Overcoming Implementability Challenges:
Activated Carbon Slurry PRB Installation to Prevent LNAPL Migration to Surface Water Body

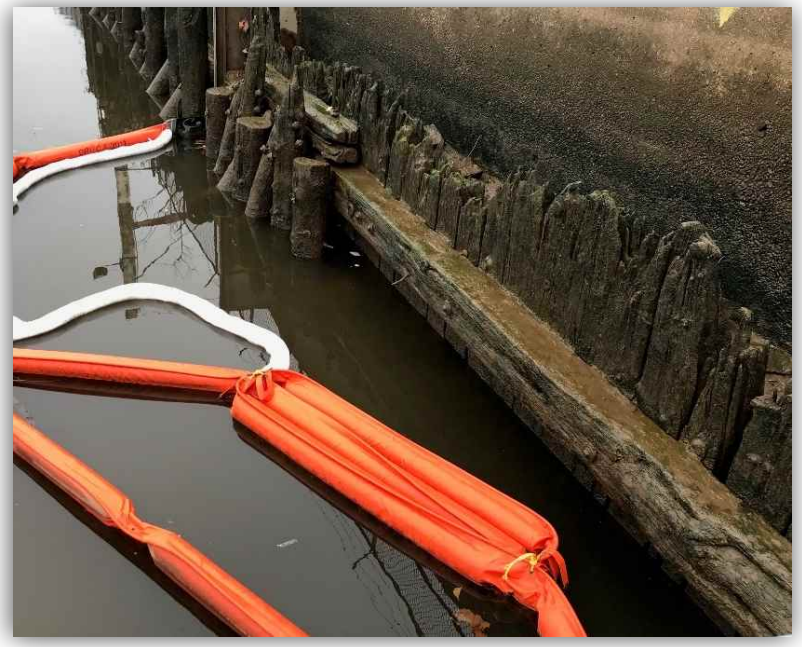
Chad Smith (Chad.Smith@pbfenergy.com) PBF Energy, Inc.

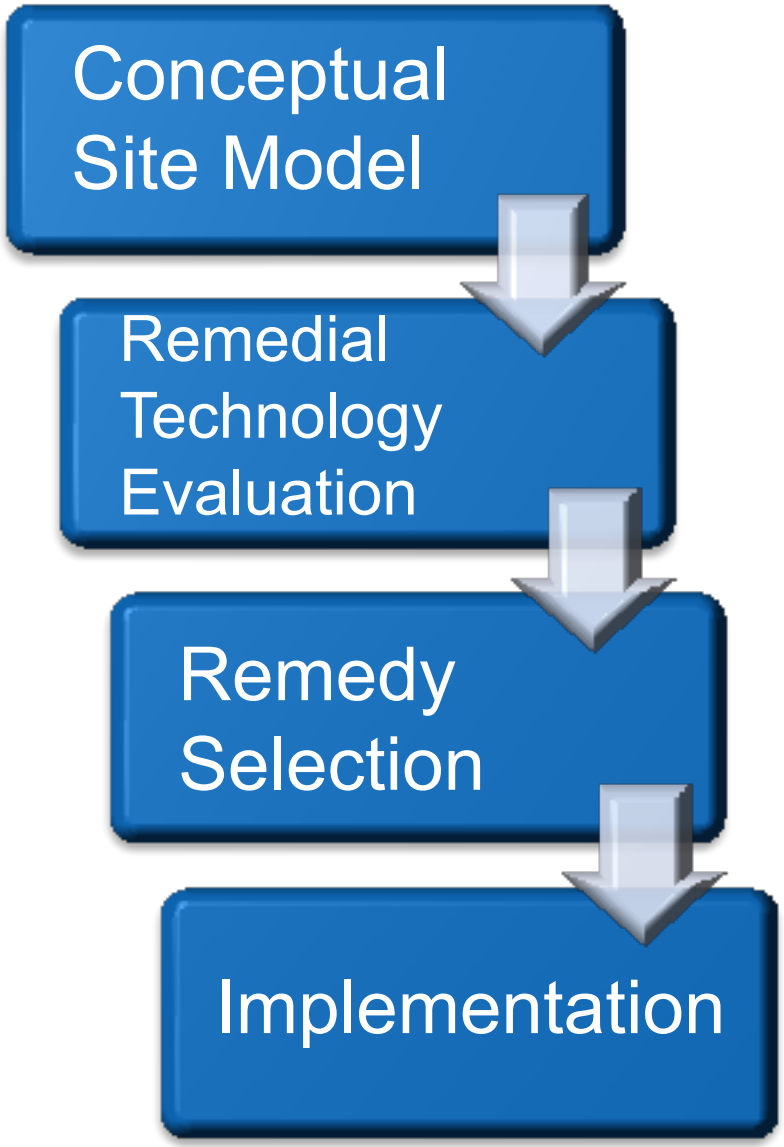
Site Background

- Active petroleum product storage and distribution facility located along a surface water body
- Light non-aqueous phase liquid (LNAPL) observed seeping beneath a bulkhead (seawall) at low tides
- LNAPL source was mitigated, and recovery efforts focused on removing LNAPL accumulating behind the seawall
- Occasional LNAPL seeping continued at low tides

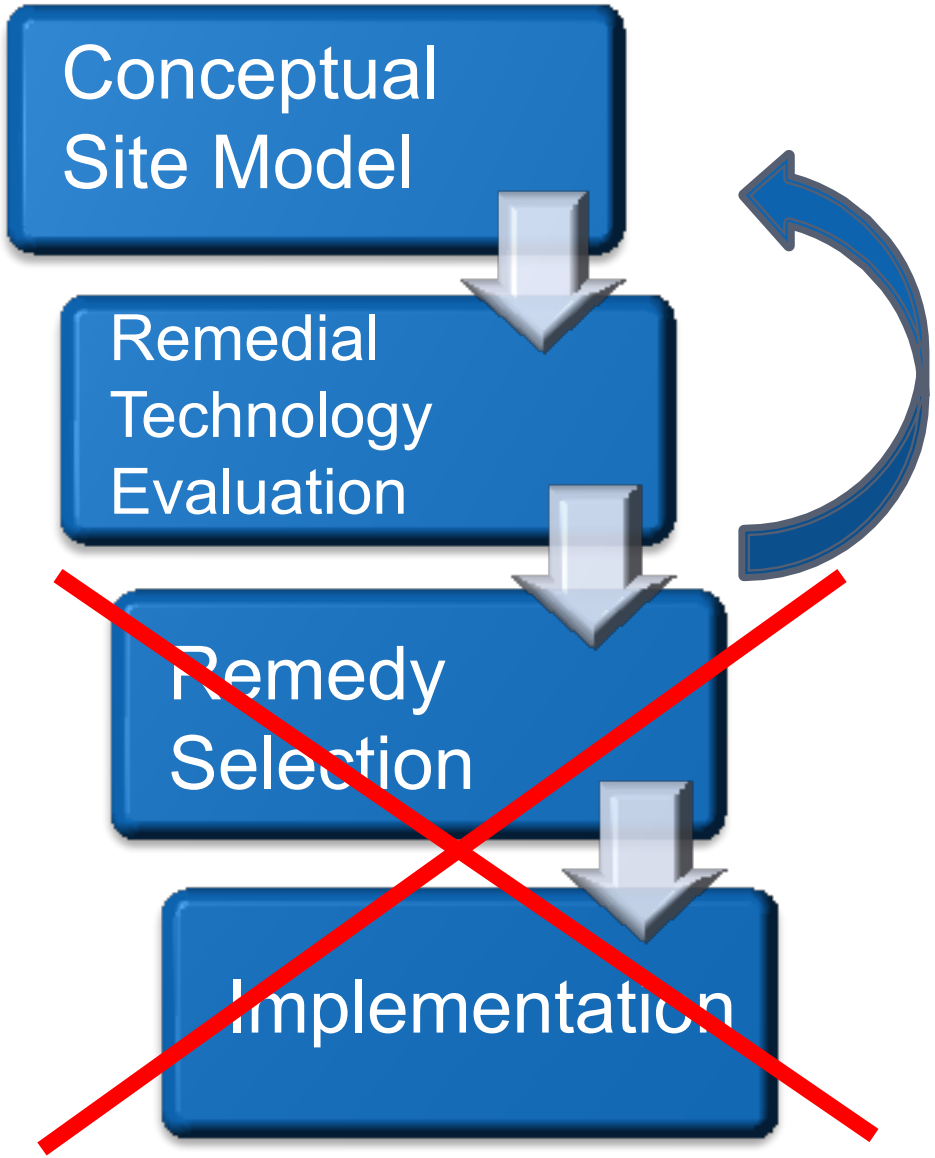
Project Objectives & Approach

- Primary remedial objective was to mitigate seepage of LNAPL at two areas along seawall
- Secondary remedial objective was removing mobile LNAPL and reducing dissolved-phase concentrations to acceptable levels to facilitate project closure



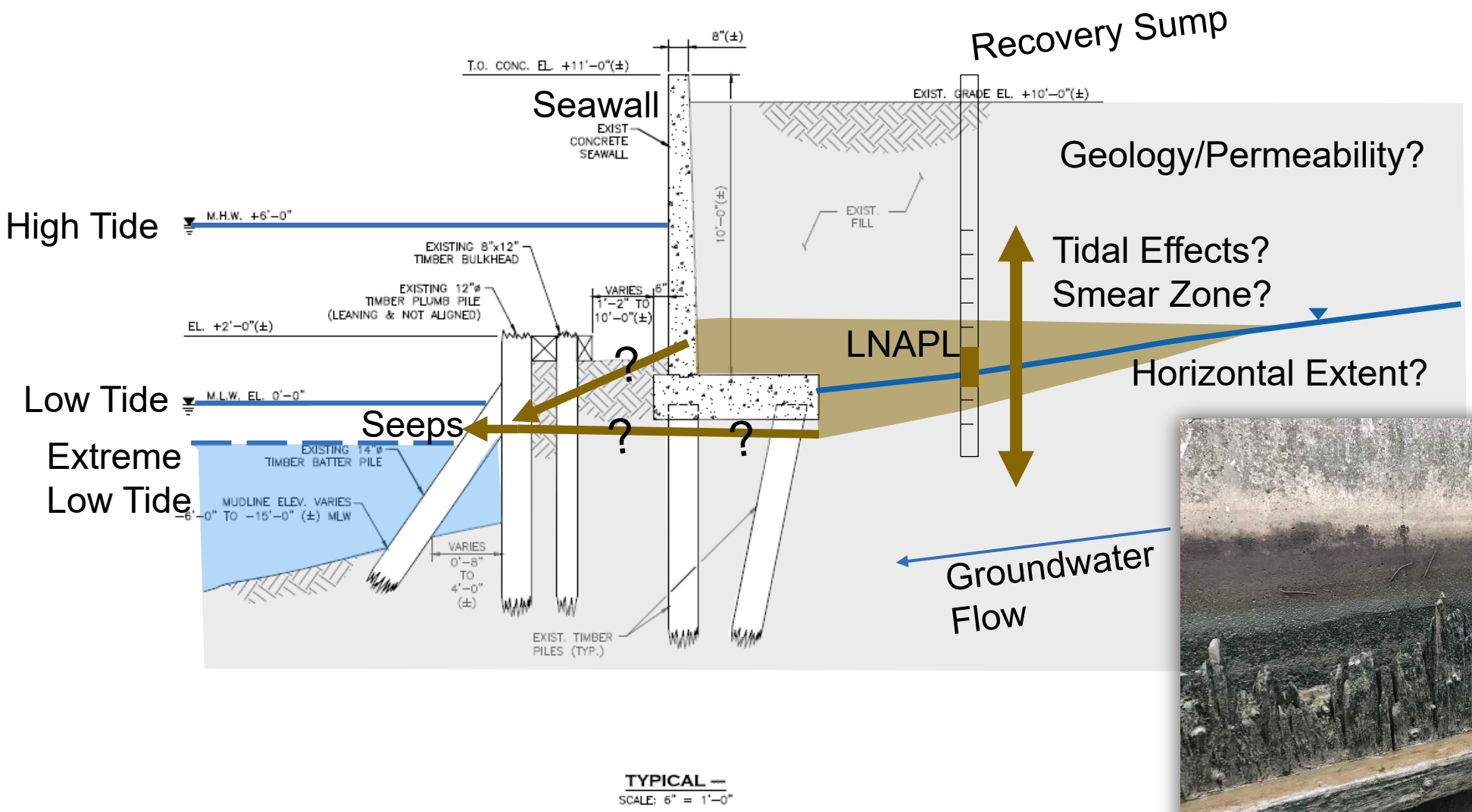


Methodology



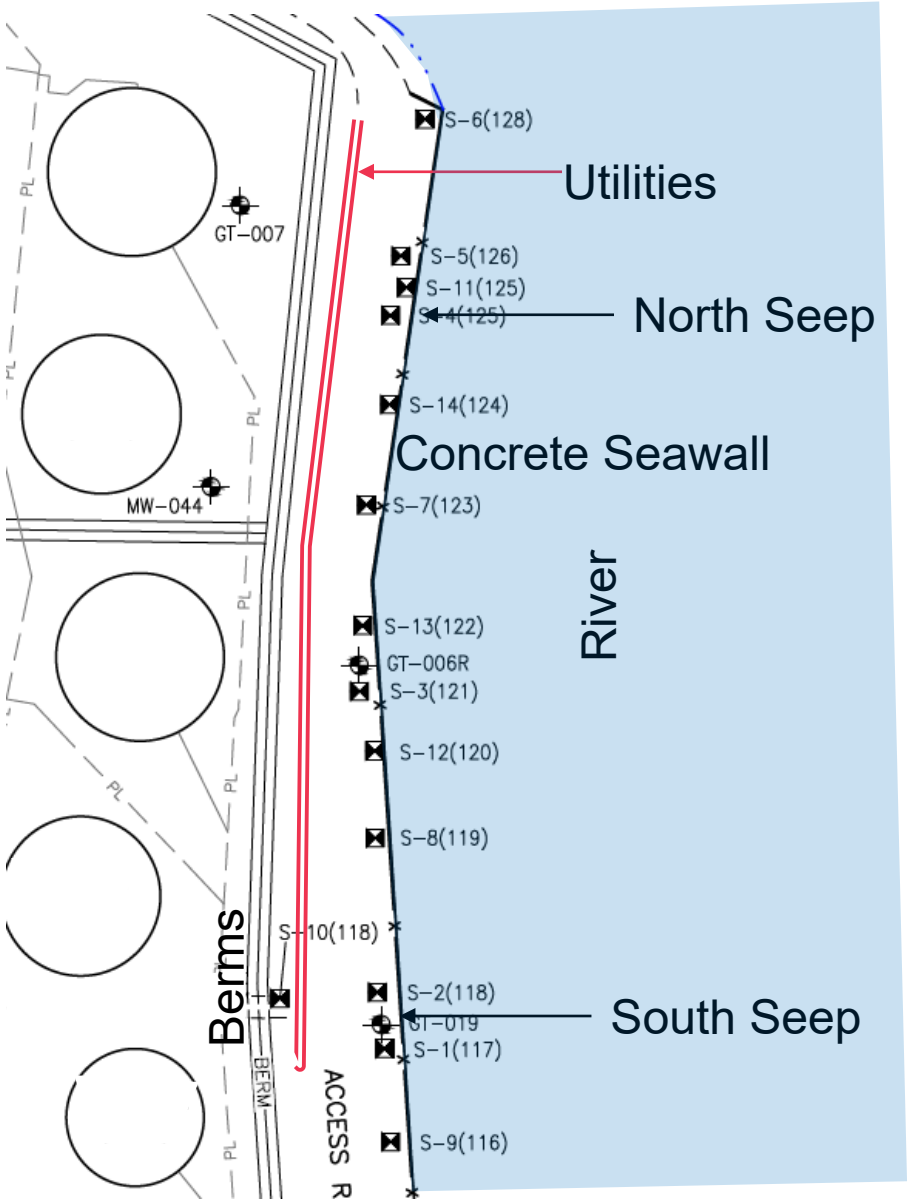
- Initial CSM developed during interim response
- Technology evaluations included geotechnical and structural engineering under strict safety protocols
- Maintaining the structural integrity of the seawall during and after remediation was paramount
- Feasible implementation of many ‘typical’ remedial options became a concern
- Remedial selection ‘hit a wall’ - Needed to revisit the Conceptual Site Model with new limitations

Conceptual Site Model



Remedial Technology Evaluation – Implementability Challenges/Key Factors

- Stability of Seawall –
  - Restricted activity within 8 feet of seawall
  - Hydrodynamic pressure concerns
- Space limitations (~30 feet accessible width)
- Groundwater
  - Tidal fluctuations and likely smear zone
  - Remedy affect on groundwater/LNAPL migration
- Geology
  - Fill and sand present; overlies silt/clay
  - Permeability not well understood
- No on-site wastewater treatment plant



Remedial Technology Evaluation

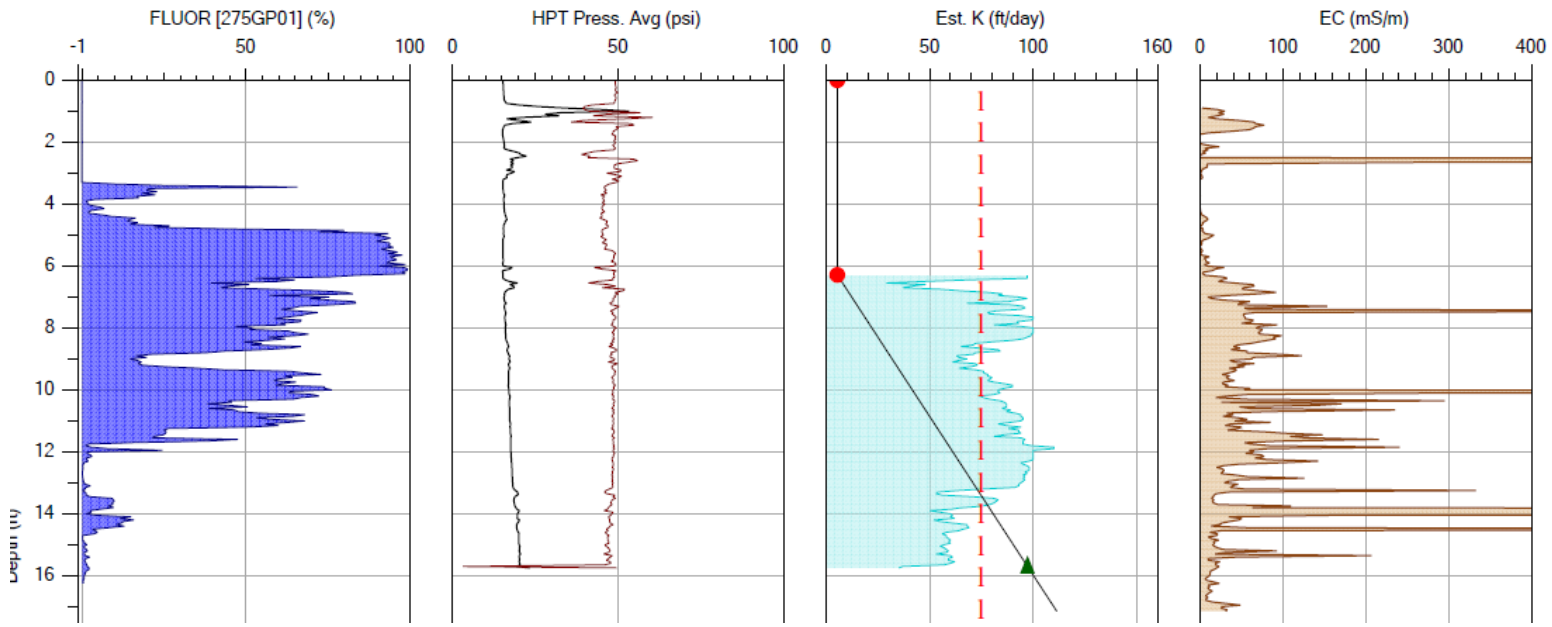
Remedial Alternatives	Effective	Implementable	Cost	Recommended for Further Evaluation	
Continued LNAPL Skimming	Low	Yes	$	Yes	
Horizontal Recovery Well	Medium	No	$$$	No	
Surfactant Flush/LNAPL Recovery	Medium	No	$$	No	
Steam Injection/LNAPL Recovery	Medium	No	$$$	No	
Excavation	High	No	$$$	No	
Bulkhead Moat	High	No	$$	No	
Impermeable Barrier	High	Yes	$$$	Yes	
Air Sparge/Soil Vapor Extraction	Low	Yes	$	No	
Permeable Barrier	High	Yes	$	Yes	
Funnel and Gate	High	No	$$$	No	
Barrier outside of Seawall	High	No	$$$	No	

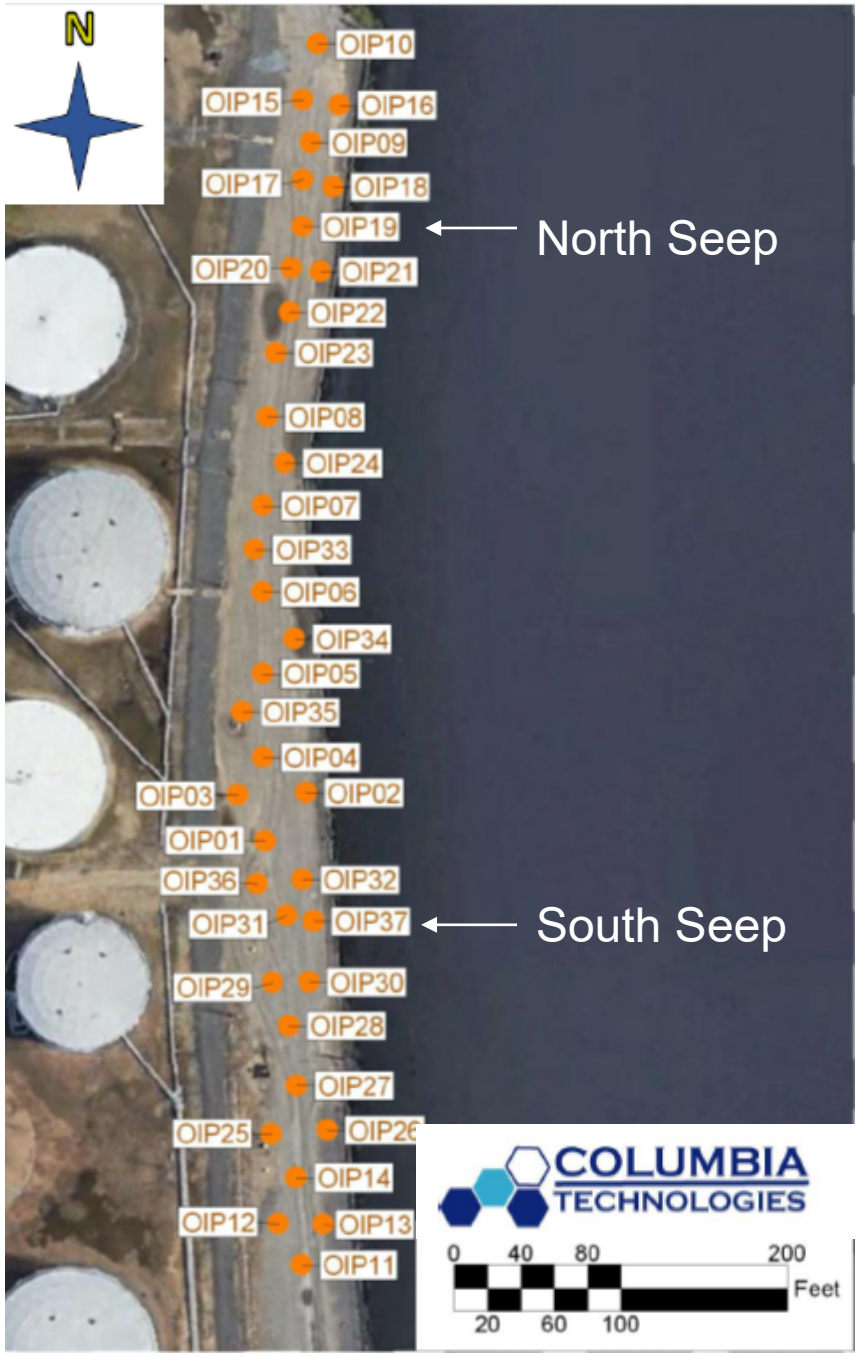
Data Gap Analysis

Data Gaps

- Delineate vertical and horizontal limits of LNAPL
- Soil structure and permeability data
- Contaminant mass

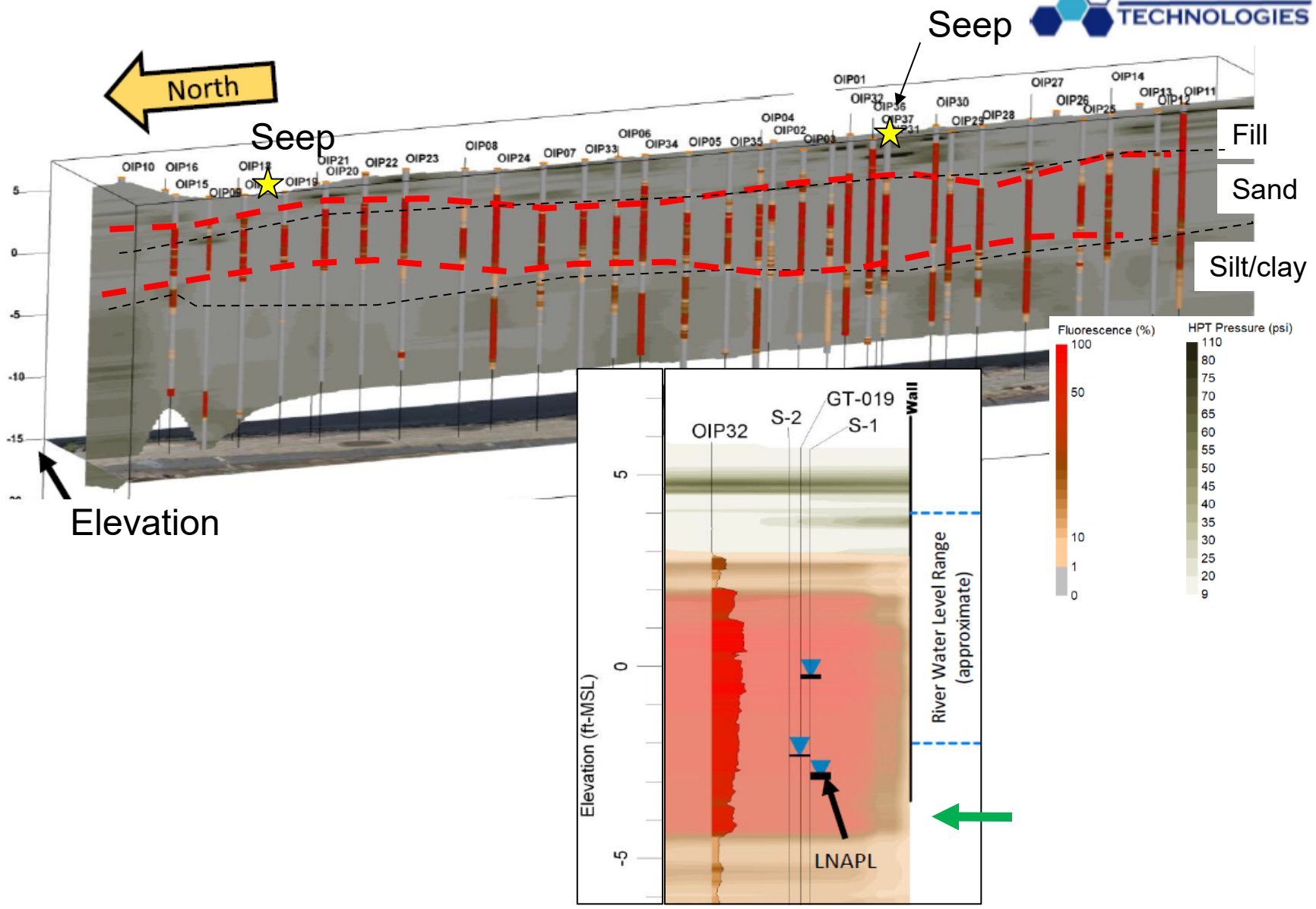
High Resolution Optical Image/Hydraulic Profiling Tool





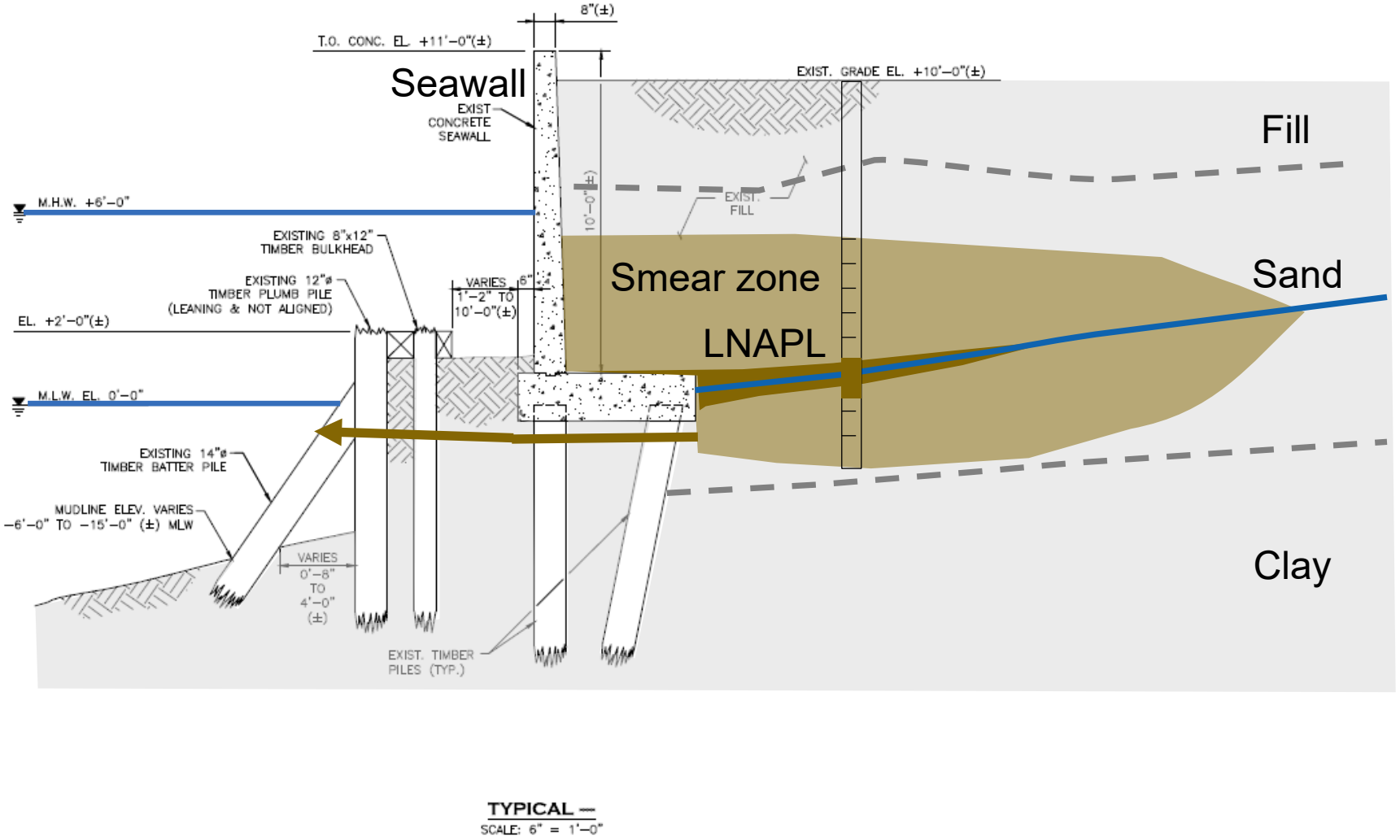
High Resolution OIP-HPT Investigation

- Three distinct geologic zones: Fill, Sand, Silt/Clay
- Clear vertical limits of LNAPL; extends beneath seawall
- LNAPL thicker near wall; LNAPL diminishes away from wall
- Showed majority of LNAPL limited to higher permeable sands



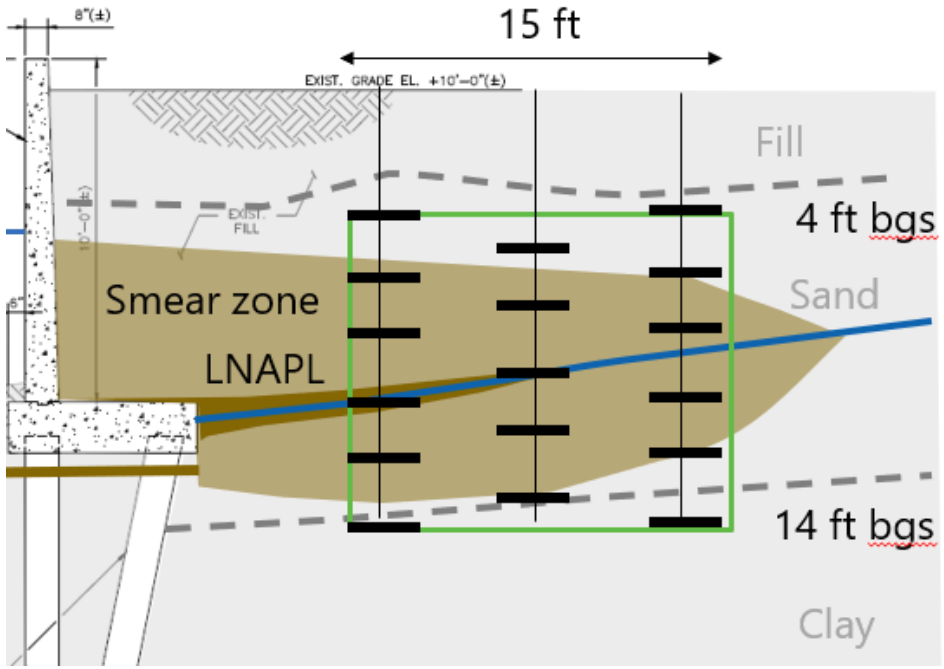
Updated Conceptual Site Model

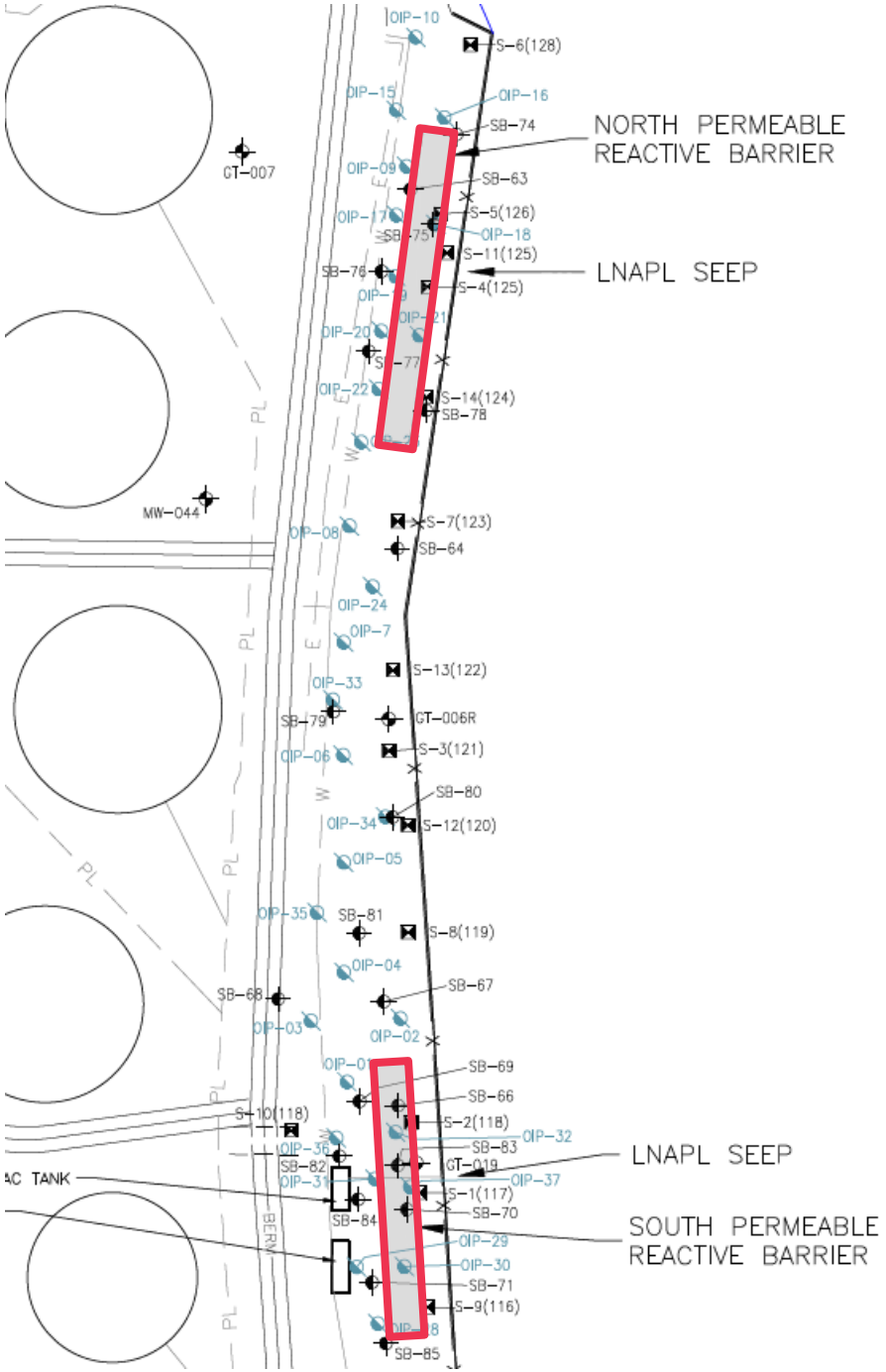
- Refined geologic understanding
- Interim response reducing LNAPL
- Mobile/Residual LNAPL in smear zone 5 ft - 12 ft bgs, corresponding with tidal fluctuation
- LNAPL primarily present in permeable sands
- LNAPL primarily within 20 ft of wall
- OIP Tool/Soil analysis quantified mass



Remedial Technology Selection

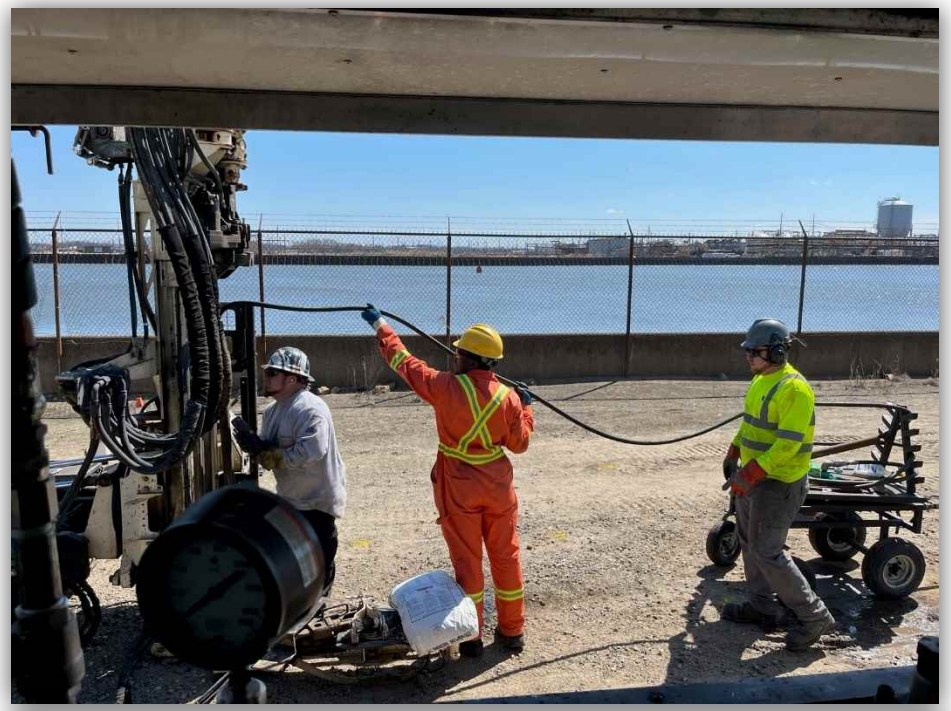
- Injectable Permeable Reactive Barrier using Activated Carbon Slurry with Bioremediation (BOS 200®)
  - Suitable for both LNAPL and dissolved groundwater impacts
  - Injectable using small Direct Push rig
  - Focus on seep areas, can expand treatment area as needed
  - Can augment with substrate as needed

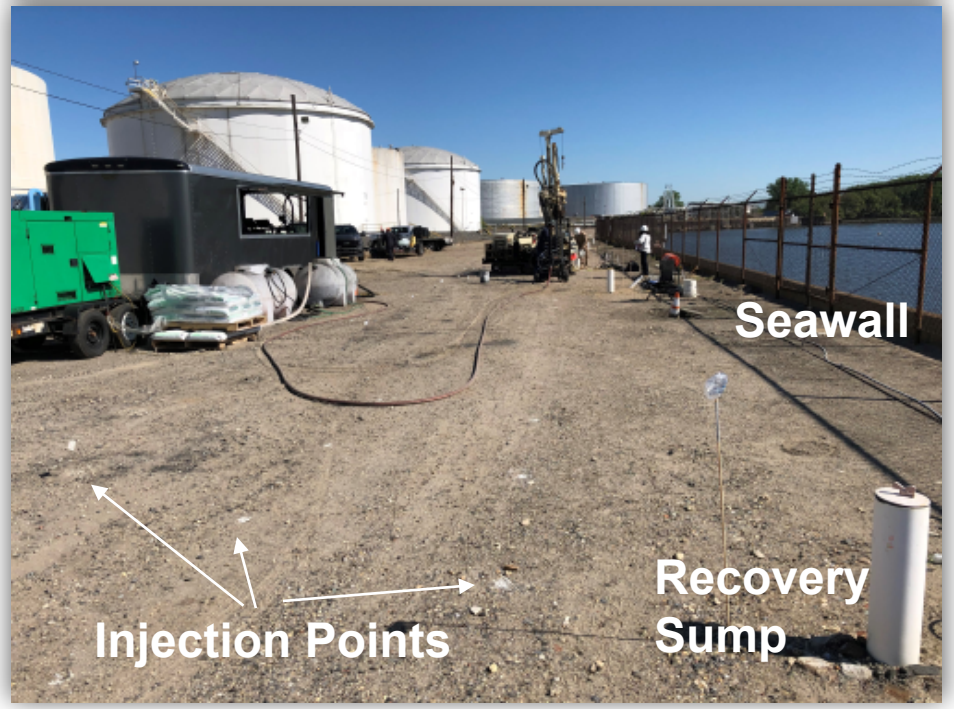




Remedial Technology Design and Implementation

- South PRB
  - 1,800 ft^2, 120 ft long, 76 points
  - 3 rows in triangular grid pattern at 5-ft spacing
  - Interval – 4 to 14 ft
  - 13,000 lbs BOS 200®
- North PRB
  - 2,200 ft^2, 145 ft long, 88 points
  - 3 rows in triangular grid pattern at 5-ft spacing
  - Interval – 4 to 14 ft
  - 15,850 lbs BOS 200®
- Post-Injection Monitoring:
  - Performance monitoring for VOCs
  - EA/Nutrient monitoring for substrate augmentation
  - Routine LNAPL gauging along seawall



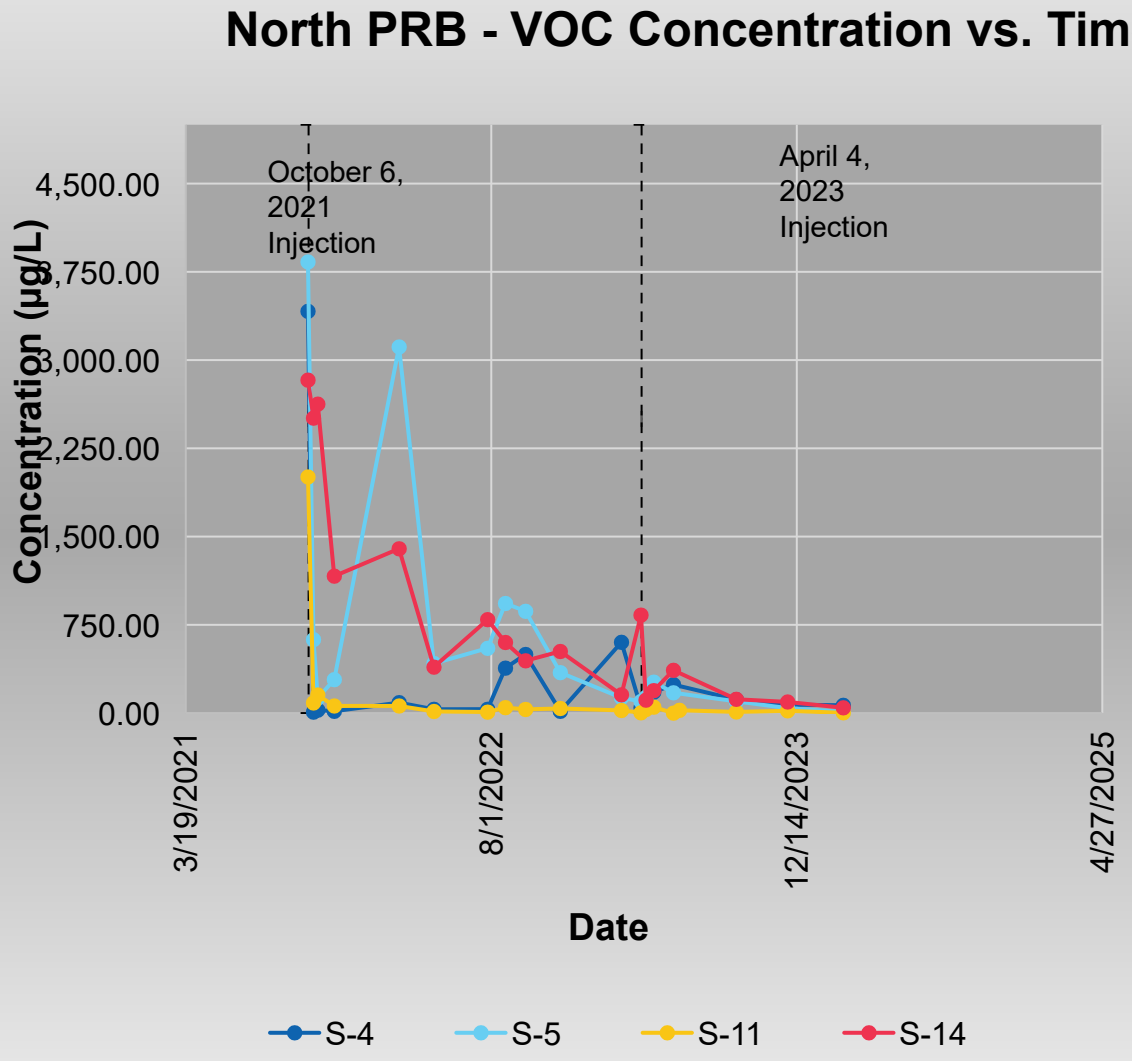


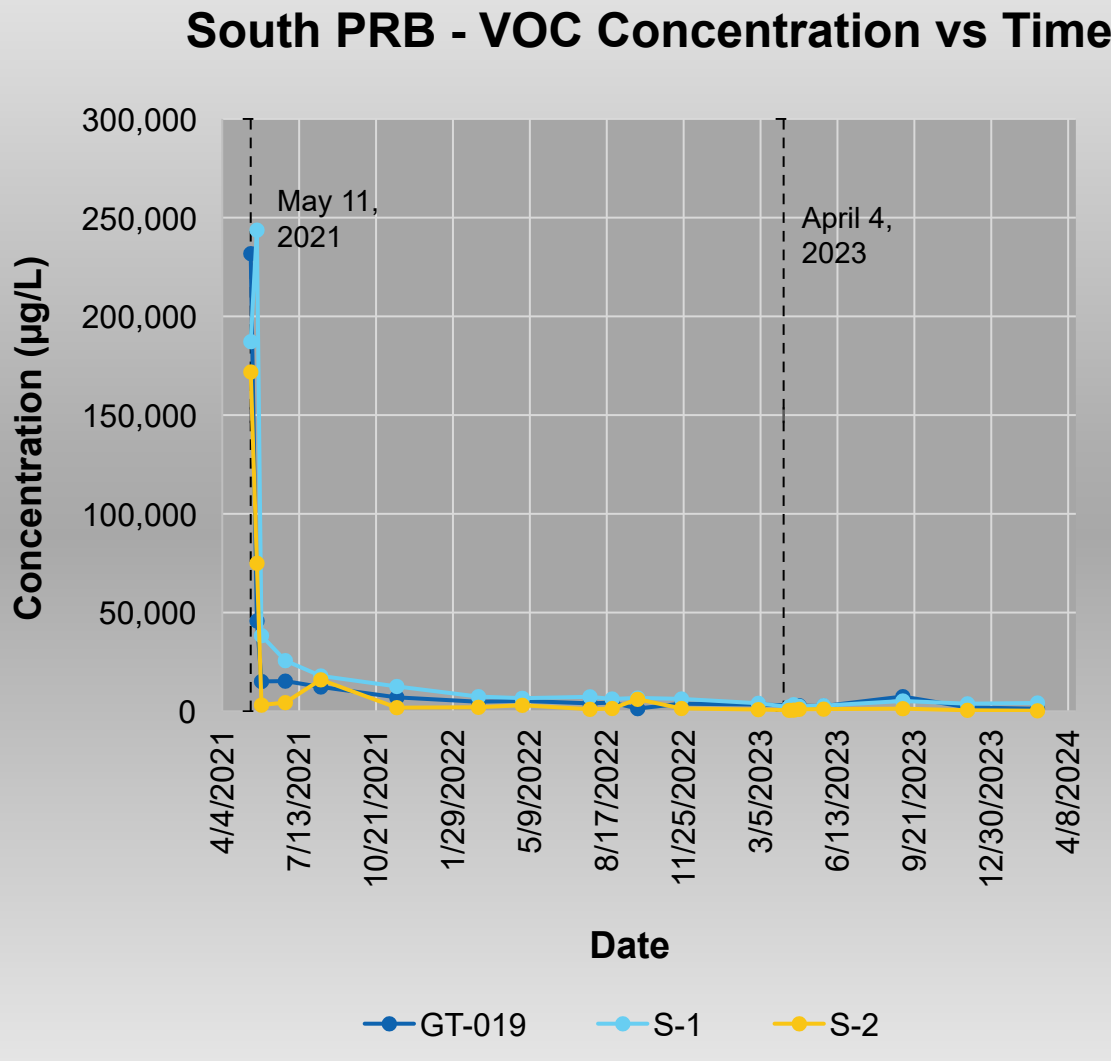
Results

- Initial Conditions:
  - LNAPL thicknesses up to 1.6 feet along seawall; sheening observed at low tides
  - Dissolved-phase hydrocarbons up to 230 ppm total VOCs
  - Soil concentrations up to 4,700 ppm BETX

Metric	1st Full Scale Injection (2021)	2nd Full Scale Injection (2023)
LNAPL observed at downgradient edge of injection grid	Trace LNAPL at 1 of 7 sumps	LNAPL not detected
Performance Monitoring - VOCs	>90 % Reduction	>95 % Reduction
Sheening observed in river	None	None
Seawall condition	No impact	No impact

Performance Monitoring Results





Summary and Conclusions

- Maintaining the stability of the seawall required reevaluation of remedial approach
- Data gap assessment and revised CSM resulted in successful remedy selection and design
- Successful outcomes:
  - No damage to seawall
  - LNAPL not observed
  - Dissolved phase concentrations reduced >95%
  - No sheening since 1st injection (just passed 3 years)
- Sulfate concentrations enduring longer than anticipated
  - Continued elevated sulfate concentrations in post-injection monitoring show positive results of the injections and long-term effectiveness of the remedy
- OIP/HPT tool gave us confidence that material could be injected successfully, despite present of fill; injection duration reduced 75% from original estimate

THANK YOU

Co-Author:
Tim Uhler (tuhler@gesonline.com) Groundwater & Environmental Services, Inc.