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October 06, 2020

Attention: Stuart Leitch, P.Eng.
Manager Capital Delivery, Hamilton Water
City of Hamilton, Public Works Department
77 James Street North, Hamilton, ON L8R 2K3

Project Name: Impacted Soil Management – Kenilworth Reservoir Upgrades
Project Number: CE796700

Subject: Kenilworth Reservoir Upgrades – Letter of Opinion

Dear Mr. Leitch,

CH2M Hill Canada Limited (CH2M), now Jacobs Engineering Group Inc. (Jacobs), has prepared this letter of opinion based on our proposal dated September 17, 2020. The following letter of opinion is in regards to contaminated soil discovered by others as part of infrastructure repair and upgrade works at the Kenilworth Reservoir (Site). R.V. Anderson Associates Limited (RVA) was previously retained on behalf of the City of Hamilton (City) to complete interior repairs to the columns and exterior repairs to the expansion joins along the roof of the Kenilworth Reservoir. Exterior work also includes crack and concrete spalling repairs (RVA, 2020). In June 2020, Bennett Group collected two soil samples at the Kenilworth Reservoir and identified benzo(a)pyrene, a polycyclic aromatic hydrocarbon (PAH), greater than the Ministry of the Environment Conservation and Parks (MECP) *Table 3 Full Depth Generic Site Condition Standards in a Non-Potable Groundwater Condition* for industrial/commercial/community property use and coarse textured soil condition (Table 3 SCS). RVA contracted Sirati & Partners Consultants Ltd. (Sirati) on behalf of the City to conduct a soil investigation at the Site to confirm the benzo(a)pyrene results and conduct a sitewide assessment of PAHs.

The purpose of this letter is to summarize the information collected to date and to formulate a strategy for potential reuse of the PAH contaminated soils on Site. For the purpose of this opinion letter, it has been assumed that the reservoir repair project undertaking soil excavation will not generate excess soil and that the excavated soil is intended for reuse on-site.

1. Summary of Applicable Regulations

PAHs were identified in soils in discrete locations across the site, as determined by other consultants, with some locations exceeding the Table 3 SCS. The potential origin of impacts is anticipated to be from existing or imported fill/material used to cover the reservoir and has been in place since the reservoir was initially constructed. If these existing soils can be reused on-site, it promotes soil conservation by maximizing the reuse of the Site soil and available fill materials, and minimizing the volume of soil and fill potentially disposed offsite.

The following subsections summarize the key details and elements associated with potentially relevant regulations to the Site.

1.1 O. Reg. 153/04 (Records of Site Condition)

In Ontario, the standard for the assessment and remediation (cleanup) of contaminated land or groundwater when a record of site condition (RSC) is being contemplated is set out in Ontario Regulation 153/04 (as amended and known colloquially as O. Reg. 153/04). An RSC is only required by the regulation if a property is changing land use from a less sensitive to a more sensitive land use.

O. Reg. 153/04 was initially promulgated in October 2004, and amended on July 1, 2011, which provides the framework for the cleanup and management of contaminated sites (MECP, 2011a). MECP-published standards, procedures, protocols, and guidance, including the amended Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (EPA) (MECP, 2011b) and the Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act (MECP, 2011c) serve as the typical reference documents for assessing subsurface soil and groundwater conditions.

The RSC process described in O. Reg. 153/04 is prescriptive and lays a framework for managing risk associated with environmental issues. It includes:

- Phase One Environmental Site Assessment (ESA)
- Phase Two ESA
- Risk Assessment and or Remediation if warranted leading to a RSC

Some or all of these phases are required for obtaining an RSC. An RSC is not mandatory in every case and is not applicable in the present situation for the subject property. It is only required when certain property development activities are desired on the site, such as changing property use from less sensitive uses to more sensitive uses (for example, industrial to residential) or may be required for rezoning, financing, or land transfer. For assessment of soil and groundwater conditions at non-RSC sites or situations when the work is being conducted for general due diligence purposes, comparison of sampling results to the O. Reg 153/04 generic standards may be done for general comparison purposes. In the event that one or more soil or groundwater constituents/contaminants is identified above the generic MECP Standards, as long as the constituents/contaminants are not considered to have a potential to cause an adverse effect within the meaning of the EPA, or impair water quality under the Ontario Water Resources Act, R.S.O. 1990, c. O.40 (OWRA), a property owner is not obligated to remove the soil.

In fact as outlined in both the MECP's Management of Excess Soil – A Guide for Best Management Practices, dated January 2014, and, once in force, Ontario Regulation (O. Reg.) 406/19 On-Site and Excess Soil, the MECP encourages use of the excess soil for a beneficial purpose, provided that the use complies with applicable legislation and where the use does not have a potential to cause an adverse effect within the meaning of the EPA, or impair water quality under the OWRA.

The MECP also promotes the reuse of excavated soil from civil construction or infrastructure projects at the site where the soil is excavated, or reuse of excess soil (i.e. soil not needed at the project site) at other similar civil construction projects.

Jacobs' current understanding is that O.Reg. 153/04 does not apply to the infrastructure and repair work at the Site, however, a comparison to the applicable Table 3 SCS is appropriate for due diligence purposes.

1.2 Reg. 347 (Waste Management)

In Ontario, O.Reg. 347 prescribes the tracking and disposal of hazardous and non-hazardous subject wastes from the waste generator (a site) to the waste carrier (transport), and finally the receiver (disposal site) (MECP, 2003). A generator is considered the operator of a waste generation facility, as defined in Section 1 of Reg. 347, where a waste generation facility is defined to refer to sites that produce, handle or store waste at a Site.

The regulation also requires the waste generator to identify their wastes prior disposal and provides guidance in the *Registration Guidance Manual for Generators of Liquid Industrial and Hazardous Waste* (MECP, 1995). Generator of subject wastes (liquid wastes or hazardous wastes) are required to register with the MECP annually.

Hazardous wastes are defined in Section 1 of Reg. 347 and includes characteristic wastes, listed waste, polychlorinated biphenyl (PCB) waste, or radioactive wastes (MECP, 2003). The PAHs at the site are not considered a listed waste. Further, for the waste to be considered a characteristic waste it must be a corrosive waste, ignitable waste, reactive waste, or a leachate toxic waste. Based on the definition of characteristic wastes provided in Section 1 of Reg. 347, PAHs are not considered corrosive, ignitable, or reactive. However, leachate toxicity potential has not been determined at the Site.

Under Section 1 of Reg. 347, a leachate toxic waste is "a waste producing leachate containing any of the contaminants listed in Schedule 4 at a concentration equal to or in excess of the concentration specified for that contaminant in Schedule 4 using the Toxicity Characteristic Leaching Procedure (TCLP)" (MECP, 2003) Of the PAHs detected at the Site, only benzo(a)pyrene has been identified in Schedule 4 with a value of 0.001 mg/L TCLP.

Jacobs' current understanding is that soils excavated in the process of renovations are intended to be used again as fill on Site, and therefore no waste soil will be generated. However, in the event that soils are targeted for removal during the infrastructure and repair activities, TCLP testing may be a requirement for offsite disposal at a licensed landfill facility. The conceptual site model discusses potential soils leaching of PAHs in more detail.

1.3 O. Reg. 406/19 (Excess Soil Regulation)

O. Reg. 406/19 *On-Site and Excess Soil Management* (hereafter referred to as the Excess Soil Regulation), was recently finalized by the MECP in December 2019. The Excess Soil Regulation was developed to regulate excess soil management activities and to provide clear rules and associated guidance on the reuse of excess soil, excess soil planning actions and requirements, and landfilling of excess soil. Under the regulation, "excess soils", are define as "soil, or soil mixed with rock, that has been excavated as part of a project and removed from the project area for the project" (MECP, 2019). The purpose of the Excess Soil Regulation is to promote the beneficial reuse of soils as opposed to landfill disposal. Under the Excess Soil Regulation, infrastructure projects are defined as "*all physical structures, facilities and corridors relating*" to "*sewage collection and water distribution systems*". Therefore, the Kenilworth Reservoir is defined as an infrastructure project (or undertaking) under the Excess Soil Regulation. Excess soils that are generated during infrastructure projects are, based on Jacobs review and understanding of the Excess Soil Regulation, subject to some, but not all, of the requirements of the Excess Soil Regulation.

Jacobs' current understanding is that soils excavated in the process of renovations are intended to be used again as fill on Site, and therefore no excess soil will be generated. However, in the event that soils are targeted for removal during the infrastructure and repair activities, that some of the requirements of the Excess Soils Regulation may be applicable to the Site.

2. Data Compilation

Jacobs compiled available soil data completed by others from reports provided by the City. The following subsections describe the methodology used to select Contaminants of Concerns (COCs).

2.1 Applicable Criteria

Based on review of the available information provided by the City and given that the current industrial/commercial/community land use, Jacobs has selected the MECP *Table 3 Full Depth Generic Site Condition Standards in a Non-Potable Groundwater Condition* (2011b) for industrial/commercial/community property use and coarse textured soil condition (Table 3 SCS) for evaluating the soil sampling data conducted by Sirati. Selection of the Table 3 Standards is also based on the understanding that Hamilton obtains its water from Lake Ontario as opposed to groundwater, and as such Table 3 (non-potable) Standards are typically applied to sites in Hamilton. This is consistent with both the Sirati and RVA letters which reference the comparison of results to the MECP Table 3 industrial/Commercial/Community property use and coarse textured soil condition.

2.2 Data Summary

The Kenilworth Reservoir is located at 111 Kenilworth Access in Hamilton, Ontario. The water reservoir consists of underground concrete structure to hold treated water and covered by a soil cap of approximately 1 metre (m) in depth with a "roof" area of approximately 18,000 square metres (m^2) (Sirati, 2020).

2.2.1 Soil Data

At the request of RVA and on behalf of the City, Sirati completed 195 test pits in a 10 m by 10 m grid across the roof area at a depth of approximately 0.6 to 0.7 metres below ground surface (mbgs) and sampled soil from each test pit for PAHs. Samples were collected between July 20 and 22, 2020. Sirati identified PAHs greater than the Table 3 SCS in 44% of soil samples (that is in 85 of the 195 test pit locations) for one or more PAH parameters (Sirati, 2020). Test pit locations are shown on the Sirati figure provided in Attachment 1. The potential origin of impacts is anticipated to be from existing fill/material present in the area since initial construction.

A summary of the soil sampling results from Sirati's 195 test pits is provided in Table 1.

The following sections outline the assessment of the Site soil data.

Table 1: Summary of PAH Results

Analyte	Table 3 SCS (µg/g)	No. of Samples	No. of Non-detects	Maximum Concentration (µg/g)	Average Concentration (µg/g)	No. of Detects greater than the Table 3 SCS	No. of Non-detects greater than the Table 3 SCS
1-(+2-) Methlynaphthalene	76	195	60	9.8	0.32	--	--
Acenaphthene	96	195	85	30	1.03	--	--
Acenaphthylene	0.15	195	3	0.2	0.03	--	1
Anthracene	0.67	195	105	28	1.64	59	--
Benz(a)anthracene	0.96	195	115	22	1.87	60	--
Benzo(a)pyrene	0.3	195	113	22	1.30	79	--
Benzo(b)fluoranthene	0.96	195	117	25	1.62	60	--
Benzo(g,h,i)perylene	9.6	195	92	6.3	0.44	--	--
Benzo(k)fluoranthene	0.96	195	109	15	0.92	52	--
Chrysene	9.6	195	120	22	1.90	7	--
Dibenz(a,h)anthracene	0.1	195	67	1.6	0.14	54	--
Fluoranthene	9.6	195	137	72	5.28	37	--
Fluorene	62	195	85	35	1.07	--	--
Indeno(1,2,3-cd)pyrene	0.76	195	92	7	0.48	42	--
Naphthalene	9.6	195	62	3.4	0.19	--	--
Phenanthrene	12	195	118	96	5.65	29	--
Pyrene	78	195	135	53	4.03	--	--

Notes:

Bold parameters indicate an exceedance of the Table 3 SCS

No. = number

µg/g = microgram per gram

2.2.2 Water Data

The City has provided Jacobs with a summary of influent and effluent sampling data from the Kenilworth Reservoir. A total of six samples were collected on August 31, September 7 and September 14, 2020 and sampled for a variety of chemical compounds including the 17 PAHs listed by O.Reg. 153/04 (see Table 1 for listing of PAHs). Water samples were compared to the O.Reg. 169/03 Ontario Drinking Water Quality Standards (ODWQS) (MECP, 2003, as amended) by the City of Hamilton. PAH data collected from both sampling events indicate that all PAHs are non-detect. Additionally, the method detection limits reported by the analyzing laboratory for the collected water samples are less than or equal to the reporting limits of the MECP potable groundwater standards derivation, as listed in the *Rationale for the Development of Soil* *and Ground Water Standards for Use at Contaminated Sites (Rationale Document) (MECP, 2011c).* Both influent water being stored in the reservoir and effluent water are absent of PAH. Therefore, PAHs in soil above the reservoir do not appear to be leaching or migrating to the water contained in the reservoir.

2.3 Data Gaps

Jacobs evaluated the data collected by others as part of the data gap assessment. In general, the following observations were noted during the evaluation:

- No surface soil samples were collected during previous investigations. All soil samples were collected at a depth of 0.6 to 0.7 mbgs. Therefore, soil quality for soils located at depths less than 0.6 mbgs or greater than 0.7 mbgs has currently not been determined.

- No testing was carried out for assessing the leaching potential of PAH from soil

3. Conceptual Site Model

To evaluate the potential effects from the presence of PAHs in soil over the reservoir, Jacobs utilized principles from O.Reg. 153/04 and developed a conceptual site model (CSM) by identifying various risk components, namely chemicals detected, exposure pathways, and receptors. This section describes elements considered in the development of the CSM.

3.1 Risk Paradigm

Three components must be present for risks to human and ecological health to exist at contaminated sites impacted by chemicals:

1) The chemical must be present at concentrations sufficient to cause a possible adverse effect.
2) A receptor must be present.
3) There must be a complete exposure pathway by which the receptor can make contact with the chemical.

These three factors are interdependent because the significance of the environmental concentration and the potential environmental or health effects depend on the pathway by which the exposure occurs. The exposure pathway, in turn, is influenced by the nature (that is, the behaviour) of the receptor. These components are collectively integrated into models to illustrate potential pathways and to assist in the RA process.

The risk evaluation is intended to effectively identify potential risk from the presence of PAHs in soil, and help focus risk management efforts and resources, if needed, to address adverse effect considering the reuse of the soil on site.

3.2 Summary of Contaminants of Concern

PAHs (that is COCs) were selected for consideration according to the following screening process:

1) A maximum concentration was identified for each analyte. The maximum concentration in soil was determined as either the maximum measured value or the greatest detection limit (if greater than the maximum measured value).

2) PAHs were retained for further consideration under the screening process for soil if the identified maximum concentration exceeded the Table 3 SCS as identified in Table 1.

As a result, the following 11 PAHs of the original 17 were retained for further assessment:

Table 2: Summary of PAHs

Contaminants of Concern	
Acenaphthylene	**Chrysene**
Anthracene	**Dibenz(a,h)anthracene**
Benz(a)anthracene	**Fluoranthene**
Benzo(a)pyrene	**Indeno(1,2,3-cd)pyrene**
Benzo(b)fluoranthene	**Phenanthrene**
Benzo(k)fluoranthene	

3.3 Physical Properties of PAHs

The potential fate and transport of a chemical is characterized, in part, by its physical and chemical properties. The physical-chemical properties of PAHs were reviewed using information from Physical-Chemical Properties and Environmental Fate Handbook (Mackay et al., 2000). PAHs are sparingly soluble in water and have low or negligible volatility. As discussed in the Canadian Council of Ministers of the Environment (CCME) (2010), PAHs are relatively hydrophobic organic substances. The tendency of PAHs to partition in organic matter, onto soil or other particle surfaces, and into biological lipids (and out of aqueous environmental compartments such as soil moisture or groundwater) generally increases with an increase in the number of benzenoid rings in the aromatic ring structure (from two rings for naphthalene to six rings for benzo[g,h,i]perylene). There are approximately three to six orders of magnitude difference between naphthalene and benzo[g,h,i]perylene in aqueous solubility of PAH compound, in the tendency to partition from water to hydrophobic organic matter, in the vapour pressure that PAH congeners at room temperature, and the measured tendency to partition between water and air (Henry's Law Constant). CCME (1999) indicates volatilization plays an important role in the removal of low-molecular-weight PAHs, such as naphthalene, from aquatic systems. Naphthalene has the highest vapour pressure of the PAHs, and volatilization from aquatic environments is probably the most important removal mechanism for this compound. Based on their Henry's law constants, acenaphthene, anthracene, fluorene, and phenanthrene may be considered to have moderate volatility; however, other studies have suggested volatilization is insignificant for PAHs with three or more aromatic rings (CCME 1999). The heavier PAHs generally pose far less vapour phase exposure risk than naphthalene, due to their much higher molecular weight and lower vapour pressures (BCELQAAC 2008; Mackay 2000).

They also have high melting points (160 to 275 degrees Celsius [°C]) and would, therefore, appear to be preferentially solid at average groundwater temperatures (10 to 15°C), which can also inhibit mobility in the environment. According to Mackay et al. (2000), phase partitioning (that is, Level III, four-compartment model air, water, soil, and sediment) indicates when the PAH source is contained in soil, on average, more than 98 percent of the PAH's mass will remain in soil. In addition to the high melting point, PAHs generally exhibit a very high soil sorption coefficient, indicating that in the solid phase, this class of compounds tends to be strongly adsorbed to soil.

In summary the physical-chemical properties of PAH congeners predict their lack of mobility in the environment and once associated with soil, the tendency is for PAHs to remain in soil.

3.4 Receptor Use of site

It is Jacobs understanding that the Site is not used for recreational or institutional activities. The Site cover is mainly grass with small asphalt areas and two onsite buildings (an onsite access building and a pumping station). No gardens or trees are present onsite and access to the Site is restricted by ornamental fencing. The Site landscaping is maintained regularly. No changes to land use are expected in the future.

Based on the current and future site use the following receptors were identified:

Human Receptors

- Plant Operations (PO) staff – PO Staff only visit the station to collect chlorine samples or to operate controls in the buildings on-site. PO Staff mainly use the road, asphalt, and the pumping station/valve houses. Their use of the grass area is minimal and only access the grassed areas for occasional work on the drain or interconnecting valves; usually this is only related to project requests where the cells need to be taken out of service. There is no anticipated contact with subsurface soils.
- Plant Maintenance (PMAT) staff – PMAT Staff are responsible for any maintenance/emergency type scenarios that may arise. Emergency scenarios are infrequent; staff mainly access the road, asphalt, pumping station/valve house. PMAT is responsible for landscape workers (that is, to mow the lawn). Lawn care staff go to site on a monthly basis – due to size of the site they may be on site for a few hours cutting grass on top of the reservoir using a riding lawn mower. The sloped portion of the site have to be done with push mowers and other equipment. There is no anticipated contact with subsurface soils.
- Construction Workers - A Construction Worker is considered to be an adult worker conducting excavation activities, such as those that would occur during construction or repair activities. The Construction Worker is anticipated to be onsite full-time, 5 days a week, for a limited number of years, and would represent a sub-chronic subsurface worker exposure scenario.

Ecological Receptors

The following onsite ecological receptor types are considered possibly present for the CSM:

- Soil organisms – worms
- Terrestrial plants – trees, shrubs etc.
- Birds and mammals

3.5 Pathways of Exposure

A complete exposure pathway must exist for risk to be present at a site. An exposure pathway is the means by which a receptor may make contact with a COC from a site. A complete exposure pathway has the following five elements:

1) A source of chemical released to the environment (for example, PAHs to soil)
2) A mechanism for release of the source (for example, volatilization of vapours)

3) An environmental transport medium (for example, air)
4) An exposure point (for example, a workplace)
5) A feasible route of exposure (for example, inhalation)

Exposure may occur when environmental media containing chemicals migrate or are physically moved from the site to an exposure point, such as a location where receptors can make contact with chemicals in environmental media. It may also take place when a receptor makes direct contact with the source material containing the COCs. An exposure pathway is complete (that is, there is exposure) if a receptor takes in chemical constituents through ingestion, inhalation, or dermal absorption (contact with the skin).

Direct contact with contaminants occurs when receptors make direct contact with the medium that contains the contaminants (for example, placing hands in water or touching soil with hands). Indirect contact with the contaminants occurs when the contaminants are transported from their presently identified location to a receptor through a variety of mechanisms (for example, the inhalation of indoor vapours originating from soil or groundwater).

This section discusses possible pathways of exposure to COCs by receptors on the Site. Incomplete or implausible pathways where there can be no exposure are not retained for further consideration.

The potential soil exposure pathways have been evaluated based on current Site conditions and considering future Site conditions (soil being reused).

Human Exposures

Based on current and future Site use, the following pathways of exposure for human receptors is as follows:

- PMAT Staff and PO Staff - The PMAT Staff and PO staff could be exposed to surface soil by direct contact (incidental ingestion, dermal contact, and dust inhalation) and via the inhalation of vapours (COC vapour emissions from soil) in outdoor air. Inhalation of indoor air is also possible in the pumping house/valve house and access building, though exposure is expected to be minimal based on frequency of access. Based on site conditions (that is, PAH characterized at 0.6-0.7 mbgs) PMAT and PO staff are unlikely to be exposed to PAH in soil.
- Construction Workers - The Construction Worker could be exposed to subsurface soil via direct contact (incidental ingestion, dermal contact, and dust inhalation) and via the inhalation of vapours in outdoor air (for those PAH that are sufficiently volatile may have vapour emissions from soil).

Under normal Site conditions (that is, the soil cap is undisturbed), direct contact, dust inhalation, and inhalation of outdoor air is limited by the landscaped grass covering the surface of the soil cap. Therefore, PMAT and PO staff are unlikely to be exposed by these exposure pathways. During excavation work, the most likely exposed receptor will be the construction worker. Direct contact, dust inhalation, and inhalation of outdoor air was also considered for further assessment for a disturbed soil condition.

Ecological Exposures

Based on current and future Site use, the following pathways of exposure for ecological receptors is as follows:

- Soil organisms – ingestion and dermal contact with soil
- Terrestrial plants – root uptake from soil
- Birds and mammals – ingestion of soil and food-chain transfer by the consumption of contaminated prey or forage items

However, the Site is industrial/commercial/community and does not contain significant ecological habitat. Trees and gardens are not present on the Site, providing minimal or low-quality habitat for ecological receptors. Additionally, the Site is partially paved, and the landscaped areas are maintained regularly (that is, mowed). Therefore, the ecological exposure pathways are considered incomplete and are not assessed further.

Other Exposures

The potential for soil to leach PAHs (from infiltration of precipitation) and then carry PAH to the reservoir was also considered for further assessment.

3.6 Summary of Potential Adverse effects if soil reused

The following sections provide a summary and discussion of risk to human receptors at the Site. Selected soil component values used in this assessment were referenced from the Modified Generic Risk Assessment (MGRA) model (MECP, 2016). The use of the MECP's MGRA model makes use of MECP default conservative (protective of health) assumptions that were utilized in the development of Ontario's generic soil standards found in O.Reg. 153/04. Each pathway is represented by a health-based soil concentration component value. The component values are back calculated from toxicity data and human receptor behaviour assumptions. If PAH soil concentrations are equal to or less than a component value, then risk to people present at the site is expected to be below the exposure that can cause an adverse health effect.

3.6.1 Direct Contact

To assess the direct contact pathway, a comparison of the maximum concentrations of PAH concentrations to the MECP S3 component value (for direct exposure to soil via ingestion and dermal contact for a subsurface commercial/industrial condition) was considered. The S3 component value is representative of a short-term adult worker, such as the Construction Worker, exposed to sub-surface soil during excavation activities. Table 3 presents the comparison of the S3 component values to the maximum concentration of PAHs in soil.

Table 3: Comparison of PAH Soil Concentrations from Test Pitting Program to S3 Component Values

COC	S3 Soil concentration (µg/g)	Maximum Concentration (µg/g)	Average Concentration (µg/g)	No. of Detects greater than the S3	Test Pit IDs for Exceedance Locations
Acenaphthylene	2600	0.2	0.03	--	--
Anthracene	2600	28	1.64	--	--

Table 3: Comparison of PAH Soil Concentrations from Test Pitting Program to S3 Component Values

COC	S3 Soil concentration (µg/g)	Maximum Concentration (µg/g)	Average Concentration (µg/g)	No. of Detects greater than the S3	Test Pit IDs for Exceedance Locations
Benz(a)anthracene	260	22	1.87	--	--
Benzo(a)pyrene	**17**	**22**	**1.30**	**2**	**TP024, TP096**
Benzo(a)pyrene	17	15[a]	1.09[a]	--	--
Benzo(b)fluoranthene	260	25	1.62	--	--
Benzo(k)fluoranthene	260	15	0.92	--	--
Chrysene	2600	22	1.90	--	--
Dibenz(a,h)anthracene	26	1.6	0.14	--	--
Fluoranthene	2600	72	5.28	--	--
Indeno(1,2,3-cd)pyrene	260	7	0.48	--	--
Phenanthrene	NV	96	5.65	--	--

[a.] maximum concentration and average after removing results of 2 highest test pit results

Based on the comparison of maximum concentrations to the S3 direct contact value, there may be unacceptable risks from benzo(a)pyrene in soil through the direct contact pathway for the Construction Worker. There are 2 possible locations, TP024 and TP096, on site (of 195 test locations) where this exposure may occur. Test pit TP024 and TP096 locations are provided on the Sirati figure, modified by Jacobs, in Attachment 1. All other PAHs and locations would not be expected to present unacceptable risks. Risk management measures (RMMs) may be used to reduce or eliminate exposure and reduce risk to acceptable targets.

3.6.2 Dust Inhalation

Jacobs evaluated the exposure pathway related to the inhalation of fugitive dust derived from soil to determine the need, if any, for dust control measures during current and future construction activities. This evaluation considers exposure to dust originating from contaminated soil during current conditions in the absence of RMMs (that is, no paving or grass covers). Jacobs used the following equation to estimate exposure from dust inhalation (MECP, 2011b; Health Canada, 2010):

$$DAD = \frac{C * PM_{10} * CF * IR_A * FPM_{inh} * EF1 * EF2 * EF3 * ED}{BW * AT}$$

Where:

DAD = Daily adsorbed or administered dose (mg/kg/d)
C = Chemical concentration in soil (mg/kg)
PM_{10} = Particulate concentration in air (µg-soil/m^3)
CF = Conversion factor, 1 kg/10^9 µg
IR_A = Inhalation rate (cubic metres per hour [m^3/hr])

FPM_{inh} = Fraction of particulate matter smaller than 10 microns in diameter (PM10) (unitless); Ministry default value of 0.6 is applied herein
$EF1$ = Exposure frequency (days per week)
$EF2$ = Exposure frequency (weeks per year)
$EF3$ = Exposure frequency (hours per day)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (lifetime or ED in years × 365 days per year)

A summary of exposure inputs is provided in Table 4.

Table 4: Exposure Assumptions

Parameter	Units	Symbol	PO and PMAT Staff	Construction Worker
Body Weight	Kg	BW	70.7	70.7
Exposure Duration	Years	ED	56	0.5
Averaging Time Non-Cancer	Days	AT_{NC}	20440	182.5
Averaging Time Cancer	Days	AT_C	20440	20440
Frequency of Exposure for Outdoors	Weeks/year	EF1	39	39
Frequency of Exposure for Indoors and Outdoors	Days/week	EF2	0.5[a]	5
Frequency of Exposure for Outdoors	Hours/day	EF3	4.9[a]	9.8
Concentration of PM10 in Air	$\mu g_{soil}/m^3$	PM_{10}	0.76[b]	100[c]
FPMinh: Fraction of PM10 that is deposited	unitless	FPMinh	0.6	0.6
IRw: Inhalation rate during exposure period	m^3/hr	IR_A	1.5	1.5

Notes:
Exposure parameters are MECP default parameters from the Rationale Document (MECP, 2011c) unless otherwise specified.
a. Based on knowledge of receptor use of the Site.
b. Based on average airborne concentration of respirable particulate matter presented in Health Canada (2012).
c. Value of 100 is applied to represent higher PM10 levels that could be present at the Site; this value is consistent with a subsurface worker, as presented in the Rationale Document (Ministry, 2011c)
kg = kilogram
$\mu g_{soil}/m^3$ = micrograms of soil per cubic metre
m^3/hr = cubic metre per hour

To assess the dust inhalation pathway, the maximum concentrations of PAHs in soil were inputted into the dust exposure model to calculate the risk to the Construction Worker and PMAT Staff and PO Staff from dust at the Site.

Table 5 presents a summary of dust risks using maximum concentration in soil. It is important to note, that this assessment method assumes all soils exposed at the site that can generate dust contain PAHs at the maximum concentration. Based on data collected to date, soils are more likely to contain PAHs at concentrations much less that the value used in the assessment. Therefore, the risk estimates are likely less than those presented in the following table.

To help assess the potential risk from dust exposure, Jacobs compared the estimated worker exposure (calculated as described above) to the toxicity reference values (TRVs) used by the MECP in the development of the generic site condition standards. These TRVs are considered to be protective of human health and often more conservative than occupational exposure limits (OELs).

A comparison of the estimated exposure for each PAH compound to the appropriate TRV will provide an estimate of the potential risk associated with each. If the estimated exposure is less than the appropriate TRV, adverse health impacts are not expected. The comparison estimates are as described by the following ratio:

$$Hazard\ Quotient\ (HQ) = \frac{DAD}{RfD_i}$$

Where:
HQ = hazard quotient (unitless)
DAD = daily absorbed dose (mg/kg/day)
RfD_i = Reference Dose (mg/kg/day) Toxicity Reference Value

This approach is used for benzo(a)pyrene since there is a TRV for non-cancer risks via inhalation used by the MECP.

Estimates of risk for carcinogenic health effects are derived by the following relationship, where the ILCR is calculated:

$$\text{ILCR} = \text{DAD} \times \text{Cancer SF}_i$$

Where:
ILCR = Incremental Lifetime Cancer Risk (unitless)
DAD = daily absorbed dose (mg/kg/day)
SF_i = Inhalation Slope Factor (mg/kg/day) Toxicity Reference Value

Toxicity reference values that correspond to exposure doses (as opposed to concentrations) are required for the evaluation of risk from particulates. Therefore, reference concentrations (RfCs) and unit risk factors (URFs) are converted to RfDi and SFi values using the conversion used by the United States Environmental Protection Agency (USEPA) defaults of the adult daily inhalation rate of 20 cubic metres per day (m3/day) and an adult body weight of 70 kg (University of Tennessee, 2013). The conversion is as follows:

$$RfD_i(mg/kg/day) = \frac{RfC(mg/m^3)*20(m^3/day)}{70(kg)}$$

and

$$SF_i([mg/kg/day]^{-1}) = \frac{URF([mg/m^3]^{-1})*10^3(\mu g/mg)*70(kg)}{20(m^3/day)}$$

For non-cancer health effects, the MECP considers an HQ of 0.2 or lower to be acceptable for any one environmental medium, if multimedia exposure is possible (MECP, 2011b). The target HQ used in this assessment for benzo(a)pyrene was 0.2.

For carcinogenic health effects, the MECP has selected a target ILCR of 1×10^{-6} (1 in 1 million) or lower as the acceptable level of minimal risk. This same limit was used in this assessment.

Table 5: Summary of Dust Risks – Using Maximum Concentration in Soil

COC	Maximum Concentration (µg/g)	PO and PMAT Staff		Construction Worker	
		Estimated ILCR	Estimated HQ	Estimated ILCR	Estimated HQ
Acenaphthylene	0.2	1.E-14	--	7.E-13	--
Anthracene	28	1.E-12	5.E-09	1.E-10	1.E-05
Benz(a)anthracene	22	1.E-11	--	8.E-10	--
Benzo(a)pyrene	22	1.E-10	1.E-04	8.E-09	**3.E-01**
Benzo(a)pyrene[a]	15	8.E-11	7.E-05	6.E-09	2.E-01
Benzo(b)fluoranthene	25	1.E-11	--	9.E-10	--
Benzo(k)fluoranthene	15	8.E-12	--	6.E-10	--
Chrysene	22	1.E-12	--	8.E-11	--
Dibenz(a,h)anthracene	1.6	9.E-12	--	6.E-10	--
Fluoranthene	72	4.E-12	--	3.E-10	--
Indeno(1,2,3-cd)pyrene	7	4.E-12	--	3.E-10	--
Phenanthrene	96	--	2.E-08	--	4.E-05
Benzo(a)pyrene Equivalent [b]	30.8	2.E-10	1.E-04	1.E-08	--

Notes:

[a] maximum concentration and average after removing results of 2 highest test pit results

[b] The MECP guidance indicates that when it is possible for exposure to a PAH mixture to occur at a site, the combined carcinogenic risk from all PAHs with the same mode of action must be assessed, even if an individual PAH is present at less than its individual SCS. MECP toxicity equivalence factor (TEF) were used to total the risk from carcinogenic PAHs as the approach to assess risks related to environmental mixtures of carcinogenic PAHs. For each sample, the calculated B(a)PE values were evaluated, and the maximum calculated concentration was retained for analysis.

Shaded and **Bold** values indicate a predicted risk exceeding MECP target risk values (i.e., ILCR>10-6, HQ>0.2)

ILCR = incremental lifetime cancer risk

HQ = hazard quotient

B(a)PE = benzo(a)pyrene equivalent

All risk estimates were below MECP targets except for non-cancer risks from benzo(a)pyrene. While the risk estimate was slightly greater than the target HQ of 0.2 (which allows for exposure to benzo(a)pyrene in other environmental media) typical human exposures to PAHs are more likely from soil and air alone and not multiple environmental media. As discussed, this risk estimate also assumes that all the excavated soil contains benzo(a)pyrene at the maximum measured concentration, when the likely case is that the concentration of benzo(a)pyrene is significantly less (as demonstrated by data collected to date). A hazard quotient (HQ) value much less than 1 represents exposures that are lower than the TRV.

The assessment was repeated, with the data from the two test pits TP024 and TP096 removed (see Figure in Attachment 1 for test pit locations). As shown in Table 5, the row identified as benzo(a)pyrene(b) indicates a maximum soil concentration of 15 mg/kg with the resulting HQ equal to 0.2.

Based on the assessment inhalation of dust from soil, the risks from most PAHs in soil are not expected to present a health risk to Construction Workers. If benzo(a)pyrene was present in all excavated soil at the maximum concentration reported, then dust inhalation risks may slightly exceed the MECP target non-cancer risks (HQ>0.2) for the Construction Worker during construction activities, but still be less that 1.0. Adverse health effects from inhalation of dust derived from excavates soils on-site are not expected for PO and PMAT staff since all risk estimates are less than MECP target values.

3.6.3 Vapour Inhalation

To assess the vapour inhalation pathway, a comparison of the maximum concentrations of each PAH to the MECP S-IA (soil-to-indoor air) and S-OA (Soil-to-outdoor air) component values was completed. These component values are soil concentration considered to be protective of the potential volatilization of PAHs from soil to indoor and outdoor air respectively. The MECP used conservative assumption to back calculate these values from health based indoor and outdoor air standards. Soil concentration measured to be less than these values are expected to be without adverse health effects. The PMAT Staff and PO staff could be exposed to the inhalation of indoor air in the pumping house/valve house and access building, though exposure is expected to be minimal based on frequency of access.

The PO and PMAT Staff and Construction Workers could also be exposed to the inhalation of outdoor air while performing outdoor activities such as drain access or repair work. Tables 6 and 7 present the comparison of the component values to the maximum concentration of COCs. Again, please note that this comparison assumes that soils are uniformly contaminated at the maximum concentration measured on-site. Soils on site are more likely to contain PAH concentrations less than the measured maximums. Both indoor air and outdoor air assessments are present in the following tables.

Table 6: Comparison for Risk to Indoor Air using MECP Component Value S-IA

COC	S-IA (µg/g)	Maximum Concentration (µg/g)	Average Concentration (µg/g)	No. of Detects greater than the S-IA	Test Pit IDs for Exceedance Locations
Acenaphthylene	12	0.2	0.03	--	--
Anthracene	270	28	1.64	--	--

Table 6: Comparison for Risk to Indoor Air using MECP Component Value S-IA					
COC	S-IA (µg/g)	Maximum Concentration (µg/g)	Average Concentration (µg/g)	No. of Detects greater than the S-IA	Test Pit IDs for Exceedance Locations
Benz(a)anthracene	1800	22	1.87	--	--
Benzo(a)pyrene	5400	22	1.30	--	--
Benzo(b)fluoranthene	150000	25	1.62	--	--
Benzo(k)fluoranthene	180000	15	0.92	--	--
Chrysene	50000	22	1.90	--	--
Dibenz(a,h)anthracene	880000	1.6	0.14	--	--
Fluoranthene	6700	72	5.28	--	--
Indeno(1,2,3-cd)pyrene	1200000	7	0.48	--	--
Phenanthrene	NV	96	5.65	--	--
Notes: NV = no value					

Table 7: Comparison for Risk to Outdoor Air using MECP Component Value S-OA					
COC	S-OA (µg/g)	Maximum Concentration (µg/g)	Average Concentration (µg/g)	No. of Detects greater than the S-OA	Test Pit IDs for Exceedance Locations
Acenaphthylene	2600	0.2	0.03	--	--
Anthracene	2600	28	1.64	--	--
Benz(a)anthracene	260	22	1.87	--	--
Benzo(a)pyrene	17	22	1.30	--	--
Benzo(b)fluoranthene	260	25	1.62	--	--
Benzo(k)fluoranthene	260	15	0.92	--	--
Chrysene	2600	22	1.90	--	--
Dibenz(a,h)anthracene	26	1.6	0.14	--	--
Fluoranthene	2600	72	5.28	--	--
Indeno(1,2,3-cd)pyrene	260	7	0.48	--	--
Phenanthrene	NV	96	5.65	--	--

Based on the comparison of maximum concentrations of PAH concentrations in soil to the S-IA and S-OA component values, Soils on site are not expected to present an inhalation risk to construction workers or PO/PMAT staff from potential PAH vapour emissions in indoor air or outdoor air.

3.6.4 Soil Leaching

As described previously, the physical-chemical properties of PAHs are unlikely to promote leaching of PAH from soil as a potential risk pathway. PAHs are sparingly soluble and have high affinity for adsorbing to soils. Infiltration of the soil cap over the reservoir is limited to precipitation event, and is unlikely to mobilize PAHs from soil.

It is Jacob's understanding that the issue with soil leaching is related to PAHs in the soil cap over the reservoir (that contains potable water for the City) and the potential for PAHs to leach from soil, migrate to the reservoir structure and enter the water supply. The structure of the reservoir is composed of concrete tank with a membrane at joints to prevent groundwater and other material from entering the water supply. In the unlikely event that soil does leach PAH compounds, it is very unlikely that PAHs will migrate any significant distance through the soil column, particularly without significant amounts of infiltration. It is also very unlikely that soil moisture with leached PAHs will be able to penetrate the membrane or concrete to enter the water supply.

Furthermore, multiple recent water samples collected from the reservoir influent water supply and the discharge water supply of the Kenilworth Reservoir indicate that PAHs were not detected, suggesting that PAHs in soil above the reservoir do not appear to be impacting the water supply.

Therefore, it is Jacobs opinion that risks from soil leaching are negligible and impacts to the water supply are unlikely through the soil leaching pathway.

3.6.5 Uncertainties

- Jacobs relied on soil investigation data provided by the City of Hamilton
- Concentrations of contaminants are not distributed uniformly across the Site. The maximum detected values for chemicals in soil were used in the assessment. These concentrations may appear in localized areas on the Site. Receptors would not consistently be exposed to the maximum concentration present at a site over their lifetime; therefore, the predicted risks have likely been overestimated.
- Site receptors were assumed to have access to the maximum detected concentrations of chemicals (regardless of depth) on an ongoing and constant basis. Under normal circumstances, only a Construction Worker may have access to soil located at depths impacted with COCs at maximum detected concentrations.
- Risk to offsite receptors would likely be less than experienced by Site users, since the concentration of COC-impacted fugitive dusts and volatile COCs diminishes rapidly with dispersion and dilution in air and with distance.
- The total dust in the air is highly variable; as a result of the uncertainty in the dust concentrations, this assessment has used conservative assumptions, likely resulting in an overestimate of exposure and risk.
- Risks from dust were calculated independent of particle size. This may over or underestimate risk.

4. Strategy for Managing Potential Risks

This section identifies the conceptual RMMs intended to reduce the risks from exposure to that COCs in soil to acceptable levels. RMMs are needed for the pathways identified by the assessment to pose potential risks to human or ecological receptors. The purpose of the RMMs is to reduce receptors' potential risk to acceptable target levels (that is, less than the MECP component values or for the dust pathway, the ILCR reduced to less than or equal to 1×10^{-6}, and the HQ is reduced to less than or equal to 0.2).

The assessment assumed that workers did not employ any specific personal protective equipment, and used standard MECP factors to estimate exposure or used soil concentrations developed by the MECP for use in management of contaminated sites under O.Reg. 153/04. Based on the assessment completed as part of this evaluation, risks are possible for the following receptors (in the absence of RMMs) at two locations (TP024 and TP096, see the modified Sirati figure in Attachment 1 for locations):

- PMAT Staff
- PO Staff
- Construction Workers

The potential for unacceptable risk at the Site can be placed in one of the following broad categories:

- Exposure to soil through direct contact (ingestion or dermal)
- Exposure to soil through dust inhalation

Since the site is not uniformly contaminated at the maximum concentrations used in the assessment, location with PAH concentrations less than the maximum concentrations will have lower exposure and risk. The following performance objectives have been established for the RMMs to address and mitigate the risks associated with these pathways and receptors at TP024 and TP096:

- Block direct contact (dermal or ingestion) of COCs in soil
- Block inhalation exposure of COCs on dust particles

These objectives can be achieved by implementing the following RMMs:

- Capping (fill caps, hard caps, or both to prevent direct contact with soil COCs)
- Administrative controls, including requirements for health and safety plans (HSPs), personal protective equipment (e.g. gloves), and soil management plans (SMPs) to mitigate exposure to soil COCs

5. Recommendations

Based on the assessment described in the previous sections, Jacobs determined that there is a potential for risks to human receptors on the Site from PAHs in sub-surface soil at TP024 and TP096 with no RMMs or if standard PPE is not utilized during the completion of subsurface construction work where PAH impacted soils are present. However, based on the assessment, soils may be reused at the site including soils from locations TP024 and TP096, with RMMs in place.

As a result, Jacobs recommends the following:

- Preparation of a HSP to make workers aware of the presence of PAHs in soil, and to protect human receptors at the Site from potential risks from exposure to soil under current and future Site conditions where excavations may take place.

- Completing a surface soil investigation to close data gaps and determine if soils between 0 and 0.6 mbgs are contaminated with PAHs. The results of the surface soil investigation will be used to determine if existing soils can be utilized as a protective cap for human receptors or if soil should be excavated or covered with an additional fill cap applied, or some combination thereof.
- Preparation of a SMP to outline the beneficial reuse of soil at the Site.
- Should excavated soil be required to be removed from site (i.e. excavated soil becomes excess soil) and is considered a waste, the SMP should include detail to characterize and manage waste soil according to legislation requirements.

5.1 Terms of Reference based on Soil Reuse Strategy

Proposed Terms of Reference for implementing the recommendations are detailed below.

5.1.1 Health and Safety Plan

The HSP will consist of:

- Provisions for occupational hygiene requirements, personal protective equipment (PPE), contingency plans, and contact information that account for the presence of the COCs in soil at the Site and related to potential risks to the Construction Worker and PO and PMAT Staff.
- The HSP will not address other health and safety Project related requirements that must be addressed by the Constructor.

5.1.2 Data Gap Investigation

The surface soil investigation will consist of:

- A sampling and analysis program (SAP) to delineate possible impacts to surface soil
- A report outlining methodology, data summary, results, and conclusions/recommendations
- Recommendations for capping requirements, if any.

5.1.3 Soil Management Plan

The SMP will involve an approach specific to where excavation activities are proposed and based on the data compiled for this assessment and the data gap assessment. The plan will identify, at a minimum:

- Provisions for soil excavation, stockpiling, tracking, dust management (tarping), odour management, characterization, disposal, and recordkeeping. Temporary barriers during stock piling excavated soil (by tarping).
- Provisions for sampling frequency and quality requirements. Potential leaching concerns can be assessed using synthetic precipitation leaching procedure (SPLP) methods.
- Identification and strategy for soil for reuse

Imported soil placed at the Site must meet the Table 3 SCS.

6. Closure

We trust that this letter of opinion supports the reuse of soils at the site based on a technical examination of soil conditions and assessment of potential risks. If site conditions change or new information becomes available, the results and recommendations of this letter should be reassessed in light of the new data.

Yours sincerely

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Acronyms and Abbreviations

°C	degrees Celsius
CCME	Canadian Council of Ministers of the Environment
City	City of Hamilton
CH2M	Ch2M Hill Canada Limited
COC	contaminant of concern
CSM	conceptual site model
EPA	Environmental Protection Act
ESA	environmental site assessment
Excess Soils Regulation	O. Reg. 406/19 On-Site and Excess Soil Management
HQ	hazard quotient
HSP	health and safety plan
ILCR	incremental lifetime cancer risk
Jacobs	Jacobs Engineering Group Inc.
MECP	Ministry of the Environment, Conservation and Parks
m	metre
m^2	square metre
mbgs	metres below ground surface
O. Reg.	Ontario Regulation
ODWQS	Ontario Drinking Water Quality Standards
OELs	occupational exposure limits
OWRA	Ontario Water Resources Act
PAHs	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PO Staff	Plant Operations staff

PMAT Staff	Plant Maintenance staff
RMM	risk management measure
RSC	record of site condition
RVA	R.V. Anderson Associates Limited
S-IA	soil-to-indoor air MECP component value
S-OA	soil-to-outdoor air component value
SAP	sampling and analysis plan
Sirati	Sirati & Partners Consultants Ltd.
Site	Kenilworth Reservoir
SMP	soil management plant
S3	MECP component value direct exposure to soil via ingestion and dermal contact for a subsurface commercial/industrial condition
Table 3 SCS	*Table 3 Full Depth Generic Site Condition Standards in a Non-Potable Groundwater Condition* for industrial/commercial/community property use and coarse textured soil condition
TCLP	Toxicity Characteristic Leaching Procedure
TRV	toxicity reference value

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Limitations

This letter of opinion for Kenilworth Reservoir located at 111 Kenilworth Access, Hamilton Ontario, was prepared for the exclusive use of the City of Hamilton. Third parties cannot rely upon the findings and conclusions presented in this report without the express written consent of CH2M HILL Canada Limited (CH2M), now a wholly owned subsidiary of Jacobs Engineering Group Inc. (Jacobs), and the City of Hamilton through an extension of reliance using a Reliance Letter signed by both parties. CH2M accepts no responsibility for damages, if any, incurred by any third party as a result of decisions made or actions based on this report.

Other considerations and limitations applicable to this letter of opinion include the following:

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a. CH2M's services are governed by the negligence standard for professional services, measured as of the time those services are performed.

b. CH2M shall not be liable to the City of Hamilton for any damages where it has exercised a reasonable standard of care.

No Third-party Beneficiaries

a. This letter of opinion gives no rights or benefits to anyone other than the City of Hamilton and CH2M, and has no third-party beneficiaries. All work products prepared are for the sole and exclusive use of the City of Hamilton for specific application to the Site; is not for the benefit of any third party; and may not be distributed to, disclosed in any form to, used by, or relied upon by any third party without the prior written consent of CH2M, which consent may be withheld in its sole discretion.

b. No warranty, expressed or implied, is made regarding the services performed.

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a. Any opinions or recommendations presented apply to Site conditions existing when services were performed. CH2M cannot report on or accurately predict events that may change the Site conditions after the described services are performed, whether occurring naturally or caused by external forces.

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c. CH2M's services shall not include an independent verification of the quality of work conducted and information provided by independent laboratories or other independent contractors retained by CH2M in connection with CH2M's services.

In preparing this letter of opinion, CH2M relied, in whole or in part, on data and information provided by the City of Hamilton and third parties. This information was not independently verified by CH2M, and CH2M has assumed it to be accurate, complete, reliable, and current. Therefore, while CH2M has used its professional efforts in preparing this letter of opinion, CH2M does not warrant or guarantee the conclusions set forth in this letter of opinion that are dependent or based upon data, information, or statements supplied by third parties or the City of Hamilton.

Attachment 1

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King City, ON. L7B 1H5
Phone# 905 833 1582, Fax#905 833 5360

North:

Legend:

TP# TP Location Without Exceedance

TP# TP Location With Exceedance

TP with benzo(a)pyrene risks

Project Title:

Site Location:

111 Kenilworth Access, Hamilton, ON

Figure Title:

Sampling and Exceedance Locations

Scale:	Project Number:
As Shown	SP20-703-00
Date:	Figure Number:
August 2019	2