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A Simple Solution to Product Recovery

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Abstract

Historical sources, since removed, at CN's Smithers yard in northern British Columbia have resulted in the presence of over 150,000 litres of light nonaqueous phase liquids (LNAPL) under discontinuous clay.

A product recovery system was initially installed in 1996, which consisted of 19 recovery wells complete with floating skimmers connected to a central eductor vacuum system. The extracted product and groundwater mixture was transferred to an existing oil/water separator. Operational problems included poor discharge quality (emulsified oils), and significant maintenance.

Improvements to the eductor system were successful in reducing emulsification and lowering operating costs. However, product recovery rates remained low, discharge water quality was poor, and maintenance costs were high. These challenges were magnified by the remote location and sensitive receiving environment (the yard is bounded by salmon bearing streams).

CN Revisited the remedial approach began in 1999 by mapping subsurface stratigraphy using ground penetrating radar. The studies found that LNAPL tended to collect at anticlines in the clay layer. The existing system, and other complex alternatives were rejected in favour of strategically placed stand-alone rope skimmers. Ten systems were installed in November 2000 and have had the following benefits:

- The oil/water separator and associated discharge has been removed.
- No emulsification.
- Low maintenance, minimal local expertise required.
- Independent operation, easily relocated.
- Year round operation.
- Increased recovery rate.

The new system has been able to remove over 9,400 L of product in the first two seasons of operation.

Introduction

Smithers railway yard is a divisional point where train crews change, some locomotives are fuelled, engineering forces are stationed and minor maintenance is undertaken on railcars and other equipment. It was established by the Grand Truck Pacific Railway in 1914. Historically it was a major divisional headquarters. Steam locomotives were serviced in a roundhouse and fuelled at a bunker C fuelling facility. Following dieselization in approximately 1955, diesel locomotives were fuelled and serviced at the car shop until 1994.

A number of environmental investigations have been conducted at the site since 1993. During these investigations, a product plume was identified beneath approximately 9,000 m² of the site in the area of the car shop. Gas chromatograph (GC) scans of the free product collected from the car shop area indicate presence of both bunker C and diesel. The potential sources are the former bunker C facilities and the diesel fuelling stand and associated fuel lines. The free product plume and the potential sources associated with the plume are presented on Figure 1.

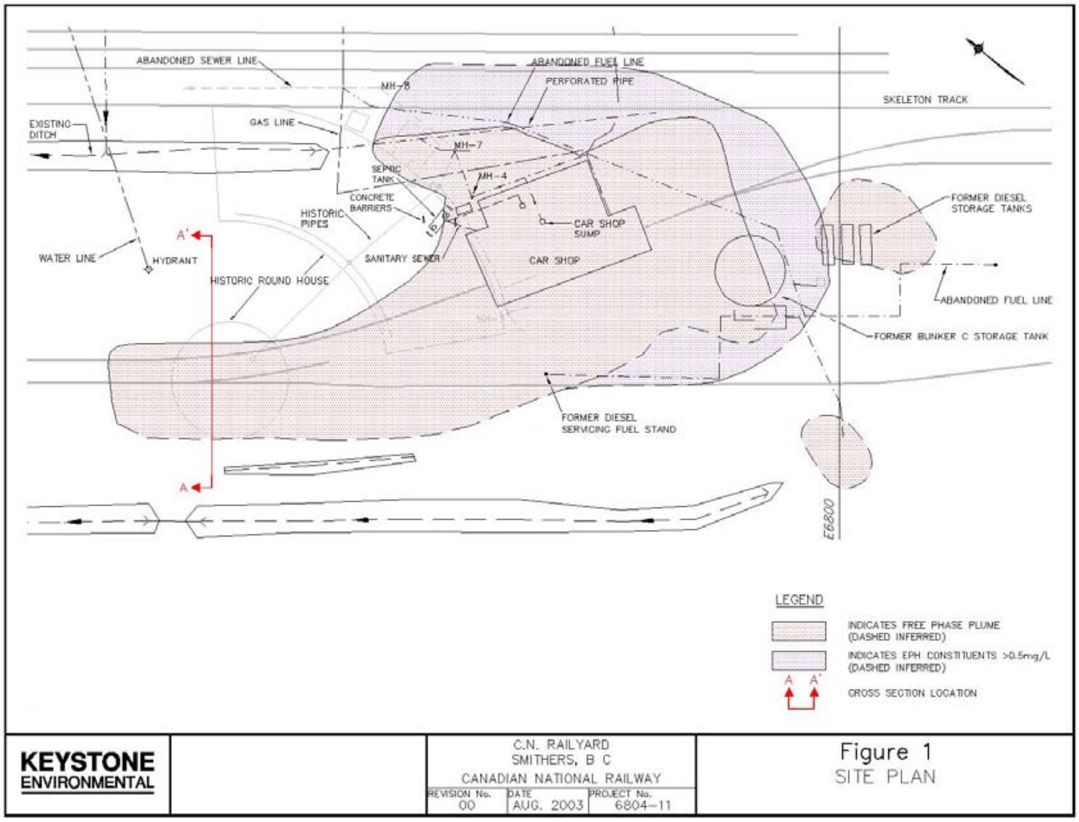

Figure 1
SITE PLAN

A liquid recovery system consisting of recovery wells with floating skimmers connected to a central eductor system was installed in 1996/1997 and was operated through to 2000. High operating costs and ongoing problems with maintenance and operations warranted a review of the product recovery system. CN then retained Keystone Environmental to provide options to develop a simpler solution to product recovery, with the expectation of increased product recovery and lower operational and maintenance costs.

Site Description

The shallow sediments beneath the car shop area consist of three distinct units; an upper sand and gravel fill, a middle clay confining layer, and a lower sand unit that contains the free phase hydrocarbons. The middle clay layer tends to be contiguous, but varies in thickness and elevation across the site. The lower sand unit tends to be confined by the clay layer, resulting in an artesian type aquifer (upward vertical gradient).

Product released at the surface was transported through breaks within the clay layer such as utilities and building foundations installed at depth into the lower sand unit. The migration likely occurred during historic seasonal fluctuations in the groundwater table and product is now trapped below the clay layer. The product, a diesel and bunker C mixture, floats on the water (LNAPL) and is forced hydraulically by the artesian aquifer to collect into pools within areas of higher interface of the sand/clay elevation (anticlines). As a result of this, the pattern of contamination at the site is strongly influenced by the site geology. This is presented on the cross section of Figure 2.

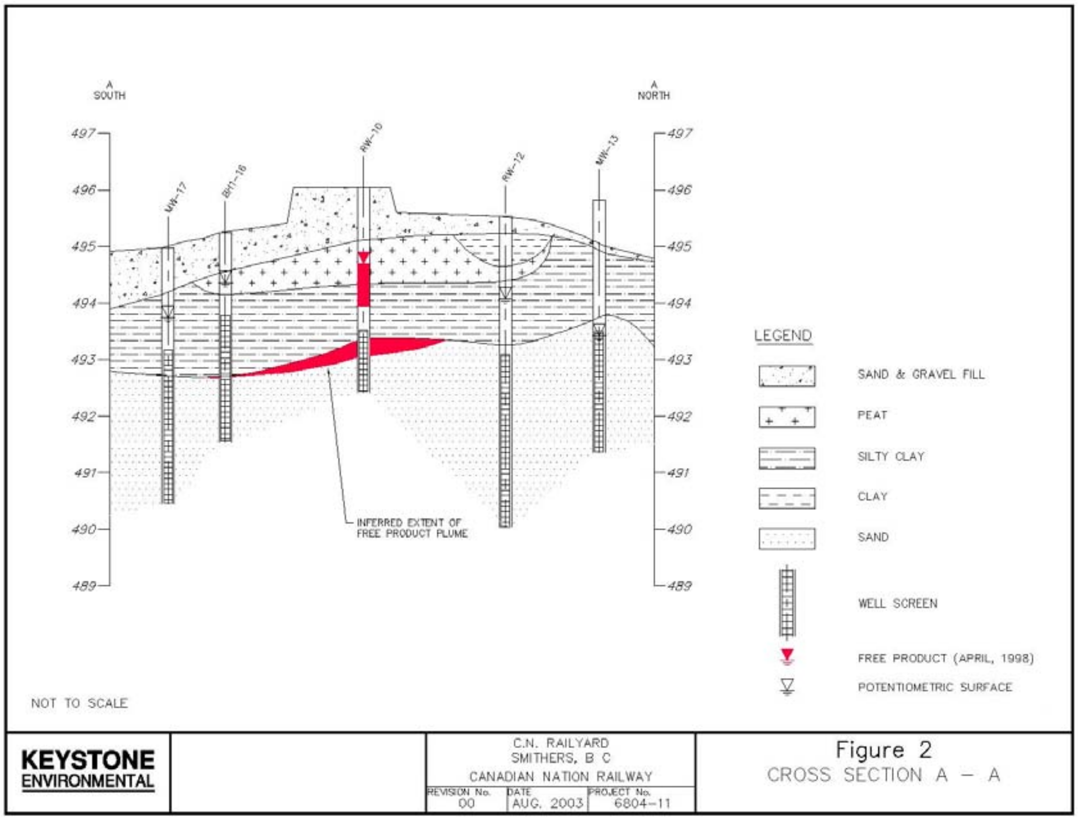

Figure 2
CROSS SECTION A – A

The groundwater flows beneath the car shop area in a northerly direction with an average hydraulic gradient ranging from 0.005 to 0.009 m/m. The hydraulic gradient fluctuates seasonally with the higher gradient present in springtime due to snowmelt. Using an effective porosity of 30% and a hydraulic conductivity of 1.1 x 10^{-5} m/s, a groundwater velocity of 6 to 10.5 metres per year was calculated for the lower sand unit. The product migration is severely affected by the geology, as the sand/clay contact descends deeper (synclines) at the northern extent of the plume. As a result, the plume has expanded laterally, rather than migrating with the groundwater gradient in a northerly direction

Approach to Product Recovery 1997-2000

Recovery wells were installed in November 1996 as part of a liquid recovery system, which was installed in May of 1997. Product recovery was accomplished through liquid hydrocarbon skimmers connected to a central vacuum system. The basic principle of operation was:

- Hydrocarbon skimmers were installed within each of nineteen recovery wells selected for product recovery. The skimmers were connected to the eductor by drop tube recovery lines.
- A vacuum was induced on the eductor with a multistage centrifugal pump, drawing in product and groundwater from the skimmers.
- The recovered fluid (oil and water) collected in the eductor tank was then sent through an 18,500L holding tank, transfer box, and an oil water separator.
- Separated oil was recovered and transported for recycling.
- Recovered groundwater was discharged to the drainage ditches, eventually discharging to Chicken Lake Creek.

In 1998, Keystone Environmental was retained by CN to maintain, monitor and evaluate the product recovery system. The evaluation of the product recovery system raised several concerns:

- Extreme heating of the main product recovery system tank, due to high recirculation rates.
- Emulsions were formed and caused operational deficiencies. As a result, exceedances of total extractable hydrocarbon (TEH) concentrations were observed in the effluent samples. The effluent from the recovery system was discharged to a surface drainage ditch that flowed though a second downstream oil/water separator into salmon bearing streams. Discharges of TEH to the stream could not be tolerated.
- Low product recovery rates and high cost per litre of recovered oil. The recovery rates are presented in Table 1 below.

Table 1: Eductor Product Recovery Rates

	1997	1998	1999	2000
Annual Product Recovery (Litres)[1]	2,650	3,295	2,300	310
Average Product Recovery Rate (Litres per operating hour)	1.0	3.7	0.5	0.5

[1] Assuming emulsified oil contains 50 % water content.

In 1999, upgrades were completed to the system to decrease the operating temperature to reduce the tendency for the system to form emulsions. The upgrades completed were as follows:

- A recycle line was connected from the holding tank to the eductor tank to increase the volume of water recirculated and decrease the temperature of the water.
- Installation of a passive oil skimmer within the wastewater holding tank was conducted to improve the efficiency of oil removal.

- A cycle timer was installed to control the pump run time to reduce the introduction of air into the system thereby reducing the formation of an emulsion.
- Two new recovery wells were added in key locations.

Following these modifications, improvements were noted in reduced operating temperatures and improved effluent quality, but the effluent analytical data continued to exceed allowable TEH concentrations, and tertiary treatment would have been required to meet discharge requirements. With the objectives of simplifying the system and lowering operating costs, tertiary treatment was not a desirable option. Instead, a significant change in focus was considered.

Approach to Product Recovery 2001-2003

CN requested that Keystone Environmental review product recovery options with consideration to the following:

- reducing the operation and maintenance costs;
- increased product recovery; and
- simplifying operational checks and maintenance for the on-site operator.

Selecting the locations for product recovery was an important process in the design of the systems. These systems are passive recovery systems and rely on the natural migration of the product, which is affected by the geology. The goal of the preliminary investigation was to locate local anticlines in the clay, where product will naturally accumulate, and to install product recovery systems there. The locations were selected based on:

- review of monitoring data for wells within the plume area and borehole logs;
- review of geologic cross sections to determine where anticlines in the clay may exist;
- a review of ground penetrating radar results to determine the location and thickness of the clay layer; and
- location of historical structures and underground utilities.

Ten new individual product recovery systems consisting of stand-alone rope skimmers were installed in November 2000 and commenced operation in May 2001. Each product recovery system consisted of the following components:

- a 10 cm recovery well;
- ¼ hp product recovery skimmer. “Fuzzy belts” are used at locations with low viscosity product, and polymer belts are used with viscous product;
- concentrator tank;
- skimmed hydrocarbon (waste oil) holding tank; and
- structure for enclosing the equipment.

The individual product recovery systems operate by skimming product floating on the groundwater off of the surface and transfer it up the recovery well by a recovery belt. After picking up the product, the belt travels through tandem wiper blades, scraping off the product into a small concentrator tank. The concentrated product is then discharged into an above ground storage tank (AST) and any collected water is returned to the well.

The ten product recovery systems are labelled RW-23 to RW-34. Currently two of the ten (RW-26 and RW-27) are inactive. Three of the systems transfer product into a common tank, located approximately 15 m north of the system structures. This was completed to maintain the required distance from the waste oil tank to operational railway tracks. The layout of the product recovery locations is presented on Figure 3.

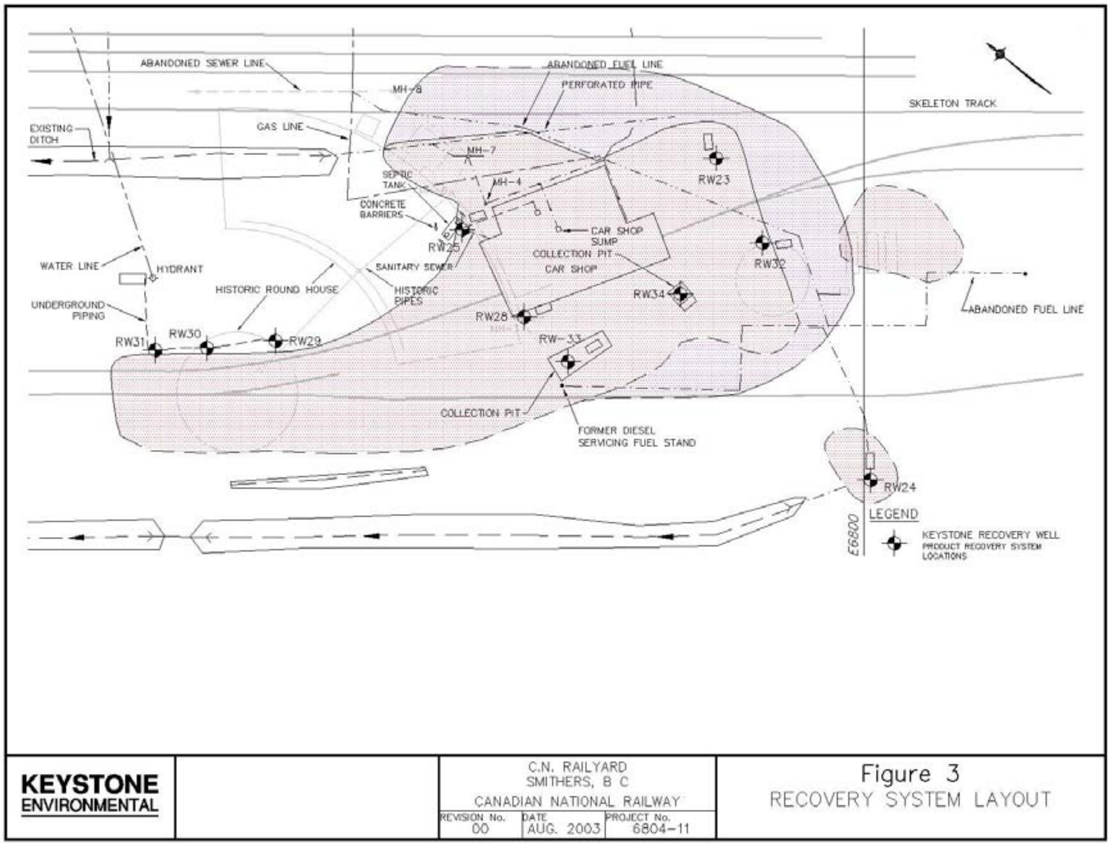

Figure 3
RECOVERY SYSTEM LAYOUT

During the May to October 2001 operating period, 1,550 litres of product was collected from the recovery wells. There were few mechanical difficulties with the systems over the 2001 reporting period. Several recovery wells (23 to 27 and 30 to 31) did not collect a measurable amount of product owing to a lack of product present in the recovery wells. The lack of free product migration into the product recovery wells may be due to a highly viscous product with low mobility, or that the confining layer near the recovery well has been compromised, allowing the product to be perched above a recoverable level.

During the May to December 2002 operating period, significantly larger quantities of product were recovered from product recovery systems RW-24, RW-25, RW-28, RW-29, and RW-32. The total product recovered during the 2002 operation period was 7,900 L with the greatest recovery occurring at RW-25 and RW-28, recovering 3,096 L and 2,830 L respectively. Greater product recovery was observed at these two locations due to a high permeability fill surrounding the recovery wells, allowing product to pool around the well.

In an attempt to duplicate this rate of recovery and improve on the overall product recovery rate, two 20 m^2 infiltration trenches were excavated to below the clay layer, backfilled with drainrock, and product recovery systems were installed within these collection trenches. Results for the January to August 2003 operating period product recovery was observed at product recovery systems RW-24, RW-25, RW-28, RW-29, RW-32, and RW-34 (trench recovery system). The greatest product recovery remains at RW-25 and RW-28, and this is likely due to the high permeability fill surrounding the recovery wells, and the location of the wells at anticlines. The product recovery rates for 2001 to 2003 are presented on Table 2.

Table 2: Rope Skimmer Product Recovery Rates

	May to October 2001	**May to December 2002**	**May to August 2003**
Annual Product Recovery (Litres)	1,550	7,900	5,200[1]
Average Product Recovery Rate (Litres per operating hour)	0.5	2.7	3.1

[1] to August 20, 2003

The 2002 and 2003 results represent roughly a 365% increase in product recovery compared to the earlier vacuum eductor system. In an effort to further improve the recovery of this simplified system, options were evaluated to continue product recovery in freezing conditions during the five months of winter as well. During the fall of 2002, three product recovery enclosures were insulated, which would allow the operation of the belt recovery systems through the winter months. However, due to constant sub-zero temperature conditions the waste oil tanks became ice laden and even heat taped transfer piping froze and plugged. Therefore the systems did not operate through the winter of 2002/2003. It was proposed to winterise selected product recovery systems by constructing insulated enclosures encompassing the transfer piping and the waste oil tanks, and providing a small heater at four product recovery locations. Four product recovery locations were selected for winterisation owing to their high product recovery rates. The winterisation program will be completed in the Fall of 2003.

Benefits to the 'Simple Solution'

The benefits to the simple design of the rope skimmer system are:

- Simpler operation (not complicated to operate; no lengthy operator training is required).
- No water discharge is created; therefore, no effluent treatment equipment is required, eliminating the risk of impact on salmon in the streams. This is not only a benefit to the environment and the salmon, but also avoids the process of obtaining authorisation to discharge.

- Little or no oil emulsification. Oil emulsification increases the water content within the separated oil, increasing both the volume for disposal and the unit cost of disposal, which varies according to water content.
- Year round operation. This enables the recovery systems to operate during peak recovery periods (September to December) when the groundwater table is low, and product migration is higher.
- Individual recovery systems for each recovery well. This allows recovery to continue should a component at one location be down, and allows some parts of the overall recovery system to be shut down when not productive.
- Low cost. As presented in Table 3 the rope skimmer system has a lower operating cost than the eductor system.
- Increased recovery rate. As presented in Table 4 below, the average annual product recovery is greater for the rope skimmer system.

Table 3: Cost Comparison

	Eductor Recovery System	**Rope Skimmer System**
Capital Costs	\$258,000[1]	\$160,000
Operating Costs[2]	\$15,000	\$10,000

[1] Based on the 1996 capital cost for the system and assumes \$100,000 in tertiary treatment. However, the upgrades were not completed.

[2] Operating costs consist of operator labour costs, materials, product disposal and effluent sampling if required.

Table 4: Average Product Recovery Rate

	Eductor Recovery System	**Rope Skimmer System**
Average Annual Product Recovery (Litres)	2,150[1]	5,500[2]
Average Product Recovery Rate (Litres per operating hour)	1.4	2.1

[1] Assuming emulsified oil contains 50 % water content

[2] Average results include projected annual recovery for 2003

Conclusion

The simplistic approach to product recovery was selected over more complex alternatives due to the following benefits:

- Little or no emulsification and no discharge, which eliminates impact on salmon.
- Low maintenance, simple operation, therefore minimal local expertise required.
- Year round operation to capitalise on high yield months in the fall.

The solution to product recovery was simple, but the preliminary investigation for the design of the systems included high tech solutions such as ground penetrating radar surveying. Since the pattern of contamination at the site is strongly influenced by the site geology, understanding the geology was an important factor in selecting optimum locations for the product recovery systems. Once the product recovery locations were selected, the solution was simple.

Acknowledgements

Jack Stroet, Product Recovery System operator.

References

"Manual of Operations for Product Recovery System and Car Shop Ditch Oil/Water Separator System, CN Railway Yard, Smithers British Columbia" Keystone Environmental Ltd., August 1999.

"Manual of Operations, CN Railway Yard, Smithers Product Recovery System" Keystone Environmental Ltd., February 2002.

"2001 Annual Report of Product Recovery, Smithers Railway Yard, PIN 26551, 25228, Canadian National" Keystone Environmental Ltd., March 2002.

"2002 Annual Report of Product Recovery, Smithers Railway Yard, PIN 25228, 2400609, Canadian National" Keystone Environmental Ltd., June 2003.