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B   Borehole Logs
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Introduction

Dillon Consulting Limited (Dillon) was retained by Hamilton Waterfront Trust (HWT) to conduct a remediation program to remove the light non-aqueous phase liquid (LNAPL) identified in the vicinity of a former underground fuel storage tank (UST) on Pier 8 in Hamilton, Ontario (the Site). The Site location plan is presented on Figure 1 in Attachment A.
2.0 Objective

Dillon completed a Phase One Environmental Site Assessment (P1ESA) and Phase Two Environmental Site Assessment (P2ESA) at the Site to support a Risk Assessment and Risk Management Plan (RA/RMP) which will, in turn, support the filing of a Record of Site Condition (RSC) for the redevelopment of the Site, per the requirements of the Environmental Protection Act, Part XV.1 – Ontario Regulation 153/04 (O.Reg.153/04). The O.Reg.153/04 requires that reasonable efforts be employed to “mitigate the formation of free product,” and to “ensure that the volume of any free flowing product removed from ground water on, in, or under the phase two property is monitored and recorded.” Therefore, the primary objective of this remediation program was to recover the identified LNAPL to the extent practicable to satisfy the requirements of the O.Reg.153/04. Prior to implementation Dillon completed a remedial option evaluation of various LNAPL recovery options and concluded that a total fluids extraction approach using vacuum extraction methods was the appropriate option to achieve the objective for the Site.
3.0 Background

During Dillon's P2ESA (2016), LNAPL was identified in the subsurface below the Shed 6 building located on the northeast portion of the Site. The identified LNAPL appeared to be associated with the historical leakage of a former fuel UST located adjacent to the south side of the building. Reportedly, the last use of the tank was in 1992 when natural gas was brought to Pier 8. The test pitting program completed during the P2ESA confirmed that the tank has been removed. The LNAPL was observed on groundwater surface in three monitoring wells (i.e., MW113, MW114, and MW146) during monitoring events completed in October 2015, November 2015, and/or March 2016. The measured LNAPL thickness during these monitoring events ranged from 0.03 to 0.43 m, with the highest thickness measured on March 11, 2016 at monitoring well MW113. The area below the building where LNAPL was observed in soil was estimated to be approximately 1,400 m$^2$; however, the area with measurable LNAPL on groundwater surface was estimated to be approximately 600 m$^2$. The approximate extent of LNAPL in soil and groundwater are shown on Figure 2 in Attachment A.

The overburden in the area impacted by LNAPL generally consists of a fill layer that extends to a maximum investigated depth of 6.1 m below ground surface (mbgs). This fill layer is comprised of a thin sand and gravel layer near surface (to approximately 0.5 mbgs) and transitions to a sandy silt and sandy clay fill at greater depth and within the zone of the water table.

Hydraulic conductivity testing of the underlying soils (i.e., fill) via rising head tests was completed during the P2ESA at four monitoring wells (i.e., MW28, MW74, MW134, and MW147) on March 16, 2016. Estimated hydraulic conductivities ranged from $6.4 \times 10^{-10}$ m/s to $2.5 \times 10^{-5}$ m/s at the tested wells. The hydraulic conductivity at MW147, the monitoring well closest to the LNAPL impacts, was $1.0 \times 10^{-5}$ m/s.

Depth to ground water for the monitoring wells located in or near the LNAPL area ranged between 1.0 m to 2.3 mbgs. The estimated shallow groundwater flow direction in the LNAPL area is generally towards the northeast.

Further details on the Site's conceptual site model are presented under separate cover, "Draft Phase Two Environmental Site Assessment, Pier 8, Hamilton, Ontario" dated June 2016; however, borehole and monitoring well logs are provided in Attachment B for monitoring wells MW133, MW114, MW146, and MW147 that located within the area impacted by LNAPL.
4.0 Methodology

4.1 Extraction Well Design

Between March 3 and 7, 2017, a total of 10 recovery wells (RW1 to RW10) were drilled to depths ranging from approximately 2.7 to 3.0 mbgs within the LNAPL area inside Shed 6 building. The drilling was completed utilizing a track-mounted drill rig equipped with hollow stem augers operated by Direct Environmental Drilling Inc. The recovery wells were constructed of 154 mm nominal diameter schedule 40 polyvinyl chloride (PVC) consisting of 1.5 m of machine slotted screen (60-slot, approximately 1.5 mm), intersecting the water table and LNAPL layer. Wells were extended to ground surface with a solid riser pipe. The annular space around the recovery well screen was filled with a No. 3 sand filter pack to approximately 0.3 m above the top of the screen. The annular space above the screened interval was sealed with bentonite or grout to prevent short circuiting of atmospheric air from the surface to approximately 0.3 mbgs. The well construction details for the recovery wells are provided on the borehole logs provided in Attachment B. The recovery wells were located within the area of measurable LNAPL thickness. The radii of influence for the recovery wells was estimated using the Dupuit\(^1\) (1863) equation (modified version of the Thiem equation, 1906). The following assumptions were considered when using the equation:

- The aquifer is unconfined
- The aquifer is homogenous
- The gradient between the extraction well and observation well is at steady-state

Using site-specific parameters in Dupuit equation, the well radii was estimated to be approximately 5.0 m. Based on the estimated LNAPL area of 600 m\(^2\), a total of 10 extraction wells were installed approximately equidistant from one another such that there was some intended overlap of the area of influence for each well. It is also noted that site specific constraints (e.g., underground utilities, building structural columns) also influenced the placement of the recovery wells. The locations of the extraction wells are shown in Figure 2 in Attachment A.

4.2 Vacuum Extraction

The vacuum extraction was completed in all 10 recovery wells and the three existing monitoring wells within the LNAPL area (i.e., MW113, MW114, and MW146) using a vacuum truck. The extraction was completed three hours a day, for three days a week from March 13, 2017 to April 10, 2017, and for two

\(^1\) Dupuit, J., Etudes theoriques et pratiques sur le mouvement des eaux dans les canaux decouverts et a travers les terrains permeables, 2eme edition; Dunot, Paris, 1863.
days a week from April 10, 2017 to April 21, 2017. The extracted water and LNAPL were placed into a 16,000 L vacuum box container that was kept on-site for the duration of the work.

To avoid additional smearing of LNAPL below the water table, the flow rate for the vacuum extraction was set low enough to achieve the desired drawdown of approximately 0.5 m. The vacuum hose depth was also adjusted during extraction activities to minimize water drawdown and smearing of more than 0.5 m in the recovery wells.

Prior to daily extraction, the depth to water and LNAPL was measured at each of the recovery wells and the three existing monitoring wells in the LNAPL area (i.e., MW113, MW114, and MW146) using a Solinst interface probe.

4.3 LNAPL Sampling

During the LNAPL extraction, it was noticed that there were two types of LNAPL (i.e., light and heavy LNAPL) present in the recovery and monitoring wells. The source of the light LNAPL appears to be the fuel UST formerly located along the south side of the building. These lighter impacts were generally located in the recovery wells located in southern portion of the LNAPL area. The source for the heavier LNAPL is likely related to the historical storage of “oil” drums in the area. These heavier impacts are generally located in the northern portion of the LNAPL impacted area.

By the end of the second week of the extraction program, the observed recovery (i.e., measurable thicknesses) of the light LNAPL in the southern recovery wells had notably declined. However, measurable heavy LNAPL remained present in the more northern recovery wells. In order to obtain information regarding the physical characteristics of the observed heavy LNAPL, a composite sample (required to collect sufficient volume for analysis) of the LNAPL was collected from RW2, RW3, and MW113 on March 29, 2017 and submitted to Maxxam Analytics Inc. (Maxxam) of Mississauga, Ontario for specific gravity and viscosity analysis.
5.0 Results

5.1 Extraction Program

The results of the daily measurement of depth to water and LNAPL in the extraction wells and monitoring wells are presented in Table 1 in Attachment C. The daily measurement of LNAPL thickness is also plotted for each well and provided in Attachment D.

A total of 8,550 L of water and LNAPL were removed from the Site which consisted of approximately 1,200 L of LNAPL, 3,100 L of emulsified water and LNAPL, and 4,250 L of water. The vacuum box container was shipped off-site for disposal (treatment) at the end of the extraction program.

5.2 Analytical Testing

The laboratory analytical results indicated a density of 0.9017 g/mL (specific gravity / relative density of 0.9025) at 15°C and kinematic viscosity of 8.80 centiStokes (cSt) at 40°C for the analyzed LNAPL sample. The laboratory certificates of analysis are presented in Attachment E. Table 1 provides a comparison of the viscosity and density of different petroleum products to the analyzed LNAPL sample. The viscosity and density values for more hydrocarbon products, obtained from API Interactive LNAPL Guide (API, 2004), are provided in Attachment C.

### Table 1 - LNAPL Sample Characterization

<table>
<thead>
<tr>
<th>Product</th>
<th>Dynamic Viscosity(^a) (cP)</th>
<th>Density(^ab) (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15°C</td>
<td>20°C</td>
</tr>
<tr>
<td>Gasoline (Leaded)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Diesel Fuel Oil (Canada)</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Fuel Oil No. 2</td>
<td>-</td>
<td>5.91</td>
</tr>
<tr>
<td>Crude-West Texas Intermediate</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Shed 6 (LNAPL)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lubricating Oil</td>
<td>102</td>
<td>-</td>
</tr>
<tr>
<td>Fuel Oil No. 6 (Bunker C Fuel Oil)</td>
<td>45,030</td>
<td>5,980,000</td>
</tr>
</tbody>
</table>

Notes:
- " - " : No value available
- \(^a\) Values obtained from the American Petroleum Institute (API) Interactive LNAPL Guide version 2.0 (August 2004).
- \(^b\) Relative density values measured at 15°C.
- \(^c\) Dynamic viscosity of the LNAPL product calculated from the kinematic viscosity value of 8.80 cSt (at 40°C) reported by Maxxam.
6.0 **Interpretation**

As stated previously, the depth to LNAPL, depth to water, and LNAPL thickness were measured every day prior to extraction activities. These results are summarized in Table 1 in Attachment C and shown in graphs provided in Attachment D. As shown in the graphs, measurable LNAPL was not observed in extraction wells RW5, RW6, and RW9 during the extraction program. Further, a decreasing trend was observed for LNAPL thickness at RW1, RW4, MW113, MW114, and MW146 in which by the end of the extraction program, LNAPL were either not observed or measured at thickness less than 0.01 m at these locations. Measurable LNAPL ranging from 0.08 to 0.25 m in thickness, were still present in extraction wells RW2, RW3, RW7, RW8, and RW10 at the end of the extraction program. With the exception of RW3 which showed decreasing trend in LNAPL thickness, LNAPL thickness at the other four locations appear to have reached a steady-state level with only minor fluctuations following additional extraction. It should be mentioned that the measured LNAPL thickness in the field is usually greater than the true thickness of free product in the aquifer (US EPA, 1996). This is most noticeable in media with strong capillary effects (e.g., fine grained silts and clay). Given the medium and fine texture of the fill (i.e., sandy silt, sandy clay, and silty clay) at depths greater than 1.0 mbgs within the LNAPL area, the thickness of LNAPL is considered lower than the field measurements. This is further confounded by the fact the heavy LNAPL identified in the field had a tendency to coat the interface probe resulting in difficulties in determining the depth to the top of water resulting in a bias towards the interpretation of a thicker LNAPL layer.

As indicated in Section 5.2, the LNAPL product has a density heavier than gasoline, diesel and Fuel Oil No.2 but lighter than hydrocarbon products such as lubricating oil and Bunker C. The identified LNAPL appears to be also more viscous than gasoline, diesel and Fuel Oil No.2. Given that liquids show a reduction in viscosity with increasing temperature, the viscosity of the LNAPL measured at 40°C (i.e., 7.9 cP) is anticipated to be higher at 15°C and 20°C; and subsequently, would have a viscosity value higher than gasoline, diesel, and Fuel Oil No.2.

In order to assess the potential recoverability of the LNAPL, the site specific parameters (i.e., hydraulic conductivity, product viscosity, and maximum apparent LNAPL thickness) were compared to two Recoverability Screening Charts obtained from the API Guide (API, 2004). These charts were developed by API through a series of numerical modelling exercises in conjunction with empirical observations. The charts illustrate the relationship between the type of LNAPL, the thickness of the LNAPL (as represented by apparent product thickness measured in monitoring wells), and the hydraulic conductivity of the soil matrix. For each set of conditions, the potential LNAPL recoverability was assessed as either ‘not likely to be recoverable’ or ‘potentially recoverable’, based on the position the site-specific conditions plot on the Recoverability Screening Charts. The Recoverability Screening Charts for LNAPL thickness of 0.15 m and 0.3 m are provided in Figure 1 and Figure 2, respectively.
As shown in Figure 1 and Figure 2, based on the measured hydraulic conductivity of the fill in the LNAPL area (i.e., $1.0 \times 10^{-4}$ cm/s), the type of the LNAPL (i.e., more viscous than Fuel Oil No. 2), and the maximum thickness of the LNAPL remaining in the extraction wells (i.e., 0.25 m), the residual LNAPL in the soil is considered ‘not likely to be recoverable’. Therefore, under typical conditions at the Site and LNAPL thickness of less than 0.3 m, LNAPL remaining at the Site is considered “not likely to be recoverable” or not practically recoverable. This is supported by the fact that at the end of the six weeks extraction program, the ratio of extracted LNAPL to water had diminished even though residual LNAPL remains in the recovery wells and the soil.
The remaining LNAPL is considered stable and effectively trapped within the pore space of the silty clay, sandy silt, and sandy clay fill. According to API Interactive LNAPL Guide (API, 2004) soils that are predominantly silt or clay, such as those found at the Site, can retain residual saturation of LNAPL in the unsaturated zone of 4 to 7% of the pore space. For the saturated zone, residual LNAPL saturation for medium and fine based soils can be in the range of 5 to 19% of the pore space. Residual LNAPL saturation refers to the amount of immobile LNAPL trapped in the soil pore space, held in place by surface tension and capillary forces. While this residual LNAPL can be measured within a monitoring well it is unlikely to be recoverable or mobile.

Based on these findings it is not expected that LNAPL saturations at the Site following the completion of the extraction program are sufficiently high enough to result in the lateral dispersion of LNAPL. The LNAPL mass is considered stable and trapped as a residual within the pore space of the silty and clayey soils. Furthermore, it is further recovery efforts are not expected to result in the effective removal of additional LNAPL mass, and applying more aggressive technics (e.g., increasing the draw down) have the potential negatively impact the Site by increasing the smear zone to deeper horizons. It is therefore concluded that practical efforts have been made to remove and reduce the LNAPL at the Site.
Summary

Dillon Consulting Limited (Dillon) was retained by Hamilton Waterfront Trust (HWT) to conduct a remediation program to remove the LNAPL identified beneath a building on the northeast portion of Pier 8 in Hamilton, Ontario (the Site).

Between March 3 and 7, 2017, a total of 10 extraction wells were installed within the LNAPL area inside the building. The vacuum extraction was completed in all 10 extraction wells and the three existing monitoring wells within the LNAPL area using a vacuum truck. The extraction program was completed in six weeks from March to April 2017. A total of 8,550 L of water and LNAPL were removed from the Site which consisted of approximately 1,200 L of LNAPL, 3,100 L of emulsified water and LNAPL, and 4,250 L of water.

Based on the results of the extraction program and site conditions, it is Dillon’s opinion that further recovery of LNAPL through standard industry practices is not considered practical. It would require the extraction and treatment of thousands of litres of groundwater from the silty clay aquifer with limited LNAPL recovery. The lowering of the water table, for the collection of LNAPL, would also result in the vertical migration of LNAPL to deeper areas (smearing) where it would become trapped in soils previously unimpacted by LNAPL, further reducing recoverability.
8.0 Closure

This report was prepared exclusively for the purposes, project and site location(s) outlined in the report. The report is based on information provided to, or obtained by Dillon Consulting Limited (“Dillon”) as indicated in the report, and applies solely to site conditions existing at the time of the site investigation. Although Dillon conducted a reasonable investigation, the investigation was by no means exhaustive and cannot be construed as a certification of the absence of any contaminants from the site. Rather, Dillon’s report represents a reasonable review of available information within an agreed work scope, schedule and budget. It is therefore possible that currently unrecognized contamination or potentially hazardous materials may exist at the site, and that the levels of contamination or hazardous materials may vary across the site. Further review and updating of the report may be required as local and site conditions, and the regulatory and planning frameworks, change over time.

This report was prepared by Dillon for the sole benefit of our client, Hamilton Waterfront Trust and the City of Hamilton. The material in the report reflects Dillon’s judgment in light of the information available to Dillon at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Dillon accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made based on this report.

Yours sincerely,

DILLON CONSULTING LIMITED

Ashkan Arefi, M.Sc., P.Eng.
Risk Assessor

Tom Grimminck, P.Eng.
Environmental Engineer, Associate
9.0 References


Dillon Consulting Limited, 2015, Phase One Environmental Site Assessment, Piers 5 to 8 and Bayview Park, Hamilton, Ontario, Draft Report, June 2015.


Thiem, G., 1906. Hydrologische Methoden [Hydrologic methods], Gebhardt, Leipzig, Germany.

Appendix A

Figures
SITE LOCATION
FIGURE 1

- **Study Area (Pier B)**
- **Pier 6 & 7**

**MAP DRAWING INFORMATION:**
- DATA PROVIDED BY MNRF
- MAP CREATED BY: AA
- MAP CHECKED BY: THG
- MAP PROJECTION: NAD 1983 UTM Zone 17N

**FILE LOCATION:** I:\GIS\141137 - Hamilton Waterfront Trust\mxd\Figure 1 Site Location.mxd

**PROJECT:** 163780
**STATUS:** ISSUED
**DATE:** 2017-06-12

**CITY OF HAMILTON**

- **Study Area (Pier 8)**
- **Pier 6, 7**
Appendix B

Borehole Logs
**Client:** Hamilton Waterfront Trust  
**Project No.:** 16-3780  
**Drilling Co.:** Direct Environmental Drilling Inc.  
**Observer:** M. Tredree  

**Project:** Shed 6 LNAPL Recovery Project  
**Location:**  
**Drilling Method:** Hollow Stem Auger (Geoprobe 7822 DT)  
**Date Started:** March 3, 2017  
**Date Completed:** March 3, 2017  

### Stratigraphic Description

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Stratigraphic Description</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sand and gravel, PHC odour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- slight dark staining, PHC odour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- clay, PHC odour</td>
<td></td>
</tr>
</tbody>
</table>

End of Borehole at 3.05 m bgs.

**Notes:**
1) m bgs = metres below ground surface; m asl = metres above sea level.
2) PHC = Petroleum Hydrocarbons.
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822 DT).
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.
5) LNAPL and groundwater level measured on March 13, 2017.

**LITHOLOGY SYMBOLS**

- ❌ Fill

**Water Level (No Measureable Product)**

**Casing:** Flushmount  
**Grade Elevation (m asl):** 77.059  
**Reference Point Elevation (m asl):** 77.184
FILL
Sand and gravel, loose, PHC odour.

- sandy silt, PHC odour

End of Borehole at 3.05 m bgs.

Notes:
1) m bgs = metres below ground surface; m asl = metres above sea level.
2) PHC = Petroleum Hydrocarbons.
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822DT).
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.
5) LNAPL and groundwater level measured on March 13, 2017.

Bentonite backfill
Screen with filter sand
Borehole Completion Detail

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Stratigraphic Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>FILL Sand and gravel, loose, PHC odour.</td>
</tr>
<tr>
<td>2</td>
<td>- sandy silt, PHC odour</td>
</tr>
<tr>
<td>3</td>
<td>End of Borehole at 3.05 m bgs.</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Casing: Flushmount
Grade Elevation (m asl): 76.972
Reference Point Elevation (m asl): 77.102
**Client:** Hamilton Waterfront Trust  
**Project No.:** 16-3780  
**Drilling Co.:** Direct Environmental Drilling Inc.  
**Observer:** M. Tredree  
**Project:** Shed 6 LNAPL Recovery Project  
**Location:**  
**Drilling Method:** Hollow Stem Auger (Geoprobe 7822 DT)  
**Date Started:** March 3, 2017  
**Date Completed:** March 3, 2017

<table>
<thead>
<tr>
<th>Depth Scale (m)</th>
<th>Stratigraphic Description</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FILL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand and gravel, loose, PHC odour.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- sandy silt, stained, strong PHC odour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- sandy silt and clay, LNAPL observed</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>End of Borehole at 3.05 m bgs.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3.05</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1) m bgs = metres below ground surface; m asl = metres above sea level.  
2) PHC = Petroleum Hydrocarbons.  
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822 DT).  
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.  
5) LNAPL and groundwater level measured on March 13, 2017.
Client: Hamilton Waterfront Trust  
Project No.: 16-3780  
Drilling Co.: Direct Environmental Drilling Inc.  
Observer: M. Tredree  

Project: Shed 6 LNAPL Recovery Project  
Location:  
Drilling Method: Hollow Stem Auger (Geoprobe 7822 DT)  
Date Started: March 6, 2017  
Date Completed: March 6, 2017  

Depth Scale (m)  
Stratigraphic Description  
Letter Symbol  
Stratigraphy  
Depth (m)  
Sample  
Soil Sample ID (analysis)  
Vapour PID/OVM  
Rec %  
Borehole Completion Detail  
Elev. (m asl)  

FILL  
- sand and gravel, loose, PHC odour.  
- sandy clay with gravel, strong PHC odour  
- sandy silt, moist, LNAPL observed  
End of Borehole at 2.74 m bgs.  

Notes:  
1) m bgs = metres below ground surface; m asl = metres above sea level.  
2) PHC = Petroleum Hydrocarbons.  
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822DT).  
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.  
5) LNAPL and groundwater level measured on March 13, 2017.  

Casing: Flushmount  
Grade Elevation (m asl): 76.574  
Reference Point Elevation (m asl): 76.854
FILL
Sand and gravel, loose, PHC odour.

- sandy clay and silt, moist, strong PHC odour

- sandy clay, strong PHC odour

End of Borehole at 2.74 m bgs.

Notes:
1) m bgs = metres below ground surface; m asl = metres above sea level.
2) PHC = Petroleum Hydrocarbons.
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822 DT).
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.
5) LNAPL and groundwater level measured on March 13, 2017.

Notes:
1) m bgs = metres below ground surface; m asl = metres above sea level.
2) PHC = Petroleum Hydrocarbons.
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822 DT).
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.
5) LNAPL and groundwater level measured on March 13, 2017.
**Client:** Hamilton Waterfront Trust  
**Project No.:** 16-3780  
**Drilling Co.:** Direct Environmental Drilling Inc.  
**Observer:** M. Tredree

**Project:** Shed 6 LNAPL Recovery Project  
**Location:**  
**Drilling Method:** Hollow Stem Auger (Geoprobe 7822 DT)  
**Date Started:** March 6, 2017  
**Date Completed:** March 6, 2017

**Depth Scale (m)**

<table>
<thead>
<tr>
<th>Stratigraphic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FILL Sand and gravel, loose, PHC odour.</td>
</tr>
<tr>
<td>- silty clay, moist, strong PHC odour</td>
</tr>
</tbody>
</table>

**Borehole ID:** RW6

**Water Level (No Measureable Product)**

**Casing:** Flushmount  
**Grade Elevation (m asl):** 77.029  
**Reference Point Elevation (m asl):** 77.149

---

**Notes:**
1. m bgs = metres below ground surface; m asl = metres above sea level.  
2. PHC = Petroleum Hydrocarbons.  
3. 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822DT).  
4. Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.  
5. LNAPL and groundwater level measured on March 13, 2017.
Client: Hamilton Waterfront Trust
Project No.: 16-3780
Drilling Co.: Direct Environmental Drilling Inc.
Observer: M. Tredree

Project: Shed 6 LNAPL Recovery Project
Location:
Drilling Method: Hollow Stem Auger (Geoprobe 7822 DT)
Date Started: March 6, 2017
Date Completed: March 6, 2017

Depth Scale (m) | Stratigraphic Description |
--- | --- |
1 | FILL Sand, gravel, silt and clay, loose, PHC odour.
2 | - sandy silt and clay, moist, LNAPL observed
3 | End of Borehole at 2.74 m bgs.
4 | Notes:
   1) m bgs = metres below ground surface; m asl = metres above sea level.
   2) PHC = Petroleum Hydrocarbons.
   3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822DT).
   4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.
   5) LNAPL and groundwater level measured on March 13, 2017.

2.74 | No samples collected.

Casing: Flushmount
Grade Elevation (m asl): 76.849
Reference Point Elevation (m asl): 76.899

Product Level (LNAPL) & Water Level
**Client:** Hamilton Waterfront Trust  
**Project:** Shed 6 LNAPL Recovery Project  
**Project No.:** 16-3780  
**Drilling Co.:** Direct Environmental Drilling Inc.  
**Observer:** M. Tredree

---

**Drilling Method:** Hollow Stem Auger (Geoprobe 7822 DT)  
**Date Started:** March 7, 2017  
**Date Completed:** March 7, 2017

---

<table>
<thead>
<tr>
<th>Depth Scale (m)</th>
<th>Stratigraphic Description</th>
<th>Soil Sample ID (analysis)</th>
<th>Vapour PID/OVM</th>
<th>Rec. %</th>
<th>Borehole Completion Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.74</td>
<td>FILL: Sand, gravel, silt and clay, PHC odour.</td>
<td>No samples collected.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

End of Borehole at 2.74 m bgs.

**Notes:**
1) m bgs = metres below ground surface; m asl = metres above sea level.
2) PHC = Petroleum Hydrocarbons.
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822DT).
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.
5) LNAPL and groundwater level measured on March 15, 2017.

---

**LITHOLOGY SYMBOLS:**

- **Fill**

---

**Product Level (LNAPL) & Water Level:**

**Casing:** Flushmount

**Grade Elevation (m asl):** 76.688

**Reference Point Elevation (m asl):** 76.893
FILL
Sand, gravel, silt and clay, PHC odour.

- sandy silt and clay, strong PHC odour

End of Borehole at 2.74 m bgs.

Notes:
1) m bgs = metres below ground surface; m asl = metres above sea level.
2) PHC = Petroleum Hydrocarbons.
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822 DT).
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.
5) LNAPL and groundwater level measured on March 15, 2017.

Casing: Flushmount
Grade Elevation (m asl) : 76.719
Reference Point Elevation (m asl) : 76.959
**Client:** Hamilton Waterfront Trust  
**Project No.:** 16-3780  
**Drilling Co.:** Direct Environmental Drilling Inc.  
**Observer:** M. Tredree  

**Project:** Shed 6 LNAPL Recovery Project  
**Location:**  
**Drilling Method:** Hollow Stem Auger (Geoprobe 7822 DT)  
**Date Started:** March 7, 2017  
**Date Completed:** March 7, 2017  

---

**Depth (m)**  
**Scale (m)**  
**Stratigraphic Description**  
**Sample**  
**Soil Sample ID (analysis)**  
**Vapour PID/OVM**  
**Rec. %**  
**Borehole Completion Detail**  
**Elev. (m asl)**

- **FILL**  
  Sand, gravel, silt and clay, loose, PHC odour, staining.  
  - sandy silt and clay, strong PHC odour, staining  
  - LNAPL observed at bottom of borehole  
  End of Borehole at 3.05 m bgs.

**Notes:**  
1) m bgs = metres below ground surface; m asl = metres above sea level.  
2) PHC = Petroleum Hydrocarbons.  
3) 0.34 m diameter borehole advanced through overburden using the hollow stem auger system (Geoprobe 7822DT).  
4) Monitoring well constructed of 150 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 1.52 m long PVC well screen (No. 60 slot) surrounded by No. 3 filter sand.  
5) LNAPL and groundwater level measured on March 13, 2017.

**Lithology Symbols**  
**Fill**  
**Casing:** Flushmount  
**Grade Elevation (m asl):** 76.741  
**Reference Point Elevation (m asl):** 76.906

---

**Product Level (LNAPL) & Water Level**
ASPHALT
Brown, coarse-grained sand and gravel, damp, dense.
- becomes dark brown-orange mixed clayey fill, some
  fine-grained sand, damp, hard, trace slag and brick debris
- PHC odour
- brick debris layer; 0.05 m thick, below, becomes dark
  brown in colour, few gravel
- becomes wet, black, oily, some brick debris
- becomes brown in colour, soft, trace brick, slight PHC
  odour
- coarse gravel and stone fragments; 0.15 m thick
- coarse and fine gravel, wood debris, moist to wet
- increasing sand content with depth
- becomes soft, no odour

End of Borehole at 6.1 m bgs.

Notes:
1) m bgs = metres below ground surface; m asl = metres
   above sea level.
2) Vapour readings collected using an RKI Eagle
   Hydrocarbon detector and MiniRAE 2000 Photoionization
   Detector.
3) * = all vapour readings expressed in parts per million
   (ppm) unless otherwise indicated.
4) PHC = Petroleum Hydrocarbons, VOC = Volatile
   Organic Compounds, PAH = Polycyclic Aromatic
   Hydrocarbons, PCB = Polychlorinated Biphenyls.
5) 0.08 m diameter borehole advanced through
   overburden using direct push technology (Geoprobe).
6) Monitoring well constructed of 32 mm diameter
   Schedule 40 flush-threaded PVC riser pipe with a 3.05 m
   long PVC well screen (No. 10 slot) surrounded by filter
   sand.
7) Groundwater and LNAPL levels measured on March 11,
   2016.
### Stratigraphic Description

**ASPHALT**
- Coarse, gravel, dense, some concrete debris.
- Becomes red clay, some coarse-grained sand, damp, hard
- Becomes dark brown in colour, few brick debris, trace slag
- Concrete and stone fragments; 0.15 m thick
- Becomes brown sand, silt and clay, few fine gravel and coarse-grained sand, wet, soft, brick debris, occasional black staining, slight PHC odour
- Becomes coarse; stone fragments, brick debris, some sand, silt and clay

End of Borehole at 4.57 m bgs.

### Notes:
1. m bgs = metres below ground surface; m asl = metres above sea level.
2. Vapour readings collected using an RKI Eagle Hydrocarbon detector and MiniRAE 2000 Photoionization Detector.
3. * = all vapour readings expressed in parts per million (ppm) unless otherwise indicated.
5. 0.08 m diameter borehole advanced through overburden using direct push technology (Geoprobe).
6. Monitoring well constructed of 32 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 3.05 m long PVC well screen (No. 10 slot) surrounded by filter sand.
**Stratigraphic Description**

<table>
<thead>
<tr>
<th>Depth Scale (m)</th>
<th>STRATIGRAPHIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Asphalt Fill: Light brown fine-grained sand and gravel, damp, loose.</td>
</tr>
<tr>
<td></td>
<td>- becomes brown clayey silt, firm, trace brick debris, occasional dark lenses</td>
</tr>
<tr>
<td></td>
<td>- becomes brown silty fine sand, some coarse gravel, little clay, dense, brick debris</td>
</tr>
<tr>
<td></td>
<td>- wood debris present</td>
</tr>
<tr>
<td></td>
<td>- becomes grey-brown sand, some coarse gravel, few silt, trace wood debris, organic odour</td>
</tr>
<tr>
<td>4.57</td>
<td>End of Borehole at 4.57 m bgs.</td>
</tr>
</tbody>
</table>

**Notes:**
1) m bgs = metres below ground surface; m asl = metres above sea level.
2) Vapour readings collected using an RKI Eagle Hydrocarbon detector and MiniRAE 2000 Photoionization Detector.
3) * = all vapour readings expressed in parts per million (ppm) unless otherwise indicated.
5) 0.08 m diameter borehole advanced through overburden using direct push technology (Geoprobe).
6) Monitoring well constructed of 32 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 3.05 m long PVC well screen (No. 10 slot) surrounded by filter sand.
7) Groundwater and LNAPL levels measured on March 11, 2016.
**Client:** Hamilton Waterfront Trust  
**Project No.:** 15-2428  
**Drilling Co.:** Direct Environmental Drilling Inc.  
**Observer:** S. Dosman

**Project:** Phase Two ESA  
**Location:** Hamilton, Ontario  
**Drilling Method:** Direct Push (Geoprobe)  
**Date Started:** Nov 23, 2015  
**Date Completed:** Nov 23, 2015

### Depth Scale (m) vs. Stratigraphic Description

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Stratigraphic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grey sand and gravel (possibly concrete debris), becomes brown silty fine sand, trace fine gravel, damp, loose, occasional stiff clay lenses, becomes brown clay, some sand and coarse gravel, dense, becomes brick debris, becomes coarse, damp, dense</td>
</tr>
<tr>
<td>2</td>
<td>Grey sand and gravel (possibly concrete debris), becomes brown silty fine sand, trace fine gravel, damp, loose, occasional stiff clay lenses, becomes brown clay, some sand and coarse gravel, dense, becomes brick debris, becomes coarse, damp, dense, becomes wet, trace coarse gravel and glass debris, slight PHC odour</td>
</tr>
<tr>
<td>3</td>
<td>Increased clay content, few fine and coarse gravel, no odour</td>
</tr>
<tr>
<td>4</td>
<td>Becomes dark brown in colour, increased coarse gravel content</td>
</tr>
</tbody>
</table>

*End of Borehole at 4.57 m bgs.*

### Notes:
1. 1 m bgs = metres below ground surface; m asl = metres above sea level.
2. Vapour readings collected using an RKI Eagle Hydrocarbon detector and MiniRAE 2000 Photoionization Detector.
3. * = all vapour readings expressed in parts per million (ppm) unless otherwise indicated.
5. 0.08 m diameter borehole advanced through overburden using direct push technology (Geoprobe).
6. Monitoring well constructed of 32 mm diameter Schedule 40 flush-threaded PVC riser pipe with a 3.05 m long PVC well screen (No. 10 slot) surrounded by filter sand.

### Casing:
- **Flushmount**
- **Grade Elevation (m asl):** 77.22
- **Reference Point Elevation (m asl):** n/a

### Geotechnical Summary

<table>
<thead>
<tr>
<th>Stratigraphy Symbol</th>
<th>Depth (m)</th>
<th>Sample Soil Sample ID (analysis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASPHALT</td>
<td>0.08</td>
<td>0.005</td>
</tr>
<tr>
<td>Fill</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>0.870</td>
<td>0.870</td>
</tr>
<tr>
<td></td>
<td>4.57</td>
<td>4.57</td>
</tr>
</tbody>
</table>

**Rushmount casing**

---

**LITHOLOGY SYMBOLS**
- Asphalt
- Fill

**Water Level (No Measurable Product)**
Appendix C

Tables
### Table 1. Water and LNAPL Levels Measurements

<table>
<thead>
<tr>
<th>Date</th>
<th>RW1 Water Level (mtboc)</th>
<th>Measured Product Layer Thickness (m)</th>
<th>RW2 Water Level (mtboc)</th>
<th>Measured Product Layer Thickness (m)</th>
<th>RW3 Water Level (mtboc)</th>
<th>Measured Product Layer Thickness (m)</th>
<th>RW4 Water Level (mtboc)</th>
<th>Measured Product Layer Thickness (m)</th>
<th>RW5 Water Level (mtboc)</th>
<th>Measured Product Layer Thickness (m)</th>
<th>RW6 Water Level (mtboc)</th>
<th>Measured Product Layer Thickness (m)</th>
<th>RW7 Water Level (mtboc)</th>
<th>Measured Product Layer Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-Mar-17</td>
<td>2.28</td>
<td>0.10</td>
<td>2.01</td>
<td>0.11</td>
<td>1.89</td>
<td>0.11</td>
<td>1.74</td>
<td>0.11</td>
<td>1.59</td>
<td>0.11</td>
<td>1.36</td>
<td>0.11</td>
<td>1.17</td>
<td>0.11</td>
</tr>
<tr>
<td>15-Mar-17</td>
<td>2.21</td>
<td>0.14</td>
<td>2.12</td>
<td>0.14</td>
<td>1.87</td>
<td>0.14</td>
<td>1.69</td>
<td>0.14</td>
<td>1.64</td>
<td>0.14</td>
<td>1.15</td>
<td>0.14</td>
<td>1.36</td>
<td>0.14</td>
</tr>
<tr>
<td>17-Mar-17</td>
<td>1.14</td>
<td>0.04</td>
<td>1.05</td>
<td>0.04</td>
<td>1.95</td>
<td>0.04</td>
<td>1.56</td>
<td>0.04</td>
<td>1.25</td>
<td>0.04</td>
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<td>0.04</td>
<td>0.15</td>
<td>0.04</td>
</tr>
<tr>
<td>20-Mar-17</td>
<td>2.54</td>
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<td>1.91</td>
<td>0.12</td>
<td>1.48</td>
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<td>-</td>
<td>0.12</td>
<td>-</td>
<td>0.12</td>
<td>1.32</td>
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<tr>
<td>22-Mar-17</td>
<td>2.36</td>
<td>0.12</td>
<td>2.12</td>
<td>0.12</td>
<td>1.84</td>
<td>0.12</td>
<td>-</td>
<td>0.12</td>
<td>-</td>
<td>0.12</td>
<td>-</td>
<td>0.12</td>
<td>-</td>
<td>0.12</td>
</tr>
<tr>
<td>24-Mar-17</td>
<td>2.29</td>
<td>0.08</td>
<td>1.99</td>
<td>0.08</td>
<td>1.92</td>
<td>0.08</td>
<td>-</td>
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<td>-</td>
<td>0.08</td>
<td>-</td>
<td>0.08</td>
<td>-</td>
<td>0.08</td>
</tr>
<tr>
<td>27-Mar-17</td>
<td>2.12</td>
<td>Trace</td>
<td>1.98</td>
<td>0.11</td>
<td>1.97</td>
<td>0.11</td>
<td>-</td>
<td>0.11</td>
<td>-</td>
<td>0.11</td>
<td>-</td>
<td>0.11</td>
<td>-</td>
<td>0.11</td>
</tr>
<tr>
<td>29-Mar-17</td>
<td>2.12</td>
<td>0.01</td>
<td>2.06</td>
<td>0.01</td>
<td>1.79</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
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<td>0.01</td>
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<td>0.01</td>
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<tr>
<td>31-Mar-17</td>
<td>2.36</td>
<td>0.01</td>
<td>2.01</td>
<td>0.01</td>
<td>1.79</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
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<tr>
<td>5-Apr-17</td>
<td>2.23</td>
<td>0.01</td>
<td>2.01</td>
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<td>1.94</td>
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<td>0.01</td>
<td>-</td>
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<td>0.01</td>
<td>-</td>
<td>0.01</td>
</tr>
<tr>
<td>7-Apr-17</td>
<td>2.25</td>
<td>0.02</td>
<td>2.01</td>
<td>0.02</td>
<td>1.94</td>
<td>0.02</td>
<td>-</td>
<td>0.02</td>
<td>-</td>
<td>0.02</td>
<td>-</td>
<td>0.02</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>9-Apr-17</td>
<td>1.98</td>
<td>0.02</td>
<td>2.00</td>
<td>0.02</td>
<td>1.79</td>
<td>0.02</td>
<td>-</td>
<td>0.02</td>
<td>-</td>
<td>0.02</td>
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</tr>
<tr>
<td>11-Apr-17</td>
<td>1.99</td>
<td>0.07</td>
<td>1.95</td>
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<td>1.72</td>
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<td>-</td>
<td>0.07</td>
<td>-</td>
<td>0.07</td>
<td>-</td>
<td>0.07</td>
<td>-</td>
<td>0.07</td>
</tr>
<tr>
<td>13-Apr-17</td>
<td>2.19</td>
<td>0.01</td>
<td>1.87</td>
<td>0.01</td>
<td>1.62</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**Notes:**
- mbtoc: metres below top of casing
- NM: No measured product
- **:** Water level and LNAPL thickness could not be measured due to high viscosity of the product that coated the interface probe resulting in inaccurate readings.
<table>
<thead>
<tr>
<th>Product</th>
<th>Min (g/mL)</th>
<th>Max (g/mL)</th>
<th>Midpoint (g/mL)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile Lub Oil</td>
<td>0.88</td>
<td>0.94</td>
<td>0.91</td>
<td>Testa and Winegardner, 1991</td>
</tr>
<tr>
<td>Coke Oven-Tar</td>
<td>1.12</td>
<td>1.12</td>
<td>1.12</td>
<td>Testa and Winegardner, 1991</td>
</tr>
<tr>
<td>Crude Oil</td>
<td>0.70</td>
<td>0.98</td>
<td>0.84; 0.88</td>
<td>Mercer and Cohen, 1990; Huntley and Beckett, 2002</td>
</tr>
<tr>
<td>Crude-Alaska North Slope (Northern Pipeline)</td>
<td>0.8828</td>
<td>0.8719</td>
<td>ESD 96</td>
<td></td>
</tr>
<tr>
<td>Crude-Alberta</td>
<td>0.8500</td>
<td>0.8430</td>
<td>0.8400</td>
<td>Mackay 82a</td>
</tr>
<tr>
<td>Crude-Atkinson</td>
<td>0.9219</td>
<td>0.9110</td>
<td>EETD 84; EETD 85</td>
<td>USEPA, 1996</td>
</tr>
<tr>
<td>Crude-California</td>
<td>0.9968</td>
<td>0.9942</td>
<td>0.9882</td>
<td>USEPA, 1996</td>
</tr>
<tr>
<td>Crude-Pennsylvania</td>
<td>0.80</td>
<td>0.85</td>
<td>0.83</td>
<td>Testa and Winegardner, 1991</td>
</tr>
<tr>
<td>Crude-Prudhoe Bay</td>
<td>0.8150</td>
<td>0.9110</td>
<td>0.9050</td>
<td>Mackay 82a</td>
</tr>
<tr>
<td>Crude-Prudhoe Bay (1995)</td>
<td>0.8948</td>
<td>0.8637</td>
<td>ESD 95</td>
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</tr>
<tr>
<td>Crude-Texas/Oklahoma</td>
<td>0.9150</td>
<td>0.9110</td>
<td>0.9050</td>
<td>Mackay 82a</td>
</tr>
<tr>
<td>Crude-Transmountain Blend</td>
<td>0.8650</td>
<td>0.8550</td>
<td>EETD 84</td>
<td></td>
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<tr>
<td>Crude-West Texas Intermediate</td>
<td>0.8536</td>
<td>0.8212</td>
<td>0.8420</td>
<td>OES 92; USEPA, 1996</td>
</tr>
<tr>
<td>Crude-Wyoming/Montana</td>
<td>0.80</td>
<td>0.85</td>
<td>0.83</td>
<td>Testa and Winegardner, 1991</td>
</tr>
<tr>
<td>Diesel</td>
<td>0.80</td>
<td>0.85</td>
<td>0.83</td>
<td>USEPA, 1996; Mercer and Cohen, 1990; Huntley and Beckett, 2002</td>
</tr>
<tr>
<td>Diesel Fuel Oil (Alaska)</td>
<td>0.8409</td>
<td>0.8300</td>
<td>ESD 96</td>
<td></td>
</tr>
<tr>
<td>Diesel Fuel Oil (Canada)</td>
<td>0.8380</td>
<td>0.8245</td>
<td>0.8171</td>
<td>EETD 84; ESD 95; Shell 99a</td>
</tr>
<tr>
<td>Diesel Fuel Oil (Southern USA, 1997)</td>
<td>0.8467</td>
<td>0.8362</td>
<td>0.8291</td>
<td>ESD 98</td>
</tr>
<tr>
<td>Diesel Fuel Oil No. 2D</td>
<td>0.82</td>
<td>0.95</td>
<td>0.89</td>
<td>RISA 91; Huntley and Beckett, 2002</td>
</tr>
<tr>
<td>Diesel Fuel Oil No. 3D</td>
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<td>0.95</td>
<td>0.89</td>
<td>Testa and Winegardner, 1991</td>
</tr>
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<td>Diesel Fuel Oil No. 4D</td>
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<td>0.95</td>
<td>0.89</td>
<td>Testa and Winegardner, 1991</td>
</tr>
<tr>
<td>Diesel Fuel Oil No. 5D</td>
<td>0.82</td>
<td>0.95</td>
<td>0.89</td>
<td>Testa and Winegardner, 1991</td>
</tr>
<tr>
<td>Fuel Oil No. 1</td>
<td>0.8080</td>
<td>0.7994</td>
<td>0.7895</td>
<td>CHRIS 91</td>
</tr>
<tr>
<td>Fuel Oil No. 1 (JP-1)</td>
<td>0.7699</td>
<td>0.7549</td>
<td>0.7400</td>
<td>CHRIS 91</td>
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<tr>
<td>Fuel Oil No. 1 (JP-2)</td>
<td>0.8390</td>
<td>0.8244</td>
<td>0.8021</td>
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<tr>
<td>Fuel Oil No. 1 (JP-3)</td>
<td>0.7790 to 0.8060</td>
<td>Dukelk 78</td>
<td></td>
<td></td>
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<tr>
<td>Fuel Oil No. 1 (JP-4)</td>
<td>0.7790 to 0.8060</td>
<td>Dukelk 78</td>
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<tr>
<td>Fuel Oil No. 1 (Kerosene)</td>
<td>0.8390</td>
<td>0.8095</td>
<td>0.8050</td>
<td>CHRIS 91</td>
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<tr>
<td>Fuel Oil No. 2</td>
<td>0.8490; 0.8740</td>
<td>0.8660</td>
<td>0.8400</td>
<td>EETD 84; Mackay 82b</td>
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<tr>
<td>Product Specific Gravity (g/mL) @ 0 (weight %) Evaporation</td>
<td>Reference</td>
<td>Specific Gravity (g/mL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>-----------</td>
<td>------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temp °C</td>
<td>Min (g/mL)</td>
<td>Max (g/mL)</td>
<td>Midpoint (g/mL)</td>
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<tr>
<td>Fuel Oil No. 2 (Typical Heating Fuel Oil)</td>
<td>0 5 10 15 16 20 25 30 38 40</td>
<td>0.8641</td>
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<tr>
<td>Fuel Oil No. 3</td>
<td>0.9380</td>
<td>0.9250</td>
<td></td>
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<tr>
<td>Fuel Oil No. 5</td>
<td>0.9349</td>
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<td></td>
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</tr>
<tr>
<td>Fuel Oil No. 6</td>
<td>&lt;0.9910</td>
<td></td>
<td></td>
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<tr>
<td>Fuel Oil No. 6 (Bunker C Fuel Oil)</td>
<td>0.9800; 0.9941</td>
<td>0.9760; 0.9904</td>
<td>0.9730; 0.9867</td>
<td>0.9690; 0.9830; &lt;1.0290</td>
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<tr>
<td>Gas House-Tar</td>
<td></td>
<td></td>
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<td>1.16</td>
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<tr>
<td>Gasoline</td>
<td>0.6855</td>
<td>0.6730</td>
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<tr>
<td>Gasoline (Casinghead)</td>
<td>0.7460</td>
<td>0.7501</td>
<td>0.7290</td>
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<td>Gasoline (Polymer)</td>
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<td>Gasoline (Unleaded)</td>
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<td>Gasoline Blending Stocks (Alkylates)</td>
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<tr>
<td>Gasoline Blending Stocks (Reformates)</td>
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<tr>
<td>Jet A</td>
<td>0.8269</td>
<td>0.7750 to 0.8400; 0.8159</td>
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<td>0.8086</td>
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<td>Jet B</td>
<td>0.7689</td>
<td>0.7500 to 0.8010; 0.7567</td>
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<td>Jet Fuel</td>
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<td>0.74</td>
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<td>Lubricating Oil (Hydraulic, Esso XD3-10)</td>
<td>0.8833</td>
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<td>Lubricating Oil (Mineral)</td>
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<td>Navy No. 1 Fuel Oil</td>
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<td>0.95</td>
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<td>Navy No. 2 Fuel Oil</td>
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<td>Transmission Oils*</td>
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<td>0.88</td>
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<td>Turbine (Light or Heavy)</td>
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2SAE 10, 20, 30, 40, 50, 60, & 70
3SAE 90, 140, 250
## Dynamic Viscosity

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<tr>
<th>Product</th>
<th>Dynamic Viscosity (mPa*s or cP)</th>
<th>Reference</th>
<th>Other References</th>
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<tbody>
<tr>
<td>Crude Oil</td>
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<td>ESD 96</td>
<td>Mercer and Cohen, 1990</td>
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<tr>
<td>Crude-Alaska North Slope (Northern Pipeline)</td>
<td>29, 14</td>
<td>USEPA 96</td>
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<td>Crude-Alberta</td>
<td>18, 12</td>
<td>Mackay 86a</td>
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<tr>
<td>Crude-Athabasca</td>
<td>9, 6</td>
<td>ESD 96</td>
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<td>Crude-California (API 11)</td>
<td>220,000</td>
<td>EETD 85</td>
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<tr>
<td>Crude-Prudhoe Bay</td>
<td>577, 196, 103</td>
<td>USEPA 96</td>
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<tr>
<td>Crude-Prudhoe Bay (1995)</td>
<td>46</td>
<td>ESD 95</td>
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<tr>
<td>Crude-Transmountain Blend</td>
<td>650</td>
<td>EETD 85</td>
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<tr>
<td>Crude-West Texas Intermediate</td>
<td>15, 7</td>
<td>USEPA 96</td>
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<tr>
<td>Diesel Fuel Oil</td>
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<td>Diesel Fuel Oil (Alaska)</td>
<td>4, 2</td>
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<tr>
<td>Diesel Fuel Oil (Canada)</td>
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<td>Diesel Fuel Oil (Southern USA, 1997)</td>
<td>7, 4</td>
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<td>Fuel Oil No. 1 (JP-1)</td>
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<td>Fuel Oil No. 1 (JP-3)</td>
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<td>Fuel Oil No. 2</td>
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<td>Fuel Oil No. 4</td>
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<td>Fuel Oil No. 5</td>
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<td>Fuel Oil No. 6</td>
<td>53-175</td>
<td>USEPA 96</td>
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<td>Fuel Oil No. 6 (Bunker C Fuel Oil)</td>
<td>73,500,000, 28,700,000, 5,980,000</td>
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<tr>
<td>Fuel Oil No. 6 (Bunker C Fuel Oil)</td>
<td>1,037,000, 45,030</td>
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<tr>
<td>Fuel Oil No. 6 (Bunker C Fuel Oil)</td>
<td>1,037,000</td>
<td>USEPA 96</td>
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<td>Gasoline</td>
<td>0.62</td>
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<td>Gasoline (Casaghead)</td>
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<td>USEPA 96</td>
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<td>Gasoline (Isolated)</td>
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<td>Gasoline Blending Stocks (Alkylates)</td>
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<td>Gasoline Blending Stocks (Reformates)</td>
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<td>USEPA 96</td>
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<td>Jet A, Jet A-1</td>
<td>2.3</td>
<td>USEPA 96</td>
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<td>Jet B</td>
<td>2</td>
<td>USEPA 96</td>
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<tr>
<td>Jet B (Alaska)</td>
<td>2</td>
<td>USEPA 96</td>
<td></td>
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<td>Lubricating Oil (Hydraulic, Esso XD3-10)</td>
<td>253, 102</td>
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<tr>
<td>Water</td>
<td>1.31</td>
<td>0.66</td>
<td>Fetter, 1994</td>
</tr>
</tbody>
</table>

---

Appendix D

Graphs
Appendix E

Laboratory Certificates of Analysis
Attention: SUB CONTRACTOR
MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2017/04/06
Report #: R2366562
Version: 1 - Final

<table>
<thead>
<tr>
<th>Job/Sample</th>
<th>Analysis Type</th>
<th>Well Name/Sample ID</th>
<th>Sample Point</th>
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<tbody>
<tr>
<td>B725241/</td>
<td>Certificate of Analysis</td>
<td>EDI031-SHED 6 (LNAPL)</td>
<td></td>
</tr>
</tbody>
</table>

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Melissa Gelineau, Project Manager
Email: MGelineau@maxxam.ca
Phone# (780)378-8593

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports.
### CERTIFICATE OF ANALYSIS

**Operator Name:**
EDI031-SHED 6 (LNAPL)

**Well Status Type:**
N/A

**Well Type:**
MAXXAM ANALYTICS

**Well Fluid Status:**
GLASS BOTTLE

**Field or Area:**
EDI031-SHED 6 (LNAPL)

**Sample Point:**
As Received

**Test Type:**
Well/Plant/Facility

**Test Recovery:**
2017/03/29 09:00

**Date Sampled Start:**
2017/04/06

**Date Sampled End:**
2017/04/06

**Date Received:**
2017/04/06

**Date Reported:**
2017/04/06

**Client ID:**
MS7,JKM

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Result</th>
<th>Unit</th>
<th>Method</th>
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</thead>
<tbody>
<tr>
<td>Absolute Density @ 15 °C</td>
<td>901.7</td>
<td>kg/m³</td>
<td>ASTM D5002</td>
</tr>
<tr>
<td>Measured Relative Density @ 15 °C</td>
<td>0.9025</td>
<td>N/A</td>
<td>ASTM D5002</td>
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<tr>
<td>API Gravity @ 15 °C</td>
<td>25.3</td>
<td>N/A</td>
<td>ASTM D5002</td>
</tr>
</tbody>
</table>

**Remarks:**

Reference Method suffix "M" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

**Results relate only to items tested.**

**Information not supplied by Client -- data derived from LSD information.**

**Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 6744 - 50th Street T6B 3M9 Telephone(780) 378-8500 FAX(780) 378-8699**
April 12, 2017

Christine Gripton
Maxxam Analytical Services
6740 Campobello Road
Mississauga, Ontario  L5N 2L8

TEL:  (800) 268-7396
FAX  (905) 817-5775

RE:  B763623

Order No.:  R17040015

Dear Christine Gripton:

Stericycle Environmental Solutions received 1 sample on 4/6/2017 for the analyses presented in the following Certificate of Analytical Results.

The analyses and all data for associated QC met regulatory and/or laboratory specifications. Exceptions will be noted in an enclosed Case Narrative.

The results on the attached Certificate of Analytical results relate only to items tested or to the samples as received by the laboratory. This Certificate of Analytical Results shall not be reproduced, except in full, without the written approval of Stericycle Environmental Solutions, Hatfield, PA.

Please note that any unused portion of the samples will be disposed of 30 days following issuance of report, unless you have requested otherwise.

If you have any questions regarding these tests results, please feel free to call.

Sincerely,

[Signature]

Vaughan O’Neill
Project Manager
Sample Receipt Checklist

Client: Maxxam

1. Carrier: Client (UPS) FedEx US Mail Airborne Express PSC Courier Other:
2. Cooler Temperature: °C Specify presence of: Ice Blue Ice No Ice
3. Shipping container/coolers received in good condition?
4. Sample containers received intact?
5. Custody seals intact on shipping container/coolers?
6. Custody seals intact on sample bottles?
7. Chain of custody present?
   If No, have second person check sample delivery group also.
8. Chain of custody signed - relinquished AND received?
9. Chain of custody agrees with sample labels?
   No extraneous or missing samples; all sampling into (sample, Air Volumes, dates/times, etc) matches
10. Samples received in proper containers including headspace requirements?
11. Do all Containers have sample in them?
12. Are all samples single phase? (e.g. no Oil and Water, no solids > 1% in Liquid, etc.)
   If No the P.M. needs to have instructions from the client on how to properly analyze the samples
13. Analysis requirements clearly listed on COC?
14. Sufficient sample volume received for indicated tests?
15. All samples received within holding time/sufficient time to start analysis?
16. Volatile samples received with zero headspace?
   Specify: vials (waters) MeOH jars Soil Kit EnCores Other:
17. Water - pH acceptable upon receipt?

Any "No" response must be detailed in the comments section below. If a CAR is not initiated, explain why.

Corrective Action/Resolution (Reference CAR ID #):

Client Notification (Regarding which item #s, Date & time, PSC Employee initials, Person contacted):

Comments:

PM 24 4pm SUB COMP UR OA
PSC USE ONLY
<table>
<thead>
<tr>
<th>Date: 2011/04/04</th>
<th>Time (MM/DD/YYYY)</th>
<th>Temperature (°C)</th>
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</thead>
<tbody>
<tr>
<td>2:42</td>
<td>09/06/2011</td>
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</tbody>
</table>

**REGULATORY CRITERIA**

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

**SPECIAL INSTRUCTIONS**

- Please retain a copy of this form with the report.
- Please inform Maxxam immediately if you are not notified for the requested test(s).

**ADDITIONAL SAMPLE INFORMATION**

- Maxxam Project #: B76923
- Phone: (800) 268-7396 ext. 250
- Email: CJ@maxxam.com, contact@maxxam.com
- Contact Name: Christine Gipson
- Address: 640 Commercial Rd, Muskegon, MI 49444
- Company: Maxxam

**REPORT INFORMATION**

- [Maxxam](#)
Certificate of Analytical Results

Date: 12-Apr-17

Lab Order: R17040015

CLIENT: Maxxam Analytical Services
6740 Campobello Road
Mississauga, Ontario L5N 2L8

Project: B763623

Lab ID: R17040015-01 Date Received: 04/06/2017 Date Sampled: 03/29/2017 9:00
Client Sample ID: ED1031-SHED 6 (LNAPL)
Matrix: OIL

Analyses Result Limit Qual Units DF Date Analyzed

| KINEMATIC VISCOSITY | D445 | 8.80 | 0.100 | cSt | 1 | 4/12/2017 |

Qualifiers:

- BRL - Below Reporting Limit
- J - Analyte detected below quantitation limits
- B - Analyte detected in the associated Method Blank
- * - Value exceeds Maximum Contaminant Level
- N - Tentatively identified compound based on mass spectral library search
- S - Spike Recovery outside accepted recovery limits
- R - RPD outside accepted recovery limits
- E - Value above quantitation range
- H - Hold Time exceedance
Viscosity @ 40 degC