DALHOUSIE UNIVERSITY
FACULTY OF ENGINEERING

Remediation Design for a Petroleum Condensate Contaminated Site

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Department of Civil and Resource Engineering

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Introduction

The site of interest, as seen in **figure 1**, is a decommissioned gas scrubbing facility located in southwestern Saskatchewan. Over the course of the site's operation, naphtha condensate has leaked from an underground storage tank and polluted surrounding soil and groundwater. The contamination is primarily composed of BTEX compounds in the free product phase. The goal of this project is to remediate the site contamination to SERM guidelines.

Figure 1: Location of contaminated site

Previous Site Remediation

Previously, dual phase vacuum extraction (DPVE) remediation was completed on the site between 2000 and 2001. A total of 46 boreholes were installed, with 30 of these including monitoring wells.
After October 2001, a peak Benzene concentration of 429.8 µg/L was found, which is higher than the 300 µg/L guidelines.

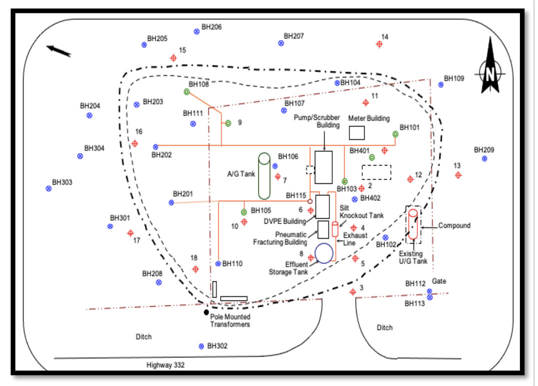

Figure 2: Site overview with design of previous remedial efforts

Initial Site Condition

Table 1: Initial site soil and contaminant conditions

Parameter	Value
Soil classification	Silty clay, sand, and clay matrix till
Hydraulic conductivity	In the range of 10^{-7} to 10^{-5} (m/s)
Porosity	30 – 53.1%
Contaminants: mainly	$C_5 – C_{10}$ hydrocarbons
Hydrocarbons:	BTEX
Free product	Trace to >1800 mm
Vapor concentration	>10,000 ppm
Groundwater table	4.8 – 13.2 m below ground surface
Contaminated area	~ 3500 m^2

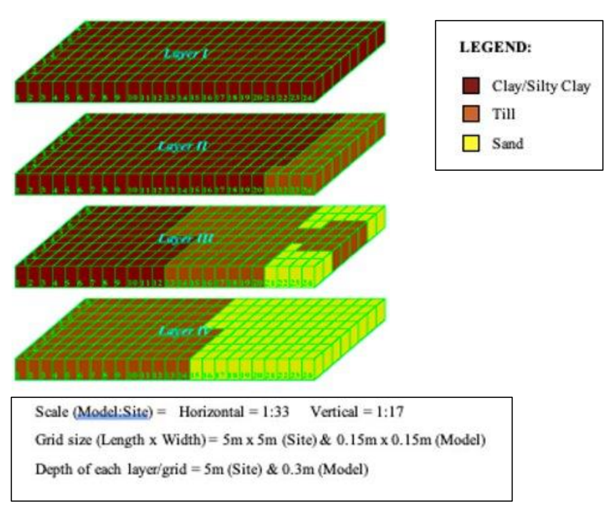

Figure 3: Initial site soil and contaminant conditions

Remediation Technology Background

Air Sparging:

An in-situ technology that involves injecting air into and below the saturated zone to volatize free product contaminant.
This technology works with Soil Vapour Extraction, SVE, which pulls the volatized contaminants out of the soil. Through the use of hydraulic soil fracturing, the effectiveness and radius of air sparging increases due to the higher hydraulic conductivity that is induced.

Hydraulic Soil Fracturing:

A technique used to increase the permeability of soil by inducing fractures using highly pressurized water, before filling the fracture with an engineered slurry.

Soil Vapour Extraction (SVE)

Applies a vacuum to pull the volatized contaminants that are above the water table out of the soil. Hydraulic soil fracturing enables SVE to become more effective due to the higher induced porosity and hydraulic conductivity.

Final Design – Air Sparging & Hydraulic Soil Fracturing

Air Sparging:

- The final design is to have 6 air injection wells that will cover the whole site area.
- The radius of influence for the wells is 10 m.
- Using a pressure of 0.8 atm, hydraulic soil fracturing increases the radius of influence in our soil conditions.
- The system will operate by injecting air into the saturated zone for 5 seconds every 10 minutes.

Hydraulic Soil Fracturing:

- HSF will be deployed in each of the SVE and Air Sparging wells prior
- 9 wells will undergo hydraulic soil fracturing.
- Estimated to increase the permeability by a factor of 8 and range of influence by 4.9 m, bringing overall radius of influence to 14.9 m.
- The fractures will be induced at intervals of 0.6 m down the wells
- Once a fracture is induced by highly pressurized water at a desired depth, a slurry of water, sand, and guar gel is injected to the fracture.

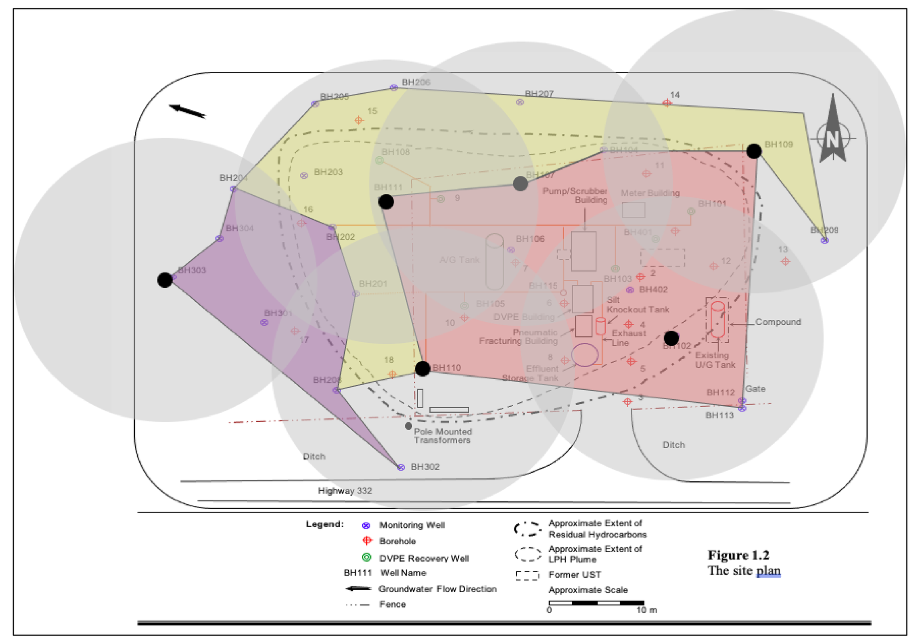

Figure 4: Plan View Map of Air Sparging

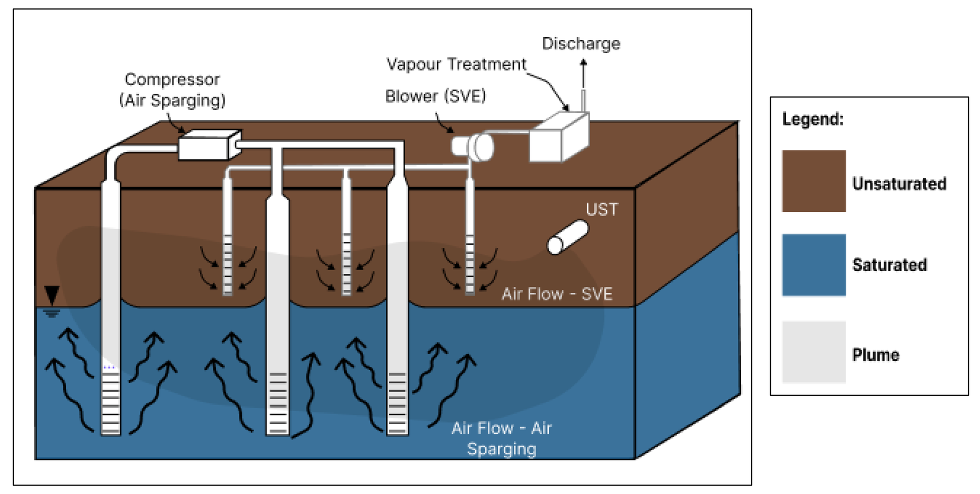

Figure 5: Cross-Section View of Air Sparging and SVE Design

Final Design - SVE and Contaminant Disposal System

Soil Vapour Extraction (SVE):

- Volatized petroleum contaminants will be collected from the soil using a network of nine SVE boreholes drilled on the site, seen in **figure 5**.
- The SVE boreholes will be drilled down to the local water table depth, and will contain a sand pack overlain by a cement grout cap
- Boreholes will be connected to a centralized pumping system using 1 inch diameter PVC piping.
- A centralized vacuum will apply a 0.1 atm vacuum to all boreholes

Contaminant Disposal System:

- Extracted contaminant will first pass through an air-water separator connected to the vacuum system.
- Volatized contaminant will pass through a (16in x 16in) 5 layer coconut bulk activated carbon filter system.
- Filter lifetimes are expected to be 3-6 months.
- Liquid contaminant will be stored in a 5000 gallon bulk liquid storage tank.
- Liquid contaminant will be disposed offsite at a class 1a disposal facility located within 200km of the site

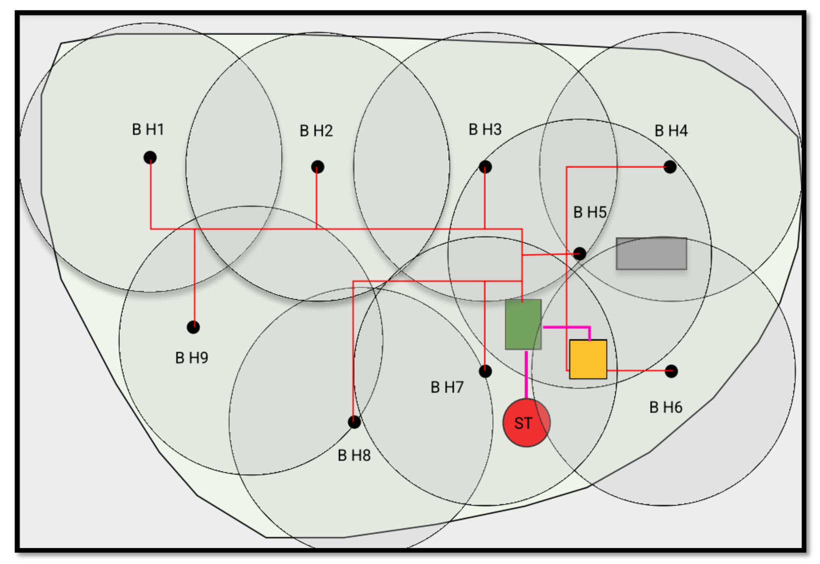

Figure 6: Plan view schematic of SVE system

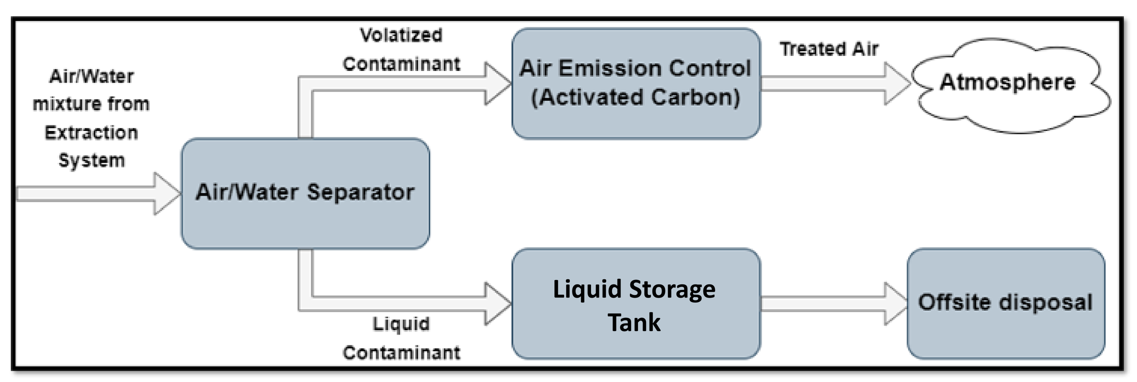

Figure 7: Flowchart of petroleum contaminant disposal system

Conclusions and Recommendations

The remediation design for the gas scrubbing facility will remove the naphtha contamination and associated BTEX compounds from surrounding soil and groundwater. The design will remove the contamination to SERM guidelines within **3 years** in an efficient, economical and safe manner.
In the future we would recommend:

- Obtaining access to the raw data from the previous remedial efforts to help better understand the site conditions
- Continue to monitor the site to ensure that SERM guidelines are met after remediation has finished

Economical Analysis

Table 2: Itemized Cost Breakdown

Category	Item	Quantity	Price	Total
Air Sparging	Installation	45,500 m^3	\$27 / m^3	\$1,228,500
Soil Fracturing	Fracture	6	\$3,937.5	\$23,625
SVE	Remediation	1	\$225,000	\$225,000
Liquid Extract	Disposal	1	\$46,000	\$46,000
Air Sparging & SVE	Operation	3 years	\$40,000	\$120,000
Total Costs				**\$1,643,125**

Safety Plan

- Looking beyond the remediation, further monitoring must be done for the site to ensure the safety of the community.
- Although the site will be remediated to values below the guidelines, it is recommended that a monitoring program be completed.
- It is advised that free product should be monitored in the wells monthly for the first five years.
- Changes in the free product within the wells can drastically change due to water level fluctuations and should be monitored accordingly.

Risk Assessment

- The current levels of contaminant found in the soils of the site exceed the Saskatchewan Environment and Resource Management Soil Quality Guidelines, with a particular emphasis on BTEX.
- With the benzene in BTEX being a well-known carcinogen, the site's risk assessment would additionally have to include the risks of cancer from any contaminants left behind.
- Under the current plan, only 5ug/g of BTEX would remain after XX years, this is well below the SERM guidelines.
- The level of Benzene that would remain in the ground would put some limits on the uses for the land due to cancer risks.
- It would only be able to be used for commercial or industrial land use, and any water on the site would be able to be considered potable, but as it would be right at the limit of 5ug/g, it would be prudent to continue monitoring to ensure safety.

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