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# A New User-Friendly Passive Contaminant Flux Measurement Device: Development and Testing

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# Agenda

- Introduction to Mass Flux
- How is Mass Flux Measured
- What has the Data Shown Us
- Effects of Mass Flux Measurements on Remedial Designs
- Case Studies

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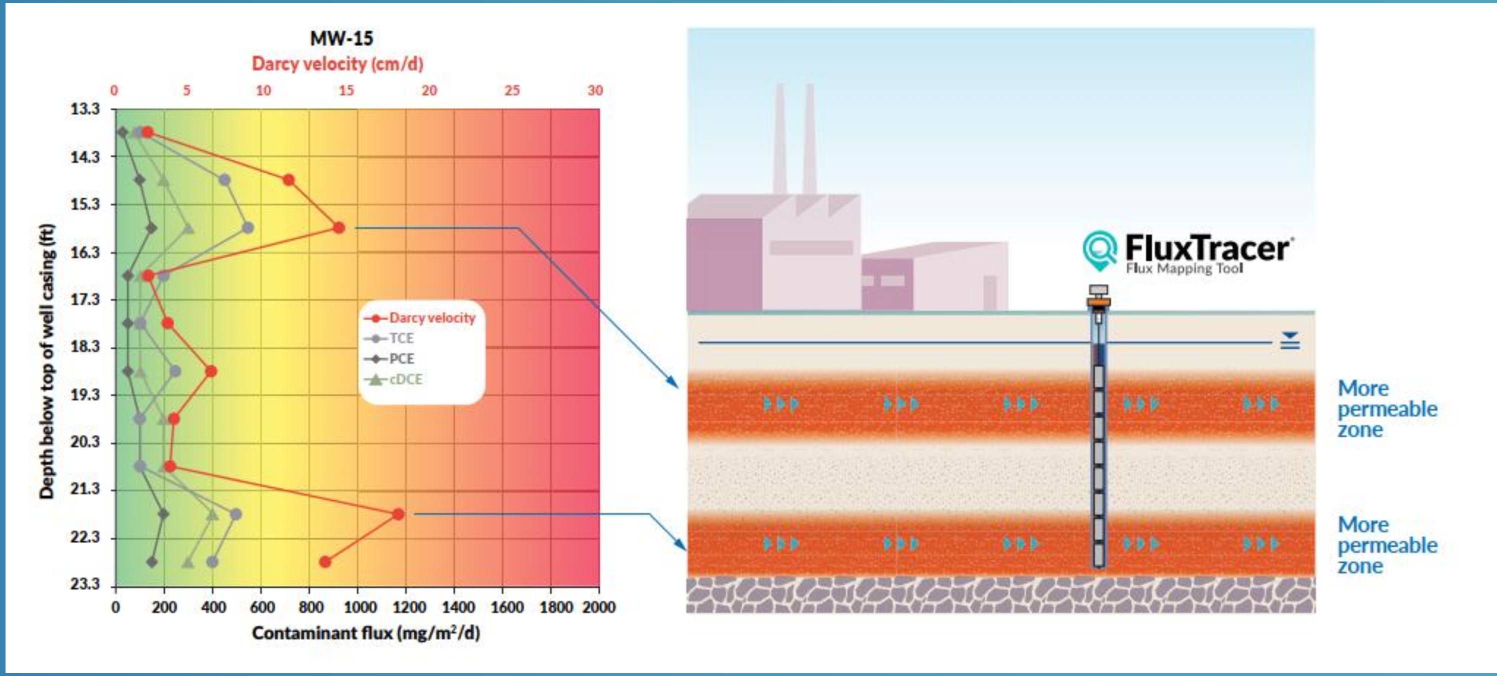
# Introduction

- Passive Flux Meters (PFMs) been around for 20 years
- Measuring contaminant flux and Darcy velocity
- Vertical distribution profiles
  - PFAS
  - cVOCs
  - Chromium
  - 123-TCP
  - Petroleum Hydrocarbons & BTEX
- Provides understanding of groundwater velocity, contaminant flux and geology
- Direct impacts to remedial designs

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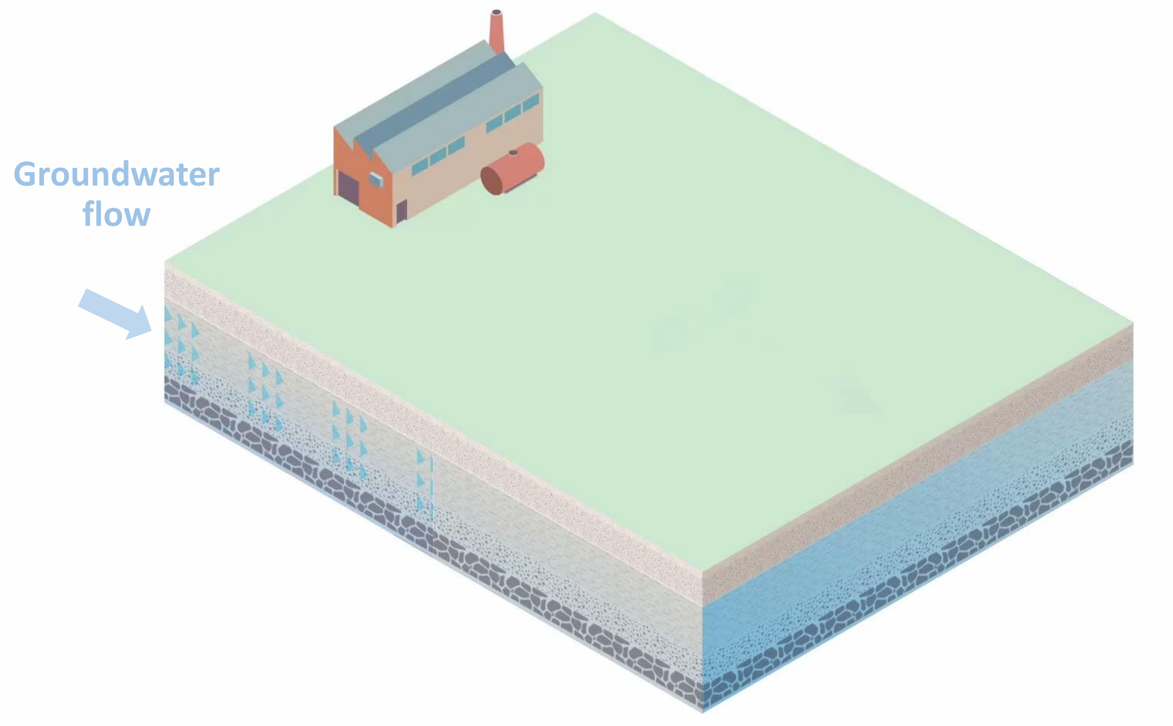
# What is Mass Flux?

$$Mass\ flux\ = GW\ Concentration \cdot Darcy\ velocity$$

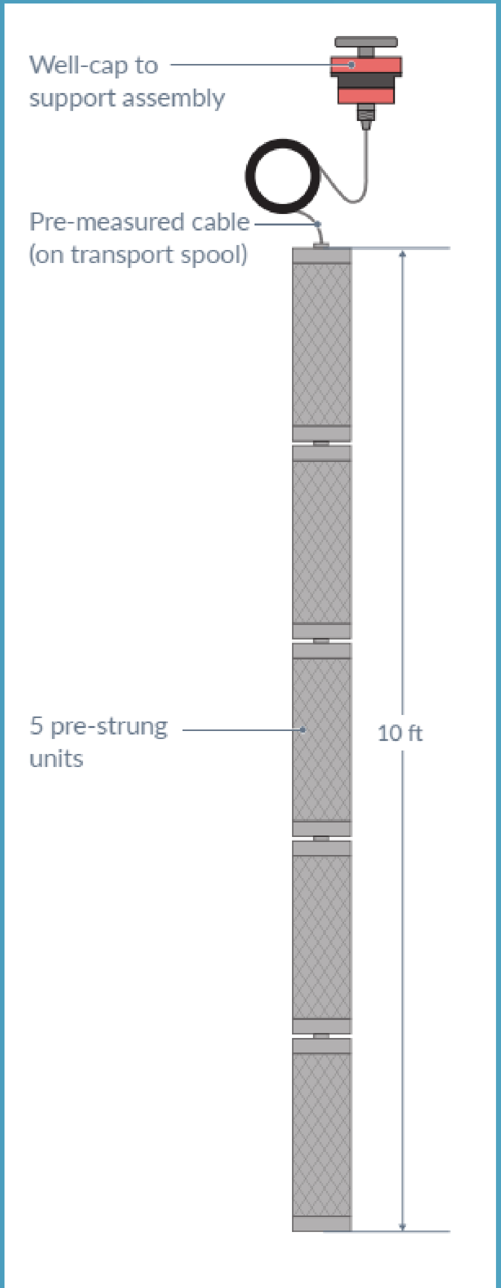



- Contaminant mass across a unit area of aquifer over time.
  - Mass/area/ time ($mg/m^2/day$)
- Perpendicular to GW flow
- Ideally determined for a transect perpendicular to ground water flow

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

# How is Groundwater and Contaminant Mass Flux Measured?

- Vertically delineate contaminant mass flux and Darcy velocity across the well screen interval
- Granular activated carbon inside the meter units to sorb migrating contaminants
- Chemical tracers in the activated carbon are released
- Sorbed contaminants and residual tracers are measured
- Direct measurement of contaminant flux and Darcy velocity
- Similar to passive diffusion bags, but PFMs provide far more information.

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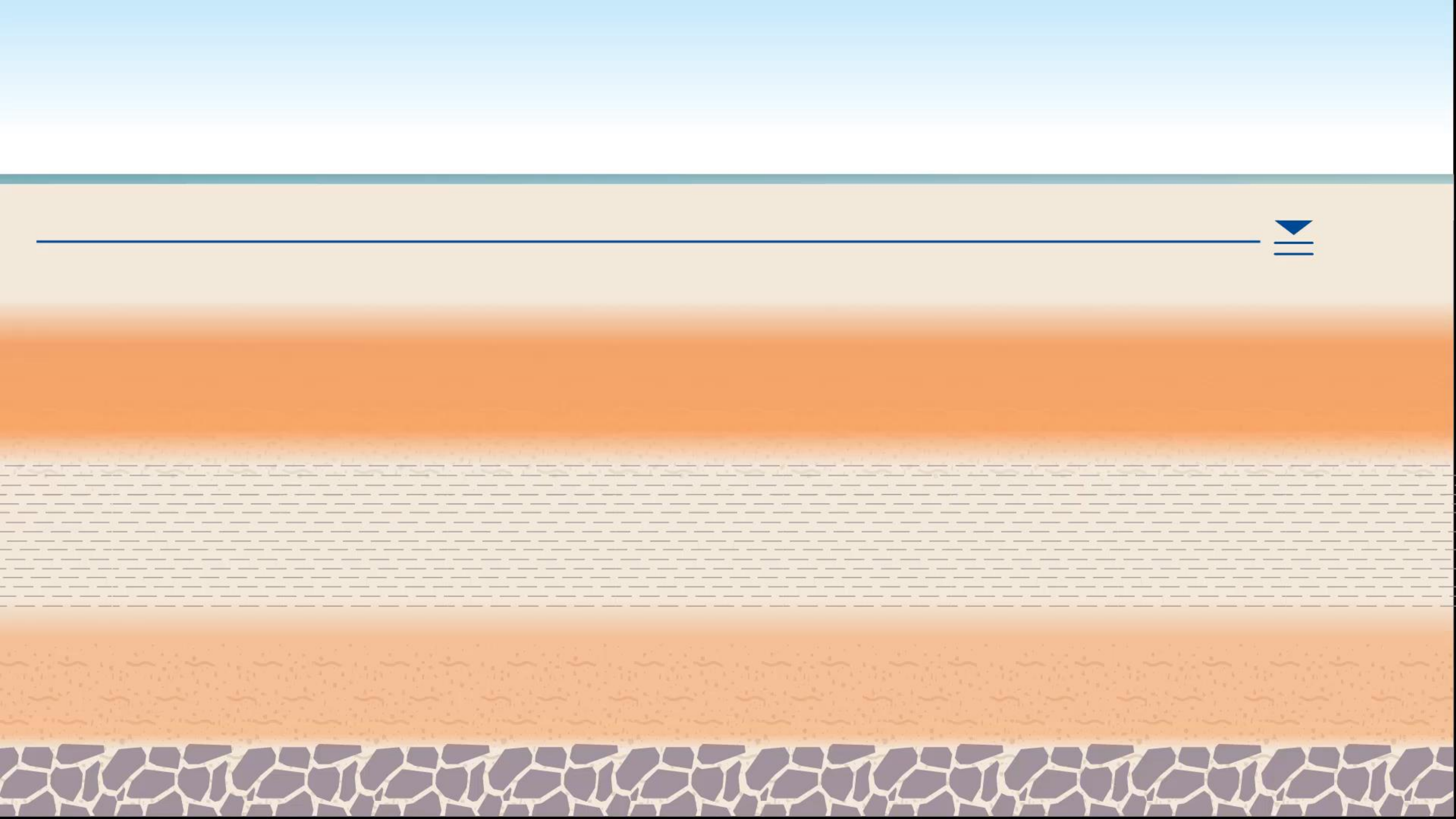
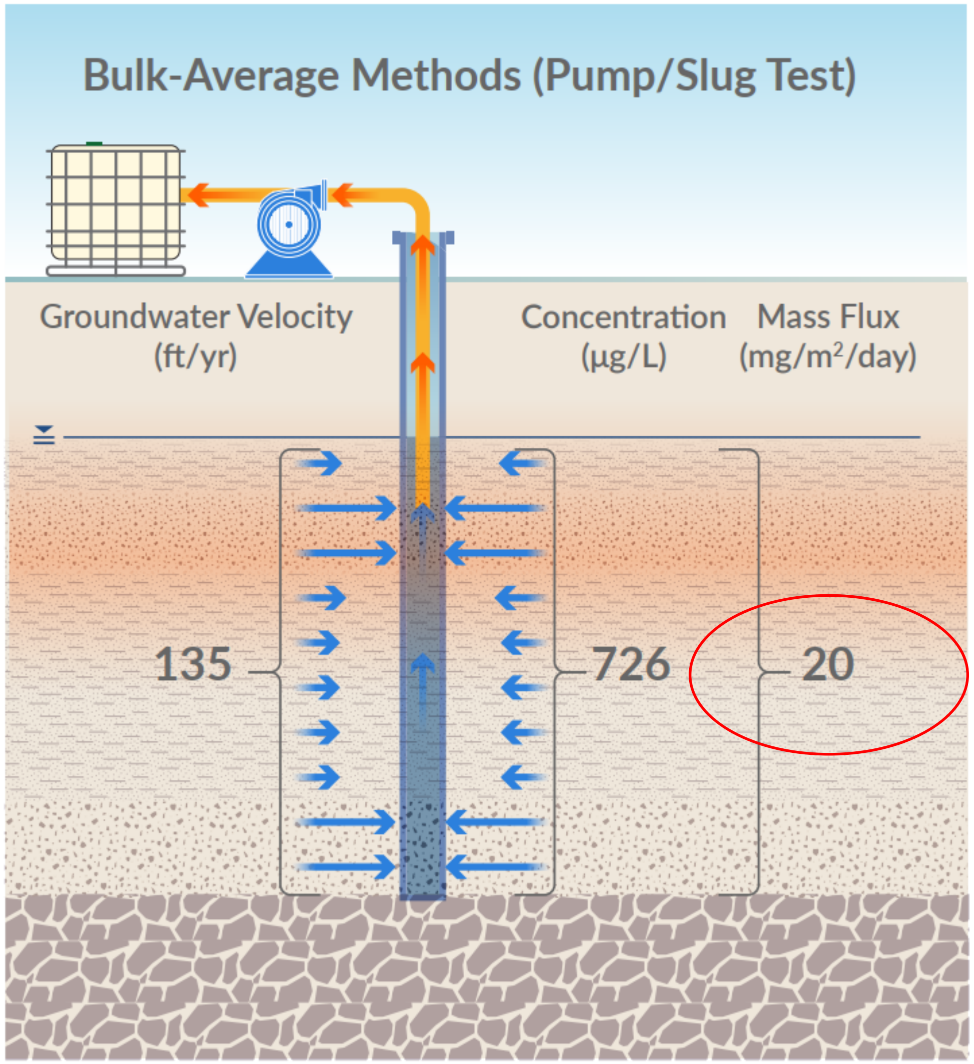
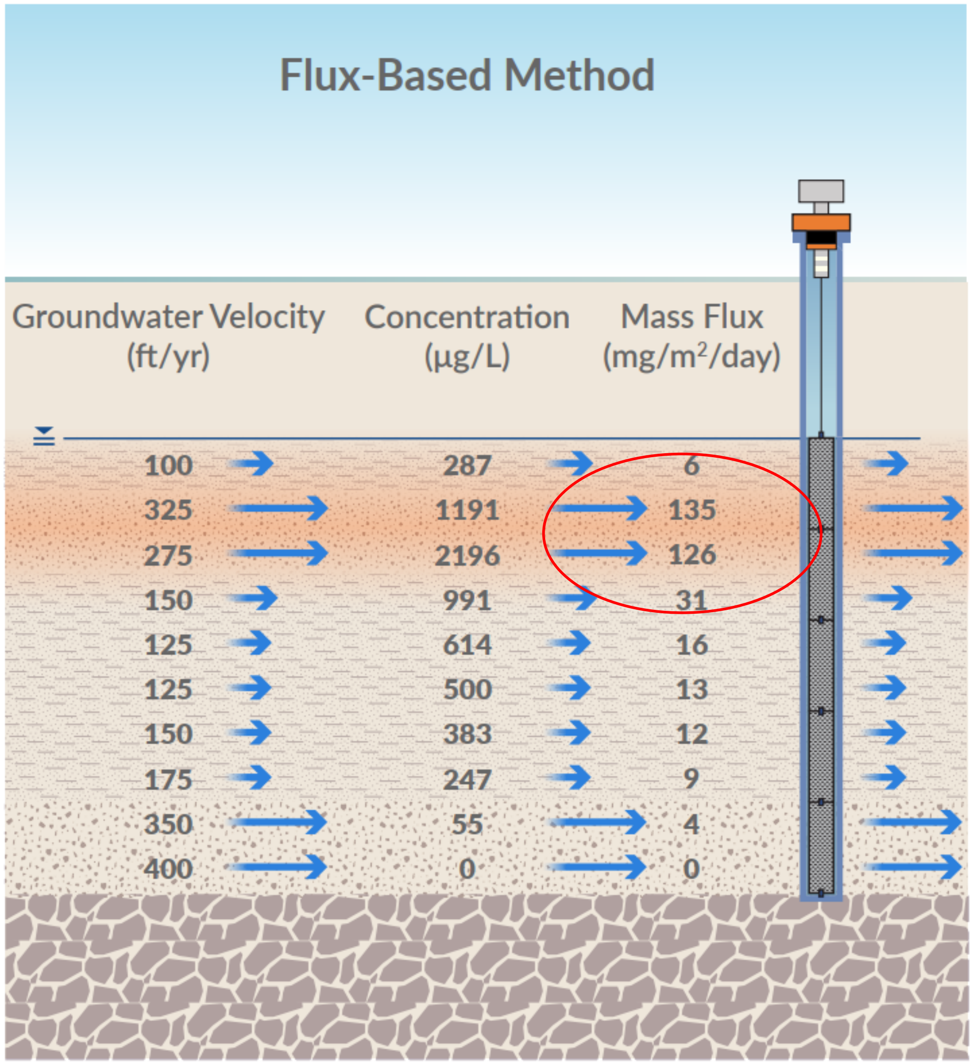


# Contaminant Mass Flux & Velocity Profile

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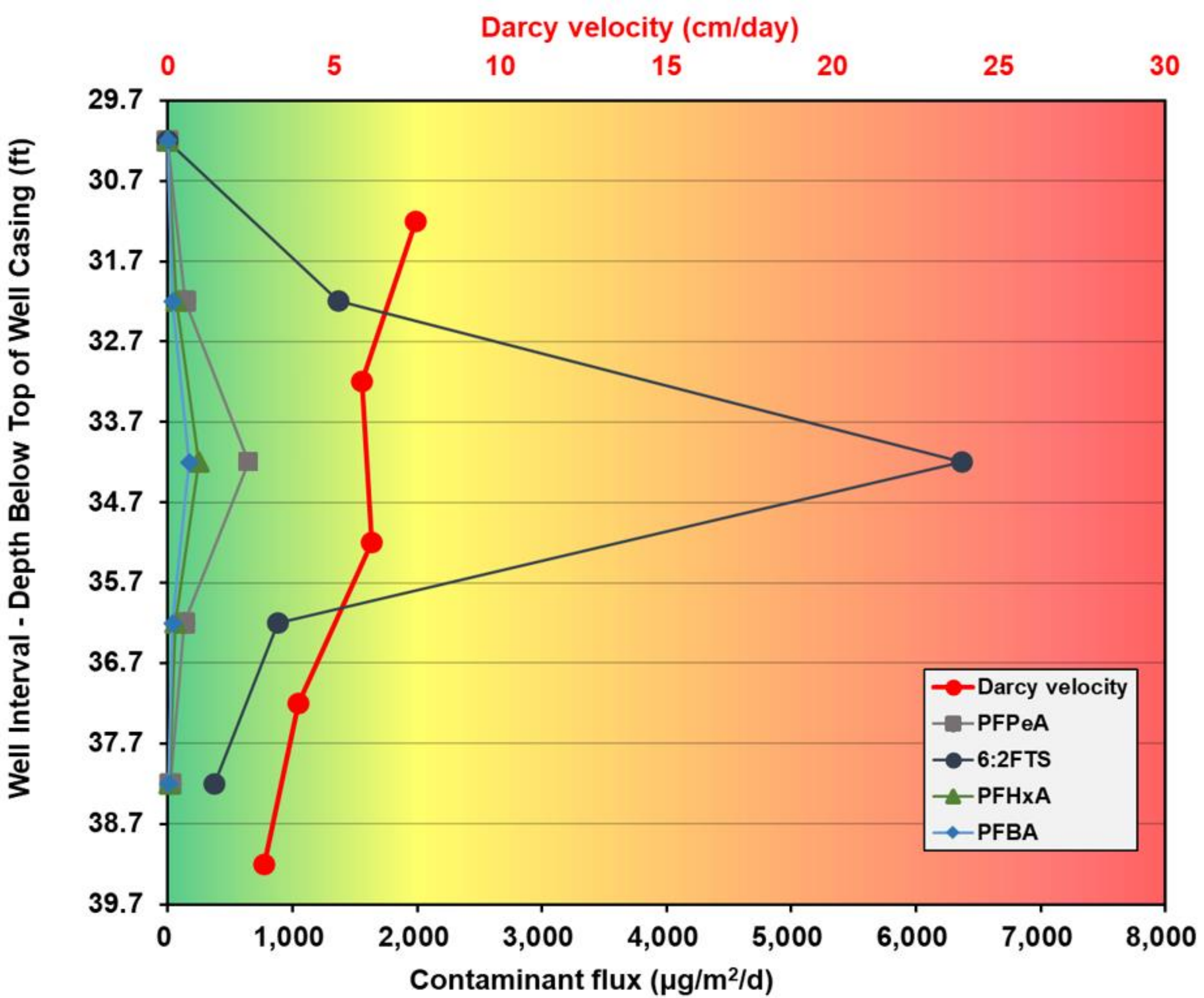
# PFAS Data

PFAS mass flux not correlating to velocity, but taking a preferential zone

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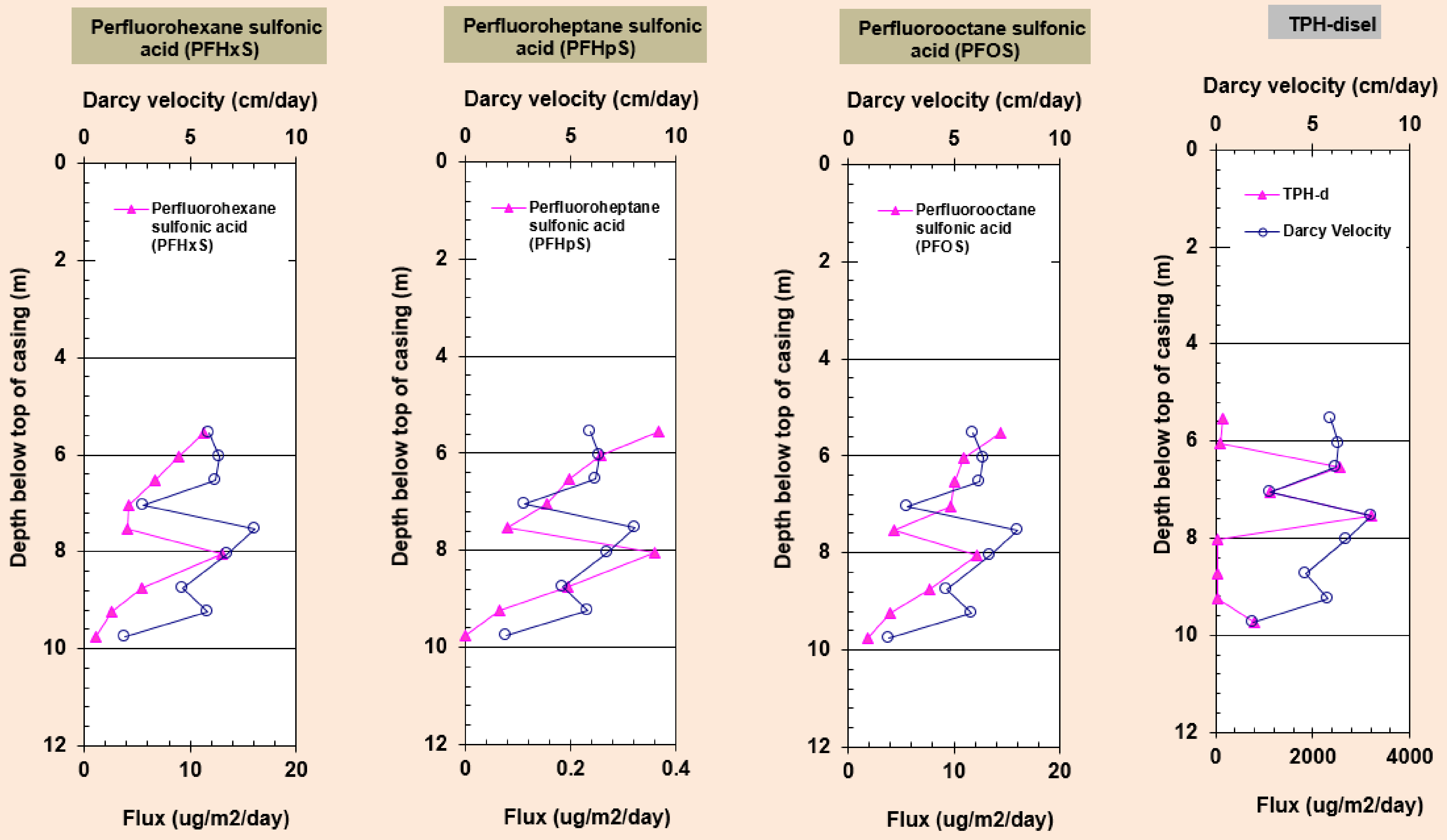
# PFAS Data

Correlation of PFAS Mass Flux to Velocity

TPH-D not as vertically dispersed as PFAS compounds

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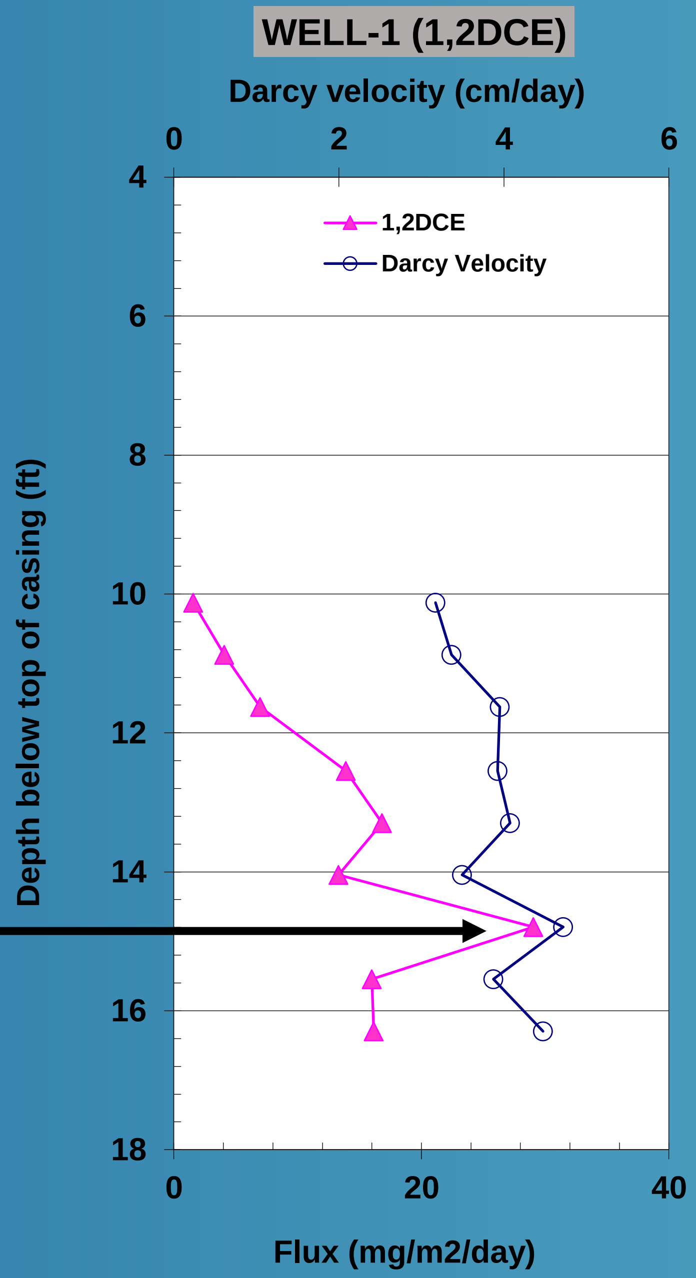
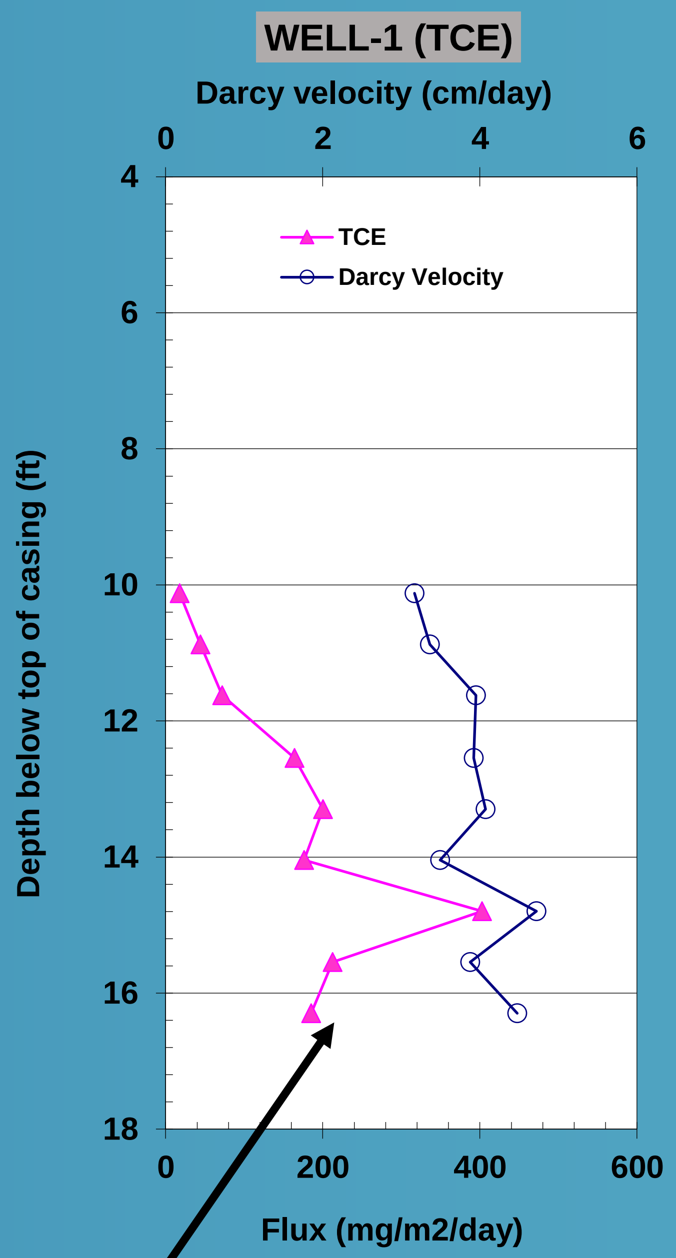
# cVOC Data

## Preferential Zone Example

| | |
|---|---|
| Sand-SP | 8-11 ft |
| Clayey Sand-SC | 11-12.5 ft |
| Silty Sand-SM | 12.5-14 ft |
| Sand-SP | 14-15.5 ft |
| Silt-ML | 15.5 to 20 ft |



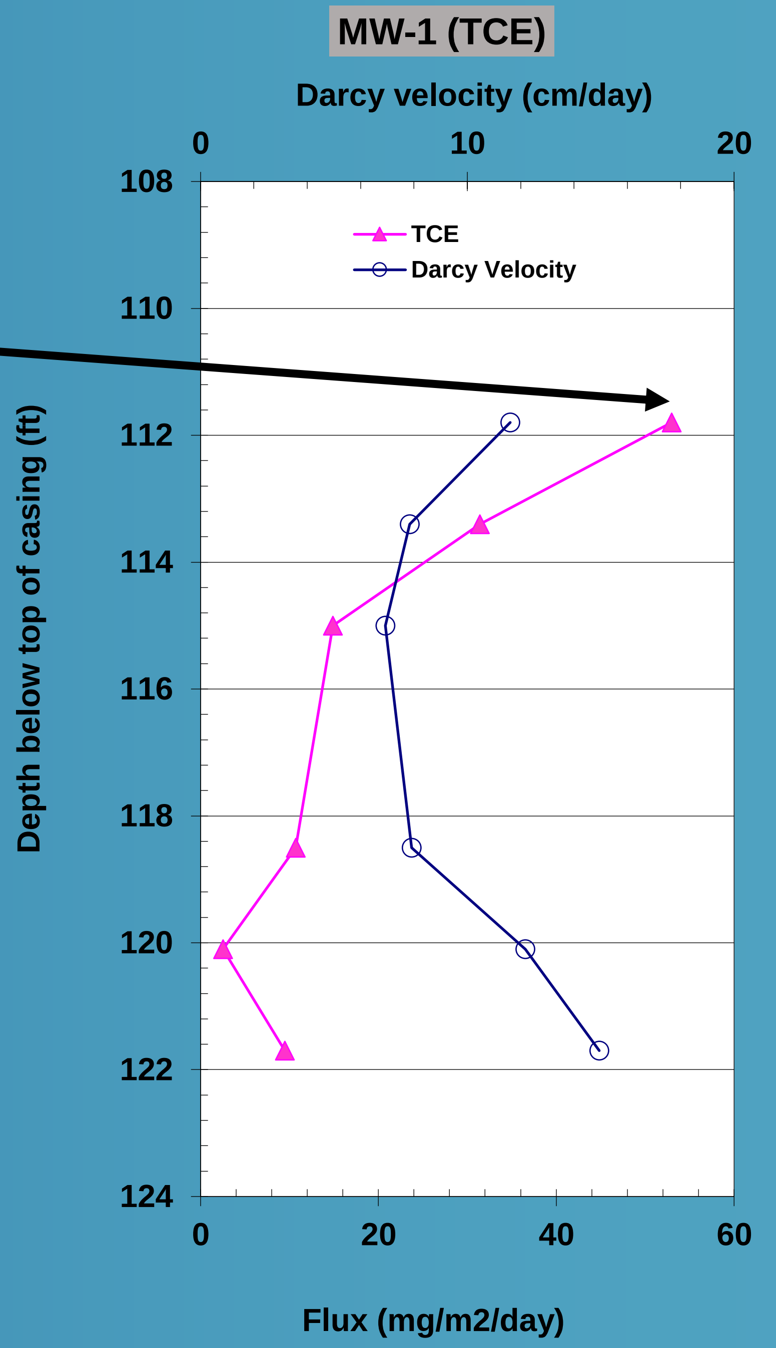




TCE flux still very high at based of screen

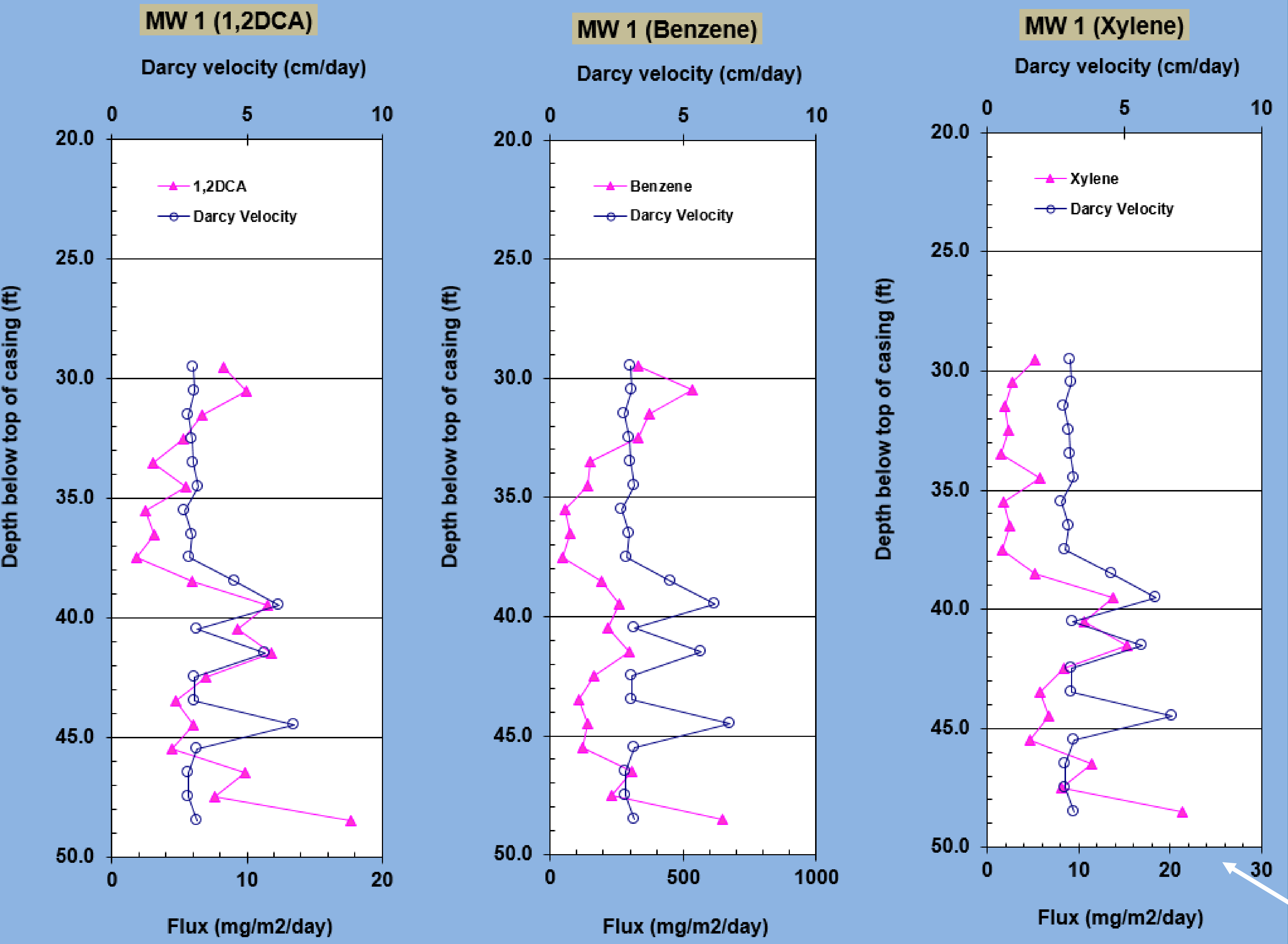
# cVOC Data

Bulk of cVOC flux
near top of screen

| | |
|---|---|
| Fine-Med Sand | 110-112 ft |
| Very Fine Sand | 112-114 ft |
| Fine Sand | 114-116 ft |
| Fine-Med Sand | 116-119 ft |
| Fine Sandy Silt | 119-121 ft |
| Fine Silty Sand | 121-123 ft |



# Petroleum Hydrocarbon Flux Data Example



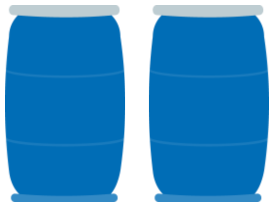

Direct flux measurement using PFM suggests a different interpretation than PID data based on soil vapors

| Geology | PID |
|---|---|
| Sand, med, trace gravel | 71 |
| Sand, with clay lense | 104 |
| Sand, med, trace gravel | 35 |
| | 31 |
| Sand with clay lenses | 7 |
| | 3 |
| | 3 |
| Sand | 4 |
| Clay with Silt lenses | 3 |

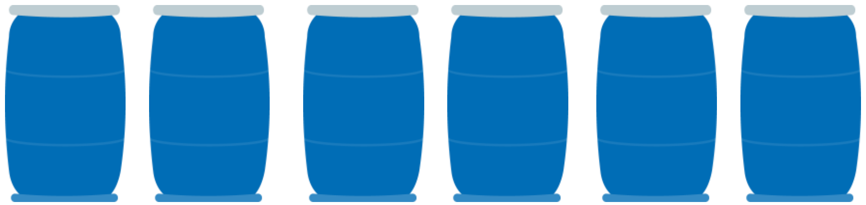
Preferential flow zones with increased contaminant mass flux measurements

# Effects of GW Velocity on Designs

- **Example 1**
- cVOC plume
- 10 ppm PCE
- Aerobic conditions
- Barrier application
- 15 m/year velocity
- 376 kg of product needed



- **Example 2**
- cVOC plume
- 10 ppm PCE
- Aerobic conditions
- Barrier application
- 90 m/year velocity
- 177 kg of product needed



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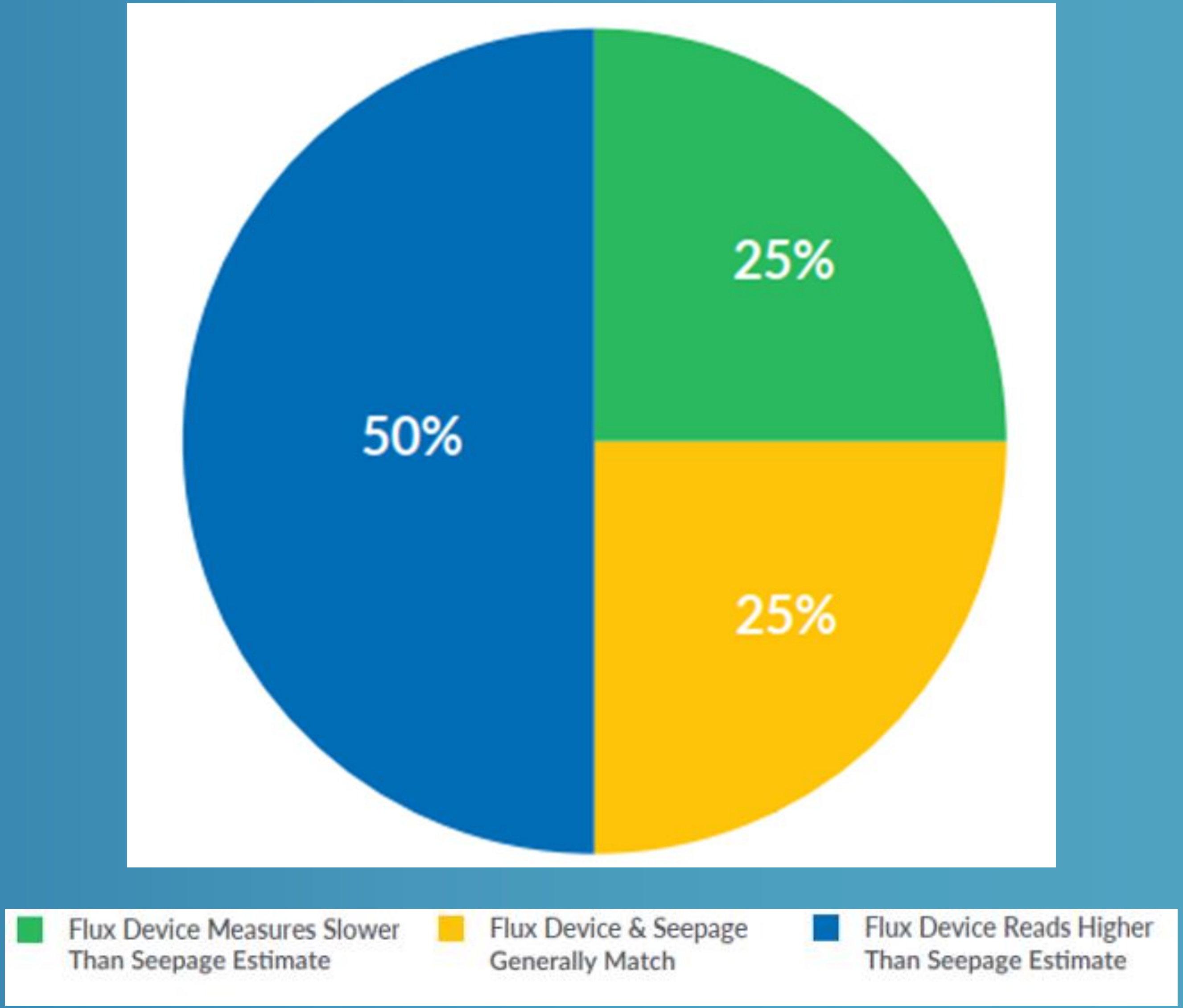
# Flux Data Impacts on Remedial Designs

- Understanding the target zone
  - Optimize design
  - Target the contaminants
- Better modeling predictions
  - Manage expectations for success
  - Understand remedial timeframe
  - Estimate longevity

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# Study Site 1

- ~1 ppm TCE
- Focus on abiotic destruction
- Sulfidated Micron Scale ZVI
- 15-30 ft target zone for application
- DPT application
- Quick turn


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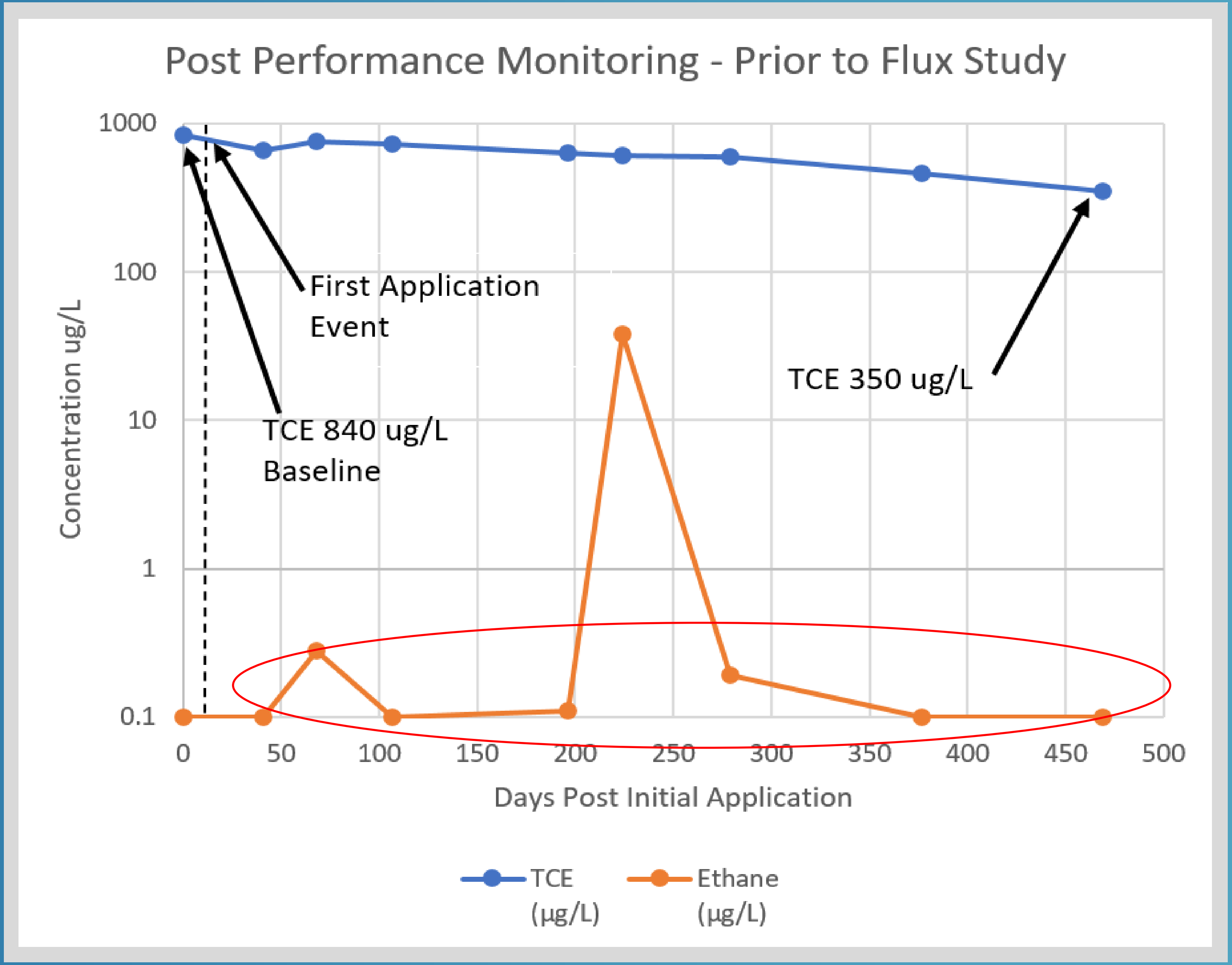
# Study Site 1

- Detailed monitoring
- Performance evaluation
- How do we improve performance?
- Answer: Flux Study
- $10,500 CAD

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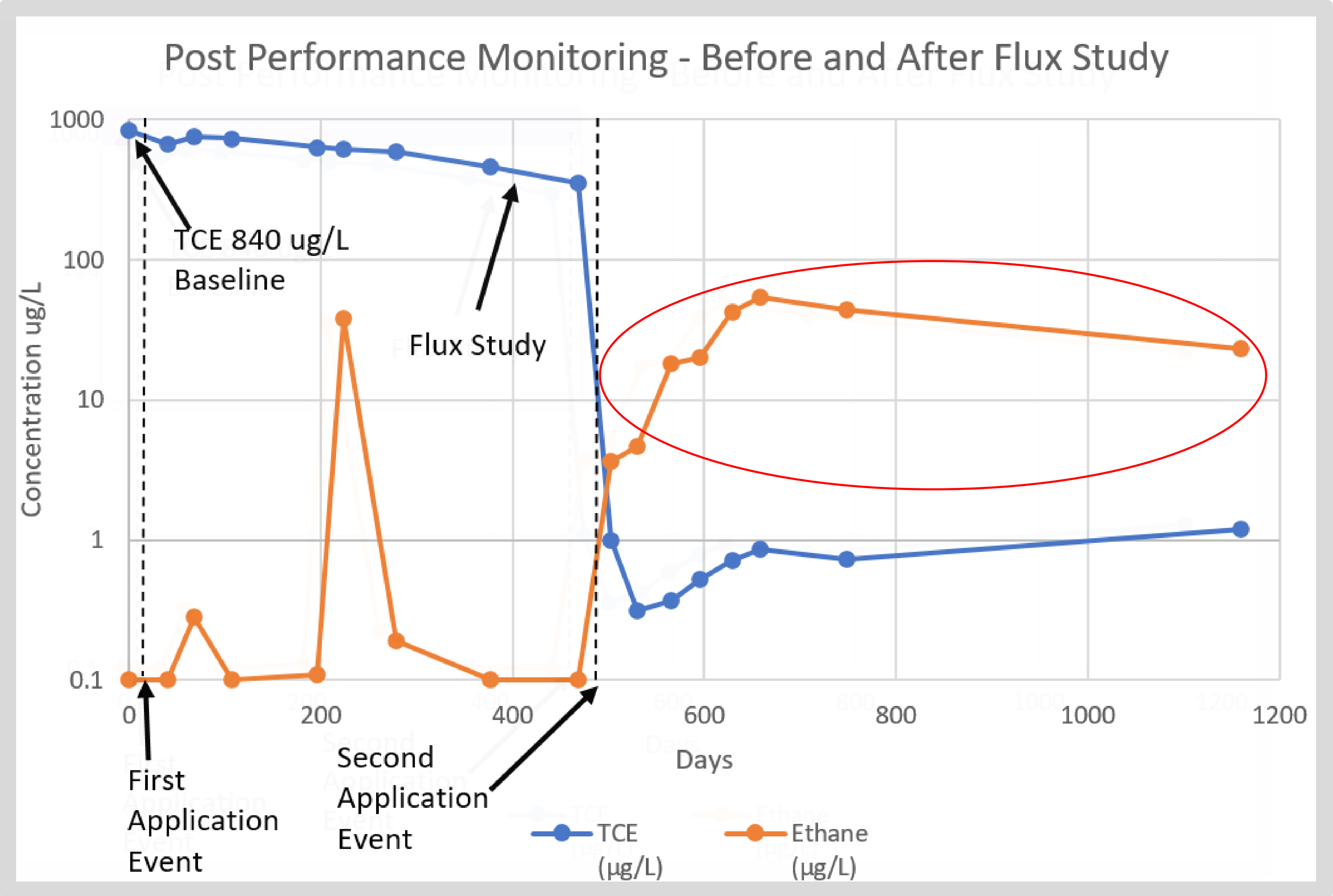
# Study Site 1

- 65% of mass in bottom 2 ft
- Adjust product placement
- Treat up to 5 feet below the well

| Depth below top of well casing (ft) | Darcy Velocity (cm/day) | TCE (mg/m^2/day) | TCE (ug/L) | Distribution % | Groundwater Velocity ft/yr |
|---|---|---|---|---|---|
| 19.0 | 4.5 | 3.9 | 86 | 7.2% | 257 |
| 21.0 | 4.1 | 3.9 | 93 | 6.8% | 237 |
| 23.0 | 4.8 | 3.9 | 81 | 9.7% | 273 |
| 25.0 | 5.4 | 1.8 | 32 | 6.2% | 310 |
| 27.0 | 5.5 | 1.8 | 33 | 4.5% | 312 |
| 29.0 | 5.9 | 10.8 | 182 | 22.3% | 339 |
| 31.0 | 6.3 | 24.5 | 391 | 43.3% | 358 |

# Study Site 1

- Reapplication completed
- Near 100% reduction
- Ethane response
- Sustained performance

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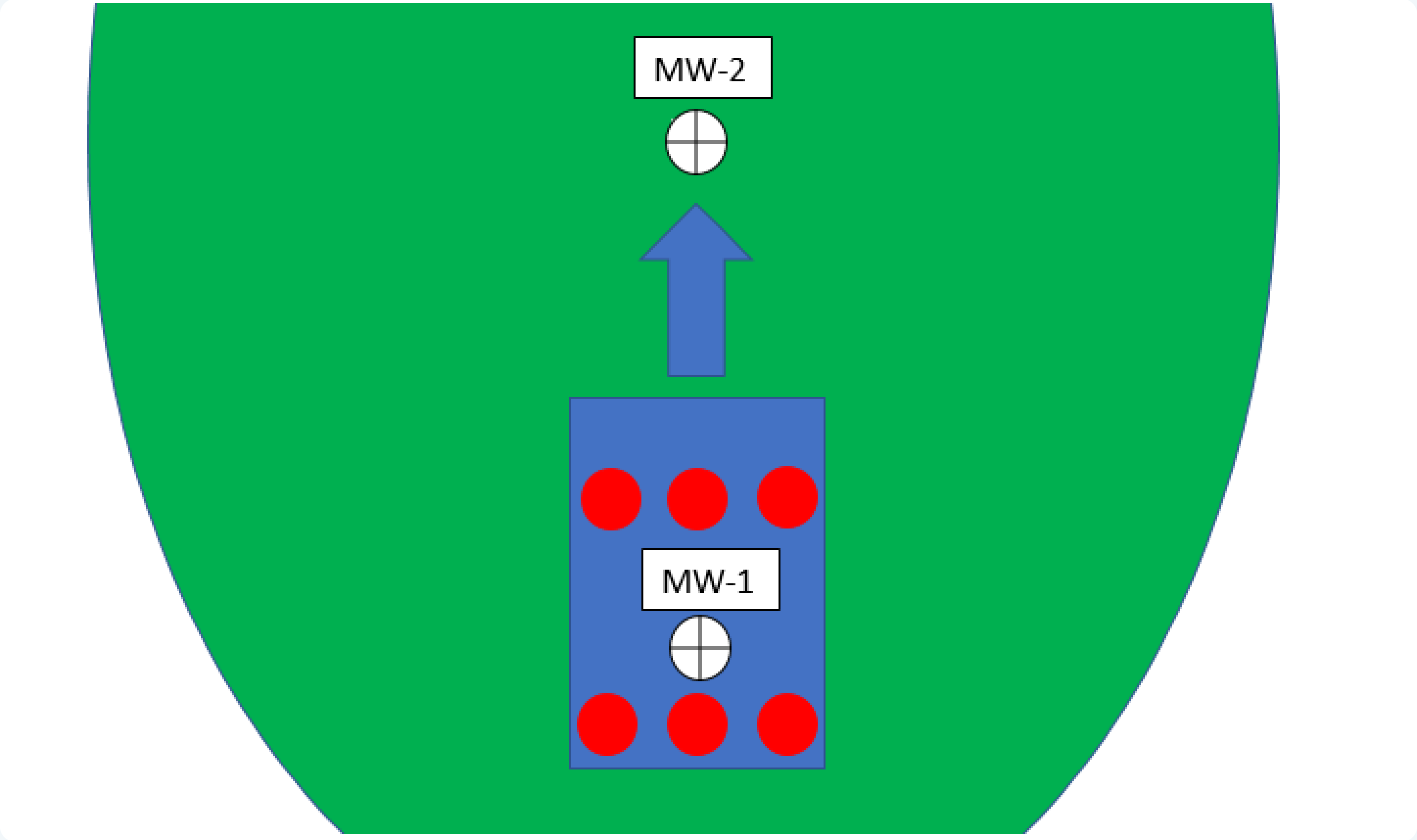
# Study Site 2

**Generalized Site Map**




- 18 ppm of TCE, 1 ppm of Cis 1,2-DCE
- Previously treated with lactate
- 3DME/SMZVI/BDI
- Pilot Test in source area
- Installed flux devices

# Study Site 2

| Well ID | Depth (ft) | Darcy Velocity (cm/day) | GW Velocity ft/yr | 1,2DCE (ug/L) | TCE (ug/L) | 1,2DCE (mg/m^2/day) | TCE (mg/m^2/day) | Total cVOC Flux (mg/m^2/day) | Flux % |
|---|---|---|---|---|---|---|---|---|---|
| MW-1 | 10.1 | 3.2 | 173 | 50 | 564 | 1.57 | 17.89 | 19 | 1.2% |
| | 10.9 | 3.4 | 183 | 121 | 1319 | 4.09 | 44.39 | 48 | 3.0% |
| | 11.6 | 3.9 | 215 | 177 | 1822 | 6.97 | 71.97 | 79 | 5.0% |
| | 12.5 | 3.9 | 214 | 354 | 4179 | 13.90 | 163.95 | 178 | 11.2% |
| | 13.3 | 4.1 | 222 | 413 | 4916 | 16.81 | 200.23 | 217 | 13.6% |
| | 14.0 | 3.5 | 190 | 381 | 5045 | 13.29 | 176.25 | 190 | 11.9% |
| | 14.8 | 4.7 | 257 | 615 | 8530 | 29.04 | 402.53 | 432 | 27.1% |
| | 15.5 | 3.9 | 211 | 412 | 5483 | 15.98 | 212.45 | 228 | 14.3% |
| | 16.3 | 4.5 | 244 | 361 | 4139 | 16.15 | 185.15 | 201 | 12.6% |

- Revisit the design
- Shifted treatment deeper
- Adjust dosing
- No additional cost

**Flux Data**

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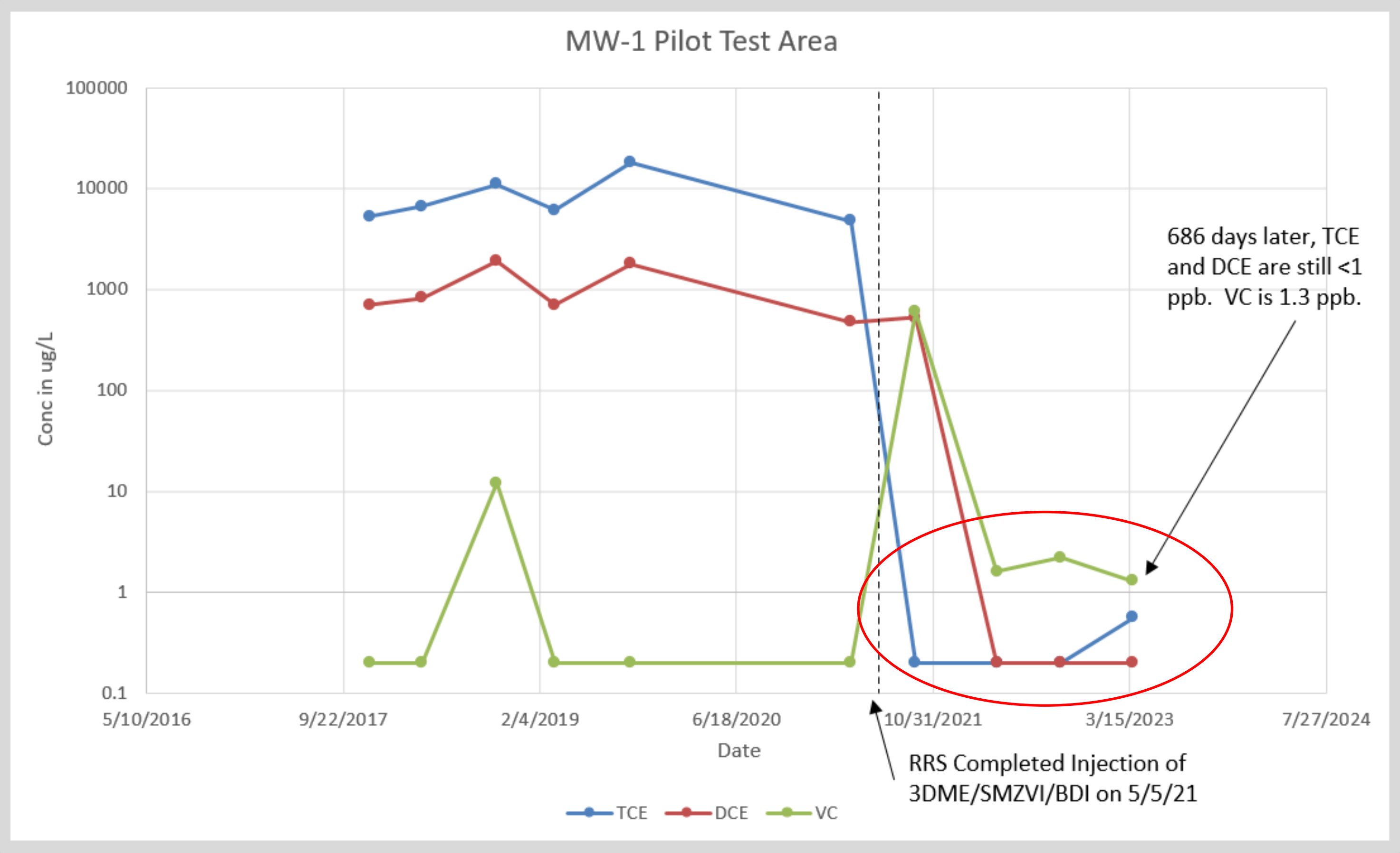
# Study Site 2

**Post Injection Performance Monitoring**




- Rapid performance
- Minimal daughter products
- 2 years and still on-going performance
- $61.5K CAD Turnkey Pilot Test
- $15K CAD for Flux Study

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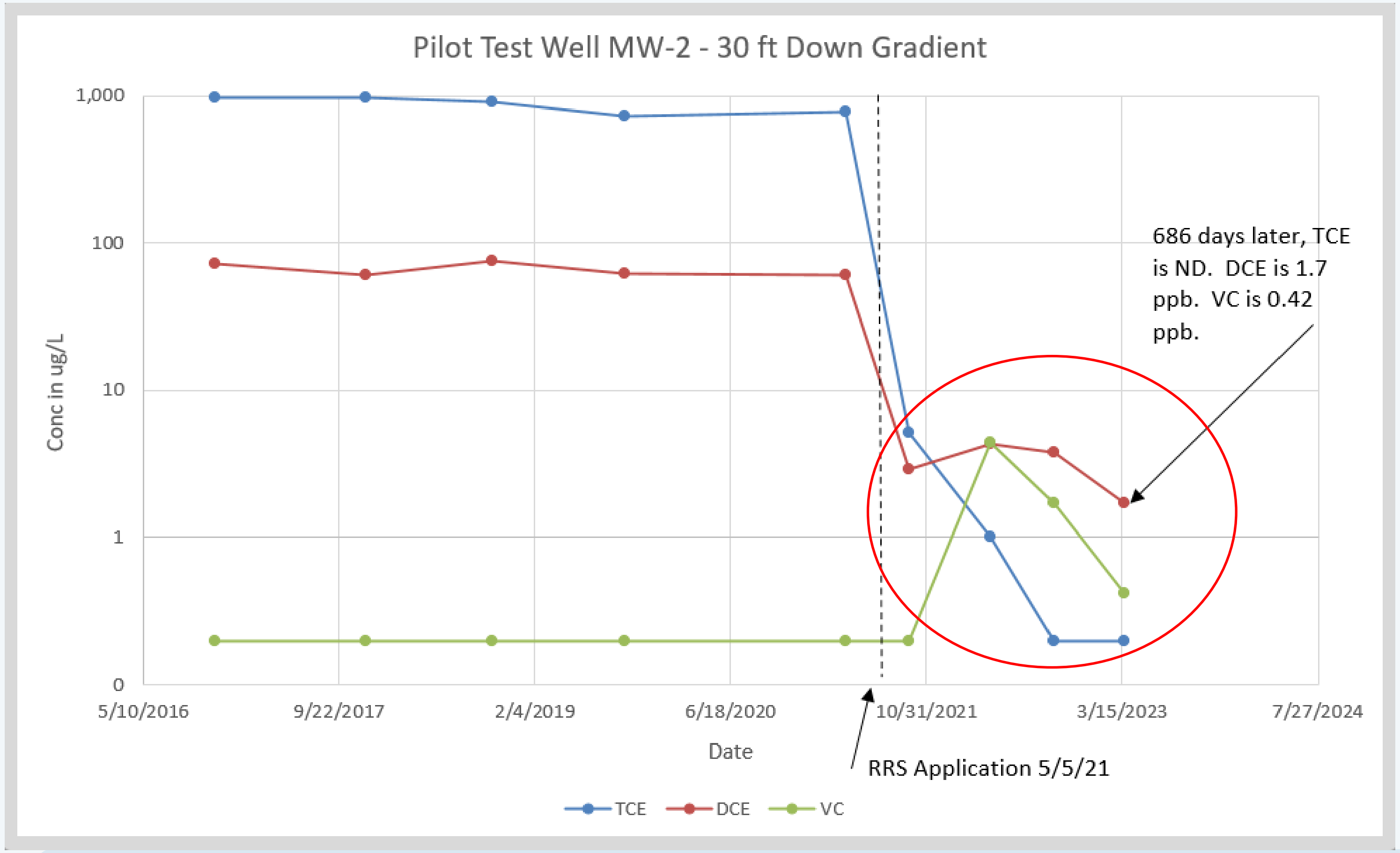
# Study Site 2

## Post Injection Performance Monitoring




- Results spread 30 ft downgradient to second monitoring well
- Sustained performance

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# Conclusions

- 10 to 20 ft well screens are ideal for flux investigations
- The highest contaminant mass flux is:
  - Not always the coarse-grained zone
  - Sometimes the fastest zones
  - Sometimes prefers the finer grained zones
- Less noticeable site characteristics such as density, compaction, cementation, bedding planes can affect velocity and flux zones
- cVOCs bulk flux is not always a sinker
- Hydrocarbons bulk flux are not ways a floater
- PFAS is usually well dispersed over thick zones
- Direct measurement with flux tools provides answers

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# Questions?

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