

## **V. FUEL CONTAMINATION**

### **A. General**

Much progress was made this year in the area of fuel contamination. Further exploratory work was undertaken at the imploded tank and drainage pathway, and a pond and filter system were constructed. At the beach POL tank area, the pond between the tanks was largely drained and further environmental assessment samples taken; as a result a remediation plan for this location has been proposed. Work on the experimental trial landfarm was continued this year and a new large landfarm constructed by the imploded tank which was composed of all soils known to contain > 8000 ppm of diesel fuel. A major laboratory experiment was set up to mimic the field study.

In this chapter, the abbreviation TPH (total petroleum hydrocarbon) is used synonymously with petroleum hydrocarbon.

### **B. Remediation Criteria**

This topic was covered in detail in the ASU 2003 Resolution Island report. Briefly the following matters were discussed and resolved. Until 2002, the cleanup criteria used at Resolution Island was based on the original DLCU criteria established in 1991 but hydrocarbon contamination was not part of the original DLCU investigations. The CCME Canada-Wide Standards for petroleum hydrocarbons<sup>1</sup> were introduced in 2001. As stated in these standards, “The Canada-Wide Standards for Petroleum Hydrocarbons in Soil (PHC CWS) is a tier framework offering the proponent the option to comply with a set of reasonably conservative risk-based standards corresponding to a number of defined land uses, exposure scenarios and site characteristics (Tier 1) or to use additional site-specific information to assess and manage the risks through a more precise knowledge of actual or potential exposures (Tiers 2 and 3)”. For the Resolution Island site and the Canadian Arctic in general, Tier 2 remediation criteria were developed according to the framework. This was originally done for the F2 fraction (diesel fuel) in surface coarse grained soils but has since been expanded as shown in Table V-1 for all four fractions and for F2 at various distances from a water body.

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<sup>1</sup> Canadian Council of Ministers of the Environment (CCME) 2001. Canada-Wide Standard for Petroleum Hydrocarbon (PHC) in Soil User Guidance. April 2001.

**Table V-1: CCME-TPH Tier 2 Derived Remediation Criteria for Arctic Soils**

CCME Fraction	Unit	Tier 2 Remediation Criteria
F1 > 55 m to water body	ppm	15000
F2 > 55 m to water body	ppm	8000
F3 > 55 m to water body	ppm	18000
F4 > 55 m to water body	ppm	25000
F2 – 50 m to water body	ppm	6600
F2 – 40 m to water body	ppm	3300
F2 – 30 m to water body	ppm	1400
F2 – 20 m to water body	ppm	520
F2 – 10 m to water body equal to Tier 1 value	ppm	150

The use of the 8000 ppm clean up criteria for the imploded tank area was proposed in the 2003 ASU report and approved by INAC and Environment Canada; an independent risk assessment (Tier 3) had proposed a lower remediation criteria of 26,860 ppm.

## C. Analytical Methods

### 1. Sampling

A test pit was dug in the desired sampling area. Using a new scoopula, each sample was composed of either a designated depth composite or a specific depth profile sample. To prevent volatilization during transport, the sample containers were completely filled allowing no headspace in the 250 mL glass amber bottles and kept cold. The samples were sealed and analysed at the ASU laboratories at Queen's University. Some samples were analysed in the on-site laboratory.

### 2. Total TPH Analysis

Soil samples were homogenized and sub-samples dried for moisture determination. A wet sample (10 g dry equivalent weight) was mixed with anhydrous sodium sulphate and Ottawa sand in an Erlenmeyer flask. Pesticide grade hexane (20 mL) was added, and the flask ultrasonically agitated. A 1-mL aliquot of the hexane extract was pipetted from the flask in a manner ensuring no transfer of solid material, applied to a purchased silica column for cleanup and sealed in a gas chromatography (GC) vial.

For water samples, 100 mL was accurately measured and transferred to a clean, 125 mL glass separatory funnel. Hexane, 5 mL, was added and the mixture shaken vigorously and then allowed to separate. If emulsions formed, the funnel was briefly sonicated to ensure adequate phase separation. An aliquot of the hexane phase was then transferred to a GC vial. For low level detection the samples were concentrated by blowing down with nitrogen gas before transfer to a GC vial.

The hexane extracts were analysed by GC/FID using a Hewlett Packard gas chromatograph with flame ionization detector. TPH was quantified by comparing the chromatogram peak area of the sample with that of the standard; standards of fuel oil and lubricating oil were prepared in hexane. Compound identity was determined by comparing the sample chromatogram with those of known hydrocarbon mixtures.

### 3. CCME TPH Analysis

Analysis was carried out according to the Canada-Wide standard for petroleum hydrocarbon in soil method.

For Soil Fraction F1, accurately weighed samples of wet soil (5 g) were extracted on a shaker for 1 hour with 10 mL of methanol. The methanol layer was then transferred into a vial and refrigerated until analysis. A 1 mL aliquot of the extract made up to 5 mL with water, was directly syringed into the purge and trap apparatus. The sample was purged with high purity helium gas for 11 minutes. The trapped components were desorbed from the trap in the unit by heating to 225 °C and holding for 4 minutes. A SPB-1 fused silica capillary column (30 m, 0.25 mm ID x 0.25 µm film thickness) was used. Retention time marking was done using nC6 and nC10 hydrocarbons and calibration using toluene. A wet/dry ratio for the sample was determined using a sub-sample and the final result was calculated using the dry weight of the sample. BTEX concentrations were subtracted from the F1 fraction results, if present.

For Soil Fractions F2-F4, samples were homogenized and sub-samples dried for moisture determination. Accurately weighed samples of wet soil (10 g) were extracted by soxhlet for 4 hours at 4 - 6 cycles per hour using 250 mL of hexane/acetone (1:1). The extract was filtered through sodium sulphate and 3 mL of toluene was added. The extract was then concentrated by rotoevaporation and transferred to a 50 mL tube. Hexane/dichloromethane (1:1) was added to bring the volume up to 30 mL. Silica was added and the sample shaken for 5 minutes. Once the sample had settled, a GC vial was then filled and the sample analysed by GC/FID. Blanks, control samples and duplicates were run at a frequency of approximately 20%. Calibration and retention time marking was done using nC10, nC16 and nC34 hydrocarbons and the final result reported in ug/g for each fraction. If PAH analysis had been present in the sample, naphthalene would have been subtracted from fraction F2 and the other 15 priority pollutant PAHs would have been subtracted from fraction F3.

#### *4. Identification*

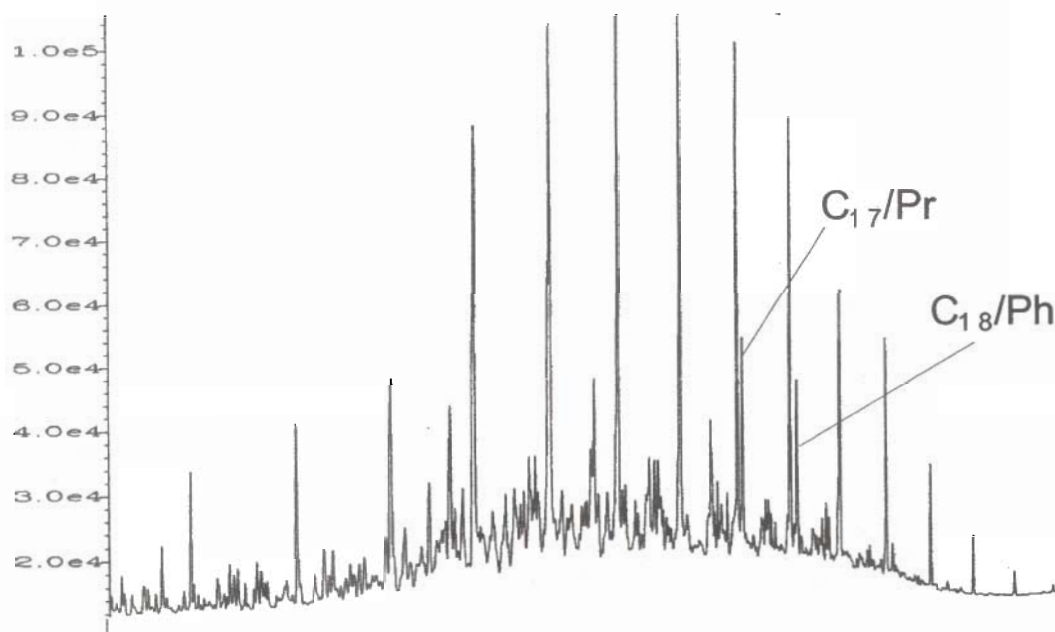
The nature of the petroleum product present in the contaminated soils can be determined by comparison to known hydrocarbons and mixtures. Comparison of retention times indicate whether sample peaks are in the range of hydrocarbons found in fuels such as gasoline or diesel or due to lubricating oils and greases. Closer comparison of the chromatograms allows some insight into the change in the composition of the mixture by environmental factors.



## 5. $C_{17}$ /pristane and $C_{18}$ /phytane Ratios

Diesel fuel contains two pairs of compounds with very similar boiling points but for each pair, one is a straight chain alkane while the other is branched. Because the straight chain alkane is volatilized at the same rate as its branched counterpart but the straight chain hydrocarbon is bioremediated faster than the branched counterpart, these two pairs of compounds can be used to discriminate between the two remediation pathways of volatilization and bioremediation. The four compounds are the two straight chain alkanes, heptadecane ( $C_{17}H_{36}$ ;  $C_{17}$ ) and octadecane ( $C_{18}H_{38}$ ;  $C_{18}$ ), and the two branched alkanes 2,6,10,14 tetramethylpentadecane ( $C_{19}H_{40}$ ; pristane Pr) and 2,6,10,14-tetramethylhexadecane ( $C_{20}H_{42}$ ; phytane Ph). These branched alkanes are sometimes referred to as isoprenoids. The ratio of the masses of each pair in the hydrocarbon mixtures (equivalent to the ratio of the peak areas) are given as the mass of the straight chain alkane divided by the mass of the branched alkane; these are abbreviated as  $C_{17}$ /Pr and  $C_{18}$ /Ph in this report. Figure V-1 below shows the two pairs of peaks in a diesel standard.

Figure V-1  
Chromatogram of a Diesel Standard



## D. Imploded Tank Area

This year, five water and two soil samples were collected in the imploded tank drainage area and below the cliff at the end of the main drainage area. In order to assist the natural remediation taking place, an experimental pond and barrier system was constructed. A landfarm was also constructed and this is described in section F.2

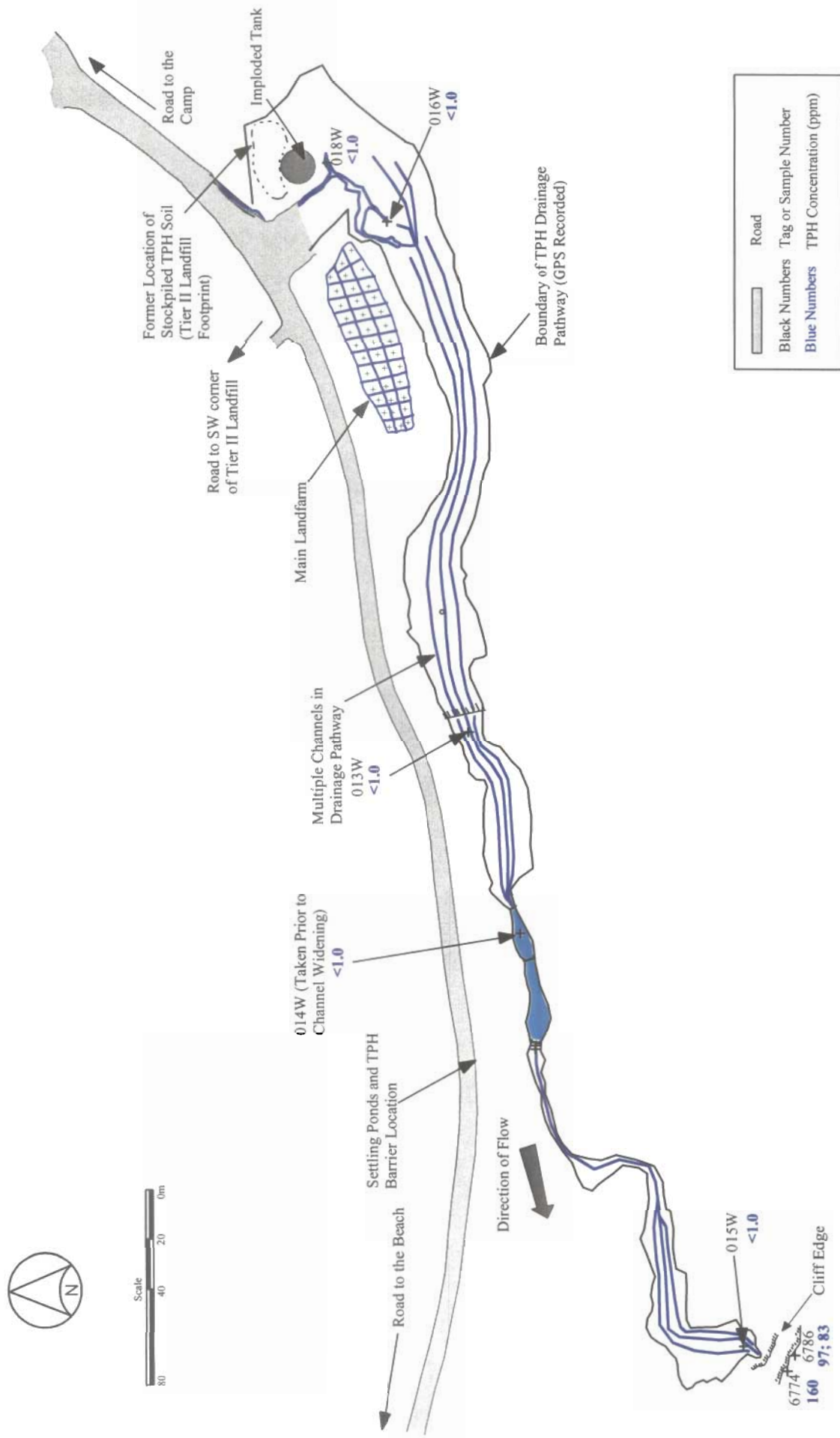
### 1. Further Characterisation

Five water samples were collected along the drainage pathway (Photographs V-1 and V-2) at locations shown in Map V-1. Results given in Table V-2 show that all contained less than the detection limit of 1.0 ppm TPH. The reason for collecting these five samples was to confirm that TPH was not being transported in the water along the drainage pathway in measurable quantities. Two soil samples were taken below the cliff at the end of the drainage pathway. This was done in order to extend the assessment area. The 2003 study had shown levels of TPH dropping from values of several thousand ppm near the imploded tank to values of around 300 ppm in the last 100 m of the pathway (actual values 610, 46, 340, 220 ppm). The values obtained from the analysis of two soil samples (one field duplicate) collected from below the cliff were 160 and 90 ppm (field duplicate 97 and 83 ppm). These show that the TPH level has dropped even lower.

**Table V-2: Results of Analyses of Assessment Water and Soil Samples for TPH at the Imploded Tank Area**

Sample Number	Tag Number	Type	Units	TPH	Comment
RI04-013W	-	water	mg/L	<1.0	-
RI04-014W	-	water	mg/L	<1.0	-
RI04-015W	-	water	mg/L	<1.0	-
RI04-016W	-	water	mg/L	<1.0	-
RI04-018W	-	water	mg/L	<1.0	-
RI04-330	6774	soil	ug/g	160	weathered diesel
RI04-328	6786	soil	ug/g	90	weathered diesel

# V-1: Sampling Locations and TPH Concentrations Along the Drainage Pathway Leading from the Imploded Tank







**Photograph V-1: The Initial Part of the Drainage Pathway Leading from the Imploded Tank Area**



**Photograph V-2: The Mid-Section of the Imploded Tank Drainage Area Where the Ponds and Barrier Were Constructed**



## *2. Ponding and Barrier Construction*

### *a) Rationale*

As discussed in section B, the remediation criteria of 8000 ppm TPH was adopted for the imploded tank area. Part of the argument used to justify this was falling TPH concentrations along the drainage pathway and the absence of TPH in water flowing in the pathway. These two facts have been confirmed again this year as reported above. It was proposed by ASU and endorsed by INAC that it would be useful to design and construct a pond and barrier system in the drainage pathway for the following reasons:

- A pond would help in the removal of volatile TPH by adding a larger surface area for evaporation.
- The use of an oil absorbent boom at the pond would remove any hydrocarbon on the water surface.
- The placement of a barrier system incorporating materials to absorb TPH from water would remove any TPH from the water or entrapped particles.
- To foster research in this area in order to ascertain if such systems would be useful in the Canadian Arctic to deal with the widespread hydrocarbon contamination problem.
- To mitigate against possible migration of TPH due to excavation and the construction of main landfill
- To be proactive in remediating residual TPH

### *b) Design and Construction*

Through chromatographic analysis of soil samples it was determined that as the distance increases from the source of contamination at the imploded tank, there is both a decrease in TPH concentration and an increase in degree of hydrocarbon degradation. The site chosen for the location of the pond and barrier system was such that it served to contain 95% of the hydrocarbons present in the existing drainage course of the imploded tank pathway. Its location was also in an easily accessible area and one that lent itself to the construction of the contouring for the systems with limited movement of materials. The topography and location of the pond and barrier system is shown in Figure V-2.

The hydrocarbon barrier is designed and constructed as a two-part system. The first structure consists of a pond through which water exits from its base and is basically designed to increase volatilization of TPH through the increased surface area of the pond. The second part consists of a filter barrier system such that all water flowing in the drainage course must pass through the filter system which is designed to remove both small particles and any dissolved hydrocarbon. The position of the systems in the drainage course and their elements are shown in Map V-2 and Figure V-3.

The majority of the berm construction and molding work of the barrier sections was carried out with an excavator (Photograph V-3). Both areas were prepared in typical buttress fashion to ensure stability and longevity of the systems. This process involved gradually decreasing the soil gradation as the berms were constructed starting with large boulders as the berm skeleton and finishing with course-grained soils.

The drainage and control for the pond was provided by a 4 inch ABS pipe in the form of an outpouring drainage conduit (Photograph V-4). The water is drained from the base of the pond and the water level in the pond is maintained by the height on the outpouring drainage pipe (Figure V-3). The pond was made water tight using a black PVC pond liner and the outpouring ABS drain was secured in place with rocks. The pipe was attached to the liner at the pond bottom using rubber cement pond sealant. The PVC liner was placed over a soft, non-woven geotextile material to mitigate rock punctures in the liner facing. The liner was held in place by toeing the PVC into the outer berms as well as securing the submerged base with sand bags. The face of the main weir was protected and sealed with a manually constructed stonewall. Matasorb absorbent booms were affixed across the mouth of the pond both as a precautionary measure in case of an overpowering spring runoff event, and to provide a second mechanism to remove any TPH. From an experimental point of view, PVC liner was chosen in order to test its durability in the Arctic and because of its low cost. PVC liners are widely available as pond liners in southern Canada but are generally susceptible to UV degradation. The liner in this case is expected to be shielded from direct sunlight by silt.

The barrier section of the system is similar to the funnel and gate barrier constructed in the S1/S4 valley for PCB migration control as described in Chapter VI. The barrier is designed to trap hydrocarbons as water passes through a filter and absorbent system. The system is fed directly by the drainage pipe from the pond and water is directed to a filter box assembly in a bermed, watertight ponding area. The existing bedrock was used as the foundation for the filter box to which it was anchored

with rock bolts (Photograph V-5). The base liner was formed first with a layer of GCL (Geo-Composite Liner Bentofix CNSL, Terrafix Geosynthetics Inc.) containing bentonite clay. The GCL was laid on the reservoir floor, up the sides of the berms and to the edges and base of the filter box. An impermeable textured flexible HDPE liner (Terrafix Geosynthetics Inc.) was placed on top of the GCL (Photograph V-6). Both the GCL and HDPE liner were attached to the filter boxes before securing the liner to the berms. This step was modified from the S1/S4 barrier construction protocol where instead the berm-to-liner junction was secured before that of the liner-to-filter box. Each filter box was fitted with 1.5 inch gravel filter followed by a 3 inch GAC filter. The filters were designed similarly to the S1/S4 valley system where in order to maintain flow, the void size was maintained for a  $D_{85}$  pass allowance. For the first filter, gravel was taken from radio hill and sieved to 2-10 mm particle size. The GAC used in the second filter was sieved through a US 6 and 12 standard sieve sizes to achieve a grain distribution of 1.68-3.36 mm. Most HDPE material used as landfill liners are much thicker, generally 60 mil, but these were not flexible enough for this design. The HDPE liner used had a thickness of 20 mil. The material, which was made available to the project by Terrafix Geosynthetics Inc, was a small remnant remaining from a special order project for another client and was ideal for this application. It will be susceptible to UV degradation but, as with the PVC liner, should be shielded from direct sunlight by sediment build up.

Photograph V-7 shows the dam at the end of the pond and the water exiting from the pipe. Construction of the pond and barrier system was completed on 12 August 2004 as shown in Photograph V-8.



Figure V-2: Topography of Imploded Tank Drainage Pathway

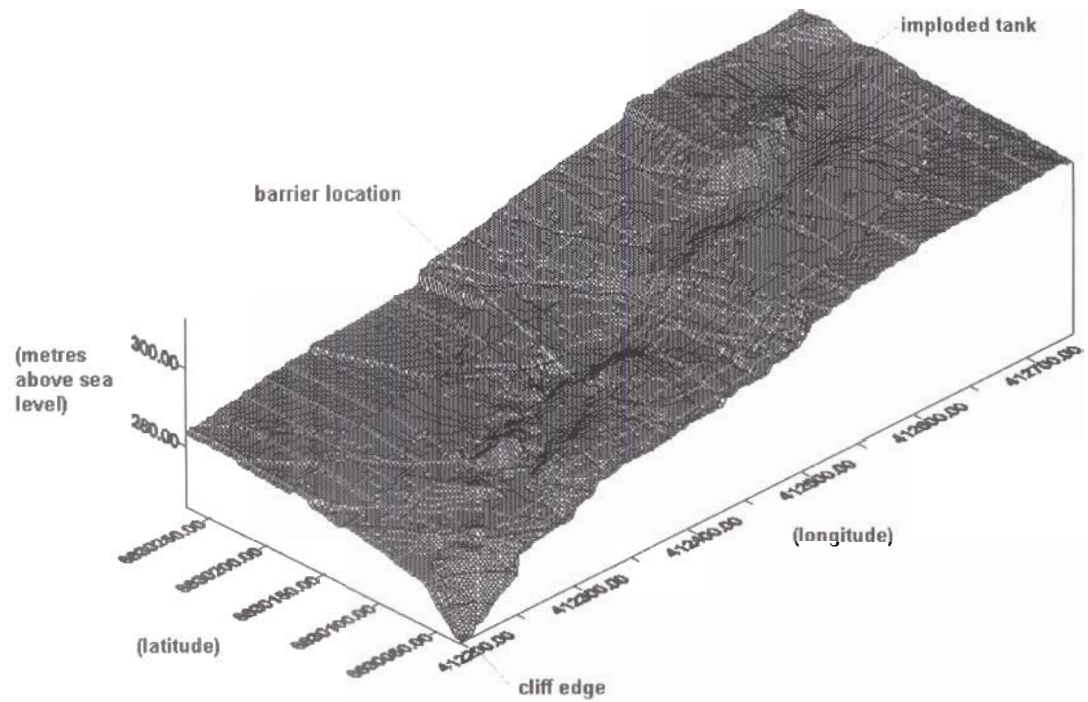
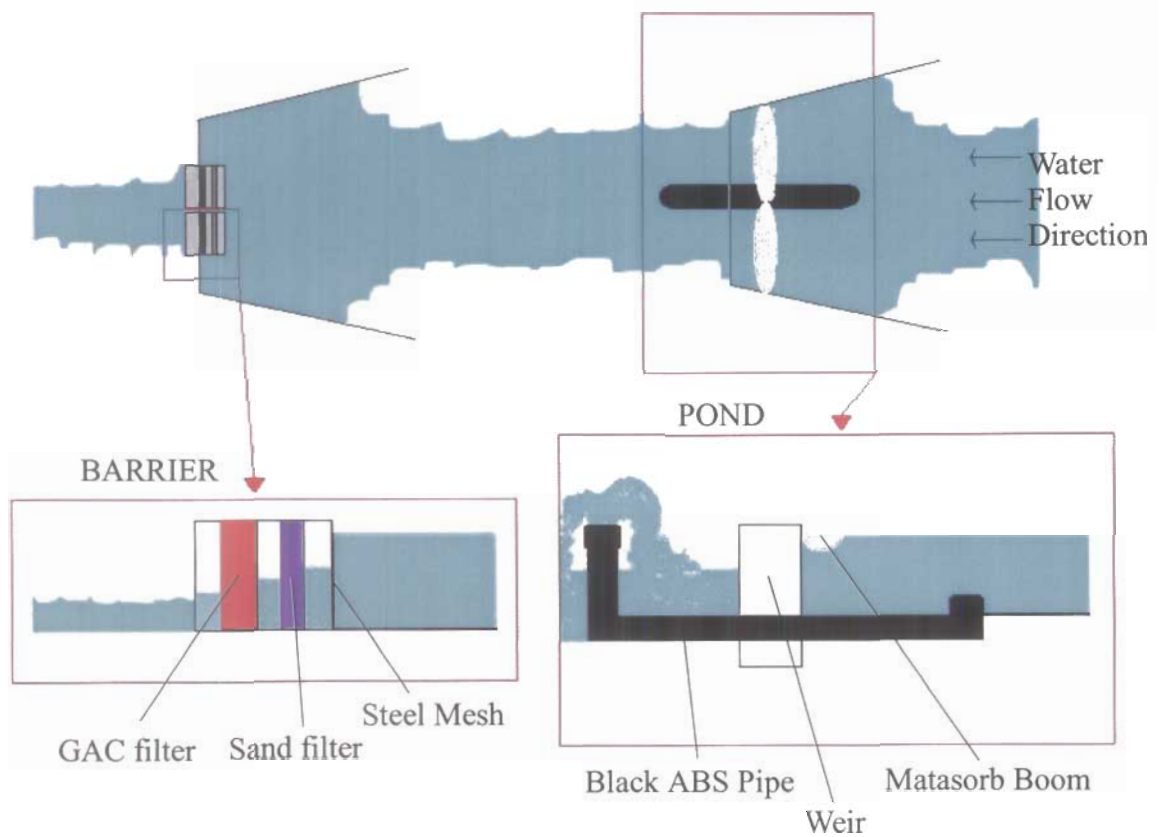
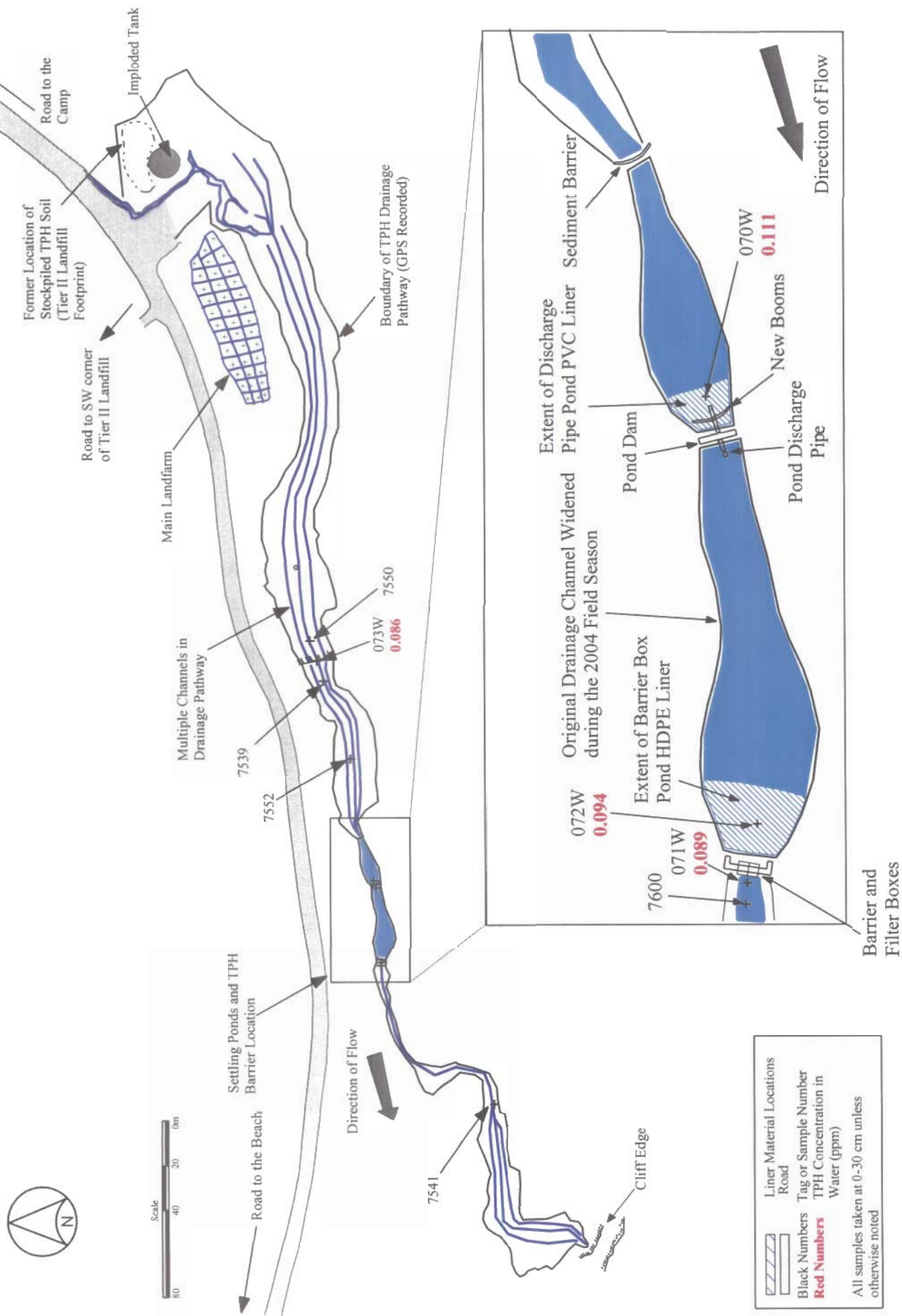


Figure V-3: Schematic of the Pond and Barrier System



Map V-2: The Pond and Barrier System in the Drain.

Pathway Leading from the Imploded Tank





**Photograph V-3: Excavating the Drainage Channel For the Pond and Barrier**



**Photograph V-4: Constructing the Pond: The ABS Pipe Allows Water to be Siphoned Off From the Base of the Pond and Also Controls the Water Level in the Pond**





**Photograph V-5: Installing the Filter Boxes in the Barrier**



**Photograph V-6: The Barrier in Position but Without Filters: The Pond is Shown in the Background**





**Photograph V-7: The Division Between the Pond, Which is Draining into a Second Pond Created by the Barrier, with Filters in Place**



**Photograph V-8: The Completed Trial Remediation System Showing the Pond With Boom in the Foreground and Barrier Filter Box Beyond and Down Stream**

c) Monitoring performance

In order to gauge the performance and effectiveness of the pond and barrier system, a monitoring system needed to be established. This requires the testing of soil, water and components of the system to establish whether TPH is indeed being removed.

Five soil samples were collected at locations upstream, downstream and within the system reservoirs as shown on Map V-2. These soil samples are currently frozen but will soon be thawed and analysed for CCME-TPH, nitrogen, phosphorus. As was described in section F.2, nutrients were added to the upstream landfarm and monitoring these nutrients throughout the drainage pathway will help model both their mobility and the features of degradation plumes. Samples of the Matasorb boom samples were taken at the end of the 2004 field season. These will be used to develop an analytical method for TPH in this material and to establish a baseline. Matasorb samples will be collected in 2005 and analysed for TPH to determine their effectiveness. Similarly, sand and GAC filter materials will be sampled and analysed in the 2005 season. Water samples were taken at the beginning of the 2004 season and were found to have levels of <1.0 mg/L TPH both upstream and downstream from the current barrier location. When construction of the barrier was completed, there was considerable activity upstream from the barrier during the landfarm construction and it is likely that this soil disturbance may have remobilized the hydrocarbons in the area. Water samples were taken from various points in the barrier system to determine low-level concentrations of TPH in water. Results given in Table V-3 show that TPH levels are currently in the range from 0.086- 0.111 ppm. In 2005 the effectiveness of the barrier system will be evaluated using these background TPH level results. In addition in 2005, the liner material will be inspected for degradation, (chemical: UV and hydrocarbon influence, mechanical: punctures, freeze thaw effects), as well as TPH concentrations in the material.

**Table V-3: Results of Water Analyses for TPH at the Imploded Tank Drainage Area Ponds and Barriers**

Sample Number	Location	Type	Units	TPH
RI04-070W	Pond #1	water	ppm	0.111
RI04-071W	Filter System Discharge	water	ppm	0.089
RI04-072W	Pond #2	water	ppm	0.094
RI04-073W	Small Waterfall Area Upstream of Pond	water	ppm	0.086