Swan Hills Facilities

- Original discovery well 1956
- Major development in 1950s and 1960s
- Miscible injection in 1980s
- Currently 385 operational oil wells
- About 25 abandoned wells
- CO₂ injection pilot undertaken in 2005
Environmental Strategy

- Sequential completion of Phase 1 and 2 investigations for approximately 400 sites
- Implementation of remediation for high risk and abandoned sites
- Construction of a purpose-built landfill to service the field
The Challenge!

To develop a risk-based closure strategy for well sites.

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
Two Stage Approach:

1) Field Wide Background “Framework”
   - define areas of common physical and ecological setting
   - develop appropriate exposure scenarios

2) Site-specific risk assessment(s)
   - adjust for site-specific conditions
   - early demonstration project to prove concept
Used a GIS approach to identify areas of common physical and ecological setting:

- Physiography
- Surface water
- Land use (town, forestry management areas, trap lines)
- Vegetation ecozones
- Surficial and bedrock geology
- Water well use

Compiled species lists for:

- vegetation
- terrestrial wildlife (mammals, birds, amphibians),
- aquatic species (fish and invertebrates)
Physiography

Topography

Surface Water Bodies
Four Natural Area “A” Zones:
A1 = River valley
A2 = Tertiary Sands and Gravels
A3 = Moraine Blankets
A4 = Organic Deposits (bogs and fens)

One Residential “B” Zone:
B = Town of Swan Hills
Swan Hills Residential Area
Conceptual Exposure Model

WorleyParsons Komex
resources & energy
Former Oil Well and Battery Site

- Drilled in 1960 and abandoned in 1963
- Former battery with 2 ASTs and a flare pit noted in 1966 airphoto
- All infrastructure removed by 1971
- Phase 2 investigations in 2003 and 2005.
WorleyParsons Komex
resources & energy

1994 Aerial Photo
Major Contaminant Sources
Problem Formulation

Risk Zone A3

- Morainal Blanket

Land Use

- Natural Area, within Blueridge FMA

Contaminants of Concern

- BTEX, PHC F1 to F4
- Arsenic, boron
Operable Pathways
- plant and invertebrate soil contact
- wildlife ingestion
- protection of potable groundwater

Inoperable Pathways
- protection of groundwater for:
  - aquatic life
  - wildlife ingestion
  - livestock
Issues:

• F3 guideline tends to be a remediation driver for crude oil contamination
• Often not achievable through bio-treatment

Hypothesis for guideline re-evaluation:

• Boreal forest plant species may be less hydrocarbon sensitive
• Weathered hydrocarbons may be less bioavailable and less toxic

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Fine Soil (mg/kg)</th>
<th>Coarse Soil (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Contact</td>
<td>800</td>
<td>400</td>
</tr>
<tr>
<td>Wildlife Soil Ingestion</td>
<td>17,000</td>
<td>17,000</td>
</tr>
<tr>
<td>Subsoil Management Limit</td>
<td>3,500</td>
<td>2,500</td>
</tr>
</tbody>
</table>
### Vegetation Bioassays

**Conventional Test Species**

<table>
<thead>
<tr>
<th>Species</th>
<th>Endpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern wheatgrass</td>
<td>emergence</td>
</tr>
<tr>
<td>Perennial rye</td>
<td>root length</td>
</tr>
<tr>
<td>Alsike clover</td>
<td>shoot length</td>
</tr>
<tr>
<td></td>
<td>shoot and root mass (wet/dry)</td>
</tr>
</tbody>
</table>

**Env Canada Boreal Species**

<table>
<thead>
<tr>
<th>Species</th>
<th>Endpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trembling Aspen</td>
<td>emergence</td>
</tr>
<tr>
<td>Black spruce</td>
<td>root length</td>
</tr>
<tr>
<td>White spruce</td>
<td>shoot length</td>
</tr>
<tr>
<td>Bluejoint reedgrass</td>
<td>shoot and root mass (dry)</td>
</tr>
<tr>
<td>Canada goldenrod</td>
<td></td>
</tr>
</tbody>
</table>
## Invertebrate Bioassays

<table>
<thead>
<tr>
<th>Test Species</th>
<th>Endpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthworm (<em>Eisenia andrei</em>)</td>
<td>Survival, reproduction, progeny mass</td>
</tr>
<tr>
<td>Springtail (<em>Folsomia candida</em>)</td>
<td>Survival, reproduction, fecundity</td>
</tr>
</tbody>
</table>
Bioassays

- Screening level test using 100% “strength”, PHC F3 ~ 7,000 mg/kg or 10,000 mg/kg

Definitive tests:

- Geometric series of concentrations:
  - 0% (background reference soil)
  - 1%, 2.5%, 5%, 10%, 20%, 40%, 60%, 100% “strength”
- Used to identify LOAEC, NOAEC, EC$_{25}$, EC$_{50}$
artificial, background, 1%, 2.5%, 5%, 10%, 20%, 40%, 60%, 80%, 100%
Guideline Data Requirements:

- CCME guideline minimum requirement:
  - 10 endpoints from 3 species
- This study: 10 species providing up to 52 endpoints

Eco – Contact Guideline:

- 25th percentile of the EC$_{25}$
- Endpoints screened for validity (statistically and biologically relevant, monotonic etc).
Rank Sensitivity analysis of EC/IC
All “Acceptable” Datapoints

F3 Guideline = 1460 mg/kg
Rank Sensitivity analysis of EC/IC
Boreal Forest and Invertebrates Only

F3 Guideline = 2950 mg/kg
Extension to Other Well Sites

- Remediation ongoing at a second site using the same site-specific F3 guideline

- Screening level bio-assays will be completed on “clean” samples from excavation perimeter to validate F3 guideline

- Testing will be limited to 2 boreal plants and 1 invertebrate species
Summary And Status

- Field wide review and development of “risk zones” completed
- Site-specific risk assessment completed for demonstration site
- Regulatory review underway
- Foundation for Field Wide Risk Assessment
- Application to other fields / regions
Acknowledgements

- Brent Moore, Devon Canada
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