REPORT

THE CORPORATION OF THE CITY OF SARNIA

FORMER MICHIGAN AVENUE LANDFILL

2020 LIF REPORT
RWDI #1801685
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SUBMITTED TO

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1 INTRODUCTION & BACKGROUND

1.1 Introduction

RWDI Air Inc. (RWDI) was retained by the City of Sarnia (the City) to delineate the extent of light nonaqueous phase liquid (LNAPL) otherwise known as oil and/or 'product' that is known to exist within select areas of the waste mound of the Former Michigan Avenue Landfill (FMAL). The subsurface delineation efforts utilized laser-induced fluorescence (LIF) technology to detect 'floating' oil within the subsurface.

1.2 Background

The City owns and operates the FMAL (Site), which is located north of Michigan Avenue, east of Front Street, and west of Christina Street in the Village of Point Edward, ON. The Site has an area of approximately 19-hectares (ha) and is now part of Canatara Park. A Site Location Plan is provided on **Figure 1.**

Between the 1920s and 1940s, oily waste from the Imperial Oil refinery located south of Sarnia was disposed at the Site. The oily waste reportedly consisted largely of oily sludge and/or oily clay hauled to the Site and dumped from rail cars (Golder, 2015). Between approximately 1930 and 1967, the Site was used by the City for the disposal of municipal waste. The inferred limits of the landfill are presented on **Figure 1**.

Ongoing environmental monitoring completed to date at the Site has identified the presence of LNAPL, also referred to as floating oil, oil, or product at the Site in three (3) distinct areas:

1) the former Canada Lands Commission property (CLC Area);
2) the area along Michigan Avenue (G2 Area); and
3) the Lake Chipican Area.

Remedial measures undertaken to date at the Site have included the installation of a sheet-pile barrier wall in 2000 in the Lake Chipican Area and five (5) recovery wells (RW3, RW4, RW5, RW6, RW7) were installed immediately south of the sheet-pile barrier wall and each was equipped with an air-operated diaphragm pump. The sheet-pile barrier wall was extended southwest in 2011 and again in 2013 (Golder Associates Ltd. (Golder), 2013). In the G2 Area, a sheet-pile barrier wall was installed near the property line, north of Michigan Avenue in 2000. Two (2) recovery wells (RW1A and RW2) were also installed immediately north of the barrier wall. Each recovery well was equipped with a pneumatic pump. Currently, no remedial measures or preventative engineer controls (e.g., oil recovery system, sheet pile wall). have been implemented in the CLC Area. The current Trigger and Contingency Plan (Golder, 2015) for the CLC Area indicates that if LNAPL is identified within 5 metres (m) of the western property boundary, and is considered to be actively migrating, an active containment and recovery system should be installed in the CLC Area within 12 months.

In 2012, Golder was retained by the City to complete a LNAPL delineation program in the Lake Chipican Area to assess the northwestern extent of the LNAPL and to install additional monitoring wells to allow further assessment of LNAPL migration. The program included the use of the laser induced fluorescence (LIF) characterization technology and conventional monitoring wells. The LNAPL delineation program was completed between April 2012 and April 2013. Golder (2014) concluded that LNAPL is located between 10 to 30 m from the water bodies in the northwestern area of the Lake Chipican Area and the estimated thickness of the LNAPL ranged from 0.15 and 1.49 m. The LNAPL was noted to be limited to depths from 0.7 to 2.7 metres below ground surface (mbgs). In 2013, Golder completed a similar investigation in the Lake Chipican Area and again in the G2 Area in 2014 to further delineate LNAPL in these areas (Golder, 2015). In this investigation, Golder interpreted that LNAPL was present at locations where the peak percent of the Reference Emitter (%RE) was greater than 50%. For locations where the peak %RE was less than 20%, it was inferred that oil was not present. In the Lake Chipican Area, the LIF and borehole drilling programs successfully identified the western and eastern flanks of the LNAPL plume, including the area west of the Animal Farm parking lot. In the G2 area, no LNAPL was detected south of the sheet-pile wall except for well G2. North of the sheet-pile wall, LNAPL was inferred in LIF boreholes near monitoring well MW-1403 to approximately 20 m west of monitoring well MW-1431.

RWDI has been completing the monitoring program at the Site since 2018. The monitoring program is a requirement of the Waste ECA No. 9802-8TNKXK, dated March 8, 2013 and amended June 26, 2015, and is intended to determine if Lake Chipican and/or groundwater near the Site are being impacted by the waste disposed in the landfill. The long-term monitoring program also includes monitoring for combustible gas to assess the potential for explosive vapour conditions and to evaluate risks to nearby buildings and/or residential properties.

The RWDI 2019 Annual Monitoring Report (RWDI 2020) results continued to identify the presence of LNAPL in the CLC Area, G2 Area, and Lake Chipican Area. Generally, the results for 2019 were consistent with the historical interpreted extent of the LNAPL plumes, with the following exceptions:

- In the CLC Area, LNAPL was only detected within monitoring well 705, which is identified as a sentry well. LNAPL has been detected at monitoring well 705 historically, however, the LNAPL thicknesses measured at this monitoring well appears to be increasing and detections of LNAPL have also increased in frequency.
- In the G2 Area, the monitoring well locations where LNAPL were detected in 2019 were generally consistent with historical results. The LNAPL thickness measured within monitoring well 803 and monitoring well MW-1403 were slightly greater than historically observed, although continued LNAPL migration does not appear to be occurring.
- For the Lake Chipican Area, the monitoring well locations where LNAPL were detected in 2019 were generally consistent with historical results; however, the LNAPL thickness measured within monitoring wells 313, MW-1201, MW-1408, and MW-1426 were noted to be slightly greater than historically observed. LNAPL was not measured at the location of monitoring well MW-1428 in 2019 and, therefore, the interpreted extent of the plume slightly shifted in a westerly direction in that area. LNAPL was not detected at nearby monitoring wells MW-1001, MW-1422, and MW-1423. As such, LNAPL migration from the area of monitoring wells 313, MW-1101A, MW-1111, and MW-1201 toward the nearby surface water bodies does not appear to be occurring based on the 2019 monitoring results.

Due to the increasing thickness of LNAPL within sentry monitoring well 705 in the CLC Area near the property boundary and the downgradient residential properties to the west, a high-resolution subsurface investigation using the LIF technology was recommended to refine and delineate the extent of LNAPL plume(s) and identify if additional remedial measures may be warranted. As noted above, there are currently no remedial measures in the CLC Area.

LIF investigations in both the G2 Area and the Lake Chipican Area were recommended to more accurately define the extent of LNAPL plume(s) in each area and to identify if additional remedial measures may be warranted.

The current LIF investigation was completed to enhance and/or build upon existing subsurface knowledge of previous LIF investigations and the ongoing groundwater monitoring program. The results of the LIF investigation are intended to provide insight with respect to possible plume migration, assess the effectiveness of the current remedial measures in place, and determine if the current monitoring program is adequate in areas of potential plume migration.

Further to the discussion presented above, a representative from the Ministry of Environment, Conservation and Parks (MECP) was on-site during the 2020 LIF investigation and expressed a concern regarding the potential for vapour intrusion into a nearby residential dwelling located at 720 Ernest Street, in the Village of Point Edward, ON (Point Edward) based on the proximity of the inferred LNAPL plume to the property boundary. As a result, RWDI completed a supplementary investigation to further delineate the LNAPL plume and to install additional gas probes in this area. The results of this investigation were provided in a memorandum to the City dated July 13, 2020 and are also briefly summarized in this report as they are relevant to the delineation of LNAPL in that area.

Historical data collected by others has been relied upon by RWDI for the purposes of preparing this report. RWDI has assumed that historical information provided was factual and accurate as presented.

1.3 Scope of Work

RWDI was retained by the City to delineate the vertical and lateral extent of LNAPLs in the CLC Area, G2 Area, and Lake Chipican Area. The program included the use of the LIF technology mounted to a geoprobe drilling rig. The LIF technology is owned and operated by Vertex Environmental Inc. (Vertex) of Cambridge, Ontario who were sub-contracted by RWDI for this project.

The City also retained RWDI to conduct a soil vapour assessment program to address concerns raised by the MECP as it relates to the potential for migrating vapours from a LNAPL plume in the CLC Area of the FMAL to a nearby residential dwelling located at 720 Ernest Street in Point Edward.

2 SUBSURFACE LIF INVESTIGATION

2.1 Laser Induced Fluorescence

The LIF technology is based on the principle that certain compounds found in petroleum hydrocarbons (PHCs) fluoresce under ultraviolet (UV) light. The process involves emitting ultraviolet light generated from a laser into the subsurface from a specialized tooling in the drill string. The measured wavelength response pattern is indicative of the type of product that is present. For example, lower fluorescence wavelengths are indicative of lighter mixtures such as diesel and gasoline and higher wavelengths are considered representative of the heavier PHC products such as tar, bunker oil and creosote. The system allows for centimeter (cm)-scale vertical resolution that allows for a high-resolution vertical delineation of LNAPL in the subsurface.

The LIF is specifically designed to evaluate the potential presence or absence of free PHCs; however, due to the relative response measured by the laser, soil impacts can also be inferred. Soil impacts refer to PHCs that are both adsorbed to the soil and present within the void space, also referred to as ganglia. The amount to which a PHC will fluoresce by the LIF is referred to as the Reference Emitter (RE) response or %RE. A strong response may indicate mobile product where a weaker response may indicate ganglia. This process is semi-qualitative, and there is variance between sites and types of PHCs. The LIF data can be modelled to create a 3D image of the subsurface.

Strata Drilling Group (Strata) was retained by Vertex to advance the LIF direct push boreholes in each of the three (3) areas using a direct push Geoprobe 6620DT drill rig. The LIF field work was completed between May 4, 2020 and May 29, 2020. In total, 191 boreholes were advanced to depths ranging from 3 - 6 meters below ground surface (mbgs) across the three (3) areas of investigation. The LIF boreholes were distributed across the three areas as follows:

- 52 LIF boreholes were advanced in the CLC Area
- 38 LIF boreholes were advanced in the G2 Area
- 101 LIF boreholes were completed in the Lake Chipican Area

LIF borehole locations for each of the three (3) areas are illustrated on **Figure 2.** Additional details for the CLC Area, the G2 Area, and the Lake Chipican Area are provided on **Figures 3**, **4**, and **5**, respectively.

The LIF probe is fastened to the end of a string of drilling rods and is advanced into the subsurface either by hydraulic direct push or percussion hammer to screen for potential PHCs. For each LIF location, a log is produced illustrating the total fluorescence versus depth where the signal is relative to the Reference Emitter (RE). The total area of the waveform is divided by the total area of the RE to produce the %RE, which scales with the NAPL fluorescence. The LIF laser is “calibrated” prior to each location being pushed, which allows for maximum quality assurance and quality control (QA/QC) of the measured data.

Upon completion of each LIF location, the open hole was backfilled with benseal hole plug to surface and finished with cold patch when required. The GPS co-ordinates and ground surface elevations at each of the LIF locations were recorded in the field.

Following completion of the field work, Vertex created three-dimensional visualizations of the %RE results using the Earth Volumetric Studio (EVS) software package. The %RE data was interpolated in each of the three (3) areas of interest using a kriging process. Interpolated zones of higher %RE responses may be indicative of higher levels of LNAPL in contrast to extrapolated zones with lower %RE response, which may be indicative of lower levels or LNAPL impacts or soil impacts. It should be noted higher %RE responses are more likely to be due to the presence of LNAPL rather than soil impacts; however, the presence or absence of LNAPL should be verified with additional intrusive sampling and testing. Lastly, as with all methods of interpolating data such as kriging, the extrapolated values are more representative of actual conditions in areas with more data input points. Extrapolated results in areas with a limited number of data points should be treated with caution.

The final Vertex Memorandum, including the LIF borehole logs and three-dimensional visualization figures, is provided in **Appendix A**.

2.2 Supplementary Soil Vapour Assessment

Two (2) gas monitoring probes labelled GP20149 and GP20150 were installed by RWDI within the CLC Area east of the residential property at 720 Ernest Street. One (1) of the gas monitoring probes was installed within the product plume to evaluate off-gassing concentrations that may be present directly from the product plume while the second gas monitoring probe was installed closer to the residence located at 720 Ernest Street and outside the product plume to evaluate for the presence of potential vapours in the vadose zone beyond the product plume front. The screen intervals extended from about 0.5 to 2.9 mbgs for both gas probes so that the screened interval would intersect the saturated and non-saturated hydro-stratigraphic boundaries in consideration of the product elevation, and a fluctuating groundwater table throughout the year. The gas monitoring probe installations were completed manually by RWDI staff using a hand auger. Each gas monitoring probe was equipped with sampling ports such that handheld gas monitoring equipment can be directly connected to measure in-situ soil vapour concentrations. Additional details were provided in a July 13, 2020 RWDI Memorandum to the City (**Appendix B)**.

In addition to installing the two (2) gas probes, two (2) additional boreholes (BH20149A and BH20149B) were hand augered in a line between these two (2) locations to inspect subsurface conditions and to better delineate the extent of the LNAPL plume in this area.

The locations of these installations are illustrated in the inset box on **Figure 3**.

3 LIF INVESTIGATION RESULTS

The results of the LIF survey indicated "low" to "high" responses from the LIF probe. The maximum %RE for the LIF logs range from 0.9 to 648.3 %RE. The responses ranged in thickness from 0 to approximately 5 m. The LIF boreholes with the greatest thickness were not associated with those with the higher %RE response over the entire Site in any of the three (3) areas of study.

As noted above, Interpolated zones of higher %RE responses may be indicative of higher levels of LNAPL in contrast to extrapolated zones with lower %RE response, which may be indicative of lower levels or LNAPL impacts or soil impacts. The minimum %RE response threshold that may be representative of LNAPL is very site specific as the LNAPL type and geology for that Site can all be contributing factors to this type of analysis. The presence or absence of LNAPL should be verified with additional intrusive sampling and testing. However, Golder (2015) completed a limited drilling program to asses for soil impacts beside several LIF boreholes. As outlined in **Section 1.2**, Golder interpreted that LNAPL was present at locations where the peak %RE was greater than 50%. Trace LNAPL was inferred at location where the peak %RE ranged from 20 to 50. For locations where the peak %RE was less than 20%, it was inferred that oil (LNAPL) was not present. However, as illustrated on numerous LIF borehole logs (**Appendix A**) completed as part of the current study, most %RE responses between approximately 2.5 and 20 fluoresce a noticeable signal with variable thickness. LIF boreholes with %RE responses less than approximately 2.5 did not produce a noticeable signal. As such, LIF boreholes with %RE responses in the 2.5 to 20 %RE range are interpreted to represent potential soil impacts, whereas boreholes with %RE responses <2.5 were interpreted to represent no soil impacts. Physical testing and analysis would be required to confirm this interpretation.

The results of the LIF investigations for the CLC Area, the G2 Area, and the Lake Chipican Area are illustrated on **Figure 3** through **Figure 5**, respectively. On each figure, the LIF boreholes were colour-coded based on the %RE response in order to visually differentiate those LIF boreholes results with potential LNAPL impacts from those with little or no potential LNAPL impacts, as follows:

- Red LIF boreholes - ≥50 %RE response and inferred to represent potential NAPL;
- Yellow LIF boreholes - 20 – 50 %Re response and inferred to represent potential trace LNAPL;
- Green LIF boreholes - 2.5 - 20 %Re response and inferred to represent potential soil impacts;
- Blue LIF boreholes - ≤2.5 %Re represent potential background unimpacted soil. .

The existing monitoring wells with the known presence of LNAPL are also highlighted on **Figure 3** through **Figure 5**. The inferred limits of LNAPL based on the 2017 monitoring results (Golder, 2018) is also presented on each figure to provide an indication of how and where the LNAPL plume may have changed since that time.

Additional details are provided in the following subsections.

3.1 CLC Area

As noted in the 2019 RWDI annual monitoring report (RWDI, 2020), of the current groundwater monitoring locations, LNAPL was only detected in the CLC Area in monitoring well 705 located near the west property boundary near the Victoria Avenue and Front Street intersection. LNAPL has not been detected at adjacent monitoring well 704, which is located less than 2 m west of 705 and is between that well and the property boundary. As noted, there are currently no remedial measures or preventative controls installed in the CLC Area.

The results of the CLC Area LIF survey are illustrated on **Figure 3** and provided in **Table 1**. Of the 52 LIF boreholes advances, the %RE ranged from 1.4 %RE to 648.3 %RE. The CLC Area had the highest positive responses observed on-site. The vertical responses ranged in thickness from 0 to approximately 3.5 m.

Based on the visualization results within the CLC Area, the higher LIF responses (≥50 %RE) are scattered in small clusters away from the western boundary of the LIF survey from LIF20159 in the northeast to LIF20026 south of monitoring well 705 (refer to **Table 1**). Another small cluster was noted in the area of LIF20149 just east of the residential property located at 720 Ernest Street. West of these LIF boreholes, near the perimeter of the surveyed area, the responses from LIF boreholes indicated little or no presence of LNAPL. This is illustrated on **Figure 3** by the LIF boreholes that are colour-coded blue or green.

As noted on **Figure 3**, there are numerous LIF boreholes with relatively high %RE responses west and northwest of the 2017 inferred limit of LNAPL and which are closer to the Site boundary. This may be a result of plume migration in this direction; however, additional subsurface sampling and testing would be required to confirm this interpretation. As highlighted on **Figure 3**, there are several LIF boreholes with relatively high %RE responses near groundwater monitoring wells where LNAPL was not present based on the 2019 monitoring program. Examples of this include LIF20014 and LIF20015 near monitoring wells 706 and 709, and LIF200020 near monitoring well 702. This demonstrates the need to conduct additional field characterization in areas where LNAPL may be present based on the %RE response.

Multiple types of LNAPL were interpreted in the CLC Area based on the callouts of the LIF logs and the colouring of the waveforms in the LIF logs. The majority of the LIF boreholes with a noticeable %RE response were green, yellow or orange, which is indicative of diesel or weathered gasoline, highly weathered fuels / mixtures, or heavy ended oil products, respectively. Some LIF logs within the CLC Area had potential multiple LNAPL types within the same boring location (e.g., LIF20014, LIF20020, and LIF20156).

3.2 G2 Area

As noted in the 2019 RWDI annual monitoring report (RWDI, 2020), LNAPL was detected within the G2 Area in monitoring wells 801, 802, and 803, MW-1403, MW-1403, and recovery wells RW1, RW1a, and RW2. These locations are north of the sheet-pile barrier wall, which was installed in 2000 in response to floating oil being noted in well G2 just north of Michigan Ave. LNAPL was not present in monitoring wells 606, 611, and 612, which are located on the non-landfill side of the sheet-pile barrier wall based on the 2019 monitoring data.

The results of the LIF survey are illustrated on **Figure 4** and summarized in **Table 2**. Of the 38 LIF boreholes advanced, the %RE ranged from 0 %RE to 168.3 %RE and were generally lower than the other two (2) areas (CLC and Lake Chipican areas) investigated for this study. The vertical responses ranged in thickness from 0 to approximately 4.6 m.

Based on the results within the G2 Area, 10 LIF boreholes had LIF %RE responses ≥50 %RE, as outlined in **Table 2**. Of these, three (3) (LIF20131, LIF20174, and LIF20170) were in the area east and north of the sheet-pile barrier wall in an area where LNAPL had not previously been noted. Moderate %RE responses representing potential trace LNAPL (ranging between 20 and 50 %RE and denoted by yellow borehole symbols on **Figure 4**) were noted immediately north and east of the sheet-pile barrier wall. The LIF boreholes north of the sheet-pile barrier wall occur in an area of know LNAPL based on the 2019 monitoring and may correspond to the actual presence of subsurface LNAPL.

The LIF boreholes (LIF20187 and LIF20188) with moderate %RE responses east of the sheet-pile barrier wall and north of Michigan Avenue occur in an area where LNAPL had not previously been detected and represents a risk of potential off-site migration. No LIF boreholes were advanced immediately south of the sheet-pile barrier wall near Michigan Avenue due to concerns of an unmarkable utility. Additional field characterization should be completed in areas where LNAPL may be present based on the %RE responses.

Multiple types of LNAPL were interpreted in the G2 Area based on the callouts of the LIF logs and the colouring of the waveforms in the LIF logs. The majority of the LIF boreholes with a noticeable %RE response were either yellow or orange in colour, which is indicative of highly weathered fuels / mixtures, or heavy ended oil products, respectively. Some LIF logs within the G2 Area had potential multiple LNAPL types within the same boring location (e.g., LIF20130, and LIF20132).

3.3 Lake Chipican

As noted in the 2019 RWDI annual monitoring report (RWDI, 2020), LNAPL was detected in the Lake Chipican Area in monitoring wells MW-1426, MW-1408, MW-1201, MW-1122, MW-1101A, MW-1111, 313 and recovery wells EW1, EW2, RW3, RW4, RW5,and RW6. A number of these locations (MW-1201, MW-1122 and Recovery Wells EW1 and EW2) are located northwest of the sheet-pile barrier wall and southeast of the Duck Pond.

The results of the LIF survey are illustrated on **Figure 5** and summarized in **Table 3**. Of the 101 LIF boreholes advanced, the %RE ranged from 1.2 %RE to 403 %RE. The vertical responses ranged in thickness from 0 to approximately 5 m.

Based on the visualization results within the Lake Chipican Area, numerous boreholes had LIF %RE responses ≥50 %RE (refer to **Table 3**), which are indicative of the potential presence of LNAPL. These LIF boreholes are scattered throughout the area and not concentrated in one (1) area, which could be indicative of several individual blobs of subsurface LNAPL. Several of these were in areas outside of the 2017 delineated plume, as follows:

- LIF20161, located in the southwest portion of the Lake Chipican Area. The plume had not been delineated this far south previously;

- LIF20123 and LIF20134 were located slightly west of the western extent of the 2017 inferred delineated plume;
- LIF20037, LIF20038 and LIF20049 were located slightly north of the 2017 inferred delineated plume in the parking lot area south of the Animal Farm;
- LIF20070 was located just east of the historically identified plume "finger" of LNAPL near Recovery Wells EW1 and EW2;
- LIF20106, LIF20107, LIF20094 and LIF20095 located north of Cathcart Blvd. and east of the 2017 inferred delineated plume. It should be noted that LIF20094 is within approximately 20 m of Lake Chipican, but appears to be in line with the edge of the sheet-pile barrier wall; and
- LIF20110, LIF20112. and LIF20117 located south of Cathcart Blvd. and east of 2017 inferred delineated plume.

In the area between the northwest-southeast trending sheet-pile barrier wall and Lake Chipican to the northeast, none of the LIF boreholes had elevated %RE responses.

Moderate %RE responses indicated the potential for the presence of trace subsurface LNAPL (20-50 %RE) north of Cathcart Boulevard and west of the 2017 inferred delineated plume (LIF20096 and LIF20091). LIF20091 is in the same vicinity as LIF20094 referenced above and is also relatively close to Lake Chipican.

Moderate responses indicating the potential for the presence of trace subsurface LNAPL (20-50 %RE) were also noted northwest of the sheet-pile barrier wall and east of the historically identified LNAPL "finger" (LIF20073 and LIF20074).

Additional field characterization is recommended to be completed in areas where LNAPL may be present based on the %RE responses.

Multiple types of LNAPL were interpreted to be present in the subsurface in the Lake Chipican Area based on the callouts and the colouring of the waveforms on the LIF logs. The majority of the LIF boreholes with a noticeable %RE response were either yellow or orange in colour, which is indicative of highly weathered fuels / mixtures, or heavy ended oil products, respectively. Numerous LIF logs within the Lake Chipican Area had potential multiple LNAPL types within the same boring location (e.g., LIF20043, LIF20049, LIF20123, and LIF20123).

4 SUPPLEMENTARY SOIL VAPOUR ASSESSMENT RESULT

Detailed results for the supplementary soil vapour assessment completed in the CLC Area were provided in a memorandum to the City dated July 17, 2020. The results summarized below are considered relevant to the interpretation of LNAPL in a portion of the CLC Area.

As noted in the inset box on **Figure 5**, the gas probe boreholes were completed from GP20149 in a southwest linear direction to GP0150 located within 3 m of the approximate property line and shed at 720 Ernest Street. GP20149 was intended to be in the vicinity of LIF20149, which had a %RE response of 187.8 %RE and, as such, interpreted to be within the LNAPL plume. GP20150 was intended to be in the vicinity of LIF20150, which had a %RE response of 2.8 %RE and interpreted to be outside of the plume.

The following summarizes pertinent results from that investigation.

- Visual and olfactory evidence of LNAPL or hydrocarbon was only noted in soil collected from GP20149. There was no evidence of product-like impacts in the soil at BH20149B, which was located 0.8 m further east than LIF BH20149.
- Based on the June 18, 2020 field observations, the product plume appears to be located approximately 8 m east of the residential property boundary.
- Soil samples were collected from GP20149 (Sample ID 20149C), BH20149A (sample ID 20149), and GP20150 (Sample ID 20150) and submitted to Eurofins Scientific for analytical testing for polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and petroleum hydrocarbons (PHCs) Fractions F1 to F4.
- Soil quality results were below the laboratory detection limit for the tested parameters except for PHC Fraction F2 at GP20149, and PHC Fraction F3 at BH20149A and GP20150. However, the results were less than 5 times the laboratory reportable detection limit (RDL) and considered negligible. As noted above, the soil sample from GP20149 exhibited a distinct sheen and had a hydrocarbon odour. The negligible analytical results for this sample may be due to the potentially highly weathered nature of the product as suggested by LIF responses (see **Section 3.1**); however, additional sampling and analytical testing would be required to confirm this interpretation.
- There were no combustible gas readings detected at gas monitoring probes GP20149 and GP20150 during three (3) different monitoring events (June 18th, July 2nd, or July 9, 2020). The lack of combustible gas readings from a location with visual indications of product suggests that the existing product in the area does not readily volatilize.

Based on the above, there are indications based on the LIF %RE response from LIF20149 (and other nearby LIF boreholes), and visual and olfactory evidence collected during the field investigation, that the LNAPL plume has migrated west of the 2017 inferred LNAPL plume delineation illustrated on **Figure 5**. However, the analytical testing results and gas vapour monitoring results from this location are not indicative of impacts typically expected in areas with LNAPL. Additional field characterization will be required to determine the limit of the LNAPL plume where soil quality is degraded to unacceptable concentrations in this area. Based on the existing information, the LNAPL plume is conservatively estimated to be at least 8 m west of the 720 Ernest property boundary.

5 CONCLUSIONS

Based on the above discussion of findings, the LNAPL plume boundaries may have shifted in some Areas of the FMAL compared to its inferred limit in 2017. However, the LIF findings are utilized as a guidance tool to assess an overall subsurface soil condition. A 'ground-truthing' exercise whereby the %RE signals from the LIF logs would require correlation to subsurface soil quality in the same area, which would provide a more accurate delineation of the LNAPL plume.

In consideration of the findings presented in this report, conclusions are provided below for each of the Areas investigated at the FMAL.

5.1 CLC Area

Generally, based on the LIF findings in the CLC Area, the LNAPL plume appeared to be similarly shaped as noted in 2017. The %RE responses indicated a potential plume edge that may have slightly shifted westward compared to 2017. Technical details are presented below.

- Of the 52 LIF boreholes advances, the %RE ranged from 1.4 %RE to 648.3 %RE and the responses ranged in thickness from 0 to approximately 4.0 m.
- The majority of the LIF boreholes with noticeable %RE responses had responses indicative of diesel or weathered gasoline, highly weathered fuels / mixtures, or heavy ended oil products. Some LIF logs within the CLC area appear to have potential multiple LNAPL types within the same boring location.
- There were numerous LIF boreholes with relatively high %RE (>50 %RE) responses west and northwest of the 2017 inferred limit of LNAPL and are closer to the Site boundary.
- Several LIF boreholes with a relatively high %RE responses were located near groundwater monitoring wells where LNAPL was not present during the 2019 monitoring program. Examples of this include LIF20014 and LIF20015 near monitoring wells 706 and 709, and LIF200020 near monitoring well 702.
- During the gas probe installation work completed by RWDI in 2020 near the property boundary at 720 Ernest Road, the LIF %RE response from LIF20149 (and other nearby LIF boreholes), and visual and olfactory evidence of LNAPL or hydrocarbon impact from samples collected from GP20149 suggest that the LNAPL plume had migrated west of the 2017 inferred LNAPL plume delineation and may be as close as 8 m from the western property line. However, the analytical testing results and gas vapour monitoring results from this location are not indicative of impacts associated with LNAPL or hydrocarbon.
- Additional field characterization will be required to determine the limit of the LNAPL plume in this area. There are currently no remedial measures or preventative controls installed in the CLC Area, which would be required if LNAPL was determined to be 5 m or less of the property line.

5.2 G2 Area

Generally, based on the LIF findings in the G2 Area, the LNAPL plume based on the %RE responses indicated a potential plume edge that may have extended east and southeast in comparison to the 2017. Technical details are presented below.

- Of the 38 LIF boreholes advanced, the %RE ranged from 0 %RE to 168.3 %RE and the responses ranged in thickness from 0 to approximately 4.5 m.
  Multiple types of LNAPL were interpreted in the G2 Area based on the LIF results and include highly weathered fuels / mixtures, or heavy ended oil products, respectively. Some LIF logs within the G2 Area had potential multiple LNAPL types within the same boring location.
- Ten LIF boreholes had relatively high %RE (>50 %RE) responses indicative of potential LNAPL impacts. Of these, three (3) (LIF20121, LIF20174, and LIF20170) were in the area east and north of the sheet-pile barrier wall in an area where LNAPL had not previously been noted. Moderate %RE responses (ranging between 20 and 50 %RE) were noted immediately north of the sheet-pile barrier wall in areas with known LNAPL presence based on the 2019 monitoring program findings.
- No LIF boreholes were advanced immediately south of the sheet-pile barrier wall near Michigan Avenue due to concerns of an unmarkable utility, therefore, the presence or absence of LNAPL in that area could not been assessed.
- Moderate responses (10 – 25 %RE) indicative of potential trace LNAPL were noted north and east of the sheet-pile barrier wall. The LIF boreholes with moderate %RE responses east of the sheet-pile barrier wall and north of Michigan Avenue occur in an area where LNAPL had not previously been detected and represent a risk of potential off-site migration.
- Additional field characterization will be required to confirm the potential presence of LNAPL in areas with moderate to high %RE responses.

5.3 Lake Chipican Area

Generally, based on the LIF findings in the Lake Chipican Area, the LNAPL plume may have increased in size overall. The %RE responses indicated a potential plume edge that may have slightly extended westward, northwest, and eastward in comparison to 2017. Technical details are presented below.

- Of the 101 LIF boreholes advanced, the %RE ranged from 1.2 %RE to 403 %RE and the responses ranged in thickness from 0 to approximately 5 m.
- Multiple types of LNAPL were interpreted in the Lake Chipican area based on the LIF results. Most of the higher %RE responses were indicative of highly weathered fuels / mixtures, or heavy ended oil products, respectively. Numerous LIF logs may have multiple LNAPL types within the same boring location.

- Numerous boreholes had relatively high %RE (>50 %RE) responses. A number of these are in areas outside of the 2017 inferred delineated plume, as follows.
    - LIF20161 located in the southwest portion of the Lake Chipican Area.
    - LIF20123 and LIF20134 located slightly west of the western extent of the 2017 inferred delineated plume;
    - LIF20037, LIF20038, and LIF20049 located slightly north of the 2017 inferred delineated plume in the parking lot area south of the Animal Farm;
    - LIF20070 located just east of the "finger" of LNAPL near Recovery Wells EW1 and EW2;
    - LIF20106, LIF20107, LIF20094 and LIF20095 located north of Cathcart Blvd. and east of the 2017 inferred delineated plume. LIF20094 is within approximately 20 m of Lake Chipican; and
    - LIF20110, LIF20112 and LIF20117 located south of Cathcart Blvd. and east of the 2017 inferred delineated plume.
- Moderate responses indicative of potential trace LNAPL (20-50 %RE) were noted north of Cathcart Blvd. east of the 2017 inferred delineated plume (LIF20096 and LIF20091). LIF20091 is in the same vicinity as LIF20094 referenced above and is relatively close to Lake Chipican.
- Moderate responses indicative of potential trace LNAPL (20-50 %RE) were also noted northwest of the sheet-pile barrier wall and east of the LNAPL "finger" (LIF20073 and LIF20074).
- Additional field characterization will be required to confirm the potential presence of LNAPL in areas with moderate to high %RE responses.

6 RECOMMENDATIONS

Based on the findings of the 2020 LIF Investigation, the following recommendations are provided for consideration:

- Overall, to better understand the %RE subsurface responses and utilize these responses to correlate subsurface soil conditions across the Site, it is recommended that discrete soil sampling and chemical analysis be completed at a minimum of 10% of the completed LIF borehole locations (i.e. ~5 in the CLC Area, 3 in the G2 Area, and 10 in the Lake Chipican Area). This would be a 'ground-truthing' exercise whereby the %RE signals would be correlated to the subsurface soil quality. A more accurate updated inferred delineated plume could then be prepared based on this exercise. The subsurface soil quality assessment may also provide insight about whether additional monitoring wells should be installed to monitor the movement of the LNAPL plume, specifically in areas where LNAPL has been inferred in the subsurface for the first time. Specific subsurface investigative measures are being proposed for the three (3) main Areas of the FMAL below and may be incorporated into the ground-truthing exercise.
    - In the CLC Area, LNAPL may be present west of the area previously delineated near the property boundary based on the 2020 LIF results. However, there is some uncertainty regarding the presence of LNAPL in these areas based on the conflicting groundwater monitoring data and soil quality analyses. Additionally, there are currently no remedial measures or preventative engineer controls installed in the CLC Area (e.g., oil recovery system, sheet-pile barrier wall, etc.). As such, additional subsurface investigative measures, including soil quality analyses and supplemental groundwater monitoring well installations to monitor subsurface plume movement, may be warranted in areas of potential LNAPL where the plume may be migrating towards the property boundary.

- In the G2 Area, potential LNAPL or trace LNAPL may be present in the area east and north of the sheet-pile barrier wall where LNAPL had not previously been identified. Additional subsurface investigative measures, including soil quality analyses and supplemental groundwater monitoring well installations to monitor subsurface plume movement, may be warranted to confirm the presence or absence of LNAPL east of the sheet-pile barrier wall and north of Michigan Avenue as LNAPL as this area represents a potential risk for off-site migration.
    - No LIF boreholes were advanced south of the sheet-pile barrier wall in the G2 Area. Though there are a few groundwater monitoring wells currently being monitored south of the sheet-pile barrier wall, which continue to show acceptable groundwater conditions (i.e. no presence of LNAPL or floating oil), should ongoing monitoring indicate a significant change in the location or thickness of LNAPL in this area, further intrusive investigation south of the sheet-pile barrier wall would be recommended.
- In the Lake Chipican Area, there were numerous LIF boreholes with relatively high %RE in areas outside of the 2017 inferred delineated LNAPL plume. Most of these LIF boreholes are in areas away from Lake Chipican and the sheet-pile barrier wall except for the area of the LNAPL "finger" north west of the sheet-pile barrier wall and immediately south and east of the eastern extent of the sheet-pile barrier wall. As such, additional subsurface investigative efforts are recommended in these two (2) areas to characterize the potential presence of due their proximity to Lake Chipican. If LNAPL is determined to be present in these areas, additional monitoring wells are recommended for incorporation into the ongoing groundwater monitoring program to assess the subsurface movement of the LNAPL plume.

- The findings of this LIF investigation and follow-up ground-truthing effort will be considered toward the preparation of the updated Trigger and Contingency Plan for the FMAL.

7 STUDY LIMITATIONS AND USE OF REPORT

This report was prepared using scientific principles and professional judgment in assessing available facts and presenting subjective interpretations. The professional judgments presented within this document are based on available facts within the limits of the existing information, budgeted scope of work, and schedule. It is RWDI's intent that the professional judgment and interpretive conclusions be utilized as guidance and not be necessarily construed as a firm course of action, unless explicitly stated otherwise. We make no warranties, expressed or implied, including without limitation, or warranties as to merchantability or fitness of the property for a particular purpose. The information presented in this report is not to be construed as legal advice.

RWDI relied on information obtained from Site representatives, independent sources, and other historical documentation as referenced in this report. The accuracy and completeness of third-party sources was not verified. It is noted that regulatory guidelines, standards, and related documents as they may be referenced in this report are subject to interpretation and may change over time.

This report was prepared for the exclusive use of The Corporation of the City of Sarnia and the Ministry of the Environment, Conservation and Parks. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. RWDI accepts no responsibility for damages, if any, suffered by any third party as result of decisions made or actions based on this report.

8 CLOSURE

We trust that this 2020 LIF Report for the Former Michigan Avenue Landfill in the City of Sarnia, Ontario, is satisfactory for your requirements. Should there be any questions or comments, please contact us.

Sincerely,

RWDI

Report Prepared By:

No signatures on drafts

Steve Davies, M.Sc., P.Geo.
Technical Director

Phil Janisse, B.Sc., P.Geo., QP_{ESA}
Senior Geoscience Specialist

SGD/PEJ/kta

Attach.

9 REFERENCES

Golder Associates Ltd. 2014. Light Non-Aqueous Phase Liquid (LNAPL) Delineation, Lake Chipican Area, Former Michigan Avenue Landfill, Sarnia, Ontario. Report No. 07-1135-029-0-R05, January 2014.

Golder Associates Ltd. 2015. Light Non-Aqueous Phase Liquid (LNAPL) Delineation, Remedial Action Plan Addendum #2 Results, Lake Chipican and G2 Areas, Former Michigan Avenue Landfill, Sarnia, Ontario. Report No. 07-1135-029-0-R09, April 2015.

Golder Associates Ltd. 2018. Michigan Avenue 2017 Monitoring Program, Point Edward, Ontario. Report No. 07-1135-029-0-R13, May 2018.

RWDI. 2020. 2019 Annual Report, Former Michigan Avenue Landfill, May 2020.

TABLES

Table 1 - CLC Area LIF Results

LIF Borehole	Max Signal (%RE)	Max Signal Depth (m)	Approximate LNAPL Thickness (m)	Potential Impacts
20001	7.4	0	0.05	soil impact
20002	265	2.97	3.5	NAPL
20003	377.9	2.85	2.7	NAPL
20004	27.1	0	1	trace NAPL
20005	6.8	0.48	0.1	soil impact
20006	55.7	2.03	1.5	NAPL
20007	1.9	2.24	0	no impact
20008	443.1	2.66	1.5	NAPL
20009	408.5	1.82	1.15	NAPL
20010	15.6	0.71	0.3	soil impact
20011	2	2.49	0	no impact
20012	408.6	1.35	1	NAPL
20013	3.5	0.36	0.05	soil impact
20014	648.3	2.28	2	NAPL
20015	469.6	1.62	2.55	NAPL
20016	7.9	0.11	0.1	soil impact
20017	2.3	3.13	0	no impact
20018	602.6	2.64	1.1	NAPL
20019	610.4	2.64	2	NAPL
20020	430.1	2.17	1.6	NAPL
20021	1.9	2.46	0	no impact
20022	279.9	2.07	2.8	NAPL
20023	304.6	1.77	2.3	NAPL
20024	3.5	2.45	1.6	soil impact
20025	179.4	2.43	1	NAPL
20026	80.8	1.61	1.65	NAPL
20027	1.5	2.65	0	no impact
20028	1.4	3.07	0	no impact
20029	14.2	2.16	2.05	soil impact
20030	113.2	3.37	2.7	NAPL
20031	1.8	0.97	0	no impact
20034	1.8	1.55	0	no impact
20035	7.9	1.74	0.65	soil impact
20143	2.4	2.72	0.25	no impact
20144	2.4	0.6	0.05	no impact
20145	2.2	2.47	0.1	no impact

LIF Borehole	Max Signal (%RE)	Max Signal Depth (m)	Approximate LNAPL Thickness (m)	Potential Impacts
20146	4.5	1.02	0.15	soil impact
20147	2.1	0.36	0.01	no impact
20148	1.7	2.37	0	no impact
20149	187.8	1.16	1.35	NAPL
20150	2.8	2.21	0.1	soil impact
20151	7.5	0.02	0.1	soil impact
20152	2.4	2.37	0.05	no impact
20153	1.5	1.44	0	no impact
20154	432.9	2.25	2.75	NAPL
20155	2.3	2.42	0	no impact
20156	431.4	3.27	2.1	NAPL
20157	3	0.07	0.03	soil impact
20158	2.7	0.01	0.01	soil impact
20159	364	3.01	2	NAPL
20190	2	1.81	0	no impact
20191	292.2	2.28	3.35	NAPL

Table 2 - G2 Area LIF Results

Borehole	Max Signal (%RE)	Max Signal Depth (m)	Approximate LNAPL Thickness (m)	Potential Impacts
20032	1.3	1.17	0	no impact
20033	39.1	2.61	1.15	trace NAPL
20127	62.4	2.43	2.4	NAPL
20128	112.5	3.32	1.7	NAPL
20129	58.6	2.79	3.55	NAPL
20130	29.8	3.14	4.6	trace NAPL
20131	97.4	3.85	3.35	NAPL
20132	17.3	2.36	0.75	soil impact
20133	30	2.26	0.65	trace NAPL
20134	14.2	2.67	1.4	soil impact
20162	3	0.61	0.13	soil impact
20163	46.2	2.95	1.25	trace NAPL
20164	5.8	2.88	0.3	soil impact
20165	3.5	0.89	0.05	soil impact
20166	3.5	2.38	0.5	soil impact
20167	58.3	1.52	1.05	NAPL
20168	22	1.52	1.5	trace NAPL
20169	2.1	3.07	0	no impact
20170	168.3	2.29	2.2	NAPL
20171	10	2.06	0.4	soil impact
20172	2	3.05	0	no impact
20173	16.5	1.64	0.9	soil impact
20174	110	2.69	3.2	NAPL
20175	38.3	1.2	2.5	trace NAPL
20176	52.4	2.55	2.2	NAPL
20177	29	3.07	2.3	trace NAPL
20178	63.5	2.39	2.4	NAPL
20179	65.2	2.86	1.45	NAPL
20180	9.4	0.89	0.55	soil impact
20181	1.9	2.15	0	no impact
20182	4.5	1.97	0.4	soil impact
20183	2.3	2.09	0.02	no impact
20184	12	1.13	1.4	soil impact
20185	5.5	0.94	0.4	soil impact
20186	14	1.27	0.6	soil impact
20187	21.2	1.02	1.5	trace NAPL
20188	21.1	1.24	0.6	trace NAPL
20189	41.6	1.56	2.25	trace NAPL

Table 3 - Lake Chipican Area LIF Results

Borehole	Max Signal (%RE)	Max Signal Depth (m)	Approximate LNAPL Thickness (m)	Potential Impacts
20036	3.3	0.28	0.05	soil impact
20037	116.3	1.37	1.5	NAPL
20038	71.1	1.77	1.4	NAPL
20039	9.3	1	0.05	soil impact
20040	1.6	2.23	0	no impact
20041	5.2	1.3	0.05	soil impact
20042	1.5	2.86	0	no impact
20043	101.9	2.43	2.2	NAPL
20044	1.5	1.04	0	no impact
20045	4.8	0	0.35	soil impact
20046	40.7	1.11	1.25	trace NAPL
20047	2.8	0.02	0.15	soil impact
20048	3.7	0.05	0.6	soil impact
20049	103	1.53	1.25	NAPL
20050	3.6	0.91	0.2	soil impact
20051	81.4	1.7	1.3	NAPL
20052	79.4	1.64	2.1	NAPL
20053	4.6	0.07	0.15	soil impact
20054	136.9	1.42	1.8	NAPL
20055	6.1	0	0.7	soil impact
20056	29.1	1.48	0.5	trace NAPL
20057	2.3	1.14	0.17	no impact
20058	1.7	1.49	0	no impact
20059	43.3	1.98	1	trace NAPL
20060	1.3	2.82	0	no impact
20061	52.6	1.89	0.25	NAPL
20062	105.7	1.54	1.3	NAPL
20063	23.1	1.79	0.15	trace NAPL
20064	3.8	2.61	0.1	soil impact
20065	128.7	1.44	1.05	NAPL
20066	61.3	2.26	0.75	NAPL
20067	130.4	0.88	1.4	NAPL
20068	145.2	0.92	1.25	NAPL
20069	123.8	1.01	1.5	NAPL
20070	137.1	0.86	1.05	NAPL
20071	138	0.84	1.05	NAPL

Borehole	Max Signal (%RE)	Max Signal Depth (m)	Approximate LNAPL Thickness (m)	Potential Impacts
20072	3.4	0.74	0.05	soil impact
20073	45.6	1.3	0.9	trace NAPL
20074	23.1	1.31	0.6	trace NAPL
20075	2.2	1.22	0	no impact
20076	17.5	1.68	0.2	soil impact
20077	1.7	0.53	0	no impact
20078	1.6	0.88	0	no impact
20079	4.1	2.85	0.45	soil impact
20080	71.2	1.69	0.7	NAPL
20081	100.7	1.01	1.4	NAPL
20082	80.5	1.15	1.45	NAPL
20083	64.4	1.41	1.45	NAPL
20084	1.7	0.87	0	no impact
20085	52.8	0.96	1.1	NAPL
20086	47.8	1.17	1.3	trace NAPL
20087	22	1.56	1	trace NAPL
20088	1.9	2.93	0	no impact
20089	28.1	1.7	0.75	trace NAPL
20090	6.2	0.74	0.35	soil impact
20091	22.6	0	0.25	trace NAPL
20092	1.8	2.64	0	no impact
20093	4.5	0.9	0.05	soil impact
20094	56.3	2.43	1.1	NAPL
20095	57.8	2.55	1.5	NAPL
20096	31.5	2.4	0.75	trace NAPL
20097	11.8	0.04	0.1	soil impact
20098	12.9	2.39	0.9	soil impact
20099	13	2.22	1.5	soil impact
20100	19.1	2.46	1.1	soil impact
20101	1.9	2.26	0	no impact
20102	2.3	0.51	0.05	no impact
20103	2.9	0.58	0.55	soil impact
20104	14.5	1.62	0.7	soil impact
20105	3.6	1.72	0.5	soil impact
20106	76.2	2.38	1.75	NAPL
20107	82.5	2.24	2.25	NAPL
20108	4	0.75	0.02	soil impact
20109	2.4	0.15	0.05	no impact

Borehole	Max Signal (%RE)	Max Signal Depth (m)	Approximate LNAPL Thickness (m)	Potential Impacts
20110	102.8	2.3	3.1	NAPL
20111	5.2	1.88	0.15	soil impact
20112	50.1	4	3.65	NAPL
20113	14.9	2.34	1.55	soil impact
20114	15.4	1.93	2.3	soil impact
20115	17.8	2.52	1.2	soil impact
20116	2.7	0.51	0.02	soil impact
20117	185.9	2.88	5	NAPL
20118	351	2.1	4.5	NAPL
20119	119	1.19	4.2	NAPL
20120	4.6	3.18	1.65	soil impact
20121	3.1	3.32	1.5	soil impact
20122	160.3	2.17	4.2	NAPL
20123	133.2	2.11	3.65	NAPL
20124	85.5	0.9	4.3	NAPL
20125	19	1.14	0.9	soil impact
20126	2.3	3.06	0.04	no impact
20135	120.2	3.23	1.75	NAPL
20136	1.2	4.2	0	no impact
20137	1.2	2.78	0	no impact
20138	1.7	3.66	0	no impact
20139	130.5	2.58	4.7	NAPL
20140	2.7	4.25	0.1	soil impact
20141	97.3	4.86	2	NAPL
20142	34.1	4.87	2	trace NAPL
20160	6.3	0.2	0.4	soil impact
20161	403.2	4.79	2.3	NAPL

FIGURES

386000

Lake Huron

Lake Chipican

Lake Chipican Drive

LAKE CHIPICAN AREA

CANATARA PARK

ANIMAL FARM

CLC AREA

CLC PROPERTY

Approximate Property Limit

CLOSED LANDFILL

G2 AREA

Sandy Lane

Ernest Street

Louisa Street

Victoria Avenue

Arthur Street

Alfred Street

Front Street

Kendall Street

Michigan Avenue

Alexandra Avenue

Christina Street North

Highbury Park

Flamingo Drive

Hollywood Place

Prentice Avenue

Marcin Road

AREA OF PLAN

Key Plan

0 0.4 0.8 1.2 1.6 2 km

Legend

Approximate Area of Buried Waste (Closed Michigan Avenue Landfill)

0 75 150 225 300 375 m

4761800

386000

Map Document: K:\1801685\6. Deliverables\Annual Reports\2019 Annual Report\Figures\F01_Area Location Plan_20200102.mxd

Area Location Plan

Former Michigan Avenue Landfill, Point Edward, Ontario

Map Projection: NAD 1983 UTM Zone 17N

DRAFT

City of Sarnia

Notes:
1. Drawing based on 2015 aerial image from The County of Lambton interactive web mapping site.
2. This drawing is schematic only and is to be read in conjunction with accompanying text.
3. All locations are approximate.

True North

Project #: 1801685

Drawn by: JVV	Figure:	1
Approx. Scale:	1:4,500	
Date Revised:	Jul 13, 2020	

386000

CANATARA PARK

ANIMAL FARM

CLC PROPERTY

LAKE CHIPICAN AREA

CLC AREA

G2 AREA

Christina Street N

County Road 19

4761800

4761800

386000

Legend

- Area Delineation
- Property Lines
- LIF Borehole Locations

0 25 50 75 100 m

Site Plan

Former Michigan Avenue Landfill, Point Edward, Ontario

Map Projection: NAD 1983 UTM Zone 17N

City of Sarnia

DRAFT

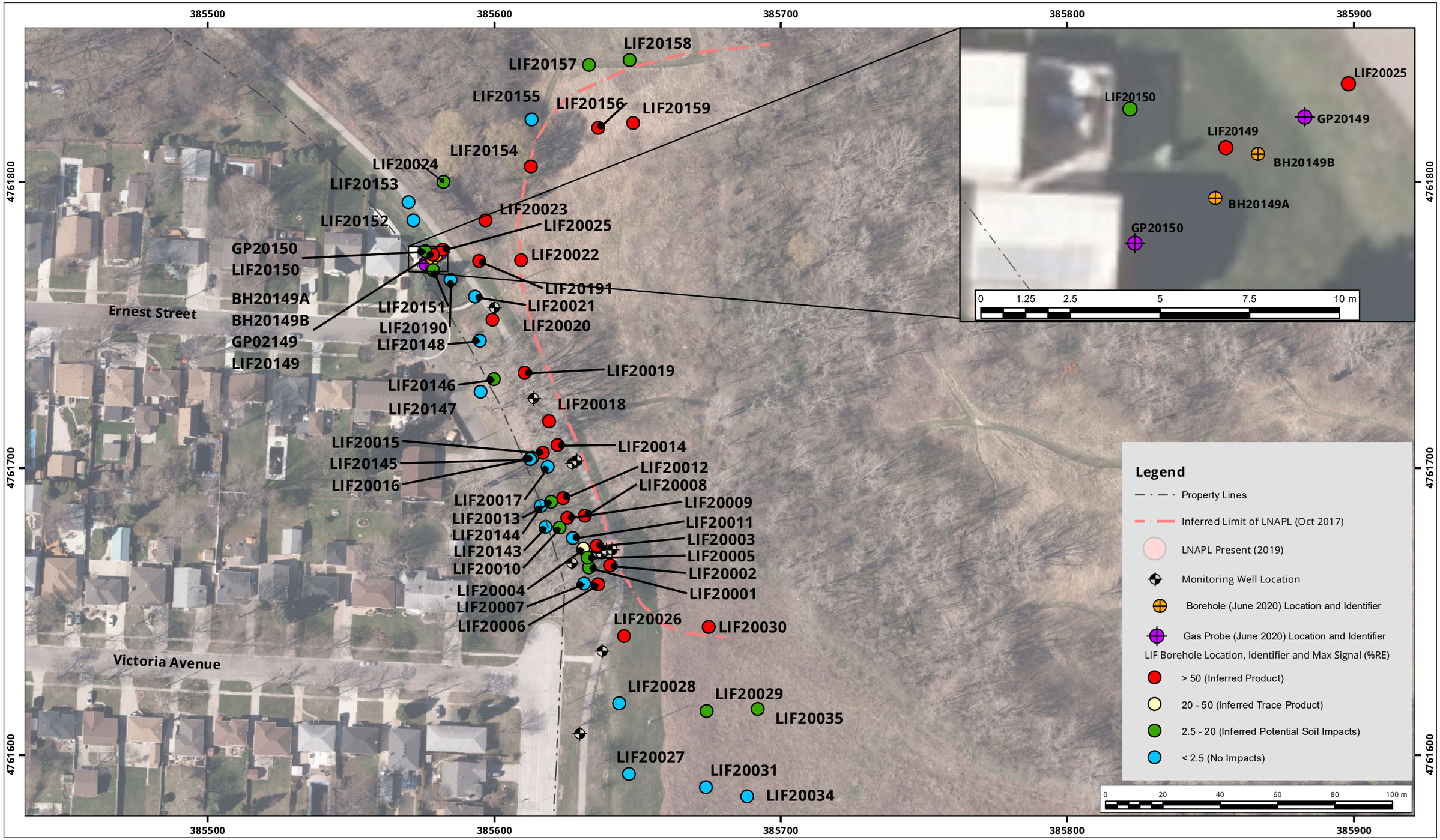
Notes:
1. Aerial image and property lines obtained from The County of Lambton interactive web mapping site.
2. Borehole locations measured using a handheld GPS unit with an accuracy of approximately 3 to 5 m.

True North

Project #: 1801685

Drawn by:	JVV	Figure:	2
Approx. Scale:		1:2,800	
Date Revised:		Jul 13, 2020	

Map Document: K:\1801685\6. Deliverables\LIF Report\Figures\Working Files\F02_SitePlan.mxd



CLC Area Location Plan

Former Michigan Avenue Landfill, Point Edward, Ontario

Map Projection: NAD 1983 UTM Zone 17N

DRAFT

City of Sarnia

Notes:
1. Aerial image obtained from The County of Lambton interactive web mapping site.
2. Orthoimagery obtained from First Base Solutions (2017).
3. Borehole locations measured using a handheld GPS unit with an accuracy of approximately 3 to 5 m.

True North

Drawn by: JVV	Figure: 3		
Approx. Scale:	1:1,250		
Date Revised:	Jul 22, 2020		

Project #: 1801685

Map Document: K:\1801685\6. Deliverables\LIF Report\Figures\Working Files\F03_CLC Area Location Plan.mxd

385680

385760

4761560

4761480

0 10 20 30 40 50 m

Legend

- Property Lines
- Inferred Limit of LNAPL (Oct 2017)
- LNAPL Present (2019)
- 2014 Monitoring Well
- Monitoring Well
- Monitoring Well (By Others)
- Recovery Well

LIF Borehole Location, Identifier and Max Signal (%RE)

- > 50 (Inferred Product)
- 20 - 50 (Inferred Trace Product)
- 2.5 - 20 (Inferred Potential Soil Impacts)
- < 2.5 (No Impacts)

LIF20032
LIF20033
LIF20127
LIF20128
LIF20129
LIF20130
LIF20131
LIF20132
LIF20133
LIF20134
LIF20162
LIF20163
Sheet-Pile Wall
LIF20179
LIF20175
LIF20174
LIF20170
LIF20183
LIF20177
LIF20176
LIF20168
LIF20164
LIF20165
Laneway
LIF20173
LIF20172
LIF20169
LIF20182
LIF20171
LIF20167
LIF20187
LIF20185
LIF20189
LIF20188
LIF20181
LIF20180
LIF20186
LIF20184
LIF20166
County Road 19

Map Document: K:\1801685\6. Deliverables\LIF Report\Figures\Working Files\F04_G2 Area Location Plan.mxd

G2 Area Location Plan

Former Michigan Avenue Landfill, Point Edward, Ontario

DRAFT

Map Projection: NAD 1983 UTM Zone 17N

City of Sarnia

Notes:
1. Orthoimagery obtained from First Base Solutions (Sarnia 2017).
2. Property lines obtained from The County of Lambton interactive web mapping site.
3. Borehole locations obtained from handheld GPS units with an accuracy of approximately 3 to 5 m.

True North

Project #: 1801685

Drawn by:	JVV	Figure:	4
Approx. Scale:			1:750
Date Revised:			Jul 22, 2020

385680

385760

4761560

4761480

Animal Farm

Duck Pond

Duck Pond

Sheet-Pile Wall

Lake Chipican

Canatara Park

LIF20078
LIF20080
LIF20072
LIF20075
LIF20074
LIF20073
LIF20084
LIF20085
LIF20077
LIF20076
LIF20079
LIF20070
LIF20069
LIF20086
LIF20088
LIF20090
LIF20092
LIF20091
LIF20089
LIF20087
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LIF20058
LIF20106
LIF20094
LIF20093
LIF20097
LIF20101
LIF20039
LIF20064
LIF20062
LIF20056
LIF20061
LIF20107
LIF20095
LIF20099
LIF20102
LIF20040
LIF20038
LIF20037
LIF20049
LIF20059
LIF20096
LIF20098
LIF20100
LIF20042
LIF20055
LIF20041
LIF20043
LIF20054
LIF20109
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LIF20052
LIF20121
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LIF20124
LIF20111
LIF20112
LIF20117
LIF20116
LIF20135
LIF20139
LIF20138
LIF20136
LIF20137
LIF20113
LIF20114
LIF20115
LIF20142
LIF20140
LIF20141
LIF20160
LIF20161

Legend

- Inferred Limit of LNAPL (Oct 2017)
- LNAPL Present (2019)
- Recovery Well Head
- 2014 Monitoring Well
- 2014 Borehole
- Monitoring Well
- Recovery Well
- Extraction Well

LIF Borehole Location, Identifier and Max Signal (%RE)

- > 50 (Inferred Product)
- 20 - 50 (Inferred Trace Product)
- 2.5 - 20 (Inferred Potential Soil Impacts)
- < 2.5 (No Impacts)

0 10 20 30 40 50 m

Map Document: K:\1801685\6. Deliverables\LIF Report\Figures\Working Files\F05_Lake Chipican Area Location Plan.mxd

Lake Chipican Area Location Plan

Former Michigan Avenue Landfill, Point Edward, Ontario

Map Projection: NAD 1983 UTM Zone 17N

DRAFT

City of Sarnia

Notes:
1. Drawing based on 2015 aerial image from The County of Lambton interactive web mapping site.
2. Borehole locations measured using a handheld GPS unit with an accurately of approximately 3 to 5 m.

True North

Project #: 1801685

Drawn by: JVV	Figure:	5
Approx. Scale:	1:1,250	
Date Revised:	Jul 22, 2020	

APPENDIX A

VERTEX

Environmental Inc.

MEMORANDUM - DRAFT

To:	Claire Finoro, P.Eng., B.Sc. (Eng) – RWDI
From:	Patrick O'Neill, M.A.Sc. – Vertex
Subject:	Laser Induced Fluorescence Survey Results Canatara Park, Sarnia, ON
Date:	July 22, 2020
Reference:	VE848

Vertex Environmental Inc. (Vertex) has produced this memorandum summarizing the Laser Induced Fluorescence (LIF) survey completed at the Canatara Park, Sarnia, ON (the Site).

LIF Survey Objective

RWDI retained Vertex to provide LIF services to delineate the edges of three (3) areas of suspected Light Non-Aqueous Phase Liquid (LNAPL) plume(s) on-Site. These areas on-Site are known as;

- Lake Chipican Area,
- CLC Area, and
- G2 Area.

Timeline

- **HRSC Survey:** During the period from May 4 to 14, 2020 Vertex personnel mobilized the LIF equipment to Site. A total of one hundred and ninety-one (191) LIF points were advanced in the above-noted three (3) areas to various depths.

Laser Induced Fluorescence

The LIF probe (UVOST probe) is direct push a real time sensing system that responds to the presence of free-phase petroleum hydrocarbons (PHCs) including gasoline, diesel, kerosene, motor oil, cutting oils, and hydraulic oils. Ultraviolet light is generated from a laser and emitted into the subsurface from specialized tooling in the drill string. The laser

excites polycyclic aromatic hydrocarbons (PAHs) within the PHCs in the subsurface adjacent to the probe, causing them to fluoresce. The relative response of the sensor depends on the specific analyte being measured as well as the relative contaminant concentration. The system typically provides a vertical resolution on the order of centimeters, allowing for precise vertical delineation of the extent of inferred free phase PHC product. For the purposes of LIF identification, "free phase" will refer to both mobile and non-mobile free phase, as both will equally fluoresce.

The LIF is specifically designed to evaluate the potential presence or absence of free phase PHCs, however, due to the relative response measured by the laser, soil impacts can also be inferred. Soil impacts refer to PHCs that are both adsorbed to the soil and present in between the soil particles (within the void space). PHCs present between soil particles are often referred to as ganglia. The amount to which a PHC will fluoresce by the LIF is referred to as the Reference Emitter (RE) response. A strong response may indicate mobile product where a weaker response may indicate ganglia. This process is semi-qualitative, and there is variance between sites and type of PHCs.

Methodology

From May 4 to 14, 2020 Vertex advanced a total of one hundred and ninety-one (191) LIF points to depths ranging from approximately 3 to 6 meters below ground surface (mbgs) using a direct push Geoprobe 6620DT drill rig. Prior to LIF advancement, Vertex completed standard calibration of the LIF instrumentation to ensure it was working properly and able to generate reliable data for the Site. Upon completion of each LIF location the open hole was backfilled with clean benseal hole plug to surface and finished with cold patch when required. Vertex recorded GPS co-ordinates at each of the LIF locations. Later, RWDI provided surface elevations for each LIF location which were used for the three-dimensional (3D) visualization of the LIF data collected within each specific area on-Site. The Site plan is provided as a Google Earth image map (Attachment A). Ground conditions experienced on-Site were generally adequate for LIF deployment. The final logs for each LIF probe point advanced at the Site by Vertex are presented in Attachment B.

Three-Dimensional Visualization

Three-dimensional (3D) results can be used to visualize where the potential LNAPL impacts are located in the subsurface. The LIF data from the Site was entered into a 3D software package, Earth Volumetric Studio (EVS), to develop and produce 3D visualizations of the percent reference emitter (%RE) data collected by the LIF. The LIF response data were processed using a log-based approach versus a linear-based approach. This is the preferred data processing method when data sets have multiple orders of magnitude in range in a relatively small area (both vertically and horizontally). Based on Vertex's experience a log-based interpretation also provides a more realistic interpretation of natural systems and is less likely to overestimate the special extent of identified impacts. As such, the 3D visualizations presented herein may underestimate the actual extent of the inferred LNAPL present at the Site. The log processing of the data also allows for better

visualization of the data along the property boundaries where many points of data were collected and visualized without overestimating the potential LNAPL impacts along these areas.

The ground surface elevations were provided from RWDI for each LIF location. Each elevation was input into the 3D visualization with the exception of two (2) locations, LIF20073 and LIF20074 which appeared to be much higher than adjacent locations and were adjusted to match similar elevation of the surrounding area.

EVS is using a kriging process to interpolate and extrapolate the information between input data points from the LIF survey. Uncertainty in the EVS model can be produced when relatively high data (above the minimum %RE) are extrapolated out relatively far from the original input data point, resulting in predicted high responses that carry a relatively low degree of confidence. Basically, as data (%RE) are extrapolated away from the input point the level of uncertainty generally increases with distance. Therefore, caution should be taken on placing too much emphasis on these interpreted results. It should be noted that the extrapolated data not directly connected to any LIF location in these areas of the Site has not been confirmed by any actual LIF locations and should be treated as theoretical and unverified.

As the response from the LIF increases, the level of impacts present at these volumes increases, showing localized “hot spots” or pockets of higher levels of LNAPL versus wider-spread lower responses and lower levels of LNAPL impacts. These areas of the Site are considered most likely to contain LNAPL and more significant LNAPL impacts.

The plan and profile views of the combined 3D visualized results from the LIF are provided separately for the Lake Chipican, CLC and G2 areas in Attachments C, D and E respectively. Note that the coloring used in the 3D visualizations does not correspond to the assigned colours for different types of LNAPL shown on the LIF logs; rather the colours correspond to the %RE signal strength as shown by the scales on the 3D plots.

Finally, the maximum LIF response for each location was projected onto a 2D surface for each area and plotted using the EVS software. This was completed to show where the maximum responses were located on-Site in relation to the completed survey locations. These visualizations are included in the profile view of the 3D images and as stand-alone plan images for the Lake Chipican, CLC and G2 areas on-Site in Attachments C, D and E respectively. The stand-alone maximum LIF responses projections were created for the lowest response level (5 %RE) for each area.

Lake Chipican Area – 3D Visualization

The Lake Chpican area was the largest investigation area on-Site, located south of Lake Chipican and the north and west of the adjacent public bicycle track on-Site.

The LIF responses presented for the 3D visualizations for the Lake Chipican Area range from 5 to 300 %RE which are on the low to high end of %RE for LIF surveys based on Vertex’s experience.

Based on the visualization results within the Lake Chipican area, the higher LIF responses (≥150 %RE) are scattered throughout the area ranging from the South West corner (LIF20161) to the vicinity of the Northern edge (LIF2068) of the survey area. For much of the Lake Chipican area, LIF responses indicate no presence of LNAPL along the perimeter of the surveyed locations. The visualization of the LIF responses indicated that the bulk of the LNAPL located away from northern boundary of Lake Chipican with the exception of the two (2) "fingers" of LNAPL projecting into the wooded area between the on-Site petting zoo and Lake Chipican. These "fingers" of LNAPL appear to be protruding in a North Western direction towards a season creek feeding Lake Chipican and are in the vicinity of LIF20080 and LIF20074 and surrounding area.

CLC Area – 3D Visualization

The CLC area is located on the western property boundary on-Site, located along a pedestrian walking path east of the neighboring residential properties and surrounding area.

The LIF responses presented for the 3D visualizations for the CLC Area range from 5 to 600 %RE which are on the low to high end of %RE for LIF surveys based on Vertex's experience. The highest %RE LIF responses on-Site were observed in this area and the visualizations correspond to these high response levels.

Based on the visualization results within the CLC area, the higher LIF responses (≥150 %RE) are scattered throughout the survey ranging from the vicinity of the north edge (LIF20156) to midway through the survey area (LIF2002). With the highest LIF responses clustered in the vicinity of the pedestrian pathway that runs through the area, north of the end of Front Street between LIF20018 and LIF20014. The remaining clusters of 600 %RE indicated on the 3D visualization (near LIF20002, LIF2003, LIF 2008, LIF2009, LIF2012) are extrapolated based on the data input into the 3D software and should be treated as theoretical and unverified. For much of the CLC area, LIF responses indicate little or no presence of LNAPL along the perimeter of the surveyed locations. However, there were some locations relatively close to the LIF perimeter which indicated much higher LIF observations which is reflected in the visualization of the LIF responses. Based on the 3D visualizations the bulk of the LNAPL located away from western boundary of the CLC area but is relatively close in proximity based on the LIF survey locations.

G2 Area – 3D Visualization

The G2 area is located on the southern property boundary on-Site. The G2 area located north of Michigan Avenue and east of Front Street. The G2 area also include a pedestrian walking path and surrounding grassed area.

The LIF responses presented for the 3D visualizations for the G2 Area range from 5 to 80 %RE which are on the low to moderate end of %RE for LIF surveys based on Vertex's experience.

Based on the visualization results within the G2 area, the higher LIF responses (≥80 %RE) are isolated at LIF20174 located north of the pedestrian pathway. For much of the G2 area,

LIF responses indicate little or no presence of LNAPL along the perimeter of the surveyed locations. However, there were some locations at the southern property boundary (LIF20167 and LIF20189) where some higher LIF responses were observed and visualized. Based on the 3D visualizations the bulk of the LNAPL located away from southern property boundary of the G2 area.

Summary of the Results

The results of the LIF survey for the Site indicated "low" to "high" responses from the LIF probe. The maximum %RE for the Site LIF logs range from 0.9 to 648.3 %RE. The LIF survey locations were plotted on a Google Earth map and presented in Attachment A. The main objective of the LIF survey program was for LNAPL delineation along the downgradient boundaries in three (3) different areas known as "Lake Chipican Area," "CLC Area," and "G2 Area" on-Site. The results for each of the area is as follows;

Lake Chipican Area

- The Lake Chipcican Area LIF responses indicated that little or no presence of LNAPL along the boundaries of the survey in this area of the Site.
- Based on the LIF survey it appears that some LNAPL impacts are present in a North Western direction away from the bulk of the LNAPL impacts in the vicinity of a seasonal creek as evidenced in the areas around LIF20080 and LIF20074.

CLC Area

- The CLC Area LIF responses indicated little or no presence of LNAPL along the perimeter of the surveyed locations. However, there were some locations relatively close to the LIF perimeter which indicated much higher LIF observations.
- The CLC Area had the highest positive LIF responses observed on-Site with the majority of the highest LIF response clustered in small areas away from the western boundary of the LIF survey. These locations with the highest LIF responses are at (and assumed based on the 3D visualization between) LIF20018 and LIF20014.

G2 Area

- The G2 Area LIF responses generally indicated little or no presence of LNAPL along the perimeter of the surveyed locations which included the western and southern property boundaries for the area. However, two (2) locations, LIF20167 and LIF20189, along the southern property boundary indicated presence of LNAPL.

General Site results indicate the following;

- The LNAPL observed by the LIF ranges over depths from approximately 0.17 to 6.0 mbgs for the areas surveyed on-Site. However over the entire Site the ground elevations changed significantly and the depths of the positive LIF response should be measured relative to the ground elevation at that specific location.

- Based on the LIF results there appear to be multiple types of LNAPL located on-Site. The different LNAPL types can be highlighted by the different "fingerprints" located in the callouts of each positive identification of LNAPL on the LIF logs. The colouring on the LIF log responses and callouts suggest different LNAPL types based on the fluorescence signal observed from the product(s) in-situ. Some LIF logs had potential multiple LNAPL types within the same boring location. An example of potential multiple LNAPL types is observed in LIF20094 and LIF20115. Based on Vertex's understanding of the history of the Site observing multiple types of LNAPL would not be unexpected.
- The different assigned colours of response presented on the LIF logs in Attachment B generally correspond to the following typical LNAPL source products:
    - Blue – This colouring generally indicates lighter ended type of fuels such as kerosene or higher octane gasoline type products.
    - Green – This colouring generally indicates diesel and weathered gasoline type fuels/products.
    - Yellow – This colouring generally indicates highly weathered fuels and/or oil mixtures type products.
    - Orange/ Red – This colouring generally indicates heavy ended oil type products.

It should be noted that the descriptions for each of the log colorings noted above are intended to act as a general guide and not meant to be specific identification tool.

Limitations

The information, approach, and discussions presented in this memorandum are based on information recorded by Vertex Environmental Inc. at selected observation and sampling locations at Canatara Park, Sarnia, ON (the Site). LIF survey locations were chosen based upon previous subsurface investigations completed by others, historical information provided by others, and visual observations. Conditions observed on the property or noted in documents regarding the property may differ from time to time and may become apparent during future investigations or on-site work. Observations are made for select sampling / observation points only, conditions between and beyond these sampling points may be different. As a result, some conditions may not have been detected or anticipated at the time of this work and as such Vertex Environmental Inc. cannot be held responsible for environmental conditions at the Site.

The scope of this report is limited to the matters expressly covered. This report is prepared for the sole benefit of RWDI, and may not be relied upon by any other person or entity without the written authorization of Vertex Environmental Inc. Any use or reuse of this document (or the opinions, findings, or conclusions represented herein), by parties other than RWDI is at the sole risk of those parties.