ADDENDUM TO
SITE CONCEPTUAL MODEL UPDATE AND CONTAMINANT ATTENUATION ZONE DELINEATION

WASTE MANAGEMENT
RICHMOND LANDFILL SITE

Submitted to:

Waste Management of Canada Corporation
1271 Beechwood Road
R.R. #6 Napanee, ON K7R 3L1

Prepared by:

BluMetric Environmental Inc.
4 Cataraqui Street
The Woolen Mill, The Tower
Kingston, ON K7K 1Z7

Project Number: 190222-02
May 2019

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1. INTRODUCTION

This report is an addendum to the Site Conceptual Model (SCM) Update and Contaminant Attenuation Zone (CAZ) Delineation report dated October 2018 (BluMetric, 2018). The purpose of this document is to provide supplementary technical information to support Waste Management of Canada Corporation's (WM) upcoming application to amend Environmental Compliance Approval (ECA) No. A371203 for the WM Richmond Landfill (the Site), to incorporate the use of a land parcel as a CAZ to bring the Site into compliance with the Reasonable Use Limits (RULs) in Guideline B-7, and the continued use of the property for general rural purposes. The site location is presented on Figure 1.

The complementary hydrogeological work described in this report was conducted to address concerns outlined in the technical review comments from Ministry of the Environment, Conservation and Parks (MECP) hydrogeologists Kyle Stephenson and Shawn Trimper, as outlined in their letter dated November 29, 2018. These review comments and a possible work plan to address outstanding concerns were discussed with MECP hydrogeologists during a meeting held on January 30, 2019. A work plan, outlined in a memorandum dated February 8, 2019, was developed to further refine the interpretation of the eastern edge of the impacted groundwater plume delineated from interpolated chemistry data collected during previous hydrogeological investigations. The work plan was reviewed and accepted by MECP technical staff in their e-mail dated February 19, 2019.

The methodology associated with these tasks is described in more detail in Section 2 while results are provided in Section 3 and Section 4 provides a discussion and interpretation of the results including an update to the hydrogeological SCM based on historical and recent results. Finally, Section 5 provides updated recommendations regarding the proposed CAZ associated with the Richmond Landfill.

2. FIELD PROGRAM

One new borehole (M216) targeting the intermediate bedrock groundwater flow zone was drilled in the eastern portion of the proposed CAZ to characterize groundwater conditions in this area. The borehole location, shown on Figure 2, is just south of Beechwood Road between existing monitoring wells M168 and M191.

2.1 BOREHOLE DRILLING

Borehole M216 was drilled to a depth 35.28 m below ground surface (mbgs) between March 1 and 4, 2019. Drilling was completed by GET Drilling Ltd. of Napanee, ON, using air-rotary techniques. After drilling through the overburden, steel casing was installed from ground surface and cemented into the upper portion of the bedrock, prior to advancing the borehole into bedrock to the target depth. Supervising BluMetric staff made notes regarding stratigraphy and water encountered during drilling. A borehole log is provided in Appendix A.

2.2 GROUNDWATER LEVEL MEASUREMENTS

Groundwater level measurements in borehole M216 were recorded over a period of 94 hours following drilling using an electronic water level tape.

2.3 GROUNDWATER SAMPLING

On March 8, 2019, approximately 5 days after drilling the borehole, an oily substance was observed on the water level tape after the water level was measured, with texture and smell resembling that of fuel oil. Drilling equipment was immediately inspected and ruled out as a potential source of contamination.

On March 11, 2019, a new disposable bailer was used to collect a bulk sample from the open borehole, which was submitted to Maxxam for analysis of total petroleum hydrocarbons (TPH fractions F1 to F4), BTEX (benzene, toluene, ethylbenzene and xylenes) and 1,4-dioxane.

A second sample was collected April 12, 2019 and submitted to Maxxam for analysis of 1,4-dioxane.

2.4 BOREHOLE DECOMMISSIONING

Borehole M216 was decommissioned on April 18, 2019 as it was not suitable for monitoring well installation. High sulphate resistance hydraulic cement was used for the abandonment barrier to prevent potential vertical movement of water, natural gas and other contaminants encountered in the borehole. The grout mixture was pumped using a tremie line to seal the borehole from the bottom up.

3. RESULTS

3.1 GEOLOGY

The overburden materials and bedrock encountered in borehole M216 were consistent with previous interpretations of the local geology. The overburden thickness was 3.08 m and consisted of topsoil and sandy silt with gravel and clay (till). Limestone bedrock was encountered at a depth of 3.08 mbgs. A section of softer rock was encountered between depths of 13.96 to 14.46 mbgs, where a sulphur smell was noted. Drilling was paused for several minutes but no groundwater was produced. The borehole was advanced to the target depth and no noticeable water bearing features were encountered during drilling. A borehole log is provided in Appendix A.

3.2 GROUNDWATER LEVELS

The borehole was dry immediately after drilling and a small amount (0.11 m) of water had accumulated at the bottom of the hole approximately 90 minutes after drilling. Water levels recorded over a period of 94 hours following drilling exhibited a very slow recovery of approximately 0.25 m/hr, corresponding to a very slow recovery rate of 0.1 L/min (0.03 usgpm).

3.3 GROUNDWATER CHEMISTRY

Groundwater chemistry results from the samples collected on March 11 and April 12, 2019 are summarized in Table 1. Both samples were below the laboratory reporting limit for 1,4-dioxane (0.001 mg/L), confirming that this location is beyond the zone of leachate impacted groundwater in the Intermediate Bedrock flow zone, consistent with previous interpretations of the groundwater plume delineation.

TPH and BTEX constituents were detected in the sample collected March 11, 2019 (Table 1). As these constituents are inconsistent with the well documented historical groundwater flow directions and analytical results observed between the landfill and M216 borehole, the TPH/BTEX impacts do not appear to be associated with the previously identified leachate release. Analytical results are compared in Table 1 against the standards for the assessment and remediation of contaminated groundwater (Ontario Regulation 153/04 Table 2: Full Depth Generic Site Condition Standards in a Potable Ground Water Condition). Results exceeded the criteria for all parameters except xylenes.

The analytical results for TPH and BTEX were communicated to MECP in a draft memorandum dated April 1, 2019, and discussed with MECP technical staff during a meeting held at the MECP Kingston office on April 3, 2019. The landfill was ruled out as the source of the TPH/BTEX contamination observed in the M216 borehole, and MECP has assumed investigation of the issue.

Table 1: Results from bulk groundwater sample from open borehole M216

Parameter	O.Reg. 153/04	Units	M216-OPEN	
	Table 2 - Potable GW*		3/11/2019	4/12/2019
1,4-Dioxane	nv	mg/L	< 0.001	< 0.001
Benzene	0.005	mg/L	**0.28**	-
Ethylbenzene	0.0024	mg/L	**0.0057**	-
Toluene	0.024	mg/L	**0.29**	-
m+p-Xylene	nv	mg/L	0.069	-
o-Xylene	nv	mg/L	0.021	-
Total Xylenes	0.3	mg/L	0.09	-
TPH (F1 C6-C10 - BTEX)	nv	mg/L	< 0.025	-
TPH (F1 C6-C10)	1	mg/L	**0.69**	-
TPH (F2 C10-C16)		mg/L	**1.3**	-
TPH (F3 C16-C34)	1	mg/L	**2.9**	-
TPH (F4 C34-C50)		mg/L	**0.23**	-

**Shaded bold values exceed Ontario Regulation 153/04 Table 2: Full Depth Generic Site Condition Standards in a Potable Ground Water Condition.*
"nv" indicates no value.

4. INTERPRETATION AND UPDATE TO SITE CONCEPTUAL MODEL

The current SCM for the WM Richmond Landfill was initially introduced in BKA and WESA (2009). Refinements to the SCM were developed as part of the Action Plan investigation documented in BKA and WESA (2012). Subsequent phases of hydrogeological investigation beginning in 2012 have focused on properties south of Beechwood Road, as well as the adjacent property to the east of the WM property and north of Beechwood Road. The information obtained from these complementary investigations has been used to further refine and extend the SCM, and to establish the extent of the proposed CAZ for the site. Subsequent updates to the SCM were reported in BluMetric (2016a, 2016b, 2017 and 2018). The information has also been used to develop the interim EMP for the landfill (BluMetric, 2016c).

This section provides an up-to-date conceptualization of the SCM for the WM Richmond Landfill, building on the previous SCM updates presented in the documents listed above, among others, and taking into account the findings from the latest hydrogeological investigation documented in sections 2 and 3 of the present report. Section 5 provides recommendations related to the proposed CAZ boundary based on the updated SCM and delineation of landfill leachate impacted groundwater.

4.1 GEOLOGY

The Richmond Landfill Site is located within the Napanee Plain which, on a regional scale, is a flat to slightly undulating plain of limestone dipping slightly to the south and typically covered with a relatively thin veneer of overburden. In the immediate vicinity of the Site, the ground surface slopes approximately 1 m to 3 m per kilometre to the south. A drumlin (Empey Hill) is present on the Site southwest of the landfill. The dominant drainage feature on the Site is Marysville Creek located north of the landfill, while Beechwood Ditch provides Site drainage south of the landfill.

The overburden consists of less than 0.5 m to 10 m of clayey silt till and thickens to approximately 20 m in the area of Empey Hill drumlin to the southwest of the landfill. The overburden is underlain by the Verulam Formation which consists of horizontally bedded, medium to coarse crystalline limestone with interbedded shale layers. The Verulam is interpreted to be a few metres thick at the Site and is underlain by the Bobcaygeon Formation which generally consists of horizontally bedded, crystalline limestone with interbedded shale in the upper part and interbedded calcarenite in the lower part. The thickness of the Bobcaygeon Formation beneath the Site varies from approximately 11 m to 15 m. The Bobcaygeon Formation is underlain by the Gull River Formation which consists of horizontally bedded limestone and exhibits a thickness of approximately 75 m beneath the Site.

Three distinct karst conditions are also present within the proposed CAZ south of Beechwood Road: 1) a deep, likely paleokarst-controlled, conduit system in the west; 2) a shallower conduit system developing under post-glacial conditions in the east (represented by a groundwater trough); and, 3) a very shallow epikarst, located in areas of shallow soil over bedrock (BluMetric, 2017).

4.2 PHYSICAL HYDROGEOLOGY

The active groundwater flow zone at the Site extends between the saturated overburden where present to a depth of approximately 30 m below the top of bedrock. The dominant fracture orientation in the upper 30 m of bedrock is parallel to bedding (horizontal to sub-horizontal) distributed throughout the upper 30 m of bedrock, implying that there are no particular depth horizons exhibiting anomalous amounts of fracturing. Some borings exhibit a shallow weathered zone, however, in which fracturing is more pronounced. A moderate amount of vertical to sub-vertical fractures exists providing hydraulic connections between the various horizontal fractures.

4.2.1 Shallow Groundwater Zone

The shallow groundwater flow zone comprises overburden, the overburden-bedrock contact, and the first one to two metres of depth into bedrock. Water level monitoring indicates that these three portions of the shallow flow system act in concert and can be treated as a single flow zone or hydrostratigraphic unit. The directions of groundwater flow in the shallow flow zone are strongly influenced by ground surface topography.

Shallow zone flownets are constructed seasonally (spring, summer and fall) at the site using water level data from hydraulically responsive wells. The flownets, documented in semi-annual reports, show that there is a water level high beneath Empey Hill stemming from the elevated topography of this feature. Empey Hill creates a flow divide west of the landfill with shallow groundwater being directed both to the north and the south. The northerly flowing groundwater discharges to Marysville Creek. The southerly flowing groundwater flows towards Beechwood Ditch in the southwest portion of the Site. Shallow groundwater south of the landfill and south of Beechwood Road also flows towards the area of lower water levels in the southwest portion of the Site.

Shallow groundwater east of the landfill is influenced by a local zone of higher water elevations in the vicinity of monitoring well M96. Shallow groundwater north of well location M96 flows to the north and ultimately into Marysville Creek while groundwater south of well location M96 flows to the south-southeast. The shallow groundwater flow directions described here do not vary significantly with season despite the fact that water levels at the Site can be up to approximately 2 m higher in the spring months compared to the fall months. The lack of variation of shallow groundwater flow direction with season stems from the fact that the shallow flow system is topographically controlled and indicates that an appropriately located monitoring well network will detect a potential contaminant plume in the shallow zone.

Farther south, shallow groundwater discharges into a low-lying area in the central portion of the proposed CAZ south of Beechwood Road where a surface water course is present. The land surface rises south of this low-lying area which acts as a local divide for the shallow groundwater flow in this part of the CAZ (BluMetric, 2018). Shallow groundwater flows towards the local divide from the north, east and south, consistent with the local ground surface topography.

4.2.2 Intermediate Bedrock Groundwater Zone

The intermediate bedrock groundwater flow zone extends from approximately one to two metres below the top of bedrock to a depth of approximately 30 m below the top of bedrock. The 30 m limitation was selected on the basis of the fact that groundwater salinity increases significantly below depths of approximately 30 m into bedrock and the fact that fresher groundwater, including leachate, does not have the ability to displace the denser, saline groundwater. In addition, because of the significant anisotropy exerted by the dominance of horizontal to sub-horizontal fractures, the primary groundwater flow direction in bedrock is horizontal. This does not, however, rule out localized occurrences of vertical flow within the intermediate flow zone. The deep groundwater below 30 m depth into bedrock is classified as non-potable according to the Ontario Drinking Water Standards, Objectives and Guidelines. At some well locations, naturally saline waters exist in the intermediate bedrock at depths of less than 30 metres, particularly in areas of lower hydraulic conductivity and slower groundwater flow rates. These waters are distinguishable by naturally elevated sodium, chloride and TDS concentrations, low alkalinity and often the presence of ammonia and BTEX compounds.

As with shallow groundwater, the intermediate zone groundwater will always flow from regions of high hydraulic head to regions of low hydraulic head, with flow velocity controlled by hydraulic conductivity along the groundwater flowpaths. The hydraulic testing programs conducted since 2009 have revealed that there is continuity of hydraulically connected fractures in the intermediate flow zone surrounding the landfill to the west, south and southeast. Pumping of individual wells at various depths induced hydraulic responses up to 450 m away, supporting the interpretation that groundwater flow occurs primarily through horizontal and sub-horizontal fractures that are connected to each other by vertical to sub-vertical fractures.

The intermediate bedrock groundwater flow zone potentiometric surface, documented in semi-annual monitoring reports and previous hydrogeological investigations (most recently BluMetric, 2018), illustrates that groundwater flowing under the landfill generally flows to the west from the western edge of the landfill, to the south-southeast from the southern edge of the landfill, and to the southwest from the southwest corner of the landfill. The hydraulic influence of Empey Hill is seen in the intermediate flow zone in that a relatively stagnant zone (weaker hydraulic gradients) is created southwest of the landfill.

Unlike the shallow groundwater zone flow system, however, the intermediate zone flow system exhibits significant flow direction changes with season. This stems from the fact that the intermediate flow zone is not as constrained by topographic control as the shallow zone flow system. The regional groundwater flow direction is southward, following the dip of the limestone bedrock as well as the general slope of the topographic surface.

Area South of Landfill

The area south of the landfill footprint and east of the landfill entrance road is characterized by interconnected fractures that appear to be well connected to recharge/discharge features, which are likely in direct connection to surface infiltration. The well-connected area has a significant role in the local variation of the potentiometric surface as the water levels vary throughout the year by as much as 4 to 6 m. The results of various CAZ investigations over the past several years, which demonstrated hydraulic connection between monitoring wells north and south of Beechwood Road, have confirmed that the hydraulically well-connected area extends onto the proposed CAZ properties, as far south and southeast as well locations M188-1, M190 and M167.

It is important to emphasize that the area of well-connected bedrock fractures described above interacts hydraulically with other areas of the Site. It is distinct due to its behavioral differences during recharge/discharge time periods, but does not represent a separate flow regime. Furthermore, the zones of lower hydraulic conductivity surrounding the area to the west, south and east do not represent a barrier to flow; rather the rate of groundwater flow is slower within these lower permeability zones within the fractured bedrock. The presence of the less permeable zones to the west and to the east is clearly seen by comparison of temporal water level variations inside and outside of the area of well-connected fractures.

Flow out of the area is controlled by the lower hydraulic conductivity in the surrounding rock. Infiltrating water recharging into the well-connected area is stored, resulting in the noticeable rise in water levels, which then dissipate as groundwater flow moves through and out of the area.

The low recovery rate observed at borehole M216 (described above in Sections 2 and 3) is consistent with the low bulk hydraulic conductivity observed in the intermediate bedrock at nearby decommissioned boreholes M169 and M171, as well as low permeability monitoring well locations M191 and M193. This indicates that the well-connected area does not extend to the east in this area of the proposed CAZ. Similar results were obtained in the western portion of the proposed CAZ (BluMetric, 2018), where low bulk bedrock permeability in the Intermediate Bedrock flow zone was determined from results at several borehole locations (M120, M124, M196, M197 and M198), determined to be unsuitable for groundwater monitoring.

Another area that exhibits a distinct hydraulic behaviour was identified in the southern portion of the proposed CAZ. Static groundwater elevations in intermediate bedrock zone monitoring wells located within this area (e.g., M173, M174, M181, M187, M189, M194-1, M194-2 and M195) were observed to be much deeper compared to wells in the area of higher hydraulic conductivity monitoring wells introduced previously. While most wells in this group exhibit low permeability across the vertical profile, relatively more permeable fracture zones were identified in some boreholes (e.g., M189, M187 and M194-1).

The karst conduits found within the southwestern and central portions of the CAZ (BluMetric, 2017) do not appear to be directly influencing water levels in the aforementioned area of higher hydraulic conductivity in the northern portion of the proposed CAZ and south part of the landfill property. This higher hydraulic conductivity area lies upgradient of the karst and includes an area of artesian conditions near its southern/eastern boundary (e.g. M167, M178R-2 and -3). The presence of artesian conditions in juxtaposition to karst is of interest as karst conduits are characterized by relatively high hydraulic conductivities. If the entire site were affected by the karst, one would not expect the presence of areas with such high hydraulic heads (artesian conditions), rather the karst would serve to act as a drain, keeping heads low.

The groundwater piezometric contours and orientations of groundwater flow for the intermediate bedrock in the area of well-connected fractures south of the landfill and east of the landfill access road can be distinguished by periods of higher groundwater levels and periods of lower groundwater levels. During periods of high groundwater levels, the groundwater generally flows south-southeast across this area toward Beechwood Road. Groundwater from the southern edge of the landfill east of the entrance road flows towards the southeast in the direction of well location M105 and continues southeastward toward Beechwood Road. Based on the water level contours, groundwater flows eastward in the intermediate bedrock flow zone south of the landfill, and continues toward the east-southeast. During periods of low water level, the data suggest that a groundwater divide is established south of Beechwood Road, along an approximate orientation from northwest to southeast. The groundwater divide is present only during periods of low water levels; at other times, the flow is more consistently southeastward.

Flownets developed over the past several years indicate that the groundwater flow continues in a southeastward orientation across the properties that are proposed to be used for the CAZ. Monitoring wells outside of the well-connected area typically exhibit much lower water levels than the wells within the area. Monitoring wells within this area had similar water levels to each other, which is indicative of an environment of higher bulk rock hydraulic conductivity and lower hydraulic gradients. The identification of karst systems in the southwest and southeast portions of the proposed CAZ area is consistent with this interpretation.

The implication of the changing flow direction seen in the intermediate bedrock is that hydraulically downgradient locations within the intermediate flow zone will vary with season, and that an appropriate monitoring network to assess groundwater quality in the downgradient flow direction will need to comprise a network of monitoring wells at various locations. A corollary to this is that the changing groundwater flow directions in the intermediate flow zone will cause potential leachate plumes to shift in flow direction with season, thereby ensuring that a network of monitoring wells is capable of detecting their presence.

Groundwater from the intermediate bedrock groundwater flow zone is believed to be naturally discharging to ground surface in a large wet area located in the central portion of the proposed CAZ (BluMetric, 2018). Covering approximately 500 m by 100 m, this low lying area extends between well locations M178/M178R and M173/M194. This diffuse discharge area is located on the north side of the local shallow groundwater flow divide that corresponds to the topographically low area, as described above in section 4.1.2.1.

Karst features have been observed south of Beechwood Road in the central portions of the proposed CAZ area. The karst assessment (BluMetric, 2017) revealed that three distinct karst conditions exist within the proposed CAZ:

1. A deep, likely paleokarst-controlled, conduit system in the west;
2. A shallower conduit system developing under post-glacial conditions in the east (represented by a groundwater trough); and,
3. A very shallow epikarst, located in areas of shallow soil over bedrock.

The karst conduits drain portions of the southwestern and central portions of the CAZ but do not appear to be influencing water levels in the area of the leachate impacted plume (see Section 4.1.3). Additionally, the supplementary study conducted by the karst expert (BluMetric, 2017) of the unnamed creek running from northeast to southwest along the southeast limits of the proposed CAZ confirm that, while minor losses or gains from shallow bedrock in the vicinity of the creek cannot be ruled out, there is no evidence of karst interconnections within the proposed CAZ.

Area North and Northwest of Landfill

The area north and northwest of the landfill footprint, between the landfill and Marysville Creek, has been identified through hydraulic testing as an area where relatively lower hydraulic conductivity exists. This does not imply that there is zero groundwater flow through this area, but rather that the groundwater flow rate is lower than in other areas around the landfill site.

Marysville Creek is the primary potential receptor and should continue to be monitored north of the landfill. The extensive amount of monitoring to date, including testing for 1,4-dioxane and other primary leachate indicators, demonstrates that impacts have not been identified in the groundwater adjacent to the creek or in the surface water in the creek.

Impacts are seen in the groundwater within approximately 50 metres north and west of the unlined Phase 1 portion of the landfill (see section 4.1.3); however, because of the lower hydraulic conductivity and slow rate of groundwater flow, no impacts are observed in groundwater along the creek.

4.2.3 Deep Bedrock

The deep bedrock zone is defined as groundwater occurring greater than approximately 30 m below the top of bedrock. The deep groundwater is saline and not suitable for potable use. There is limited hydraulic interaction between the intermediate bedrock flow zone and the deep bedrock because of the differences in groundwater density related to salinity. Deep bedrock groundwater generally flows to the south in a horizontal direction, although vertical components of flow may also exist. Bulk rock hydraulic conductivity is generally lower at depths greater than 30 m below the top of bedrock, and fracture apertures are generally smaller below this depth. It follows that the movement of groundwater in the deep bedrock will be slower than in the shallow and intermediate bedrock flow zones.

4.3 GROUNDWATER QUALITY AND EXTENT OF IMPACTS

Background groundwater quality in the shallow and intermediate bedrock flow zones is characterized by geochemistry in several monitoring wells on the landfill property, as described in the latest EMP (BluMetric, 2016c). The primary indicators that are used to delineate impacts from landfill leachate at the site are 1,4-dioxane and alkalinity. 1,4-dioxane is a synthetic volatile organic compound (VOC) used as a chemical stabilizer for chlorinated solvents that does not exist in nature, is entirely miscible in water and does not readily biodegrade or adsorb onto soils or rock (U.S. EPA, 2014). Consequently, the presence of 1,4-dioxane in groundwater at detectable concentrations (> 0.001 mg/L) is used to indicate the furthest extent of impacts. In addition, where 1,4-dioxane is detected, alkalinity has been found to be generally above 400 mg/L. Other parameters are also used to assist in determining impacts and are included in the routine monitoring program.

Groundwater sample data collected from on-site monitoring wells indicate that leachate impacted groundwater is flowing from the northwest corner of the unlined Phase 1 footprint of the landfill in the shallow and intermediate bedrock groundwater flow zones. Figure 6 and Figure 7 in BluMetric (2018) illustrate on a site plan the approximate extents of the impacted area in the shallow and intermediate bedrock flow zones, respectively.

In the shallow groundwater zone north of Beechwood Road, impacts from landfill leachate are evident at monitoring wells M100, M101, M103 and M104 north and west of the Phase 1 landfill cell. Further downgradient, in particular along Marysville Creek, no impacts have been observed in the shallow groundwater. Similarly, monitoring well M41, located approximately 25 m south from the landfill footprint, has been impacted by leachate while no subsurface impacts from landfill leachate have been observed at shallow groundwater monitoring locations farther downgradient (e.g., M54-4 or M70-3, located south and southeast of the landfill, respectively). An area of shallow groundwater discharge has been delineated within the proposed CAZ, approximately 400 m south of Beechwood Road in an area just upgradient (north) from the local surface water course that extends between two dug ponds (see Figure 6 in BluMetric (2018)).

In the intermediate bedrock groundwater zone, impacts are evident within 50 m north of the landfill footprint at monitoring wells M6-3 and OW4 where the highest concentrations of 1,4-dioxane have been measured, while no evidence of impacts is seen further downgradient, closer to Marysville Creek. This is consistent with the hydraulic testing results which show an area of low hydraulic conductivity north and northwest of the landfill.

There is no evidence of impacts in any of the monitoring wells located to the west of the landfill footprint, nor to the south of the landfill footprint and west of the site entrance road.

Along the eastern boundary of the landfill property, 1,4-dioxane has been detected above the RUL of 0.001 mg/L at monitoring wells M168 and M170. The leachate impacted groundwater plume extends onto the southwestern corner of the property located to the east of the southeast limit of the WM property, up to monitoring well M192. Figure 3, derived from Figure 7 in BluMetric (2018), provides a detailed view of the eastern edge of the delineated area of landfill leachate impacted groundwater in the intermediate bedrock flow zone.

South of the landfill, 1,4-dioxane has been detected in monitoring wells located on the landfill property, north of Beechwood Road and east of the site access road. Landfill leachate impacts are also seen in intermediate bedrock groundwater monitors located within the north and central portion of the proposed CAZ at concentrations above the RUL of 0.001 mg/L and show impact to groundwater quality originating from the landfill.

Based on the results of previous hydrogeological investigations and the latest iteration reported in this document, it is concluded that groundwater impacts have been delineated and extend downgradient from the landfill onto the proposed CAZ as far southwest, south and southeast as well locations M64-2, M178R and M167, respectively.

5. RECOMMENDATIONS FOR CONTAMINANT ATTENUATION ZONE

Figure 4 shows the properties south of Beechwood Road where WM owns or controls the groundwater rights, as well as the updated proposed CAZ. The impacted area has been delineated conservatively using the detection limit for 1,4-dioxane (0.001 mg/L). Based on 1,4-dioxane concentration results collected since 2013 from an extensive network of hydraulically active groundwater monitoring wells, the extent of the contaminant plume originating from the landfill has been adequately defined. The limits of the proposed CAZ extend a minimum buffer of 400 m downgradient of the distal extent of the delineated plume, which includes a number of unimpacted downgradient groundwater monitoring wells suitable for detecting potential landfill leachate impacts.

Eastern CAZ Limits: Recent monitoring results have confirmed that the groundwater in a small portion of the southwest corner of the property located to the east of the southeast corner of the landfill property limit has been impacted by landfill leachate (Figure 3). WM proposes to extend the eastern limit of the proposed Contaminant Attenuation Zone (CAZ) north of Beechwood Road by adding an area of approximately 20 acres east of the landfill property, shown as a dashed red outline on Figure 4, if an agreement can be reached with the property owner. If such a negotiated agreement cannot be achieved, WM will implement an alternative solution consisting of a purge well system located along the eastern landfill property limit, and designed to hydraulically control the off-site migration of landfill leachate groundwater in the intermediate bedrock flow zone.

Western CAZ Limits: The proposed CAZ extends westerly to Deseronto Road to include additional buffer. This is conservative considering the low permeability bedrock encountered in the western portion of the proposed CAZ area south of Beechwood Road, and the well-defined direction of groundwater flow in the intermediate bedrock in the northern portion of the CAZ in this area.

Respectfully submitted,
BluMetric Environmental Inc.

Madeleine Corriveau, M.Sc., P.Geo.
Senior Environmental Geochemist

Francois Richard, Ph.D., P.Geo.
Senior Hydrogeologist

6. REFERENCES

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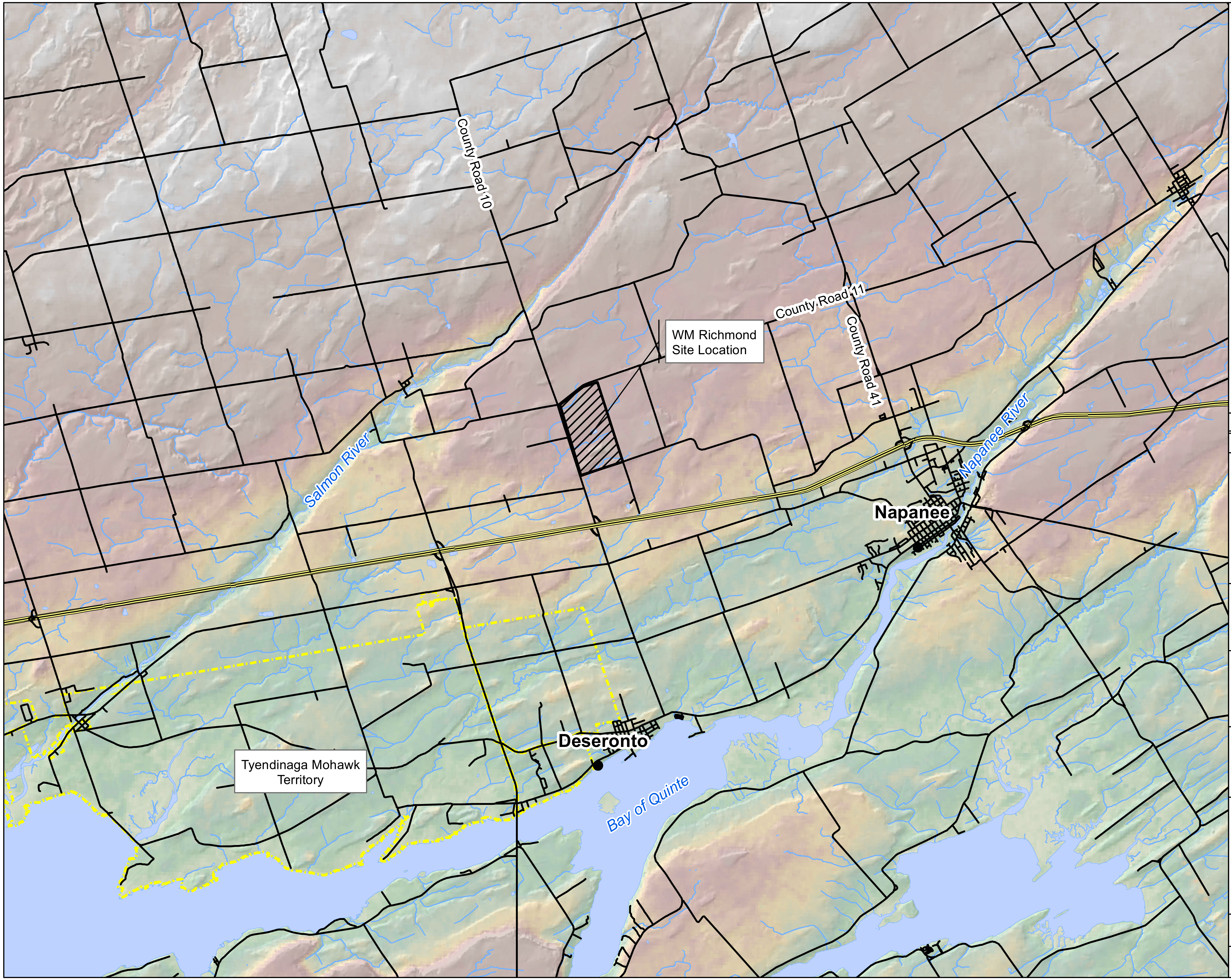
FIGURES



LEGEND

- Streams
- Water bodies
- ▨ Site Location

Topography (m)

High : 180

Low : 50

1				
REV.	DESCRIPTION	YY/MM/DD	BY	CHK

REFERENCES

DO NOT SCALE DRAWING.

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED ARE BASED ON 11"x17" FORMAT DRAWINGS.

0 1 2 4 Kilometres

N

CLIENT

WASTE MANAGEMENT

PROJECT

WASTE MANAGEMENT RICHMOND - COMPLEMENTARY CAZ INVESTIGATION

TITLE

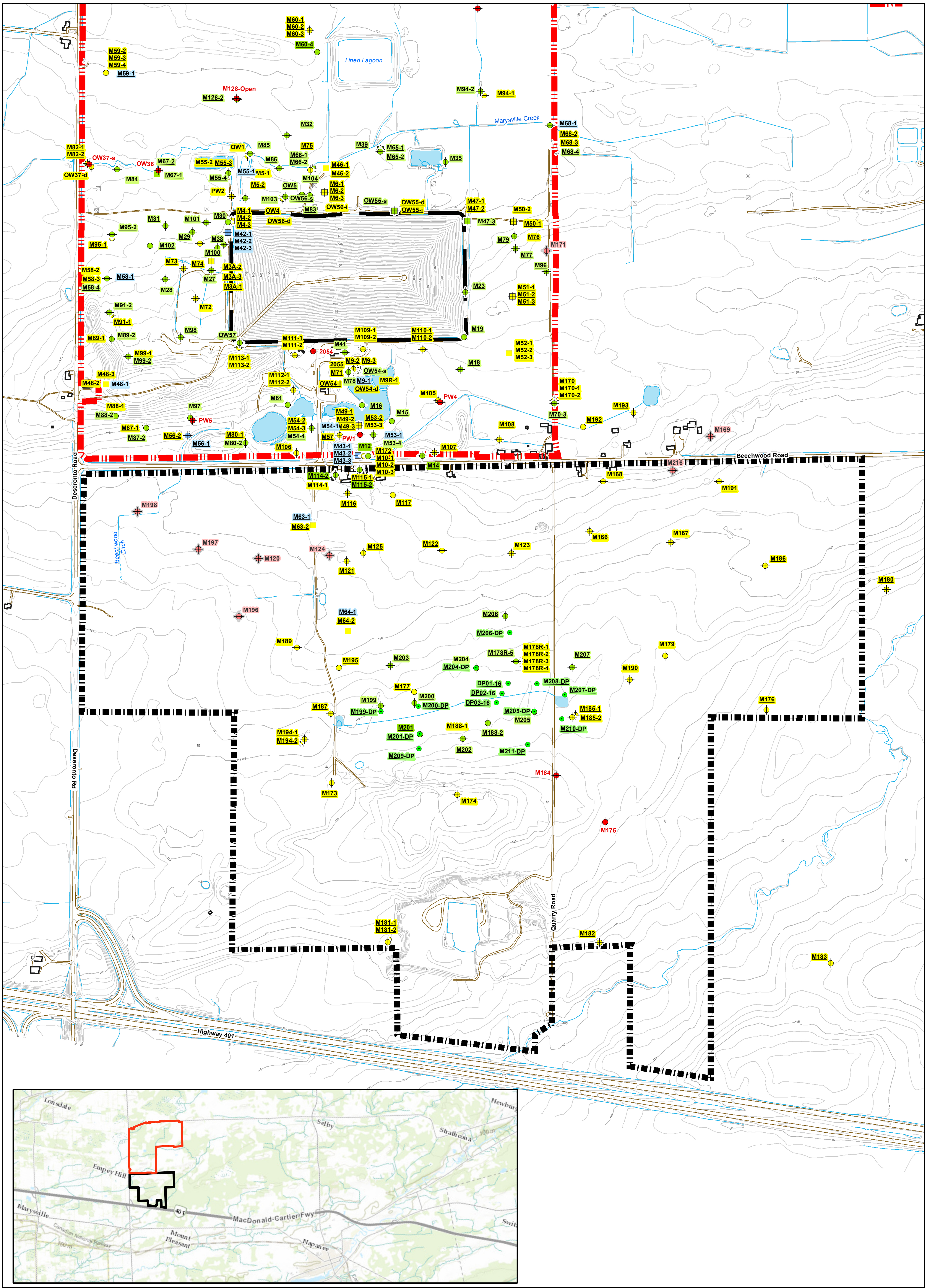
SITE LOCATION MAP

BluMetric™ Environmental

The Tower - The Woolen Mill,
4 Cataraqui St.,
Kingston, Ontario K7K 1Z7
TEL: (613) 531-2725
FAX: (613) 531-1852
Email: info@blumetric.ca
Web: http://www.blumetric.ca

PROJECT #	*DATE*
190222-02	May 09, 2019

DRAWN	*CHECKED*	*FIG NO.*	*REV*
IB	FR	1	0



LEGEND

OW36	Open Borehole
M198	Decommissioned Borehole
DP	Drive Point Piezometer

Single Well

M39	Active Shallow Monitoring Well
M9R-1	Active Intermediate Monitoring Well
M69-1	Active Deep Monitoring Well

Multi-Level Wells

M65-2	Active Shallow Monitoring Wells
M63-2	Active Intermediate Monitoring Wells
M42-1	Active Deep Monitoring Wells

☒	Hydro Tower
▭	Buildings
—	Roads
—	Topographic Contours (1 m)
—	Watercourses
▬	Property Boundary
▬	Waterbodies
▬	Previously Proposed Contaminant Attenuation Zone (CAZ), BluMetric (2016a)

REFERENCES

PROPRIETARY INFORMATION MAY NOT BE REPRODUCED OR DIVULGED WITHOUT PRIOR WRITTEN CONSENT OF BLUMETRIC ENVIRONMENTAL INC.
DO NOT SCALE DRAWING.
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED ARE BASED ON 11"x17" FORMAT DRAWINGS.
-UNITS: METERS
-PROJECTION: UTM NAD83CSRS ZONE 18
-DATA SOURCE: WM CANADA, BLUMETRIC, OMNR, NRCAN

N

0 25 50 100 150 200
Metres

CLIENT

WASTE MANAGEMENT

PROJECT

WASTE MANAGEMENT RICHMOND - COMPLEMENTARY CAZ INVESTIGATION

TITLE

SITE PLAN AND MONITORING LOCATIONS

BluMetric Environmental
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Kingston, Ontario K7K 1Z7
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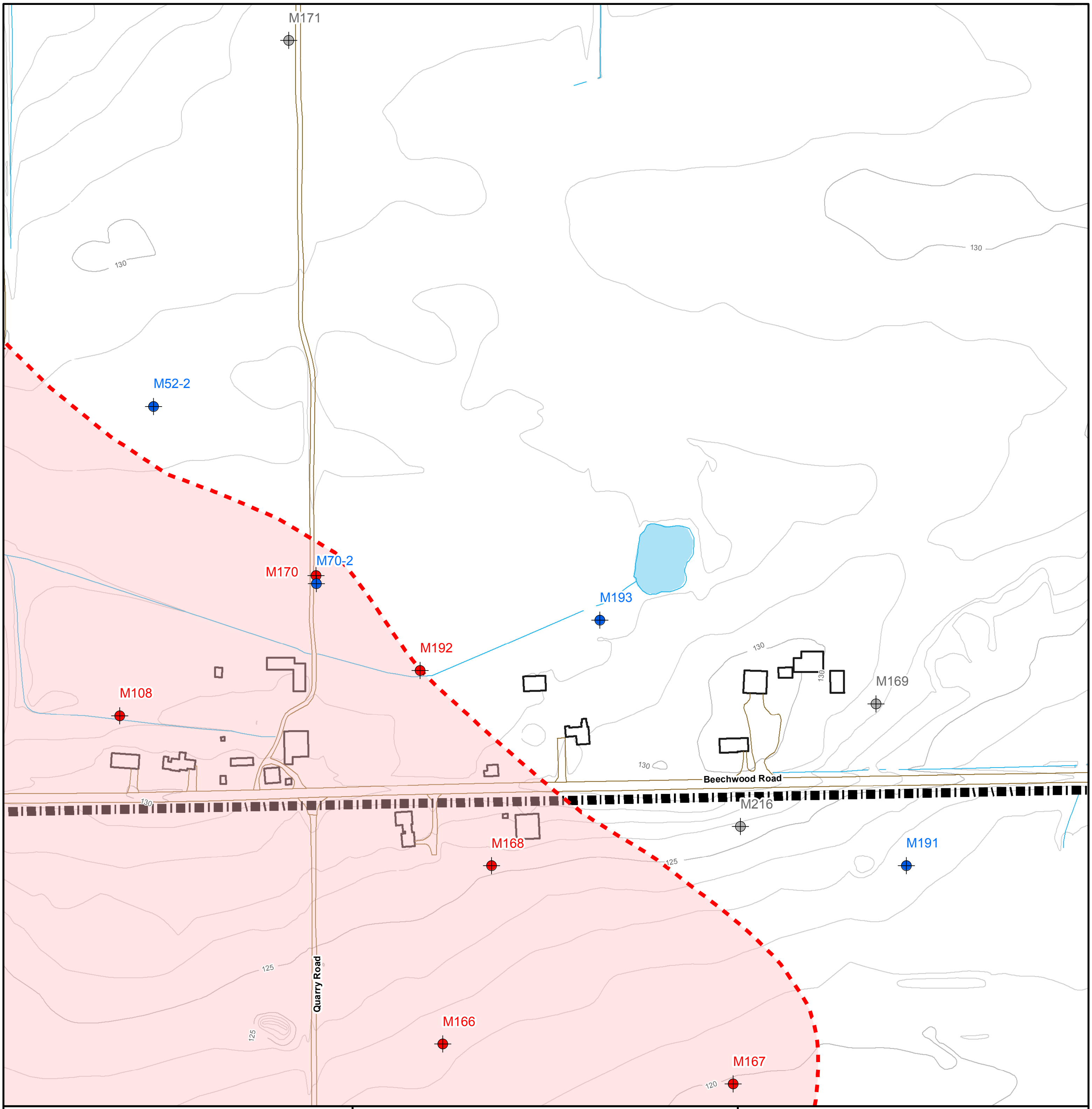
FAX: (613) 531-1852
Email: info@blumetric.ca
Web: http://www.blumetric.ca

PROJECT #		DATE	
190222-02		May, 2019	
DRAWN	CHECKED	FIG NO.	REV
AL	FR	2	0



LEGEND

● **M64-2**	Intermediate Bedrock Monitoring Well (No 1,4 dioxane impacts)
● **M121**	Intermediate Bedrock Monitoring Well (1,4 dioxane ≥ 0.001 mg/L)
○ **M121**	Intermediate Bedrock Monitoring Well (no results1,4 dioxane)
● **M169**	Decomissioned Intermediate Bedrock Monitoring Well
—	Topographic Contour Lines
—	Surface Water
▬ ▬	Proposed Contaminant Attenuation Zone (CAZ)
🟥	Approximate Extent of Known 1,4 Dioxane Impacted Area

REFERENCES

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N W E S

0 50 100 Meters

The Tower - The Woolen Mill,
4 Cataraqui St.,
Kingston, Ontario K7K 1Z7
TEL: (613) 531-2725
FAX: (613) 531-1852
Email: info@blumetric.ca
Web: http://www.blumetric.ca

CLIENT

PROJECT

WASTE MANAGEMENT RICHMOND - COMPLEMENTARY CAZ INVESTIGATION

TITLE

Delineation of Eastern Edge of 1,4 Dioxane Impacted Area – Intermediate Bedrock Groundwater Flow Zone

PROJECT #	DATE
190222-02	May 13, 2019

DRAWN	CHECKED	FIG NO.	REV
AL	MC	03	0

REV.	DESCRIPTION	YY/MM/DD	BY	CHK
1				

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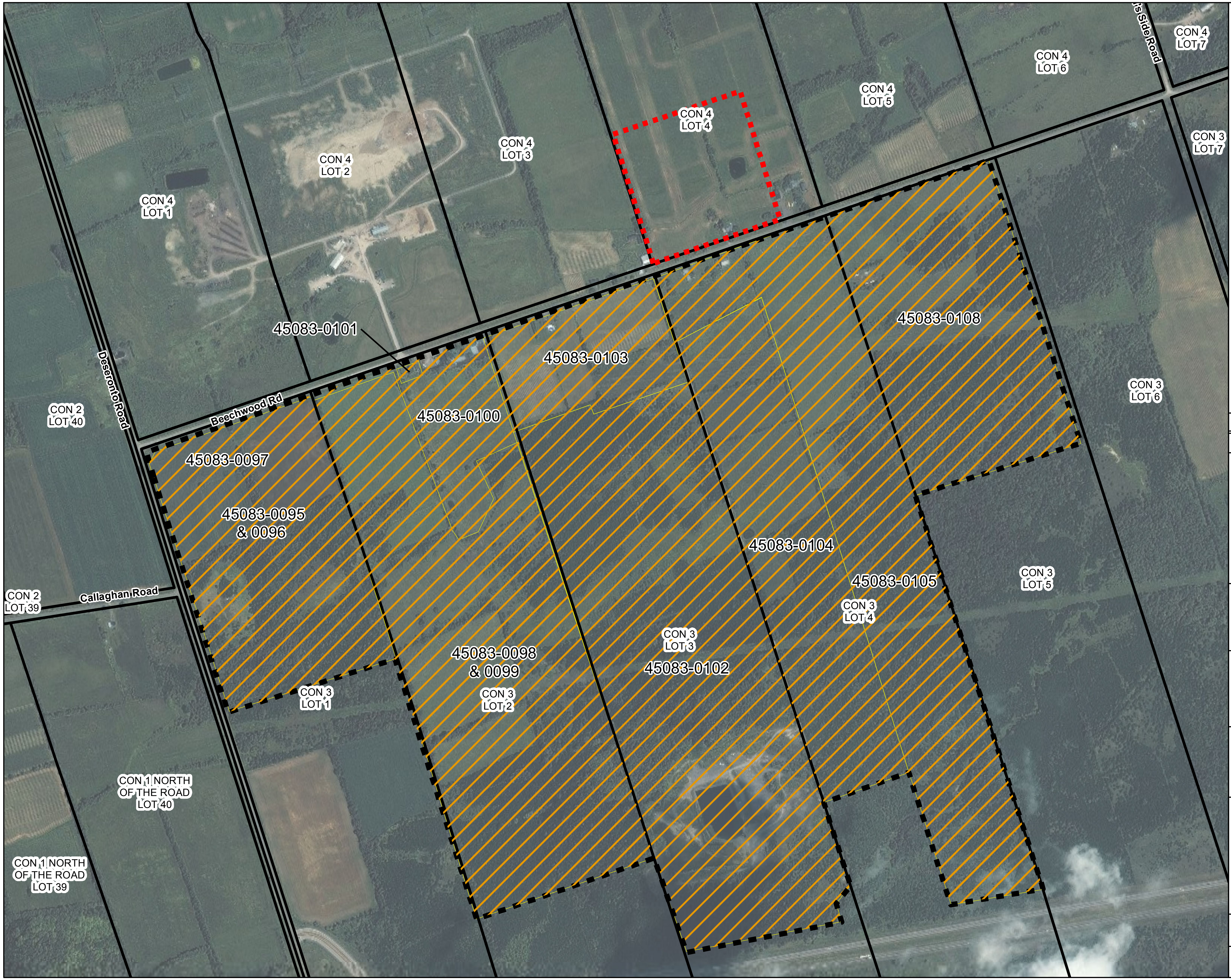

LEGEND

▨ WM Owned Property

▭ Updated Proposed Contaminant Attenuation Zone (CAZ)

▭ Potential Supplementary CAZ Boundary

▭ Lot Parcels

REV.	DESCRIPTION	YY/MM/DD	BY	CHK
1				

REFERENCES

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0 100 200 Metres

N W E S

CLIENT

WASTE MANAGEMENT

PROJECT

WASTE MANAGEMENT RICHMOND -
COMPLEMENTARY CAZ INVESTIGATION

TITLE

PROPERTIES INCLUDED IN
THE PROPOSED CAZ

BluMetric™ Environmental

3108 Carp Road PO Box 430
Ottawa, Ontario K0A 1L0
TEL: (613) 839-3053
FAX: (613) 839-5376
Email: info@blumetric.ca
Web: http://www.blumetric.ca

PROJECT #	*DATE*		
190222-02	May, 2019		
DRAWN	*CHECKED*	*FIG NO.*	*REV*
AL	FR	4	0

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APPENDIX A

Borehole Log

Project No: 190222-02

Project: Complementary CAZ Investigation

Client: Waste Management

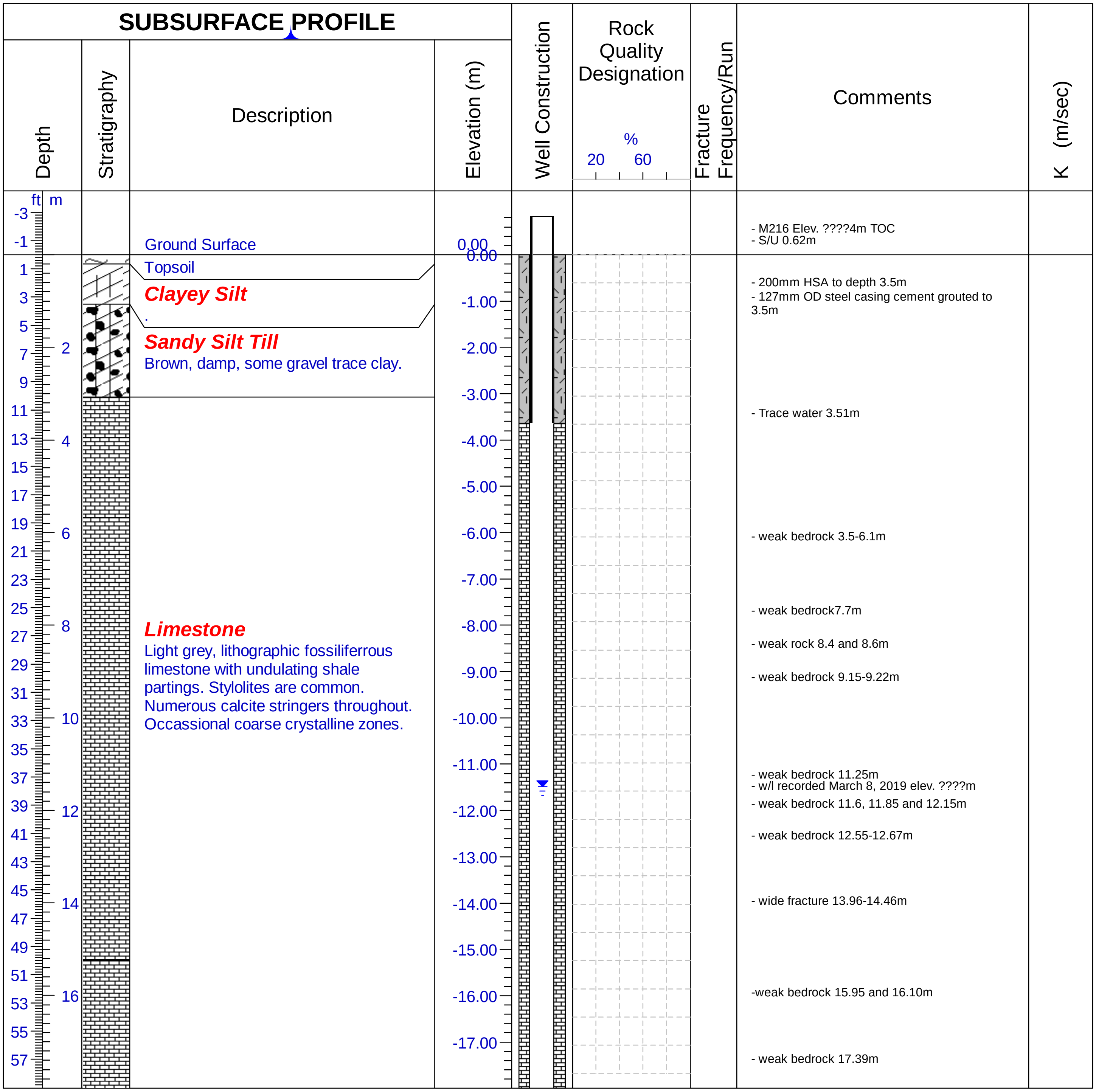
Location: Richmond Landfill, Napanee, ON

Well ID: M216

Decommissioned

Easting: 336216
Northing: 4902792
Field Personnel: B.McC.

SUBSURFACE PROFILE



Ground Surface

Topsoil

Clayey Silt

.

Sandy Silt Till
Brown, damp, some gravel trace clay.

Limestone
Light grey, lithographic fossiliferrous limestone with undulating shale partings. Stylolites are common. Numerous calcite stringers throughout. Occassional coarse crystalline zones.

- M216 Elev. ????4m TOC
- S/U 0.62m

- 200mm HSA to depth 3.5m
- 127mm OD steel casing cement grouted to 3.5m

- Trace water 3.51m

- weak bedrock 3.5-6.1m

- weak bedrock7.7m

- weak rock 8.4 and 8.6m

- weak bedrock 9.15-9.22m

- weak bedrock 11.25m
- w/l recorded March 8, 2019 elev. ????m
- weak bedrock 11.6, 11.85 and 12.15m

- weak bedrock 12.55-12.67m

- wide fracture 13.96-14.46m

-weak bedrock 15.95 and 16.10m

- weak bedrock 17.39m

Drilled By: GET Drilling Ltd.
Drill Method: Air Rotary Hammer
Hole Size: 4.5" (114mm)
Drill Date: March 1, 4, 2019

Drill Angle: Vertical
Azimuth: n.a.
Datum: NAD83
Checked By: M.C.

Sheet: 1 of 2

Project No: 190222-02

Project: Complementary CAZ Investigation

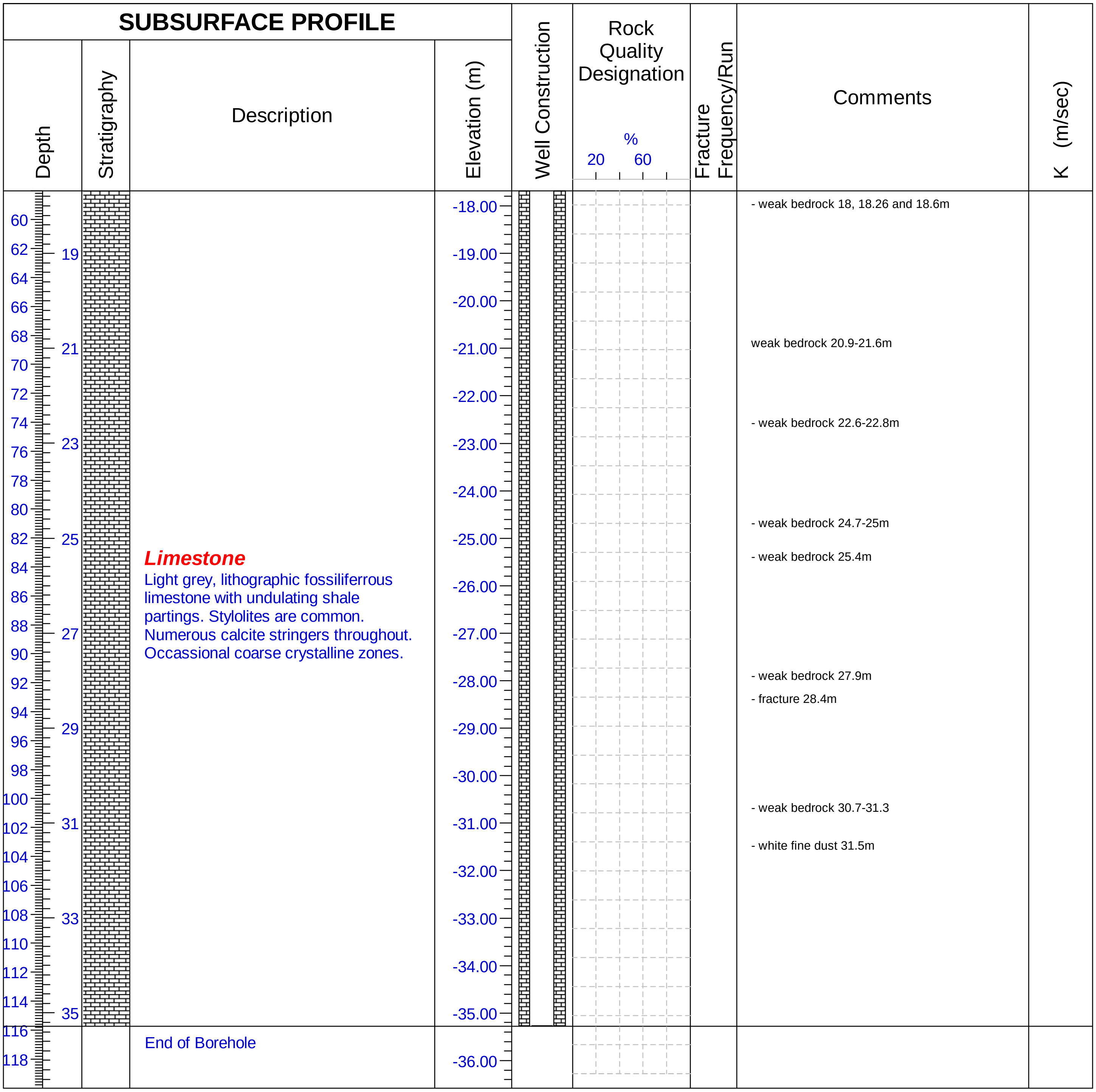
Client: Waste Management

Location: Richmond Landfill, Napanee, ON

Well ID: M216-OPEN Decommissioned

Easting: 336216
Northing: 4902792
Field Personnel: B.McC.

SUBSURFACE PROFILE



Limestone

Light grey, lithographic fossiliferrous limestone with undulating shale partings. Stylolites are common. Numerous calcite stringers throughout. Occassional coarse crystalline zones.

End of Borehole

- weak bedrock 18, 18.26 and 18.6m

weak bedrock 20.9-21.6m

- weak bedrock 22.6-22.8m
- weak bedrock 24.7-25m
- weak bedrock 25.4m
- weak bedrock 27.9m
- fracture 28.4m
- weak bedrock 30.7-31.3
- white fine dust 31.5m

Drilled By: GET Drilling Ltd.
Drill Method: Air Rotary Hammer
Hole Size: 4.5" (114mm)
Drill Date: March 1, 4, 2019

Drill Angle: Vertical
Azimuth: n.a.
Datum: NAD83
Checked By: M.C.

Sheet: 2 of 2

BluMetric Environmental Inc.

BluMetric Offices

4-41 de Valcourt Street
Gatineau, Québec
Canada J8T 8G9
Téléphone: 819 243.7555
Télécopieur: 819 243.0167
gatineau@blumetric.ca

3108 Carp Road
PO Box 430
Ottawa, Ontario
Canada K0A 1L0
Tel: 613.839.3053
Fax: 613.839.5376
ottawa@blumetric.ca

825 Milner Avenue
Toronto, Ontario
Canada M1B 3C3
Tel: 877.487.8436
toronto@blumetric.ca

276, Saint-Jacques Street
Suite 818
Montréal, Québec
Canada H2Y 1N3
Téléphone: 514 844.7199
Télécopieur: 514 841.9111
montreal@blumetric.ca

4 Cataraqui Street
The Tower, The Woolen Mill
Kingston, Ontario
Canada K7K 1Z7
Tel: 613.531.2725
Fax: 613.531.1852
kingston@blumetric.ca

4916 – 49th Street
Yellowknife, NT
Canada X1A 1P3
Tel: 867.873.3500
Fax: 867.873.3499
yellowknife@blumetric.ca

171 Victoria Street North
Kitchener, Ontario
Canada N2H 5C5
Tel: 519.742.6685
Fax: 519.742.9810
kitchener@blumetric.ca

102-957 Cambrian Heights Drive
Sudbury, Ontario
Canada P3C 5S5
Tel: 705.525.6075
Fax: 705.525.6077
sudbury@blumetric.ca

PO Box 36
Shebandowan, Ontario
Canada P0T 2T0
Tel: 807.707.1687
thunderbay@blumetric.ca

www.blumetric.ca