Groundwater Monitoring Optimization for a Long Term, Large-Scale Program in Swan Hills, Alberta

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Introduction to field
Environmental risk strategy
Monitoring program
Results to date
Cost optimization
HC in the soil phase vs. the dissolved phase
Summary and moving forward
Swan Hills Field

- Approximately 420 km²
- Devon operates on behalf of more than 20 production companies
- 400+ operating or suspended sites
- Initial development in 1950s, peak production in mid-1970s
Flare Pits and Drill Sumps

Flare Pits – Contaminant Migration

Sumps – Limited Migration
Surficial Geology

- Morainal till deposits
  - Pink – thin till (<1m)
  - Green – thicker till (≥3m)
- Brown – Sands and gravels
- Orange - Alluvial sands and gravels along the Swan River
- Grey – Peaty/mossy deposits
Compliance with AEW Tier 1 - most straightforward way to achieve closure

Developing site-specific criteria to provide reachable alternatives, if necessary
The assessment and remediation program consists of three main activities:

- environmental site assessments (ESAs);
- source material management; and
- post-remediation monitoring, if required.

Groundwater assessment and monitoring
Key components of closure strategy:

1. Source removal to the extent practical
2. Long term (but not perpetual) monitoring
3. Achievable risk-based remedial objectives appropriate to the remote boreal forest setting of the Swan Hills field
109 sites instrumented (87 monitored in past 5 yrs)

Contaminants of concern: weathered petroleum hydrocarbons

Focus on natural attenuation (NA) and status of dissolved plumes (shrinking, stable or increasing)
From Norris et al. 1994
Sampling Frequency

- 3 monitoring events for gw characterization
  - Routine, HCs, metals and PAHs

- Discontinue seasonal monitoring - no seasonal variability observed for dissolved phase at 109 sites

- Ongoing sampling where risk to off-site receptors
Number of Piezometers Per Site

- Range – 3 to 43
- Median – 5
- **Range** – 1 to 18
- **Median** – 6
### Results – Number of Plumes Identified

<table>
<thead>
<tr>
<th>HC Phase</th>
<th>No. of Multi-Point Plumes</th>
<th>No. of Single Point Plumes</th>
<th>Total No. of Plumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free</td>
<td>8</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Dissolved</td>
<td>19</td>
<td>25</td>
<td>44</td>
</tr>
</tbody>
</table>

- Encompasses BTEX compounds and HC F1 and F2
- Free phase excluded detections of trace free product or hydrocarbon sheen (1 cm minimum thickness)
- Dissolved phase plumes = concentrations of at least one component exceeded the AEW Tier 1 groundwater remediation guideline
### Results – Plume Trends

<table>
<thead>
<tr>
<th>Plume Trend</th>
<th>Free Phase</th>
<th>Dissolved Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing</td>
<td>0 (0%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Decreasing</td>
<td>3 (18%)</td>
<td>6 (14%)</td>
</tr>
<tr>
<td>Stable</td>
<td>14 (82%)</td>
<td>37 (84%)</td>
</tr>
</tbody>
</table>

- Free phase trends based on thickness
- Dissolved phase based on concentrations
CORONA Research Project

- COnsortium for Research On Natural Attenuation

- Reviewed monitoring data from 124 Alberta upstream oil and gas facilities for evidence of NA

- Included sites in Swan Hills Field
CORONA - 102 HC plumes; Swan Hills – 44 HC plumes

<table>
<thead>
<tr>
<th>Dissolved Plume Trend</th>
<th>CORONA</th>
<th>Swan Hills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>Decreasing</td>
<td>26%</td>
<td>14%</td>
</tr>
<tr>
<td>Stable</td>
<td>47%</td>
<td>84%</td>
</tr>
<tr>
<td>Variable</td>
<td>21%</td>
<td>0%</td>
</tr>
</tbody>
</table>

No correlation between plume classification and geologic setting, geographic location, permeability and flow velocity
### Groundwater Monitoring - Costs

<table>
<thead>
<tr>
<th>Year</th>
<th># of Sites</th>
<th>Lab Costs ($)</th>
<th>Total Costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>55</td>
<td>116,000</td>
<td>355,000</td>
</tr>
<tr>
<td>2008</td>
<td>54</td>
<td>68,000</td>
<td>343,000</td>
</tr>
<tr>
<td>2009</td>
<td>17</td>
<td>18,000</td>
<td>101,000</td>
</tr>
<tr>
<td>2010</td>
<td>56</td>
<td>82,000</td>
<td>394,000</td>
</tr>
<tr>
<td>2011</td>
<td>32</td>
<td>49,000</td>
<td>224,000</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
<td>2,000</td>
<td>12,000</td>
</tr>
</tbody>
</table>

Cost optimization:
- Fall 2007 – implemented no-purge sampling
- Spring 2008 – critical review of frequency and analytical
- 2011 – less frequent sampling for low impact sites
- 2012 – reduced monitoring
Heavily Instrumented – Traditional Approach
How Many Piezometers Required for Delineation?
Soil HC vs. Dissolved HC Concentrations

- What dissolved HC concentrations result from soil HC impacts?

- Is there a “threshold” concentration where the need for groundwater investigation could be reduced or perhaps eliminated?
Soil HC vs. Dissolved HC Concentrations

BTEX+F1+F2 - Soil Concentration vs. Groundwater Concentration - Fine- and Coarse-Grained Soils

- Coarse-Grained
- Fine-Grained
- GW Rem - BTEX + F1 + F2 Guideline
- Soil Nat Subsoil - BTEX + F1 + F2
88 sites - 16% free phase, 40% dissolved plumes

98% of HC plumes in field are stable or decreasing (agrees with literature)

Monitoring frequency reduced due to steady-state conditions

Supplemental delineation has had limited benefit

No dissolved phase concentrations exceeding guidelines at soil concentrations <2,000 mg/kg (88 sites)
Moving Forward

- Critically review the need for **a)** ongoing monitoring and **b)** complete plume delineation

- Determine what the protocol/requirements are for monitoring to support site closure

- Develop a standardized, results-based protocol for ongoing/future monitoring