



**An Innovative and Cost-Effective Approach to DNAPL Removal
from Sediment Deposits in the Tittabawasse River**

Battelle: 2019 Sediments Conference

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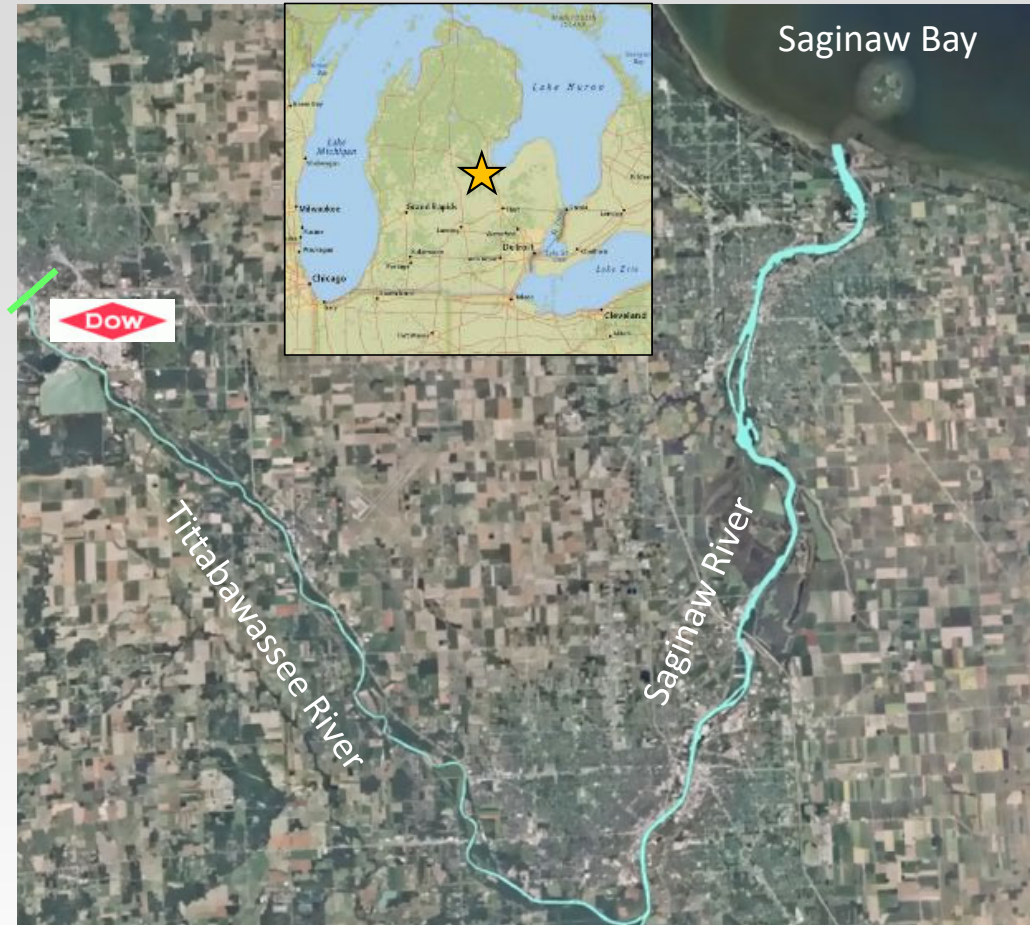
Outline

1. Background
2. DNAPL Removal Design
3. DNAPL Removal Implementation
4. Recovery Monitoring and Optimization
5. Residual In Situ Containment
6. Results and Lessons Learned



Site Location

- Dow plant located in Midland, MI
- Tittabawassee River
 - From plant to confluence with Saginaw River (24 miles)
- Divided site into 7 manageable units (river segments)
- Presentation focuses on Segment 1 of the Tittabawassee River
 - 3 mile stretch next to the Dow plant



DNAPL Release and Source Control

- Historical operations led to the release of dense non-aqueous phase liquid (DNAPL) into the River
- Resulting in DNAPL accumulation in the river sediments, adjacent to facility
- Beginning in the 1930s, Dow controlled wastewater discharges to the Tittabawassee River through wastewater treatment technologies
- A groundwater revetment system (RGIS) was installed in the 1970s that creates a barrier around the plant, preventing the migration of untreated groundwater to the river



Segment 1 and RGIS

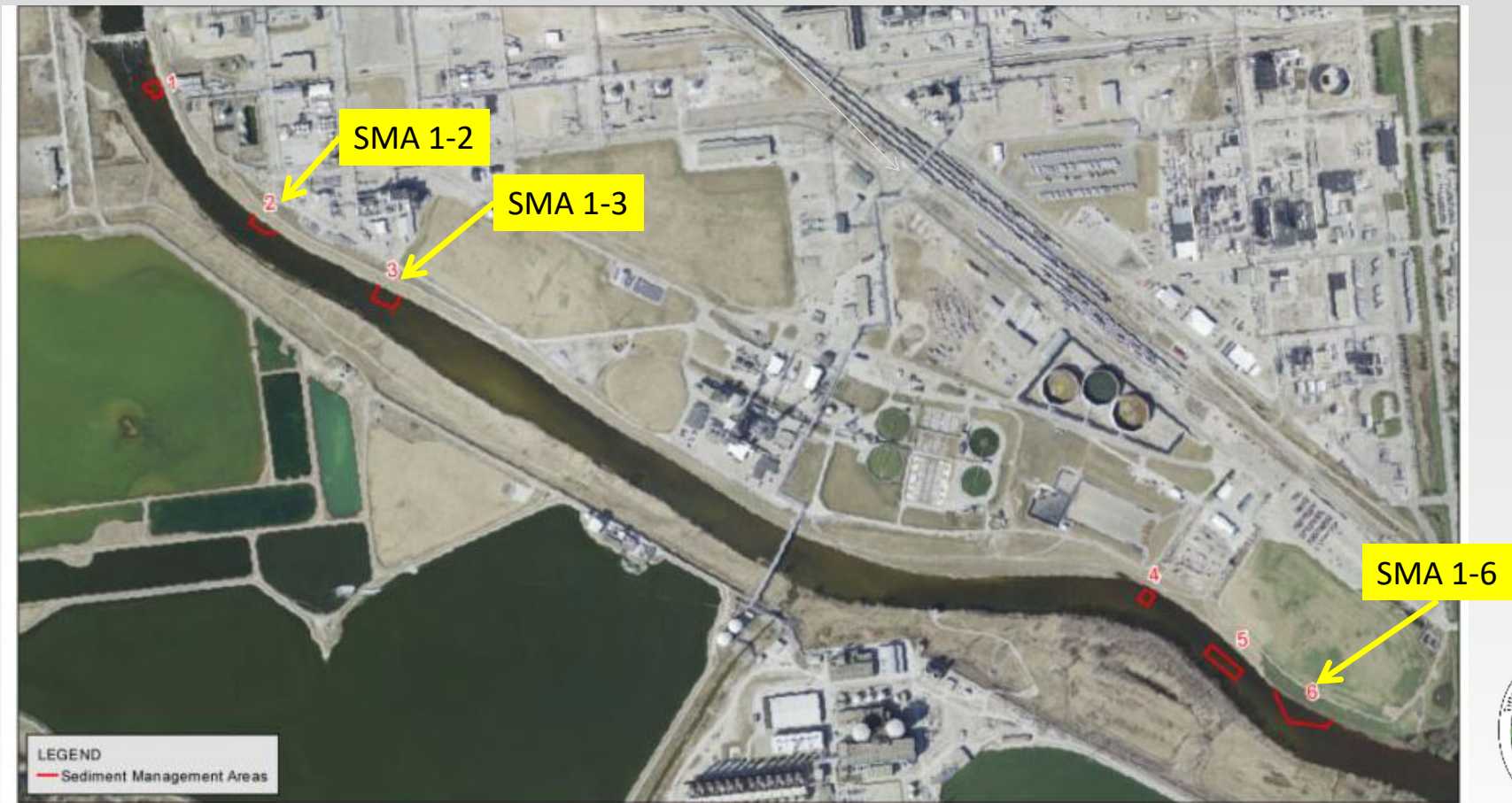


DNAPL Discovery and Identification

- DNAPL was identified in the Tittabawassee River sediments while investigating furan and dioxin impacts
- DNAPL deposits occurred in isolated areas in sandy sediments, overlying a low permeability till
- DNAPL settled in low areas and depressions on till layer
- DNAPL consisted of a mix of chlorinated volatile organic compounds, predominantly chlorobenzenes
- Sediment management areas (SMAs) were established at each of the DNAPL deposit areas



Segment 1 SMAs – DNAPL Deposits



Remedial Objectives

1. Safely remove free phase DNAPL prior to installation of sediment containment system
2. Delineate horizontal extent of DNAPL deposits during removal operation
3. Prevent exposure of DNAPL to remedial workers and the environment during removal



Pre-Design Study - Bail Down Test

- Installed 9 wells through sandy sediment, into top of till
- Wells sampled to determine if free phase DNAPL was present
- Bail down test were conducted over a period of 5 to 12 days to determine recoverability of DNAPL
- Test results showed that 3 SMAs contained free phase DNAPL
- DNAPL had a low viscosity, it could be pumped from the wells and the wells generally recovered within 24 hours

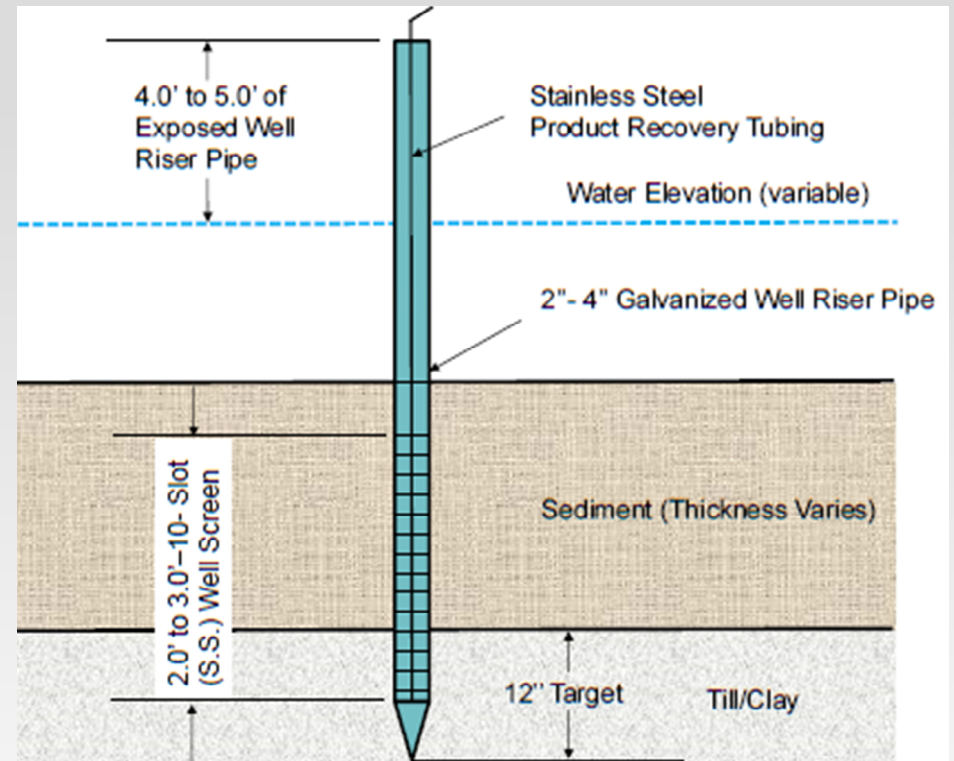


Passive Extraction Well Design

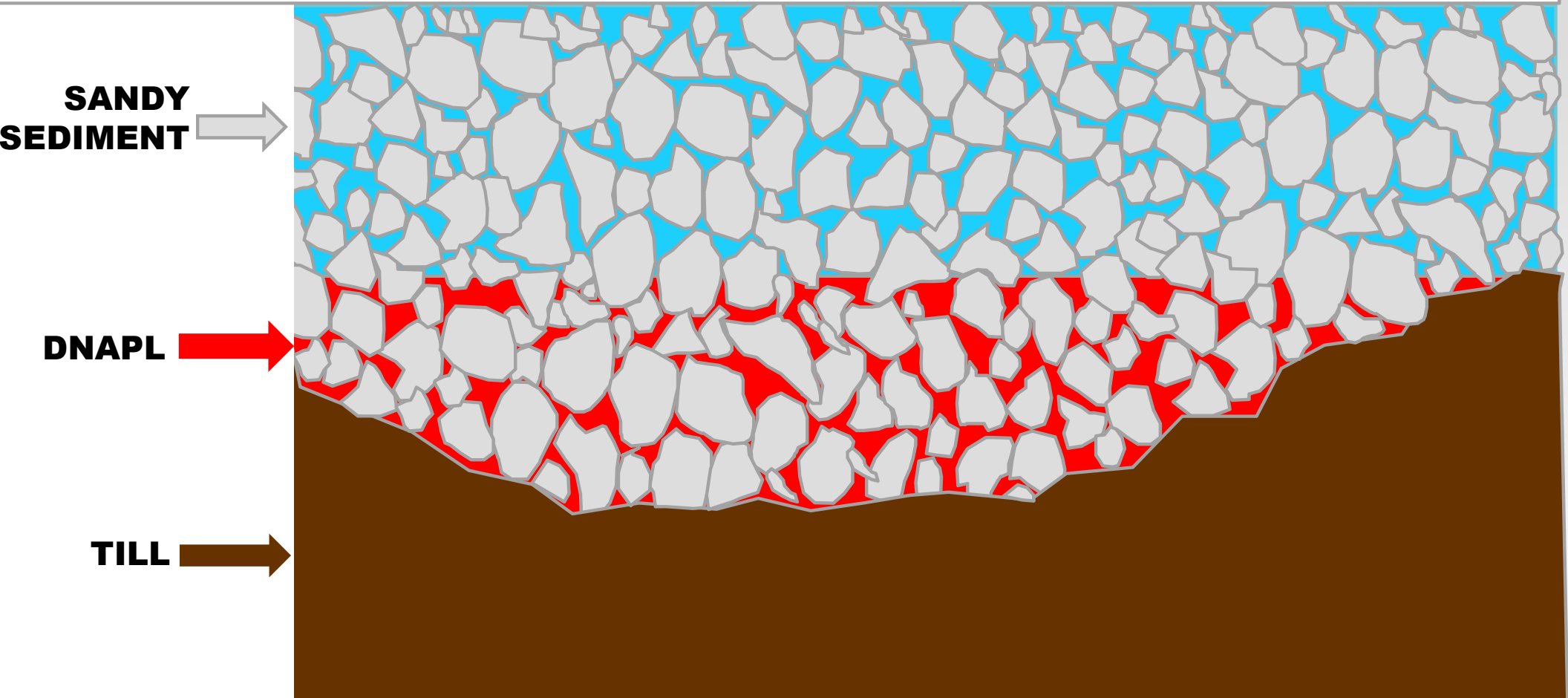


Passive Extraction Well Design

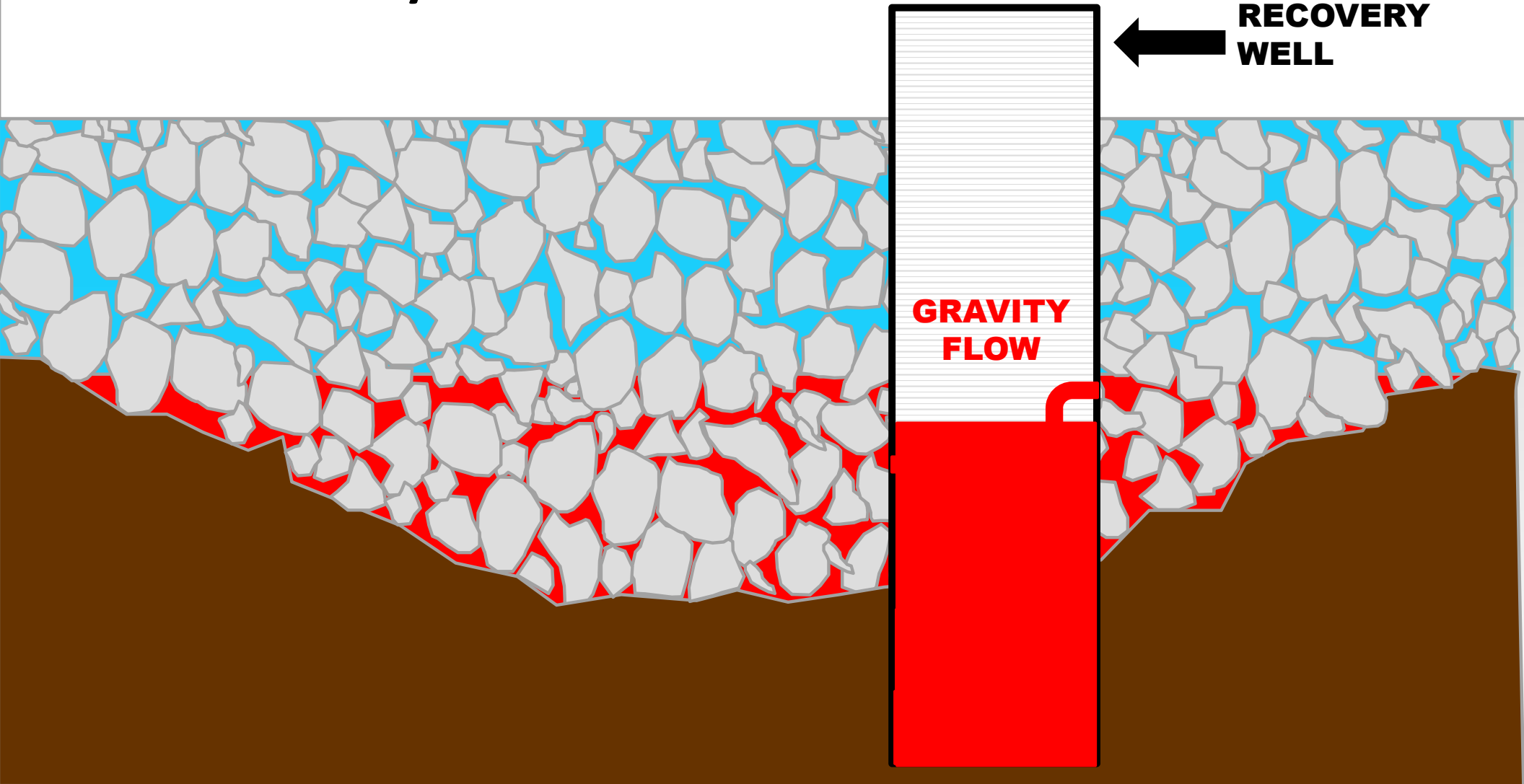
- The free phase DNAPL was removed using vertical recovery wells installed through the sandy sediment and into the low permeability till
- These in-river extraction wells also served as monitoring wells to evaluate the presence of recoverable DNAPL
- Additional recovery wells installed in DNAPL deposit, generally spaced 10 feet apart



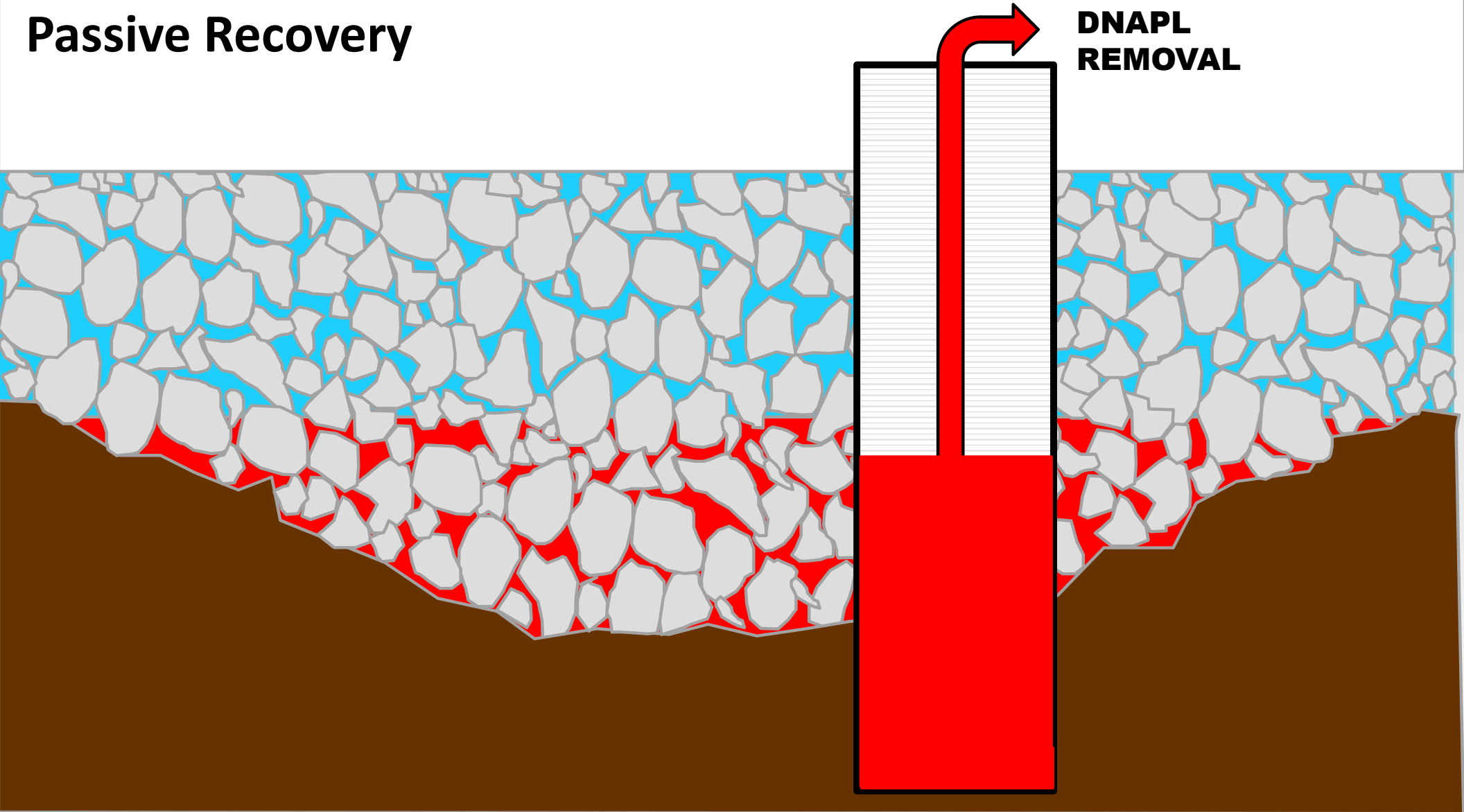
Passive Recovery



Passive Recovery

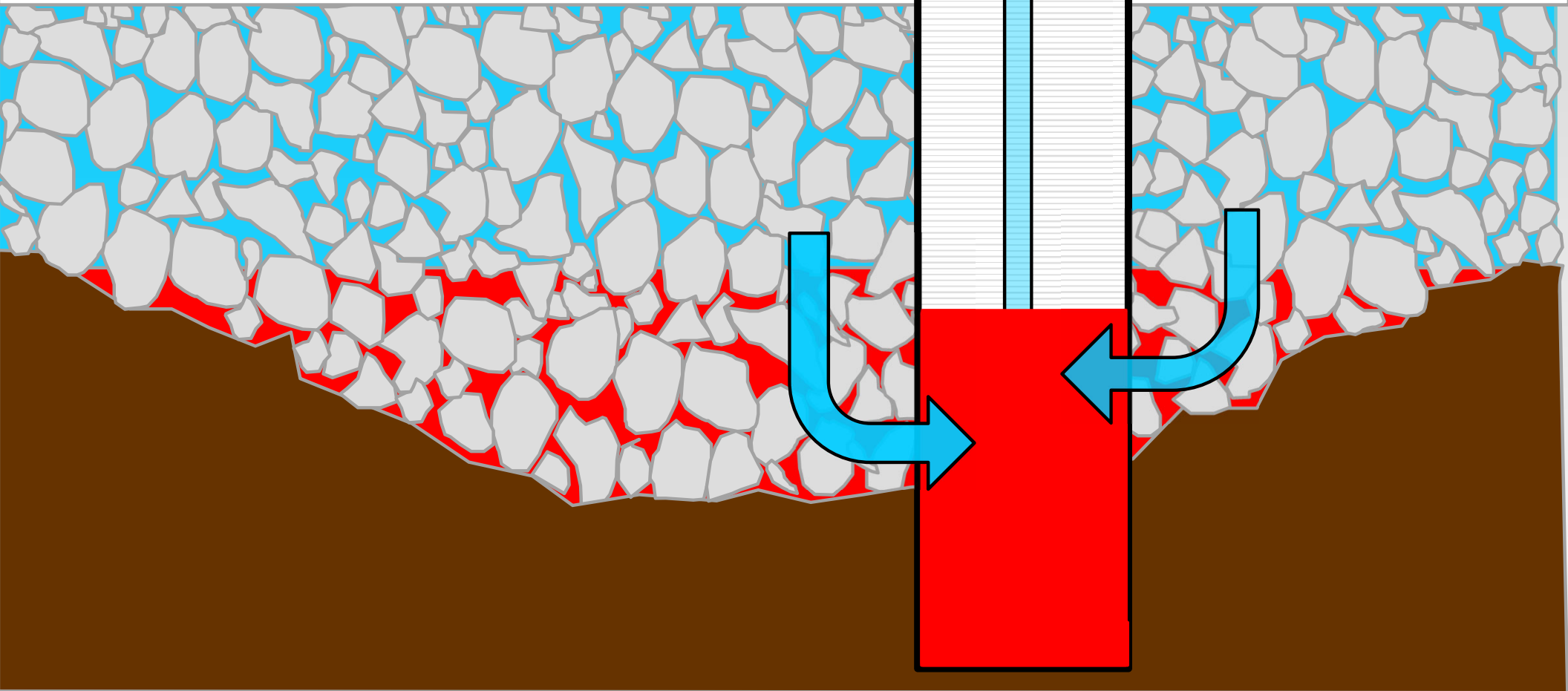


Passive Recovery



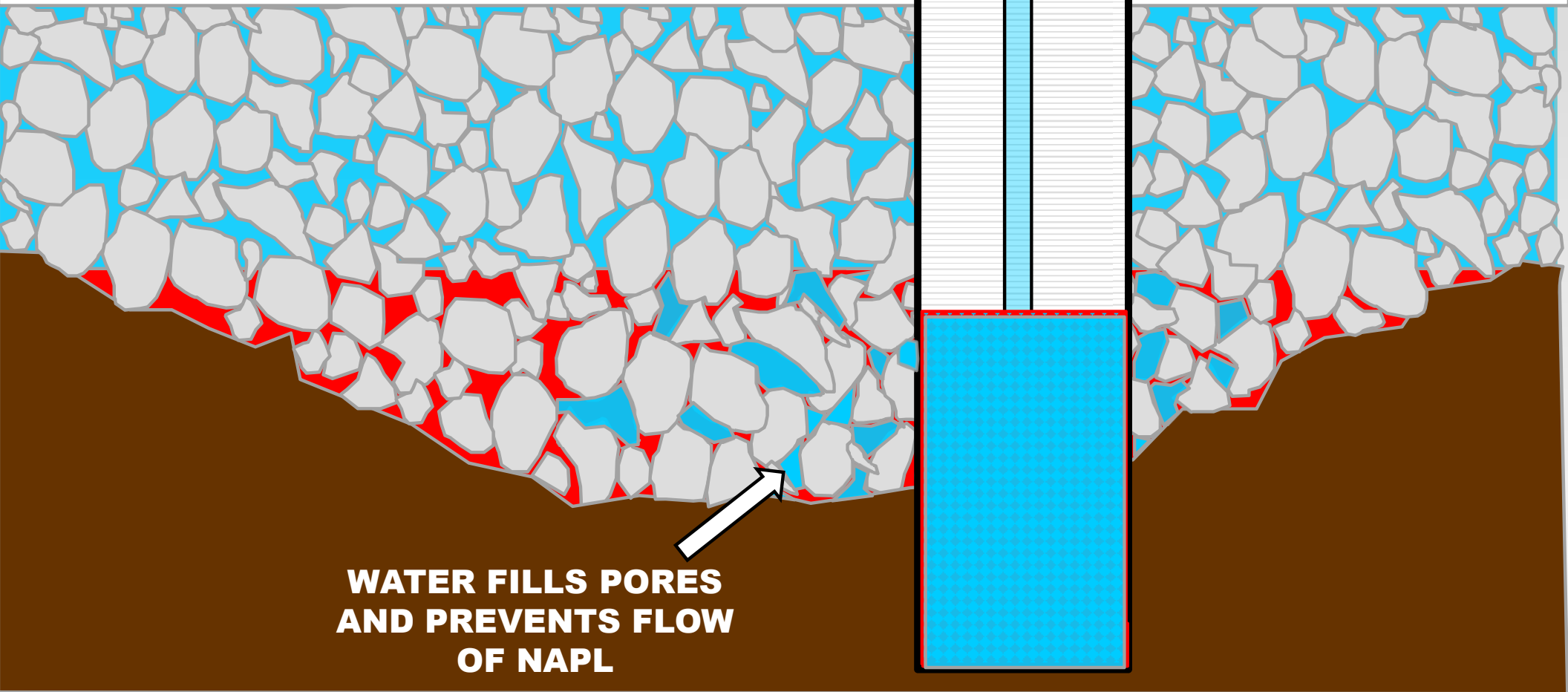
Active Recovery

**ACTIVE
PUMPING**



Active Recovery

**Active
Pumping**



**WATER FILLS PORES
AND PREVENTS FLOW
OF NAPL**

Recovery Well Installation and Operation



Recovery Well Installation and Operation

1. Recovery well casings installed using a sonic drill rig mounted on a pontoon boat
2. Developed well using a surge block and submersible pump
3. Allowed well to recover
4. Tested well with oil interface probe to determine the presence of recoverable DNAPL
5. Removed DNAPL collected from each well using a peristaltic pump
6. Monitored DNAPL collection into well using oil interface probe and continued to removed DNAPL using a peristaltic pump
7. Performed shut down procedures for each well to confirm DNAPL recovery completed



Sonic Drill Rig During Well Installation



Recovery Pontoon Boats



Sink and Collection System



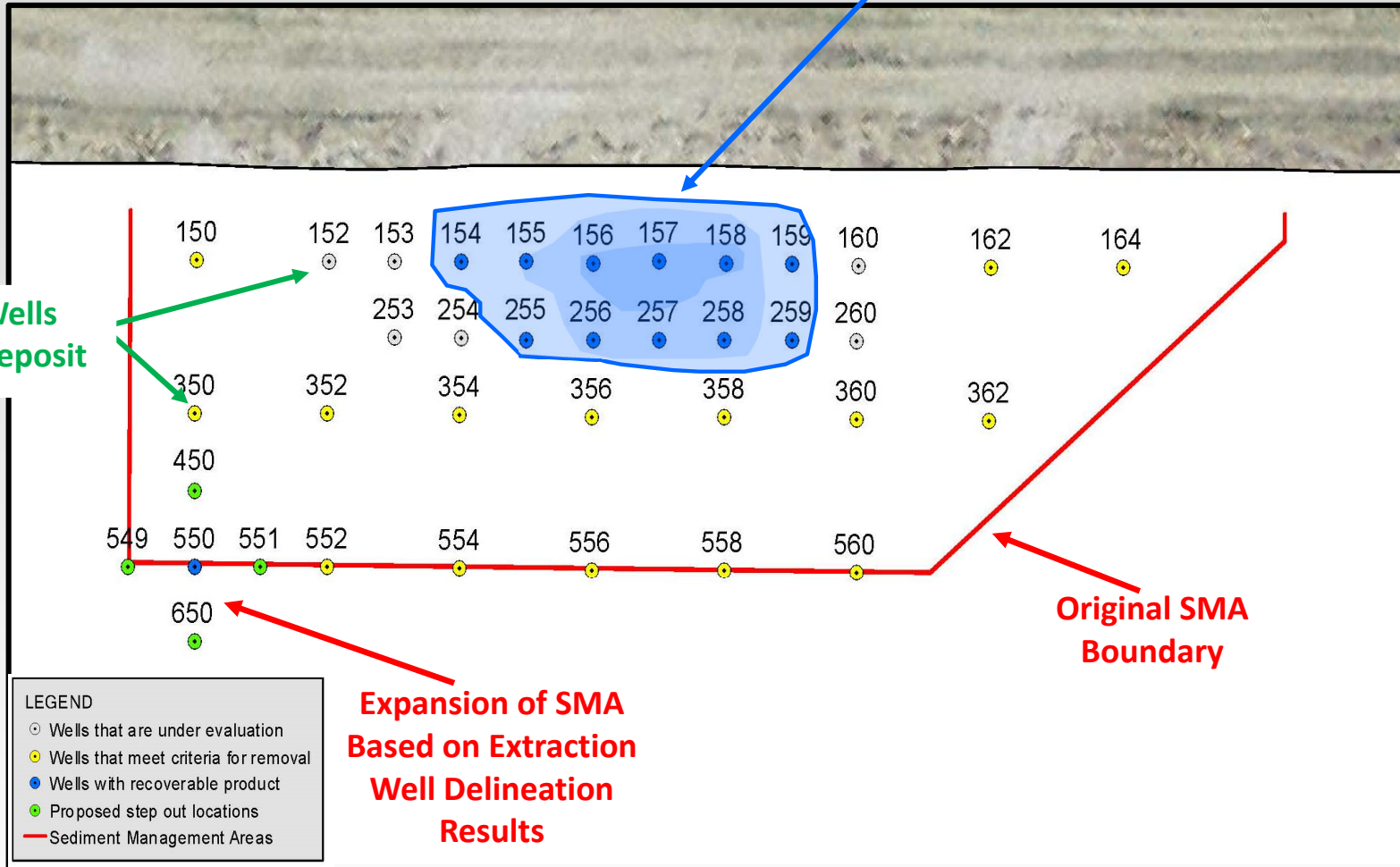
Pontoon Boat Collection System



DNAPL Deposit Delineation

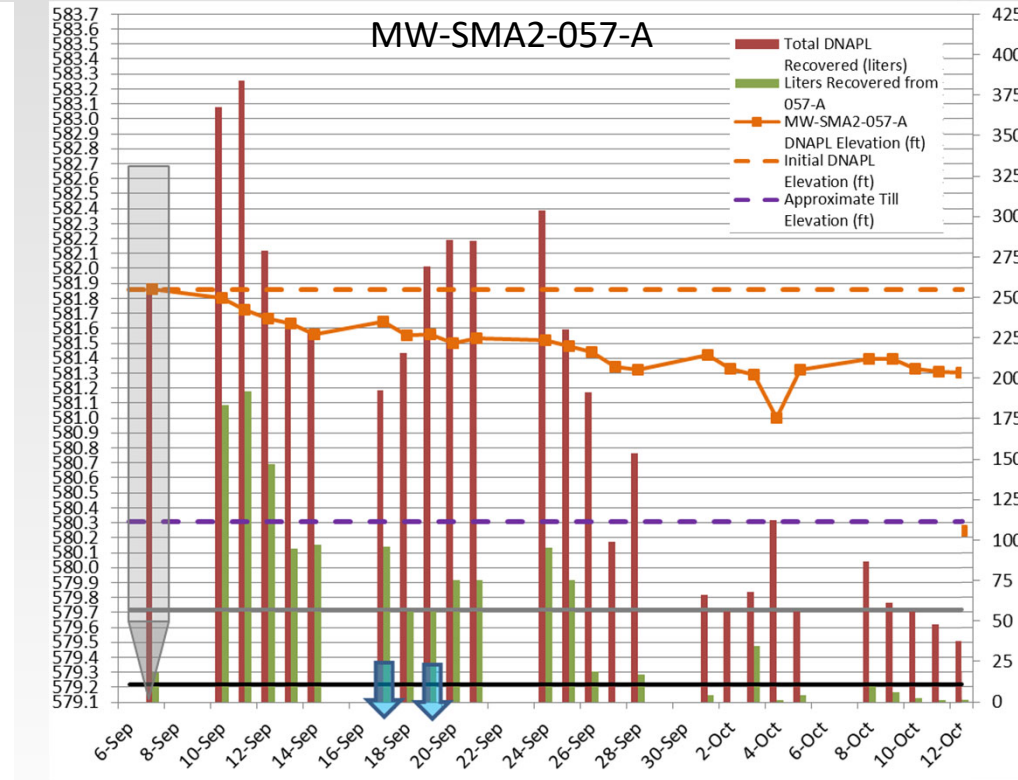
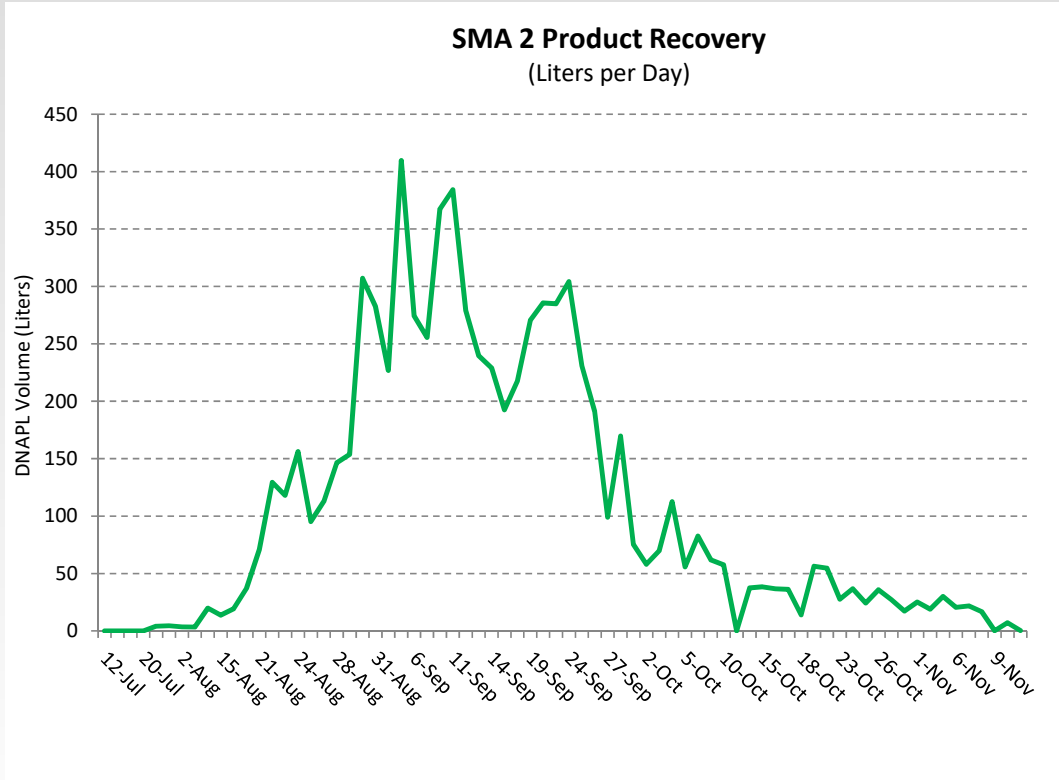
Extraction Wells with Recoverable DNAPL

Extraction Wells Delineating Deposit



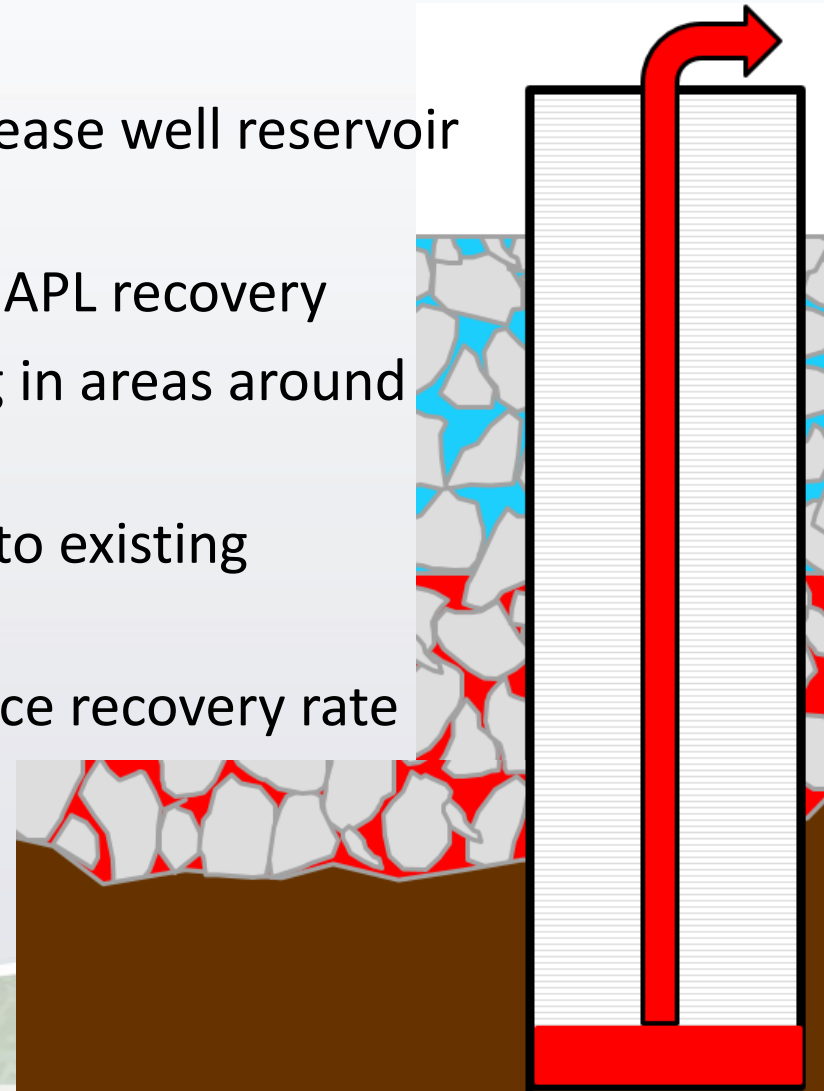
DNAPL Recovery Monitoring

- Removal frequency and volume was tracked for each well, and the information was used in real time to optimize recovery.



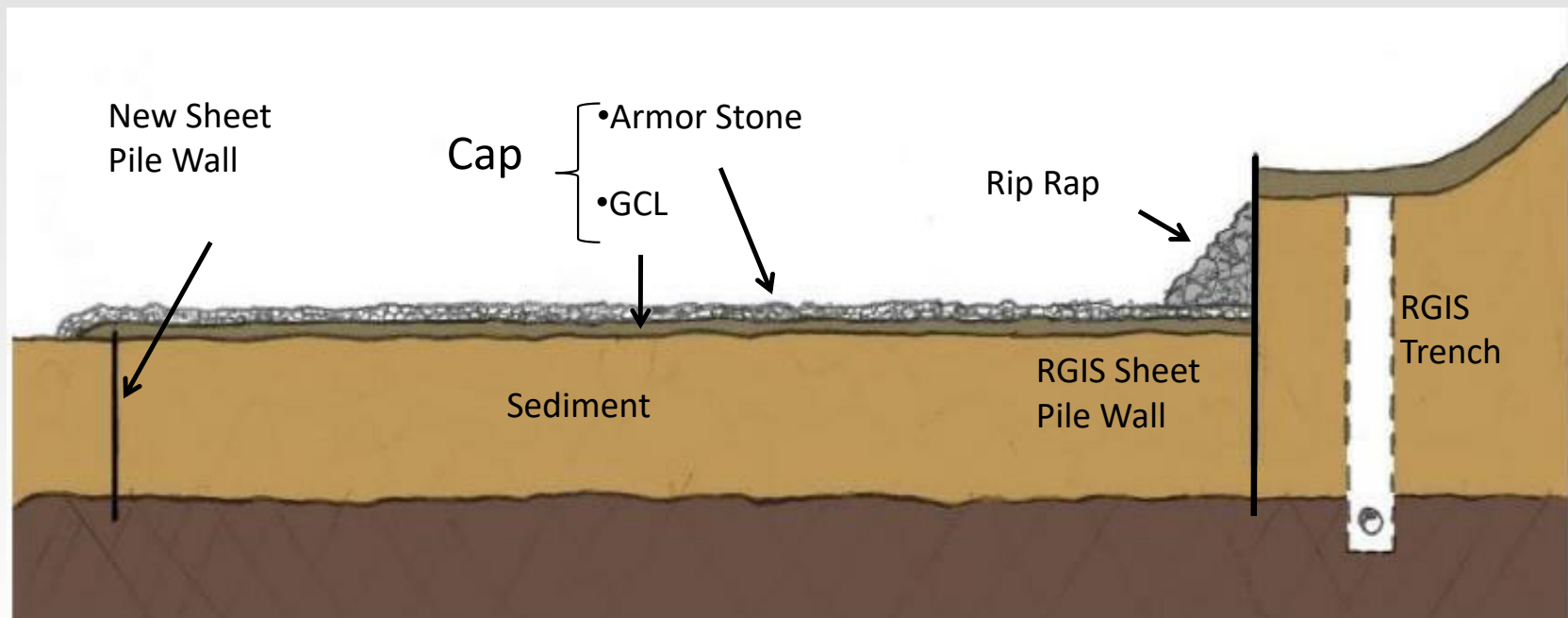
DNAPL Recovery Optimization

- Pushed wells deeper into the till unit to increase well reservoir capacity
- Adapted pumping frequency to optimize DNAPL recovery
- Installed additional wells in a tighter spacing in areas around productive wells
- Installed additional recovery wells adjacent to existing productive wells
- Installed larger diameter wells (4") to enhance recovery rate



Residual In Situ Containment

- Following the removal of free phase DNAPL, the residual DNAPL deposit areas were contained using sheet pile walls and an impermeable cap.



Results

- More than 4,200 gallons of DNAPL were recovered and incinerated
- Less than 4,000 gallons of water recovered
 - Mostly during well development, very little during DNAPL recovery
- Approximately 380 wells were installed for this project
- Work was conducted safely during 10 months of operation over 2 construction seasons
- DNAPL was safely managed, it was never exposed to the environment (i.e. water and fish), resulting in a very safe removal process.
- The successful DNAPL removal program allowed the EPA and the MDEQ to approve the in-situ containment remedy for residual DNAPL
- Dow has received a Notice of Completion of Work for Segment 1



Lessons Learned

- Till topography (low points in the till layer) were successfully used to identify and delineate DNAPL pools
- DNAPL deposits were delineated concurrent with the removal process, saving significant in river time and costs
 - Dedicated drilling equipment facilitated quick delineation and recovery well optimization
 - Decision tree developed to identify next steps based on well recovery results
- Passive recovery proved to be an effective method to recover the free phase DNAPL
 - DNAPL needs to be free phase and flowable
 - Continuous pumping would have recovered more water and less DNAPL
- Clean incident free removal, no exposure to environment or workers
- While labor intensive, removal method proved to be a very cost effective approach



Acknowledgements

- Todd Konechne – Project Coordinator



- Chris Bowen – Construction Manager



- Troy Wyss



- Mary Logan – USEPA

- Allan Taylor - MDEQ

