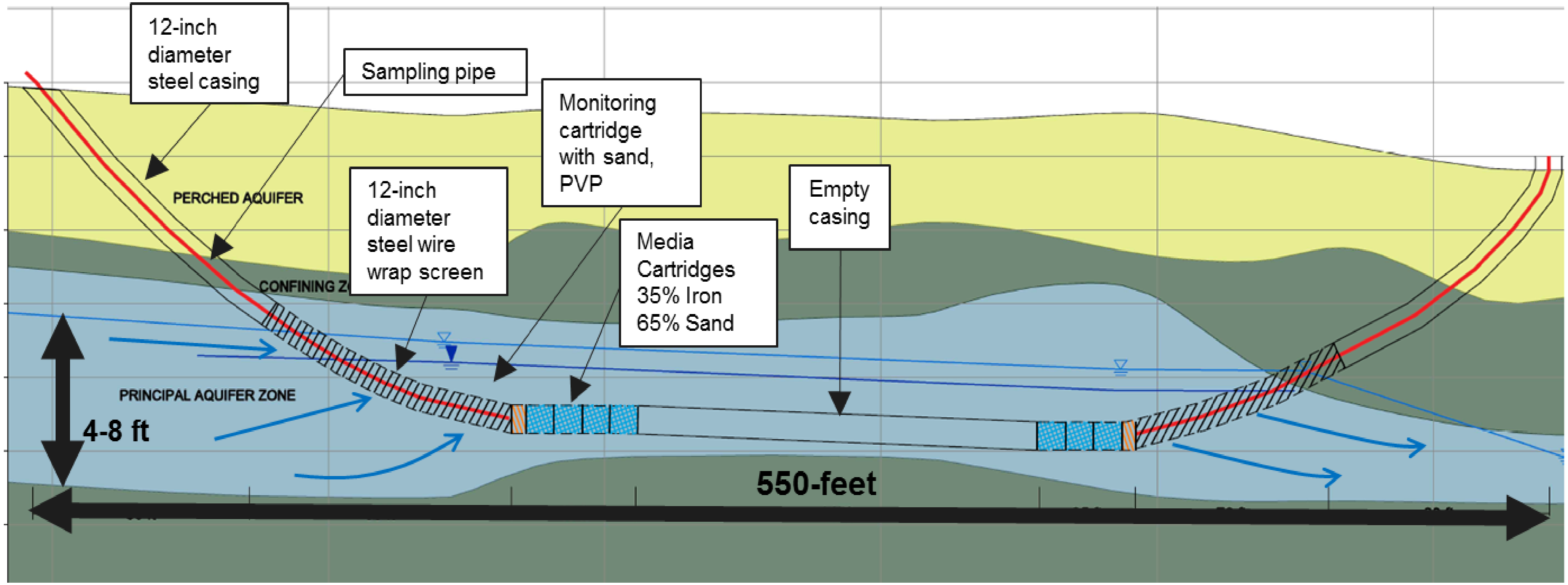
I Fusing HDPE screen

Site 1 (CVOCs), Passive Configuration

- Vandenberg Space Force Base (VSFB)
- Aquifer thickness ~10 ft
- Depth 22 ft
- Hydraulic conductivity: 0.2 ft/day
- Groundwater velocity: <0.1 ft/day
- HRX Well installation: Aug 2018

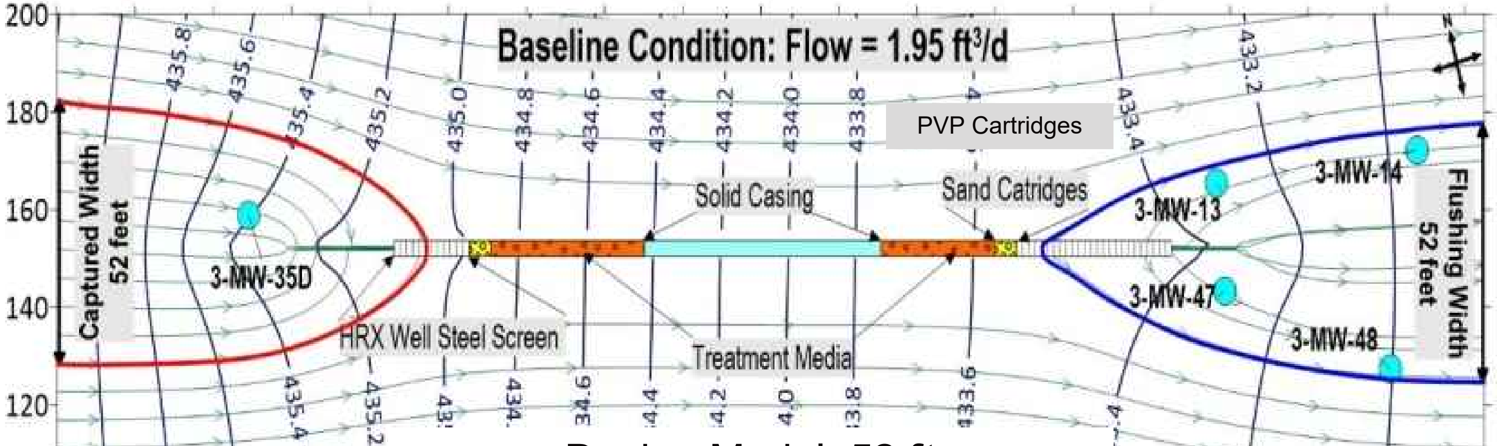


HRX Well Design

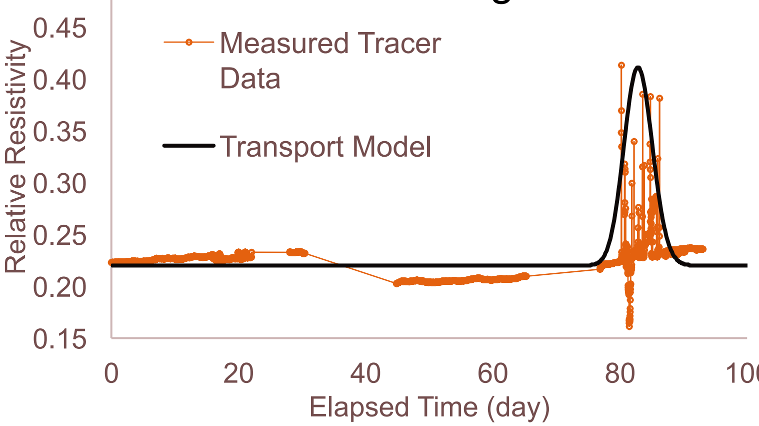


- Length: 550 ft; Depth: 20 ft; Diameter: 12 in;
- Target treatment width: 40-50 ft
- Inlet and outlet Point Velocity Probes (PVPs) to measure in-well flow
- Target residence time: 6-20 days in ZVI (35%, 70 ft), ~100 days total
- **Reactive media usage: 0.7 m³ ZVI (1,390 lbs ZVI)**

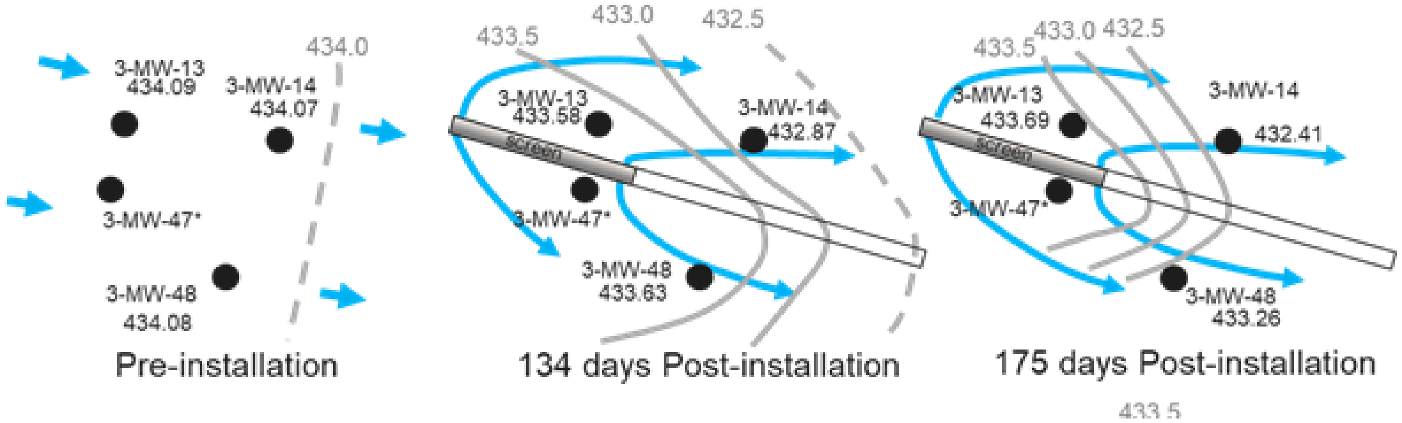
Comparison of Model-Calculated Hydraulics and Treatment Zone to Performance Data



Design Model: **52 ft**

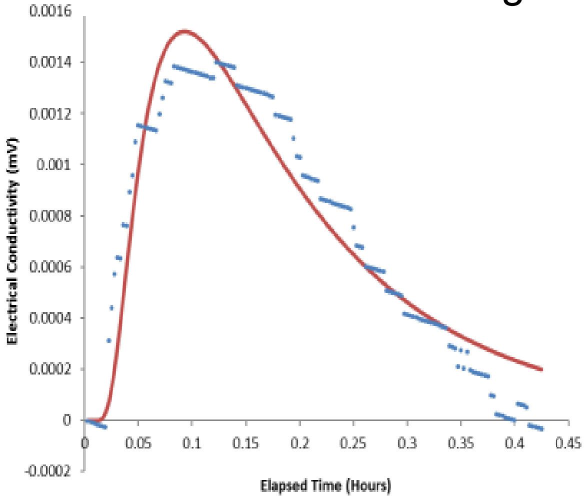


Tracer Testing: **49 ft**



Groundwater Elevations: **50 ft**

PVP Tracer Testing: **69 ft**



Performance

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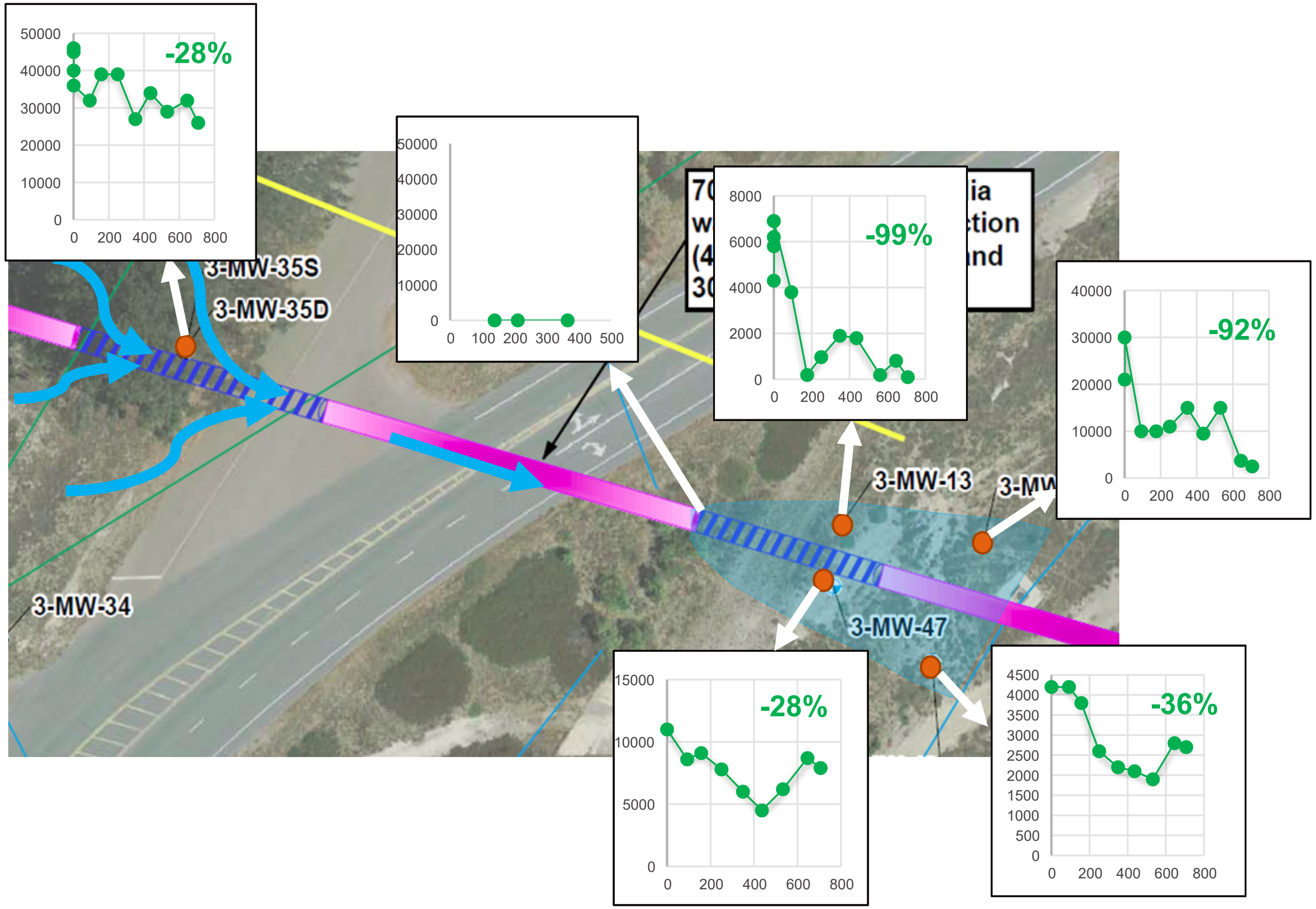
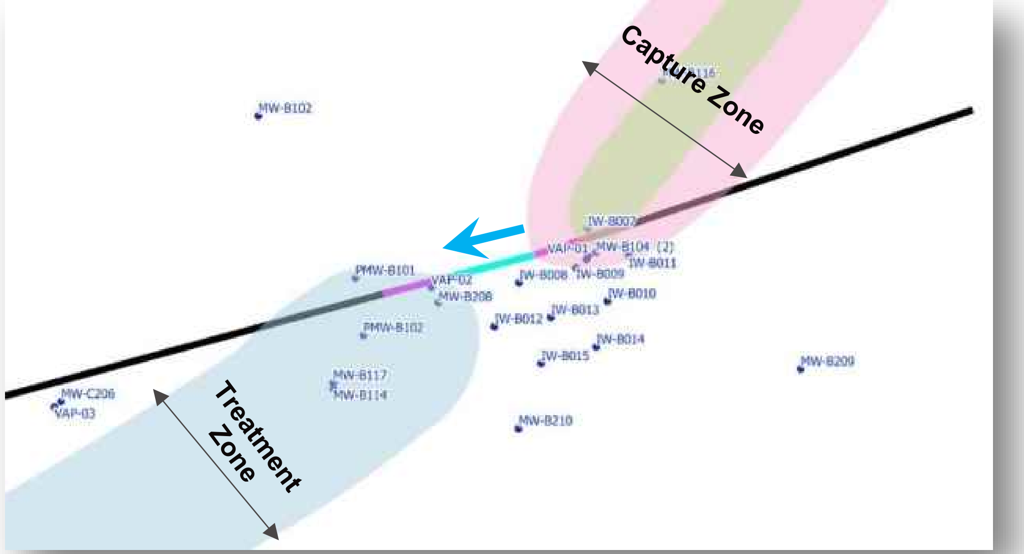
Green series represent TCE (ug/L)
Y-axes are ***ug/L****, X-axes are* ***Elapsed Days***



- **Treatment zone width about 50 ft under passive configuration**
- **99.99% TCE concentration reduction at HRX Well Outlet**
- **29-99% TCE concentration reduction at wells**
- **Mass discharge reduction 0.7 kg/yr**

Site 2 (CVOCs), Active Configuration

- Aquifer thickness ~20 ft
- Depth 100 ft
- Glacial moraine, sandy glacial till, granitic cobbles and boulders
- Average Hydraulic conductivity: 0.55 ft/day



- Active Configuration : 120 ft capture width, residence time 2.5 hrs,

Column testing to support adsorbent media selection

Selected media:

- 35 ft Hoganas CleanER-300/PRB-300 ZVI
- 8 ft Filtrasorb 400 GAC for polish

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- Aquifer thickness ~20 ft
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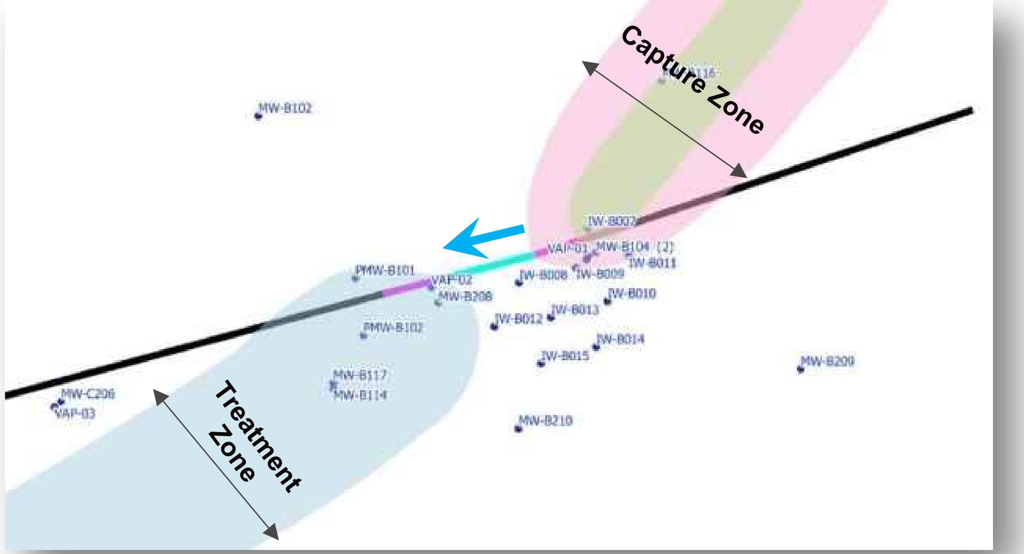

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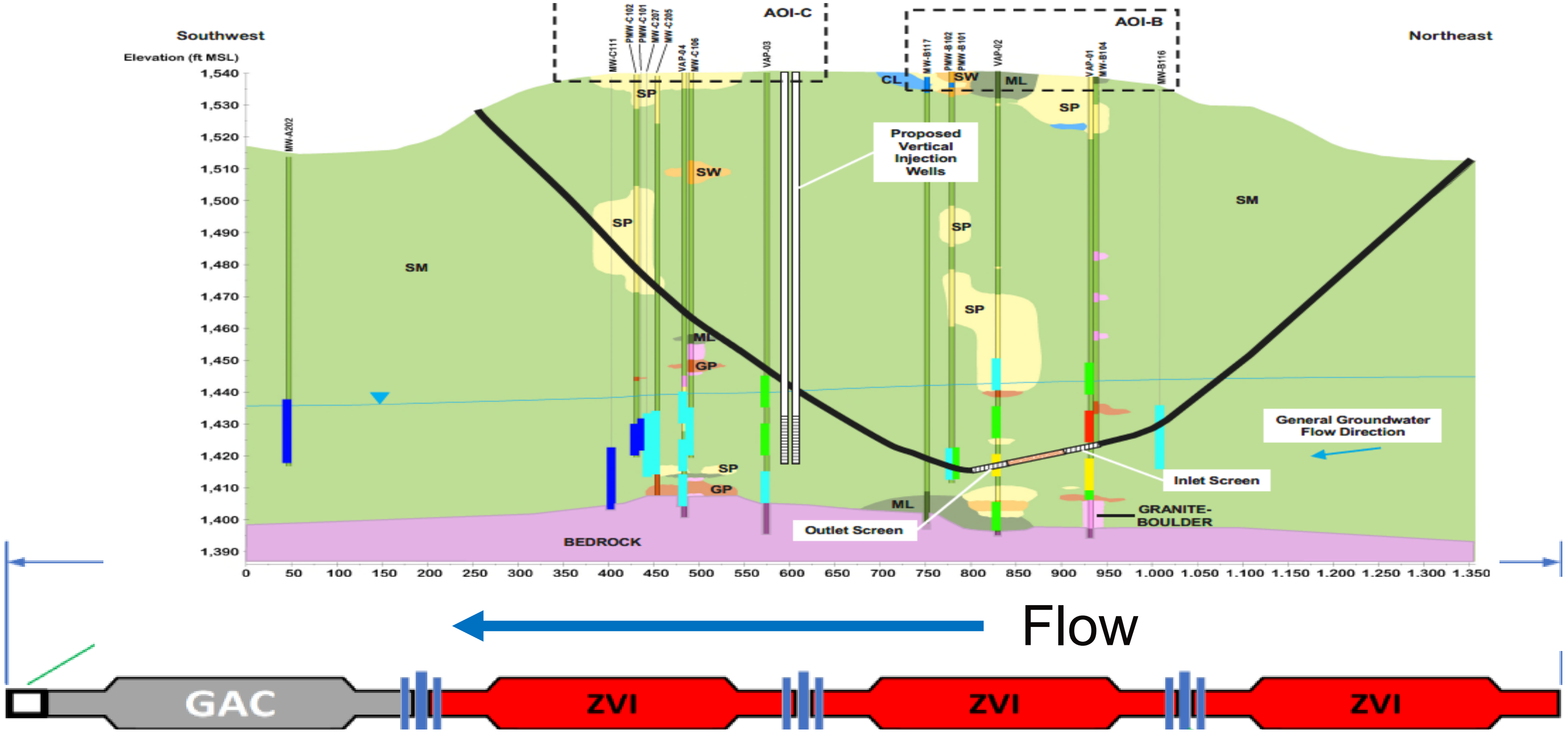
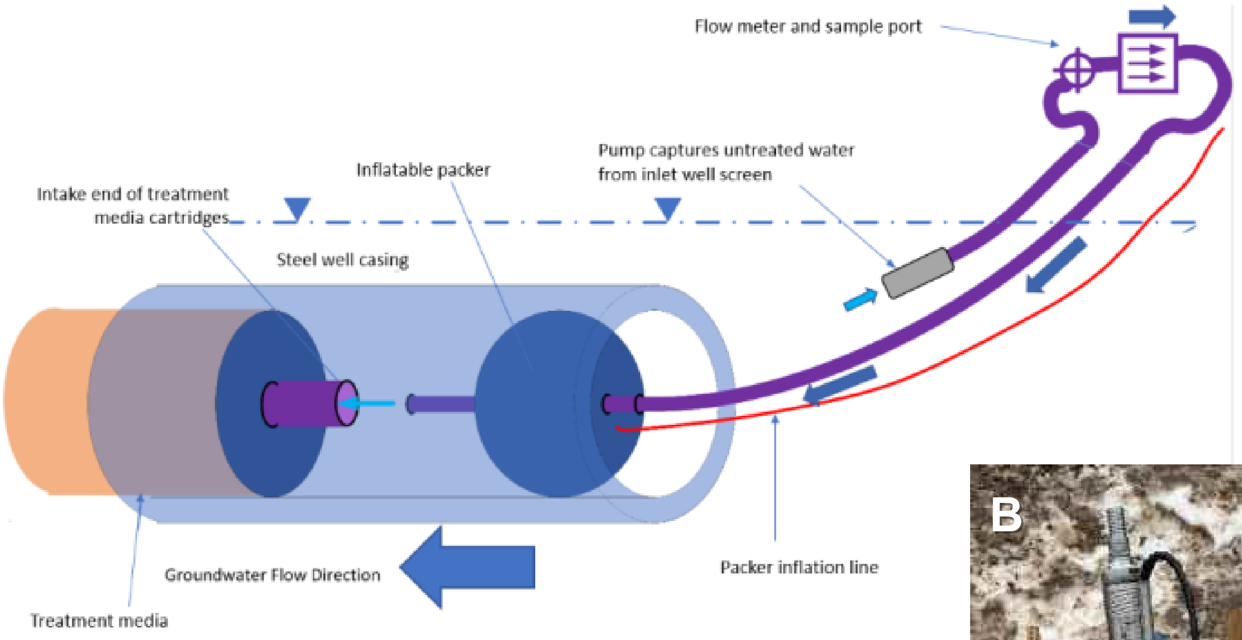
HRX Well Design

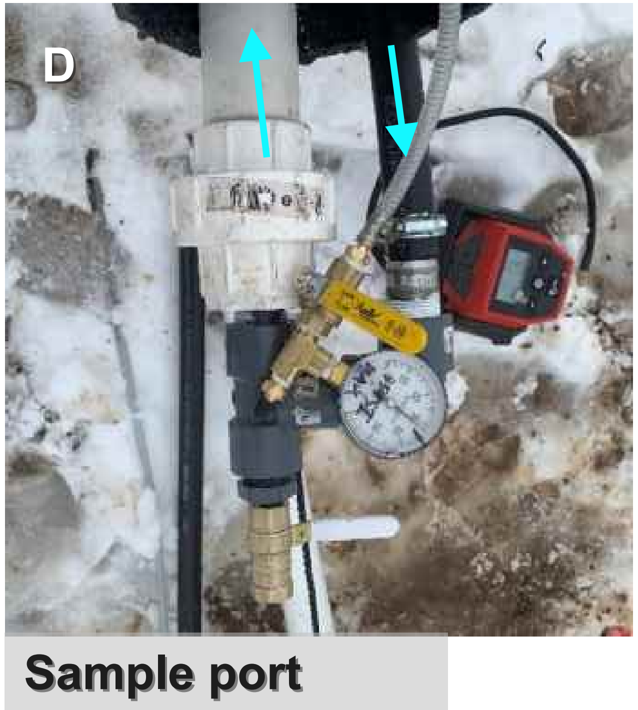


Pump System


Flow meter and sample port
Pump captures untreated water from inlet well screen
Inflatable packer
Intake end of treatment media cartridges
Steel well casing
Groundwater Flow Direction
Packer inflation line
Treatment media

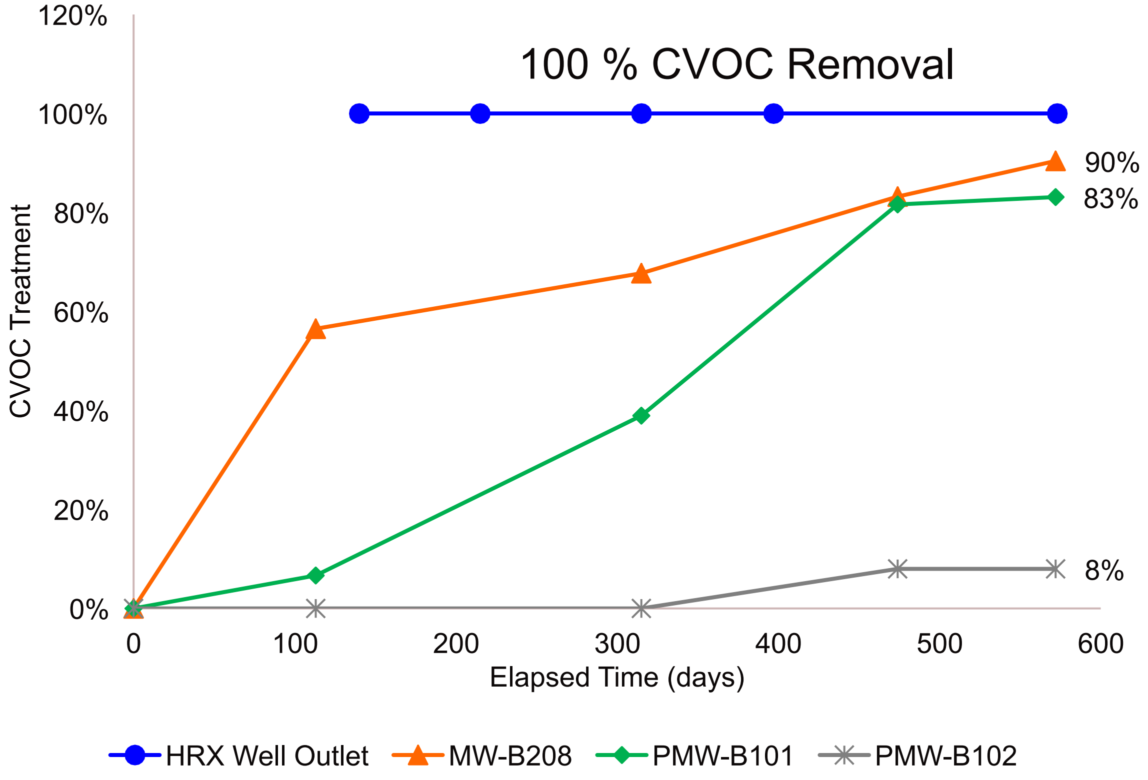

C
Pump & transducer bundled to packer pipe

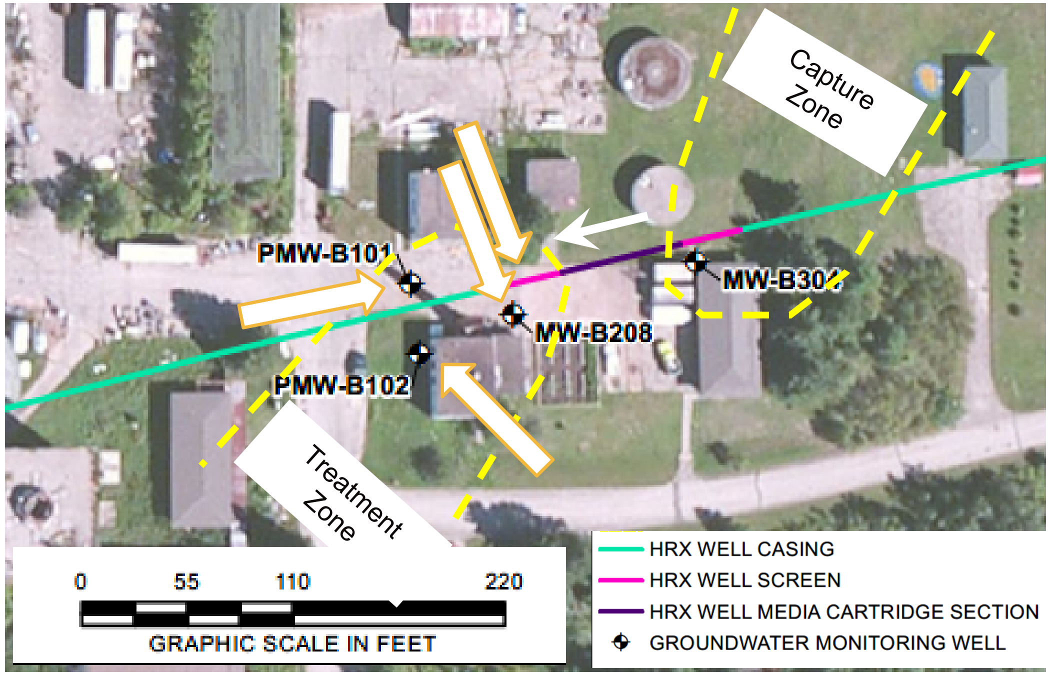

B
Pump


D
Sample port


A
Packer

Performance

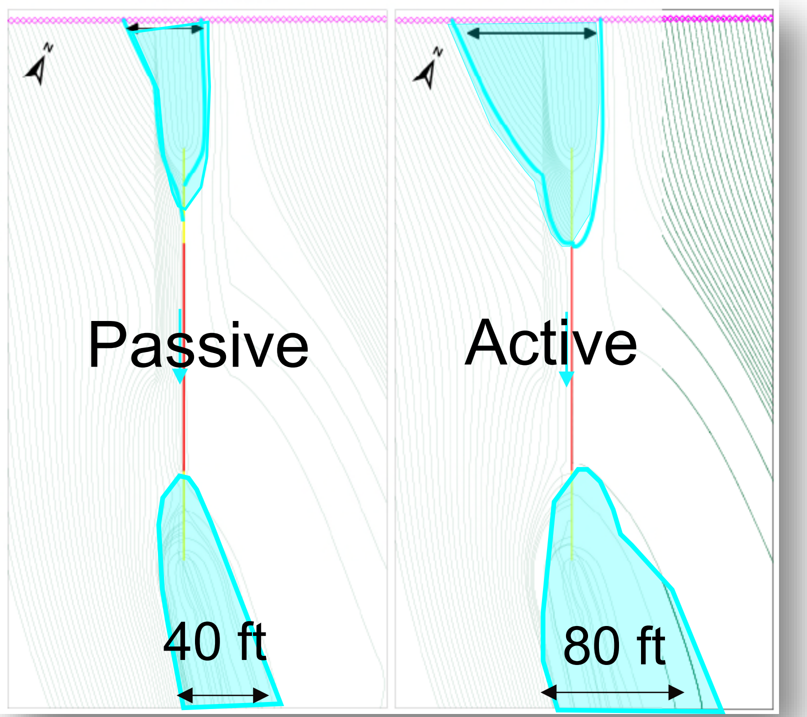




- ~1.5 years of operation
- 100% treatment at HRX Well outlet
- 9-90% treatment at downgradient wells

Site 3 (PFAS), Passive and Active Configuration

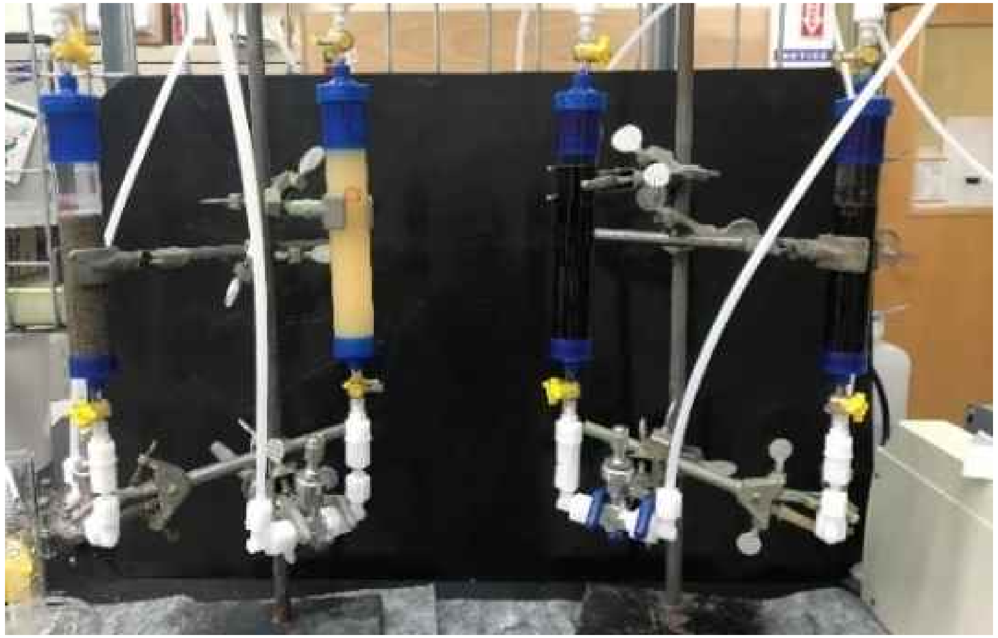
- Aquifer thickness 5-10 ft
- Target depth: 35 ft
- Sandy alluvium within paleochannel
- Hydraulic conductivity: 3 ft/day



Design model results

- Passive: 40 ft width, residence time 8 hrs
- Active: 80 ft width, residence time 4 hrs

Both being field tested

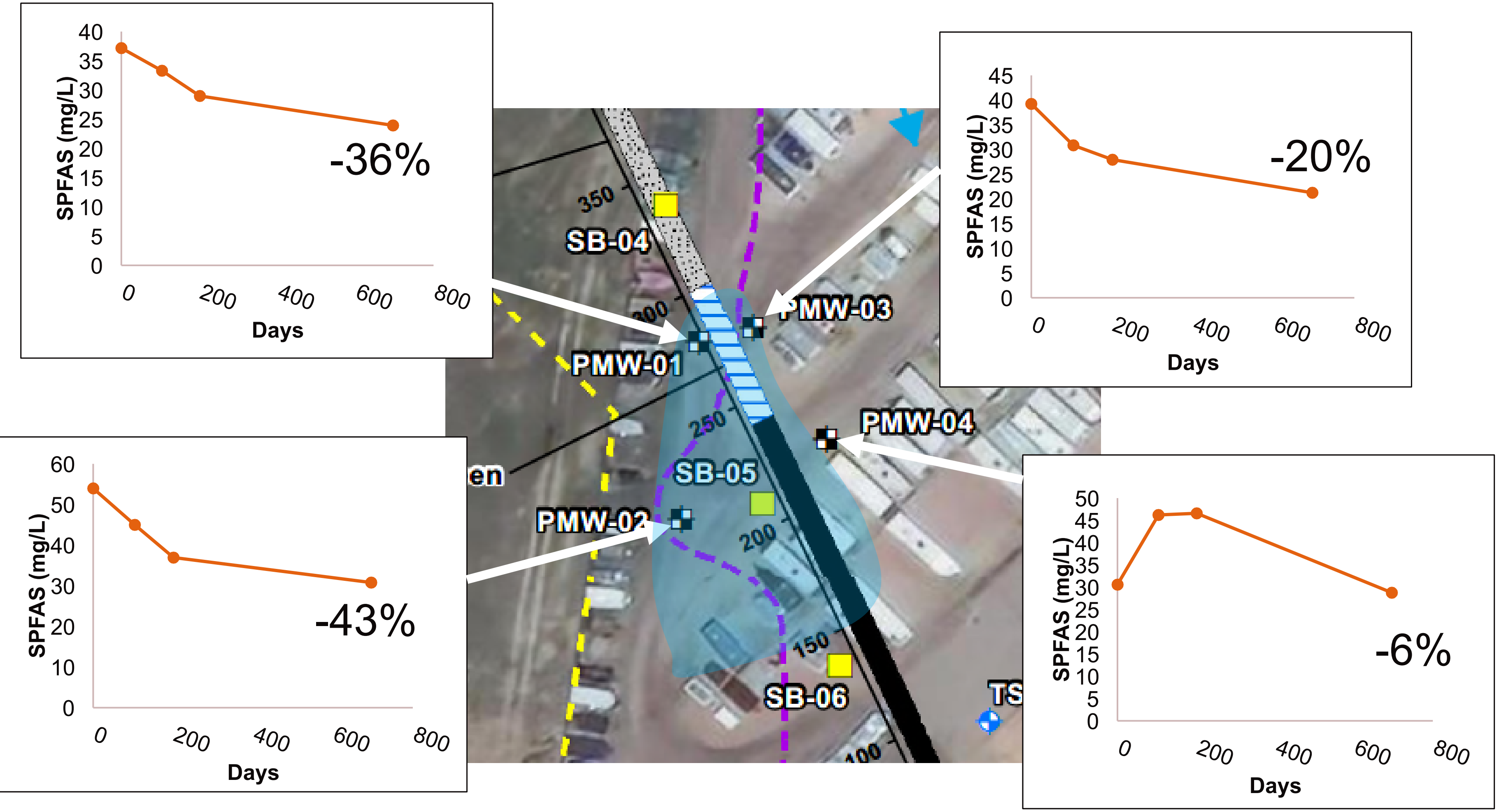


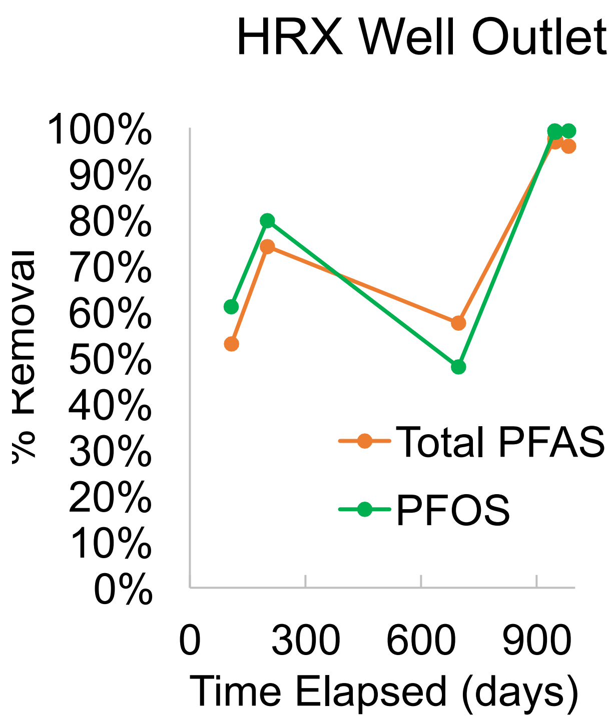
Column testing to support adsorbent media selection

Tested media: Fluorosorb 400, Osorb 4-mesh, Filtrasorb 400 GAC, Purolite IX

Selected: Filtrasorb 400, Filtrasorb 800 pretreatment

Performance

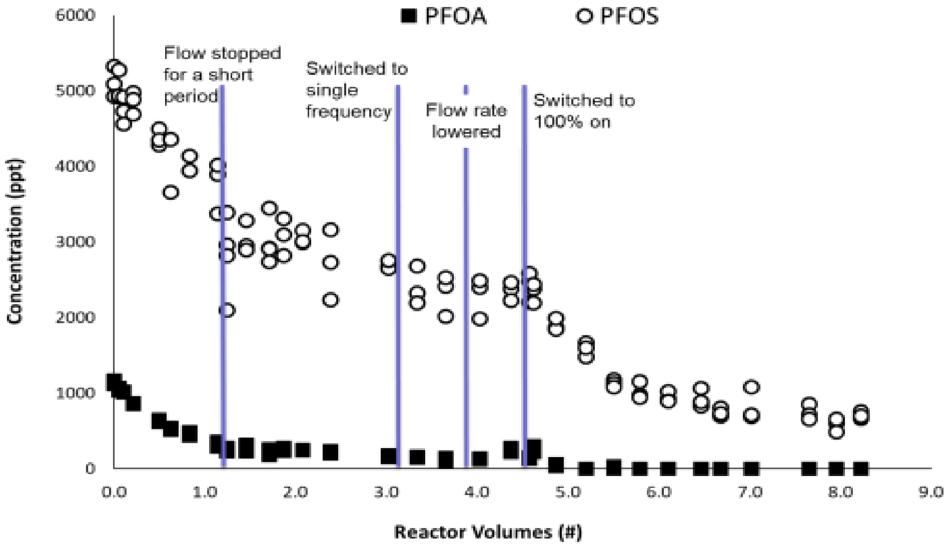


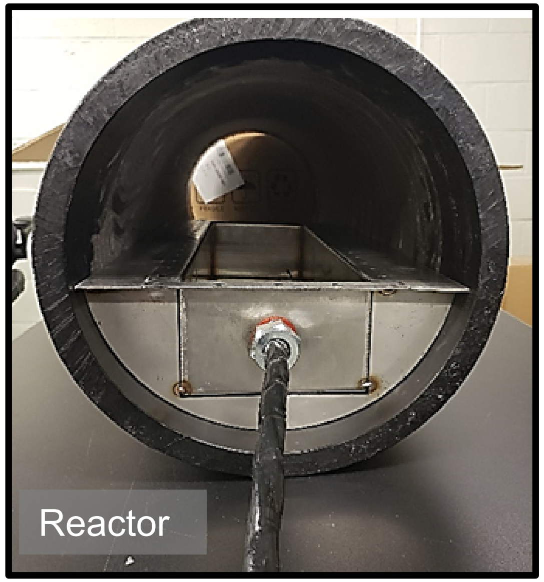


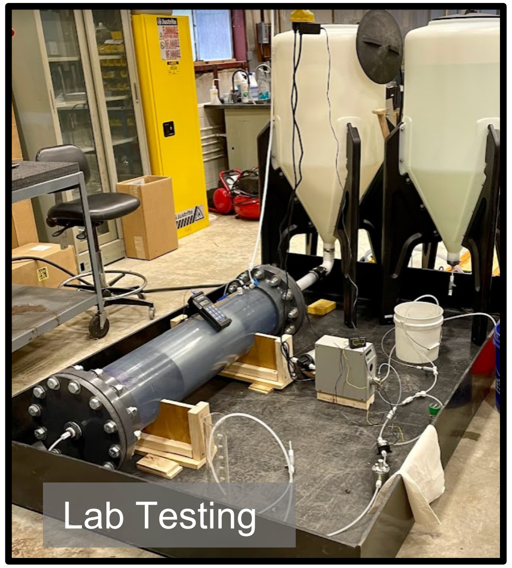
- Treatment zone width 20-40 ft under passive configuration
- 50-99% PFAS treatment for 3 yrs at HRX Well Outlet
- 20-43% SPFAS concentration reduction at wells

In Situ Sonolytic Reactor for Destructive Treatment

- Sonolytic reactor developed for destructive PFAS treatment within HRX Well
- Preliminary treatment efficiencies of 99% PFOA and 86% PFOS
- Installed in Fall 2023 (ESTCP project ER21-5045)
- Multiple reactors could be installed in series, could be paired with GAC




Reactor

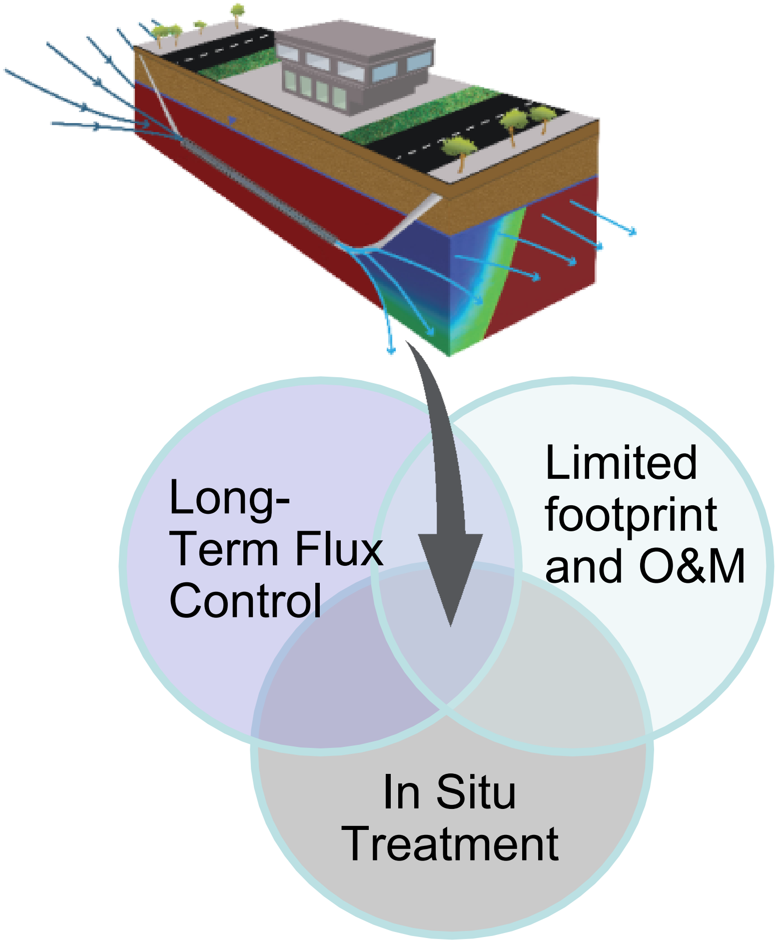

Lab Testing


Reactor installation


Control panel

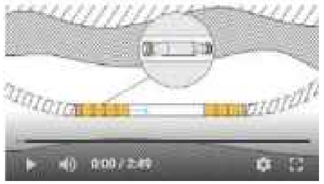
Design and Implementation

1. Complete simple **screening analysis**
2. Perform **treatability study** to optimize treatment media
3. Collect **focused field data** along HRX Well alignment
4. Construct local numerical **design model** to optimize design
5. Install HRX Well and initiate **performance monitoring**



Resources

Explainer Video: https://youtu.be/1I8CwiYIjS4



Divine, et al., 2020. Field Demonstration of the Horizontal Reactive Media Treatment Well (HRX Well®) for Passive In-Situ Remediation. GWMR, 40(3): 42-554, https://doi.org/10.1111/gwmr.12407.

Nzeribe, et al., 2020. Hydraulic Performance of the Horizontal Reactive Media Treatment Well: Pilot and Numerical Study. GWMR, 40(3): 30-41. https://doi.org/10.1111/gwmr.12406

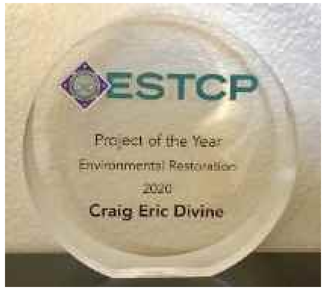
Divine et al., 2018. The Horizontal Reactive Media Treatment Well (HRX Well®) for Passive In-Situ Remediation. *GWMR,* DOI: 10.1111/gwmr.12252

Divine et al., 2018. The Horizontal Reactive Media Treatment Well (HRX Well®) for Passive In-Situ Remediation. *GWMR,* DOI: 10.1111/gwmr.12252

Divine et al., 2018. The Horizontal reactive media treatment well (HRX Well®) for passive in-situ remediation: Design, implementation, and sustainability considerations. *Remediation*, DOI: 10.1002/rem.21571

ER-2016 Final Report and Design Tool anticipated 2Q2020. https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-201631/ER-201631

2019 National Groundwater Association Technology Award



2020 ESTCP Project of the Year Award

2021 Environment Business Journal Project Merit Award

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