MURPHY

Challenges and Learnings from a Condensate Spill in Muskeg

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Challenges and Learnings from a Condensate Spill in Muskeg

- Initial Spill Site Conditions
- Initial Spill Response
- Remediation Strategy
- Remediation – Areas 2 and 3
- Remediation Area 1

Initial Spill Site Conditions

Site Challenges

- **Condensate Flammability**
- **Multiple Stakeholders**
- **Protected Species**
- **Organic Soils (Muskeg)**
  - Site Access
  - Water Management
- **Product Recovery and Remediation Constraints**

Stakeholder Engagement

- Protection of receptors
- Protection of traditional land use
- Impact to local wildlife/vegetation
- Transparency
- Maximizing involvement
- Site security and protection of public

Initial Spill Containment and Surface Water Management

- Diversion trenches
- Clay plug cutoff walls
- Recovery bell holes

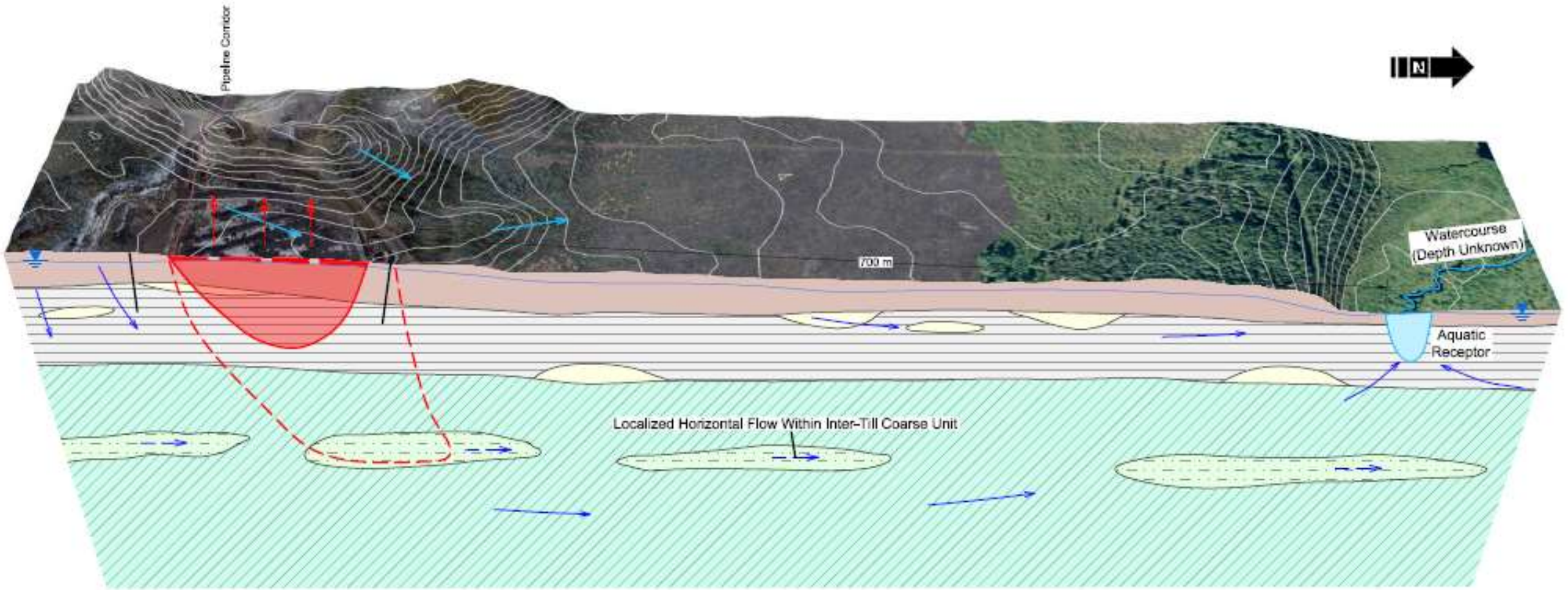
Subsurface Containment and Surface Water Management

- **Subsurface Containment**
  - Area 1: sheet piling wall
  - Areas 2 and 3: clay plug and trench around
- **Surface Water Management:**
  - Prevent entry of overland flow into containment area
  - Contain precipitation falling into containment area

Condensate Recovery

- Over 1,500 m of condensate recovery trenches and 17 bell holes
- Fire suppressant limited the ability to recover product
- Estimated recovery of 200 m^3 of condensate

Subsurface Assessment and Conceptual Site Model



Monitoring

- **No impacts to surface water bodies from spill**
  - Petrogenic vs. biogenic toluene
- **Wildlife Monitoring**
  - Fencing, deterrents (effigies & auditory), remote cameras, acoustic recording units and nest sweeps
  - Common night hawk and other migratory bird nests

Remediation Strategy

- Developed Risk Management Plan
- Risk Assessment
- Phased Remediation Approach
- Bench Scale Test

Technology	Safety	Stewardship	Sustainability	Science
Thermal Desorption Unit (TDU)	- Well established procedures - Experienced Canadian vendor - Extensive treatment train, many moving parts	- FN employment as laborers and operator assistants - AER endorses soil treatment	- Costly in remote areas - High electricity and propane/natural gas inputs - Clean water required to rehydrate treated soils	- Effective for PHCs - Questionable with PAHs
Multi-Phase Extraction (MPE)	- Highly engineered systems with shutdowns and controls	- Specialized technology - Minimal to no FN involvement - Longer remediation timeframe	- No soil removal - Treat and re-inject groundwater - High electricity inputs	- Effective with conde - Minimally effective in lower permeability soils (glacial till) - Short-circuiting effect in peat, suction loss
Dig & Dump	- Trucking hazards - Rollovers, wildlife encounters slippery/muddy roads	- FN employment as laborers and truckers	- Pre treatment required to meet non-DOW - Occupying landfill space - Waste generator has liability in Canada	- 100% certainty on the remediation outcome - Not sophisticated, relatively easy to implement
Allu & Bio-Treatment	- No off-site trucking risks - Multiple machines in small work area	- FN employment as laborers and site trucker - AER endorses soil treatment	- Less GHG emissions than dig & dump - Soil recycling/reuse, no borrow needed - Mother nature helping (PHC degraders)	- Proven technology - Used in Canada for 10 to 20 yrs

Bench Scale Test

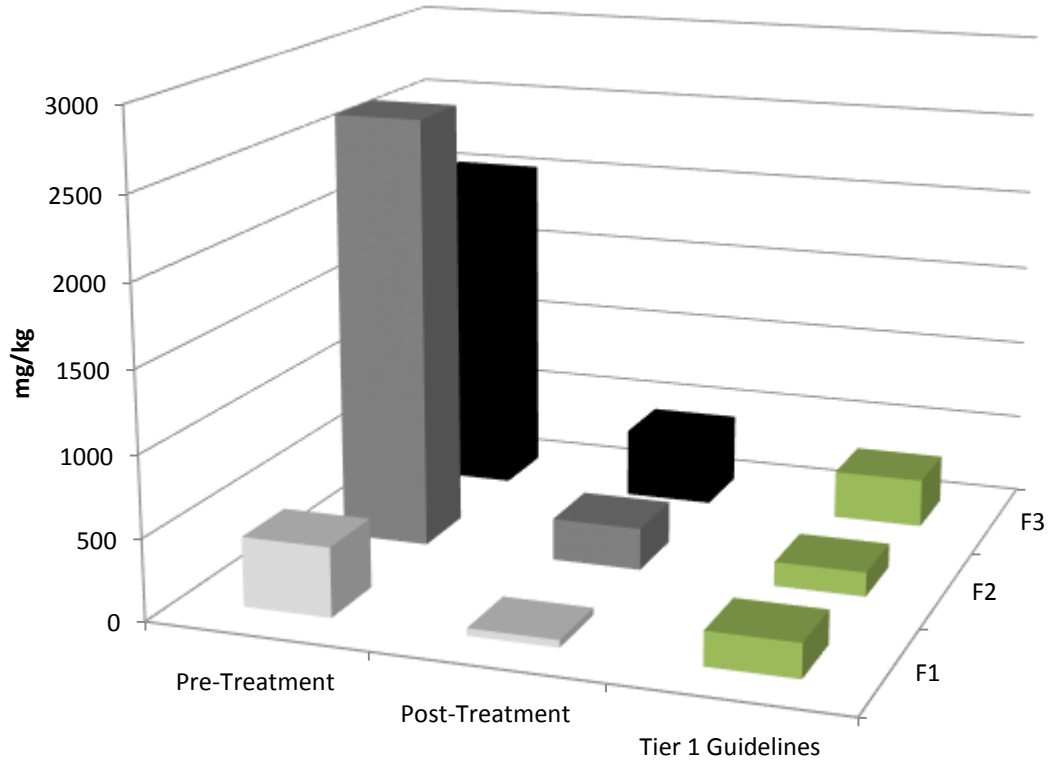
- **Challenge: 37,000 m^3 of impacted soil**
  - Large cost implications
  - Potential to introduce new contaminants
- **Learnings: Natural bacteria already present at high concentrations**
  - Determined maximum PHC concentrations that can be effectively treated onsite
  - Reduce final concentrations by adding minor amounts of inexpensive fertilizers

Remediation – Areas 2 and 3

- Excavated soil, segregating mineral and organic
- Treated soil within containment structures.
- Incorporated oxygen and nutrients using Allu™ buckets.
- Analysis of soil after each treatment to determine rate of PHC reduction and nutrient requirements.

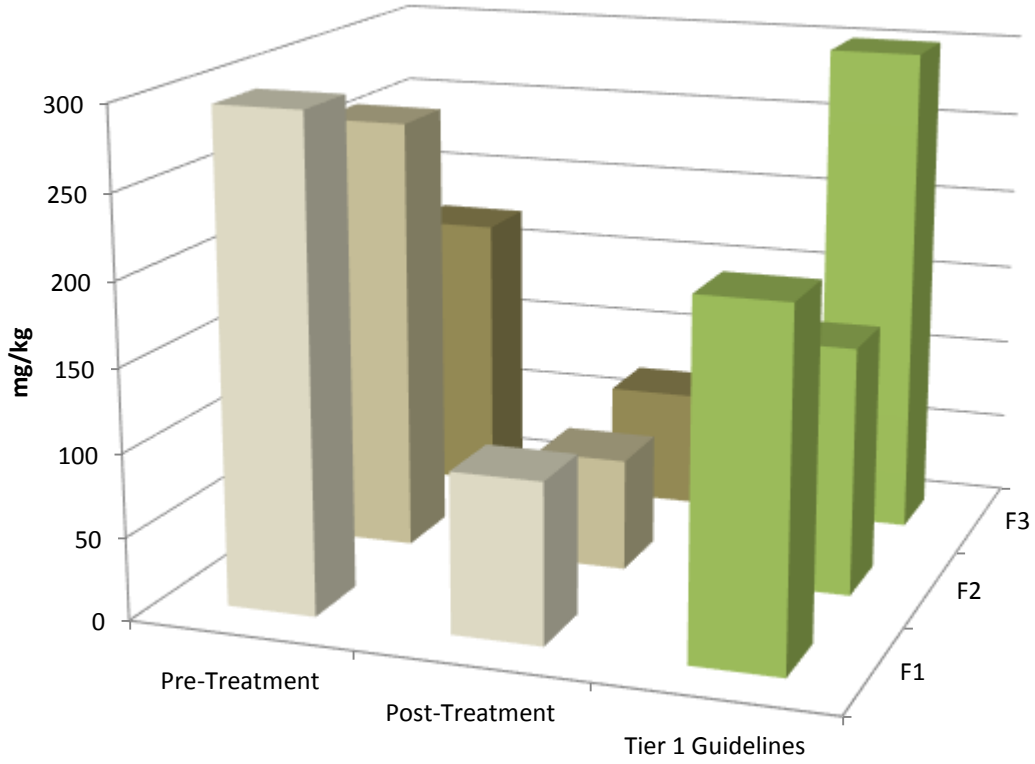
Bioremediation Treatment Effectiveness

Peat x 3 Allu's with Nutrients



80-90% reduction in F1
85-95% reduction in F2
70-80% reduction in F3

Clay Till x 3 Allu's



55-75% reduction in F1
75% reduction in F2
45-70% reduction in F3

Remediation – Area 1

- Work is ongoing
- Learnings from bench test validated at by site results
- Larger volume of organic soil than Areas 2 and 3

Learnings