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Shoreline Remediation of Petroleum Hydrocarbons Using an Oleophilic Bio-barrier for Sheen Control

ESAA Webinar Presentation

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May 2020

1. The Problem: Seeps and Sheens
2. NAPL CSMs
3. Oleophilic Bio-barriers (OBBs) to Manage Sheens
4. OBB Case Studies
5. Ongoing Research

Who Am I?

Professionally

- Chemical Engineer with environmental masters
- Been with Jacobs and predecessor CH2M HILL for 30+ years
- Specialize in NAPL Sites with first NAPL cap installed in 1995
- Session chair at Battelle Sediment conference on NAPL sites in 2017 and 2019

Previous Alberta Experience

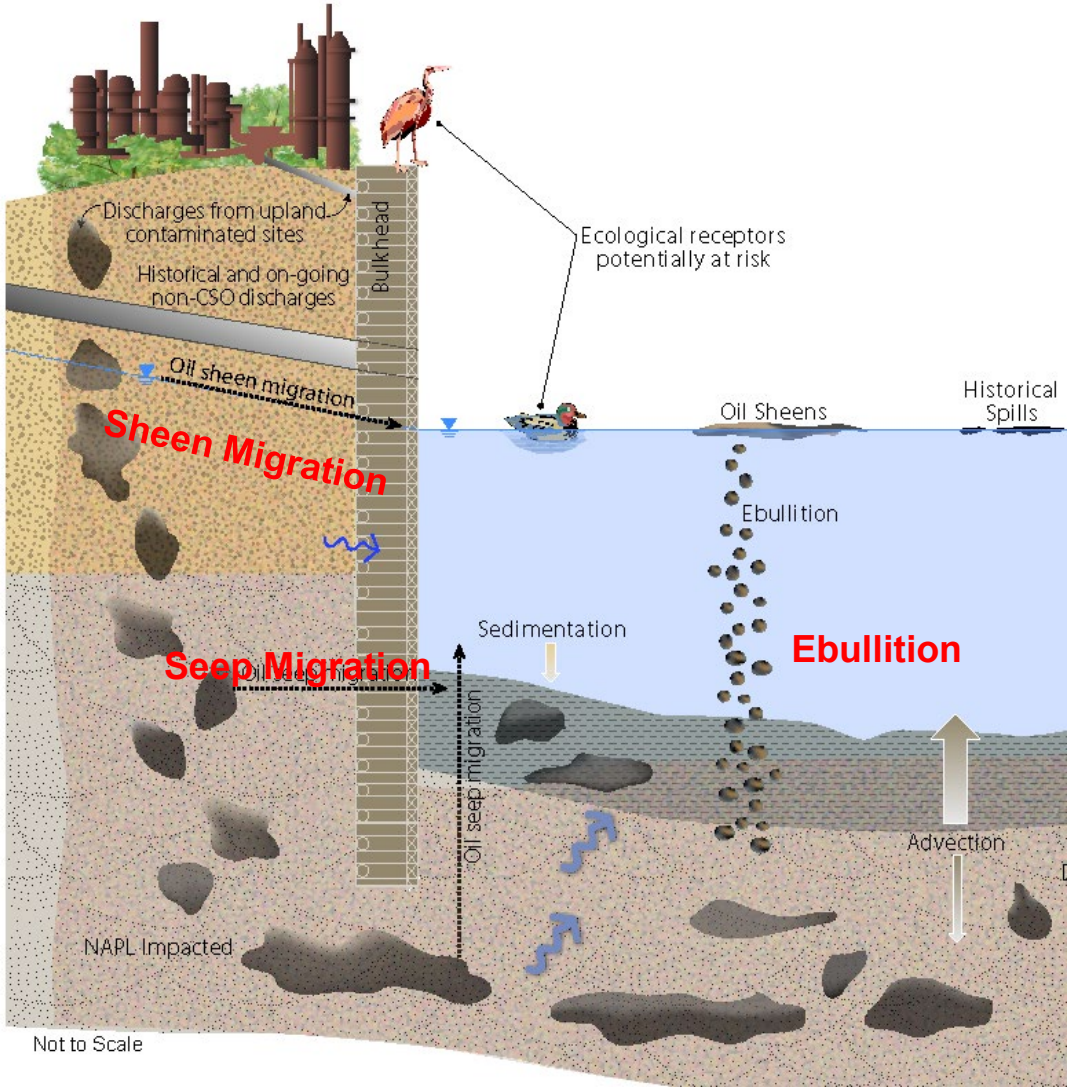
- Two bike trips in Alberta in 2007 and 2014
- First on Tandems with my two young boys
  - Whitefish, USA to Waterton and back
- Second Lake Louise to Whitefish USA through Waterton

The Problem: Seeps and Sheens

The Problem: Seeps and Sheens

- Sheens of hydrocarbons form at Groundwater/Surface water Interfaces (GSIs) due to releases of petroleum liquids. Form thin films on water surfaces that spread
- Result from:
  - Seeps (“blebs”) of hydrocarbons migrating as mobile LNAPL to the GSI,
  - Sheens of hydrocarbons migrating from residual LNAPL across the top of the air-water interface in porous media to the GSI
  - Ebullition from sediments
  - Erosion/scour of banks.
- Challenges include
  - Quantifying (and differentiating from natural)
  - Understanding the location and source
  - Regulatory and public perception
  - Access

NAPL Migration Mechanism is Important Part of CSM



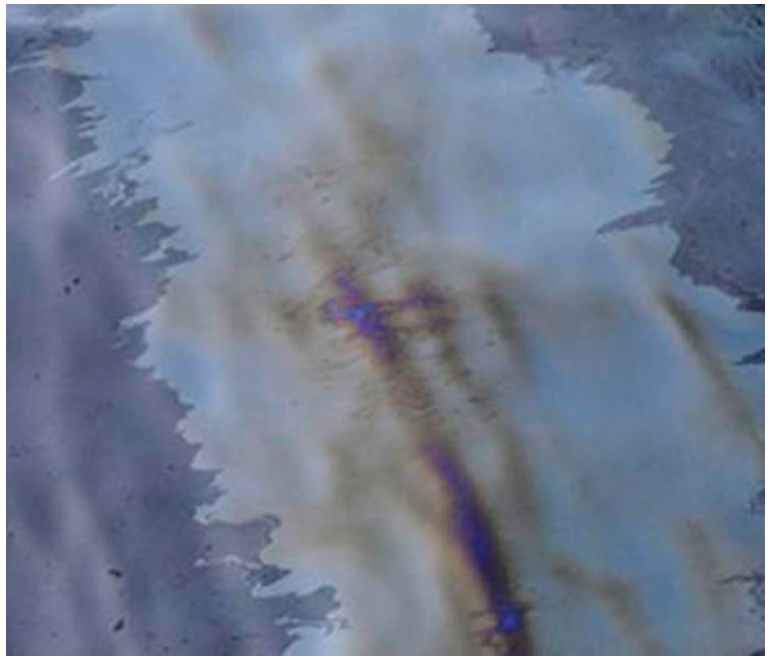


Photo from

Sale, T., and M. Lyverse. 2014. Sheens Associated with Subsurface Petroleum Releases – Current Knowledge and Best Practices. Chevron USA, Inc.

Sheen Migration

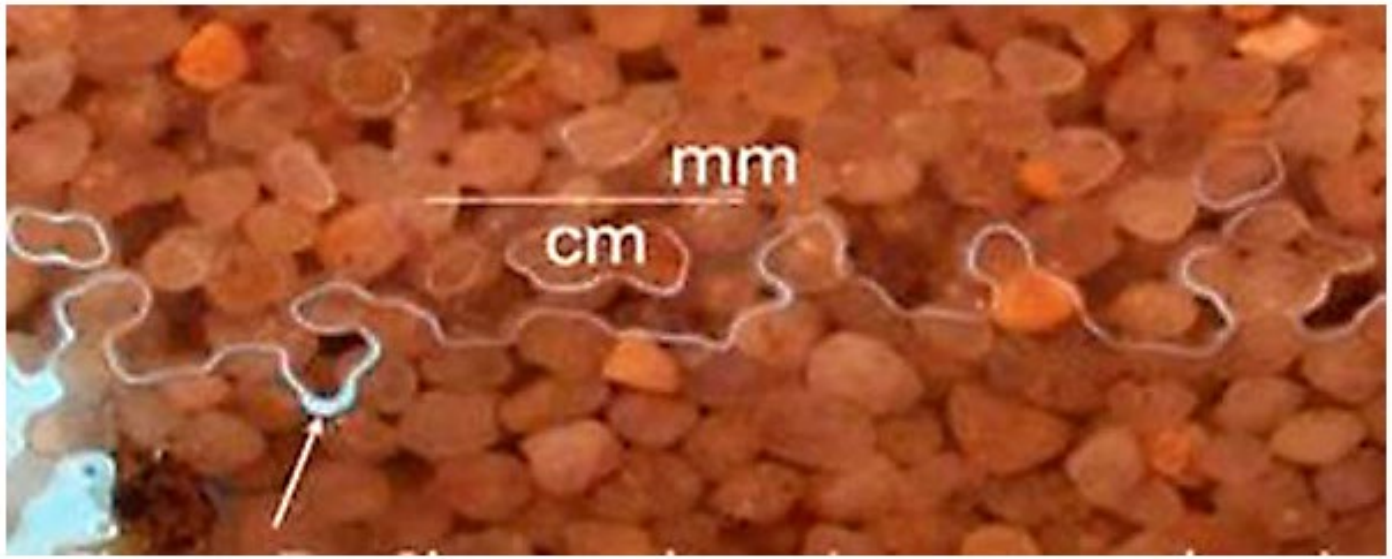


Figure S-6. Sheen advancing across the air-water interface at the top of the capillary fringe.

(Provided by Dr. Julio Zimbron, authorization to use by Author/Colorado State University.)

- NAPLs can move across the air-water interface
- Similar to the spreading of sheens on surface water
- Caused by surface tension differences
- Does not need a NAPL head to migrate
- Can occur with residual NAPL

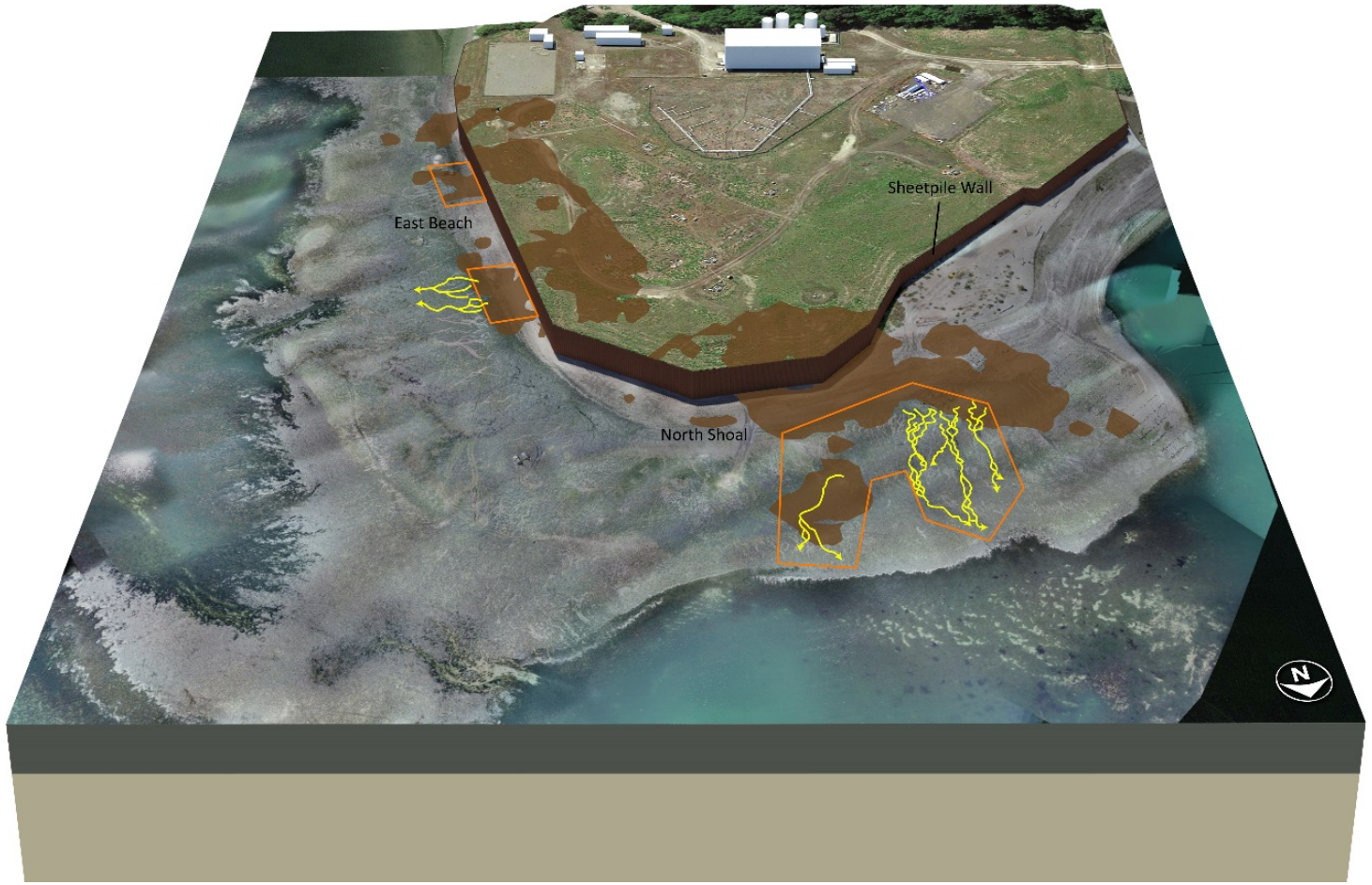
Reference LNAPL-3: LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies, Appendix E

NAPL Migration CSMs

NAPL Migration along Tidal Drainage

1986 EPA Video of Wyckoff Intertidal Area

Surface NAPL Flow Informed Design Stage CSM



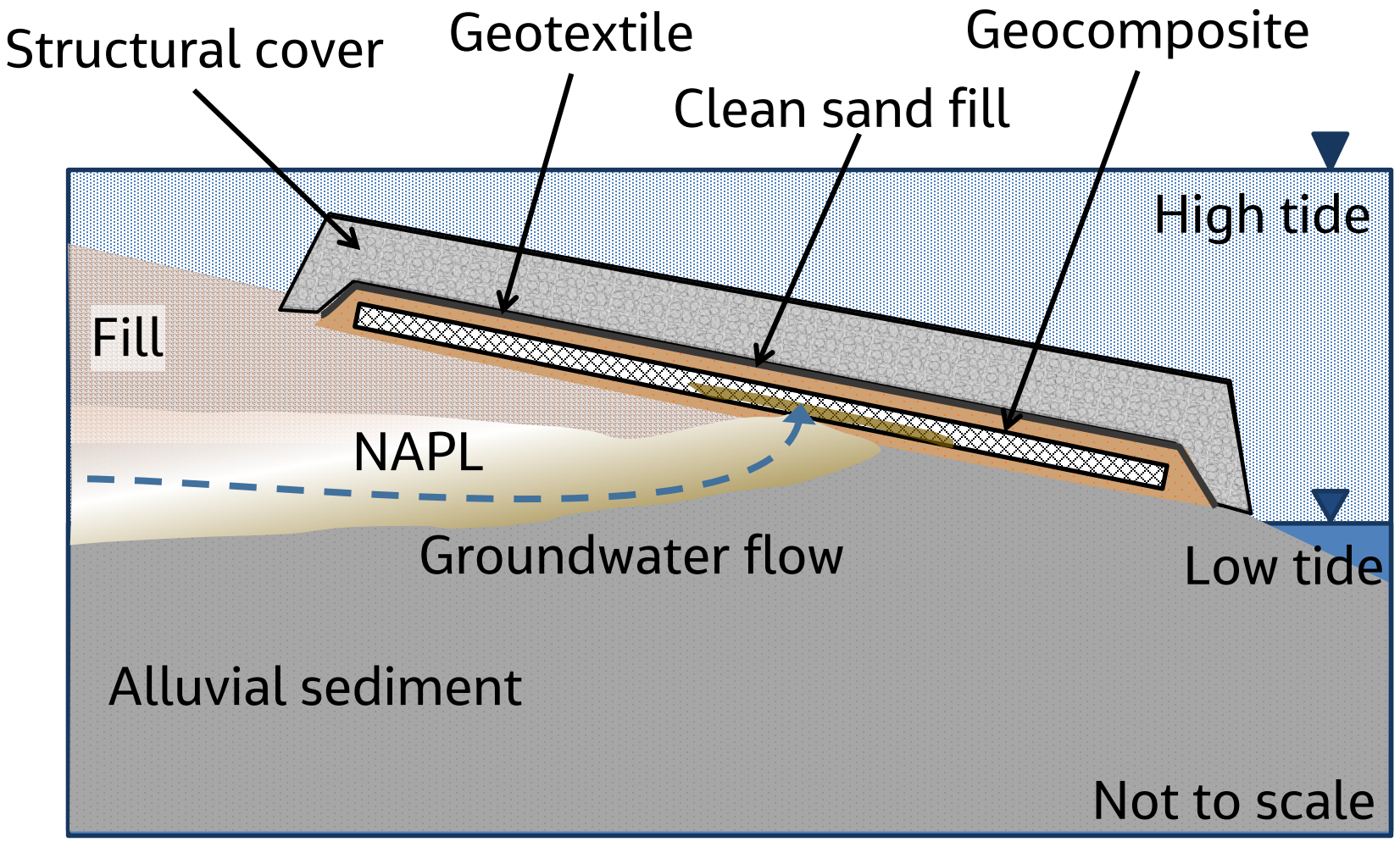
- NAPL surface discharge and transport explains the lateral NAPL distribution the site
- Tidal drainages are also accumulation areas for NAPL resulting in deeper NAPL impacts

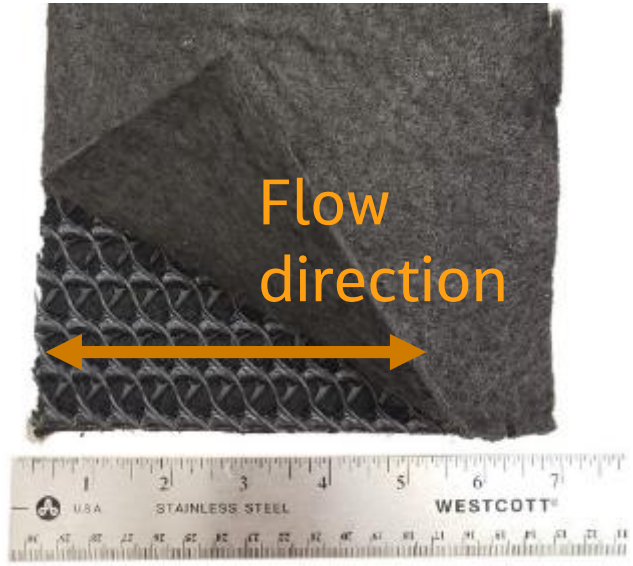
And Even Thick NAPL can Migrate and Create Seeps and Sheens

- Measured viscosity of >100,000 centipoise
  - Sour Cream!
- NAPL migrates at this high of viscosity

Oleophilic Bio-barriers (OBBs) To Manage Sheens

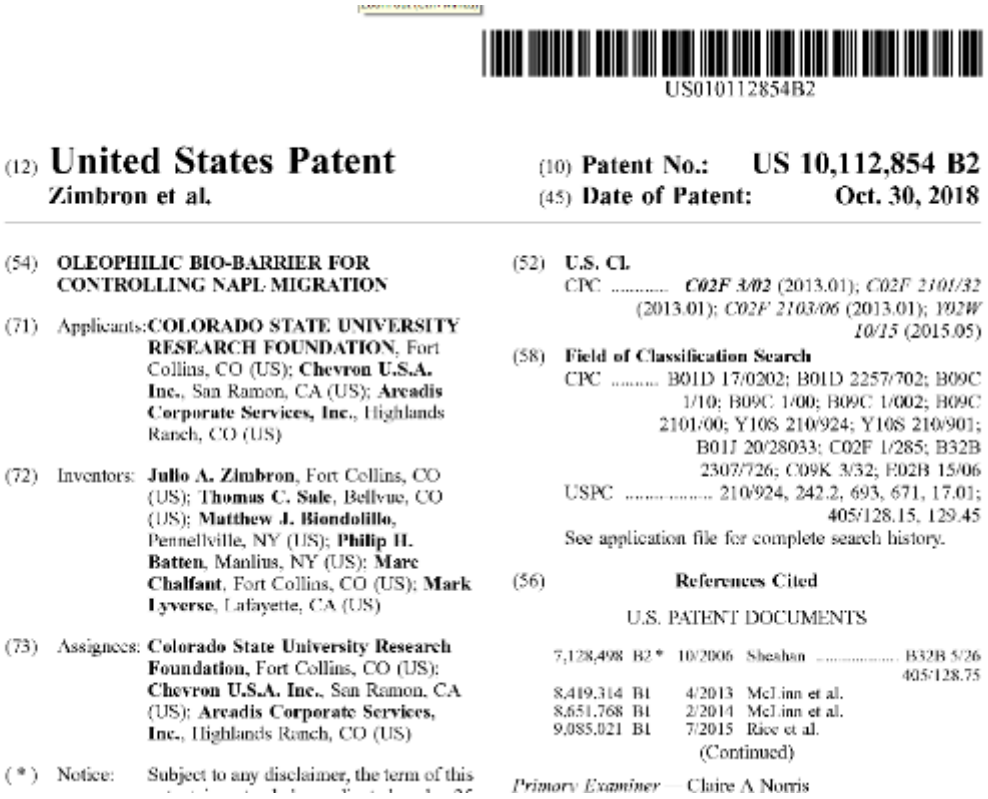
OBB Utilizes Multiple Layers





- OBB Mechanisms
  - Oleophilic geocomposite sorbs NAPL and Seeps
  - Aerobic biodegradation enhanced by cycling of surface water, resulting in rejuvenation of geocomposite

OBB United States Patent



US010112854B2

(12) **United States Patent**
Zimbron et al.

(10) **Patent No.: US 10,112,854 B2**
(45) **Date of Patent: Oct. 30, 2018**

(54) **OLEOPHILIC BIO-BARRIER FOR CONTROLLING NAPL MIGRATION**

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(*) Notice: Subject to any disclaimer, the term of this

(52) **U.S. Cl.**
CPC *C02F 3/02* (2013.01); *C02F 2101/32* (2013.01); *C02F 2103/06* (2013.01); *Y02W 10/15* (2015.05)

(58) **Field of Classification Search**
CPC B01D 17/0202; B01D 2257/702; B09C 1/10; B09C 1/00; B09C 1/002; B09C 2101/00; Y10S 210/924; Y10S 210/901; B01J 20/28033; C02F 1/285; B32B 2307/726; C09K 3/32; E02B 15/06
USPC 210/924, 242.2, 693, 671, 17.01; 405/128.15, 129.45
See application file for complete search history.

(56) **References Cited**

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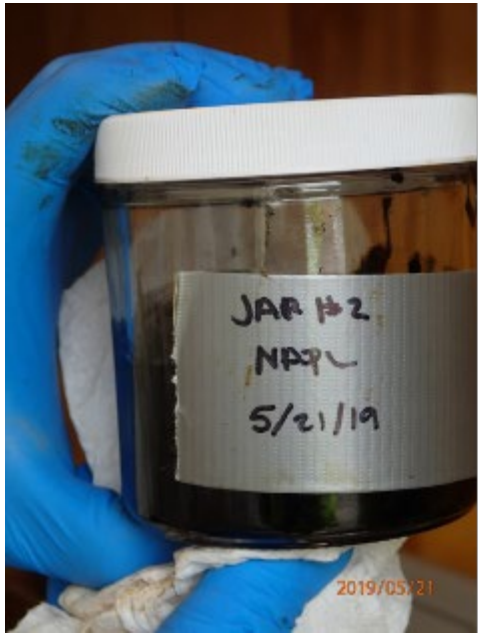
(Continued)

Primary Examiner — Claire A Norris

- Colorado State University Research Foundation and others have a US patent on the OBB technology
- Jacobs has a agreement with CSU to implement the OBB technology

Geocomposite NAPL Capacity Comparison



Capacity tests performed on site LNAPL

Results

- For diesel, 3 L NAPL/m^2 OBB (Chalfant, 2015).
- Thick NAPL OBB capacity is more than double - 7.5 L NAPL/m^2 OBB.

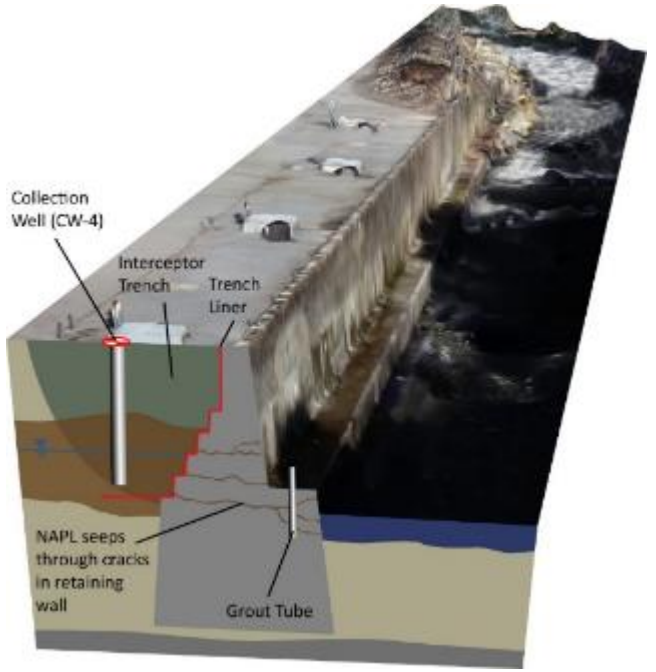
OBB Applications

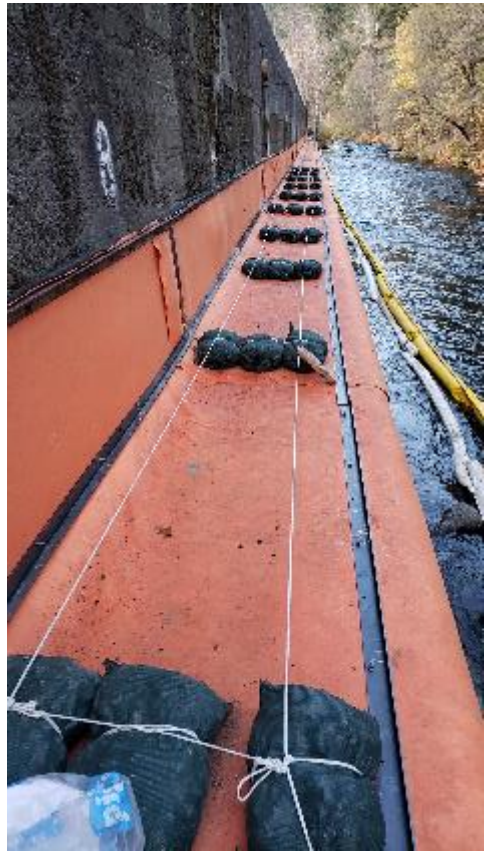
On Shorelines

Relatively flat application

Slope application

On Retaining Walls (vertical application)





Case Studies

Portland Harbor Superfund Site

Image from EPA ROD, Figure 1, January 2018

- Located in Portland, Oregon, USA
- Approximately 9 miles of the Willamette River (RM 2 to 11)
- Kinder Morgan Linnton Bulk Terminal Facility at ~RM 4
- Record of Decision issued in January 2018
- Requires the remediation of over 10,000 feet of river bank

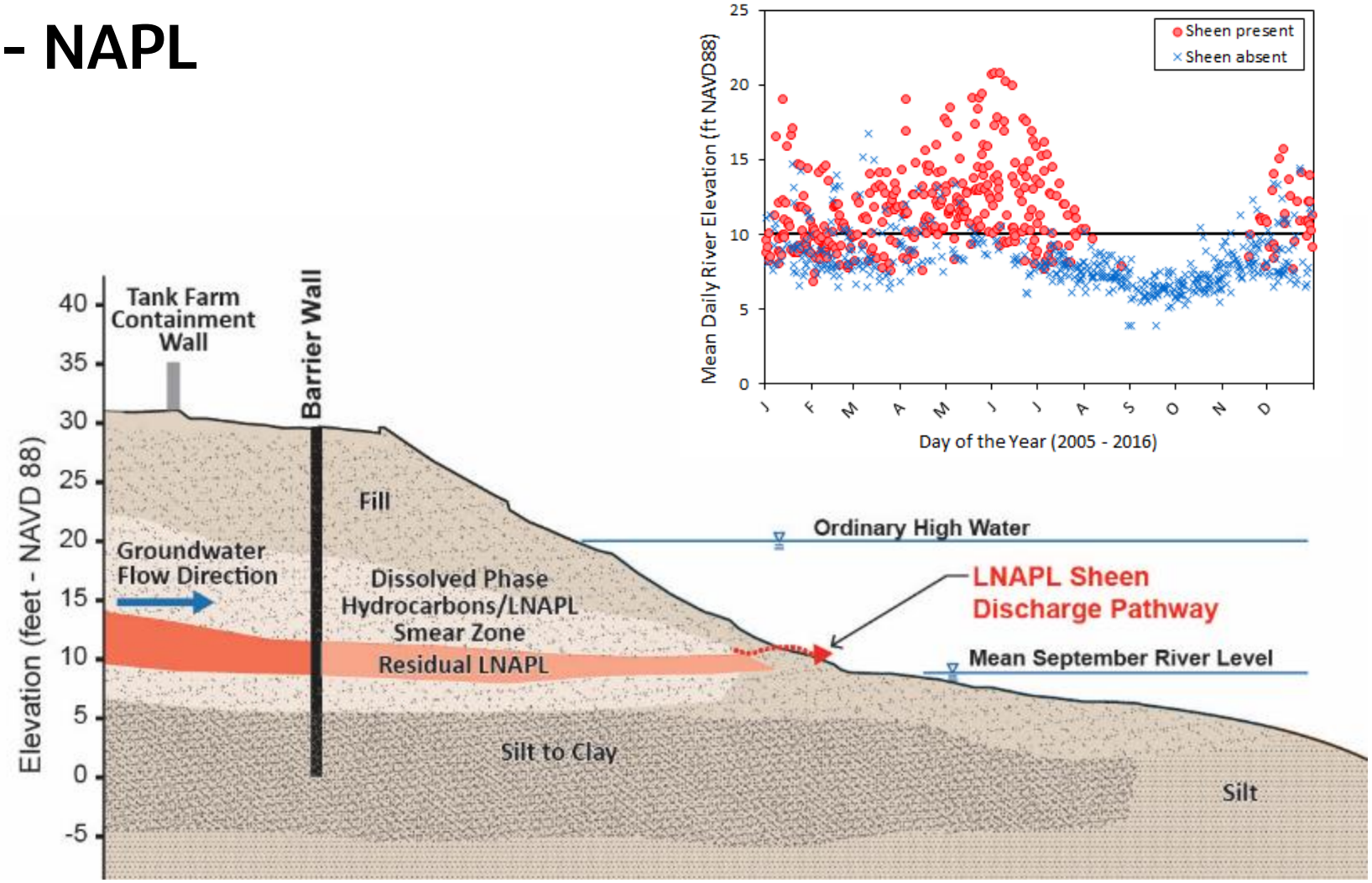
Linnton Terminal Bank

- 1,052 feet of river bank
- 100 feet of river bank has intermittent sheen discharge

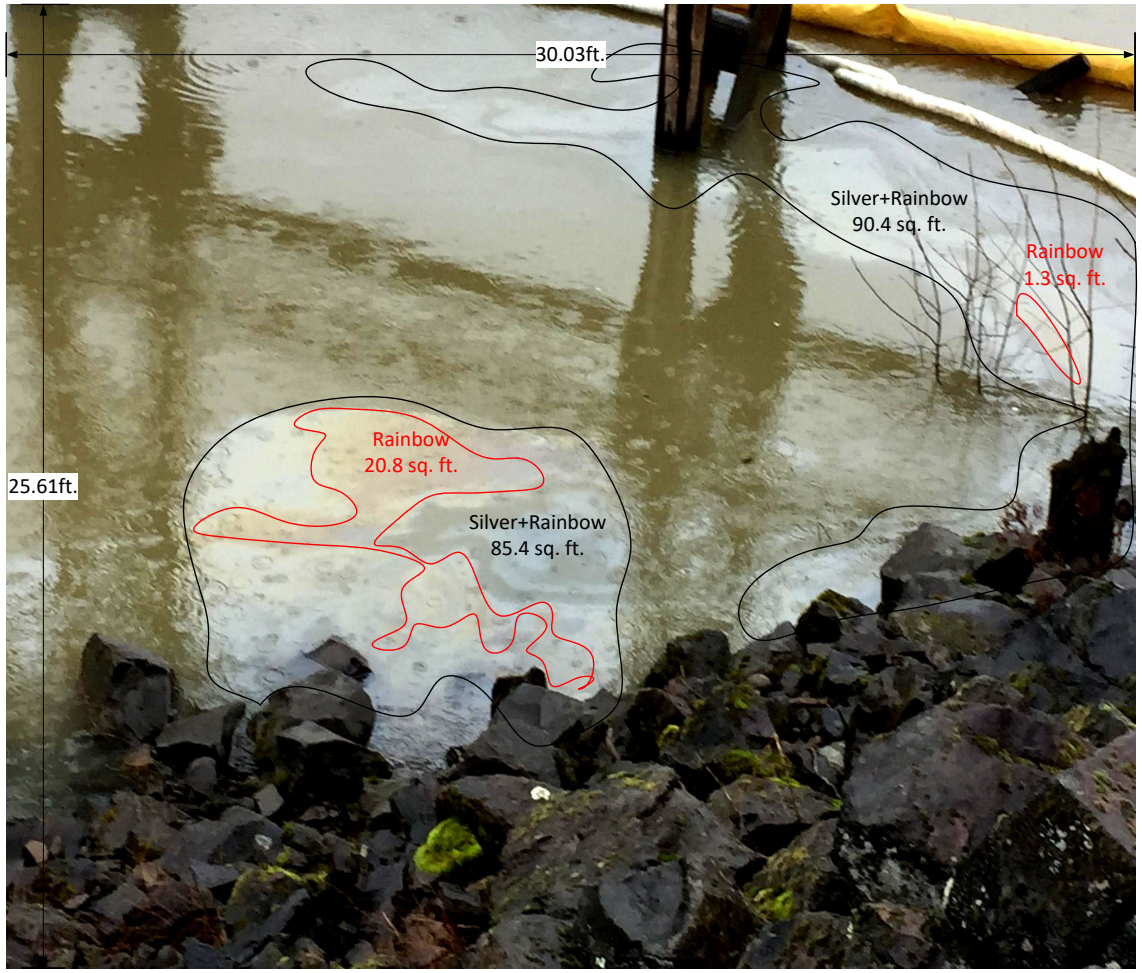
Linnton Terminal Bank

- Barrier wall installed to block NAPL flow path to the river
- Fiberglass sheet piles with Viton seals
- Bottom penetrated silt underlying silt layer
- No heavy sheens after installation but infrequent light sheens persist

Conceptual Site Model - NAPL

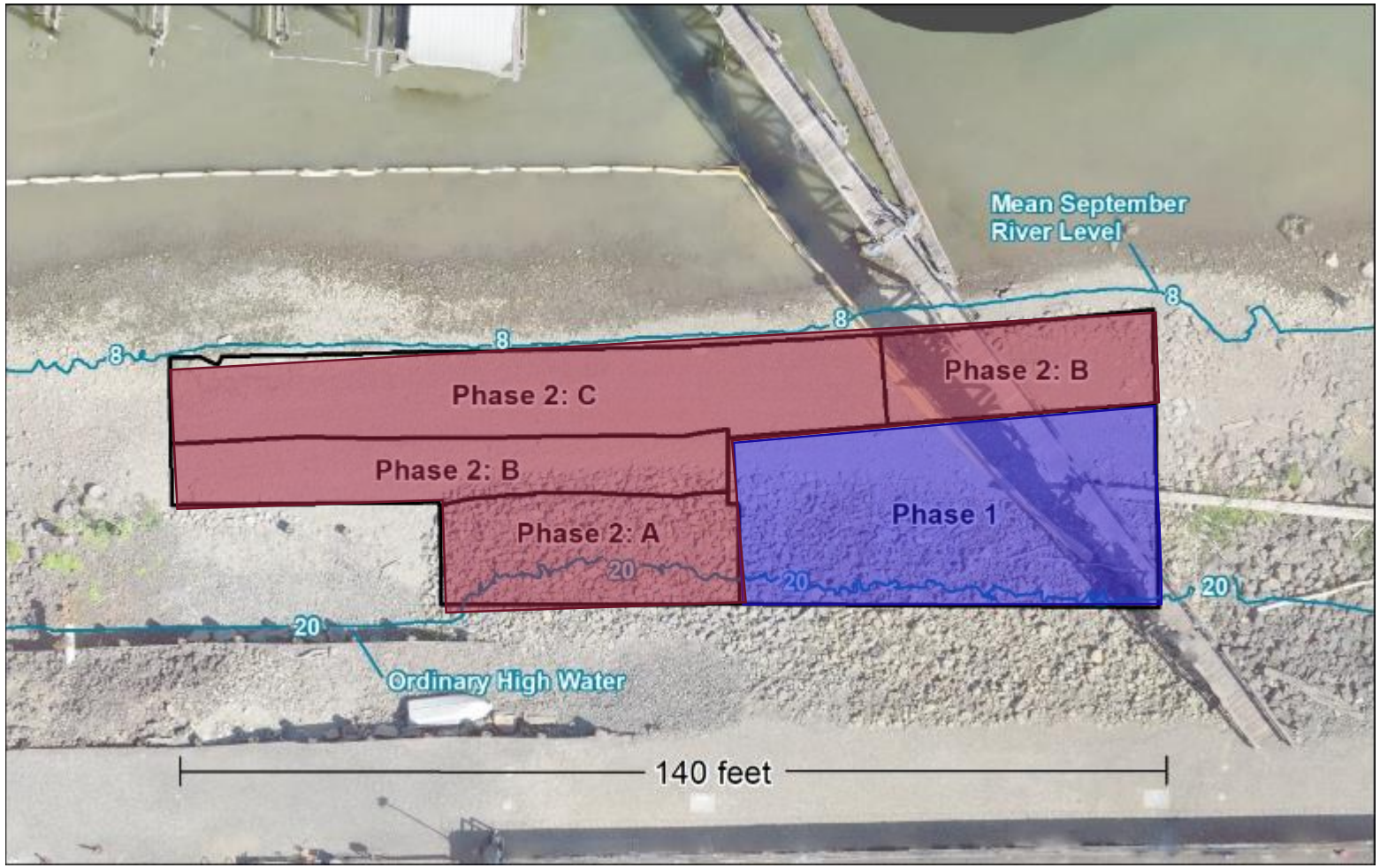


Oleophilic Bio Barrier Design



- Sheen area and intensity was measured
- Sheen volume 1 to 15 milliliters
- OBB capacity 3 liters/square meter
  - Capacity >5,000 sheen events without degradation
  - Years of absorption capacity to allow biodegradation
- Added activated carbon layer to address dissolved phase
  - Conservative assumptions to design the active cap layer using CapSim
  - A six-inch layer of a mixture of 20% activated carbon can treat discharge for 100 years

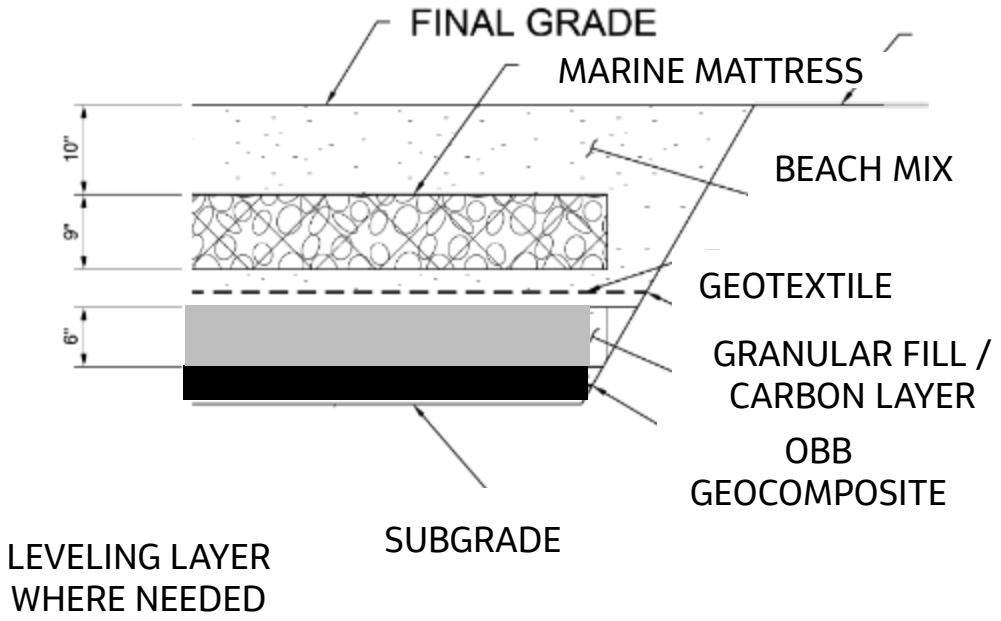
Cap Constructed in Two Phases



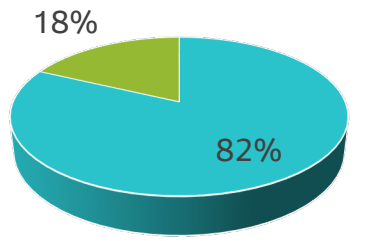
- Phase 1 constructed in Fall 2017
  - All work above Fall river stage
- Phase 2 constructed in Fall 2018
  - In-water work allowed by permit

Cap Type 3 to Maintain Beach Habitat

- Marine mattresses used to reduce cut needed to support beach mix

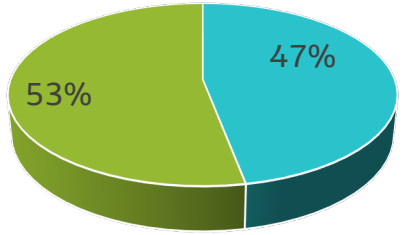


Habitat Before and After



Unsuitable Beach Habitat

Suitable Beach Habitat



Unsuitable Beach Habitat

Beach Habitat

2,100 square feet of new beach habitat was created

Sheen Before and After

No sheens have been observed since Phase 1 completion in November 2017

Results Published in Remediation Journal

DOI: 10.1002/rem.21642

RESEARCH ARTICLE

WILEY

Novel shoreline cap for controlling sheen and dissolved-phase constituent discharge

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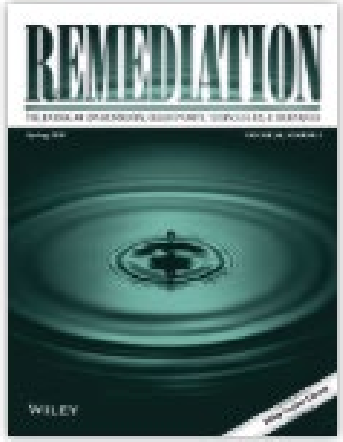
Abstract

A novel, multilayered shoreline cap was designed and installed to mitigate the release of petroleum light nonaqueous phase liquid (LNAPL) and dissolved-phase groundwater constituents to the Willamette River in Portland, OR. Releases of LNAPL related to upland impacts caused occasional sheens on a portion of the river within the Portland Harbor Superfund Site. The frequency and volume of sheens decreased following the installation of an upland sheet pile barrier wall, but occasional sheens related to LNAPL impacts stranded downgradient of the wall continued–prompting the design of a shoreline remedy. Because the site is located within the Portland Harbor Superfund Site, the cap was designed to mitigate sheen and to meet the objectives specified in the Portland Harbor Record of Decision including limiting the discharge of certain dissolved-phase constituents of interest. The cap design was the first instance of combining an oleophilic bio-barrier to mitigate sheen and an activated carbon layer to capture dissolved-phase constituents. No sheens have been visually observed since cap installation.



Western Railyard with Historic Impacts

- Bunker C Oil and Diesel impacts
- Releases to the river over 800 feet of railyard on and under 1920's retaining wall
- Releases date back 100 years
- Under order to stop discharge in 3 years

Western Railyard with Historic Impacts – Vertical Application

Light sheening

Heavy discharge

- Variable NAPL discharge
- 2 layers of OBB installed in heavy discharge areas

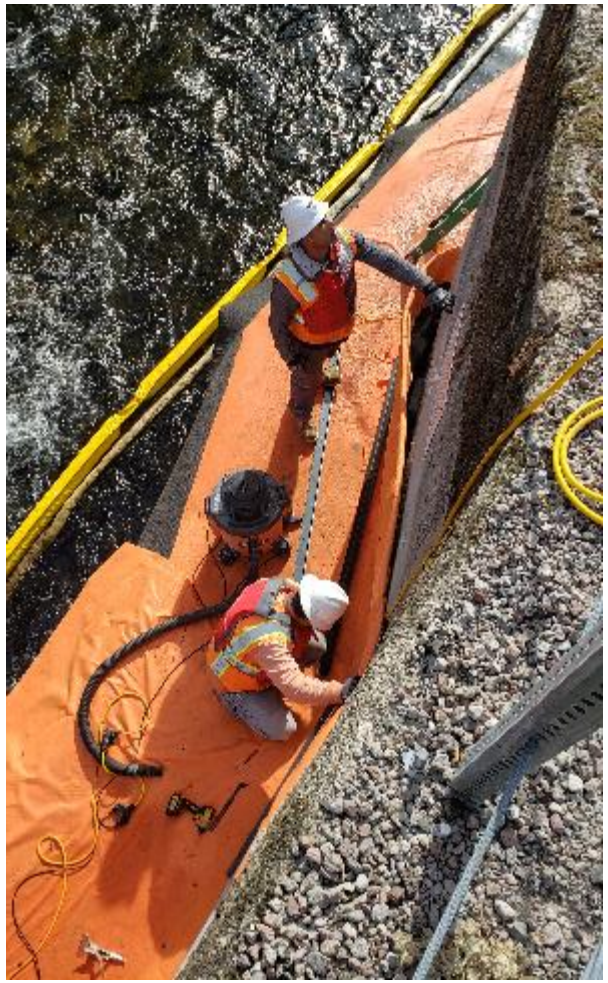
Adapting the OBB to a Retaining Wall – Anchoring

- OBB was secured with batten plates or roped gravel bags

Adapting the OBB to a Retaining Wall - Installation

- Design challenges include no heavy equipment within 20 ft (6 m) of top of wall

Adapting the OBB to a Retaining Wall – Wall Irregularities



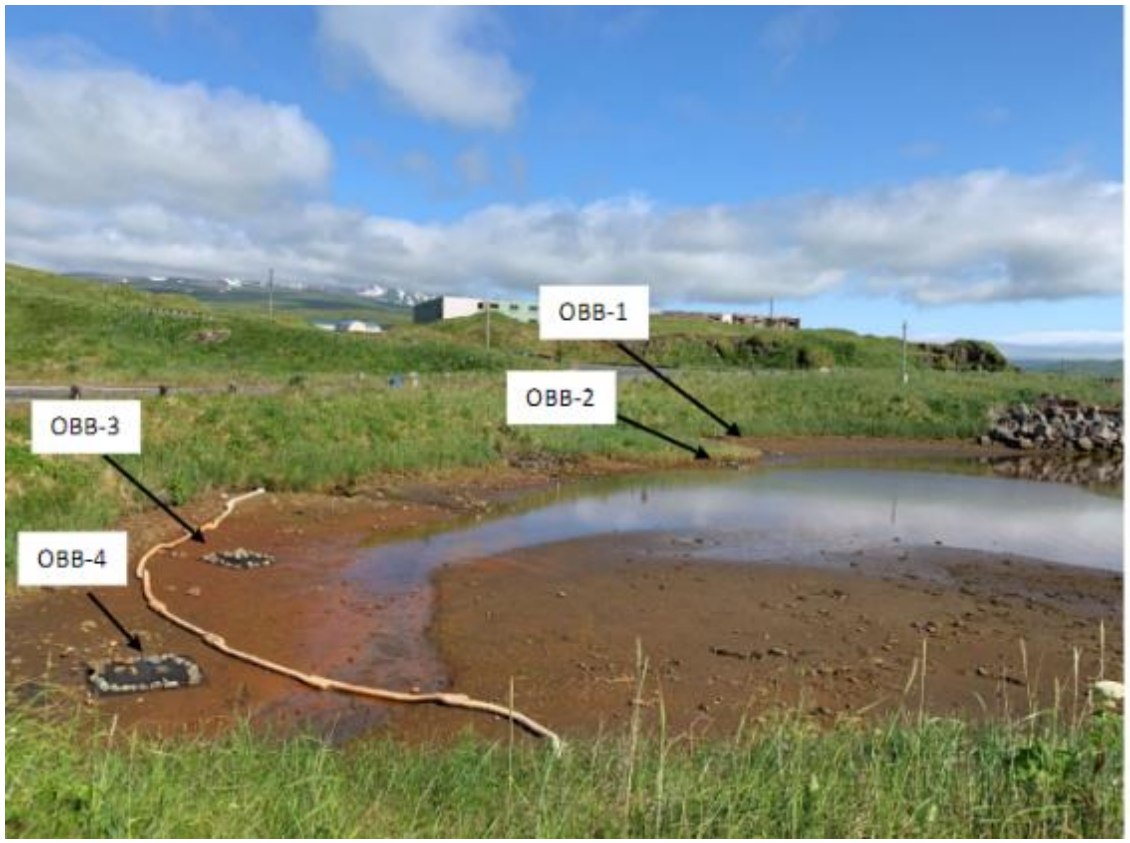
- OBB had to be cut and heat seamed to wrap around wall irregularities

Wall Before and After

Current Performance

- Reduction but not total elimination of NAPL discharge to river
- Monitoring of cover to document sheens and breakthrough
- Potential for OBB replacement in sections

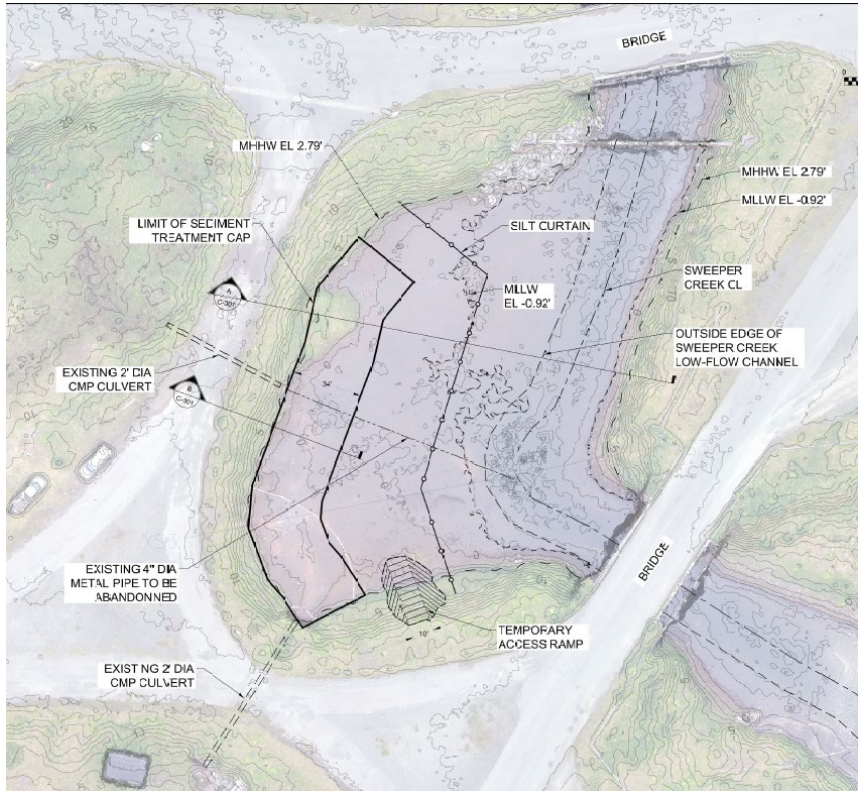
Adapting the OBB to Remote Alaska



Proof of Concept Study

conducted last summer for six weeks to address sheens in tidally-influenced stream in Aleutian Islands, Alaska

OBB Design in Progress



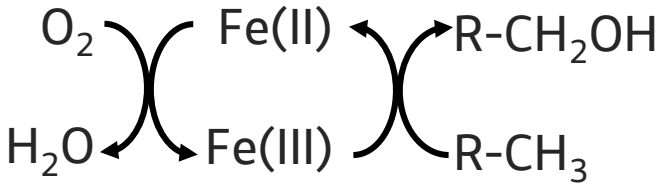
Ongoing Research

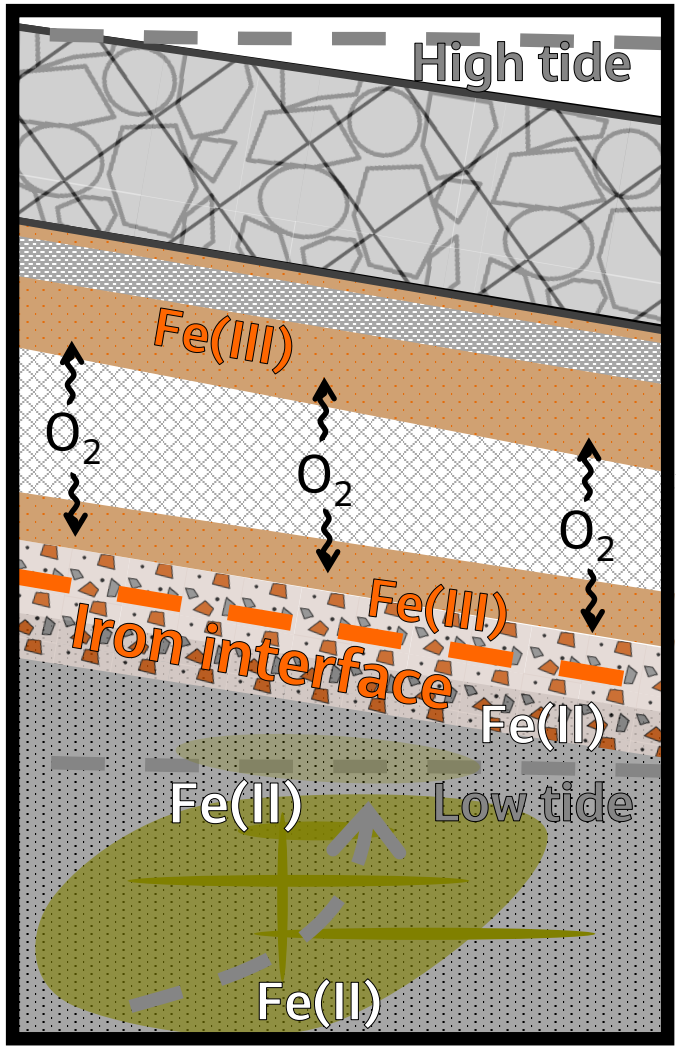
Future Work

Aerobic degradation:

$R\text{-}CH_3 + O_2 \rightarrow R\text{-}CH_2OH + H^+$

Iron redox cycling:





- Adapt OBB for wider-range of conditions including non-tidal
- Evaluation of OBBs in constantly submerged setting
- Develop internet-connected monitoring systems to track parameters such as ORP, temperature, and water levels
- Explore role of iron at sites with petroleum sheens

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Reinventing tomorrow.

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