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UPRR Tie Treating Plant, The Dalles, OR

DNAPL Recovery Progress

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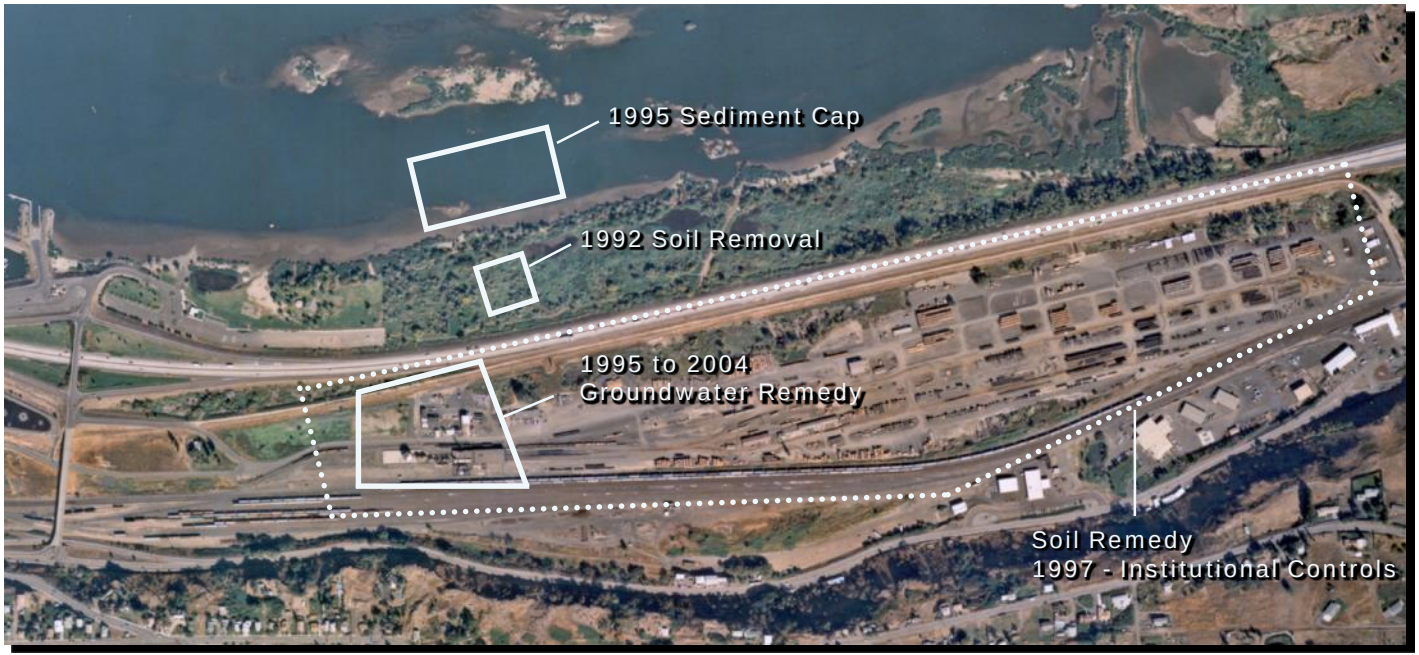
Overview

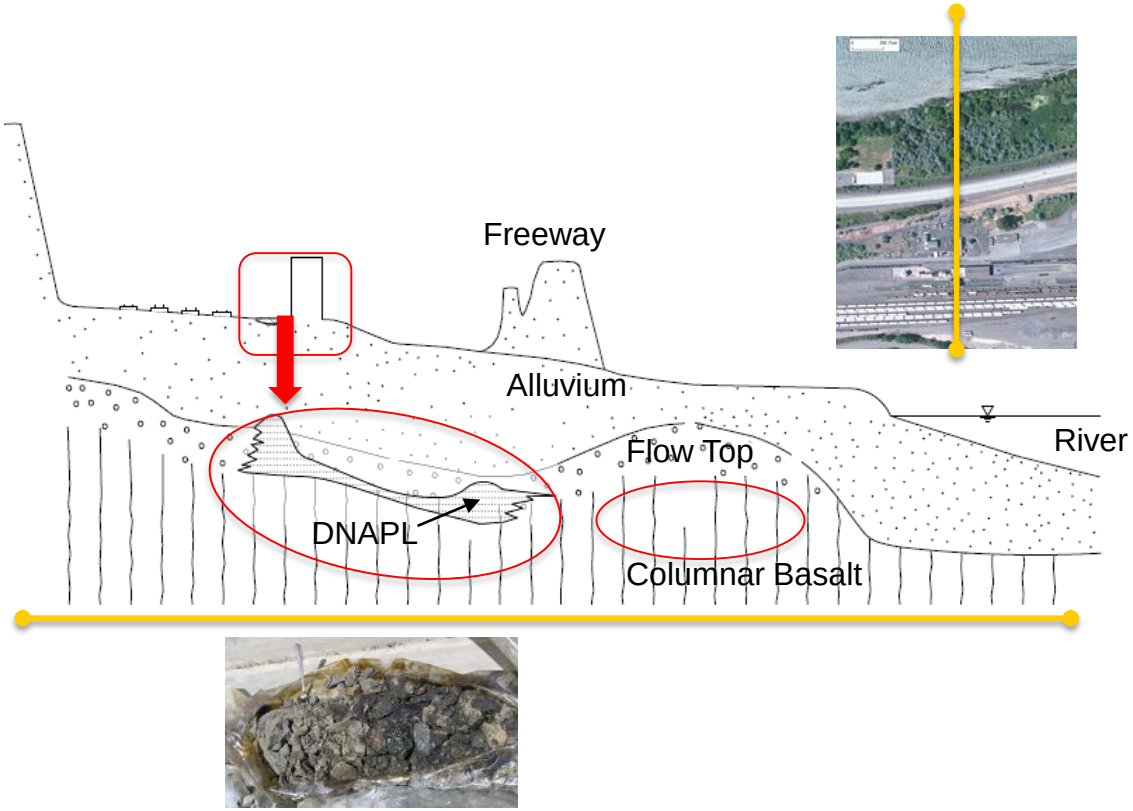
- Historic wood treating operations led to releases of creosote oil to the environment
  - This DNAPL is difficult to treat
- In 1997, a multi-faceted remedy was implemented to control migration of impacted groundwater and remove DNAPL to the extent practicable
- Shutdown of DNAPL recover systems is challenging
  - Continual recovery
  - Need to evaluate how to meet Remedial Action Objectives (RAO)
    - No vertical or horizontal migration
- Transmissivity and pool height were determined to be an effective way to evaluate if RAO have been met

Site Overview

Remedial Action Summary



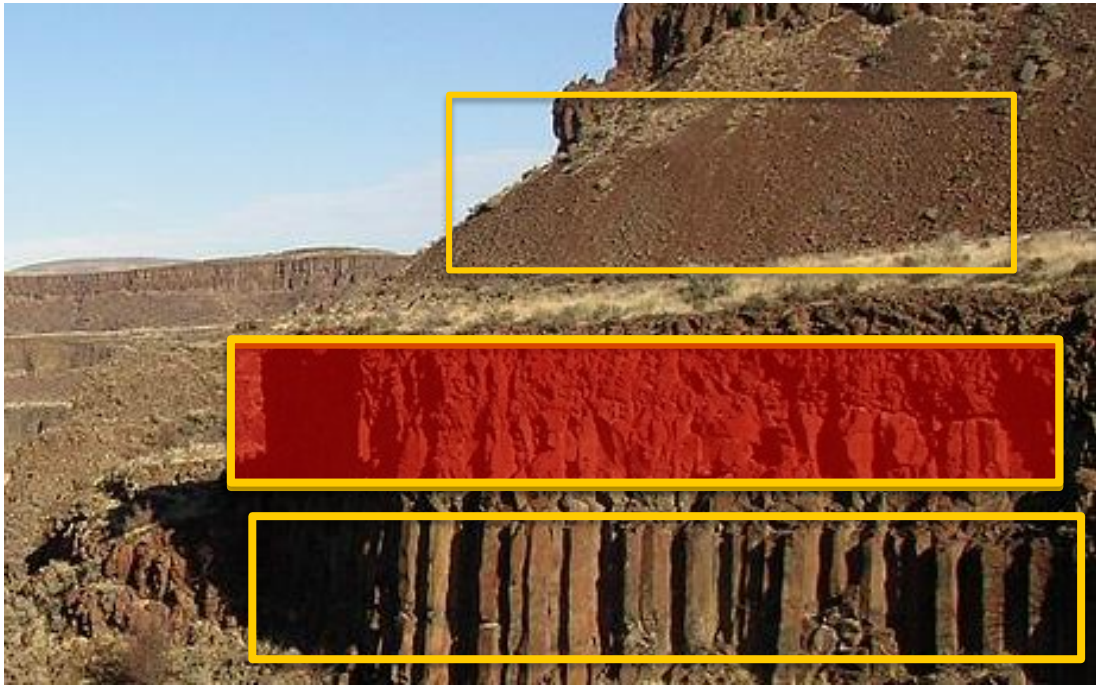
Cross Section



- DNAPL released from process ponds and retort building
- DNAPL accumulated in the basalt flow top
- DNAPL contained by ridge of columnar basalt in park

DNAPL Recovery from Fractured Rock

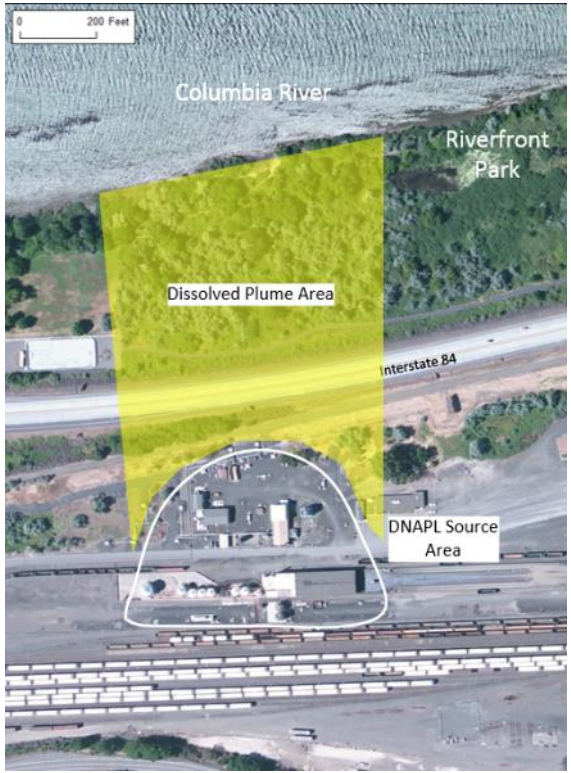
Geology from Adjacent Area Where Exposed



- Upper geology consists of three layers:
  - Alluvium
  - Basalt Flow Top
  - Columnar Basalt
- DNAPL recovery is focused on the fractured flow top

Groundwater Remedy Overview

Impact Areas and Remedial Objectives



- The groundwater remedy is characterized by two separate areas
  - DNAPL source area
  - Dissolved plume area
- Before remedy, wells in Riverfront Park were all above water quality standards for surface water
- 1996 remedy required
  - Containment of DNAPL source area and groundwater restoration if technically feasible
    - Technical Impracticability waiver obtained for source area
  - Monitoring of dissolved area plume
  - Achieve DNAPL RAO

DNAPL Recovery RAO

- The Final Groundwater Remedial Action Plan (CH2M HILL 1997) used operational endpoint based on recovery volume to meet this objective
  - Operational endpoint of 95% of the maximum potential volume established
- However, the RAO is specific to potential migration of DNAPL, not based on volume
- DNAPL migration is controlled by
  - Horizontal migration - DNAPL transmissivity
  - Vertical migration - DNAPL head

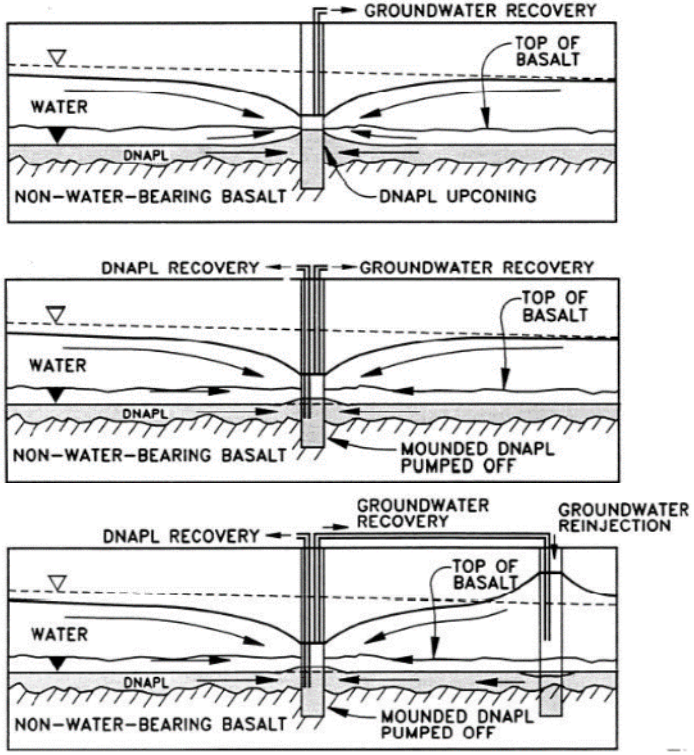
Remove DNAPL to the extent practicable to prevent continued vertical or horizontal migration to the uncontaminated portions of the aquifer

Groundwater Remedy Overview

Design Objectives

- Design hydraulic containment system to capture source area and recover DNAPL
  - Groundwater model used for capture design
  - Water treatment for PAH's, arsenic, and iron
  - NPDES discharge to creek out of capture area
- Design DNAPL recovery systems using water-flooding method (Sale and Applegate 1997)
  - Recover DNAPL and reinject water
  - Control iron fouling
  - Install DNAPL recovery systems sequentially

Water Flooding Enhances DNAPL Recovery

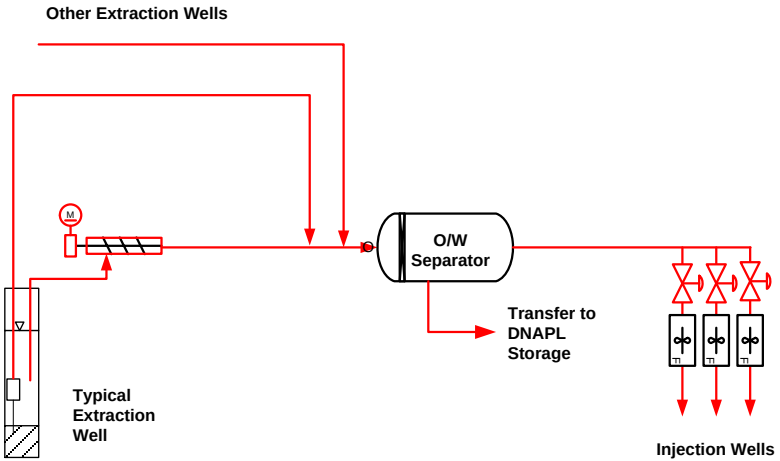


- Groundwater extraction results in DNAPL upconing
- DNAPL removal is controlled to prevent cutoff of DNAPL flow paths
- Water reinjection increases hydraulic gradients to well and increases rate of DNAPL recovery

DNAPL Recovery Equipment

System Comparison

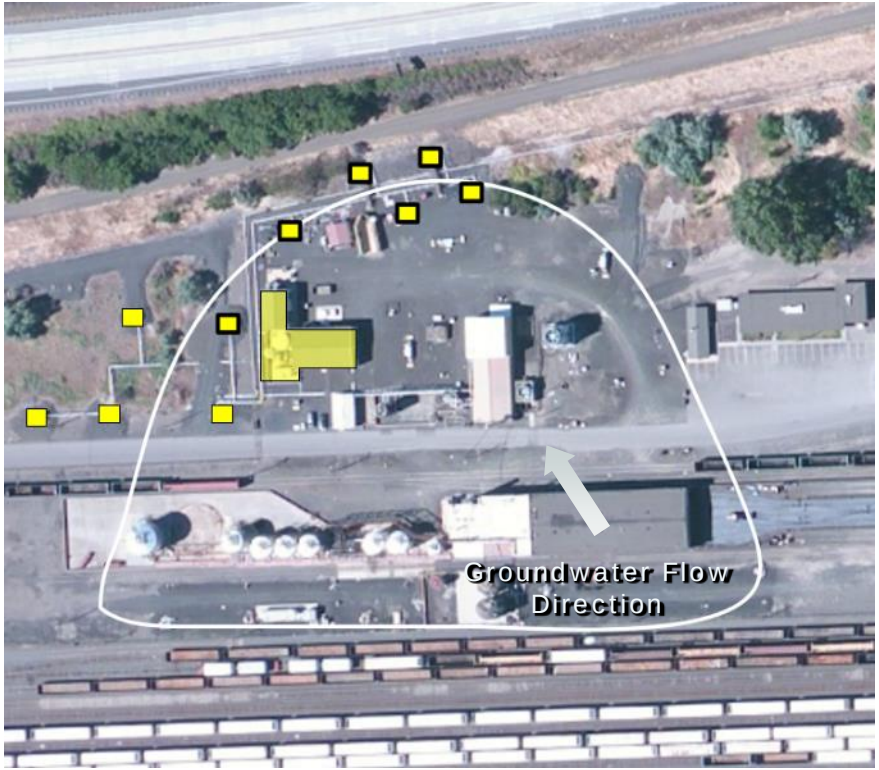
Process Flow Diagram



Pressurized Oil/Water Separators

- Closed loop system with DNAPL recovery, storage, and reinjection

Hydraulic Containment System

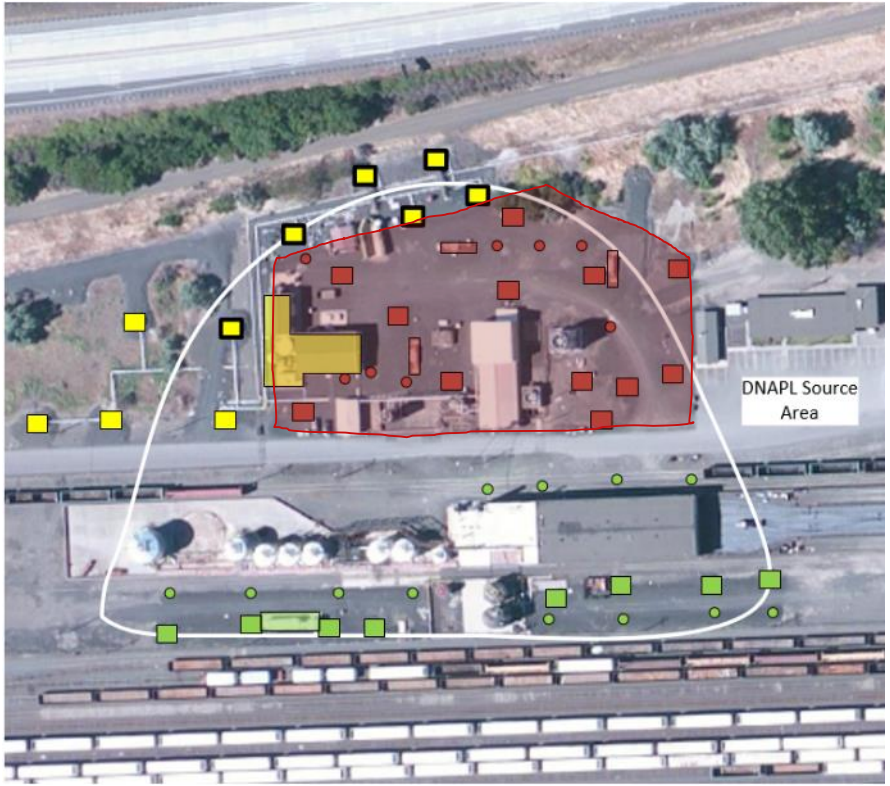


- System provides hydraulic containment of source area and DNAPL recovery
- Started in 1996
- Equipment
  - Originally 6 wells; expanded to 10 wells; now back to 6
  - Water treatment plant
  - Effluent discharge
- Nearly 60,000 gallons of DNAPL recovered

Module 1 DNAPL Recovery System

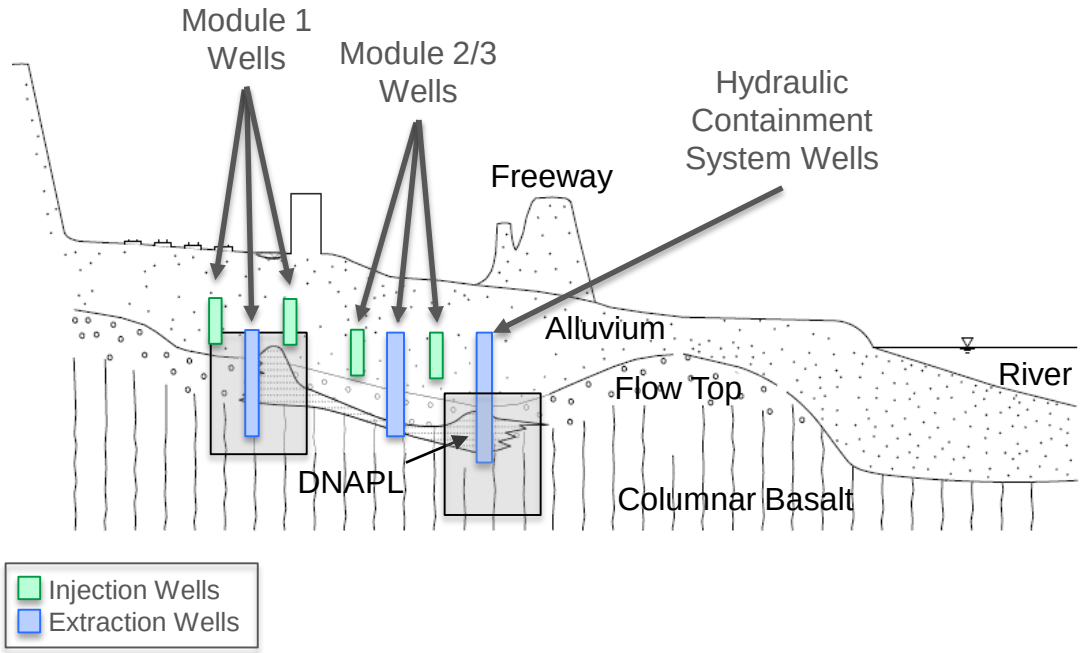
- Module 1 constructed on the upgradient edge of DNAPL source area
- Started in 1999
- Equipment:
  - 8 extraction wells
  - 1 pressurized oil water separator
  - 8 injection wells
- Operated ~10 years
- Over 12,000 gallons of DNAPL recovered

Module 2/3 DNAPL Recovery System



- Module 2 constructed in center of DNAPL area
- Started in 2004
- Equipment
  - 11 extraction wells
  - 3 pressurized oil water separators
  - 8 injection wells
- Over 50,000 gallons of DNAPL recovered

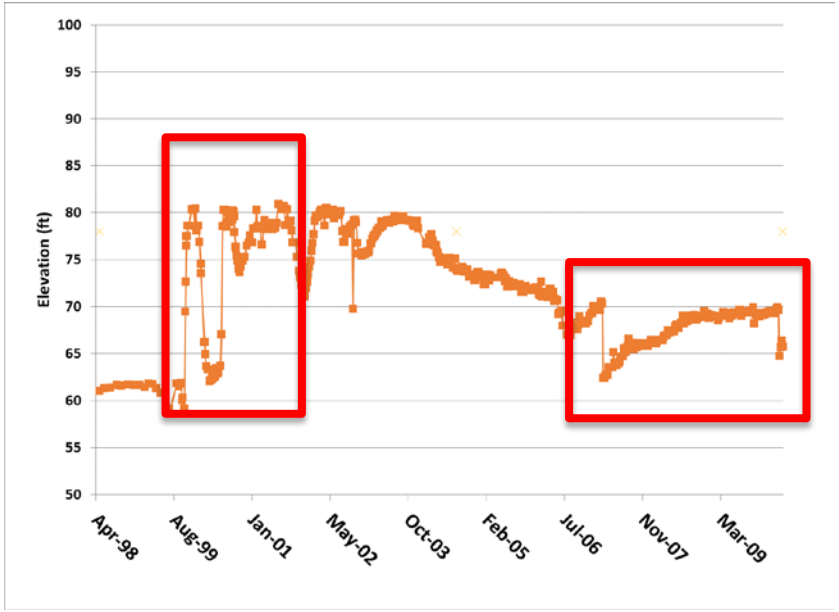
NAPL Site Conceptual Model



- DNAPL is in fractures of basalt flow top
- Hydraulic Containment System has depleted downgradient pooled NAPL
- Module 1 has depleted upgradient pooled NAPL
- Mod 2/3 is still in operation

DNAPL Tranmissivity

Early Observations



- Transmissivity changes were observed in 2008 in DNAPL recharge data
  - DNAPL recharge rates of one month in 1999
  - Same well recharged in two years in 2006

Transmissivity Analysis Program

- DNAPL transmissivity testing program
  - Historic data
  - Planned tests
- Measurements at different times for different wells
  - 1 hydraulic containment well
  - 6 Module 1 wells
  - 4 Module 2/3 wells

REMEDY PERFORMANCE

Remedy Performance Metrics

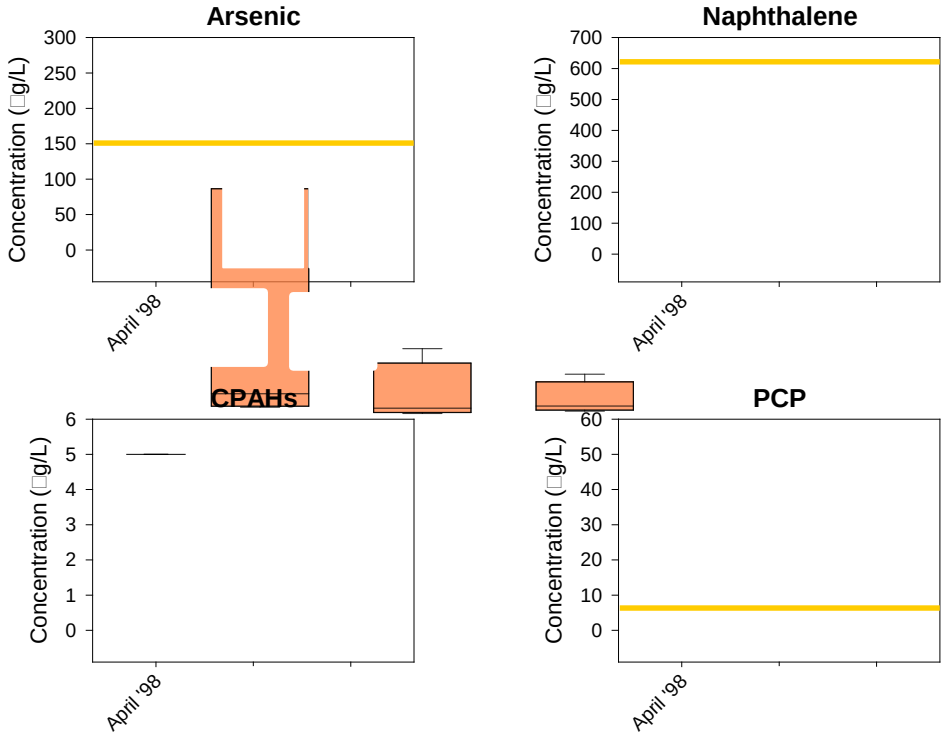
- Hydraulic containment of DNAPL source area
  - Capture analysis using water levels
  - Down gradient concentration monitoring
- Prevent horizontal DNAPL migration
  - Recovery endpoint
  - DNAPL transmissivity
- Prevent vertical migration of DNAPL
  - DNAPL head on columnar basalt

Hydraulic Capture

- Water level measurements used to assess hydraulic capture
- Results have been consistent with capture of the leading edge of the dissolved groundwater plume

Dissolved Plume Reduction

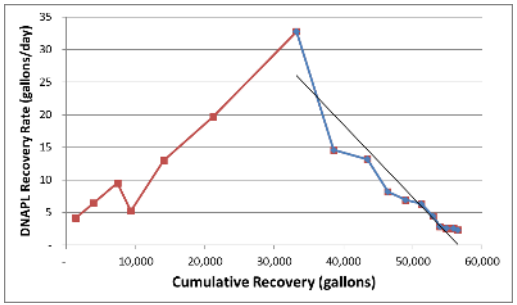
Downgradient Results Below Ambient Groundwater Criteria



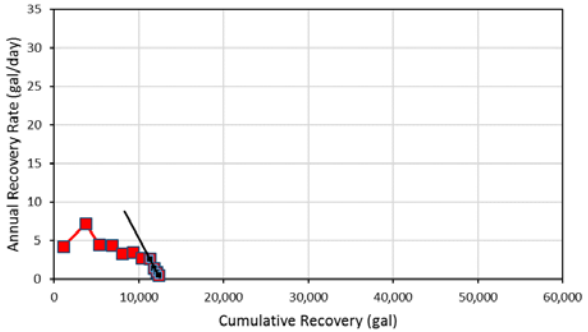
Freshwater Screening Criteria

System Recovery Curves

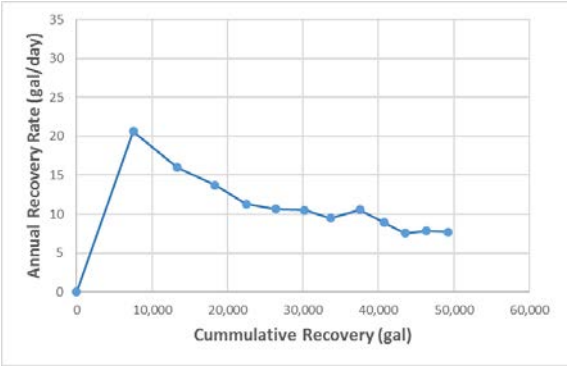
Hydraulic Containment



Module 1



Module 2/3

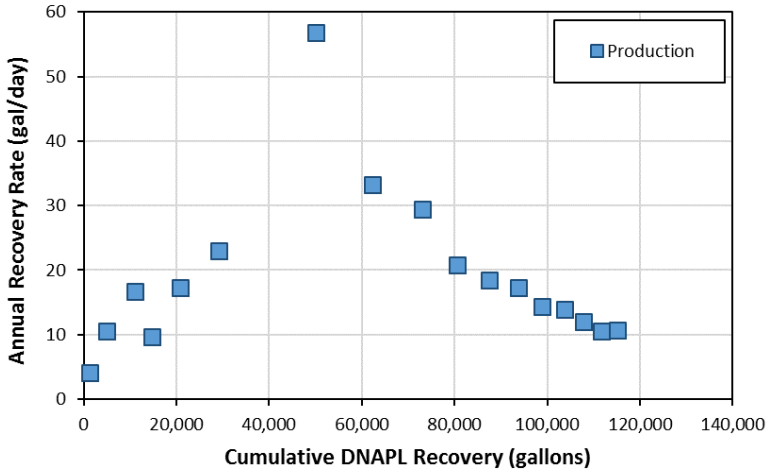


- Current Status
  - Hydraulic containment endpoint achieved, operated for hydraulic containment
  - Module 1 endpoint achieved in 2009 – system abandoned
  - Module 2/3 endpoint not achieved, operation continues
- Over 120,000 gallons of DNAPL recovered from fractured rock

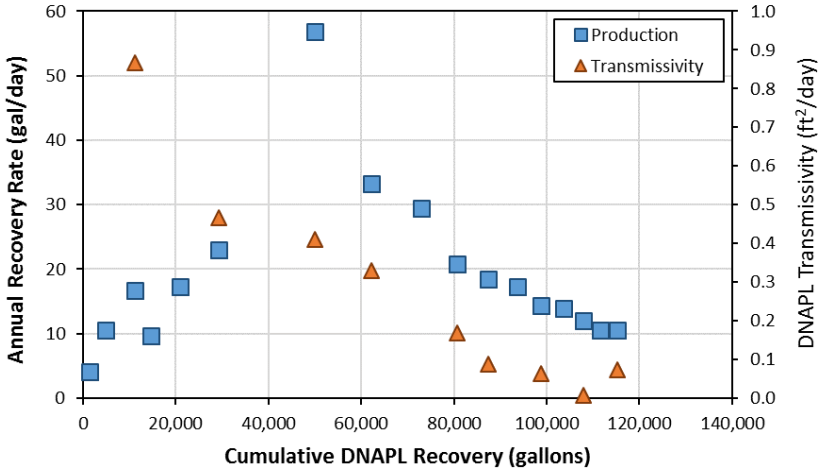
Overall Production and Decline Curve

Combined Systems

Production



Production and Transmissivity



Data analysis method: Reyenga, Lisa. 2016. “Estimating Expected Ultimate Recovery.” Applied NAPL Science Review. Vol. 6, Issue 2, July.

DNAPL Head on Columnar Basalt

Example Top of Columns

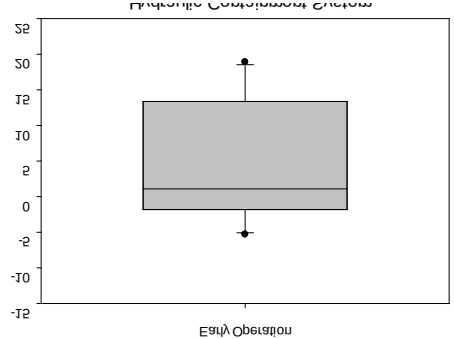
Removal Objectives

- Prevent downward migration of DNAPL
- Analytical calculations show it takes five feet of head on the columns for downward migration
- Prior to remediation, up to 18 feet of head was observed in some locations

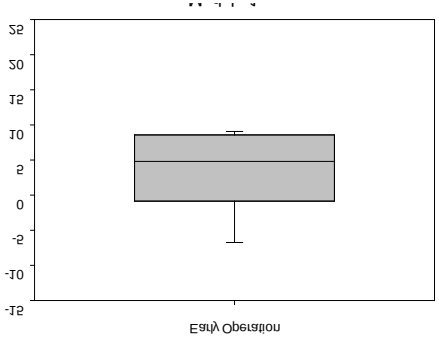
DNAPL Head on Columnar Basalt

Before and after recovery

Hydraulic Containment



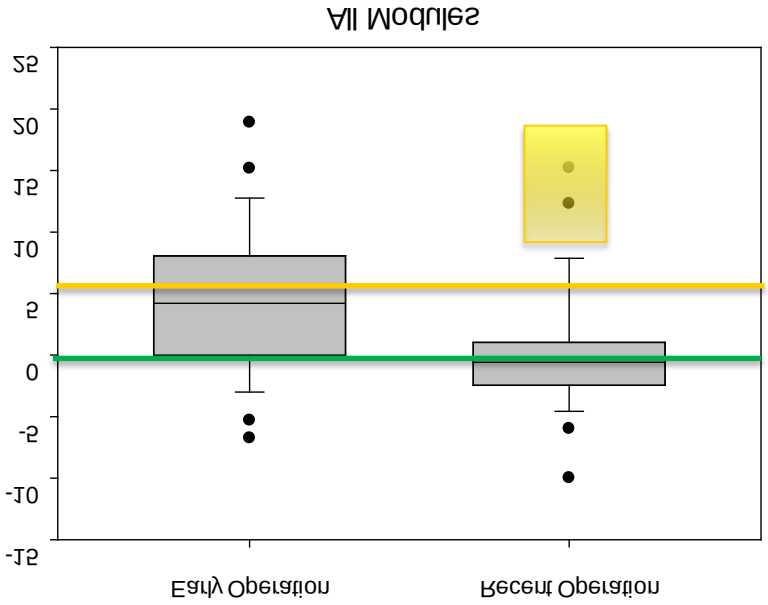
Module 1



Module 2/3

- Static DNAPL levels above columnar basalt
  - Range up to 18 feet
- Analysis is subjective since the interface between the flow top and columnar basalt is transitional and irregular

Current DNAPL Head Levels



- Median of all wells near 5 feet DNAPL head in early operation
- Current median of all wells near zero
- Current focus on two wells with higher heads

Summary and Path Forward

- 30 years of groundwater remedy operation have achieved the RAOs for the site:
  - Source area hydraulically contained
  - Downgradient plume remediated
  - Horizontal DNAPL migration abated
  - Vertical DNAPL migration abated
- DNAPL recovery will continue to achieve:
  - Operational endpoint of Module 2/3 with new endpoint criteria
  - DNAPL head reduction in select wells

THANK YOU

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