Environment Canada Environnement Canada

Canada

Initial Diluted Bitumen Studies

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Environment Canada

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Federal Partners

- Environment Canada
- Fisheries and Oceans Canada
- Natural Resources Canada

Environment Canada – S&T

World Class Phase 1a

- Initial dilbit samples obtained (2 winter & 1 summer)
- Initial sediment samples from Douglas Channel
- Fate and Behaviour studies
  - Literature review
  - Physical/Chemical properties measurement
  - Weathering/Buoyancy
  - Evaporation and Emulsification
- Shoreline studies
  - Aerial survey and shoreline characterization
  - Shoreline fate and behaviour
  - Detection, penetration, shoreline response tactics

Environment Canada – S&T

World Class Phase 1a

- Spill modelling
  - Literature review
  - Develop new dilbit databases
  - Incorporate new wind and hydrodynamic data
  - Simulation of hypothetical spills
- Countermeasures
  - Literature review
  - Dispersant testing fresh/weathered dilbit samples
    - Traditional Swirling Flask Test
    - Up to 4 dispersant products

Environment Canada – S&T

World Class Phase 1b

- Additional dilbit samples (4-6)
- Fate and behaviour studies
  - Chemical/physical properties measurement
  - Analytical method review
  - Emulsion formation test protocol
  - Feasibility study – enhanced weathering capabilities
- Spill modelling
  - Continued algorithm development (fate & behaviour)
- Countermeasures
  - New protocol development
  - Additional dispersant evaluation Baffled Flask Test

Initial Dilbit Study

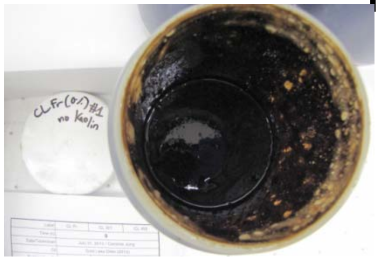
- The physical properties and chemical composition of any oil product in the environment changes over time (known as weathering).
- Weathering affects the fate and behaviour of oil in the environment.
- Oil generally becomes more dense over time as some components begin to evaporate.
- Weathered “heavy” oils may become suspended in the water column or may begin to sink.
- Sediment and oil mixtures may become too dense to float.

Oil Buoyancy Test

- The objectives of this preliminary study are:
  - Establish the physical characteristics and chemical composition of <u>two</u> representative diluted bitumen (dilbit) products.
    - Cold Lake Blend and Access Western Blend [Winter]
  - Establish the conditions that control buoyancy for the two dilbit samples by
    - Varying
      - Amount of weathering, i.e., evaporation (hours to weeks: fresh, light, moderate, heavy)
      - Sediment sizes (fine to coarse) — sediment in water
    - Keeping constant
      - Mixing energy (high energy)
      - Sediment Concentration
      - Temperature (15°C)
      - Salt water composition

Buoyancy Test Setup

- Experiments conducted in controlled laboratory conditions
  - Used uniform sediment sizes rather than mixtures of sizes
  - Products were weathered and then subjected to tests, rather than allowed to weather in place
- Designed with highest likely temperature, wave energy and sediment concentrations.
  - Sediment concentrations: highest normal seasonal variation
  - Substantial mixing: high wave/storm conditions
- Common science plan: shared oil types, fine sediment



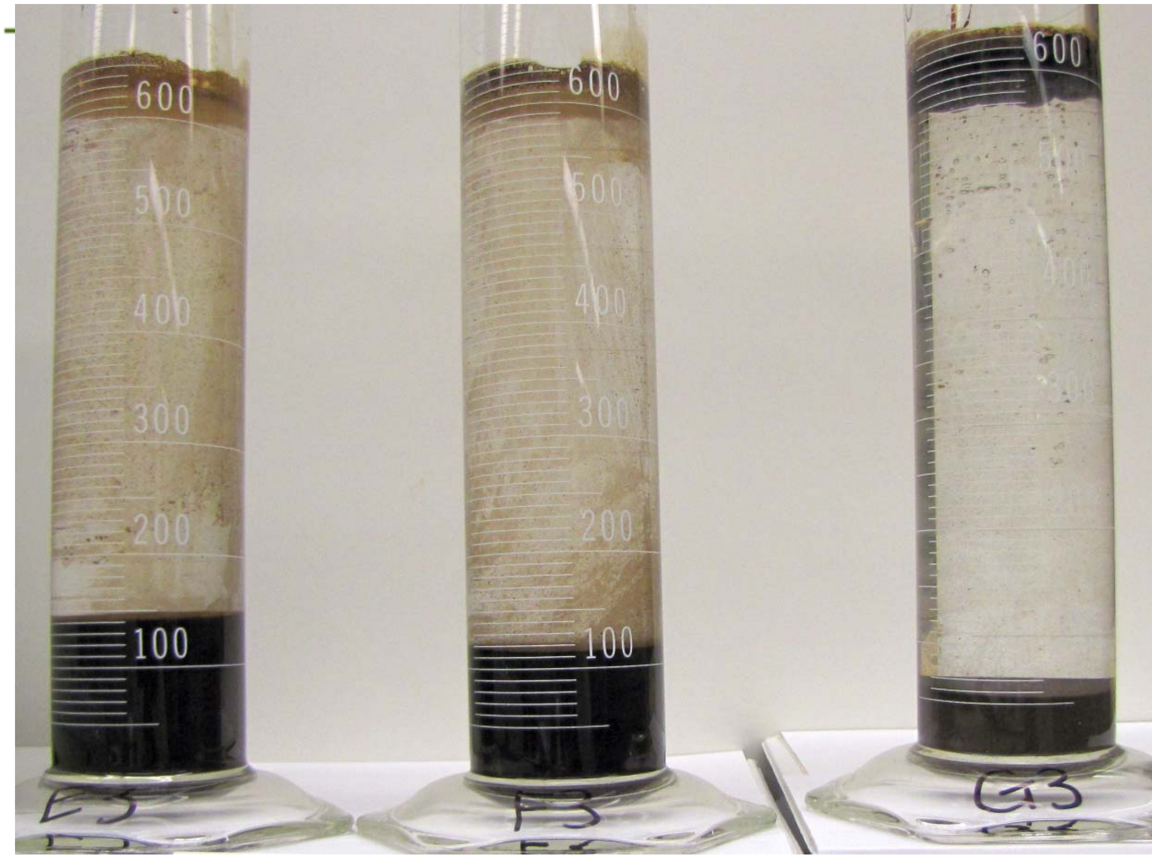
Fresh Cold Lake Bitumen, no sediment

Results: Oil Buoyancy

Conditions	Fate	Behaviour
• No sediment • All weatherings of oil	• Floats as oil-water mixture	• Floats and spreads like thick oil, e.g., Burnaby, BC
• Suspended fine and medium sediment • Fresh to moderate weathering of oil	• Large part of oil sinks as fine oil particles	• Suspended in water column, sinks, and disperses, e.g., Kalamazoo MI
• Suspended fine and medium sediment • Highly weathered oil	• Floating oil "tarballs"*	• Floats and "tarballs" can disperse
• Suspended coarse sediment • All weatherings of oil	• Large part of oil floats as water-oil mixture • Some sunken oil/sand agglomerations	• Most oil floats and spreads like thick oil • Few oil/sand agglomerations sink

* The use of the term "tarball" follows convention in the literature and refers to the consistency of floating, heavily-weathered oil. It does not describe the chemical composition of the product.

Submerged and Sunken Oil

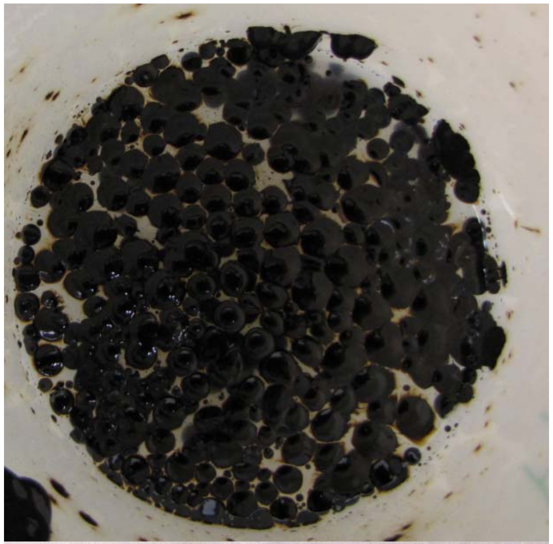


Oil mixed with fine sediment for 8 hours, allowed to settle for 24 hours

(15 °C, sea water---3.3% salt, Access Western Blend oil)

Fresh   Light evaporation   Moderate evaporation

Floating Oil "Tarballs"



Highly evaporated oil mixed with saltwater and fine sediment

Oil has very high viscosity, similar to native bitumen

Discrete oil "tarballs" form after mixing (fingernail size)

Floats in seawater

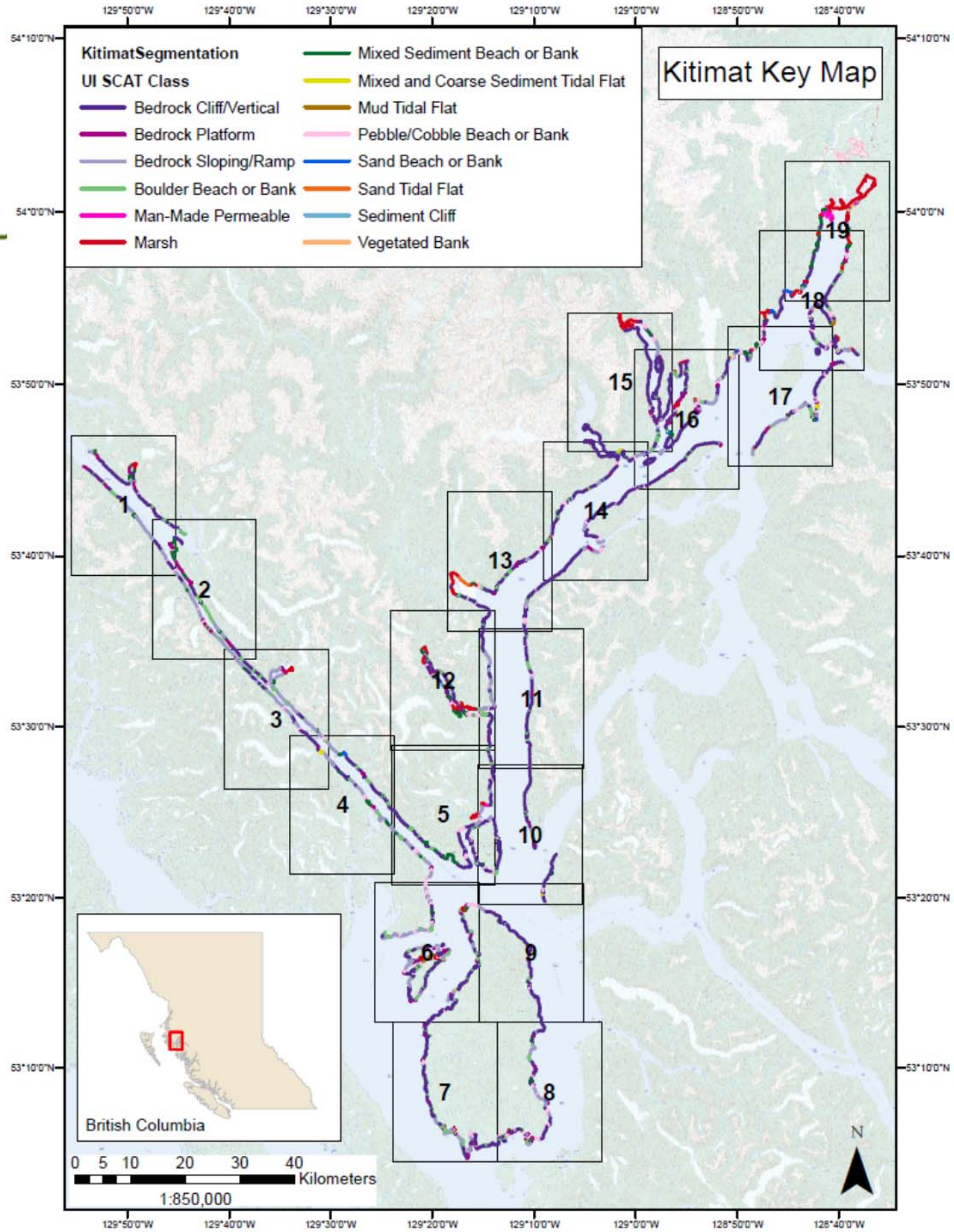
(Photos: Access Western Blend, 25% evaporated, 8 hours at 15 °C)

*The use of the term "tarball" follows convention in the literature and refers to the consistency of floating, heavily-weathered oil. It does not describe the chemical composition of the product.

Initial Shoreline Studies

- Objectives
  - study the fate and behaviour and cleanup of diluted bitumen on marine shorelines under various conditions
  - deliver operational guidance and scientific information that is legally defensible and credible to spill responders for shoreline treatment option decisions
- Literature review of the impacts of bitumen and fuels on marine shorelines
- Initial aerial shoreline survey of the Douglas and Grenville Channels, BC in 2013
  - Shoreline classification
- Mesoscale study on the fate, penetration & retention of diluted bitumen on marine shorelines underway

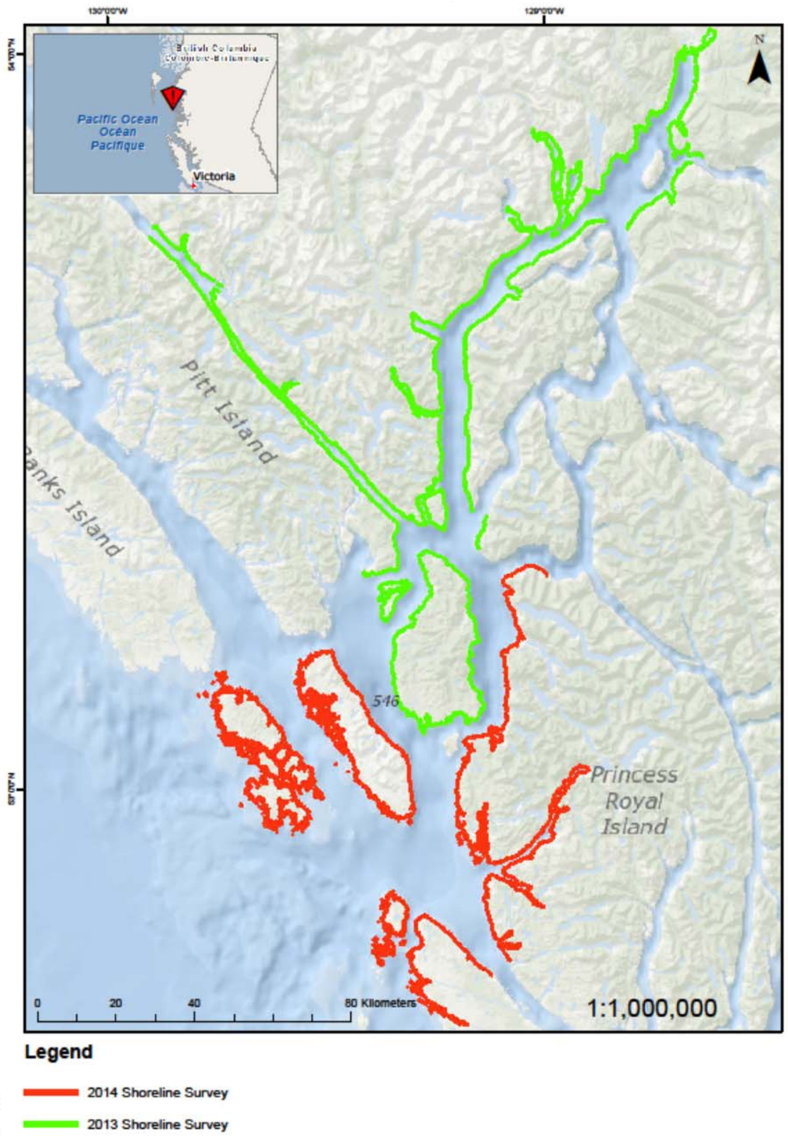
Map of the aerial survey in September 2013 and the final segmentation



2014 Shoreline Field Studies

- Additional aerial (helicopter) and shoreline (boat) surveys
  - Coastal BC
- Shoreline segmentation and classification
- Shoreline material collection for laboratory studies
- Collaboration with WCMRC – provision of vessels and crew

2014 and 2013 Shoreline Surveys near Kitimat, BC



Kitimat Estuary, September 2013

Detection

- Oil profiling using portable instruments
  - Identification and differentiation of oil (including dilbit) from background materials *in-situ*
  - Infrared (FTIR) and fluorescence

- Detection and monitoring of oil (including dilbit) in the water column
  - Towed fluorometers
  - C-3 Turner

Comparison of Dispersant Effectiveness Tests

- 2 bench-scale effectiveness test apparatus, similar in concept, different in energy profile
  - Swirling Flask: low energy mixing
  - Baffled Flask: high energy mixing

Note test variations: apparatus, analytical, temperature, others
***Test conditions not always consistent
→ Confusion

Dilbit Weathering and Implications on Dispersant Effectiveness

- Access Western Blend (AWB) and Cold Lake Blend (CLB)
  - Artificially weathered - 4 weathering states fresh to highly weathered residue
- Dispersant effectiveness determined by the low-energy Swirling Flask Test & the high-energy Baffled Flask Test at temperatures from 5 to 25 °C
- Dispersants were essentially ineffective at all temperatures in the SFT, while the BFT had a positive response for most conditions

Limitations to Dispersion

- The oil's intrinsic resistance to flow poses a physical barrier to droplet formation
  - A limiting parameter relative to the mixing energy
- The BFT provides idealized, controlled test conditions to isolate this rheological property as a variable
  - Limit of dispersibility correlates to the oil's resistance to flow
- Bitumen is a viscoelastic material
  - Viscosity does not capture flow behaviour well
    - A measure of velocity, destructive to elasticity character
- Alternative parameter is the complex modulus
  - Non-destructive measure of overall resistance to deformation, including elasticity

Time Window-of-Opportunity

- Rheological barrier to dispersion at 1000 Pa for BFT test conditions
- 100 Pa represents reasonable threshold value for estimating operational limit of dispersant effectiveness
  - Bench-scale tests present idealized conditions
  - 100 Pa inflection point for loss of effectiveness
- Use temperature-controlled open pan evaporation to estimate time to reach weathered states under study
- Plot complex modulus against time to estimate when rheological threshold reached
- Estimated time window-of-opportunity for dispersant effectiveness <12 hours below 15 °C

Outputs to date

- Federal Government Technical Report, 2014
  - Environment Canada, Fisheries and Oceans Canada, Natural Resources Canada, "*Properties, Composition and Marine Spill Behaviour, Fate and Transport of Two Diluted Bitumen Products from the Canadian Oil Sands*".
  - http://www.ec.gc.ca/scitech/6A2D63E5-4137-440B-8BB3-E38ECED9B02F/1633_Dilbit%20Technical%20Report_e_v2%20FINAL-s.pdf
- International Oil Spill Conference - Poster
  - M. Goldthorp, P. Lambert and C. Brown, "*Survey of Portable Oil Detection Methods*".
- 37th AMOP Technical Seminar on Environmental Contamination and Response, Canmore, AB June 2014
  - B. Fieldhouse, A. Mihailov, and V. Moruz, "*Weathering of Diluted Bitumen and the Implications to the Effectiveness of Dispersants* ", pp. 388-352.
  - M. Goldthorp, B. Fieldhouse, P.G. Lambert, C. Yang, and C.E. Brown, "*Oil Profiling Using Portable Instruments*", pp. 401-414.
  - S. Laforest, P.G. Lambert, J. Duffe, L. Gamble, B. Chaudhary, and C.E. Brown, "*Studies on the Fate and Behaviour of Diluted Bitumen on Marine Shorelines*", pp. 415-427.
- EC Oil Properties Database

Future Outputs

- Two plenary presentations will be delivered at the Interspill 2015 Conference in Amsterdam, The Netherlands in March 2015.
  - "Diluted bitumen weathering, fate and behaviour and buoyancy in the marine environment"
  - "Studies on the environmental impact of spills of non-conventional crude oil (dibit) on marine shorelines"

Phase 2

- Next Generation Environmental Simulator
  - A next generation test tank for oil fate and behaviour studies with full temperature control, allowing for year-round cold water testing, and continuous cycling, for tests over days and weeks.
- Evaluate on-site sampling and analytical systems for monitoring the effectiveness of spill countermeasures.
- Develop the framework for a Network of Expertise on Oil Spill Science and Technology.

Phase 2 - Area Response Plan (ARP) Scientific Studies

- Objective – to undertake scientific studies on specific petroleum products used and/or transported in high volumes in 4 pilot ARPs
  – Physical/Chemical property measurement
  – Fate and Behaviour
  – Spill countermeasures
  – Oil-Shoreline interactions
  – Spill modelling
- Variables to be considered;
  – Oil type (e.g. dilbit, Bakken, railbit, fuel oil, marine diesel etc.)
  – Environmental/Hydrodynamic conditions – temperature, winds, salinity, tide, sediment load etc.
- Anticipated output – new knowledge to enhance Canada's preparedness and response capabilities

Thank you!

Contact Information

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