Environmental Risk Management Plan
Historic Waste Disposal Site
Riverside Heavy Dry Waste Site
The City of Red Deer

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Preface

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

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

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

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

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

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1.0 INTRODUCTION

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

For example, a proposed residential development project within a prescribed river flood plain will have several environmental factors associated to vulnerabilities and potentials for an adverse effect to the proposed development from the river (flood, high groundwater, pollution impact from an upstream source are some examples). The 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 Riverside Heavy Dry Waste Site, the Health Canada model is considered more appropriate relative to the above noted alternative risk assessment models.

Health Canada outlines a preliminary quantitative risk assessment (PQRA) in order for various industries to apply a standard method and assumptions to ensure potential environmental exposures and their risks are not underestimated in the risk model. This approach is to address historic problems during peer review. The PQRA applies a conservative interpretation to the risk outcome. Such that in the event of an identified potential risk outcome being negligible or acceptable; the actual site condition(s) will essentially present a negligible or acceptable level of risk. Conversely, should the outcome for a potential level of risk be deemed unacceptable, 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. The output from the PQRA incorporates into risk management strategies and the development of a risk management plan.

Tiamat Environmental Consultants Ltd. (Tiamat) presents this Environmental Risk Management Plan (ERMP) for a historic waste disposal site designated as the Riverside Heavy Dry Waste Site.

This report presents the scope of work, a summary of the PQRA and a proposed ERMP for the Riverside Heavy Dry Waste 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 Riverside Heavy Dry Waste Site as prepared by Tiamat.

1.1 Scope of Work

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

Compile Data for PQRA

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

ERMP

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

1.2 Summary of Previous Work & Project Status

Municipal records and historical information pertaining to the disposal of historic waste indicate dry construction waste was placed on the site for stabilization of the hill slope, as the site was a borrow source during development of the Red Deer Waste Water Treatment Plant. Records indicate historic waste disposal occurred between 1994 and 2007. Documentation indicates disposal activity was under approval of the City of Red Deer and the Red Deer Regional Health Unit.

The estimated age of the waste material, post closure, is approximately seven (7) years, more or less. Other nearby developments include light industrial and commercial land uses. The Red Deer River is about 800 m, more or less, from the northeast boundary of the site.

Previous geotechnical and environmental investigations for the site have been conducted by various consultants since 1993:

- Geotechnical Investigation – Slope Failure Investigation, Red Deer Riverside Industrial Park, Red Deer, Alberta, December 1993. Prepared by HBT AGRA Ltd.

- Geotechnical Investigation – Proposed Dry Waste Disposal Facility, Section 33-38-27-W4M, Red Deer Alberta, January 1994. Prepared by HBT AGRA Ltd.

- Summary Report Former City Landfill Riverside Dry Waste, Part of 33-38-27-W4M, Red Deer, Alberta, April 2007. Prepared by Stantec Inc. and Parkland Geotechnical Consulting Ltd.

- Phase I Environmental Site Assessment, Historic Waste Disposal Sites, Riverside Dry Waste Site, September 24, 2013, prepared by Tiamat.

- Phase II Environmental Site Assessment, Historic Waste Disposal Sites, Riverside Dry Waste Site, February 26, 2014, prepared by Tiamat.

The scope of investigation for the 2014 Phase II ESA was designed to address the environmental concerns identified from the 2013 Phase I ESA.

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

- Waste materials were encountered in a series of testholes advanced at various points along the hill slope through the fill material.

- Laboratory results of groundwater samples show elevated concentrations of routine water parameters and metals exceeding the Alberta Tier 1 Guidelines.

- Laboratory results of soil vapour show trace amounts of volatile organic compounds (VOC`s) and siloxanes.

The findings of the 2014 Phase II ESA suggests in addition to construction type waste materials, municipal sanitary waste (MSW) materials were encountered in the central area of the site. This is contrary to previous information compiled for the 2013 Phase I ESA. Laboratory results indicate mild strength leachate constituents from the MSW are present in the groundwater leaving the site and may migrate towards the Red Deer River.

The initial assessment of landfill gas (LFG) shows the concentration of soil gas constituents to be low and composed of numerous volatile chemicals. A summary of the identified chemicals of concern are tabulated in Table 2A.

1.2.1 Site Description and Environmental Setting

Riverside Heavy Dry Waste Site is located within two legal land descriptions. The larger portion to the north lies within the NE 33-38-27 W4M and the smaller portion to the south is within SE 33-38-27 W4M. The site is currently zoned A2 – Environmental Preservation (Land Use Bylaw #3357/2006).

The historic waste disposal area lies within a portion of the Riverside Heavy Industrial Park, a business district utilized predominantly for various industrial and commercial activities. The industrial park is subdivided and serviced; there are no identified underground municipal utilities within the area of the historic waste site.

The site is bounded on the north and east by a Canadian National (CN) rail spur line. Further to the north is Northland Drive followed by The City of Red Deer Waste Water Treatment Plant and then The Red Deer River. The Red Deer Fire Training Centre is east of the site, across the CN track rail. The south side of the site is bounded by a permanent slough followed by the CN track. A hiking/bike trail and overhead electrical power lines run along the west perimeter of the site along the top of the slope followed by various commercial and industrial businesses in the Northlands Industrial Park. A site plan showing the current surrounding land uses and the approximate footprint of the historic waste material is presented as Figure 1.

1.3 Regional Geology and Hydrogeology

Within the immediate area of the historic waste, principal overland flow and surface run-off appear to be directed to two areas. Surface run-off on the southern portion is directed to the slough. Drainage on the north side of the site is directed to a drainage swale reportedly installed in September 2000. This swale directs surface run-off northward to another drainage channel along the south side of Northland Drive. There are no obvious environmental concerns for surface water run-off or run-on throughout this area.

The historic waste sites entirely lie within the hillside overlooking the Red Deer River valley. This hill is interpreted to be within a zone of groundwater recharge with a downward component of flow. The Red Deer River is located northeast of the site and is approximately 800 m, more or less, from the nearest point of the historic waste. The section of the Red Deer River nearest to the site meanders in a southeast to northwest direction, before changing direction to the northeast. Local ground topography suggests the groundwater should trend to the northeast, towards the river.

It should be noted that local topography, geology, land development and soil disturbances might influence the local movement and pattern of groundwater. Furthermore, groundwater may also fluctuate from seasonal and climatic conditions.

A summary of the published geological and hydrogeological information is presented in the September 2013 Phase I ESA report.

There are no underground municipal utilities identified in the area of the historic waste site. The relative locations of the nearby 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 flows in a natural pattern to down gradient areas.

Several geochemical processes and physical settlement occurs as the buried historic waste materials decompose. There are some minor visual indications of differential settlement for the ground cover on the hill slope at the site. Testhole observations indicate the vegetation and underlying loam is variable across the site.

Landfill gas (LFG) 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.

Figure 1 illustrates a relative 300 m radius, from the historic waste, encompassing a portion of Northland Drive, a section of the wastewater treatment plant to the north and various commercial businesses and industrial activities to the east, south and west.

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 underlying 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.

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

1.4 Environmental Guidelines & Regulations

This historic waste site has been closed from landfilling for approximately seven (7) years and is considered to be a non-operating municipal landfill. It is understood there is no regulatory requirement to remediate or decommission/remove the waste material from its present location.

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

Within the Province of Alberta Municipal Government Act, Alberta Regulation 43/2002 with amendments up to and including AB Reg. 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 historic waste is buried into the hill slope, the areas down gradient of the waste material are considered to be the primary 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 Riverside Heavy Dry Waste Site reflects a summer (August 2013) testing event. To gain a “snap shot” of the seasonal range of soil vapour it is recommended a winter data set be obtained. The intent is to obtain subsurface data during frozen ground conditions where soil vapour constituents that would normally vent to atmosphere in the summer would be in a confined state and accumulate beneath the frozen ground. This scenario would reflect a “worst-case” for potential intrusion of soil vapour into a heated building.

2.1 Groundwater

The interpreted pattern of the local flow of groundwater appears to be in a northeast direction relative to the historic waste disposal site. Some flow may also move to the south towards the slough. The water quality at both the up gradient and down gradient test locations suggest indicators of the relative strength of landfill leachate to be relatively low with no detectable dissolved volatile compounds.

The natural gravel and sand sediments in the river valley is pervious and interpreted to not influence the pattern of local groundwater. Thus, the migration of leachate would be governed by the natural pattern of flow governed by the topography.

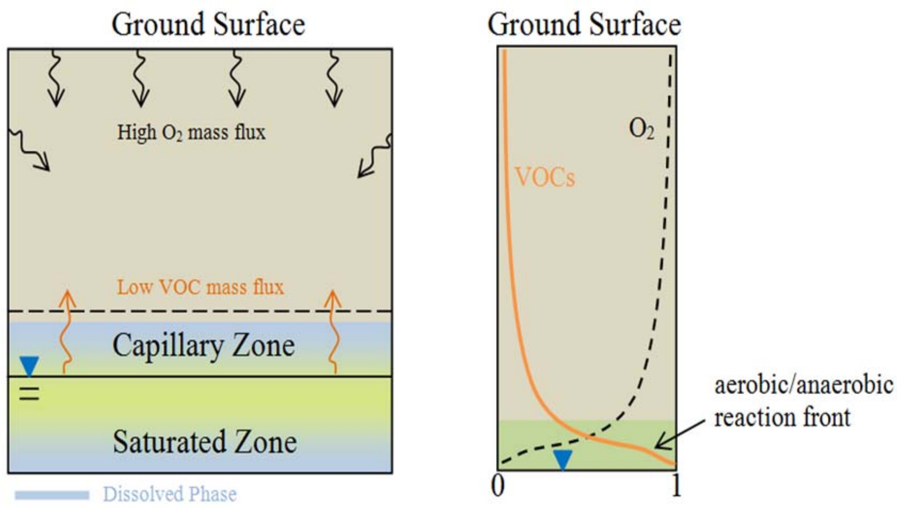
Per the data collected in August 2013, the horizontal gradient across the site ranges from 7 to 10% with an average linear groundwater velocity ranging between 0.21 to 0.29 m/day. On the basis of this field velocity, the groundwater containing leachate constituents may not (practically) reach the river that is about 800 m from the perimeter of the site. Groundwater with leachate constituents may more likely be attenuated by natural geophysical processes including microbial biodegradation and adsorption to various sediments along the flow path these processes may reduce the leachate load in the groundwater before reaching the river. Conversely, a potential also exists for groundwater to gain other types of contaminants along the flow path from other potential sources or events. It should be noted, natural seasonal fluctuations to the groundwater will affect the local gradient and the resulting horizontal flow velocity.

2.2 Soil Vapour

The concentration of landfill soil gas at the one test location, VW-01, located at the top of the hill slope was not significant. However, the composition of the measured LFG exhibited a variety of chemical types including VOCs and various siloxanes, which is indicative 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. Thus, parameterizing a potential non-point source scenario for this project with the available data will include significant uncertainties and the output results would not be considered reliable.

To evaluate whether the potential attenuation of some soil 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 Riverside Heavy Dry Waste Site 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 the Riverside Heavy Dry Waste Site.

Soil Vapours

Subsurface soil vapour may migrate to near-by commercial buildings. Soil vapour may migrate into buildings by way of pipe penetrations, crack and joints on ground floors and cracks and joints in foundation walls which can serve as point-of-ingress (POIs). The exposure pathway for vapour inhalation via vapour intrusion mechanisms is always considered to human health.

The relative porosity of the overburden material observed during the Phase II ESA suggests natural venting processes are occurring during non-freezing conditions. Field data and laboratory results for groundwater suggest the degree of saturation is very low.

Thus, the potential for soil vapours containing landfill gas to degas from groundwater underlying the Riverside Heavy Dry Waste Site is proportionately considered to be low or negligible.

The nearest residential community is located hydraulically up-gradient from the site, approximately 1.2 km to the west and are not considered to be at risk relative to the Riverside Heavy Dry Waste Site. The commercial and industrial buildings situated at the crest of the hill above the Riverside Heavy Dry Waste Site are also not considered to be at significant risk to LFG. Conversely, for buildings and infrastructure located down gradient of the historic waste area, POIs for potential subsurface soil vapours are anticipated to be from pipe penetrations, cracks and joints in the foundation floors and foundation walls. The potential down gradient receptors will have some risk for exposure though this risk is considered to be manageable due to the relatively low concentrations measured during the 2014 Phase II ESA. Presently, there is no other information to suggest this risk would increase with the existing conditions at the site.

Groundwater

Dissolved organic hydrocarbons were not detected in the groundwater during the summer 2013 sampling event. Presently, local groundwater is not utilized at the site. A well record for a City owned water source well in LSD 7 33-38-27 W4M lies within a quarter section (804 m, more or less) of the waste site. This water source well is likely hydraulically up-gradient relative to the waste site. However, there is a minor potential for inorganic leachate constituents to impact groundwater It is noted, 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.

Soil Contamination

Given the depth to the zone of impact, direct contact, by local residents with the impacted soil underlying the waste material is considered to be practically negligible. However, direct contact with impacted soil and groundwater may be possible by excavation contractors involved with maintenance of the slope drain installed in 2000 and construction activities relating to future slope stability actions.

Presently, there are no buried utilities within the area of concern. Contractors intending to work at this waste site should be informed and made aware of the potential hazards and implement an appropriate safe work (ECO, environmental construction operations) plan.

3.0 ENVIRONMENTAL RISK ASSESSMENT

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

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

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

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

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

At the Riverside Heavy Industrial Park, a potential subdivision development involving a residential land use is an unapproved activity and unlikely given the current zoning. As shown on Figure 1, the 300 m setback lies within areas of commercial and industrial lands. Other potential general commercial developments and activities associated with utility infrastructures, the potential receptor attributes input to the PQRA are outlined below.

- Non-residential Institutional includes school and hospitals. children are 32.9 kg child over 5 years old, 70.7 kg adult over 20 years old, inhalation rate 14.5 m^3/day for a child and 16.6 m^3/day for an adult, 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.

In the event land use within the Riverside Heavy Industrial Park is modified to include a future residential use, the Health Canada receptor attributes for residential activity applied to the PQRA would be:

- Residential – currently requires a land use amendment and may be a discretionary use for land lying within the regulated 300 m setback outlined in Section 13 AR 43/2002. 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.

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

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

- 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 adult worker, total annual exposure 10 hours/day, 5 days a week for 48 weeks/year for a 35 year period of employment.

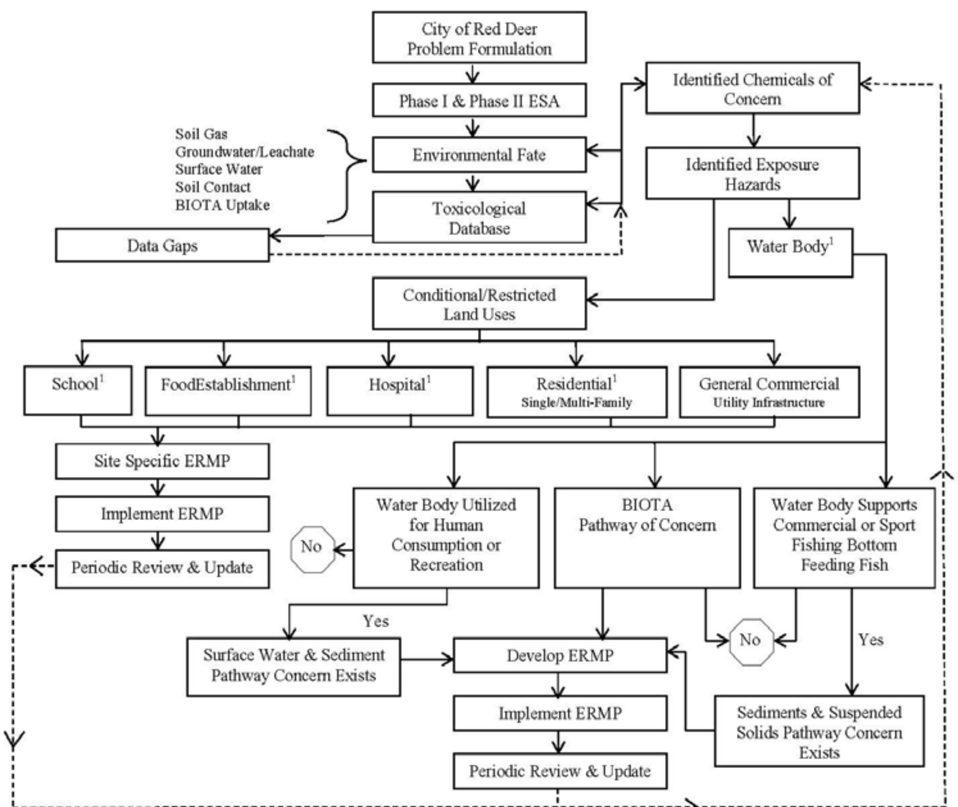
In general, the above exposure settings and the applied attributes are intended to yield a conservative outcome such that the real-case exposure situation would be expected to not be more than the model parameters for the given specified hazard. It is acknowledged the Health Canada protocol for residence time (80 years) and 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 Riverside Heavy Dry Waste Site, 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 vapours. Health effect(s) are contingent on a variety of factors including level, duration and frequency of exposure, toxicity of the chemical and individual sensitivity to the chemical. The principal concern for this PQRA is whether the identified chemicals of concern potentially pose an unacceptable level of risk for chronic health effects due to a long-term, low concentration exposure scenario.

It is recognized, the PQRA presented herein is conducted with numerous assumptions and limitations. Consequently, this PQRA should not be viewed as a comprehensive analysis for any particular property lying within the prescribed distances from the Riverside Heavy Dry Waste Site.

As noted above, the PRQA 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 Riverside Heavy Dry Waste Site.

The diagram below illustrates the process to formulate the risk assessment process to assist with the regulatory review process for future redevelopment within the regulatory setback distance of the Riverside Heavy historic waste disposal site.

Process of Developing ERMP
Riverside Heavy Dry Waste Site



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

3.1 Identified Environmental Health Concerns

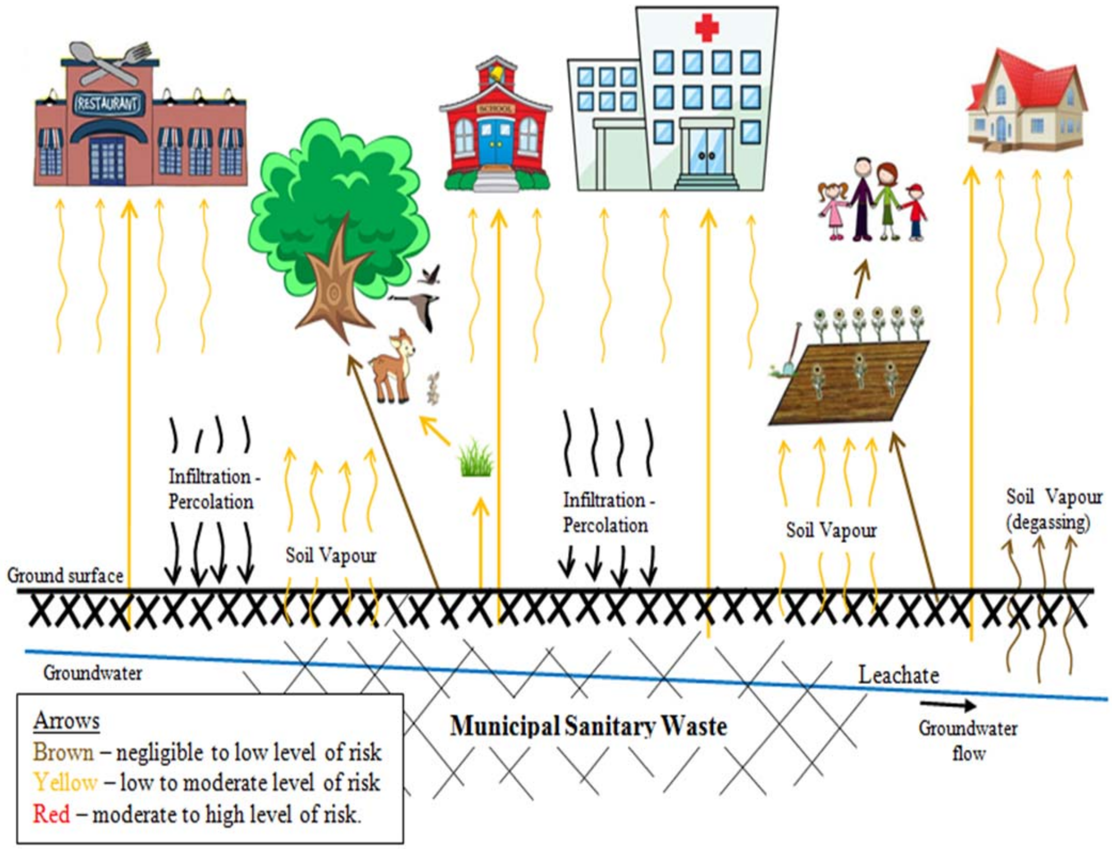
The environmental health risks presented by this historic waste site to the existing and future developments is primarily from landfill soil gas and to a lesser degree from potential volatile constituents that degas from leachate leaving the historic waste site into the unsaturated zone above the groundwater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

The age of this non-operating landfill (approximately 7 years) suggests the production and quantity of landfill gas may not have peaked and/or stabilized, as noted in the Phase II ESA. The initial assessment for soil vapour occurred during the summer and higher subsurface concentrations may result during the winter, in frozen ground conditions. Generally, the potential risk of exposure to soil vapours increases during rising groundwater and frozen ground conditions. However, on the basis of the initial data set, the measured landfill soil vapours are not viewed to be at concentrations to be of significant concern to the existing land uses within the industrial park. A future opportunity to gather further seasonal data would assist to better understand the subsurface environmental conditions and whether potentials of transient variables persist at the Riverside Heavy Dry Waste Site that could present a higher vulnerability for exposure to soil vapour.

For the leachate leaving the site, the properties down gradient relative to the natural flow pattern would be the principal receptors. Initial results indicate the leachate is predominantly composed of a mixture of inorganic and nutrient compounds. The measured concentrations do not suggest an immediate risk to the quality of local groundwater. The Red Deer River is about 800 m from the historic waste area and is not interpreted to be at notable risk from the current composition of the leachate leaving the site. Dissolved volatile compounds were not detected at the down gradient groundwater monitoring wells in August 2013. Hence, it is presumed VOCs degassing from groundwater will not be a factor to off-site subsurface soil gas.

In general, the risks associated with soil vapour and leachate to land areas off-site of the historic waste disposal area 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 is shown on Figure 1. Within this regulated setback distance, the current prescribed land uses generally excludes residential housing. As noted on Figure 1, this setback encompasses several subdivided commercial and industrial lands west and east of the historic waste area.

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 Riverside Heavy Dry Waste Site, the toxicological information applied in this PQRA should be periodically reviewed and updated.

3.2.2 Exposure Assessment

The historic waste disposal site is viewed as the source of the identified chemicals. As noted in Section 1.4, the location of the waste materials remains fixed and no further mitigative actions are planned.

Consequently, the potential exposure pathways consist of the following in order of lowest to highest priority:

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

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

3.2.3 Receptor Characterization

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

- The Red Deer River.
- Biotic factors (plants, terrestrial animals, aquatic life).
- People in occupied buildings including future buildings located within the prescribed regulatory setback.
- Workers engaged with ground disturbance activities within the prescribed historic waste disposal areas.

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

3.2.5 Potential Municipal Administrative Controls

Should soil gas and potential soil vapour intrusion controls not be feasible, other interim or permanent institutional measures can be considered by the City. These legal and administrative 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 and 3B.

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 envelopes and buried utilities. It is noted lateral migration could also be influenced by the heterogeneity of the observed texture of subsurface soil (units of silt, sand, clay and gravel).

- The lateral extent of the soil vapours may extend off-site onto third party property. However, the magnitude of the soil vapours are not considered to be significant during summer months. Presently, there is no site data for a winter condition.

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 organic hydrocarbons identified in the on-site and off-site it areas.

Convection

Convection is the mechanism of transport by diffusion and advection. As waste disposal activities ended approximately seven (7) years ago, the generation and quantity of landfill soil gas is presumed to not have peaked and/or stabilized at the Riverside Heavy Dry Waste Site. The most heavily impacted area is considered to be the central portion of the site, where MSW was encountered.

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 in 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

Field measurements suggest the relative concentration of landfill soil gas in the soil and groundwater is considered low. Accordingly, a dispersion mechanism is not considered to be a dominant factor for the migration of dissolved landfill gas in the subsurface. As the identified MSW in the central area of the site continues to decompose, LFG is expected to continue to vent to atmosphere during non-frozen ground conditions with minimal potential for subsurface dispersion to surrounding underground utilities and structures.

Natural Attenuation

Naturally occurring bio-chemical and geochemical 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 natural biodegradation. 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.

Indicators of reductive dehalogenation of chlorinated ethenes such as tetrachloroethylene (PCE), trichloroethylene (TCE), Dichloroethylene (DCE), Vinyl Chloride (VC) to basic aliphatics and ethane from the soil gas sample were detected.

4.1.1 Volatile Organic Compounds in Soil

Trace amounts of hydrocarbon fractions F3 and F4 were noted in TH-06, located along the northern boundary of the interpreted waste disposal area. Trace amounts of methylene chloride was noted in TH-09, located near the entrance road along the east boundary of the site. The concentrations do not exceed the Alberta Tier 1 Guidelines and are not considered to be significant. In general, the soil quality underlying the historic waste material appears to be relatively acceptable.

4.1.2 Volatile Organic Compounds in Groundwater

VOCs were not detected in the groundwater samples. It is uncertain whether this initial test result is indicative of the environmental quality of the local groundwater. Additional testing would be necessary to better understand the quality of the local groundwater leaving the site.

4.1.3 Combustible Headspace Vapours

On August 17, 2013, combustible headspace vapour readings at test locations lying outside of the historic waste area ranged from 20 pm to 1,100 ppm. A test event during frozen ground conditions would reveal the potential range of landfill soil gas outside of the waste area.

Volatile vapour readings at test locations ranged from non-detect to 30 ppm.

4.1.4 Lateral Transport of Groundwater

Local groundwater beneath the site and the nearby areas is interpreted to be in an unconfined condition within a zone of recharge (vertically downward flow gradient). 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 principal direction of flow is estimated to be northeast. However, some component of flow is anticipated to be directed to the slough bounding the south end of the hill. This suggests the groundwater with leachate may cross onto third party property and other adjacent municipal land in the descending direction towards the Red Deer River.

4.1.5 Volatilization and Vapour Migration from Impacted Soil and Groundwater

Generally, various volatile organic compounds and methane are the primary components in a 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 (7 years) of the waste material at this site. The August 2013 vapour measurements at the borehole locations indicate detectable soil vapours are present but are relatively low and were not considered to be a significant concern. As the site may not have reached steady-state conditions and with the limited in-situ soil vapour data extrapolation on the variability and composition cannot be undertaken. It is recognized the composition of the LFG will likely continue to be variable with the potential for higher concentrations to accumulate in the subsurface when the ground is frozen impeding ventilation to atmosphere.

The mapping of the groundwater elevations and the dissolved compounds in the groundwater suggest the groundwater flows to the northeast towards into the river valley.

Physical factors influencing the distribution of soil vapours include moisture content and texture in the soil 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 joints/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 Riverside Heavy Dry Waste Site is deemed to not warrant the costs to conduct such an evaluation. Conservatively, for this initial ERMP, no attenuating factors have been considered to reduce the potential concentration of the soil vapour constituents.

4.2 Summary of CSM

An initial interpretation of the subsurface stratigraphy, derived from borehole information, is presented as Figures 3A and 3B. A summary of the identified pathways and receptors at risk by the landfill soil gas and the leachate are as follows.

Groundwater Pathway

Groundwater lies at depths ranging from 10.4 m at MW-01 to 2.6 m at MW-03. Please note, MW-01 is located at the top of the hill slope, approximately 24 m above MW-03. The groundwater table exhibits a downward hydraulic gradient with a horizontal gradient of about 7 cm/m (easterly component) to 10 cm/m (northeasterly component). To our knowledge, groundwater is not utilized at locations down gradient of the waste material.

The soil cover over the waste material appears to be a thin layer of sod or organic loam approximately 15 cm to 45 cm thick. Minor differential and irregular settlement of the underlying waste material and soil was evident at the historic waste disposal area.

Furthermore, the texture of the observed soil cover is interpreted to be a poor material to prevent surface water from infiltrating and percolating into the waste material and generating leachate.

Groundwater is observed to flow into the river valley and may ultimately reach the Red Deer River, located about 800 m, more or less, from the northeast boundary of the site. BTEX compounds and VOCs were not detected in any groundwater samples, suggesting negligible VOCs in the leachate and local groundwater.

Vapour Pathway

There is no information available to Tiamat for soil vapour intrusion/nuisance into nearby buildings from the contaminants identified at the site. Concentrations of combustible vapours measured from the monitoring wells ranged from 20 ppm to 1,100 ppm during field testing 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. As discussed in Section 4.1, the geometry of the hill slope, the lateral dispersion mechanism is likely muted with preferential venting to atmosphere. Notwithstanding, there is a potential for a plume of soil vapour to persist and accumulate in the hill side with some upward migration and dispersion when the ground cover conditions impede venting to atmosphere, such as frozen ground.

Soil Contact Pathway

The historic waste area has remained vacant and undeveloped since the waste disposal activities ended. The potential for visitors to contact the underlying waste is considered low. Pets and burrowing animals may disturb the relatively soft and thin soil cover and the potential to expose the underlying waste exists.

Access to the site from the east is restricted by a secured gated entrance road from the fire training centre. Other portions along the east side are restricted by fencing established by the bounding industrial businesses. Public access exists from the south, north and west with a mountain bike trail traversing the crest of the hill, following the overhead electrical power lines.

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 to a potential adverse situation.

Environmental Receptors

Accordingly, the human exposure pathway is considered (qualitatively) to be low. Nevertheless, there will be a level of risk to soil contact and inhalation should future construction or re-development activities occur to depths ranging from 0.8 m to 15.2 m below surface in the areas identified by this risk management plan.

For potential developments adjacent and in the vicinity (within 300 m) of the Riverside Heavy Dry Waste Site, the risk of exposure to the identified chemicals of concern are limited to exposure via soil vapour intrusion into an enclosed building. As noted in Section 3.2, the potential for a future residential development within 300 m of this waste site is considered remote. Naturally migrating groundwater containing leachate may contribute to subsurface soil vapour by natural degasing. The primary route of exposure from the identified chemicals of concern emanating from the Riverside Heavy Dry Waste Site is adverse effects from the leachate in the local groundwater and a lesser concern for intrusion of soil vapour and LFG to nearby existing buildings and underground utility infrastructure.

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 POI's 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 regulators for soil vapour intrusion. Regulators address soil vapour intrusion on a case-by-case basis.

As noted above, the elapsed time (about 7 years, more or less) for the landfill soil gas, the natural geochemical processes may not have reached its steady-state limit, and degradation processes (if available and active) have not likely stabilized with equilibrium conditions.

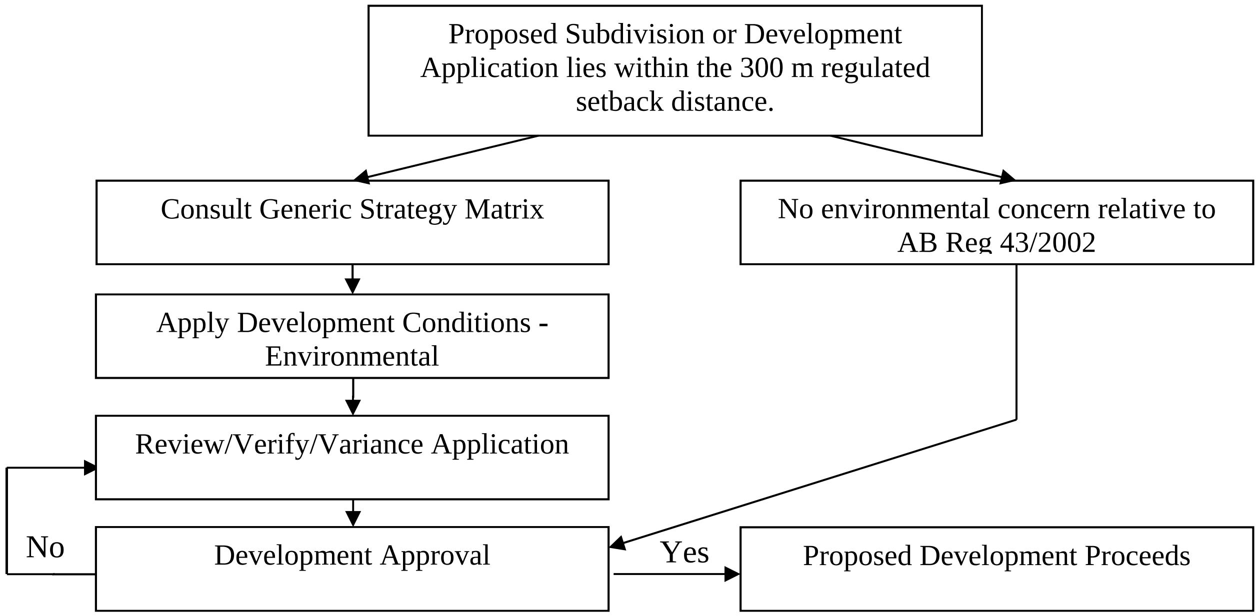
For the fully developed urban setting with consideration of the potential hazards, the level of potential exposure and the potential receptors, a proposed site-specific environmental risk management plan (ERMP) is presented in this section. The proposed ERMP is a tool to assist with the review of future subdivision applications on lands lying within the regulated setback distance from the historic waste disposal site. As noted in Section 3.2, future residential land use is presently an unapproved activity in the industrial park. However, a future amendment to permit residential land use within the industrial park could occur. Accordingly, this ERMP has considered the identified hazards from the historic waste disposal site for each of the four types of regulated land uses, specifically residential, food establishment, school and hospital as well as 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 improve the ability of 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 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 near non-operating landfill 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 defined in AB Reg. 43/2002)



Typically, residential type developments are usually identified to be the most sensitive receptors. The current allowed land uses within the industrial park precludes residential type developments. Should a future amendment occur to permit residential land use, this ERMP has identified residential activity to be the most sensitive receptor.

As such, this ERMP addresses the proposed residential and school exposure models. The initial data set applied to the PQRA is subject to review and amendment when (and if) additional data such as additional in-situ contaminant information become 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 food establishment and general commercial developments. Notwithstanding, other types of building developments such as school, public institutions and commercial complexes typically include higher performance HVAC systems with greater rates of air exchanges and lower periods of human occupancy. Unique exceptions to these generalities would need to be addressed on a specific case basis. The other noteworthy activity subject to worker exposure to potential landfill soil gas is the underground utility worker and the subsurface utility line this includes public and private underground utilities.

The results of the risk characterization model as calculated values of HQ for the identified chemicals of concern are summarised in Tables 3A to 3E. The uncertainties and the conservatism applied for this initial PQRA have been incorporated into the baseline ERMP. Generally, a HQ value greater than 1 presents a level of risk requiring a level of mitigative and/or adaptive action. This broad-based approach is designed to improve the clarity and timeliness for the development application review process. It must be recognized and acknowledged, the proposed ERMP for the Riverside Heavy Dry Waste Site is based on on-site test results. Extrapolations for potential environmental risks associated with leachate and landfill soil gas migrating from the historic waste disposal site have been factored into this proposed initial 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 5.6.

It is acknowledged, an applicant may accept the protocols applied in this ERMP or chose 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 non-operating Riverside Heavy Dry Waste historic waste disposal site; refer to Figure 1 for the approximate radial limits.

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.

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 boundary of the Riverside Heavy Dry Waste Site. The various strategies are summarised in the table below and further details are discussed Sections 5.1 to 5.5. The recommended protocols for regulatory monitoring and quality assurance for this ERMP utilities are discussed in Section 5.6.

Proposed ERMP Strategies for Subdivision or Developments within 300 m of the Riverside Heavy Dry Waste Site

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

Notes:
1) Above applicable to buildings with or without basement.
2) NR – No requirement for potential soil vapour intrusion.
3) N/A – not applicable land use for the industrial park.
4) Passive and/or Active mitigative measures for other retail/commercial developments is dependent upon the actual configuration of the enclosed space and ventilation system.

HQ's are calculated for each of the following land use types: residential, food establishment, public institutions (school/hospital), commercial developments and underground utility infrastructure are shown in Tables 3A to 3D. Calculated HQ's are based solely on receptor variables provided from Health Canada's PQRA.

Tables 3A to 3D show the calculated HQ values for land development including residential (Table 3A), food establisment (Table 3B), public institutions including school/hospital (Table 3C), general retail/commercial (Table 3D) and other commercial developments and for workers in construction and maintenance for underground utility infrastructure (Table 3E). As shown in Tables 3A the exposure outcome for residential land use are notably greater than the relative values for land uses involving food establishments, public institutions and other commercial/retail business activities.

Specifically, chloromethane and benzene measured in the soil vapour from the site appear to be the highest carcinogenic chemicals of concern identified from the Phase II ESA. Accordingly, for residential land use, the unadjusted HQ's for chloromethane and benzene are 56.7 and 5.4, respectively. Chloroform was the other identified chemical of concern exhibiting an unadjusted HQ value greater than 1.8 for a residential land use.

Various generic measures to mitigate potential soil vapour intrusion for an enclosed building are outlined in the following subsections.

5.1 Outline of Generic Mitigative Measures

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

<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

For the presently allowed land uses within the industrial park, future developments lying within the 100 m zone of the setback should include a passive mitigation strategy. This generic measure is governed by the three carcinogens that were measured in the soil vapour during the Phase II ESA. Should a future residential land use be approved within the 100 m setback, a combination of passive and active mitigation should be included in the design of the building. This will ensure an appropriate level of protection for a resident.

For development activities which are not addressed in Section 13 AB. Reg. 43/2002, the same strategy to mitigate potential exposure to soil vapour intrusion in enclosed buildings should be applied. HQ values have been calculated with the available results and summarised in Table 3D for general commercial/retail land uses.

5.3 Strategy For Subdivision and Developments Between 100 m to 300 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 are not deemed to be of sufficient concentration to adversely impact properties beyond 100 m of the boundary of the Riverside Heavy Dry Waste Site. Currently, numeric models to predict transient subsurface soil vapour concentrations from a point source are complex and parameterizing a potential scenario for this project with the available data will include significant uncertainties and the output results would not be considered reliable.

On the basis of the available information, there is presently no identified risk of soil vapour intrusion by soil landfill gas into an enclosed building where the property boundary of the subdivision development lies beyond 100 m from the boundary of the Riverside Heavy Dry Waste Site. As noted in Section 5.0, the level of risk for developments beyond 100 m is viewed as negligible and not warranting special environmental mitigative or adaptive considerations.

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

5.4 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.

5.5 Considerations For Other Commercial Developments & Subsurface Utilities

In the event a proposed utility line crosses the Riverside Heavy Dry Waste Site, the utility owner should review the proposed work with The City of Red Deer Waste Management to ensure the viability of the proposed utility line within a solid waste environment.

Maintenance activities for underground utilities including confined space entry should include hazard assessment for the potential presence of soil landfill gas in underground vaults, manway and buried chambers. Appropriate PPE for workers should be included in their respective Safe Work Plan.

5.6 Proposed Regulatory Monitoring and Quality Assurance

A follow-up monitoring event may be required to track and verify the effectiveness of 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 above (Section 5.1). Exclusion and limitations resulting from the specific mitigation measures implemented by the design professional should also be communicated on the as-built document.

5.7 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 ESA and the 2014 Phase II ESA 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.

City Management should inform other municipal departments on the potential to encounter buried historic waste material in the area identified on Figure 1. The notification is intended assist with safe work plans for city staff and their contractors involved with future ground disturbance activities.

5.8 Future Review and Update to ERMP

The identified chemicals of concern reflect the initial environmental site assessment conducted in August 2013 and reported in 2014. 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 or amended accordingly.

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

6.0 STATEMENT OF LIMITATIONS

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

Tiamat is not the sole source of information, records or documents contained in this report. Tiamat has not verified the information, records or documents of others contained in this report and is not liable for opinions based on inaccurate or misleading information. No representation, warranty, covenant or guarantee is made or given, nor is any responsibility assumed, with respect to the completeness, accuracy or reliability of the information, records or documents contained in this report. This report reflects work in progress and as such, the data and interpretations presented herein are not absolute. However, the general environmental concerns addressed are considered representative of the conditions at the site for which the data reflects. This report does not contain all available data for this project as relevant data is presented in other documents. Tiamat reserves the right to re-evaluate the conclusions in this report should new information become available.

This report has been prepared in accordance with generally accepted environmental engineering practice and no other warranty is made, either express or implied. The opinions, conclusions and recommendations presented herein reflect the best judgment of Tiamat Environmental Consultant Ltd. (Tiamat), ©2014 Tiamat, all rights reserved.

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This report was issued electronically in an encrypted PDF format. Notwithstanding, the file encryption, Tiamat cannot guarantee the contents of this report have not been altered. Should an authenticated copy be required, the reader should contact The City of Red Deer and our office.

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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/ter

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 site is currently vacant and landscaped with a mix of prairie fescue grass, prairie wildflowers and weeds. A mountain bike trail is along the west perimeter of the site at the top of the hill slope and a permanent slough is located on the south side of the site. There are currently no buildings within the boundaries of the site.
Legal Description:	Within Ptn of NE 33-38-27-W4M and Lot R-5 Block 4 Plan 7720064 within Ptn of SE 33-38-27 W4M.
Surrounding Land Use:	Urban Setting (City of Red Deer) The historic waste site is bounded on the north by Northland Drive followed by the City Waste Water Treatment Plant and then The Red Deer River. A Canadian National (CN) rail track bounds the site to the east and south. The Red Deer Fire Training Centre permanent slough are located to the east and south, respectively. A hiking/bike trail followed by industrial/commercial activities are at the top of the hill.
Groundwater Usage:	No usage on the site presently nor likely in the future.
Surface Water:	A drainage ditch is aligned along the west side of the CN rail track and directs surface run-off towards the slough or towards Northland Drive. A drainage swale at the base of the hill slope was installed circa September 2000; directing surface run-off northwards to a drainage channel on the on the south side of Northland Drive.
Underground Structures:	There are no underground structures or underground utilities located within the area of the historic waste site.
Special Environmental Conditions:	This landfill has been closed for approximately seven (7) years.

Receptor	Potential Exposure Routes	Soil Gas		
		Oxygenated	Ketone	Chlorinated
On-Site: Recreational Visitors or City Maintenance Workers	Inhalation of vapours from soil	×	×	✓
	Inhalation of vapours from groundwater	×	×	✓
	Ingestion of groundwater	✓	✓	✓
Off-Site: The Red Deer Fire Training Facility	Inhalation of vapours from soil	×	×	✓
	Inhalation of vapours from groundwater	×	×	✓
	Ingestion of groundwater	✓	✓	✓
Surrounding Industrial and Commercial Businesses	Inhalation of vapours from soil	×	×	✓
	Inhalation of vapours from groundwater	×	×	✓
	Ingestion of groundwater	✓	✓	✓
The City of Red Deer Waste Water Tratment Plant	Inhalation of vapours from soil	✓	✓	✓
	Inhalation of vapours from groundwater	✓	✓	✓
	Ingestion of groundwater	✓	✓	✓
Underground Utilities: There are no underground utilities within the boundaries of the historic waste site	Impact of vapours from groundwater	✓	✓	✓
	Impact of vapours from soil	✓	✓	✓
	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	Organic C Water	Soil/Sediment	Air	Soil	
	mg/kg	ppb	ppbv	g/mol	mmHg			mg/L	Pa m3/mol	log K_{ow}	log K_{oc}	kd	Time	Time	ppm
Dichlorodifluoromethane (FREON 12)	0.01	- -	0.20 - 1.08	120.9	4,332	1.50	4.20	Insoluble	3.48E+04	2.16	356	- -	105 - 169 yrs	- -	- -
Chloromethane	0.1	0.002	0.30 - 1.21	50.5	3,800	0.92	1.80	5,000	8.94E+02	0.91	14	- -	1 year	- -	10
Trichlorofluoromethane (FREON 11)	0.01	0.0005	0.20 - 0.40	137.4	690	1.49	4.70	Insoluble	9.83E+03	2.53	97	- -	52 - 207 years	- -	- -
Ethanol (ethyl alcohol)	- -	- -	2.3 - 21.8	46.1	44	0.80	1.60	Miscible	5.07E-01	-0.31	1	- -	5 days	- -	0.35
2-Propanol	- -	- -	3.0 - 3.2	60.1	33	2.07	0.785	Miscible	8.21E-01	0.05	1.5	- -	3.2 days	- -	- -
2-Propanone	- -	- -	0.80 - 22.8	58.1	180	0.80	2.00	Miscible	1.61E+02	-0.24	0.73	- -	22 - 23 days	1 - 7 days	20
Chloroform	0.01	0.0005	0.15 - 0.33	119.4	160	1.48	4.12	5,000*	3.72E+02	1.97	34 - 196	- -	150 days	0.3 - 1.4 days	85
Benzene	0.005	0.0004	0.18 - 0.48	78.1	75	0.88	2.70	700	5.63E+02	2.13	85	- -	13 days	- -	1.5
Toluene	0.05	0.0004	0.20 - 1.86	92.1	21	0.87	3.10	700 @ 23.3°C	6.73E+02	2.73	37 - 178	- -	3 days	3 hrs - 71 days	2.9
Ethylbenzene	0.015	0.0004	0.20 - 0.55	106.2	7	0.87	3.70	100	7.98E+02	3.15	520	- -	55 hrs	- -	2.3
o-Xylene	- -	- -	0.20 - 0.84	106.2	7	0.88	3.70	200	5.25E+02	3.12	24 - 251	- -	1.2 days	- -	- -
m Xylene	- -	- -	0.37 - 2.53	106.2	9	0.86	3.70	Slight	7.28E+02	3.20	166 - 182	- -	16.3 hrs	- -	1.1
p-Xylene	- -	- -	0.37 - 2.53	106.2	9	0.86	3.70	200	6.99E+02	3.15	246 - 540	- -	27 hrs	- -	- -
Total Xylene	0.1	0.0008	0.60 - 3.37	106.2	0.896 @ 21°C	0.86	3.70	130	6.23E+02	- -	- -	- -	8 - 14 hours	- -	0.00005
Hexane	- -	- -	0.30 - 3.44	86.2	124	0.66	3.00	20	1.85E+05	3.90	150	- -	3 days	- -	130
Heptane	- -	- -	0.30 - 0.49	100.2	40 @ 22.2°C	0.68	4.60	3	2.03E+05	4.66	8,200	- -	54 hrs	- -	220
Cyclohexane	- -	- -	0.20 - 0.40	84.2	78	0.78	2.90	Insoluble	1.52E+04	3.44	160	- -	45 hrs	- -	0.41
Tetrahydrofuran	- -	- -	0.40 - 3.49	72.1	132	0.89	2.50	Miscible	7.14E+00	0.46	18	- -	21 - 24 hrs	- -	30
Propene	- -	- -	0.30 - 1.29	42.08	760 @ -47°C	0.609	1.46	2.44 *	1.99E+04	1.77	220	- -	15 - 23 hrs	- -	- -
2,2,4-Trimethylpentane	- -	- -	0.20 - 0.25	114.22	49.3 *	0.69	3.93	Insoluble	3.05E+05	4.08	4.35	- -	4.4 days	- -	- -
Carbon Disulfide	- -	- -	0.50 - 6.98	76.1	297	1.26	2.63	3,000	1.46E+03	1.94	270	- -	5.5 days	- -	0.016

Notes:

1) Above identified chemicals of concern are dervied from the results of a 2014 Phase II ESA. Additional chemicals may be added pending future investigation and testing events.
2) Solubility in water, Vapour pressure, Specific Gravity are at 20°C unless otherwise stated
3) Henry's Law Constant and any value with * Temperature at 25°C
4) - -/N/E - Not tested, no value established or not evaluated.

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	mg/kg or mg/L	ppm	mg/m^3	mg/kg/day	ppm bw/day	mg/m^3	$(mg/m^3)^{-1}$
Dichlorodifluoromethane (FREON 12)	Non-Carcinogen	0.01	- -	0.20 - 1.08	25	1,000	4,950	- -	- -	- -	- -
Chloromethane	Carcinogen	0.1	0.002	0.30 - 1.21	3	50	105	- -	0.003	0.1	0.4
Trichlorofluoromethane (FREON 11)	Non-Carcinogen	0.01	0.0005	0.20 - 0.40	49	1,000 [2]	5,600 [2]	- -	- -	- -	- -
Ethanol (ethyl alcohol)	Carcinogen	- -	- -	2.3 - 21.8	3	1,000	1,880	- -	- -	- -	- -
2-Propanol	N/E	- -	- -	3.0 - 3.2							
2-Propanone	N/E	- -	- -	0.80 - 22.8	3.2	250 [2]	590 [2]	- -	- -	- -	- -
Chloroform	Possible Carcinogen	0.01	0.0005	0.15 - 0.33	2.9 - 10.35	10	49	- -	0.01	0.04475	0.023
Benzene	Carcinogen	0.005	0.0004	0.18 - 0.48	1.1 - 20	0.5	1.6	- -	0.004	- -	0.0033
Toluene	Non-Carcinogen	0.05	0.0004	0.20 - 1.86	13 & 90	50	188	- -	0.22	3.8	5
Ethylbenzene	Possible Carcinogen	0.015	0.0004	0.20 - 0.55	0.67 - 15	100	434	1.6	0.1	1	1
o-Xylene	Non-Carcinogen	- -	- -	0.20 - 0.84	6.2 - 21	100	434	- -	1.5	0.18	- -
m Xylene	Non-Carcinogen	- -	- -	0.37 - 2.53	6 - 23.4	100	434	- -	1.5	0.18	- -
p-Xylene	Non-Carcinogen	- -	- -	0.37 - 2.53	15	100	434	- -		0.18	- -
Total Xylene	Non-Carcinogen	0.1	0.0008	0.60 - 3.37	1 - 24	100	434	- -	1.5	0.18	0.7
Hexane	Non-Carcinogen	- -	- -	0.30 - 3.44	200	500	1,760	- -	0.7	- -	- -
Heptane	N/E	- -	- -	0.30 - 0.49	2,000	400	1,640	- -	- -	- -	- -
Cyclohexane	N/E	- -	- -	0.20 - 0.40	89	300	1,010	- -	- -	- -	- -
Tetrahydrofuran	Possible Carcinogen	- -	- -	0.40 - 3.49	3	50	147	- -	0.9	- -	- -
Propene	N/E	- -	- -	0.30 - 1.29							
2,2,4-Trimethylpentane	N/E	- -	- -	0.20 - 0.25	2.57	300	1,400	- -	- -	- -	- -
Carbon Disulfide	Non-Carcinogen	- -	- -	0.50 - 6.98	<6.1 & <60	1	3.1	- -	0.1	0.1	- -

Notes:
1) Above identified chemicals of concern are dervied from the results of a 2014 Phase II ESA. Additional chemicals may be added pending future investigation and testing events.
2) 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.
3) TC - Tolerable Concentration
4) UR - Unit Risk
5) - -/N/E - Not tested, no value established or not evaluated.

Table 2 Notes

1. Above identified chemicals of concern are derived from the results of a Phase II ESA, 2013. Additional chemicals may be added pending future investigation and testing events.
2. Solubility in water, Vapour pressure, Specific Gravity are at 20°C unless otherwise stated.
3. Henry's Law Constant and any value with * Temperature at 25°C.
4. 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.
5. TC – Tolerable Concentration.
6. UR – Unit Risk.
7. ND – Not Detected, value is below limit of detection.
8. - -/NE – Not tested, no value established or not evaluated.
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19. EPA United States Environmental Protection Agency, Chemical Summary Fact Sheets
20. NOAA National Oceanic and Atmospheric Administration - Cameo Chemicals Web Site
21. World Health Organization - International Agency For Research on Cancer
22. UNEP - United Nations Environment Programme

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

Chemical	Estimate Dosage ppm bw/day	Carcinogenic	Hazard Quotient Calculated	Hazard Quotient Adjusted
Chloromethane	0.1700	Carcinogen	**56.7**	**567**
Benzene	0.0217	Carcinogen	**5.4**	**54**
Ethanol (ethyl alcohol)	0.0097	Carcinogen	- -	- -
Chloroform	0.0180	Possible Carcinogen	**1.8**	**18**
Ethylbenzene	0.0308	Possible Carcinogen	0.3083	**3**
Tetrahydrofuran	0.0024	Possible Carcinogen	0.0027	0.0268
Dichlorodifluoromethane (FREON 12)	0.0013	Non-Carcinogen	- -	- -
Trichlorofluoromethane (FREON 11)	0.4663	Non-Carcinogen	- -	- -
Toluene	0.0272	Non-Carcinogen	0.1234	**1**
o-Xylene	0.0009	Non-Carcinogen	0.0006	0.0057
m-Xylene	0.0026	Non-Carcinogen	0.0017	0.0172
p-Xylene	0.0026	Non-Carcinogen	0.0017	0.0172
Total Xylene	0.0507	Non-Carcinogen	0.0338	0.3378
Hexane	0.0028	Non-Carcinogen	0.0041	0.0407
Carbon Disulfide	0.0051	Non-Carcinogen	0.0510	0.5101
Propene	0.0005	N/E	- -	- -
2-Propanol	0.0018	N/E	- -	- -
2-Propanone	0.0127	N/E	- -	- -
Heptane	0.0005	N/E	- -	- -
Cyclohexane	0.0003	N/E	- -	- -
2,2,4-Trimethylpentane	0.0003	N/E	- -	- -
Methane	0.7856	Asphyxiant	- -	- -

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

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

Chemical	Estimate Dosage ppm bw/day	Carcinogenic	Hazard Quotient Calculated	Hazard Quotient Adjusted
Chloromethane	0.0177	Carcinogen	**5.9**	**59**
Benzene	0.0023	Carcinogen	0.5656	**6**
Ethanol (ethyl alcohol)	0.0010	Carcinogen	- -	- -
Chloroform	0.0019	Possible Carcinogen	0.1875	**2**
Ethylbenzene	0.0032	Possible Carcinogen	0.0321	0.3211
Tetrahydrofuran	0.0003	Possible Carcinogen	0.0027	0.0271
Dichlorodifluoromethane (FREON 12)	0.0003	Non-Carcinogen	- -	- -
Trichlorofluoromethane (FREON 11)	0.1110	Non-Carcinogen	- -	- -
Toluene	0.0065	Non-Carcinogen	0.0294	0.2938
o-Xylene	0.0002	Non-Carcinogen	0.0001	0.0014
m-Xylene	0.0006	Non-Carcinogen	0.0004	0.0041
p-Xylene	0.0006	Non-Carcinogen	0.0004	0.0041
Total Xylene	0.0121	Non-Carcinogen	0.0080	0.0804
Hexane	0.0007	Non-Carcinogen	0.0010	0.0097
Carbon Disulfide	0.0012	Non-Carcinogen	0.0121	0.1215
Propene	0.0001	N/E	- -	- -
2-Propanol	0.0004	N/E	- -	- -
2-Propanone	0.0030	N/E	- -	- -
Heptane	0.0001	N/E	- -	- -
Cyclohexane	0.0001	N/E	- -	- -
2,2,4-Trimethylpentane	0.0001	N/E	- -	- -
Methane	0.1870	Asphyxiant	- -	- -

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

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

Chemical	Estimate Dosage	Carcinogenic	Hazard Quotient	
	ppm bw/day		Calculated	Adjusted
Chloromethane	0.0177	Carcinogen	**5.9**	**59**
Benzene	0.0023	Carcinogen	0.5656	**6**
Ethanol (ethyl alcohol)	0.0010	Carcinogen	- -	- -
Chloroform	0.0019	Possible Carcinogen	0.1875	**2**
Ethylbenzene	0.0032	Possible Carcinogen	0.0321	0.3211
Tetrahydrofuran	0.0003	Possible Carcinogen	0.0027	0.0271
Dichlorodifluoromethane (FREON 12)	0.0003	Non-Carcinogen	- -	- -
Trichlorofluoromethane (FREON 11)	0.1110	Non-Carcinogen	- -	- -
Toluene	0.0065	Non-Carcinogen	0.0294	0.2938
o-Xylene	0.0002	Non-Carcinogen	0.0001	0.0014
m-Xylene	0.0006	Non-Carcinogen	0.0004	0.0041
p-Xylene	0.0006	Non-Carcinogen	0.0004	0.0041
Total Xylene	0.0121	Non-Carcinogen	0.0080	0.0804
Hexane	0.0007	Non-Carcinogen	0.0010	0.0097
Carbon Disulfide	0.0012	Non-Carcinogen	0.0121	0.1215
Propene	0.0001	N/E	- -	- -
2-Propanol	0.0004	N/E	- -	- -
2-Propanone	0.0030	N/E	- -	- -
Heptane	0.0001	N/E	- -	- -
Cyclohexane	0.0001	N/E	- -	- -
2,2,4-Trimethylpentane	0.0001	N/E	- -	- -
Methane	0.1870	Asphyxiant	- -	- -

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

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

Chemical	Estimate Dosage	Carcinogenic	Hazard Quotient	
	ppm bw/day		Calculated	Adjusted
Chloromethane	0.0177	Carcinogen	**5.9**	**59**
Benzene	0.0023	Carcinogen	0.5656	**6**
Ethanol (ethyl alcohol)	0.0010	Carcinogen	- -	- -
Chloroform	0.0019	Possible Carcinogen	0.1875	**2**
Ethylbenzene	0.0032	Possible Carcinogen	0.0321	0.3211
Tetrahydrofuran	0.0003	Possible Carcinogen	0.0027	0.0271
Dichlorodifluoromethane (FREON 12)	0.0003	Non-Carcinogen	- -	- -
Trichlorofluoromethane (FREON 11)	0.1110	Non-Carcinogen	- -	- -
Toluene	0.0065	Non-Carcinogen	0.0294	0.2938
o-Xylene	0.0002	Non-Carcinogen	0.0001	0.0014
m-Xylene	0.0006	Non-Carcinogen	0.0004	0.0041
p-Xylene	0.0006	Non-Carcinogen	0.0004	0.0041
Total Xylene	0.0121	Non-Carcinogen	0.0080	0.0804
Hexane	0.0007	Non-Carcinogen	0.0010	0.0097
Carbon Disulfide	0.0012	Non-Carcinogen	0.0121	0.1215
Propene	0.0001	N/E	- -	- -
2-Propanol	0.0004	N/E	- -	- -
2-Propanone	0.0030	N/E	- -	- -
Heptane	0.0001	N/E	- -	- -
Cyclohexane	0.0001	N/E	- -	- -
2,2,4-Trimethylpentane	0.0001	N/E	- -	- -
Methane	0.1870	Asphyxiant	- -	- -

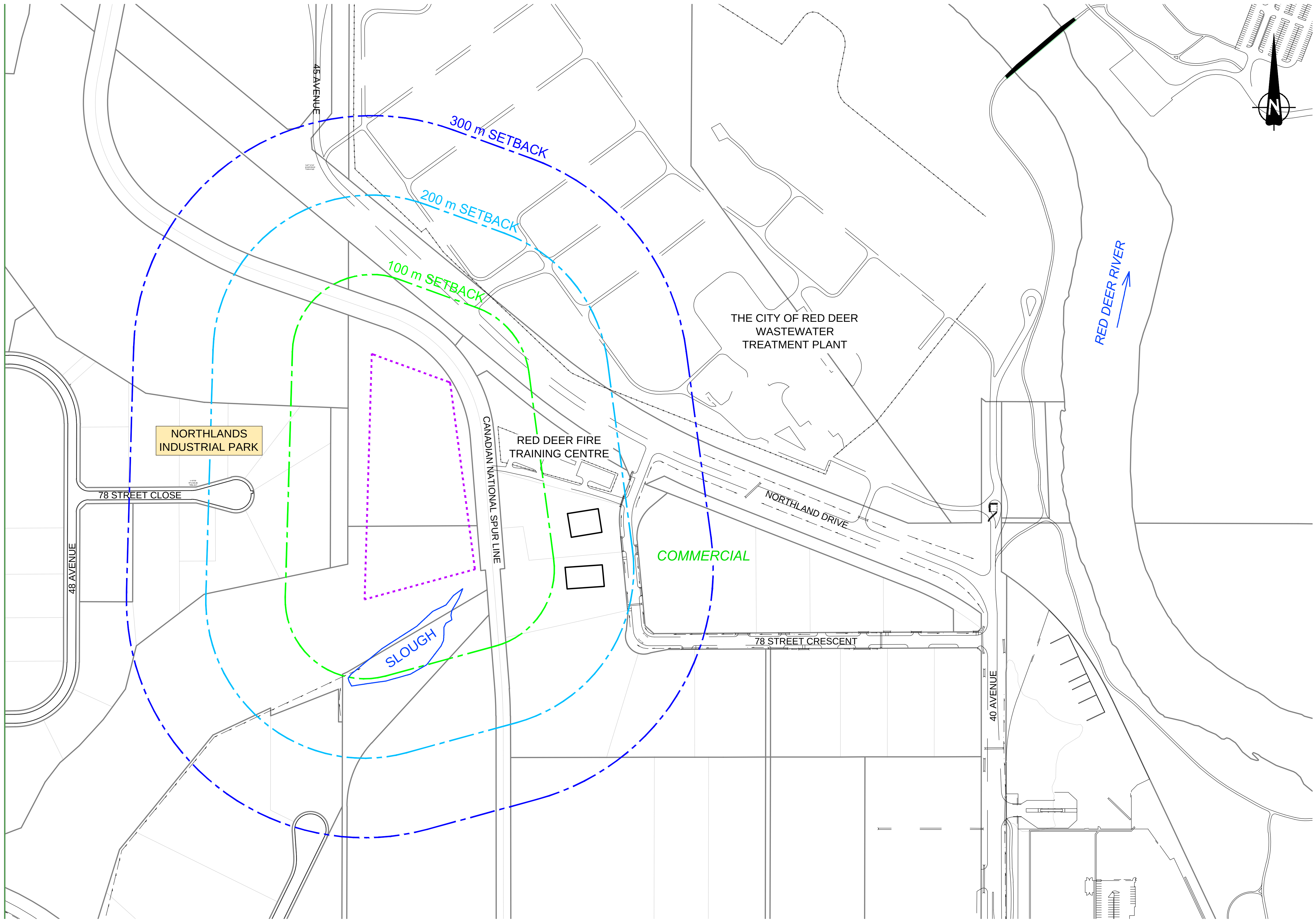
Notes:
1) HQ values are calculated solely on Health Canada exposure parameters published in the PQRA, ver 2.0 September 2010.
2) Landfill soil gas is the gaseous constituents present in the pores between soil particles.
Once the soil gas enters into a structure, the soil gas is referred to as soil vapour.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

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

Chemical	Estimate Dosage ppm bw/day	Carcinogenic	Hazard Quotient Calculated	Hazard Quotient Adjusted
Chloromethane	0.1717	Carcinogen	**5.7**	**57**
Benzene	0.0219	Carcinogen	0.5504	**6**
Ethanol (ethyl alcohol)	0.0097	Carcinogen	- -	- -
Chloroform	0.0182	Possible Carcinogen	0.1825	**2**
Ethylbenzene	0.0311	Possible Carcinogen	0.0313	0.3125
Tetrahydrofuran	0.0024	Possible Carcinogen	0.0003	0.0027
Dichlorodifluoromethane (FREON 12)	0.0053	Non-Carcinogen	- -	- -
Trichlorofluoromethane (FREON 11)	1.9859	Non-Carcinogen	- -	- -
Toluene	0.1156	Non-Carcinogen	0.0286	0.2859
o-Xylene	0.0036	Non-Carcinogen	0.0001	0.0013
m-Xylene	0.0110	Non-Carcinogen	0.0004	0.0040
p-Xylene	0.0110	Non-Carcinogen	0.0004	0.0040
Total Xylene	0.2158	Non-Carcinogen	0.0078	0.0783
Hexane	0.0121	Non-Carcinogen	0.0009	0.0094
Carbon Disulfide	0.0217	Non-Carcinogen	0.0118	0.1182
Propene	0.0022	N/E	- -	- -
2-Propanol	0.0079	N/E	- -	- -
2-Propanone	0.0542	N/E	- -	- -
Heptane	0.0001	N/E	- -	- -
Cyclohexane	0.0001	N/E	- -	- -
2,2,4-Trimethylpentane	0.0001	N/E	- -	- -
Methane	0.1820	Asphyxiant	- -	- -

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

FIGURES



0 50 100 200m

Scale 1:5000

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
HISTORIC WASTE DISPOSAL SITE
RIVERSIDE HEAVY DRY WASTE

TITLE: SITE PLAN SHOWING SURROUNDING LAND USE

Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
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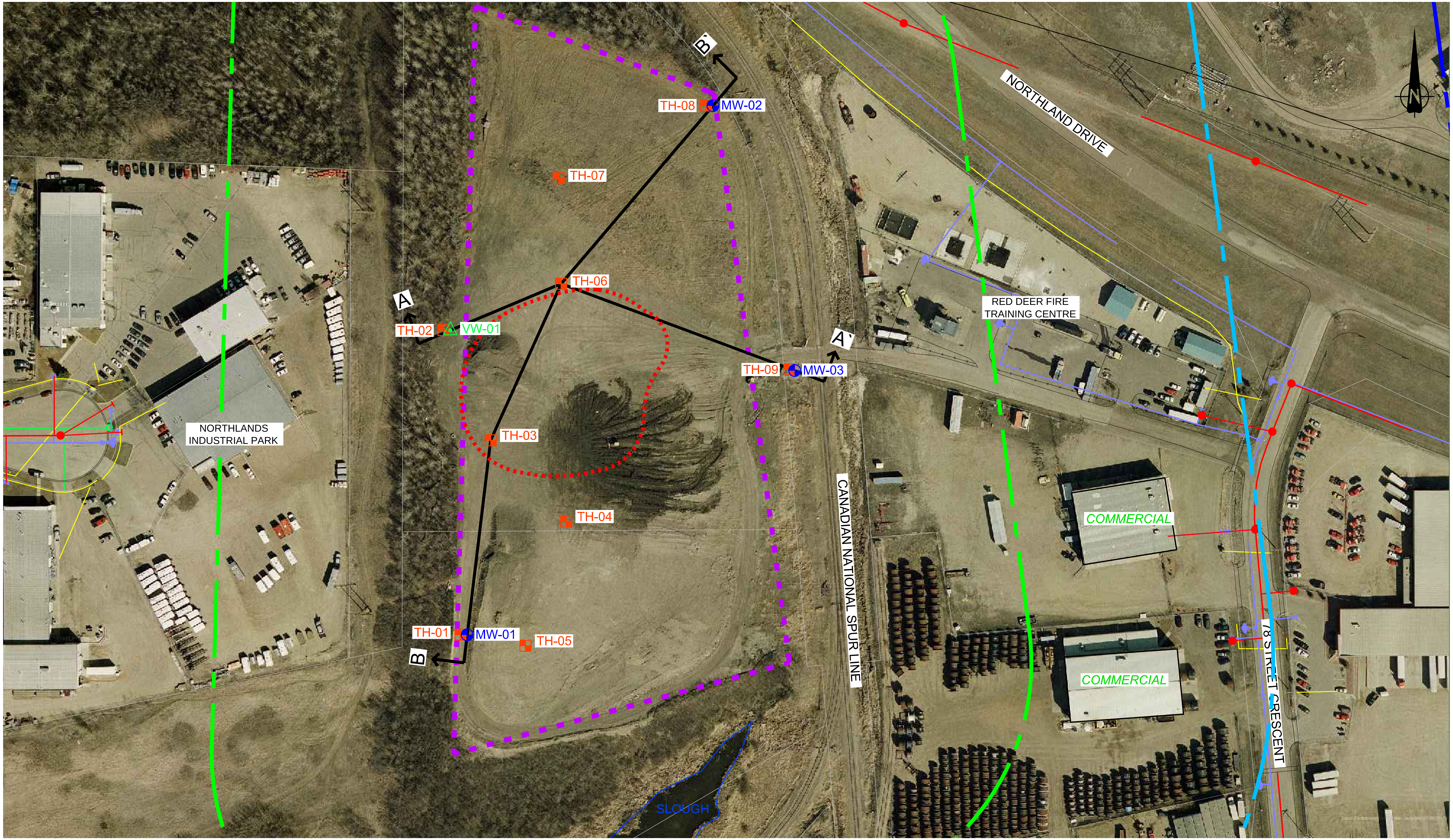
DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: ERMP v1.00.dwg	



SOURCE
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0 20 40 80m
Scale 1:1500

PHASE II TEST LOCATIONS
MW-## GROUNDWATER MONITORING WELL (3)
TH-## TESTHOLE (9)
VW-## SOIL VAPOUR MONITORING WELL (2)

LEGEND
HISTORIC WASTE DISPOSAL
MUNICIPAL SANITARY WASTE AREA
LOT BOUNDARY
CROSS SECTION LOCATION

ELECTRICAL
SANITARY
STORM
WATER

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.

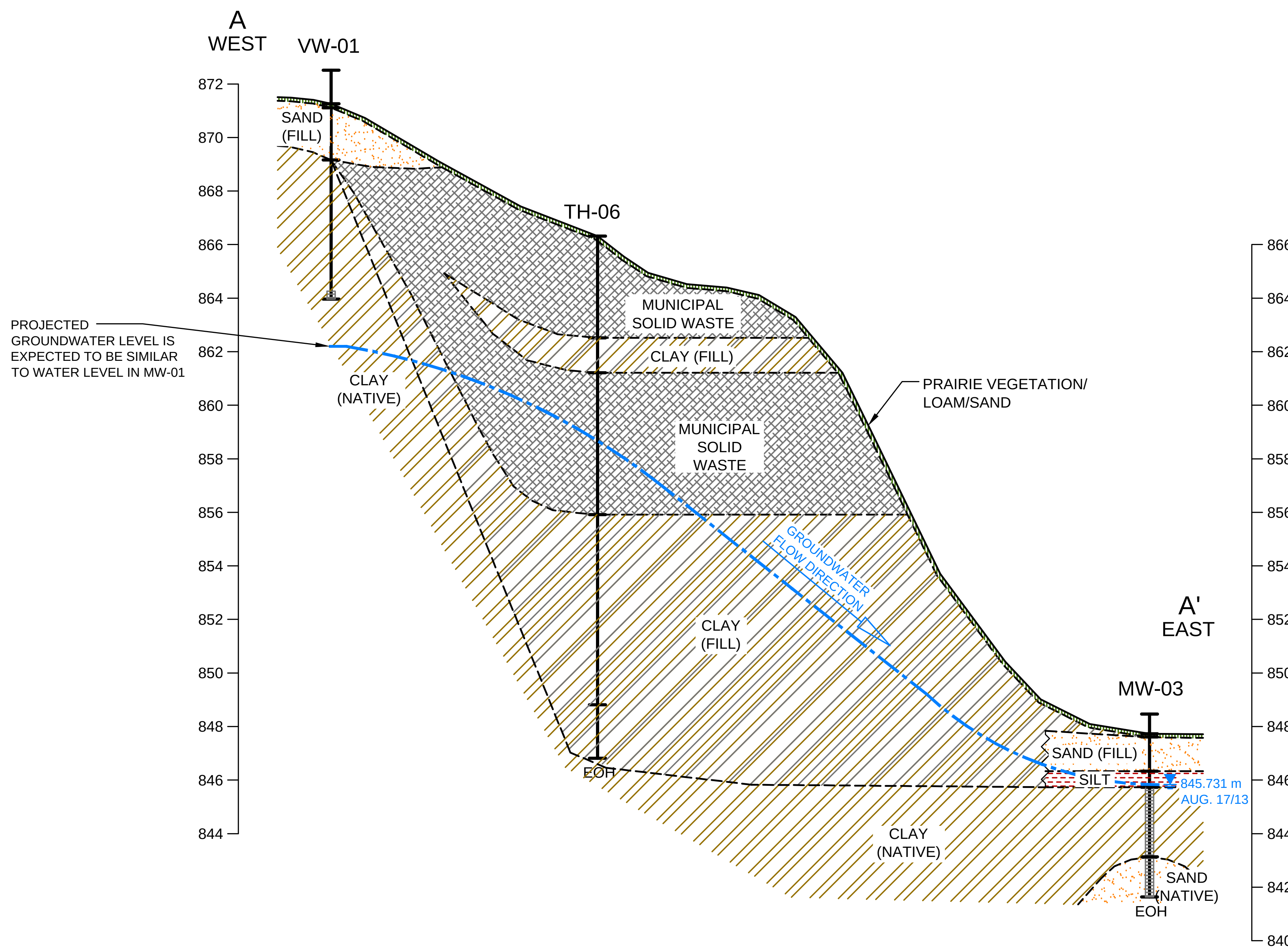
CLIENT: THE CITY OF RED DEER

PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN
HISTORIC WASTE DISPOSAL SITE
RIVERSIDE HEAVY DRY WASTE

TITLE: SITE PLAN SHOWING INTERPRETED EXTENT OF WASTE

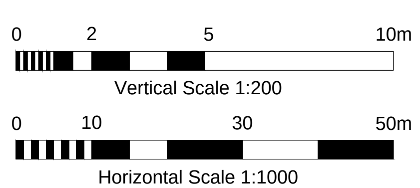
Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
1 : 1500	JUNE 10/14	12-435	FIGURE 2
DRAWN BY: LCH	CHECKED BY: LTM	CAD FILE NO.: ERMP v1.00.dwg	

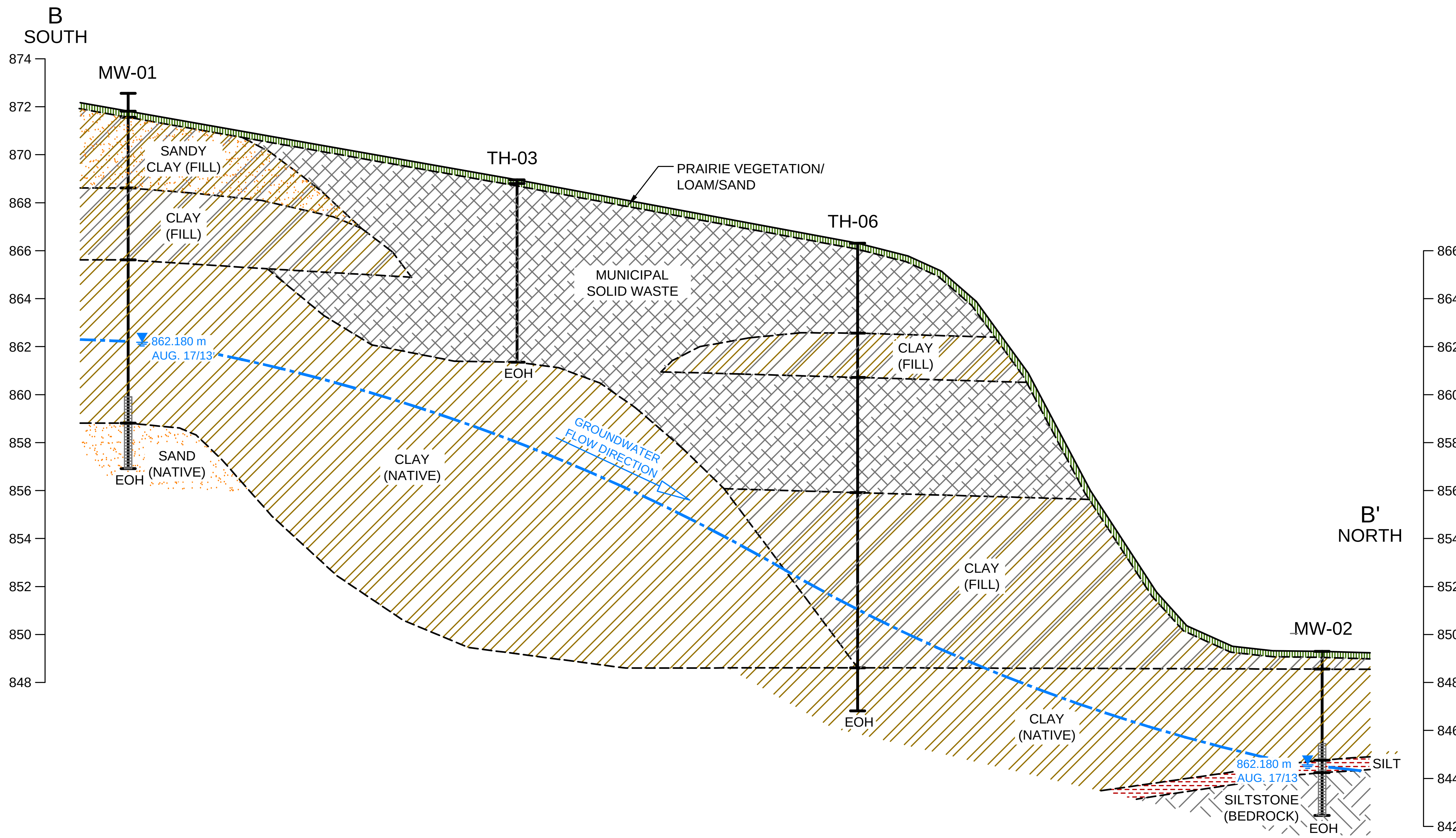


NOTE:

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.



CLIENT: THE CITY OF RED DEER	Tiamat Environmental Consultants Ltd.
PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN HISTORIC WASTE DISPOSAL SITE RIVERSIDE HEAVY DRY WASTE	SCALE: AS SHOWN; DATE: June 10/14; PROJECT NO.: 12-435; FIGURE NO.: FIGURE 3A
TITLE: CROSS SECTION A - A`	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 10 30 50m

Horizontal Scale 1:1000

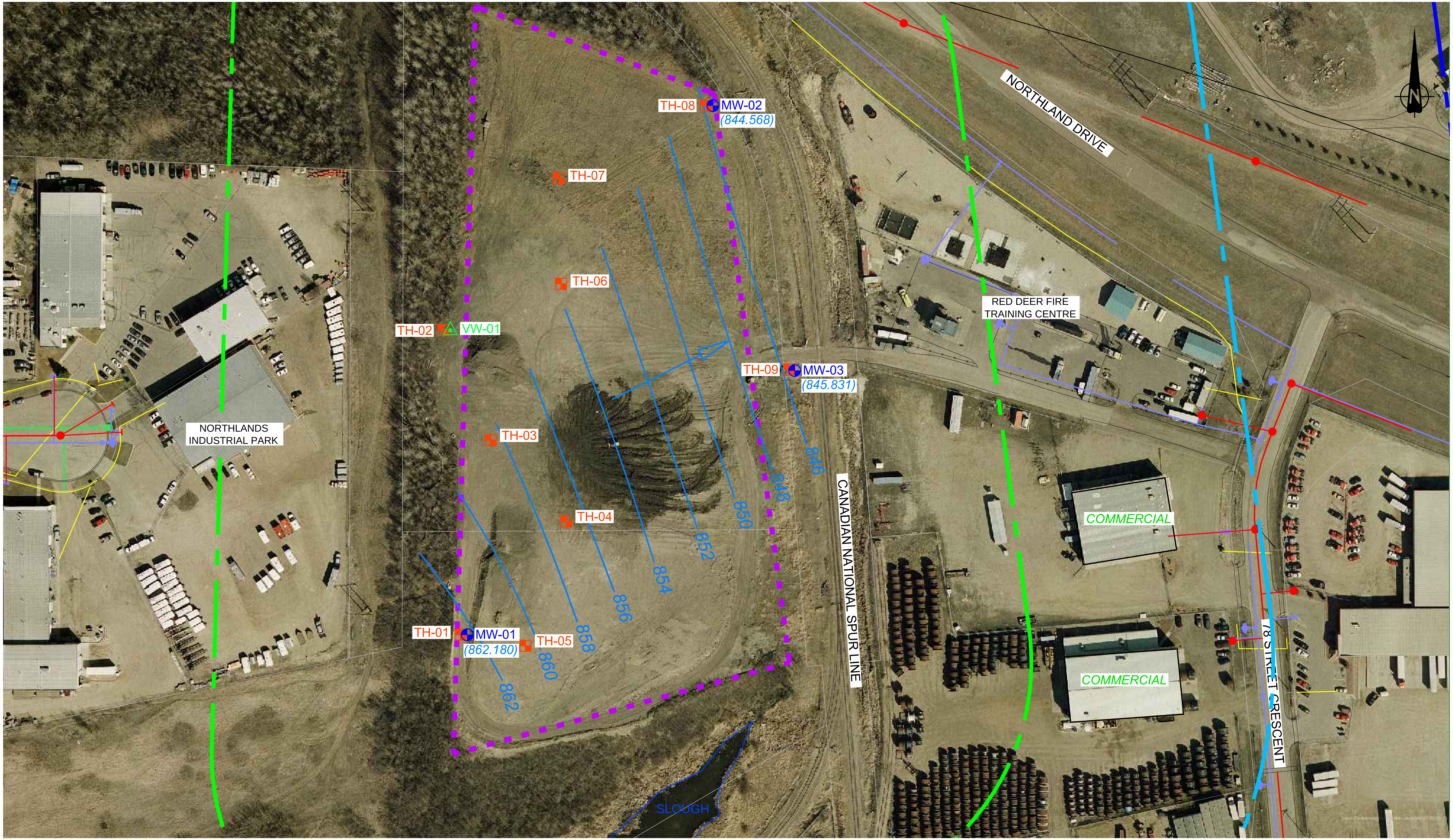
CLIENT: THE CITY OF RED DEER

PROJECT: ENVIRONMENTAL RISK MANAGEMENT PLAN
HISTORIC WASTE DISPOSAL SITE
RIVERSIDE HEAVY DRY WASTE

TITLE: CROSS SECTION B - B`

Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
AS SHOWN	June 10/14	12-435	FIGURE 3B
DRAWN BY:	CHECKED BY:	CAD FILE NO.:	
LCH	LTM	ERMP Sections v1.00	



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0 20 40 80m
Scale 1:1500

GROUNDWATER DATA
(850.150) GROUNDWATER ELEVATION (m) AUGUST 1, 2013
INTERPRETED GROUNDWATER CONTOUR (m)
INTERPRETED GROUNDWATER FLOW DIRECTION

PHASE II TEST LOCATIONS
MW-## GROUNDWATER MONITORING WELL (3)
TH-## TESTHOLE (9)
VW-## SOIL VAPOUR MONITORING WELL (2)

LEGEND
HISTORIC WASTE DISPOSAL
LOT BOUNDARY

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

CLIENT:	THE CITY OF RED DEER
PROJECT:	ENVIRONMENTAL RISK MANAGEMENT PLAN HISTORIC WASTE DISPOSAL SITE RIVERSIDE HEAVY DRY WASTE
TITLE:	INTERPRETED GROUNDWATER ELEVATIONS AUGUST 17, 2013

Tiamat Environmental Consultants Ltd.

SCALE:	DATE:	PROJECT NO.:	FIGURE NO.:
1 : 1500	JUNE 10/14	12–435	FIGURE 4
DRAWN BY:	CHECKED BY:	CAD FILE NO.:	
LCH	LTM	ERMP v1.00.dwg	

APPENDIX A

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

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

INFORMATION REQUIREMENT

May 2013

Introduction

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

Considerations for consent

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

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

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

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

Consent after development

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

Information Requirements:

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

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

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

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

INFORMATION REQUIREMENT

May 2013

Consent is not provided for developments that have already occurred.

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

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

Information Requirements cont.:

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

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

APPENDIX B

GLOSSARY

Glossary

Physical and Toxicological Terms

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

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

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

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.

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,

GLOSSARY
continued

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) is the maximum concentration of a substance that can be ingested daily over a lifetime without risk. It is expressed based in body weight.

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

Abstract for Identified Chemicals of Concern

Benzene
Chemical Formula: C_6H_6
Human Carcinogenicity: Known Carcinogen

Benzene is a well-known petroleum hydrocarbon and is a known carcinogen, 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.

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Carbon Disulfide
Chemical Formula: CS_2
Human 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.

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
Human 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}
Human 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.

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Dichlorodifluoromethane
Chemical Formula: CCL_2F_2
Human 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.

Ethanol
Chemical Formula: C_2H_6O
Human Carcinogenicity: Known Carcinogen

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

Ethylbenzene
Chemical Formula: $C_6H_5CH_2CH_3$
Human 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.

Heptane
Chemical Formula: C_7H_{16}
Human 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}
Human 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

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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.

Methane
Chemical Formula: CH_3
Human Carcinogenicity: Non-Carcinogenic

Methane is a common component of landfill gas. Methane vapour is colourless, odourless and classified as a non-toxic asphyxiant. 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. It is highly combustible with a lower explosive limit of 50,000 ppm in air (5% by volume).

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
Human 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.

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Tetrahydrofuran
Chemical Formula: C_4H_8O
Human 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: $C_5H_5CH_3$
Human 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.

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.

2,2,4-Trimethylpentane
Chemical Formula: C_8H_{18}
Human 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.

Xylenes
Chemical Formula: C_8H_{10}
Human 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.