Environmental Risk Management Plan
Historic Waste Disposal Site
Montfort Landfill Site
The City of Red Deer

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Preface

The City of Red Deer is aware of several historic waste disposal sites containing municipal solid waste situated within fully developed urban areas. The Alberta Municipal Government Act, specifically Part 2, Section 13 of the Subdivision and Development Regulation AR 43/2002 specifies a minimum setback distance between the closed historic landfill to certain types of land developments. Restrictions of types of subdivision associated with this regulation include residential, food establishment, school or hospital. This regulation includes provisions for the Provincial Deputy Minister to consider a request to vary the minimum setback distance for a specific development application, provided the local municipal subdivision or development authority supports the proponent's specific development application.

The underlying objective of the project is to develop a level of understanding of the environmental risks arising from each historic waste disposal site leading to a site specific environmental risk management plan (ERMP). To structure the project into manageable components, the work was divided into the following three stages:

1. Phase I ESA — Compilation and review of information pertaining to a historic waste disposal site.
2. Phase II ESA — Subsurface investigation to verify and characterize information from the Phase I ESA.
3. ERMP — Develop a site-specific environmental risk management plan to serve as an aid for the municipal development review process.

This document reflects the third stage, specifically presenting the ERMP for the Montfort Landfill Site. With the available information, the ERMP was developed on the basis of Health Canada guidelines for a preliminary quantitative risk assessment. The outcomes of the ERMP confirm the identified chemicals of concern and the relevant environmental risks are manageable to facilitate future developments which may lie within the regulated setback distance to the historic waste disposal site. This ERMP provides a first-order evaluation for potential future subdivision and development with a focus on methods to minimize the risk of human exposure to landfill gas and other hazards to the environment resulting from the historic waste disposal site.

Ultimately, the goal is to have an effective and timely review process for specific future subdivision and development applications while preserving an appropriate/equivalent level of protection for each stakeholder be it regulatory, developer, owner, public or the natural environment.

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1.0 INTRODUCTION

Assessment of environmental site data to identify potential hazards and exposures is, by its nature, a risk assessment process. The use of various risk assessment tools is a common practice to decision making in professional practice. The current body of knowledge and research has produced a wide assortment of methods to conduct an environmental risk assessment. The many approaches to conducting a risk assessment range from very basic site-specific empirical information gathered from the field to complex numerical quantitative models. Typically, selection of the risk assessment protocol is determined by the type of data available and the attributes which are exposed to a potential risk. The risk management process can be a relatively straight-forward analysis to a complex evaluation involving a multi-disciplinary team of professionals.

For example, a proposed residential development project within a prescribed river flood plain will have several environmental factors associated to vulnerabilities and potentials for an adverse effect to the proposed development from the river (flood, high groundwater, pollution impact from an upstream source are some examples). Current practice involves multiple avenues of review ranging from regulatory requirements, design guidelines, codes of practice, industry standards and local considerations to address the potential identifiable vulnerabilities. These reviews and considerations are intended to assist the design professional to manage the identified vulnerabilities and the associated risks to ensure appropriate levels of mitigation and adaptation are incorporated into the development with the objective of having an appropriate level of protection for each stakeholder and the natural environment.

Risk assessment can be broadly categorized into three main types: qualitative, semi-quantitative and quantitative. Each type has unique limitations to subjectivity of data and each have a common outcome to serve as a decision making tool for management.

A commonly applied qualitative risk assessment tool can be simply illustrated in a matrix form below.

Level of Risk

Severity of Consequence			
High	M	H	H
Medium	L	M	H
Low	L	M	H
	Low	**Medium**	**High**

Probability of Occurrence

A semi-quantitative approach to risk assessment requires some first-order estimates as inputs into a risk model. The semi-quantitative approach is more sophisticated relative to the subjective qualitative screening approach and is not as numerically demanding as a quantitative risk assessment involving more complex numerical models and environmental statistics. The semi-quantitative approach is commonly applied to smaller project sites and is an appropriate initial approach for this project site.

As noted, a semi-quantitative approach does not require analyzed probabilities or high level statistical and mathematical data sets, which may largely be subjective and difficult to verify, creating a new set of uncertainty. The semi-quantitative process includes a hierarchy of identified risks specific to the site, numerical risk estimation and an interpretation of qualitative considerations founded on professional experience and judgment. The hierarchy of identifiable risks is generally outlined into a matrix similar to the above, reflecting an order of project specific priorities. The matrix format is intended to illustrate, in a logical fashion, the likelihood of a possible vulnerability and its adverse impact. Risk rankings are usually divided into three groupings: low, medium and high with a prescribed level of action appropriate to respond to a potential level of adverse consequence such as:

- Low aggregate risk value. Management can decide what form of corrective action(s) to implement or accept the potential risk.

- Medium aggregate risk value indicates mitigative and/or adaptive actions would be deemed prudent to minimize the probability of an adverse effect. Immediate reaction is generally not required but action would be necessary within a site–specific time frame.

- High aggregate risk value. Mitigating and/or adaptive measures are to be exercised as soon as practical in order to reduce the identified hazard.

It should be noted, to a practical level as possible, a risk assessment should be exercised in an objective fact-based manner to avoid pre-determining a desired outcome, i.e. allow the facts to “speak.” Accordingly, to effectively develop a risk management plan with a scientifically supported project decision making process, the risk assessment should be developed in a manner which is consistent and defensible while recognizing limitations of the data set and the inherent uncertainty to available site information and subsurface parameters. This knowledge can then be applied in a defensible and justified manner to make appropriate risk-based decisions.

In summary, within the practice of risk assessment, there are many other methods and approaches to completing a risk assessment. Each has differing attributes and limitations. The results of a risk assessment are either applied to better understand the levels of risk to potential identified hazards or the results become an indicator to support further investigation and research. Information on the types and the merits of differing risk assessments are widely available to the reader. For this project, an evaluation of risk is a systematic process involving the identification and comparison of specific assets and its associated vulnerabilities with consideration of the likelihood for an adverse effect to occur.

The development of a site-specific environmental risk management plan (ERMP) is a component of a structured risk management process utilized by The City of Red Deer. The results of the risk assessment are intended to support risk-based decisions by the Management at The City of Red Deer.

In order to develop a defensible risk management plan, the approach considered to be appropriate for this project is a preliminary quantitative risk assessment. Health Canada has developed guidance documents to enable a consistent and defensible evaluation of site-specific data. A simple semi-quantitative protocol rather than a detailed analytical protocol is appropriate for the level of data available on this project. A semi-quantitative protocol is acceptable to most regulatory jurisdictions for a project of this scope and strikes a reasonable balance between a purely subjective qualitative protocol and the highly analytical intensive quantitative protocol. Health Canada refined and released the framework for environmental risk assessment in September 2010 and an update and revision in 2012. The Health Canada approach was selected over the CCME 1996 Framework for Ecological Risk Assessment. The CCME and the Health Canada risk assessment process are the two nationally accepted processes for risk assessment. Local provincial ministries have developed specific risk assessment protocols that are modeled from selected attributes of various risk protocols from various organizations. For instance, the Alberta Tier 1 and 2 Soil and Groundwater Remediation Guidelines are focused on the assessment and remediation of contaminated soil and groundwater. Generic numeric guidelines for target chemicals were derived by the application of the CCME 2006 Protocols for the Derivation of Environmental and Human Health Soil Quality Guidelines. The CCME Ecological Risk Assessment process is also focused on target chemicals at a site. These approaches are directed at the concentrations of target chemicals at a contaminated site.

The Health Canada approach focusses on the risk of exposure to a receptor and not the concentration of a target chemical. Hence, for this project, in order to develop and evaluate a risk model for potential receptors at various developments to the exposure of transient soil landfill vapours emanating from the Montfort Landfill Site, the Health Canada model is considered more appropriate relative to the above noted alternative risk assessment models.

Health Canada outlines a preliminary quantitative risk assessment (PQRA) in order for various industries to apply a standard method and assumptions to ensure potential environmental exposures and their risks are not underestimated in the risk model. This approach is to address historic problems during peer review. The PQRA applies a conservative interpretation to the risk outcome. Such that in the event of an identified potential risk outcome being negligible or acceptable; the actual site condition(s) will essentially present a negligible or acceptable level of risk. Conversely, should the outcome for a potential level of risk be deemed unacceptable; then, further investigation may be warranted to better refine the conservatism and reduce uncertainty or the actual site condition(s) become an unacceptable level of risk, warranting a site-specific response to address and reduce the predicted risk for an adverse impact.

Key results from the Phase I and II ESA have been consolidated to construct a site-specific PQRA and the output is the cornerstone to the development of the site-specific risk management strategies and the development of a risk management plan.

Tiamat Environmental Consultants Ltd. (Tiamat) presents this Environmental Risk Management Plan (ERMP) for a historic waste disposal site designated as the Montfort Landfill Site.

This report presents the scope of work, a summary of the PQRA and a proposed ERMP for the Montfort Landfill Site. The information presented is intended to be a standalone document. Specific site information that is deemed supplementary and not critical to the ERMP has been excluded in this report. Should the reader wish to review this type of information, the reader should peruse the 2013 Phase I ESA and 2014 Phase II ESA reports for the Montfort Landfill Site as prepared by Tiamat.

1.1 Scope of Work

A summary of the key tasks for this ERMP are outlined below:

Compile Data for PQRA

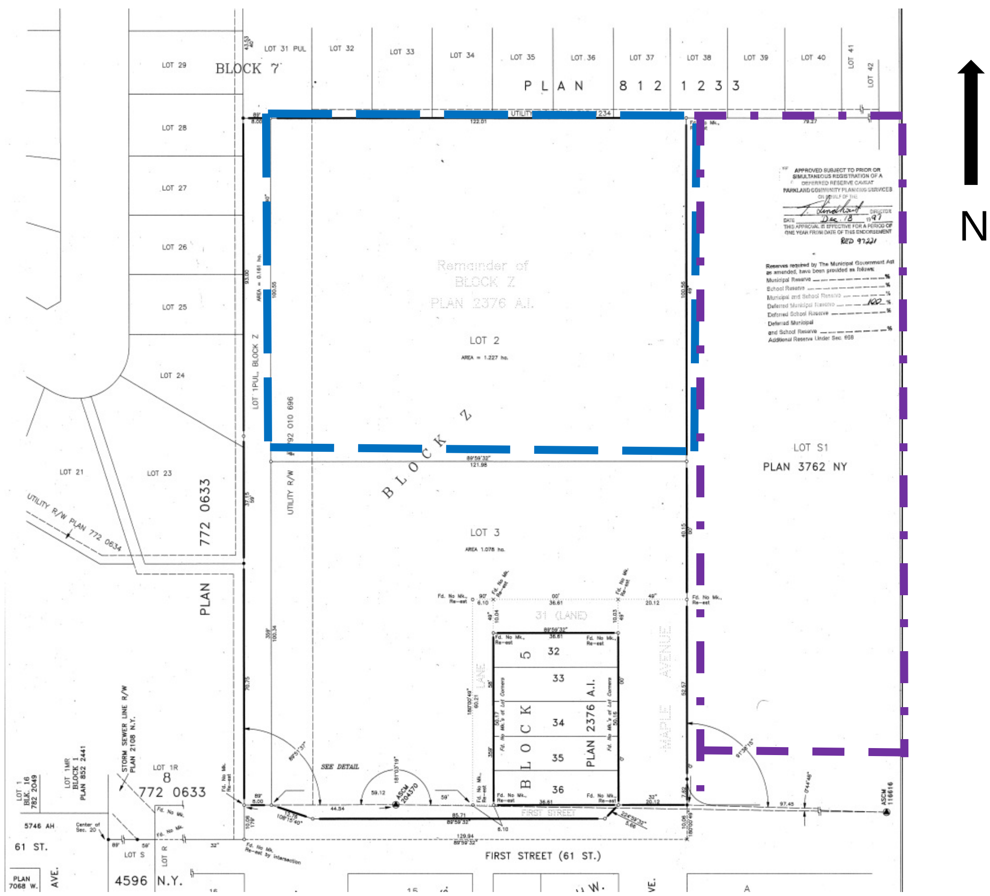
- Identify chemicals of concern in environmental media (soil, groundwater, soil gas);
- Assemble chemical and physical attributes of each identified chemical of concern;
- Collect toxicological information and identify data gap(s) for each identified chemical of concern;
- Identify receptors (human, biota and river) and the various routes of potential exposure;
- Evaluate the compiled data using a standard PQRA approach.

ERMP

- Develop a site-specific ERMP incorporating the findings of the PQRA with application to the four limited/restricted land uses (school, hospital, food establishment and residential), general commercial developments and the installation of infrastructure such as utilities.

1.2 Summary of Previous Work & Project Status

Residential developments west, north and east of the Montfort Landfill Site predates the waste disposal activity. Municipal records suggest the historic waste disposal activity occurred in 1968. The estimated age of the waste material, post closure, is about 47 years, more or less. The municipal records indicate the Provincial Board of Health issued a permit to The City of Red Deer for the waste disposal activity at this site. The area of the historic waste area is situated within two subdivided parcels of land. The two parcels of land are illustrated on a portion of survey plan 982 0142 below.



A previous environmental assessment for the site was conducted by Stantec Inc. and Parkland Geotechnical Consulting Ltd. and report titled, "Summary Report Former Montfort Landfill 52nd Avenue and 62nd Street, Red Deer, Alberta February 5 2006/June 2008.

The noted document was provided by The City of Red Deer. Key information from the referenced documents was consolidated and identified data gaps were addressed in the Phase I ESA report (Tiamat, 2013). The scope of investigation for the 2014 Phase II ESA was designed to address the environmental concerns identified from the Phase I ESA.

The key results of the 2014 Phase II ESA are as follows:

- The estimated areal footprint of the historic waste is 21,300 m^2 (5.26 ac). The waste is situated on either native sand or clay till. The sand unit governs for the flow of local groundwater.

- Groundwater is approximately 3.4 m below the ground surface and lies within the waste material. The average horizontal hydraulic gradient leaving the site is 0.4% to 1.1% to the south-southeast. Applying an intrinsic horizontal permeability of 10^{-5} m/sec for the sand, the resulting estimate horizontal flow velocity is about 3.2 m/year, more or less.

- Dissolved volatile organic compounds (VOCs) and other petroleum hydrocarbon constituents were detected at the down gradient groundwater monitoring wells.

- Laboratory results of groundwater samples from the down-gradient monitoring wells show several dissolved parameters (indicative of the presence of leachate) in the local groundwater leaving the site. This is further characterised by the field measured water quality indices showing high negative redox potential and near anoxic condition of dissolved oxygen in groundwater.

- Leachate in the down-gradient groundwater appears to be predominantly inorganic compounds and nutrients. Various VOCs and other dissolved hydrocarbons were detected in the August 2013 testing event.

- Two pre-existing monitoring wells (designated as MW-06 and MW-07) were apparently installed by Alberta Environment Sustainable Resources and Development (ESRD), formerly Alberta Environment. Groundwater from both of these wells clearly shows the presence of leachate constituents.

- Adjacent and nearby developments include a shopping mall (Village Mall), multi-family residential developments (Red Deer Village Apartments, Village Park Estates and Montfort Heights), the administration offices (Montfort Centre Red Deer Catholic Regional Schools) and numerous detached homes with basements. There are presently no obvious activities on the adjacent lands that are interpreted as an environmental concern relative to the site.

- Laboratory results from soil vapour samples during the Phase II ESA, showed subsurface methane ranging from about 6 ppm to 26% v/v. It is noted the explosive range for the concentration of methane in percent volume is 5% LEL to 15% UEL, more or less.

- Light molecular-weight petroleum gases were detected at each of the five soil vapour wells. Petroleum or petro-chemical derived soil vapours measured include aliphatic, aromatic, semi-volatile halogenated, oxygenated volatiles, ketones and several volatile chlorinated hydrocarbon compounds.

- Volatile petroleum hydrocarbon constituents to carbon chain 16 were consistently detected in each of the five soil vapour wells.

The findings of the 2014 Phase II ESA suggest mild to moderate strength leachate constituents are present in the groundwater potentially leaving the site and likely migrating to the southeast and descending the hill slope towards the Red Deer River. The initial assessment of landfill gas (LFG) shows the soil gas to compose of numerous volatile chemicals. A summary of the identified chemicals of concern are tabulated in Table 2A.

1.2.1 Site Description and Environmental Setting

The historic waste material lies within two subdivided parcels of land. The legal descriptions are:

- Lot S1 Plan 3762NY; and,
- Block Z Plan 982 0142.

The configuration of each area is illustrated in Section 1.2 and both areas lie within the NE 20-38-27 W4M.

The historic waste disposal area is completely bounded by various urban developments in the Community of Highland Green Estates. General features of the site, the surrounding community developments and the approximate footprint of the historic waste material is presented as Figure 1.

There are no buildings on the area of the historic waste site. A red shale paved pedestrian path bounds the west side of the historic landfill. This pathway extends from the south side of Hermary Street and connects to 53 Avenue, near 61 Street. The area of the landfill is currently transformed into a public park space with two ball diamonds along with some bushes and trees along the east perimeter, next to 52 Avenue.

1.3 Regional Geology and Hydrogeology

Within the immediate area of the historic waste there is no noted direction of principal overland flow or surface run-off control measures. There are no obvious environmental concerns for surface water run-off or run-on throughout this area. The site is situated on terrain that overlooks the Red Deer River valley and interpreted to be within a zone of groundwater recharge with a downward component of flow. The Red Deer River is about 580 m, more or less from the nearest point of the historic waste area.

The river flows from a south to north easterly direction. Based on a local topographic map for this area, regional groundwater flow is expected to be east-southeast towards the river valley and the Red Deer River. It should be noted that local topography, geology, land development and soil disturbances might influence the local movement and pattern of groundwater. Furthermore, groundwater may also fluctuate from seasonal and climatic conditions. A summary of the published geological and hydrogeological information is presented in the September 2013 Phase I ESA report.

Underground municipal utilities identified to be in the immediate vicinity of the historic waste site consist of an abandoned asbestos cement pipe water main located along the south margin of the site and an in-service storm water sewer lying in a north-south alignment parallel to the shale pathway located on the west side of the site. The relative locations of the underground municipal utilities are shown on Figure 2.

Potential environmental concerns arising from the historic waste site are grouped into three broad categories:

- Ground stability issue where the historic waste lies;
- Continual generation of soil vapour from the decomposing waste materials; and
- Lateral transport of groundwater which passes through the waste material and ultimately discharging to the local groundwater regime.

Several geochemical processes and physical settlement occurs as the buried historic waste materials decompose. There is visual evidence the cover for the historic waste has settled in an irregular manner at some locations within the park. Anecdotal reports from the City Parks Department on the somewhat uneven condition of the surface of the grass for cutting and during a short storm event, local ponding of rainwater is evident within the park. These indicators may suggest ongoing settlement and is indicative of the instability of the ground surface overlying the historic waste.

Landfill gas is a by-product of a geochemical process associated with the decomposing waste materials. The soil vapours comprising of constituents from landfill gas can migrate in the subsurface. The geochemical process also yields soluble hydrocarbons to the groundwater system with some volatile components capable of degassing into the soil vapour regime.

For the urban developments situated in proximity to the historic waste, the environmental health concerns are broadly defined into two categories:

1. Landfill soil gas (LFG) from the waste material, and

2. Leachate as groundwater passes through the waste material.

The ground stability overlying the waste area is deemed a structural maintenance issue and an avenue for water infiltration and percolation to the groundwater regime. As surface infiltration percolates through the historic waste materials and contacts the groundwater table, leachate is formed. This leachate is a potentially polluting liquid that can adversely affect the local groundwater system. A summary of the site-specific attributes for potential exposure to landfill soil vapours is presented as Table 1.

The concentration of landfill soil gas can be influenced by temporal effects such as temperature, precipitation, soil texture, soil moisture and the geochemical processes at the source area. Consequently, the most immediate concern to environmental health of urban developments is the potential exposure to landfill soil gas. There is also a potential for dissolved landfill soil gas constituents to degas from leachate leaving the waste area. This degassing is also capable of contributing to migrating subsurface landfill soil gas.

1.4 Environmental Guidelines & Regulations

This historic waste site has been closed from landfilling for about 47 years and is considered to be a non-operating municipal landfill. It is understood there is no regulatory requirement to remediate or decommission/remove the waste material from its present location.

The discussion and reference to sections of regulations and relevant statutes in this report should not be construed as legal advice or direction. For a legal interpretation of the applicable regulations and statutes, the reader must consult with a qualified legal professional.

Within the Province of Alberta Municipal Government Act, Alberta Regulation 43/2002 with amendments up to and including AB Reg. 31/2012, Part 2 Subdivision and Development Conditions, Section 13 "Distance from landfill, waste sites." An excerpt is reprinted below.

> **Section 13(2)** Subject to subsection (5), a subdivision authority shall not approve an application for subdivision for school, hospital, food establishment or residential use if the application would result in the creation of a building site for any of those uses
>
> (b) within 300 metres of the disposal area of an operating or non-operating landfill.
>
> **Section 13(3)** Subject to subsection (5), a development authority shall not issue a development permit for a school, hospital, food establishment or residence, nor

may a school, hospital, food establishment of residence be constructed if the building site

(b) is within 300 metres of the disposal area of an operating or non-operating landfill.

The regulation has a provision of variance to the above as described in

Section 13 (5) The requirements contained in subsections (1) to (4) may be varied by a subdivision authority or a development authority with the written consent of the Deputy Minister of Alberta Environment and Sustainable Resource Development.

Other potential developments which are not stipulated in the above regulation and may also be subject to a potential exposure risk include general retail and other commercial developments. Additionally, maintenance and construction activities associated with utility infrastructure in the vicinity of a landfill may also present workers to a potential risk of exposure to VOCs. Discretionary review for these other types of developments may be viewed by The City of Red Deer to be contextually relative to an adjacent or nearby landfill.

ESRD has published a guideline for requesting consent to vary the setback distance for a development to a non-operating landfill. A copy of this guideline is provided in Appendix A.

Presently, The Province of Alberta does not have comprehensive reference criteria for volatile chemicals in air. For this ERMP, a systematic approach to assess the potential risk for an identified chemical of concern has been applied, refer to Section 3.0.

2.0 CONTAMINANT SITUATION

Chemicals of concern identified from the Phase II ESA have been applied for the development of a site-specific ERMP. Presumptions for the identified chemicals of concern are solely sourced from the historic waste disposal site and no other off-site source. The lands bounding the historic waste disposal site are considered to be potential receptors of contaminants migrating from the historic waste disposal site. The two principal pathways for exposure are landfill soil gas and groundwater containing leachate.

The available site-specific data set for the Montfort Landfill Site reflects a summer (August 2013) testing event. To gain a "snap shot" of the seasonal range of soil vapour it is recommended a winter data set be obtained. The intent is to obtain subsurface data during frozen ground conditions where soil vapour constituents that would normally vent to atmosphere in the summer would be in a confined state and accumulate beneath the frozen ground. This scenario would reflect a "worst-case" for potential intrusion of soil gas into a heated building.

2.1 Groundwater

The interpreted pattern of local groundwater appears to flow on a southeast direction relative to the historic waste disposal site. The water quality at the down gradient test locations indicate the level of impact by landfill leachate indicators to be relatively harmful as the concentration of dissolved volatile compounds such as benzene, ethylbenzene, 1,4-dichlorobenzene, tetrachlorethene, trichloroethene and vinyl chloride exceed the referenced Tier 1 Guidelines.

The natural sand underlying the waste material is pervious and the nearby deep utilities (sewer pipes) are interpreted to not influence the pattern of local groundwater. Thus, the migration of groundwater with leachate would be governed by the natural pattern of flow.

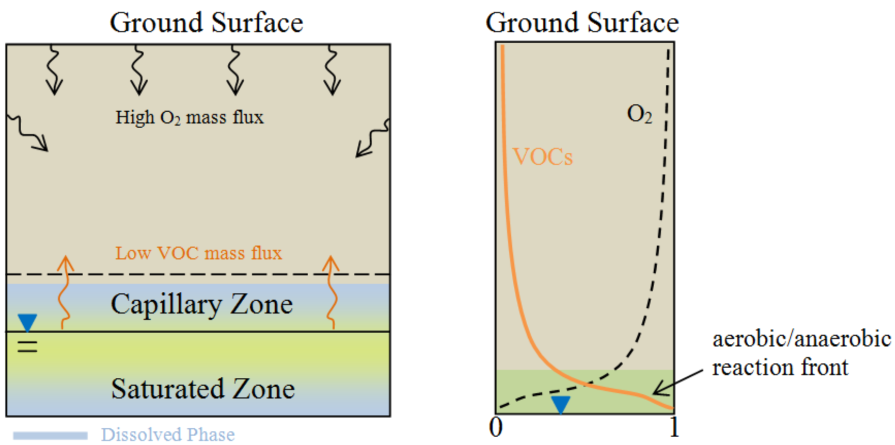
The 2013 August test results suggest the horizontal groundwater velocity may be estimated to be 3.2 m/year towards the east-southeast. The Red Deer River is about 580 m south-southeast, down-gradient of the Montfort Landfill Site. Indicators of landfill gas constituents are evident at soil vapour well at the base of the hill down gradient from the Montfort Landfill Site. At the time of preparation of this ERMP, Tiamat is not aware of a direct adverse effect to The Red Deer River from either LFG or leachate from the Montfort Landfill.

2.2 Soil Vapour

The concentrations of combustible and volatile LFG measured by field instrumentation during the 2013 August testing event did not exceed 2,500 ppm. Laboratory results from discrete samples of soil vapour showed concentration of methane ranging from 6 ppm to 23.6% v/v. In addition, laboratory results also showed a variety of VOCs with concentrations ranging from sub-ppb to 1.9 ppm. The chemical groups of the VOCs measured include aliphatics, aromatics, chlorinated, non-chlorinated, alcohols, oxygenated and ketone compounds. Of the 39 VOCs identified, six chemical compounds or about 15% of the identified VOCs are a known carcinogen and an additional six are ranked as possible carcinogens. There was no distinctive pattern of distribution of the measured LFG at the test locations. The variety of chemical types (such as VOCs including the presence of various siloxanes) was noted and clearly indicates the presence of landfill soil gas.

Aside from soil landfill gas, other potential sources of indoor air vapour intrusion include radon gas, petroleum hydrocarbons and other refined petroleum solvents (chlorinated and non-chlorinated). The presence, fate and movement of these various chemical vapours vary substantially in an unsaturated zone. These boundary conditions can influence their respective persistence in the subsurface and the risk of intrusion into a building envelope. For this project, other potential sources and types of volatile soil vapours are not evaluated.

A general conceptualized illustration of volatile organic compounds (VOCs) in the unsaturated zone along with potential naturally occurring attenuating oxygenated influences is depicted below.



The fundamentals to understanding the basic composition of soil vapour can typically be determined with a reliable level of certainty. Once the chemical identification of particular constituents in soil vapour is complete, the physical properties of each compound can be developed and/or compiled from existing chemical abstracts and databases. The predictive movement for the cause and effect (fate) of soil gas involves numerous factors of varying complexity. Thus, definitive conclusions for the behaviour of subsurface soil gas to impact a building envelope are currently limited to a semi-empirical estimation based on available technical information, professional experience and judgement.

Currently, numeric models to predict transient subsurface soil gas concentrations from a point source are complex. Thus, parameterizing a potential non-point source scenario for this project with the available data will include significant uncertainties and the output results would not be considered reliable.

To evaluate whether the potential attenuation of some soil gas constituents is occurring at a specific development would require an on-site specific evaluation. This level of assessment for the soil landfill gas encountered at the Montfort Landfill Site would require a rigorous seasonal testing program. Attenuation of a specified soil gas constituent can be indicated by observing the reduction of the concentration of the contaminant chemical in a subsurface plume as it migrates from the source area. Physical factors affecting the attenuation of an identified chemical contaminant in a soil gas plume include, in no order of priority and not an exhaustive list:

- Vertical and horizontal separation of the receptor building relative to the source;
- Range of fluctuation, gradient and depth to groundwater;
- Preferential subsurface pathways for soil gas migration and points of ingress (POIs) into a building; and
- Seasonal climatic effect from temperatures of air and soil, wind, precipitation and barometric pressure.

Chemical attributes influencing the attenuation of soil vapour constituents include:

- Rate of bio-attenuation which is affected by biological (nature and type of microbial activity) processes;
- Availability of subsurface oxygen;
- Soil moisture content and fraction of organic carbon; and
- Vapour pressure and vapour density of the soil gas constituent.

The collection of data to determine an attenuation factor for specified contaminant chemicals of concern and whether a chemical interaction exists is a complex and expensive series of tasks and (typically) the results would likely be of limited usefulness for this project. Hence, natural attenuation factors can be inherently difficult to evaluate and conservatively for this project, attenuation of the soil landfill gas has been not been considered in the calculations for the PQRA.

2.3 Exposure Pathways

Presently, the land uses adjacent to and lying within the 300 m regulatory setback to the Montfort Landfill Site comprises of the following:

Adjacent land uses:

- Detached single family homes with basements:
- Single storey multi-family apartments (Red Deer Village Apartments and Village Park Estates);
- Multi-storey condominiums (The View at St. Joseph and Montfort Heights); and

- Institutional office (Montfort Centre Red Deer Catholic Regional School)

Nearby land uses:

- Municipal green spaces, roads, underground utilities;
- Utility facility (Telus communication tower, 102 Hermary Street)
- Detached single family homes with basements; and
- Retail shopping mall (Village Mall)

The most sensitive potential receptors to contaminants from the Montfort Landfill Site are the residential homes and underground structures (basements, manholes, buried vaults) adjacent to the historic waste material.

Soil Vapours

It is possible that subsurface soil vapour may be present adjacent to and underneath the building footprints on properties adjacent to the Montfort Landfill Site, including detached homes along the portions of Hermary Street and Hill Crescent, Red Deer Village and Village Park Estates apartment units, Montfort Heights and Montfort Centre which back onto the landfill site. Soil vapours may migrate into the building by way of cracks and joints in the floor and basement foundation walls that serve as point-of-ingress (POIs). It is understood houses near the historic waste material have a basement. Tiamat has not determined whether a basement is present at the noted apartments and condominium facilities.

Subsurface soil gas may migrate to near-by residences. The exposure pathway for vapour inhalation via vapour intrusion mechanisms is always considered to human health. Based on the laboratory results and field observations, there is a potential for elevated soil gas to migrate to the residential properties located to the north and west. The August 2013 data and laboratory results for groundwater suggest the degree of saturation is low to moderate and the potential for groundwater to degas and contribute to the soil gas is proportionately considered to be low to moderate. It is recognized this condition may change during frozen ground conditions.

Groundwater

The dissolved organic hydrocarbons measured in the groundwater during the summer 2013 sampling event presents an environmental concern for general water quality objectives. Presently, local groundwater is not utilized. However, the policy of ESRD is to protect all water resources and guidance for managing contaminated groundwater in Alberta is applied using a risk-based approach.

The results from the Phase II ESA demonstrate a mild to moderate level of leachate parameters has adversely impacted the local groundwater; which is likely leaving the site. There is a minor potential for specific leachate constituents which are denser than water to impact an underlying aquifer; specifically, 1,4-dichlorobenzene, tetrachlorethene, tetrachlorethene, trichloroethene and vinyl chloride. The measured concentrations of these DNAPLs exceed the referenced Tier 1 Guidelines for coarse-grained soil in a residential/parkland setting.

Soil Contamination

Given the depth to the zone of impact, direct contact, by local residents, with the impacted soil underlying the waste material is considered to be practically negligible. Direct contact with impacted soil and groundwater may be possible by excavation contractors involved with maintenance and construction activities relating to buried utilities within the area of concern. In service buried utilities include natural gas along the west margin of the landfill and municipal utilities beneath 52 Avenue bounding the east side of the landfill.

Presently, an abandoned asbestos cement water main is parallel to the south margin of the Montfort Landfill Site. Contractors intending to work at this waste site should be informed and made aware of the potential hazards and implement an appropriate safe work (ECO, environmental construction operations) plan.

3.0 ENVIRONMENTAL RISK ASSESSMENT

The use of various risk assessment tools is a common practice to decision making in professional practice. For this discussion, an evaluation of risk is a systematic process involving the identification and evaluation of hazards, exposures and receptors with specific focus to its associated vulnerabilities with consideration of the likelihood for an adverse effect to occur. In general, a risk assessment is a tool to assist decision makers to manage the potential risk(s) for an adverse effect from an exposure to an identified hazard.

The reliability of the results from a risk assessment is contingent upon a certain amount of information. Consequently, a natural impediment for a risk assessment can arise from data gap(s) and uncertainties associated with available information. A Factor of Safety or amplification factor is typically applied with professional judgement to compensate for the uncertainties and data gaps.

Consideration of the available data and resources for this project, a preliminary quantitative risk assessment (PQRA) is viewed as an acceptable approach to conducting a risk assessment to support a site-specific environmental risk management plan. The PQRA strikes a balance between a simple qualitative (highly subjective) risk screening process and a detailed quantitative environmental risk assessment. Generally, the degree of reliability, accuracy and defensible quantification of identified risks improves as the level of uncertainty diminishes from a subjective risk assessment to a quantitative model.

The PQRA may be viewed as a working model that can be further developed into a site-specific quantitative risk assessment. In essence, a PQRA can be directly developed into a site-specific quantitative risk assessment by incorporating more extensive physical data and more complex algorithms in the risk model.

The PQRA applied for this project utilizes prescribed methods to ensure exposures and the assessed risks are not underestimated. Hence, when a risk outcome is deemed negligible then the actual site risk would most likely be presented as negligible. Contrary, when a PQRA shows a potential for an unacceptable level of risk, the actual site risk may be unacceptable or it may require further additional assessment to address the conservatism and uncertainty in the PQRA process such that the specific risk can be better understood and quantified.

At the Montfort Landfill Site, subdivision development involving residential land use is predominant and given the current zoning, the 300 m regulatory setback lies within areas of residential and commercial lands, refer to Figure 1. The potential receptor attributes input to the PQRA for the various land uses and activities associated with utility infrastructures, are outlined below:

- Residential is a primary activity of the property and includes detached houses and multi-family buildings (side-by-side, condominiums/apartments) and buildings with a residing janitor or custodian.

  Default exposure assumptions for adults and children are 32.9 kg child over 5 years old, 70.7 kg adult over 20 years old, inhalation rate 16.6 m^3/day for an adult and 14.5 m^3/day for a child, total annual exposure 24 hours a day, 365 days/year for a 80 year residence time.

- Non-residential Institutional includes school and hospitals. 70.7 kg adult over 20 years old, inhalation rate 16.6 m^3/day for an adult and 14.5 m^3/day for a child, total annual exposure 8 hours a day, 5 days a week for 52 weeks/year for a 35 year period of employment for workers and 12 years for students.

Other potential land developments which are not addressed by Section 13 of AB Reg. 43/2002 such as retail and light commercial activities and the installation and maintenance of underground utilities would also be subject to potential exposure. Thus, for other retail and light commercial activities the above attributes for non-residential activities and an additional group subject to potential exposure to remote soil landfill vapours is:

- Non-residential Commercial can include a diverse range of activities and land uses including low sensitive uses including warehousing, secured unsheltered storage yard, service station and more sensitive uses such as day care centre and medical clinic. Default exposure assumptions are 32.9 kg child over 5 years old, 70.7 kg adult worker over 20 years old, inhalation rate 14.5 m^3/day for a child and 16.6 m^3/day for an adult worker, total annual exposure 8 hours a day, 5 days a week for 52 weeks/year for a 35 year period of employment. Exposure for an adult worker is deemed to be the governing scenario on the basis of exposure time.

- Construction/Utility Worker at construction sites with exposure to soil gas, not including exposure to any other site-specific chemicals. Default exposure assumptions for workers are 70.7 kg adult, inhalation rate 1.4 m^3/hr for an adult worker, total annual exposure 10 hours/day, 5 days a week for 48 weeks/year for a 35 year period of employment.

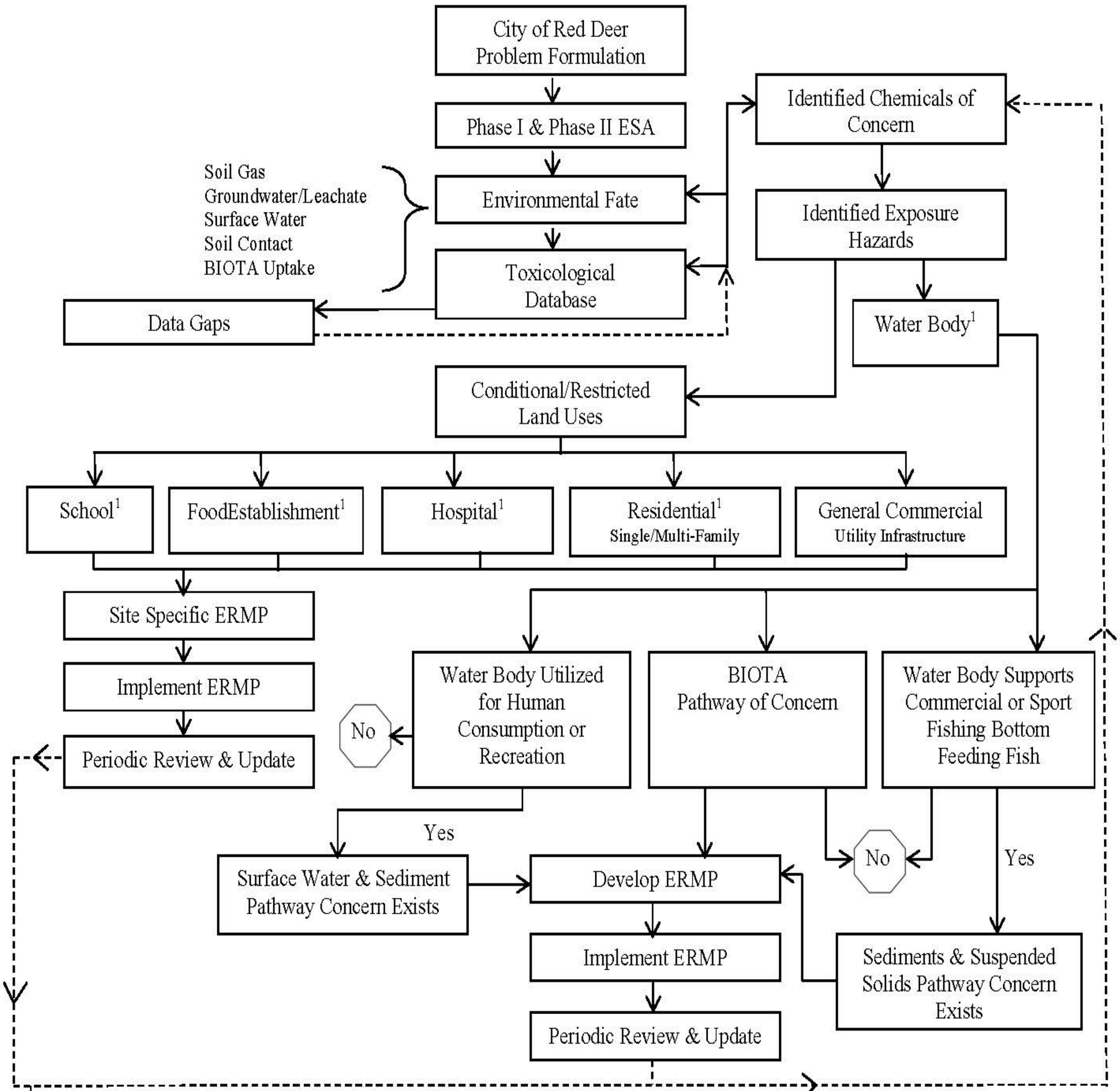
In general, the above exposure settings and the applied attributes are intended to yield a conservative outcome such that the real-case exposure situation would be expected to not be more than the model parameters for the given specified hazard. It is acknowledged the Health Canada protocol for employment time (35 years) may not be reflective of the majority of situations. Regardless, this a look-to-exempt approach, meaning that if a single HQ outcome is greater than 1 in a scenario, then a mitigative requirement is identified. With receptors being "off-site" relative to the Montfort Landfill Site, the inhalation route to a volatile chemical via vapour intrusion becomes the greatest potential concern for exposure by an occupant in a building. Leachate from the site may also degas VOCs into the subsurface thereby contributing to the subsurface soil gas.

Health effect(s) are contingent on a variety of factors including level, duration and frequency of exposure, toxicity of the chemical and individual sensitivity to the chemical. The principal concern for this PQRA is whether the identified chemicals of concern potentially pose an unacceptable level of risk for chronic health effects due to a long-term, low concentration exposure scenario.

It is recognized, the PQRA presented herein is conducted with numerous assumptions and limitations. Consequently, this PQRA should not be viewed as a comprehensive analysis for any particular property lying within the prescribed distances from the Montfort Landfill Site As noted above, the PQRA is a standardized approach developed by Health Canada, and for this project, the PQRA is intended to be utilized to support the regulatory review process for subdivision applications which fall into the regulatory framework of AB Reg. 43/2002 and other potential general commercial development and utility activities lying within the prescribed setback distance for the Montfort Landfill Site.

The diagram below illustrates the process to formulate the risk assessment process to assist with the regulatory review process for future redevelopment within the prescribed regulatory setback distance of the Montfort Landfill Site.

Process of Developing ERMP
Montfort Landfill Site



[1] As defined in relevant Alberta statues and regulations.

3.1 Identified Environmental Health Concerns

The environmental health risks presented by this historic waste site to the existing and future developments is primarily from landfill soil gas and to a lesser degree from volatile constituents that degas from leachate leaving the historic waste site into the unsaturated zone above the groundwater table.

As noted in the 2014 Phase II ESA, the age of this non-operating landfill (about 47 years) suggests the production and quantity of landfill gas may have peaked and/or stabilized. It is also noted, the initial assessment for soil vapour occurred during the summer and higher subsurface concentrations may result during the winter, in frozen ground conditions. In general, the potential risk of exposure to soil vapours increases during frozen ground conditions.

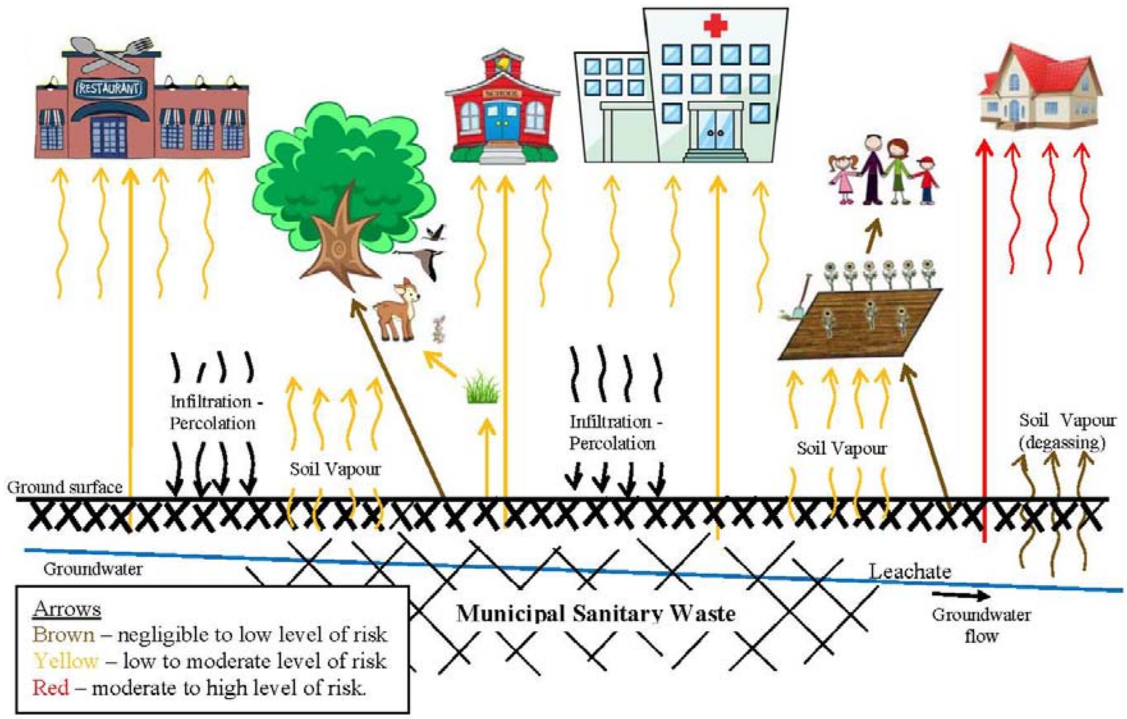
As noted in Section 1.3, the principal environmental health concerns arising from the Montfort Landfill Site which pose a risk to adjacent and nearby properties are LFG and leachate. The results from the Phase II ESA clearly characterizes the composition of the LFG. About one third of the chemical compounds measured in the LFG samples were noted to be either classified as known or suspected carcinogens. The fractional volume bulk of the LFG composed of methane was about 24%. The intermediate receptors (buildings and buried utilities) adjacent to the Montfort Landfill Site are identified to be at risk from the LFG.

Concerning leachate from the Montfort Landfill Site, the results from the Phase II ESA indicate the local groundwater exhibits typical inorganic and nutrient attributes indicative of landfill leachate. Furthermore, several dissolved petroleum and petro-chemical derivative compounds (VOCs) exceeding the Alberta Tier 1 Guidelines for coarse grained soil in a residential/parkland setting was encountered at the interpreted down gradient test location. As discussed in Section 2.1, the natural movement of groundwater across the Montfort Landfill Site is anticipated to have a flow pattern towards the crest of the hill overlooking the river valley and then descending along the hill slope to the base of the river valley. The leachate in the groundwater has the potential to off gas as it migrates in the subsurface. The off-gassing will contribute to the plume of LFG. This soil vapour poses an environmental health risk to buildings adjacent to the site and to buildings and structures situated along the direction of groundwater flow.

At its closest approach, the Red Deer River is about 580 m south-southeast from the down gradient margin of the historic landfill. Presently, there is no information available describing whether the water quality of the river has been affected by the impacted groundwater at the Montfort Landfill Site. Further investigation would be required to better understand the velocities and pattern of groundwater flow.

In general, the risks associated with soil vapour and leachate to land that is off-site of the historic waste disposal site is the focus of protection by AB Reg. 43/2002. To demonstrate the complete soil vapour intrusion pathways for this project, a source, various migration routes and receptors are shown in the pictograph below.

Pictograph Depicting Potential Environmental Exposure Hazards of Soil Vapour Intrusion At Land Uses Near Historic Waste Disposal Sites



3.2 Boundary Conditions for PQRA

The logistical boundary for the PQRA is the 300 m regulatory setback distance shown on Figure 1. The existing residential homes and buildings (circa 1980s) lying within the regulatory setback are presumed to predate AB Reg 43/2002.

Temporal factors (seasonal climate conditions, weather, and natural disasters) can influence the level and duration of exposure. Should data be insufficient to extrapolate the temporal variation; then when necessary, a reasonable conservative assumption(s) can be applied. Critically, it is important to identify the most sensitive temporal factor(s) and consider the potential maximum and minimum fluctuations and its impact to the outcome of the risk model. Accordingly, an extreme temporal event may warrant a special exposure consideration for the ERMP. This may be considered in a future iteration of the PQRA model with inclusion of appropriate climate change adaptation factors.

3.2.1 Hazard Assessment

For this PQRA, the chemicals of concern identified from the Phase II ESA form the basis of the list of target chemicals. The chemicals of concern are summarised in Table 2A. It should be noted, this list should be viewed as an interim/provisional list. Additional chemicals may be added as new information from future testing becomes available.

A database for the identified chemicals of concern has been compiled, refer to Table 2B. Additionally, a brief abstract of each identified chemical of concern is provided in Appendix B. For consistency, physical, chemical and toxicological information was referenced from Canadian sources. It is recognized some Canadian sources do not update the chemical information as frequently as other countries. However, in many instances the values published in Canadian sources are commonly obtained from American agencies, the World Health Organization and some European countries. To maintain an updated PQRA for the Montfort Landfill Site, the toxicological information applied in this PQRA should be periodically reviewed and updated.

3.2.2 Exposure Assessment

The historic waste disposal site is viewed as the source of the identified chemicals. As noted in Section 1.4, the location of the waste materials remains fixed and no further mitigative actions are planned. Consequently, the potential exposure pathways consist of the following in order of lowest to highest priority:

- Biotic uptake (plants, terrestrial animals, aquatic life).
- Dermal contact, soil ingestion and ponded water at the waste disposal site.
- Groundwater migration pathway.
- Unsaturated zone above the local groundwater table.
- Inhalation of landfill soil gas.

The calculated hazard quotient (HQ) is a risk estimate determined from the ratio of the estimated concentration in an environmental medium (air) and the toxicological reference value (TRV) or tolerable concentration for an identified chemical of concern.

3.2.3 Receptor Characterization

The historic waste disposal site is viewed as the source of the identified chemicals. As noted in Section 1.4, the location of the waste materials remains fixed and the City applies administrative controls to prevent development of occupied buildings within the area of the historic waste material. Consequently, the potential receptors consist of the following in order of lowest to highest priority:

- The Red Deer River.
- Biotic factors (plants, terrestrial animals, aquatic life).
- Workers engaged with ground disturbance activities within the prescribed historic waste disposal areas.
- People in occupied buildings including future buildings located adjacent to, down gradient of and in proximity to, the Montfort Landfill Site.

3.2.4 Risk Characterization

Toxicological parameters for the identified chemicals of concern and receptor characteristics were applied to determine a Hazard Quotient (HQ). A calculated HQ less than 1 (one) suggests the estimated potential exposure is below the TRV and the corresponding health risk to an exposed person would be negligible for this specific exposure pathway. When the HQ is greater than 1, the potential rate of exposure is predicted to exceed the established acceptable level of exposure thereby warranting a mitigative or adaptive protective requirement.

The inhalation of volatile chemical vapours by humans is quantitatively predicted by:

$$\text{Dose (mg/kg bw/day)} = \frac{C_A \times IR_A \times RAF_{Inh} \times D_1 \times D_2 \times D_3 \times D_4}{\text{BW} \times \text{LE}}$$

Where:
C_A = concentration of contaminant in air (mg/m^3)
IR_A = receptor air intake (inhalation) rate (m^3/day)
RAF_{Inh} = relative absorption factor for inhalation (unitless)
D_1 = hours per week exposed/24 hours
D_2 = days per week exposed/7 days
D_3 = weeks per year exposed/52 weeks
D_4 = total years exposed to site (to be employed for assessment of carcinogens only)
BW = body weight (kg)
LE = life expectancy (years) (to be employed for assessment of carcinogens only)

By definition, the HQ is the ratio of the estimated dose to the tolerable daily intake for a specific chemical of concern. Thus as illustrated in the equation above, an HQ value is directly proportional to the exposure concentration for a specific chemical or compound. For example, should the concentration of a chemical of concern decrease over time and the other exposure variables are unchanged, the corresponding HQ value will decrease proportionally.

3.2.5 Potential Municipal Administrative Controls

In the event physical controls to prevent or minimize the intrusion of LFG into a building are not feasible as a retrofit to an existing structure or a proposed building, the City may consider other interim or permanent institutional/administrative measures. These legal measures can include bylaw zoning conditions, restrictive covenants on land title and land use advisories.

4.0 CONCEPTUAL SITE MODEL (CSM)

A conceptual site model (CSM) has been developed to broadly identify the environmental concerns associated with the historic waste site. This CSM is a simplified representation of the identified chemicals of concern, the potential routes for contaminant migration and potential exposures. These various routes of migration and potential exposures are assessed to qualitatively develop the potential settings for risk (environmental liability). The reader should note, this CSM is preliminary in nature and is limited by the initial information compiled from the results of the 2014 Phase II ESA.

The CSM is applied to complete the PQRA. The CSM should be viewed as dynamic and be updated as additional site information becomes available. This information is solely to assist with the development of the site-specific ERMP.

To provide an overview of the contaminant situation, an initial CSM consists of bridging the identified chemicals of concern to the following two main pathways of exposure:

1. Pathways for contaminant migration; and
2. Pathways for exposure.

The migration pathway is illustrated by schematic cross sections. The cross sections are developed by integrating information from borehole logs, measured groundwater levels, measured groundwater indices and laboratory results. As shown on Figure 2, the selected cross sections transect the site in two directions, in the interpreted direction of local groundwater flow and traversing the flow direction. The interpreted cross sections are presented as Figure 3.

The primary contaminant transport pathways are described as follows:

- Lateral transport of dissolved volatile compounds in the groundwater passing through the waste material.
- Natural degradation process and the volatilization/degassing of dissolved hydrocarbon constituents from groundwater and from hydrocarbons sorbed onto soil particles which can contribute to subsurface soil vapour.

- Plume of soil vapour, which, pending several physical and temporal factors, can migrate primarily through the porous media via natural advection and diffusion processes to building envelops and buried utilities. It is noted lateral migration could be influence by the heterogeneity of the observed texture of subsurface soil (units of silt, sand, clay and gravel).

- The test results for soil vapours are interpreted to be significant as measured during the August 2013 test event. Presently, there is no site data for a winter condition. The lateral extent of the soil vapours may extend off-site onto third party properties, such as the adjacent condominiums, residential lots, Montfort Centre, utilities beneath 52 Avenue and nearby apartments and condominiums, refer to Figure 1.

4.1 Contaminant Fate and Transport

Contaminant fate and transport refers to the way a substance travels through various environmental mediums. The following is a general description for groundwater and the principal hydrochemical processes associated with subsurface contaminants impacting groundwater.

Convection

Convection is the mechanism of transport by diffusion and advection. The generation and quantity of landfill soil gas is presumed to have peaked and/or stabilized at the Montfort Landfill Site. The most heavily impacted area for contaminants was observed in the south central portion of the landfill site, where subsurface petroleum hydrocarbons (phase separate oily liquid substance and moderate hydrocarbon odours) were encountered. As reported in the 2014 Phase II ESA, the analytical test results show the composition of soil vapour includes volatile and semi-volatile petroleum hydrocarbon compounds.

Landfill soil gas may migrate slowly from an area of high concentration to regions of lower concentration. Preferential venting to atmosphere likely occurs during the summer. Exposure to volatile vapours exhibiting a specific gravity that is higher than air is generally low. For leachate, the transport process by advection is more rapid than diffusion as substances are usually transported via the bulk motion of groundwater to down gradient areas. In some instances, a dissolved plume can migrate at a rate exceeding the flow of groundwater.

Dispersion

The relative concentration of LFG in the soil and the groundwater measured in August 2013 are interpreted to be moderate. This result may be influenced by natural venting to the atmosphere during the summer test event. Accordingly, a dispersion mechanism is likely a notable factor when conditions prevent the natural venting of LFG to the atmosphere. Consequently, during frozen ground condition, LFG will likely accumulate in the subsurface and intermix with the impacted groundwater containing dissolved LFG compounds. In summary, advective dispersion for the LFG is anticipated to be notable.

On the basis of the historic aging (about five decades) of the identified waste and the reported composition of the LFG including six volatile carcinogenic compounds encountered during the 2014 Phase II ESA, the strength and quantity of LFG may become significant when frozen ground conditions occur. To our knowledge, there is no natural barrier between the source of the LFG and the nearest buildings (existing adjacent housing along the relevant section of Hermary Street, Montfort Centre and Montfort Heights). The seasonal winters and the resulting frozen ground condition may amplify the risk for LFG to adversely impact the adjacent and nearby underground utilities and buildings. Discrete building assessments should be considered to better evaluate the environmental health risk. This type of assessment program should include identification of unique confounders, temporal, spatial, climatic and seasonal factors.

Natural Attenuation

Natural bio-chemical and geochemical occurring processes can be effective in reducing the toxicity of organic contaminants in the soil and groundwater. Several factors affecting the efficiency and effectiveness of natural attenuation processes are typically monitored as a method to assess the natural biodegradation/remediation. Some factors for natural attenuation include:

- Mineral precipitation.
- Absorption – fluid permeates or dissolved by liquid or solid.
- Adsorption – formation of gas or liquid film on solid surface.
- Biological Uptake – transfer of substances from environment to plants, animals and humans.
- Microbiological - biodegradation phenomena where the contaminant constituents are completely mineralized with end products of carbon dioxide and water.

It is noted natural attenuation processes are likely occurring at the site. An example of the dechlorination reduction of cis-1,2-Dichloroethylene can be summarized as: DCE → Vinyl Chloride (VC) → Ethane. These individual compounds have been detected in the groundwater at the site.

4.1.1 Volatile Organic Compounds in Soil

BTEX compounds were not present in a soil sample underlying the waste material. A trace concentration of cis-1,2-dichloroethene, p-isopropyltoluene and tetrachlorethene were noted and are not considered to be at a significant concentration. In general the soil quality underlying the historic waste material appears to be relatively acceptable.

4.1.2 Volatile Organic Compounds in Groundwater

VOCs were detected in the groundwater samples. Concentrations of dissolved benzene, ethylbenzene, 1,4-dichlorobenzene, tetrachlorethene, trichloroethene and vinyl chloride exceed the referenced Tier 1 Guidelines. It is uncertain whether this initial test result is indicative of the environmental quality of the local groundwater. Nonetheless, a variety of dissolved VOCs (classified as LNAPL and DNAPL type chemical compounds) are present in the local groundwater. Additional testing would be necessary to better understand the quality of the local groundwater leaving the site.

4.1.3 Combustible Headspace Vapours

Combustible headspace vapour readings from the groundwater monitoring wells ranged from 15 to 2,500 ppm during field tests performed on August 7 and 8, 2013. The highest volatile vapours (5 ppm) were measured at vapour well VW-04 and VW-05 near the southeast and southwest corners of the site, respectively. A test event during frozen ground conditions would reveal the potential range of variance for the landfill soil gas along the perimeter of the waste area.

4.1.4 Lateral Transport of Groundwater

Local groundwater beneath the site and the nearby areas is interpreted to be in an unconfined condition within a zone of recharge (downward flow gradient). The mapping of the groundwater elevations and the dissolved compounds in the groundwater suggest the groundwater to flow to the southeast. The lateral migration of groundwater is one mechanism for the distribution of dissolved organic compounds and constituents of leachate, specifically ammonia, sulphates, chlorides and nitrates. The horizontal gradient is estimated to be between 0.4% to 1.1% across the site and the calculated horizontal velocity of the groundwater is about 3.2 m/year.

This suggests the groundwater with leachate will likely leave the site onto third party property that lies east, south and southeast of the Montfort Landfill Site.

4.1.5 Volatilization and Vapour Migration from Impacted Soil and Groundwater

The presence of various volatile organic compounds and methane are the primary components in LFG. Typically, under an equilibrium condition, the relative density of soil vapour would exhibit a vertical concentration gradient. Thus, it is expected the soil vapour pattern would exhibit an increasing concentration with depth and proximity to the groundwater table.

The site information has been reviewed by Tiamat along with consideration of the relative age (47 years) of the waste material at this site. Vapour measurements at the on-site borehole locations indicate detectable soil vapours are present but are relatively mild and are not presently a significant concern to users of the park. The Phase II ESA shows some soil gases to have a relative density that is less than air and will tend to rise from the subsurface via various pathways and vent to the atmosphere. Other types of soil gases encountered during the Phase II ESA have a relative density that is greater than air. These types of soil gases will tend to migrate in the subsurface along the direction of groundwater. In general, subsurface LFG may accumulate beneath the zone of near surface ground that becomes frozen. Consequently, during a winter period, a heated building will exhibit a thermal and pressure differential relative to the cooler exterior environment which will likely draw the LFG to the building foundation resulting with a risk for potential exposure.

Physical factors influencing the distribution of soil vapours include moisture content, soil texture and the chemical attributes of the contaminants of concern. Soil gas also has a tendency to migrate along pathways of less resistance, including permeable pathways and/or fractures in soil sediments.

Attenuation factors include biodegradation process at the subsurface aerobic/anaerobic interface; refer to illustration in Section 2.2, and the availability of dissolved oxygen. Attenuation can also occur from the vertical and longitudinal separation between source(s) of dissolved VOCs and a building envelope and preferential flow paths. There is a significant knowledge base demonstrating aerobic based biodegradation of VOCs is the dominant mechanism for subsurface attenuation. Ideally, a site-specific test would be necessary to assess the seasonal variability of volatile soil vapour and its propensity to biodegrade within a specific soil texture, moisture regime and availability of oxygen. The relative small footprint of the Montfort Landfill Site is deemed to not warrant the costs to conduct such an evaluation. Conservatively, for this initial ERMP, no attenuating factors have been considered to reduce the potential concentration of the soil vapour constituents.

4.2 Summary of CSM

An initial interpretation of the subsurface stratigraphy, derived from borehole information, is presented as Figure 3. There is insufficient data to map landfill soil gas or the leachate beyond the boundaries of the Montfort Landfill Site. A summary of the identified pathways and receptors at risk by the landfill soil gas and the leachate are as follows.

Groundwater Pathway

Groundwater lies at an average depth of 3.4 m below the ground surface with a downward hydraulic gradient. The groundwater table exhibits a gentle gradient of about 4 to 11 mm/m to the southeast. To our knowledge, groundwater is not utilized at locations down gradient of the waste material.

The soil cover over the waste material appears to be a thin (less than 30 cm) veneer of organic loam. Differential and irregular settlement of the underlying waste material and soil is clearly evident in specific areas of the park overlying the historic waste material. The irregular surface topography hampers the ability of previous surface grading to divert surface water from the waste material. Furthermore, the loamy sand soil cover is interpreted to allow surface water to infiltrate and percolate into the waste material generating leachate.

Vapour Pathway

There is no information concerning soil vapour intrusion/nuisance into nearby buildings from the contaminants identified at the site. Concentrations of combustible vapours measured at off-site wells ranged from 15 to 2,500 ppm in August 2013.

The pervious nature of the soil lying in the unsaturated zone will limit its effectiveness to minimize the lateral migration of the soil gas.

Soil Contact Pathway

The historic waste area has been transformed into a public park area including two baseball diamonds. The potential for visitors to contact the underlying waste is considered low. Pets and burrowing animals may disturb the relatively soft, loose and thin soil cover and the potential to expose the underlying waste exists.

Biotic Pathway

To our knowledge, there have been no notable adverse effects to the local flora and fauna located in the vicinity of the site. At this time, there is no obvious concern for food chain transfer or plant uptake leading a potential adverse situation or an environmental concern.

Environmental Receptors

Accordingly, the risk for the human exposure pathway due to the pervious soil cover is considered (qualitatively) to be of medium to medium-high. Nevertheless, there will be a level of risk to soil contact and inhalation should future construction or re-development activities occur to a depth of 4.5 m, more or less; or from an existing average ground elevation 879 m geodetic at or adjacent to the Montfort Landfill Site.

Existing and potential future developments adjacent and in the vicinity (within the prescribed 300 m regulatory setback) of the Montfort Landfill Site are interpreted to be at some measure of environmental health risk. This is characterised by the results from the Phase II ESA which confirm the following factors applicable at the Montfort Landfill Site:

- The pervious nature of the soil cover which caps the historic waste material at the Montfort Landfill Site is not anticipated to effectively prevent the generation of leachate as seasonal precipitation infiltrates into the underlying waste material. Similarly, the sand and silt underlying the waste material is deemed to be relatively porous to the movement of leachate and groundwater.

- This leachate will intermix and contaminate the local groundwater as it enters onto the Montfort Landfill from the west-northwest with a flow pattern across the site to the southeast.

- The groundwater measured in August 2013 at test locations at the Montfort Landfill Site and near Gaetz Avenue and the intersection at 60 Street shows the local pattern of groundwater to migrate towards the southeast. This groundwater pattern flows down the hill slope and beneath Gaetz Avenue towards the Red Deer River, as shown on Figure 4.

- Analytical results from groundwater monitoring wells at the Montfort Landfill Site show concentrations of various dissolved VOCs exceeding the referenced Alberta Tier 1 Guidelines for coarse grained soil in a residential/park land setting.

- Analytical results from dedicated soil vapour monitoring wells at the Montfort Landfill Site and at a location downhill adjacent to Gaetz Avenue show concentrations of various VOCs.

- Dissolved VOCs in the groundwater will degas into the subsurface as the groundwater migrates on its natural path.

- VOCs with a relative density that is less than air will tend to rise in the subsurface and vent to atmosphere during period of unfrozen ground. Conversely, VOCs with a relative density that is greater than air will tend to migrate with the flow of groundwater.

- Buildings and structures are vulnerable to the ingress of subsurface LFG. The greatest risk for potential ingress is during winter periods when buildings are typically predominantly sealed from the cold air and the pressure differential between the building interior and the exterior subsurface is greatest. Other climatic conditions (barometric pressure, temperature, wind velocity) will also influence the potential ingress of LFG into a building.

Since the Montfort Landfill is situated at the top of an escarpment which overlooks the Red Deer River Valley. Groundwater with leachate and dissolved VOCs will migrate along a natural flow pattern down this escarpment and approach the Red Deer River.

Therefore, the confirmed presence of LFG with notable carcinogenic compounds and concentrations have a potential to adversely impact the existing residential properties which bound the Montfort Landfill Site and properties which are interpreted to be down gradient relative to the Montfort Landfill Site. The down gradient properties are at the base of the hill slope north of 60 Street and west of Gaetz Avenue. The risk is a human exposure to the identified carcinogens (refer to Table 3A) in a low concentration long term exposure setting. The primary route of exposure from the identified chemicals of concern emanating from the Montfort Landfill Site is soil vapour intrusion.

Other Subsurface Contaminants

It is acknowledged that other subsurface contamination can originate from other source(s) which coincidently lie within the generic landfill setback distance and/or in proximity to a proposed subdivision and development application. This situation may present other unique risks and such situations will likely require a separate and independent environmental evaluation and consideration.

5.0 PROPOSED SITE-SPECIFIC ENVIRONMENTAL RISK MANAGEMENT PLAN

Soil vapour intrusion into enclosed buildings is well documented. Preferential pathways of least resistance and various POEs present in the building foundations are concerns for potential exposure and resulting potential impact to human health. Exposure to soil vapours typically arises from three scenarios:

1. Soil vapours may originate from volatile and semi-volatile organic compounds released into the subsurface.

2. Soil vapours may be sourced from specific inorganic compounds such as radon, hydrogen sulphide and elemental mercury.

3. Soil vapours degas in the subsurface from a dissolved state in groundwater.

In Canada, federal and provincial regulatory agencies have published vapour intrusion guidance information with an objective to educate and protect the environment and human health. Presently, there are no statutory requirements or regulations for soil vapour intrusion. Regulators address soil vapour intrusion on a case-by-case basis.

The elapsed time (about 47 years, more or less) for the landfill soil gas, the natural geochemical processes may have reached its limit steady-state and the degradation processes have likely stabilized with equilibrium conditions established.

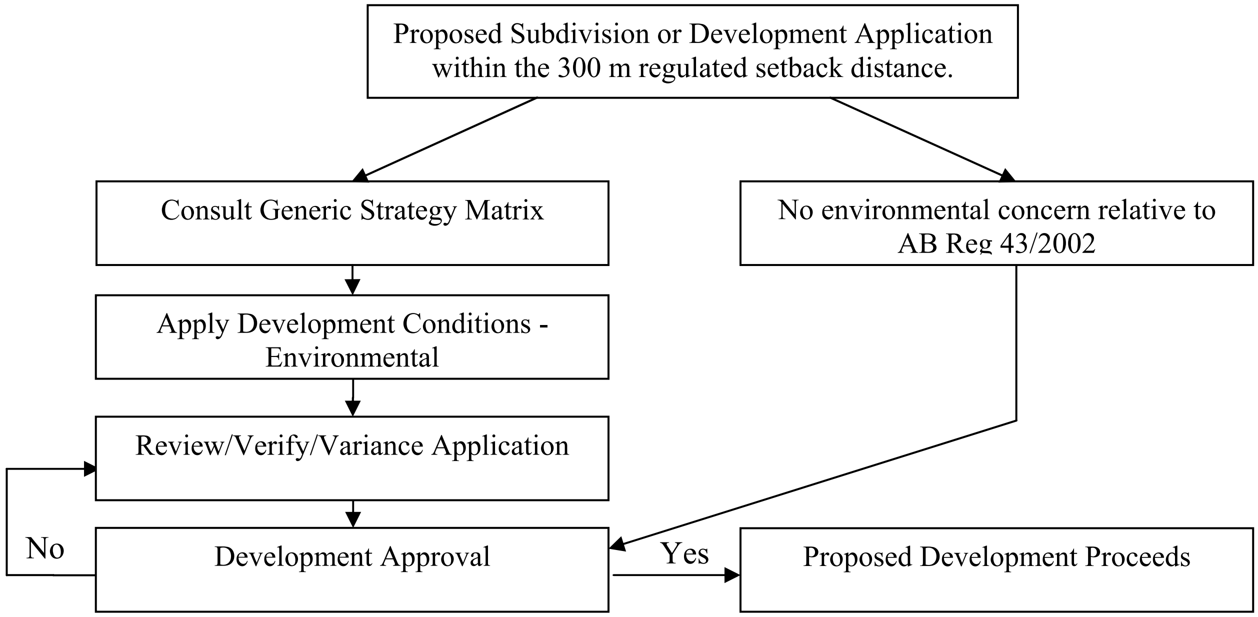
For the fully developed urban setting along with consideration of the potential hazards, the level of potential exposure and the potential receptors, a proposed site-specific environmental risk management plan (ERMP) is presented in this section. The proposed ERMP is a tool to assist with the review of future subdivision applications on lands lying within the regulated setback distance from the historic waste disposal site. The ERMP has considered the identified hazards from the historic waste disposal site for each of the four types of regulated land uses (school, food establishment, hospital and residential) as well as for land uses which are not provincially regulated, but fall within municipal discretionary review including general commercial developments and infrastructure utilities lying within the setback distance.

The proposed ERMP is intended to serve as a tool during the review process for a proposed subdivision and/or development application that is located within the regulatory setback distance. Presently, the general process for reviewing a subdivision or a development application involves City staff and/or The City's Municipal Planning Commission (MPC) who are variously responsible for regulatory review of an application. The MPC works with The City Planning Department and other municipal departments. Following approval of an application, The City's Inspections and Licensing Department issues various permits and monitors the conditions of approval. The onus is on the developer to ensure the requirements for regulatory compliance are met.

The proposed ERMP is consolidated into a spreadsheet format intended to assist the subdivision/development application review process and assist the municipality to respond in a timely and effective manner on applications involving the regulatory setback to this historic landfill. Where applicable, the risk management actions are presented in an objective-based format. This approach is to provide flexibility to the proponent for an application with minimal prescriptive restrictions to what and how environmental protective measures can be employed to provide the identified level of protection. Ultimately, responsibility for the specific mitigative measure(s) to effectively address the identified risk lies with the design professional that is acting on behalf of the proponent team for a proposed subdivision and/or development. It is anticipated site inspection during installation would become part of the verification process during construction.

An overview of the proposed process for the screening and review of subdivision development applications is presented in the flow chart below.

Flow Chart for Subdivision or Development Application Decision Review Process Near A Non-Operating Landfill School/Hospital/Food Establishment/Residential (as outlined by AB Reg. 43/2002)



The primary risks for the potential ingress of landfill soil gas are a result of the initial screening of identified chemicals of concern having a Hazard Quotient greater than 1.0. Residential type developments have been identified to be the most sensitive receptors. As such, to address uncertainties, a 10x amplification as a factor of safety has been applied in the PQRA with no attenuation factors. The amplification factor is subject to review and amendment when (and if) additional site-specific contaminant information becomes available. As additional site-specific information is evaluated into the PQRA, the uncertainties may also be reviewed and the level of conservatism may be adjusted or reduced.

The exposure ratings for the other types of land uses with enclosed buildings will generally be not more than the values for residential. Notwithstanding, other types of building developments such as school, public institutions and facilities for commercial use typically include higher performance HVAC systems with greater rates of air exchanges and lower periods of human occupancy. Unique exceptions to these generalities would need to be addressed on a specific case basis. The other noteworthy activity subject to worker exposure to potential landfill soil gas is the underground utility worker and the subsurface utility line; this includes public and private underground utilities.

The results of the risk characterization model as calculated values of HQ for the identified chemicals of concern are summarised in Tables 3A to 3E. The uncertainties and the conservatism applied for this initial PQRA have been incorporated into the baseline ERMP. Generally, a HQ value greater than 1 presents a level of risk requiring a level of mitigative and/or adaptive action. This broad-based approach is designed to improve the clarity and timeliness for the development application review process. It must be recognized and acknowledged, the proposed ERMP for the Montfort Landfill Site is an approach based on test results obtained from the Montfort Landfill Site. Extrapolations for potential environmental risks associated with leachate and landfill soil gas migrating from the historic waste disposal site have been factored into the proposed ERMP. In the event the City utilizes the proposed ERMP in whole or part, it is recommended, the City view the ERMP as a dynamic guide subject to periodic update, refer to Section 5.9.

It is acknowledged, an applicant may accept the protocols applied in this ERMP or choose to develop their own site-specific plan. In this event, it is recommended the applicant apply a similar assessment and testing methodology to ensure the results can be standardized and compared to the information presented herein. At the discretion of The City of Red Deer and in consultation with the Provincial Ministry, a blanket application of variance may be pursued to reduce the technical and administrative burden for site-specific variance applications.

The following subsections outline the suggested minimum strategy for the four stipulated types of subdivision developments identified in Part 2 Section 13, AB Reg. 43/2002 along with general commercial developments and activities associated with utility infrastructure. The strategies have been separated into three zones extending radially from the boundary of the Montfort Landfill Site (a non-operating historic waste disposal site); refer to Figure 1 for the approximate radial limits. It is impractical to envision all potential future land uses. In the event a future re-zoning occur within the prescribed setback and to adhere to the principal and intent of Section 13 AB Reg. 43/2002, this ERMP should be reviewed and, if required, updated with additional information to address proposed new land uses.

Each level of preventative/protective action is intended to prevent the ingress of landfill soil gas constituents into a building. The two general approaches to achieve this objective are:

1. Seal individual points of entries (POEs); or

2. Create a barrier to isolate/separate the building from the soil gas. The type of barrier may comprise of a liner material, a well vented air space, building pressurization or depressurization can each serve equally as a barrier to prevent vapour ingress.

Historically, either approach has been proven effective. There is a diverse range of engineered controls that can successfully satisfy a particular situation. The specifics for each are dependent on the considerations of the design professional working with a specific building configuration, chemicals of concern, subsurface conditions beneath the proposed building and other parameters and boundary conditions.

It is noted, many design standards have unclear prescriptive directions when the design professional is reviewing potential adverse impacts which may result from a known source of environmental pollution. The decisions to manage these potential impacts will include considerations (factor of safety) to address inherent uncertainties arising from subsurface conditions and the identified vulnerabilities for a proposed development and building/structure.

Consequently, in recognition of this and to provide flexibility to a development application, it is recommended in the event an applicant wishes to seek an alternative risk management solution, the existing site information requirements outlined by Alberta ESRD (copy provided in Appendix A) should be consulted.

Generic strategies for the land developments prescribed in Section 13 AB Reg. 43/2002 is divided into three lateral zones as measured from the boundary of the Montfort Landfill Site. In addition, other land uses not addressed in Section 13, namely other retail/commercial and utilities are included in the risk matrix. The various strategies are summarised in the table below and further details are discussed Sections 5.1 to 5.5. The recommended protocols for an ERMP for subsurface utilities are discussed in Section 5.6.

Proposed ERMP Strategies for Subdivision and Developments within 300 m of the Montfort Landfill Site

Distance From Boundary of Landfill	Residential	School/Hospital	Food Establishment	Other Retail/Commercial And Utility Infrastructure
0 – 100 m	Passive/Active	Passive/Active	Passive/Active	Passive/Active
100 – 200 m	Passive/Active	Passive	Passive	Passive
200 – 300 m	Passive	Passive	Passive	Passive

Notes:
1) Above applicable to buildings with or without basement.
2) NR – No requirement for potential soil vapour intrusion.
3) Passive and/or Active mitigative measures for other retail/commercial developments is dependent upon the actual configuration of the enclosed space and ventilation system.

Tables 3A to 3E show the calculated HQ values for other land development uses including residential (Table 3A), food establishment (Table 3B), public institutions including schools and hospitals (Table 3C). Tables 3D and 3E outline HQ values for other commercial developments and for workers in construction and maintenance for underground utility infrastructure respectively. Calculated values for HQ are based solely on receptor variables provided from Health Canada's PQRA

As shown in Table 3A, the exposure outcome for residential land use appears to be the scenario exhibiting the highest sensitivity for a receptor to soil vapours. Specifically, chloromethane, vinyl chloride, trichloroethylene, tetrachloroethylene and benzene measured in soil vapour at the site appear to be the carcinogenic chemicals of concern identified from the Phase II ESA.

Accordingly, the calculated values of HQ for the following carcinogenic chemicals: chloromethane, vinyl chloride, trichloroethylene, tetrachloroethylene and benzene are 56.6, 867.3, 445.8, 609.6 and 79 respectively. Thus, applying a 10x factor of safety for uncertainties yields a very significant HQ outcome. Other chemicals of concern present in the LFG include various chemicals and compounds designated as possible carcinogens, namely ethylbenzene, 1,4-dichlorobenzene, 1,1-dichloroethylene, tetrahydrofuran, methylene chloride and chloroform. These findings suggest further investigation and review to better understand the actual level of exposure and the respective health hazard at each occupied building, refer to Section 2.3. Subsequently, appropriate mitigative measures may be developed in consultation with the owner and occupant of a building.

As shown in Tables 3B, 3C and 3D the calculated HQ values are equivalent while the HQ values for the underground utility infrastructure activities (Table 3E) appears to be the scenario exhibiting a slightly lower sensitivity for a receptor to soil vapours relative to the other exposure scenarios. This is consistent with the likelihood for a less intensive exposure scenario for a utility worker. Nevertheless, the HQ values underground utility infrastructure activities relative to the residential setting, are about an order of magnitude less. Notwithstanding the various development exposure scenarios, the high HQ values signify a very evident level of concern to hazard exposure from the identified carcinogenic and possible carcinogenic soil vapour compounds. The relative proximity of the historic waste material to the detached houses along the relevant portion of Hermary Street is of particular and immediate concern.

It is clear, further investigation for soil vapour intrusion is warranted to better understand the identified risks for exposure at the residential properties adjacent to the Montfort Landfill Site. The level of methane in the soil vapour is also of concern and the risk for intrusion of methane into the house should also be further evaluated. Pending the results for buildings nearest to the historic landfill, additional building assessments (extending radially away from the Montfort Landfill Site) may be warranted to fully understand the magnitude and extent of the impact of LFG to the environmental health of building owners and occupants. In the absence of additional site information, it is recommended the generic strategy be implemented. As discussed above, the design professional may elect to apply alternate measure(s). Should the design professional prefer a site-specific approach, it is recommended the alternative measure(s) by the design professional be verified by the City Inspections and Licensing as a level of protection equivalent to or superior to the generic mitigative strategy presented in this ERMP. Various generic measures to mitigate potential soil vapour intrusion for an enclosed building are outlined in the following subsections.

5.1 Outline of Generic Mitigative Measures

The suggested approach to the implementation of mitigating the potential ingress of LFG and thereby reducing or preventing exposure to the identified chemicals of concern should consist of a passive and active mitigation strategy for new residential developments. The intended approach is a progressively increasing level of protection as the relative level of hazard increases. On the basis of the initial values of HQ, the minimum level of mitigation involves a combination of passive and active measures. In order to reduce the level of a generic mitigation action presented herein, further site specific information to justify a reduction of protection would be the responsibility of the design professional for the proposed development. Generic examples of engineered mitigative actions as directed by the maximum HQ values, refer to Tables 3A to 3E, are outlined as follows:

Passive Measures

1. Passive Measures for HQ values > 1 and < 5 – Level A
   Compacted clay liner with a minimum thickness of 1m and confirmed maximum hydraulic conductivity of 10^{-6} cm/sec.

2. Passive Measures for HQ values > 5 and < 50 – Level B
   Synthetic liner with type of material, thickness and installation details dependent on the design professional.

3. Passive Measures for HQ values > 50 and < 100 – Level C
   Passive sub-slab depressurization (SSD) system with a minimum depressurization of 4 to 10 Pa. In some instances (such as a pervious subgrade), the actual depressurization necessary may be require an active SSD or alternative active ventilation system.

Active Measures

Field verify the presence of the identified chemicals of concern and other potential chemicals in the soil gas state at the development site. If confirmed, determine the most appropriate manner to prevent soil vapour intrusion.

1. Active Measures for HQ values > 100 and < 200 – Level D
   Active SSD must be configures to compensate for depressurization of the building and have adequate negative pressure gradients across the entire footprint of the foundation.

2. Active Measures for HQ values > 200 – Level E
   Installation of geomembrane and active soil vapour extraction with system fault notification/alarm.

3. Active Measure Alternative to approach to prevent vapour intrusion – Level F
Establish a balanced building ventilation scheme to maintain an interior positive pressure gradient with adjustments for seasonal and temporal effects (extreme low and high temperatures and wind effects).

It should be noted; pending the type and configuration of a structure, the above generic alternatives for passive and active mitigative measures can be modified and/or combined by the design professional working for the specific development.

5.2 Strategy For Subdivision and Developments Within 100 m

The high HQ values for the identified carcinogen chemicals present in the soil vapour and consideration of the proximity (within 15 m, more or less) of the houses and the respective properties along the portion of Hermary Street which back onto the historic waste material creates a significant scenario of concern for the occupants. It is understood; the houses are circa 1980s and predate AB Reg. 43/2002.

As discussed in Section 4.1 and 5.0, a detailed assessment for existing houses should be undertaken to assess and verify the level of impact for indoor vapour intrusion in both transient and steady-state temporal conditions. The assessment should be conducted in a manner to eliminate confounders during, sampling of indoor air in the basement and main floor using Summa Canister® and Tedlar Bag® for sample collection and having an analytical program equivalent to the Phase II ESA. Subsequent to the findings, an appropriate level of mitigation and retrofit can then be determined with an objective to reduce the long term exposure hazard from intrusion of LFG into each house.

On the basis of the initial values of HQ, the minimum level of mitigation for new developments with occupancy (regardless of whether the occupancy is for residential, public institution or commercial activity) should involve a combination of passive and active measures.

5.3 Strategy For Subdivision and Developments Between 100 m to 200 m

As discussed in Sections 4 and 5, conservatively, the age of the historic waste and the relative concentrations of soil vapour measured during the August 2013 testing event show notable carcinogenic chemicals and the potential for methane to be of sufficient concentration to adversely impact properties lying between 100 m to 200 m from the boundary of the Montfort Landfill Site. Currently, numeric models to predict transient subsurface soil vapour concentrations from a point source are complex and parameterizing a potential scenario for this project with the available data will include significant uncertainties and the output results would not be definitive.

The relative toxicity of these identified chemicals and applying the PQRA protocol, the corresponding HQ values suggest an exposure hazard exists. On the basis of the available information, there is presently an identified risk of soil vapour intrusion by LFG composed of various chemical vapour compounds classified as carcinogen, possible carcinogen and methane into an enclosed building envelop located between 100 m to 200 m from the Montfort Landfill. The level of risk is deemed to be reduced with distance from the historic waste materials and a mitigative measures for new residential housing and public institution should incorporate a passive and active mitigative solution while the mitigative measure for occupied buildings in other land uses (food establishment and other commercial activities) may (at the discretion of the design professional) be reduced to passive options and confirmatory assessment including on-site testing.

5.4 Strategy For Subdivision and Developments Between 200 and 300 m

As noted in Section 5.0, the level of risk for developments between 200 m and 300 m is interpreted to be at a relatively lower level of risk and warranting special environmental mitigative or adaptive considerations at a passive level of mitigative action for the various types of developments.

5.5 Strategy For Subdivision and Developments Beyond 300 m

There are no considerations necessary for subdivision developments beyond 300 m from a non-operating landfill in AB Reg. 43/2002.

5.6 Strategy For Other Commercial Developments & Subsurface Utilities

For development activities which are not addressed in Section 13 AB. Reg. 43/2002, the same strategy to mitigate potential exposure to soil vapour intrusion in enclosed buildings should be applied.

For installation of underground utility, the design professional should review the site conditions with consideration of potential soil landfill gas in areas lying within 100 m of the boundary of the Montfort Landfill Site. Appropriate PPE for workers should be included in their respective Safe Work Plan.

In the event, a future utility line is proposed to traverse the Montfort Landfill Site, the utility owner should review the proposed work plan with The City of Red Deer Waste Management to ensure the viability of the proposed utility line within a solid waste environment. To assist with the administration of this, the Management at the City should "flag" the Montfort Landfill Site with an objective to ensure activities involving future public and private utilities within 100 m of the Montfort Landfill Site can be appropriately communicated to Waste Management, the utility owner and their contractor.

For other non-regulated developments such as retail and general commercial developments lying within 100 m of the Montfort Landfill, a combination of a passive and active mitigation measure should be implemented. The actual mitigation details would be subject to the intended configuration, types of activities and specific mechanical systems of a specific development. Similarly for other developments lying between 100 and 300 m of the Montfort Landfill, the noted passive mitigative measures should be considered as a component to reduce the risk of exposure to LFG.

5.7 Proposed Regulatory Monitoring and Quality Assurance

A follow-up monitoring event may be required to track and verify the effectiveness of the mitigative measure(s). The manner and specifics of verification testing should be proposed by the design professional and communicated to the City Inspections and Licensing.

The Design professional shall show all installation details on as-built drawings along with Assurance Declarations – Schedules A, B, C Alberta Building Code for the generic alternatives below.

5.8 Proposed Risk Communication Plan

Present risk management actions consist of the current environmental site investigations and regulatory review process of Part 2 Section 13 AB Reg. 43/2002. The information compiled by the 2013 Phase I and 2014 Phase II ESAs better identifies the environmental risks associated with the historic waste disposal site. This site specific information has been applied to support this site specific ERMP.

With the level of risk identified by the PQRA model, consideration should be made to consult with the local Environmental Public Health at Alberta Health Services (AHS). The consideration to consult with AHS is to gather comments and utilize their expertise to address the identified concern for possible vapour intrusion of LFG to the houses and buildings along the identified area in proximity to the Montfort Landfill Site.

Subsequent to consultation with AHS and at the discretion of the City Management other property owners should also be notified of the proposed risk management actions to address the identified contaminants of concern. In summary, a communication mechanism should be considered to advise the community stakeholders in Highland Green Estates. This communication objective should be to ensure questions and issues arising from future property and infrastructure developments within this community are responded in an appropriate manner.

5.9 Future Review and Update to ERMP

The identified chemicals of concern reflect the initial environmental site assessment. The list of identified chemicals of concern may be expanded pending results of future testing events. Furthermore, research and development of health risk information for chemical exposures whether the exposure route is direct contact, ingestion or inhalation is an ongoing progressive effort by many organizations. The objective of this proposed review and amendment strategy is to ensure the level of acceptable risk of human exposure to constituents of landfill soil gas is at an equivalent or lower level set forth in this PQRA.

Notwithstanding the above, technological advancements in building science and risk management tools continues to evolve. Accordingly, it is recommended the information presented in this PQRA be reviewed and updated as new site information becomes available. Pending the scope of an updated PQRA, a review of the ERMP should also be conducted. For instance, in the event the PQRA has been updated with higher concentrations of carcinogenic types VOCs, a review of the ERMP should then be undertaken to ensure the equivalent level of protection is preserved. Alternatively, should updates to the PQRA show no significant changes to the level of risk characterization, then the ERMP may be left as-is or amended accordingly.

Regardless of the rate of update to the PQRA, a review and amendment of the ERMP should be undertaken at intervals of not more than 5-years. This proposed 5-year interval is aligned to how standards in the construction and land development industry are generally updated. Typically, regulatory agencies target efforts to publish an updated code edition at an approximate 5-year interval. This is also aligned with technologies and innovation in the construction and building industries and the related environmental technologies. The objective of this proposed review and amendment strategy is to ensure the level of acceptable risk for human exposure to constituents of landfill soil gas is at a reasonable and justifiable state, as set forth in this PQRA.

6.0 STATEMENT OF LIMITATIONS

The conditions prevalent and noted at this time must be recognized as having a limited life. Should activities be introduced or practices change, either of which may be deemed to comply with generally accepted environmental practices, the site conditions would be altered sufficiently for this report to be invalid. This report has been prepared and is intended solely for the use of The City of Red Deer and their approved designates for the specific application described in Section 1.0 of this report.

Tiamat is not the sole source of information, records or documents contained in this report. Tiamat has not verified the information, records or documents of others contained in this report and is not liable for opinions based on inaccurate or misleading information. No representation, warranty, covenant or guarantee is made or given, nor is any responsibility assumed, with respect to the completeness, accuracy or reliability of the information, records or documents contained in this report. This report reflects work in progress and as such, the data and interpretations presented herein are not absolute.

However, the general environmental concerns addressed are considered representative of the conditions at the site for which the data reflects. This report does not contain all available data for this project as relevant data is presented in other documents. Tiamat reserves the right to re-evaluate the conclusions in this report should new information become available.

This report has been prepared in accordance with generally accepted environmental engineering practice and no other warranty is made, either expressed or implied. The opinions, conclusions and recommendations presented herein reflect the best judgment of Tiamat Environmental Consultant Ltd. (Tiamat),

Any use by a third party of this report or any reliance by a third party upon the information, records or documents in this report is undertaken solely at the risk and responsibility of such third party. Tiamat shall not in any way be responsible for any damages suffered by a third party due to decisions or actions taken by a third party on the basis of this report.

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7.0 CLOSURE

We trust the information presented herein satisfies your present requirements. Should you have any questions, we invite the reader to contact our office at (403) 640-9009.

Respectfully submitted,
Tiamat Environmental Consultants Ltd.

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/tlr

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Permit To Practice No.: P 7109

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TABLES

Table 1
General Site Attributes for Exposure to Soil Vapour Inhalation

Site Information and Environmental Setting	
Site Description:	The site is currently a recreational park with two baseball diamonds and a grassed field. A pedestrian/bike path bounds the west side of the site. There are currently no buildings within the boundaries of the site.
Legal Description:	Lot S1 Plan 3762 NY & Block Z Plan 9820142 within the NE 20-38-27 W4M.
Surrounding Land Use:	Urban Setting (City of Red Deer) Detached single family residences bound the site to the north. 52 Avenue followed by multi-family residences to the east. Multi-family condominiums (Montfort Heights and The Views at St. Joseph) are along the south side. Detached single family houses back onto the west site of the site. Montfort Centre borders a portion of the south end of the site.
Groundwater Usage:	No usage on the site presently nor likely in the future.
Surface Water:	No noted direction or control measure for on-site overland flow or surface run-off. There are no obvious environmental concerns for surface water run-off or run-on from the adjacent properties.
Underground Structures:	Municipal utilities include one abandoned asbestos cement water main aligned along the south perimeter of the site. Information from the City suggests this water main is not in service.
Special Environmental Conditions:	This landfill has been closed for about 47 years, circa 1968.

Receptor	Potential Exposure Routes	Soil Gas		
		Oxygenated	Ketone	Chlorinated
On-Site:				
Recreational Visitors	Inhalation of vapours from soil	×	×	✓
	Inhalation of vapours from groundwater	×	×	✓
	Ingestion of groundwater	✓	✓	✓
Off-Site:				
Single Family Houses (with basement)	Inhalation of vapours from soil	×	×	×
	Inhalation of vapours from groundwater	×	×	×
	Ingestion of groundwater	✓	✓	✓
Multi-Family Complexes (with underground garage)	Inhalation of vapours from soil	×	×	×
	Inhalation of vapours from groundwater	×	×	×
	Ingestion of groundwater	✓	✓	✓
Multi-Family Housing (with basement)	Inhalation of vapours from soil	×	×	×
	Inhalation of vapours from groundwater	×	×	×
	Ingestion of groundwater	✓	✓	✓
Montfort Centre (administration office)	Inhalation of vapours from soil	×	×	×
	Inhalation of vapours from groundwater	×	×	×
	Ingestion of groundwater	✓	✓	✓
Underground Utilities:				
Water Main	Impact of vapours from groundwater	×	×	×
Storm and sanitary sewers manholes, vaults	Impact of vapours from soil	×	×	×

× - Potential Exposure Hazard
✓ - "Negligible" Potential Exposure Hazard

Table 2A
Identified Chemicals of Concern - Physical Attributes

Chemical	Media: Soil	Media: Groundwater	Media: Soil Vapour	Physical Attributes: Molecular Weight	Vapour Pressure	Specific Gravity: Water	Specific Gravity: Air	Solubility in Water	Henry's Law Constant	Coefficients: Octanol Water	Coefficients: Org. C Water	Coefficients: Soil/Sediment	Half-life: Air	Half-life: Soil	Odour Threshold
	mg/kg	ppb	ppbv or % v/v	g/mol	mmHg	Water	Air	mg/L	Pa m^3/mol	log K_{ow}	log K_{oc}	kd	Time	Time	ppm
Ethane	- -	- -	160 - 2,700	30.07	31,500 *	0.546	1.10	60.2	5.07E+04	1.81	230	- -	50 - 70 days	- -	899
Ethylene	- -	- -	160 - 47,000	28.05	52,100*	0.569	1.00	131	2.92E+04	1.13	98	- -	1.9 days	- -	270 - 600
Methane	- -	- -	6,000 - 23.6%	16.04	47,000 *	0.422	0.55	Insoluble	6.69E+04	1.09	90	- -	7 - 10 years	- -	- -
Propane	- -	- -	160 - 1,100	44.09	9,823	0.59	1.50	100	7.16E+04	2.36	460	- -	14 days	- -	20,000
Dichlorodifluoromethane (FREON 12)	0.01	- -	97.9 - 1,910	120.9	4,332	1.50	4.20	Insoluble	3.48E+04	2.16	356	- -	105 - 169 years	- -	- -
1,2-Dichlorotetrafluoroethane	- -	- -	0.59 - 567	170.93	1,444	1.44	5.93	130*	2.84E+05	2.82	815	- -	126 - 310 years	- -	- -
Chloromethane	0.1	2.0	0.30 - 0.76	50.5	3,800	0.92	1.80	5,000	8.94E+02	0.91	14	- -	1 year	- -	10
Vinyl Chloride	0.2	0.5 - 26	0.94 - 1,440	62.5	2,508	0.969	2.20	2,760	2.82E+03	1.5	57	- -	55 hours	0.2 - 0.5 days	3,000
Chloroethane	0.1	1.0 - 1.5	0.30 - 5.47	64.5	1,000	0.92	2.22	6,000	1.12E+03	1.43	24	- -	39 days	- -	4.2
Trichlorofluoromethane (FREON 11)	0.01	0.5 - 1.0	0.20 - 108	137.4	690	1.49	4.70	Insoluble	9.83E+03	2.53	97	- -	52 - 207 years	- -	- -
Ethanol (Ethyl Alcohol)	- -	- -	16.4 - 24.5	46.1	44	0.80	1.60	Miscible	5.07E-01	-0.31	1	- -	5 days	- -	0.35
2-Propanol	- -	- -	3.0 - 3.2	60.1	33	2.07	0.79	Miscible	8.21E-01	0.05	1.5	- -	3.2 days	- -	- -
2-Propanone	- -	- -	17.8 - 36.5	58.1	180	0.80	2.00	Miscible	1.61E+02	-0.24	0.73	- -	22 - 23 days	1 - 7 days	20
Methyl Ethyl Ketone (2-Butanone)	- -	- -	3.0 - 15	72.1	71	0.80	2.41	Soluble	5.77E+00	0.63	0.56	- -	14 days	- -	5.4
1,4-Dichlorobenzene	0.01	0.5 - 2.3	0.40	147	0.6	1.458	5.08	73.8	2.74E+02	3.42	273 & 390	- -	50 days	- -	0.121
1,1-Dichloroethylene	0.01	0.5	0.25 - 0.56	96.94	500	1.21	3.25	400	2.64E+03	2.13	64 & 65	- -	1.5, 7.9 27 days	- -	190
cis-1,2-Dichloroethylene	0.021	0.5 - 130	1.57 - 32.1	97	180-265	1.28	3.34	4,000	4.15E+02	1.86	250	- -	6.1 days	0.14 - 9.9 years	0.085
Methylene Chloride	0.01	2	0.80 - 1.17	84.9	350	1.30	2.90	20,000	9.10E+03	1.25	24	- -	119 days	- -	250
Chloroform	0.01	0.5 - 1.6	0.15 - 6.94	119.4	160	1.48	4.12	5,000*	3.72E+02	1.97	34 - 196	- -	150 days	0.3 - 1.4 days	85
p-Isopropyltoluene	0.025	- -	- -	134.2	1.5*	0.857	4.62	23.4	1.11E+03	4.1	4,050	- -	1 - 34 days	- -	- -
1,1,1-Trichloroethane	0.01	0.5	0.30 - 0.88	133.4	100	1.31	4.60	4,000	7.30E+03	2.48	120 - 151	1.338 - 2.592	4.7 years	>485 days	0.971
Trichloroethylene	0.01	0.5 - 6.8	0.30 - 6.11	131.4	58	1.46	4.50	1,280*	9.98E+02	2.61	101	0.093	7 & 114 days	- -	28
Tetrachloroethylene	0.025	0.5 - 50	0.97 - 22.2	165.8	14	1.62	5.80	206*	1.79E+03	3.40	200 - 237	- -	96 days	1.2 - 5.4 hours	1
Benzene	0.01	0.4 - 5.9	0.47 - 1.47	78.1	75	0.88	2.70	700	5.63E+02	2.13	85	- -	13 days	- -	1.5
Toluene	0.01	0.4 - 4.5	7.64 - 19.4	92.1	21	0.87	3.10	700 @ 23.3°C	6.73E+02	2.73	37 - 178	- -	3 days	3 hours - 71 days	2.9
Ethylbenzene	0.01	0.4 - 66	1.72 - 2.31	106.2	7	0.87	3.70	100	7.98E+02	3.15	520	- -	55 hours	- -	2.3
o-Xylene	- -	- -	2.29 - 2.78	106.2	7	0.88	3.70	200	5.25E+02	3.12	24 - 251	- -	1.2 days	- -	- -
m Xylene	- -	- -	6.43 - 8.73	106.2	9	0.86	3.70	Slight	7.28E+02	3.20	166 - 182	- -	16.3 hours	- -	1.1
p-Xylene	- -	- -	6.43 - 8.73	106.2	9	0.86	3.70	200	6.99E+02	3.15	246 - 540	- -	27 hours	- -	- -
Total Xylene	0.1	0.8 - 66	8.72 - 11.5	106.2	0.896 @ 21°C	0.86	3.70	130	6.23E+02	- -	- -	- -	8-14 hours	- -	0.00005
1,3,5-Trimethylbenzene	0.01	0.5 - 9.0	0.80 - 1.22	120.2	2	0.86	4.15	20	8.89E+02	3.42	500 - 1,445	- -	11 hours	- -	0.03661
1,2,4-Trimethylbenzene	0.01	0.5 - 39	0.66 - 1.06	120.2	1 @ 13.33°C	0.88	4.10	60	5.25E+02	3.78	3.5	- -	6 hours	- -	0.4
Hexane	- -	- -	0.30 - 15.7	86.2	124	0.66	3.00	20	1.85E+05	3.90	150	- -	3 days	- -	130
Heptane	- -	- -	0.99 - 2.61	100.2	40 @ 22.2°C	0.68	4.60	3	2.03E+05	4.66	8,200	- -	54 hours	- -	220
Cyclohexane	- -	- -	5.09 - 42.0	84.2	78	0.78	2.90	Insoluble	1.52E+04	3.44	160	- -	45 hours	- -	0.41
Tetrahydrofuran	- -	- -	6.07 - 12.4	72.1	132	0.89	2.50	Miscible	7.14E+00	0.46	18	- -	21 - 24 hours	- -	30
Propene	- -	- -	0.30 - 755	42.08	760 @ -47°C	0.609	1.46	2.44 *	1.99E+04	1.77	220	- -	15 - 23 hours	- -	- -
2,2,4-Trimethylpentane	- -	- -	1.03 - 3.50	114.22	49.3 *	0.69	3.93	Insoluble	3.05E+05	4.08	4.35	- -	4.4 days	- -	- -
Carbon Disulfide	- -	- -	1.27 - 10.8	76.1	297	1.26	2.63	3,000	1.46E+03	1.94	270	- -	5.5 days	- -	0.016

Notes:
1) Above identified chemicals of concern are dervied from the results of a Phase II ESA, 2014. Additional chemicals may be added pending future investigation and testing events.
2) HQ values are calculated by the use of the highest concentration measured or the detection limit established by the analytical method.
3) Solubility in water, Vapour pressure, Specific Gravity are at 20°C unless otherwise stated.
4) Henry's Law Constant and any value with * Temperature at 25°C.
5) - -/N/E - Not Tested, No Value Established or Not Evaluated.
6) ND - Not Detected, below the limit of method detection.

Table 2B
Identified Chemicals of Concern - Guidelines and Toxicological Values

Chemical	Carcinogen	Media			Toxicological Attributes						
		Soil	Groundwater	Soil Vapour	Bioconcentration Factor	8-hour Occupational Exposure Limit		Acceptable Daily Intake	Tolerable Daily Intake	TRV	
										TC	UR
		mg/kg	ppb	ppbv or % v/v	gm/kg or gm/L	ppm	mg/m^3	mg/kg/day	ppm bw/day	mg/m^3	$(mg/m^3)^{-1}$
Ethane	N/E	- -	- -	160 - 2,700	5	1,000	1,230		- -		
Ethylene	Non-Carcinogen	- -	- -	160 - 47,000	4	200	229		- -		
Methane	Non-Carcinogen	- -	- -	6,000 - 23.6%	1	1,000	706		- -		
Propane	Non-Carcinogen	- -	- -	160 - 1,100	13.1	100	180		- -		
Dichlorodifluoromethane (FREON 12)	Non-Carcinogen	0.01	- -	97.9 - 1,910	25	1,000	4,950	- -	- -	- -	- -
1,2-Dichlorotetrafluoroethane	N/E	- -	- -	0.59 - 567	82	1,000	6,991				
Chloromethane	Carcinogen	0.1	2.0	0.30 - 0.76	3	50	105	- -	0.003	0.1	- -
Vinyl Chloride	Carcinogen	0.2	0.5 - 26	0.94 - 1,440	<10	1	2.6		0.009	0.1	0.0088
Chloroethane	N/E	0.1	1.0 - 1.5	0.30 - 5.47	2.5	100	264	- -	0.376	- -	- -
Trichlorofluoromethane (FREON 11)	Non-Carcinogen	0.01	0.5 - 1.0	0.20 - 108	49	1,000 [2]	5,600 [2]	- -	- -	- -	- -
Ethanol (Ethyl Alcohol)	Carcinogen	- -	- -	16.4 - 24.5	3	1,000	1,880	- -	- -	- -	- -
2-Propanol	N/E	- -	- -	3.0 - 3.2	3	200	492		- -		
2-Propanone	N/E	- -	- -	17.8 - 36.5	3.2	250 [2]	590 [2]	- -	- -	- -	- -
Methyl Ethyl Ketone (2-Butanone)	N/E	- -	- -	3.0 - 15	1.2 - 27.5	200	590	- -	0.6	5	- -
1,4-Dichlorobenzene	Possible Carcinogen	0.01	0.5 - 2.3	0.40	33 - 720	10	60		0.11	0.095	- -
1,1-Dichloroethylene	Possible Carcinogen	0.01	0.5	0.25 - 0.56	<13	5	20		0.05	0.2	
cis-1,2-Dichloroethylene	N/E	0.021	0.5 - 130	1.57 - 32.1	5	200	793	- -	0.002	0.15	- -
Methylene Chloride(Dichloromethane)	Possible Carcinogen	0.01	2	0.80 - 1.17	2	50	174	- -	0.05	3	0.000023
Chloroform	Possible Carcinogen	0.01	0.5 - 1.6	0.15 - 6.94	2.9 - 10.35	10	49	- -	0.01	0.04475	0.023
p-Isopropyltoluene	N/E	0.025	- -	- -	286	10	49		- -		
1,1,1-Trichloroethane	N/E	0.01	0.5	0.30 - 0.88	0.7 - 4.9	350	1,910		0.6		
Trichloroethylene	Carcinogen	0.01	0.5 - 6.8	0.30 - 6.11	4 - 39	50	269	- -	0.00146	0.04	0.00061
Tetrachloroethylene	Carcinogen	0.025	0.5 - 50	0.97 - 22.2	26 - 115	25	170	- -	0.014	0.36	- -
Benzene	Carcinogen	0.01	0.4 - 5.9	0.47 - 1.47	1.1 - 20	0.5	1.6	- -	0.004	- -	0.0033
Toluene	Non-Carcinogen	0.01	0.4 - 4.5	7.64 - 19.4	13 & 90	50	188	- -	0.22	3.8	5
Ethylbenzene	Possible Carcinogen	0.01	0.4 - 66	1.72 - 2.31	0.67 - 15	100	434	1.6	- -	0.01	1
o-Xylene	Non-Carcinogen	- -	- -	2.29 - 2.78	6.2 - 21	100	434	- -	1.5	0.18	- -
m-Xylene	Non-Carcinogen	- -	- -	6.43 - 8.73	6 - 23.4	100	434	- -	1.5	0.18	- -
p-Xylene	Non-Carcinogen	- -	- -	6.43 - 8.73	15	100	434	- -			- -
Total Xylene	Non-Carcinogen	0.1	0.8 - 66	8.72 - 11.5	1 - 24	100	434	- -	1.5	0.18	0.07
1,3,5-Trimethylbenzene	Non-Carcinogen	0.01	0.5 - 9.0	0.80 - 1.22	23 - 342	25	123		0.0015	0.0036	
1,2,4-Trimethylbenzene	Non-Carcinogen	0.01	0.5 - 39	0.66 - 1.06	439	25	123	- -	0.0016	0.007	- -
Hexane	Non-Carcinogen	- -	- -	0.30 - 15.7	200	500	1,760	- -	0.7	- -	- -
Heptane	N/E	- -	- -	0.99 - 2.61	2,000	400	1,640	- -	- -	- -	- -
Cyclohexane	N/E	- -	- -	5.09 - 42.0	89	300	1,010	- -	- -	- -	- -
Tetrahydrofuran	Possible Carcinogen	- -	- -	6.07 - 12.4	3	50	147	- -	0.9	- -	- -
Propene	N/E	- -	- -	0.30 - 755	5	50	147		- -		
2,2,4-Trimethylpentane	N/E	- -	- -	1.03 - 3.50	2.57	300	1,400	- -	- -	- -	- -
Carbon Disulfide	Non-Carcinogen	- -	- -	1.27 - 10.8	<60	1	3.1	- -	0.1	0.1	- -

Notes:
1) Above identified chemicals of concern are dervied from the results of a Phase II ESA, 2014. Additional chemicals may be added pending future investigation and testing events.
2) HQ values are calculated by the use of the highest concentration measured or the detection limit established by the analytical method.
3) Solubility in water, Vapour pressure, Specific Gravity are at 20°C unless otherwise stated.
4) Henry's Law Constant and any value with * Temperature at 25°C.
5) - -/N/E - Not Tested, No Value Established or Not Evaluated.
6) ND - Not Detected, below the limit of method detection.

Table 2 Notes

1. Eight (8) Hour occupational Exposure Limit is referenced from Alberta Occupational Health & Safety Code 2009 unless no value available in which Time Weighted Average is referenced from NIOSH standards.
2. Alberta Environment Sustainable Resource & Development.
3. Environment Canada, Health Canada.
4. Ontario Ministry of the Environment, Standards Development Branch.
5. United States of America Department of Labor, Occupational Safety & Health Administration.
6. Alberta Tier 1 Soil and Groundwater Remediation Guidelines December 2010 and May 2014.
7. National Institute for Occupational Safety and Health (NIOSH) Education and Information Division.
8. Federal Contaminated Site Risk Assessment in Canada.
9. US National Library of Medicine, National Institutes of Health, Department of Health & Human Services, Hazardous Substance Database.
10. The Merck Index, 12th Edition, 1996.
11. EPA United States Environmental Protection Agency, Technology Transfer Network – Air Toxics Web Site.
12. EPA United States Environmental Protection Agency, Integrated Risk Information System (IRIS).
13. EPA United States Environmental Protection Agency, Chemical Summary Fact Sheets.
14. NOAA National Oceanic and Atmospheric Administration - Cameo Chemicals Web Site.
15. World Health Organization - International Agency For Research on Cancer.
16. UNEP - United Nations Environment Programme.

Table 3A Residential Land Use
Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage ppm bw/day	Carcinogenic	Hazard Quotient Calculated	Hazard Quotient Adjusted
Chloromethane	0.2	Carcinogen	**56.6**	**566**
Vinyl Chloride	8	Carcinogen	**867.3**	**8,673**
Trichloroethylene	0.7	Carcinogen	**445.8**	**4,458**
Tetrachloroethylene	9	Carcinogen	**609.6**	**6,096**
Benzene	0.3	Carcinogen	**79**	**790**
Ethanol (Ethyl Alcohol)	0.01	Carcinogen	- -	- -
Ethylbenzene	5	Possible Carcinogen	**50**	**500**
1,4-Dichlorobenzene	0.06	Possible Carcinogen	0.5	**5**
1,1-Dichloroethylene	0.1	Possible Carcinogen	**2.5**	**25**
Tetrahydrofuran	0.01	Possible Carcinogen	0.01	0.1
Methylene Chloride	0.06	Possible Carcinogen	**1.3**	**13**
Chloroform	0.06	Possible Carcinogen	**6.4**	**64**
Ethylene	13	Non-Carcinogen	- -	- -
Propane	0.5	Non-Carcinogen	- -	- -
Dichlorodifluoromethane (FREON 12)	2	Non-Carcinogen	- -	- -
Toluene	0.3	Non-Carcinogen	**1.4**	**14**
o-Xylene	0.003	Non-Carcinogen	0.002	0.02
m Xylene	0.01	Non-Carcinogen	0.006	0.06
p-Xylene	0.01	Non-Carcinogen	0.006	0.06
Total Xylene	4	Non-Carcinogen	**2.6**	**26**
1,3,5-Trimethylbenzene	1	Non-Carcinogen	**506.3**	**5,063**
1,2,4-Trimethylbenzene	2	Non-Carcinogen	**1,213**	**12,133**
Carbon Disulfide	0.01	Non-Carcinogen	0.08	0.8
Hexane	0.01	Non-Carcinogen	0.02	0.2
Trichlorofluoromethane (FREON 11)	1	Non-Carcinogen	- -	- -
Chloroethane	0.2	N/E	0.4	**4**
Methyl Ethyl Ketone (2-Butanone)	0.01	N/E	0.02	0.2
1,1,1-Trichloroethane	0.3	N/E	0.6	**6**
cis-1,2-Dichloroethylene	5	N/E	**2,574.2**	**25,742**
1,2-Dichlorotetrafluoroethane	0.9	N/E	- -	- -
2-Propanol	0.002	N/E	- -	- -
2-Propanone	0.02	N/E	- -	- -
Heptane	0.003	N/E	- -	- -
Cyclohexane	0.03	N/E	- -	- -
Propene	0.3	N/E	- -	- -
2,2,4-Trimethylpentane	0.004	N/E	- -	- -
Ethane	0.8	N/E	- -	- -
p-Isopropyltoluene	--	N/E	- -	- -
Methane	36,352	Asphyxiant	- -	- -

Notes:
1) HQ values are calculated solely on Health Canada exposure parameters published in the PQRA, ver 2.0 September 2010.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles.
Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
4) - -/N/E - Not Tested, No Value Established or Not Evaluated.
5) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to address uncertainties with single data point.
6) Bold & shaded reflect a calculated HQ greater than 1 signifying a level of concern to hazard exposure.

Table 3B Food Establishment Land Use
Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage ppm bw/day	Carcinogenic	Hazard Quotient Calculated	Hazard Quotient Adjusted
Chloromethane	0.02	Carcinogen	**5.9**	**59**
Vinyl Chloride	0.8	Carcinogen	**90.3**	**903**
Trichloroethylene	0.07	Carcinogen	**46.4**	**464**
Tetrachloroethylene	0.9	Carcinogen	**63.5**	**635**
Benzene	0.03	Carcinogen	**8.2**	**82**
Ethanol (Ethyl Alcohol)	0.001	Carcinogen	- -	- -
Ethylbenzene	1	Possible Carcinogen	**5.2**	**52**
1,4-Dichlorobenzene	0.01	Possible Carcinogen	0.06	0.6
1,1-Dichloroethylene	0.01	Possible Carcinogen	0.3	**3**
Tetrahydrofuran	0.001	Possible Carcinogen	0.001	0.01
Methylene Chloride	0.01	Possible Carcinogen	0.1	1
Chloroform	0.01	Possible Carcinogen	0.7	**7**
Ethylene	3	Non-Carcinogen	- -	- -
Propane	0.1	Non-Carcinogen	- -	- -
Dichlorodifluoromethane (FREON 12)	0.5	Non-Carcinogen	- -	- -
Toluene	0.07	Non-Carcinogen	0.3	**3**
o-Xylene	0.001	Non-Carcinogen	0.0005	0.005
m-Xylene	0.002	Non-Carcinogen	0.001	0.01
p-Xylene	0.002	Non-Carcinogen	0.001	0.01
Total Xylene	0.9	Non-Carcinogen	0.6	**6**
1,3,5-Trimethylbenzene	0.2	Non-Carcinogen	**120.5**	**1,205**
1,2,4-Trimethylbenzene	0.5	Non-Carcinogen	**288.9**	**2,889**
Carbon Disulfide	0.002	Non-Carcinogen	0.02	0.2
Hexane	0.003	Non-Carcinogen	0.004	0.04
Trichlorofluoromethane (FREON 11)	0.3	Non-Carcinogen	- -	- -
Chloroethane	0.04	N/E	0.1	1
Methyl Ethyl Ketone (2-Butanone)	0.002	N/E	0.004	0.04
1,1,1-Trichloroethane	0.08	N/E	0.1	1
cis-1,2-Dichloroethylene	1.2	N/E	**612.9**	**6,129**
1,2-Dichlorotetrafluoroethane	0.2	N/E	- -	- -
2-Propanol	0.0004	N/E	- -	- -
2-Propanone	0.005	N/E	- -	- -
Heptane	0.0006	N/E	- -	- -
Cyclohexane	0.01	N/E	- -	- -
Propene	0.07	N/E	- -	- -
2,2,4-Trimethylpentane	0.001	N/E	- -	- -
Ethane	0.2	N/E	- -	- -
p-Isopropyltoluene	- -	N/E	- -	- -
Methane	8,655	Asphyxiant	- -	- -

Notes:
1) HQ values are calculated solely on Health Canada exposure parameters published in the PQRA, ver 2.0 September 2010.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles.
Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
4) - -/N/E - Not Tested, No Value Established or Not Evaluated.
5) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to address uncertainties with single data point.
6) Bold & shaded reflect a calculated HQ greater than 1 signifying a level of concern to hazard exposure.

Table 3C School & Hospital Developments Land Use
Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage	Carcinogenic	Hazard Quotient	
	ppm bw/day		Calculated	Adjusted
Chloromethane	0.02	Carcinogen	**5.9**	**59**
Vinyl Chloride	0.8	Carcinogen	**90.3**	**903**
Trichloroethylene	0.07	Carcinogen	**46.4**	**464**
Tetrachloroethylene	0.9	Carcinogen	**63.5**	**635**
Benzene	0.03	Carcinogen	**8.2**	**82**
Ethanol (Ethyl Alcohol)	0.001	Carcinogen	- -	- -
Ethylbenzene	1	Possible Carcinogen	**5.2**	**52**
1,4-Dichlorobenzene	0.01	Possible Carcinogen	0.06	0.6
1,1-Dichloroethylene	0.01	Possible Carcinogen	0.3	**3**
Tetrahydrofuran	0.001	Possible Carcinogen	0.001	0.01
Methylene Chloride	0.01	Possible Carcinogen	0.1	1
Chloroform	0.01	Possible Carcinogen	0.7	**7**
Ethylene	3	Non-Carcinogen	- -	- -
Propane	0.1	Non-Carcinogen	- -	- -
Dichlorodifluoromethane (FREON 12)	0.5	Non-Carcinogen	- -	- -
Toluene	0.07	Non-Carcinogen	0.3	**3**
o-Xylene	0.001	Non-Carcinogen	0.0005	0.005
m-Xylene	0.002	Non-Carcinogen	0.001	0.01
p-Xylene	0.002	Non-Carcinogen	0.001	0.01
Total Xylene	0.9	Non-Carcinogen	0.6	**6**
1,3,5-Trimethylbenzene	0.2	Non-Carcinogen	**120.5**	**1,205**
1,2,4-Trimethylbenzene	0.5	Non-Carcinogen	**288.9**	**2,889**
Carbon Disulfide	0.002	Non-Carcinogen	0.02	0.2
Hexane	0.003	Non-Carcinogen	0.004	0.04
Trichlorofluoromethane (FREON 11)	0.3	Non-Carcinogen	- -	- -
Chloroethane	0.04	N/E	0.1	1
Methyl Ethyl Ketone (2-Butanone)	0.002	N/E	0.004	0.04
1,1,1-Trichloroethane	0.08	N/E	0.1	1
cis-1,2-Dichloroethylene	1.2	N/E	**612.9**	**6,129**
1,2-Dichlorotetrafluoroethane	0.2	N/E	- -	- -
2-Propanol	0.0004	N/E	- -	- -
2-Propanone	0.005	N/E	- -	- -
Heptane	0.0006	N/E	- -	- -
Cyclohexane	0.01	N/E	- -	- -
Propene	0.07	N/E	- -	- -
2,2,4-Trimethylpentane	0.001	N/E	- -	- -
Ethane	0.2	N/E	- -	- -
p-Isopropyltoluene	- -	N/E	- -	- -
Methane	8,655	Asphyxiant	- -	- -

Notes:
1) HQ values are calculated solely on Health Canada exposure parameters published in the PQRA, ver 2.0 September 2010.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles.
Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
4) - -/N/E - Not Tested, No Value Established or Not Evaluated.
5) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to address uncertainties with single data point.
6) Bold & shaded reflect a calculated HQ greater than 1 signifying a level of concern to hazard exposure.

Table 3D General Retail Developments Excluding Food Establishments Land Use Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage	Carcinogenic	Hazard Quotient	
	ppm bw/day		Calculated	Adjusted
Chloromethane	0.02	Carcinogen	**5.9**	**59**
Vinyl Chloride	0.8	Carcinogen	**90.3**	**903**
Trichloroethylene	0.07	Carcinogen	**46.4**	**464**
Tetrachloroethylene	0.9	Carcinogen	**63.5**	**635**
Benzene	0.03	Carcinogen	**8.2**	**82**
Ethanol (Ethyl Alcohol)	0.001	Carcinogen	- -	- -
Ethylbenzene	0.5	Possible Carcinogen	**5.2**	**52**
1,4-Dichlorobenzene	0.01	Possible Carcinogen	0.06	0.6
1,1-Dichloroethylene	0.01	Possible Carcinogen	0.3	**3**
Tetrahydrofuran	0.001	Possible Carcinogen	0.001	0.01
Methylene Chloride	0.01	Possible Carcinogen	0.1	1
Chloroform	0.01	Possible Carcinogen	0.7	**7**
Ethylene	3	Non-Carcinogen	- -	- -
Propane	0.1	Non-Carcinogen	- -	- -
Dichlorodifluoromethane (FREON 12)	0.5	Non-Carcinogen	- -	- -
Toluene	0.07	Non-Carcinogen	0.3	**3**
o-Xylene	0.0007	Non-Carcinogen	0.0005	0.005
m-Xylene	0.002	Non-Carcinogen	0.001	0.01
p-Xylene	0.002	Non-Carcinogen	0.001	0.01
Total Xylene	0.9	Non-Carcinogen	0.6	**6**
1,3,5-Trimethylbenzene	0.2	Non-Carcinogen	**120.5**	**1,205**
1,2,4-Trimethylbenzene	0.5	Non-Carcinogen	**288.9**	**2,889**
Carbon Disulfide	0.002	Non-Carcinogen	0.02	0.2
Hexane	0.003	Non-Carcinogen	0.004	0.04
Trichlorofluoromethane (FREON 11)	0.3	Non-Carcinogen	- -	- -
Chloroethane	0.04	N/E	0.1	1
Methyl Ethyl Ketone (2-Butanone)	0.002	N/E	0.004	0.04
1,1,1-Trichloroethane	0.08	N/E	0.1	1
cis-1,2-Dichloroethylene	1.2	N/E	**612.9**	**6,129**
1,2-Dichlorotetrafluoroethane	0.2	N/E	- -	- -
2-Propanol	0.0004	N/E	- -	- -
2-Propanone	0.005	N/E	- -	- -
Heptane	0.0006	N/E	- -	- -
Cyclohexane	0.01	N/E	- -	- -
Propene	0.07	N/E	- -	- -
2,2,4-Trimethylpentane	0.0009	N/E	- -	- -
Ethane	0.2	N/E	- -	- -
p-Isopropyltoluene	- -	N/E	- -	- -
Methane	8,655	Asphyxiant	- -	- -

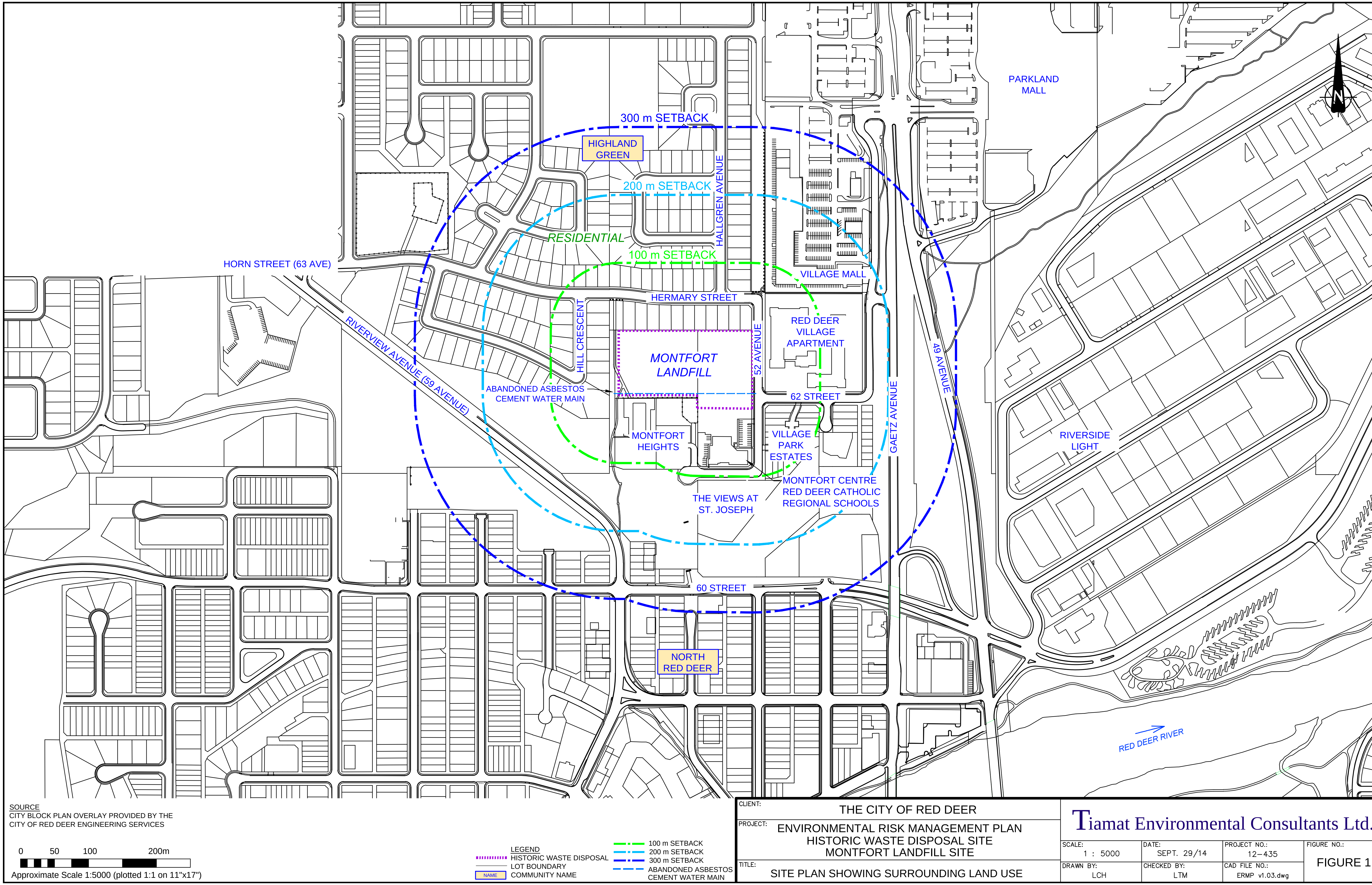
Notes:
1) HQ values are calculated solely on Health Canada exposure parameters published in the PQRA, ver 2.0 September 2010.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles.
Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
4) - -/N/E - Not Tested, No Value Established or Not Evaluated.
5) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to address uncertainties with single data point.
6) Bold & shaded reflect a calculated HQ greater than 1 signifying a level of concern to hazard exposure.

Table 3E Utility Infrastructure Activities Land Use
Calculated Hazard Quotients for Identified Chemicals of Concern

Chemical	Estimate Dosage	Carcinogenic	Hazard Quotient	
	ppm bw/day		Calculated	Adjusted
Chloromethane	0.02	Carcinogen	**5.7**	**57**
Vinyl Chloride	0.8	Carcinogen	**87.9**	**879**
Trichloroethylene	0.07	Carcinogen	**45.2**	**452**
Tetrachloroethylene	0.9	Carcinogen	**61.8**	**618**
Benzene	0.03	Carcinogen	**8.0**	**80**
Ethanol (Ethyl Alcohol)	0.001	Carcinogen	- -	- -
Ethylbenzene	0.5	Possible Carcinogen	**5.1**	**51**
1,4-Dichlorobenzene	0.01	Possible Carcinogen	0.06	0.6
1,1-Dichloroethylene	0.01	Possible Carcinogen	0.3	**3**
Tetrahydrofuran	0.0009	Possible Carcinogen	0.001	0.01
Methylene Chloride	0.01	Possible Carcinogen	0.1	1
Chloroform	0.01	Possible Carcinogen	0.7	**7**
Ethylene	3	Non-Carcinogen	- -	- -
Propane	0.1	Non-Carcinogen	- -	- -
Dichlorodifluoromethane (FREON 12)	0.5	Non-Carcinogen	- -	- -
Toluene	0.07	Non-Carcinogen	0.3	**3**
o-Xylene	0.0007	Non-Carcinogen	0.0004	0.004
m-Xylene	0.002	Non-Carcinogen	0.001	0.01
p-Xylene	0.002	Non-Carcinogen	0.001	0.01
Total Xylene	0.9	Non-Carcinogen	0.6	**6**
1,3,5-Trimethylbenzene	0.2	Non-Carcinogen	**117.3**	**1,173**
1,2,4-Trimethylbenzene	0.4	Non-Carcinogen	**281.1**	**2,811**
Carbon Disulfide	0.002	Non-Carcinogen	0.02	0.2
Hexane	0.003	Non-Carcinogen	0.004	0.04
Trichlorofluoromethane (FREON 11)	0.2	Non-Carcinogen	- -	- -
Chloroethane	0.04	N/E	0.1	1
Methyl Ethyl Ketone (2-Butanone)	0.002	N/E	0.004	0.04
1,1,1-Trichloroethane	0.08	N/E	0.1	1
cis-1,2-Dichloroethylene	1.2	N/E	**596.4**	**5,964**
1,2-Dichlorotetrafluoroethane	0.2	N/E	- -	- -
2-Propanol	0.0004	N/E	- -	- -
2-Propanone	0.005	N/E	- -	- -
Heptane	0.0006	N/E	- -	- -
Cyclohexane	0.008	N/E	- -	- -
Propene	0.07	N/E	- -	- -
2,2,4-Trimethylpentane	0.0009	N/E	- -	- -
Ethane	0.2	N/E	- -	- -
p-Isopropyltoluene	- -	N/E	- -	- -
Methane	8,423	Asphyxiant	- -	- -

Notes:
1) HQ values are calculated solely on Health Canada exposure parameters published in the PQRA, ver 2.0 September 2010.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles.
Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
3) Vapour inhalation for a coarse-grained soil in a basement.
4) - -/N/E - Not Tested, No Value Established or Not Evaluated.
5) Adjusted HQ - Calculated HQ with a Factor of Safety (10) applied to address uncertainties with single data point.
6) Bold & shaded reflect a calculated HQ greater than 1 signifying a level of concern to hazard exposure.

FIGURES



SOURCE
CITY BLOCK PLAN OVERLAY PROVIDED BY THE CITY OF RED DEER ENGINEERING SERVICES

Approximate Scale 1:5000 (plotted 1:1 on 11"x17")

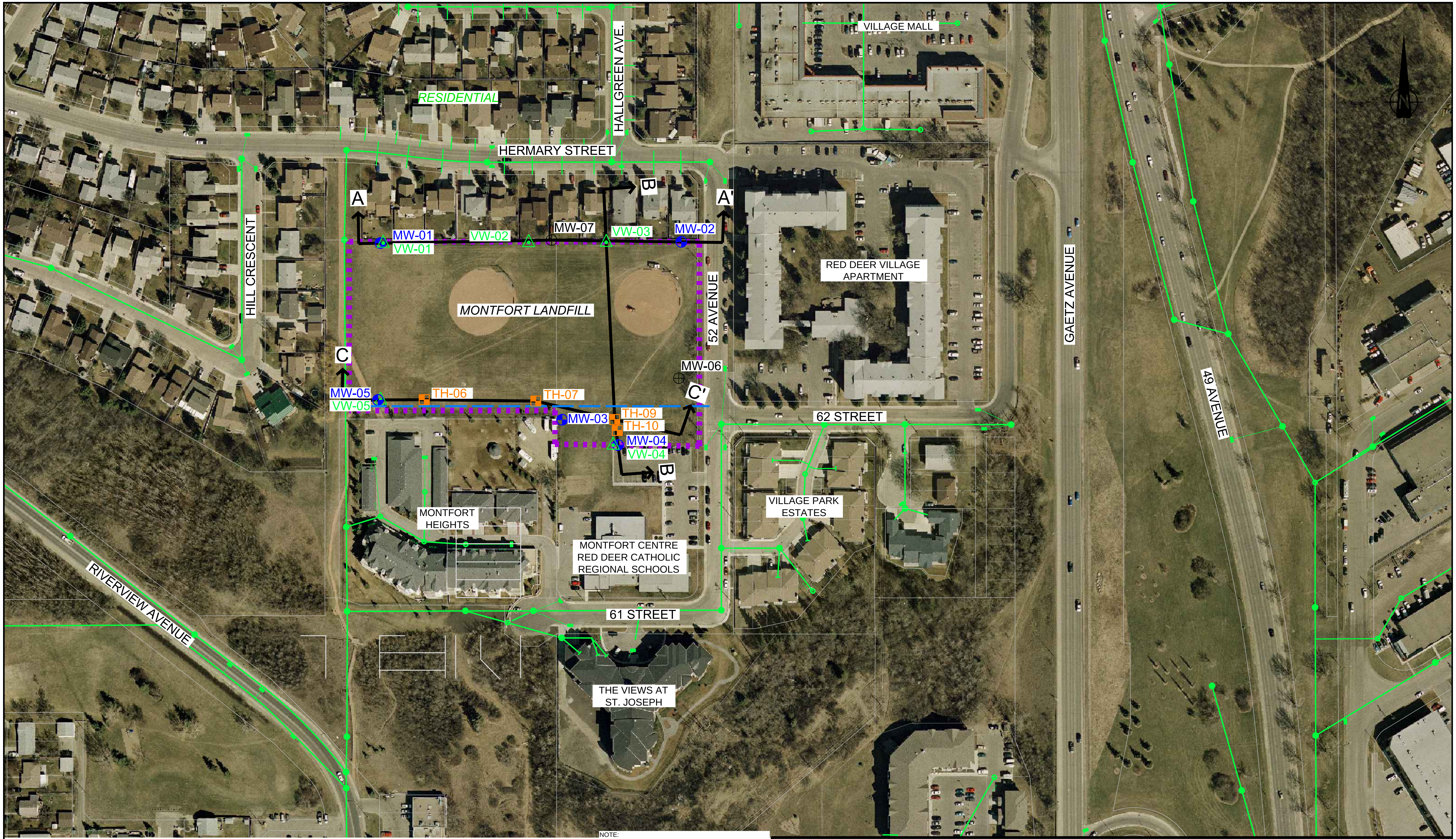
CLIENT: THE CITY OF RED DEER

PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN
HISTORIC WASTE DISPOSAL SITE
MONTFORT LANDFILL SITE

TITLE: SITE PLAN SHOWING SURROUNDING LAND USE

Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
1 : 5000	SEPT. 29/14	12-435	FIGURE 1
DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: ERMP v1.03.dwg	



SOURCE
2010 ORTHOGRAPHIC IMAGE © COPYRIGHT WITH PERMISSION FROM THE CITY OF RED DEER.

0 20 50 100m
Scale 1:2000

PHASE II TEST LOCATIONS
- MW-## GROUNDWATER MONITORING WELL INSTALLED BY TIAMAT (5)
- TH-## TESTHOLE (4)
- VW-## SOIL VAPOUR MONITORING WELL (5)
- MW-## GROUNDWATER MONITORING WELL INSTALLED BY OTHERS (2)

REFER TO TABLE 1 FOR TESTHOLE INFORMATION

LEGEND
- HISTORIC WASTE DISPOSAL
- LOT BOUNDARY
- CROSS SECTION LOCATION
- ELECTRICAL
- SANITARY
- STORM
- WATER
- ABANDONED ASBESTOS CEMENT WATER MAIN

NOTE:
LOCATION OF BURIED UTILITIES ARE APPROXIMATE, ACTUAL LOCATIONS OF THE SHOW UTILITIES AND ANY OTHER UTILITES SHOULD BE VERIFIED PRIOR TO ANY GROUND DISTURBANCE ACTIVITY.

CLIENT: THE CITY OF RED DEER

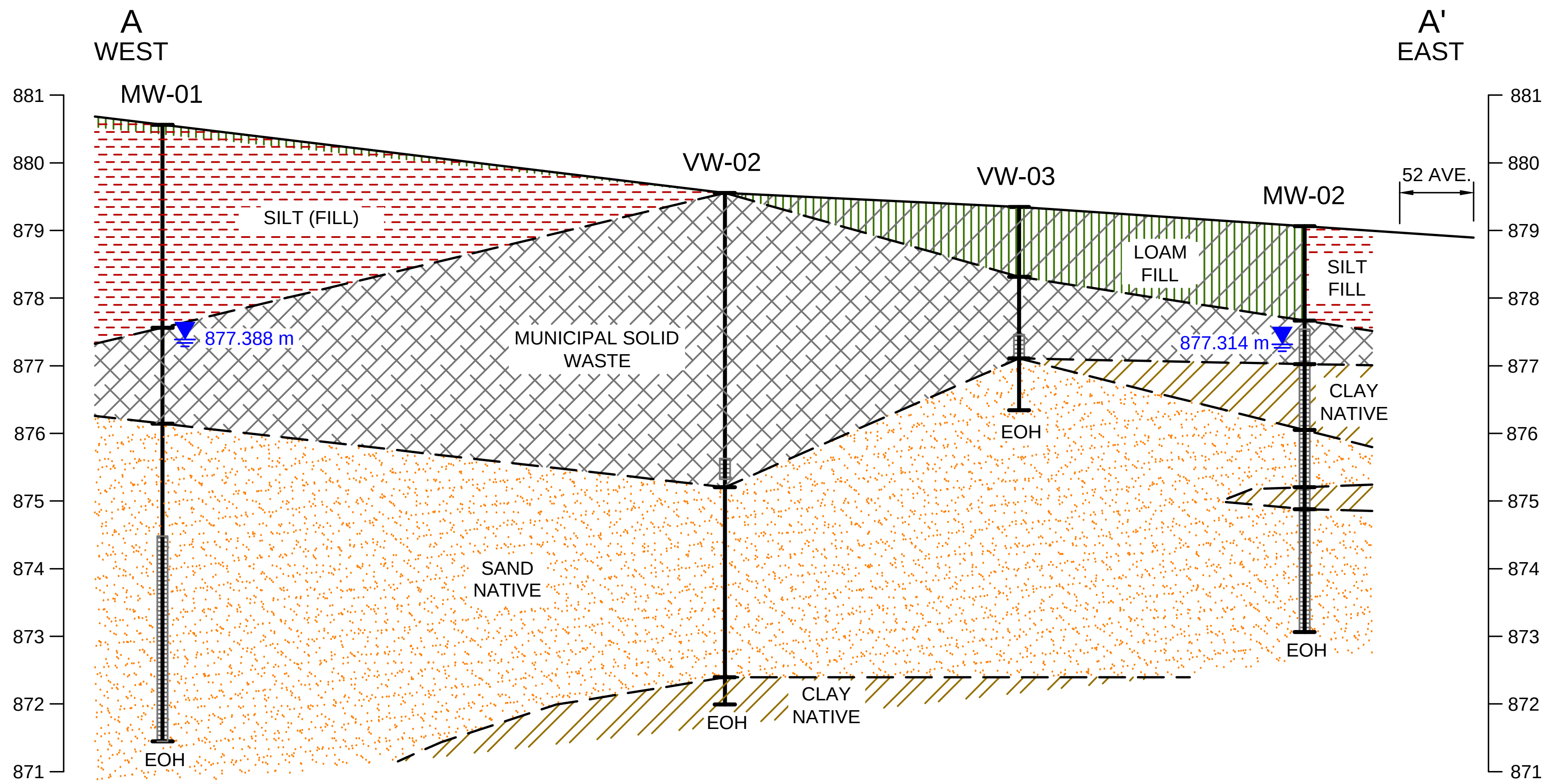
PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN
HISTORIC WASTE DISPOSAL SITE
MONTFORT LANDFILL SITE

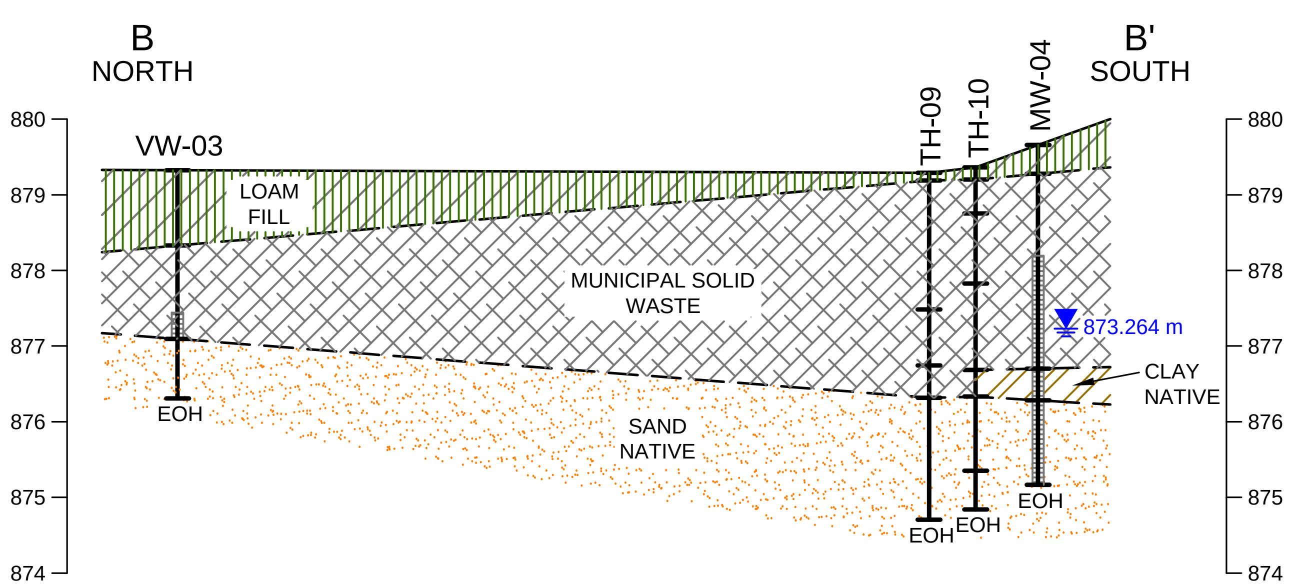
TITLE: SITE PLAN SHOWING SURROUNDING LAND USE

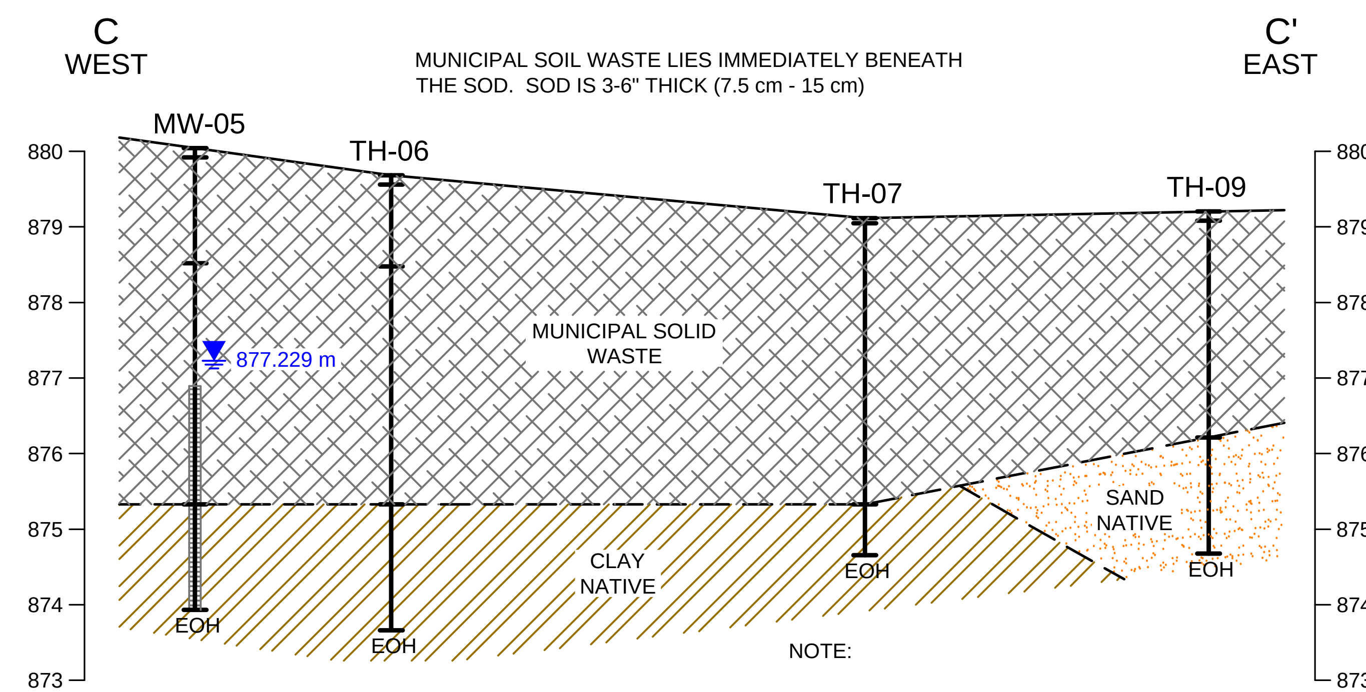
Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
1 : 2000	SEPT. 5/14	12-435	FIGURE 2
DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: ERMP v1.02.dwg	

NOTE:
GROUNDWATER ELEVATIONS
MEASURED AUGUST 7, 2013.







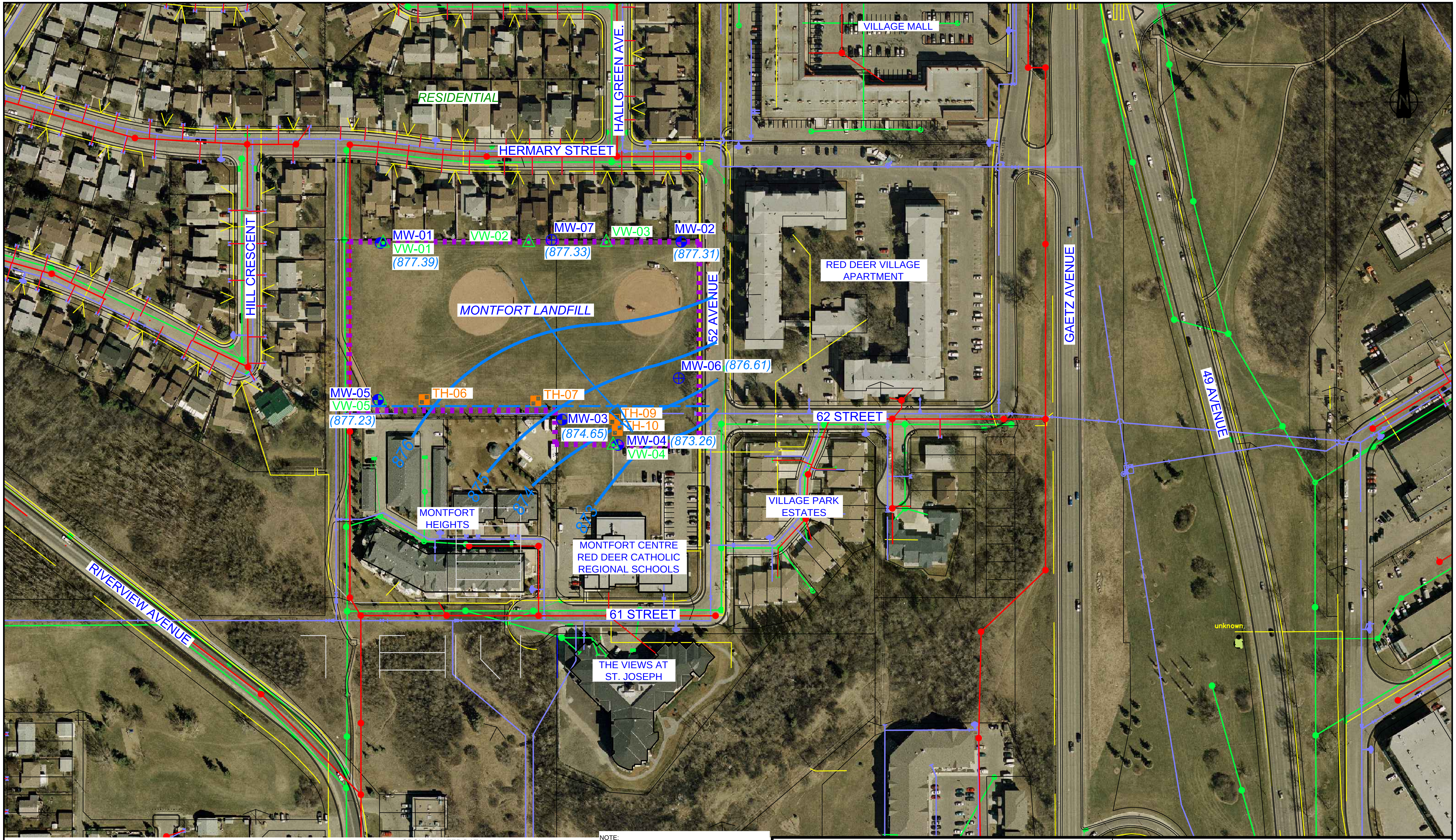
NOTE:

THE GEOLOGIC AND STRATIGRAPHIC SECTIONS SHOWN ON THIS DRAWING ARE INTERPRETED FROM BOREHOLE LOGS. STRATIGRAPHY IS KNOWN WITH CERTAINTY ONLY AT THE BOREHOLE LOCATIONS. ACTUAL STRATIGRAPHY AND GEOLOGIC CONDITIONS BETWEEN BOREHOLES MAY VARY FROM THAT INDICATED ON THIS DRAWING.

0 2 5 10m
Vertical Scale 1:200

0 20 50 100m
Horizontal Scale 1:2000

CLIENT: THE CITY OF RED DEER	Tiamat Environmental Consultants Ltd.				
PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN HISTORIC WASTE DISPOSAL SITE MONTFORT LANDFILL SITE	SCALE: AS SHOWN	DATE: FEB. 11/15	PROJECT NO.: 12–435	FIGURE NO.: FIGURE 3	
TITLE: CROSS SECTIONS A-A', B-B' AND C-C'	DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: ERMP Sections v1.02		



SOURCE
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0 20 50 100m
Scale 1:2000

PHASE II TEST LOCATIONS
- MW-## GROUNDWATER MONITORING WELL INSTALLED BY TIAMAT (5)
- TH-## TESTHOLE (4)
- VW-## SOIL VAPOUR MONITORING WELL (5)
- MW-## GROUNDWATER MONITORING WELL INSTALLED BY OTHERS (2)

REFER TO TABLE 1 FOR TESTHOLE INFORMATION

GROUNDWATER DATA
- (850.150) GROUNDWATER ELEVATION (m) AUGUST 7, 2013
- INTERPRETED GROUNDWATER CONTOUR (m)
- INTERPRETED GROUNDWATER FLOW DIRECTION

LEGEND
- HISTORIC WASTE DISPOSAL
- LOT BOUNDARY

NOTE:
LOCATION OF BURIED UTILITIES ARE APPROXIMATE, ACTUAL LOCATIONS OF THE SHOW UTILITIES AND ANY OTHER UTILITES SHOULD BE VERIFIED PRIOR TO ANY GROUND DISTURBANCE ACTIVITY.

- ELECTRICAL
- SANITARY
- STORM
- WATER
- ABANDONED ASBESTOS CEMENT WATER MAIN

CLIENT: THE CITY OF RED DEER

PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN
HISTORIC WASTE DISPOSAL SITE
MONTFORT LANDFILL SITE

TITLE: INTERPRETED GROUNDWATER ELEVATIONS - AUGUST 2013

Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
1 : 2000	FEB. 11/15	12–435	FIGURE 4
DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: ERMP v1.03.dwg	

APPENDIX A

ALBERTA ESRD
REQUESTING CONSENT TO VARY THE SETBACK DISTANCE FOR A DEVELOPMENT TO A NON OPERATING LANDFILL

Requesting Consent To Vary The Setback Distance For A Development To A Non Operating Landfill

INFORMATION REQUIREMENT

May 2013

Introduction

Section 13 of the *Subdivision and Development Regulation* defines the setback distance required from a subdivision development for a residence, school, hospital, or food establishment to a non-operating landfill. The Regulation allows the subdivision or development authority to vary regulated setback distance upon receiving written consent from Alberta Environment and Sustainable Resource Development.

Setback distance from a residence school, hospital, or food establishment to a non-operating landfill is 300m.

Considerations for consent

Alberta Environment and Sustainable Resource Development (ESRD) will consider a consent to lessen the setback distance from developments near non-operating landfills, based on the following criteria:

1. All Information Requirements set out in this document must be submitted to ESRD by the subdivision or development authority;
2. The subdivision or development authority commits to developing a mechanism whereby future property owners are made aware of any consents issued;
3. Consent will not be considered when all three of the following conditions exist:
    a. Gas levels above background are present within the waste disposal area of the landfill;
    b. The land area where development is to occur has no natural physical barrier to gas movement i.e. a valley between the development and the landfill; and
    c. The development has underground infrastructure or basements
4. Where groundwater has been contaminated, consent will only be considered where:
    a. potable water to the proposed development is being supplied from a municipal system; and
    b. vegetation, or other receptors or property will not be affected by the contaminated groundwater

Only the subdivision or development authority may submit a request for variance

Consent after development

Consent to lessen the setback distance will not be considered after a development permit or subdivision approval has been issued by the local authority**.**

Information Requirements:

Consent must be provided before proceeding with any development not adhering to landfill setback requirements.

The following information is required to be provided to ESRD by the subdivision or development authority before ESRD will consider consenting to a variance request for a development near a non-operating landfill:

1. A covering letter from the subdivision or development authority requesting a variance.
2. A letter of consent from the landfill owner consenting to the encroachment.
3. A letter from the proponent (developer) stating the reasons the site must encroach the landfill setback and the alternatives if the variance is not granted.
4. Details of the type of development within the setback (including proposed design, water supply, wastewater and stormwater systems, topography, location of proposed residences, schools, etc.).

Requesting Consent To Vary The Setback Distance For A Development To A Non Operating Landfill

INFORMATION REQUIREMENT

May 2013

Consent is not provided for developments that have already occurred.

The Standards for Landfills in Alberta can be found at: http://environment.alberta.ca/02956.html

For more information on setback variances please contact your Alberta Environment regional office. http://environment.alberta.ca/contact.html

Information Requirements cont.:

5. Department of Health Permit Number or Alberta Environment and Sustainable Resource Development approval or registration number of the landfill being encroached upon.
6. An engineering report*, completed by a professional registered with APEGA, that includes, as a minimum, the following information:
   a) landfill cell delineation including approximate waste depth (use of test pits, historical aerial photography, etc.),
   b) duration of operation (actual, or estimated if actual not available),
   c) amount, types of waste, and degree of waste stabilization in the landfill,
   d) landfill topography for site drainage,
   e) landfill final cover details such as thickness and composition,
   f) a visual inspection report that details, at a minimum, vegetative stress and degree of cover, landfill settlement, exposed refuse, leachate breakout, and any other visually notable landfill issues,
   g) regional and site specific geology and hydrogeology,\
   h) a map showing all water wells and residences within a 1 kilometre radius of the site and other topographical features, such as water bodies, within 5 kilometres of the site,
   i) the applicable sections of the area structure plan documenting the zoning and expected use of the landfill and surrounding area,
   j) groundwater monitoring results,
   k) landfill gas monitoring results,
   l) an opinion on whether encroachment is feasible (under what mitigative measures, to what distance, etc.), and
   m) if mitigative measures are proposed, the design details, monitoring, and maintenance program for the mitigative measures.
7. Documentation from the Alberta Health Services that they have provided or refused the variance to construct a private water well within the 450-metre setback as per the Public Health Regulations, if applicable. (Water wells also have a setback requirement under Public Health jurisdiction. Any development with a water well will require both waivers before it can proceed.)
8. Documentation on how the development authority will deal with potential complaints from any residents within the setback.
9. Documentation on how the development authority will convey information on the setback variance to existing and successive property owners.
10. A letter from Alberta Health Services confirming that they have no concerns with the proposed development.

**The subdivision or development authority must utilize applicable sections of the current Standards and Guidelines for Landfills in Alberta to develop the information required in (6).*

APPENDIX B

GLOSSARY

GLOSSARY

Physical and Toxicological Terms

8-Hour Occupational Exposure Limit is the maximum concentration of a substance that a worker can be exposed to during a standard 8-hour work day.

Bioconcentration Factor (BCF) provides a measure of the extent of chemical partition at equilibrium between a biological medium (e.g. fish tissue, plant tissue) and an external medium (e.g. water). The higher the BCF, the greater the accumulation in living tissue.

Carcinogenicity is the ability of a substance to produce or result in cancer.

DNPL is an acronym for Dense Non-aqueous Phase Liquid. A DNPL is a chemical or a mixture of chemicals having two common physical characteristics; having a density greater than water and being "practically" insoluble in water. Subsurface movement of a DNPL can be complex and the greater toxicity of a DNPL to human and ecological health often has much lower environmental guidelines and limits for exposure.

Estimate Dosage is the predicted intake of a substance via inhalation. Calculation is derived from Health Canada's PQRA equation for inhalation of volatile substances.

Half-life is the amount of time it takes for the concentration of a given substance to fall to half its original concentration.

Hazard Quotient (HQ) is the ratio of the calculated estimated dosage of a substance to its tolerable concentration or TRV. When the HQ is less than 1, the exposure potential is considered negligible. When the HQ is greater than 1, the potential rate of exposure could exceed the acceptable level of exposure.

Henry's Law Constant (H) provides a measure of the extent of chemical partitioning between air and water at equilibrium. The higher the Henry's Law constant, the more likely a chemical is to volatize than to remain in water.

Molecular Weight is the sum of the weight of all the atoms in a molecule.

Octanol-Water Partition Coefficient (K_{ow}) provides a measure of the extent of chemical partitioning between water and octanol at equilibrium. The greater the K_{ow} the more likely a chemical is to partition to octanol than to remain in water. Octanol is used as a surrogate for lipids (fats) and K_{ow} can be used to predict bioconcentration in aquatic organisms.

Odour Threshold is the lowest concentration of a substance that can be identified by human olfactory sense.

GLOSSARY
continued

Organic Carbon-Water Partition Coefficient (K_{oc}) provides a measure of the extent of chemical partitioning between organic carbon and water at equilibrium. A higher K_{oc}, the more likely a chemical is to bind to soil or sediment than to remain in water.

Soil/Sediment-Water Partition Coefficient (K_d) provides a soil or sediment-specific measure of the extent of the chemical partitioning between soil or sediment and water, unadjusted for dependence upon organic carbon. To adjust for the fraction of organic carbon present in soil or sediment (foc), use $K_d = K_{oc}$ H f_{oc}. The higher the K_d the more likely a chemical is to bind to soil or sediment than to remain in water.

Solubility is an upper limit of the dissolved concentration of a chemical in a solvent at a specified temperature. Aqueous concentrations in excess of solubility or 100% saturation may indicate sorption onto sediments, the presence of a non-aqueous phase liquid.

Specific Gravity is the ratio of the density of a substance to the density of a reference substance (in this case, water or air) at the same temperature. A substance with a specific gravity greater than 1.0 has a higher mass per unit volume than the reference substance and will therefore preferentially “sink” beneath the reference substance.

Toxicological Reference Value (TRV) and Acceptable Daily Intake (ADI) and Tolerable Daily Intake (TDI) by definition, is the maximum concentration of a substance that can be ingested daily over a lifetime without risk. It is expressed based in body weight.

Vapour Pressure is the pressure exerted by a chemical vapour in equilibrium with its solid or liquid phase at a given temperature. It is applied for calculating the rate of volatilization of the pure chemical compound from a surface or to estimate a constant for Henry’s Law for low solubility in water. The higher the vapour pressure, the more likely a chemical is to exist in a gaseous state.

Identified Chemicals of Concern

Benzene
Chemical Formula: C_6H_6
Carcinogenicity: Known Carcinogen

Benzene is a well-known petroleum hydrocarbon and is a known carcinogenic, based on numerous toxicity studies. The odour threshold is 1.5 ppm. The current Alberta Tier 1 Guidelines for benzene in soil and groundwater are 0.078 mg/kg and 0.005 mg/L. The 1-hour Alberta Ambient Air Quality Objective for benzene is 0.009 ppm. The Alberta 8-hour occupational exposure limit is 0.5 ppm. Benzene is on Health Canada's Cosmetic Ingredient Hot List and Canada's National Pollutant Release Inventory.

GLOSSARY
continued

Carbon Disulfide
Chemical Formula: CS_2
Carcinogenicity: Non-Carcinogenic

Carbon disulfide has an odour threshold of 0.016 ppm. Currently, there are no guidelines or standards in Alberta for carbon disulfide in soil and water; the 1-hour average Alberta Ambient Air Quality Objective is 0.010 ppm. The Alberta 8-hour occupational exposure Limit is 1 ppm. Carbon disulfide is not classified as toxic under the Canadian Environmental Protection Act (1999). Carbon disulfide is included in Health Canada’s Cosmetic Ingredient Hotlist.

Chloroethane
Chemical Formula: C_2H_5Cl
Carcinogenicity: Not Classified

Chloroethane has an odour threshold of 4.2 ppm. There are no published standards or guidelines in Alberta for chloroethane in soil or groundwater. British Columbia and the State of New Jersey have implemented an interim water guideline of 0.005 mg/L.
The Alberta 8-hour occupational exposure limit is 100 pm. Chloroethane is on Canada's National Pollutant Release Inventory.

Chloroform
Chemical Formula: $CHCl_3$
Carcinogenicity: Possible Carcinogen

Chloroform is a chlorinated hydrocarbon. The established odour threshold is 85 ppm. The current Alberta Tier 1 Guidelines for chloroform in soil and groundwater are 0.0010 mg/kg and 0.0018 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 10 ppm. Chloroform is on Health Canada's Cosmetic Ingredient Hot List and Canada's National Pollutant Release Inventory.

Chloromethane
Chemical Formula: CH_3Cl
Carcinogenicity: Not Classified

Chloromethane has an odour threshold of 10 ppm. There are no published standards or guidelines in Alberta for chloromethane in soil and groundwater. The State of New Hampshire has implemented a drinking water guideline of 0.03 mg/L. The Alberta 8-hour occupational exposure limit is 50 ppm. Chloromethane is on Canada's National pollutant Release Inventory.

GLOSSARY
continued

Cyclohexane
Chemical Formula: C_6H_{12}
Carcinogenicity: Not Classified

Limited information exists regarding cyclohexane. The established odour threshold is 0.41 ppm. There are no published standards or guidelines in Alberta for cyclohexane in soil or groundwater. The Alberta 8-hour occupational exposure limit is 300 ppm.

1,4-Dichlorobenzene
Chemical Formula: $C_6H_4Cl_2$
Carcinogenicity: Possible Carcinogen

1,4-Dichlorobenzene has an odour threshold of 0.121 ppm. . The current Alberta Tier 1 Guidelines for benzene in soil and groundwater are 0.098 mg/kg and 0.001 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 75 ppm.

Dichlorodifluoromethane
Chemical Formula: CCL_2F_2
Carcinogenicity: Non-Carcinogenic

Dichlorodifluoromethane (Freon 12) is part of a group of synthetic chemicals called Chlorofluorocarbons (CFC’s). An odour threshold for Freon 12 has not been established. Currently, there are no published guidelines or standards in Alberta for Freon 12 in soil or groundwater. The Alberta 8-hour occupational exposure limit is currently 1,000 ppm.

1,1-Dichloroethylene
Chemical Formula: $C_2H_2Cl_2$
Carcinogenicity: Possible Carcinogen

1,1-Dichloroethylene is a chlorinated hydrocarbon with an odour threshold of 190 ppm. The current Alberta Tier 1 guidelines for 1,1-dichloroethylene are 0.021 mg/kg and 0.014 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 5 ppm. 1,1-Dichloroethylene is listed on Health Canada's Cosmetic Ingredient Hotlist.

cis-1,2-Dichloroethylene
Chemical Formula: $C_2H_2Cl_2$
Carcinogenicity: Not Classified

cis-1,2-Dichloroethylene is a chlorinated hydrocarbon with an odour threshold of 0.085 ppm. There are no published standards or guidelines in Alberta for cis-1,2-dichloroethylene in soil or groundwater. The Alberta 8-hour occupational exposure limit is 200 ppm.

GLOSSARY
continued

trans-1,3-Dichloropropene
Chemical Formula: $C_3H_4Cl_2$
Carcinogenicity: Possible Carcinogen

trans-1,3-Dichloropropene is a chlorinated hydrocarbon. The established odour threshold is 1 ppm. There are currently no published standards or guidelines for trans-1,3-dichloropropene in soil and groundwater in Alberta. The Alberta 8-hour occupational exposure limit is 1 ppm.

1,2Dichlorotetrafluoroethane
Chemical Formula: $C_2Cl_2F_4$
Carcinogenicity: Non-Carcinogenic

1,2-Dichlorotetrafluoroethane (Freon 114) is a CFC. No odour threshold has been established for Freon 114. There are currently no published standards or guidelines in Alberta for Freon 114 in soil and groundwater. The Alberta 8-hour occupational exposure limit is currently 1,000 ppm.

Ethane
Chemical Formula: C_2H_6
Carcinogenicity: Not Classified

Ethane has an odour threshold of 899 ppm. There are currently no standards or guidelines in Alberta for ethane in soil and groundwater. The Alberta 8-hour occupational exposure limit is 1,000 ppm.

Ethanol
Chemical Formula: C_2H_6O
Carcinogenicity: Known Carcinogen

Ethanol has an odour threshold of 0.35 ppm. There are no published standards or guidelines in Alberta for ethanol in soil or groundwater. The Alberta 8-hour occupational exposure limit is 1,000 ppm.

Ethylbenzene
Chemical Formula: $C_6H_5CH_2CH_3$
Carcinogenicity: Possible Carcinogen

Ethylbenzene is a petroleum hydrocarbon and has an odour threshold of 2.3 ppm. The current Alberta Tier 1 Guidelines for Ethylbenzene in soil and groundwater are 0.21 mg/kg and 0.0024 mg/L, respectively. The 1-hour Alberta Ambient Air Quality Objective for Ethylbenzene is 0.460 ppm. The Alberta 8-hour occupational exposure limit is 100 ppm.

GLOSSARY
continued

Ethylene
Chemical Formula: C_2H_4
Carcinogenicity: Non-Carcinogenic

Ethylene vapour has an odour threshold of 270 pm. There are currently no standards or guidelines in Alberta for ethylene in in soil and groundwater. The 1-hour Alberta Ambient Air Quality Objective is 1.05 ppm. The Alberta 8-hour occupational exposure limit is 200 ppm. Ethylene is listed on Environment Canada's National Pollutant Release Inventory.

Heptane
Chemical Formula: C_7H_{16}
Carcinogenicity: Not Classified

Heptane vapour has an odour threshold of 220 ppm. There are no published standards or guidelines in Alberta for heptane in soil and groundwater. The State of New Jersey has adopted a groundwater standard of 0.1 mg/L. The Alberta 8-hour occupational exposure limit is 400 ppm.

Hexane
Chemical Formula: C_6H_{14}
Carcinogenicity: Non-Carcinogenic

Hexane vapour has an odour threshold of 130 ppm. There are no published standards or guidelines in Alberta for hexane in soil and groundwater. The Canadian Council for the Ministers of the Environment (CCME) recommends soil guidelines ranging between 0.49 to 21 mg/kg, depending on land use. The 1-hour average Alberta Ambient Air Quality Objective is 5.958 ppm. The Alberta 8-hour occupational exposure limit is 500 ppm.

p-Isopropyltoluene
Chemical Formula: $C_{10}H_{14}$
Carcinogenicity: Not Classified

p-Isopropyltoluene does not have an established odour threshold. There are currently no published standards or guidelines in Alberta for p-isopropyltoluene in soil and groundwater. The Alberta 8-hour occupational exposure limit is 10 ppm.

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Methane
Chemical Formula: CH_3
Carcinogenicity: Non-Carcinogenic

Methane is a common component of landfill gas. Methane vapour is colourless and odourless; no odour threshold has been established. There are no published standards or guidelines in Alberta for in methane soil and groundwater. The current Alberta 8-hour occupational exposure limit is 1,000 ppm.

Methylene Chloride
Chemical Formula: CH_2Cl_2
Carcinogenicity: Possible Carcinogen

Methylene Chloride is a chlorinated hydrocarbon and had an odour threshold of 250 ppm. The current Alberta Tier 1 Guidelines for methylene chloride in soil and groundwater are 0.095 mg/kg and 0.05 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 50 ppm. Methylene Chloride is on Health Canada's Cosmetic Ingredient Hot List and Canada's National Pollutant Release Inventory.

Methyl Ethyl Ketone
Chemical Formula: C_4H_8O
Carcinogenicity: Not Classified

Methyl Ethyl Ketone has an odour threshold established at 5.4 ppm. There are no published standards or guidelines in Alberta for methyl ethyl ketone in soil or groundwater. The Alberta 8-hour occupational exposure limit is 200 ppm.

Propane
Chemical Formula: C_3H_8
Carcinogenicity: Non-Carcinogenic

Propane has an odour threshold of 20,000 ppm. There are no published standards or guidelines in Alberta for propane in soil or groundwater. The Alberta 8-hour occupational exposure limit is 100 ppm.

2-Propanol
Chemical Formula: C_3H_8O
Carcinogenicity: Not Classified

2-Propanol has an odour threshold ranging from 1.6 ppm to 2,214 ppm. There are no published standards or guidelines in Alberta for 2-propanol in soil or groundwater. The 1-hour Alberta Ambient Air Quality Objective is 3.19 ppm. The 8-hour Alberta occupational exposure limit is 200 ppm.

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2-Propanone
Chemical Formula: C_3H_6O
Carcinogenicity: Not Classified

2-Propanone (Acetone) has an odour threshold of 20 ppm. There are no published standards or guidelines in Alberta for Acetone in soil or groundwater. The 1-hour Alberta Ambient Air Quality Objective is 2.4 ppm. The 8-hour occupational exposure limit is 250 ppm. Acetone is on Canada's National Pollutant Release Inventory.

Propene
Chemical Formula: C_3H_6
Carcinogenicity: Not Classified

Propene does not have an established odour threshold. There are no published standards or guidelines in Alberta for propene in soil and groundwater. The Alberta 8-hour occupational exposure limit is 50 ppm.

Tetrachloroethylene
Chemical Formula: $Cl_2C=CCl_2$
Carcinogenicity: Known Carcinogen

Tetrachloroethylene (PCE) is a chlorinated hydrocarbon and a known carcinogen. The established odour threshold is 1 ppm. The current Alberta Tier 1 Guidelines for PCE in soil and groundwater are 0.77 mg/kg and 0.03 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 25 ppm. PCE is on Canada's National Pollutant Release Inventory.

Tetrahydrofuran
Chemical Formula: C_4H_8O
Carcinogenicity: Possible Carcinogen

Tetrahydrofuran vapour has an odour threshold of 30 ppm. There are no published standards or guidelines in Alberta for tetrahydrofuran in soil and groundwater. The Alberta 8-hour occupational exposure limit is 50 ppm.

Toluene
Chemical Formula: $C_5H_5CH_3$
Carcinogenicity: Not Classified

Toluene is a petroleum hydrocarbon with an odour threshold of 2.9 ppm. The current Alberta Tier 1 Guidelines for Toluene in soil and groundwater are 0.29 mg/kg and 0.024 mg/L, respectively. The 1-hour Alberta Ambient Air Quality Objective for Toluene is 0.499 ppm. The Alberta 8-hour occupational exposure limit is 50 ppm.

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1,1,1-Trichloroethane
Chemical Formula: $C_2H_3Cl_3$
Carcinogenicity: Not Classified

1,1,1-Trichloroethane is a chlorinated hydrocarbon. The established odour threshold is 0.971 ppm. There are no published standards or guidelines in Alberta for 1,1,1-trichloroethane in soil and groundwater. The CCME has established a residential soil quality guideline of 5 mg/kg for the protection of environmental and human health. The Alberta 8-hour occupational exposure limit is 350 ppm.

Trichloroethylene (TCE)
Chemical Formula: $ClCH=CCl_2$
Carcinogenicity: Known Carcinogen

Trichloroethylene (TCE) is a chlorinated hydrocarbon and a known carcinogen. The established odour threshold is 28 ppm. The current Alberta Tier 1 Guidelines for TCE in soil and groundwater are 0.012 mg/kg and 0.005 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 50 ppm.

Trichlorofluoromethane
Chemical Formula: CCl_3F
Carcinogenicity: Non-Carcinogenic

Trichlorofluoromethane (Freon 11) is a CFC with an odour threshold of 5 ppm. Currently, there are no published guidelines or standards in Alberta for Freon 11 in soil or groundwater. The NIOSH 8-hour occupational exposure limit is currently 1,000 ppm.

Trichlorotrifluoroethane
Chemical Formula: $C_2Cl_3F_3$
Carcinogenicity: Non-Carcinogenic

Trichlorotrifluoroethane (Freon 113) is a CFC with an odour threshold of 5 ppm. Currently, there are no published guidelines or standards in Alberta for Freon 113 in soil or groundwater. No occupational exposure guideline has been established.

1,3,5-Trimethylbenzene
Chemical Formula: C_9H_{12}
Carcinogenicity: Non-Carcinogenic

1,3,5-Trimethylbenzene has an odour threshold of 0.036 ppm. There are no published standards or guidelines for 1,3,5-trimethylbenzene in soil and groundwater. The State of California adopted a drinking water guideline of 0.334 mg/L. The Alberta 8-hour occupational exposure limit is 25 ppm.

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1,2,4-Trimethylbenzene
Chemical Formula: C_9H_{12}
Carcinogenicity: Non-Carcinogenic

1,2,4-Trimethylbenzene has an odour threshold of 0.4 ppm. There are no published standards or guidelines for 1,2,4-trimethylbenzene in soil and groundwater. The State of California adopted a drinking water guideline of 0.334 mg/L. The Alberta 8-hour occupational exposure limit is 25 ppm.

2,2,4-Trimethylpentane
Chemical Formula: C_8H_{18}
Carcinogenicity: Not Classified

Limited information exists regarding 2,2,4-trimethylpentane. No odour threshold for 2,2,4-trimethylpentane has been established. Currently, there are no published guidelines or standards in Alberta for 2,2,4-trimethylpentane in soil, water or air.

Vinyl Chloride
Chemical Formula: C_2H_3Cl
Carcinogenicity: Known Carcinogen

Vinyl Chloride is a chlorinated hydrocarbon and a known carcinogen. An odour threshold of 3,000 ppm has been established. The current Alberta Tier 1 Guidelines for vinyl chloride are 0.00034 mg/kg and 0.0011 mg/L in soil and groundwater, respectively. The Alberta Ambient Air Quality 1-hour objective for vinyl chloride is 0.051 ppm. Vinyl chloride is listed on Health Canada's Cosmetic Ingredient Hotlist and Environment Canada's National Pollutant Inventory.

Xylenes
Chemical Formula: C_8H_{10}
Carcinogenicity: Not Classified

Mixed (or total) xylenes are composed of isomers o-xylene, m-xylene and p-xylene. Each isomer has an odour threshold of 0.5 ppm. The current Alberta Tier 1 Guidelines for Xylenes in soil and groundwater are 12 mg/kg and 0.3 mg/L, respectively. The 1-hour Alberta Ambient Air Quality Objective for Xylenes is 0.529 ppm. The Alberta 8-hour occupational exposure limit is 100 ppm.