# Environmental Risk Management Plan
# Historic Waste Disposal Sites
# Red Deer College & Red Deer Motors Landfill Sites
# 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 historic landfills designated as Red Deer College Landfill and Red Deer Motors Landfill. The genesis and their proximity to each other (separated by the right-of-way for Taylor Drive) lends to a single ERMP encompassing both landfill sites. 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 these historic waste disposal sites.

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 etc.). 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 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 for 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 to 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. 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 Red Deer College and Red Deer Motors Sites, 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, 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 the two historic waste disposal sites designated as the Red Deer College and Red Deer Motors Landfill Sites.

This report presents the scope of work, a summary of the preliminary quantitative risk assessment (PQRA) and a proposed ERMP for the Red Deer College and Red Deer Motors 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 and 2014 Phase II ESA reports for the Red Deer College and Red Deer Motors Landfill Sites 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

Commercial developments north and east of the historic (1968-1969) Red Deer Motors Landfill predate this landfill. Similarly, the college facilities, residential developments west and north and Taylor Drive predate the historic (1970-1972) Red Deer College Landfill. Since 1972, the estimated age of the waste material, post closure, is about 43 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 both of these historic waste disposal sites.

Previous environmental investigations performed at the Red Deer Motors and Red Deer College landfill sites were conducted by various consultants:

- Summary Report Former Site Landfill Red Deer Motors Site, Part of SE 8-38-27-W4M, Red Deer, Alberta, March 2007 and Summary Report Former City Landfill Site Red Deer College Site (Part of SE 8-38-27-W4M), April 2008. Prepared by Stantec Inc. and Parkland Geotechnical Consulting Ltd.

- Phase I Environmental Site Assessment, Historic Waste Disposal Sites, Red Deer Motors Site, September 24, 2013, prepared by Tiamat.

- Phase I Environmental Site Assessment, Historic Waste Disposal Sites, Red Deer College, September 24, 2013, prepared by Tiamat.

- Phase II Environmental Site Assessment, Historic Waste Disposal Sites, Red Deer Motors Site, February 26, 2014, prepared by Tiamat.

- Phase II Environmental Site Assessment, Historic Waste Disposal Sites, Red Deer College, February 26, 2014, prepared by Tiamat.

A copy of the 2007 and 2008 Summary Reports were provided by The City of Red Deer. Key information from the referenced documents was consolidated and the identified data gaps for each historic landfill site were addressed in the respective Phase I ESA reports (Tiamat, 2013). The scope of investigation for the Phase II ESA was designed to address the environmental concerns identified from the Phase I ESA. The Phase II ESA was conducted between June and September 2013 and final reports were issued in February 2014.

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

- The waste material is situated on either native sand or clay till. The sand unit governs for the flow of local groundwater while clay (where present) is expected to retard the downward mobility of various chemical contaminants associated with the MSW material.

- In August 2013, the average depth to groundwater from the ground surface was about 4.2 m at the Red Deer Motors Landfill Site and 2.9 m at the Red Deer College Landfill Site. For each landfill site, the groundwater lies within the waste material. The average horizontal hydraulic gradient moving through the MSW and leaving the respective landfill sites are 5% to the northwest on the Red Deer Motors Landfill and 4% to the northeast on the Red Deer College Landfill. The interpreted pattern of local groundwater appears to converge beneath Taylor Drive and Waskasoo Creek which divides the two landfills. Waskasoo Creek flows from a south to north direction between the two landfills. Applying an intrinsic horizontal permeability of $10^{-5}$ m/sec for the sand and an effective porosity of 30%, the resulting estimate horizontal (Darcy) groundwater flow velocity is about 4.7 m/year, more or less.

- Dissolved volatile organic compounds (VOCs) and other petroleum hydrocarbon constituents were detected during the 2013 August test event at groundwater monitoring wells located at down gradient locations at each landfill site. The 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 that is likely leaving each landfill site. This leachate is further characterised by field measured water quality indices showing high negative redox potentials (-83.6 mV to -104 mV) and near anoxic conditions for dissolved oxygen (0.77 mg/L to 1.3 mg/L) in the local groundwater.

- Adjacent and nearby developments include a variety of commercial businesses including restaurant, hotel, apartment complex, detached residential houses and various facilities of the Red Deer College including student residences.

- Each historic landfill is capped with a thin (about 15 to 30 cm thick) veneer of loamy sandy soil with grass coverage. There is clear evidence notable differential settlement has and continues to occur with the underlying MSW material at each landfill site. There are presently no obvious activities on the adjacent lands that are interpreted as an environmental concern relative to the site.

- Light molecular-weight petroleum gases were detected at the soil vapour wells at both landfill sites. Petroleum hydrocarbon contaminants were confirmed in the northwesterly quadrant of the Red Deer Motors Landfill Site.

- Volatile petroleum hydrocarbon constituents to carbon chain 12 were consistently detected in each of the three soil vapour wells at the Red Deer Motors Landfill and at the five soil vapour wells at the Red Deer College Landfill. Additionally, semi-volatile, halogenated, oxygenated volatile hydrocarbons and ketones were identified in the soil vapour samples.

The findings of the Phase II ESA suggest various dissolved constituents present in the groundwater include inorganic compounds, nutrients, various VOCs and other dissolved hydrocarbons. Mild to moderate strength leachate constituents are present in the groundwater and is likely leaving each landfill site and flowing towards the urbanized Waskasoo Creek. The environmental health of Waskasoo Creek, as it flows by the landfill sites, is identified in this ERMP as a potential receptor at risk. Hence, this ERMP includes aspects of an ecological risk assessment for Waskasoo Creek and the initial assessment of landfill gas (LFG). A summary of the identified chemicals of concern are tabulated in Table 2A.

### 1.2.1 Site Description and Environmental Setting

The areas of the historic waste are situated within two subdivided parcels of land. The two parcels of land are summarised as follows:

<u>Red Deer Motors Landfill Site</u>
Lot 6MR, Block 2, Plan 002 0018 with a plan area of 2.11 ha (5.21 ac), more or less and with a landfill footprint of about 11,180 $m^2$ (2.76 ac) or about 53% of Lot 6MR. The historic waste material extends beyond the north legal property line onto a portion of the road easement for 32$^{nd}$ Street.

<u>Red Deer College Landfill Site</u>
Lot 1, Block 1, Plan 012 0303 with a plan area of 884.63 ha (209.12 ac), more or less and with a landfill footprint of about 38,530 $m^2$ (9.52 ac) or about 4.6% of Lot 1. The historic waste materials extend beneath the man-made knoll that is adjacent to the student residence buildings.

Each historic waste disposal area is contiguous with municipal solid waste (MSW) material and is separated by Waskasoo Creek and Taylor Drive. The above areas lie within the SE 08-38-27 W4M.

The historic waste disposal area is completely bounded by various urban developments in the Communities of Southill, Westpark and Red Deer College. General features of the landfill sites relative to the surrounding community developments and the approximate footprint of the historic waste material is presented as Figure 1.

The City of Red Deer is the registered Owner of the Red Deer Motors Landfill Site while The Red Deer College is the registered Owner of the Red Deer College Landfill Site. It is understood both municipal sanitary landfill sites were operated by The City of Red Deer. The land containing the Red Deer College Landfill was transferred from The City of Red Deer to The Red Deer College, refer to the September 24, 2013 Phase I ESA prepared by Tiamat. Accordingly, The Red Deer College has control and responsibility for the college campus land and the associated facilities. The college campus is independent of The City of Red Deer.

Excepting for a fiber optic line that was installed through the Red Deer College Landfill, circa 2011, there are no buildings or other infrastructure within the historic waste disposal area of each landfill site.

## 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 Waskasoo Creek is the sole permanent surface water in proximity of the two landfill sites.

The site and immediate area are interpreted to lie within a zone of groundwater recharge with a downward component of flow.

A local topographic map for this area suggest the groundwater should converge towards Waskasoo Creek. It is noted during construction of Taylor Drive, circa late-1980s, a section of Waskasoo Creek that crosses the southeast quadrant of The Red Deer College campus was altered. This alteration of the creek path may have influenced the natural pattern of groundwater flow, refer to the Assessment for Red Deer College Proposed Residential Housing, December, 1999 prepared by AGRA Earth & Environmental Limited). Waskasoo Creek meanders north of the landfill sites and ultimately discharges into The Red Deer River. It should be noted that local topography, geology, land development and soil disturbances may 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 prepared by Tiamat.

Underground municipal utilities identified to be in the immediate vicinity of the historic waste site consist of electrical power lines, communication cables, natural gas services and storm water sewers. 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 each landfill site. These indicators suggest ongoing settlement and are indicative of the instability of the ground surface overlying the historic waste at both landfills.

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 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.

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 the landfill soil gas matrix. As noted in Section 1.2, Waskasoo Creek is an identified at risk ecological receptor.

## 1.4 Environmental Guidelines & Regulations

The historic waste sites have been closed from landfilling for about 43 years and both are considered to be non-operating municipal landfills. 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. 119/2014, Part 2 Subdivision and Development Conditions, Section 13 "Distance from landfill, waste sites" controls the subdivision and development for four distinct land uses within a prescribed distance from a non-operating landfill. An excerpt from the above regulation 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 Red Deer Motors and Red Deer College Landfill Sites reflect 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 vapour into a heated building.

## 2.1 Groundwater

Taylor Drive and Waskasoo Creek separate the two landfill sites and the local groundwater measurement from each respective landfill site appears to converge to Waskasoo Creek. The landfills at Red Deer Motors and Red Deer College have been built up such that the bounding streets (32$^{nd}$ Street and Taylor Drive) are at a lower ground elevation, refer to cross sections presented on Figures 3A, 3B and 3C illustrating the relative surface elevation of the landfill waste and the approximate depth to the first groundwater relative to the roadways. The geometry indicates the roadways and the deep utilities beneath the roadways will not serve as a natural barrier to the migration of subsurface landfill gas due to the following in-situ conditions:

- Dissolved leachate containing VOCs encountered at each landfill site will tend to migrate with the groundwater lying beneath the adjacent roadways and deep utilities. VOCs will persistently degas/volatilize from the groundwater into the vadose zone. Typically, the concentration gradient and soil vapour flux are expected to decrease with distance from the source areas. However, given the waste mass and a conservative approach, the source of VOCs (historic waste material) is deemed to be a constant and non-diminishing source for soil vapours. As discussed in Section 3.1, it is presumed the subsurface equilibrium conditions for the landfill gas have likely developed.

- Soil vapours to preferentially rise in the subsurface is a misconception on how VOCs transfer in the vapour phase subsurface. Advection and diffusion are the two primary physical processes which are associated with the transport of subsurface VOCs. Advection is governed by pressure differential i.e. variation of atmospheric, subterranean and building interior pressures. Gaseous diffusion is the "mobility" of a VOC by molecular processes. Subsurface diffusional transport occurs radially in every direction from an area of high to low concentration. Thus, VOCs in the waste material above the groundwater table will exhibit a diffusive flux radially and vertically upwards and downwards in each direction.

The water quality at the down gradient test locations at the Red Deer College Landfill site indicate the level of impact by landfill leachate indicators to be relatively harmful as the concentration of dissolved volatile compounds such as benzene, toluene, ethylbenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloroethane and vinyl chloride exceed the referenced Tier 1 Guidelines. Benzene and vinyl chloride are known carcinogens and 1,2-dichloroethane and 1,4-dichlorobenzene are classified as a possible carcinogens, refer to Table 3A and the Glossary in Appendix B. Thus, the above noted chemicals identified to be present from the Phase II ESA are considered chemicals of concern for this ERMP.

For the Red Deer Motors Landfill, vinyl chloride was the sole VOC in groundwater exceeding the referenced Tier 1 Guideline. Trace concentration of benzene was also present in the groundwater at the down gradient monitoring well.

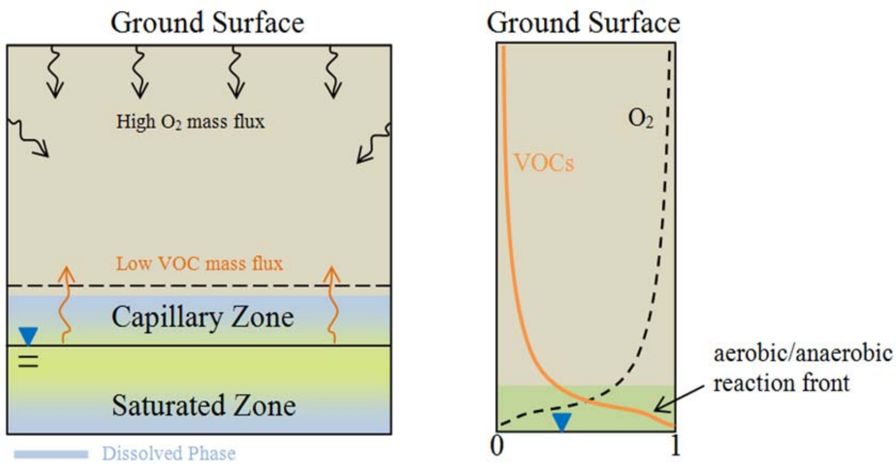
The natural sand underlying the waste material is pervious and the nearby deep utilities (sewer pipes) are interpreted to not influence the pattern of local groundwater. Thus, the migration of groundwater with leachate would likely be governed by the natural pattern of flow. Results from the Phase II ESA suggest the groundwater velocity (August 2013) is estimated to be 4.7 m/year. It should be noted, the horizontal flow velocity will be variable subject to climatic conditions and seasonal variation.

## 2.2 Soil Vapour

The concentration of landfill soil gas is considered to be moderately elevated at test locations on the Red Deer College Landfill and to a lesser degree at the Red Deer Motors Landfill. Nevertheless, the variety of chemical types (such as VOCs, including the presence of various siloxanes) was noted and clearly suggests 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 soil vapour in the unsaturated zone along with potential naturally occurring attenuating 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 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 considered reliable.

To evaluate whether the potential attenuation of some soil vapour 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 Red Deer Motors and Red Deer College Landfill Sites would require a rigorous seasonal testing program. Attenuation of a specified soil vapour constituent is 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 vapour 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 vapour 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 vapour 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

As noted in Sections 1.2.1, 2.1 and 2.2, soil vapours and groundwater containing leachate present the potential exposure risks. This section provides a general discussion on soil vapours, groundwater and soil contamination associated with each of the landfill sites.

Presently, the land uses adjacent to and lying within the 300 m regulatory setback to the Red Deer College and Red Deer Motors Landfill Sites comprises of the following:

Adjacent land uses:

- Detached student residence housing with basements;
- Main college campus facility with basement;
- Commercial hotel and detached liquor store; and
- Underground utilities crossing the waste area (fiber communication cable) and immediately adjacent to the waste material (storm sewer and electrical service).

Nearby land uses:

- Municipal green spaces, roads, underground utilities;

- Detached single family homes with basements; and
- Commercial automotive dealerships and auto repair businesses.

The most sensitive potential receptors to contaminants from the landfill sites are the student housing and underground structures (basements, manholes, buried vaults) adjacent to the historic waste material.

## Soil Vapours

There is a potential for the presence of subsurface soil vapour beneath the building footprint for the student residences at the Red Deer College. Soil vapour may migrate into buildings by way of pipe penetrations, cracks, fractures and joints in the floor and foundation walls that serve as point-of-ingress (POIs). It is understood the student residence housing near the historic waste material have a basement and a passive soil vapour barrier was implemented during the development of these student residences. Information on follow-up monitoring for the performance of the soil vapour barrier and assessment for effectiveness was not available to Tiamat.

Subsurface soil vapour may also migrate to near-by buildings located on the north side of 32$^{nd}$ Street and to other nearby campus facilities. The exposure pathway for vapour inhalation via vapour intrusion mechanisms is always considered to human health. Field data and laboratory results for groundwater suggest the degree of saturation is low to moderate and the potential for soil vapours is proportionately considered to be low to moderate.

To our knowledge, there has not been a documented record from a building owner for potential exposure of landfill gas into their respective building. At The Red Deer College, it is understood that during the construction of the student housings that are located in proximity of the landfill, soil vapour mitigation measures were implemented. To our knowledge, there was no confirmation for the installation and performance of the vapour mitigation measures proposed. Furthermore, the mitigative measures have not been monitored for performance and effectiveness since the completion of the student residences. In addition, there is no documented information concerning monitoring and testing for the presence of landfill gas at nearby underground manholes and utility infrastructure. As noted in Section 1.2.1, The City has no authority to undertake such an assessment of the soil vapour mitigation measures at these student residences.

## 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. Present findings demonstrate a moderate level of leachate parameters has adversely impacted the groundwater; which is likely leaving the site. There is a minor potential for specific leachate constituents which are denser than water (DNAPL, dense non-aqueous phase liquid) to impact an underlying aquifer; specifically, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloroethane and vinyl chloride are chlorinated hydrocarbons with a relative specific density greater than water. DNAPL compounds will exhibit a downward tendency via joints, voids in soil and through cracks, joints, fractures in bedrock until a contact to a uniform impermeable surface. The rate and extent of downward migration is governed by the relative concentration and chemical attributes of a specific DNAPL compound. The measured concentrations of the above DNAPLs encountered exceed the referenced Tier 1 Guidelines for coarse-grained soil in a residential/parkland setting.

**Soil Contamination**

Given the green space setting for each of the landfill sites and 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.

With the exception of a third party fiber optic cable traversing through the Red Deer College Landfill Site, there are no other buried utilities within the landfills. Nearby underground utilities beneath 32 Street and Taylor Drive are potential receptors to LFG. Contractors intending to work at these waste sites 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.

With the current zoning, as shown on Figure 1, the 300 m setback lies within areas of commercial and residential lands. Other potential general commercial developments, activities associated with utility infrastructures and Waskasoo Creek are also potential receptors to LFG and leachate. The potential receptor attributes input to the PQRA are outlined below:

- Residential – is an approved land use, by the City of Red Deer for specific areas lying within the regulated 300 m setback. Residential land use includes detached house, 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. 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 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 are:

- 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, medical clinic and entertainment facility. Default exposure assumptions for workers are 32.9 kg child over 5 years old, 70.7 kg adult, inhalation rate 16.6 $m^3$/day for an adult worker 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 an adult. 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 vapours, 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 Red Deer Motors and Red Deer College Landfill Sites, the inhalation route to a volatile chemical via vapour intrusion becomes the greatest potential concern for exposure. 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.

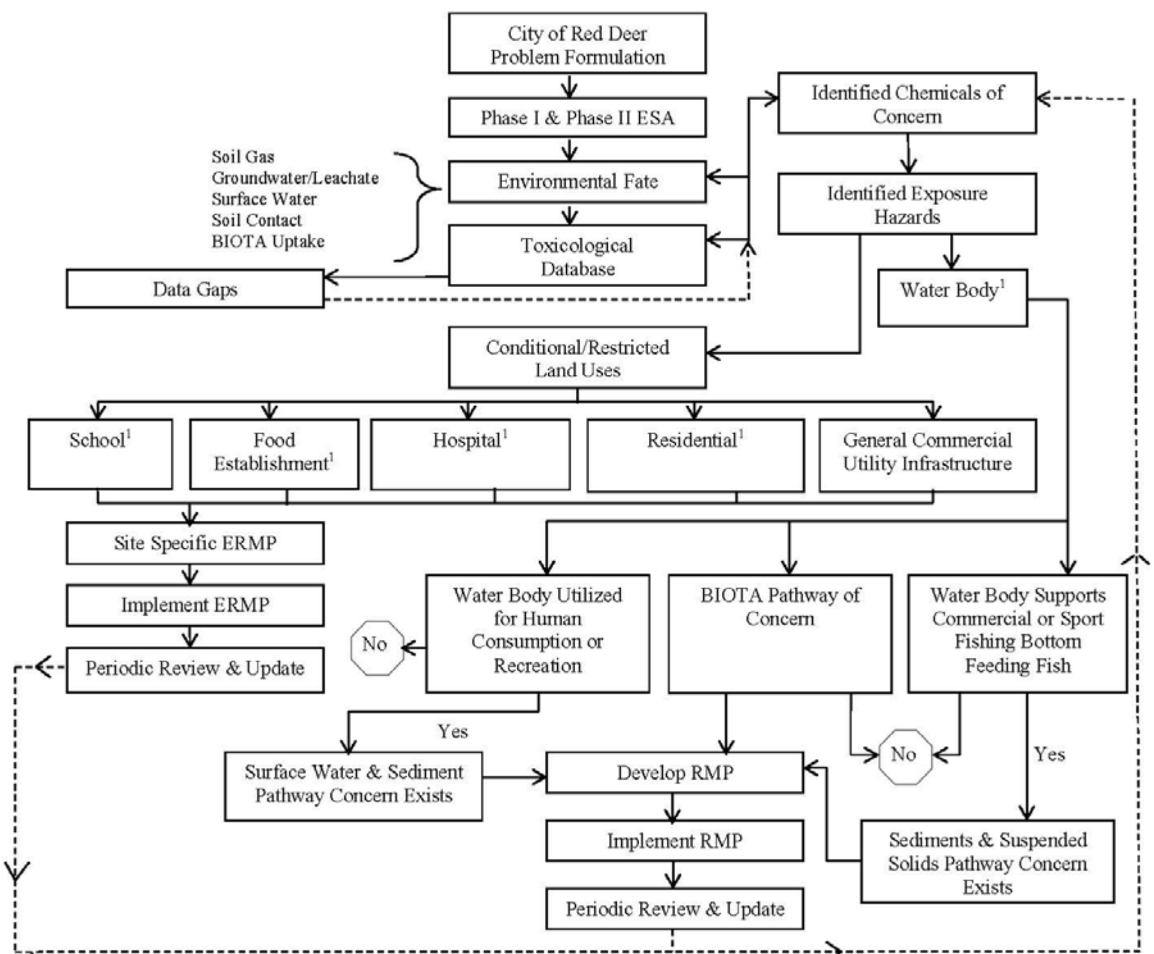
As discussed in Section 2.1, Waskasoo Creek flows between the two landfills and the leachate generated at each landfill are suspected to contact the creek. Accordingly, this portion of the creek is identified to be potentially at risk to a variety of chemicals in the leachate. A PQRA protocol has been applied as a preliminary screen to review the potential ecological risks presented by these two landfill sites to the creek. To illustrate a level of the ecological risk for exposure via an ingestion pathway for select wildlife was evaluated on a preliminary first-order basis. The Federal Contaminated Sites Action Plan Ecological Risk Assessment Guideline, March 2012 was referenced for this preliminary evaluation. The ecological risk factors applied to the PQRA screening tool for wildlife users of Waskasoo Creek include:

- Water ingestion rates for select wildlife users of Waskasoo creek include muskrat and snowshoe hare 0.10 L/kg bw/day, white-tailed deer and mallard 0.06 L/kg bw/day, meadow vole 0.21 L/kg bw/day, red fox 0.09 L/kg bw/day and deer mouse 0.19 L/kg bw/day.

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 Red Deer Motors and Red Deer College Landfill Sites  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 Red Deer Motors and Red Deer College Landfill Sites.

The diagram below illustrates the process to formulate the risk assessment process to assist with the regulatory review process for future redevelopment within the regulatory setback distance of the Red Deer Motors and Red Deer College Landfill Sites.

**Process of Developing ERMP**
**Red Deer Motors & Red Deer College Landfill Site**




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

## 3.1 Identified Environmental Health Concerns

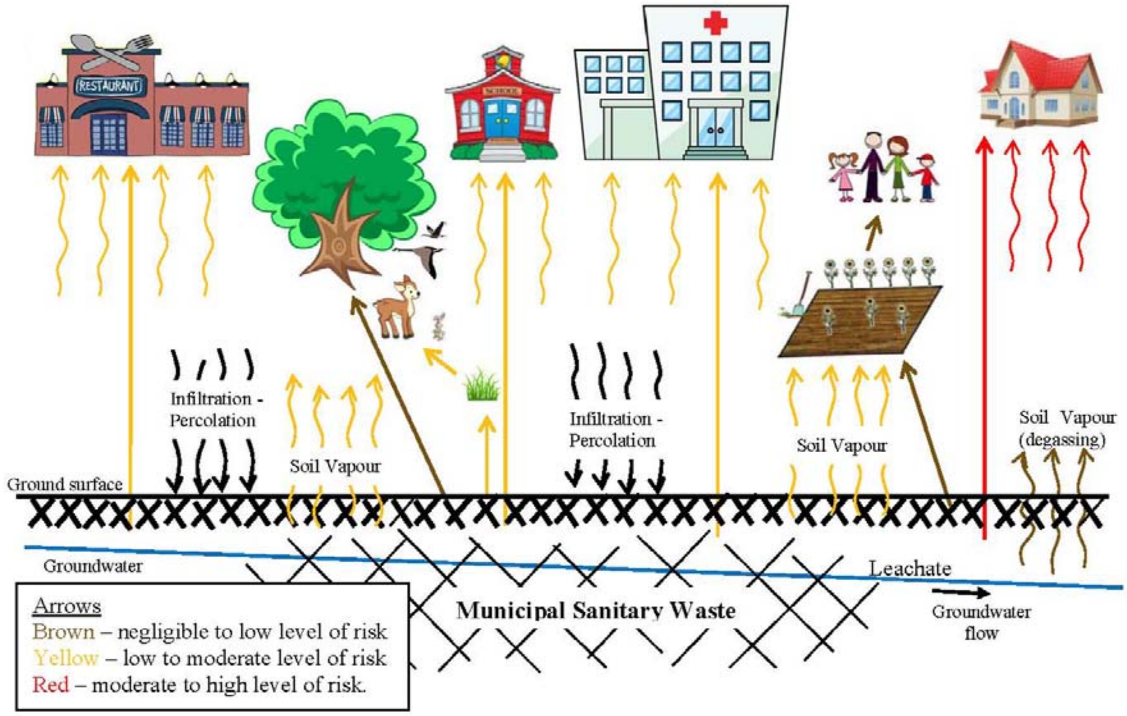
The environmental health risks presented by this historic waste site to the existing and future developments is primarily from landfill soil gas and to a lesser degree from volatile constituents that degas from leachate leaving the historic waste site into the unsaturated zone above the groundwater table.

As noted in the Phase II ESA, the age of this non-operating landfill (about 43 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. The potential risk of exposure to soil vapours increases during frozen ground conditions.

For the leachate leaving the site, the creek is considered to be the most sensitive receptor. However, the intermediate receptors (buildings and buried utilities present near and between the landfill sites) potentially pose a higher level of risk to exposure to soil vapour containing off-gases from dissolved state to soil vapour state. Initial results indicate the leachate is predominantly composed of a mixture of inorganic and nutrient compounds and a variety of petroleum and petro-chemical derivative compounds. The measured concentrations suggest a moderate level of risk to the water quality in the creek. It is noted, Waskasoo Creek is an “urbanized” creek subject to surface water from municipal storm water outfalls and other surface water drainage systems. These systems are vulnerable to a variety of potential chemicals, fuels and other deleterious substances which can enter surface water and released into the creek. Hence, it is anticipated the leachate will not likely be the sole contributor impacting the water quality of the creek. Dissolved volatile compounds were detected at the down gradient groundwater monitoring wells in August 2013. Hence, it is presumed VOCs degassing from groundwater will also be a factor to off-site soil vapour.

In general, the risks associated with soil vapour and leachate to land areas 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 some buildings lying within the regulatory setback are presumed to predate the historic waste disposal activity and 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 Red Deer College and Red Deer Motors Landfill Sites, 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 and Waskasoo Creek.
- 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 (TC) 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:

- Biotic factors (plants, terrestrial animals, aquatic life).

- Waskasoo Creek.

- Workers engaged with ground disturbance activities within the prescribed historic waste disposal areas.

- People in occupied buildings including future buildings.

Currently, various commercial businesses for the automotive industry are located on ground that is east and at a higher ground elevation relative to the Red Deer Motors Landfill Site. The elevation difference by these natural uplands is interpreted to be a natural physical barrier isolating these commercial lots from the subsurface LFG. Similarly, the higher ground elevation also suggests the groundwater at the commercial properties would be considered to be up gradient relative to the Red Deer Motors Landfill. Consequently, the various automotive businesses located upgradient of the Red Deer Motors Landfill are interpreted to not be a potential receptor to the environmental risks associated with LFG and leachates in groundwater.

As depicted on Figure 1, the 300 m regulated setback extends to parcels of land adjacent to the north, south and west area of the college campus. The current land uses as defined in The City of Red Deer Land Use Bylaw 3357/2006 Part 1: Titles, Definitions, General Operative Clauses; which are encompassed by a 300 m setback of each landfill site include:

- PS – Public Service District (institutional or Governmental), example Red Deer College;

- C4 – Commercial District (Major Arterial), example various automotive business fronting 51 Avenue;

- A2 – Environmental Preservation, example land allowance for natural area and Waskasoo Creek;

- R1 – Residential District (Low Density), example housing along the north side of 32 Street; and

- P1 – Parks and Recreation District, example public park along the north side of 32 Street.

Accordingly, land uses (excluding the area east of the Red Deer Motors Landfill Site) lying within this prescribed 300 m setback are considered to be vulnerable to subsurface LFG. On the basis of the available information, potential exposures resulting from degassing of VOCs from leachate in groundwater are limited to the interpreted direction and pattern of the local groundwater.

### 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 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:

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

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, 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.

The exposure (ingestion via water and plant uptake) for ecological receptors is quantitatively predicted by:

$$D_w = I_w \, x \, C_w$$

Where:
$D_w$ = total dose from drinking water ingestion (mg/kg bw/day)
$I_w$ = drinking water ingestion rate ( L/kg dw/day)
$C_w$ = concentration of contaminate in water (mg/L)

### 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 controls.

# 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 to initial information compiled from the results of the 2014 Phase II ESA.

The CSM is applied to complete the PQRA. A complete environmental risk assessment and evaluation of environmental liability is beyond the context of this report. The 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 Figures 3A to 3D.

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 develop into 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 influenced by the heterogeneity of the observed texture of subsurface soil (units of silt, sand, clay and gravel).

- Test results for soil vapours at the Red Deer College Landfill are interpreted to be more significant relative to the lower concentrations measured at the Red Deer

Motors Landfill Site during the August 2013 test event. The lateral extent of the soil vapours may extend down gradient of the landfill sites to off-site areas including beneath a portion of 32 Street and Taylor Drive, nearby residential and commercial buildings, refer to Figure 1. Presently, there is no site data for a winter condition at either landfill site.

## 4.1 Contaminant Fate and Transport

Contaminant fate and transport refers to the way a substance travels through various environmental mediums. This section discusses the physical and chemical processes that affect the subsurface migration of dissolved chlorinated hydrocarbons identified in the on-site and off-site it areas.

**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 and the most heavily impacted area appears to be the central third of the Red Deer College Landfill and the north portion of the Red Deer Motors Landfill.

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**

Generally, the relative concentration of LFG in the soil and the groundwater measured in August 2013 are interpreted to be significant at the Red Deer College Landfill Site. 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 and may increase the risk of exposure, particularly at the student housing units.

On the basis of the historic aging (about four 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. 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. As discussed in Section 2.3 Exposure Pathways, subsection Soil Vapours, discrete building assessment should be considered to better evaluate the environmental health risk at the student housing. This type of assessment program should include identification of unique confounders, temporal, spatial, climatic and seasonal factors. As discussed in Section 1.2.1, The City of Red Deer has no direct control on the maintenance and operation of the student residences located on the college campus.

**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 summarized as: DCE → Vinyl Chloride (VC) → Ethane. These compounds have been detected in the groundwater at the site.

### 4.1.1 Volatile Organic Compounds in Soil

BTEX compounds were generally not present in a soil samples underlying the waste material at the Red Deer Motors Landfill Site. A trace concentration of 1,2,4-trimethylbenzene was noted in a soil sample at the Red Deer Motors Landfill and is not considered to be significant. Overall, the soil quality underlying the historic waste material at the Red Deer Motors Landfill Site appears to be relatively acceptable given the overburden of MSW materials.

Concentrations of benzene, ethylbenzene, xylenes, chloroform and methylene chloride were detected at the Red Deer College Landfill. The results for soil at the Red Deer College Landfill show an exceedance to the referenced Tier 1 Guidelines for ethylbenzene, chloroform, methylene chloride and petroleum hydrocarbon fraction F1 in a soil sample underlying the waste material. In general, the measured exceedances in the soil are not considered to be significant beneath the historic waste material at the Red Deer College Landfill Site and would not likely warrant immediate remedial work.

### 4.1.2 Volatile Organic Compounds in Groundwater

As discussed in Section 2.1, numerous VOCs were detected in the groundwater samples from the Red Deer College Landfill. For the Red Deer Motors Landfill, lesser concentrations of some VOC were detected with vinyl chloride exceeding the referenced Tier 1 Guideline. 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 each of the landfills.

### 4.1.3 Combustible Headspace Vapours

Combustible and volatile headspace vapour readings from the groundwater monitoring wells were measured at the Red Deer Motors Landfill Site on August 3, 2014 and between August 13 and 14, 2014 at the Red Deer College Landfill Site. The combustible and volatile soil vapour concentrations ranged from non-detect to 1,600 ppm and non-detect to 64 ppm respectively at the Red Deer Motors Landfill Site and non-detect to 2,450 ppm and non-detect to 89 ppm respectively at the Red Deer College Landfill Site. 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 each 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 principal direction of groundwater flow from each of the landfills is interpreted to flow towards Waskasoo Creek. 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 3.7% to 5% across the combined landfill sites and the calculated horizontal velocity of the groundwater is about 4.7 m/year.

This suggests the groundwater with leachate will likely leave the landfill sites and migrate onto other City property and third party property lying north of the respective landfill sites.

### 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 landfill soil gas. 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 (43 years) of the waste material at this site. Vapour measurements at the on-site borehole locations indicate detectable soil vapours are present and subjectively range from a mild to moderate level. The soil vapours, particularly at the Red Deer College Landfill Site present a concern to the adjacent student housing, underground utilities and Waskasoo Creek. Soil vapour concentrations at the Red Deer Motors Landfill were found to be slightly less relative to the Red Deer College Landfill. Higher concentrations may occur when the ground is frozen impeding low molecular weight soil vapours from venting to the atmosphere.

Physical factors influencing the distribution of soil vapours include moisture content, soil texture and 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 to 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 landfill sites 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 Figures 3A to 3D. There is insufficient data to map landfill soil gas or the leachate beyond the boundaries of the Red Deer Motors and Red Deer College Landfill Sites. A summary of the identified pathways and receptors at risk by the landfill soil gas and the leachate are as follows.

**Groundwater Pathway**

On the Red Deer College Landfill, groundwater lies at an average depth of 2.9 m below the ground surface with a principal flow pattern to the east-northeast, towards Waskasoo Creek. While at the Red Deer Motors Landfill, the groundwater was at an average depth of 4.2 m below the ground surface with an interpreted pattern to the northwest, towards Waskasoo Creek. For this area of the City of Red Deer, the Red Deer College Landfill and the Red Deer Motors Landfill are interpreted to be situated in a zone of recharge or a downward hydraulic gradient. The groundwater table across both landfills exhibits a gentle gradient ranging between 3% (at the Red Deer Motors Landfill) to 5% (at the Red Deer College Landfill). To our knowledge, groundwater and water from Waskasoo Creek are 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 the previous surface grading to divert surface water from the underlying waste material. Furthermore, the soil cover is interpreted to be a poor material to prevent surface water from infiltrating and percolating into the waste material and generating leachate.

**Vapour Pathway**

There is no indication of 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 at the Red Deer Motors Landfill has been transformed into a green space. 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.

Similarly at the Red Deer College Landfill, the area overlying the historic waste has been sodded. The surface cover is generally less than 30 cm thick and the area is openly accessible to the public and students. Pedestrian pathways transect a section of the landfill.

**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**

The poor soil cover, proximity of the waste material to campus facilities and differential settlement create a potential risk for the human exposure pathway. Qualitatively, the level of risk is considered to be medium, refer to matrix in Section 1.0. There will also be a level of risk to soil contact and inhalation of fugitive soil vapours should future construction or re-development activities involving ground disturbance to a depth of 7.6 m, more or less at the Red Deer College Landfill Site. Similarly, a level of exposure risk by soil contact and inhalation of fugitive soil vapours will arise should future construction or re-development activities involving ground disturbance to a depth of 4.6 m, more or less, occurs at the Red Deer Motors Landfill Site; or from an equivalent existing ground elevation ranging between 875 m to 878 m geodetic, more or less.

For potential developments, exclusive of the properties on the hilltop east of the Red Deer Motors Landfill, the remaining adjacent land in the vicinity (within 300 m) of the Red Deer Motors and Red Deer College Landfill Sites, the risk of exposure to the identified chemicals of concern are limited to exposure vie soil vapour intrusion into an enclosed building and soil vapours entering deep utilities which also act as pathways for soil vapour migration. 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 Red Deer Motors and Red Deer College Landfill Sites is soil vapour intrusion and inhalation.

**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 POIs present in the building foundations are concerns for potential exposure and the resulting 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 43 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.

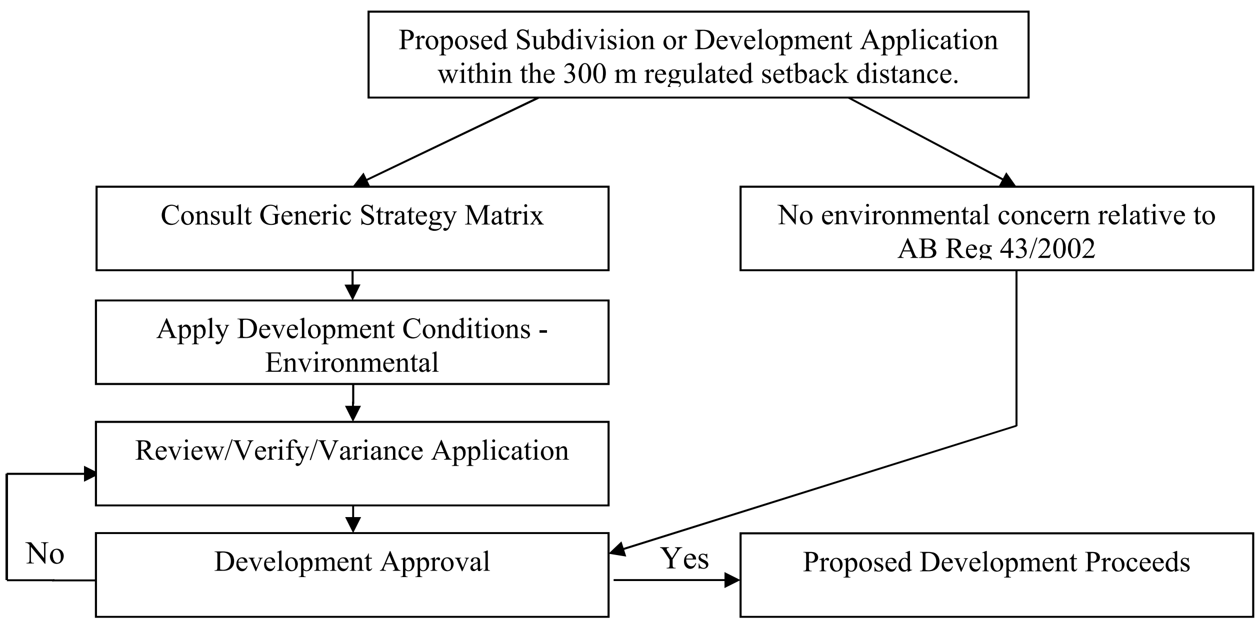
For the fully developed urban setting along with consideration of the potential hazards, the level of potential exposure and the potential receptors, a proposed site-specific environmental risk management plan (ERMP) is presented in this section. The proposed ERMP is a tool to assist with the review 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 planning authority 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 risk for the potential ingress of landfill soil gas is 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 data such as 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 3F. 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 Red Deer College and Red Deer Motors Landfill Sites is an approach based on test results obtained from each landfill site. Extrapolations for potential environmental risks associated with leachate and landfill soil gas migrating from the historic waste disposal sites 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 Red Deer Motors and Red Deer College Landfill Sites (both defined as 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 the 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 ingress (POIs); or

2. Create a barrier to isolate/separate the building from the soil gas. The type of barrier is not limited to a 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 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. 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 combined boundaries of the Red Deer College and Red Deer Motors Landfill Sites. 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.

Recommendations for quality assurance and risk communication are outlined in Section 5.7 and 5.8, respectively. A preliminary review for the protection of Waskasoo Creek is presented in Section 5.9.

**Proposed ERMP Strategies for Subdivision or Developments within 300 m of the Red Deer Motors and Red Deer College Landfill Sites**

| 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.

Calculated HQ values are based solely on receptor variables provided from Health Canada's PQRA. HQ values are calculated for each land use type: residential, food establishment, school/hospital, commercial developments, public institutions and underground utility infrastructure are presented in Tables 3A to 3E. Table 3F illustrates a preliminary screening for ecological HQ values for select receptors.

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, trans-1,3-dichloropropene, trichloroethylene, tetrachloroethylene and benzene measured in soil vapour from the site appear to be the highest carcinogenic chemicals of concern identified from the Phase II ESA.

Accordingly, the calculated HQ values for chloromethane, vinyl chloride, trans-1,3-dichloropropene, trichloroethylene, tetrachloroethylene and benzene are 57, 471, 64, 121, 31 and 495 respectively. Thus, applying a 10x factor of safety for uncertainties yields a very significant HQ outcome implying further investigation to better understand the level of risk and exposure.

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. Nevertheless, the HQ values relative to the residential setting are about an order of magnitude higher. Notwithstanding the various development exposure scenarios, the high HQ values signify a very evident level of concern to hazard exposure from the identified carcinogenic soil vapour compounds. As noted, the HQ values of the PQRA are intended to identify the need to further investigate and to better understand whether the risk of exposure to LFG 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 residential houses and nearby buildings. The level of methane in the soil vapour is also of concern and the risk for intrusion of methane into the buildings and underground utilities should be further evaluated.

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 measures 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 mitigation action, further site specific information would be justified. Examples of engineered mitigative actions as directed by the maximum HQ values, refer to Tables 3A to 3E, are outlined as follows:

**<u>Passive Measures</u>**

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.

**<u>Active Measures</u>**

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 relative toxicity of these identified chemicals and applying the PQRA protocol, the corresponding HQ values suggest an exposure hazard exists for the identified carcinogen chemicals present in the soil vapour and with consideration of the proximity (within 15 m, more or less) of the student residences along the south end of the Red Deer College Landfill creates a significant scenario of concern for the occupants. It is understood; the houses are circa 2000 and mitigative measures for each student residential building were implemented at the time of construction. To our knowledge, no authority (Red Deer College or regulatory agency) has undertaken follow-up confirmatory testing for the presence of various LFG constituents in the indoor air at the student housing or completion of interim performance assurance tests to ensure the mitigative measures are effective.

For the existing student residences, a detailed assessment should be completed to assess and verify whether an adverse condition exists for indoor vapour intrusion in both transient and steady-state temporal conditions. This information can then be reviewed with an objective to ensure the long term exposure hazard from intrusion of LFG into each student house is appropriately managed. The City of Red Deer should share the findings presented in this ERMP to the Management at The Red Deer College and the relevant regulatory agencies. These consultations should include a discussion to formulate a Risk Communication Plan, refer to Section 5.8.

For future residential, public institution, food establishments and other commercial developments within 100 m of the landfill, the proposed development should include measures to prevent the potential ingress of subsurface soil vapours which can migrate from the landfill. Measures would include both passive and active soil vapour management.

## 5.3 Strategy For Subdivision and Developments Between 100 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 Red Deer Motors and Red Deer College Landfill Sites. Currently, numeric models to predict transient subsurface soil vapour concentrations from either a point or non-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.

On the basis of the available information, there is presently an identified risk of soil vapour intrusion by soil landfill gas consisting of various chemical vapour compounds classified as carcinogen, possible carcinogen and methane into an enclosed building envelop. The sample ERMP strategies outlined in Section 5.1 would be viewed as the minimum generic level of mitigative measures for a proposed residential development lying between 100 m to 200 m from the boundary of the historic landfill. The mitigative measures would include passive and active soil vapour management. For other types of new development including public institution, food establishments and other commercial buildings located between 100 m and 200 m from the boundary of the two historic landfills should at minimum have a passive mitigative measure incorporated into the occupied building.

## 5.4 Strategy For Subdivision and Developments Between 200 m to 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 lower level of risk requiring a mitigative or adaptive consideration at a passive level of action for the various types of developments; refer to samples of generic passive measures outlined in Section 5.1.

## 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 activitises 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 the installation of an 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 Red Deer Motors and Red Deer College Landfill Sites. Appropriate PPE for workers should be included in their respective Safe Work Plan.

In the event, a future utility line is proposed to traverse either 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 Red Deer Motors and Red Deer College Landfill Sites with an objective to ensure activities involving future public and private utilities within 200 m of the Red Deer Motors and Red Deer College Landfill Sites 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 within 100 m of the Red Deer Motors and Red Deer College Landfill Sites, 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 Red Deer Motors and Red Deer College Landfill Sites, 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 specific mitigative measure(s) incorporated into a development. 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 Management at the Red Deer College and the local Environmental Public Health at Alberta Health Services (AHS). The consideration to consult with AHS is to gather comments and their expertise to address the identified concern for vapour intrusion of LFG to the student housing and other campus buildings which are in the identified area in proximity to the Red Deer College Landfill.

Subsequent to consultation with AHS and at the discretion of the City Management other stakeholders such as the community associations of South Hill and West Park lying within the setback for the Red Deer Motors Landfill 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 for each affected community stakeholder with the objective to ensure questions and issues arising from future property and infrastructure developments within the communities are responded in an appropriate manner.

## 5.9 Considerations for Protection and Preservation of Waskasoo Creek

Hazard Quotients for the protection of animals are calculated on the basis of site-specific values obtained from the Phase II ESA and applied to the model developed by the Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guideline, March 2012. As shown in Table 3F, a screening of HQ values for select wildlife show some HQ values greater than 1 suggesting further investigation of a variety of VOCs that have been identified in local groundwater from the Phase II ESA. It is noted the presence of VOCs in groundwater does not imply a direct presence of these chemicals in surface water in Waskasoo Creek. However, preliminary data suggest a risk for leachate constituents to enter the creek which may adversely impact the environmental health and the protection of aquatic life and animals using the creek. Further investigation and review by a qualified aquatic environmental specialist would be required to better understand whether wildlife users of the creek are vulnerable to these identified chemicals. Similarly, exposure of the creek water to domestic animals/pets may also present a health risk to this group of animals.

## 5.10 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.

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.

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. 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. 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 approximately 5-year intervals. This review cycle would also generally align with technical and code adaptations for industry innovations in the construction, building and related environmental technologies.

# 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 express or implied. The opinions, conclusions and recommendations presented herein reflect the best judgment of Tiamat Environmental Consultant Ltd. (Tiamat), ©2014, all rights reserved.

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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

The Association of Professional Engineers and Geoscientists of Alberta
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 historic waste material lies in two distinct areas within the boundaries of the Red Deer College and the South Hill neighbourhood. Each landfill is separated by Taylor Drive and Waskasoo Creek. Presently, the site on the college campus is an open landscaped area with an asphalt paved pedestrian path. The Red Deer Motors site is currently a vacant grassed area. There are currently no buildings located within the boundaries of the two historic landfills. |
| Legal Description: | Red Deer College - Lot J Plan 012 0303 within SE 08-38-27 W4M<br>Red Deer Motors - Lot 3MR Block 2 Plan 842 2279 within SE 08-38-27 W4M |
| Surrounding Land Use: | Urban Setting (City of Red Deer)<br>The sites are bounded on the north by 32 Street followed by various commercial and residential developments. The community of West Park is located to the northwest. Commercial developments are to the east and southeast. On campus housing borders the Red Deer College Landfill. Other campus facilities are southwest of the landfill. Red Deer Motors Landfill is a green space with no direct assess from Taylor Drive or 32 Street and considered to be semi-isolated from the public. |
| Groundwater Usage: | No usage on either landfill site presently nor likely in the future. |
| Surface Water: | No noted direction of principal overland flow or drainage control measures.<br>There are no obvious environmental concerns for surface water run-off or run-on throughout this area. |
| Underground Structures: | A private communication line (installed July 2011) traverses the waste area at the college campus. Buried electrical cable is along the south side of 32 Street.<br>A storm sewer traverses south of the Red Deer Motors Landfill with an outfall into Waskasoo Creek. |
| Special Environmental Conditions: | The landfills have been closed for approximately 43 years, circa 1972. |

| Receptor | Potential Exposure Routes | Soil Gas | | |
|---|---|---|---|---|
| | | Oxygenated | Ketone | Chlorinated |
| On-Site: | | | | |
| Recreational Visitors | Inhalation of vapours from soil | ✗ | ✗ | ✓ |
| Maintenance Workers | Inhalation of vapours from groundwater | ✗ | ✗ | ✗ |
| Students | Ingestion of groundwater | ✓ | ✓ | ✓ |
| Student Housing (with basement) | Inhalation of vapours from soil | ✗ | ✗ | ✗ |
| Off-Site: | | | | |
| Red Deer College Buildings in proximity to the landfill | Inhalation of vapours from soil | ✗ | ✗ | ✓ |
| | Inhalation of vapours from groundwater | ✗ | ✗ | ✓ |
| | Ingestion of groundwater | ✓ | ✓ | ✓ |
| Single and Multi-Family Houses (with basement/underground garage) | Inhalation of vapours from soil | ✓ | ✓ | ✓ |
| | Inhalation of vapours from groundwater | ✗ | ✗ | ✗ |
| | Ingestion of groundwater | ✓ | ✓ | ✓ |
| Commercial Developments | Inhalation of vapours from soil | ✓ | ✓ | ✓ |
| | Inhalation of vapours from groundwater | ✗ | ✗ | ✗ |
| | Ingestion of groundwater | ✓ | ✓ | ✓ |
| West Park Middle School | Inhalation of vapours from soil | ✓ | ✓ | ✓ |
| | Inhalation of vapours from groundwater | ✓ | ✓ | ✓ |
| | Ingestion of groundwater | ✓ | ✓ | ✓ |
| Underground Utilities: | | | | |
| Communication Line | Impact of vapours from groundwater | ✗ | ✗ | ✗ |
| Electrical Cable | Impact of vapours from soil | ✗ | ✗ | ✗ |
| Storm Sewer | Ingestion of groundwater | ✗ | ✗ | ✗ |

✗ - Potential Exposure Hazard
✓ - "Negligible" Potential Exposure Hazard

## Table 2A
## Identified Chemicals of Concern - Physical Attributes

| Chemical | Media | | | Physical Attributes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soil | Groundwater | Soil Vapour | Molecular Weight | Vapour Pressure | Specific Gravity | | Solubility in Water | Henry's Law Constant | Coefficients | | | Half-life | | Odour Threshold |
| | | | | | | Water | Air | | | Octanol Water | Org. C. Water | Soil/Sediment | Air | Soil | |
| | mg/kg | ppb | ppbv | g/mol | mmHg | Water | Air | mg/L | Pa $m^3$/mol | log $K_{ow}$ | log $K_{oc}$ | kd | Time | Time | ppm |
| Ethane | - - | - - | 190 - 1100 | 30.07 | 31,500 * | 0.546 | 1.1 | 60.2 | 5.07E+04 | 1.81 | 230 | - - | 50 - 70 days | - - | 899 |
| Ethylene | - - | - - | 190 - 670 | 28.05 | 52,100* | 0.569 | 1 | 131 | 2.31E+04 | 1.13 | 98 | - - | 1.9 days | - - | 270 - 600 |
| Methane | - - | - - | 44,000 - 260 x $10^6$ | 16.04 | 47,000 * | 0.422 | 0.55 | Insoluble | 6.69E+04 | 1.09 | 90 | - - | 7 - 10 years | - - | - - |
| n-Pentane | - - | - - | 190 - 14,000 | 72.15 | 420 | 0.63 | 2.5 | 38.0 | 1.27E+05 | 3.39 | 80 | - - | 4 days | - - | 10 |
| n-Butane | - - | - - | 358 - 2400 | 58.12 | 1,820 | 0.60 | 2.1 | Insoluble | 9.63E+04 | 2.89 | 900 | - - | 6.3 days | - - | 1,200 |
| Propane | - - | - - | 190 - 340 | 44.09 | 9,823 | 0.59 | 1.5 | 100 | 7.16E+04 | 2.36 | 460 | - - | 14 days | - - | 20,000 |
| Propene | - - | - - | 190 - 220 | 42.08 | 760 @ -47°C | 0.609 | 1.46 | 2.44 * | 1.99E+04 | 1.77 | 220 | - - | 15 - 23 hours | - - | - - |
| Dichlorodifluoromethane (FREON 12) | 0.010 | - - | 0.2 - 348 | 120.9 | 4,332 | 1.50 | 4.20 | Insoluble | 3.48E+04 | 2.16 | 356 | - - | 105 - 169 years | - - | - - |
| 1,2-Dichlorotetrafluoroethane | - - | - - | 0.17 - 34.4 | 170.93 | 1,444 | 1.44 | 5.93 | 130 * | 1.27E+05 | 2.82 | 815 | - - | 126 - 310 years | - - | - - |
| Chloromethane | 0.10 | 2.00 | 0.3 - 29 | 50.5 | 3,800 | 0.92 | 1.80 | 5,000 | 8.94E+02 | 0.91 | 14 | - - | 1 year | - - | 10 |
| Vinyl Chloride | 0.20 | 3.0 - 470 | 0.18 - 519 | 62.5 | 2,508 | 0.969 | 2.2 | 2,760 | 8.82E+01 | 1.5 | 57 | - - | 55 hours | 0.2 - 0.5 days | 3,000 |
| Chloroethane | 0.10 | 1.0 - 45 | 0.30 - 29 | 64.5 | 1,000 | 0.92 | 2.22 | 6,000 | 1.11E+03 | 1.43 | 24 | - - | 39 days | - - | 4.2 |
| Trichlorofluoromethane (FREON 11) | 0.01 | 5.0 | 0.20 - 50.6 | 137.4 | 690 | 1.49 | 4.70 | Insoluble | 9.83E+03 | 2.53 | 97 | - - | 52 - 207 years | - - | - - |
| Ethanol (Ethyl Alcohol) | - - | - - | 101 - 648 | 46.1 | 44 | 0.80 | 1.60 | Miscible | 5.07E-01 | -0.31 | 1 | - - | 5 days | - - | 0.35 |
| 2-Propanol | - - | - - | 3.0 - 290 | 60.1 | 33 | 2.07 | 0.785 | Miscible | 8.21E-01 | 0.05 | 1.5 | - - | 3.2 days | - - | - - |
| 2-Propanone | - - | - - | 0.80 - 76 | 58.1 | 180 | 0.80 | 2.00 | Miscible | 1.61E+02 | -0.24 | 0.73 | - - | 22 - 23 days | 1 - 7 days | 20 |
| p-Isopropyltoluene | 0.010 - 0.813 | - - | - - | 134.2 | 1.5 * | 0.857 | 4.62 | 23.4 | 1.11E+03 | 4.1 | 4,050 | - - | 1 - 34 days | - - | - - |
| Methyl Ethyl Ketone (2-Butanone) | - - | - - | 3.0 - 290 | 72.1 | 71 | 0.80 | 2.41 | Soluble | 5.77E+00 | 0.63 | 0.56 | - - | 14 days | - - | 5.4 |
| 1,1-Dichloroethylene | 0.01 | 0.50 | 0.25 - 24 | 96.94 | 500 | 1.21 | 3.25 | 400 | 2.64E+03 | 2.13 | 64 & 65 | - - | 5 - 12 days | - - | 190 |
| cis-1,2,-Dicholoroethylene | 0.010 - 1.04 | 330 - 3,000 | 0.42 - 123 | 96.95 | 180 | 1.28 | 3.34 | 4,000 | 4.13E+02 | 1.86 | 250 | - - | 6.1 days | 0.14 - 9.9 years | 0.085 |
| trans-1,2-Dichloroethene | 0.01 - 0.048 | 0.5 - 3.4 | 0.20 - 30 | 96.95 | 265 | 1.27 | 3.34 | 6,300 | 6.81E+02 | 2.09 | 1.56 | - - | 3.79 days | - - | 0.26 |
| Methylene Chloride | 0.010 - 0.101 | 2.0 - 7.8 | 0.80 - 120 | 84.9 | 350 | 1.30 | 2.90 | 20,000 | 3.29E+02 | 1.25 | 24 | - - | 119 days | - - | 250 |
| Chloroform | 0.010 - 0.062 | 0.50 | 0.15 - 18.2 | 119.4 | 160 | 1.48 | 4.12 | 5,000 * | 3.72E+02 | 1.97 | 34 - 196 | - - | 150 days | 0.3 - 1.4 days | 85 |
| 1,2-Dichloroethane | 0.010 - 0.087 | 0.5 - 9.4 | 0.20 - 19 | 98.96 | 64 | 1.24 | 3.40 | 8,690 | 1.11E+01 | 1.48 | 1.28 - 1.62 | - - | 73 days | - - | 12 - 100 |
| 1,1,1-Trichloroethane | 0.01 | 0.50 | 0.30 - 29 | 133.4 | 100 | 1.31 | 4.6 | 4,000 | 7.30E+03 | 2.48 | 120 - 151 | 1.8, 2.592 & 1.338 | 4.7 years | >97 & >485 days | 0.971 |
| trans-1,3-Dichloropropene | 0.01 | 0.50 | 0.17 - 16 | 110.98 | 34 * | 1.220 * | 1.40 | 2,800 * | 3.60E+02 | 2.03 | 28 | - - | 76 days | 6 - 17 days | 1 |
| Trichloroethylene | 0.01 | 0.5 - 0.77 | 0.30 - 81.9 | 131.4 | 58 | 1.46 | 4.50 | 1,280 * | 9.98E+02 | 2.61 | 101 | 0.093 | 7 & 114 days | - - | 28 |
| Tetrachloroethylene | 0.01 | 0.50 | 0.20 - 221 | 165.8 | 14 | 1.62 | 5.80 | 206 * | 1.79E+03 | 3.40 | 200 - 237 | - - | 96 days | 1.2 - 5.4 hours | 1 |
| Benzene | 0.0050 - 0.0058 | 1.5 - 37 | 0.18 - 5.17 | 78.1 | 75 | 0.88 | 2.70 | 700 | 5.63E+02 | 2.13 | 85 | - - | 13 days | - - | 1.5 |
| Toluene | 0.048 - 0.050 | 0.4 - 40 | 0.20 - 4.80 | 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 | 0.015 - 1.04 | 0.4 - 46 | 0.20 - 27 | 106.2 | 7 | 0.87 | 3.70 | 100 | 7.98E+02 | 3.15 | 520 | - - | 55 hours | - - | 2.3 |
| o-Xylene | - - | - - | 0.20 - 19 | 106.2 | 7 | 0.88 | 3.70 | 200 | 5.25E+02 | 3.12 | 24 - 251 | - - | 1.2 days | - - | - - |
| m-Xylene | - - | - - | 0.37 - 99 | 106.2 | 9 | 0.86 | 3.70 | Slight | 7.28E+02 | 3.20 | 166 - 182 | - - | 16.3 hours | - - | 1.1 |
| p-Xylene | - - | - - | 0.37 - 99 | 106.2 | 9 | 0.86 | 3.70 | 200 | 6.99E+02 | 3.15 | 246 - 540 | - - | 27 hours | - - | - - |
| Total Xylene | 0.1 - 7.28 | 1.8 - 260 | 0.60 - 190 | 106.2 | 0.896 @ 21°C | 0.86 | 3.70 | 130 | 6.23E+02 | - - | - - | - - | 8 - 14 hours | - - | 0.05 - 0.27 |
| Styrene | 0.010 - 0.050 | 0.50 | 0.20 - 42 | 104.2 | 5 | 0.91 | 3.60 | 300 | 2.81E+04 | 2.95 | 960 | - - | 3.5 - 9 hours | 4 months | 0.008 |
| 1,2,4-Trimethylbenzene | 0.013 - 7.72 | 4.0 - 89 | 0.50 - 48 | 120.2 | 1 @ 13.33°C | 0.88 | 4.10 | 60 | 5.25E+02 | 3.78 | 3.5 | - - | 6 hours | - - | 0.4 |
| 1,3,5-Trimethylbenzene | 0.010 - 2.01 | 1.8 - 17 | 0.50 - 48 | 120.2 | 2 | 0.86 | 4.15 | 20 | 8.89E+02 | 3.42 | 500 - 1,445 | - - | 11 hours | - - | 0.03661 |
| Chlorobenzene | 0.01 | 0.5 - 0.97 | 0.20 - 19 | 112.56 | 8.8 | 1.11 | 3.88 | 498 * | 3.15E+02 | 2.84 | 4.8 - 313 | 166.34 | 21 days | 7 days | 0.217 - 1.738 |
| 1,2-Dicholorobenzene | 0.01 | 0.5 - 6.7 | 0.40 - 38 | 147 | 1.47 * | 1.30 | 5.10 | 140.000 | 1.93E+02 | 3.38 | 2.5 - 3.76 | - - | <50 days | - - | 50 |
| 1,4-Dicholorobenzene | 0.01 | 0.5 - 2.0 | 0.40 - 38 | 147 | 0.6 | 1.458 | 5.08 | 73.8 | 2.74E+02 | 3.42 | 273 & 390 | - - | 50 days | - - | 0.121 |
| Hexane | - - | - - | 0.30 - 17,800 | 86.2 | 124 | 0.66 | 3.00 | 20 | 1.85E+05 | 3.90 | 150 | - - | 3 days | - - | 130 |
| Heptane | - - | - - | 0.58 - 1,970 | 100.2 | 40 @ 22.2°C | 0.68 | 4.60 | 3 | 2.03E+05 | 4.66 | 8,200 | - - | 54 hours | - - | 220 |
| Cyclohexane | - - | - - | 0.35 - 4,900 | 84.2 | 78 | 0.78 | 2.90 | Insoluble | 1.52E+04 | 3.44 | 160 | - - | 45 hours | - - | 0.41 |
| Tetrahydrofuran | - - | - - | 0.40 - 38 | 72.1 | 132 | 0.89 | 2.50 | Miscible | 7.14E+00 | 0.46 | 18 | - - | 21 - 24 hours | - - | 30 |
| 2,2,4-Trimethylpentane | - - | - - | 0.20 - 19 | 114.22 | 49.3 * | 0.69 | 3.93 | Insoluble | 3.05E+05 | 4.08 | 4.35 | - - | 4.4 days | - - | - - |
| Carbon Disulfide | - - | - - | 0.50 - 48 | 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 derived from the results of a 2014 Phase II ESA. 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 is 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 | 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 | - - | - - | 190 - 1100 | 5 | 1,000 | 1,230 | - - | - - | - - | - - |
| Ethylene | N/E | - - | - - | 190 - 670 | 4 | 200 | 229 | - - | - - | - - | - - |
| Methane | Non-Carcinogen | - - | - - | $44,000 - 260 \times 10^6$ | 1 | 1,000 | 706 | - - | - - | - - | - - |
| n-Pentane | N/E | - - | - - | 190 - 14,000 | 80 | 600 | 1,770 | - - | - - | - - | - - |
| n-Butane | N/E | - - | - - | 358 - 2400 | 33 | 1,000 | - - | - - | - - | - - | - - |
| Propane | Non-Carcinogen | - - | - - | 190 - 340 | 13.1 | 100 | 180 | | - - | | |
| Propene | N/E | - - | - - | 190 - 220 | 5 | 50 | 147 | | - - | | |
| Dichlorodifluoromethane (FREON 12) | Non-Carcinogen | 0.010 | - - | 0.2 - 348 | 25 | 1,000 | 4,950 | - - | - - | - - | - - |
| 1,2-Dichlorotetrafluoroethane | N/E | - - | - - | 0.17 - 34.4 | 82 | 1,000 | 6,991 | | - - | | |
| Chloromethane | Carcinogen | 0.10 | 2.00 | 0.3 - 29 | 3 | 50 | 105 | - - | 0.003 | 0.1 | 0.4 |
| Vinyl Chloride | Carcinogen | 0.20 | 3.0 - 470 | 0.18 - 519 | <10 | 1 | 2.6 | | 0.009 | 0.1 | 0.0088 |
| Chloroethane | Carcinogen | 0.10 | 1.0 - 45 | 0.30 - 29 | 2.5 | 100 | 264 | - - | - - | - - | - - |
| Trichlorofluoromethane (FREON 11) | Non-Carcinogen | 0.01 | 5.0 | 0.20 - 50.6 | 49 | 1,000 [2] | 5,600 [2] | - - | - - | - - | - - |
| Ethanol (Ethyl Alcohol) | Carcinogen | - - | - - | 101 - 648 | 3 | 1,000 | 1,880 | - - | - - | - - | - - |
| 2-Propanol | N/E | - - | - - | 3.0 - 290 | 3 | 200 | 492 | | - - | | |
| 2-Propanone | N/E | - - | - - | 0.80 - 76 | 3.2 | 250 [2] | 590 [2] | - - | - - | - - | - - |
| p-Isopropyltoluene | N/E | 0.010 - 0.813 | - - | - - | 286 | 10 | 49 | | - - | - - | - - |
| Methyl Ethyl Ketone (2-Butanone) | N/E | - - | - - | 3.0 - 290 | 1.2 - 27.5 | 200 | 590 | - - | 0.6 | 5 | - - |
| 1,1-Dichloroethylene | N/E | 0.01 | 0.50 | 0.25 - 24 | <13 | 5 | 20 | | 0.05 | 0.2 | |
| cis-1,2,-Dicholoroethylene | N/E | 0.010 - 1.04 | 330 - 3,000 | 0.42 - 123 | 5 | 200 | 793 | - - | 0.002 | - - | 0.15 |
| trans-1,2-Dichloroethylene | N/E | 0.01 - 0.048 | 0.5 - 3.4 | 0.20 - 30 | 5 | 200 | 790 | 0.0003 | - - | - - | - - |
| Methylene Chloride | Possible Carcinogen | 0.010 - 0.101 | 2.0 - 7.8 | 0.80 - 120 | 2 | 50 | 174 | - - | 0.05 | 3 | 0.000023 |
| Chloroform | Possible Carcinogen | 0.010 - 0.062 | 0.50 | 0.15 - 18.2 | 2.9 - 10.35 | 10 | 49 | - - | 0.01 | 0.04475 | 0.023 |
| 1,2-Dichloroethane | Possible Carcinogen | 0.010 - 0.087 | 0.5 - 9.4 | 0.20 - 19 | 2 | 10 | 40 | - - | 1.2 | - - | - - |
| 1,1,1-Trichloroethane | N/E | 0.01 | 0.50 | 0.30 - 29 | 0.7 - 4.9 | 350 | 1,910 | | 0.6 | | |
| trans-1,3-Dichloropropene | Carcinogen | 0.01 | 0.50 | 0.17 - 16 | 5 | 1 | 4.5 | 0.0003 | - - | - - | - - |
| Trichloroethylene | Carcinogen | 0.01 | 0.5 - 0.77 | 0.30 - 81.9 | 4 - 39 | 50 | 269 | - - | 0.00146 | 0.04 | 0.00061 |
| Tetrachloroethylene | Carcinogen | 0.01 | 0.50 | 0.20 - 221 | 26 - 115 | 25 | 170 | - - | 0.014 | 0.36 | - - |
| Benzene | Carcinogen | 0.0050 - 0.0058 | 1.5 - 37 | 0.18 - 5.17 | 1.1 - 20 | 0.5 | 1.6 | - - | 0.004 | - - | 0.0033 |
| Toluene | Non-Carcinogen | 0.048 - 0.050 | 0.4 - 40 | 0.20 - 4.80 | 13 - 90 | 50 | 188 | - - | 0.22 | 3.8 | 5 |
| Ethylbenzene | Possible Carcinogen | 0.015 - 1.04 | 0.4 - 46 | 0.20 - 27 | 0.67 - 15 | 100 | 434 | 1.6 | 0.1 | 1 | 1 |
| o-Xylene | Non-Carcinogen | - - | - - | 0.20 - 19 | 6.2 - 21 | 100 | 434 | - - | 1.5 | 0.18 | - - |
| m-Xylene | Non-Carcinogen | - - | - - | 0.37 - 99 | 6 - 23.4 | 100 | 434 | - - | 1.5 | 0.18 | - - |
| p-Xylene | Non-Carcinogen | - - | - - | 0.37 - 99 | 15 | 100 | 434 | - - | 1.5 | 0.18 | - - |
| Total Xylene | Non-Carcinogen | 0.1 - 7.28 | 1.8 - 260 | 0.60 - 190 | 1 - 24 | 100 | 434 | - - | 1.5 | 0.18 | 0.7 |
| Styrene | Non-Carcinogen | 0.010 - 0.050 | 0.50 | 0.20 - 42 | 13.5 | 85 | 0.133 | 0.12 | 0.092 | 0.26 | |
| 1,2,4-Trimethylbenzene | Non-Carcinogen | 0.013 - 7.72 | 4.0 - 89 | 0.50 - 48 | 439 | 25 | 123 | - - | 0.0016 | 0.007 | - - |
| 1,3,5-Trimethylbenzene | Non-Carcinogen | 0.010 - 2.01 | 1.8 - 17 | 0.50 - 48 | 23 - 342 | 25 | 123 | | 0.0015 | 0.0036 | |
| Chlorobenzene | Non-Carcinogen | 0.01 | 0.5 - 0.97 | 0.20 - 19 | 3.9 - 40 | 75 | 350 | | 0.01 | | |
| 1,2-Dicholorobenzene | Non-Carcinogen | 0.01 | 0.5 - 6.7 | 0.40 - 38 | 90 - 28,840 | 25 | 150 | | 0.43 | | |
| 1,4-Dicholorobenzene | Possible Carcinogen | 0.01 | 0.5 - 2.0 | 0.40 - 38 | 33 - 720 | 10 | 60 | | 0.11 | 0.095 | - - |
| Hexane | Non-Carcinogen | - - | - - | 0.30 - 17,800 | 200 | 500 | 1,760 | - - | 0.7 | - - | - - |
| Heptane | N/E | - - | - - | 0.58 - 1,970 | 2,000 | 400 | 1,640 | - - | - - | - - | - - |
| Cyclohexane | N/E | - - | - - | 0.35 - 4,900 | 89 | 300 | 1,010 | - - | - - | - - | - - |
| Tetrahydrofuran | Possible Carcinogen | - - | - - | 0.40 - 38 | 3 | 50 | 147 | - - | 0.9 | - - | - - |
| 2,2,4-Trimethylpentane | N/E | - - | - - | 0.20 - 19 | 2.57 | 300 | 1,400 | - - | - - | - - | - - |
| Carbon Disulfide | Non-Carcinogen | - - | - - | 0.50 - 48 | <6.1 & <60 | 1 | 3.1 | - - | 0.1 | 0.1 | - - |

Notes:
1) Above identified chemicals of concern are derived from the results of a 2014 Phase II ESA. 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 is 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 | Carcinogen | Hazard Quotient Calculated | Hazard Quotient Adjusted |
|---|---|---|---|---|
| Chloromethane | 0.2 | Carcinogen | **57** | **570** |
| Vinyl Chloride | 4 | Carcinogen | **470.9** | **4,709** |
| Chloroethane | 5 | Carcinogen | - - | - - |
| trans-1,3-Dichloropropene | 0.02 | Carcinogen | **63.6** | **636** |
| Trichloroethylene | 0.2 | Carcinogen | **120.7** | **1,207** |
| Tetrachloroethylene | 0.4 | Carcinogen | **31.2** | **312** |
| Benzene | 2 | Carcinogen | **494.9** | **4,949** |
| Ethanol (Ethyl Alcohol) | 0.3 | Carcinogen | - - | - - |
| Chloroform | 0.04 | Possible Carcinogen | **3.8** | **38** |
| Methylene Chloride | 0.2 | Possible Carcinogen | **4.9** | **49** |
| 1,2-Dichloroethane | 0.03 | Possible Carcinogen | 0.02 | 0.2 |
| Ethylbenzene | 3 | Possible Carcinogen | **34.8** | **348** |
| 1,4-Dichlorobenzene | 0.1 | Possible Carcinogen | 1 | **10** |
| Tetrahydrofuran | 0.004 | Possible Carcinogen | 0.004 | 0.04 |
| Propane | 0.1 | Non Carcinogen | - - | - - |
| Dichlorodifluoromethane (FREON 12) | 0.4 | Non Carcinogen | - - | - - |
| Trichlorofluoromethane (FREON 11) | 0.5 | Non Carcinogen | - - | - - |
| Toluene | 3 | Non Carcinogen | **11.6** | **116** |
| o-Xylene | 0.002 | Non Carcinogen | 0.001 | 0.01 |
| m Xylene | 0.004 | Non Carcinogen | 0.002 | 0.02 |
| p-Xylene | 0.004 | Non Carcinogen | 0.002 | 0.02 |
| Total Xylene | 15 | Non Carcinogen | **10.2** | **102** |
| Styrene | 1 | Non Carcinogen | **14.9** | **149** |
| 1,2,4-Trimethylbenzene | 4 | Non Carcinogen | **2,769** | **27,690** |
| 1,3,5-Trimethylbenzene | 1 | Non Carcinogen | **957.6** | **9,576** |
| Chlorobenzene | 0.05 | Non Carcinogen | **5** | **50** |
| 1,2-Dicholorobenzene | 0.1 | Non Carcinogen | 0.3 | **3** |
| Hexane | 15 | Non Carcinogen | **21** | **210** |
| Carbon Disulfide | 0.03 | Non Carcinogen | 0.3 | **3** |
| Ethane | 0.3 | N/E | - - | - - |
| Ethylene | 0.2 | N/E | - - | - - |
| n-Pentane | 10 | N/E | - - | - - |
| n-Butane | 1 | N/E | - - | - - |
| Propene | 0.1 | N/E | - - | - - |
| 1,2-Dichlorotetrafluoroethane | 0.06 | N/E | - - | - - |
| 2-Propanol | 0.003 | N/E | - - | - - |
| 2-Propanone | 0.02 | N/E | - - | - - |
| Methyl Ethyl Ketone (2-Butanone) | 0.004 | N/E | 0.007 | 0.07 |
| 1,1-Dichloroethylene | 0.1 | N/E | **2.5** | **25** |
| cis-1,2,-Dicholoroethylene | 118 | N/E | **58,828** | **588,280** |
| trans-1,2-Dichloroethene | 0.2 | N/E | **824.5** | **8,245** |
| 1,1,1-Trichloroethane | 0.4 | N/E | 0.6 | **6** |
| Heptane | 2 | N/E | - - | - - |
| Cyclohexane | 4 | N/E | - - | - - |
| 2,2,4-Trimethylpentane | 0.01 | N/E | - - | - - |
| Methane | 40,049 | 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 and 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 | Carcinogen | Hazard Quotient | |
|---|---|---|---|---|
| | ppm bw/day | | Calculated | Adjusted |
| Chloromethane | 0.02 | Carcinogen | **5.9** | **59** |
| Vinyl Chloride | 0.4 | Carcinogen | **49.1** | **491** |
| Chloroethane | 0.5 | Carcinogen | - - | - - |
| trans-1,3-Dichloropropene | 0.002 | Carcinogen | **6.6** | **66** |
| Trichloroethylene | 0.02 | Carcinogen | **12.6** | **126** |
| Tetrachloroethylene | 0.05 | Carcinogen | **3.3** | **33** |
| Benzene | 0.2 | Carcinogen | **51.5** | **515** |
| Ethanol (Ethyl Alcohol) | 0.03 | Carcinogen | - - | - - |
| Chloroform | 0.004 | Possible Carcinogen | 0.4 | **4** |
| Methylene Chloride | 0.03 | Possible Carcinogen | 0.5 | **5** |
| 1,2-Dichloroethane | 0.003 | Possible Carcinogen | 0.002 | 0.02 |
| Ethylbenzene | 0.4 | Possible Carcinogen | **3.6** | **36** |
| 1,4-Dichlorobenzene | 0.01 | Possible Carcinogen | 0.1 | 1 |
| Tetrahydrofuran | 0.0004 | Possible Carcinogen | 0.0004 | 0.004 |
| Propane | 0.03 | Non Carcinogen | - - | - - |
| Dichlorodifluoromethane (FREON 12) | 0.1 | Non Carcinogen | - - | - - |
| Trichlorofluoromethane (FREON 11) | 0.1 | Non Carcinogen | - - | - - |
| Toluene | 0.6 | Non Carcinogen | **2.8** | **28** |
| o-Xylene | 0.0004 | Non Carcinogen | 0.0003 | 0.003 |
| m-Xylene | 0.0009 | Non Carcinogen | 0.0006 | 0.006 |
| p-Xylene | 0.0009 | Non Carcinogen | 0.0006 | 0.006 |
| Total Xylene | 4 | Non Carcinogen | **2.4** | **24** |
| Styrene | 0.3 | Non Carcinogen | **3.6** | **36** |
| 1,2,4-Trimethylbenzene | 1 | Non Carcinogen | **659.3** | **6,593** |
| 1,3,5-Trimethylbenzene | 0.3 | Non Carcinogen | **228** | **2,280** |
| Chlorobenzene | 0.01 | Non Carcinogen | **1.2** | **12** |
| 1,2-Dicholorobenzene | 0.03 | Non Carcinogen | 0.08 | 0.8 |
| Hexane | 4 | Non Carcinogen | **5** | **50** |
| Carbon Disulfide | 0.007 | Non Carcinogen | 0.07 | 0.7 |
| Ethane | 0.08 | N/E | - - | - - |
| Ethylene | 0.04 | N/E | - - | - - |
| n-Pentane | 2 | N/E | - - | - - |
| n-Butane | 0.3 | N/E | - - | - - |
| Propene | 0.04 | N/E | - - | - - |
| 1,2-Dichlorotetrafluoroethane | 0.01 | N/E | - - | - - |
| 2-Propanol | 0.0007 | N/E | - - | - - |
| 2-Propanone | 0.005 | N/E | - - | - - |
| Methyl Ethyl Ketone (2-Butanone) | 0.001 | N/E | 0.002 | 0.02 |
| 1,1-Dichloroethylene | 0.03 | N/E | 0.6 | **6** |
| cis-1,2,-Dicholoroethylene | 28 | N/E | **14,006.7** | **140,067** |
| trans-1,2-Dichloroethene | 0.06 | N/E | **196.3** | **1,963** |
| 1,1,1-Trichloroethane | 0.08 | N/E | 0.1 | 1 |
| Heptane | 0.5 | N/E | - - | - - |
| Cyclohexane | 0.9 | N/E | - - | - - |
| 2,2,4-Trimethylpentane | 0.001 | N/E | - - | - - |
| Methane | 9,535 | 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 and 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 ppm bw/day | Carcinogen | Hazard Quotient Calculated | Hazard Quotient Adjusted |
|---|---|---|---|---|
| Chloromethane | 0.02 | Carcinogen | **5.9** | **59** |
| Vinyl Chloride | 0.4 | Carcinogen | **49.1** | **491** |
| Chloroethane | 0.5 | Carcinogen | - - | - - |
| trans-1,3-Dichloropropene | 0.002 | Carcinogen | **6.6** | **66** |
| Trichloroethylene | 0.02 | Carcinogen | **12.6** | **126** |
| Tetrachloroethylene | 0.05 | Carcinogen | **3.3** | **33** |
| Benzene | 0.2 | Carcinogen | **51.5** | **515** |
| Ethanol (Ethyl Alcohol) | 0.03 | Carcinogen | - - | - - |
| Chloroform | 0.004 | Possible Carcinogen | 0.4 | **4** |
| Methylene Chloride | 0.03 | Possible Carcinogen | 0.5 | **5** |
| 1,2-Dichloroethane | 0.003 | Possible Carcinogen | 0.002 | 0.02 |
| Ethylbenzene | 0.4 | Possible Carcinogen | **3.6** | **36.3** |
| 1,4-Dichlorobenzene | 0.01 | Possible Carcinogen | 0.1 | 1 |
| Tetrahydrofuran | 0.0004 | Possible Carcinogen | 0.0004 | 0.004 |
| Propane | 0.03 | Non Carcinogen | - - | - - |
| Dichlorodifluoromethane (FREON 12) | 0.10 | Non Carcinogen | - - | - - |
| Trichlorofluoromethane (FREON 11) | 0.1 | Non Carcinogen | - - | - - |
| Toluene | 0.6 | Non Carcinogen | **2.8** | **28** |
| o-Xylene | 0.0004 | Non Carcinogen | 0.0003 | 0.003 |
| m-Xylene | 0.0009 | Non Carcinogen | 0.0006 | 0.006 |
| p-Xylene | 0.0009 | Non Carcinogen | 0.0006 | 0.006 |
| Total Xylene | 4 | Non Carcinogen | **2.4** | **24** |
| Styrene | 0.3 | Non Carcinogen | **3.6** | **36** |
| 1,2,4-Trimethylbenzene | 1 | Non Carcinogen | **659.3** | **6,593** |
| 1,3,5-Trimethylbenzene | 0.3 | Non Carcinogen | **228** | **2,280** |
| Chlorobenzene | 0.01 | Non Carcinogen | **1.2** | **12** |
| 1,2-Dicholorobenzene | 0.03 | Non Carcinogen | 0.08 | 0.8 |
| Hexane | 4 | Non Carcinogen | **5** | **50** |
| Carbon Disulfide | 0.007 | Non Carcinogen | 0.07 | 0.7 |
| Ethane | 0.08 | N/E | - - | - - |
| Ethylene | 0.04 | N/E | - - | - - |
| n-Pentane | 2 | N/E | - - | - - |
| n-Butane | 0.3 | N/E | - - | - - |
| Propene | 0.04 | N/E | - - | - - |
| 1,2-Dichlorotetrafluoroethane | 0.01 | N/E | - - | - - |
| 2-Propanol | 0.0007 | N/E | - - | - - |
| 2-Propanone | 0.005 | N/E | - - | - - |
| Methyl Ethyl Ketone (2-Butanone) | 0.001 | N/E | 0.002 | 0.02 |
| 1,1-Dichloroethylene | 0.6 | N/E | 0.6 | **6** |
| cis-1,2,-Dicholoroethylene | 28 | N/E | **14,006.7** | **140,067** |
| trans-1,2-Dichloroethene | 0.06 | N/E | **196.3** | **1,963** |
| 1,1,1-Trichloroethane | 0.08 | N/E | 0.1 | 1 |
| Heptane | 0.5 | N/E | - - | - - |
| Cyclohexane | 0.9 | N/E | - - | - - |
| 2,2,4-Trimethylpentane | 0.001 | N/E | - - | - - |
| Methane | 9,535 | 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 and 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 ppm bw/day | Carcinogen | Hazard Quotient Calculated | Hazard Quotient Adjusted |
|---|---|---|---|---|
| Chloromethane | 0.02 | Carcinogen | **5.9** | **59** |
| Vinyl Chloride | 0.4 | Carcinogen | **49.1** | **491** |
| Chloroethane | 0.5 | Carcinogen | - - | - - |
| trans-1,3-Dichloropropene | 0.002 | Carcinogen | **6.6** | **66** |
| Trichloroethylene | 0.02 | Carcinogen | **12.6** | **126** |
| Tetrachloroethylene | 0.05 | Carcinogen | **3.3** | **33** |
| Benzene | 0.2 | Carcinogen | **51.5** | **515** |
| Ethanol (Ethyl Alcohol) | 0.03 | Carcinogen | - - | - - |
| Chloroform | 0.004 | Possible Carcinogen | 0.4 | **4** |
| Methylene Chloride | 0.03 | Possible Carcinogen | 0.5 | **5** |
| 1,2-Dichloroethane | 0.003 | Possible Carcinogen | 0.002 | 0.02 |
| Ethylbenzene | 0.4 | Possible Carcinogen | **3.6** | **36** |
| 1,4-Dichlorobenzene | 0.01 | Possible Carcinogen | 0.1 | 1 |
| Tetrahydrofuran | 0.0004 | Possible Carcinogen | 0.0004 | 0.004 |
| Propane | 0.03 | Non Carcinogen | - - | - - |
| Dichlorodifluoromethane (FREON 12) | 0.1 | Non Carcinogen | - - | - - |
| Trichlorofluoromethane (FREON 11) | 0.1 | Non Carcinogen | - - | - - |
| Toluene | 0.6 | Non Carcinogen | **2.8** | **28** |
| o-Xylene | 0.0004 | Non Carcinogen | 0.0003 | 0.003 |
| m-Xylene | 0.0009 | Non Carcinogen | 0.0006 | 0.006 |
| p-Xylene | 0.0009 | Non Carcinogen | 0.0006 | 0.006 |
| Total Xylene | 4 | Non Carcinogen | **2.4** | **24** |
| Styrene | 0.3 | Non Carcinogen | **3.6** | **36** |
| 1,2,4-Trimethylbenzene | 1 | Non Carcinogen | **659.3** | **6,593** |
| 1,3,5-Trimethylbenzene | 0.3 | Non Carcinogen | **228** | **2,280** |
| Chlorobenzene | 0.01 | Non Carcinogen | **1.2** | **12** |
| 1,2-Dicholorobenzene | 0.03 | Non Carcinogen | 0.08 | 0.8 |
| Hexane | 4 | Non Carcinogen | **5** | **50** |
| Carbon Disulfide | 0.007 | Non Carcinogen | 0.07 | 0.7 |
| Ethane | 0.08 | N/E | - - | - - |
| Ethylene | 0.04 | N/E | - - | - - |
| n-Pentane | 2 | N/E | - - | - - |
| n-Butane | 0.3 | N/E | - - | - - |
| Propene | 0.04 | N/E | - - | - - |
| 1,2-Dichlorotetrafluoroethane | 0.01 | N/E | - - | - - |
| 2-Propanol | 0.0007 | N/E | - - | - - |
| 2-Propanone | 0.005 | N/E | - - | - - |
| Methyl Ethyl Ketone (2-Butanone) | 0.001 | N/E | 0.002 | 0.02 |
| 1,1-Dichloroethylene | 0.03 | N/E | 0.6 | **6** |
| cis-1,2,-Dicholoroethylene | 28 | N/E | **14,006.7** | **140,067** |
| trans-1,2-Dichloroethene | 0.06 | N/E | **196.3** | **1,963** |
| 1,1,1-Trichloroethane | 0.08 | N/E | 0.1 | 1 |
| Heptane | 0.5 | N/E | - - | - - |
| Cyclohexane | 0.9 | N/E | - - | - - |
| 2,2,4-Trimethylpentane | 0.001 | N/E | - - | - - |
| Methane | 9,535 | 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 and 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 | Carcinogen | Hazard Quotient | |
|---|---|---|---|---|
| | ppm bw/day | | Calculated | Adjusted |
| Chloromethane | 0.02 | Carcinogen | **5.8** | **58** |
| Vinyl Chloride | 0.4 | Carcinogen | **47.7** | **477** |
| Chloroethane | 0.5 | Carcinogen | - - | - - |
| trans-1,3-Dichloropropene | 0.002 | Carcinogen | **6.4** | **64** |
| Trichloroethylene | 0.02 | Carcinogen | **12.2** | **122** |
| Tetrachloroethylene | 0.04 | Carcinogen | **3.2** | **32** |
| Benzene | 0.2 | Carcinogen | **50.2** | **502** |
| Ethanol (Ethyl Alcohol) | 0.03 | Carcinogen | - - | - - |
| Chloroform | 0.004 | Possible Carcinogen | 0.4 | **4** |
| Methylene chloride | 0.02 | Possible Carcinogen | 0.5 | **5** |
| 1,2-Dichloroethane | 0.003 | Possible Carcinogen | 0.002 | 0.02 |
| Ethylbenzene | 0.4 | Possible Carcinogen | **3.5** | **35** |
| 1,4-Dichlorobenzene | 0.01 | Possible Carcinogen | 0.1 | 1 |
| Tetrahydrofuran | 0.0004 | Possible Carcinogen | 0.0004 | 0.004 |
| Propane | 0.03 | Non Carcinogen | - - | - - |
| Dichlorodifluoromethane (FREON 12) | 0.09 | Non Carcinogen | - - | - - |
| Trichlorofluoromethane (FREON 11) | 0.1 | Non Carcinogen | - - | - - |
| Toluene | 0.6 | Non Carcinogen | **2.7** | **27** |
| o-Xylene | 0.0004 | Non Carcinogen | 0.0003 | 0.003 |
| m-Xylene | 0.0009 | Non Carcinogen | 0.0006 | 0.006 |
| p-Xylene | 0.0009 | Non Carcinogen | 0.0006 | 0.006 |
| Total Xylene | 4 | Non Carcinogen | **2.4** | **24** |
| Styrene | 0.3 | Non Carcinogen | **3.5** | **35** |
| 1,2,4-Trimethylbenzene | 1 | Non Carcinogen | **641.6** | **6,416** |
| 1,3,5-Trimethylbenzene | 0.3 | Non Carcinogen | **221.9** | **2,219** |
| Chlorobenzene | 0.01 | Non Carcinogen | **1.1** | **11** |
| 1,2-Dicholorobenzene | 0.03 | Non Carcinogen | 0.08 | 0.8 |
| Hexane | 3 | Non Carcinogen | **4.9** | **49** |
| Carbon Disulfide | 0.007 | Non Carcinogen | 0.07 | 0.7 |
| Ethane | 0.07 | N/E | - - | - - |
| Ethylene | 0.04 | N/E | - - | - - |
| n-Pentane | 2 | N/E | - - | - - |
| n-Butane | 0.3 | N/E | - - | - - |
| Propene | 0.03 | N/E | - - | - - |
| 1,2-Dichlorotetrafluoroethane | 0.01 | N/E | - - | - - |
| 2-Propanol | 0.0007 | N/E | - - | - - |
| 2-Propanone | 0.005 | N/E | - - | - - |
| Methyl Ethyl Ketone (2-Butanone) | 0.0009 | N/E | 0.002 | 0.02 |
| 1,1-Dichloroethylene | 0.03 | N/E | 0.6 | **6** |
| cis-1,2,-Dicholoroethylene | 27 | N/E | **13,630.2** | **136,302** |
| trans-1,2-Dichloroethene | 0.06 | N/E | **191** | **1,910** |
| 1,1,1-Trichloroethane | 0.08 | N/E | 0.1 | 1 |
| Heptane | 0.4 | N/E | - - | - - |
| Cyclohexane | 0.9 | N/E | - - | - - |
| 2,2,4-Trimethylpentane | 0.001 | N/E | - - | - - |
| Methane | 9,279 | Asphyxiant | - - | - - |

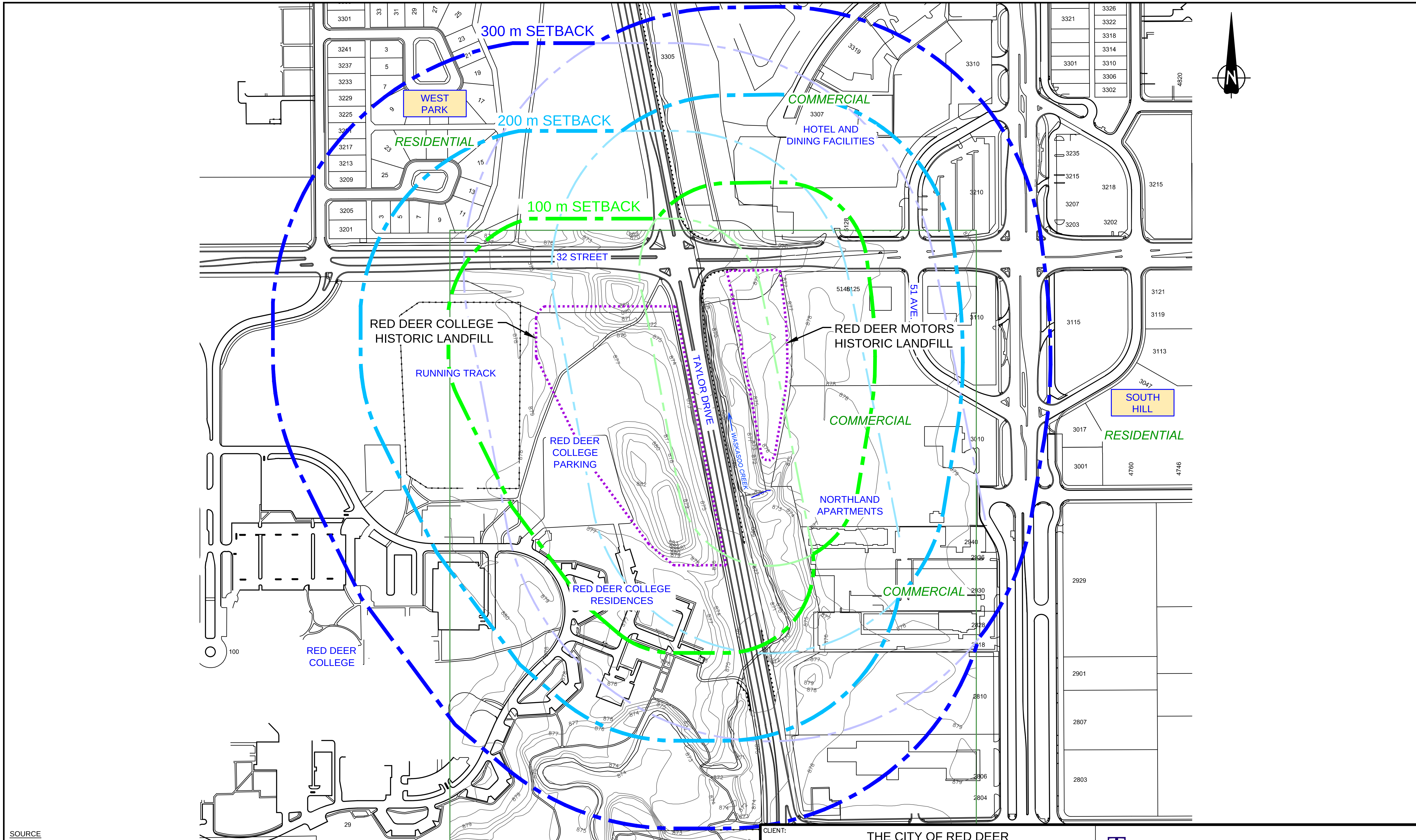
Notes:
1) HQ values are calculated solely on Health Canada exposure parameters published in the PQRA, ver 2.0 September 2010.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles.
Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.
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 and shaded reflect a calculated HQ greater than 1 signifying a level of concern to hazard exposure.

## Table 3F - Wildlife Receptors within the Vicinity of Waskasoo Creek Flowing Between the Red Deer College and Red Deer Motors Landfills
## Calculated Hazard Quotients for Identified Chemicals of Concern

| Chemical | Estimate Dosage (ppm bw/day) | | | | | | | Carcinogen | Hazard Quotient Selected Animals | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | White-Tailed Deer | Snowshoe Hare | Muskrat | Meadow Vole | Red Fox | Deer Mouse | Mallard | | White-Tailed Deer | Snowshoe Hare | Muskrat | Meadow Vole | Red Fox | Deer Mouse | Mallard |
| Chloromethane | 0.0001 | 0.0002 | 0.0002 | 0.0004 | 0.0002 | 0.0004 | 0.0001 | Carcinogen | 0.04 | 0.07 | 0.07 | 0.1 | 0.06 | 0.1 | 0.04 |
| Vinyl Chloride | 0.03 | 0.05 | 0.05 | 0.1 | 0.04 | 0.09 | 0.03 | Carcinogen | **3** | **5** | **5** | **11** | **5** | **10** | **3** |
| Chloroethane | 0.003 | 0.005 | 0.005 | 0.009 | 0.004 | 0.009 | 0.003 | Carcinogen | - - | - - | - - | - - | - - | - - | - - |
| trans-1,3-Dichloropropene | 0.00003 | 0.00005 | 0.00005 | 0.0001 | 0.00005 | 0.0001 | 0.00003 | Carcinogen | 0.1 | 0.2 | 0.2 | 0.4 | 0.2 | 0.3 | 0.1 |
| Trichloroethylene | 0.00005 | 0.00008 | 0.00008 | 0.0002 | 0.00007 | 0.0001 | 0.00005 | Carcinogen | 0.03 | 0.05 | 0.05 | 0.1 | 0.05 | 0.1 | 0.03 |
| Tetrachloroethylene | 0.00003 | 0.00005 | 0.00005 | 0.0001 | 0.00005 | 0.0001 | 0.00003 | Carcinogen | 0.002 | 0.004 | 0.004 | 0.008 | 0.003 | 0.007 | 0.002 |
| Benzene | 0.002 | 0.004 | 0.004 | 0.008 | 0.003 | 0.007 | 0.002 | Carcinogen | 0.6 | 0.9 | 0.9 | **2** | 0.8 | **2** | 0.6 |
| Chloroform | 0.00003 | 0.00005 | 0.00005 | 0.0001 | 0.00005 | 0.0001 | 0.00003 | Possible Carcinogen | 0.003 | 0.005 | 0.005 | 0.01 | 0.005 | 0.010 | 0.003 |
| Methylene Chloride | 0.0005 | 0.0008 | 0.0008 | 0.002 | 0.0007 | 0.001 | 0.0005 | Possible Carcinogen | 0.009 | 0.02 | 0.02 | 0.03 | 0.01 | 0.03 | 0.009 |
| 1,2-Dichloroethane | 0.0006 | 0.0009 | 0.0009 | 0.002 | 0.0008 | 0.002 | 0.0006 | Possible Carcinogen | 0.0005 | 0.0008 | 0.0008 | 0.002 | 0.0007 | 0.001 | 0.0005 |
| Ethylbenzene | 0.003 | 0.005 | 0.005 | 0.01 | 0.004 | 0.009 | 0.003 | Possible Carcinogen | 0.03 | 0.05 | 0.05 | 0.10 | 0.04 | 0.09 | 0.03 |
| 1,4-Dichlorobenzene | 0.0001 | 0.0002 | 0.0002 | 0.0004 | 0.0002 | 0.0004 | 0.0001 | Possible Carcinogen | 0.001 | 0.002 | 0.002 | 0.004 | 0.002 | 0.003 | 0.001 |
| Toluene | 0.002 | 0.004 | 0.004 | 0.008 | 0.004 | 0.008 | 0.002 | Non Carcinogen | 0.01 | 0.02 | 0.02 | 0.04 | 0.02 | 0.03 | 0.01 |
| Total Xylene | 0.02 | 0.03 | 0.03 | 0.05 | 0.02 | 0.05 | 0.02 | Non Carcinogen | 0.01 | 0.02 | 0.02 | 0.04 | 0.02 | 0.03 | 0.01 |
| Styrene | 0.00003 | 0.00005 | 0.00005 | 0.0001 | 0.00005 | 0.0001 | 0.00003 | Non Carcinogen | 0.0003 | 0.0005 | 0.0005 | 0.001 | 0.0005 | 0.001 | 0.0003 |
| 1,2,4-Trimethylbenzene | 0.005 | 0.009 | 0.009 | 0.02 | 0.008 | 0.02 | 0.005 | Non Carcinogen | **3** | **6** | **6** | **12** | **5** | **11** | **3** |
| 1,3,5-Trimethylbenzene | 0.001 | 0.002 | 0.002 | 0.004 | 0.002 | 0.003 | 0.001 | Non Carcinogen | 0.7 | 1 | 1 | **2** | 1 | **2** | 0.7 |
| Chlorobenzene | 0.00006 | 0.0001 | 0.0001 | 0.0002 | 0.00009 | 0.0002 | 0.00006 | Non Carcinogen | 0.006 | 0.01 | 0.01 | 0.02 | 0.009 | 0.02 | 0.006 |
| 1,2-Dicholorobenzene | 0.0004 | 0.0007 | 0.0007 | 0.001 | 0.0006 | 0.001 | 0.0004 | Non Carcinogen | 0.0009 | 0.002 | 0.002 | 0.003 | 0.001 | 0.003 | 0.0009 |
| 1,1-Dichloroethylene | 0.00003 | 0.00005 | 0.00005 | 0.0001 | 0.00005 | 0.0001 | 0.00003 | N/E | 0.0006 | 0.001 | 0.001 | 0.002 | 0.0009 | 0.002 | 0.0006 |
| cis-1,2,-Dichloroethylene | 0.2 | 0.3 | 0.3 | 0.6 | 0.3 | 0.6 | 0.2 | N/E | **90** | **150** | **150** | **315** | **135** | **285** | **90** |
| trans-1,2-Dichloroethene | 0.0002 | 0.0003 | 0.0003 | 0.0007 | 0.0003 | 0.0006 | 0.0002 | N/E | 0.7 | 1 | 1 | **2** | 1 | **2** | 0.7 |
| 1,1,1-Trichloroethane | 0.00003 | 0.00005 | 0.00005 | 0.0001 | 0.00005 | 0.0001 | 0.00003 | N/E | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0002 | 0.0001 |

Notes:
1) Hazard Quotients are calculated on the basis of site-specific values. Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guideline, March 2012.
2) Factors for select animal species are applied to illustrate the relative risk for exposure on the basis of ingestion.
3) HQ Values based on drinking water ingestion rate in Wildlife Receptor Characteristics in the Ecological Risk Assessment Guidance
4) - -/N/E - Not Tested, No Value Established or Not Evaluated.
5) Bold and shaded represents HQ values 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

0 50 100 200m

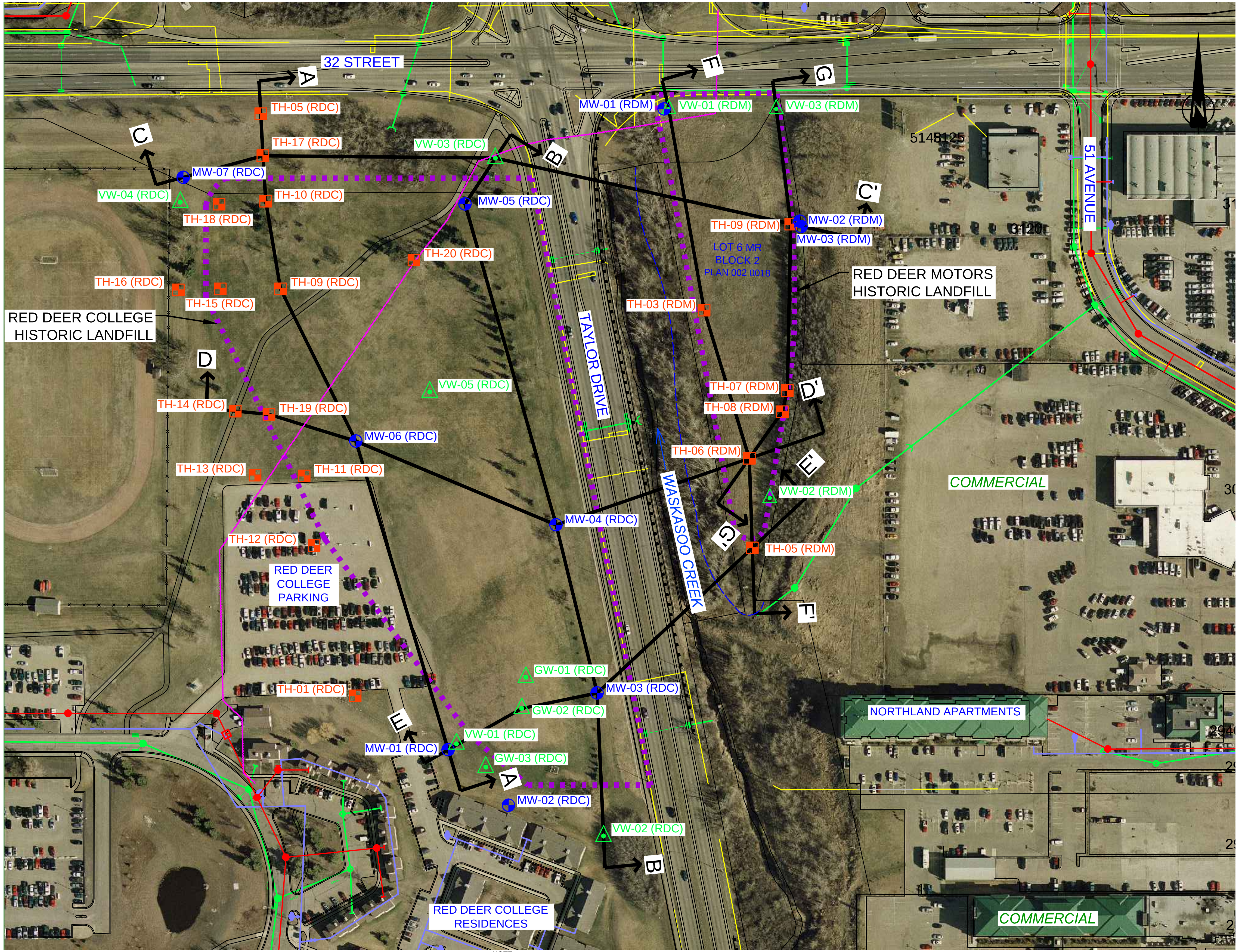
Approximate Scale 1:4000 (plotted 1:1 on 11"x17")

LEGEND
HISTORIC WASTE DISPOSAL
LOT BOUNDARY
100 m SETBACK
200 m SETBACK
300 m SETBACK

| | | | |
|---|---|---|---|
| CLIENT: THE CITY OF RED DEER | | | |
| PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN<br>HISTORIC WASTE DISPOSAL SITE<br>RED DEER COLLEGE AND RED DEER MOTORS | | | |
| TITLE: SITE PLAN SHOWING SURROUNDING LAND USE | | | |

Tiamat Environmental Consultants Ltd.

| SCALE: | DATE: | PROJECT NO.: | FIGURE NO.: |
|---|---|---|---|
| 1 : 4000 | JAN. 18/15 | 12-435 | FIGURE 1 |
| DRAWN BY: LCH | CHECKED BY: LTM | CAD FILE NO.: ERMP v1.03 | |




SOURCE
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0 20 50 100m
Scale 1:2000

PHASE II TEST LOCATIONS
MW-## GROUNDWATER MONITORING WELL INSTALLED BY TIAMAT
TH-## TESTHOLE
VW-## SOIL VAPOUR MONITORING WELL
MW-## GROUNDWATER MONITORING WELL INSTALLED BY OTHERS
REFER TO TABLE 1 FOR TESTHOLE INFORMATION

LEGEND
HISTORIC WASTE DISPOSAL
LOT BOUNDARY
100 YEAR FLOOD LINE
CROSS SECTION LOCATION

ELECTRICAL
SANITARY
STORM
WATER
PRIVATE COMMUNICATIONS CABLE INSTALLED JULY 2011

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

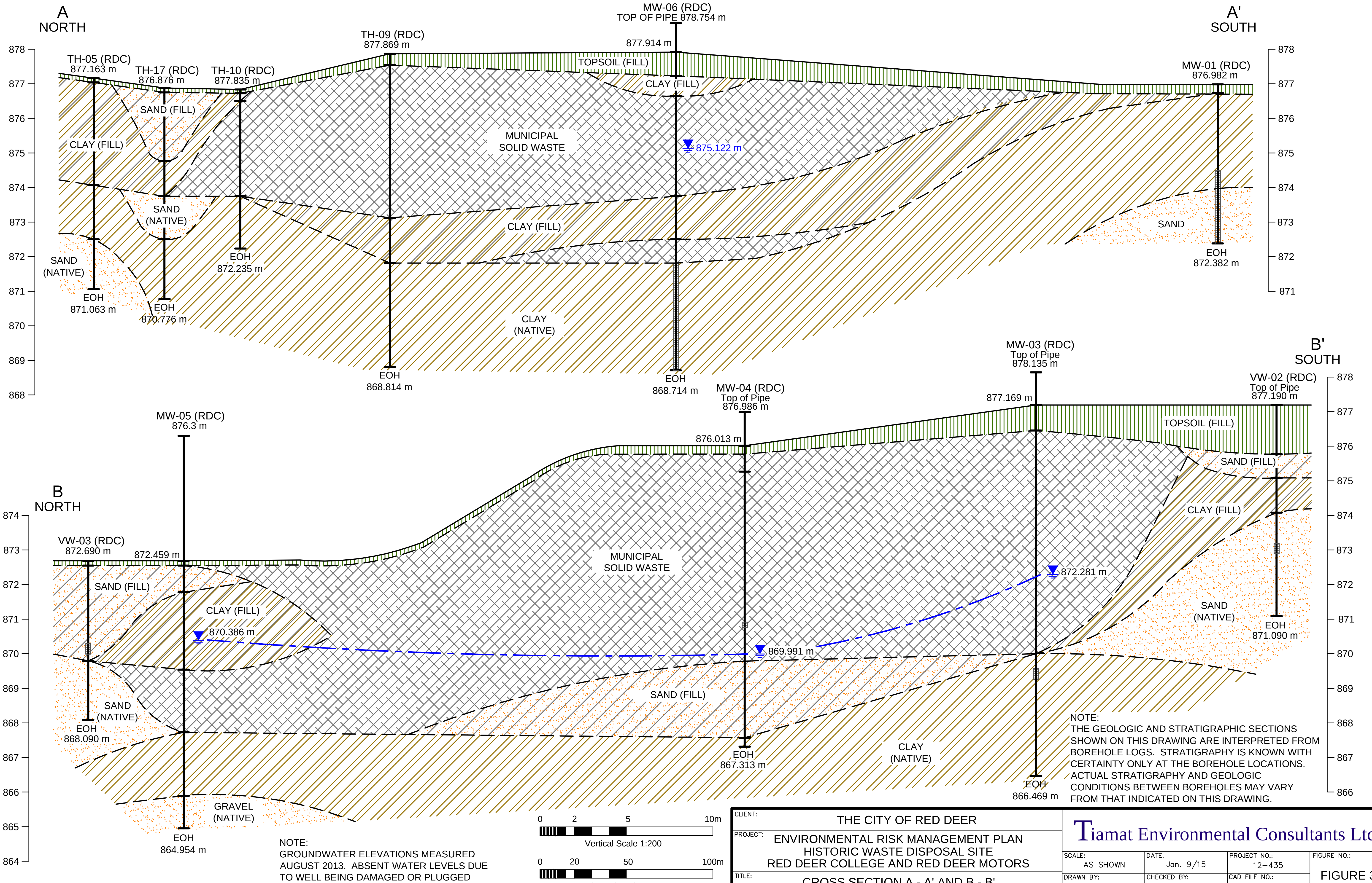
CLIENT: THE CITY OF RED DEER

PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN
HISTORIC WASTE DISPOSAL SITE
RED DEER COLLEGE AND RED DEER MOTORS

TITLE: INTERPRETED EXTENT OF WASTE

Tiamat Environmental Consultants Ltd.

| SCALE: | DATE: | PROJECT NO.: | FIGURE NO.: |
|---|---|---|---|
| 1 : 2000 | JAN. 18/15 | 12-435 | FIGURE 2 |
| DRAWN BY: LCH | CHECKED BY: LTM | CAD FILE NO.: ERMP v1.03 | |



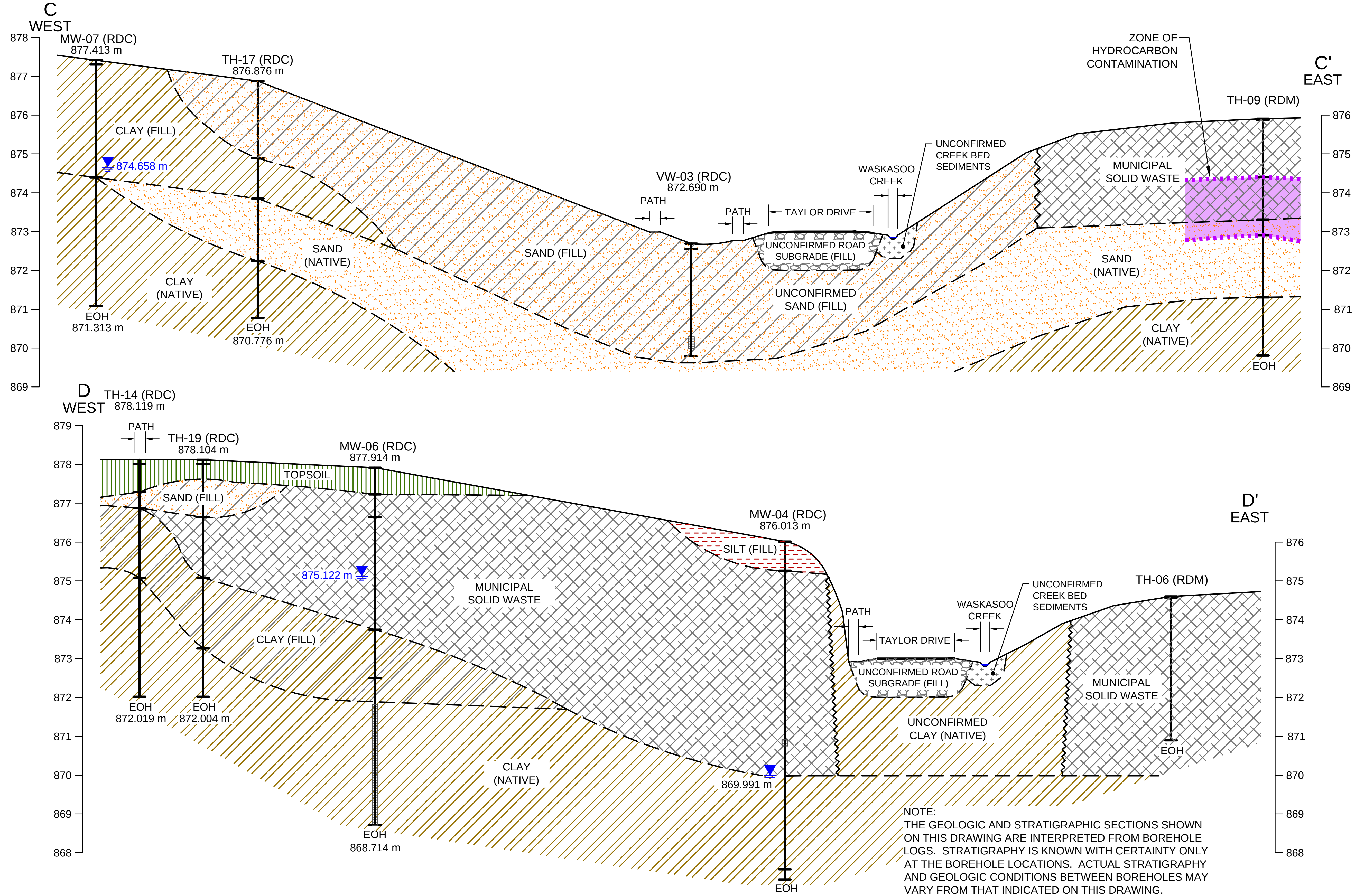

NOTE:
THE GEOLOGIC AND STRATIGRAPHIC SECTIONS SHOWN ON THIS DRAWING ARE INTERPRETED FROM BOREHOLE LOGS. STRATIGRAPHY IS KNOWN WITH CERTAINTY ONLY AT THE BOREHOLE LOCATIONS. ACTUAL STRATIGRAPHY AND GEOLOGIC CONDITIONS BETWEEN BOREHOLES MAY VARY FROM THAT INDICATED ON THIS DRAWING.

NOTE:
GROUNDWATER ELEVATIONS MEASURED AUGUST 2013. ABSENT WATER LEVELS DUE TO WELL BEING DAMAGED OR PLUGGED

| | |
|---|---|
| CLIENT: | THE CITY OF RED DEER |
| PROJECT: | ENVIRONMENTAL RISK MANAGEMENT PLAN<br>HISTORIC WASTE DISPOSAL SITE<br>RED DEER COLLEGE AND RED DEER MOTORS |
| TITLE: | CROSS SECTION A - A' AND B - B' |

Tiamat Environmental Consultants Ltd.

| SCALE: | DATE: | PROJECT NO.: | FIGURE NO.: |
|---|---|---|---|
| AS SHOWN | Jan. 9/15 | 12-435 | FIGURE 3A |
| DRAWN BY: LCH | CHECKED BY: LTM | CAD FILE NO.: ERMP Sections v1.01 | |




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

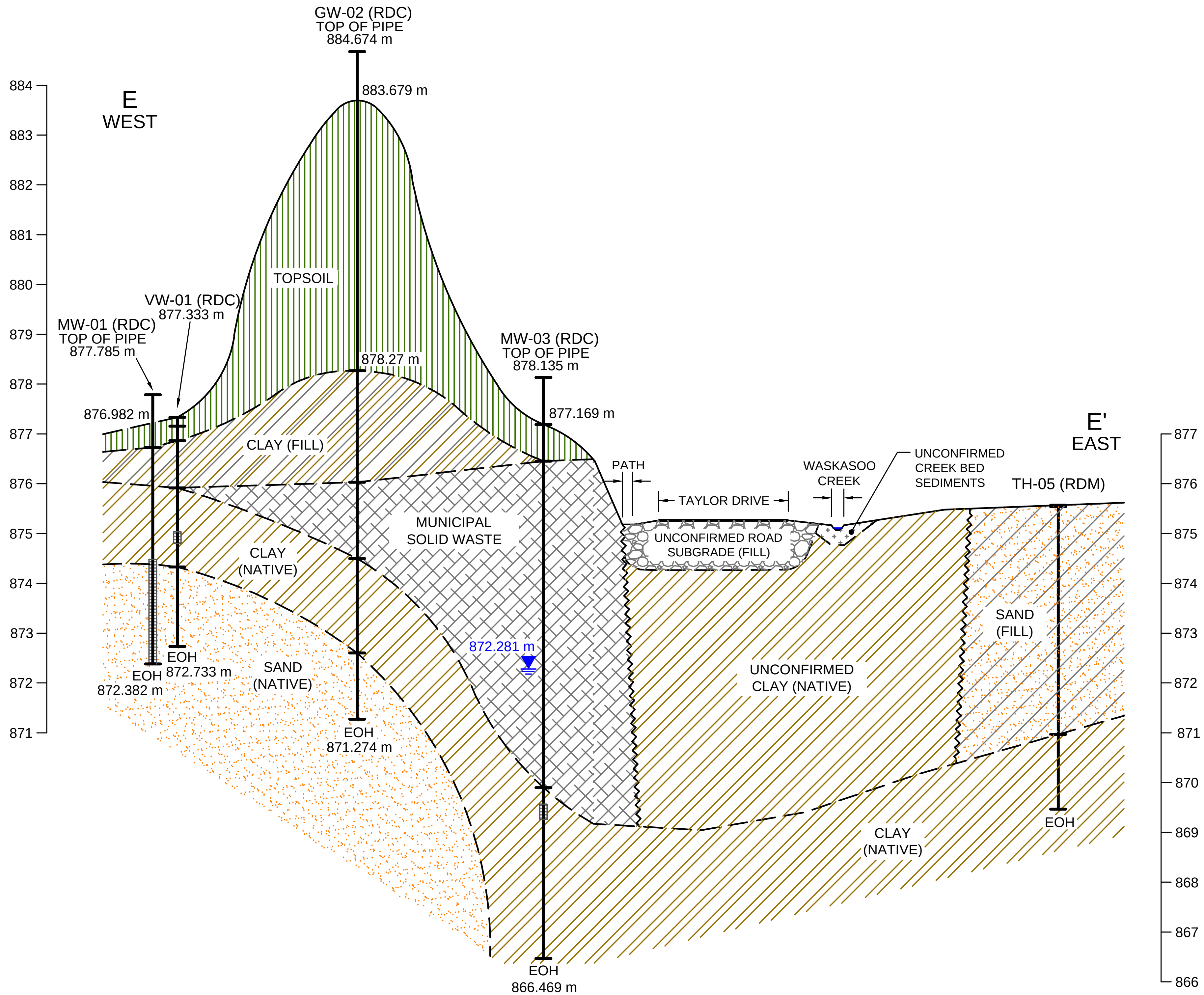
0 20 50 100m
Horizontal Scale 1:2000

NOTE:
GROUNDWATER ELEVATIONS MEASURED AUGUST 2013. ABSENT WATER LEVELS DUE TO WELL BEING DAMAGED OR PLUGGED

| | |
|---|---|
| CLIENT: | THE CITY OF RED DEER |
| PROJECT: | ENVIRONMENTAL RISK MANAGEMENT PLAN<br>HISTORIC WASTE DISPOSAL SITE<br>RED DEER COLLEGE AND RED DEER MOTORS |
| TITLE: | CROSS SECTION C - C' AND D - D' |

**Tiamat Environmental Consultants Ltd.**

| SCALE: | DATE: | PROJECT NO.: | FIGURE NO.: |
|---|---|---|---|
| AS SHOWN | June 27/14 | 12-435 | FIGURE 3B |
| DRAWN BY: | CHECKED BY: | CAD FILE NO.: | |
| LCH | LTM | ERMP Sections v1.00 | |



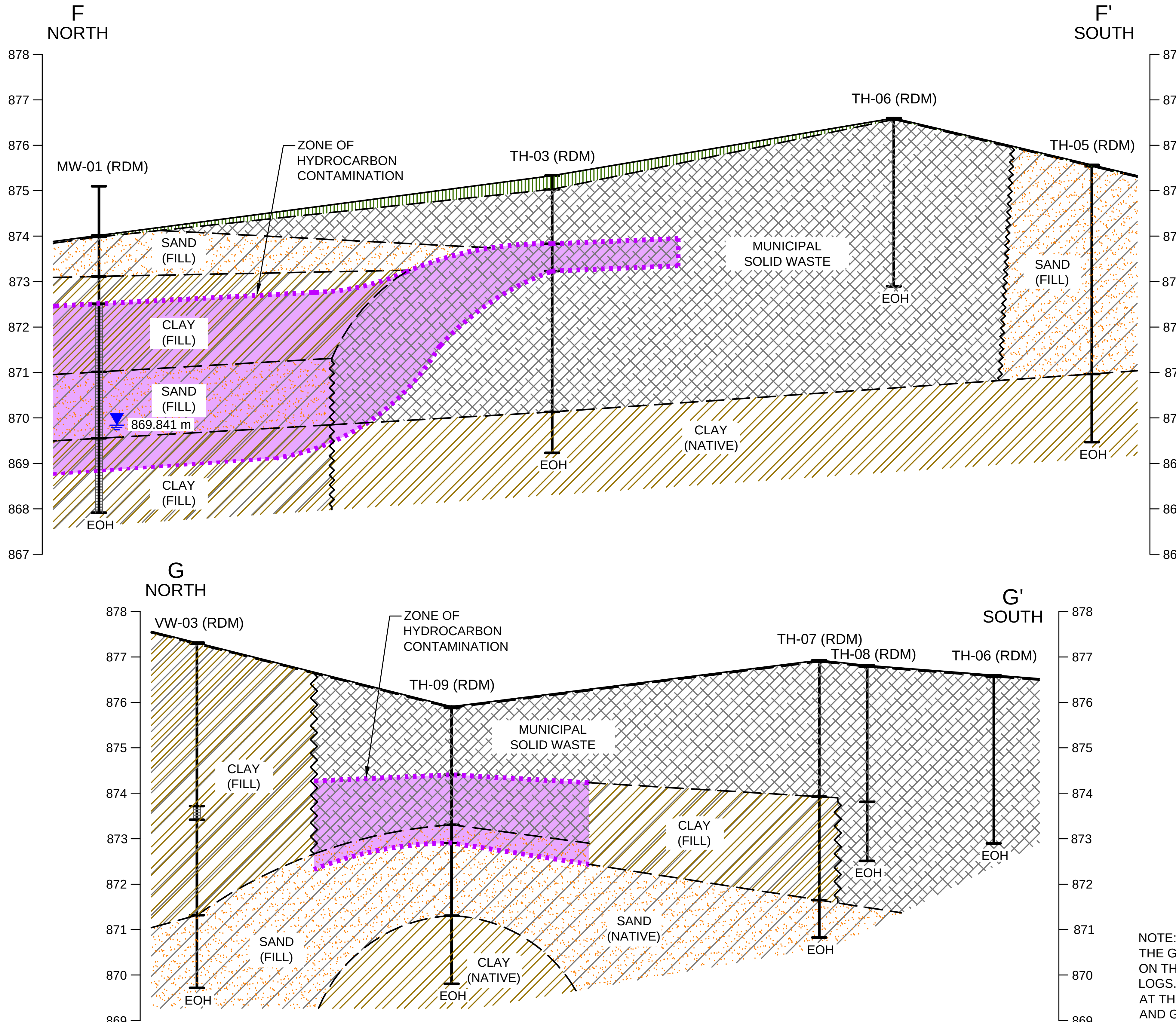

NOTE:
THE GEOLOGIC AND STRATIGRAPHIC SECTIONS SHOWN ON THIS DRAWING ARE INTERPRETED FROM BOREHOLE LOGS. STRATIGRAPHY IS KNOWN WITH CERTAINTY ONLY AT THE BOREHOLE LOCATIONS. ACTUAL STRATIGRAPHY AND GEOLOGIC CONDITIONS BETWEEN BOREHOLES MAY VARY FROM THAT INDICATED ON THIS DRAWING.

0 2 5 10m
Vertical Scale 1:200

0 20 50 100m
Horizontal Scale 1:2000

NOTE:
GROUNDWATER ELEVATIONS MEASURED AUGUST 2013. ABSENT WATER LEVELS DUE TO WELL BEING DAMAGED OR PLUGGED

| | | | | |
|---|---|---|---|---|
| CLIENT: THE CITY OF RED DEER | Tiamat Environmental Consultants Ltd. | | | |
| PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN<br>HISTORIC WASTE DISPOSAL SITE<br>RED DEER COLLEGE AND RED DEER MOTORS | SCALE: AS SHOWN | DATE: June 27/14 | PROJECT NO.: 12-435 | FIGURE NO.: FIGURE 3C |
| TITLE: CROSS SECTION E - E' | DRAWN BY: LCH | CHECKED BY: LTM | CAD FILE NO.: ERMP Sections v1.00 | |




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

NOTE:
GROUNDWATER ELEVATIONS MEASURED AUGUST 2013. ABSENT WATER LEVELS DUE TO WELL BEING DAMAGED OR PLUGGED

CLIENT: THE CITY OF RED DEER

PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN
HISTORIC WASTE DISPOSAL SITE
RED DEER COLLEGE AND RED DEER MOTORS

TITLE: CROSS SECTION F - F' AND G - G'

Tiamat Environmental Consultants Ltd.

| SCALE: AS SHOWN | DATE: June 27/14 | PROJECT NO.: 12-435 | FIGURE NO.: FIGURE 3D |
|---|---|---|---|
| DRAWN BY: LCH | CHECKED BY: LTM | CAD FILE NO.: ERMP Sections v1.00 | |


GROUNDWATER DATA

(850.150) GROUNDWATER ELEVATION (m) AUGUST 2013

INTERPRETED GROUNDWATER CONTOUR (m)

INTERPRETED GROUNDWATER FLOW DIRECTION

ABSENT WATER LEVELS DUE TO WELL BEING DAMAGED OR PLUGGED

SOURCE

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0 20 50 100m

Scale 1:2000

PHASE II TEST LOCATIONS

MW-## GROUNDWATER MONITORING WELL INSTALLED BY TIAMAT

TH-## TESTHOLE

VW-## SOIL VAPOUR MONITORING WELL

MW-## GROUNDWATER MONITORING WELL INSTALLED BY OTHERS

REFER TO TABLE 1 FOR TESTHOLE INFORMATION

LEGEND

LOT BOUNDARY

100 YEAR FLOOD LINE

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

ELECTRICAL

SANITARY

STORM

WATER

PRIVATE COMMUNICATIONS CABLE INSTALLED JULY 2011

| | |
|---|---|
| CLIENT: | THE CITY OF RED DEER |
| PROJECT: | ENVIRONMENTAL RISK MANAGEMENT PLAN<br>HISTORIC WASTE DISPOSAL SITE<br>RED DEER COLLEGE AND RED DEER MOTORS |
| TITLE: | INTERPRETED GROUNDWATER ELEVATIONS AUGUST 2013 |

Tiamat Environmental Consultants Ltd.

| SCALE: | DATE: | PROJECT NO.: | FIGURE NO.: |
|---|---|---|---|
| 1 : 2000 | June 29/14 | 12-435 | FIGURE 4 |
| DRAWN BY: LCH | CHECKED BY: LTM | CAD FILE NO.: ERMP v1.00 | |

# 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.).

# 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 Nonaqueous 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)/Acceptable Daily Intake (ADI)/Tolerable Daily Intake (TDI)** are 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 form at any 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

**n-Butane**
Chemical Formula: $C_4H_{10}$
Carcinogenicity: Not Classified

n-Butane has an odour threshold of 1,200 ppm. Currently, there are no guidelines or standards in Alberta for n-Butane in soil and water. The Alberta 8-hour occupational exposure limit is 1,000 ppm.

**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.

**Chlorobenzene**
Chemical Formula: $C_6H_5Cl$
Carcinogenicity: Not Classified

Chlorobenzene has an odour threshold that ranges from 0.217 ppm to 1.738 ppm. The current Alberta Tier 1 Guidelines for chlorobenzene in soil and groundwater are 0.018 mg/kg and 0.0013 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 75 ppm. Chloroethane is on Canada's National Pollutant Release Inventory.

**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.

## GLOSSARY
**Continued**

**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.

**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.

**1,2-Dichlorobenzene**
Chemical Formula: Non-Carcinogen
Chemical Formula: $C_6H_4Cl_2$

1,2-Dichlorobenzene has an odour threshold of 50 ppm. The current Alberta Tier 1 Guidelines for 1,2-dichlorobenzene in soil and groundwater are 0.18 mg/kg and 0.0007 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 25 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 1,4-dichlorobenzene in soil and groundwater are 0.098 mg/kg and 0.001 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 10 ppm.

# GLOSSARY
**Continued**

**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.

**1,2-Dichloroethane**
Chemical Formula: $C_2H_4Cl_2$
Carcinogenicity: Probable Carcinogen

1,2-Dichloroethane is a chlorinated hydrocarbon with an odour threshold of 6 ppm to 10 ppm. The current Alberta Tier 1 Guidelines for 1,2-Dichloroethane in soil and groundwater are 0.0027 mg/kg and 0.005 mg/L, respectively. The Alberta 8-hour occupational exposure limit is 10 ppm. 1,2-Dichloroethane is on Canada's National Pollutant Release Inventory and Health Canada's Cosmetic Ingredient Hotlist.

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

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

trans-1,2-Dichloroethylene is a chlorinated hydrocarbon with an odour threshold of 0.26 ppm. There are no published standards or guidelines in Alberta for trans-1,2-dichloroethylene in soil or groundwater. The Alberta 8-hour occupational exposure limit is 200 ppm.

**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.

**1,2-Dichlorotetrafluoroethane**
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.

# GLOSSARY
**Continued**

**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.

**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.

# GLOSSARY
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**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.

**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.

**n-Pentane**
Chemical Formula: $C_5H_{12}$
Carcinogenicity: Not Classified

n-Pentane has an odour threshold of 10 ppm. Currently, there are no guidelines or standards in Alberta for n-Pentane in soil and water. The Alberta 8-hour occupational exposure limit is 600 ppm.

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**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.

**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.

**Styrene**
Chemical Formula: $C_6H_5CH{=}CH_2$
Human Carcinogenicity: Possible Carcinogen

Styrene has an odour threshold of 0.008 ppm. The current Alberta Tier 1 Guidelines for styrene in soil and groundwater is 0.80 mg/kg and 0.072 mg/L, respectively. The 1-hour Alberta Ambient Air Quality Objective is 0.052 ppm. The Alberta 8-hour occupational exposure limit is 200 ppm.

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**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.

**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

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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.

**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.

**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

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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.