FINAL REPORT

HYDROGEOLOGIC ASSESSMENT REPORT
PROPOSED WEST CARLETON ENVIRONMENTAL CENTRE LANDFILL
OTTAWA, ONTARIO

Submitted to:

WASTE MANAGEMENT OF CANADA CORPORATION

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1. INTRODUCTION

This report provides a Hydrogeological Assessment of the proposed waste disposal facility to be constructed and operated at the West Carleton Environmental Centre (WCEC) in Ottawa, Ontario. The report is being submitted to the Ontario Ministry of Environment as part of the technical documentation required for an application being made by Waste Management (WM) for the approval of a waste disposal site under the *Environmental Protection Act*. This report is intended to address the requirements of Section 8 of Ontario Regulation 232/98 and Section 4.3 of the Landfill Standards Guideline[1].

The WCEC property includes a closed 35 hectare landfill and a proposed 37.8 hectare landfill to be located north of the closed landfill. The total site area is approximately 233 hectares located on Part of Lots 2, 3 and 4, Concession II, and Lots 3, 4 and the South Half of Lot 5, Concession III of the former Township of West Carleton (Geographic Township of Huntley), now in the City of Ottawa, Ontario (see Figure 1). The total site area includes 51.4 hectares of land east of the closed landfill site which were designated as Contaminated Attenuation Zones (CAZs) in 2006 and 2011. The landfill site layout and features, and the locations of the adjacent CAZs are shown on Figure 1. The existing landfill is closed to further waste disposal, and has been capped with final cover and vegetative layers.

1.1 Scope of Report

This report provides a hydrogeologic assessment of the proposed landfill development at the West Carleton Environmental Centre in Ottawa, Ontario. The purpose of the assessment is to provide the information necessary to adequately design the landfill site, and to ensure that it can be effectively monitored and acceptable contingency plans can be developed. The specific objectives of this hydrogeological assessment are to determine the characteristics of the subsurface materials (overburden and bedrock); to define the groundwater flow characteristics and potential contaminant plume migration pathways; to provide the information necessary to establish an appropriate groundwater monitoring network; and determine the feasibility of contingency plans for the control of contamination migration from the landfill, if necessary.

This assessment has been completed within the context that the design of the new WCEC landfill is in accordance with the Generic Option 2 design for groundwater protection specified in Ontario Regulation 232/98. According to the Landfill Standards Guideline, although the generic design is fully protective of groundwater quality, a hydrogeological assessment is still needed

[1] Landfill Standards, A Guideline on the Regulatory and Approval Requirements for New or Expanding Landfill Sites; Ontario Ministry of Environment, January 2012.

"to ensure that the conditions for use of the generic designs are present, and to ensure that effective groundwater monitoring and leachate contingency plans can be developed for the site".

The focus of this report is to assess the potential impacts to groundwater in the vicinity of the proposed landfill footprint. This report does not describe the corrective actions that have been taken at the existing (now closed) WM Ottawa Landfill, except where they are relevant to potential impacts on the portion of the property where the new landfill footprint is to be developed. The groundwater impacts from the closed landfill are mitigated by a final clay soil and synthetic cap, an operating purge well system, a landfill gas extraction system, and the establishment of Contaminant Attenuation Zones (CAZs). The closed landfill and CAZs are subject to continued post-closure monitoring and annual reporting requirements that are beyond the scope of this report.

For purposes of this report, the term "WCEC property" refers to the On-Site Study Area (described below in Section 2.0) where the new landfill is to be located, and the existing (closed) landfill property of 155.4 hectares as described in the current Environmental Compliance Approval No. A461002. Together, these two overlapping parcels of land comprise the total site area of 233 hectares for the WCEC property.

1.2 DESCRIPTION OF THE PROPOSED WCEC LANDFILL FOOTPRINT

The proposed landfill is to be located north of the existing closed landfill. The location and layout of the proposed landfill final contours, stormwater management ponds, access roads and other site features are shown on Figure 2 (reproduced entirely from Drawing No. 131-19416-00-4 of the Draft Development and Operations Report, prepared by WSP Canada Inc.). The southern half of the proposed landfill footprint is on WM-owned lands and the northern half is on lands that WM has options to purchase. A 100 m buffer is to be maintained between the north limit of the footprint and the lands further to the north owned by WM but not included as part of the expanded landfill, in accordance with Ontario Regulation 232/98. An approximate 380 m buffer is maintained between the east limit of the footprint and Carp Road. A light industrial building (known as the Laurysen building) is situated in the eastern portion of WM optioned lands, which WM anticipates using for equipment storage/maintenance or waste diversion activities in the future. An approximate 35 to 50 m buffer is maintained between the toe of slope of the existing and new landfills, thus allowing sufficient area for a new waste haul road to the new footprint, and for maintenance and monitoring access. A buffer of approximately 120 m is maintained between the west limit of the proposed footprint and William Mooney Road. This buffer preserves a portion of the existing woodlot within the west part of the WM-owned lands.

The final contours of the proposed landfill are shown in Figure 2 and reflect a rectangular landform with a maximum elevation of 155 mASL. The contours reflect maximum side slopes of 4H to 1V, and a minimum crown slope of 5%. The total footprint area of the new landfill is 37.8 ha.

2. STUDY AREA

The specific On-Site and Regional Study Areas for this hydrogeologic assessment are listed below, and are shown in Figure 3:

On-Site .... the lands owned and/or optioned by Waste Management, required for the proposed WCEC landfill and surrounding buffer areas. The lands lie immediately north of the existing landfill footprint and extend west to William Mooney Road, east to Carp Road and north to the northern boundary of lands owned by Waste Management but not included as part of the expanded landfill; and

Regional .... the lands beyond the On-Site Study Area, within natural hydrogeologic boundaries, including Huntley Creek to the north, Feedmill Creek to the south, and extending to Carp River in the east. The upgradient boundary of the Regional Study Area extends a minimum of 500 metres beyond the boundary of the WCEC property.

3. STUDY METHODOLOGY

This hydrogeologic assessment was completed through a series of steps that were based, in part, on a number of previous site investigations and reports prepared for the Environmental Assessment (EA) approval (Geology and Hydrogeology Existing Conditions Report, Geology and Hydrogeology Comparative Evaluation Technical Report, and Detailed Impact Assessment). The potential effects that were derived for the Preferred Alternative Landfill Footprint, as identified in the EA were reviewed within the context of the more detailed landfill design documented in the Draft Development and Operations Report prepared by WSP Canada Inc. Additional evaluations were then carried out, where necessary, in order to augment the previous work undertaken.

Based on these evaluations, the potential effects, mitigation measures, and net effects associated with the detailed landfill design were confirmed and documented.

The general requirements for groundwater and surface water monitoring are also presented in this report. Details of the monitoring programs, including specific sampling locations, analytical parameters and sampling frequencies, are presented in the Environmental Monitoring Plan (EMP).

4. DESCRIPTION OF REGIONAL STUDY AREA

In this section, a description of the physical setting of the Regional Study Area is presented. This includes a discussion of the physiography and topography, geology, physical hydrogeology and groundwater quality.

4.1 PHYSIOGRAPHY AND TOPOGRAPHY

The Regional Study Area lies within the Ottawa Valley clay plain physiographic sub-region, part of the Ottawa-St. Lawrence Lowlands, as classified by Chapman and Putnam (1984). The physiography in the area ranges from sandy upland areas in the northwest and west to poorly drained swampy areas, clay plains and the Carp River floodplain toward the northeast. The primary natural topographic feature in the area is a northwest-southeast trending sand and gravel ridge, which has historically been exploited for aggregate extraction. This feature is described in more detail in Section 4.2.4.

Within the Regional Study Area, the natural topography, which has been modified by extraction and waste disposal activities, ranges from an elevation of approximately 131 metres above sea level (mASL) southwest of the existing landfill site to less than 100 mASL along Carp River. The dominant man-made topographic features in the study area are the closed WM Ottawa Landfill, which extends to an elevation of approximately 172 mASL, and the Huntley Quarry, which has been mined to a floor elevation of less than 75 mASL (refer to Figure 4).

The Regional Study Area is situated within the Carp River watershed. The watershed drains approximately 306 km^2 of land in the northwestern portion of the City of Ottawa (Robinson Consultants, 2004). Carp River is located approximately four kilometres northeast of the existing landfill (see Figure 3), and discharges to the Ottawa River at Fitzroy Harbour, approximately 20 km northwest of the landfill property. Surface drainage within the area is controlled by the ground surface topography and small tributaries of Carp River, as modified by the surrounding quarry operations and the Highway 417 drainage system. North and west of the existing landfill site, surface drainage flows within the Huntley Creek subwatershed, and discharges via Huntley Creek to Carp River east of Huntmar Road, approximately 1 km north of Richardson Side Road. The Huntley Quarry, operated by AECON, is located within this subwatershed and pumps groundwater from the quarry into Huntley Creek.

East and southeast of the existing landfill site, surface drainage flows within the Feedmill Creek subwatershed. Feedmill Creek discharges to Carp River east of Huntmar Road, approximately 0.3 km north of Highway 417. Surface water flow along Highway 417 within the study area is controlled by a system of ditches, catch basins and culverts, and discharges into Feedmill Creek. Because of these drainage features, surface water downgradient of the existing landfill property does not flow from north to south across Highway 417.

A more detailed description of local surface water flow is provided in Section 5.1.

4.2 GEOLOGY

4.2.1 Surficial Geology

The Regional Study Area lies within the upper Ottawa clay plains region. The surficial deposits in this region consist of glacial and related materials from the late Wisconsian glaciation. During this glacial period, thick sequences of sand and gravel were deposited along the Ottawa River valley, followed by deposits of silt and clay during encroachment of the Champlain Sea. The surficial geology within the study area is shown on Figure 5.

The materials observed in the vicinity of the WM Ottawa Landfill are interpreted to be ice-contact stratified drift sediments, consisting of a mixture of poorly to well-sorted, stratified gravels and sands, interbedded with lenses of silty sand-gravel till (GSC, 1982; Natural Resources Canada, 2002). The deposits are interpreted to have been submerged during the Champlain Sea encroachment, and therefore show indications of re-working in a nearshore, subaqueous environment. The deposits are horizontally bedded and often display evidence of cross-bedding, as observed in excavation faces on and near the existing landfill property. Across the area covering the proposed landfill footprint (known as the "North Envelope" in the Environmental Assessment), sand and gravel are the predominant surficial deposits to the east; these grade into sand and till deposits to the west. Along the Highway 417 alignment west of the WCEC site boundary, shallow organic and till deposits overlie the limestone bedrock.

Closer to Carp River, thick deposits of silt, clay and organic materials (peat and muck) have been deposited in a lower energy, offshore marine environment consistent with the deeper waters of the Champlain Sea. Organic deposits are found on the southeastern portion of the Huntley Quarry property, east of Carp Road.

4.2.2 Bedrock Geology

The Regional Study Area is underlain by several carbonate rock-types. Throughout the majority of the portion of the Regional Study Area that encompasses the On-Site Study Area, bedrock consists of grey, fine to medium-grained fossiliferous limestone with some shaly or sandy interbeds. The bedrock is classified as the Bobcaygeon Formation, a member of the Middle Ordovician-aged Ottawa Group, and is described regionally as a limestone with shaly partings with intermittent sandstone (Derry Michener Booth & Wahl and OGS, 1989; Natural Resources Canada, 2002; Williams, 1991). Geologic mapping of the Huntley Quarry northeast of the landfill has interpreted the quarry to extend within the lower member of the Bobcaygeon Formation (Derry Michener Booth & Wahl and OGS, 1989). The bedrock is horizontally-bedded and discretely-fractured, with the fracture frequency decreasing with depth. The total estimated thickness of the Bobcaygeon Formation is approximately 95 metres, with the upper, middle and lower members being approximately 40, 25 and 30 metres thick, respectively.

Within the Regional Study Area, the Bobcaygeon Formation is in contact with interbedded silty dolostone, limestone, shale and sandstone of the underlying (older) Gull River Formation and overlying (younger) Verulam Formation, which is classified as limestone with shale interbeds. Both formations are also members of the Middle Ordovician-aged Ottawa Group. Within the Regional Study Area, lateral contacts between the bedrock formations are primarily along faults, with the exception of the contact between the Bobcaygeon and Gull River Formations in the southwest and southeast portions of the study area. The bedrock geology within the study area is shown on Figure 6.

The bedrock surface generally slopes at less than 1 degree in a northeasterly direction under the Regional Study Area.

4.2.3 Structural Features and Seismic Activity

The Ottawa River Valley rift zone, which developed from tectonic extension several million years ago, was created through the occurrence of block faulting to form the regional structural feature known as the Ottawa-Bonnechere graben. The Paleozoic formations in the Ottawa area are transected by steeply dipping normal faults associated with the rift zone, three of which are found within the Regional Study Area oriented from northwest to southeast (refer to Figure 6). Carp River follows the orientation of the Hazeldean Fault, which separates the Paleozoic bedrock found within the Regional Study Area from the much older Precambrian rocks that compose the Carp Ridge northeast of the study area. Another one of the regional faults (unnamed) is exposed in the Bobcaygeon Formation as a result of excavation in the Clarke Quarry located southeast of the WCEC property. This fault is described as a steeply-dipping normal fault system with a total downthrow of approximately 9 metres to the northeast. (Derry Michener Booth & Wahl and OGS, 1989).

Regionally, joints commonly occur close to faults and are parallel to them, suggesting a genetic relationship between the joints and faults (Natural Resources Canada, 2002).

Compared to active seismic areas around the world (e.g., Western North America, Eastern Asia), Eastern Canada is located in a stable continental region and, as a result, has a relatively low rate of earthquake activity. The Regional Study Area lies within the Western Quebec Seismic Zone (WQSZ), which covers the Ottawa Valley from Montreal to Temiscaming, as well as the Laurentians and Eastern Ontario (Natural Resources Canada, Earthquake Zones of Eastern Canada, http://earthquakescanada.nrcan.gc.ca). The urban areas of Montreal, Ottawa-Gatineau and Cornwall are located in this zone. The WQSZ is described as a zone of moderate seismic activity, with earthquakes occurring at an average frequency of once every five days. However, those large enough to be felt occur once every couple months. Within the WQSZ, the pattern of seismic activity is concentrated in two sub-zones: one along the Ottawa River and the second along a more active Montreal-Maniwaki axis. The largest recorded earthquake in the zone occurred near Temiscaming in 1935, at a magnitude of 6.2.

The seismic activity in the Ottawa region is not associated directly with any specific fault line. Rather, the activity in stable continental areas such as Eastern Canada and the WQSZ are believed to be related to the regional stress fields, with the earthquakes concentrated in general zones of weakness in the earth's crust (Natural Resources Canada, Earthquake Zones of Eastern Canada, http://earthquakescanada.nrcan.gc.ca).

4.2.4 Aggregate Resources

Aggregate resources, including sand, gravel and bedrock formations are found within the Regional Study Area. A detailed aggregate assessment was completed in 1993 by Gorrell Resource Investigations (GRI, 1993) within the former Regional Municipality of Ottawa-Carleton. A summary of the aggregate resources and restrictions identified within the study area is provided below.

Bedrock found within the western portion of the Regional Study Area consists of the Bobcaygeon Formation, a limestone with shaley interbeds. Parts of the formation are alkalide reactive and cannot be used for concrete aggregate (GRI, 1993). However, these portions of the formation are suitable for use as crushed stone. The formation is ranked as a Class 3 bedrock deposit (a ranking of 1 is a high value aggregate; a ranking of 5 is low value). Properties immediately east of Carp Road (Concession II of the Geographic Township of Huntley, Lots 3, 4 and the south half of Lot 5) are designated as a Limestone Resource Area in the City of Ottawa Official

Plan Schedule A (City of Ottawa, 2014). This area includes the Huntley Quarry as well as the concrete and aggregate production areas on the east side of Carp Road operated by AECON, Tomlinson Ltd., West Carleton Concrete, and CBM. The Clarke Quarry, located outside of the study area to the southwest of the landfill property and operated by AECON, is also designated as a Limestone Resource Area.

The remainder of the Regional Study Area toward Carp River is primarily underlain by the Verulam Formation, with a small area to the south that is interpreted by Williams et al (1984) as being underlain by the Gull River Formation. The Verulam Formation is a limestone with shale interbeds. Because of the thickness of the shale zones and beds, the formation is generally not suitable for use as concrete and asphalt aggregate, and is used as crushed stone only. The formation is ranked as a Class 5 (low value) bedrock deposit, and is not quarried within the Regional Study Area. The small area underlain by the Gull River Formation along Highway 417 is also not quarried at present; however, the western portion of the deposit is located within the designated Limestone Resource Area. The Gull River Formation, a silty dolostone with limestone, shale and some sandstone, is ranked as a Class 2 (moderate-high value) bedrock deposit. The eastern portion of the area underlain by Gull River Formation is within the City of Ottawa Urban Area (City of Ottawa, 2014) and is not suitable for the development of a quarry.

Sand and gravel resources are associated with glaciofluvial and nearshore beach ridge deposits oriented along the Carp Road corridor and underlying the eastern half of the WM Ottawa Landfill. These aggregate resource deposits have been identified as part of the much larger Galetta-Stittsville Ridge System (GRI, 1993). The portion of the ridge system from south of Stittsville to north of the WM Ottawa Landfill is classified as a Class 1 overburden deposit, which is defined as a high value sand-gravel resource with sufficient reserves and gradational characteristics to potentially support a large-scale aggregate operation (GRI, 1993). However, large areas of this Class 1 deposit have already been exhausted or are restricted from future extraction because of alternate land uses (roads, urban areas, subdivisions, existing landfill site, etc.), or because the remaining reserves are below the water table. Within the On-Site Study Area, the sand and gravel deposits are no longer designated as mineral resources in the Rural Policy Plan of the City of Ottawa Official Plan (City of Ottawa, 2014).

Elsewhere in the Regional Study Area toward Carp River, the overburden deposits consist of glacial till, silt, clay and organic deposits (peat and muck), which are not viable as an aggregate resource. There are no designated sand and gravel resource areas within the Regional Study Area. Clay has been identified as a potential overburden resource, primarily for use as landfill cover material (GRI, 1993); however, the market for the material is considered small and not sufficient to support a stand-alone operation.

4.3 HYDROGEOLOGY

4.3.1 Physical Hydrogeology

Groundwater occurs within the unconsolidated overburden units and the Paleozoic bedrock fracture systems found within the Regional Study Area. The general direction of regional groundwater flow is northeast toward Carp River. Water table elevations range from approximately 135 metres southwest of the existing landfill to between 92 and 105 metres along Carp River (Robinson Consultants, 2004). On a larger regional scale, Figure 7 illustrates the groundwater elevations (also known as the *hydraulic heads*) obtained from the MOE Water Well Record inventory. In general, groundwater flows from areas of higher hydraulic head toward areas of lower head. The highest groundwater elevations are observed southwest of the Regional Study Area, in Lanark County, with lower water table elevations along the Carp River corridor.

Locally, groundwater recharge occurs along the sand and gravel ridge and upland areas extending north and south of the existing landfill (Dillon, 2004; Robinson Consultants, 2004). Overall, the WCEC property and adjacent areas are generally interpreted as having strong to weak downward gradients, indicating that these areas are considered recharge zones.

In a regional aquifer vulnerability study completed for the City of Ottawa, the glaciofluvial and beach ridge deposits in the study area are identified as having a high to very high intrinsic vulnerability (Waterloo Hydrogeologic Inc. and CH2M Hill, 2001). A high groundwater recharge potential and relatively shallow depth to the water table are the principal factors in this determination of aquifer vulnerability.

The Mississippi-Rideau Source Protection Region has also completed an analysis of aquifer vulnerability within the Mississippi River and Rideau River watersheds as part of the Drinking Water Source Protection Program (Mississippi-Rideau Source Protection Region, 2011). The Regional Study Area, with the exception of the clay plains found east of Oak Creek Road toward Carp River (refer to the Surficial Geology on Figure 5) is classified as a high vulnerability aquifer, due to the shallow water table and permeable soil conditions. It should be noted that 89% of the Mississippi-Rideau Source Protection Region is designated as being underlain by highly vulnerable aquifers. The area is also classified as a significant groundwater recharge area (Mississippi-Rideau Source Protection Region, 2011).

Closer to Carp River, groundwater discharge zones occur, with upward hydraulic gradients becoming more pronounced in proximity to Carp River (Dillon, 2004). Intrinsic aquifer vulnerability in this area is classified as low to medium (Waterloo Hydrogeologic Inc. and CH2M Hill, 2001).

The hydrogeological unit of prime interest with regard to groundwater resource potential is the overburden-shallow bedrock zone. In areas of aggregate extraction, much of the overburden unit has been removed, and it is generally not considered to be a viable resource for groundwater supply. However, in localized areas, where the sand-gravel has not been removed and there is a sufficient saturated thickness, groundwater may be encountered and extracted from the overburden unit. The Paleozoic bedrock aquifers (primarily limestone, dolostone and sandstone) supply over 90% of the water wells within the Carp River watershed, whereas less than 5% of the wells are supplied by the overburden unit (Robinson Consultants, 2004).

Within the Regional Study Area, the largest permitted use of groundwater authorized under a Permit to Take Water (PTTW) from the Ontario Ministry of Environment is to dewater the Huntley Quarry, which is operated by AECON. The maximum allowable groundwater taking for this permit is 11.78 million litres per day (Dillon, 2004). The purge well system for the WM Ottawa Landfill is permitted to take 2.5 million litres of groundwater per day, and the Thunderbird Athletic Club at 1927 Richardson Side Road reportedly has a PTTW with a maximum allowable taking of 156,900 L/day. These are the only significant users identified under a PTTW in the Regional Study Area.

In the Carp River watershed study report (Robinson Consultants, 2004), it is noted that groundwater use from domestic wells in the watershed comprises less than 1% of the annual recharge, and that usage from all takings combined is estimated to be less than 10% of total recharge in the watershed.

4.3.2 Groundwater Quality

Groundwater quality within the Carp River watershed is generally acceptable for potable usage, and is free from recognizable regional-scale groundwater impact (Robinson Consultants, 2004). In a recent groundwater study along the Carp Road corridor, no widespread problems of health related parameters were detected in the groundwater (Dillon, 2004). Non-health related water quality parameters, such as total dissolved solids, hardness, iron, sulphate and chloride commonly exceeded the Ontario Drinking Water Standards, although the concentrations in the groundwater tend to vary considerably with the type of bedrock formation. Natural groundwater quality appears to be better in areas where the Verulam Formation aquifer is used for water supplies as compared to areas where the Bobcaygeon and Gull River Formation aquifers are used (Dillon, 2004). In general, the regional groundwater quality reflects the characteristics of the limestone bedrock, being dominated by calcium carbonate (hardness) and also containing iron and sulphur compounds (sulphate, hydrogen sulphide) from the shaley interbeds.

Elevated concentrations of sodium and chloride observed in groundwater along Carp Road and the Highway 417 corridor may be the result of road salting practices (Dillon, 2004; WESA, 2005). Extensive use of road salt along Carp Road, Highway 417 and the interchanges, combined with the high groundwater recharge potential, make aquifers in these areas particularly susceptible to impacts from road salting operations.

Impacts from other anthropogenic activities such as private sewage systems, industrial activities and agricultural operations are sometimes seen in isolated occurrences, but do not appear as widespread problems within the study area (Dillon, 2004; Robinson Consultants, 2004).

5. DETAILED DESCRIPTION OF EXISTING SITE CONDITIONS

In this section of the report, more detail is provided on the existing geologic and hydrogeologic conditions specific to the On-Site Study Area. The existing site conditions form the basis of the information that is used to develop the site design, environmental monitoring programs and contingency plans. Because of the close inter-relationship between the On-Site Study Area where the proposed landfill is to be located and the geology and hydrogeology of the existing closed landfill site, the following description of site conditions includes information from the closed landfill property where it has relevance to the On-Site Study Area.

5.1 TOPOGRAPHY AND DRAINAGE

The natural topography in the area of the WCEC property, which has been modified by extraction and waste disposal activities, ranges from an elevation of approximately 131 metres above sea level (mASL) southwest of the landfill site to less than 110 mASL on the Huntley Quarry property. As noted for the Regional Study Area, the WM Ottawa Landfill extends to an elevation of approximately 172 mASL, and the Huntley Quarry has been mined to a floor elevation of less than 75 mASL.

From within the boundaries of the existing closed landfill property, there is no direct off-site discharge of surface water that is in contact with waste that has been landfilled; internal surface water drainage is contained within the landfill property and is directed to on-site ponds, which are engineered, natural or remain following extraction of aggregate. The exceptions to this are the external slopes of the vegetated site perimeter berms along the east and south boundaries of the landfill property; however, this amount of surface runoff is very minor and is not in contact with activities at the closed landfill. Runoff from the vegetated berms flows into the Carp Road and Highway 417 drainage systems. There is also a small area of drainage from the extreme western end of the site, north of the existing service entrance, which flows into a ditch that crosses under William Mooney Road, and then flows northward into a tributary of Huntley Creek.

The above-noted tributary of Huntley Creek originates from the wetland situated west of William Mooney Road and west of the WCEC property. The wetland feeds this tributary that collects surface drainage from the agricultural and residential properties along William Mooney Road, west of the WCEC property. Flowing from southwest to northeast under William Mooney Road, the tributary then flows toward Richardson Side Road. Along the south side of Richardson Side Road, the tributary is aligned as a roadside drainage ditch, flowing eastward to a point approximately 450 metres east of William Mooney Road. Surface water from the agricultural land east of William Mooney Road and south of Richardson Side Road is controlled by drainage ditches and flows northward to the roadside ditch along Richardson Side Road.

The Huntley Creek tributary then flows northward through a culvert under Richardson Side Road. Here the tributary collects drainage from the area north of Richardson Side Road, including several residential and commercial/industrial properties. Approximately 250 metres west of Carp Road, the tributary flows in a southeasterly direction under Richardson Side Road and bends toward the northeast, where it passes under Carp Road. From there, the tributary flows northeastward, parallel to Richardson Side Road, then northward through a culvert under the road where it reaches Huntley Creek, which eventually discharges into Carp River approximately 3.8 km northeast of the landfill property. Ditches along both sides of Carp Road between the landfill property and Richardson Side Road also drain into the Huntley Creek tributary.

The surface water flow pattern on the On-Site Study Area can be divided into two zones. On the south half of the area, adjacent to the existing landfill, surface water flow is controlled by a series of ditches and a stormwater recharge pond. Surface flow is generally from southwest to northeast. Because the east end of the property was used for aggregate extraction, the ground surface elevation is now lower than the surrounding area. Consequently, there is no direct off-site surface water runoff from this area. On the residential properties located beyond the eastern limit of the former extraction area, surface water flow is northeastward, following the slope of the land surface.

The north half of the On-Site Study Area is used primarily as agricultural land and residential properties, with the southeast corner used by a manufacturing facility (Laurysen Kitchens Ltd.). The western portion of the area is flat-lying and surface drainage follows the land contours and agricultural ditches in a northerly to northwesterly orientation toward Richardson Side Road and into the tributary of Huntley Creek described above.

On the eastern portion of the On-Site Study Area, the land slopes in a north-northeasterly orientation along the edge of the post-glacial beach ridge. Surface drainage follows the slope of the land surface into a ditch along the west side of Carp Road. The ditch drains northward into the Huntley Creek tributary. Immediately north of the Laurysen Kitchens plant is a former aggregate extraction area, approximately 5 hectares in size. Where the land surface in the former extraction area is depressed, surface water collects in localized ponds. The water level in these small depressions reflects the local groundwater table elevation.

There are no flood hazard zones located within the On-Site Study Area. The elevated topography and high recharge potential of the beach ridge deposits along the Carp Road corridor mitigate the potential for surface flooding.

5.2 GEOLOGY

The following detailed site geology description is based on the observations made during drilling investigations conducted on the closed landfill property and within the On-Site Study Area. The stratigraphy interpreted from the drilling investigations is illustrated on three cross-sections, which locations are shown on Figure 4. These sections include the interpreted geologic units on the property being proposed for the new landfill footprint, and are presented in Figure 8. The bedrock surface elevation in the area surrounding the WCEC property, interpreted from all available borehole logs, is shown in Figure 9.

5.2.1 Surficial Geology

The surficial geology across the On-Site Study Area reflects the same glacial history as the Regional Study Area (see Section 4.2.1). The unconsolidated deposits observed during subsurface investigations consist principally of sand, silt, gravel and glacial till, and range in thickness from approximately 3 to 17 metres. An overburden thickness map for the area surrounding the WCEC property is presented on Figure 10. The surficial deposits are interpreted to be ice-contact stratified drift sediments, consisting of a mixture of poorly to well-sorted, stratified gravels and sands, interbedded with a silty sand-gravel till. The deposits are interpreted to have been submerged during the Champlain Sea encroachment, and therefore show indications of re-working in a subaqueous environment. The deposits are horizontally bedded and often display cross-bedding features. The stratigraphic units overlying the bedrock within the On-Site Study Area include (from ground surface down):

- Topsoil: Organic deposits, including peat & muck deposits.
- Sand: Uniform, fine grained, silty, well sorted, non-cohesive.
- Silt: Generally uniform and well sorted, non-cohesive to slightly cohesive.

- Sand and gravel: Silt to very fine or coarse grained sand with gravel and cobble size rounded to sub-rounded rock fragments, often as discrete layers.
- Glacial till: Very abundant rock fragments, mainly of limestone and becoming increasingly abundant with depth, in a matrix of poorly sorted sand, silt and clay.

Overburden deposits were found to be relatively heterogeneous across the site, both laterally and vertically. The till unit is generally less than 3 m thick, and is found as a discontinuous layer overlying bedrock. Overlying the till is a sand and silt deposit, varying in thickness from 2 to over 10 m. Generally the thickness of this deposit increases from west to east. A sand and gravel deposit is interlayered with the silt and sand, primarily in the eastern portion of the area.

The unconsolidated deposits observed on the property where the new landfill will be located consist principally of sand-gravel and sand. The deposits were found to be relatively homogeneous across the property, grading from sand-gravel in the eastern portion along the post-glacial beach ridge to fine sand further west, away from the edge of the ridge. At borehole locations on the property, the overburden deposits ranged in thickness from 4.3 to 15.6 metres. The overburden thickness was greatest in the southeast corner of the area, and least in the northwest corner.

5.2.2 Bedrock Geology

The bedrock sections observed during drilling investigations generally consist of light to medium grey, fine to medium-grained fossiliferous limestone with some shaly and sandy interbeds. The bedrock is classified as the Bobcaygeon Formation which is described regionally as a limestone with shaly partings and intermittent sandstone (Natural Resources Canada, 2002). The bedrock is generally most fractured in its upper few metres, while the frequency of fractures in the bedrock decreases starting at depths of approximately 6 to 8 metres below the bedrock surface. Boreholes on the WCEC property average between 2 and 10 fractures per 1.5m of core. The fractures are generally found along horizontal to sub-horizontal discontinuities such as bedding planes, shaley layers and mud seams, although some high-angle fractures were observed in the bedrock core samples.

The Rock Quality Designation (RQD) of the bedrock was recorded during bedrock coring investigations. In general, the RQD was observed to be poor to fair near the top of the bedrock (upper 2 to 4 metres), and at discrete intervals at greater depths (from approximately 6 m to more than 10 to 12 m below bedrock surface). These less competent (lower RQD) intervals also correspond loosely to depth intervals where fracture frequency is increased.

The bedrock surface generally slopes toward the north and northeast across the On-Site Study Area, ranging between elevations of 123 mASL and 110 mASL. The bedrock surface features an apparent topographic high point located in the western portion of the existing landfill site (see Figure 9).

5.3 Physical Hydrogeology

5.3.1 Hydrostratigraphic Units and Interconnectivity of Aquifers

A hydrostratigraphic unit is defined as a distinct unit of the geologic sequence that displays physical and chemical continuity. The unit may be shown to be extensive laterally but it is typically well defined and bounded vertically. The unit will typically show both physical hydraulic continuity and connection as well as consistent groundwater geochemical quality in its natural or undisturbed state. For these reasons the hydrostratigraphic unit will act as a potential pathway for contaminants in the presence of a contaminant source(s) and a driving force (gradient).

Previous hydrogeologic investigations conducted at the WM Ottawa Landfill and on surrounding properties have led to the development of a conceptual model for the hydrogeology of the On-Site Study Area. These investigations have been supplemented with the available geologic information from the Regional Study Area. The On-Site Study Area is interpreted to be underlain by two hydrostratigraphic units:

a) the unconsolidated ice contact sands, gravels, and glacial till, and the hydraulically connected weathered upper bedrock surface; and
b) the deeper bedrock fracture systems.

These units are described in further detail below.

Unconsolidated Deposits and Weathered Bedrock Surface (Overburden-Shallow Bedrock Zone)

The unconsolidated deposits across the WCEC property have a variable thickness ranging from approximately 3 to 17 metres. In the higher topographic elevations along Carp Road, the water table in the unconsolidated deposits (ie., sand, silty sand and silty sand-gravel till) is generally found at over 10 metres depth, indicating that the majority of the unconsolidated deposits are unsaturated. The saturated thickness of these deposits, which represents the water table aquifer, is generally limited to 5 metres or less. In areas where the bedrock is closer to the surface or where the topographic elevations decline, the depth to the water table decreases, however, the saturated thickness remains limited. Groundwater is also found in the weathered bedrock at the overburden-bedrock interface. This part of the unit extends to a depth of approximately 6 to 8 metres below the bedrock surface.

The unit has good vertical and lateral hydraulic connection due to a lack of any continuous confining layers in the sequence of unconsolidated deposits and the upper bedrock. Low vertical gradients are typically measured within the unit, which is also an indication of good hydraulic connection. This zone, herein termed the *overburden-shallow bedrock zone*, can therefore be interpreted to act as a single hydrostratigraphic unit. It ranges in saturated thickness from approximately 5 to 10 metres.

Based on the frequency of fractures observed in the shallow bedrock and the relatively higher hydraulic conductivities, the overburden-shallow bedrock zone is the primary groundwater-bearing formation across the study site and potentially the primary pathway for the transport of dissolved phase constituents.

Deep Bedrock Zone

Groundwater flow in the limestone bedrock is controlled by open joints and fractures. Consequently, the fractured bedrock unit does not always behave as a continuous porous medium, and traditional methods of hydraulic analysis must be adjusted to successfully evaluate the physical characteristics of the unit. Data collected during investigations on and around the WM Ottawa Landfill provide a reasonable understanding of the physical flow characteristics in the deeper bedrock within the On-Site Study Area.

Investigations have indicated that the deeper bedrock, below approximately 6 to 8 metres from the bedrock surface, contains fewer fractures than above, and produces significantly lower groundwater yields in monitoring wells developed into this unit. As discussed in Section 2.2.2.2, lower fracture frequencies are generally observed beginning approximately 6 to 8 metres below bedrock surface.

Although it is reasonable to predict that there is some vertical fracturing from the upper bedrock to the deeper zone, the results from site investigations suggest that the connection is limited. Low groundwater yields observed in the deeper bedrock in combination with the hydraulic head separations between the shallow and the deep bedrock units demonstrate that this deeper zone is not well connected vertically to the overburden-shallow bedrock unit above or laterally within the deep bedrock. Overall, the water level and hydraulic conductivity data obtained during these studies further supports the distinctiveness of the two hydrostratigraphic units (overburden-shallow bedrock and deep bedrock units).

Across the western portion of the WCEC property and further to the west, where the bedrock is found at shallower depths, the hydraulic heads in the deep bedrock zone are generally more consistent with those in the overburden-shallow bedrock zone than they are on the eastern portion of the study area. This indicates that there may be more hydraulic connectivity between the shallow and deep hydrostratigraphic units in this area.

5.3.2 Direction of Groundwater Flow and Hydraulic Gradients

Site-wide groundwater levels are measured as part of the landfill environmental monitoring program once annually each spring. Groundwater levels are also measured monthly at selected monitoring wells as part of the purge well monitoring program. The water level measurements (converted to groundwater elevations or *hydraulic heads*) are used to interpret the flow directions on and around the landfill site. The groundwater contours and interpreted flow direction are presented each year in the Annual Report for the landfill site.

As part of the EA Study for the proposed undertaking, the site-wide groundwater levels were measured quarterly during 2011 to provide additional information on any seasonal variations in the water levels and groundwater flow directions within the study area. The interpreted hydraulic head contours and flow directions for the overburden-shallow bedrock from the January, April, August and November 2011 data are shown on Figures 11(a) to 11(d), respectively. The groundwater elevations from April 2011 are also shown on the geologic cross-sections presented in Figure 8. Comparison of the January (winter), April (spring), August (summer) and November (fall) contours illustrates that there is seasonal variation in the groundwater elevations; however, the general characterization of the flow directions and gradients remains consistent.

Shallow groundwater flow generally follows the bedrock topography (see Figure 9), with a water table elevation varying from 127 to 129 mASL in the southwest portion of the landfill property to less than 112 mASL east of Carp Road. The direction of groundwater flow within the overburden-shallow bedrock in the southwest portion of the site is towards the north. Groundwater flow in this area exhibits a horizontal hydraulic gradient of approximately 0.005 to 0.010. In the northwest corner of the existing landfill site, the topographic high present in the bedrock appears to influence shallow groundwater flow and induces an area of localized northwesterly flow toward the northwest corner of the site. Across the majority of the landfill site, the direction of groundwater flow in the overburden-shallow bedrock is towards the northeast, with an average gradient of approximately 0.006.

On the western half of the On-Site Study Area, groundwater flow in the overburden-shallow bedrock is northerly with a horizontal hydraulic gradient of approximately 0.007. Toward the eastern half of the property the flow trends more north-easterly, influenced by the topographic decline along the edge of the post-glacial beach ridge. The horizontal hydraulic gradient on this portion of the property is approximately 0.015.

The groundwater flow directions remain relatively consistent between seasons, which are seen by comparing the orientations of the groundwater contours on Figures 11(a) to 11(d). The hydraulic heads varied from approximately 0.3 to 2 metres between winter and spring 2011, with higher heads generally found in the spring. The August (summer) and November (fall) groundwater elevations were generally 0.5 to 2.0 metres lower than the spring measurements. The largest variations were seen around the surface water ponds south (PW13 and PW15) and north (W63 and W64) of the closed landfill, and west of the WCEC property (W78-2). This is typical of a recharge area, where runoff collects in surface water bodies during wetter periods of the year, and gradually infiltrates into the subsurface.

The regional direction of groundwater flow in the deep bedrock is interpreted to be toward the northeast. Hydraulic heads in the deep bedrock are plotted on Figures 12(a) to 12(d) for the January, April, August and November 2011 measurements. Hydraulic heads are found to be highly variable across the area, and are not contoured due to the lateral discontinuity in this hydrogeologic unit. Groundwater flow in the deep bedrock is interpreted to be influenced by isolated fracture zones, which do not appear to be well-connected across most of the area. However, it is noted that upgradient of the existing landfill site where the bedrock is found at shallower depths, the hydraulic heads in the deep bedrock are generally more consistent with those in the overburden-shallow bedrock zone (eg., W57, W76, W77 and W78). This indicates a higher degree of hydraulic connection between the shallow and deep bedrock in this area. Further to the east, the hydraulic heads in the deep bedrock are generally less consistent with the shallow bedrock, indicating less vertical and horizontal connectivity between the two units (eg., W44, W50, W54 and W65). Overall, the hydraulic heads in the deep bedrock indicate that the groundwater flow orientation is consistent with the regional groundwater flow system toward Carp River (refer to Figure 7).

Vertical gradients between the overburden-shallow bedrock and the underlying deep bedrock are determined by comparing the water levels in adjacent monitoring wells screened at different elevations. Groundwater will flow with an upward or downward component depending on whether the water levels in the deep bedrock are higher or lower, respectively, than in the shallow bedrock. If the water levels in the shallow and deep bedrock are within a metre or two of one another, it implies that groundwater may flow between the two units. However, if there is a significant difference in hydraulic head between the shallow and deep bedrock, such as east of the closed landfill (e.g., W44, W50, W54, W55 and W56) where the heads differ by 10 metres or more, it implies that there is little or no hydraulic connection between the shallow and deep bedrock.

With few exceptions, the vertical gradients across the WCEC property are downward (see Table 1). This is consistent with the area being a zone of groundwater recharge, where flow is generally downward. In August 2011, more of the monitoring well locations were found to exhibit upward gradients. This is an indication of a higher magnitude of seasonal water level fluctuation in the overburden-shallow bedrock aquifer, relative to the deeper bedrock.

5.3.3 Hydraulic Conductivity

The hydraulic conductivity (K) of a stratigraphic unit is a measure of the ability of a fluid to move through the pore spaces and along fracture pathways. Larger values of hydraulic conductivity (e.g., in sands and gravels, and highly fractured bedrock) imply faster movement of groundwater (depending on the hydraulic gradient) whereas smaller values of K generally indicate that the unit does not transmit water as readily (e.g., clays, and unfractured bedrock).

The hydraulic conductivity can be estimated from empirical data such as soil grain size, or it can be obtained using borehole tests such as slug or packer tests, or aquifer pumping tests. Within the WCEC property encompassing the existing closed landfill and the area to the north where the new landfill is to be located, the hydraulic conductivity has been determined at 62 discrete locations including slug tests in 25 monitoring wells and 37 packer tests in seven monitoring wells. A summary of the hydraulic conductivity test results is presented in Table 2.

The range in hydraulic conductivity measurements in various borehole tests on the WCEC property is from $>1 \times 10^{-3}$ m/s (represented by a rapid response in slug tests) to $<1 \times 10^{-11}$ m/s (a very slow response in bedrock packer tests). This is typical of geologic environments with highly permeable sands and gravels (large K) overlying bedrock that has zones of very little fracturing (small K).

The geometric mean of K calculated from slug tests in monitors completed in the overburden-shallow bedrock zone is 4.3×10^{-5} m/s. This represents a typical hydraulic conductivity in this unit on the WCEC property. The geometric mean value of K calculated for the packer tests conducted in the upper two metres of bedrock on the WCEC property was 9.8×10^{-7} m/s, indicating that the upper bedrock is somewhat less permeable than the overburden, but still moderately permeable. The geometric mean of K calculated from the packer tests conducted in the upper 8 metres of the bedrock, where the fracture frequency is observed to be higher (see Section 5.2.2) is 6.8×10^{-8} m/s. At depths greater than 8 metres below the bedrock surface, the average K is calculated to be approximately one order of magnitude smaller at 8.3×10^{-9} m/s.

From these results, it is seen that the limestone bedrock is consistently less permeable than the overburden across the WCEC property.

A summary of the geometric mean values of K calculated from the tests conducted on the WCEC property is provided below:

	Hydraulic Conductivity (geometric mean; m/s)	
Type of Test	Existing Landfill	North Envelope
Slug tests (overburden and upper 8m of bedrock)	$3.0x10^{-5}$	$1.5x10^{-4}$
Packer tests (upper 8 m of bedrock)	$3.0x10^{-8}$	$9.6x10^{-8}$
Packer tests (greater than 8 m into bedrock)	$5.0x10^{-9}$	$9.6x10^{-9}$

From this summary it is seen that the slug testing, which represents the hydraulic conductivities measured in the monitoring wells screened in both the overburden and shallow bedrock, produced larger values of K than the hydraulic conductivities determined from the bedrock packer tests. The average hydraulic conductivities measured in the packer tests are relatively consistent between the existing landfill and the North Envelope (10^{-8} to 10^{-9} m/s), and are seen to decrease with depth below the bedrock surface. The average hydraulic conductivities obtained from depths greater than 8 metres below the bedrock surface are 4 to 5 orders of magnitude less than those obtained from slug tests completed in the overburden-shallow bedrock zone.

5.3.4 Groundwater-Surface Water Interaction

The WCEC property represents a zone of groundwater recharge, with a relatively shallow water table, an unconfined aquifer, and permeable hydrostratigraphic units. The area is classified as a significant groundwater recharge area (Mississippi-Rideau Source Protection Region, 2011). In recharge areas, a higher proportion of surface water enters the subsurface to become groundwater, as opposed to groundwater discharging to become surface water. Groundwater gradients are generally downward in recharge areas.

Surface water features that interact with the groundwater regime on the WCEC property include a local wetland along the northern edge of the property where the new landfill will be located, and stormwater management ponds on the existing landfill. Precipitation will also directly infiltrate through the permeable surface soils, moving downward to the water table.

The stormwater recharge ponds on the south side of the existing landfill property exert localized influence on the groundwater flow patterns in these areas (Figures 11(a) to 11(d)).

5.3.5 Calibrated Numerical Model of Groundwater Flow

A three-dimensional numerical model of groundwater flow was developed for the Regional Study Area, using the USGS finite-difference MODFLOW computer application. The computer model extends to regional hydrologic boundaries beyond the Regional Study Area, while supporting a relatively high resolution for the analysis of the conditions in the On-Site Study Area. The computer model is based on the conceptual hydrogeologic model, which has been developed from the available hydrogeologic data, including published sources and data from site-specific investigations. Regional data that were used for the computer model includes the following:

- Regional topography from the Ontario Ministry of Natural Resources (OMNR);
- Ontario Base Map layers (including streams, lakes, wetlands, drainage lines, bedrock and surficial geology, etc.);
- Domestic well records from the Ontario provincial database, in particular lithologic information, water levels, and specific capacities contained therein;
- Hydrograph data available from the HYDAT monitoring network in the area; and
- Land use information derived from Landsat satellite imagery.

Site-specific data included:

- Local survey data (including waste mound topography);
- Physical data, including hydraulic properties of overburden deposits and bedrock;
- Historical hydrograph data, water levels, and water quality data for leachate and groundwater; and
- Borehole log data.

The three dimensional groundwater flow model was calibrated to the available field data, including hydraulic heads and baseflow estimates. The January 2011 water levels available from the landfill site monitoring program were used to provide accurate measurements of hydraulic head in the immediate vicinity of the site. Water level information from private water supply wells provided the broader geographical coverage needed for the remainder of the model area. Sensitivity analyses were conducted to develop the best-fit model and to assess the reliability of predictions in groundwater flow characteristics. For the sensitivity analyses, model properties were adjusted within reasonable ranges to match field observations.

The results of the simulation of groundwater elevations using the computer model are shown on Figure 13. Within the Regional Study Area, the simulated heads are in good agreement with the observed heads obtained from the MOE Water Well Records (Figure 7). On the WCEC property, the groundwater elevation contours and flow directions are generally consistent with those developed from actual field measurements (Figures 11(a) to 11(d)). Some of the localized details, such as the local flow regime around the higher bedrock surface topography in the northwestern corner of the existing landfill, are not as well-defined in the computer model; however, the general trends in groundwater elevations and flow directions can be seen in the computer-simulated conditions.

5.4 OVERBURDEN-SHALLOW BEDROCK GROUNDWATER QUALITY

The following discussion of the overburden-shallow bedrock groundwater quality focuses on the On-Site Study Area where the new landfill is to be located. Where relevant to the discussion of groundwater quality within the On-Site Study Area, information from the existing landfill site is included. Groundwater samples from monitoring wells are collected annually as part of the Environmental Monitoring Plan (EMP) for the existing landfill. In addition, samples were collected from wells north of the existing landfill property in May 2011 as part of the EA Study (W73, W75 and W76-2). Historical water quality for 20 overburden-shallow bedrock monitoring wells within the On-Site Study Area is presented in Appendix A (Appendix A1: Overburden-Shallow Bedrock Water Quality). The locations of these wells are shown on Figure 4.

Recent information regarding the existing conditions of groundwater quality in the vicinity of the closed landfill site is presented in the 2013 Annual Report, which provides the results from the EMP conducted at the site. Historical groundwater quality information is also found in the annual report.

5.4.1 Background Groundwater Quality

An updated evaluation of the background groundwater quality in the overburden-shallow bedrock zone has been completed for this hydrogeologic assessment. The re-evaluation is to ensure that the range of background concentrations used for comparison to downgradient concentrations adequately represent all areas of the WCEC property. Data from eighteen monitoring wells and domestic water wells are included in the background water quality assessment. These locations have all been used historically to characterize background groundwater quality; three of the locations (W57-2, W70 and W77-2) are used for routine background monitoring in the current EMP. The eighteen locations are shown on Figure 4, and are as follows:

- OW10
- OW11-01
- OW12
- OW13
- OW14
- P35
- P83
- W37
- W57-2
- W60-2
- W70
- W74
- W76-2
- W77-2
- W88-2
- W89-2
- W90-2
- W91-2

The results for the background monitors generally indicate low concentrations of water quality parameters. Some elevated concentrations of chloride, sodium and TDS are seen in monitoring wells that are located upgradient from the WCEC property, but close to Highway 417 (e.g., W37, W70 and W77-2), and at two monitoring wells in the far northwestern area (W90-2 and W91-2). The ranges in concentrations and the median values for the general water quality constituents that are used in the current environmental monitoring program for the closed landfill are presented in Table 3. The background groundwater quality dataset is found in Appendix B.

Groundwater chemistry is also typically characterized using a Piper water quality diagram. This type of geochemical representation plots the major ions on two ternary diagrams representing the relative proportions of anions and cations, as well as on a quadrangle that combines all ions. The major ions include sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), bicarbonate (HCO_3), sulphate (SO_4) and chloride (Cl), which typically account for the vast majority of the total dissolved solids present in natural groundwater. Different water quality types will plot in different areas of the central quadrangle. Therefore, Piper diagrams constitute a useful diagnostic chemical indicator of the various sources that combine to define the geochemical nature of a particular water sample. Natural background groundwater quality in the vicinity of the WCEC property typically plots on the left-hand side of the Piper quadrangle in the Ca-Mg-HCO_3 facies (see Piper diagram on Figure 14(a), which shows the available data for the past three years from background monitoring wells). This is typical of shallow groundwater in areas underlain by carbonate (limestone) bedrock, which has a higher proportion of calcium and bicarbonate ions relative to other major ions. Some notable exceptions in the background water quality are at monitoring well W60-2, which has a higher proportion of sodium ions relative to calcium and magnesium (softer water), and at W91-2 which exhibits slightly higher proportions of sodium and chloride relative to other ions.

5.4.2 Western Boundary

Groundwater quality in the overburden-shallow bedrock zone along the western boundary of the On-Site Study Area where the new landfill will be located is characterized by the following locations:

- W3-3
- W61
- W60-2
- W76-2

Monitoring wells W60-2 and W76-2 are used to characterize background water quality, and exhibit low concentrations of dissolved constituents. Similarly, W61 has low concentrations of dissolved solids. Monitoring well W3-3, located in the northwest corner of the closed landfill property adjacent to W61, was sampled for 20 years from 1987 to 2007. Prior to 2000, several water quality parameters routinely exceeded the range of background concentrations; however, from 2001 to 2007 the observed concentrations were lower and only sodium and sulphate regularly exceeded the maximum background. The lack of any key leachate indicators routinely exceeding background concentrations, such as ammonia, TKN, boron, COD, chloride and potassium shows that this location is not impacted by leachate.

The Piper water quality diagram for wells along the western boundary is presented on Figure 14(b). The diagram shows the data from the past three years from W60-2, W61 and W76-2. The data from W61 and W76-2 plot in the Ca-Mg-HCO_3 facies, consistent with carbonate background, while W60-2 shows softer water quality with a higher proportion of sodium ions, as noted above in the description of background water quality.

The four monitoring wells along the western boundary have been sampled for VOCs at various times between 2004 and 2011. No VOCs have been detected in these samples collected from the western boundary.

5.4.3 Southern Boundary (along north side of closed landfill)

Historically, groundwater quality has been monitored at the following locations along the northern side of the existing landfill footprint:

- P65 (1988-1996)
- P79 (1993 to present)
- P80-1 (1993 to present)
- P80-2 (1993-2007)
- W2-3 (1991-2007)
- W42-2 (1995)
- W46-2 (1995)

In the current environmental monitoring program, the groundwater conditions along the north side of the closed landfill are monitored at P79 and P80-1. The concentrations of leachate indicator parameters at P79, immediately adjacent to the closed landfill, are elevated above background and indicate migration of leachate near the toe of the landfill. At P80-1, located to the west, the concentrations of some parameters are elevated above background and have remained stable or have increased slightly since 2000 (e.g., alkalinity, sodium, conductivity, iron). These observations of elevated concentrations of leachate indicators on the north side of the closed landfill are consistent with the groundwater flow direction in this area and the computer simulations of groundwater flow and transport from the unlined sections of the former landfill (see Section 6.0 of this report).

The Piper water quality diagram with the past three years of results for P79 and P80-1 is presented on Figure 14(c). On the diagram, P80-1 plots in the area of carbonate background, and P79 plots further to the right.

5.4.4 Interior Portion of On-Site Study Area

For the discussion of groundwater quality, the interior portion of the On-Site Study Area (away from the upgradient and downgradient property boundaries) can be subdivided into its southern and northern halves, with the former being coincident with the area north of the closed landfill and the latter being further north on land currently used for agricultural purposes. Groundwater quality in these areas is represented by the following monitoring wells:

- W62-2
- W63
- W64
- W75

These monitoring wells are all located within the area that is proposed to be used for the new landfill footprint.

Monitoring well W63 is located in the former Dibblee Pit area, north of the unlined landfill and east of the stormwater recharge pond. The concentrations of most dissolved parameters at this location have increased since the monitor was installed in 2004. Given this monitor's location downgradient from the unlined landfill footprint, this suggests that leachate is the source of the elevated concentrations. However, it is noted that the concentrations of several water quality parameters are higher at W63 than at locations closer to the landfill footprint (eg., alkalinity, ammonia, barium, chloride, hardness, sodium, TDS, etc.), which suggests that the source of the elevated concentrations at W63 may also be due to other factors, such as the stormwater recharge pond or the former sewage biosolids storage in this area. The monitoring well was sampled in 2004 for the five VOCs listed in Schedule 5 of Ontario Regulation 232/98 (Comprehensive List for Groundwater). Benzene was detected in the sample at a concentration of 3.3 μg/L; no other VOCs were detected.

Monitoring wells W62-2 and W64 are located from west to east, respectively, in the central portion of the On-Site Study Area. The concentrations of dissolved parameters at W62-2 reflect background groundwater conditions. Monitor W64 is situated downgradient from W63, at the eastern end of an area of ponded water that collects runoff from a swale that originates at the northwest corner of the landfill footprint. The concentrations of some dissolved constituents at

W64 are slightly elevated in comparison to background concentrations (e.g., ammonia, nitrate, manganese); however, the majority of parameters are within the range of background concentrations. The Piper water quality diagram for this area is shown on Figure 14(d) and the results for these wells plot in the area consistent with background groundwater quality (W62-2), or areas indicating water quality impacts (W63 and W64). Monitoring wells W62-2 and W64 were sampled in 2004 for the five VOCs listed in Schedule 5 of Ontario Regulation 232/98. No VOCs were detected in the samples.

Monitoring well W75 is located on the northern half of the On-Site Study Area in an agricultural field. The water quality parameters at this monitoring well are within the range of background concentrations with the exception of nitrate. The slightly elevated nitrate concentrations (0.3 to 0.82 mg/L) are likely due to agricultural fertilization on this field. The groundwater samples from this well plot in a location on the Piper diagram that is consistent with natural background water quality (see Figure 14(d)). Groundwater samples from monitoring well W75 have also been analyzed for VOCs. Trace levels of toluene (0.6 µg/L) were measured in one groundwater sample collected in 2007; however, no VOCs were detected in the sample from this well collected in 2011.

5.4.5 Eastern Boundary

Monitoring wells screened in the overburden-shallow bedrock zone along the eastern boundary of the On-Site Study Area include the following (from north to south):

- W73-2
- W65-2
- W87
- W72
- W86

Monitoring well W73-2 was sampled in 2007 and 2011; the concentrations of water quality parameters are consistent with the range of background levels, with the exception of nitrate and copper (one test completed in 2007). No VOCs were detected in the single sample collected in 2007. Leachate impacts are not evident at this location.

Monitoring well W65-2 is sampled as part of the EMP for the existing landfill site. Several of the water quality parameters have exceeded the maximum background concentrations on a sporadic basis; in the past two years, the concentrations of chloride, sodium, nitrate, conductivity and TDS have exceeded background levels. Leachate indicators such as ammonia, TKN, potassium and COD are within the range of background concentrations. This monitoring well was sampled in 2004 for the five VOCs listed in Schedule 5 of Ontario Regulation 232/98. No VOCs were detected in the sample. The location of this monitoring well on the Piper diagram indicates impacts to water quality, in particular an increased proportion of chloride and sodium relative to background (see Figure 14(e)). However, the magnitude of this impact, indicated by the shift in water quality beyond that expected from leachate (see the description below of water quality for W72 and W86), and the lack of high concentrations of the primary leachate parameters, indicates that an alternate source is affecting the water quality at W65-2.

Further south, monitoring well W87 was sampled in 2010; at that time, only alkalinity and nitrate exceeded the maximum background concentration. However, trace levels of chlorinated alkanes were detected in the sample at concentrations of 1 μg/L or less. This monitoring well location is interpreted to represent the northern edge of leachate impacts from the closed landfill along the eastern boundary of the On-Site Study Area. Its position on the Piper diagram (Figure 14(e)) indicates slight impacts to water quality compared to background.

At monitoring wells W72 and W86, located in the furthest southeast corner of the On-Site Study Area and downgradient of the closed landfill, several water quality parameters have been detected at concentrations above the maximum background levels (e.g., alkalinity, ammonia, hardness, conductivity, etc.). Volatile organic compounds are also detected at these locations. These monitoring wells are interpreted to be impacted by leachate from the existing landfill. These monitoring wells plot in a similar location to W87, to the right of background water quality (see Figure 14(e)).

5.5 DEEP BEDROCK GROUNDWATER QUALITY

The deep bedrock zone is considered to be a secondary, discontinuous groundwater pathway controlled by open joints and fractures. The inorganic chemistry of the deep bedrock shows different characteristics than the overburden-shallow bedrock zone discussed above (refer to the water quality results in Appendix A2). Generally poor water quality and a higher degree of natural variability are observed in the deep bedrock groundwater across the On-Site Study Area. Deep bedrock groundwater quality is monitored at the following six locations within the On-Site Study Area (refer to Figure 4 for locations):

- W46-1
- W60-1
- W62-1
- W65-1R
- W73-1
- W76-1

At locations that are on the western boundary of the WCEC property, which are not influenced by the existing landfill, including W60-1 and W76-1, the deep bedrock groundwater exhibits a wide range in concentrations of inorganic parameters. Some of the concentrations are greater than the maximum background in the overburden-shallow bedrock, including ammonia, boron, sodium, potassium and sulphate. These results show that deep background groundwater can be more naturally mineralized than the shallower groundwater. No VOCs were detected in the sample collected from W76-1 in 2007.

At location W62-1, located within the interior of the On-Site Study Area, the water quality parameter concentrations observed from the single sample in 2004 do not exceed the values from along the western boundary of the site, with the exception of barium (0.22 mg/L versus 0.11 mg/L at W76-1).

High variability in the parameter concentrations is observed in the deep bedrock monitoring wells along the eastern boundary of the On-Site Study Area. To the north at W73-1, mineralized groundwater is evident in the single sample from 2011, with high concentrations of most constituents (as indicated by the total dissolved solids of 2,950 mg/L and conductivity of 4,540 μS/cm). The pH is also high at 12.1. Further south at W65-1R, the concentrations (measured in 2004) are within the ranges observed along the western side of the site, with the exception of manganese (0.07 mg/L), nitrate (0.22 mg/L) and TKN (1.46 mg/L). Three VOCs were detected in the sample collected in 2004 from W65-1R: bromodichloromethane (2.8 μg/L), chloroform (39.8 μg/L), and toluene (3.5 μg/L).

At W46-1, located in the southeast corner of the On-Site Study Area, immediately adjacent to the existing landfill footprint, the water quality concentrations are generally higher than along the western boundary. Although elevated, the concentrations have remained stable since the mid-1990's. The low concentrations of leachate parameters (ammonia, TKN, potassium, COD) indicate a water quality that is naturally poor at this location, and not impacted by leachate. In eight samples analyzed for VOCs at this location, only one detection of benzene was observed (0.6 μg/L).

6. HYDROGEOLOGIC ASSESSMENT OF PROPOSED DEVELOPMENT

The potential effects on the hydrogeology of the On-Site Study Area from the construction and operation of the proposed landfill are described in this section. The environmental criteria used to determine the potential effects are *Groundwater Flow* and *Groundwater Quality*. The potential effects are defined as the impacts to groundwater that would be expected to occur with no further mitigation or compensation measures in place beyond the facility design and operational procedures, and implementation of best management practices for pollution prevention.

To complete this assessment, the potential effects and recommended mitigation measures for the proposed WCEC landfill described in the Detailed Impact Assessment completed for the WCEC Environmental Assessment were reviewed to ensure their accuracy in the context of the updated landfill design. Based on the more detailed development of the landfill design components (e.g., footprint location, cover material, stormwater management pond design), additional groundwater modeling was completed to assess the potential effects on the hydrogeology environment. The predicted potential effects, mitigation measures, and net effects are summarized in Table 4 and described in further detail in the sections below.

The potential effects from the proposed landfill are evaluated in relation to the future baseline conditions that are projected to occur from the existing closed landfill. Computer modeling simulations were used to predict future conditions for groundwater flow and quality in the On-Site and Regional Study areas. A detailed description of the groundwater modelling component of this assessment is provided in Appendix C. The simulations were run using chloride as an indicator of contaminant movement, because of its conservative nature in dissolved phase transport. Whether chloride is appropriate to be used as a monitoring indicator and compliance trigger for the site will be determined during the implementation of the Environmental Monitoring Plan.

The potential effects from the development of a new landfill footprint and stormwater management ponds are described in this section. The design assumptions and preliminary design of the new landfill and stormwater management system were prepared by WSP Canada Inc., and are described in the Draft Development and Operations Report.

6.1 Potential Effects on Groundwater Flow

The new landfill footprint will include the development of a double-composite lined leachate collection and containment system. This will have the effect of reducing the amount of recharge to the groundwater within the confines of the landfill footprint. The result is predicted to be a general decrease in the groundwater heads immediately below the landfill. However, because the effect of the landfill at reducing the amount of recharge is localized, away from the edges of the landfill the impacts are predicted to be much less noticeable. At the downgradient property boundaries, the decrease in groundwater elevation is predicted to be much less than the normal seasonal variations in the water table, and is not expected to have negative effects on off-site water supplies.

The orientations of the local and regional groundwater flow are also not expected to be impacted by the small change in groundwater elevations as a result of the reduced recharge under the landfill.

A more significant effect on the groundwater flow direction within the On-Site Study Area is predicted to occur from the operation of the stormwater management ponds for the proposed landfill. The two proposed ponds are each designed with two stages, a lined stage for settlement and containment, and an unlined stage to permit discharge via groundwater infiltration. Each of the stages is designed to hold the runoff volume in excess of the amount from a 1:100 year precipitation event. The estimated amount of infiltration that would occur from each unlined infiltration basin on an average annual basis is provided in Table 5.

This amount of infiltration is predicted to cause the groundwater levels to rise on the order of 2 to 3 metres immediately under the infiltration basins. The predicted groundwater head contours in the On-Site Study Area and surrounding properties from the development of the new landfill and the infiltration basins are shown on Figure 15.

The effects of this groundwater mounding diminish with increased distance from the ponds; however, the localized groundwater flow orientations are predicted to be affected, in that radial flow away from the ponds can be expected. Downgradient from Carp Road and north of the north property boundary, the groundwater elevations are not projected to change significantly, and the regional groundwater flow patterns are not expected to be altered. The impacts of this localized effect on groundwater flow are seen in the future projections of groundwater quality, as described in the next section.

In summary, the potential effects on Groundwater Flow from the proposed landfill (including the stormwater management ponds) are as follows:

1. Recharge to the groundwater is expected to be reduced within the area of the new landfill footprint. This will have the effect of lowering the groundwater elevations immediately below the landfill, but is predicted to have minimal effects away from the footprint. The local and regional groundwater flow directions are not expected to be impacted.

2. Infiltration from the unlined basins is predicted to cause the groundwater levels to rise under the unlined pond stages. The effects of this groundwater mounding diminish with increased distance from the ponds. The groundwater flow will be radially away from the ponds, which is predicted to affect the orientation of the local flow regime and influence groundwater quality in the vicinity.

6.2 POTENTIAL EFFECTS ON GROUNDWATER QUALITY

The proposed development of the new landfill footprint and the stormwater management ponds is expected to have the following potential effects on the future conditions for Groundwater Quality:

1. Surface water that infiltrates to the groundwater table from the stormwater management ponds may contain elevated concentrations of contaminants from surface runoff, traffic and landfill operations. These contaminants may migrate with the groundwater flow toward the downgradient property boundary, which is situated approximately 90 to 125 metres to the east of the ponds.

2. Radial groundwater flow predicted to occur around the stormwater management ponds (refer to Section 6.1) is expected to intercept the movement of leachate-impacted groundwater from the existing unlined landfill. This is expected to have the effect of re-orienting leachate-impacted groundwater further northward across the WM property and extending beyond the northern property boundary. A southern arm of leachate-impacted groundwater is expected to migrate eastward onto the existing CAZ; however, because of the reduced mass of contaminants being transported in this direction, the impacts may remain within the CAZ boundaries.

The potential effects from the stormwater management ponds and from the migration of leachate-impacted groundwater from the existing unlined landfill as calculated from the numerical modeling are shown on Figure 16. Figure 16(a) shows the maximum predicted extent of chloride concentrations greater than 130 mg/L from the infiltration basins (130 mg/L is the MOE Guideline B-7 limit for groundwater with an assumed (conservative) background concentration of 10 mg/L; the actual Guideline B-7 limit for the WCEC site, based on a median chloride concentration of 46 mg/L is calculated to be 148 mg/L). Note that, in order to meet the criterion of 130 mg/L at the downgradient property boundary, the maximum source concentration of chloride infiltrating from the basins in the modeling simulations had to be restricted to 130 mg/L during landfill operations. This effluent concentration limit restricts the mass of contaminant that is available for transport, as will be discussed further in Section 7.0, Mitigation Measures. Once the landfill site is closed, final cover will be applied and operations traffic reduced. In the simulations, the projected source concentration in the basins was reduced to 0 mg/L in a linear function over five years of post-closure.

Figure 16(b) shows the predicted maximum extent of leachate-impacted groundwater from the existing unlined landfill, as influenced by the new landfill footprint and stormwater management ponds. From the results of the simulations, it is apparent that with no mitigation measures in place, it is predicted that the potential effects to groundwater quality would extend beyond the WM property boundary to the north.

The predicted contaminant flux through the double-composite liner of the new landfill footprint is described in the Facility Characteristics Report prepared for the Environmental Assessment. The chloride concentrations predicted to discharge through the base of the attenuation layer of the new landfill were used as source concentration inputs to the groundwater model. Since the mass flux of contaminant through the double-composite liner is very small (transport through the low permeability liner components is dominated by diffusion rather than by advection), the changes in chloride concentrations in the groundwater at the base of the attenuation layer are negligible. This is consistent with the regulatory definition of the Generic Design Option II (G2) liner system, which is designed to provide protection to groundwater quality without reliance on attenuation in the landfill buffer area.

7. MITIGATION MEASURES

The results of the numerical modeling predict that mitigation measures will be required to reduce the potential effects of the proposed landfill on Groundwater Quality to acceptable levels. The proposed mitigation measures are design-based and operational in nature, related to the movement of leachate-impacted groundwater from the existing landfill and effluent from the infiltration basins, respectively.

Within the context of this report to accompany an application for *Environmental Protection Act* approval, the proposed mitigation measures have been developed to a conceptual design level, using computer-based numerical modeling simulations. This is considered reasonable and sufficient in order to evaluate general trends in flow orientation and contaminant concentrations, and to assess the conceptual feasibility of the proposed measures. A detailed design of the mitigation measures, including additional modeling simulations and field testing, would need to be completed at such time as actual contaminant transport dictates. This will be driven by the results from the Environmental Monitoring Plan.

7.1 PURGE WELLS

The potential effects of the proposed landfill and associated operations relative to the future baseline conditions are that contaminant concentrations from leachate-impacted groundwater exceeding acceptable levels (as defined by the Reasonable Use Limits and as modeled using chloride as an indicator parameter) are predicted to extend beyond the northern boundary of the site. The source of the leachate-impacted groundwater is the existing unlined (closed) landfill footprint.

Purge wells are an effective method for controlling leachate migration from landfills in permeable geologic environments. The existing purge wells on the site control the eastward movement of impacted groundwater. A proposed mitigation measure to reduce the potential effects of the new landfill is to install a series of purge wells along the northern site boundary, northwest of the new footprint. The existing geologic conditions in the area consist of sand to sand-gravel overburden, underlain by fractured limestone bedrock of the Bobcaygeon Formation. The average hydraulic conductivity in the overburden-shallow bedrock zone for the closest monitoring well in the area (W75) is on the order of 2.4×10^{-4} m/s, which is considered a permeable formation with favourable conditions for hydraulic capture via purge wells. The purge wells would target the saturated overburden and the upper six to eight metres of fractured limestone as the primary pathway for leachate migration; the hydraulic conductivity values in the calibrated groundwater flow model for these hydrostratigraphic units range from 10^{-5} to 10^{-4} m/s. Actual conditions at the proposed purge well locations would be confirmed at the time of installation and testing.

The concept of purge wells installed as a mitigation measure was simulated using the numerical model of groundwater flow and contaminant transport. The results of the modeling simulations indicate that sufficient capture could be achieved by installing eight purge wells spaced evenly along the northern site boundary, completed in the overburden-shallow bedrock zone. The predicted maximum extent of leachate-impacted groundwater with chloride concentrations greater than 130 mg/L with the operation of the new purge wells is shown in Figure 17(b). The six most westerly wells purge wells were simulated to pump 30 m^3/day (21 L/min), and the two most easterly wells were simulated to pump 45 m^3/day (31 L/min), which are considered to be reasonable pumping rates for this type of aquifer.

Under this modeling scenario, the predicted distribution of leachate-impacted groundwater exceeding Reasonable Use Limits would not extend beyond the property boundaries of the proposed landfill. In addition, although there would be drawdown of groundwater levels in the vicinity of the purge wells and changes to the localized groundwater flow directions, no impacts to groundwater levels or flow directions are expected beyond the property boundaries.

The actual number and spacing of purge wells required and the design pumping rates would be determined during the detailed design of the mitigation measures, when required. However, for conceptual design purposes, the proposed mitigation measure is considered to provide a reasonable method of reducing the potential effects on groundwater quality to acceptable levels.

7.2 Operational Controls on Stormwater Management Pond Effluent

As described in Section 6.2, the stormwater management ponds have the potential effect of allowing elevated concentrations of contaminants to infiltrate to the groundwater table. The ponds are designed with two stages: surface runoff first flows into a lined stage and then overflows to an unlined infiltration basin. Effluent in the lined stage can be contained in case of a spill or other emergency.

The stormwater management ponds are located relatively close to the downgradient property boundary and beyond the zones of influence of the existing purge well system and the proposed northern purge wells described in the previous section. Because of the pond locations and the types of underlying geologic formations, once in the groundwater there is limited attenuation capacity available to further reduce the effluent concentrations. Therefore, the potential effects on groundwater quality from the operation of the stormwater management ponds should be controlled by establishing limits on the concentration of effluent in the unlined infiltration basins. These operational effluent limits would restrict the concentrations of dissolved constituents entering the groundwater system such that groundwater quality at the property boundaries would continue to meet acceptable levels.

Several predictive analyses of groundwater quality were completed using various effluent concentrations from the ponds. The results of the simulations indicate that a chloride concentration of approximately 130 mg/L would reduce the potential effects from the ponds to acceptable levels. Figure 17(a) shows the predicted maximum extent of impacted groundwater with chloride concentrations greater than 130 mg/L, using this same concentration as the maximum effluent limit from the infiltration basins. The impacted groundwater in this scenario (i.e., groundwater with chloride concentrations greater than 130 mg/L) does not extend beyond the property boundaries.

Based on this assessment, the proposed mitigation measure for the potential effects from the stormwater management ponds is to establish a concentration limit of 130 mg/L on the effluent infiltrating to the groundwater from the unlined pond stages.

7.3 Net Effects on Groundwater

The mitigation measures described in Sections 7.1 and 7.2 are intended to reduce the potential effects from the proposed landfill to acceptable levels.

For the Groundwater Flow criterion used to assess the impacts of the proposed landfill on hydrogeology, the potential effects described in Section 6.1 are acceptable and do not require further mitigation.

For the Groundwater Quality criterion, mitigation measures have been applied to the potential effects described in Section 6.2. With the implementation of mitigation measures, the resultant net effects are considered acceptable. A summary of the potential effects, mitigation measures and net effects for each criterion are summarized in Table 4.

8. PROPOSED MONITORING PROGRAMS

To ensure that the mitigation measures identified in Section 7 are implemented as envisioned and are effective in reducing the potential groundwater effects to acceptable levels, an environmental monitoring program should be conducted at the WCEC site. The groundwater and surface water components of the environmental monitoring program are described below.

8.1 Environmental Monitoring – Groundwater Component

The predicted net effects from the design and operation of the proposed landfill and stormwater management ponds with the mitigation measures in-place as described in Section 7 are that any negative impacts to groundwater flow and groundwater quality will remain within the site boundaries. Monitoring of groundwater levels and groundwater quality will be required to ensure that the predicted net effects are as expected. Refer to Table 6 for a list of proposed monitoring requirements for each potential effect identified in this assessment.

Groundwater flow on-site and within the site-vicinity should be monitored by measuring water levels in monitoring wells and the stormwater management ponds at a prescribed frequency. The water levels should be measured in selected monitoring wells completed in the overburden-shallow bedrock zone and the deeper bedrock. The water level measurements should be converted to groundwater elevations and be plotted on a site map to interpret the groundwater flow orientations and hydraulic gradients. Monitoring wells situated around the stormwater management ponds should be used to observe flow conditions around the ponds, specifically whether localized radial flow occurs as expected.

Groundwater quality should be monitored by analyzing groundwater chemistry in samples collected from monitoring wells on-site and within the site-vicinity at prescribed frequencies. An appropriate site-specific list of groundwater quality monitoring parameters should be developed using the approved Environmental Monitoring Plan for the current landfill site, and with reference to the indicator list specified in Schedule 5 of O. Reg. 232/98.

The overall strategy in monitoring groundwater quality is to: i) observe conditions from the existing closed landfill site over time; and ii) observe conditions surrounding the new landfill footprint and the stormwater management ponds. This can be accomplished by monitoring groundwater quality at the following locations:

- between the two landfill footprints;
- surrounding the new landfill and stormwater management ponds;
- effluent from the unlined stages of the stormwater management ponds; and
- at varying distances downgradient from the stormwater management ponds and the new landfill footprint.

New monitoring wells will need to be installed north and east of the new landfill footprint. Selected monitoring wells on the existing landfill site currently used for groundwater quality monitoring should continue to be used.

Water samples from the primary and secondary leachate collection systems of the new landfill should be collected and analyzed for an appropriate suite of parameters using the guidance from Schedule 5 of O.Reg. 232/98. This will allow for comparison of water quality between the new landfill, the existing closed landfill and groundwater in the vicinity of the two footprints. This information can be used to verify the source of any observed impacts to groundwater quality.

Details of the groundwater monitoring program, including specific sampling locations, physical/chemical parameters, and sampling frequencies, as well as trigger/compliance locations and parameter concentrations, have been developed as part of the Environmental Monitoring Plan (EMP) for the proposed landfill, which accompanies this document as part of the proponent's application for approval under the *Environmental Protection Act (EPA).*

8.2 ENVIRONMENTAL MONITORING – SURFACE WATER COMPONENT

The purpose of the surface water monitoring program is to determine if the new landfill footprint are having any adverse impacts on the neighbouring surface water environment, and to monitor surface water quality in the new stormwater management ponds. The monitoring locations and analytical parameters should be selected to identify the characteristics of the water downgradient from the landfill.

Surface water elevations should be monitored in the new infiltration basins, and compared to the adjacent groundwater elevations in monitoring wells. These measurements can be used to complement the groundwater elevations to determine the local directions of groundwater flow.

The purpose of surface water sampling is to monitor the quality of surface water to evaluate whether the quality of the water is impacted by the operation of the new landfill and stormwater management ponds. Samples should be collected from the lined stormwater management ponds and from the unlined infiltration basins.

Details of the surface water monitoring program, including specific sampling locations, physical/chemical parameters, and sampling frequencies, as well as trigger/compliance locations and parameter concentrations, have been developed as part of the Environmental Monitoring Plan (EMP) for the proposed landfill.

9. CONTINGENCY PLANS

Contingency plans for groundwater and surface water have also been developed as part of the Environmental Monitoring Plan document which accompanies the application for EPA approval. Within the scope of that document, contingency plans are defined as general procedures that will be followed to respond to potential future environmental impacts associated with the closed WM Ottawa Landfill and the new WCEC facility. These plans typically include assessing the scope of a potential problem, additional investigation to determine the precise extent of a problem, assessing potential remedial alternatives ("contingency measures") and the installation of any additional engineered facilities not originally part of the landfill design, or the implementation of other mitigative action.

Brief descriptions of the contingency measures that potentially could be implemented as part of the Contingency Plans are provided in the EMP.

The status of contingency plans is to be reviewed annually as part of the environmental reporting process. Proposed contingency actions should be implemented if necessary in consultation with the MOE District Office.

Sincerely,

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TABLES

Table 1: Summary of Vertical Hydraulic Gradients, 2008 to 2013

	Vertical Hydraulic Gradients								
Monitors (deep/shallow)	May 21/08	Apr. 28/09	Apr. 26/10	Jan. 19/11	Apr. 27/11	Aug. 17/11	Nov. 7/11	May 7/12	May 22/13
W42-1/W42-2	↓	↓	↓	↓	↓	↑	↓	↓	↓
W44-1/W44-3	↓	↓	↓	↓	↓	↓	↓	↓	↓
W46-1/W46-2	↓	↓	↓	↓	↓	↓	↓	↓	↓
W48-1/W48-2	↓	↓	↓	↓	↓	↓	↑	↓	↓
W50-1/W50-2	↓	↓	↓	↓	↓	↓	↓	↓	↓
W53-1/W53-2	↓	↓	↓	↓	↓	↓	↓	↓	↓
W54-1/W54-2	↓	↓	↓	↓	↓	↓	↓	↓	↓
W56-1/W56-2	↓	↓	↓	↓	↓	↓	↓	↓	↓
W57-1/W57-2	↓	↓	↓	↓	↓	↑	↑	↓	↓
W59-1/W59-2	↓	↓	↓	↓	↓	↑	↓	↓	↓
W60-1/W60-2	↓	↓	↓	↑	↓	↑	↓	↑	↓
W62-1/W62-2	↓	↓	↓	↓	↑	↓	↓	↑	↓
W65-1R/W65-2	↓	↓	↓	↓	↓	↓	↓	↓	↓
W67-1/W67-2	↓	↓	↓	↓	↓	↑	↓	↓	↓
W73-1/W73-2	n.m.	n.m.	n.m.	↓	↓	↓	↓	↓	↓
W76-1/W76-2	no vertical gradient	↓	no vertical gradient	↓	↓	↓	↓	↓	no vertical gradient

n.m. - denotes water levels not measured.

Table 2 - Summary of Hydraulic Testing Results, WCEC Property

(a) *Slug Test Results*

Borehole	Area	Hydraulic Conductivity (m/s)
W57-2	Existing Landfill	1.6E-05
W58		2.3E-05
W59-2		4.0E-06
W61		9.1E-06
W66		>2.8E-04
W67-2		>2.8E-04
W68		>2.8E-04
W69		1.9E-04
W70		6.7E-06
W72		1.6E-04
W53-1	Existing Landfill; downgradient	6.5E-06
W53-2		4.7E-06
W55-2		1.4E-05
W56-2		1.2E-05
W84		9.5E-06
W85		8.9E-06
W86		1.4E-05
W60-2	Existing Landfill; North Envelope	5.2E-05
W62-2		7.1E-06
W63		3.6E-05
W64		>2.8E-04
W65-2		>2.8E-04
W73-2	North Envelope	>1.0E-03
W75		2.4E-04
W76-2		>1.0E-03

(b) Packer Test Results

Borehole	Area	Mid-Packer Depth below Bedrock Surface (m) / Hydraulic Conductivity (m/s)					
W57-1	Existing Landfill	2.7	5.5	8.0	10.5	13.0	
		7.8E-07	1.4E-08	4.3E-08	2.1E-09	1.2E-08	
W59-1	Existing Landfill	1.5	4.1	6.5	8.9	11.3	13.7
		1.3E-06	<1.0E-11	7.7E-08	1.7E-10	2.9E-09	5.7E-07
W60-1	Existing Landfill; North Envelope	1.3	3.8	6.4	8.9	11.6	13.9
		1.7E-05	5.1E-10	8.3E-09	1.1E-09	1.8E-07	2.0E-07
W62-1	Existing Landfill; North Envelope	1.6	3.3	6.1	8.3	10.6	12.9
		7.5E-07	2.0E-08	4.4E-08	<1.0E-11	3.9E-07	<1.0E-11
W65-1	Existing Landfill; North Envelope	1.2	3.6	6.1	8.5	11	
		5.5E-08	2.5E-11	4.4E-07	5.2E-09	1.9E-08	
W73-1	North Envelope	4.0	6.0	8.0	10.0	12.0	
		6.2E-08	6.0E-08	1.4E-08	2.0E-09	8.3E-08	
W76-1	North Envelope	3.0	4.2	6.2	8.2		
		9.0E-05	2.2E-06	1.9E-06	2.6E-06		

Table 3: Summary of Background Groundwater Quality,
Range of Concentrations and Median Values

	Overburden-Shallow Bedrock	
Parameter	Background Range	Median Background
General and Inorganic Parameters		
alkalinity	127 - 367	202
ammonia	< 0.02 - 1.1	< 0.15
barium	0.01 - 1.04	0.11
boron	< 0.01 - 0.67	0.03
cadmium	< 0.0001 - 0.005	0.0001
calcium	8.4 - 365	68
COD	< 3 - 120	5
chloride	< 1 - 759	46
chromium	< 0.001 - 1.09	0.003
conductivity (µS/cm)	329 - 4890	620
cyanide (free)	< 0.002	< 0.002
DOC	< 0.5 - 10.3	2.4
hardness	39 - 630	267
iron	< 0.01 - 6.77	0.05
lead	< 0.0005 - 0.002	0.0005
magnesium	2 - 80	18
manganese	< 0.002 - 0.22	0.02
nitrate	< 0.01 - 8.44	< 0.1
nitrite	< 0.01 - 0.17	< 0.1
pH (no units)	7.30 - 8.80	7.92
potassium	< 1 - 12	2
sodium	3 - 610	15
sulphate	11 - 130	27
TDS	10 - 1626	400
TKN	< 0.05 - 5	< 0.7

Note: All units expressed as mg/L, except where noted.

Table 4: Potential Effects, Proposed Mitigation Measures and Resulting Net Effects

Number	Potential Effect	Mitigation Measures	Net Effect
Groundwater Flow			
1	Local groundwater elevations may be lowered as a result of a reduction in the amount of recharge to groundwater below the new landfill footprint. The local and regional groundwater flow directions are not expected to be impacted.	None required.	No impacts to off-site groundwater flow.
2	Infiltration from the SWM Ponds may cause water levels to rise in the vicinity of the ponds. Groundwater flow is expected to be oriented radially away from the ponds, which will affect the orientation of the local flow regime.	None required.	No impacts to off-site groundwater flow.
Groundwater Quality			
3	Surface water that infiltrates to the groundwater table from the SWM Ponds may contain elevated concentrations of contaminants from surface runoff, traffic and landfill operations. These contaminants may migrate with the groundwater flow toward the downgradient property boundary, which is situated approximately 90-125 metres east of the ponds.	Effluent limits should be established on the concentration of indicator parameters that are discharged to groundwater from the SWM Ponds.	The effluent limits will restrict the migration of contaminants so that there are no impacts to off-site groundwater quality above acceptable standards.
4	Radial groundwater flow predicted to occur around the SWM Ponds is expected to intercept the movement of leachate-impacted groundwater from the existing unlined landfill, which may have the effect of re-orienting leachate-impacted groundwater further northward, extending beyond the northern site boundary.	A series of purge wells may need to be installed north of the proposed footprint. The purge wells would be designed to control the migration of leachate-impacted groundwater before it reaches the WM property boundary (as per MOE Guideline B-7).	The proposed mitigation measure is considered to provide a reasonable method of reducing the potential effects on groundwater quality. No impacts to off-site groundwater quality are expected above acceptable standards.

Table 5: Infiltration Estimates from Unlined Infiltration Basins

Pond	Volume of Runoff (m^3/yr)	Area of Base of Unlined Stage (m^2)	Annual Infiltration Rate (mm/yr)
New SWM Infiltration Basin #1	59,100	18,300	3,230
New SWM Infiltration Basin #2	120,900	25,600	4,725

Table 6: Proposed Groundwater Monitoring Requirements

Potential Effect	Proposed Monitoring Requirement	Associated Licences, Permits or Authorizations
Groundwater Flow		
	▸ Monitor groundwater elevations in monitoring wells on-site and within the site-vicinity. ▸ Use the collected data to map and interpret the groundwater flow orientations.	Development of an approved EMP as part of the EPA application.
Groundwater Quality		
	▸ Collect groundwater samples from selected monitoring wells located on-site and within the site-vicinity; analyze the samples for an appropriate site-specific indicator list. ▸ Use the collected data to interpret groundwater quality conditions upgradient, between the landfill footprints, and downgradient from the new landfill facilities.	Development of an approved EMP as part of the EPA application.

FIGURES

LEGEND

- Proposed Access Roads
- WCEC Site Boundary
- Proposed WCEC Landfill Footprint
- Proposed Stormwater Management Ponds

1				
REV.	DESCRIPTION	YY/MM/DD	BY	CHK

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.
PROJECTION: NAD27, MTM ZONE 9

0 100 200 400
Meters

N W E S

CLIENT

WASTE MANAGEMENT

PROJECT

WASTE MANAGEMENT
WEST CARLETON ENVIRONMENTAL CENTRE

TITLE

SITE LOCATION MAP

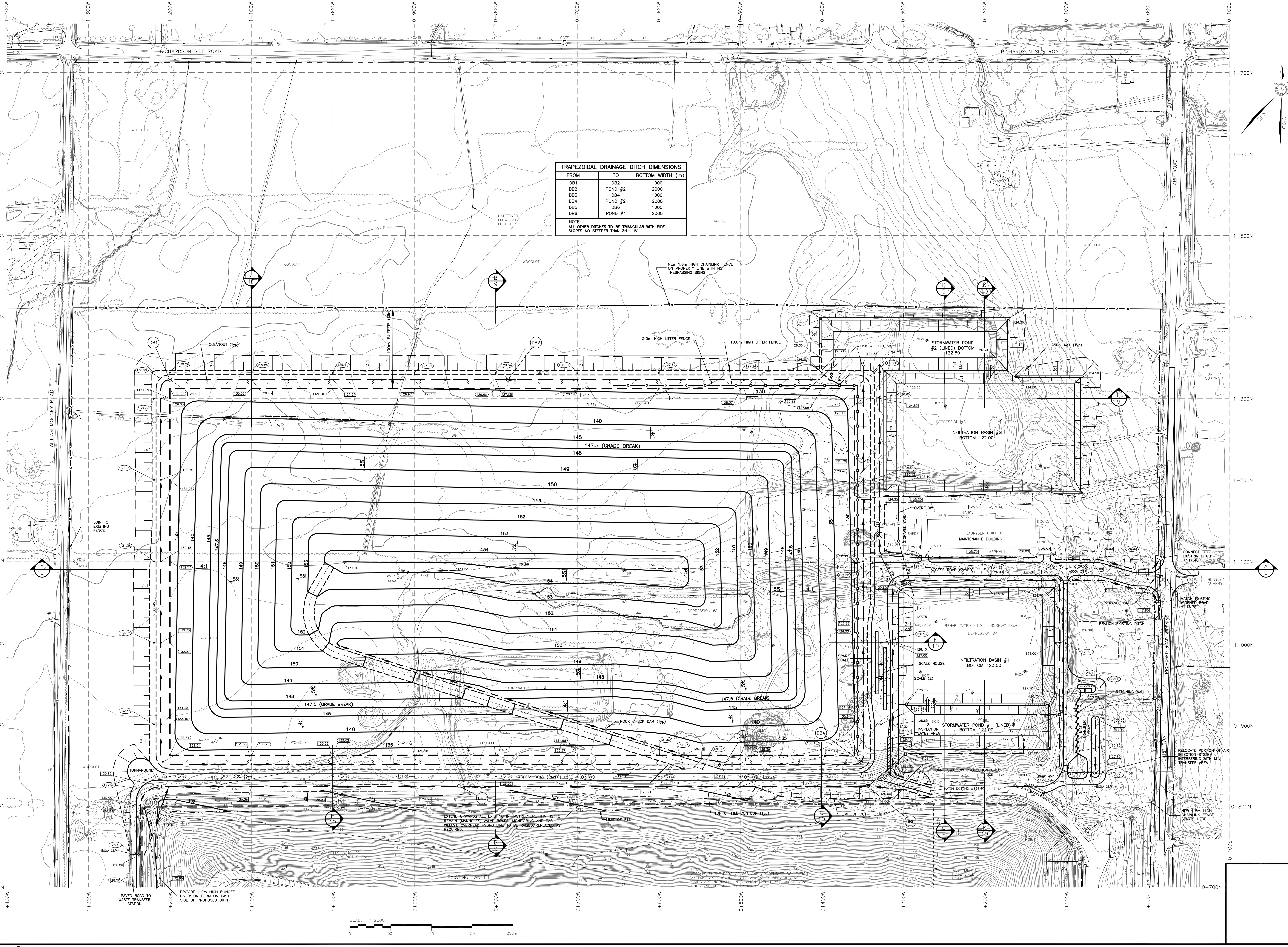
WESA, a division of BluMetric Environmental Inc.

WESA
a BluMetric company

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

BluMetric includes WESA, Seprotech, WESAtech, Envir-Eau, OEL-HydrosSys, WESAtechnologias

PROJECT #		DATE	
C-B8831		2014-02-28	
DRAWN	CHECKED	FIG NO.	REV
YL	DH	01	0



TRAPEZOIDAL DRAINAGE DITCH DIMENSIONS		
FROM	TO	BOTTOM WIDTH (m)
DB1	DB2	1000
DB2	POND #2	2000
DB3	DB4	1000
DB4	POND #2	2000
DB5	DB6	1000
DB6	POND #1	2000

NOTE :
ALL OTHER DITCHES TO BE TRIANGULAR WITH SIDE SLOPES NO STEEPER THAN 3H : 1V

WSP
101-1450 1st AVENUE W
OWEN SOUND (ONTARIO) CANADA N4K 6W2
TEL: 519-376-7612 | FAX: 519-376-8008 | WWW.WSPGROUP.COM

WM WASTE MANAGEMENT

PROPOSED FINAL LANDFILL CONTOURS

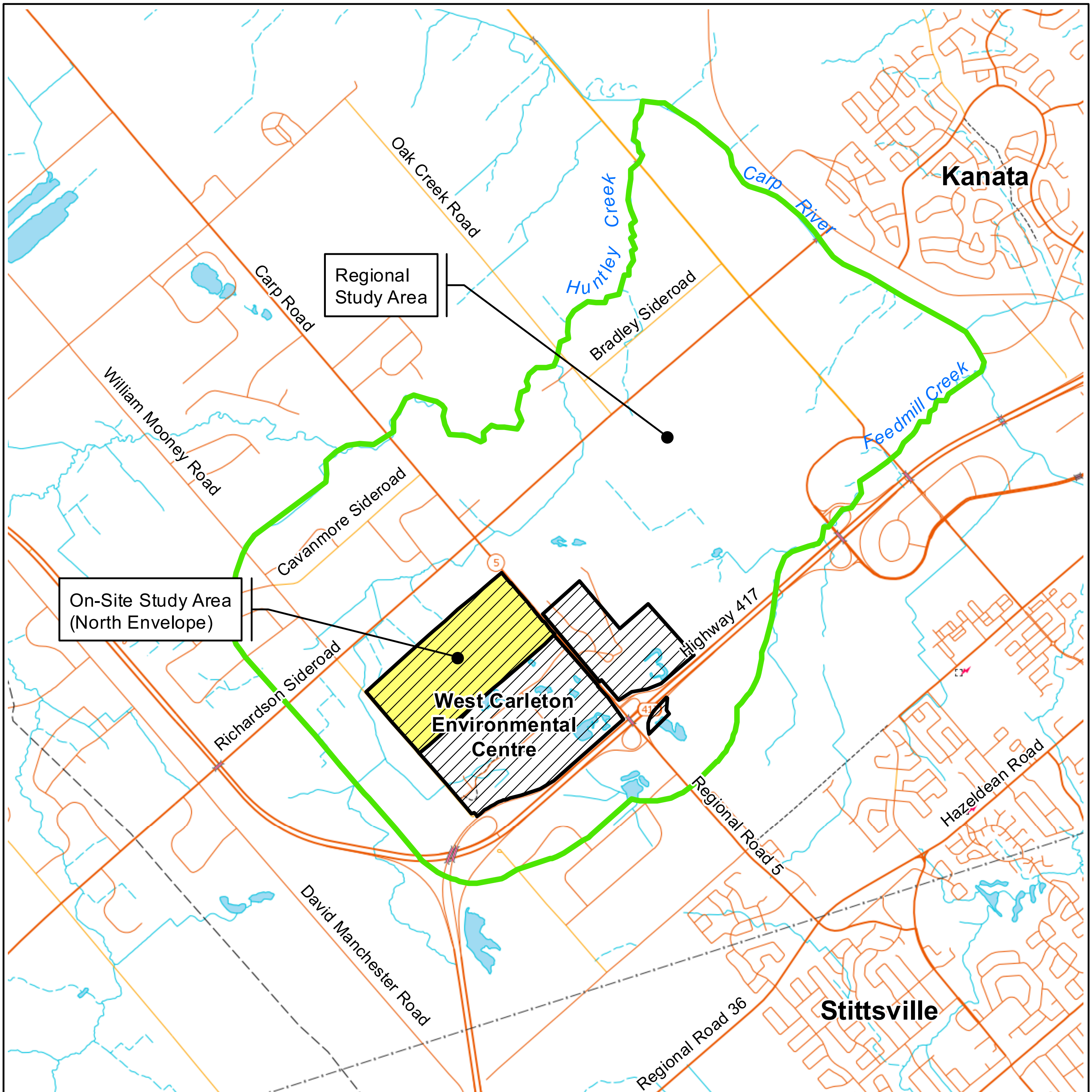
WEST CARLETON ENVIRONMENTAL CENTRE

DWN BY: T C G
CHK BY: P S B
DATE: MARCH 17, 2014
SCALE: SEE BAR SCALE

WASTE MANAGEMENT OF CANADA CORPORATION

DRAWING NO. 131-19416-00 - 4

SHEET 4



LEGEND

WCEC Facility and CAZ
On-Site Study Area
Regional Study Area

REFERENCE

Source:
-Toporama, LIO 2011
-North American Datum 1983. Zone 18 N.

0 125 250 500 750 1,000
Metres
1:40,000

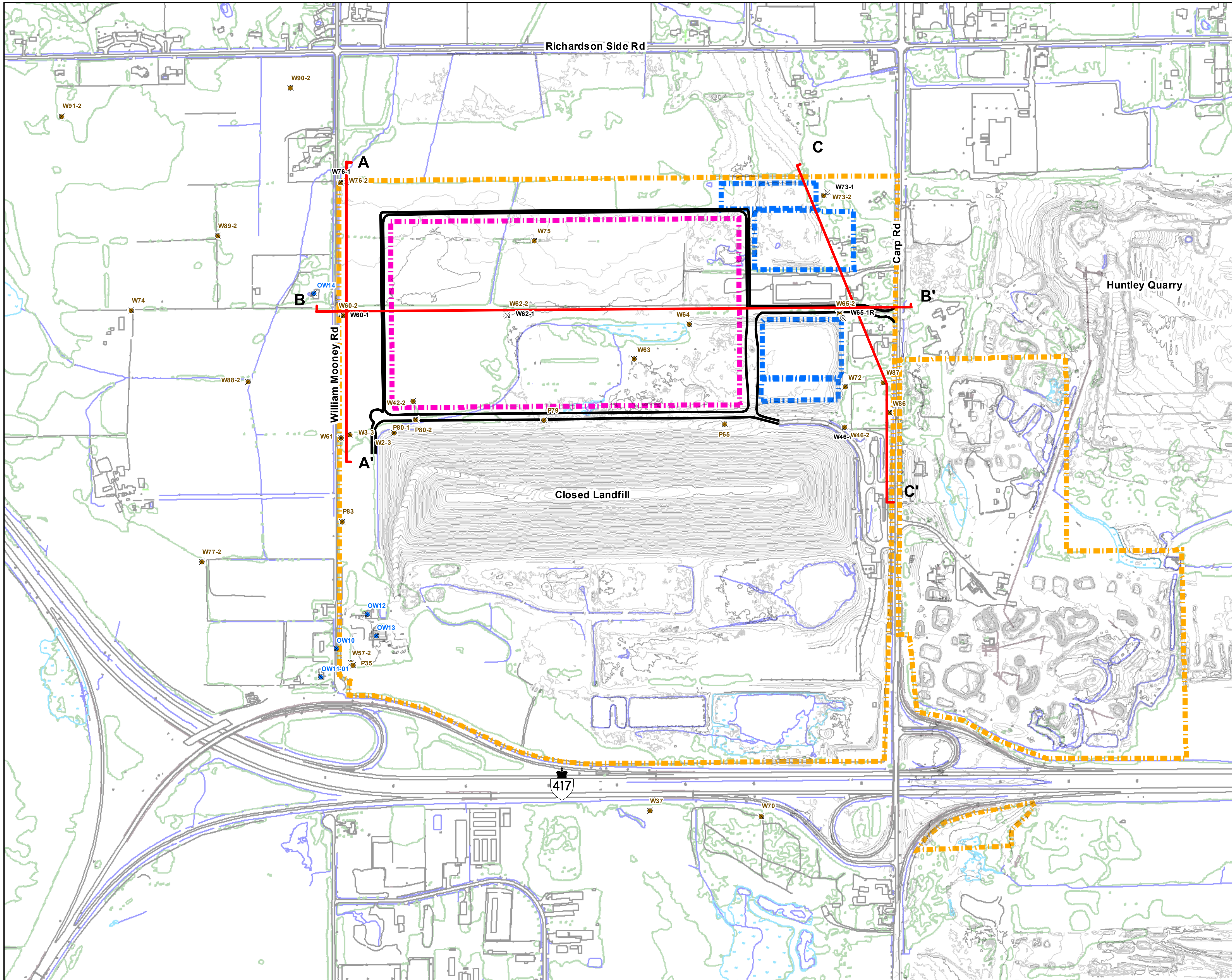
PROJECT
WASTE MANAGEMENT
WEST CARLETON ENVIRONMENTAL CENTRE

TITLE
SITE LOCATION AND
STUDY AREAS

WESA
a BluMetric company

PROJECT No. CB8831-14		
DESIGN	JFD	
GIS	JFD	2014/06/24
CHECK	DH	
REVIEW		

FIGURE 3



LEGEND

Wells referred to in Section 5.4 of report:

- Overburden-Shallow Bedrock Wells
- Deep Bedrock Wells
- Water Supply Wells

- Proposed Access Roads
- WCEC Site Boundary
- Proposed WCEC Landfill Footprint
- Proposed Stormwater Management Ponds
- Geologic Cross-Sections (Refer to Figure 8)

REV.	DESCRIPTION	YY/MM/DD	BY	CHK
1				

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.
PROJECTION: NAD27, MTM ZONE 9

0 250 500 Meters

CLIENT

WASTE MANAGEMENT

PROJECT

WASTE MANAGEMENT
WEST CARLETON ENVIRONMENTAL CENTRE

TITLE

SITE TOPOGRAPHY AND LAYOUT

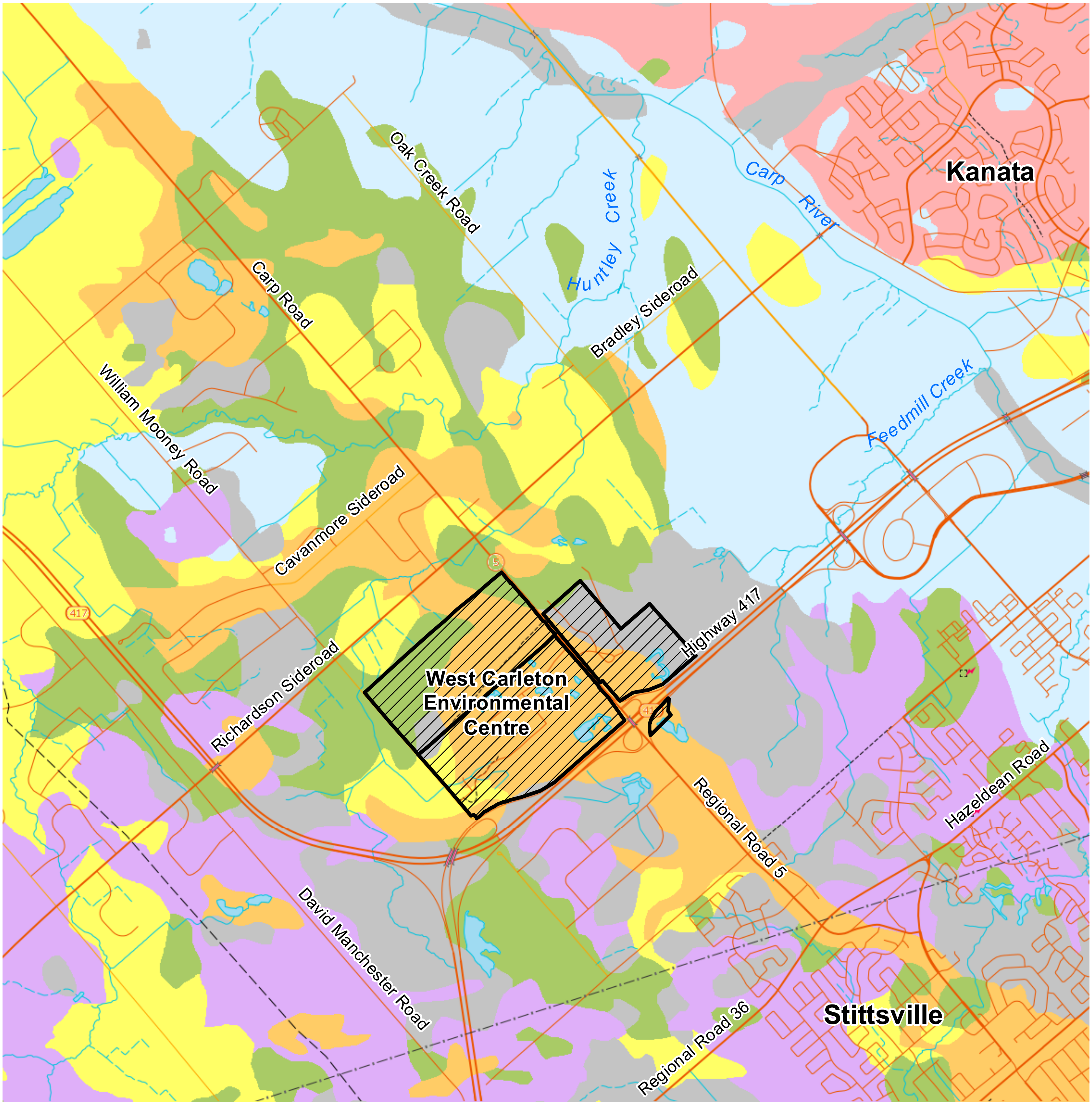
WESA, a division of BluMetric Environmental Inc.

WESA
a BluMetric company

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

BluMetric includes WESA, Seprotech, WESAtech, Envir-Eau, OEL-HydrosSys, WESAtechnologias

PROJECT #		DATE	
C-B8831		2014-06-24	
DRAWN	CHECKED	FIG NO.	REV
YL	DH	04	0



LEGEND

OGS Surficial Geology

- Fill - heterogenous, man-made deposits
- Organic deposits - peat, muck and marl
- Gravel - ice-contact and glaciolacustrine stratified deposits
- Sand - coarse-textured glaciolacustrine
- Silt - fine-textured glaciolacustrine and glaciomarine deposits
- Clay - fine-textured glaciolacustrine and glaciomarine deposits
- Till - silty sand-gravel till on Paleozoic bedrock
- Paleozoic Bedrock - carbonate and arkosic formations
- Precambrian Bedrock - undifferentiated

REFERENCE

Source:
-Toporama, LIO 2011
-North American Datum 1983. Zone 18 N.

0 125 250 500 750 1,000
Metres
1:40,000

N

PROJECT

WASTE MANAGEMENT
WEST CARLETON ENVIRONMENTAL CENTRE

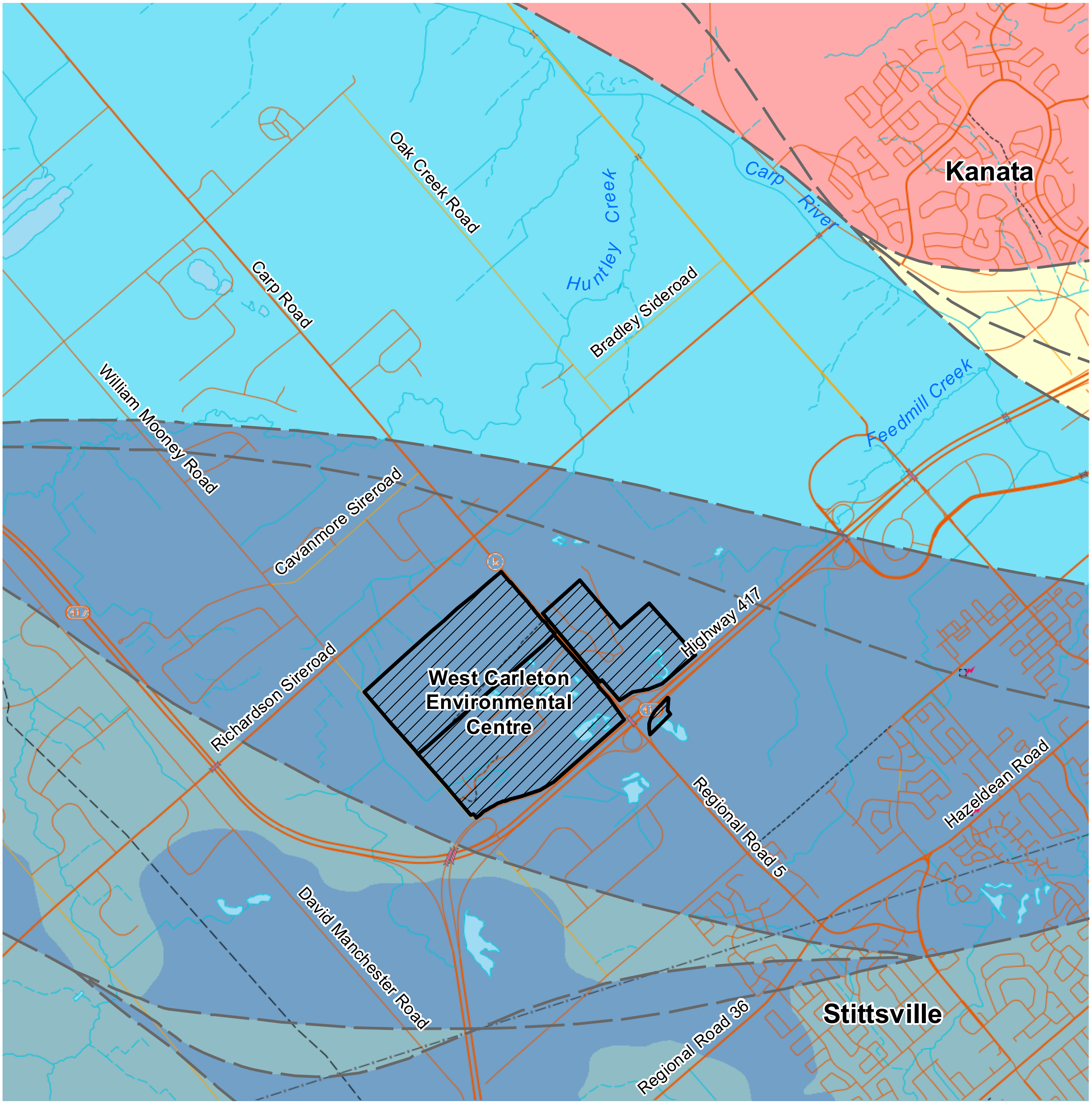
TITLE

SURFICIAL GEOLOGY

WESA a BluMetric company

PROJECT No. CB8831-14		
DESIGN	JFD	
GIS	JFD	2014-03-18
CHECK	DH	
REVIEW		

FIGURE 5



LEGEND

Formation

- Verulam
- Bobcaygeon
- Gull River
- Nepean
- Precambrian
- Faults

REFERENCE

Source:
-Toporama, LIO 2011
-North American Datum 1983. Zone 18 N.

0 125 250 500 750 1,000
Metres
1:40,000

N

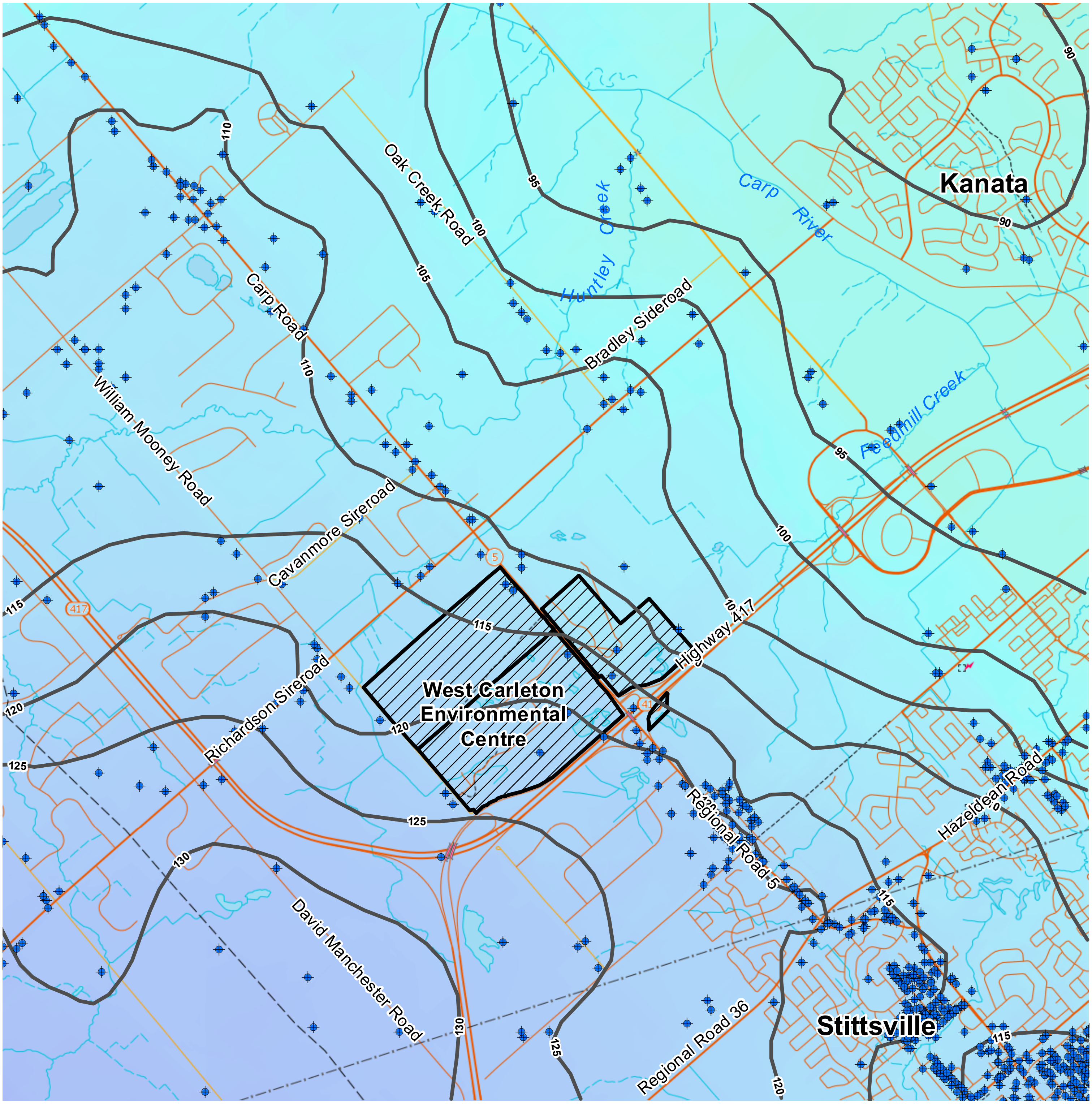
PROJECT
WASTE MANAGEMENT
WEST CARLETON ENVIRONMENTAL CENTRE

TITLE
BEDROCK GEOLOGY

WESA

PROJECT No. CB8831-14		
DESIGN	JFD	
GIS	JFD	2014-06-24
CHECK	DH	
REVIEW		

FIGURE 6



LEGEND

MOE Water Wells

Groundwater Elevation Contours (masl)

Groundwater Elevations (masl)

High : 150.3

Low : 53.9

REFERENCE

Source:
-Toporama, LIO 2011
-North American Datum 1983. Zone 18 N.

0 125 250 500 750 1,000
Metres
1:40,000

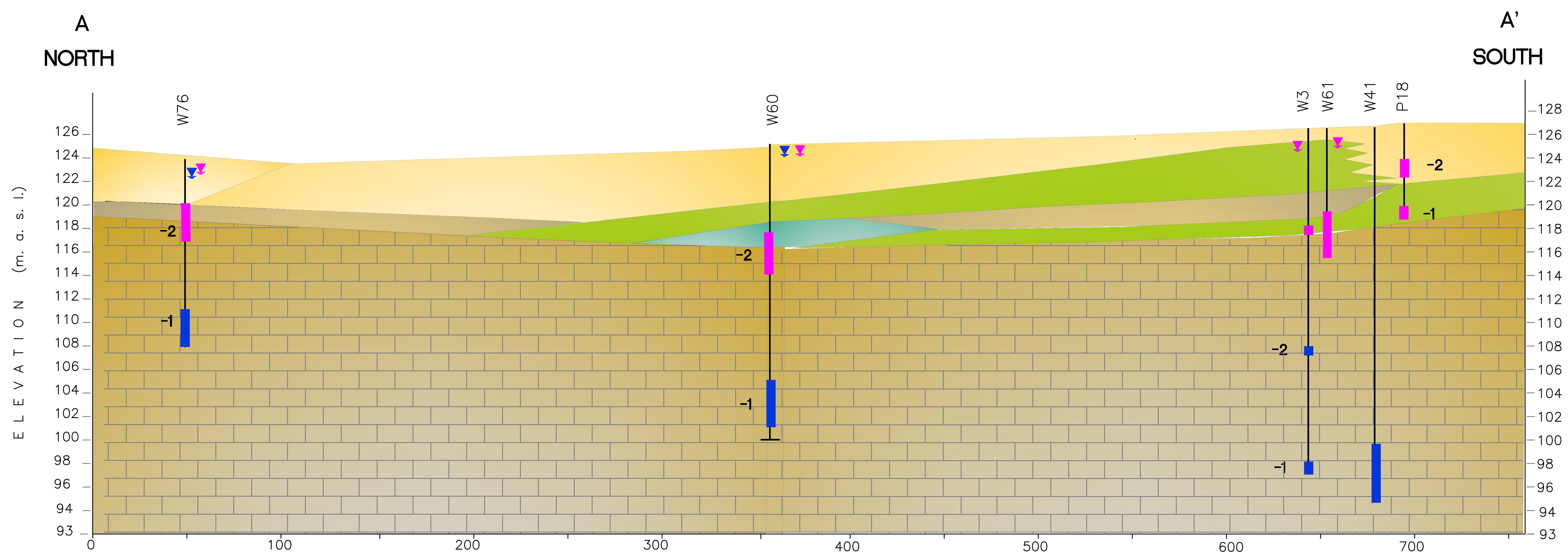
PROJECT
WASTE MANAGEMENT
WEST CARLETON ENVIRONMENTAL CENTRE

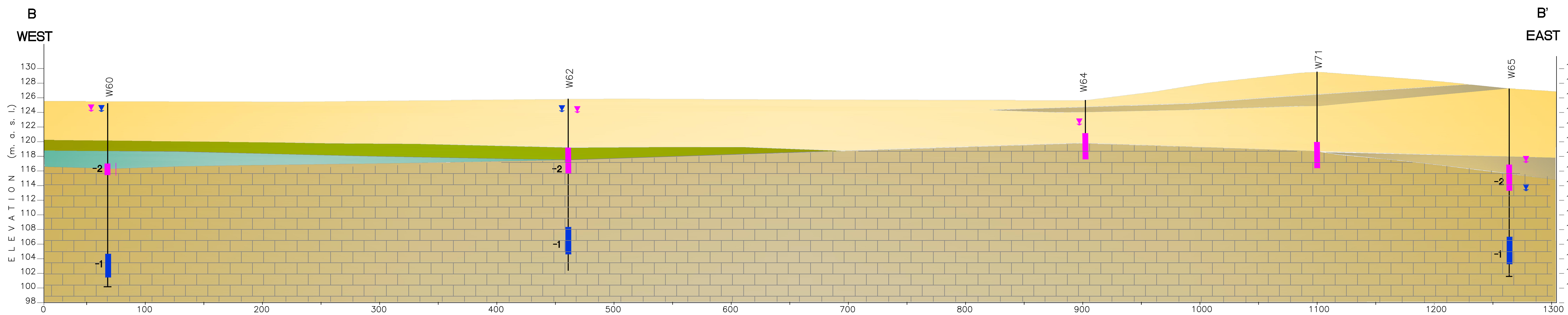
TITLE
REGIONAL GROUNDWATER ELEVATIONS
FROM MOE WATER WELL RECORDS

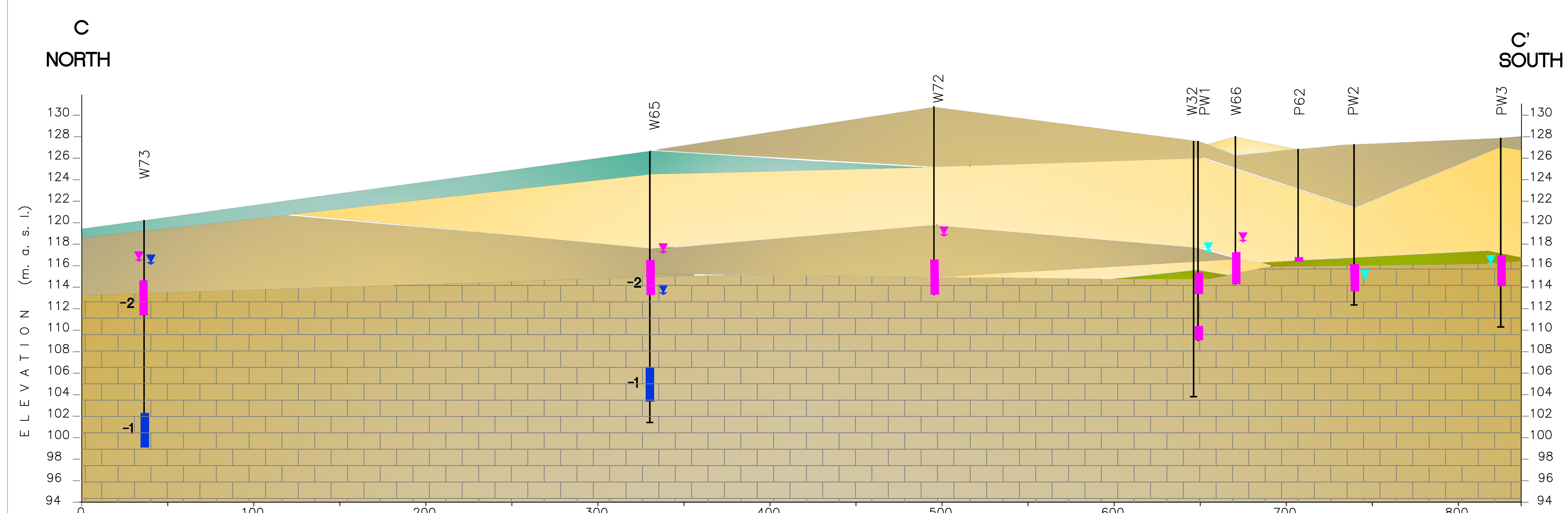
WESA
a BluMetric company

PROJECT No. CB8831-14		
DESIGN	JFD	
GIS	YL	2014-06-24
CHECK	DH	
REVIEW		

FIGURE 7







LEGEND:

- SAND & SILT
- SAND & GRAVEL
- SILT
- TILL
- LIMESTONE (BOBCAYGEON FM.)

-1 -2 MONITORING WELL SCREEN LOCATION INDICATOR (-1 = DEEPEST SCREEN)

SHALLOW SCREEN

DEEP SCREEN

GROUNDWATER ELEVATIONS (APRIL 2011)

OVERBURDEN–BEDROCK INTERFACE

DEEP BEDROCK

CAD FILE: 88831-SECTIONS-RV MAR 2014

STRATIGRAPHIC CROSS-SECTIONS

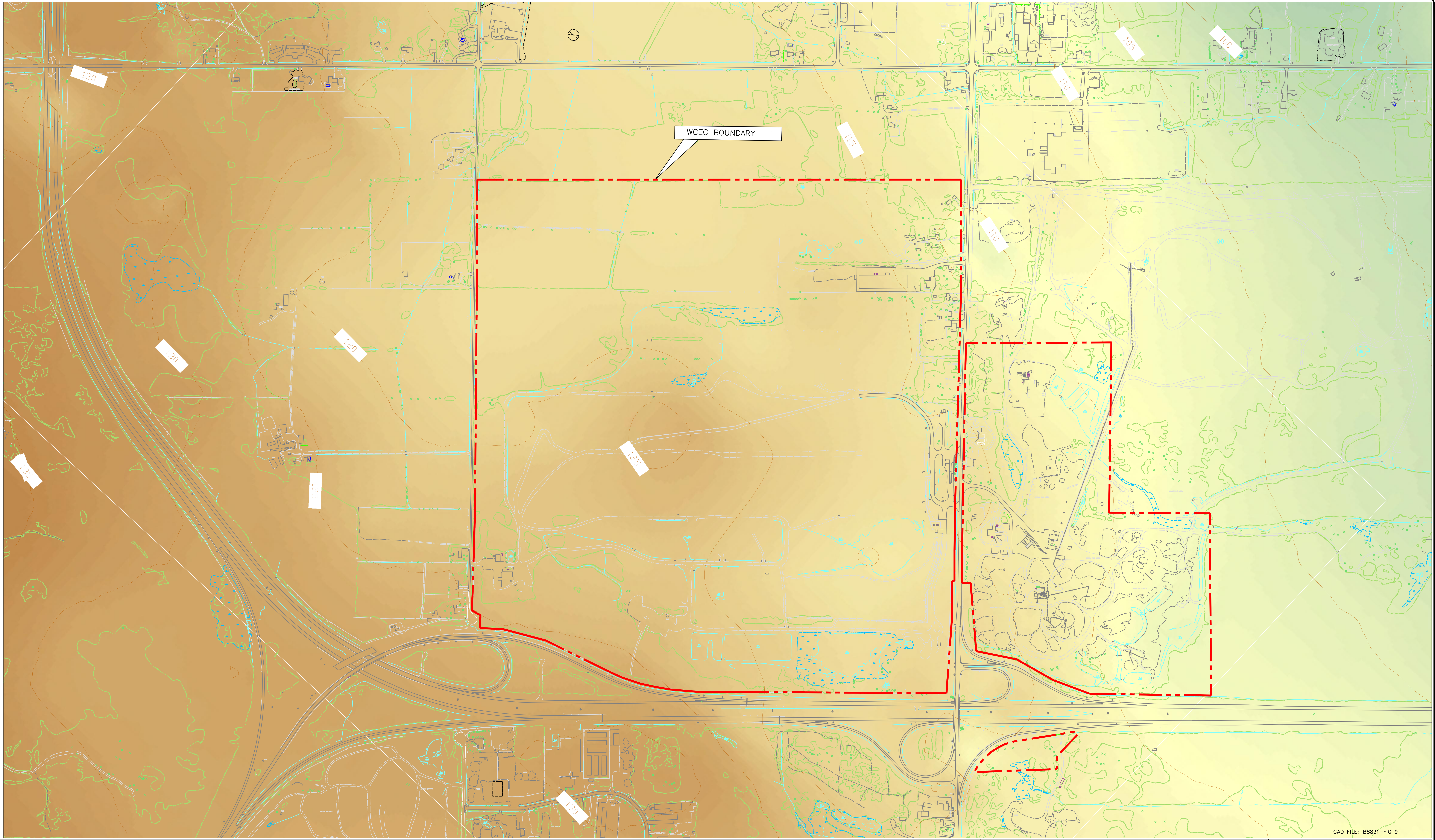
WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

WM - OTTAWA LANDFILL SITE

DWN BY: C.M.R.
CHK BY: D.H.

DATE: 01/05-14
SCALE: AS SHOWN

FIGURE:
8



LEGEND :

WCEC PROPERTY BOUNDARY (APPROX.)
EXISTING DITCH, SWALE
EXISTING ROADS
EXISTING TREE LINE
EXISTING BUILDINGS

Bedrock Elevation (masl)

Value

High : 150

Low : 70

BEDROCK SURFACE CONTOURS (m)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE	CONTOUR INT.	HORIZ. DATUM	VERTICAL DATUM
1:2000	1 METRE	NAD 27	GEODETIC
PHOTO SCALE 1:4000	PHOTO DATE JUNE 29, 2007	CONTRACT NO. 2124-07	

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING
37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7V3
TEL: 613 723-8100 FAX: 613 723-8569
WWW.BASEMAP.CA

GEODETIC NORTH

N

1 : 2000 MAP SCALE

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a BluMetric company

WASTE MANAGEMENT

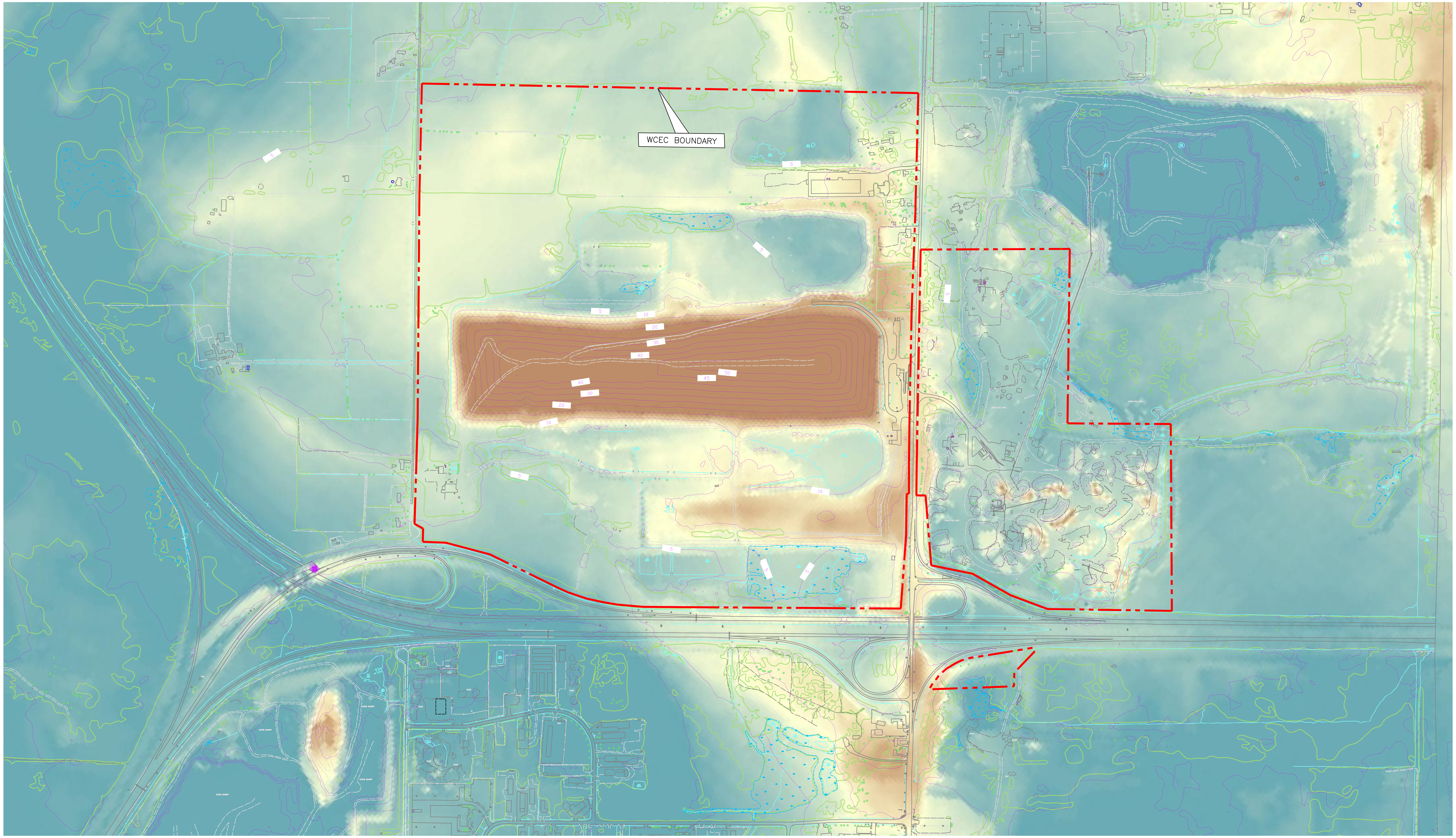
BEDROCK SURFACE TOPOGRAPHY

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

DWN BY: C.M.R. DATE: 02/05/11
CHK BY: D.H. SCALE: AS SHOWN

WM - OTTAWA LANDFILL SITE

FIGURE:
9



CAD FILE: B8831-FIGURE 10

LEGEND :

- WCEC PROPERTY BOUNDARY (APPROX.)
- EXISTING DITCH, SWALE
- EXISTING ROADS
- EXISTING TREE LINE
- EXISTING BUILDINGS

Overburden Thickness (m)

Value

High : 55

Low : 0

OVERBURDEN THICKNESS CONTOURS (m)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE	CONTOUR INT.	HORIZ. DATUM	VERTICAL DATUM
1:2000	1 METRE	NAD 27	GEODETIC
PHOTO SCALE 1:4000	PHOTO DATE JUNE 29, 2007	CONTRACT NO. 2124-07	

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING
37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7V3
TEL: 613 723-8100 FAX: 613 723-8569
WWW.BASEMAP.CA

GEODETIC NORTH

N

20 0 20 40 60 80 100 120 140 160 METRES
1 : 2000 MAP SCALE
1 CM = 20 METRES

WESA a BluMetric company

WM WASTE MANAGEMENT

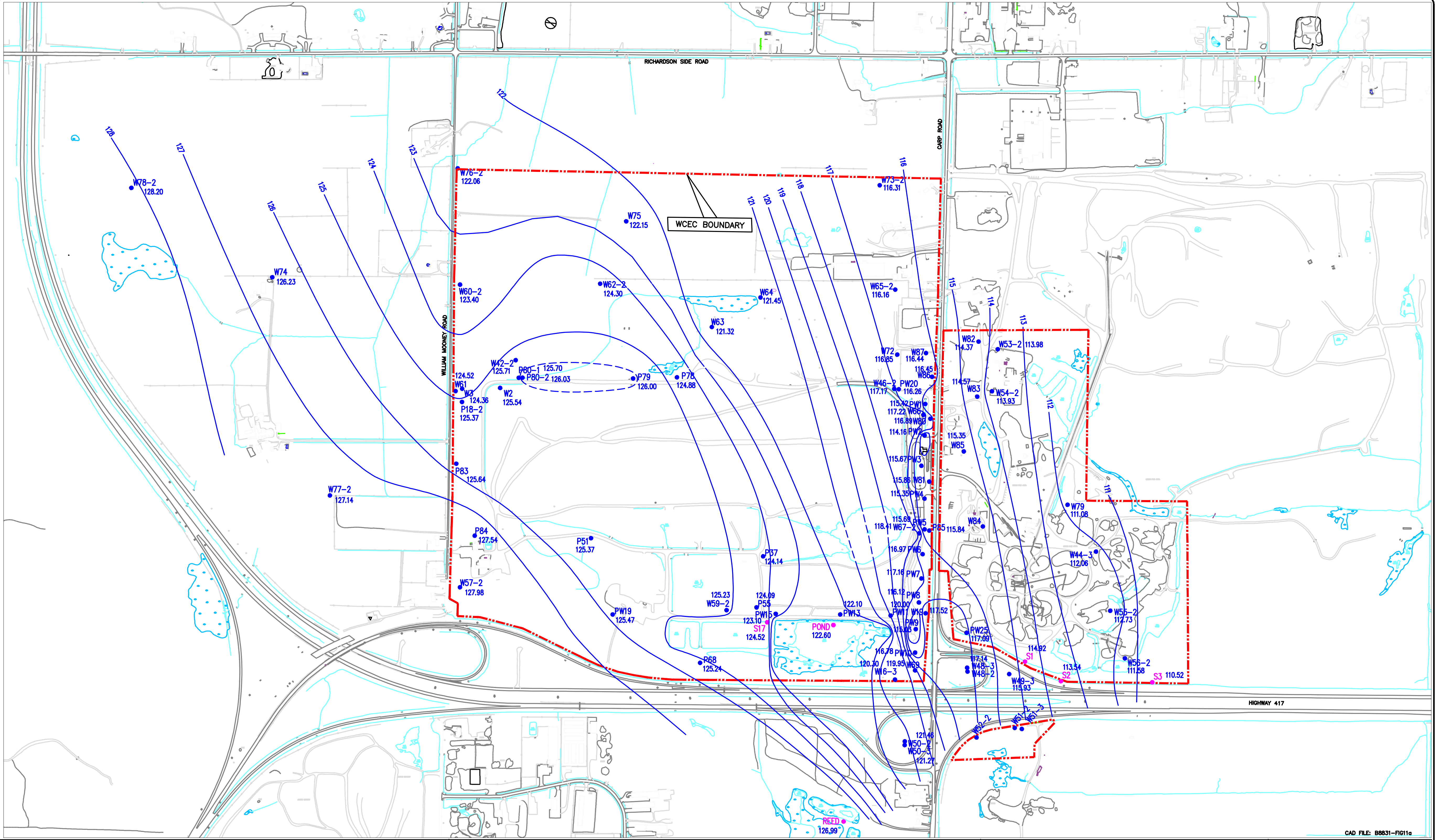
OVERBURDEN THICKNESS

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

DWN BY: C.M.R. DATE: 19/03/14
CHK BY: D.H. SCALE: AS SHOWN

WM - OTTAWA LANDFILL SITE

FIGURE: 10



LEGEND :

WCEC PROPERTY BOUNDARY (APPROX)

EXISTING DITCH, SWALE

EXISTING ROADS

EXISTING BUILDINGS

LEGEND:

OVERBURDEN-SHALLOW BEDROCK MONITORING WELLS

SURFACE WATER MONITORING LOCATIONS

OVERBURDEN-SHALLOW BEDROCK GROUNDWATER CONTOURS (m)

125.24 GROUNDWATER ELEVATION – JANUARY 2011 (masl)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE	CONTOUR INT.	HORIZ. DATUM	VERTICAL DATUM
1:2000	1 METRE	NAD 27	GEODETIC
PHOTO SCALE 1:4000	PHOTO DATE JUNE 29, 2007	CONTRACT NO. 2124-07	

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING
37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7V3
TEL: 613 723-8100 FAX: 613 723-8500
WWW.BASEMAP.CA

GEODETIC NORTH

N

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WM WASTE MANAGEMENT

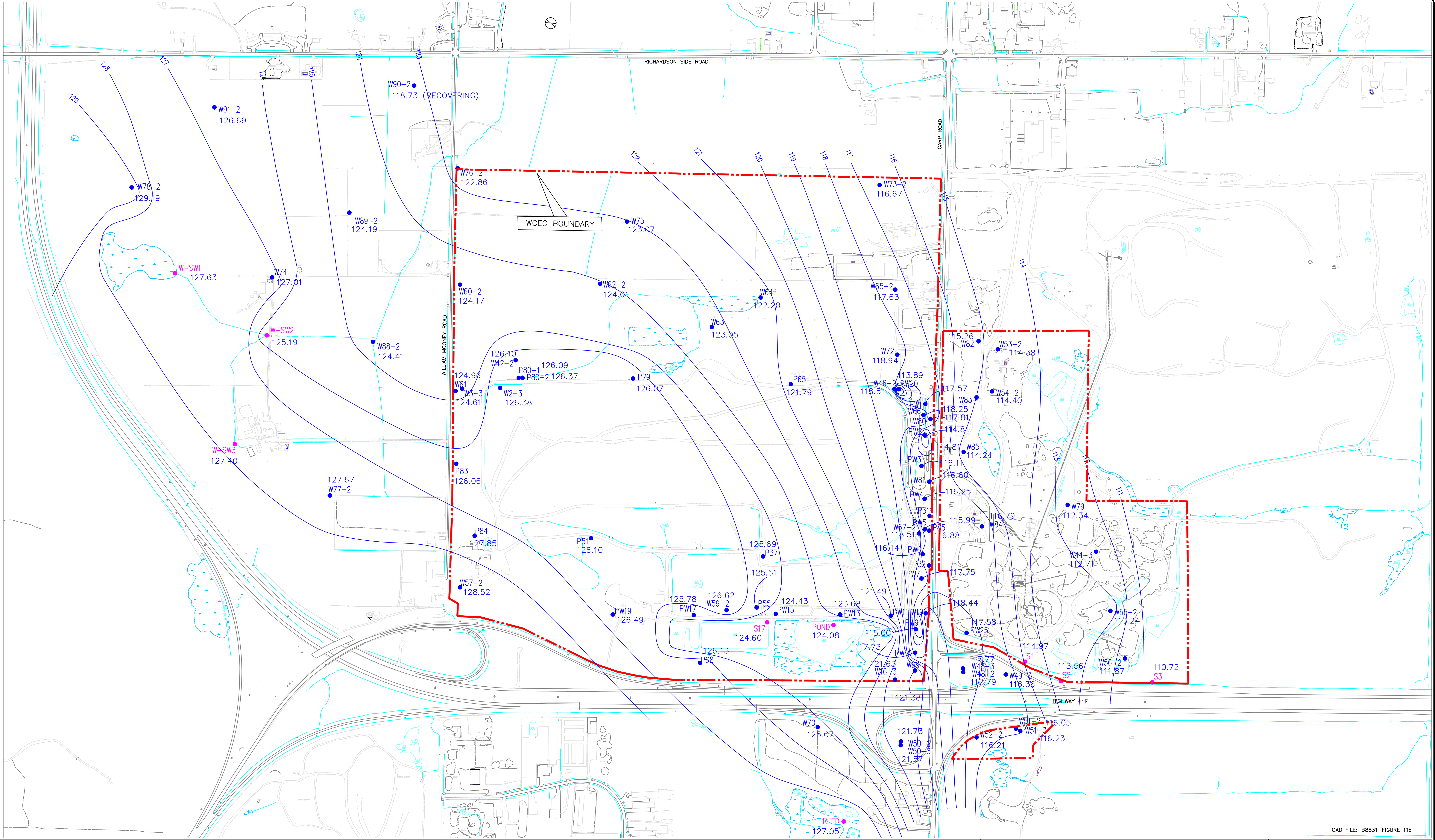
GROUNDWATER ELEVATIONS
OVERBURDEN-SHALLOW BEDROCK – WINTER 2011

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

DWN BY: C.M.R. DATE: 19/03/14
CHK BY: D.H. SCALE: AS SHOWN

WM - OTTAWA LANDFILL SITE

FIGURE: 11(a)



LEGEND :

WCEC PROPERTY BOUNDARY (APPROX.)

EXISTING DITCH, SWALE

EXISTING ROADS

EXISTING BUILDINGS

LEGEND:

OVERBURDEN-SHALLOW BEDROCK MONITORING WELLS

SURFACE WATER MONITORING LOCATIONS

OVERBURDEN-SHALLOW BEDROCK GROUNDWATER CONTOURS (m)

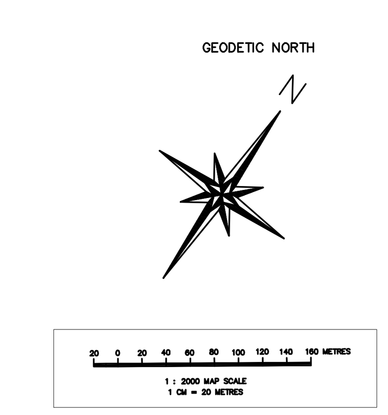
125.24 GROUNDWATER ELEVATION – APRIL 2011 (masl)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE	CONTOUR INT.	HORIZ. DATUM	VERTICAL DATUM
1:2000	1 METRE	NAD 27	GEODETIC
PHOTO SCALE	PHOTO DATE	CONTRACT NO.	
1:4000	JUNE 29, 2007	2124-07	

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING
37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7V3
TEL: 613 723-8100 FAX: 613 723-8569
WWW.BASEMAP.CA



WESA
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WASTE MANAGEMENT

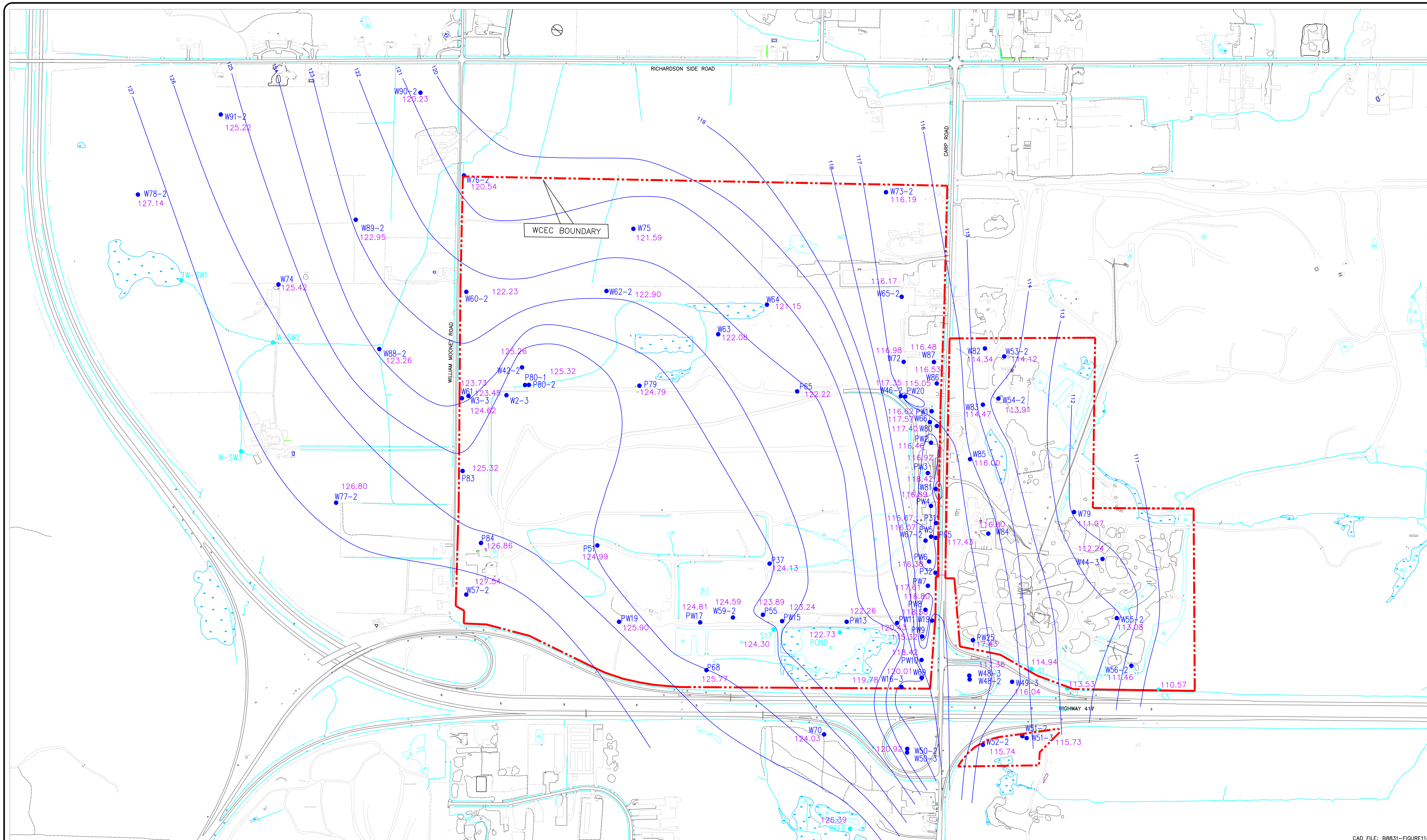
GROUNDWATER ELEVATIONS,
OVERBURDEN-SHALLOW BEDROCK (SPRING 2011)

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

DWN BY: C.M.R. DATE: 03/19/14
CHK BY: D.H. SCALE: AS SHOWN

WM - OTTAWA LANDFILL SITE

FIGURE:
11(b)



LEGEND :

- WCEC PROPERTY BOUNDARY (APPROX.)
- EXISTING DITCH, SWALE
- EXISTING ROADS
- EXISTING BUILDINGS

LEGEND:

- OVERBURDEN-SHALLOW BEDROCK MONITORING WELLS
- SURFACE WATER MONITORING LOCATIONS
- OVERBURDEN-SHALLOW BEDROCK GROUNDWATER CONTOURS (m)
- 125.24 GROUNDWATER ELEVATION – AUGUST 2011 (masl)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE	CONTOUR INT.	HORIZ. DATUM	VERTICAL DATUM
1:2000	1 METRE	NAD 27	GEODETIC
PHOTO SCALE	PHOTO DATE	CONTRACT NO.	
1:4000	JUNE 29, 2007	2124-07	

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING
37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7V3
TEL: 613 723-8100 FAX: 613 723-8569
WWW.BASEMAP.CA

GEODETIC NORTH

WESA
a BluMetric company

WM WASTE MANAGEMENT

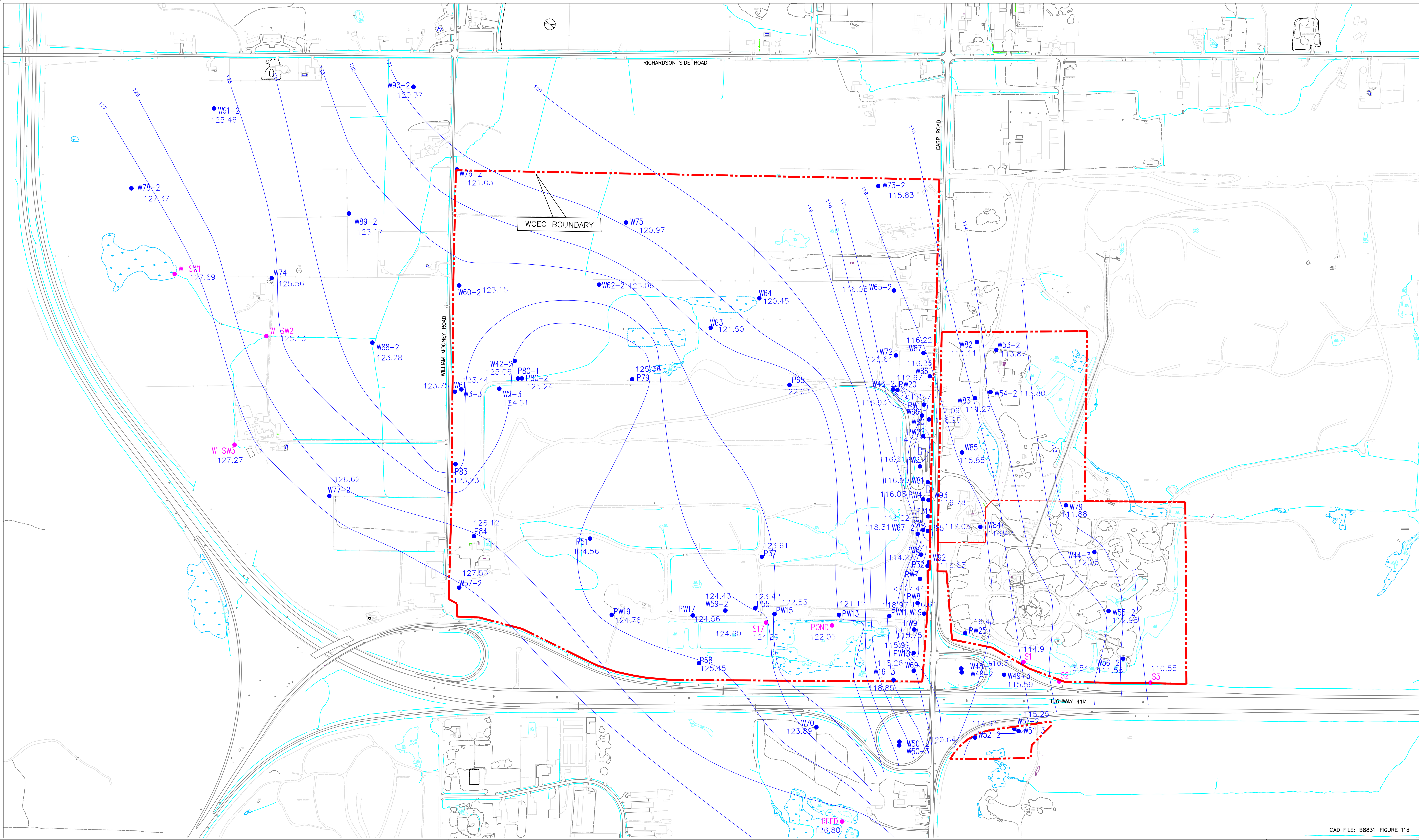
GROUNDWATER ELEVATIONS, OVERBURDEN-SHALLOW BEDROCK (SUMMER 2011)

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

WM - OTTAWA LANDFILL SITE

DWN BY: C.M.R.
CHK BY: D.H.
DATE: 19/03/14
SCALE: AS SHOWN

FIGURE: 11(c)



LEGEND :

WCEC PROPERTY BOUNDARY (APPROX.)
EXISTING DITCH, SWALE
EXISTING ROADS
EXISTING BUILDINGS

LEGEND:

OVERBURDEN-SHALLOW BEDROCK MONITORING WELLS
SURFACE WATER MONITORING LOCATIONS
OVERBURDEN-SHALLOW BEDROCK GROUNDWATER CONTOURS (m)
125.45 GROUNDWATER ELEVATION – NOVEMBER 2011 (masl)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE	CONTOUR INT.	HORIZ. DATUM	VERTICAL DATUM
1:2000	1 METRE	NAD 27	GEODETIC
PHOTO SCALE	PHOTO DATE	CONTRACT NO.	
1:4000	JUNE 29, 2007	2124-07	

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING

GEODETIC NORTH

WESA a BluMetric company

WASTE MANAGEMENT

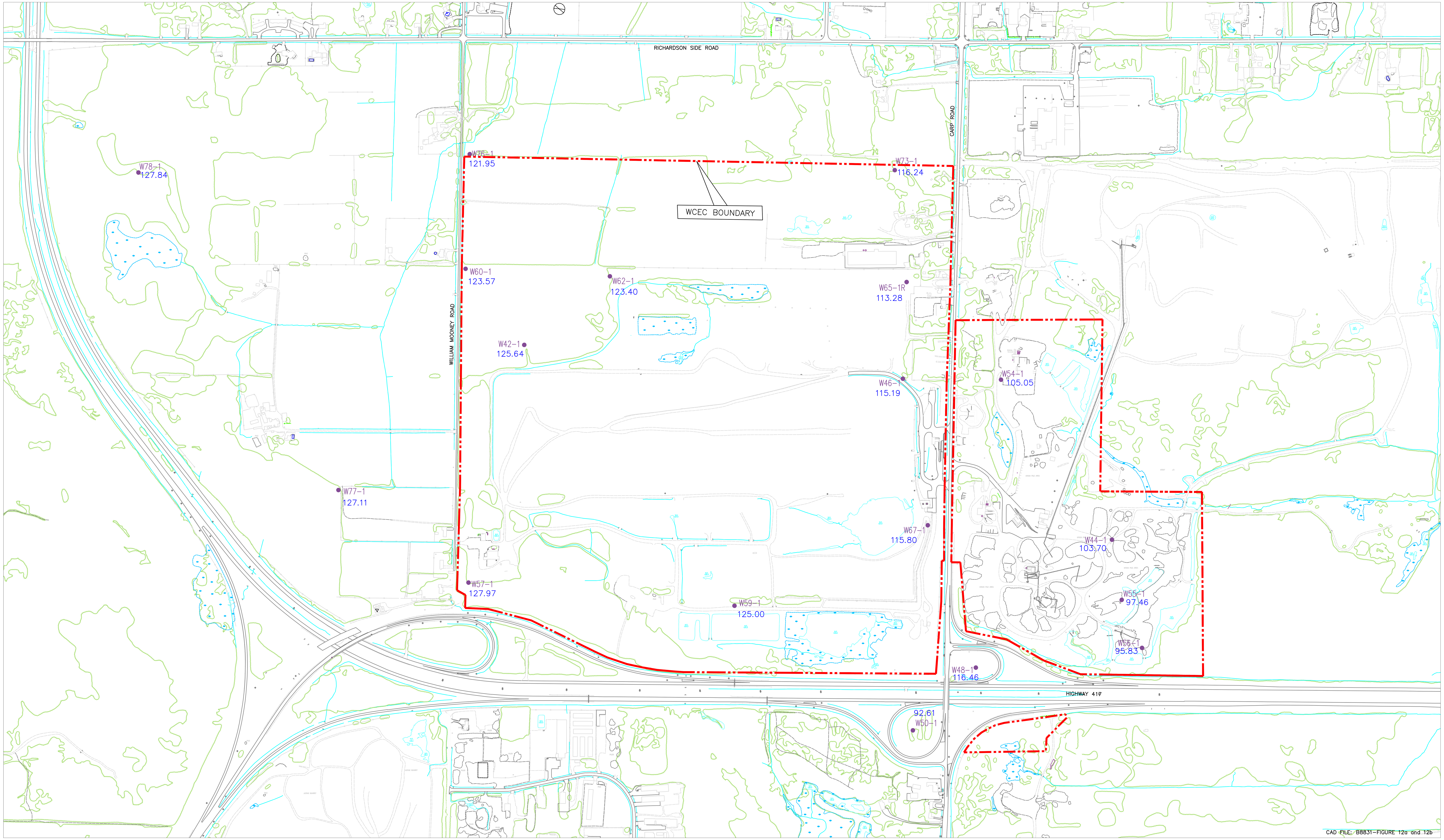
GROUNDWATER ELEVATIONS, OVERBURDEN-SHALLOW BEDROCK (FALL 2011)

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

WM - OTTAWA LANDFILL SITE

DWN BY: C.M.R. DATE: 19/03/14
CHK BY: D.H. SCALE: AS SHOWN

FIGURE: 11(d)



LEGEND :

- WCEC BOUNDARY (APPROX.)
- EXISTING DITCH, SWALE
- EXISTING ROADS
- EXISTING BUILDINGS

● DEEP BEDROCK MONITORING WELLS

125.00 GROUNDWATER ELEVATION – JANUARY 2011 (masl)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE	CONTOUR INT.	HORIZ. DATUM	VERTICAL DATUM
1:2000	1 METRE	NAD 27	GEODETIC
PHOTO SCALE 1:4000	PHOTO DATE JUNE 29, 2007	CONTRACT NO. 2124-07	

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING
37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7V3
TEL: 613 723-8100 FAX: 613 723-8569
WWW.BASEMAP.CA

GEODETIC NORTH

N

WESA
a BluMetric company

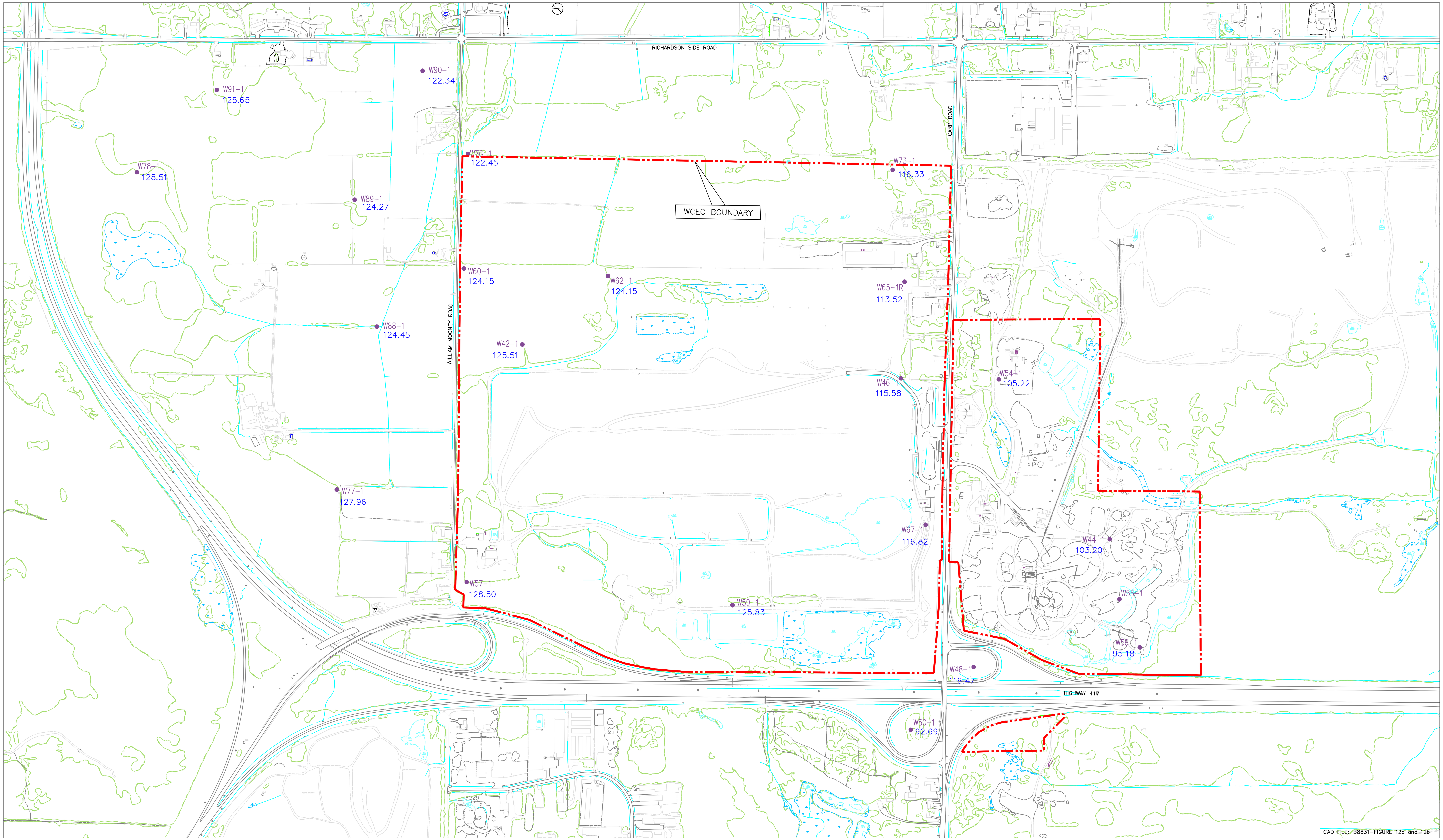
WASTE MANAGEMENT

GROUNDWATER ELEVATIONS
DEEP BEDROCK (WINTER 2011)
WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

DWN BY: C.M.R. DATE: 19/03/14
CHK BY: D.H. SCALE: AS SHOWN

WM - OTTAWA LANDFILL SITE

FIGURE:
12(a)



LEGEND :

- WCEC BOUNDARY (APPROX.)
- EXISTING DITCH, SWALE
- EXISTING ROADS
- EXISTING BUILDINGS

● DEEP BEDROCK MONITORING WELLS

125.83 GROUNDWATER ELEVATION – APRIL 2011 (masl)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE 1:2000	CONTOUR INT. 1 METRE	HORIZ. DATUM NAD 27	VERTICAL DATUM GEODETIC
PHOTO SCALE 1:4000	PHOTO DATE JUNE 29, 2007	CONTRACT NO. 2124-07	

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING
37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7Y3
TEL: 613 723-8100 FAX: 613 723-8569
WWW.BASEMAP.CA

GEODETIC NORTH

WESA
a BluMetric™ company

WASTE MANAGEMENT

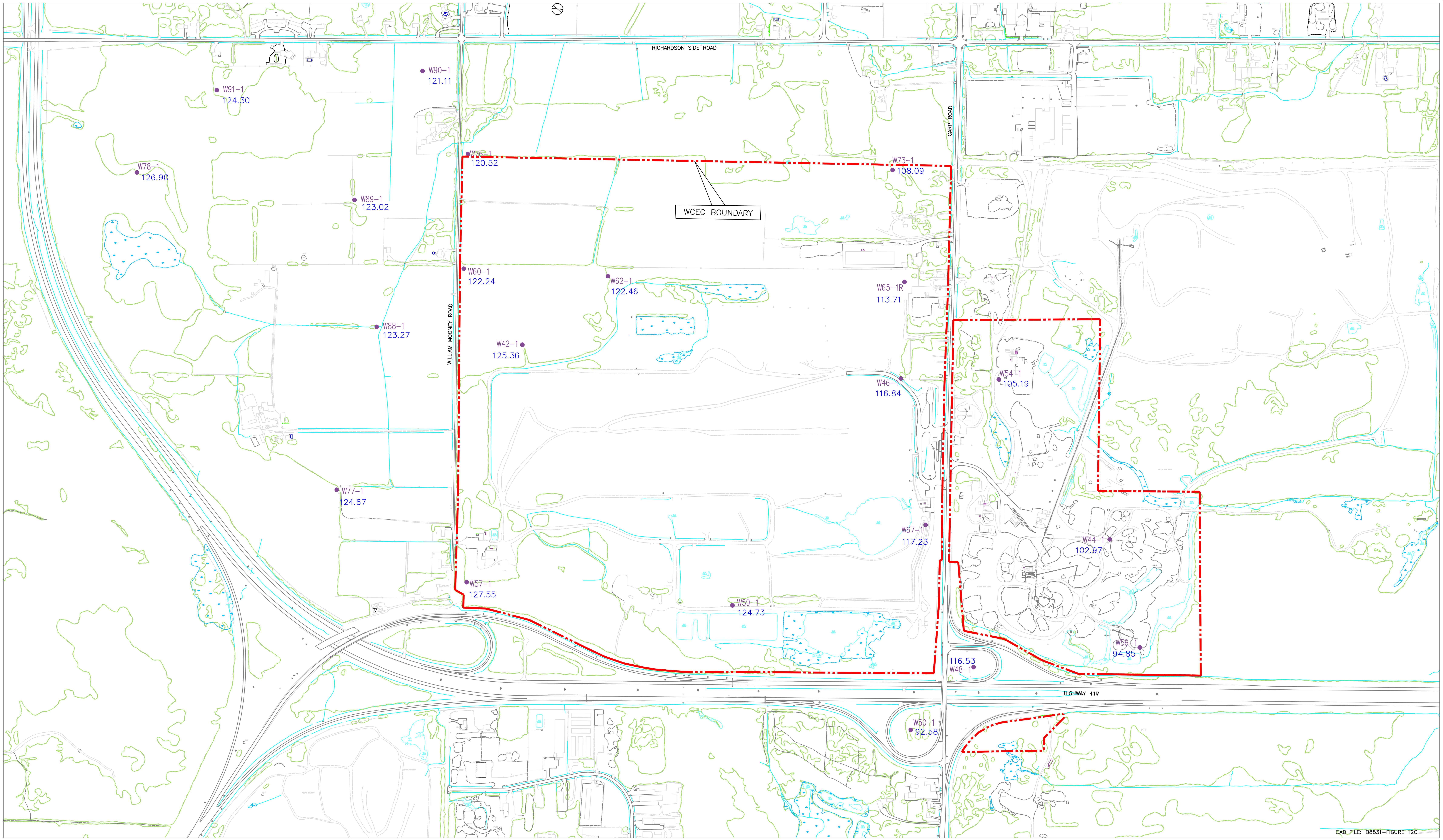
GROUNDWATER ELEVATIONS, DEEP BEDROCK (SPRING 2011)

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

WM - OTTAWA LANDFILL SITE

DWN BY: C.M.R.
CHK BY: D.H.
DATE: 19/03/14
SCALE: AS SHOWN

FIGURE: 12(b)



LEGEND :

- WCEC BOUNDARY (APPROX.)
- EXISTING DITCH, SWALE
- EXISTING ROADS
- EXISTING BUILDINGS

● DEEP BEDROCK MONITORING WELLS

124.73 GROUNDWATER ELEVATION – AUGUST 2011 (masl)

WASTE MANAGEMENT 2301 CARP ROAD, R.R. 3 CARP, ONTARIO K0A 1L0 TEL: (613) 836-2461			
MAP SCALE 1:2000	CONTOUR INT. 1 METRE	HORIZ. DATUM NAD 27	VERTICAL DATUM GEODETIC
PHOTO SCALE 1:4000	PHOTO DATE JUNE 29, 2007	CONTRACT NO. 2124-07	
PROJECT LOCATION TWP. OF W. CARLETON	BASE MAPPING 37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7V3 TEL: 613 723-8100 FAX: 613 723-8569 WWW.BASEMAP.CA		

WESA a BluMetric company

WASTE MANAGEMENT

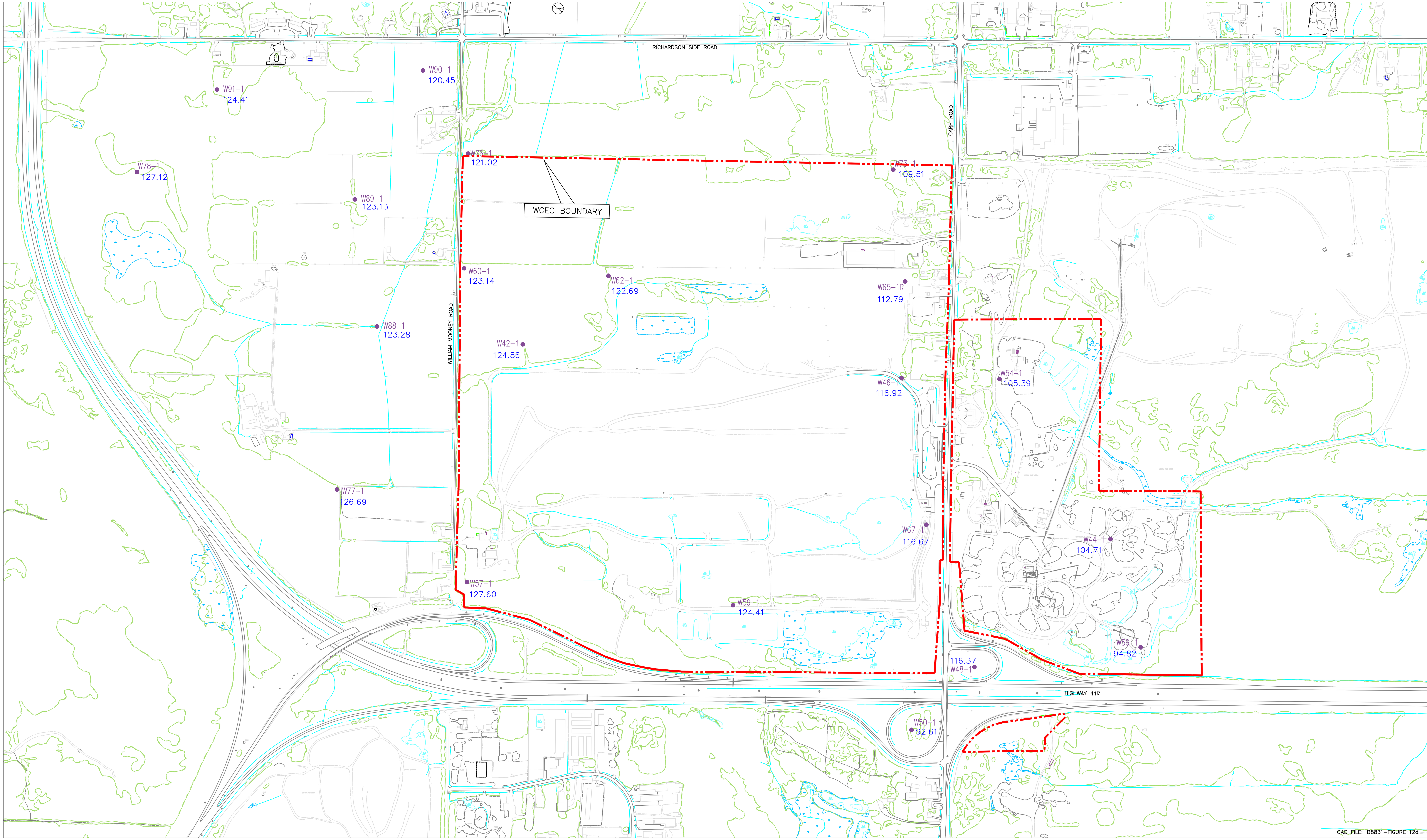
GROUNDWATER ELEVATIONS, DEEP BEDROCK (SUMMER 2011)

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

DWN BY: C.M.R. DATE: 19/03/14
CHK BY: D.H. SCALE: AS SHOWN

WM - OTTAWA LANDFILL SITE

FIGURE: 12(c)



LEGEND :

WCEC BOUNDARY (APPROX.)

EXISTING DITCH, SWALE

EXISTING ROADS

EXISTING BUILDINGS

DEEP BEDROCK MONITORING WELLS

124.73 GROUNDWATER ELEVATION – NOVEMBER 2011 (masl)

WASTE MANAGEMENT
2301 CARP ROAD, R.R. 3
CARP, ONTARIO
K0A 1L0
TEL: (613) 836-2461

MAP SCALE	CONTOUR INT.	HORIZ. DATUM	VERTICAL DATUM
1:2000	1 METRE	NAD 27	GEODETIC

PHOTO SCALE	PHOTO DATE	CONTRACT NO.
1:4000	JUNE 29, 2007	2124-07

PROJECT LOCATION
TWP. OF W. CARLETON

BASE MAPPING
37-81 AURIGA DRIVE, OTTAWA, ONTARIO K2E 7V3
TEL: 613 723-8100 FAX: 613 723-8569
WWW.BASEMAP.CA

GEODETIC NORTH

N

WESA a BluMetric company

WM WASTE MANAGEMENT

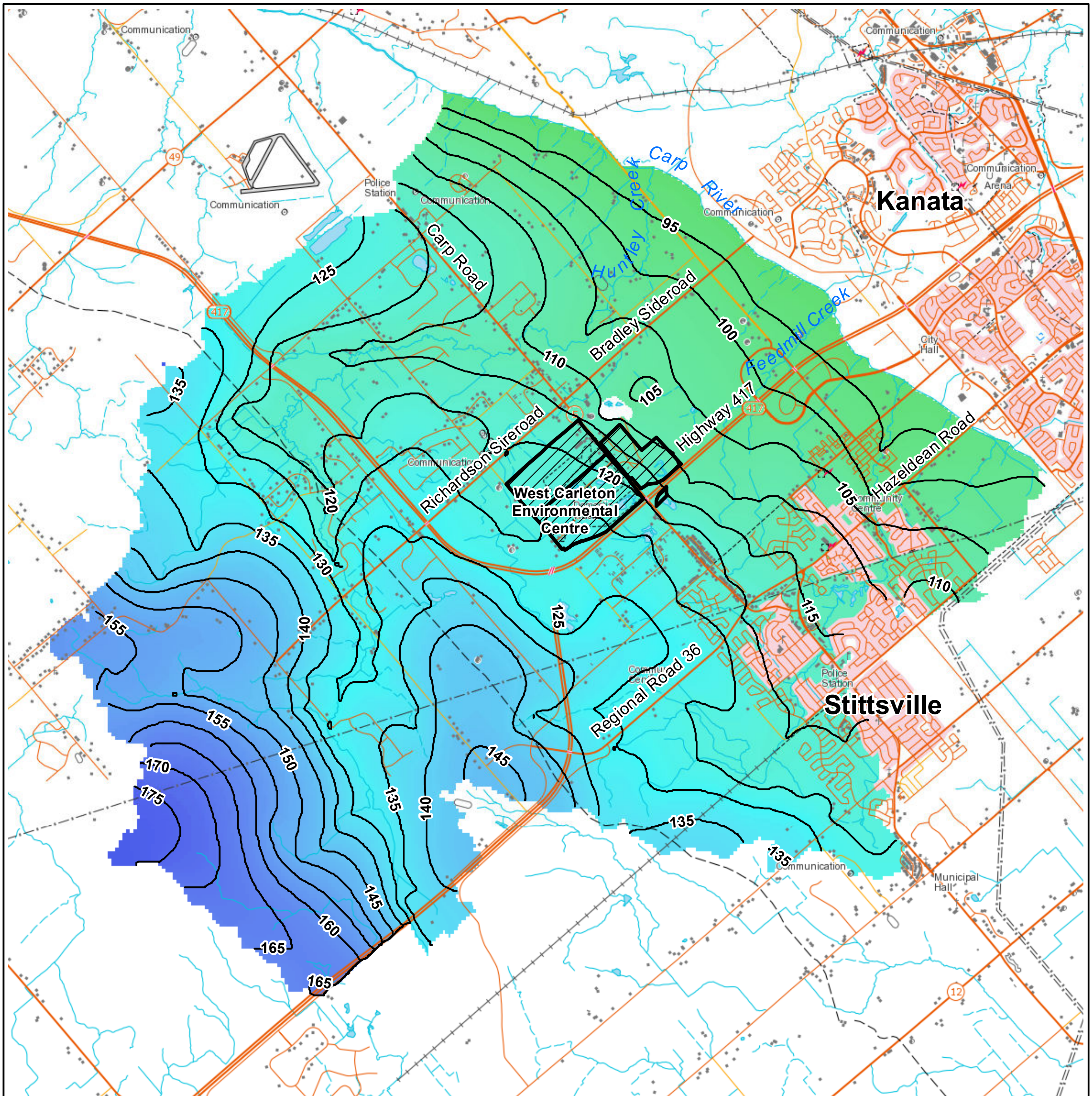
GROUNDWATER ELEVATIONS, DEEP BEDROCK (FALL 2011)

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

WM - OTTAWA LANDFILL SITE

DWN BY: C.M.R.
CHK BY: D.H.
DATE: 19/03/14
SCALE: AS SHOWN

FIGURE: 12(d)



LEGEND

Simulated Groundwater Elevation Contours (masl)

Simulated Groundwater Elevations (masl)

Value

High : 180

Low : 80

REFERENCE

Source:
-Toporama, LIO 2011
-North American Datum 1983. Zone 18 N.

0 250 500 1,000 1,500 2,000
Metres
1:75,000

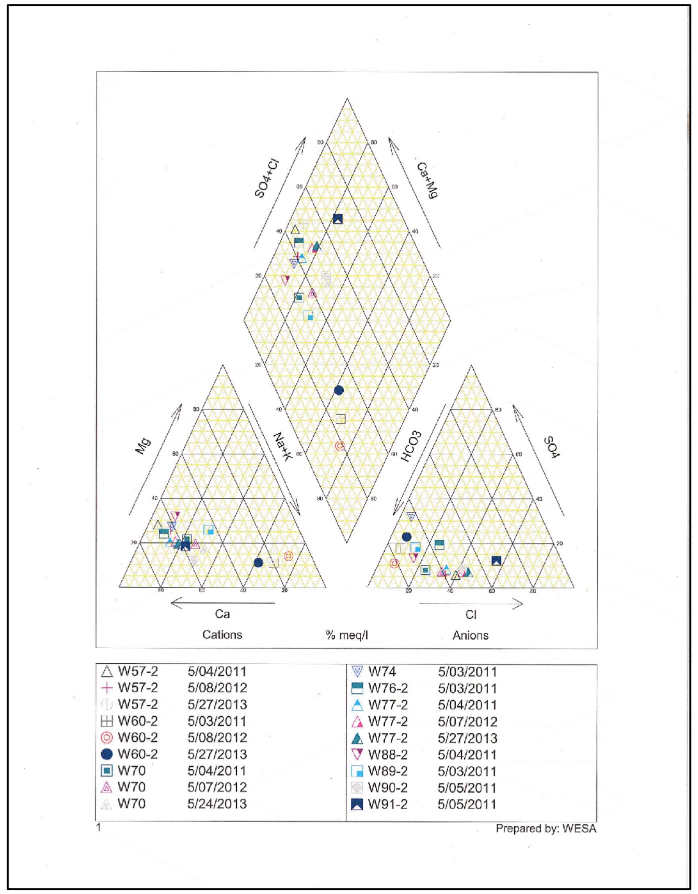
PROJECT
WASTE MANAGEMENT
WEST CARLETON ENVIRONMENTAL CENTRE

TITLE
SIMULATED GROUNDWATER ELEVATIONS
NUMERICAL MODELING

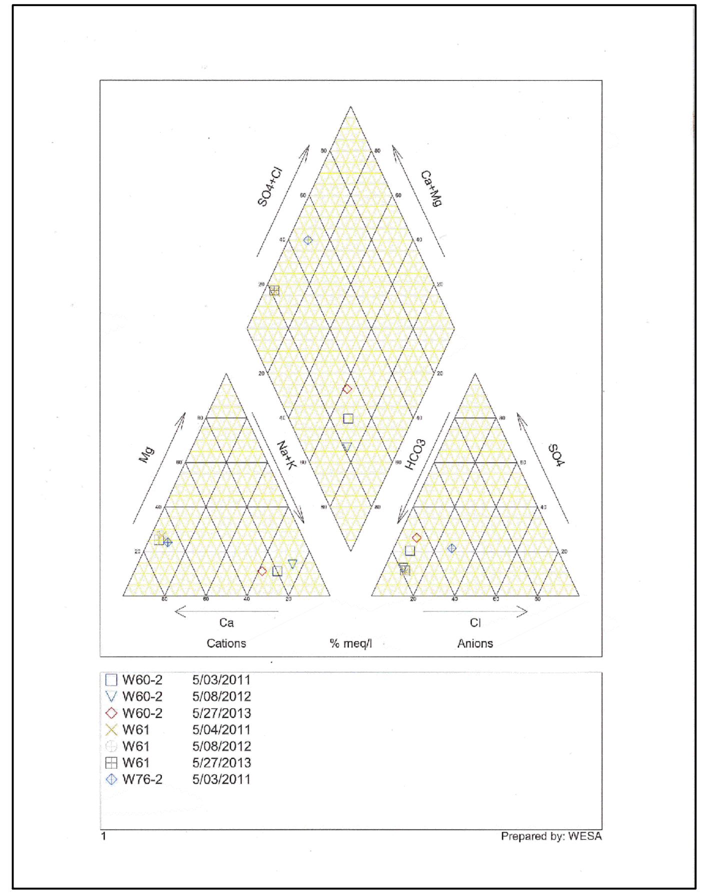
WESA

PROJECT No. CB8831-14		
DESIGN	JFD	
GIS	JFD	2014-06-24
CHECK	DH	
REVIEW		

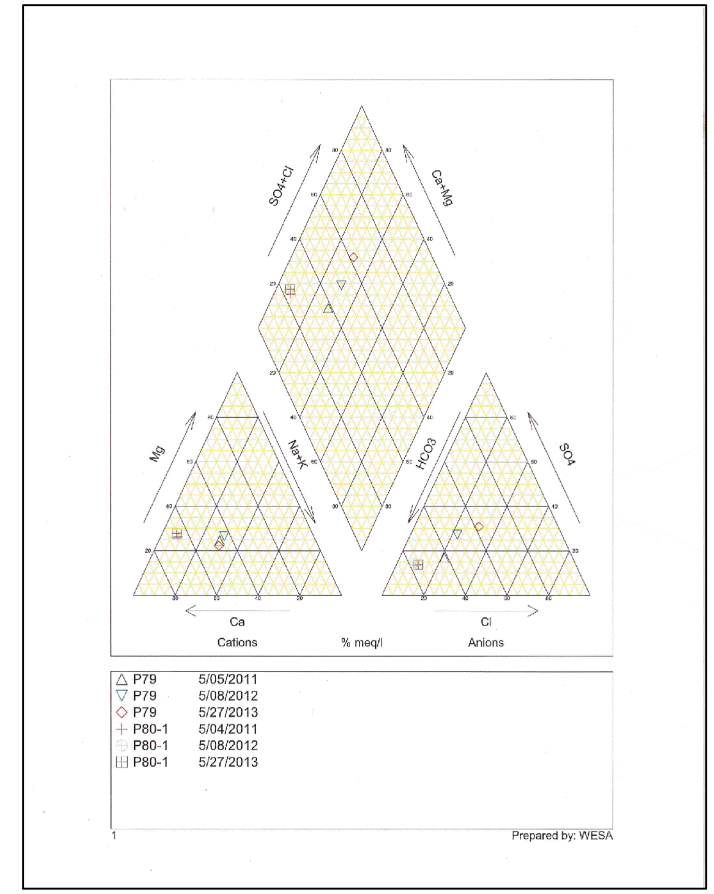
FIGURE 13



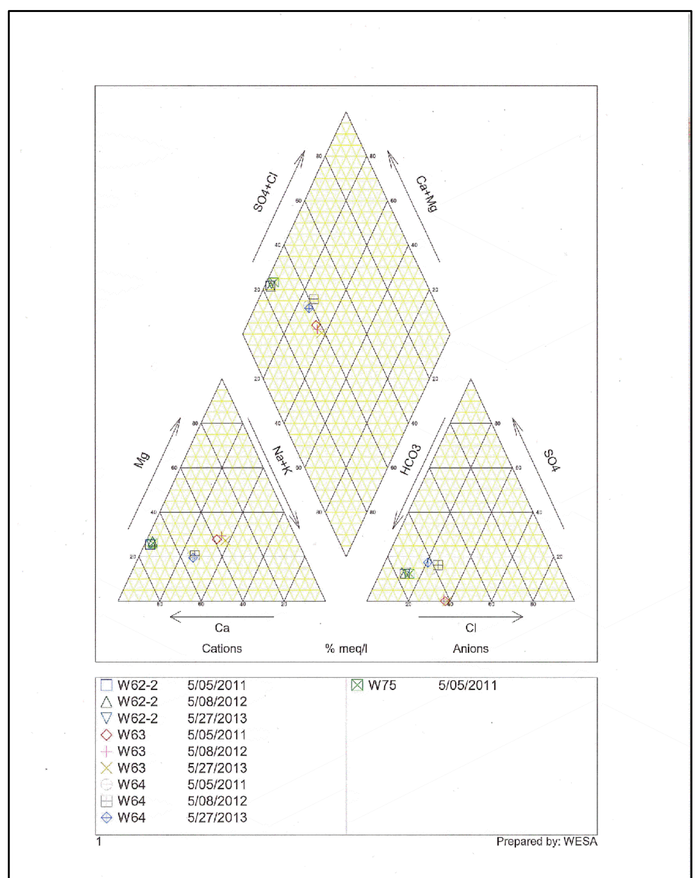
(a) Background Groundwater Quality



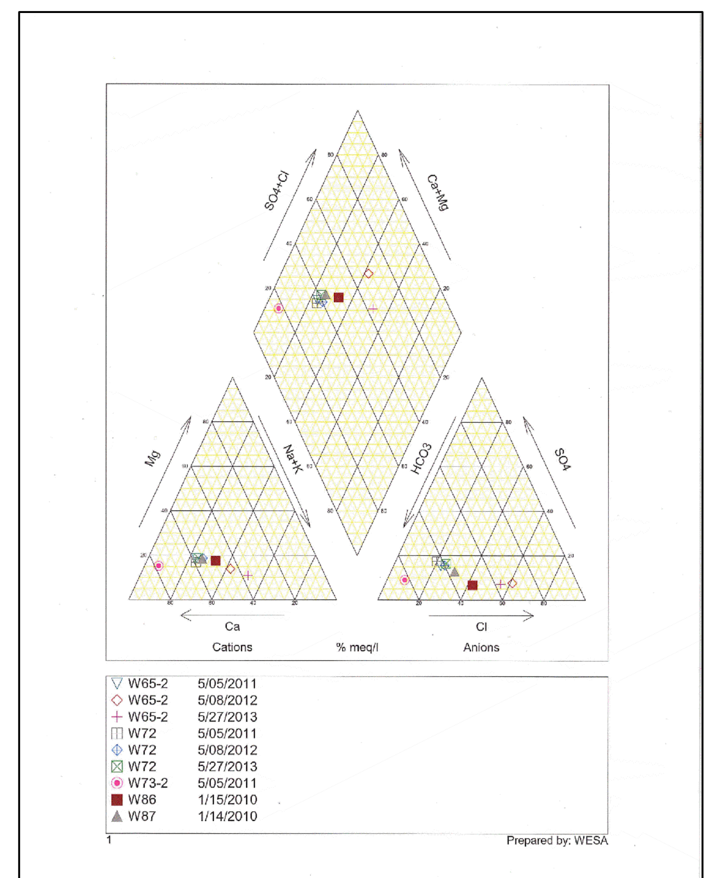
(b) Western Boundary



(c) Southern Boundary (North of existing landfill)



(d) Interior Portion of Site



(e) Eastern Boundary

CAD FILE: B8831-FIGURE 14

WESA™
a BluMetric® company

PIPER WATER QUALITY DIAGRAMS

WEST CARLETON ENVIRONMENTAL CENTRE
OTTAWA, ONTARIO

DWN BY: C.M.R. DATE: 19/03/14
CHK BY: D.H. SCALE: AS SHOWN

WM - OTTAWA LANDFILL SITE

FIGURE:
14

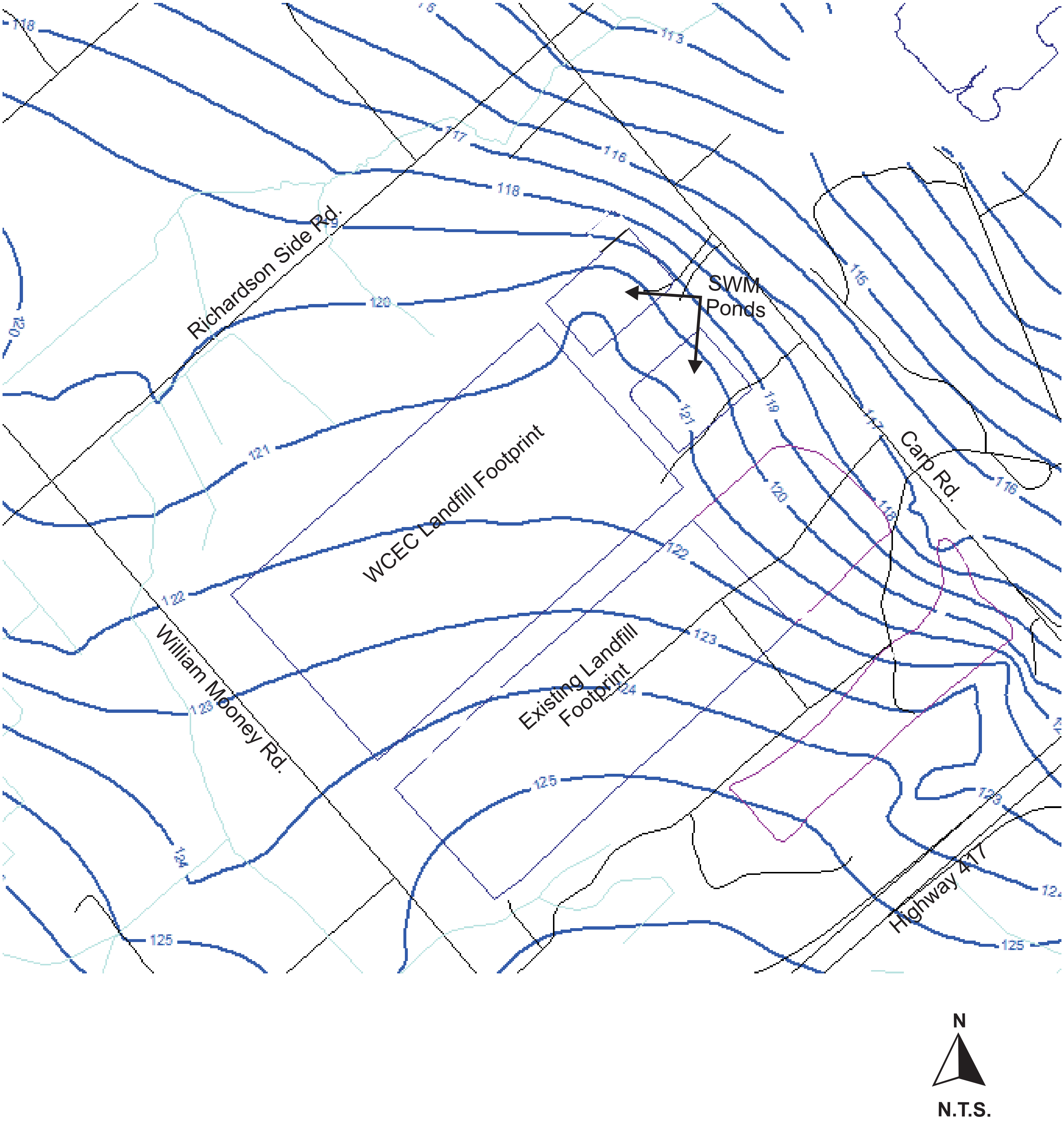
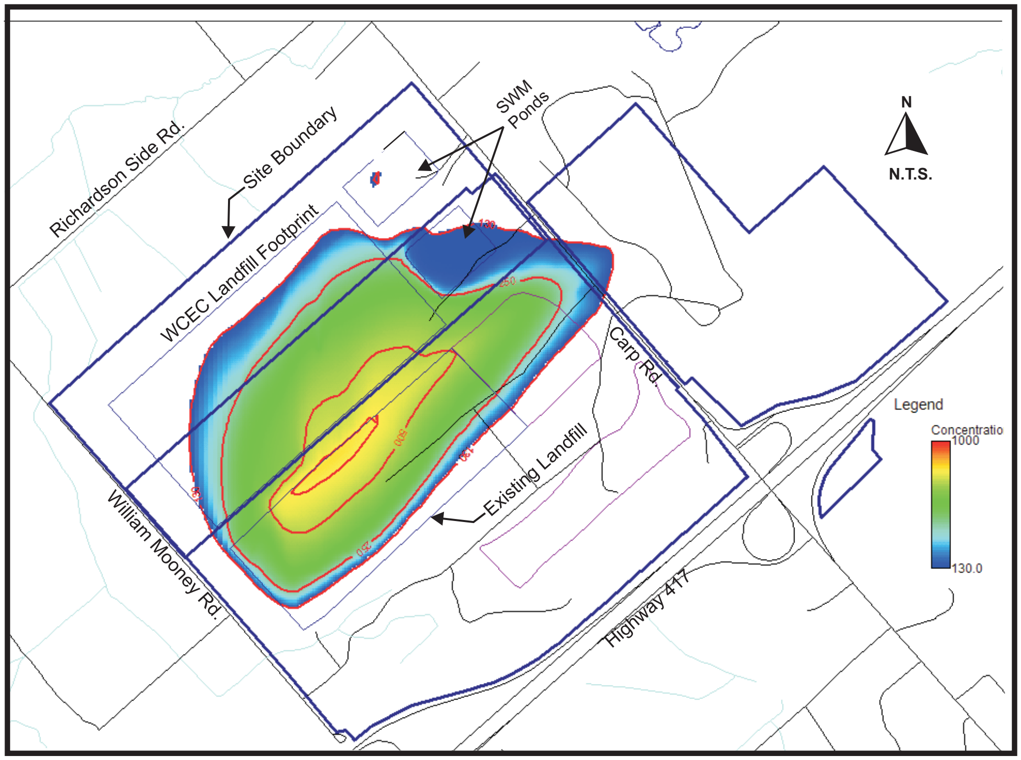
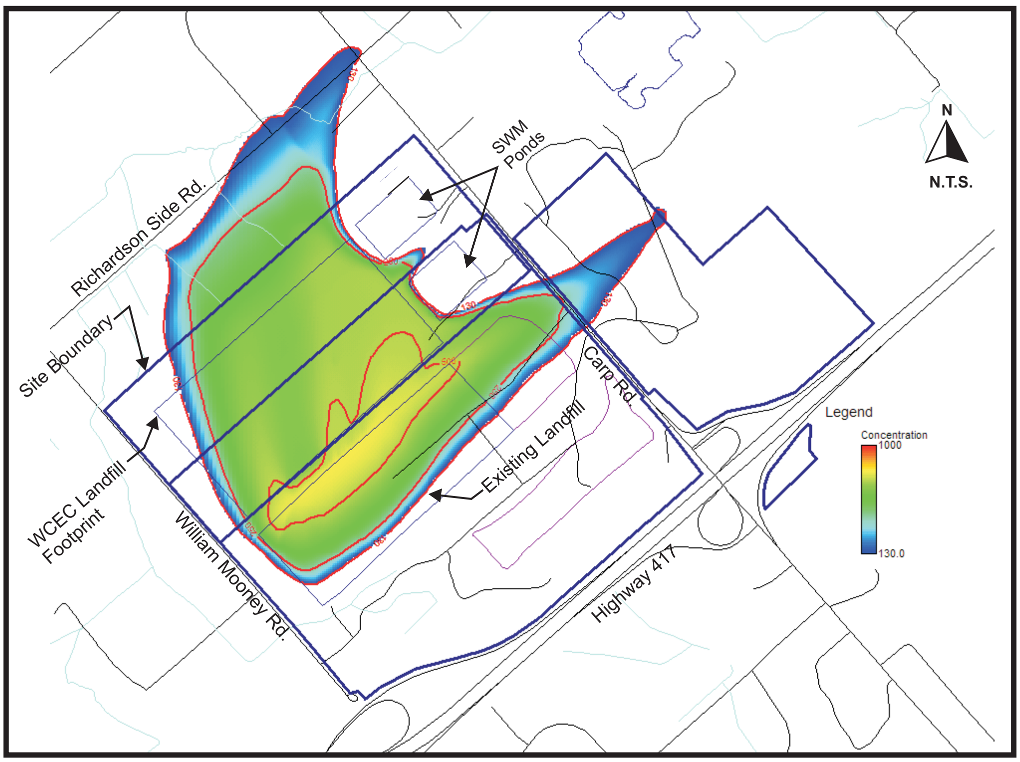


Figure 15:
Modeled Groundwater Head Contours, assuming operation of the new landfill footprint and stormwater management ponds (in metres above sea level).

WESA a BluMetric company



(a) Predicted maximum extent of chloride from the stormwater management ponds, operating with an effluent concentration of 130 mg/L (Model year 2025). Extent of plume is 130 mg/L chloride.



(b) Predicted maximum extent of chloride from the existing landfill (Model year 2107). Extent of plume is 130 mg/L chloride.

B8831-14-01

Figure 16:
Predicted chloride concentrations, assuming operation of the new landfill footprint and stormwater management ponds (in mg/L). Note that the dates shown are based on the modeled conditions with Year 1=1975. Actual conditions on specific dates may vary from those shown.

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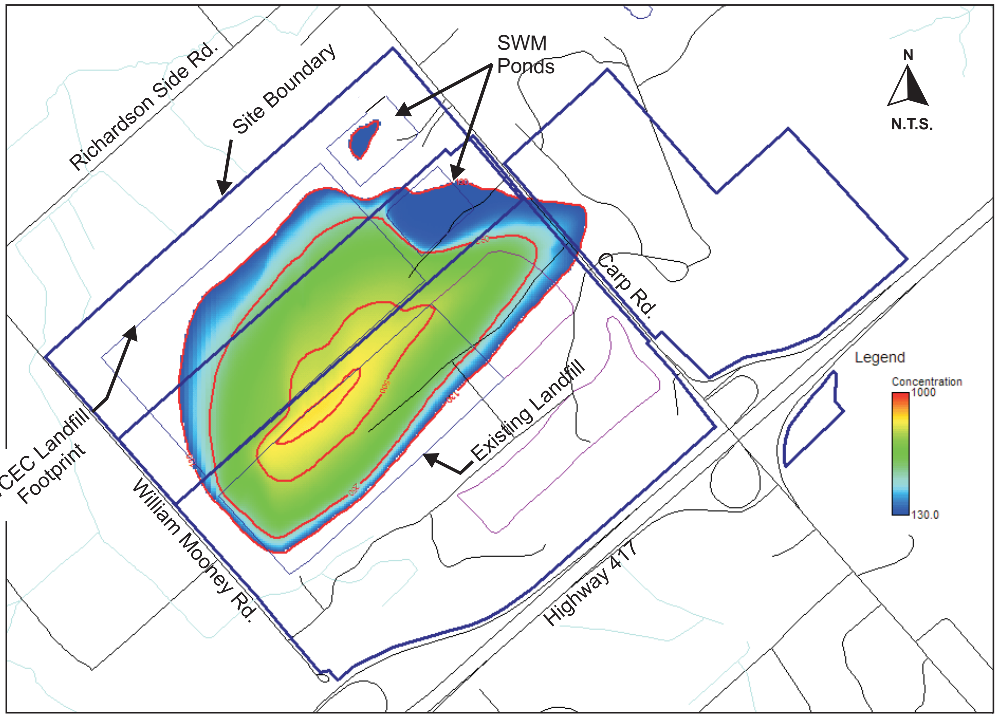
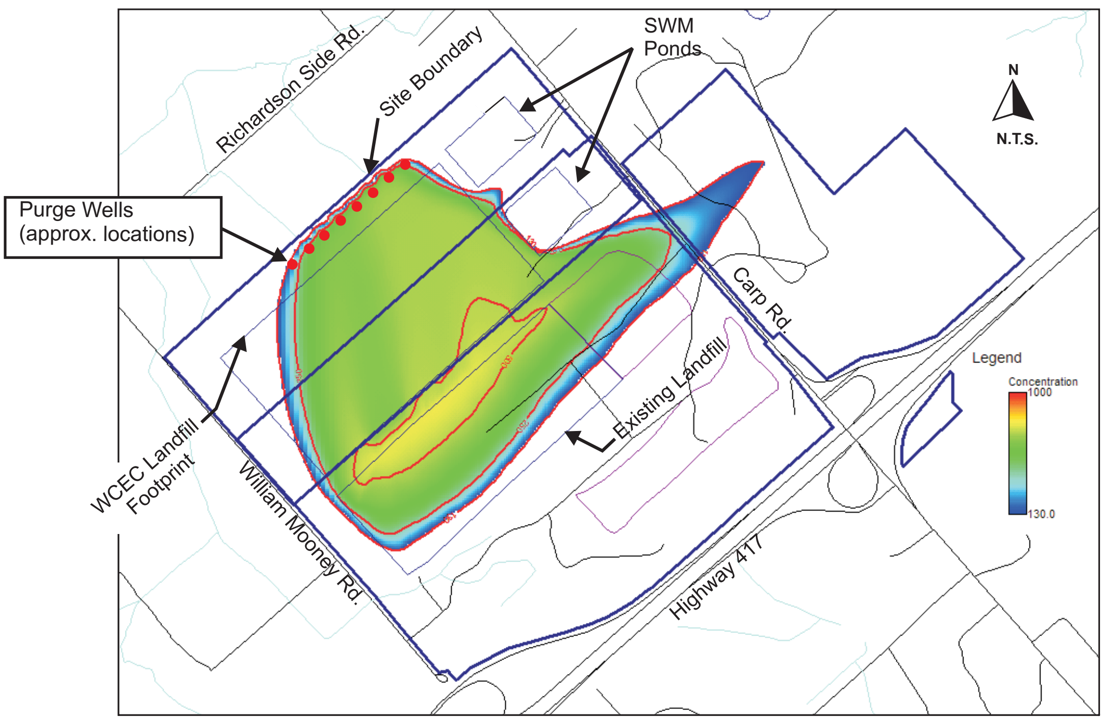


(a) Predicted maximum extent of chloride from the stormwater management ponds, operating with an effluent concentration of 130 mg/L (Model year 2025). Extent of plume is 130 mg/L chloride.



(b) Predicted maximum extent of chloride from the existing landfill, with mitigation measures in-place (Model year 2089). Extent of plume is 130mg/L chloride.

CB8831-14-00

Figure 17:
Predicted chloride concentrations, assuming operation of the new landfill footprint and stormwater management ponds, and with mitigation measures in-place (in mg/L). Note that the dates shown are based on the modeled conditions with Year 1=1975. Actual conditions on specific dates may vary from those shown.

WESA™
a BluMetric™ company

APPENDIX A

Water Quality Information from Monitoring Wells, On-Site Study Area

Appendix A1: Overburden – Shallow Bedrock Water Quality
Appendix A2: Deep Bedrock Water Quality

Appendix A1- Overburden - Shallow Bedrock Water Quality Inorganic General

Name	Date	Alkalinity mg/L	Ammonia mg/L	Arsenic mg/L	Barium mg/L	Biochemical Oxygen Demand mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Copper mg/L	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Mercury mg/L	Nickel mg/L
Western Boundary																								
W3-3	03/12/1987	142	1.09			4				10	13		1122					220	0.48	0.42		0.46		
	04/04/1988	178	0.37			4				13	16		1468						0.6	0.02		0.36		
	01/05/1989	216	0.1			6	0.16		87	22	9		1290					349	0.52		32	1.1		
	20/03/1990	218	0.2				0.06		88	11	12		1397					385	2.05		40	0.56		
	25/02/1991	252	0.34				0.04		77	8	10		1310						2.59		37	0.74		
	17/03/1992	258	0.2		0.09		0.03		83	11	9		1239						1.95		38	0.46		
	19/02/1993	263	0.24		0.07		0.04		77	10	7		1182						0.1		33	0.28		
	15/03/1994	256	0.02		0.06				76	10	10		1083								29			
	01/08/1995		0.23		0.09		0.05		75	17	9		1001						2.88		26	0.43		
	01/06/1996		0.05		0.07		0.04		74	8	9		937						0.11		26	0.18		
	21/05/1997				0.06				70	14	10		928						0.11		28			
	13/05/1998		0.07		0.06		0.02		72	10	10		882						0.06		28			
	11/05/1999	358	0.46		0.32		0.02		109	29	167		1099						2.02		49	0.09		
	17/05/2000	228	0.03		0.5		0.11	< 0.005	64	10	9	< 0.01	856			< 0.02			0.02	< 0.002	25	0.04		
	09/05/2001	223	< 0.02		0.59		0.21	< 0.005	57	< 5	11	< 0.01	808			< 0.005			0.17	< 0.001	23	0.02		
	15/05/2002	223	< 0.02		0.06		< 0.05	< 0.005	60	8	9	< 0.001	806			< 0.005			< 0.01	< 0.001	21	< 0.01		
	21/05/2003	223	< 0.02		0.05		< 0.05	< 0.001	64	< 5	10	< 0.005	775			< 0.005			0.02	< 0.001	24	< 0.005		
	29/04/2004	217	0.05		0.06		0.03	< 0.001	60	< 5	11	< 0.005	754			< 0.005			< 0.01	< 0.001	24	< 0.01		
	29/04/2005	215	0.12		0.06		0.05	< 0.0001	68	< 5	11	< 0.001	746			< 0.005			0.03	< 0.001	25	< 0.01		
	28/04/2006	216	< 0.02		0.03		0.02	< 0.0001	29	< 5	13	0.001	1040			< 0.005			< 0.03	< 0.001	15	< 0.01		
	26/04/2007	214	0.02		0.01		0.02	< 0.0001	13	< 5	15	0.001	1160			< 0.005			< 0.03	< 0.001	8	< 0.01		
W60-2	24/02/2004	266	0.14		0.24		0.11	0.001	83	14	4	0.005	513			0.005			0.55	0.001	20	0.03		
	06/05/2004	256	0.17	< 0.001	0.31		< 0.01	< 0.0001	81	15	3	< 0.001	507	< 0.001		< 0.005	6.1		0.7	< 0.001	20	0.04	< 0.0001	
	26/05/2008	127	0.34		0.033		0.36	< 0.0001	10	15	12	< 0.005	356		< 0.002		2.7	39	< 0.1	< 0.0005	3.3	< 0.002		
	29/04/2009	210	0.28		0.052		0.45	< 0.0001	8.8	12	10	< 0.005	457		< 0.002		3.4	45	< 0.1	< 0.0005	5.7	< 0.002		
	28/04/2010	161	0.23		0.038		0.43	< 0.0001	8.4	18	11	< 0.005	409		< 0.002		1.7	46	< 0.1	< 0.0005	6.2	< 0.002		
	03/05/2011	147	0.2		0.031		0.29	< 0.0001	15	8	10	< 0.005	390		< 0.002		4	59	< 0.1	< 0.0005	5.1	< 0.002		
	08/05/2012	180	0.2		0.049		0.4	< 0.0001	10	11	12	< 0.005	440		< 0.002		3.5	58	< 0.1	< 0.0005	7.8	< 0.002		
	27/05/2013	130	< 0.15		0.029		0.29	< 0.0001	23	14	10	< 0.005	390		< 0.002		4.7	81	< 0.1	< 0.0005	5.7	< 0.002		
W61	24/02/2004	269	0.03		0.21		0.05	0.001	86	5	16	0.006	563			0.005			0.45	0.001	19	0.02		
	06/05/2004	269	0.05	< 0.001	0.22		< 0.01	< 0.0001	90	< 5	12	< 0.001	581	< 0.001		< 0.005	1.6		0.6	< 0.001	20	0.02	< 0.0001	
	26/05/2008	263	< 0.15		0.24		< 0.02	< 0.0001	88	12	17	0.019	568		< 0.002		1.5	310	0.68	< 0.0005	22	0.018		
	29/04/2009	277	< 0.15		0.23		< 0.02	< 0.0001	85	< 4	17	< 0.005	616		< 0.002		3.1	300	0.8	< 0.0005	21	0.018		
	28/04/2010	272	< 0.15		0.22		< 0.02	< 0.0001	92	30	16	0.018	580		< 0.002		1.9	320	0.65	< 0.0005	21	0.018		
	04/05/2011	277	< 0.15		0.22		< 0.02	< 0.0001	91	9	22	< 0.005	644		< 0.002		2.2	320	0.71	< 0.0005	22	0.018		
	08/05/2012	270	< 0.15		0.21		< 0.02	< 0.0001	86	9.2	20	< 0.005	610		< 0.002		3.1	300	0.84	< 0.0005	21	0.018		
	27/05/2013	270	< 0.15		0.21		< 0.02	< 0.0001	110	5.3	21	< 0.005	630		< 0.002		2.5	360	0.84	< 0.0005	24	0.021		
W76-2	27/04/2007	367	0.06	< 0.001	0.21		0.03	< 0.0001	196	36	125	0.002	1280	0.001		< 0.005	10.3		0.14	< 0.001	39	0.21	< 0.0001	
	28/11/2007																							
	03/05/2011	301	< 0.15		0.14		< 0.02	< 0.0001	150	12	96	0.021	1030		< 0.002		1.9	510	< 0.1	< 0.0005	33	0.082		
Eastern Boundary																								
W65-2	25/02/2004	267	0.03		0.12		0.05	0.001	114	5	40	0.005	783			0.005			0.01	0.001	20	0.05		
	27/04/2004	222	0.03		0.1		0.04	< 0.001	91	7	40	< 0.005	671			< 0.005			< 0.01	< 0.001	16	< 0.01		
	05/05/2004	210	< 0.02	< 0.001	0.09		0.05	< 0.0001	91	< 5	40	< 0.001	627	0.002		< 0.005	2.2		< 0.01	< 0.001	16	< 0.01	< 0.0001	
	26/05/2008	201	< 0.15		0.17		0.07	< 0.0001	120	22	190	0.005	1260		< 0.002		6.5	380	< 0.1	< 0.0005	21	< 0.002		
	29/04/2009	210	< 0.15		0.12		0.031	< 0.0001	100	9	140	0.01	892		< 0.002		3.6	330	0.91	0.0011	18	0.12		
	28/04/2010	242	< 0.15		0.12		0.047	< 0.0001	100	6	120	0.01	879		< 0.002		2.5	330	< 0.1	< 0.0005	18	< 0.002		
	05/05/2011	196	< 0.15		0.087		0.089	< 0.0001	72	20	42	< 0.005	597		< 0.002		4.8	240	< 0.1	< 0.0005	14	< 0.002		
	08/05/2012	230	< 0.15		0.18		0.047	< 0.0001	120	< 4	260	0.014	1500		< 0.002		4.7	390	< 0.1	< 0.0005	23	< 0.002		
	27/05/2013	230	< 0.15		0.15		0.03	< 0.0001	100	17	200	< 0.005	1300		< 0.002		3.5	330	< 0.1	< 0.0005	18	< 0.002		

Appendix A1- Overburden - Shallow Bedrock Water Quality Inorganic General

Name	Date	Alkalinity mg/L	Ammonia mg/L	Arsenic mg/L	Barium mg/L	Biochemical Oxygen Demand mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Copper mg/L	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Mercury mg/L	Nickel mg/L
W72	25/02/2004	618	0.12		0.23		0.05	0.001	231	12	51	0.017	1290			0.005			0.89	0.001	38	1.57		
	05/05/2004		0.37		0.1		0.05			< 5			751						0.01					
	23/05/2008	208	0.32		0.23		0.092	< 0.0001	130	32	210	< 0.005	1360		< 0.002		9.5	420	< 0.1	< 0.0005	24	< 0.002		
	19/11/2008	298	< 0.15		0.14		0.058	< 0.0001	120	12	150	< 0.005	1140		< 0.002		2.9	400	< 0.1	< 0.0005	24	< 0.002		
	29/04/2009	418	< 0.15		0.19		0.079	< 0.0001	150	13	100	< 0.005	1190		< 0.002		6.3	510	< 0.1	< 0.0005	29	0.004		
	28/10/2009	502	< 0.15		0.24		0.11	< 0.0001	180	17	120	< 0.005	1390		< 0.002		8.6	600	< 0.1	< 0.0005	34	1.2		
	28/04/2010	420	< 0.15		0.2		0.092	< 0.0001	150	8	100	< 0.005	1240		< 0.002		5.1	510	< 0.1	< 0.0005	31	0.003		
	02/11/2010	448	< 0.15		0.23		0.12	< 0.0001	170	27	120	< 0.005	1360		< 0.002		7.2	580	< 0.1	< 0.0005	35	0.76		
	05/05/2011	261	< 0.15		0.12		0.076	< 0.0001	110	19	48	< 0.005	780		< 0.002		4	350	1.4	0.0007	19	0.25		
	09/11/2011	426	0.42		0.25		0.14	< 0.0001	180	24	130	< 0.005	1310		< 0.002		8.1	600	< 0.1	< 0.0005	35	0.51		
	08/05/2012	460	0.69		0.22		0.17	< 0.0001	160	23	110	< 0.005	1300		< 0.002		6.7	530	< 0.1	< 0.0005	33	0.18		
	30/10/2012	450	0.73		0.23		0.16	< 0.0001	160	57	100	0.022	1300		< 0.002		6.1	540	< 0.1	< 0.0005	34	0.59		
	27/05/2013	450	< 0.15		0.21		0.13	< 0.0001	190	21	110	< 0.005	1400		< 0.002		5.5	640	< 0.1	< 0.0005	38	0.01		
	31/10/2013	510	< 0.15		0.24		0.15	< 0.0001	190	11	110	< 0.005	1400		< 0.002		5.3	630	< 0.1	< 0.0005	39	0.2		
W73-2	27/04/2007	280	< 0.02	< 0.001	0.07		< 0.01	< 0.0001	105	< 5	7	< 0.001	575	0.004		< 0.005	2.2		< 0.03	< 0.001	11	0.02	< 0.0001	
	05/05/2011	280	< 0.15		0.078		< 0.02	< 0.0001	110	15	17	0.01	635		< 0.002		2.2	320	< 0.1	< 0.0005	13	< 0.002		
W86	15/01/2010	685	2.15		0.5		0.43	< 0.0001	240	58	330	< 0.005	2400		< 0.002		20.5	810	0.18	< 0.0005	52	2		
W87	14/01/2010	382	< 0.15		0.19		0.08	< 0.0001	140	17	120	< 0.005	1220		< 0.002		5.1	470	< 0.1	< 0.0005	28	0.016		
Southern Boundary (along existing closed landfill)																								
P65	24/03/1988	294	0.48			12				15	39		875						0.17	0.07		0.05		
	09/05/1989	202				4			48	28	10		392	0.002				178		0.002	14	0.12		
	27/04/1990	72	0.23			2	0.04		39	25	7		456						0.47		15	0.11		
	09/05/1991	200				3	0.06		30	11	4		420						0.17		15	0.08		
	10/05/1992	236			0.23	1	0.07		91	8	4		491						1.84		21	0.3		
	13/04/1993	321	0.09		0.17	12	0.09		79	13	2		639						0.71		21	0.22		
	18/04/1994	287	0.05		0.18	6	0.06		58	8	3		562						2.57		20	0.18		0.02
	01/06/1996		0.41		0.14		0.06		95	22	2		614						3.76		22	0.33		
P79	16/08/1993				0.49		0.32			604	100		3371						0.41					
	16/04/1994				0.27	93	0.13		73	155	54		1023						17.2					0.02
	01/08/1995		0.17		0.27		0.35		101	47	69	0.01	1016						18.5		26	0.22		
	01/06/1996		0.18		0.29		0.25		130	60	59		1045						15.4		27	0.22		
	20/05/1997		0.3		0.4		0.09		176	85	47		1228						19.2		41	0.42		
	14/05/1998		0.39		0.14		0.13		327	27	150		1980						0.52		70	0.25		
	11/05/1999	320	0.65		0.23		0.11		238	56	66		1330						10.9		42	0.41		
	17/05/2000	350	0.91		0.18		0.1	< 0.005	261	87	96	< 0.01	1570			< 0.02			11.3	< 0.002	46	0.66		
	08/05/2001	459	1.34		0.56		0.18	< 0.005	270	76	51	< 0.01	1580			0.008			19	< 0.001	46	0.94		
	14/05/2002	398	1.49		0.13		0.19	< 0.005	256	68	51	< 0.001	1510			< 0.005			21.5	< 0.001	38	0.71		
	21/05/2003	494	1.37		0.12		0.18	< 0.001	258	63	66	< 0.005	1510			0.005			18.8	< 0.001	41	0.95		
	27/04/2004	542	1.07		0.19		0.31	< 0.001	233	61	96	< 0.005	1490			< 0.005			23.3	< 0.001	38	1.05		
	03/05/2005	542	0.98		0.25		0.22	< 0.0001	233	52	138	0.004	1660			0.005			25.4	< 0.001	51	1.3		
	28/04/2006	545	1.12		0.25		0.21	< 0.0001	271	64	196	0.004	1840			< 0.005			23.5	< 0.001	43	0.86		
	26/04/2007	636	1.02		0.26		0.25	< 0.0001	276	91	252	0.006	2140			< 0.005			36.1	< 0.001	51	1.28		
	26/05/2008	654	1.55		0.12		0.26	< 0.0001	370	170	380	0.018	2850		< 0.002		48	1300	13	< 0.0005	92	0.99		
	29/04/2009	793	1.92		0.17		0.31	< 0.0001	290	150	330	0.019	2800		< 0.002		46.7	1000	29	< 0.0005	70	0.81		
	28/04/2010	848	4.64		0.18		0.35	< 0.0001	250	130	270	0.015	2500		< 0.002		45.4	890	27	< 0.0005	67	0.5		
	05/05/2011	648	11.4		0.15		0.27	< 0.0001	180	77	130	0.026	1770		< 0.002		23.6	680	19	< 0.0005	58	0.5		
	08/05/2012	540	10.9		0.15		0.3	< 0.0001	160	60	140	0.012	1800		< 0.002		24.6	650	17	< 0.0005	60	0.43		
	27/05/2013	550	13.4		0.14		0.35	< 0.0001	280	80	260	< 0.005	2400		< 0.002		24.1	1000	25	< 0.0005	79	0.59		

Appendix A1- Overburden - Shallow Bedrock Water Quality Inorganic General

Name	Date	Alkalinity mg/L	Ammonia mg/L	Arsenic mg/L	Barium mg/L	Biochemical Oxygen Demand mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Copper mg/L	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Mercury mg/L	Nickel mg/L
P80-1	16/08/1993				0.25		0.05			10	342		3592						0.24					
	18/04/1994	215	0.22		0.04	3	0.06		18	5	277	0.42	1399						0.13		7			
	01/08/1995		0.23		0.31		0.04		89	5	250	0.02	1162						11.1	0.002	15	0.41		
	01/06/1996		0.34		0.45		0.01		63	16			1580						1.37		18	0.25		
	20/05/1997		0.27		0.32				178	8	251		1258						1.02		38	0.13		
	13/05/1998		0.05		0.15				12	10	129		744						0.26		2	0.06		
	11/05/1999	242	0.02		0.14				136	8	107		825						0.11		25	0.09		
	17/05/2000	296	0.08		0.26		0.02	< 0.005	184	18	148	< 0.01	1150			< 0.02			0.97	< 0.001	43	0.1		
	08/05/2001	403	0.06		0.46		0.02	< 0.005	239	44	109	< 0.01	1440			< 0.005			1.66	< 0.001	49	0.11		
	15/05/2002	452	0.15		0.07		< 0.05	< 0.005	244	45	87	0.001	1420			< 0.005			1.75	< 0.001	54	0.09		
	21/05/2003	525	0.05		0.07		< 0.05	< 0.001	251	34	91	< 0.005	1510			< 0.005			1.98	< 0.001	61	0.16		
	27/04/2004	454	0.12		0.08		0.05	< 0.001	227	30	67	< 0.005	1240			< 0.005			3.86	< 0.001	55	0.32		
	03/05/2005	569	0.13		0.1		0.02	< 0.0001	212	30	62	0.002	1400			< 0.005			2.76	< 0.001	67	0.46		
	28/04/2006	683	0.09		0.11		0.03	< 0.0001	250	38	64	0.003	1600			< 0.005			2.64	< 0.001	61	0.72		
	26/04/2007	687	0.09		0.09		0.03	< 0.0001	259	34	61	0.002	1580			< 0.005			3.18	< 0.001	62	0.71		
	26/05/2008	723	< 0.15		0.13		0.037	< 0.0001	250	47	74	< 0.005	1620		< 0.002		11.8	900	2.8	< 0.0005	69	0.43		
	29/04/2009	746	0.23		0.12		0.036	< 0.0001	250	110	65	< 0.005	1660		< 0.002		14.4	910	4	< 0.0005	70	0.36		
	28/04/2010	779	< 0.15		0.12		0.035	< 0.0001	270	38	54	0.006	1640		< 0.002		12.6	980	4.6	< 0.0005	74	0.38		
	04/05/2011	868	< 0.15		0.12		0.05	< 0.0001	290	44	66	< 0.005	1840		< 0.002		14.8	1000	2	< 0.0005	71	1.2		
	08/05/2012	730	< 0.15		0.11		0.035	< 0.0001	240	40	47	< 0.005	1600		< 0.002		13.9	870	4.8	< 0.0005	68	0.46		
	27/05/2013	770	< 0.15		0.11		0.047	< 0.0001	280	32	62	< 0.005	1700		< 0.002		11.7	990	3.6	< 0.0005	72	0.78		
P80-2	16/08/1993				0.09		0.05			8	140		1255						0.13					
	18/04/1994	154			0.12	4			95	5	72		576						0.02		15	0.05		0.01
	01/08/1995		0.01						91	5	83		593						0.23		21			
	01/06/1996		0.03		0.1				81	5	78		670						0.43		15			
	20/05/1997		0.05		0.09				81	5	67		550						0.26		17	0.02		
	13/05/1998		0.03		0.07				58	5	15		374						0.06	0.004	12			
	11/05/1999	253			0.13				92		28		604								19			
	16/05/2000	604	0.03		0.31		0.03	< 0.005	296	43	58	< 0.01	1530			< 0.02			0.1	< 0.002	61	0.05		
	08/05/2001	439	0.02		0.13		< 0.01	< 0.005	222	36	74	< 0.01	1490			< 0.005			< 0.01	< 0.001	49	0.08		
	15/05/2002	908	0.03		0.15		< 0.05	< 0.005	443	71	68	0.003	2350			< 0.005			0.05	< 0.001	84	0.18		
	22/05/2003	655	0.05		0.1		< 0.05	< 0.001	291	59	67	< 0.005	1660			< 0.005			0.02	< 0.001	58	0.6		
	27/04/2004	613	0.04		0.11		0.08	< 0.001	266	48	37	< 0.005	1490			< 0.005			< 0.01	< 0.001	53	2.16		
	03/05/2005	647	0.05		0.16		0.06	< 0.0001	254	48	42	0.002	1540			< 0.005			< 0.01	< 0.001	61	3.21		
	28/04/2006	829	0.03		0.2		0.06	< 0.0001	280	44	36	0.003	1730			< 0.005			< 0.03	< 0.001	55	3.94		
	26/04/2007	797			0.19		0.07		268	14	34	0.002	1580						< 0.03	< 0.001	55	3.56		

Appendix A1- Overburden - Shallow Bedrock Water Quality Inorganic General

Name	Date	Alkalinity mg/L	Ammonia mg/L	Arsenic mg/L	Barium mg/L	Biochemical Oxygen Demand mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Copper mg/L	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Mercury mg/L	Nickel mg/L
W2-3	25/04/1991	162					0.07		50		31		630								17			
	18/03/1992				0.03		0.03		47												14	0.52		
	10/04/1992	156			0.03	1	0.03		41	11	18		542						0.08		16	0.17		
	19/02/1993	155			0.03		0.03		34	5	10		486						0.05		14	0.04		
	22/03/1994	158	0.24		0.07				40	10	4		390						0.46		12	0.66		
	01/08/1995		1.13		0.13				37	8	2		363						1.14		13	0.35		
	01/06/1996		4.9		0.1				39	38	2		830						2.53		12	0.02		
	21/05/1997		4.16						190	136	129	0.01	1934						10.8		85	1.15		
	13/05/1998		4.27		0.13				7	125	126		1555						4.53		1	0.82		
	17/05/2000	160	0.1		0.93		0.11	< 0.005	50	5	4	< 0.01	341			< 0.02			0.2	< 0.002	12	0.06		
	08/05/2001	158	0.02		0.69		0.11	< 0.005	48	< 5	6	< 0.01	370			< 0.005			0.09	< 0.001	13	< 0.01		
	15/05/2002	157	0.02		0.17		< 0.05	< 0.005	49	7	5	0.001	392			< 0.005			0.09	< 0.001	12	0.02		
	20/05/2003	148	0.03		0.14		< 0.05	< 0.001	50	< 5	5	< 0.005	315			< 0.005			0.22	< 0.001	11	0.02		
	27/04/2004	148	0.04		0.17		0.02	< 0.001	41	< 5	5	< 0.005	318			< 0.005			0.02	< 0.001	10	0.03		
	03/05/2005	141	0.1		0.14		0.02	< 0.0001	41	< 5	6	< 0.001	292			< 0.005			0.2	< 0.001	12	0.04		
	27/04/2006	151	0.03		0.13		< 0.01	< 0.0001	42	< 5	6	< 0.001	322			< 0.005			< 0.03	< 0.001	10	< 0.01		
	25/04/2007	145	< 0.02		0.13		< 0.01	< 0.0001	43	< 5	6	0.001	319			< 0.005			< 0.03	< 0.001	11	< 0.01		
W42-2	01/07/1995				0.29		0.01		79	11	41		540						0.02		20	0.02		
W46-2	01/07/1995		4.89		0.47		0.35		154	35	69		1214						1.34		33	0.68		
Within Property Boundaries																								
W62-2	25/02/2004	185	0.05		0.15		0.05	0.001	66	5	7	0.005	392			0.005			0.07	0.001	14	0.05		
	05/05/2004	234	0.05	< 0.001	0.17		0.02	< 0.0001	89	7	11	0.001	519	< 0.001		< 0.005	1.9		0.65	< 0.001	17	0.16	< 0.0001	
	26/05/2008	244	< 0.15		0.19		< 0.02	< 0.0001	91	22	21	0.012	575		< 0.002		1.6	310	0.44	< 0.0005	20	0.13		
	29/04/2009	234	< 0.15		0.44		0.021		1000	76	19	0.008	554		< 0.002		3.8	2700	12	0.0051	41	1.1		
	28/04/2010	241	0.17		0.18		< 0.02	< 0.0001	95	80		0.037	568		< 0.002		2.2	320	0.68		20			
	05/05/2011	249	< 0.15		0.18		< 0.02	< 0.0001	93	13	23	< 0.005	585		< 0.002		2.1	310	0.68	< 0.0005	20	0.12		
	08/05/2012	240	< 0.15		0.21		< 0.02	< 0.0001	90	7	22	0.008	570		< 0.002		2.5	310	0.68	< 0.0005	21	0.1		
	27/05/2013	270	< 0.15		0.23		< 0.02	< 0.0001	110	8.3	26	< 0.005	670		< 0.002		2.6	380	0.71	< 0.0005	24	0.13		
W63	24/02/2004	1030	0.25		0.48		0.14	0.001	327	77	253	0.035	2490			0.005			21	0.001	95	0.66		
	07/05/2004	1100	0.29	0.001	0.49		0.11	< 0.0001	338	89	264	0.001	2660	0.001		< 0.005	28.2		22.2	< 0.001	97	0.59	< 0.0001	
	26/05/2008	1300	16.3		0.87		0.29	< 0.0001	380	120	430	< 0.005	3350		< 0.002		37.4	1400	1.4	< 0.0005	120	0.43		
	29/04/2009	1240	23.7		0.93		0.29	< 0.0001	300	100	390	< 0.005	3290		< 0.002		36.2	1100	19	< 0.0005	96	0.38		
	29/04/2010	1340	22.8		1		0.35	< 0.0001	350	110	440	< 0.005	3620		< 0.002		38.4	1400	19	< 0.0005	140	0.35		
	05/05/2011	1660	21.5		1.1		0.45	< 0.0001	390	130	580	< 0.005	4400		< 0.002		45.3	1700	20	< 0.0005	170	0.26		
	08/05/2012	1600	23.9		1.1		0.59	< 0.0001	360	140	540	< 0.005	4300		< 0.002		51.4	1600	18	< 0.0005	180	0.26		
	27/05/2013	1700	36.6		1.2		0.69	< 0.0001	400	160	620	< 0.005	4600		< 0.002		53.2	1800	21	< 0.0005	190	0.23		

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Name	Date	Alkalinity mg/L	Ammonia mg/L	Arsenic mg/L	Barium mg/L	Biochemical Oxygen Demand mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity μs/cm	Copper mg/L	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Mercury mg/L	Nickel mg/L
W64	25/02/2004	407	0.37		0.16		0.09	0.001	160	29	61	0.01	1090			0.005			0.16	0.001	37	1.17		
	05/05/2004	332	0.61	< 0.001	0.13		0.1	< 0.0001	116	20	53	0.001	856	0.002		< 0.005	8.8		0.4	< 0.001	25	1.02	< 0.0001	
	26/05/2008	401	3.68					< 0.0001	130	34	93	< 0.005			< 0.002		10.9	460	5.5	< 0.0005	32	0.72		
	29/04/2009	405	3.71		0.24		0.17	< 0.0001	200	35	110	< 0.005	1190		< 0.002		12.2	650	6	0.0013	34	0.84		
	28/04/2010	274	1.83		0.14		0.17	< 0.0001	83	130	62	0.035	790		< 0.002		7.6	300	0.64	< 0.0005	23	0.35		
	15/07/2010	235	2.11		0.11		0.15	< 0.0001	62	33	64	0.006	688		< 0.002		9.2	220	0.25	< 0.0005	15	0.29		
	03/11/2010	258	0.48				0.088		79		28		621				3.2		< 0.1			0.34		
	03/02/2011	297	0.68		0.18		0.13	< 0.0001	110	22	81	< 0.005	950		< 0.002		7.9	400	< 0.1	< 0.0005	27	0.52		
	05/05/2011	288	2.8		0.14		0.14	< 0.0001	87	20	65	< 0.005	851		< 0.002		6.6	300	< 0.1	< 0.0005	20	0.3		
	09/08/2011	220	2.26		0.11		0.16	< 0.0001	59	32	42	< 0.005	594		< 0.002		9.6	200	< 0.1	< 0.0005	14	0.27		
	09/11/2011	241	1		0.11		0.1	< 0.0001	77	21	31	< 0.005	632		< 0.002		4.3	270	< 0.1	< 0.0005	18	0.28		
	23/02/2012	280	0.77		0.13		0.093	< 0.0001	93	7	38	< 0.005	715		< 0.002		3.4	320	< 0.1	< 0.0005	22	0.35		
	08/05/2012	270	0.48		0.14		0.15	< 0.0001	93	22	71	< 0.005	850		< 0.002		7.8	320	< 0.1	< 0.0005	22	0.24		
	20/08/2012	260	0.88		0.14		0.15	< 0.0001	86	20	47	< 0.005	770		< 0.002		6.3	300	< 0.1	< 0.0005	20	0.32		
	29/10/2012	260	0.52		0.11		0.086	< 0.0001	88	16	34	< 0.005	690		< 0.002		3.4	300	< 0.1	< 0.0005	20	0.26		
	15/02/2013	300	0.32		0.14		0.1	< 0.0001	110	8.8	74	< 0.005	890		< 0.002		4.9	380	< 0.1	< 0.0005	26	0.36		
	27/05/2013	250	0.2		0.13		0.17	< 0.0001	96	23	48	< 0.005	780		< 0.002		7.2	320	< 0.1	< 0.0005	21	0.037		
	07/08/2013	230	0.73		0.11		0.17	< 0.0001	63	27	46	< 0.005	650		< 0.002		9.7	220	< 0.1	< 0.0005	15	0.31		
	31/10/2013	260	0.43		0.12		0.16	< 0.0001	78	16	48	< 0.005	720		< 0.002		7.1	270	< 0.1	< 0.0005	19	0.4		
W75	27/04/2007	214	0.07	< 0.001	0.1		0.05	< 0.0001	66	16	22	0.001	527	< 0.001		< 0.005	4.3		0.42	< 0.001	15	0.12	< 0.0001	
	28/11/2007																							
	05/05/2011	210			0.17		< 0.02	< 0.0001	80	11		< 0.005	512		< 0.002		1.7	270	< 0.1	< 0.0005	18	0.013		

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Name	Date	Nitrate mg/L	Nitrite mg/L	pH unitless	Phenol mg/L	Phosphorus mg/L	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
Western Boundary											
W3-3	03/12/1987									850	
	04/04/1988									1030	
	01/05/1989					0.15		115	443	918	
	20/03/1990	0.18		7.55			2	165	560	850	0.23
	25/02/1991	0.36		7.6		0.19	2	169	370	798	0.59
	17/03/1992	0.15		7.68		0.2	2	139	357	750	0.29
	19/02/1993			7.62		0.11	2	132	365	720	0.47
	15/03/1994	0.57		7.8			3	126	331		0.17
	01/08/1995							107	290		0.38
	01/06/1996	0.28						101	245		0.24
	21/05/1997	0.15						106	258		0.15
	13/05/1998	0.22						102	228		0.19
	11/05/1999						3	78	14		1.13
	17/05/2000	0.15	< 0.1				2	93	< 3		0.29
	09/05/2001	0.1	< 0.1				2	76	226		0.13
	15/05/2002	< 0.1	< 0.1				2	71	222		0.22
	21/05/2003	< 0.1	< 0.1				2	74	175		0.12
	29/04/2004	0.17	< 0.1				2	77	183		0.18
	29/04/2005	0.5	< 0.1				2	88	165		0.12
	28/04/2006	0.21	< 0.1				2	191	280		0.37
	26/04/2007	0.13	< 0.1				1	239	331		0.24
W60-2	24/02/2004	0.1	0.1				1	5	28		0.57
	06/05/2004	< 0.1	< 0.1		< 0.001	0.23	1	4	27		0.44
	26/05/2008	< 0.1	< 0.01	8.8			3.2	68	33	351	< 4
	29/04/2009	< 0.1	< 0.01	7.7			3.6	79	33	295	< 0.7
	28/04/2010	< 0.1	< 0.01	8.4			3.5	73	33	272	< 1
	03/05/2011	< 0.1	0.17	8.35			3	58	33	258	< 0.7
	08/05/2012	< 0.1	< 0.01	8.3			3.4	76	23	246	< 0.7
	27/05/2013	0.25	< 0.01	8.24			3.3	58	41	222	< 0.7
W61	24/02/2004	0.1	0.1				2	7	24		0.09
	06/05/2004	< 0.1	< 0.1		< 0.001	2.27	2	8	33		0.18
	26/05/2008	< 0.1	< 0.01	8.1			1.7	6.7	30	385	< 4
	29/04/2009	< 0.1	< 0.01	7.8			1.6	6.5	31	410	< 0.7
	28/04/2010	< 0.1	< 0.01	8			1.6	6.4	32	384	< 10
	04/05/2011	< 0.1	< 0.01	7.84			1.5	7	31	402	< 0.7
	08/05/2012	< 0.1	< 0.01	8.04			1.5	6.4	31	366	< 0.7
	27/05/2013	< 0.1	< 0.01	7.97			1.7	7.4	31	368	< 0.7
W76-2	27/04/2007	0.17	< 0.1	7.65	< 0.001	1.09	12	25	128	832	0.41
	28/11/2007										
	03/05/2011	< 0.1	< 0.01	7.79			4.2	22	100	628	2
Eastern Boundary											
W65-2	25/02/2004	5.42	0.1				3	34	74		0.36
	27/04/2004	< 0.1	< 0.1				2	25	57		0.27
	05/05/2004	2.19	< 0.1		< 0.001	0.66	2	25	59		0.23
	26/05/2008	4.6	0.05	8			4	100	111	773	< 1
	29/04/2009	1.1	< 0.01	7.6			2.2	64	38	585	< 1
	28/04/2010	2.1	< 0.01	7.9			2.2	62	37	564	< 4
	05/05/2011	2	< 0.01	8.06			2.2	32	38	392	1.1
	08/05/2012	2.9	< 0.01	7.95			2.6	130	44	882	< 0.7
	27/05/2013	3.9	< 0.01	8.01			2.6	160	35	680	1.3

Appendix A1- Overburden - Shallow Bedrock Water Quality Inorganic General

Name	Date	Nitrate mg/L	Nitrite mg/L	pH unitless	Phenol mg/L	Phosphorus mg/L	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
W72	25/02/2004	0.1	0.1				3	29	60		0.45
	05/05/2004										
	23/05/2008	4.7	0.12	8.1			5.4	100	136	855	1.6
	19/11/2008	2.9	< 0.01	8			1.8	63	65	745	< 0.7
	29/04/2009	1	< 0.01	7.6			2.3	55	65	850	0.9
	28/10/2009	< 0.1	< 0.01	7.4			2.6	74	82	895	< 0.7
	28/04/2010	2.9	0.07	7.7			2.2	60	93	790	0.7
	02/11/2010	1	< 0.01	7.73			2.8	77	100	862	0.8
	05/05/2011	3.4	< 0.01	8.01			2	50	57	492	< 0.7
	09/11/2011	0.6	< 0.01	7.91			3.6	92	100	862	1
	08/05/2012	1	< 0.01	7.88			3.7	86	94	788	1.3
	30/10/2012	2.5	< 0.01	7.77			3.7	91	83	756	1.4
	27/05/2013	1.1	< 0.01	7.72			3.5	90	98	814	< 0.7
	31/10/2013	4.5	< 0.01	7.6			3.3	84	88	794	< 0.7
W73-2	27/04/2007	1.62	0.1	7.78	< 0.001	0.78	1	4	24	374	0.13
	05/05/2011	3.1	< 0.01	7.71			1.4	10	24	388	0.9
W86	15/01/2010	< 0.1	< 0.01	7.4			8.5	180	70	1580	4.1
W87	14/01/2010	2.6	< 0.01	7.7			3	74	68	810	< 0.7
Southern Boundary (along e											
P65	24/03/1988									500	
	09/05/1989			7.64		0.12		26	27	270	0.18
	27/04/1990	0.81		7.45		0.26	6	25	15	258	1.17
	09/05/1991	0.21		7.9		0.54	4	44	45	244	0.11
	10/05/1992	0.41		7.36		0.26	4	23	33	290	0.14
	13/04/1993			7.1		0.18	5	23	23	380	0.21
	18/04/1994	0.54					4	26	23		0.18
	01/06/1996							25	14		0.68
P79	16/08/1993							134			
	16/04/1994							83			0.62
	01/08/1995							83			1
	01/06/1996							56	21		1
	20/05/1997							47	131		1.07
	14/05/1998							87	657		0.68
	11/05/1999						2	37	359		1.55
	17/05/2000	< 0.1	< 0.1				3	50	486		2.09
	08/05/2001	< 0.1	< 0.1				5	40	397		2.43
	14/05/2002	< 0.1	< 0.1				7	36	385		3.19
	21/05/2003	< 0.1	< 0.1				9	40	390		2.75
	27/04/2004	< 0.1	< 0.1				11	79	167		2.68
	03/05/2005	< 0.1	< 0.1				11	79	226		2.49
	28/04/2006	< 0.1	< 0.1				10	92	189		2.55
	26/04/2007	< 0.1	< 0.1				10	102	176		3.06
	26/05/2008	< 0.1	< 0.01	7.5			15	240	405	1710	< 7
	29/04/2009	< 0.1	< 0.01	7.5			14	220	270	1810	6
	28/04/2010	< 0.1	< 0.01	7.6			17	260	100	1600	9
	05/05/2011	< 0.1	< 0.01	7.93			18	120	140	1120	12
	08/05/2012	< 0.1	< 0.01	7.82			17	120	230	1120	10
	27/05/2013	< 0.1	< 0.01	7.62			21	190	350	1580	14

Appendix A1- Overburden - Shallow Bedrock Water Quality Inorganic General

Name	Date	Nitrate mg/L	Nitrite mg/L	pH unitless	Phenol mg/L	Phosphorus mg/L	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
P80-1	16/08/1993							94			
	18/04/1994						3	281	90		0.22
	01/08/1995							159	32		0.28
	01/06/1996	0.33						155	32		0.87
	20/05/1997							7	38		0.27
	13/05/1998							1	32		0.14
	11/05/1999						2	3	61		0.12
	17/05/2000	< 0.1	< 0.1				2	8	128		0.16
	08/05/2001	< 0.1	< 0.1				2	10	250		0.61
	15/05/2002	< 0.1	< 0.1				2	14	192		0.92
	21/05/2003	< 0.1	< 0.1				2	19	300		0.69
	27/04/2004	< 0.1	< 0.1				2	19	173		0.61
	03/05/2005	< 0.1	< 0.1				3	21	178		0.58
	28/04/2006	< 0.1	< 0.1				2	22	181		0.74
	26/04/2007	0.13	< 0.1				2	23	175		0.82
	26/05/2008	< 0.1	< 0.01	7.6			2.8	28	142	985	< 4
	29/04/2009	< 0.1	< 0.01	7.5			2.7	27	120	1110	< 7
	28/04/2010	< 0.1	< 0.01	7.4			2.7	25	120	1020	< 4
	04/05/2011	< 0.1	< 0.01	7.48			2.7	40	120	1130	0.9
	08/05/2012	< 0.1	< 0.01	7.61			2.4	27	110	1010	0.8
	27/05/2013	< 0.1	< 0.01	7.37			2.7	32	110	1070	0.8
P80-2	16/08/1993							24			
	18/04/1994	0.83					3	3	27		0.15
	01/08/1995	1.28						4			0.15
	01/06/1996	0.94						5	24		0.16
	20/05/1997	1.45									0.13
	13/05/1998	1.17						5	13		0.14
	11/05/1999	1					1	5	38		0.19
	16/05/2000	< 0.1	< 0.1				2	11	8		0.62
	08/05/2001	3.63	< 0.1				2	19	307		0.38
	15/05/2002	0.64	< 0.1				2	50	381		1.48
	22/05/2003	2.03	< 0.1				2	40	286		1.33
	27/04/2004	0.98	0.43				2	31	192		1.13
	03/05/2005	0.43	< 0.1				2	41	237		0.83
	28/04/2006	0.33	< 0.1				2	36	197		0.95
	26/04/2007	1.1	< 0.1				1	31	114		0.74

Appendix A1- Overburden - Shallow Bedrock Water Quality Inorganic General

Name	Date	Nitrate mg/L	Nitrite mg/L	pH unitless	Phenol mg/L	Phosphorus mg/L	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
W2-3	25/04/1991	0.1		7.9	0.005		2	58	94	360	0.17
	18/03/1992						2	60			
	10/04/1992	0.35		7.65		0.28	2	57	113	340	0.32
	19/02/1993	0.12		7.79		0.14	1	43	82	290	0.06
	22/03/1994	0.13		7			2	26	43		0.24
	01/08/1995							20	40		1.17
	01/06/1996	0.26						17	38		0.11
	21/05/1997	0.11						108	572		5.42
	13/05/1998								491		7.91
	17/05/2000	< 0.1	< 0.1				1	5	25		0.36
	08/05/2001	< 0.1	< 0.1				2	4	32		0.19
	15/05/2002	< 0.1	< 0.1				1	4	34		0.2
	20/05/2003	< 0.1	< 0.1				2	82	16		0.16
	27/04/2004	< 0.1	< 0.1				2	7	15		0.11
	03/05/2005	< 0.1	< 0.1				2	7	14		0.28
	27/04/2006	< 0.1	< 0.1				1	6	16		0.22
	25/04/2007	< 0.1	< 0.1				2	9	16		< 0.05
W42-2	01/07/1995	0.17						7			0.2
W46-2	01/07/1995							56	20		8.16
Within Property Boundaries											
W62-2	25/02/2004	0.1	0.1				2	4	24		0.16
	05/05/2004	< 0.1	< 0.1		< 0.001	1	< 1	4	37		0.43
	26/05/2008	< 0.1	< 0.01	8.1			1.1	3.4	40	378	< 4
	29/04/2009		< 0.01	7.7			4.1	4	37	380	< 4
	28/04/2010			7.8			1.1	3.3	35	370	< 10
	05/05/2011	< 0.1	< 0.01	8.14			1	3.3	32	370	< 0.7
	08/05/2012	< 0.1	< 0.01	8			1.1	3.8	31	348	< 0.7
	27/05/2013	< 0.1	< 0.01	7.94			1.4	4.1	37	388	< 0.7
W63	24/02/2004	0.1	0.1				4	122	74		1.85
	07/05/2004	< 0.1	< 0.1		< 0.001	0.12	3	127	62		2.1
	26/05/2008	< 0.1	< 0.01	7.4			12	280	47	2320	18
	29/04/2009	< 0.1	< 0.01	7.4			12	220	75	2160	23
	29/04/2010	< 0.1	< 0.01	7.7			15	290	39	2260	25
	05/05/2011	< 0.1	< 0.01	7.38			14	380	< 1	2620	24
	08/05/2012	< 0.1	< 0.01	7.43			15	400	20	2500	27
	27/05/2013	< 0.1	< 0.01	7.33			21	490	< 1	2600	42

Appendix A1- Overburden - Shallow Bedrock Water Quality Inorganic General

Name	Date	Nitrate mg/L	Nitrite mg/L	pH unitless	Phenol mg/L	Phosphorus mg/L	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
W64	25/02/2004	0.1	0.1				6	42	115		1.02
	05/05/2004	< 0.1	< 0.1		< 0.001	0.77	5	36	61		1.47
	26/05/2008	< 0.1	0.01	7.9			8.3	70	95	738	5
	29/04/2009	< 0.1	< 0.01	7.6			8.2	69	77	780	6
	28/04/2010	0.2	0.21	7.9			8.8	48	48	494	< 7
	15/07/2010	0.1	0.02	7.9			9.3	47	20	430	4
	03/11/2010	2.4	0.03	7.87			5.8			388	1.1
	03/02/2011	0.7	0.04	7.76			7.3	56	69	592	1.4
	05/05/2011	< 0.1	0.02	8.06			8.8	41	51	530	3.2
	09/08/2011	0.3	< 0.01	7.94			10	40	14	408	2.8
	09/11/2011	5.7	< 0.01	8.1			7.7	28	20	360	1.6
	23/02/2012	3.5	< 0.01	7.86			7.4	28	29	434	1.8
	08/05/2012	0.57	0.2	8.01			8.2	49	60	476	1.1
	20/08/2012	4	0.033	7.77			8.8	43	38	468	1.6
	29/10/2012	4.6	< 0.01	7.57			5.7	28	24	358	< 0.7
	15/02/2013	2	< 0.01	7.93			6.8	41	42	412	1.4
	27/05/2013	0.31	0.088	7.88			11	47	55	444	0.7
	07/08/2013	< 0.1	< 0.01	8			11	43	26	366	1.3
	31/10/2013	1.8	< 0.01	7.86			9.5	45	30	338	1.1
W75	27/04/2007	0.82	< 0.1	7.82	< 0.001	1.87	2	21	38	343	0.52
	28/11/2007										
	05/05/2011	0.3	< 0.01	8.08				3.9		356	

Appendix A1 -Overburden - Shallow Bedrock Water Quality VOCs

Name	Date	1,1,1,2-Tetrachloroethane mg/L	1,1,1-Trichloroethane mg/L	1,1,2,2-Tetrachloroethane mg/L	1,1,2-Trichloroethane mg/L	1,1-Dichloroethane mg/L	1,1-Dichloroethene mg/L	1,2-Dichlorobenzene (o) mg/L	1,2-Dichloroethane mg/L	1,2-Dichloropropane mg/L	1,3,5-Trimethylbenzene mg/L	1,3-Dichlorobenzene (m) mg/L	1,4-Dichlorobenzene (p) mg/L	Benzene mg/L	Bromodichloromethane mg/L	Bromoform mg/L	Bromomethane mg/L	Carbon Tetrachloride mg/L	Chlorobenzene mg/L	Chlorodibromomethane mg/L	Chloroethane mg/L
Western Boundary																					
W3-3	26/04/2007	< 0.0005	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.0005	< 0.0004	< 0.0005	< 0.0005	< 0.0003	< 0.0004	< 0.0004	< 0.0005	< 0.0003	< 0.0004	< 0.0005	< 0.0005	< 0.0002	< 0.0003	< 0.001
W60-2	06/05/2004												< 0.0024	< 0.0013							
W61	06/05/2004												< 0.0024	< 0.0013							
W76-2	27/04/2007	< 0.0005	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.0005	< 0.0004	< 0.0005	< 0.0005	< 0.0003	< 0.0004	< 0.0004	< 0.0005	< 0.0003	< 0.0004	< 0.0005	< 0.0005	< 0.0002	< 0.0003	< 0.001
	28/11/2007	< 0.0005	< 0.0004	< 0.0005															< 0.0002		
	03/05/2011	< 0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	< 0.0002
Eastern Boundary																					
W65-2	05/05/2004												< 0.0024	< 0.0013							
W72	23/05/2008	< 0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	< 0.0002
	29/04/2009	< 0.0001	< 0.0001	< 0.0002	< 0.0002	0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	0.0003
	28/04/2010	< 0.0001	< 0.0001	< 0.0002	< 0.0002	0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	< 0.0002
	05/05/2011	< 0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	< 0.0002
	08/05/2012	< 0.0002	< 0.0001	< 0.0002	< 0.0002	0.00028	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	0.00022
	27/05/2013	< 0.0002	< 0.0001	< 0.0002	< 0.0002	0.00027	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	0.0002
W73-2	27/04/2007	< 0.0005	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.0005	< 0.0004	< 0.0005	< 0.0005	< 0.0003	< 0.0004	< 0.0004	< 0.0005	< 0.0003	< 0.0004	< 0.0005	< 0.0005	< 0.0002	< 0.0003	< 0.001
W86	15/01/2010	< 0.0001	< 0.0001	< 0.0002	< 0.0002	0.0012	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	0.0007	< 0.0001	< 0.0002	< 0.0005	< 0.0001	0.0003	< 0.0002	0.0016
W87	14/01/2010	< 0.0001	< 0.0001	< 0.0002	< 0.0002	0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	< 0.0002
Within Property Boundaries																					
W62-2	05/05/2004												< 0.0024	< 0.0013							
W63	07/05/2004												< 0.0024	0.0033							
W64	05/05/2004												< 0.0024	< 0.0013							
W75	27/04/2007	< 0.0005	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.0005	< 0.0004	< 0.0005	< 0.0005	< 0.0003	< 0.0004	< 0.0004	< 0.0005	< 0.0003	< 0.0004	< 0.0005	< 0.0005	< 0.0002	< 0.0003	< 0.001
	28/11/2007	< 0.0005	< 0.0004					< 0.0004	< 0.0005	< 0.0005	< 0.0003		< 0.0004			< 0.0004	< 0.0005	< 0.0005			< 0.001
	05/05/2011	< 0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0005	< 0.0001	< 0.0001	< 0.0002	< 0.0002

Appendix A1 -Overburden - Shallow Bedrock Water Quality VOCs

Name	Date	Chloroform mg/L	Chloromethane mg/L	Cis-1,2-Dichloroethene mg/L	Cis-1,3-Dichloropropene mg/L	Ethylbenzene mg/L	Ethylene Dibromide mg/L	m+p-Xylene mg/L	Methylene Chloride mg/L	o-Xylene mg/L	Styrene mg/L	Tetrachloroethylene mg/L	Toluene mg/L	Trans-1,2-dichloroethene mg/L	Trans-1,3-dichloropropene mg/L	Trichloroethene mg/L	Trichlorofluoromethane mg/L	Vinyl Chloride mg/L
Western Boundary																		
W3-3	26/04/2007	< 0.0005	< 0.001	< 0.0004	< 0.0002	< 0.0005	< 0.001	< 0.001	< 0.004	< 0.0005	< 0.0005	< 0.0003	< 0.0005	< 0.0004	< 0.0002	< 0.0003	< 0.0005	< 0.0002
W60-2	06/05/2004								< 0.0048				< 0.0015					< 0.0049
W61	06/05/2004								< 0.0048				< 0.0015					< 0.0049
W76-2	27/04/2007	< 0.0005	< 0.001	< 0.0004	< 0.0002	< 0.0005	< 0.001	< 0.001	< 0.004	< 0.0005	< 0.0005	< 0.0003	< 0.0005	< 0.0004	< 0.0002	< 0.0003	< 0.0005	< 0.0002
	28/11/2007	< 0.0005	< 0.001		< 0.0002		< 0.001					< 0.0003	< 0.0005	< 0.0004	< 0.0002	< 0.0003		
	03/05/2011	< 0.0001	< 0.0005	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0005	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0002
Eastern Boundary																		
W65-2	05/05/2004								< 0.0048				< 0.0015					< 0.0049
W72	23/05/2008	< 0.0001	< 0.0005	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0005	< 0.0001	< 0.0002	0.0002	< 0.0002	< 0.0001	< 0.0002	0.0003	< 0.0002	< 0.0002
	29/04/2009	< 0.0001	< 0.0005	0.0009	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0005	< 0.0001	< 0.0002	0.0005	< 0.0002	< 0.0001	< 0.0002	0.0014	< 0.0002	< 0.0002
	28/04/2010	< 0.0001	< 0.0005	0.0008	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0005	< 0.0001	< 0.0002	0.0004	< 0.0002	< 0.0001	< 0.0002	0.0013	< 0.0002	< 0.0002
	05/05/2011	< 0.0001	< 0.0005	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	0.0005	< 0.0001	< 0.0002	0.0002	< 0.0002	< 0.0001	< 0.0002	0.0004	< 0.0002	< 0.0002
	08/05/2012	< 0.0001	< 0.0005	0.0013	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0005	< 0.0001	< 0.0002	0.00044	< 0.0002	< 0.0001	< 0.0002	0.0017	< 0.0002	< 0.0002
	27/05/2013	< 0.0001	< 0.0005	0.0013	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0005	< 0.0001	< 0.0002	0.00059	< 0.0002	< 0.0001	< 0.0002	0.002	< 0.0002	< 0.0002
W73-2	27/04/2007	< 0.0005	< 0.001	< 0.0004	< 0.0002	< 0.0005	< 0.001	< 0.001	< 0.004	< 0.0005	< 0.0005	< 0.0003	< 0.0005	< 0.0004	< 0.0002	< 0.0003	< 0.0005	< 0.0002
W86	15/01/2010	0.0005	< 0.0005	0.0027	< 0.0002	< 0.0001	< 0.0002	0.0002	< 0.0005	< 0.0001	< 0.0002	0.0004	< 0.0002	0.0001	< 0.0002	0.0021	< 0.0002	0.0006
W87	14/01/2010	< 0.0001	< 0.0005	0.0005	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0005	< 0.0001	< 0.0002	0.0004	< 0.0002	< 0.0001	< 0.0002	0.001	< 0.0002	< 0.0002
Within Property Boundaries																		
W62-2	05/05/2004								< 0.0048				< 0.0015					< 0.0049
W63	07/05/2004								< 0.0048				< 0.0015					< 0.0049
W64	05/05/2004								< 0.0048				< 0.0015					< 0.0049
W75	27/04/2007	< 0.0005	< 0.001	< 0.0004	< 0.0002	< 0.0005	< 0.001	< 0.001	< 0.004	< 0.0005	< 0.0005	< 0.0003	0.0006	< 0.0004	< 0.0002	< 0.0003	< 0.0005	< 0.0002
	28/11/2007	< 0.0005	< 0.001	< 0.0004	< 0.0002		< 0.001					< 0.0003						
	05/05/2011	< 0.0001	< 0.0005	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0005	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0002

Appendix A2 - Deep Bedrock Water Quality Inorganic General

Name	Date	Alkalinity mg/L	Ammonia mg/L	Arsenic mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium mg/L	Conductivity µs/cm	Copper mg/L	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L
W46-1	01/07/1995		1.72		0.17	0.42		77	27	72		1157						0.12		23
	01/06/1996		0.53		0.07	0.79		32	22	368		2477						0.22		18
	22/05/1997		0.59		0.11	1.04		33	46	413		3111						0.38		20
	13/05/1998		0.47		0.07	1.12		40	20	532		3537						4.11		28
	11/05/1999	897	0.37		0.09	1.08		53	5	542		3510						0.04		28
	10/05/2001	946	0.57		0.49	1.07	< 0.005	25	13	573	< 0.01	3430			< 0.005			0.21	< 0.001	20
	16/05/2002	999	0.7		0.09	1.1	< 0.005	30	19	581	< 0.001	3600			< 0.005			0.53	< 0.001	23
	20/05/2003	1030	0.62		0.09	1.05	< 0.001	31	< 5	677	< 0.005	3580			< 0.005			0.15	< 0.001	23
	21/05/2003																			
	30/04/2004	1060	0.59		0.13	0.99	< 0.001	31	24	593	< 0.005	3670			< 0.005			0.83	< 0.001	24
	03/05/2005	1150	0.81		0.18	1.04	< 0.0001	29	12	581	0.003	3660			< 0.005			0.12	< 0.001	27
	28/04/2006	1030	0.58		0.16	1.03	< 0.0001	37	15	557	< 0.005	3540			< 0.005			0.14	< 0.001	20
	25/04/2007	914	0.78		0.25	0.99	< 0.0001	34	17	455	0.008	3100			< 0.005			4.71	< 0.001	16
W60-1	06/05/2004	233	0.34					14	26	34		636			< 0.005					8
W62-1	05/05/2004	183	0.43		0.22	0.12	< 0.0001	44	13	42	0.002	485			< 0.005			< 0.01	< 0.001	25
W65-1	28/04/2004	37	0.22		0.02	< 0.01	< 0.001	9	< 5	7	< 0.005	156			< 0.005			0.03	< 0.001	2
	05/05/2004	122	0.53		0.03	0.05	< 0.0001	54	11	10	< 0.001	490			< 0.005			0.03	< 0.001	7
W73-1	05/05/2011	842	7.97		0.14	0.046	< 0.0001	35	58	23	< 0.005	4540		< 0.002		16.3	87	0.3	< 0.0005	< 0.05
W76-1	27/04/2007	315	0.65	0.001	0.08	0.47	< 0.0001	62	9	104	0.002	1150	< 0.001		< 0.005	4.5		0.03	< 0.001	39
	04/05/2011	333	0.61		0.11	0.55	< 0.0001	45	10	110	< 0.005	1070		< 0.002		4.6	250	< 0.1	< 0.0005	33

Appendix A2 - Deep Bedrock Water Quality Inorganic General

Name	Date	Manganese mg/L	Mercury mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Phenol mg/L	Phosphorus (total) mg/L	Potassium mg/L	Selenium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L	Zinc mg/L
W46-1	01/07/1995	0.12									141	40		2.45	
	01/06/1996	0.08									516	122		1.16	
	22/05/1997	0.06									725	70		0.93	
	13/05/1998	0.06									921	237		0.83	
	11/05/1999	0.03							9		737	244		0.92	
	10/05/2001	0.05		< 0.1	< 0.1				8	< 0.0042	756	109		0.62	
	16/05/2002	0.01		< 0.1	< 0.1				9	< 0.0042	794	97		0.79	
	20/05/2003	0.02		< 0.1	< 0.1				9		805	66		0.79	
	21/05/2003									< 0.0042					
	30/04/2004	0.03		< 0.1	< 0.1				10		882	128		1.29	
	03/05/2005	0.02		< 0.1	< 0.1				10		809	35		1.34	
	28/04/2006	< 0.01		< 0.1	< 0.1				9		706	68		1.05	
	25/04/2007	0.05		< 0.1	< 0.1				8		619	5		1.24	
W60-1	06/05/2004			< 0.1	0.26				5		119	40		0.39	
W62-1	05/05/2004	< 0.01		< 0.1	< 0.1				6		18	11		0.78	
W65-1	28/04/2004	< 0.01		0.16	< 0.1				< 1		18	26		0.38	
	05/05/2004	0.07		0.22	< 0.1				6		40	123		1.46	
W73-1	05/05/2011	0.002		< 0.1	< 0.01	12.1			180		460	220	2950	7.7	
W76-1	27/04/2007	0.04	< 0.0001	0.16	< 0.1	8.03	0.002	0.31	33		95	137	748	1.06	< 0.01
	04/05/2011	0.014		< 0.1	0.01	7.86			10		120	60	660	0.9	

Appendix A2 - Deep Bedrock Water Quality VOCs

Name	Date	1,1,1,2-Tetrachloroethane mg/L	1,1,1-Trichloroethane mg/L	1,1,2,2-Tetrachloroethane mg/L	1,1,2-Trichloroethane mg/L	1,1-Dichloroethane mg/L	1,1-Dichloroethene mg/L	1,2-Dichlorobenzene (o) mg/L	1,2-Dichloroethane mg/L	1,2-Dichloropropane mg/L	1,3,5-Trimethylbenzene mg/L	1,3-Dichlorobenzene (m) mg/L	1,4-Dichlorobenzene (p) mg/L	Benzene mg/L	Bromodichloromethane mg/L	Bromoform mg/L	Bromomethane mg/L	Carbon Tetrachloride mg/L	Chlorobenzene mg/L	Chlorodibromomethane mg/L
W46-1	10/05/2001	< 0.0006	< 0.0021	< 0.0034	< 0.0019	< 0.0035	< 0.0016	< 0.0019	< 0.0029	< 0.0024	< 0.0016	< 0.0024	< 0.0024	< 0.0013	< 0.002	< 0.0019	< 0.0005	< 0.0013	< 0.0002	< 0.0023
	16/05/2002	< 0.0006	< 0.0021	< 0.0034	< 0.0019	< 0.0035	< 0.0016	< 0.0019	< 0.0029	< 0.0024	< 0.0016	< 0.0024	< 0.0024	< 0.0013	< 0.002	< 0.0019	< 0.0005	< 0.0013	< 0.0002	< 0.0023
	20/05/2003	< 0.0006	< 0.0004	< 0.0006	< 0.0004	< 0.0004	< 0.0005	< 0.0004	< 0.0007	< 0.0007	< 0.0003	< 0.0004	< 0.0004	< 0.0005	< 0.0003	< 0.0004	< 0.0005	< 0.0009	< 0.0002	< 0.0003
	21/05/2003	< 0.0006	< 0.0021	< 0.0034	< 0.0019	< 0.0035	< 0.0016	< 0.0019	< 0.0029	< 0.0024	< 0.0016	< 0.0024	< 0.0024	< 0.0013	< 0.002	< 0.0019	< 0.0005	< 0.0013	< 0.002	< 0.0023
	30/04/2004	< 0.0006	< 0.0021	< 0.0034	< 0.0019	< 0.0035	< 0.0016	< 0.0019	< 0.0029	< 0.0024	< 0.0016	< 0.0024	< 0.0024	< 0.0013	< 0.002	< 0.0019	< 0.0005	< 0.0013	< 0.002	< 0.0023
	03/05/2005	< 0.0006	< 0.0021	< 0.0034	< 0.0019	< 0.0035	< 0.0016	< 0.0019	< 0.0029	< 0.0024	< 0.0016	< 0.0024	< 0.0024	< 0.0013	< 0.002	< 0.0019	< 0.0005	< 0.0013	< 0.002	< 0.0023
	28/04/2006	< 0.0005	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.0005	< 0.0004	< 0.0005	< 0.0005	< 0.0003	< 0.0004	< 0.0004	< 0.0005	< 0.0003	< 0.0004	< 0.0005	< 0.0005	< 0.0002	< 0.0003
	25/04/2007	< 0.0005	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.0005	< 0.0004	< 0.0005	< 0.0005	< 0.0003	< 0.0004	< 0.0004	0.0006	< 0.0003	< 0.0004	< 0.0005	< 0.0005	< 0.0002	< 0.0003
W65-1	28/04/2004	< 0.0006	< 0.0021	< 0.0034	< 0.0019	< 0.0035	< 0.0016	< 0.0019	< 0.0029	< 0.0024	< 0.0016	< 0.0024	< 0.0024	< 0.0013	0.0028	< 0.0019	< 0.0005	< 0.0013	< 0.002	< 0.0023
W76-1	27/04/2007	< 0.0005	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.0005	< 0.0004	< 0.0005	< 0.0005	< 0.0003	< 0.0004	< 0.0004	< 0.0005	< 0.0003	< 0.0004	< 0.0005	< 0.0005	< 0.0002	< 0.0003

Appendix A2 - Deep Bedrock Water Quality VOCs

Name	Date	Chloroethane mg/L	Chloroform mg/L	Chloromethane mg/L	Cis-1,2-Dichloroethene mg/L	Cis-1,3-Dichloropropene mg/L	Ethylbenzene mg/L	Ethylene Dibromide mg/L	m+p-Xylene mg/L	Methylene Chloride mg/L	o-Xylene mg/L	Styrene mg/L	Tetrachloroethylene mg/L	Toluene mg/L	Trans-1,2-dichloroethene mg/L	Trans-1,3-dichloropropene mg/L	Trichloroethene mg/L	Trichlorofluoromethane mg/L	Vinyl Chloride mg/L
W46-1	10/05/2001	< 0.001	< 0.0014	< 0.001	< 0.0012	< 0.0026	< 0.0016	< 0.0038	< 0.0034	< 0.0048	< 0.0027	< 0.0005	< 0.0022	< 0.0015	< 0.0011	< 0.0021	< 0.0019	< 0.002	< 0.0049
	16/05/2002	< 0.001	< 0.0014	< 0.001	< 0.0012	< 0.0026	< 0.0016	< 0.0038	< 0.0034	< 0.0048	< 0.0027	< 0.0005	< 0.0022	< 0.0015	< 0.0011	< 0.0021	< 0.0019	< 0.002	< 0.0049
	20/05/2003	< 0.001	< 0.0005	< 0.001	< 0.0004	< 0.0002	< 0.0005	< 0.001	< 0.001	< 0.004	< 0.0005	< 0.0005	< 0.0003	< 0.0005	< 0.0004	< 0.0002	< 0.0003	< 0.0005	< 0.0005
	21/05/2003	< 0.001	< 0.0014	< 0.001	< 0.0012	< 0.0026	< 0.0016	< 0.0038	< 0.0034	< 0.0048	< 0.0027		< 0.0022	< 0.0015	< 0.0011	< 0.0021	< 0.0019	< 0.002	< 0.0049
	30/04/2004	< 0.001	< 0.0014	< 0.001	< 0.0012	< 0.0026	< 0.0016	< 0.0038	< 0.0034	< 0.0048	< 0.0027	< 0.0042	< 0.0022	< 0.0015	< 0.0011	< 0.0021	< 0.0019	< 0.002	< 0.0049
	03/05/2005	< 0.001	< 0.0014	< 0.001	< 0.0012	< 0.0026	< 0.0016	< 0.0038	< 0.0034	< 0.0048	< 0.0027	< 0.0042	< 0.0022	< 0.0015	< 0.0011	< 0.0021	< 0.0019	< 0.002	< 0.0049
	28/04/2006	< 0.001	< 0.0005	< 0.001	< 0.0004	< 0.0002	< 0.0005	< 0.001	< 0.001	< 0.004	< 0.0005	< 0.0005	< 0.0003	< 0.0005	< 0.0004	< 0.0002	< 0.0003	< 0.0005	< 0.0002
	25/04/2007	< 0.001	< 0.0005	< 0.001	< 0.0004	< 0.0002	< 0.0005	< 0.001	< 0.001	< 0.004	< 0.0005	< 0.0005	< 0.0003	< 0.0005	< 0.0004	< 0.0002	< 0.0003	< 0.0005	< 0.0002
W65-1	28/04/2004	< 0.001	0.0398	< 0.001	< 0.0012	< 0.0026	< 0.0016	< 0.0038	< 0.0034	< 0.0048	< 0.0027	< 0.0042	< 0.0022	0.0035	< 0.0011	< 0.0021	< 0.0019	< 0.002	< 0.0049
W76-1	27/04/2007	< 0.001	< 0.0005	< 0.001	< 0.0004	< 0.0002	< 0.0005	< 0.001	< 0.001	< 0.004	< 0.0005	< 0.0005	< 0.0003	< 0.0005	< 0.0004	< 0.0002	< 0.0003	< 0.0005	< 0.0002

APPENDIX B

Background Groundwater Quality Data

Appendix B - Background Groundwater Quality Data

Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
OW10	06/12/1988		< 0.1		< 0.02				13							0.07										276	
OW10	16/01/1989		< 0.1		< 0.02				14							0.08										286	
OW10	22/02/1989		< 0.1		< 0.01				132							< 0.05										496	
OW10	22/03/1989		< 0.1		0.03				340							< 0.05											
OW10	26/04/1989		< 0.1		< 0.01				24							< 0.05										275	
OW10	24/05/1989		< 0.1		0.02				11							< 0.05										254	
OW10	21/06/1989		< 0.1		< 0.01				11							< 0.05										264	
OW10	19/07/1989		< 0.1		0.03				15							< 0.05										262	
OW10	23/08/1989		< 0.1		< 0.01				36							0.1										352	
OW10	28/09/1989		< 0.1		< 0.01				153							< 0.05										483	
OW10	30/10/1989		< 0.1		0.04				759							0.09										1626	
OW10	23/11/1989		< 0.1		< 0.01				79							0.08										412	
OW10	22/03/1990		< 0.1		< 0.02				52							< 0.05										322	
OW10	25/04/1990		< 0.1		0.12				15							< 0.05										258	
OW10	30/05/1990		0.15		< 0.02				16							< 0.05										290	
OW10	28/06/1990		< 0.1		< 0.01				20							< 0.05										270	
OW10	26/07/1990		< 0.1		0.03				60							< 0.05										322	
OW10	22/08/1990		< 0.1		0.01				182							0.05										590	
OW10	27/09/1990		< 0.1		< 0.01				475							0.07										1264	
OW10	25/10/1990		< 0.1		< 0.01				34							< 0.05										278	
OW10	28/11/1990		< 0.1		0.01				22							< 0.05										288	
OW10	19/12/1990		< 0.1		< 0.01				17							< 0.05										266	
OW10	29/01/1991		< 0.1		< 0.01				21							< 0.05										276	
OW10	28/02/1991		0.74		< 0.01				19							< 0.05										264	
OW10	28/03/1991		< 0.1		< 0.01				18							< 0.05										262	
OW10	30/07/1991		< 0.1		< 0.01				55							< 0.05										344	
OW10	29/08/1991		< 0.1		< 0.01				79							0.06										358	
OW10	24/09/1991		< 0.1		< 0.01				120							< 0.05										440	
OW10	31/10/1991		0.12		0.03				596							0.05										1330	
OW10	22/11/1991		< 0.1		< 0.01				638							0.09										1560	
OW10	23/12/1991		< 0.1		< 0.01				167							< 0.05										570	
OW10	29/01/1992		< 0.1		0.02				267							0.04										780	
OW10	25/02/1992		< 0.1		< 0.01				617							0.63										1430	
OW10	31/03/1992		< 0.1		< 0.01				287							0.23										790	
OW10	27/04/1992		< 0.1		< 0.01				26							0.08										300	
OW10	29/05/1992		< 0.1		< 0.01				28							0.05										280	
OW10	26/06/1992		< 0.1		0.02				21							0.05										280	
OW10	30/07/1992		< 0.1		< 0.01				19							0.05										290	
OW10	25/08/1992		< 0.1		0.01				27							0.13										300	
OW10	28/09/1992		< 0.1		< 0.01				16							0.05										280	
OW10	27/10/1992		< 0.1		< 0.01				13							0.02										260	
OW10	10/12/1992		< 0.1		< 0.01				13							0.08										266	
OW10	31/12/1992		< 0.1		< 0.01				14							< 0.01										240	
OW10	29/01/1993		0.05		< 0.01				18							0.11										260	
OW10	26/02/1993		0.01		< 0.01				21							0.03										280	
OW10	01/04/1993		< 0.1		< 0.01				26							0.3										280	
OW10	03/05/1993		0.02		< 0.01				12							0.05										270	
OW10	01/06/1993		< 0.1		0.01				13							< 0.01										270	
OW10	06/07/1993		< 0.1		< 0.01				16							0.07										260	
OW10	04/08/1993		< 0.1		< 0.01				37							< 0.01										320	
OW10	02/09/1993		< 0.1		< 0.01				60							0.11										350	
OW10	06/10/1993		< 0.1		0.02				314							0.13										830	
OW10	12/11/1993		< 0.1		0.05				42							0.18										320	
OW10	06/12/1993		< 0.1						19							0.08											
OW10	13/01/1994		< 0.1		0.01				22							0.06										280	

Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
OW10	08/02/1994		< 0.1		0.01				31							0.05										290	
OW10	07/03/1994		< 0.1		< 0.01				50							0.07										320	
OW10	08/04/1994															0.07										290	
OW10	05/05/1994		< 0.1		0.01				17							0.04										260	
OW10	07/06/1994		< 0.1		< 0.01				18							0.09										280	
OW10	13/07/1994		< 0.1		< 0.01				14							0.03										260	
OW10	30/08/1994		0.02						27																	300	
OW10	17/10/1994				0.02				29		484					0.07										310	
OW10	28/11/1994		0.01						17							0.04										236	
OW10	30/12/1994		0.04		0.01				13							0.02										256	
OW10	20/01/1995		0.01		0.02				14							0.07										272	
OW10	09/03/1995								16							0.08										280	
OW10	30/03/1995								15							0.06										252	
OW10	24/04/1995								14																	252	
OW10	25/05/1995								15							0.04										252	
OW10	05/07/1995								22							0.11										292	
OW10	31/08/1995		0.25						32							0.09										344	
OW10	29/11/1995			0.08	0.01			8			405					0.04											
OW10	16/02/1996		0.04	0.07	0.02						408					0.02											
OW10	14/06/1996			0.07	0.01						416					0.03											
OW10	30/08/1996			0.09							616					0.02											
OW10	01/11/1996			0.07							436					0.04											
OW10	01/02/1997			0.06	0.01						416					0.06											
OW10	01/05/1997			0.06							423					0.14											
OW10	01/08/1997							5			1237					0.1											
OW10	01/11/1997		0.04	0.09							678					0.04											
OW10	01/02/1998		0.02	0.05							476					0.01											
OW10	01/05/1998			0.07							440																
OW10	01/08/1998			0.1							640					0.13											
OW10	01/11/1998		0.02	1.04	0.06			3			3510					0.29											
OW10	01/02/1999			0.11							670					0.12											
OW10	01/05/1999		0.02	0.21	0.02						489					0.07											
OW10	01/08/1999			0.12							703																
OW10	01/11/1999	204	< 0.02	0.12	< 0.01			< 3			666					0.03											
OW10	10/02/2000		< 0.02	0.09	< 0.01			7			551					0.03											
OW10	29/05/2000		< 0.02	0.08	< 0.01			< 4			489					0.01											
OW10	29/08/2000		< 0.02	0.06	< 0.01			11			566					< 0.01											
OW10	21/11/2000		0.06	0.1	< 0.01			5			672					0.06											
OW10	20/02/2001		< 0.02	0.08	< 0.01			< 4			461					< 0.01											
OW10	08/05/2001		< 0.02	0.08	< 0.01			13			477					0.05						8.03					
OW10	30/08/2001		< 0.02	0.15	< 0.01			< 5			949					0.06											
OW10	29/11/2001		< 0.02	0.12	< 0.05			10			1040					0.05											
OW10	28/02/2002		< 0.02	0.1	< 0.05			< 5			609					0.01											
OW10	14/05/2002		< 0.02	0.08	< 0.05			< 5			520					0.02											
OW10	26/08/2002			0.1	< 0.05						621					0.03											
OW10	06/11/2002		< 0.02	0.4	< 0.05			< 5			3090					0.08											
OW10	06/02/2003		< 0.02	0.13	< 0.05			< 5			763					0.02											
OW10	27/05/2003		< 0.02	0.08	< 0.05			< 5			553					0.02											
OW10	20/08/2003		< 0.02	0.1	< 0.05			< 5			658					0.06											
OW10	06/11/2003		< 0.02	0.1	< 0.05			< 5			574					0.02											
OW10	11/02/2004		0.02	0.08	0.05			5			508					0.03											
OW10	27/04/2004		0.03	0.09	0.01			< 5			522					0.02											
OW10	11/08/2004		0.03	0.1	< 0.01			< 5			696					0.03											
OW10	03/11/2004		0.02	0.1	0.01			< 5			609					0.03											
OW10	09/02/2005		0.22	0.07	0.01			< 5			535					0.03											
OW10	27/04/2005		< 0.02	0.07	0.01			< 5			556					0.02											

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Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
OW10	24/08/2005		< 0.02	0.11	< 0.01			< 5			791					0.05											
OW10	28/11/2005			0.08	< 0.05			< 5			637																
OW10	22/02/2006		0.05	0.08	0.01			< 5			589					< 0.03											
OW10	02/05/2006		0.19	0.08	0.02			< 5			545					0.05											
OW10	28/08/2006		0.04	0.15	0.01			< 5			866					0.09											
OW10	07/11/2006		< 0.02	0.08	0.02			< 5			581					< 0.03											
OW10	15/02/2007		0.02	0.07	< 0.01			< 5			553					< 0.03											
OW10	24/04/2007		0.03		0.02						566					< 0.03											
OW10	16/08/2007		< 0.02	0.12	0.01			< 5			788					0.05											
OW10	30/11/2007		0.05	0.9	< 0.1			16			4890					< 0.3											
OW10	21/02/2008		< 0.15	0.13	< 0.02			< 4			702					< 0.1											
OW11-01	29/11/2001		0.36	0.16	0.36			29			1610					< 0.01											
OW11-01	24/01/2002	292	0.49	0.08	0.33	< 0.005	81	5	293		1540		< 0.005			0.05	< 0.001	52	0.02	< 0.1	< 0.1		6	130	72		0.87
OW11-01	28/02/2002		< 0.02	0.08	0.33			7			1520					0.01											
OW11-01	14/05/2002		0.53	0.07	0.37			19			1690					0.04											
OW11-01	26/08/2002			0.08	0.35						1760					0.07						7.78					
OW11-01	06/11/2002		0.42	0.07	0.44			25			1620					0.02											
OW11-01	20/02/2003		0.5	0.08	0.36			12			1720					0.07											
OW11-01	27/05/2003		0.38	0.06	0.42			18			1510					0.03											
OW11-01	20/08/2003		0.38	0.08	0.43			25			1620					0.09											
OW11-01	12/09/2003							25								0.08											
OW11-01	06/11/2003		0.42	0.12	0.52			32			1620					0.05											
OW11-01	11/02/2004		0.32	0.1	0.37			27			1790					0.01											
OW11-01	27/04/2004		0.45	0.11	0.4			27			1680					0.02											
OW11-01	11/08/2004		0.48	0.11				30			1700																
OW11-01	03/11/2004		0.39	0.13	0.67			39			1710					0.02											
OW11-01	09/02/2005		0.76	0.14	0.5			57			1890					0.04											
OW11-01	27/04/2005		0.39	0.12	0.49			31			1610					0.01											
OW11-01	24/08/2005		0.43	0.13	0.53			29			1750					< 0.03											
OW11-01	28/11/2005		0.44	0.15	0.5			37			1890					0.07											
OW11-01	23/02/2006		0.33	0.17	0.42			36			1930					0.11											
OW11-01	02/05/2006		0.55	0.16	0.5			32			1790					0.05											
OW11-01	28/08/2006		< 0.02	0.17	0.49			26			1990					< 0.03											
OW11-01	07/11/2006		0.18	0.18	0.49			32			2030					0.08											
OW11-01	15/02/2007		0.33	0.17	0.47			27			2130					< 0.03											
OW11-01	24/04/2007		0.41	0.15	0.48			19			1980					< 0.03											
OW11-01	30/11/2007		0.2	0.21	0.66			32			2040					< 0.03											
OW11-01	22/02/2008		0.43	0.25	0.52			26			2130					< 0.1											
OW12	25/02/1992		< 0.1		0.02				19							0.02										310	
OW12	31/03/1992		< 0.1		< 0.01				42							0.01										440	
OW12	27/04/1992		< 0.1		0.1				16							< 0.01										340	
OW12	29/05/1992		< 0.1		< 0.01				33							< 0.01										430	
OW12	26/06/1992		< 0.1		0.04				26							0.01										330	
OW12	30/07/1992		0.17		< 0.01				20							0.01										260	
OW12	25/08/1992		< 0.1		0.06				49							0.07										480	
OW12	28/09/1992		< 0.1		0.09				38							0.01										450	
OW12	27/10/1992		< 0.1		0.08				40							0.01										450	
OW12	10/12/1992		< 0.1		0.07				8							0.01										240	
OW12	31/12/1992		< 0.1		0.07				24							< 0.01										390	
OW12	29/01/1993		0.03		0.04				29							0.04										400	
OW12	02/04/1993		< 0.1		0.02				35							< 0.01										420	
OW12	03/05/1993		0.04		0.06				4							0.03										280	
OW12	01/06/1993		0.28		< 0.01				< 1							< 0.01										30	
OW12	06/07/1993		0.03		0.04				7							0.05										220	
OW12	04/08/1993		0.09		0.02				2							< 0.01										70	
OW12	02/09/1993		0.03		< 0.01				14							0.04										280	

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Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
OW12	06/10/1993		< 0.1		< 0.01				7							0.02										170	
OW12	12/11/1993		0.01		0.05				9							0.08										220	
OW12	06/12/1993		0.06		< 0.01				2							0.02										100	
OW12	14/01/1994		< 0.1		0.08				18							< 0.01										360	
OW12	08/02/1994		0.01		0.06				21							0.02										390	
OW12	07/03/1994		0.04		< 0.01				6							< 0.01										10	
OW12	08/04/1994		< 0.1		0.05				72							0.01										400	
OW12	05/05/1994		< 0.1		0.07				23							< 0.01										280	
OW12	07/06/1994		< 0.1		0.05				21							0.04										260	
OW12	13/07/1994		0.02		0.08				58							< 0.01										370	
OW12	30/08/1994		0.01		0.06				40																	400	
OW12	17/10/1994				0.09				33		649					0.05										380	
OW12	28/11/1994				0.05				36							0.02										348	
OW12	30/12/1994		0.19		0.07				46							0.03										392	
OW12	03/01/1995				0.05				100							0.04										512	
OW12	20/02/1995				0.05				36							0.07										364	
OW12	24/04/1995		0.02		0.04				123																	528	
OW12	25/05/1995		0.02		0.06				123							0.04										592	
OW12	05/07/1995		0.01		0.06				121							0.07										624	
OW12	31/07/1995		0.01		0.04				18							0.11										320	
OW12	29/11/1995		0.13	0.04	0.06			5			538					0.07											
OW12	16/02/1996			0.04	0.06			5			727					0.03											
OW12	30/08/1996			0.04	0.05			8			575					0.04											
OW12	01/11/1996			0.03	0.03						466					0.06											
OW12	01/02/1997			0.04	0.05			5			699					0.08											
OW12	01/05/1997		0.03	0.1	0.02			13			2019					0.02											
OW12	01/08/1997				0.05			5			696					0.07											
OW12	01/11/1997				0.03			5			938																
OW12	01/02/1998		0.1		0.04						1201																
OW12	01/05/1998		0.07	0.04	0.03			5			767					0.02											
OW12	01/09/1998		0.03	0.05	0.04						1023																
OW12	01/11/1998			0.36	0.07						1135					0.09											
OW12	01/02/1999			0.33	0.07			11			1451																
OW12	01/05/1999			0.18	0.05			5			648					0.04											
OW12	01/08/1999		0.02	0.05	0.04			32			1057					0.02											
OW12	01/12/1999		< 0.02	0.05	0.04			9			1020					0.24											
OW12	01/02/2000		< 0.02	0.05	0.05			7			1230					< 0.01											
OW12	01/05/2000		< 0.02	0.05	0.05			17			1070					0.02											
OW12	01/08/2000		< 0.02	0.03	0.05			25			1060					< 0.01											
OW12	21/11/2000		< 0.02	0.05	0.06			37			1050					< 0.01											
OW12	20/02/2001		< 0.02	0.04	0.05			8			967					0.07											
OW12	08/05/2001		< 0.02	0.02	< 0.01			18			477					0.18						7.94					
OW12	30/08/2001		< 0.02	0.04	0.04			5			836					0.05					< 0.1						
OW12	01/11/2001		< 0.02	0.04	0.07			6			942					0.02											
OW12	02/03/2002		0.03	0.04	0.05			< 5			1020					0.04											
OW12	02/05/2002		< 0.02	0.02	< 0.05			< 5			662					0.03											
OW12	26/08/2002			0.03	< 0.05						776					0.03											
OW12	06/11/2002		< 0.02	0.05	< 0.05			< 5			887					0.02											
OW12	06/02/2003		0.06	0.04	< 0.05			< 5			889					0.02											
OW12	22/05/2003		0.05	0.02	< 0.05			< 5			534					0.05											
OW12	20/08/2003		0.06	0.04	< 0.05			< 5			850					0.04											
OW12	06/11/2003		0.14	0.04	0.05			< 5			708					0.02											
OW12	11/02/2004		0.04	0.02	0.05			5			544					0.06											
OW12	27/04/2004		0.04	0.02	0.03			< 5			463					0.1											
OW12	11/08/2004		0.08	0.05	0.05			< 5			906					0.02											
OW12	03/11/2004		< 0.02	0.04	0.07			< 5			879					0.03											

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Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
OW12	09/02/2005		0.07	0.06	0.06			6			1180					0.03											
OW12	10/08/2012	320	0.14	0.39	0.033	< 0.0001	140		110	< 0.005	1000			1.2	500	< 1.6	< 0.0026	46	0.024	< 0.1	< 0.01	7.79	4.6	12	34	543	
OW13	29/11/1995		0.03	0.24	0.03			3			468					0.02											
OW13	16/02/1996			0.2	0.03						455					0.04											
OW13	14/06/1996			0.2	0.03						482					0.02											
OW13	30/08/1996			0.47	0.01						542																
OW13	01/11/1996		0.05	0.22	0.02						502					0.26											
OW13	01/02/1997			0.2	0.02						491					0.03											
OW13	01/05/1997		0.02	0.22	0.02						478					0.02											
OW13	01/08/1997		0.06	0.22	0.02			5			554					0.02											
OW13	01/11/1997			0.23							554																
OW13	01/02/1998		0.02	0.22							531					0.03											
OW13	01/05/1998		0.08	0.23				5			530					0.2											
OW13	01/08/1998		0.04	0.26							604					0.24											
OW13	01/11/1998		0.06	0.49	0.04						605					0.3											
OW13	01/02/1999		0.05	0.22	0.02						552					1.23											
OW13	01/05/1999		0.03	0.25	0.02						543					0.24											
OW13	01/08/1999		0.06	0.36	0.16			6			615					6.77											
OW13	01/11/1999	248	0.04	0.23	< 0.01			< 3			569					0.18											
OW13	10/02/2000		0.03	0.2	0.01			5			554					< 0.01											
OW13	01/05/2000		0.05	0.22	0.02			5			547					0.21											
OW13	01/08/2000		0.04	0.17	0.01			22			568					< 0.01											
OW13	21/11/2000		< 0.02	0.19	0.02			8			614					0.03											
OW13	20/02/2001		< 0.02	0.2	0.02			< 4			517					< 0.01											
OW13	08/05/2001		< 0.02	0.23	< 0.01			13			569					0.02						7.97					
OW13	01/08/2001		< 0.02	0.26	0.02			< 5			650					0.02											
OW13	12/11/2001		0.09	0.19	0.06			< 5			605					< 0.01											
OW13	02/02/2002		0.05	0.19	< 0.05			< 5			568					0.14											
OW13	17/05/2002		0.05	0.05	0.45			< 5			547					0.27											
OW13	02/08/2002			0.27	< 0.05						733					0.37											
OW13	06/11/2002		0.05	0.22	< 0.05			< 5			656					0.34											
OW13	06/02/2003		0.07	0.23	< 0.05			< 5			666					0.15											
OW13	22/05/2003		0.06	0.2	< 0.05			< 5			569					0.22											
OW13	20/08/2003		0.03	0.25	< 0.05			< 5			607					0.13											
OW13	06/11/2003		0.06	0.25	< 0.05			< 5			700					0.16											
OW13	11/02/2004		0.05	0.21	0.05			5			610					0.13											
OW13	27/04/2004		0.09	0.24	0.02			< 5			620					0.13											
OW13	11/08/2004		0.09	0.3	0.02			< 5			914					0.24											
OW13	03/11/2004		0.05	0.24	0.03			< 5			801					0.17											
OW13	09/02/2005		0.08	0.21	0.03			< 5			667					0.13											
OW13	27/04/2005		0.05	0.2	0.03			< 5			614					0.16											
OW13	24/08/2005		0.03	0.26	0.03			< 5			783					0.29											
OW13	28/11/2005		0.09	0.2	0.06			< 5			745					0.23											
OW13	22/02/2006		0.06	0.22	0.03			< 5			679					0.18											
OW13	02/05/2006		0.21	0.24	0.03			< 5			695					0.19											
OW13	28/08/2006		0.09	0.25	0.03			< 5			792					0.33											
OW13	07/11/2006		0.04	0.22	0.03			< 5			738					0.23											
OW13	15/02/2007		0.05	0.21	0.02			< 5			729					0.09											
OW13	24/04/2007		0.05	0.21	0.04			< 5			721					0.23											
OW13	16/08/2007		0.1	0.24	0.02			< 5			866					0.66											
OW13	30/11/2007		0.05	0.19	0.03			< 5			910					0.06											
OW13	21/02/2008		< 0.15	0.19	< 0.02			< 4			689					0.16											

Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
OW14	01/08/1988		< 0.1		0.13				89							1.17										498	
OW14	25/10/1988		0.16		0.17				94							0.37										844	
OW14	06/12/1988		< 0.1		0.14				94							0.45										581	
OW14	22/02/1989		1.1		0.1				86							0.46										483	
OW14	22/03/1989		0.12		0.17				81							0.41											
OW14	21/06/1989		< 0.1		0.18				92							0.5										533	
OW14	19/07/1989		< 0.1		0.09				94							0.57										531	
OW14	23/08/1989		0.18		0.09				84							0.55										490	
OW14	28/09/1989		< 0.1		0.16				68							0.38										455	
OW14	30/10/1989		0.12		0.22				72							0.14										432	
OW14	23/11/1989		< 0.1		0.21				95							0.59										542	
OW14	22/03/1990		< 0.1		0.13				82							0.56										490	
OW14	25/04/1990		< 0.1		0.19				100							0.62										528	
OW14	30/05/1990		0.23		0.14				100							0.65										538	
OW14	28/06/1990		< 0.1		0.2				104							0.39										528	
OW14	26/07/1990		< 0.1		0.16				88							0.44										494	
OW14	22/08/1990		< 0.1		0.16				83							0.44										488	
OW14	27/09/1990		< 0.1		0.14				71							0.25										484	
OW14	25/10/1990		< 0.1		0.04				101							0.27										514	
OW14	28/11/1990		< 0.1		0.16				100							0.5										536	
OW14	29/01/1991		< 0.1		0.18				94							0.08										558	
OW14	28/02/1991		0.1		0.15				89							0.67										502	
OW14	28/03/1991		0.1		0.03				86							0.45										466	
OW14	30/04/1991		< 0.1		0.11				90							0.56										514	
OW14	30/05/1991		< 0.1		0.18				88							0.42										506	
OW14	28/06/1991		0.14		0.22				87							0.59										488	
OW14	29/08/1991		0.18		0.08				55							0.49										372	
OW14	24/09/1991		< 0.1		0.09				48							0.53										382	
OW14	31/10/1991		< 0.1		< 0.01				62							0.39										448	
OW14	22/11/1991		< 0.1		0.19				74							0.94										448	
OW14	23/12/1991		< 0.1		< 0.01				84							< 0.05										530	
OW14	29/01/1992		0.18		0.18				79							< 0.01										510	
OW14	25/02/1992		< 0.1		0.14				65							< 0.01										480	
OW14	31/03/1992		< 0.1		0.07				43							0.01										400	
OW14	27/04/1992		< 0.1		0.16				84							< 0.01										530	
OW14	29/05/1992		< 0.1		0.07				99							< 0.01										550	
OW14	26/06/1992		< 0.1		0.17				106							0.01										570	
OW14	30/07/1992		< 0.1		0.07				109							0.02										570	
OW14	25/08/1992		< 0.1		0.14				108							0.01										580	
OW14	28/09/1992		< 0.1		0.17				104							0.02										570	
OW14	27/10/1992		< 0.1		0.17				104							< 0.01										560	
OW14	31/12/1992		0.02		0.04				91							0.22										540	
OW14	29/01/1993		0.05		0.13				81							0.03										510	
OW14	01/03/1993		0.02		0.14				77							0.02										520	
OW14	03/05/1993		0.08		0.17				85							0.78										510	
OW14	01/06/1993		0.08		0.16				84							0.71										500	
OW14	06/07/1993		0.06		0.17				86							0.99										500	
OW14	04/08/1993		< 0.1		0.18				86							0.86										480	
OW14	02/09/1993		0.14		0.15				88							0.42										470	
OW14	06/10/1993		0.08		0.16				84							0.43										470	
OW14	13/01/1994		< 0.1		0.18				93							0.03										520	
OW14	08/02/1994		0.01		0.21				94							0.06										530	
OW14	07/03/1994		< 0.1		0.14				73							0.02										490	
OW14	08/04/1994		< 0.1		0.14				81							0.01										540	
OW14	05/05/1994		< 0.1		0.15				89							0.03										510	

Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
OW14	07/06/1994		0.15		0.13				89							0.02										540	
OW14	13/07/1994		0.01		0.15				87							< 0.05										510	
OW14	30/08/1994		0.09		0.14				79							0.38										480	
OW14	17/10/1994								77		795					0.31										480	
OW14	28/11/1994		0.08		0.16				92							0.2										472	
OW14	30/12/1994		0.11		0.18				80																	480	
OW14	20/01/1995		0.02		0.18				82																	516	
OW14	01/03/1995		0.11		0.14				69							0.02										476	
OW14	30/03/1995		0.03		0.13				79							0.01										520	
OW14	24/04/1995		0.08		0.15				81							0.59										488	
OW14	25/05/1995		0.08		0.14				85							0.02										500	
OW14	31/07/1995		0.02		0.13				62							0.03										532	
OW14	29/11/1995		0.02		0.17			8			786					0.08											
OW14	01/05/1997			0.07							642					0.07											
OW14	01/05/1998		0.19	0.08	0.11			10			665					0.37											
OW14	01/05/1999		0.2	0.21	0.13			5			698					0.29											
OW14	02/06/2000		0.09	0.13	0.11			11			663					0.29											
OW14	09/05/2001		0.06	0.08	0.11			< 5			624					0.26											
OW14	14/05/2002		0.06	0.07	0.1			< 5			623					0.27											
OW14	27/05/2003		0.06	0.08	0.1			< 5			619					0.32											
OW14	27/04/2004		0.1	0.08	0.1			6			574					0.29											
OW14	27/04/2005		0.1	0.07	0.11			< 5			572					0.31											
OW14	02/05/2006		0.08	0.08	0.11			5			591					0.3											
OW14	24/04/2007		0.05	0.08	0.11			< 5			633					0.34											
P35	20/04/1992	173		0.01			54	5	2		376					0.05		13	0.22			8.02	2	3	11	210	0.19
P35	14/04/1993	171	0.08	0.04	0.01		49	11	4		369					0.75		14	0.07	0.19		8.1	3	12	15	220	0.08
P35	16/04/1994	155	0.12	0.02	0.01		38		5		329					0.05		17	0.02				2	6	18		0.06
P35	01/08/1995		0.01	0.04			55	8	4		366					0.17		15	0.02					5	20		0.04
P35	01/06/1996		0.14	0.03	0.01		57	5	4		365					0.18		12	0.04					5	19		0.28
P35	21/05/1997		0.26	0.02		0.005	52	21	6		404					0.22		13	0.06	5.47				4	20		0.38
P35	13/05/1998		0.09				51	15	4		366							15							17		0.19
P35	13/05/1999	177	0.14	0.04	0.02		55	5	4		411					5.86		15	0.22				3	4	16		0.5
P35	17/05/2000	183	0.07	0.26	0.04	< 0.005	51	13	4		358		< 0.02			0.06	< 0.002	14	0.03	< 0.1	< 0.1		2	4	16		0.27
P35	09/05/2001	257	0.14	0.87	0.2	< 0.005	165	6	341		1720		0.01			0.07	< 0.001	43	0.12	8.44	< 0.1		4	81	74		0.24
P35	09/07/2001	175	0.05	0.02	< 0.01	< 0.005	46	8	3		346		< 0.005			0.23	< 0.001	15	0.04	< 0.1	< 0.1		2	4	15		0.17
P35	15/05/2002	177	< 0.02	0.02	< 0.05	< 0.005	51	5	4		377		< 0.005			0.11	< 0.001	13	0.02	< 0.1	< 0.1		2	3	19		0.15
P35	21/05/2003	178	0.05	0.02	< 0.05	< 0.001	49	< 5	5		359		< 0.005			0.07	< 0.001	13	0.02	< 0.1	< 0.1		2	3	13		0.14
P35	29/04/2004	172	0.16	0.02	< 0.01	< 0.001	50	< 5	9		340		< 0.005			0.03	< 0.001	13	0.03	< 0.1	< 0.1		2	4	16		0.36
P35	03/05/2005	171	0.04	0.02	0.02	< 0.0001	48	< 5	9		347		< 0.005			0.12	< 0.001	13	0.03	< 0.1	< 0.1		2	4	18		0.08
P35	28/04/2006	173	0.05	0.02	< 0.01	< 0.0001	49	< 5	3		350		< 0.005			0.04	< 0.001	13	0.02	< 0.1	< 0.1		2	4	17		0.09
P35	25/04/2007	165	0.04	0.02	< 0.01	< 0.0001	49	< 5	4		350		< 0.005			0.1	< 0.001	13	0.03	< 0.1	< 0.1		2	3	17		< 0.05
P83	01/07/1995		0.07	0.35	0.03		58	8	11		444					0.89		24	0.05					5	26		0.24
P83	01/06/1996		0.09	0.31	0.03		49		10		458					0.43		21	0.03					4	21		0.62
P83	20/05/1997		0.09	0.27	0.02		54	5	9		415					0.43			0.02					5	22		0.14
P83	13/05/1998		0.08	0.16			48	5	9		414					0.1		2							20		0.23
P83	11/05/1999	199	0.04	0.22	0.03		55		8		415					0.12	0.002	26					3	10	20		0.24
P83	17/05/2000	204	0.03	0.25	0.04	< 0.005	54	5	9		447		0.02			0.05	< 0.002	25	0.02	< 0.1	< 0.1		2	12	28		0.06
P83	10/05/2001	198	0.06	0.69	0.1	< 0.005	41	8	5		384		< 0.005			0.47	< 0.001	20	0.02	< 0.1	< 0.1		2	5	20		0.11
P83	15/05/2002	209	0.03	0.11	< 0.05	< 0.0001	49	< 5	7		484		< 0.005			0.02	< 0.001	20	0.02	< 0.1	< 0.1		3	14	44		0.06
P83	21/05/2003	207	0.03	0.14	< 0.05	< 0.001	48	< 5	6		453		< 0.005			0.03	< 0.001	21	0.02	< 0.1	< 0.1		3	13	49		0.1
P83	27/04/2004	207	0.08	0.11	0.04	< 0.001	52	< 5	8		460		< 0.005			< 0.01	< 0.001	20	0.02	< 0.1	< 0.1		3	16	27		0.15
P83	29/04/2005	205	0.05	0.17	0.04	< 0.0001	58	< 5	7		425		< 0.005			0.01	< 0.001	21	0.02	< 0.1	< 0.1		3	15	27		0.18
P83	01/05/2006	240	0.04	0.11	0.02	< 0.0001	72	< 5	18		585		< 0.005			< 0.03	< 0.001	25	0.01	< 0.1	< 0.1		3	18	54		0.31
P83	27/04/2007	223	< 0.02	0.1	0.02	< 0.0001	60	< 5	8		499		< 0.005			< 0.03	< 0.001	21	0.01	< 0.1	< 0.1		2	10	43		0.12

Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
W37	30/05/1988								38		525					0.08										370	
W37	10/05/1989	200					86	3	37		565				297			20		0.61				8	28	323	
W37	06/04/1990	208			0.03		83	12	48		604							29		0.54		7.43	1	12	35	364	
W37	09/05/1991	166					65	6	20		480							17		1.15		7.68	1	3	36	304	
W37	20/03/1992	212		0.11			78	8	46		577					0.06		22		0.7		7.76	1	8	24	340	
W37	11/02/1993	208		0.11	0.08		74		35		559				267	0.11		20	0.03	1.24		7.49	2	7	19	330	0.08
W37	16/04/1994	213		0.09	0.01		82		49		614					0.02		27		0.61			1	7	31		0.04
W37	01/08/1995		0.06	0.3			148	8	338		1195					0.35		34	0.01	1				97	40		0.25
W37	01/06/1996			0.1			76				578					0.08		18	0.02	1.31				16	27		0.13
W37	23/05/1997			0.08			66		24		464					0.32		18		1.09				4	30		0.13
W37	14/05/1998		0.03	0.74			365	11			4375					0.12		80	0.07	0.25				610	81		0.22
W37	13/05/1999	206	0.05	0.39	0.05		87	10	45		605					0.03		19		0.72			1	10	30		0.26
W37	17/05/2000		0.02	0.21			100	< 4	116		769		< 0.02			0.07	< 0.002	24		0.97				29	33		0.4
W37	10/05/2001	209	< 0.02	0.63	0.04	< 0.005	81	5	68		651		< 0.005			0.08	< 0.001	19	< 0.01	0.79	< 0.1		1	17	35		0.11
W37	15/05/2002	202	< 0.02	0.12	< 0.05	< 0.005	91	15	91		803		< 0.005			0.15	< 0.001	18	< 0.01	1.06	< 0.1		< 1	27	36		0.56
W37	20/05/2003	215	< 0.02	0.14	< 0.05	< 0.001	123	10	207		1120		< 0.005			0.11	< 0.001	23	0.007	0.81	< 0.1		2	68	36		0.17
W37	30/04/2004	202	0.04	0.11	0.01	< 0.001	91	< 5	94		747		< 0.005			0.06	< 0.001	20	< 0.01	1.23	< 0.1		1	28	33		0.17
W37	02/05/2005	214	0.09	0.12	0.03	< 0.0001	96	< 5	96		761		< 0.005			0.02	< 0.001	23	< 0.01	0.95	< 0.1		2	30	35		0.2
W37	26/04/2006	224	< 0.02	0.14	0.02	< 0.0001	98	< 5	143		958		< 0.005			< 0.03	< 0.001	21	< 0.01	1.06	< 0.1		2	47	38		0.06
W37	25/04/2007	207	< 0.02	0.12	0.02	< 0.0001	90	< 5	97		771		< 0.005			< 0.03	< 0.001	21	< 0.01	0.85	< 0.1		< 10	22	42		0.1
W57-2	24/02/2004	192	0.02	0.04	0.05	0.001	65	5	25		444		0.005			0.02	0.001	14	0.05	0.1	0.1		2	8	18		0.12
W57-2	06/05/2004	173	0.04	0.04	< 0.01	< 0.0001	61	< 5	19		411		< 0.005	1.1		0.02	< 0.001	15	< 0.1	0.11	< 0.1		2	6	17		0.11
W57-2	26/05/2008	166	< 0.15	0.047	< 0.02	< 0.0001	66	23	49	0.11	492	< 0.002		1.1	230	< 0.1	< 0.0005	17	0.007	< 0.1	< 0.01	8.1	1.5	7.3	18	325	< 10
W57-2	29/04/2009	177	< 0.15	0.047	< 0.02		61	76	47	0.07	493				220	< 0.1		15	0.005			7.3	1.3	6.3	18		< 7
W57-2	28/04/2010	179	< 0.15	0.049	< 0.02	< 0.0001	71	15	46	0.034	502	< 0.002		1.1	250	< 0.1	< 0.0005	17	0.004	< 0.1	< 0.01	8	1.4	5.2	17	330	< 7
W57-2	04/05/2011	157	< 0.15	0.051	< 0.02	< 0.0001	75	7	81	0.023	585	< 0.002		1.1	270	< 0.1	< 0.0005	19	0.002	< 0.1	< 0.01	7.89	1.3	5.1	16	374	< 0.7
W57-2	08/05/2012	170	< 0.15	0.06	< 0.02	< 0.0001	68	< 4	70	0.033	570	< 0.002		1	240	< 0.1	< 0.0005	17	0.006	< 0.1	< 0.01	8.01	1.4	14	16	340	< 0.7
W57-2	27/05/2013	150	< 0.15	0.047	< 0.02	< 0.0001	88	< 4	97	< 0.005	640	< 0.002		1	310	< 0.1	< 0.0005	21	0.003	< 0.1	< 0.01	8.02	1.6	9.7	15	466	< 0.7
W60-2	24/02/2004	266	0.14	0.24	0.11	0.001	83	14	4		513		0.005			0.55	0.001	20	0.03	0.1	0.1		1	5	28		0.57
W60-2	06/05/2004	256	0.17	0.31	< 0.01	< 0.0001	81	15	3		507		< 0.005	6.1		0.7	< 0.001	20	0.04	< 0.1	< 0.1		1	4	27		0.44
W60-2	26/05/2008	127	0.34	0.033	0.36	< 0.0001	10	15	12	< 0.005	356	< 0.002		2.7	39	< 0.1	< 0.0005	3.3	< 0.002	< 0.1	< 0.01	8.8	3.2	68	33	351	< 4
W60-2	29/04/2009	210	0.28	0.052	0.45	< 0.0001	8.8	12	10	< 0.005	457	< 0.002		3.4	45	< 0.1	< 0.0005	5.7	< 0.002	< 0.1	< 0.01	7.7	3.6	79	33	295	< 0.7
W60-2	28/04/2010	161	0.23	0.038	0.43	< 0.0001	8.4	18	11	< 0.005	409	< 0.002		1.7	46	< 0.1	< 0.0005	6.2	< 0.002	< 0.1	< 0.01	8.4	3.5	73	33	272	< 1
W60-2	03/05/2011	147	0.2	0.031	0.29	< 0.0001	15	8	10	< 0.005	390	< 0.002		4	59	< 0.1	< 0.0005	5.1	< 0.002	< 0.1	0.17	8.35	3	58	33	258	< 0.7
W60-2	08/05/2012	180	0.2	0.049	0.4	< 0.0001	10	11	12	< 0.005	440	< 0.002		3.5	58	< 0.1	< 0.0005	7.8	< 0.002	< 0.1	< 0.01	8.3	3.4	76	23	246	< 0.7
W60-2	27/05/2013	130	< 0.15	0.029	0.29	< 0.0001	23	14	10	< 0.005	390	< 0.002		4.7	81	< 0.1	< 0.0005	5.7	< 0.002	0.25	< 0.01	8.24	3.3	58	41	222	< 0.7
W70	25/02/2004	175	0.03	0.08	0.05	0.001	72	20	69		579		0.005			0.01	0.001	15	0.01	0.11	0.1		2	28	20		0.1
W70	07/05/2004	173	0.02	0.08	0.03	< 0.0001	68	< 5	52		547		< 0.005	< 0.5		0.02	< 0.001	15	< 0.01	< 0.1	< 0.1		1	20	19		0.15
W70	21/05/2008	192	< 0.15	0.089	< 0.02	< 0.0001	65	< 4	84	0.018	661	< 0.002		1	220	< 0.1	< 0.0005	15	0.002	< 0.1	< 0.01	7.9	1.2	35	23	421	< 4
W70	09/04/2009	187	< 0.15	0.09	0.011	< 0.0001	68	11	64	0.021	602	< 0.002		2.2	230	< 0.1	< 0.0005	15	< 0.002	0.2	< 0.01	7.8	1.2	38	23	345	< 4
W70	28/04/2009	205	< 0.15	0.08	< 0.02	< 0.0001	60	< 4	49	0.011	550	< 0.002		1.8	200	< 0.1	< 0.0005	14	< 0.002	0.2	< 0.01	7.6	1.1	25	21	410	< 4
W70	07/07/2009	183	< 0.15	0.074	< 0.01	< 0.0001	57	8	39	< 0.005	509	< 0.002		1.2	190	< 0.1	< 0.0005	13	< 0.002	0.1	< 0.01	7.8	1	20	19	330	< 0.7
W70	28/10/2009	179	< 0.15	0.14	< 0.01	< 0.0001	93	< 4	160	0.005	900	< 0.002		1.7	320	< 0.1	< 0.0005	22	< 0.002	0.2	< 0.01	7.8	1.8	87	24	610	< 0.7
W70	17/12/2009	191	< 0.15	0.12	< 0.01	< 0.0001	80	5	160	< 0.005	944	< 0.002		1.4	270	< 0.1	< 0.0005	18	< 0.002	0.2	< 0.01	8	1.4	66	29	619	< 0.7
W70	29/04/2010	196	< 0.15	0.085	< 0.02	< 0.0001	64	5	43	0.009	547	< 0.002		1.1	220	< 0.1	< 0.0005	15	< 0.002	0.2	< 0.01	8	1.2	24	23	344	< 4
W70	04/05/2011	188	< 0.15	0.083	< 0.02	< 0.0001	65	< 4	47	< 0.005	570	< 0.002		3.3	220	< 0.1	< 0.0005	15	< 0.002	0.1	< 0.01	7.97	1.2	28	21	336	< 0.7
W70	07/05/2012	180	< 0.15	0.093	< 0.02	< 0.0001	72	11	68	< 0.005	600	< 0.002		1.1	250	< 0.1	< 0.0005	16	< 0.002	< 0.1	< 0.01	7.95	1.4	41	21	340	< 0.7
W70	24/05/2013	200	< 0.15	0.11	< 0.02	< 0.0001	89	< 4	120	< 0.005	790	< 0.002		1.4	300	< 0.1	< 0.0005	19	< 0.002	< 0.1	< 0.01	8.15	1.7	66	25	448	< 0.7
W74	27/04/2007	245	0.14	0.11	0.03	< 0.0001	101	34	21		741		< 0.005	8.6		0.58		31		< 0.1	< 0.1	7.82	3	15	122	482	0.37
W74	03/05/2011	268	< 0.15	0.053	< 0.02	< 0.0001	100	6	16	< 0.005	775	< 0.002		3.4	370	0.37	< 0.0005	27	0.03	< 0.1	< 0.01	8.01	2	21	130	476	< 0.7
W76-2	27/04/2007	367	0.06	0.21	0.03	< 0.0001	196	36	125		1280		< 0.005	10.3		0.14	< 0.001	39	0.21	0.17	< 0.1	7.65	12	25	128	832	0.41
W76-2	03/05/2011	301	< 0.15	0.14	< 0.02	< 0.0001	150	12	96	0.021	1030	< 0.002		1.9	510	< 0.1	< 0.0005	33	0.082	< 0.1	< 0.01	7.79	4.2	22	100	628	2

Appendix B - Background Groundwater Quality Data

Name	Date	Alkalinity mg/L	Ammonia mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chemical Oxygen Demand mg/L	Chloride mg/L	Chromium (total) mg/L	Conductivity µs/cm	Cyanide (free) mg/L	Cyanide mg/L
W77-2	27/04/2007	223	0.05	0.16	0.01	< 0.0001	85	19	51		622		< 0.005
W77-2	26/05/2008	223	0.2	0.1	< 0.02	< 0.0001	92	73	66	0.14	672	< 0.002	
W77-2	29/04/2009	234	< 0.15	0.14	< 0.02	< 0.0001	82	25	44	0.027	596	< 0.002	
W77-2	28/04/2010	221		0.12	< 0.02	< 0.0001	85	34	34	0.07	555	< 0.002	
W77-2	04/05/2011	214	0.23	0.12	< 0.02	< 0.0001	95	120	89	0.17	740	< 0.002	
W77-2	07/05/2012	220	< 0.15	0.18	< 0.02	< 0.0001	110	30	130	0.051	880	< 0.002	
W77-2	27/05/2013	210	0.16	0.2	< 0.02	< 0.0001	130	15	140	< 0.005	930	< 0.002	
W88-2	04/05/2011	217	< 0.15	0.073	0.06	< 0.0001	68	< 4	34	< 0.005	596	< 0.002	
W89-2	03/05/2011	278	< 0.15	0.074	0.12	< 0.0001	73	< 4	41	0.007	790	< 0.002	
W90-2	05/05/2011	311	< 0.15	0.15	0.022	< 0.0001	130	22	180	0.027	1200	< 0.002	
W91-2	05/05/2011	240	< 0.15	0.57	< 0.02	< 0.0001	190	15	300	0.007	1690	< 0.002	

Name	Date	Dissolved Organic Carbon mg/L	Hardness mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Nitrate mg/L	Nitrite mg/L	pH unitless	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Total Dissolved Solids mg/L	Total Kjeldahl Nitrogen mg/L
W77-2	27/04/2007	7.3		0.78	< 0.001	16	0.05	< 0.1	< 0.1	7.86	2	15	29	404	0.83
W77-2	26/05/2008	8.3	310	0.56	< 0.0005	18	0.15	< 0.1	0.02	8.1	1.9	19	29	433	< 7
W77-2	29/04/2009	6.8	270	0.43	< 0.0005	16	0.074	< 0.1	0.02	7.6	1.5	15	32	395	< 4
W77-2	28/04/2010	6.3	270	0.28	< 0.0005	15	0.054		0.01	8	1.5	13	26	352	< 7
W77-2	04/05/2011	6	310	0.11	< 0.0005	18	0.08	< 0.1	< 0.01	7.77	1.5	23	30	470	5
W77-2	07/05/2012	5.4	370	0.38	< 0.0005	22	0.057	< 0.1	< 0.01	7.84	1.9	33	30	564	1.9
W77-2	27/05/2013	6.4	420	0.42	< 0.0005	25	0.053	< 0.1	0.012	7.82	2	44	30	620	0.9
W88-2	04/05/2011	2.7	260	0.75	< 0.0005	23	0.026	< 0.1	< 0.01	8.1	2.2	14	39	378	< 0.7
W89-2	03/05/2011	2.5	290	0.19	< 0.0005	26	0.013	< 0.1	< 0.01	8.12	3.9	55	72	486	1
W90-2	05/05/2011	2.9	390	0.18	< 0.0005	16	0.05	< 0.1	< 0.01	7.79	1.2	76	52	762	1
W91-2	05/05/2011	1.8	630	0.5	0.0005	36	0.029	< 0.1	< 0.01	7.88	1.7	83	89	1020	0.8

APPENDIX C

Detailed Description of Groundwater Modeling

Hydrogeologic Assessment for a New Landfill Footprint at the West Carleton Environmental Centre

Description of Groundwater Modelling

INTRODUCTION

The finite-difference model 'MODFLOW-SURFACT', an extension of the United States Geological Survey's MODFLOW code, was selected to simulate groundwater flow and mass transport. MODFLOW-SURFACT was selected because of its computational speed, stability and performance. This model is capable of simulating three-dimensional groundwater flow and mass transport in both steady and transient states with various degrees of complexity. EarthFX's ViewLog and Golden Software's Surfer were also used in conjunction with Groundwater Vistas (GV) as the pre and post processing tools. Multiple data sets were utilized over a number of iterations and combined to develop the conceptual and numerical models. Some of the key data used during the model's development included:

Referenced regional data:

- Regional topography from the Ontario Ministry of Natural Resources (OMNR);
- Ontario Base Map layers (including streams, lakes, wetlands, drainage lines, bedrock and surficial geology, etc.);
- Domestic well records from the Ontario provincial database, in particular lithologic information, water levels, and specific capacities contained therein;
- Hydrograph data available from the HYDAT monitoring network in the area; and
- Land use information derived from Landsat satellite imagery.

Site-specific data:

- Local survey data (including waste mound topography);
- Physical data, including hydraulic properties of overburden deposits and bedrock;
- Historical hydrograph data, water levels, and water quality data for leachate and groundwater;
- Borehole log data; and
- Purge well system data from within the Waste Management (WM) Ottawa landfill site (PW1 through PW10 and PW20).

MODEL DISCRETIZATION

The total area of the active model domain is approximately 100 km^2 (see Figure 1). The model grid cells range from 100 m x 100 m at the periphery to 6.25 m x 6.25 m at the landfill site (Figure 2). Any cells outside of the model boundary were defined as no-flow. The horizontal discretization reflects the density and resolution of the data available (site data and MOE Water Well Records).

The vertical discretization is divided into 5 layers, as shown in Table 1. This layer configuration is based on the site conceptual model which was developed based on available regional and site specific geological and physical hydrogeological information.

MODEL BOUNDARY CONDITIONS

Model boundary conditions and site-specific influential aspects which represent the conceptual understanding of the geological and physical hydrogeological conditions of this site are provided below:

- The extent of the model domain was set to natural hydrogeologic boundaries where possible (Figure 1): the Carp River constitutes the northeast model boundary while the Carp River watershed/subwatershed boundaries were used to define other lateral model limits. Model extents were defined from a combination of topography (DEM, Figure 3) and refined interpolated water level (WL) information from the MOE Water Well Information System (WWIS, Figure 4);
- Constant heads were assigned along the Carp River in the upper model layers interpreted to be hydraulically connected and controlled by the river (Layers 1 through 4);
- General Head Boundaries were used to represent inferred regional groundwater flow into and out of the model domain, and were assigned along the up-gradient boundary in the southwest in Layers 3 through 5 and to the down-gradient boundary, which corresponds to the Carp River, in Layer 5 and;
- All other lateral model boundaries were specified as No-Flow Boundaries (regional groundwater divides).

Additional boundary conditions were assigned according to the following rules for the remaining surface water bodies, and adjusted based on local physiographic settings:

- Streams and creeks were represented in the model based on their Strahler class as River boundaries (Strahler classes 3 and 4) or Drain boundaries (Strahler classes 1 and 2), Figure 5;
- The lined portion of the current landfill was represented as a River boundary (to allow control of conductance (low permeability liners) and stage (leachate head));
- The nearby Huntley Quarry was represented using drain boundaries; and
- The aggregate washwater ponds located on the quarry property northeast of the landfill, on the east side of Carp Road, were represented as River boundaries using surveyed water levels (the stage in these ponds is artificially maintained at a relatively constant elevation).

MODEL CALIBRATION

Model calibration was completed by iteratively adjusting the modeling input parameters of: 1) hydraulic conductivity of model layers, 2) reliability factor (RF) of groundwater head levels at site wells (highly reliable) and MOE water wells (low reliability), and 3) water levels in the Carp River.

In order to evaluate adjustments to these parameters the differences between observed and modeled water levels were evaluated. These differences, known as residuals, are aggregated into calibration checks called the Root Mean Squared Error (RMSE) and Normalized Root Mean Squared Error (NRMSE) (Equation 1 and Equation 2). The O_i and E_i represent the observed and evaluated values, respectively and $O_{max}$and O_{min} represent the observed maximum and observed minimum, respectively and the n represents the number of target values utilized.

Equation 1 $$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(O_i - E_i)^2}{n}}$$

Equation 2 $$NRMSE = \frac{\sqrt{\sum_{i=1}^{n} \frac{(O_i - E_i)^2}{n}}}{O_{max} - O_{min}}$$

The finalized model had a RMSE and NRMSE of 5.9 m and 7.9%, respectively, which is acceptable as the NRMSE is less than 10%. Further evaluation of these error calculations reveals that if the residuals were adjusted by the RF, the RMSE and NRMSE reduces to 2.0 m and 2.8%, respectively. The scatter plot shown on Figure 6 represents the observed versus simulated groundwater elevations, whereby the 45 degree line indicates a perfect fit. The wells indicated on this figure are segregated into four groups, MOE wells (RF=0.1), site wells (RF=1), site wells partially below model domain (RF=1), and non-pumping purge wells (RF=1). In conjunction with these calibration targets, mass balance verification of model inputs and outputs (water entering and leaving the modeling domain) and comparisons to previously developed groundwater contours of the region were conducted to ensure model convergence was achieved within acceptable accuracy. The mass balance error for the final calibrated model was calculated to be 0.5%, as shown in Table 2. The calibrated hydraulic parameters for all active zones are provided in Table 3.

GROUNDWATER FLOW MODELING RESULTS

Baseline Model (Existing Conditions)

The calibrated model simulating the groundwater contours in and around the current landfill site is shown on Figure 7. This figure indicates that general groundwater flow direction within the property limits of the WM landfill site is in a north to northeast direction with hydraulic head values ranging from 126 to 116 metres above sea level (mASL), consistent with the interpolated observed regional groundwater elevations (Figure 4).

New Landfill Footprint Model

The incorporation of the new landfill design into the model was accomplished by applying recharge rates within the areas corresponding to the proposed new landfill. These zones include the new landfill footprint and two unlined infiltration basins located immediately east of the landfill footprint (South Infiltration Basin #1 and North Infiltration Basin #2). These basins are designed to collect and infiltrate storm water into the shallow groundwater. These footprints are shown to the north of the current landfill as seen in Figure 8. The recharge rates of the new landfill change over time (transient) while the rates applied to the stormwater ponds are steady and are listed in Table 4. Figure 8 illustrates the mounding of the groundwater table that is predicted to occur as a result of the infiltrated water beneath the stormwater ponds. The predicted mounding ranges from 2.13 to 2.97 across the two stormwater ponds, as shown in Table 5.

TRANSPORT MODELING RESULTS

Initial Transport Model Set-up and Calibration

The initial set-up for the purpose of calibrating the transport model to the observed conditions and mass entering the domain was simulated at the closed south cell and the existing landfill between the years 1975 and 2030. This period was subdivided into a pre-current landfill period, when only the closed south cell was contributing mass (1975-1999), and a landfilling/post-landfill period when both areas were contributing (1999-2030). The model assumptions relative to mass transport are summarized in Table 6 for these two periods. Mass was introduced as a recharge concentrations on model Layer 1 with the recharge rates applied at the landfill footprints.

The transport simulations were calibrated using potassium as the selected leachate indicator. Potassium was used because it is elevated in the leachate, it is found at relatively low concentrations in background groundwater, and there are no other significant sources in the study area. Chloride, which is often used as a parameter in groundwater modeling studies, was not used to calibrate the transport model in this case because of interferences from road salt contamination which would affect the results in the southern area of the landfill site.

On the other hand, chloride was retained as the most appropriate parameter to use for future conditions predictive solute transport modeling and to examine various development scenarios (e.g., future baseline, potential effects, net effects) since it has a Reasonable Use Limit (potassium does not) and is elevated in the leachate relative to background conditions.

Concentration profiles of potassium for the closed south cell and the current landfill that were used for calibration are provided in Figures 9 and 10, respectively. A set of sensitivity analyses were completed to examine the best fit with respect to simulated versus observed concentrations of potassium at the source and downgradient. Seven scenarios with a range of dispersivities were used in the analyses as summarized in Table 7. Based on these sensitivity analyses, it was determined that a model having longitudinal, transverse and vertical dispersivities of 10 m, 1 m, and 0.1 m, respectively, was the optimal configuration.

Future Baseline Transport Modeling

Once it was calibrated to existing conditions, the transport model was used to predict impacts from old, existing and new landfills up to the year 3004. These "future baseline" scenarios assumed existing conditions, with no development of the new landfill or stormwater management ponds. Chloride was used as a conservative tracer to predict the trends in concentration as the dissolved groundwater plume evolved away from the sources. The concentration profiles for chloride for the closed south cell and the current landfill are summarized in Table 8 and on Figures 11 and 12, respectively.

To illustrate the predicted migration of the landfill contaminants, simulated concentration plumes were plotted for Model Layer 3 (overburden/bedrock contact zone) with contour plots and colour flooding for the years 2005, 2037, 2064, 2232 and 2434 (Figures 13 to 17, respectively). The extent of the simulated concentration plume on each of the figures is defined by a contour line having a concentration of 130 mg/L, which corresponds to a Reasonable Use Limit (RUL) for an aquifer with a median background concentration of 10 mg/L. This is considered to be a conservative limit for the WCEC facility, since the median background chloride concentration (unaffected by road salting activities) is greater than 10 mg/L.

Under future baseline conditions, the transport modeling scenarios suggest that groundwater impacts exceeding the hypothetical RUL could extend beyond WM's property boundaries, to the north and northeast. The unlined portion of the current landfill is the major contributor to the predicted groundwater impacts. The maximum extent of the concentration plume was simulated to occur at approximately 2064; the extents of the simulated chloride plume at that date in each of the Model Layers (1 through 5) are shown on Figures 18 to 22, respectively.

Transport Modeling with New Landfill Footprint and Stormwater Ponds

Adding the new landfill to the north of the existing landfill, as well as the stormwater infiltration basins, was achieved in the model using transient concentration profiles applied via groundwater recharge. This allowed modeling of the potential effects predicted from the new landfill. The transient chloride concentration profile of contaminant flux through the G2 liner for the new landfill footprint was provided by AECOM and presented in the Facility Characteristics Report[1]. Figure 23 presents the concentration profile of chloride through the G2 liner predicted over time.

[1] WCEC Landfill Footprint Expansion, Draft Facility Characteristics Report; prepared by AECOM Canada Ltd., dated October 2011.

The modeled concentration source function for the new landfill which fits this curve according to the applied timesteps is also plotted on Figure 23, and summarized in Table 8 ("Source 3").

The concentration profile for the stormwater ponds was determined through an iterative process which simulated the concentrations being held constant from 2015 to 2025 (i.e., during landfill operations), followed by a linear decrease in concentration for a period of five years after closure to 2030. The source concentration profile for the stormwater ponds is summarized in Table 8 and presented on Figure 24. The maximum concentration that was simulated to be discharged from the stormwater ponds was 130 mg/L. At this maximum concentration, the extent of predicted groundwater impacts from the infiltration basins with concentrations greater than 130 mg/L (the hypothetical Reasonable Use Limit) is predicted to remain within WM property boundaries. The maximum extent of the simulated chloride concentration created by the stormwater ponds is predicted to occur in 2025 (Figure 25).

The results of the potential impacts from the chloride plume dissolved in groundwater, predicted by the modeling simulations, are presented on Figures 26 to 30. These figures show the maximum extent of chloride concentrations greater than 130 mg/L in Model Layers 1 through 5, predicted to occur in the year 2107. The results indicate that the predicted groundwater mounding created by the infiltration basins, combined with the influence on groundwater flow directions resulting from the reduced recharge across the new landfill footprint (lined using an G2 liner), would have the effect of re-orienting the concentration plume further northward relative to the future baseline conditions. Similarly, the extent of the plume to the east is expected to be smaller with the new landfill and infiltration basins in place, compared to future baseline conditions. The groundwater quality is predicted to be affected beyond the WM property boundary to the north; consequently, mitigation measures would be required.

The final set of simulations involved the evaluation of mitigative measures to achieve acceptable net effects to groundwater quality. The net effects simulations include the existing and proposed new landfills, stormwater ponds and eight simulated purge wells located along the northern property boundary to capture the contaminated groundwater and intercept the dissolved chloride plume. The contingency purge wells were installed in model layers 2 to 4, and turned on starting in 2032, before the chloride plume reaches the property boundary. The pumping rates range from 30 m^3/d (6 wells) to 45 m^3/d (2 wells) toward the east where hydraulic conductivities are generally higher, for a predicted total combined pumping rate of 270 m^3/d.

Figures 31 to 35 show the maximum extent of chloride plume above the hypothetical RUL of 130 mg/L in Model Layers 1 through 5, respectively, in the year 2089 with mitigation measures in-place. The maximum extent of the chloride concentration plume is predicted to be effectively contained within the WM property boundaries, indicating acceptable net effects beyond the property boundaries.

Table 1: Modelled Vertical Discretization and Layer Description

Layer	Unit	Top Elevation	Thickness
1	Overburden	Ground Surface	Varies
2	Contact Zone Overburden	2 m Above Bedrock	Varies
3	Contact Zone Bedrock	Bedrock Elevation	3 m
4	Fractured Bedrock	3 m Below Bedrock	5 m
5	Bedrock	8 m Below Bedrock	10 m

Table 2: Mass Balance of the Final Calibrated Flow Model

Overall Model Water Budget								
INFLOW (m^3/d)				OUTFLOW (m^3/d)				
Carp River	Recharge	River	General Head Boundaries	Carp River	Purge Wells	Drains	River	General Head Boundaries
11494.28	61096.58	6371.61	2.68	35001.85	708.53	22576.70	19478.34	782.21
Water Balance (Inflow – Outflow) = -417.52 m^3/d (0.5%)								

Table 3: Calibrated Hydraulic Parameters for Each Model Layer

Layer	Description	Kx (m/s)	Ky (m/s)	Kz (m/s)	Ss	Sy	Porosity
1	Offshore Marine	5.00E-07	5.00E-07	2.50E-07	0.01	0.03	0.45
1	Alluvial	2.00E-06	2.00E-06	1.00E-07	0.01	0.05	0.40
1	Organic	5.00E-06	5.00E-06	2.50E-07	0.01	0.01	0.35
1	Bedrock Outcrops	3.11E-05	3.11E-05	5.00E-05	0.01	0.08	0.15
1	Nearshore	5.00E-05	5.00E-05	2.50E-06	0.01	0.05	0.38
1	Till	1.00E-05	1.00E-05	5.00E-07	0.01	0.10	0.30
1	Glaciofluvial	5.00E-05	5.00E-05	5.00E-05	0.01	0.30	0.36
2	Contact Zone Overburden	1.67E-05	1.67E-05	5.00E-05	0.01	0.10	0.35
3	Contact Zone Bedrock	1.07E-04	1.07E-04	5.00E-05	0.01	0.08	0.15
4	Fractured Bedrock	1.88E-05	1.88E-05	2.31E-05	0.01	0.04	0.15
5	Bedrock	1.00E-05	1.00E-05	1.16E-05	0.01	0.01	0.15

Table 4: Recharge Rates Applied to New Landfill and Stormwater Ponds

	Recharge m/d				
Year	Source 1 (Closed South Cell)	Source 2 (Current LF*)	Source 3 (New LF)	South Infiltration Basin #1	North Infiltration Basin #2
1975	6.63E-04	n/a	n/a	n/a	n/a
1999	6.63E-04	6.63E-04	n/a	n/a	n/a
2005	6.63E-04	6.63E-04	n/a	n/a	n/a
2015	6.63E-04	6.63E-04	1.80E-05	7.37E-03	1.23E-02
2114	6.63E-04	6.63E-04	1.99E-05	7.37E-03	1.23E-02
2484	6.63E-04	6.63E-04	6.02E-04	7.37E-03	1.23E-02
3004	6.63E-04	6.63E-04	6.02E-04	7.37E-03	1.23E-02

* unlined portion of current landfill only

Table 5: Groundwater Mounding at Stormwater Ponds

	South Infiltration Basin #1	North Infiltration Basin #2
Existing Conditions (mASL)	117.85	118.73
Current Design (New Landfill and Stormwater Ponds)	120.81	120.86
Predicted Groundwater Mounding (m)	2.97	2.13

Table 6: Model Details Relative to Mass Transport

	Pre-Current Landfill Period (1975-1999)	Landfilling/Post-Landfill Period (1999-2015)	New Landfill Period (2015 and beyond)
Current Landfill	Does not exist	Exists; 2/3rd unlined, 1/3rd lined	
Closed South Cell	Exists; unlined		
Recharge on Landfills (see Table 4)	242 mm/yr (closed south cell only)	242 mm/yr on unlined portion (2/3) of existing landfill; 0 mm/yr on lined portion of existing landfill (1/3)	Recharge rates applied for new landfill footprint and stormwater ponds (see Table 4)
Quarries	Current Huntley Quarry does not exist but the old (smaller) quarry exists	Huntley Quarry exists	
Purge wells	None	PW1 through PW10 and PW20 operating	
Initial Concentration	Initial chloride concentration of 550 mg/L in the closed south cell and 0 mg/L elsewhere.	Concentrations from previous period applied, additional sources added (see Table 8)	
Source concentration (Chloride)	See Table 8		
Wash ponds	Applied as rivers cells		

Table 7: Scenarios for Mass Transport Calibrations

Scenario	Longitudinal dispersivity (m)	Transverse dispersivity (m)	Vertical dispersivity (m)
S1	0	0	0
S2	**10**	**1**	**0.1**
S3	5	0.5	0.05
S4	20	2	0.2
S5	20	5	1
S6	10	10	1
S7	10	50	10

Table 8: Chloride Source Concentrations Applied to the Transport Model (in mg/L)

Stress Period	Year	Source 1 (Closed South Cell) *See Fig. 11*	Source 2 (Current Landfill*) *See Fig. 12*	Source 3 (New Landfill) *See Fig. 23*	Stormwater Ponds *See Fig. 24*
0	1975	550	0	0	0
1	1999	310	585	0	0
2	2005	310	1000	0	0
3	2015	310	930	0.0006	0
4	2024	310	930	0.0006	130.0
5	2025	310	930	0.0006	130.0
6	2027	310	930	0.0006	102.5
7	2029	310	930	0.0006	51.0
8	2030	310	930	3	11.5
9	2064	80	815	33	0
10	2114	80	710	89	0
11	2164	14	610	112	0
12	2224	14	500	112	0
13	2264	14	500	100	0
14	2300	14	400	100	0
15	2364	3	400	50	0
16	2404	3	280	4	0
17	2444	0	280	0.30	0
18	2464	0	280	0.30	0
19	2484	0	280	0.00	0
20	2565	0	160	0.00	0
21	2860	0	64	0	0
22	3004	0	64	0	0

* unlined portion of current landfill only

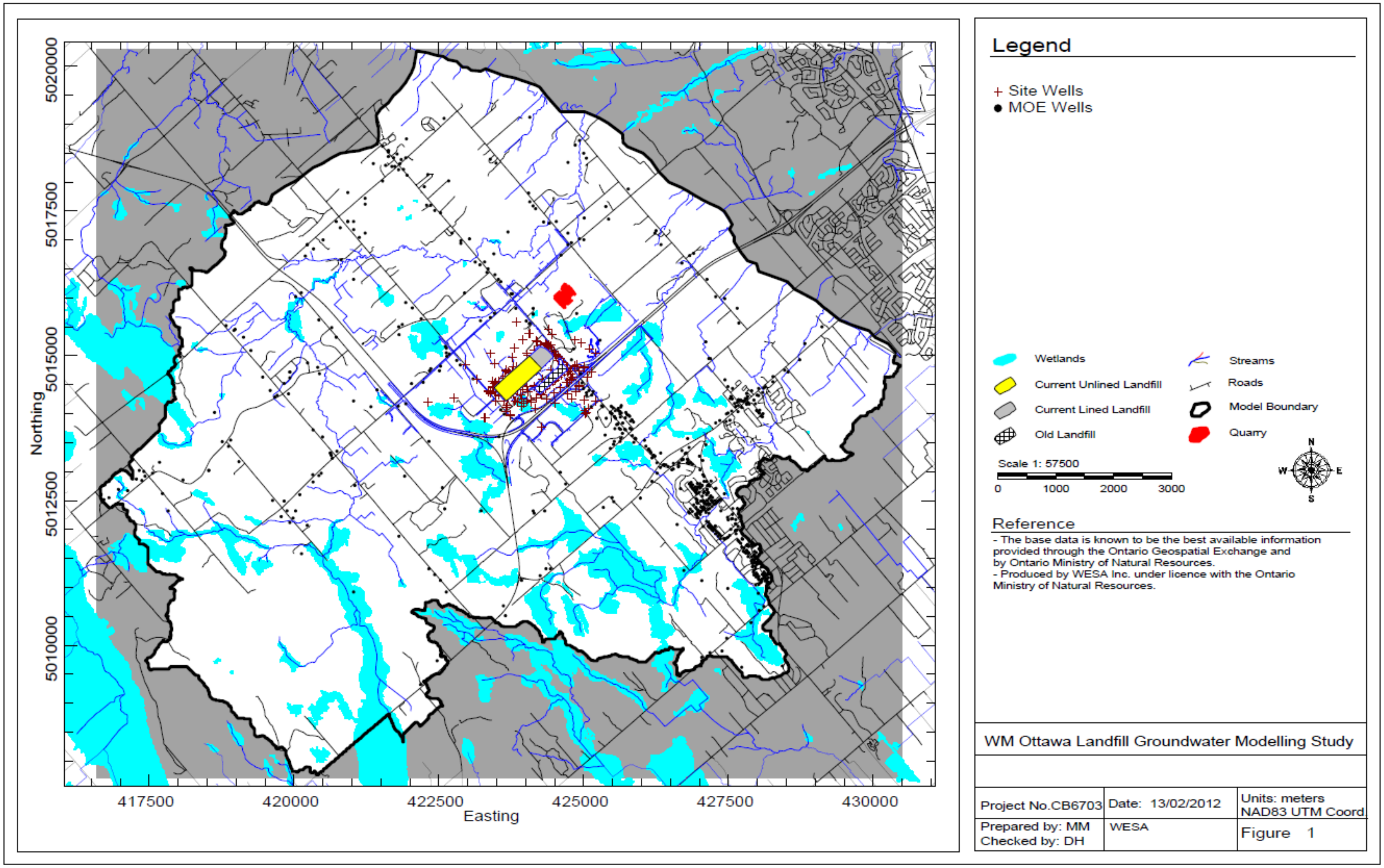

Figure 1: Extent of Groundwater Model Domain

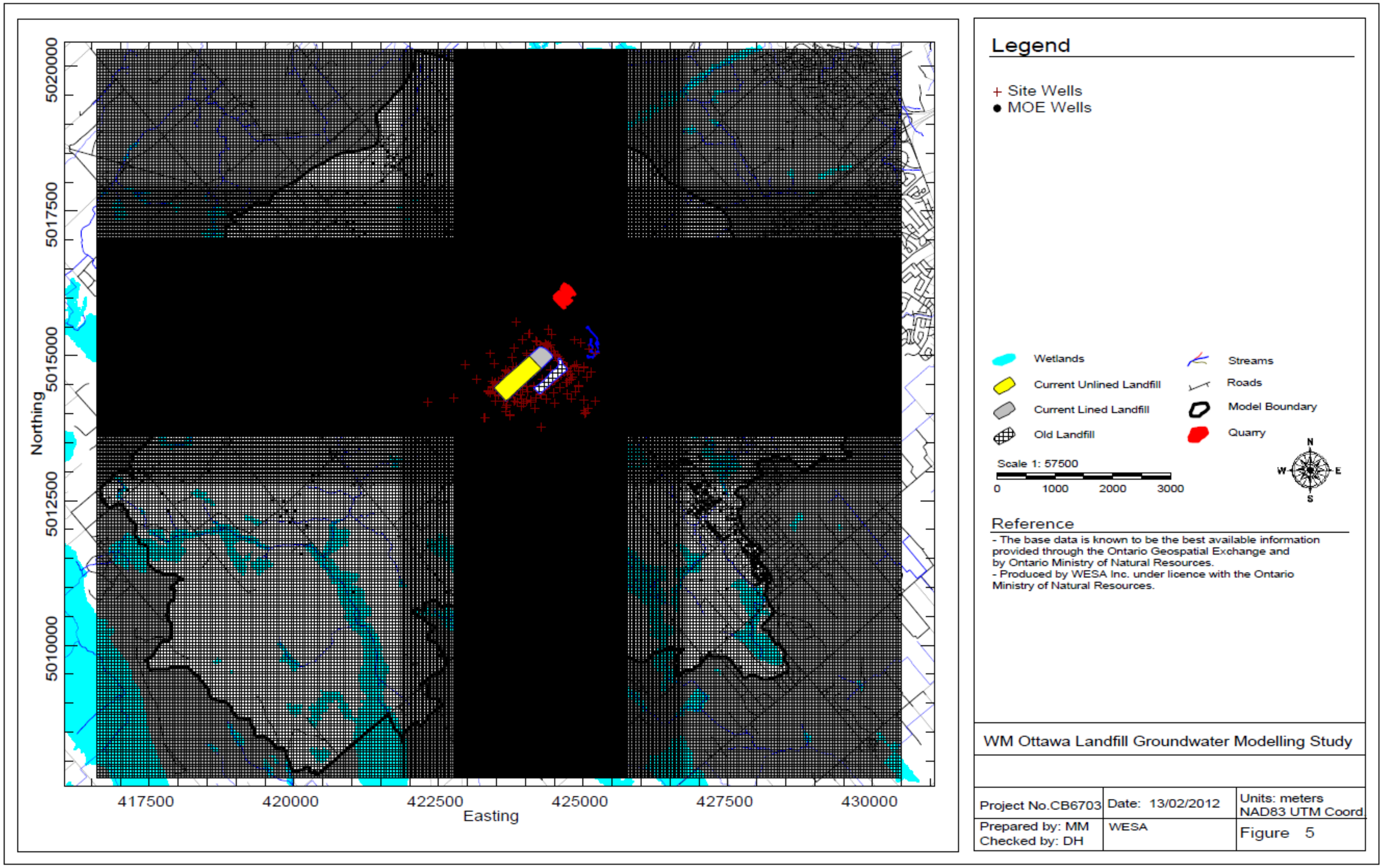

Figure 2: Groundwater Model Extent and Grid

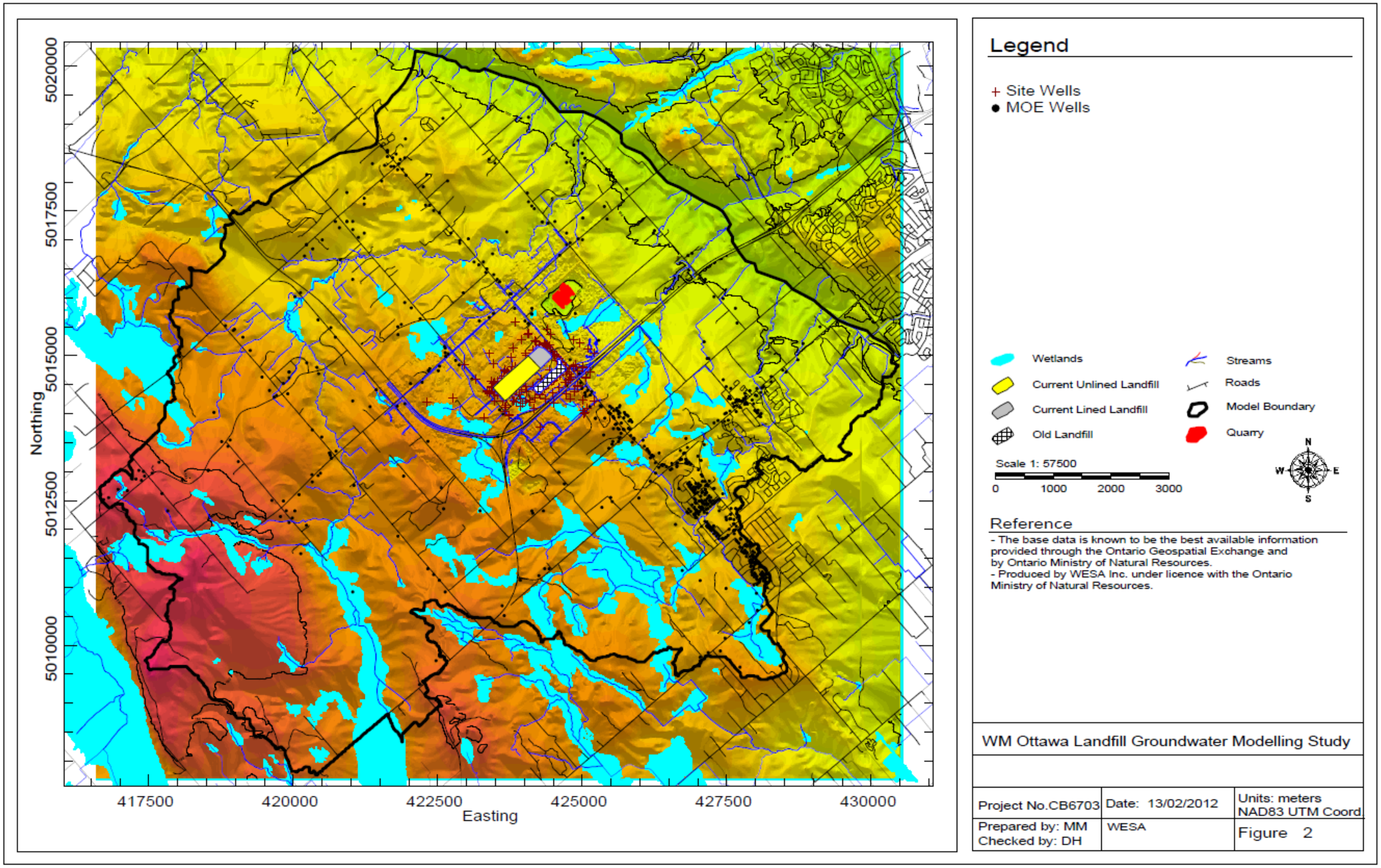

Figure 3: DEM Defining the Topography within the Groundwater Model Domain

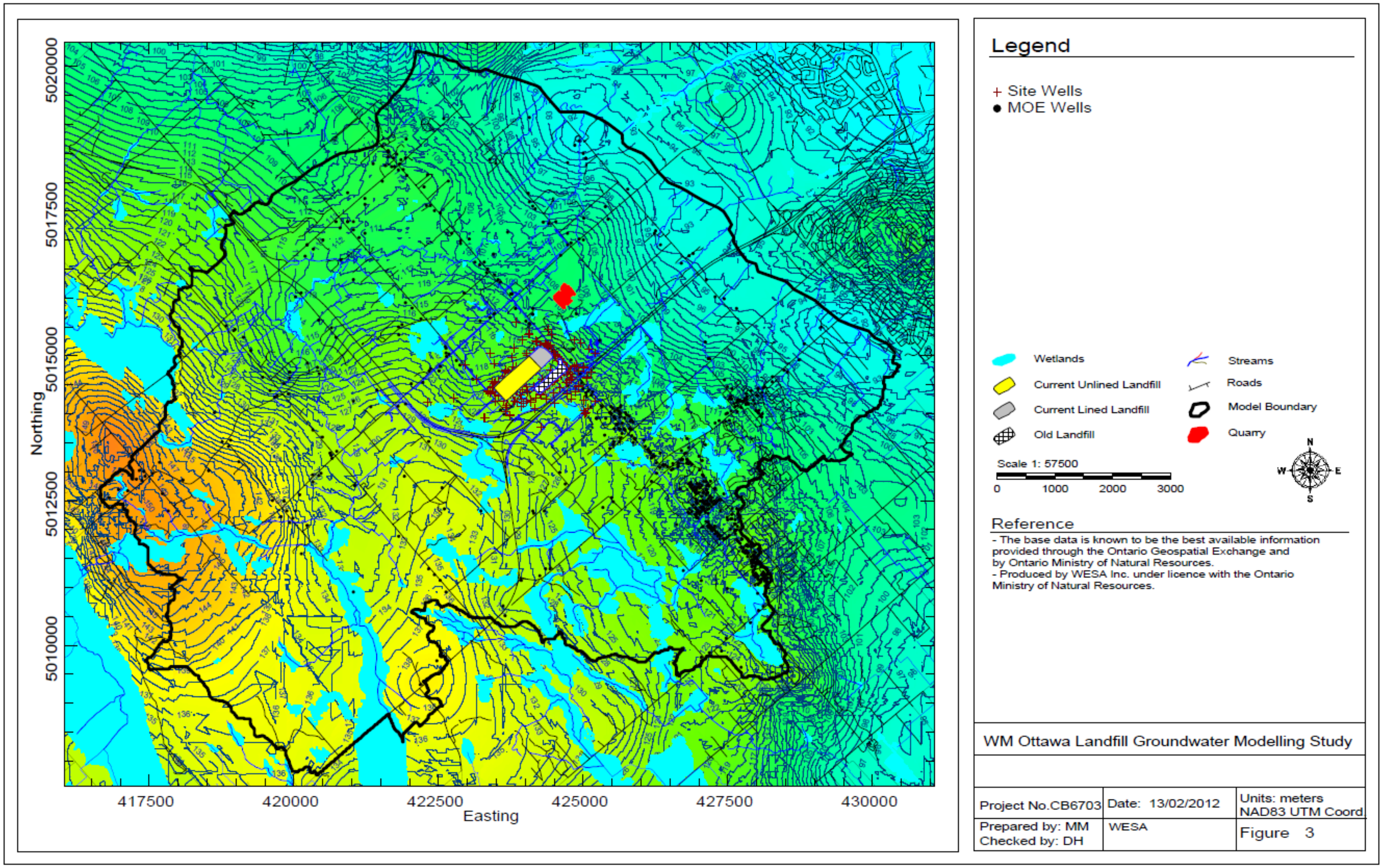

Figure 4: Refined Interpolated Groundwater Level Contours Based on Information from the MOE Water Well Information System (WWIS)

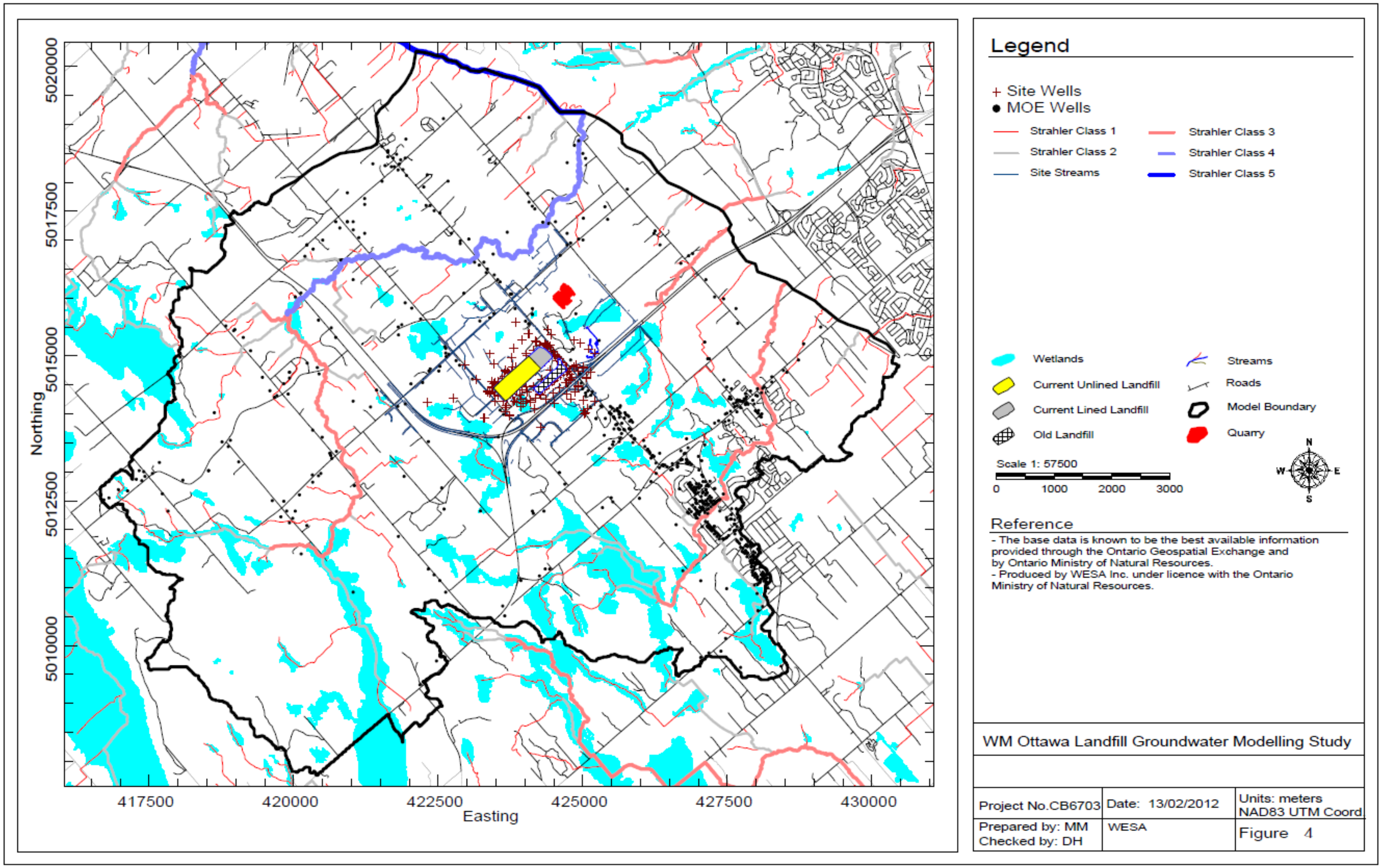

Figure 5: Strahler Classes 1 through 4 Defined as Drains and Rivers

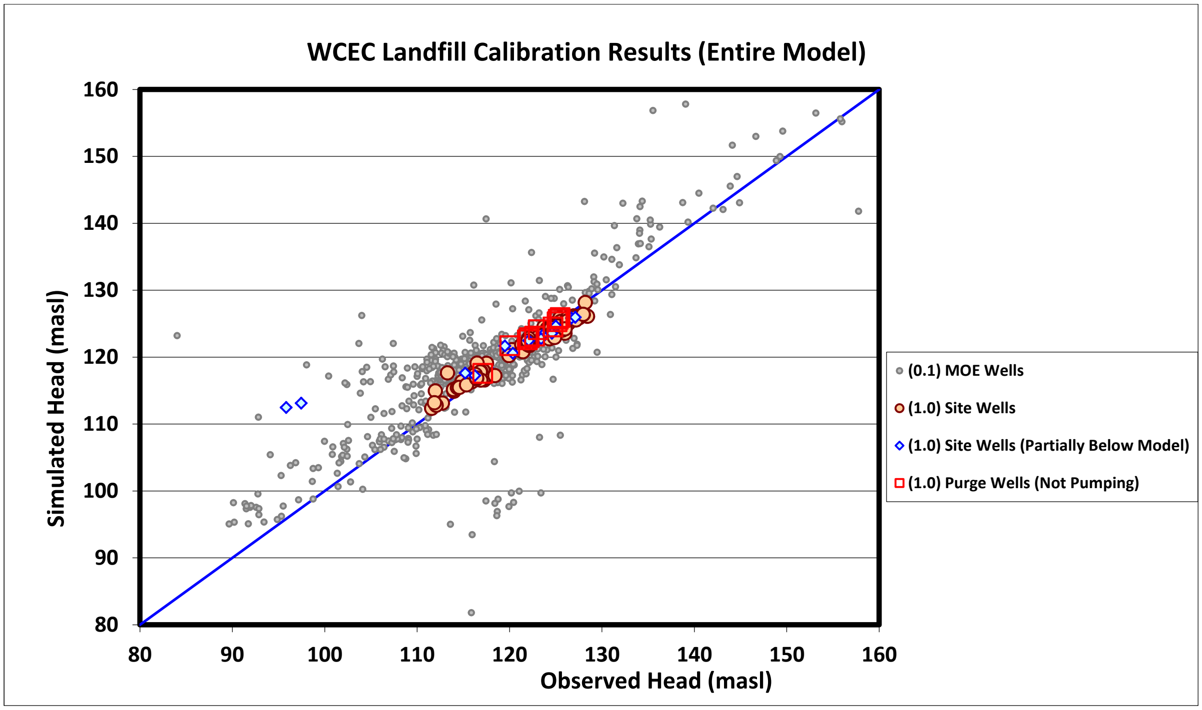

Figure 6: Simulated vs. Observed Heads used in Calibration

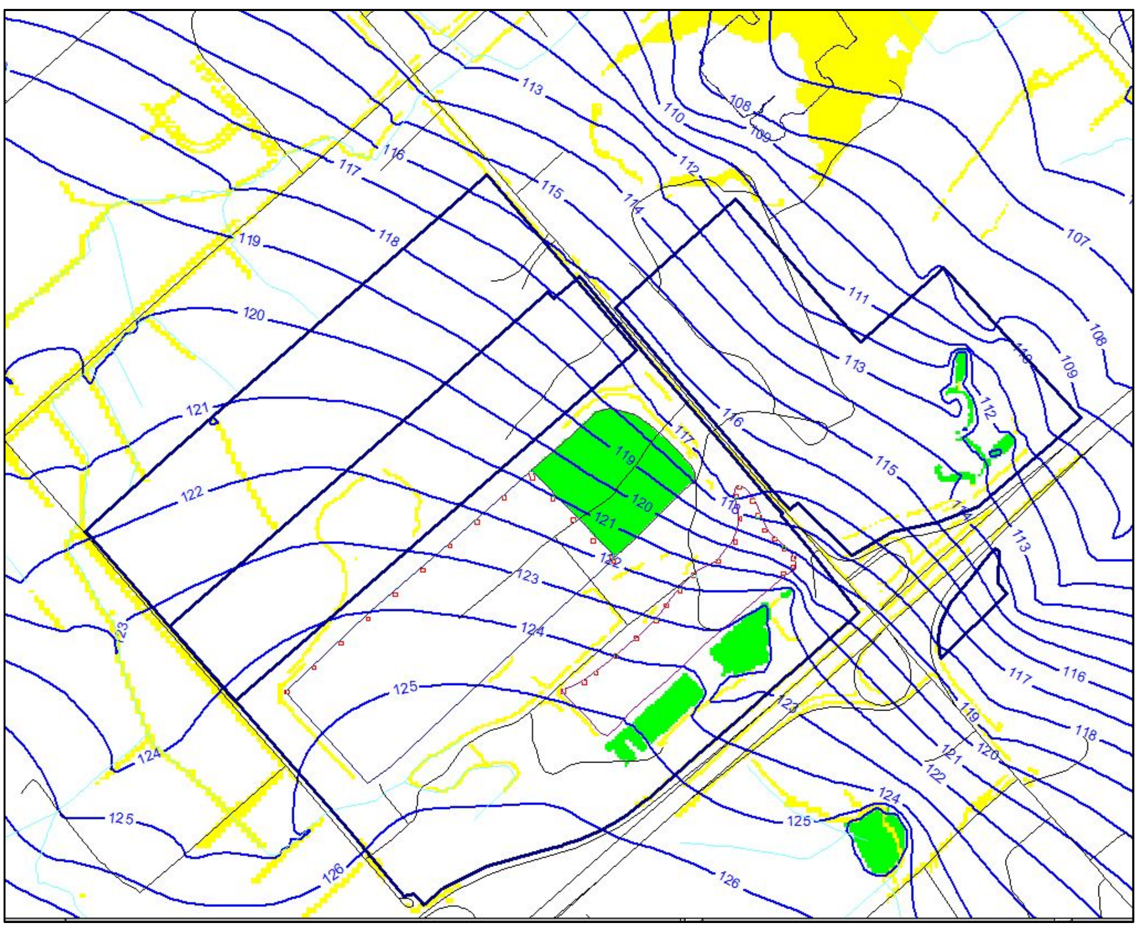

Figure 7: Groundwater Head Contours of Current Conditions (mASL)

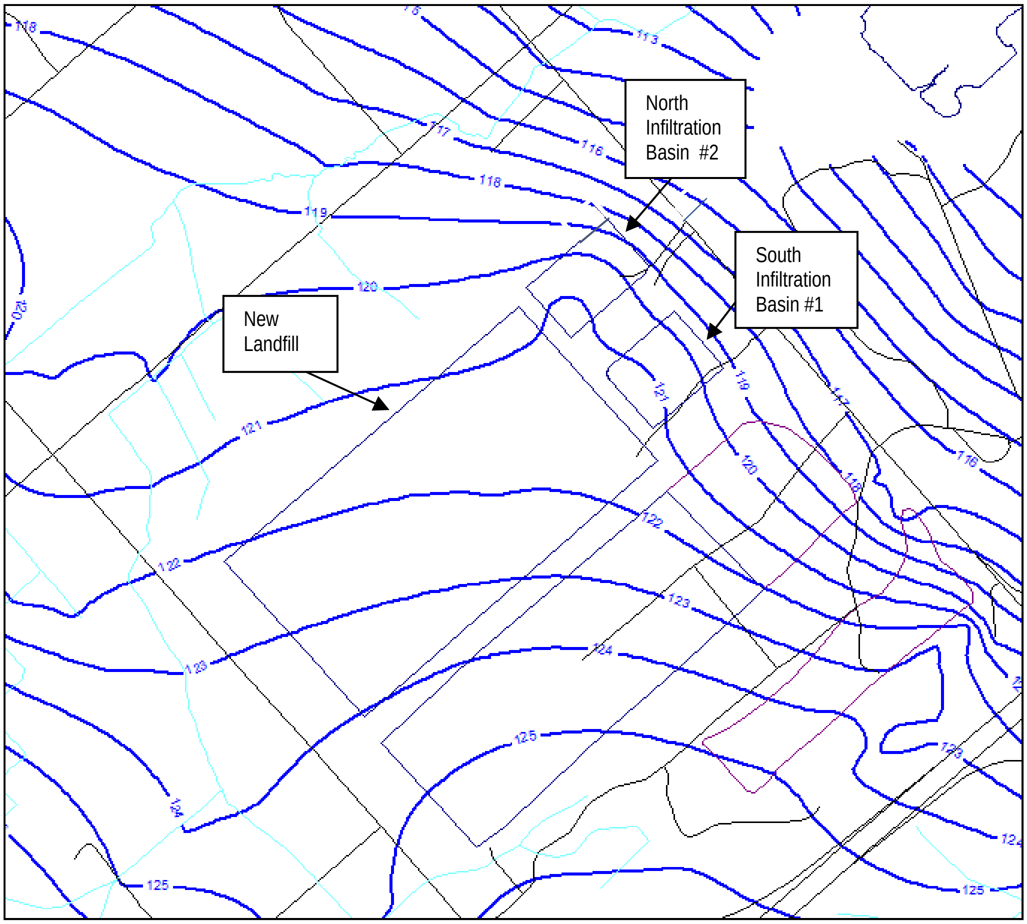

Figure 8: Groundwater Head Contours with the New Landfill and Stormwater Management Ponds

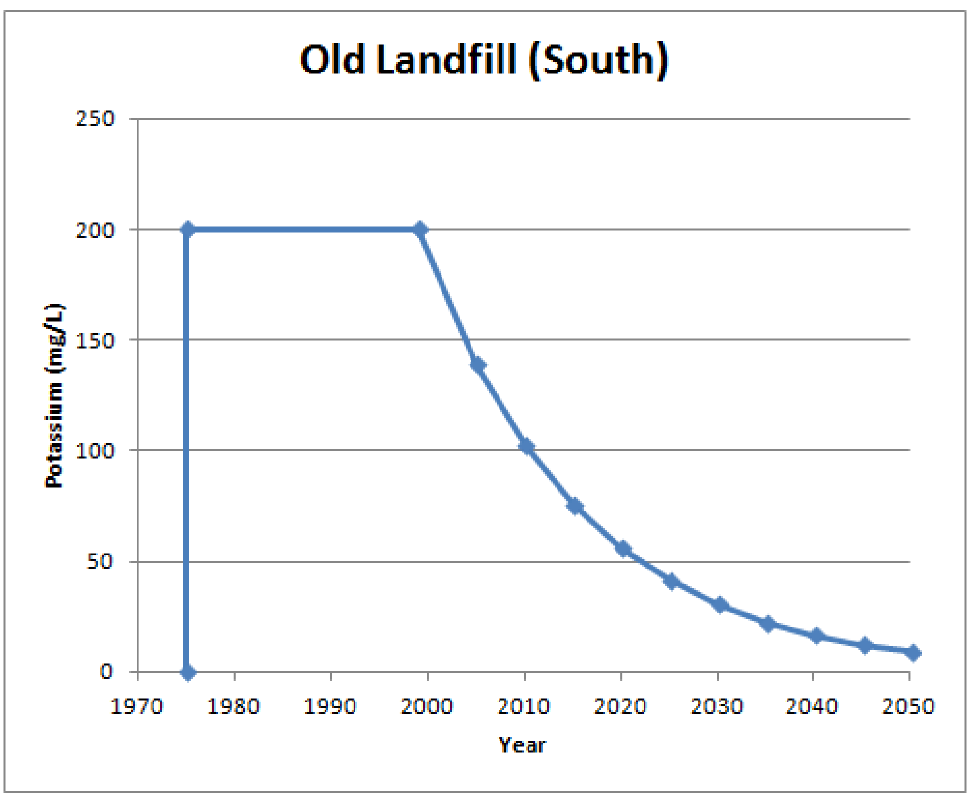

Figure 9: Potassium Source Calibration Curve for the Closed South Cell

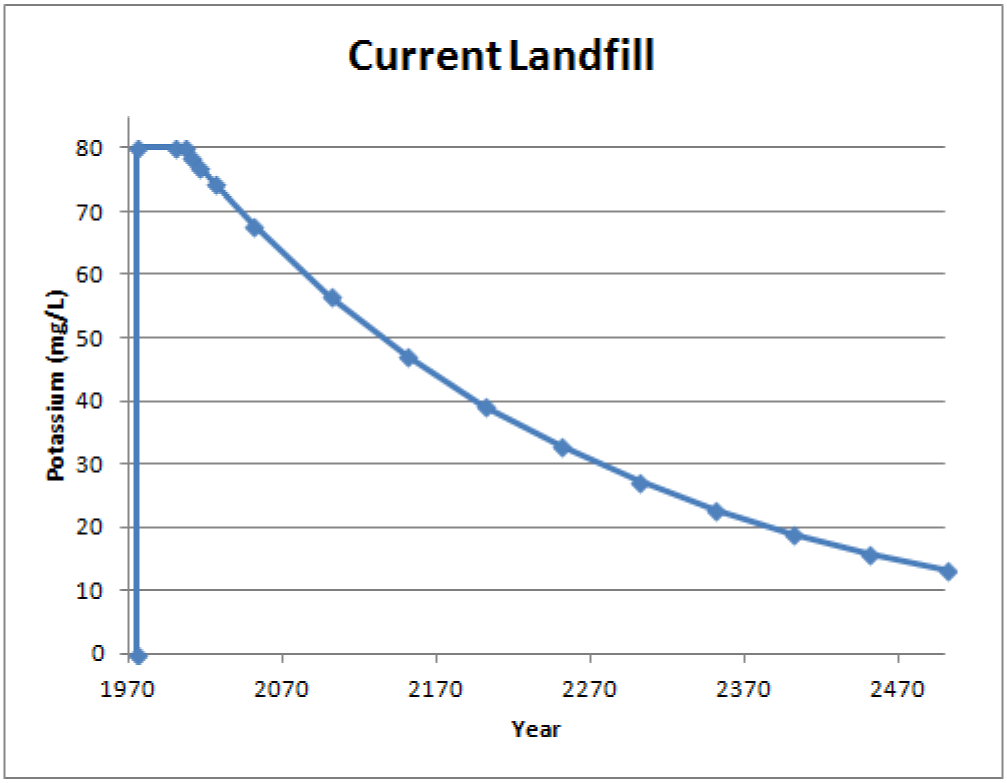

Figure 10: Potassium Source Calibration Curve for the Existing Landfill

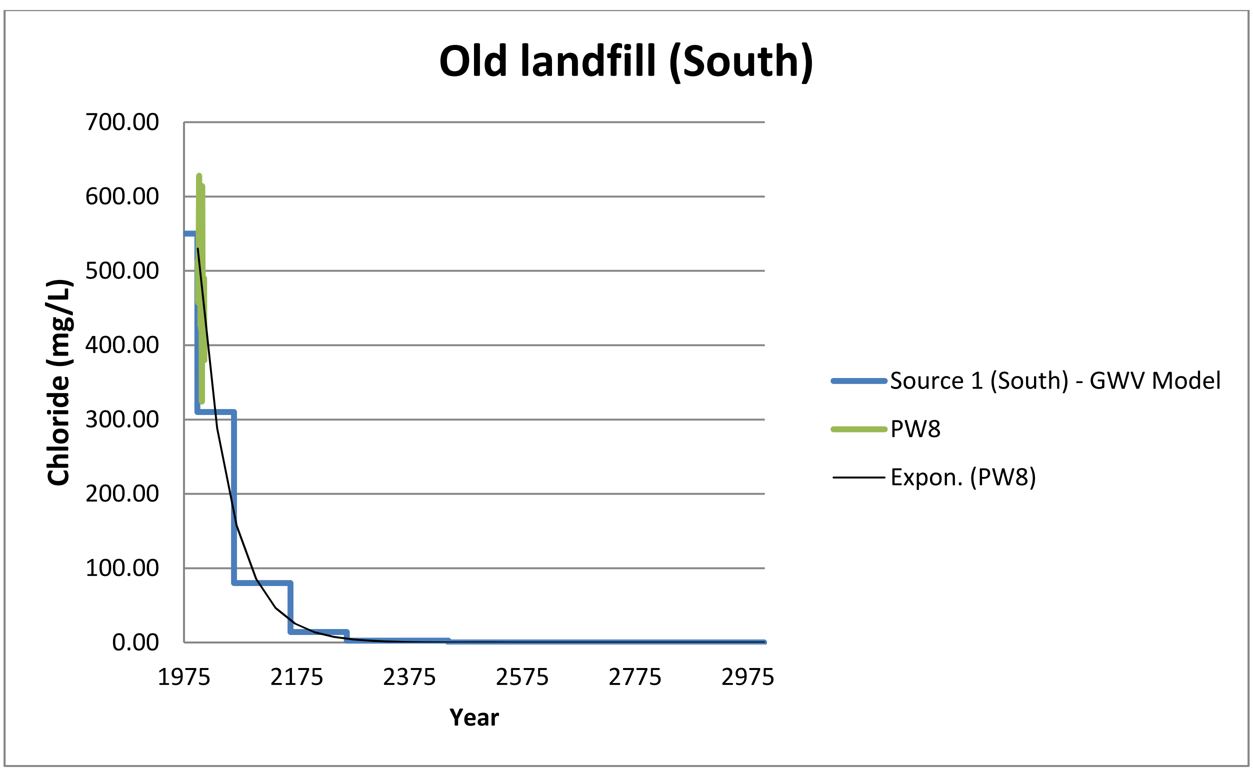

Figure 11: Chloride Source Curve for the Closed South Cell

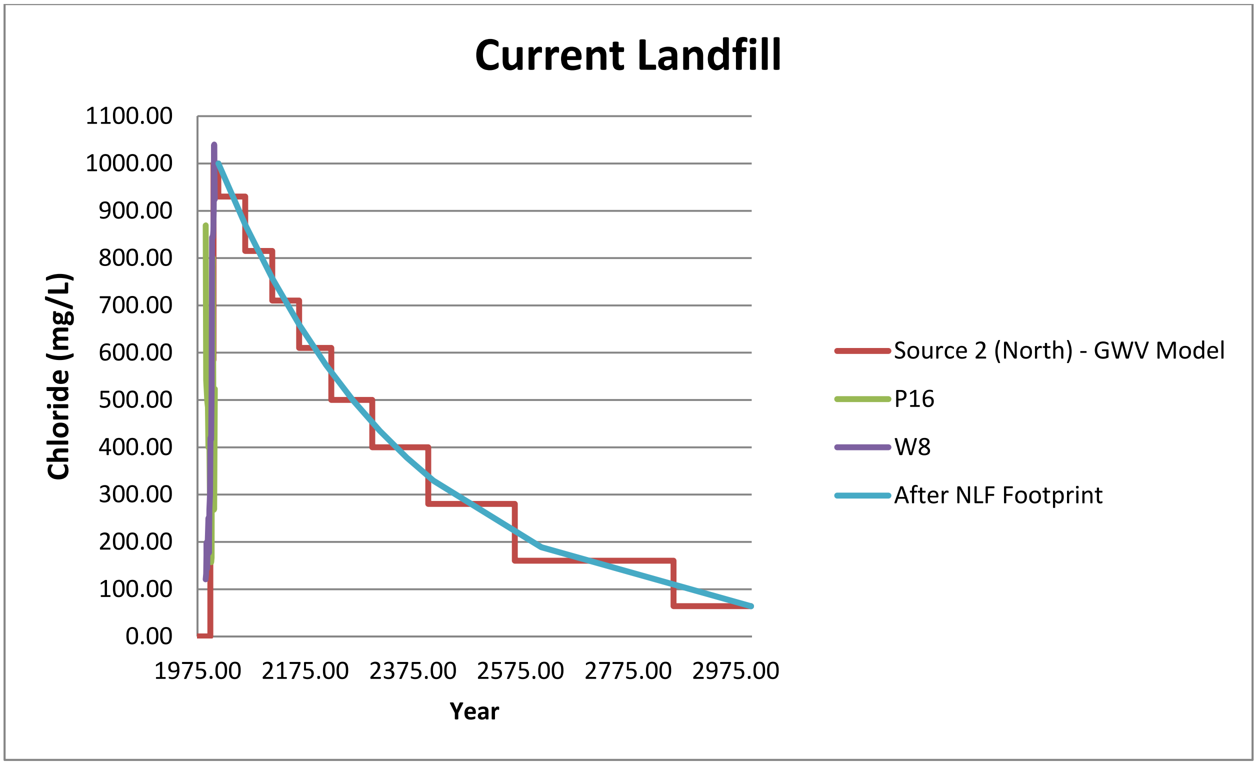

Figure 12: Chloride Source Curve for the Existing Landfill

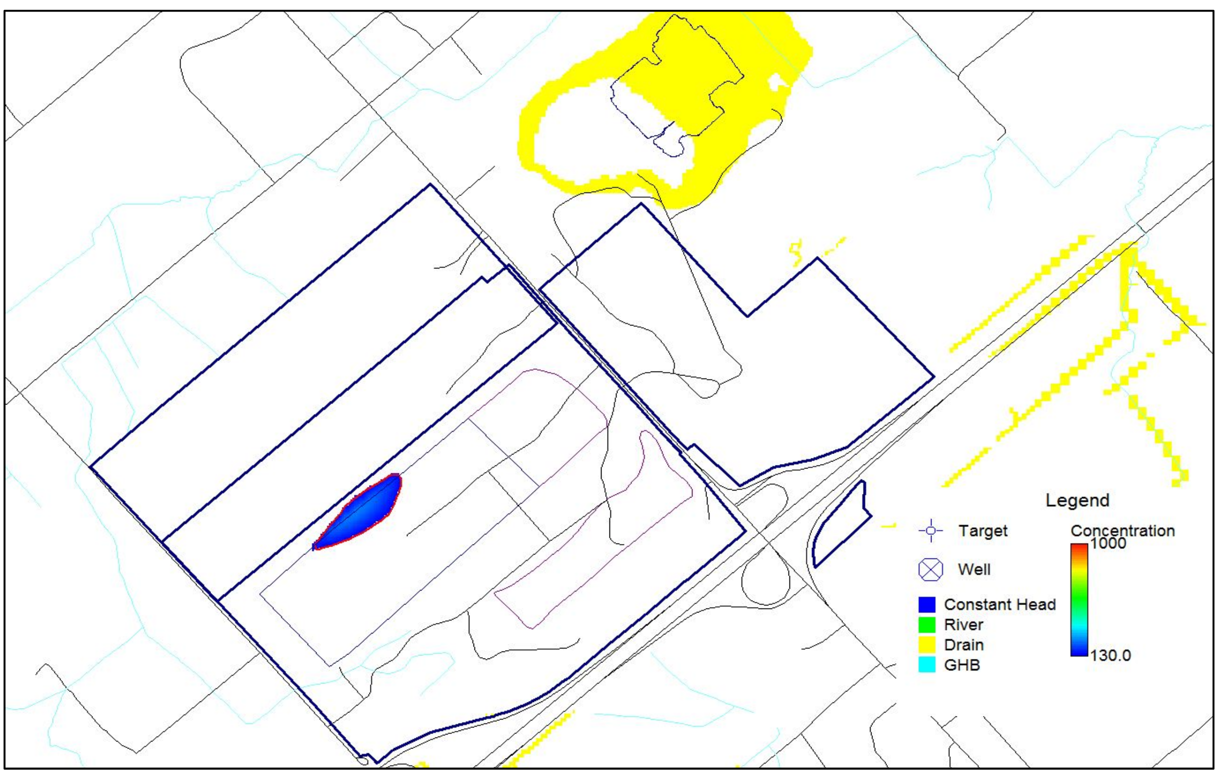

Figure 13: Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2005, Layer 3

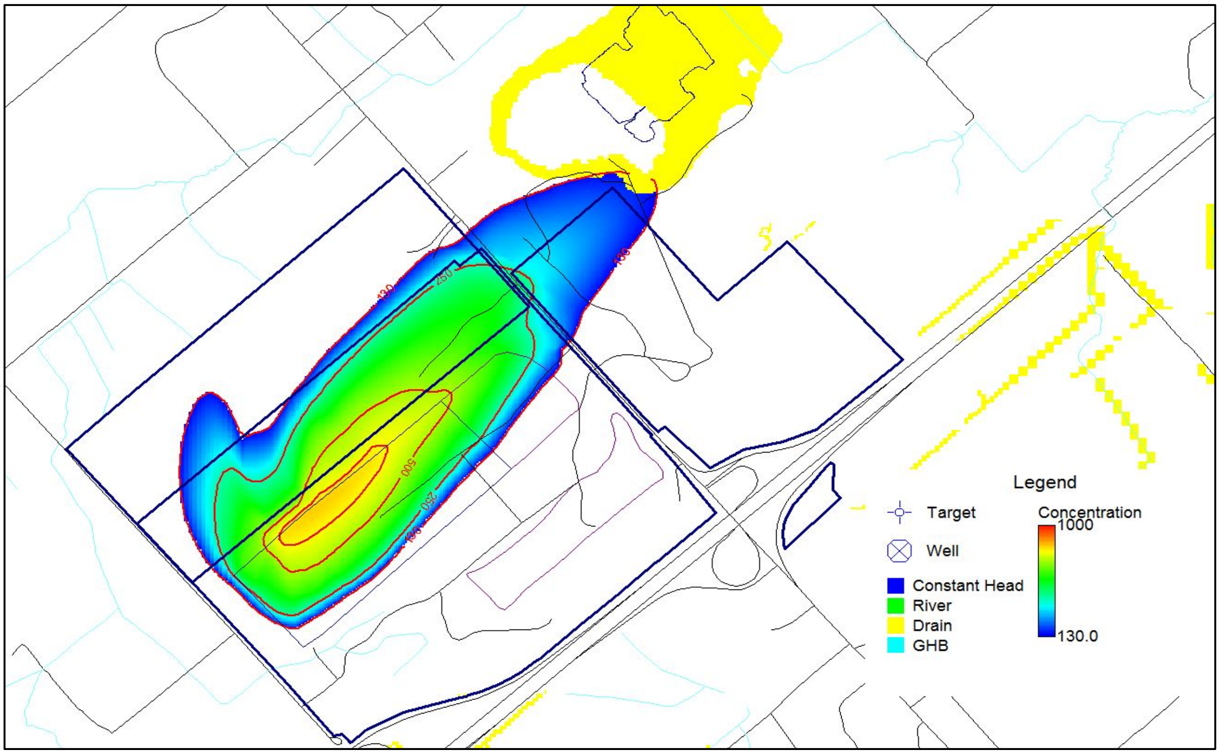

Figure 14: Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2037, Layer 3

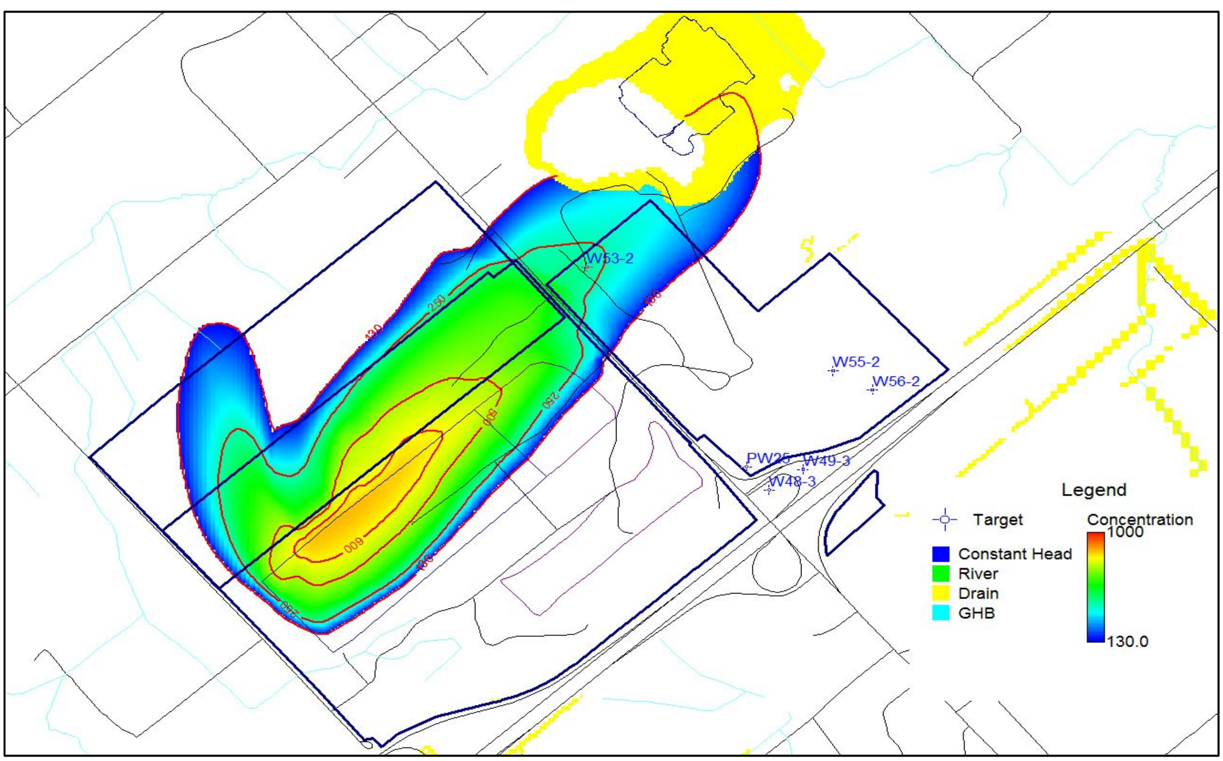

Figure 15: Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2064, Layer 3

Figure 16: Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2232, Layer 3

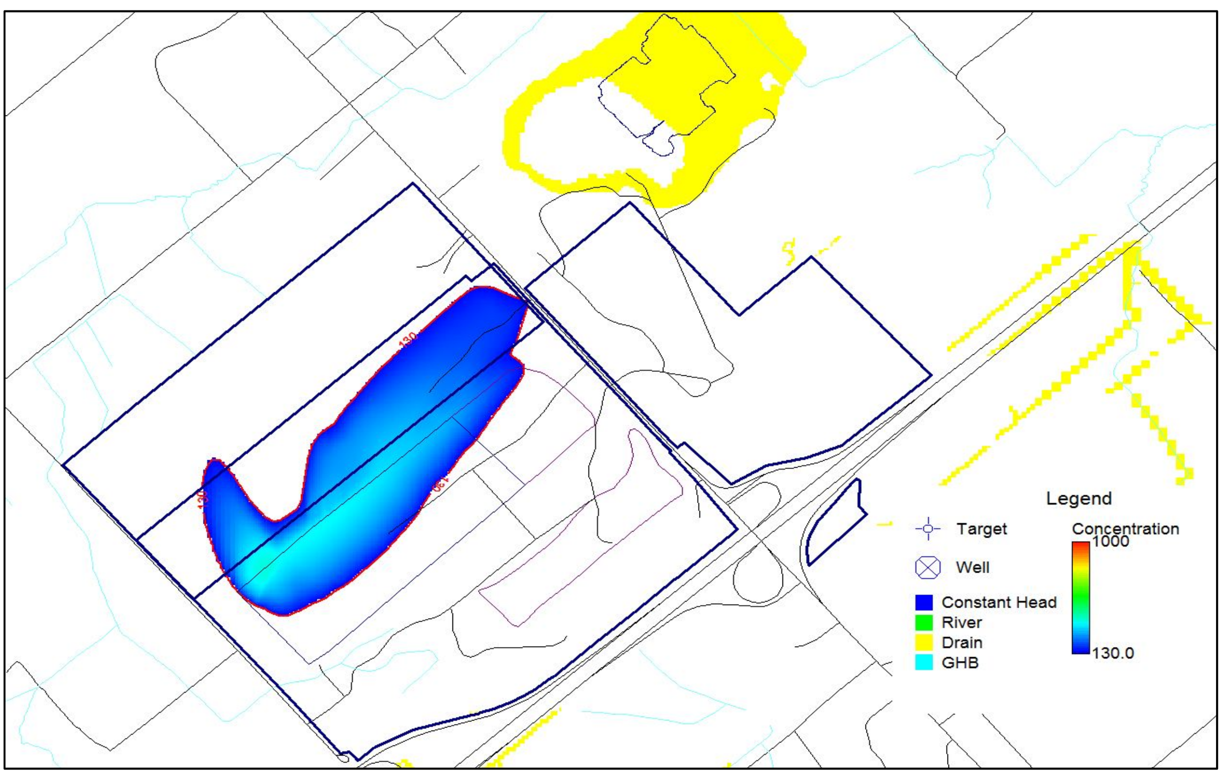

Figure 17: Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2434, Layer 3

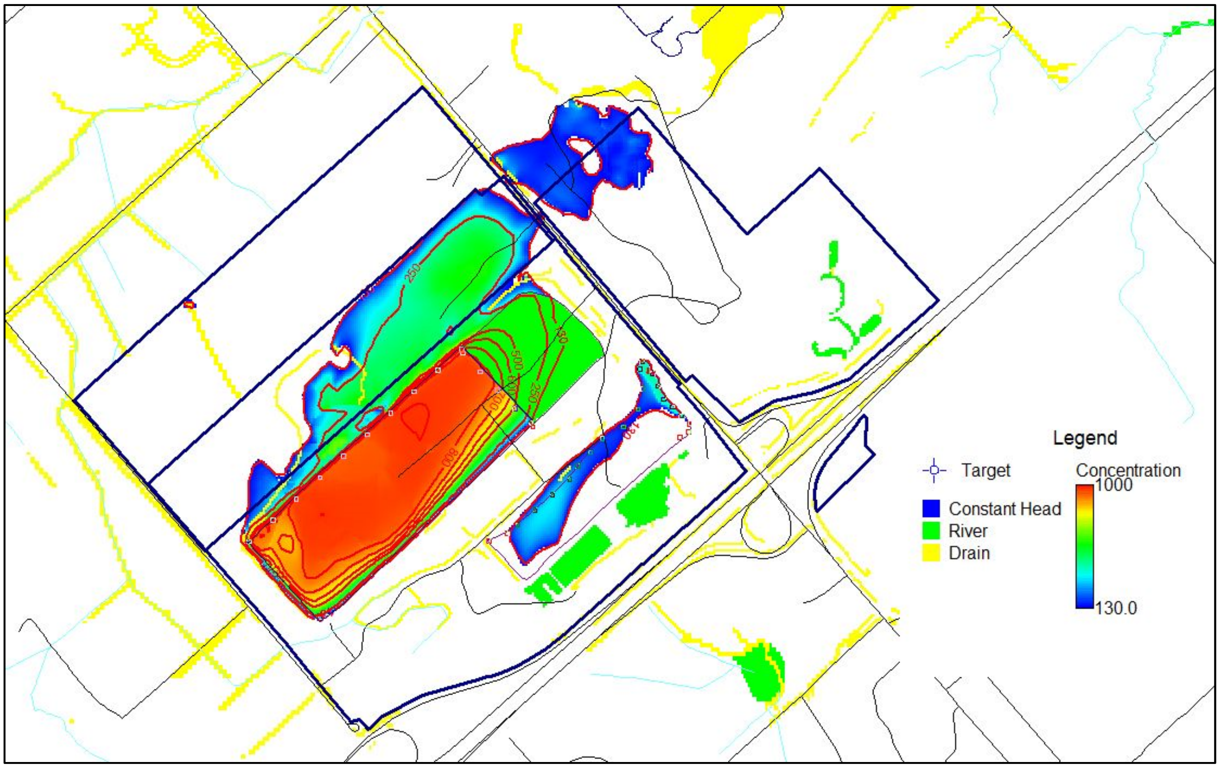

Figure 18: Maximum Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2064, Layer 1

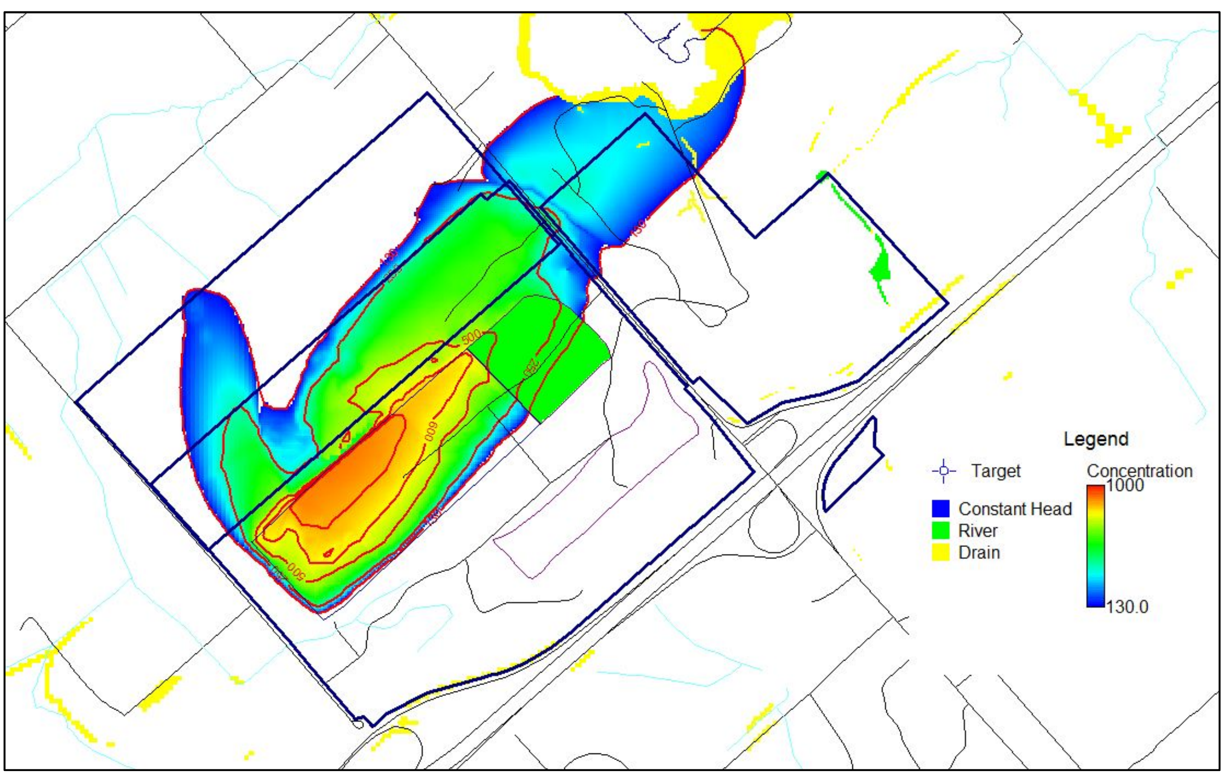

Figure 19: Maximum Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2064, Layer 2

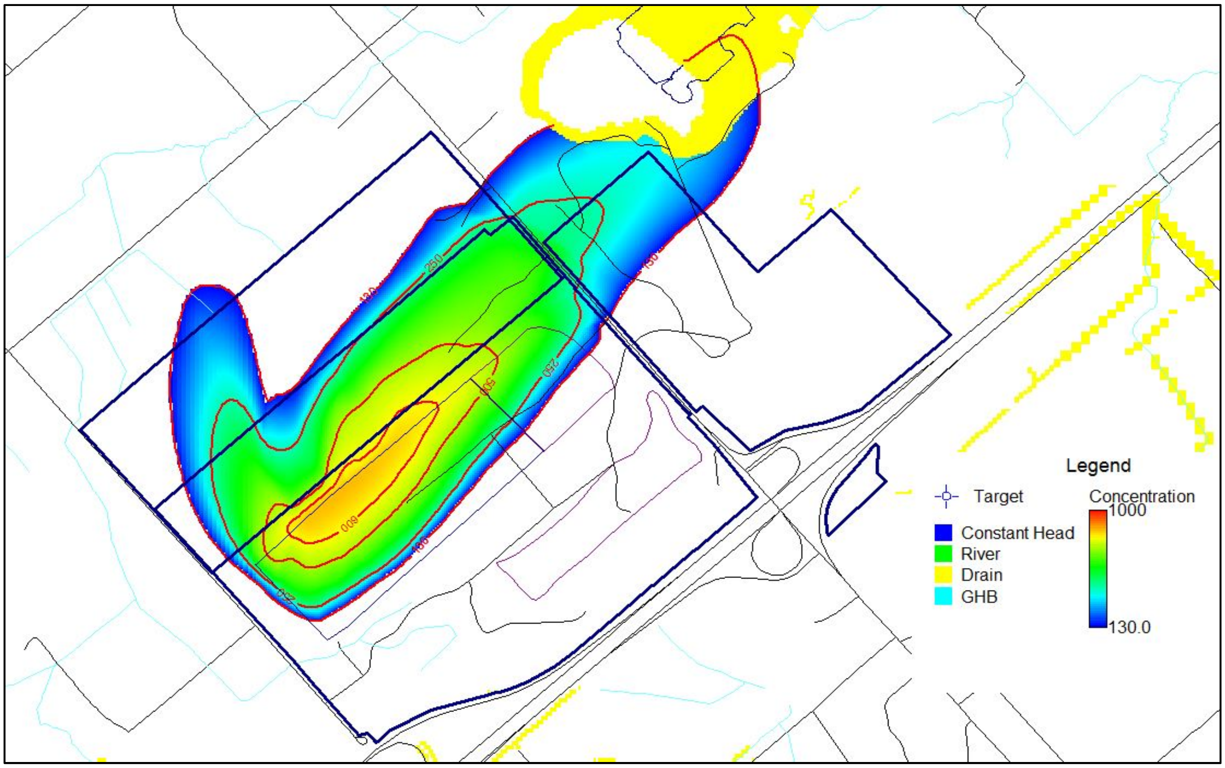

Figure 20: Maximum Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2064, Layer 3

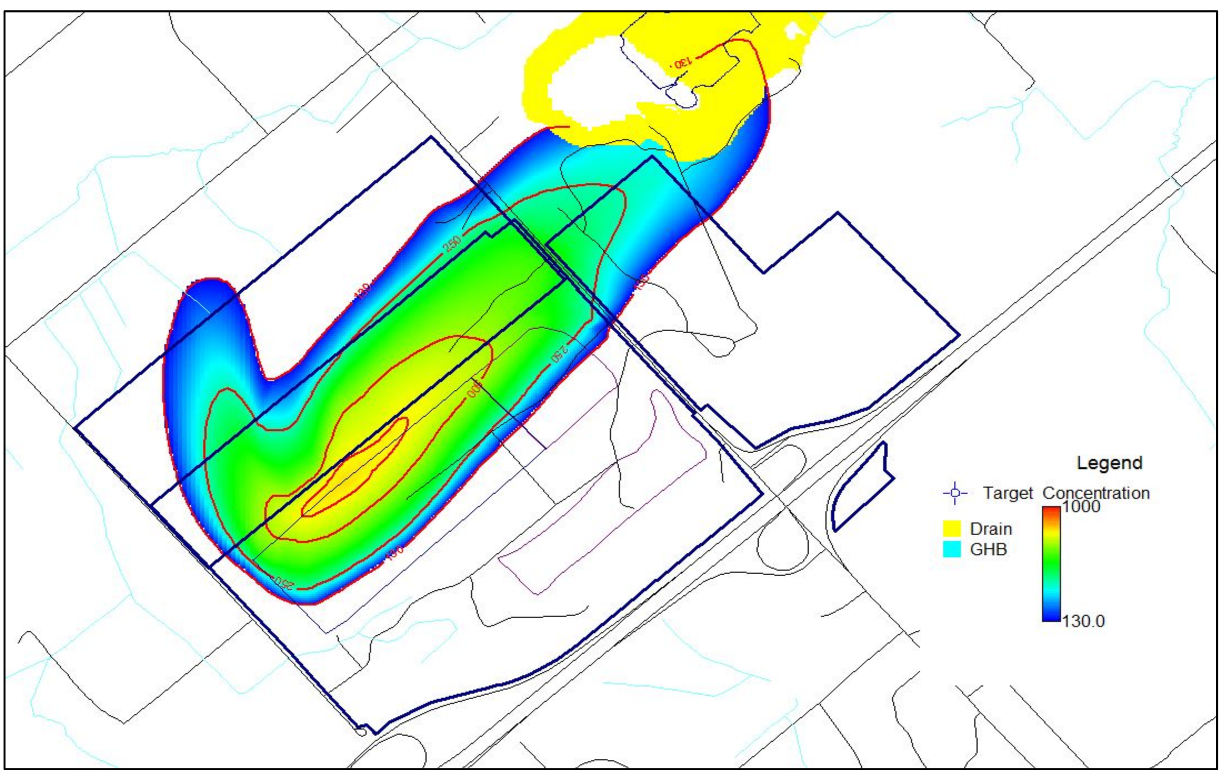

Figure 21: Maximum Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2064, Layer 4

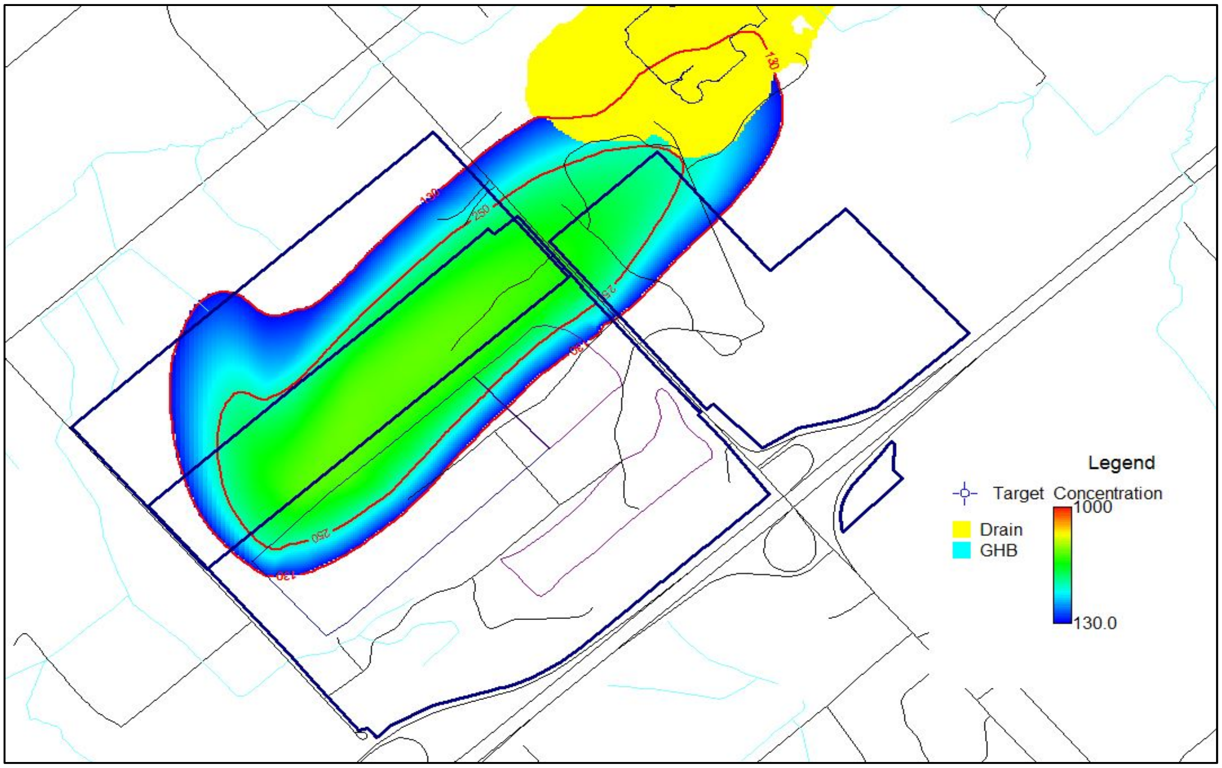

Figure 22: Maximum Simulated Concentration Plume of Baseline (Current) Conditions; Chloride Concentrations greater than 130 mg/L, Year 2064, Layer 5

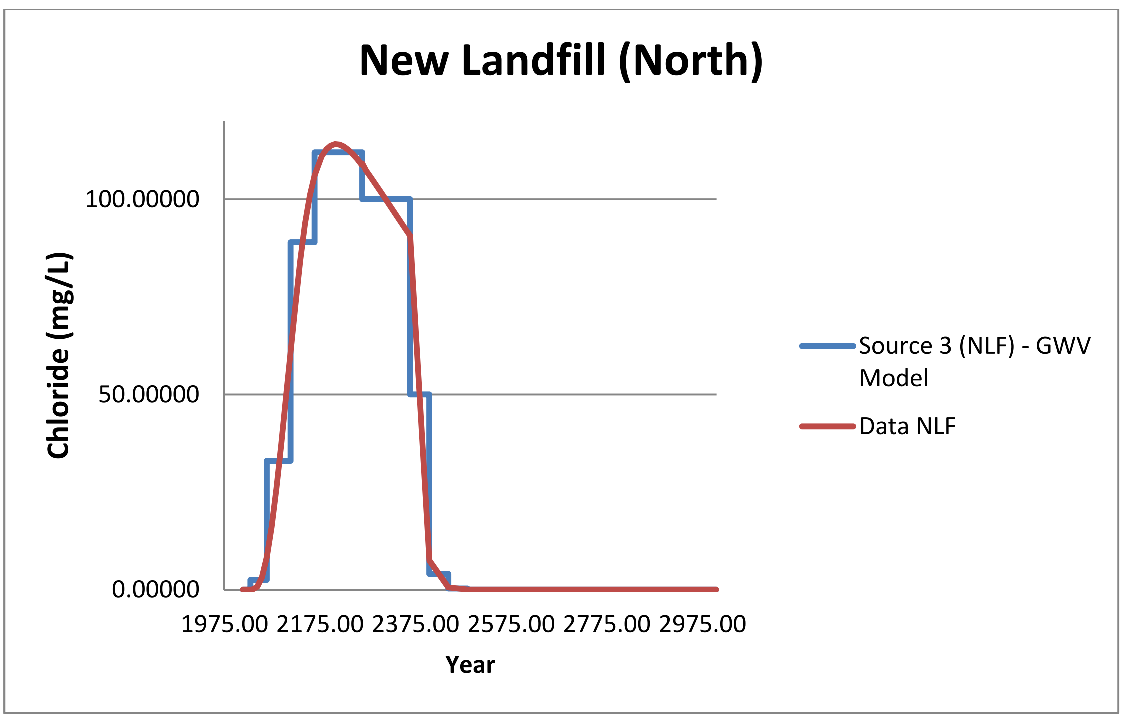

Figure 23: Chloride Source Curve for the Proposed New Landfill

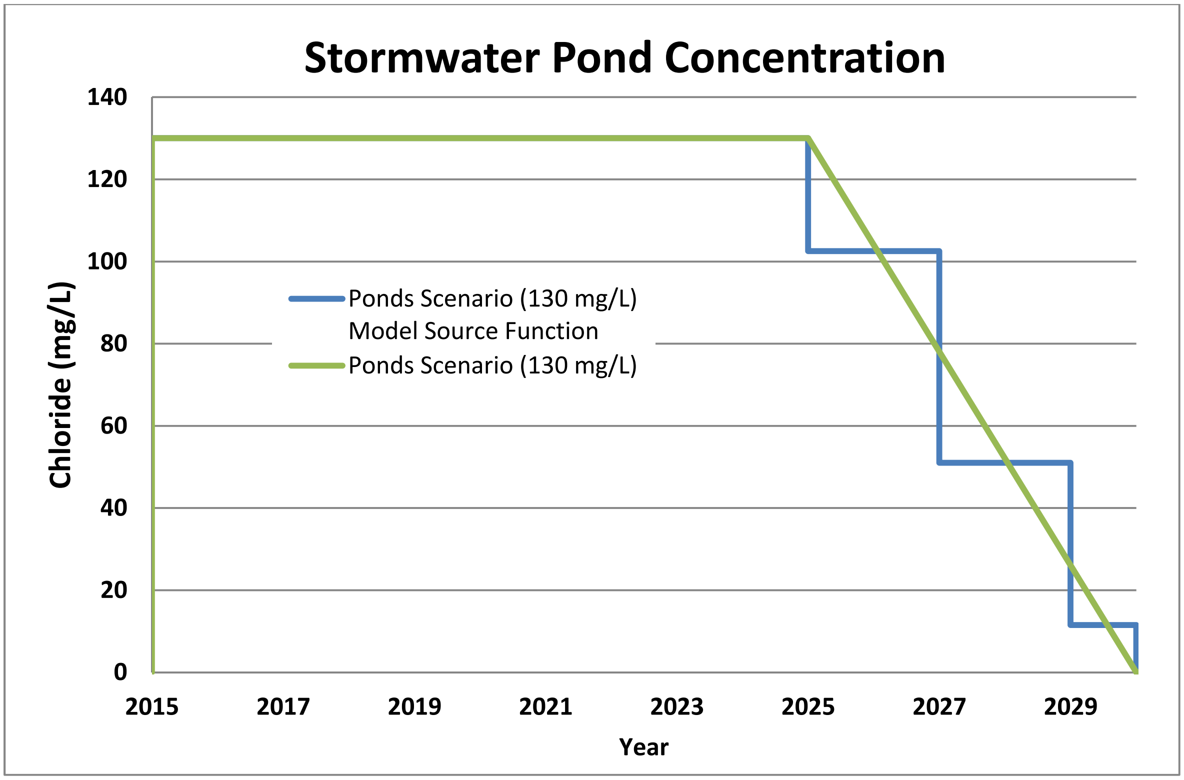

Figure 24: Chloride Source Curve for the Stormwater Management Ponds

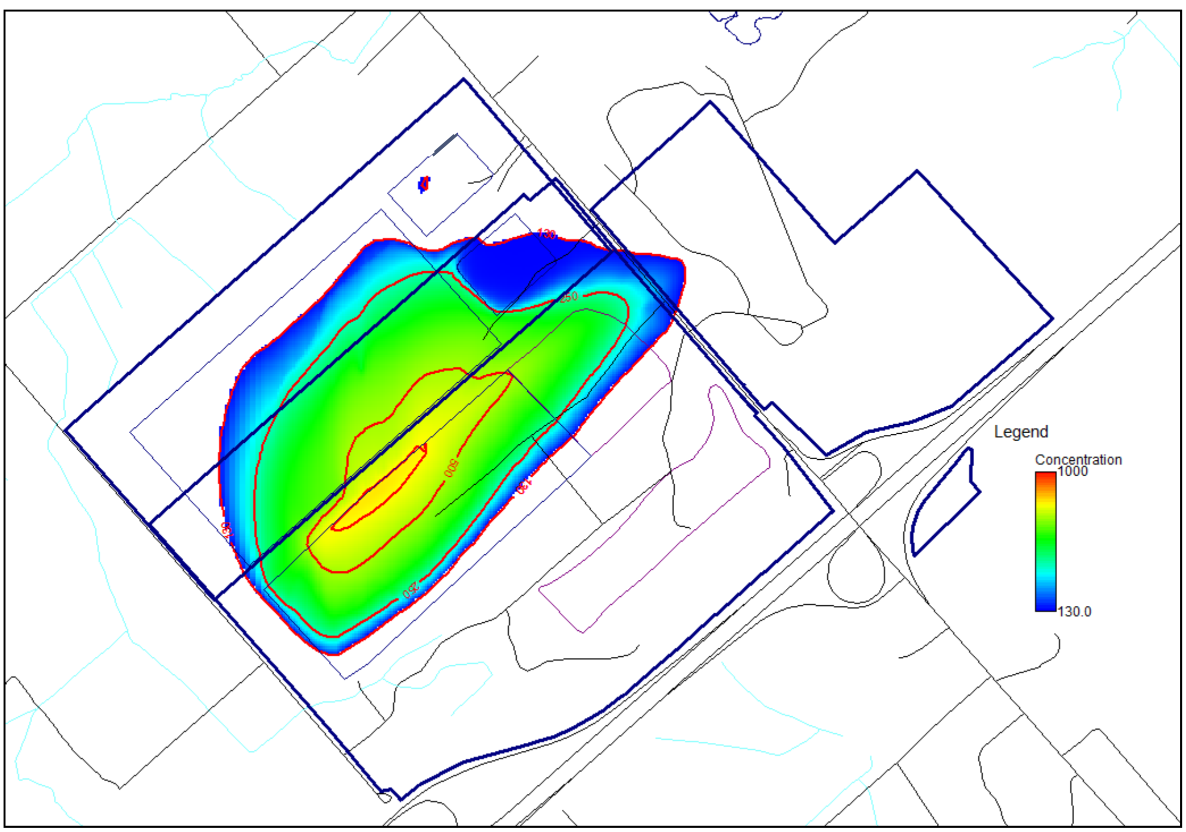

Figure 25: Maximum Simulated Concentration from Stormwater Ponds; Chloride Concentrations greater than 130 mg/L, Year 2025, Layer 3

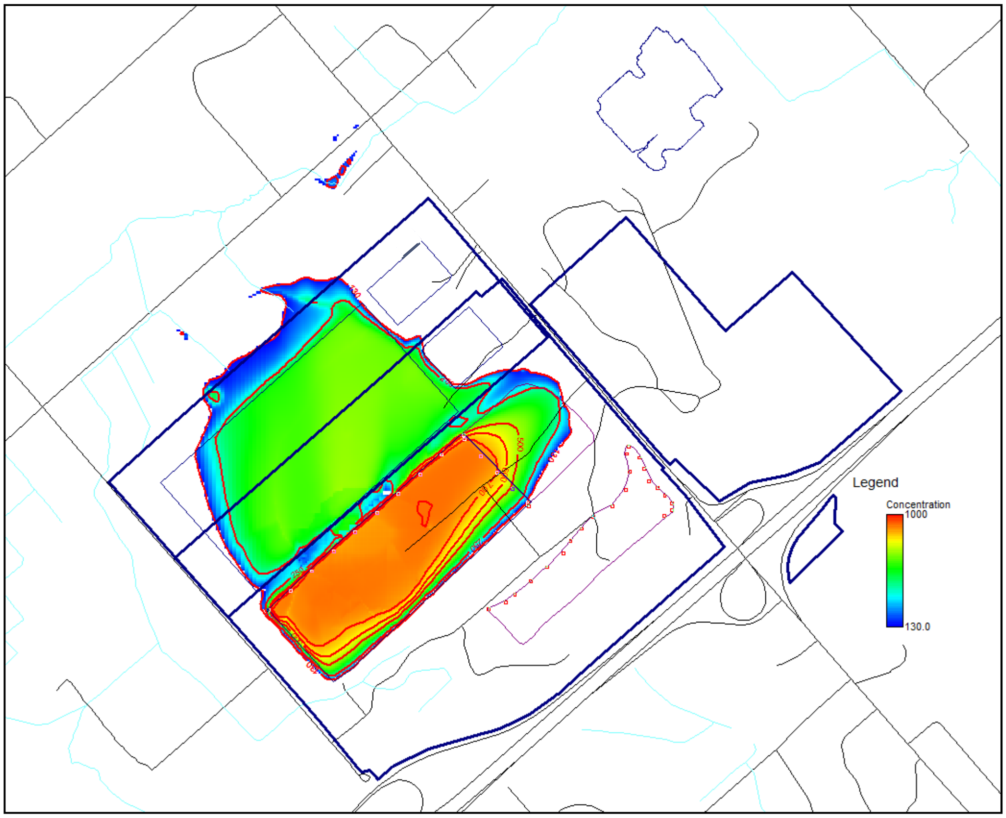

Figure 26: Maximum Simulated Concentration with New Landfill; Chloride Concentrations greater than 130 mg/L, Year 2107, Layer 1

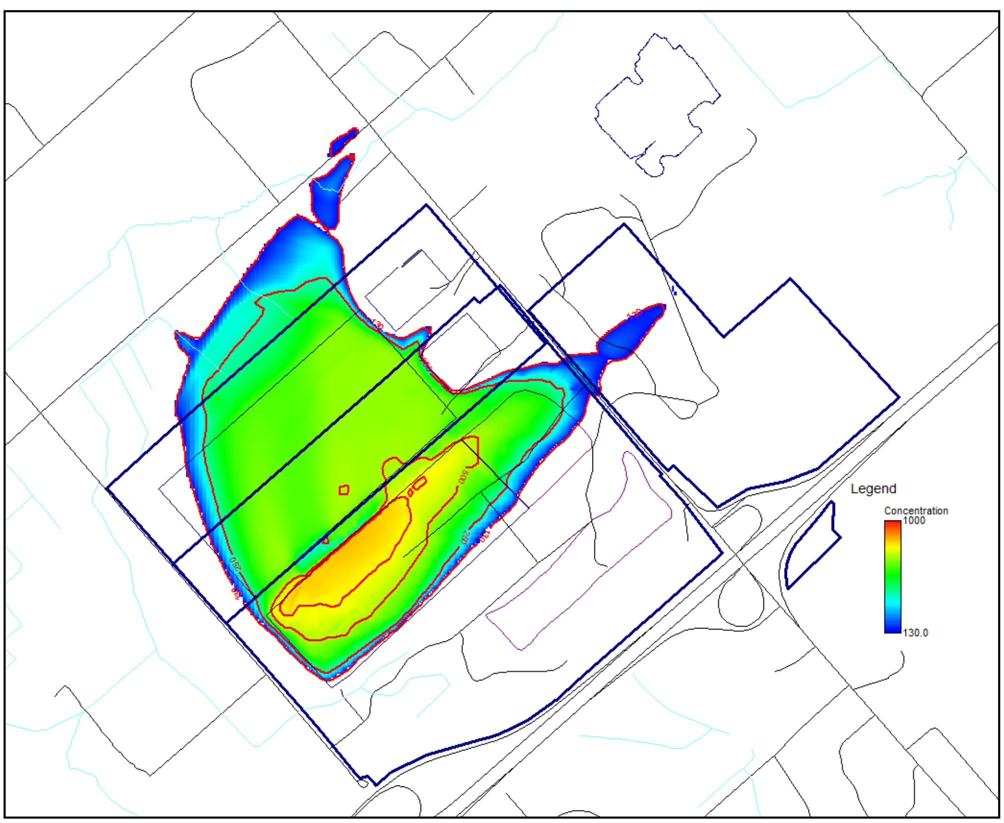

Figure 27: Maximum Simulated Concentration with New Landfill; Chloride Concentrations greater than 130 mg/L, Year 2107, Layer 2

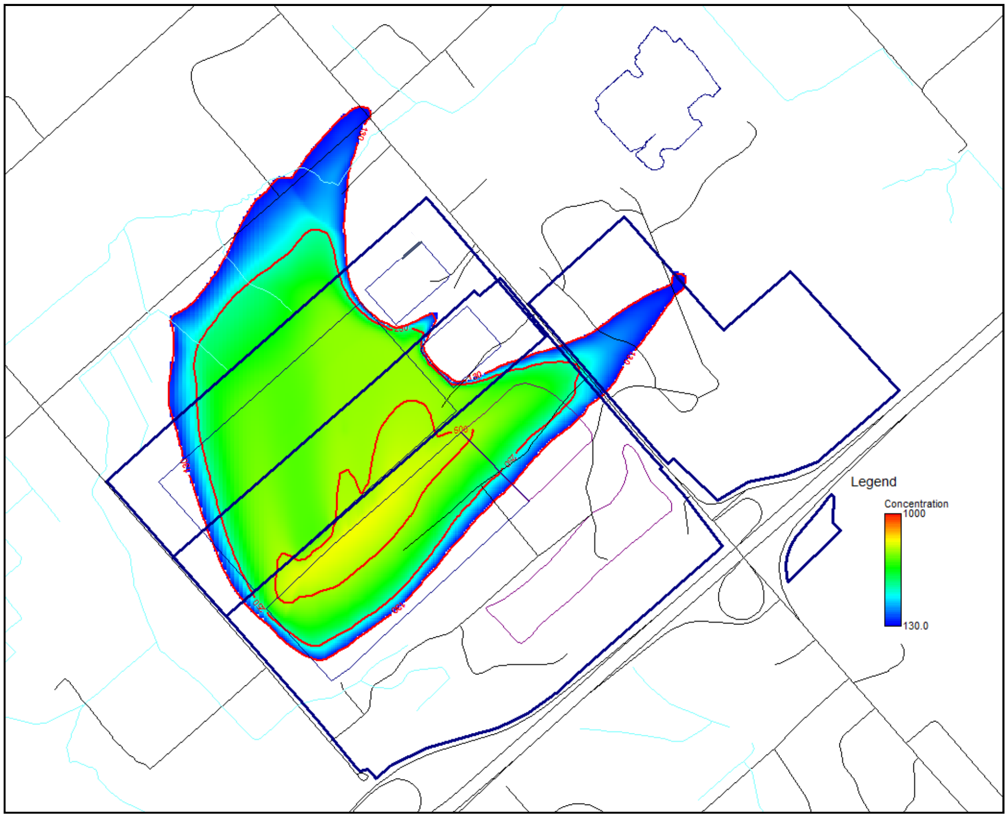

Figure 28: Maximum Simulated Concentration with New Landfill; Chloride Concentrations greater than 130 mg/L, Year 2107, Layer 3

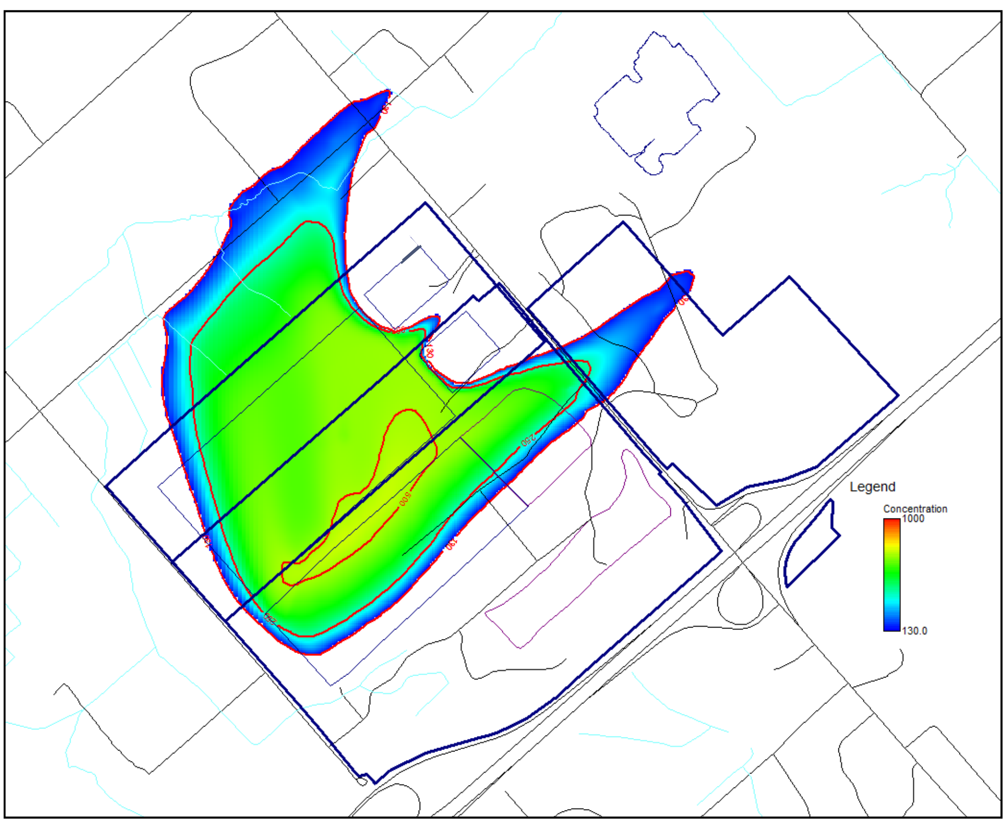

Figure 29: Maximum Simulated Concentration with New Landfill; Chloride Concentrations greater than 130 mg/L, Year 2107, Layer 4

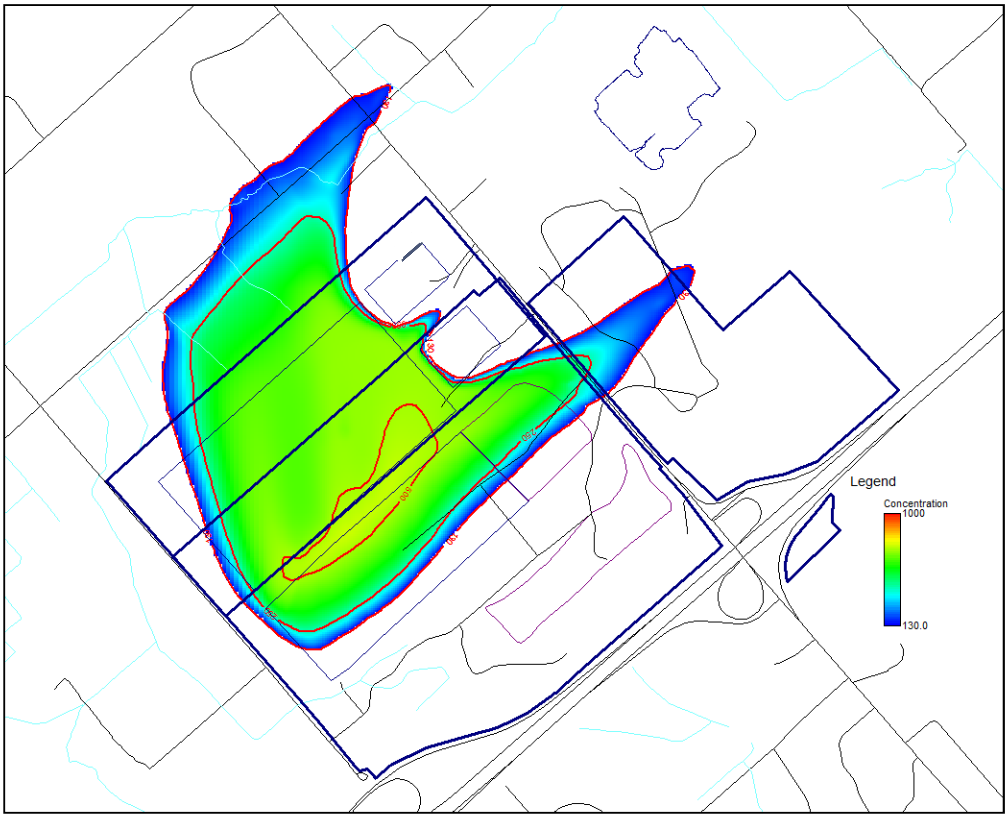

Figure 30: Maximum Simulated Concentration with New Landfill; Chloride Concentrations greater than 130 mg/L, Year 2107, Layer 5

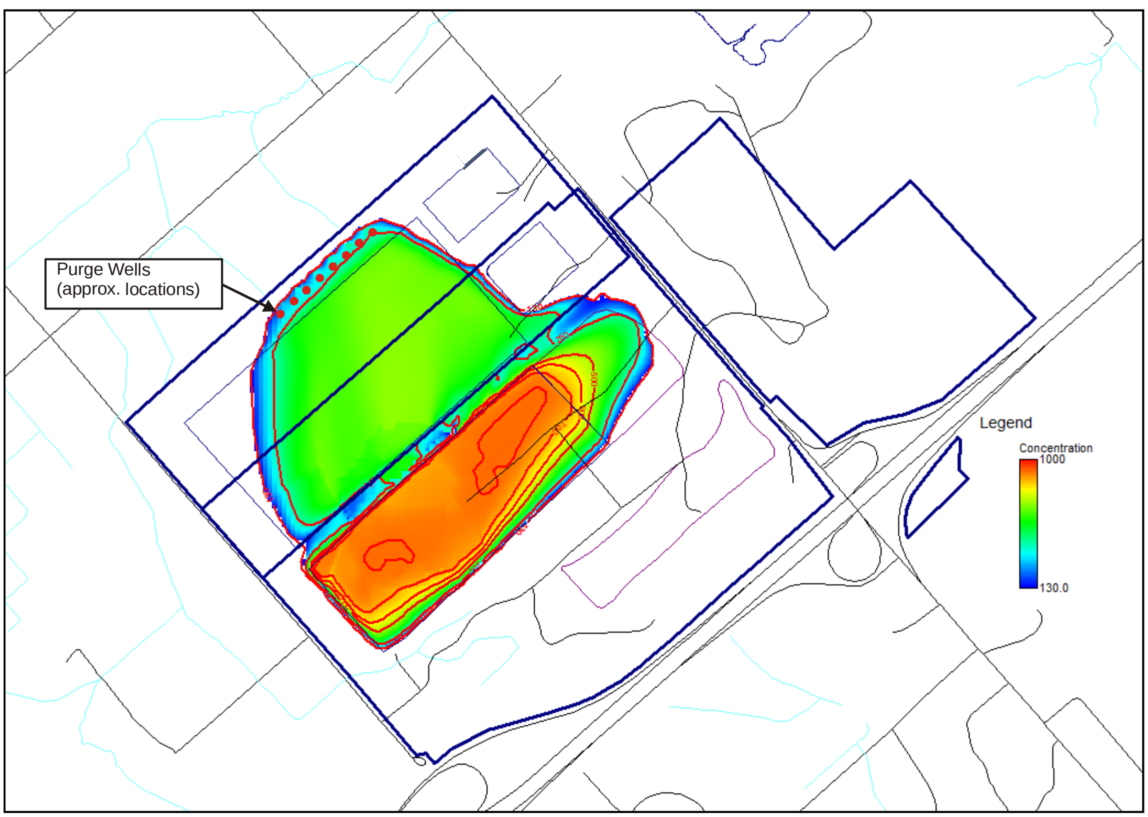

Figure 31: Maximum Simulated Concentration with New Landfill and Mitigative Measures; Chloride Concentrations greater than 130 mg/L, Year 2089, Layer 1

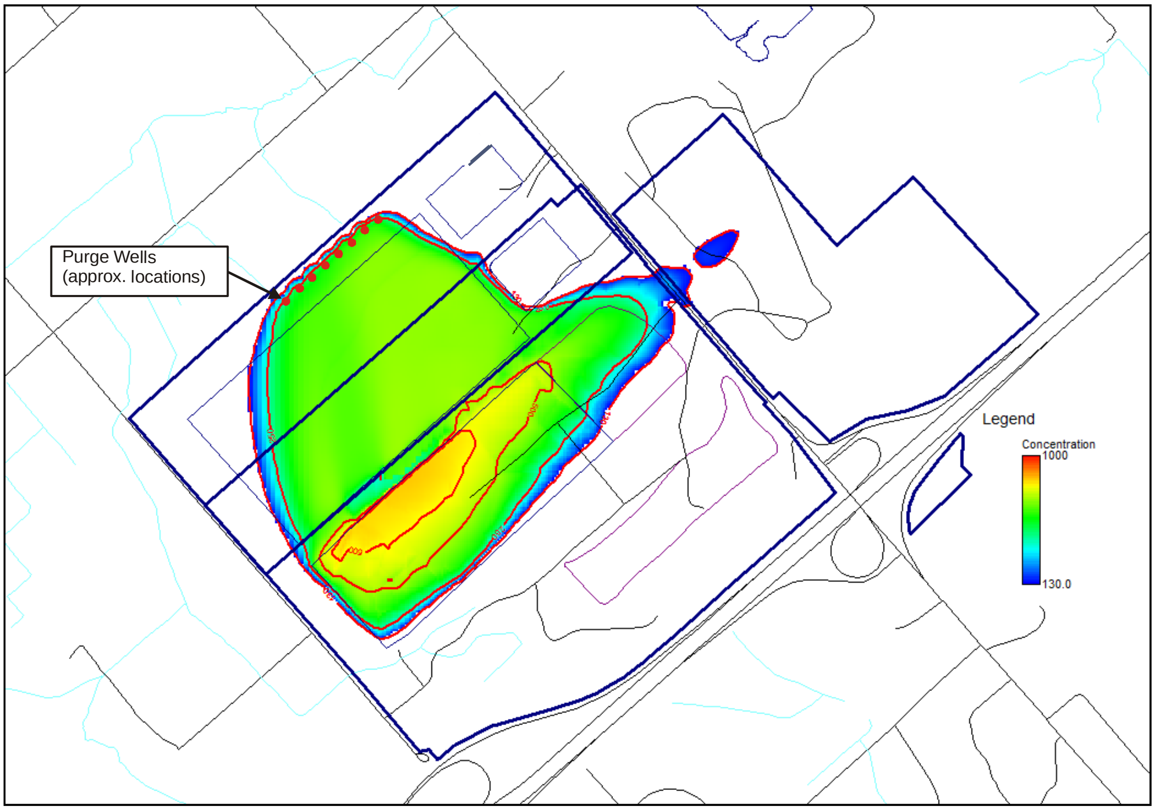

Figure 32: Maximum Simulated Concentration with New Landfill and Mitigative Measures; Chloride Concentrations greater than 130 mg/L, Year 2089, Layer 2

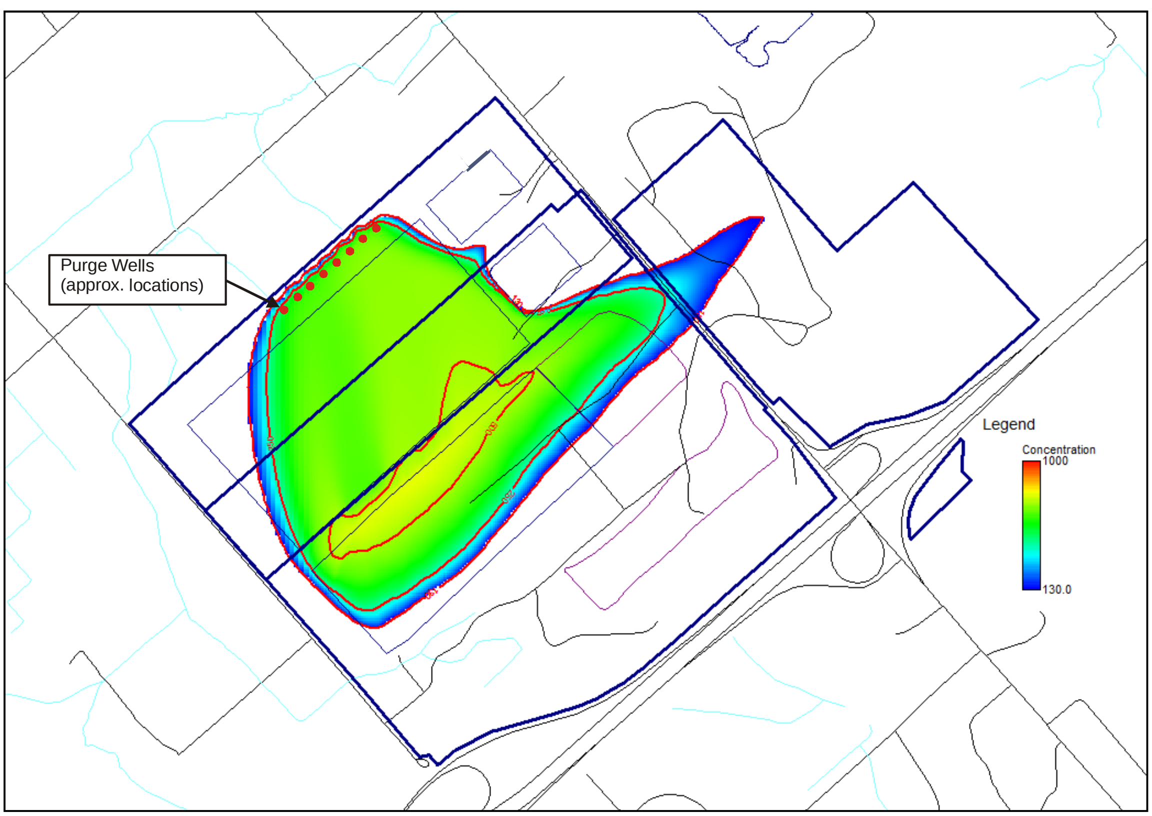

Figure 33: Maximum Simulated Concentration with New Landfill and Mitigative Measures; Chloride Concentrations greater than 130 mg/L, Year 2089, Layer 3

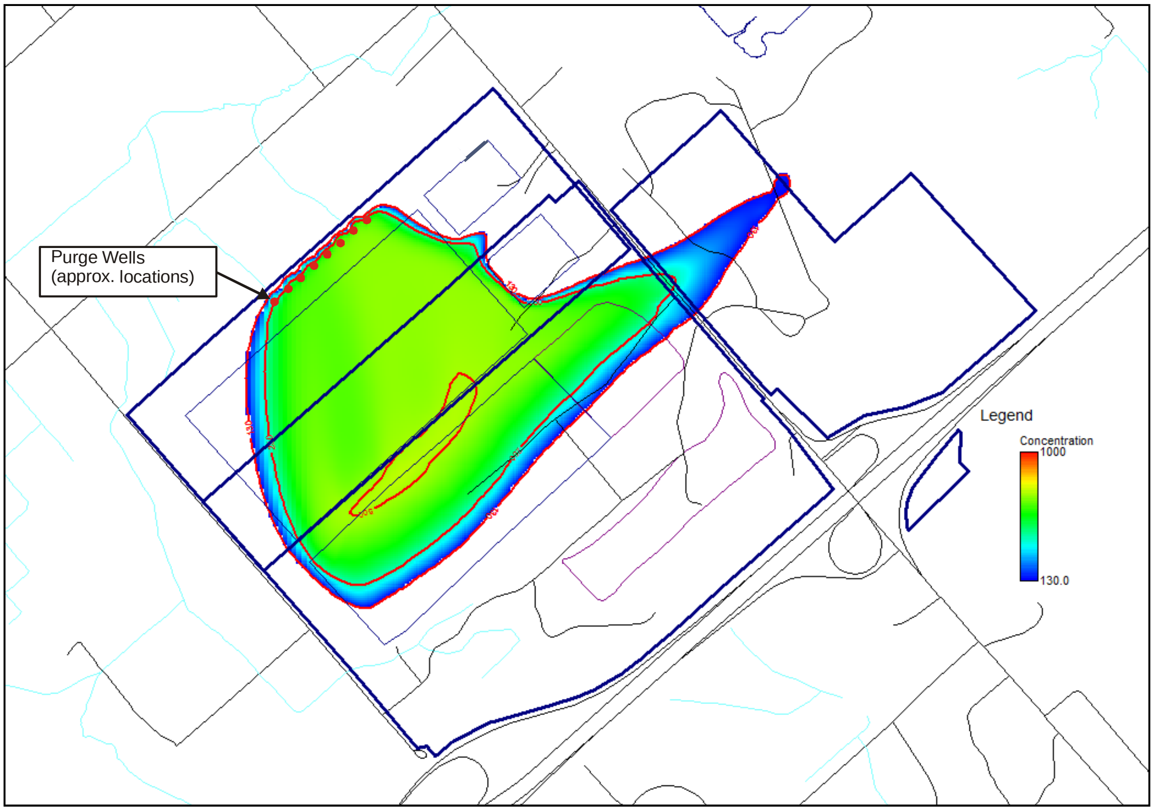

Figure 34: Maximum Simulated Concentration with New Landfill and Mitigative Measures; Chloride Concentrations greater than 130 mg/L, Year 2089, Layer 4

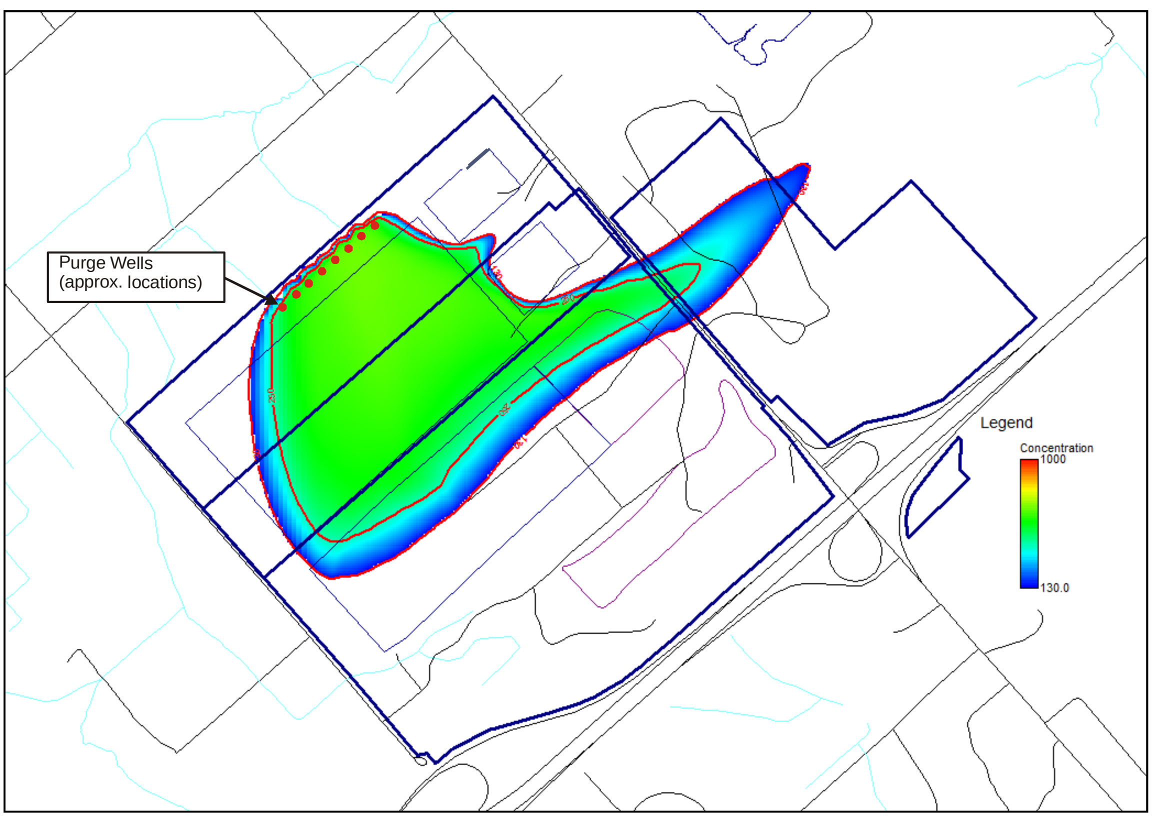

Figure 35: Maximum Simulated Concentration with New Landfill and Mitigative Measures; Chloride Concentrations greater than 130 mg/L, Year 2089, Layer 5