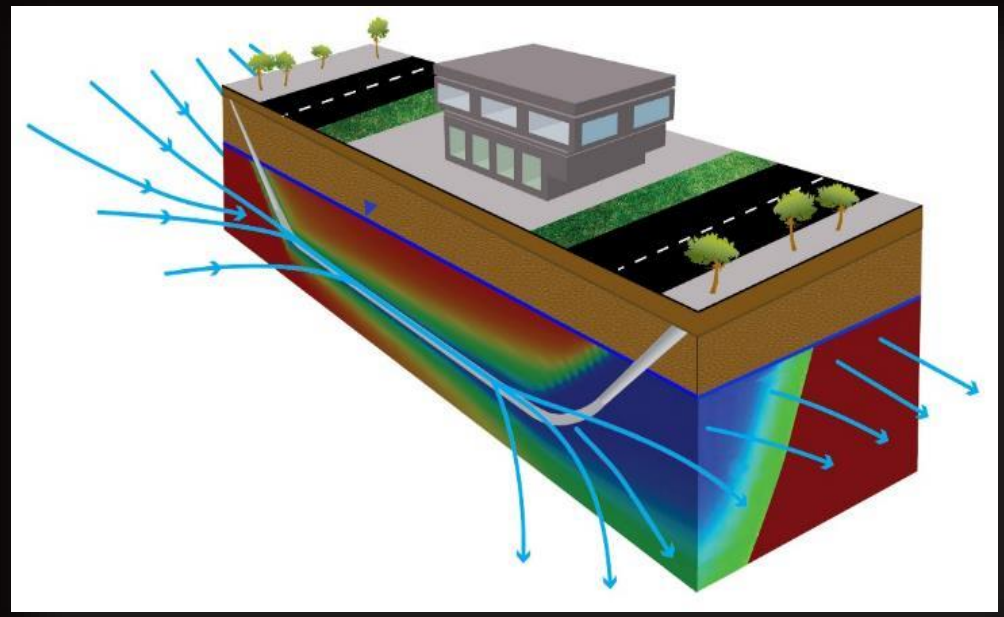
Applications of Horizontal Reactive Treatment Well (HRX Well) for Long Term Mass Discharge Control of Contaminated Sites

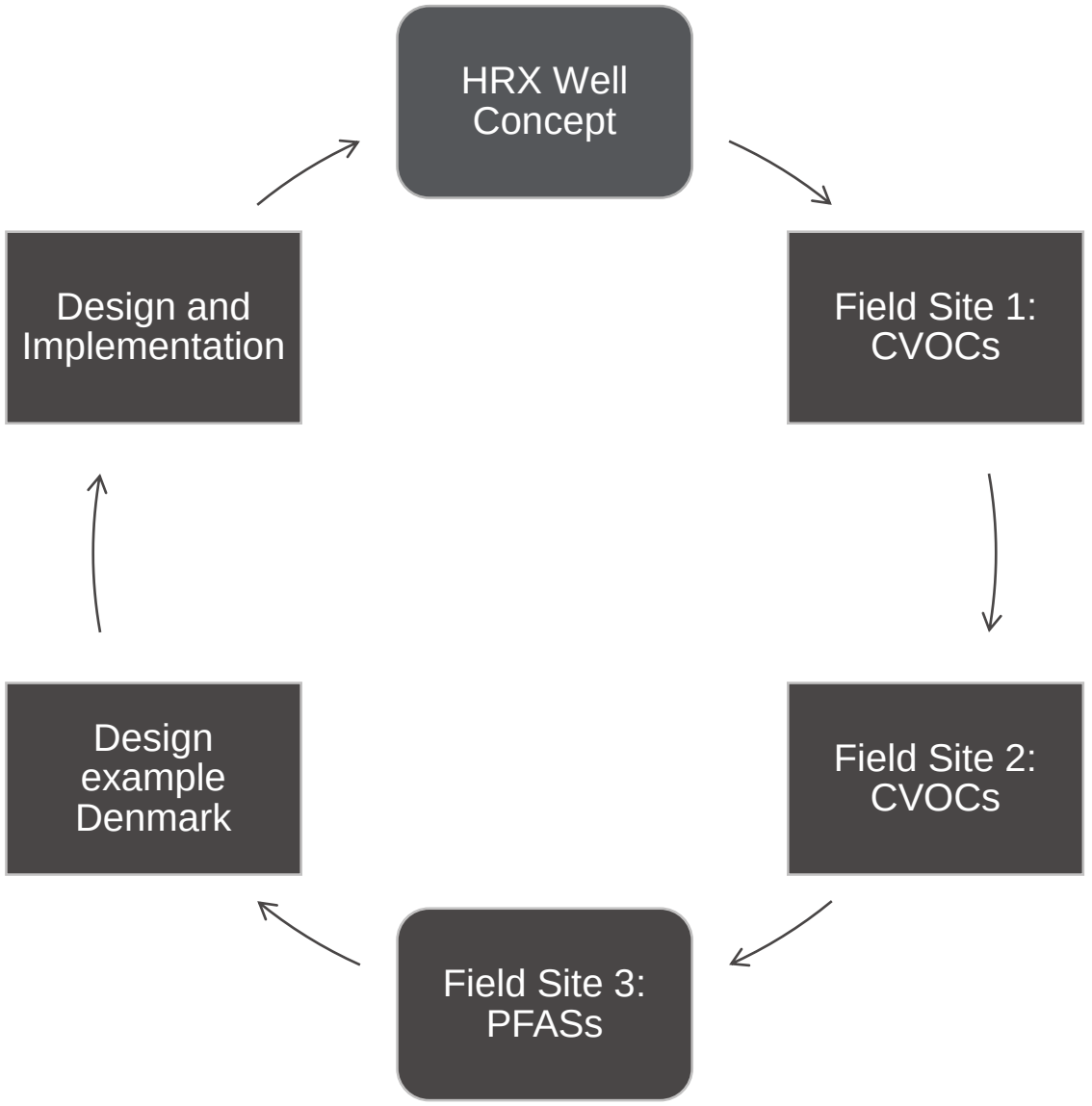
Allan Horneman, Portland, Maine
Craig Divine, Lenexa, Kansas



ATV Fall Meeting

November 2022

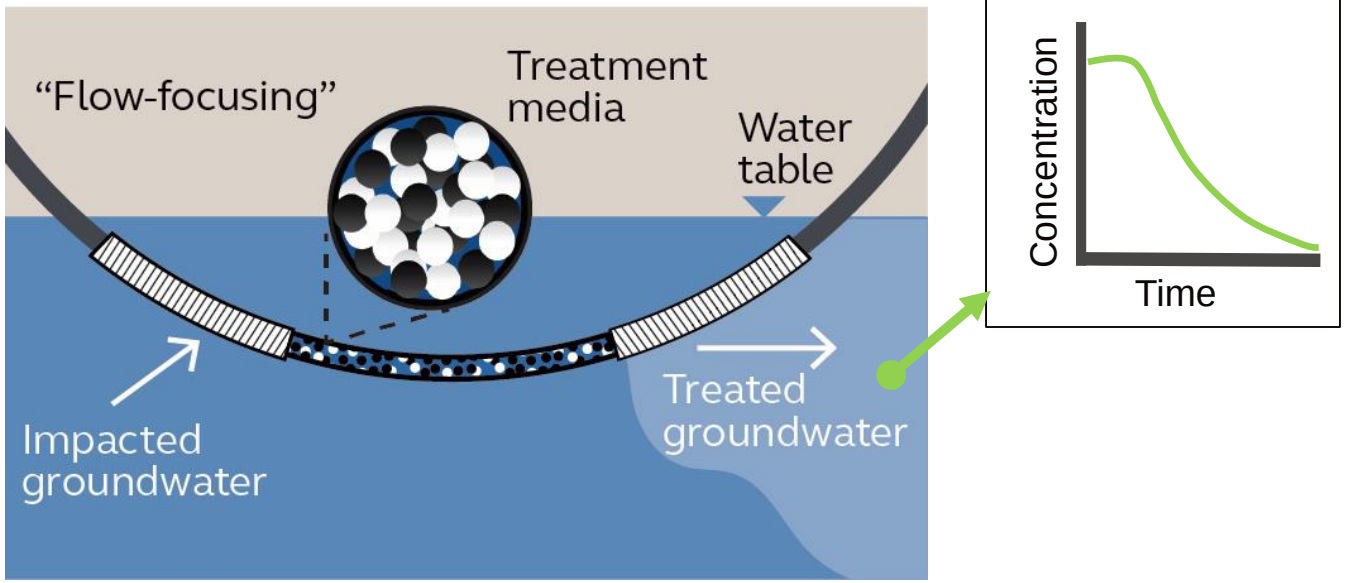
Outline


HRX Well Concept
Field Site 1: CVOCs
Field Site 2: CVOCs
Field Site 3: PFASs
Design example Denmark
Design and Implementation

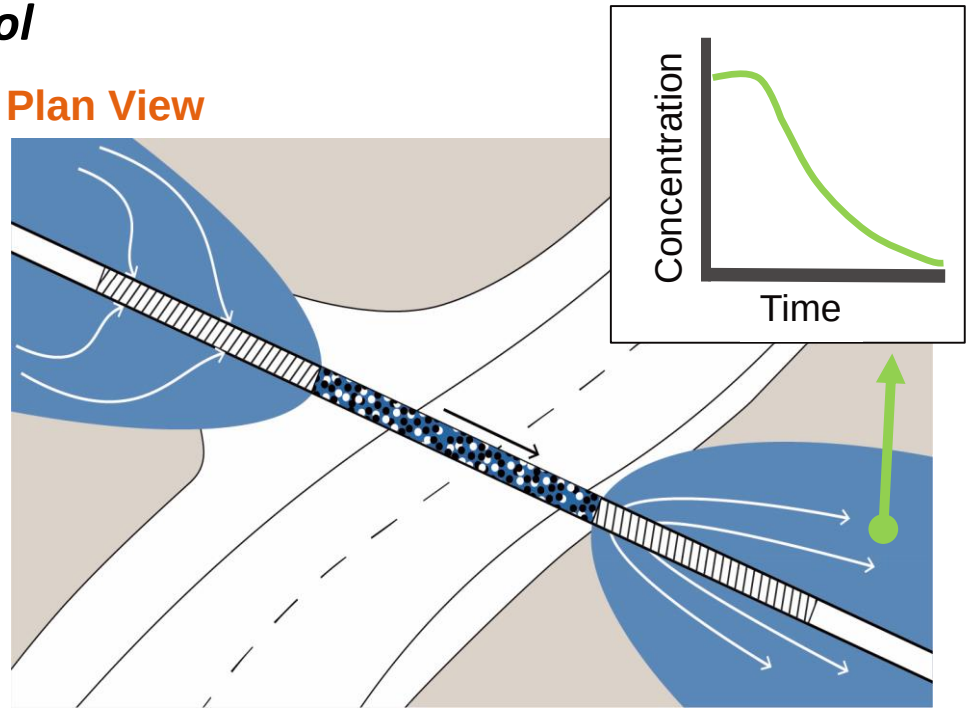
HRX Well® Description – Passive Configuration

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



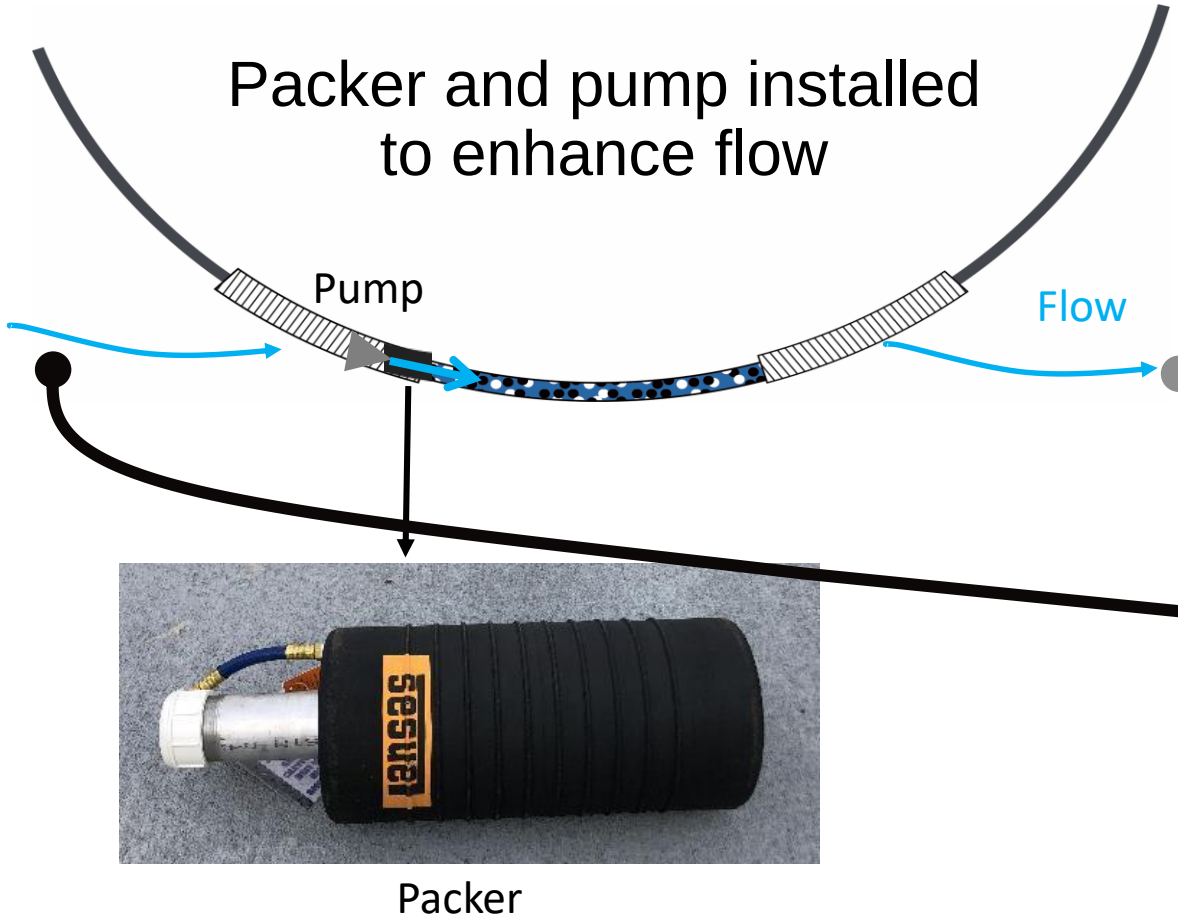
Plan View



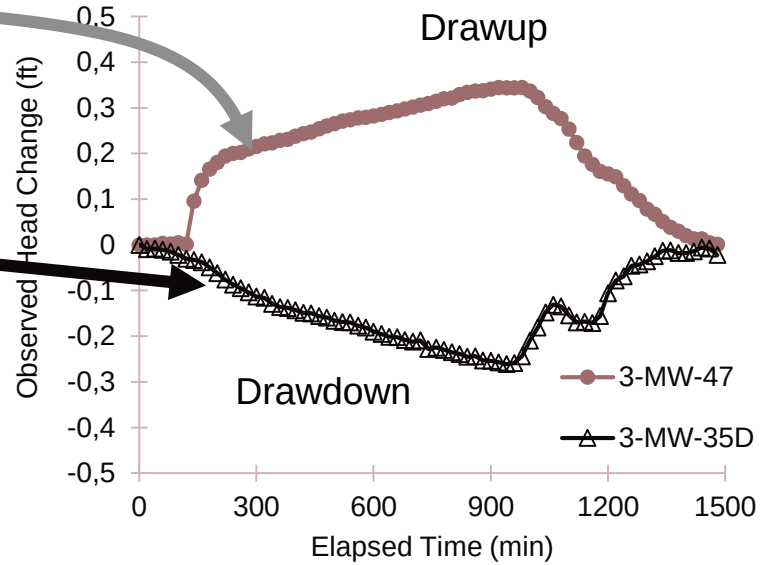
- In situ treatment
- Many solid-phase reactive media options
- Efficient use of reactive media
- Treatment trains for multiple contaminants
- Not limited to high-permeability aquifers

- Can be applied in relatively deep settings
- Limited above-ground footprint
- Minimal O&M
- No ongoing energy requirements
- Passive configuration for lower-K settings, pumping can enhance treatment zone size

Active Configuration: Pumping-Enhanced Capture and Treatment



Appropriate for more permeable aquifer settings



Capture and Treatment Zone Size

ARCADIS

Passive Configuration

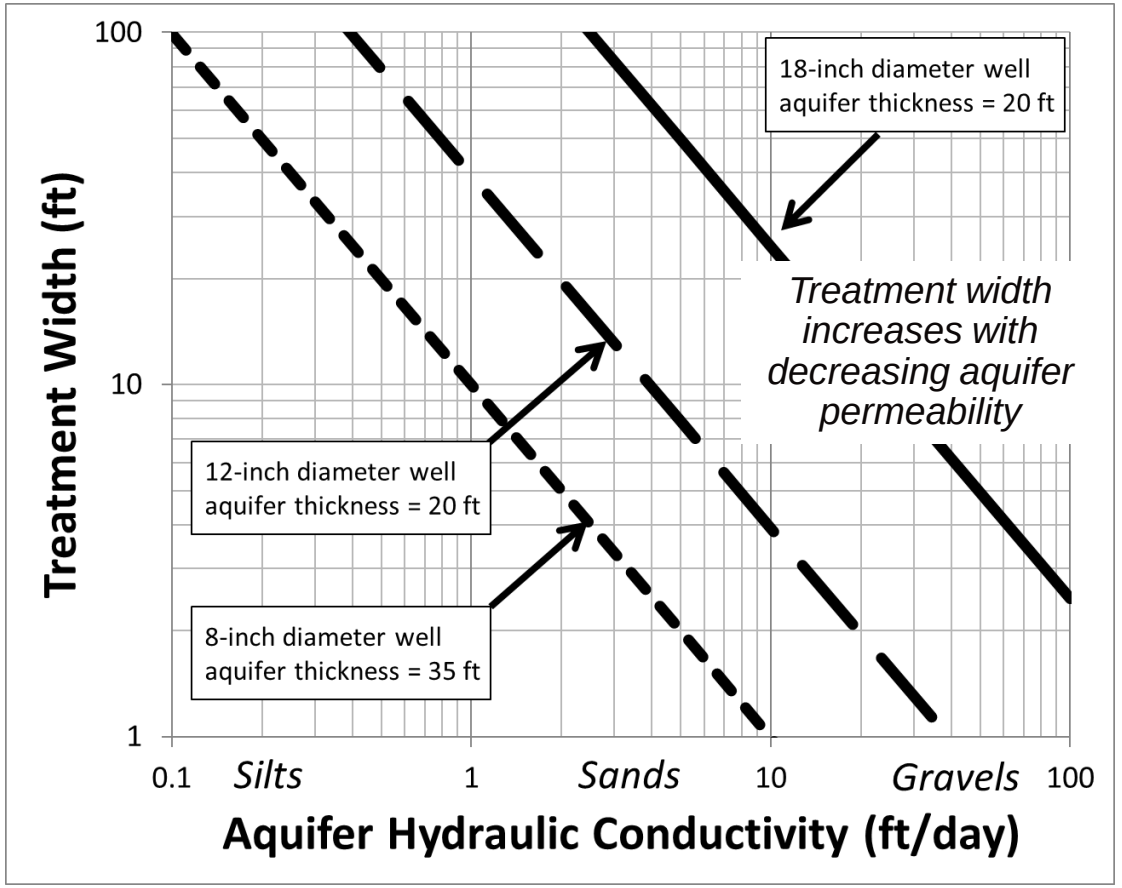
$$w_{treatment} = \frac{K_{HRX} A_{HRX} i_{HRX}}{K_A \; b_A \; i_A}$$

Active Configuration

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

$w_{treatment}$	HRX Well treatment zone width
K_{HRX}	Hydraulic conductivity of HRX Well
A_{HRX}	x-sectional area of HRX Well
i_{HRX}	Hydraulic gradient in HRX Well
K_A	Hydraulic conductivity of aquifer
b_A	Aquifer thickness
i_A	Aquifer hydraulic gradient
Q_{HRX}	Pumping rate in active configuration

Treatment Zone Width: Passive Configuration



K_{HRX} = 1,000 ft/d

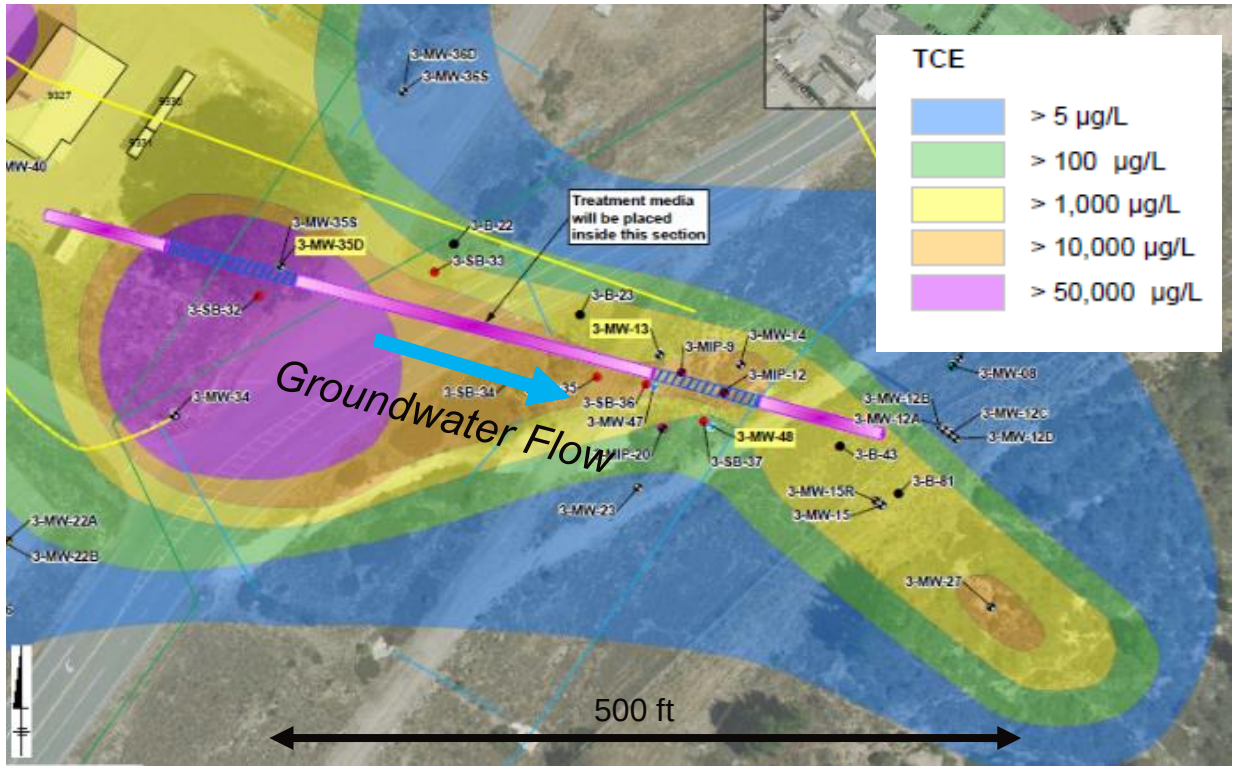
For passive configurations, treatment widths of tens of feet are feasible (*even greater with active pumping*)

Potential Reactive Media and Contaminants

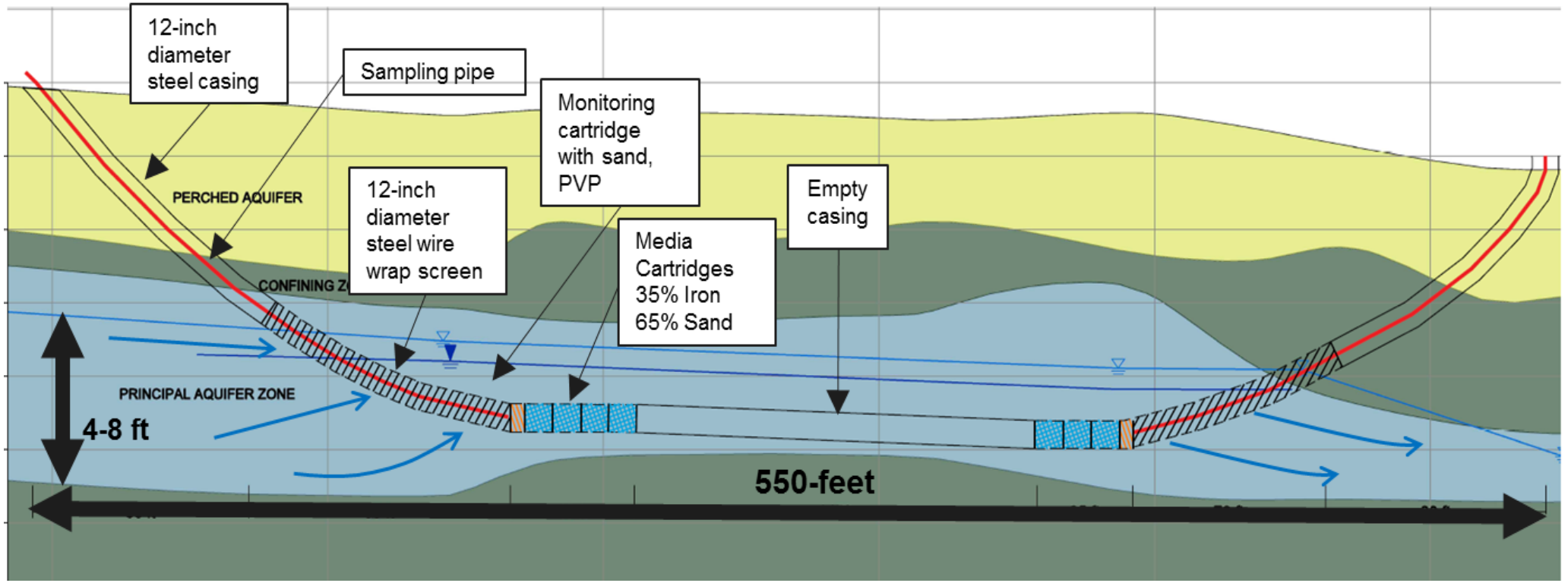
Target Groundwater Contaminant	Reactive Media
Chromium, arsenic, other metals, chlorinated solvents (CVOCs), nitrate, perchlorate, energetics,	Zero valent iron (ZVI) Bimetallics (e.g., ZVI + Pd, Pt, or Ni)
Low pH, acid rock drainage	Limestone, lime, magnesium oxide
Cr, high pH	Iron sulfide
Ammonium, radionuclides, PFAS	Zeolites
Radium	Barium sulfate (barite)
CVOCs, PFAS, 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)
Brines, PFAS	Ion exchange resins

Site 1 (CVOCs)

- Vandenberg Space Force Base
  Aquifer thickness 7-10 ft
- Depth ~22 ft
- Silty sand
- Hydraulic conductivity: 0.35 ft/day

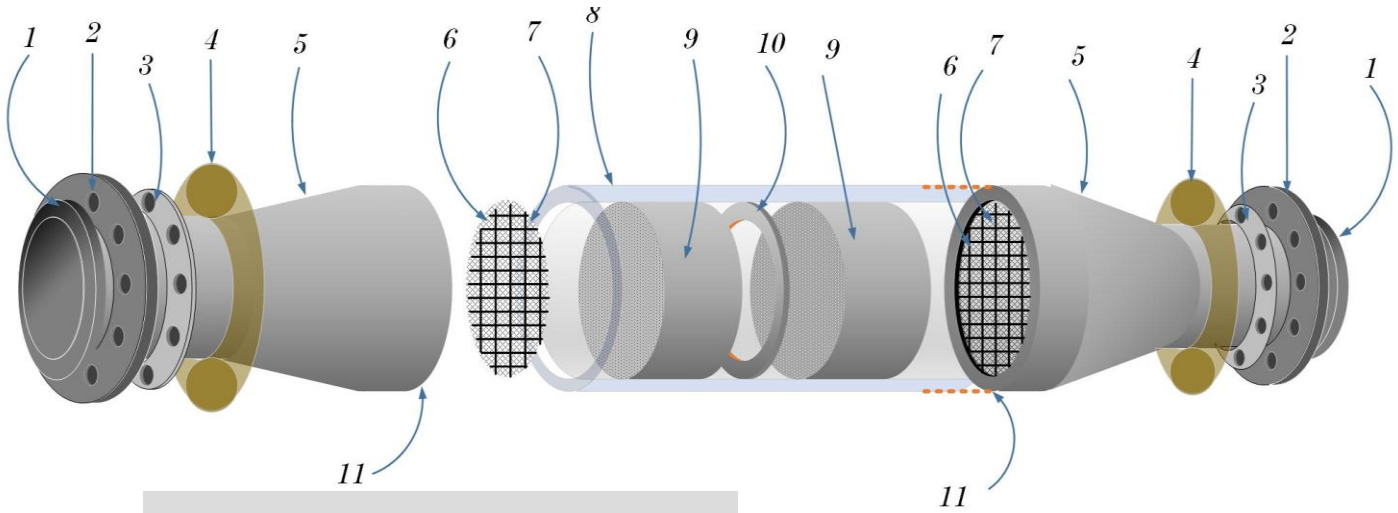


Site 1: Field HRX Well Design



- 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 m^3 ZVI (1,390 lbs ZVI)**

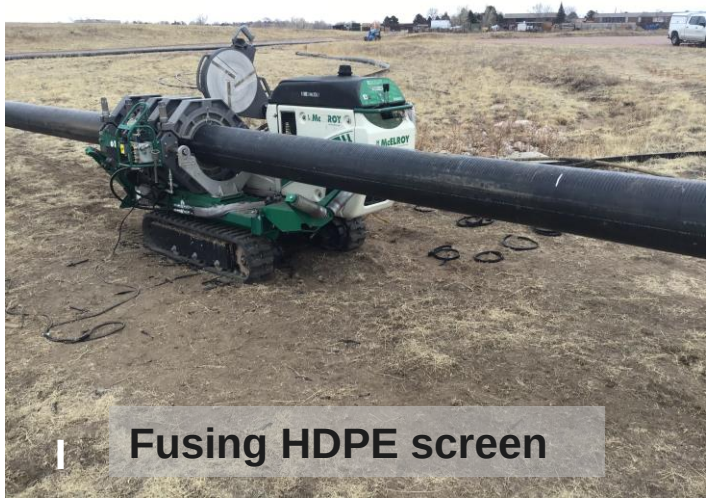
Treatment Media Cartridges*

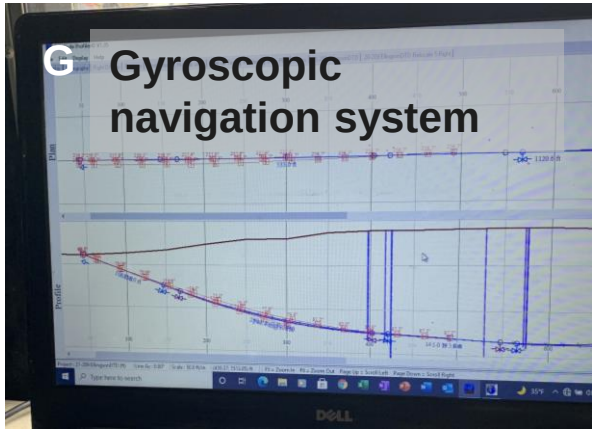


Treatment cartridge

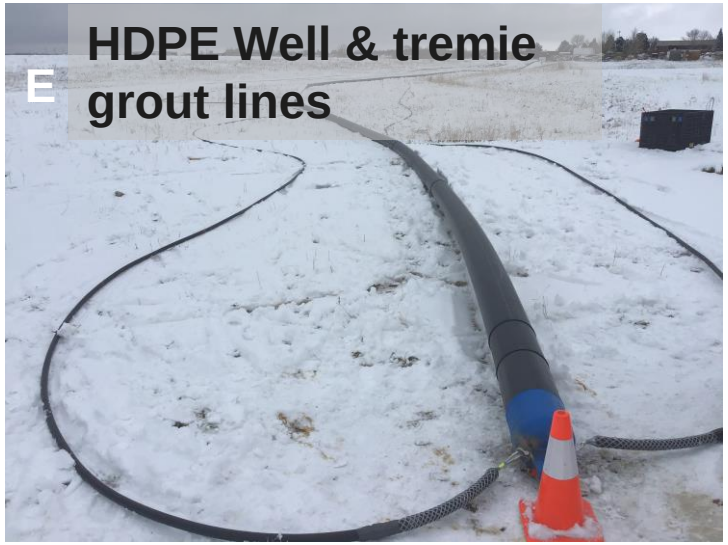
*Patent Pending

HRX Field Installations

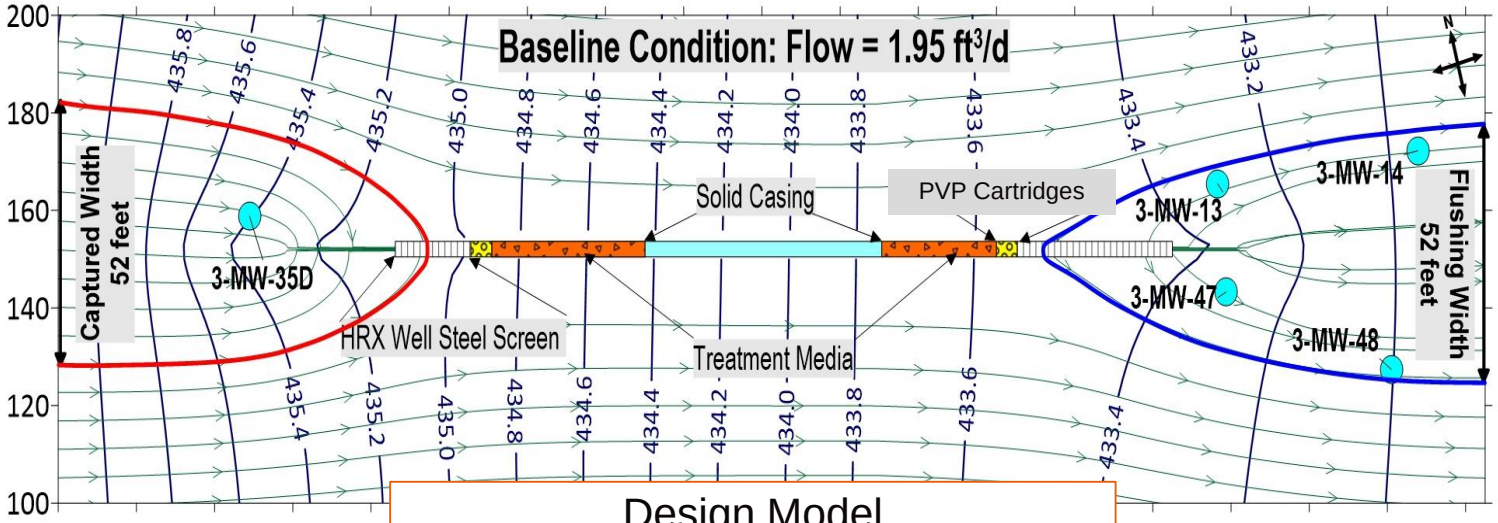




HRX Field Installation (continued)

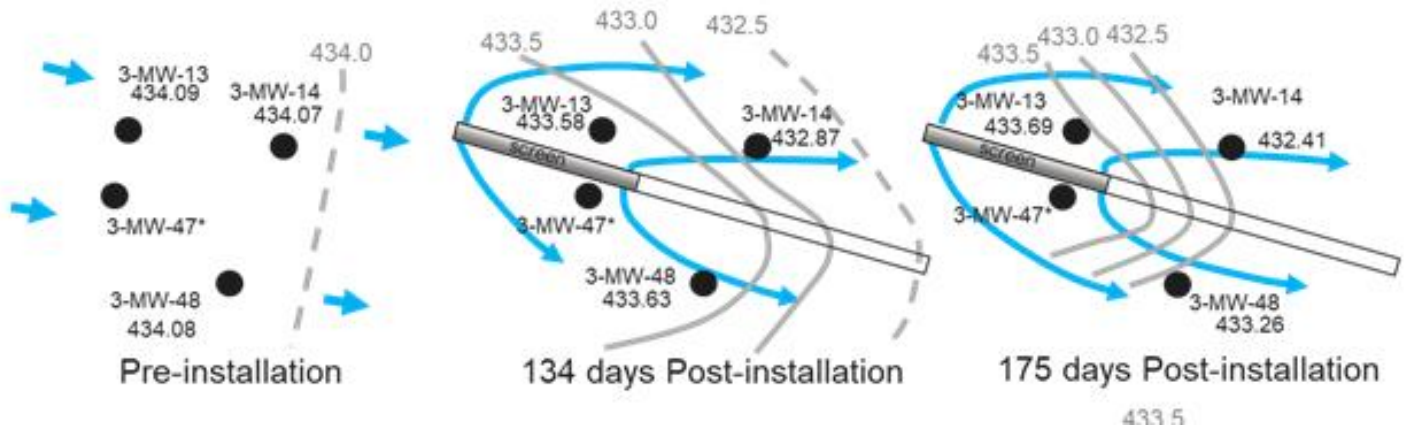


Comparison of Model-Calculated Hydraulics and Treatment Zone to Performance Data



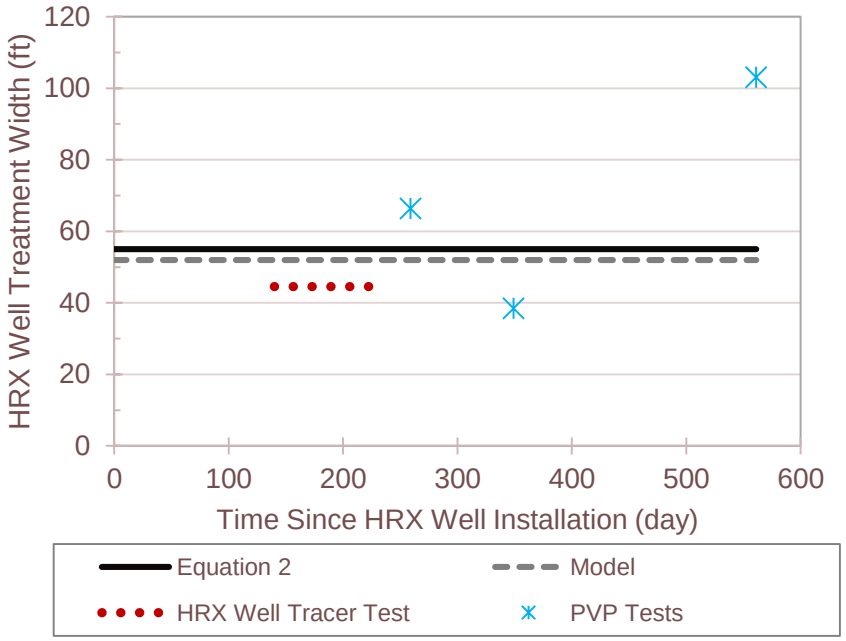
Design Model

Treatment width: 52 ft

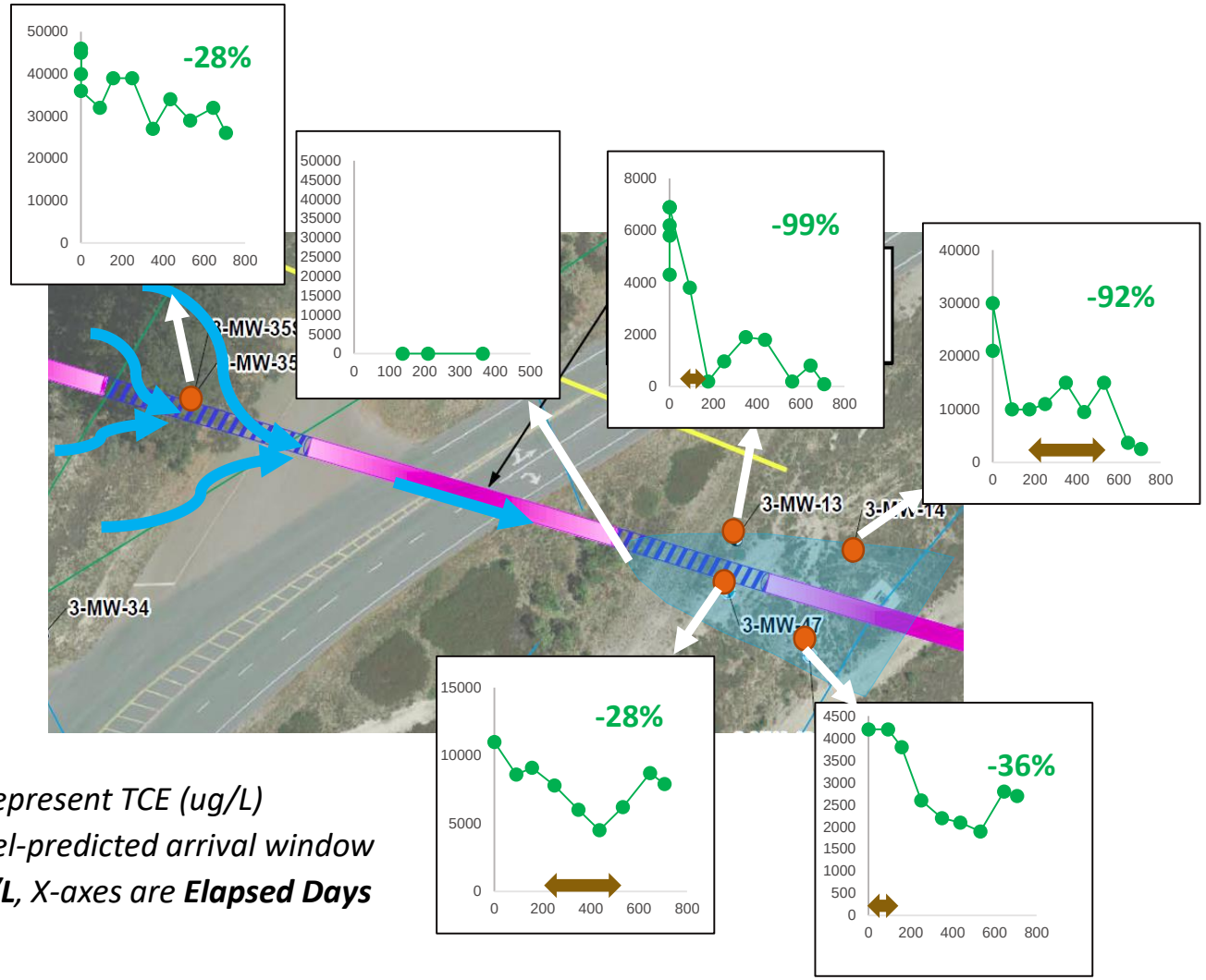


Groundwater Elevations

Treatment width: ~50 ft



Performance Data

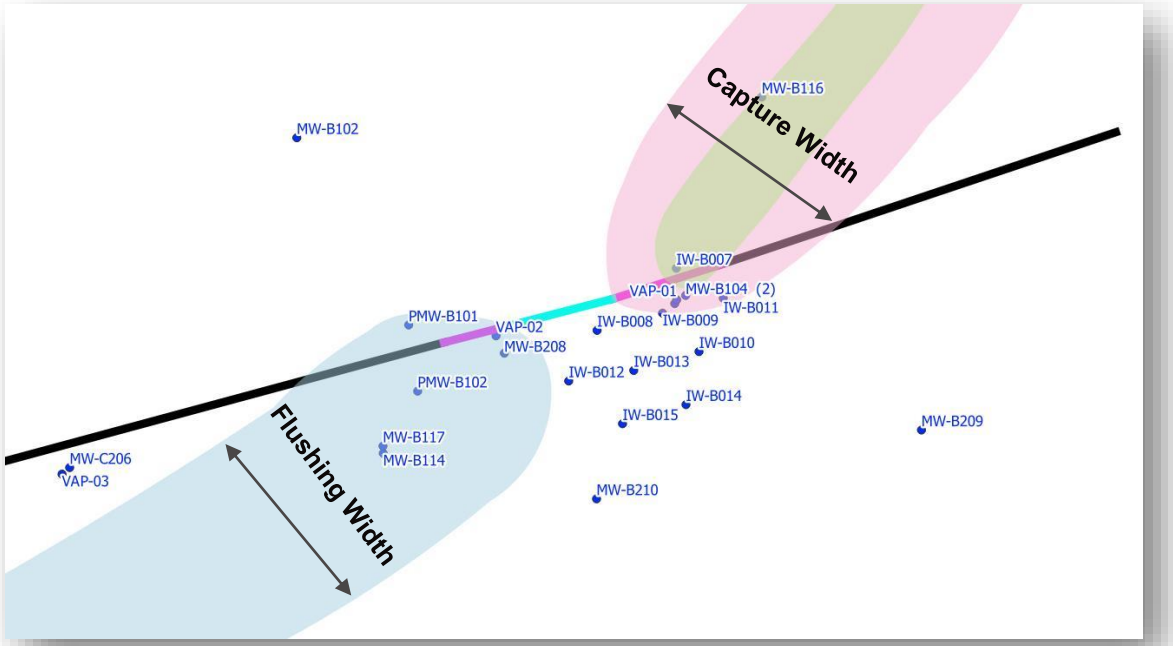


Green series represent TCE (ug/L)
Brown is model-predicted arrival window
*Y-axes are **ug/L**, X-axes are **Elapsed Days***

- Capture/Treatment zone width about 50 ft under passive configuration
- 99.99% TCE concentration reduction from 3-MW-35 to HRX Well Outlet
- Average mass discharge reduction ~2 g/day, ~2.8 kg total
- All downgradient wells indicate treatment

Site 2 (CVOCs): Treatability study and model design

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



Design model results

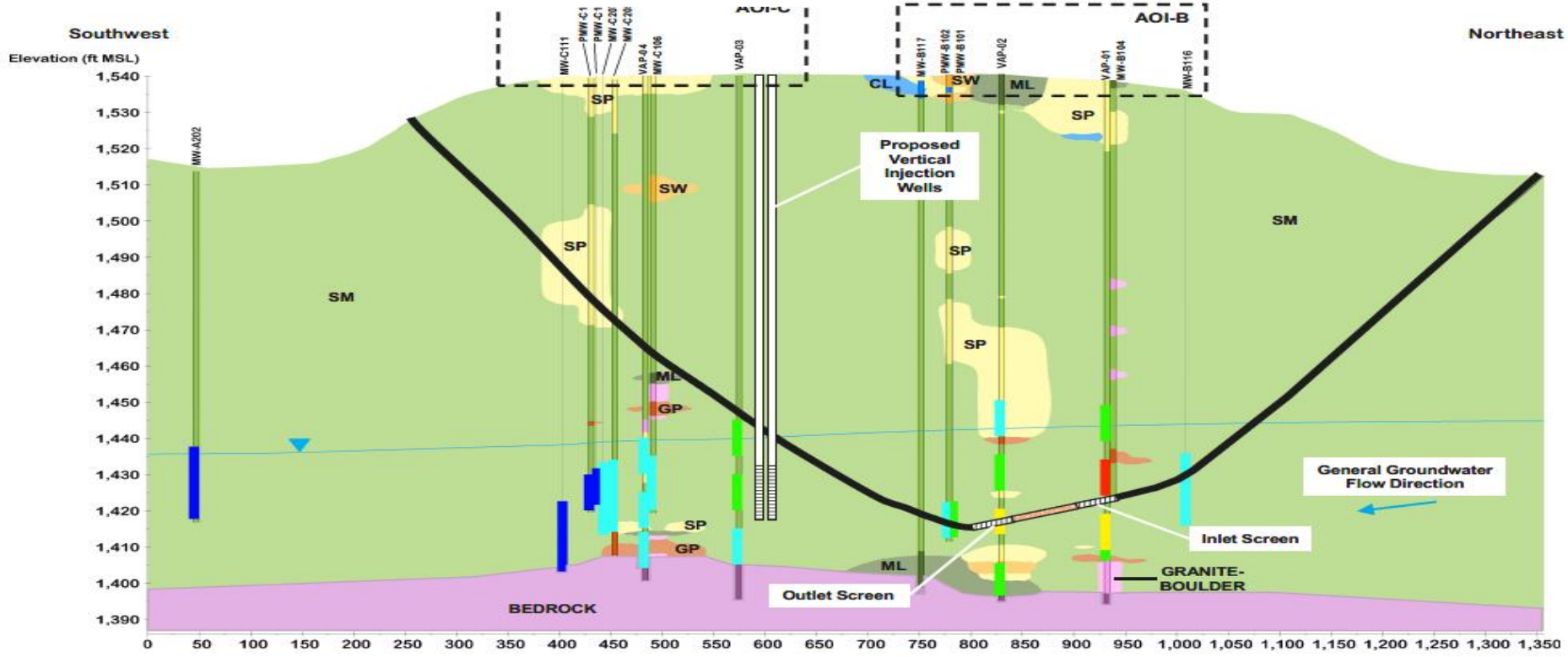
✓ Active: 120 ft capture width, residence time 2.5 hrs,

Column testing to support adsorbent media selection

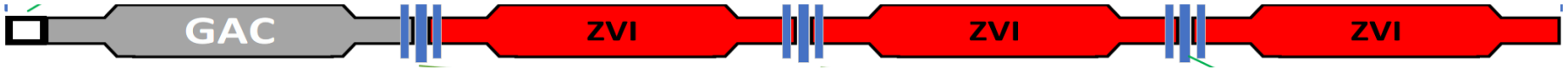
- Hoganas CleanER-PB ZVI, Hoganas Clean-ER300 ZVI, Connelly ZVI
- Sonolytic reactor will be tested after 1 year of operation with GAC

✓ Selected media: **35 feet of CleanER-300/PRB-300 ZVI (with Filtrasorb 400 GAC for polish)**

Site 2: Field Implementation



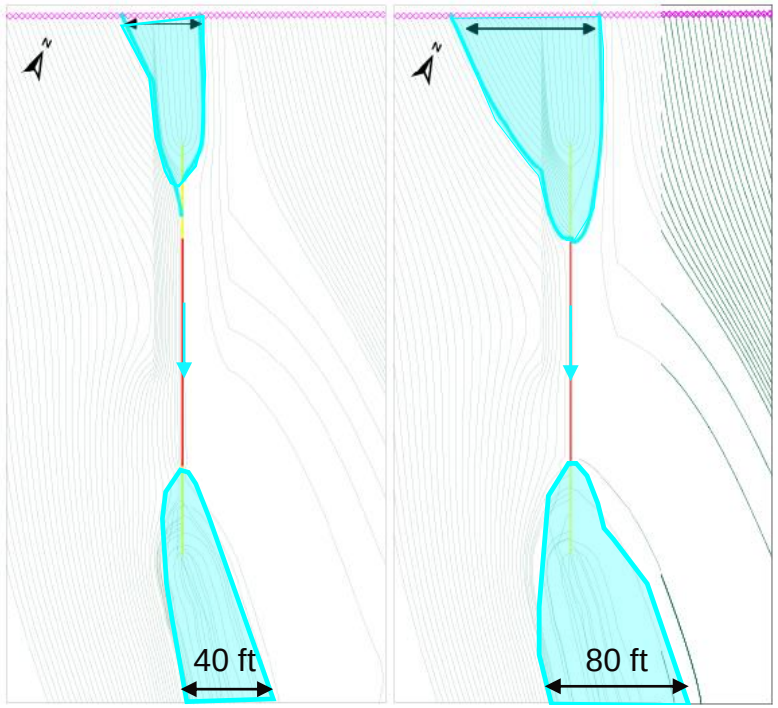
60 ft



Flow

Site 3 (PFAS): Treatability study and model design

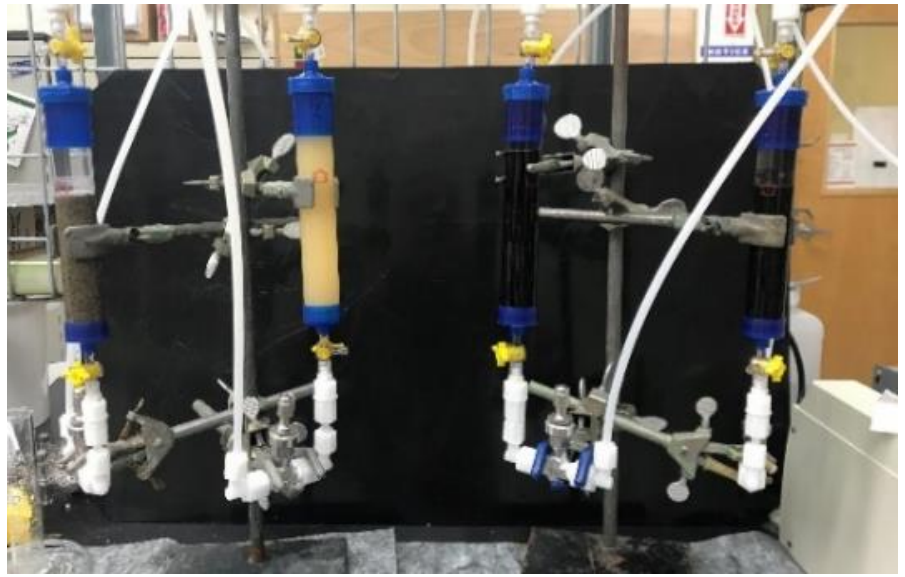
- Aquifer thickness 5-10 ft
- Target depth: 35 ft
- Sandy alluvium within paleochannel
- Hydraulic conductivity: 3 ft/day



Design model results

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

Both being tested



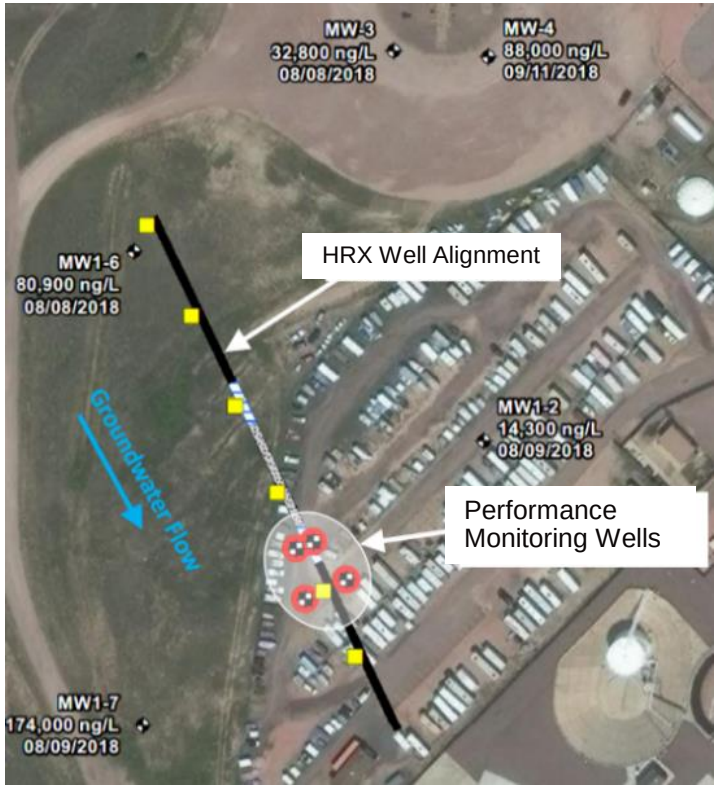
Column testing to support adsorbent media selection for the HRX Well.

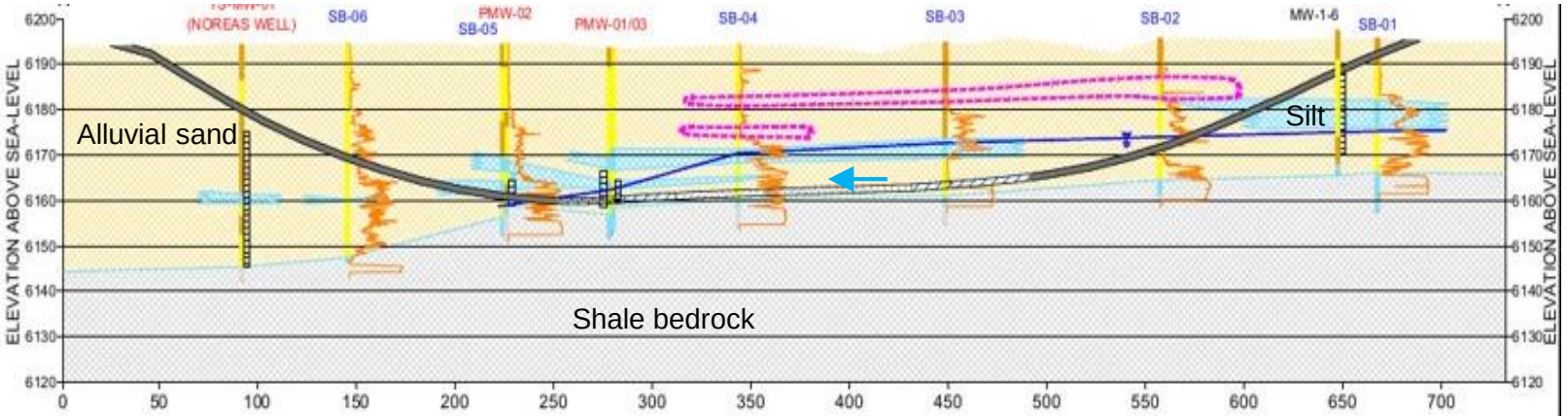
Prototype sonolytic reactor for in situ PFAS treatment (courtesy Michelle Crimi)

- ➢ Candidate media: Fluorosorb 400, Osorb 4-mesh, Filtrasorb 400 GAC, Purolite IX
- ➢ Sonolytic reactor will be installed and tested as part of ESTCP project ER21-5045

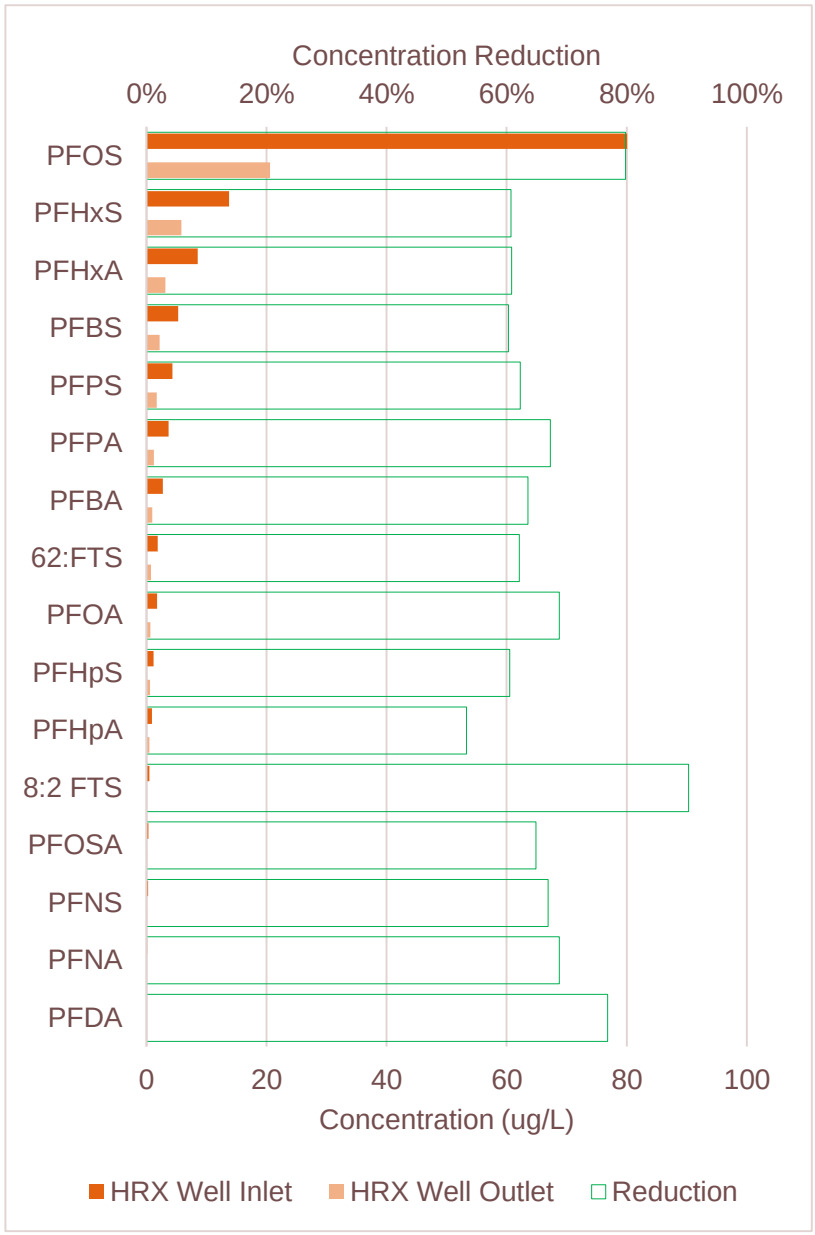
- ✓ Selected media: **Filtrasorb 400 GAC (with Filtrasorb 820 GAC for TOC pretreatment)**

Site 3: PFAS (cont)



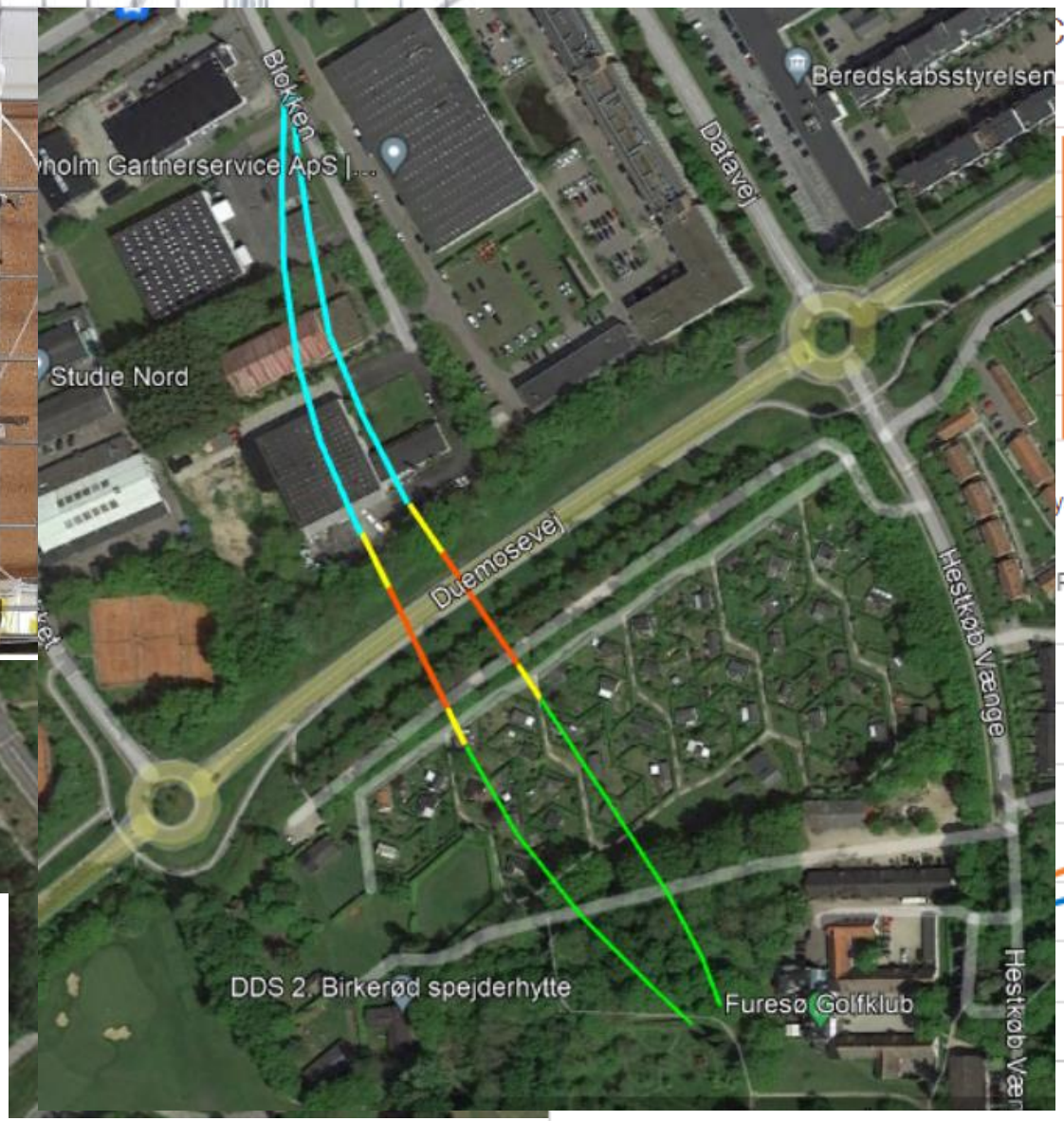


Geologic cross-section and as-built HRX Well alignment



ΣPFAS mass flux reduction: 1.3 mg/day; 0.5 kg/yr

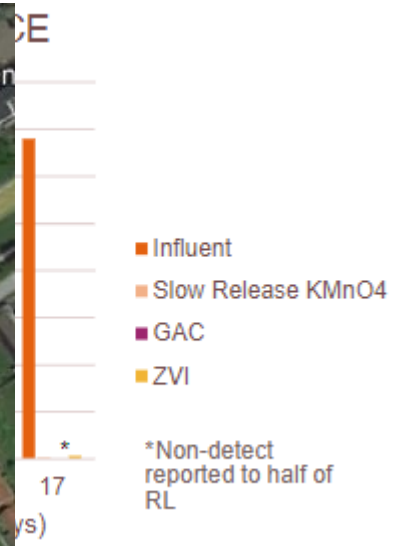
Design Example - Denmark

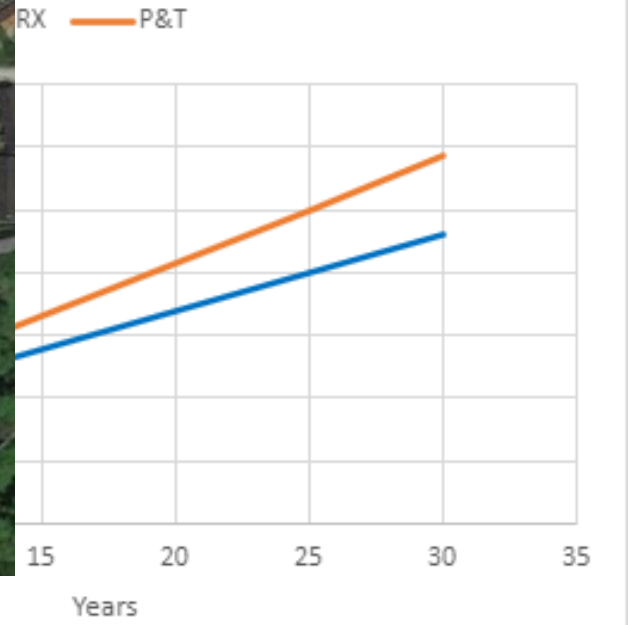


HRX Open Screen

HRX Treatment Media

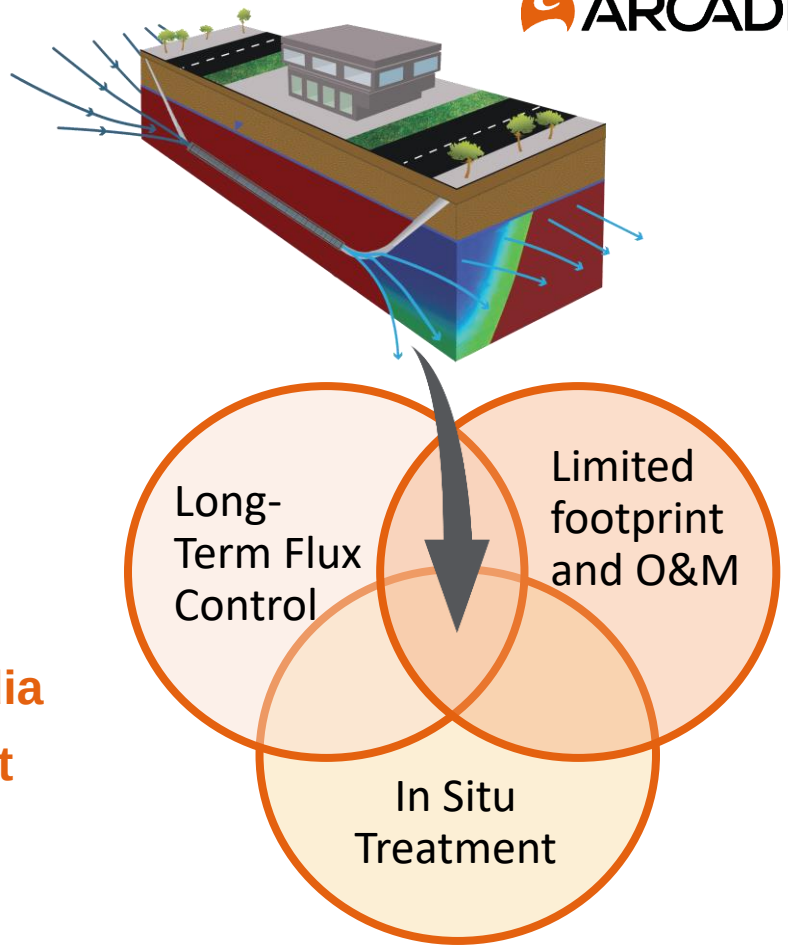
Site Boundary





Design and Implementation Steps

1. **Complete site screening analysis (Excel-based design tool)**
   - Low or High-K (for passive or active operation)
   - Aquifer thickness
   - Depth to groundwater (~5:1 setback)
   - Availability of proven media for contaminant
2. **Perform focused treatability study to optimize treatment media**
3. **Collect limited additional field data along HRX Well alignment**
   - May use HPT, geophysics, aquifer testing depending on exiting data
4. **Construct local flow model to optimize HRX Well design**
5. **Install HRX Well and initiate performance monitoring**



Contact

ALLAN HORNEMAN, PHD, VICE PRESIDENT

Solutions Leader, Portland, ME

c +1 207 553 0072

e allan.horneman@arcadis.com

CRAIG DIVINE, PHD, VICE PRESIDENT

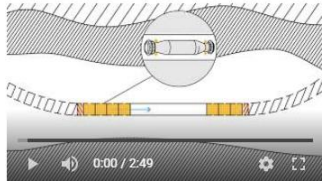
Principal Hydrogeologist, Lenexa, KS

o +1 720 3085367

e craig.divine@arcadis.com

Additional Resources and Awards

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



Summary of field demonstration

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.

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

2020 ESTCP Project of the Year Award

2019 National Groundwater Association Technology Award

EBJ

2021 Environment Business Journal Project Merit Award