Supporting Document 3-3

Geology and Hydrogeology Effects Assessment Report

Eastern Ontario Waste Handling Facility Future Development Environmental Assessment

GFL Environmental Inc.

Moose Creek, Ontario

October 7, 2022

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Executive Summary

Terrapex Environmental Ltd. (Terrapex) was contracted by GFL Environmental Inc. (GFL) to conduct an assessment of the effects of the future development of the Eastern Ontario Waste Handling Facility (EOWHF) on Geology and Hydrogeology as part of the EOWHF Future Development Environmental Assessment (EA). Groundwater quality and groundwater quantity were evaluated.

The EA is being carried out in accordance with the requirements of the Environmental Assessment Act (EAA) and Terms of Reference (ToR), which was approved by the Ministry of Environment, Conservation and Parks (MECP) on January 14, 2021.

The purpose of the proposed undertaking is to provide approximately 15.1 million cubic metres (m^3) of additional landfill disposal capacity at the existing EOWHF over a 20-year planning period, with operations anticipated to begin in 2025 and closure anticipated in 2045. The undertaking will enable GFL to continue to provide disposal services for residual non-hazardous solid waste to their customers once the landfill reaches its currently approved disposal capacity and continue to provide economic support to the local community over the long term. No changes to the approved fill rates or site access routes are proposed.

Two alternative methods for carrying out the undertaking were identified in the approved ToR and are developed to a preliminary conceptual design level in the Conceptual Design Report (CDR). Both alternative methods provide a landfill volume of approximately 15.1 million m^3 based on the approved fill rate of 755,000 tonnes per year over a 20-year planning period. Studies completed for the EOWHF have indicated that, based on the underlying soils, the design alternatives are limited to varying lateral configurations with a consistent height. Both alternative methods will continue to use established operating procedures currently in place at the EOWHF and would maximize the use of existing site infrastructure.

Alternative Method 1 consists of implementing the future development through five stages: one stage adjacent to and north of the existing landfill; and four stages oriented east-west within the future development lands located east of the existing EOWHF. Alternative Method 2 consists of implementing the future development through four stages: one stage adjacent to and north of the existing landfill; and three stages oriented north-south within the future development lands located east of the existing EOWHF.

The purpose of this Effects Assessment Report is to present the potential environmental effects of Alternative Method 1 and Alternative Method 2 on Groundwater Quality and Groundwater Quantity, a comparison of the net effects of Alternative Method 1 and Alternative Method 2, the selection of a preferred alternative, an assessment of the environmental effects of the preferred alternative, commitments and monitoring, and approvals.

Predicted effects to groundwater quality at property boundaries and off-site were evaluated, and predicted groundwater flow characteristics were evaluated for groundwater quantity. Evaluation of Alternative Method 1 and Alternative Method 2 indicated that groundwater quality will be below the maximum allowable concentration pursuant to Ontario Regulation 232/98 (*Landfilling Sites*) at the property boundary for both Alternative Method 1 and Alternative Method 2, and that there is no effect anticipated to groundwater quantity. Both Alternative Method 1 and Alternative Method 2 are equally acceptable from groundwater quality and groundwater quantity perspectives.

To confirm that the effects assessment of groundwater quality and quantity related to Geology and Hydrogeology are realized over the long term, monitoring is proposed for construction, operations and maintenance of the EOWHF landfill. Monitoring for compliance will be undertaken to confirm that the project complies with the maximum allowable concentration as identified. Groundwater monitoring wells located east of the existing EOWHF will be sampled triennially (i.e., three times per year in May, August and November) in conjunction with the existing EOWHF monitoring well network. The analytical schedule for all monitoring wells will follow the existing commitments for the EOWHF outlined in the Ministry of Environment, Conservation and Parks' Environmental Compliance Approval (ECA) No. A420018 for the existing EOWHF.

Acronyms, Units and Glossary

Acronyms

Acronym	Definition
amsl	Above Mean Sea Level.
CDR	Conceptual Design Report.
DOC	Dissolved Organic Carbon.
EAA	Environmental Assessment Act.
EOWHF	Eastern Ontario Waste Handling Facility.
GFL	GFL Environmental Inc.
HDR	HDR Corporation.
ICI Waste	Industrial/Commercial/Institutional Waste
LCS	Leachate Collection System.
MECP	Ministry of Environment, Conservation and Parks.
MSW	Municipal Solid Waste
PWQMN	Provincial Water Quality Monitoring Network.
TDS	Total Dissolved Solids.
ToR	Terms of Reference.

Units

Unit	Definition
Cb	Background concentration of the contaminant .
Cm	Maximum allowable concentration for the contaminant (per Ontario Regulation 232/98) .
c_o	Initial source concentration at the start time.
Cr	Health related drinking water objective for the contaminant or the aesthetic drinking water objective for the contaminant, whichever is applicable.
c_r	Rate of increase in concentration with time due to the addition of mass to the landfill.
Darcy velocity	Average velocity of groundwater.
H_b	Thickness of the base aquifer.
H_r	Reference height of leachate.
km	kilometre
L	litre
m	metre
m^3	metres cubed
m/s	metres per second
m/yr	metres per year
m amsl	metres above mean sea level

Units

Unit	Definition
masl	metres above sea level
mbg	metres below grade
Mg	Tonne
mg/L	milligrams per Litre
Mg/yr	Tonnes per year
n_b	Porosity of the base aquifer.
q_c	Volume of leachate collected per unit area of landfill per unit time.
v_b	Darcy velocity of the base aquifer at the down-gradient edge of the landfill.

Glossary

Term	Definition
Aggregate	Coarse- to medium-grained soil particles.
Approval	Permission granted by an authorized individual or organization for an undertaking to proceed. This may be in the form of program approval, certificate of approval or provisional certificate of approval.
Aquifer	A body of permeable soil or rock which can contain or transmit groundwater.
Berm	A mound of earth, typically at the bottom of a slope.
Capacity (Disposal Volume)	The total volume of air space available for disposal of waste at a landfill site for a particular design (typically in m^3); includes both waste and daily cover materials but excludes the final cover.
Compliance Boundary	The property boundary, which is the point at which the maximum allowable concentration for the contaminant (Cm) must be achieved.
Contaminating Lifespan	The period of time during which contaminants are generated from the waste mass.
Environment	As defined by the Environmental Assessment Act, environment means: • air, land or water; • plant and animal life, including human life; • the social, economic and cultural conditions that influence the life of humans or a community; • any building, structure, machine or other device or thing made by humans; • any solid, liquid, gas, odour, heat, sound, vibration or radiation resulting directly or indirectly from human activities; or • any part or combination of the foregoing and the interrelationships between any two or more of them (ecosystem approach).
Environmental Assessment	A systematic planning process that is conducted in accordance with applicable laws or regulations aimed at assessing the effects of a proposed undertaking on the environment.
Evaluation criteria	Evaluation criteria are considerations or factors taken into account in assessing the advantages and disadvantages of various alternatives being considered.
Groundwater	Water that exists underground in saturated zones beneath the land surface.
Hydraulic Gradient	The difference in piezometric head over distance.
Indicators	Indicators are specific characteristics of the evaluation criteria that can be measured or determined in some way, as opposed to the actual criteria, which are fairly general.

Glossary

Term	Definition
Kriging	A statistical method of interpolation between data points (Gaussian process regression).
Landfill site	An approved engineered site/facility used for the final disposal of waste. Landfills are waste disposal sites where waste is spread in layers, compacted to the smallest practical volume, and typically covered by soil.
Leachate	Liquid that drains from solid waste in a landfill and which contains dissolved, suspended and/or microbial contaminants from the breakdown of this waste.
Mitigation	Measures taken to reduce adverse impacts on the environment.
Monitoring Well	A well installed for the purpose of observing groundwater levels.
Piezometric Head	The groundwater level; a measure of pressure within an aquifer.
Proponent	A person who: • carries out or proposes to carry out an undertaking; or • is the owner or person having charge, management or control of an undertaking.
Receptor	The person, plant or wildlife species that may be affected due to exposure to a contaminant.
Service Life	The period of time during which a properly maintained engineered facility will function in accordance with the performance specifications for its design.
Stormwater	Surface water resulting from heavy falls of rain or snow.
Stratigraphy	Descriptor of layers of soil and rock.
Terms of Reference	A terms of reference is a document that sets out detailed requirements for the preparation of an Environmental Assessment.
Undertaking	Is defined in the Environmental Assessment Act as follows: • An enterprise or activity or a proposal, plan or program in respect of an enterprise or activity by or on behalf of Her Majesty in right of Ontario, by a public body or public bodies or by a municipality or municipalities; • A major commercial or business enterprise or activity or a proposal, plan or program in respect of a major commercial or business enterprise or activity of a person or persons other than a person or persons referred to in clause (1) that is designated by the regulations; or • An enterprise or activity or a proposal, plan or program in respect of an enterprise or activity of a person or persons, other than a person or persons referred to in clause (a), if an agreement is entered into under section 3.0.1 in respect of the enterprise, activity, proposal, plan or program ("enterprise").
Waste	Refuse from places of human or animal habitation; unwanted materials left over from a manufacturing process.

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1 Introduction

Terrapex Environmental Ltd. (Terrapex) was contracted by GFL Environmental Inc. (GFL) to conduct an assessment of the effects of the future development of the Eastern Ontario Waste Handling Facility (EOWHF) on Geology and Hydrogeology as part of the EOWHF Future Development Environmental Assessment (EA).

The EA is being carried out in accordance with the requirements of the *Environmental Assessment Act* (EAA) and Terms of Reference (ToR), which was approved by the Ministry of Environment, Conservation and Parks (MECP) on January 14, 2021.

The environment was divided into environmental aspects, components and evaluation criteria as listed in **Table 1-1**. Existing conditions reports and effects assessment reports have been prepared to address the environmental components.

Table 1-1. Environmental Aspects, Components and Evaluation Criteria

Environmental Aspect	Environmental Component	Evaluation Criteria
Natural Environment	Atmospheric Environment	• Air Quality • Noise • Odour
	Geology and Hydrogeology	• Groundwater Quality • Groundwater Quantity
	Surface Water Environment	• Surface Water Quality • Surface Water Quantity
	Ecological Environment	• Terrestrial Ecosystems • Aquatic Ecosystems
Socio-Economic Environment	Economic	• Economic Effects on / Benefits to Local Community
	Social	• Effects on Local Community • Visual Impact of Facility
Cultural Environment	Cultural Environment	• Cultural Heritage Resources • Archaeological Resources
Built Environment	Transportation	• Effects from Truck Transportation along Access Roads
	Current and Planned Future Land Use	• Effects on Current and Planned Future Land Uses
	Aggregate Extraction and Agricultural	• Aggregate Resources • Effects on Agricultural Land

This Groundwater Quality and Groundwater Quantity Effects Assessment Report assesses the effects of the EOWHF Future Development Project on the Geology and Hydrogeology component of the Natural Environment.

The purpose of the proposed undertaking is to provide approximately 15.1 million cubic metres (m^3) of additional landfill disposal capacity at the existing EOWHF over a 20-year planning period, with operations anticipated to begin in 2025 and closure anticipated in

2045. The undertaking will enable GFL to continue to provide disposal services for residual non-hazardous solid waste to their customers once the landfill reaches its currently approved disposal capacity and continue to provide economic support to the local community over the long term. No changes to the approved fill rates or site access routes are proposed.

Two alternative methods for carrying out the undertaking were identified in the approved ToR and are developed to a preliminary conceptual design level in the Conceptual Design Report (CDR). Both alternative methods provide a landfill volume of approximately 15.1 million m^3 based on the approved fill rate of 755,000 tonnes per year over a 20-year planning period. Studies completed for the EOWHF have indicated that, based on the underlying soils, the design alternatives are limited to varying lateral configurations with a consistent height. Both alternative methods will continue to use established operating procedures currently in place at the EOWHF and would maximize the use of existing site infrastructure.

Alternative Method 1 (**Figure 1-1**) consists of implementing the future development through five stages: one stage adjacent to and north of the existing landfill (Stage 5[1]); and four stages oriented east-west within the future development lands (Stages 6 through 9). Stages 6 through 8 will be identical in size, while Stages 5 and 9 will be smaller. A stormwater management system will be constructed consisting of conveyance ditches around the perimeter of each stage and a retention pond located northwest of Stage 8. The existing pond located northeast of Stage 5 will be modified to attenuate peak flows if required.

Alternative Method 2 (**Figure 1-2**) consists of implementing the future development through four stages: one stage adjacent to and north of the existing landfill (Stage 5); and three stages oriented north-south within the future development lands (Stages 6 through 8). Stages 6 and 7 will be identical in size, while Stages 5 and 8 will be smaller. A stormwater management system will be constructed consisting of conveyance ditches around the perimeter of each stage and a retention pond located north of Stages 6 and 7. The existing pond located northeast of Stage 5 will be modified to attenuate peak flows if required.

For both alternative methods, the design of the stages will be consistent with the existing landfill design. Visual screening will be constructed along the north and east perimeters and a portion of the south perimeter consisting of earthen berms and/or vegetation plantings. A new road entrance will be constructed from Laflèche Road, which will include a new scale facility.

The purpose of this Effects Assessment Report is to present the potential environmental effects of the Alternative Method 1 and Alternative Method 2 on Groundwater Quality and Groundwater Quantity, a comparison of the net effects of Alternative Method 1 and Alternative Method 2, the selection of a preferred alternative, an assessment of the environmental effects of the preferred alternative, commitments and monitoring, and approvals. The results from this study will be documented in an EA Study Report in accordance with the approved ToR, which will be submitted to the MECP for review.

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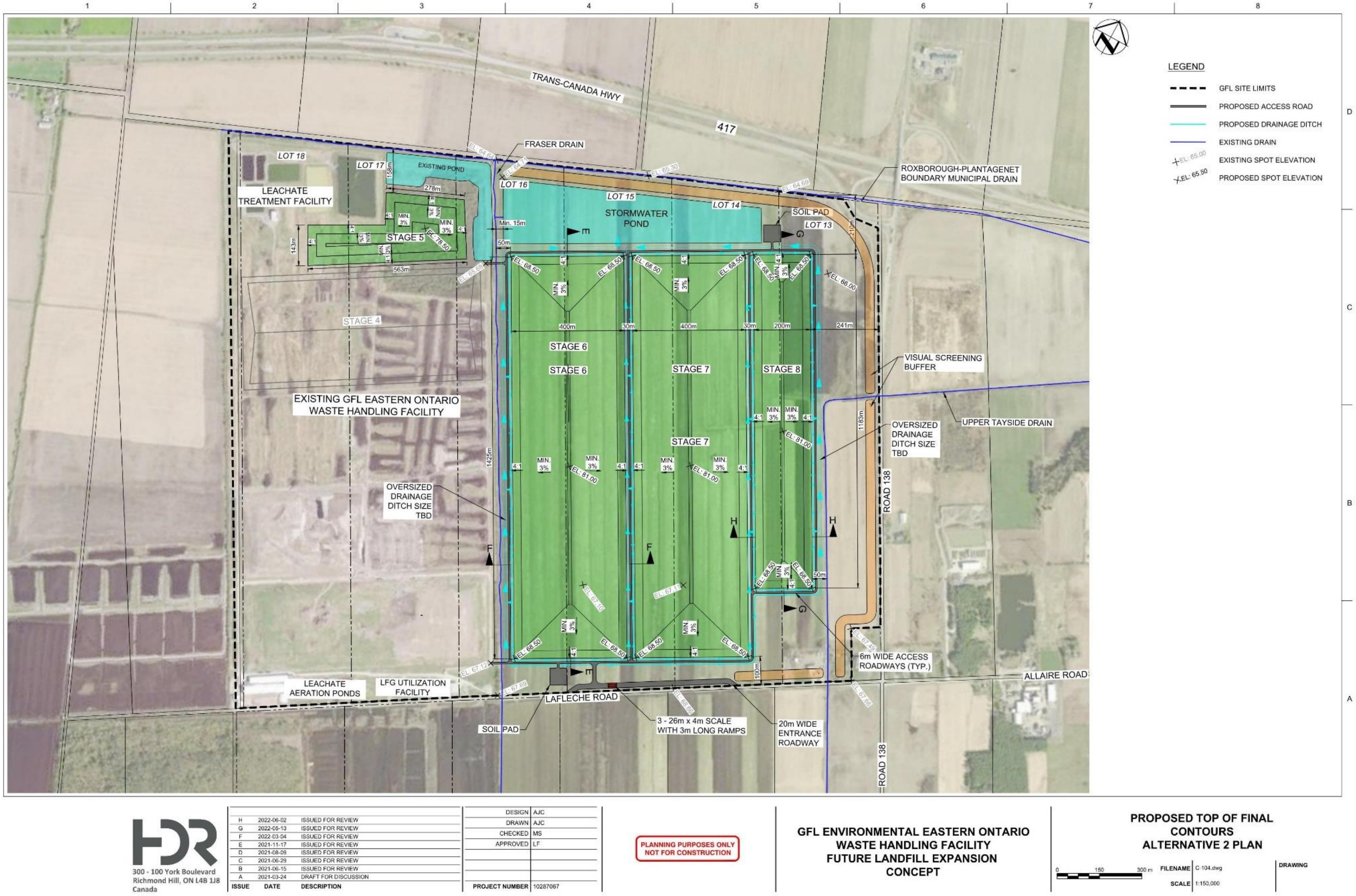
[1] The current EOWHF comprises Stages 1 through 4.

Figure 1-1. Alternative Method 1

Figure 1-2. Alternative Method 2



2 Effects Assessment Methods

Using the evaluation criteria, indicators, rationale and data sources from the approved ToR and the existing conditions from the Geology and Hydrogeology Existing Conditions Report, the effects assessment is carried out as follows:

- predict the potential environmental effects for Alternative Method 1 and Alternative Method 2 (Section 3);
- identify the preferred alternative based on a comparative evaluation of the potential environmental effects of each alternative method (Section 4); and
- conduct an effects assessment on the preferred alternative, including the identification of mitigation measures and monitoring programs (Sections 4 and 5).

2.1 Predict Potential Environmental Effects for Alternative Methods

The potential environmental effects for Alternative Method 1 and Alternative Method 2 are identified based on the application of the evaluation criteria, indicators and data sources in the approved ToR and based on the maximum allowable waste receipt level for the EOWHF landfill. The potential effects can be positive or negative, direct or indirect, and short- or long-term. Mitigation measures are identified to minimize or mitigate the potential effects and then the net effects are evaluated taking into consideration the application of mitigation measures.

2.1.1 Study Areas

The existing EOWHF is located within the Township of North Stormont, approximately 5 km north-northwest of the village of Moose Creek, Ontario, and 5 km east of the village of Casselman, Ontario, on the western half of Lot 16 and Lots 17 and 18, Concession 10, Township of North Stormont, United Counties of Stormont, Dundas and Glengarry, near the intersection of Highway 417 and Highway 138. The municipal street address for the facility is 17125 Laflèche Road, Moose Creek, Ontario. The lands to the east of the existing EOWHF being considered for the future development include the eastern half of Lot 16, Lots 14 and 15, and the majority of Lot 13 of Concession 10. The existing EOWHF encompasses a site area of 189 hectares, while the lands to the east of the existing EOWHF being considered for future development include approximately 240 hectares.

The study areas include the existing site as well as potentially affected surrounding areas. The on-site and off-site study areas identified for the EA in the approved ToR are as follows (**Figure 2-1**):

- On-site Study Area – the existing EOWHF, and the future development area comprising the eastern half of Lot 16, Lots 14 and15, and the majority of Lot 13 of Concession 10 east of the EOWHF; and

- Off-site Study Area – the lands in the vicinity of the future development extending approximately 1 kilometre from the On-site Study Area.

These study areas were used for the purposes of the Geology and Hydrogeology effects assessment.

Figure 2-1. Study Areas for Geology and Hydrogeology

2.1.2 Evaluation Criteria, Indicators and Data Sources

The evaluation criteria, rationale, indicators and data sources used for the Geology and Hydrogeology effects assessment as per the approved ToR are provided in **Table 2-1**.

Table 2-1. Evaluation Criteria, Indicators and Data Sources for Geology and Hydrogeology

Evaluation Criteria	Rationale	Indicators	Data Sources
Natural Environment – Geology and Hydrogeology			
Groundwater Quality	Contaminants associated with waste disposal sites have the potential to enter the groundwater and impact offsite groundwater.	Predicted effects to groundwater quality at property boundaries and off-site	• Hydrogeological and geotechnical studies • Determination of water well users in the area • Annual site monitoring reports • Leachate generation assessment • Provincial Water Quality Monitoring Network (PWQMN) • Proposed facility characteristics • Landfill design and operations data
Groundwater Quantity	Physical works may disrupt natural groundwater flows.	Predicted groundwater flow characteristics	• Hydrogeological and geotechnical studies • Water well records • Determination of water well users in the area • Annual site monitoring reports • Proposed facility characteristics • Landfill design and operations data

2.1.3 Key Design Considerations and Assumptions

The alternative methods of carrying out the undertaking are described in detail in the CDR. Regarding Alternative Method 1 and Alternative Method 2, the key design considerations and assumptions as they relate to Geology and Hydrogeology – Groundwater Quality and Groundwater Quantity are described below.

Summary of Existing Conditions

The EOWHF Area and the lands to the east of the EOWHF being considered for future landfill development are essentially underlain by a substantially thick package of overburden layers that rests upon bedrock. The stratigraphy, as described below was observed at boreholes in the lands east of the EOWHF, in increasing depth from grade. The summarized stratigraphy was consistent across the site, with minor exceptions.

- Topsoil / peat. Comprised of a substantial organic component with wood chips and rootlets. Thickness ranges from 0.3 to 2.1 m, with an average of 1.3 m. The topsoil/peat was absent at two locations. Regional mapping (OGS, 2010) indicates peat, muck and marl.

- Silty clay. Texture is dominantly clay with a minor component that is either silty or with some silt, sometimes with trace sand. In most of the boreholes within the proposed expansion area, this deposit contained a weathered crust at the top, which was stiff to very stiff in consistency with varying thicknesses ranging between 0.2 to 2.0 m. In all the boreholes, below the weathered crust was an unweathered grey silty clay, which was typically firm to very soft in consistency. The depth to this layer's base ranges from 4.7 to 17.8 metres below ground (mbg), with an average depth of 11.8 mbg. The elevation of the base ranges from 48.7 to 62.5 metres above sea level (masl), with an average of 54.8 masl. This layer is interpreted to be the Champlain Sea glaciomarine deposit. The silty clay layer rests upon the till, except at one location along the eastern side where the till is absent. Grain size analysis indicates the following ranges: Gravel = 0 to 2%, average of 0.3%; Sand = 1 to 8%, average of 2.3%; Silt = 11 to 42%, average of 22.5%; clay = 51 to 87%, average of 74.8%.
- Sandy gravel till. Texture is dominantly sandy gravel with some silt ranging to silty sandy gravel. The depth to the layer's base ranges from 4.9 to 23.7 mbg, with an average of 12.0 mbg. The thickness of the layer ranges from 0.6 to 10.6 m, with an average of 2.5 m. The till layer is absent at one location in the east portion of the lands being considered for future landfill development. It is thin (<1.0 m) along the southern and eastern boundaries, with the exception of one location in the east where it thickens to 4.4 m.
- Bedrock. The lithology is dominantly limestone, sometimes with shale interbeds. The top of bedrock occurs at depths ranging from 25.3 mbg, becoming shallow in the southeast corner with a depth of 5.7 mbg. The average depth to bedrock is 14.4 m. The top of bedrock surface elevation is variable, ranging from 44.0 masl, rising to 61.5 masl in the southeast, with an average of 52.2 masl.

The hydrogeological conditions include the water table, hydraulic gradients and hydraulic conductivity.

- Water table. The water table surface elevation declines northward, from approximately 67.0 masl near to Laflèche Road to approximately 64.0 masl near to the intersection of Concession Road 7 / Road 700 and Highway 138. The depth to the water table in the Spring of 2020 ranged from 0.5 to 1.5 mbg. The depth to the water table ranged from 0.7 to 1.8 mbg in the Summer of 2021.
- Gradients. The water table elevations indicate a horizontal hydraulic gradient with shallow groundwater generally moving northward. Similarly, the piezometric elevations in till and in bedrock indicate that a horizontal hydraulic gradient with generally northward movement. The vertical hydraulic gradient is variable between stratigraphic layers, with bedrock monitoring wells generally demonstrating an upward gradient towards the overlying silty clay.
- Hydraulic conductivity. The silty clay layer ranged from 5×10^{-11} to 5.0×10^{-6} m/s, with values generally below 1×10^{-8} m/s. The sandy gravel till layer ranged from 1.5×10^{-7} to 3.3×10^{-6} m/s. The bedrock ranged from 7.3×10^{-6} to 1.4×10^{-5} m/s, where not fractured. In general, the upper bedrock in the area to the east of the EOWHF being proposed for landfill development appears to be approximately 10 times more permeable than the overlying sandy gravel till, which is more permeable than the overlying silty clay, , potentially by factors of 10 to 1,000. The hydraulic conductivity

range for the sandy gravel till overlapped the hydraulic conductivity range for the bedrock, indicating there may be some locations where the sandy gravel till and bedrock exhibit similar hydraulic conductivity values.

There are no municipal piped water supplies in the On-Site Study Area and the Off-Site Study Area. Each property is likely serviced by a private supply well, with the possibility of some relying on bottled water. The presence and distribution of groundwater supply wells was assessed using the following two primary sources of information.

- MECP water well database. This database consists of well information as reported by local drilling contractors and as recorded by MECP staff. It contains information on well construction, stratigraphy and other aspects, in varying detail.
- Aerial photographic analysis. Water supply wells are assumed to be situated near to occupied buildings that are being supplied, such as a residence or a commercial operation.

Using the above information, 28 water wells have been identified within the On-site and Off-site Study Areas.

Groundwater in limestone with shale and in Champlain Sea sediments is noted for often being highly mineralized. The EOWHF, the area to the east of the EOWHF and the Off-Site Study Area are all located within Champlain Sea sediments underlain by limestone, with shale in places. As a result, mineralized background groundwater conditions are expected below the EOWHF and area east of the EOWHF being considered for landfill development (i.e., future development lands). Groundwater quality for these two areas summarized as follows:

- <u>Future development lands</u>: Elevated hardness, dissolved organic carbon (DOC) and total dissolved solids (TDS) are expected as background conditions in bedrock. Elevated TDS in deeper silty clay is independent of landfill impacts. Elevated chloride in bedrock is localized, and likely results from the historic Champlain Sea.
- <u>EOWHF</u>: Elevated alkalinity was observed in shallow and deeper silty clay below the northeastern section of the EOWHF. Elevated hardness in deeper silty clay and shallow clay were present. It was concluded that these do not appear to be related to leachate impacts.
- There are no chloride impacts evident in silty clay/clay below the EOWHF. Elevated chloride in bedrock is localized, and likely results from the historic depositional environment.
- The elevated concentrations of alkalinity, hardness, total dissolved solids, chloride and dissolved organic carbon at the southeastern limit of the EOWHF in bedrock appear unrelated to the EOWHF, as these elevated parameters are not evident in the overlying silty clay or shallow wells. These elevated parameters observed in bedrock are reflective that groundwater in the regional limestone aquifer is sometimes noted as often being highly mineralized, including to a saline condition.

Design Considerations and Assumptions

To evaluate the impacts that the proposed landfill expansion may have on groundwater quality, a non-degrading and non-adsorbing constituent of leachate, chloride, was used to represent worst-case conditions. The initial source concertation and the mass, as a proportion of total (wet) mass of waste, for chloride in leachate upon closure were obtained from Table 1- Leachate Characteristics (Section 10) found in Ontario Regulation 232/98 (O.Reg. 232/98).

The evaluation criteria, the maximum allowable concentration in the underlying aquifer, was determined using the formula provided in Section 10. (3) 2 in O.Reg. 232/98 as follows:

$$Cm = Cb + X (Cr – Cb)$$

where:

Cm is the maximum allowable concentration for the contaminant,

Cb is the background concentration of the contaminant in the groundwater of the receptor aquifer,

Cr is the health related drinking water objective for the contaminant or the aesthetic drinking water objective for the contaminant, whichever is applicable, as set out in Column 5 or 6 of Table 1, and

X is:

(a) 0.25, if Cr is a health related drinking water objective, or
(b) 0.50, if Cr is an aesthetic drinking water objective.

As chloride does not decay or adsorb, a concentration of chloride, modelled at any location underlying the landfill, greater than the maximum allowable concentration, would be considered to eventually reach the compliance boundary (property line) at some future time.

The background concentration of chloride, 104 mg/L, was determined by taking the geometric mean of chloride concentrations measured in bedrock aquifer monitoring wells MW20-2D, MW20-3D, MW20-4D, MW20-5D, MW20-6D, MW20-7D, MW20-8D, and MW20-10D in November 2020 and May, August, and November 2021, generally well distributed over the lands to the east of the EOWHF being considered for future development.

It should be noted that bedrock groundwater monitoring wells MW20-1D, MW20-9D, and MW20-11D, also located within the lands to the east of the EOWHF being considered for future development were not used for evaluating the background chloride concentration or hydraulic gradients, as these wells were screened in limestone with limited fracturing, which differ from observations within fractured limestone throughout the majority of the lands to the east of the EOWHF being considered for future development .

As the aesthetic objective for chloride in groundwater is 250 mg/L, the maximum allowable concentration (Cm) was determined to be:

$$Cm = 104 + 0.5 (250 – 104)$$

$$Cm = 177 \text{ mg/L}.$$

Leachate Source Material

It is assumed that chloride concentrations in leachate will increase linearly until they reach the initial source concentration upon closure outlined in the regulation. However, as each stage of the landfill is anticipated to be opened and closed within 1 to 7 years and given the low permeability of the underlying silty clay, contaminant transport during operational years is anticipated to be negligible in comparison with the contaminating lifespan of the proposed natural containment landfill.

Because chloride concentrations in construction and demolition waste and daily cover soil have significantly lower chloride concentrations that industrial/commercial/industrial waste (ICI waste) and municipal solid waste (MSW), the mass of contaminating waste was considered to exclude construction and demolition waste and daily cover soil in the model. As noted in Appendix B of the CDR, the maximum annual ICI waste and MSW to be landfilled is 579,840 Mg/yr.

Soil Stratigraphy

During operation, the stratigraphy at the Site will consist of a silty clay aquitard of various thickness overlying a sandy gravel till and bedrock aquifer.

The thickness of the existing in situ low permeability silty clay (the hydraulic barrier layer), measured at well distributed discrete points across the Site, was interpolated using a kriging method. Given the Site specific hydrogeological conditions and anticipated hydrogeological conditions, several thicknesses of the silty clay hydraulic barrier were evaluated for conformity.

The physical properties of the silty clay aquitard used for the evaluation included a geometric mean of measured hydraulic conductivities; a previously published porosity value (Todd, D.K., 1980); and a previously published coefficient for hydrodynamic dispersion of chloride through silty clay (Golder Associates Ltd., 1998).

Aquifer Properties

As noted in the existing conditions report, the sandy gravel till would likely function as a confined aquifer, as would the upper few meters of bedrock. For the modeling purposes, the upper 3 m underlying the silty clay aquitard is considered to represent the mixing zone for horizontal contaminant transport in the aquifer.

The physical properties of the aquifer used for the evaluation included a geometric mean of measured hydraulic conductivities and a porosity value for limestone with similar hydraulic conductivity (Todd, D.K., 1980).

Model Processes, Governing Equations, and Boundary Conditions

For unfractured clayey and silty soils, the primary transport mechanism will generally be advection and diffusion, where the flux of mass is obtained by adding each component. For conservative purposes no retardation, sorption, phase change or decay were considered, and mechanical dispersion was considered negligible given low flow velocities through the silty clay (Rowe et al. 2004).

The modelling was based on the one-dimensional contaminant migration equation (for a 1 m wide section along a down-gradient length) interpreted as follows:

$$dc/dt = D\, d^2c/dz^2 - v\, dc/dz$$

where:

- c concentration of contaminant at depth z and time t
- D coefficient of hydrodynamic dispersion (diffusion only in this case) at depth z
- v groundwater seepage velocity at depth z

The top boundary condition was considered a finite mass of waste, in which case the source concentration starts at an initial concentration, increases linearly with time, and then decreases with time as contaminant is transported into the soil and is collected in the leachate collection system. The top boundary condition was given by:

$$c\,(t) = c_o + c_r\, t - 1 / H_r \int f\,(c,\, t)\, dt - q_c / H_r \int f\,(c,\, t) dt$$

where:

- c_o initial source concentration at the start time
- c_r rate of increase in concentration with time due to the addition of mass to the landfill
- $f\,(c, t, z = 0)$ surface flux (mass per unit area time) passing into the soil at the top boundary
- q_c volume of leachate collected per unit area of landfill per unit time
- H_r reference height of leachate.

The bottom boundary condition was considered to be a fixed outflow to represent the base aquifer, where concentration varies with time as mass is transported into the aquifer from the landfill and transported out from beneath the landfill.

Given the conservation of mass across the model:

$$c(t,\, z = H_b) = [\, f(t,\, z = H_b,\, c) / n_b\, H_b - v_b\, c\, (t,\, z = H_b) / n_b\, L]\, dt$$

where:

- $c\,(t, z=H_b)$ concentration in the base aquifer, averaged over the entire thickness of the base
- $f\,(t, z=H_b, c)$ the mass flux into the aquifer
- n_b porosity of the base aquifer
- H_b thickness of the base aquifer
- v_b Darcy velocity of the base aquifer at the down-gradient edge of the landfill
- L length of the landfill

The potential impact of the proposed landfill expansion on the quality of groundwater in the underlying aquifer was evaluated using software developed by Gaea Technologies (Pollute, version 8, 2021), specifically designed for evaluating contaminant impact between engineered systems and hydrogeology. Pollute is a computer program that implements a solution to the one-dimensional dispersion-advection equation for a layered deposit of finite or infinite extent.

Based on a review of existing conditions and the concept design alternatives, the most appropriate model to evaluate the effects of the proposed landfill expansion is the simple clayey aquitard, assuming as follows:

- Uniform geologic layering and groundwater flow throughout the On-Site Study Area. Since spatial variability exists, mass transport was evaluated using various lengths and thicknesses in the direction of groundwater flow, that is along the north-south cross-sections.

- As defined in Ontario Regulation 232/98, the leachate collection system (LCS) is assumed to remain fully functional for a service life of 100 years.
- The base of the landfill (top of the silty clay aquitard) is located at an elevation 64.0 m above mean sea level (m amsl).
- Following closure, the static height of leachate is 1.5 m (65.5 m amsl) above the base of the landfill while the leachate collection system is operational, a value consistent with existing observations made by Tetra Tech elsewhere at the existing EOWHF.
- Following closure, as noted in the CDR, the infiltration rate for each closed stage will be 0.042 m/yr of precipitation. The resulting volume of leachate will be collected continuously.
- Following the passage of the 100 service life of the LCS as defined by Ontario Regulation 232/98, the LCS is deemed to fail. Upon failure of the LCS, leachate mounding will occur. For modelling purposes, the average height of the mounding was anticipated to be 73 m amsl (4 m above the top of the peripheral berm, which is set at approximately 69.0 m amsl). This value is similar to that used in previous EAs conducted at various stages of historical EOWHF landfill development.
- Vertical hydraulic gradients were calculated between the static height of leachate and the bedrock piezometric surface using a reference distance between the middle of the leachate column and the middle of the wetted screened interval (while the LCS was operational these values are effectively zero and transport is driven by diffusion with effectively no seepage of groundwater into the closed stage).
- Although a background concentration of chloride is present in the aquifer, it was not considered in the model to eliminate the upward diffusive gradient from the aquifer and better represent a worst case scenario.
- For Stage 5 (the same in both alternative methods) located immediately down-gradient of the existing landfill, the modeling considered the flow path from the up-gradient end of the existing landfill extending to the down-gradient limit of the proposed Stage 5 cell. The mass of waste per unit area was assumed equivalent to the highest value observed in Alternative Methods 1 and 2, with an underlying silty clay thickness of 10 m (as noted by Golder in 1998). Other boundary conditions were assumed to be as noted above.

The model output provides a concentration profile in depth over time at the down-gradient extent of the model length. It is understood that this occurs up-gradient of the compliance boundary (property line). However, the modelled concentrations entering the aquifer at the down-gradient limit of the model length are conservatively protective as decreases in chloride concentrations beyond this point are not anticipated and that the plug of groundwater would reach the compliance boundary at some future time.

Calculations and Model Inputs and Outputs

Various scenarios were evaluated for the Effects Assessment given the varying conditions across the Site. Calculations and model inputs and outputs are provided in **Table A-1** within Appendix A. Modelled groundwater flow paths over interpreted clay thicknesses and bedrock groundwater piezometric contours are shown in **Figures A-1A and A-1B** and **Figures A-2A and A-2B** within Appendix A, for Alternative Methods 1 and 2, respectively.

Contaminating Lifespan

The contaminating lifespan considered the amount of time, under the given conditions, when the concentration of chloride in leachate at depth 0 m was less than the maximum allowable concentration, and was modelled to be less than or equal to 500 years for either Alternative Method 1 or Alternative Method 2.

2.2 Comparative Evaluation and Identification of the Preferred Alternative

The two alternative methods are comparatively assessed and evaluated using the criteria and indicators to determine the preferred alternative. The differences in the potential environmental effects remaining following the implementation of potential mitigation/management measures (i.e., net effects) are used to identify and compare the advantages and disadvantages of each alternative method.

The net environmental effects are utilized in a comparison of the two alternatives to one another at the criteria and indicator level for each discipline. The following two step methodology was applied in order to carry out the comparative evaluation for Geology and Hydrogeology:

1. Identify the predicted net effect(s) associated with each alternative for each indicator and assign a preference rating (i.e., Preferred, Not Preferred, No Substantial Difference); and
2. Rate each alternative at the criteria level (i.e., Preferred, Not Preferred, No Substantial Difference) based on the identified preference rating for each indicator and provide a rationale.

2.3 Effects Assessment of the Preferred Alternative

An assessment of the environmental effects of the preferred alternative is carried out considering the same criteria, indicators and data sources, taking into account potential mitigation/management measures and cumulative effects. The effects assessment of the preferred alternative will be presented in the EA Study Report.

3 Net Effects Assessment

The results of the net effects assessment for each alternative method are provided in Sections 3.1 and 3.2.

3.1 Alternative Method 1

The net effects assessment for Alternative Method 1 is presented in **Table 3-1**.

Table 3-1. Net Effects Assessment – Alternative Method 1

Evaluation Criteria	Indicator	Key Design Considerations and Assumptions	Potential Effects	Mitigation Measures	Net Effects
Groundwater Quality	Predicted effects to groundwater quality at property boundaries and off-site	REFER TO APPENDIX A, TABLE A-1 FOR DETAILS OF INPUT AND OUTPUT PARAMETERS • leachate collection system (LCS) is assumed to remain fully functional for a service life of 100 years. • Infiltration rate for each closed stage will be 0.042 m/yr of precipitation. The resulting volume of leachate will be collected continuously. Stage 5 • 1,750 m section with 10.0 m of underlying silty clay (analogous to Section Stage 5 on Figures 1A and 1B) Stages 6 through 9 • 1,550 m section with 9.4 m of underlying silty clay (analogous to Section Alt 1-1 on Figures 1A and 1B) • 1,377 m section with 8.5 m of underlying silty clay (analogous to Section Alt 1-2 on Figures 1A and 1B) • 1,310 m section with 6.4 m of underlying silty clay (analogous to Section Alt 1-3 on Figures 1A and 1B) • 504 m section with 5.9 m of underlying silty clay (analogous to Section Alt 1-4 on Figures 1A and 1B)	• Following expiry of the LCS service life, the chloride concentration in leachate would increase to a maximum of 165 mg/L in year 650 (Alt 1-3). • The corresponding maximum concentration in the aquifer is 160 mg/L (Alt 1-3).	• None required	• Chloride concentrations at the property boundaries will be below the maximum allowable concentration (Cm) in the aquifer • Since Cm is met at the property boundaries, there will be no adverse effect to water well users in the Off-Site Study Area

Table 3-1. Net Effects Assessment – Alternative Method 1

Evaluation Criteria	Indicator	Key Design Considerations and Assumptions	Potential Effects	Mitigation Measures	Net Effects
Groundwater Quantity	Predicted groundwater flow characteristics	• Silty clay underlying the proposed landfill is a low-hydraulic conductivity layer (aquitard) overlying the bedrock below.	• Vertical gradients between bedrock and the silty clay aquitard are generally upwards. Therefore, no effect is anticipated.	• None required	• None anticipated

3.2 Alternative Method 2

The net effects assessment for Alternative Method 2 is presented in **Table 3-2**.

Table 3-2. Net Effects Assessment – Alternative Method 2

Evaluation Criteria	Indicator	Key Design Considerations and Assumptions	Potential Effects	Mitigation Measures	Net Effects
Groundwater Quality	Predicted effects to groundwater quality at property boundaries and off-site	REFER TO APPENDIX A, TABLE A-1 FOR DETAILS OF INPUT AND OUTPUT PARAMETERS • Leachate collection system (LCS) is assumed to remain fully functional for a service life of 100 years. • Infiltration rate for each closed stage will be 0.042 m/yr of precipitation. The resulting volume of leachate will be collected continuously. Stage 5 • 1,750 m section with 10.0 m of underlying silty clay (analogous to Section Stage 5 on Figures 2A and 2B) Stages 6 through 8 • 1,538 m section with 9.5 m of underlying silty clay (analogous to Section Alt 2-1 on Figures 2A and 2B) • 1,379 m section with 8.7 m of underlying silty clay (analogous to Section Alt 2-2 on Figures 2A and 2B) • 1,107 m section with 8.2 m of underlying silty clay (analogous to Section Alt 2-3 on Figures 2A and 2B) • 377 m section with 5.5 m of underlying silty clay (analogous to Section Alt 2-4 on Figures 2A and 2B) • 493 m section with 5.8 m of underlying silty clay (analogous to Section Alt 2-5 on Figures 2A and 2B)	• Following expiry of the LCS service life, the chloride concentration in leachate would increase to a maximum of 166 mg/L in year 1000 (Alt 2-1) and year 930 (Alt 2-2). • The maximum concentration in the aquifer occurs in year 520 at 133 mg/L (Alt 2-5).	• None required	• Chloride concentrations at the property boundaries will be below the maximum allowable concentration (Cm) in the aquifer • Since Cm is met at the property boundaries, there will be no adverse effect to water well users in the Off-Site Study Area

Table 3-2. Net Effects Assessment – Alternative Method 2

Evaluation Criteria	Indicator	Key Design Considerations and Assumptions	Potential Effects	Mitigation Measures	Net Effects
Groundwater Quantity	Predicted groundwater flow characteristics	• Silty clay underlying the proposed landfill is a low-hydraulic conductivity layer (aquitard) overlying the bedrock below.	• Vertical gradients between bedrock and the silty clay aquitard are upwards. Therefore, no effect is anticipated.	• None required	• None anticipated

4 Comparative Evaluation of Net Effects and Identification of the Preferred Alternative

A comparative evaluation of the net effects of each alternative method and the identification of a preferred alternative are carried out in accordance with the methods described in Section 2.2. The results of the comparative evaluation are provided below.

4.1 Comparative Evaluation Results

The results of the comparative evaluation for Geology and Hydrogeology are provided in **Table 4-1**.

Table 4-1. Comparative Evaluation of Net Effects for Geology and Hydrogeology

Evaluation Criteria	Indicators	Net Effects of Alternative Methods	
		Alternative Method 1	**Alternative Method 2**
Groundwater quality	Predicted effects to groundwater quality at property boundaries and off-site	Proposed Stages 5 through 9 meet the maximum allowable concentration (Cm) in the aquifer for chloride without mitigation. **No Substantial Difference**	Proposed Stages 5 through 8 meet the maximum allowable concentration (Cm) in the aquifer for chloride without mitigation. **No Substantial Difference**
	Criteria Rating & Rationale	***There is no substantial difference between Alternative Method 1 and Alternative Method 2 with regard to effects on groundwater quality.*** Alternative Method 1 and Alternative Method 2 are equally acceptable from a groundwater quality perspective.	
Groundwater quantity	Predicted groundwater flow characteristics	None anticipated **No Substantial Difference**	None anticipated **No Substantial Difference**
	Criteria Rating & Rationale	***There is no substantial difference between Alternative Method 1 and Alternative Method 2 with regard to effects on groundwater quantity.*** Alternative Method 1 and Alternative Method 2 are equally acceptable from a groundwater quantity perspective.	

4.2 Advantages and Disadvantages of the Preferred Alternative

The differences in net effects are used to identify and compare the advantages and disadvantages of each alternative method.

There is no difference to groundwater quality or groundwater quantity between Alternative Methods 1 and 2. The maximum allowable concentration (Cm) will be met at the property boundary. There are no effects anticipated due to groundwater quantity.

5 Commitments and Monitoring

To confirm that the effects assessment of groundwater quality and quantity related to Geology and Hydrogeology are realized over the long term, monitoring is proposed for construction, operations and maintenance of the EOWHF landfill. Monitoring for compliance will be undertaken to confirm that the project complies with the maximum allowable concentration (Cm) as identified in the effects assessment.

The proposed environmental effects monitoring is provided in Section 5.2. Compliance monitoring for Geology and Hydrogeology is described in Section 5.3.

5.1 Geology and Hydrogeology Commitments

Since mitigation is not required to meet maximum allowable concentration (Cm), no geological or hydrogeological commitments are required.

5.2 Environmental Effects Monitoring for Geology and Hydrogeology

Monitoring plans are developed as part of the detailed effects assessments carried out for the Preferred Alternative to confirm:

- the net effects are as predicted; and
- unanticipated negative effects are addressed.

Table 5-1 summarizes the environmental effects monitoring for the Preferred Alternative.

5.3 Geology and Hydrogeology Compliance Monitoring

Compliance monitoring will be undertaken to confirm that the construction, operation and maintenance of the project are carried out in accordance with the commitments identified in the effects assessment. Compliance monitoring is summarized in **Table 5-1**. The results of compliance monitoring, including details of the fulfillment of commitments, will be provided to the MECP.

Table 5-1. Environmental Effects and Compliance Monitoring for the Preferred Alternative

Evaluation Criteria	Potential Effect	Commitment for Mitigation	Commitment for Monitoring	Compliance Monitoring
Groundwater quality	• Predicted effects to groundwater quality at property boundaries and off-site	• None required	• Groundwater monitoring wells located east of the existing EOWHF will be sampled triennially (i.e., three times per year) in conjunction with the existing EOWHF monitoring well network. • The analytical schedule for all monitoring wells will follow the existing commitments outlined in Environmental Compliance Approval (ECA) No. A420018 for the existing EOWHF.	• Triennially in August and November (parameter “List A” as defined in ECA No. A420018) and in May (parameter “List B” as defined in ECA No. A420018)
Groundwater quantity	• Predicted effects to groundwater flow	• None required	• The monitoring schedule for all monitoring wells will follow the existing commitments outlined in Environmental Compliance Approval (ECA) No. A420018 for the existing EOWHF.	• Triennially in May, August and November

6 Geology and Hydrogeology Approvals

In addition to EA approval, the following Geology and Hydrogeology approvals may be required:

The groundwater monitoring component of Environmental Compliance Approval No. A420018.

7 References

Golder Associates Ltd.

1998 Hydrogeological and Geotechnical Characterization and Conceptual Design, Proposed Landfill Development Pare Lots 16, 17 and 18 Concession X, Township of Roxborough, Ontario.

Government of Ontario

2006 Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2003 (Revised June 2006).

HDR Corporation

2022 Conceptual Design Report, Eastern Ontario Waste Handling Facility Future Development Environmental Assessment, Moose Creek, Ontario

Terrapex

2021 Geotechnical Feasibility Report, Proposed Landfill Expansion Lot 13, 14, 15, and 16, Concession Road 10, 17125 Lafleche Road, Moose Creek, Ontario

2022 Geology and Hydrogeology Existing Conditions Report, Eastern Ontario Waste Handling Facility Future Development Environmental Assessment, Lots 13 to 18, Concession Road 10, Township of North Stormont, United Counties of Stormont, Dundas and Glengarry (Draft)

Tetra Tech

2018 Geology and Hydrogeology Effects Assessment Report, Eastern Ontario Waste Handling Facility Landfill Expansion Environmental Assessment

Todd, D.K.

1980 Groundwater Hydrology, 2nd ed. John Wiley & Sons, New York, 535p.

Appendix A. Hydrogeological Modelling Inputs

TABLE A-1 SITE CONDITION MODELING SCENARIOS
EOWHF, MOOSE CREEK, ONTARIO

Model Name			Alt 1 - 1		Alt 1 - 2		Alt 1 - 3		Alt 1 - 4		Stage 5	
Timestep	yr		**to 100**	**100 - max**	**to 100**	**100 - max**	**to 100**	**100 - max**	**to 100**	**100 - max**	**to 100**	**100 - max**
Evaluation Criteria	**Units**	**Formulae**										
Background Chloride Concentration[1]	mg/L	[1]	104	104	104	104	104	104	104	104	104	104
Aesethic Objective[2]	mg/L	[2]	250	250	250	250	250	250	250	250	250	250
Maximum Allowable Concentration	mg/L	[3] = [1] + 0.5 ([2] - [1])	177	177	177	177	177	177	177	177	177	177
Flow Path Geometry												
Length[3]	m	[4]	**1550**	**1550**	**1377**	**1377**	**1310**	**1310**	**504**	**504**	**1750**	**1750**
Width[3]	m	unity in downgradient direction	1	1	1	1	1	1	1	1	1	1
Waste Properties												
Total mass upon closure[4]	tonnes	[5a]	15,100,000	15,100,000	15,100,000	15,100,000	15,100,000	15,100,000	4,495,636	4,495,636	-	-
Mass upon closure excluding soil cover and C&D wastes[4]	tonnes	[5b] = [5a] * 0.768	11,596,800	11,596,800	11,596,800	11,596,800	11,596,800	11,596,800	3,452,648	3,452,648	-	-
Contaminating mass upon closure	kg	[6] = 1,000 [5]	1.16E+10	1.16E+10	1.16E+10	1.16E+10	1.16E+10	1.16E+10	3.45E+09	3.45E+09	-	-
Surficial Area[4]	ha	[7]	147.8	147.8	147.8	147.8	147.8	147.8	42.5	42.5	-	-
Surficial Area	m^2	[8] = 10,000 [7]	1,477,896	1,477,896	1,477,896	1,477,896	1,477,896	1,477,896	424,976	424,976	-	-
Landfill Size	tonnes / ha	[9] = [5] / [7]	78,468	78,468	78,468	78,468	78,468	78,468	81,243	81,243	-	-
Average mass per unit area	kg/m^2	[10] = [6] / [8]	7,847	7,847	7,847	7,847	7,847	7,847	8,124	8,124	8,144	8,144
Chloride content[5]	kg Cl^- / kg waste	[11]	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
Average mass Cl^- per unit area	kg $Cl-/m^2$	[12] = [10] [11]	14	14	14	14	14	14	15	15	15	15
Cl^- concentration upon closure[6]	kg/m^3	[13]	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Reference height of leachate[7]	m	[14] = [12] / [13]	**9.4**	**9.4**	**9.4**	**9.4**	**9.4**	**9.4**	**9.7**	**9.7**	**9.8**	**9.8**
Leachate Generation												
Final cover infiltration rate[8]	$m^3/ha/yr$	[17]	419	419	419	419	419	419	419	419	419	419
Leachte generation rate	m/yr	[18] = ([17] / 10,000) - [25]	**0.042**	**0.040**	**0.042**	**0.040**	**0.042**	**0.040**	**0.042**	**0.040**	**0.042**	**0.040**
Silty Clay Properties												
Average thickness[3]	m	[19]	**9.4**	**9.4**	**8.5**	**8.5**	**6.4**	**6.4**	**5.9**	**5.9**	**10.0**	**10.0**
Dry Density[9]	g/cm^3		**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**
Porosity[10]	na		**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Hydrodynamic Dispersion Coefficient[11]	m^2/yr		**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**
Distribution Coefficient[12]	m^3/kg		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fractures	na		**none**	**none**	**none**	**none**	**none**	**none**	**none**	**none**	**none**	**none**
Average Hydraulic Conductivity[13]	m/sec	[20]	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10
Upper Piezometric Surface[3]	m amsl	[21]	65.5	73.0	65.5	73.0	65.5	73.0	65.5	73.0	65.5	73.0
Lower Peizometric Surface[3]	m amsl	[22]	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5
Reference Distance[3]	m	[23]	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Vertical Gradient[14]	m/m	[24] = ([21] - [22]) / [23]	0.0000	0.4286	0.0000	0.4286	0.0000	0.4286	0.0000	0.4286	0.0000	0.4286
Vertical Darcy Velocity	m/yr	[25] = [20] [24]	**0.0000**	**0.0015**	**0.0000**	**0.0015**	**0.0000**	**0.0015**	**0.0000**	**0.0015**	**0.0000**	**0.0015**
Aquifer Properties												
Thickness[3]	m	[26]	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Porosity[15] (n)	na		**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Average Hydraulic Conductivity[13]	m/sec	[27]	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05
Upper Piezometric Surface[3]	m amsl	[28]	67	67	67	67	67	67	67	67	67	67
Lower Peizometric Surface[3]	m amsl	[29]	64	64	64	64	64	64	64	64	64	64
Reference Distance[3]	m	[30]	1725	1725	1725	1725	1725	1725	1725	1725	1725	1725
Horizontal Gradient	m/m	[31] = ([28] - [29]) / [30]	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Horizontal Darcy Velocity	m/yr	[32] = [27] [31]	0.603	0.603	0.603	0.603	0.603	0.603	0.603	0.603	0.603	0.603
Horizontal Base Outflow Velocity	m/yr	[33] = ([25] [4] + [32] [26]) / [26]	**0.603**	**1.371**	**0.603**	**1.286**	**0.603**	**1.252**	**0.603**	**0.853**	**0.603**	**1.471**
Modeling Results												
Maximum occurs in aquifer in	yr			1,000		900		650		540		1,100
Maximum concentration in aquifer	mg/L			109		119		160		135		110
Contaminating lifespan ends in	yr			500		500		500		500		520
Leachate concentration in waste (depth 0 m)	mg/L			155		155		165		162		166

Notes

1 Geometric mean of observation in monitoring wells MW20-2D, MW20-3D, MW20-4D, MW20-5D, MW20-6D, MW20-7D, MW20-8D, and MW20-10D in November 2020 and May, August, and November 2021.
2 Aesthetic objectives (AO) and operational guidelines (OG) from: Ontario Drinking Water Standards, Objectives and Guidelines, June 2003 (Revised June 2006)
3 Conceptual Site Models
4 Conceptual Design Report (pdf page 9 or 30, Appendix B)
5 O. Reg. 232/98, Table 1 Leachate Characteristics (Section 10), Column 3
6 O. Reg. 232/98, Table 1 Leachate Characteristics (Section 10), Column 2
7 H_{ref} = Average mass Cl^- / unit area / initial concentration Cl^- (Pollute Manual pdf page 137)
8 Conceptual Design Report (pdf page 45)
9 From Terrapex's 2021 Geotechnical Feasibilty Report (pdf page 12)
10 From Golder's 1998 Characterization Report (pdf page 192)
11 From Golder's 1998 Characterization Report (pdf page 195)
12 Relates to adsorption and not applicable for chloride
13 Geometric mean of K values from Terrapex's 2022 Existing Conditions Report (pdf page 166)
14 Negative is up
15 Assumed effective porosity for limestone with similar hydraulic conductivity values (Todd, D.K., 1980)

BOLD Modeling input parameter

TABLE A-1 SITE CONDITION MODELING SCENARIOS
EOWHF, MOOSE CREEK, ONTARIO

Model Name			Alt 2 - 1		Alt 2 - 2		Alt 2 - 3		Alt 2 - 4		Alt 2 - 5	
Timestep	yr		**to 100**	**100 - max**	**to 100**	**100 - max**	**to 100**	**100 - max**	**to 100**	**100 - max**	**to 100**	**100 - max**
Evaluation Criteria	**Units**	**Formulae**										
Background Chloride Concentration[1]	mg/L	[1]	104	104	104	104	104	104	104	104	104	104
Aesethic Objective[2]	mg/L	[2]	250	250	250	250	250	250	250	250	250	250
Maximum Allowable Concentration	mg/L	[3] = [1] + 0.5 ([2] - [1])	177	177	177	177	177	177	177	177	177	177
Flow Path Geometry												
Length[3]	m	[4]	**1538**	**1538**	**1379**	**1379**	**1107**	**1107**	**377**	**377**	**493**	**493**
Width[3]	m	unity in downgradient direction	1	1	1	1	1	1	1	1	1	1
Waste Properties												
Total mass upon closure[4]	tonnes	[5a]	12,089,728	12,089,728	6,044,864	6,044,864	2,255,272	2,255,272	2,255,272	2,255,272	8,300,136	8,300,136
Mass upon closure excluding soil cover and C&D wastes[4]	tonnes	[5b] = [5a] * 0.768	9,284,911	9,284,911	4,642,456	4,642,456	1,732,049	1,732,049	1,732,049	1,732,049	6,374,504	6,374,504
Contaminating mass upon closure	kg	[6] = 1,000 [5]	9.28E+09	9.28E+09	4.64E+09	4.64E+09	1.73E+09	1.73E+09	1.73E+09	1.73E+09	6.37E+09	6.37E+09
Surficial Area[4]	ha	[7]	114.0	114.0	57.0	57.0	24.0	24.0	24.0	24.0	81.0	81.0
Surficial Area	m^2	[8] = 10,000 [7]	1,140,124	1,140,124	570,062	570,062	240,403	240,403	240,403	240,403	810,465	810,465
Landfill Size	tonnes / ha	[9] = [5] / [7]	81,438	81,438	81,438	81,438	72,048	72,048	72,048	72,048	78,652	78,652
Average mass per unit area	kg/m^2	[10] = [6] / [8]	8,144	8,144	8,144	8,144	7,205	7,205	7,205	7,205	7,865	7,865
Chloride content[5]	kg Cl^- / kg waste	[11]	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
Average mass Cl^- per unit area	kg Cl/m^2	[12] = [10] [11]	15	15	15	15	13	13	13	13	14	14
Cl^- concentration upon closure[6]	kg/m^3	[13]	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Reference height of leachate[7]	m	[14] = [12] / [13]	**9.8**	**9.8**	**9.8**	**9.8**	**8.6**	**8.6**	**8.6**	**8.6**	**9.4**	**9.4**
Leachate Generation												
Final cover infiltration rate[8]	m^3/ha/yr	[17]	419	419	419	419	419	419	419	419	419	419
Leachte generation rate	m/yr	[18] = ([17] / 10,000) - [25]	**0.042**	**0.040**	**0.042**	**0.040**	**0.042**	**0.040**	**0.042**	**0.040**	**0.042**	**0.040**
Silty Clay Properties												
Average thickness[3]	m	[19]	**9.5**	**9.5**	**8.7**	**8.7**	**8.2**	**8.2**	**5.5**	**5.5**	**5.8**	**5.8**
Dry Density[9]	g/cm^3		**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**	**1.733**
Porosity[10]	na		**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Hydrodynamic Dispersion Coefficient[11]	m^2/yr		**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**
Distribution Coefficient[12]	m^3/kg		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fractures	na		**none**	**none**	**none**	**none**	**none**	**none**	**none**	**none**	**none**	**none**
Average Hydraulic Conductivity[13]	m/sec	[20]	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10	1.1E-10
Upper Piezometric Surface[3]	m amsl	[21]	65.5	73.0	65.5	73.0	65.5	73.0	65.5	73.0	65.5	73.0
Lower Peizometric Surface[3]	m amsl	[22]	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5
Reference Distance[3]	m	[23]	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Vertical Gradient[14]	m/m	[24] = ([21] - [22]) / [23]	0.0000	0.4286	0.0000	0.4286	0.0000	0.4286	0.0000	0.4286	0.0000	0.4286
Vertical Darcy Velocity	m/yr	[25] = [20] [24]	**0.0000**	**0.0015**	**0.0000**	**0.0015**	**0.0000**	**0.0015**	**0.0000**	**0.0015**	**0.0000**	**0.0015**
Aquifer Properties												
Thickness[3]	m	[26]	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Porosity[15] (n)	na		**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Average Hydraulic Conductivity[13]	m/sec	[27]	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05
Upper Piezometric Surface[3]	m amsl	[28]	67	67	67	67	67	67	67	67	67	67
Lower Peizometric Surface[3]	m amsl	[29]	64	64	64	64	64	64	64	64	64	64
Reference Distance[3]	m	[30]	1725	1725	1725	1725	1725	1725	1725	1725	1725	1725
Horizontal Gradient	m/m	[31] = ([28] - [29]) / [30]	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Horizontal Darcy Velocity	m/yr	[32] = [27] [31]	0.603	0.603	0.603	0.603	0.603	0.603	0.603	0.603	0.603	0.603
Horizontal Base Outflow Velocity	m/yr	[33] = ([25] [4] + [32] [26]) / [26]	**0.603**	**1.365**	**0.603**	**1.287**	**0.603**	**1.152**	**0.603**	**0.790**	**0.603**	**0.848**
Modeling Results												
Maximum occurs in aquifer in	yr			1,000		930		820		360		520
Maximum concentration in aquifer	mg/L			110		119		109		109		133
Contaminating lifespan ends in	yr			500		500		450		450		500
Leachate concentration in waste (depth 0 m)	mg/L			166		166		161		158		153

Notes

1. Geometric mean of observation in monitoring wells MW20-2D, MW20-3D, MW20-4D, MW20-5D, MW20-6D, MW20-7D, MW20-8D, and MW20-10D in November 2020 and May, August, and November 2021.
2. Aesthetic objectives (AO) and operational guidelines (OG) from: Ontario Drinking Water Standards, Objectives and Guidelines, June 2003 (Revised June 2006)
3. Conceptual Site Models
4. Conceptual Design Report (pdf page 9 or 30, Appendix B)
5. O. Reg. 232/98, Table 1 Leachate Characteristics (Section 10), Column 3
6. O. Reg. 232/98, Table 1 Leachate Characteristics (Section 10), Column 2
7. H_{ref} = Average mass Cl^- / unit area / initial concentration Cl^- (Pollute Manual pdf page 137)
8. Conceptual Design Report (pdf page 45)
9. From Terrapex's 2021 Geotechnical Feasibilty Report (pdf page 12)
10. From Golder's 1998 Characterization Report (pdf page 192)
11. From Golder's 1998 Characterization Report (pdf page 195)
12. Relates to adsorption and not applicable for chloride
13. Geometric mean of K values from Terrapex's 2022 Existing Conditions Report (pdf page 166)
14. Negative is up
15. Assumed effective porosity for limestone with similar hydraulic conductivity values (Todd, D.K., 1980)

BOLD Modeling input parameter

TERRAPEX

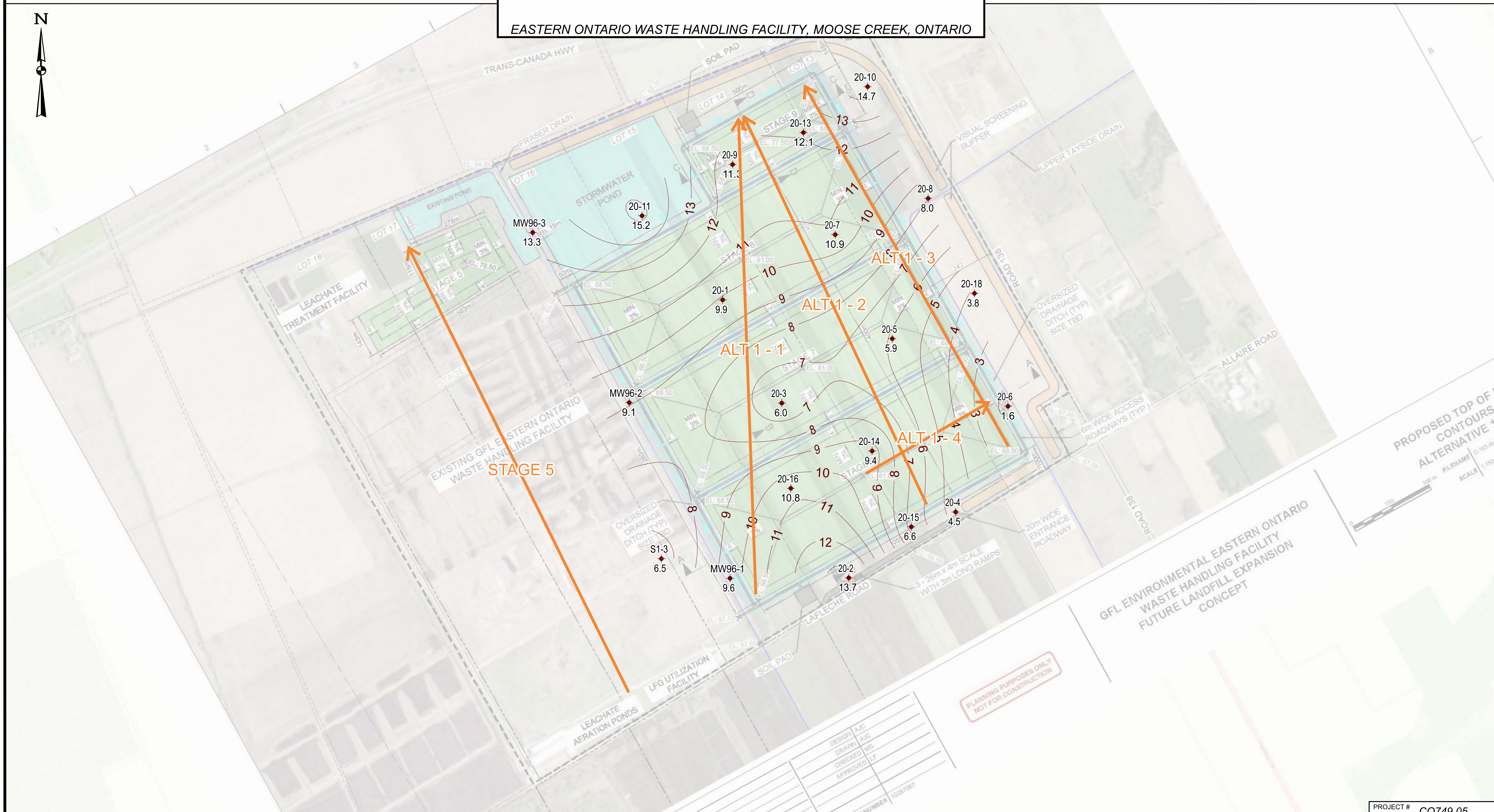
INTERPRETED SILTY CLAY THICKNESS ALTERNATIVE 1

EASTERN ONTARIO WASTE HANDLING FACILITY, MOOSE CREEK, ONTARIO

CLIENT

GFL environmental

N



LEGEND

MONITORING LOCATION

SOURCE: OPEN STREET MAP

0 500m 1000m

(APPROXIMATE)

PROJECT #	CO749.05
SCALE	AS SHOWN
DATE	MAY 2022
DRAWN JO	CHECKED
DRAWING #	FIGURE A-1A

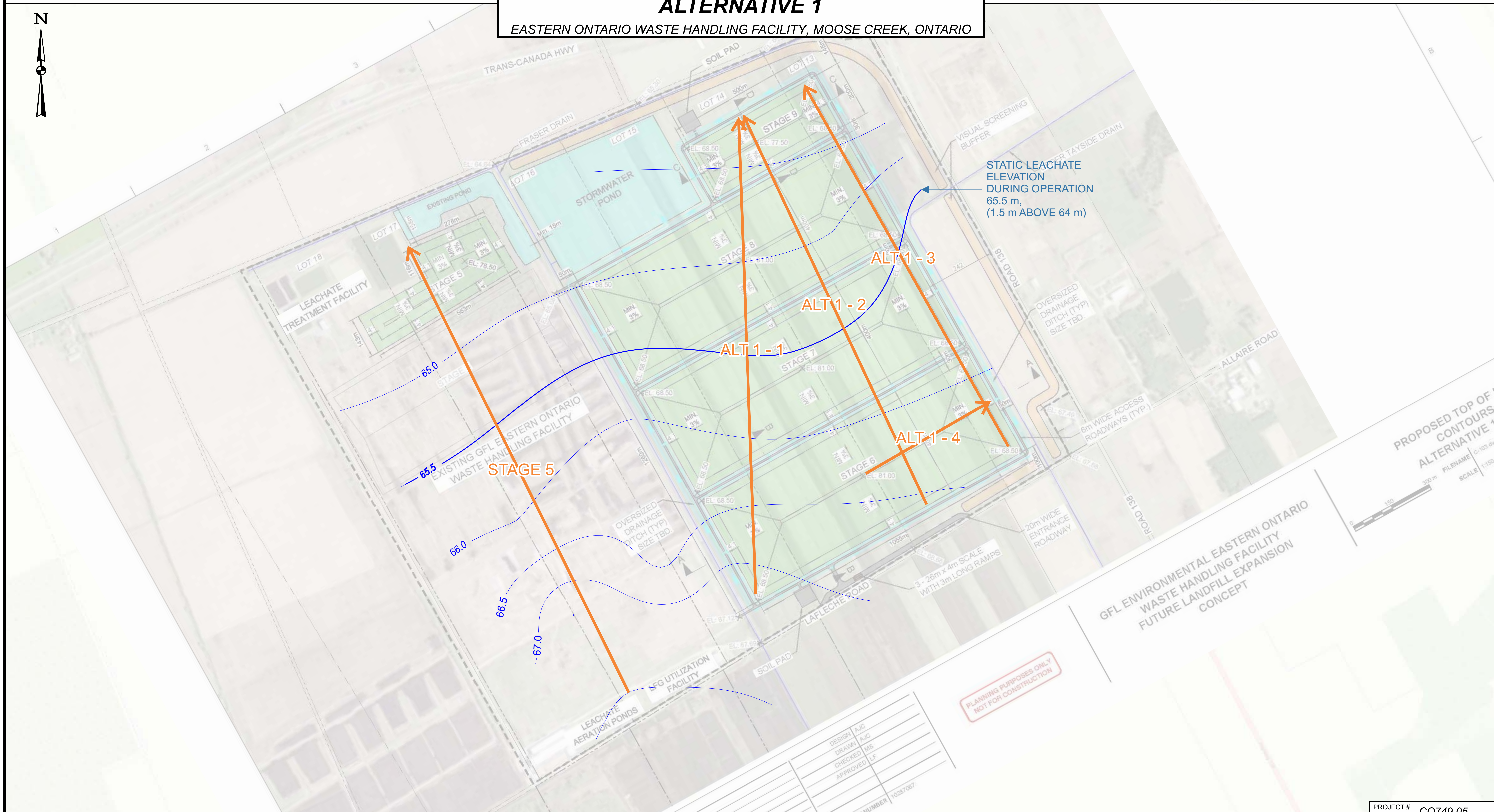
INTERPRETED BEDROCK GROUNDWATER CONTOURS - FALL 2021
ALTERNATIVE 1

EASTERN ONTARIO WASTE HANDLING FACILITY, MOOSE CREEK, ONTARIO

TERRAPEX

CLIENT

GFL environmental



LEGEND

MONITORING LOCATION

SOURCE: OPEN STREET MAP

0 500m 1000m (APPROXIMATE)

PROJECT #	CO749.05
SCALE	AS SHOWN
DATE	MAY 2022
DRAWN	JO
CHECKED	
DRAWING #	FIGURE A-1B

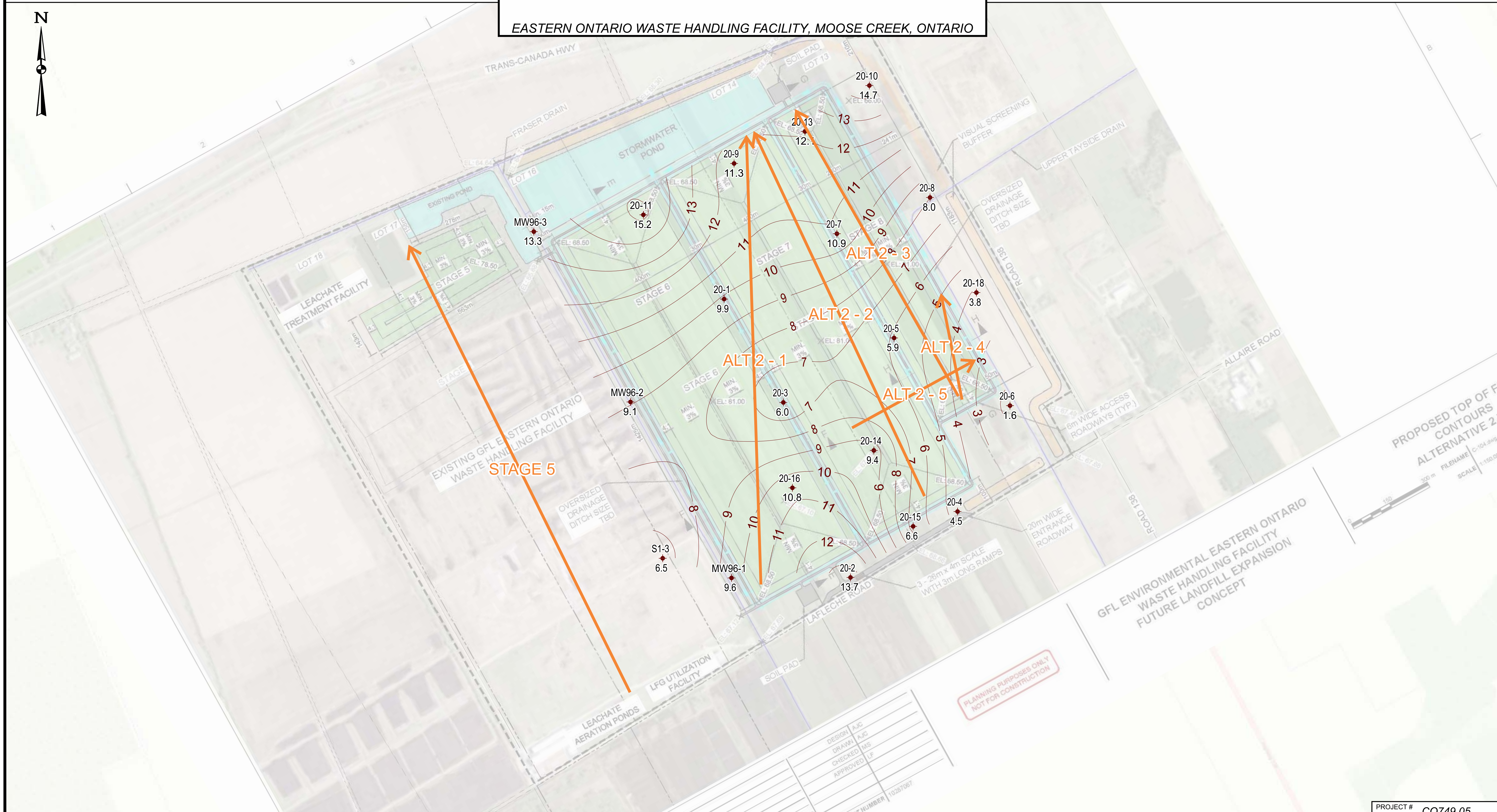
TERRAPEX

INTERPRETED SILTY CLAY THICKNESS ALTERNATIVE 2

EASTERN ONTARIO WASTE HANDLING FACILITY, MOOSE CREEK, ONTARIO

CLIENT

GFL environmental



LEGEND

MONITORING LOCATION

SOURCE: OPEN STREET MAP

0 500m 1000m
(APPROXIMATE)

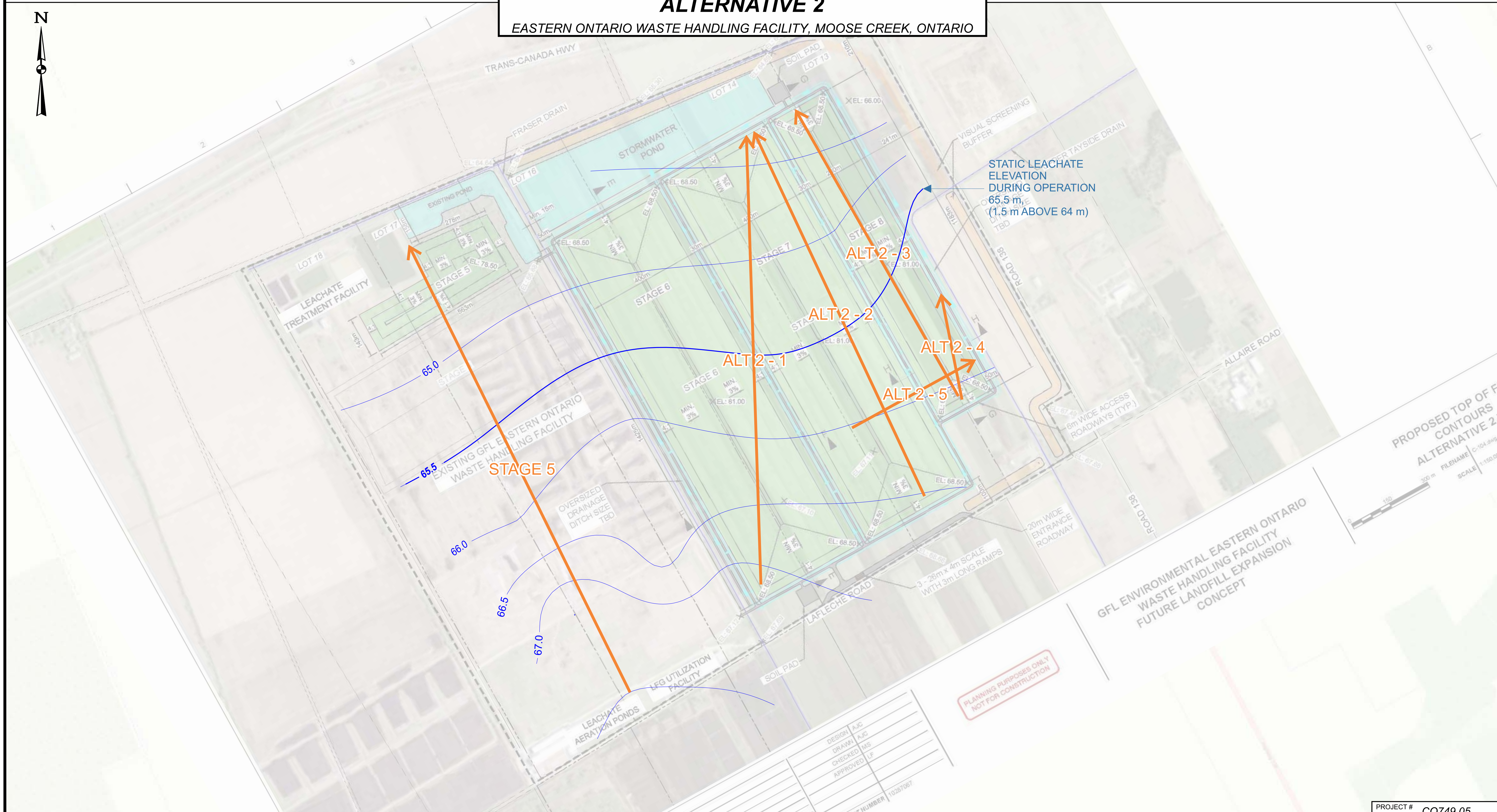
PROJECT #	CO749.05
SCALE	AS SHOWN
DATE	MAY 2022
DRAWN JO	CHECKED
DRAWING #	FIGURE A-2A

INTERPRETED BEDROCK GROUNDWATER CONTOURS - FALL 2021 ALTERNATIVE 2

EASTERN ONTARIO WASTE HANDLING FACILITY, MOOSE CREEK, ONTARIO

TERRAPEX

CLIENT: GFL environmental



0 500m 1000m (APPROXIMATE)

LEGEND

MONITORING LOCATION

SOURCE: OPEN STREET MAP

PROJECT #	CO749.05
SCALE	AS SHOWN
DATE	MAY 2022
DRAWN	JO
CHECKED	
DRAWING #	FIGURE A-2B