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MEMORANDUM

DATE: December 16, 2008
TO: Christopher Prucha (WM)
C.C:
FROM: François Richard (WESA)
PROJECT #: K-B5691-6
SUBJECT: **WM Richmond Landfill: Regional Geology and Structural Trends**

MESSAGE:

Chris:

During a recent meeting held at the MOE District office in Kingston on November 25, 2008, MOE hydrogeologist Kyle Stephenson requested additional information about the regional geologic setting at the Richmond Landfill site, specifically faulting and other significant structural features that potentially influence groundwater occurrence and flow. This document presents a brief description of the regional physiography, topography and drainage patterns observed in the area, as well as a general description of the bedrock geology based on previous studies[1,2] and an overview of fault controlled linear features observed from aerial photographs.

Physiography, Topography and Drainage

The Richmond Landfill is located within the Napanee Plain, a flat to undulating plain of limestone covered by thin to absent overburden. The topography of the immediate study area is relatively flat, generally with a slope of less than 0.5% towards the south (see Figure 1). The Salmon and Napanee Rivers provide the greatest relief in the region and form valleys in the bedrock to a depth of 15 to 30 m in places. Overburden throughout much of the Napanee area is generally thin (less than 2 m) to absent. The flat nature of the ground surface is interrupted by drumlins which are present throughout the area; their typically oblong shape can be clearly distinguished on the regional topographic map (Figure 1). One such drumlin forms Empey Hill, in the southwest portion of the site, with a local relief of approximately 15 m. Glacial striae and drumlin orientations indicate the major glacial ice movement was from the northeast trending between approximately 210 north of the site, to 240 degrees between the site and Bay of Quinte (Lake Ontario).

The drainage of the area is controlled by topographic expressions. A topographic divide is located approximately 100 m north of Selby Road (County Rd. 11) near the Salmon River. The Salmon

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[1] Dillon, 2004: *Quinte Regional Groundwater Study.*
[2] WESA, 2004: *Detailed Background Report to Discussion Paper #5, Part A, Hydrogeology Baseline Conditions. Richmond Landfill Expansion Environmental Assessment.*

River follows the topographic expression of the Salmon River fault, and runs in a steep-sided valley about 2.3 km north of the site. This valley is the most significant topographic feature in the study area. Drainage north of a topographic divide near the Salmon River generally flows to the Salmon River catchment while drainage south of this divide is generally controlled by the Napanee River catchment system. Figure 2 provides an overview of local surface water drainage patterns superimposed on an aerial photograph (circa approx. 1995). Secondary surface water bodies shown at this scale are generally parallel to the Salmon and Napanee Rivers and also flow from northeast to southwest.

Regional Bedrock Geology

Bedrock in the area consists of Middle Ordovician limestone of the Simcoe Group, with strata generally dipping slightly to the South at approximately 1 to 3 m per km. Exceptions to this occur where localized highs in the Precambrian basement have produced doming of the Paleozoic strata and anomalously high localized angles of dip. A Precambrian inlier is present near the Salmon River approximately 2.5 km north of the landfill site (Figure 3). A map of the regional bedrock geology, showing major rock types and significant regional faults (Map 3.1 from Dillon (2004)) is provided with this document.

The Simcoe Group is subdivided into the following Formations from youngest to oldest: <u>Verulam Formation</u>: this unit consists of pale to dark brown to grey, medium to coarse crystalline bioclastic limestone in beds ranging from 4 to 8 cm thick interbedded with shale layers of subequal thickness. The Verulam Formation is underlain by the Upper and Lower Members of the <u>Bobcaygeon Formation</u>. The upper member of the formation includes medium to dark grey and brown, thinly bedded finely crystalline to sublithographic limestone that weathers pale to medium grey and brown. Bioclastic limestone and shale also occur in the upper member and increase in abundance toward the top of the formation. The Lower Bobcaygeon consists of pale to dark brown and grey crystalline limestone interbedded with calcarenite. The crystalline limestone is predominantly fine to medium grained, but locally sublithographic limestone may be present. The rocks of the Lower Member are generally thin to medium bedded and locally massive. Common fossils include brachiopods and crinoids. The <u>Gull River Formation</u> underlies the Bobcaygeon and consists of pale to dark brown or pale to medium grey lithographic to sublithographic limestone that weathers pale to medium grey or brown. The formation is generally thick bedded to massive, but locally may weather to thinner beds. The <u>Shadow Lake Formation</u> is a basal member and consists of light to dark red shale, siltstone and sandstone; its strata are generally thick bedded but weather into thin rubbly and recessive beds. Undifferentiated metamorphic and igneous <u>Precambrian bedrock</u> is found beneath the Shadow Lake Formation in the area.

The Salmon and Napanee Rivers follow the topographic expressions of normal faults having displacements of approximately 30 m. One of the best exposures of the limestone in the area can be found approximately 2.3 km north of the site in a road cut that descends downward to the Salmon River Fault.

Regional Structural Features

The Study Area has undergone alternating periods of crustal extension and shortening since the Precambrian era, resulting in the development of faults and fractures. Some of these faults have not been active since their original formation in Precambrian times, while others have been reactivated from time to time (Dillon, 2004). The stresses and strains on the bedrock have resulted in the development of fracturing or jointing networks in the rock. The extent and spacing of the fractures depend upon the nature of the rock material. In general, vertical fracturing is more common in Precambrian rock than in limestone; however, horizontal fracturing along bedding planes is more prevalent in sedimentary rock. These fracture patterns often exert a strong influence on other geological processes. For example, chemical weathering tends to be concentrated along joints. Moreover, a system of joints can influence the direction of stream courses.

The major faults that cross the Study Area are shown in Map 3.1 from Dillon (2004), see attached. The faults in the southern part of the Study Area are attributed to the formation of the Atlantic Ocean 170 million years ago during Jurassic time. Many of these faults may follow along older faults that occurred during Paleozoic or Precambrian times. The southern reaches of the Salmon River follow the course of a normal fault, where the west side has been displaced downwards by approximately 30 m.

Site Bedrock Geology

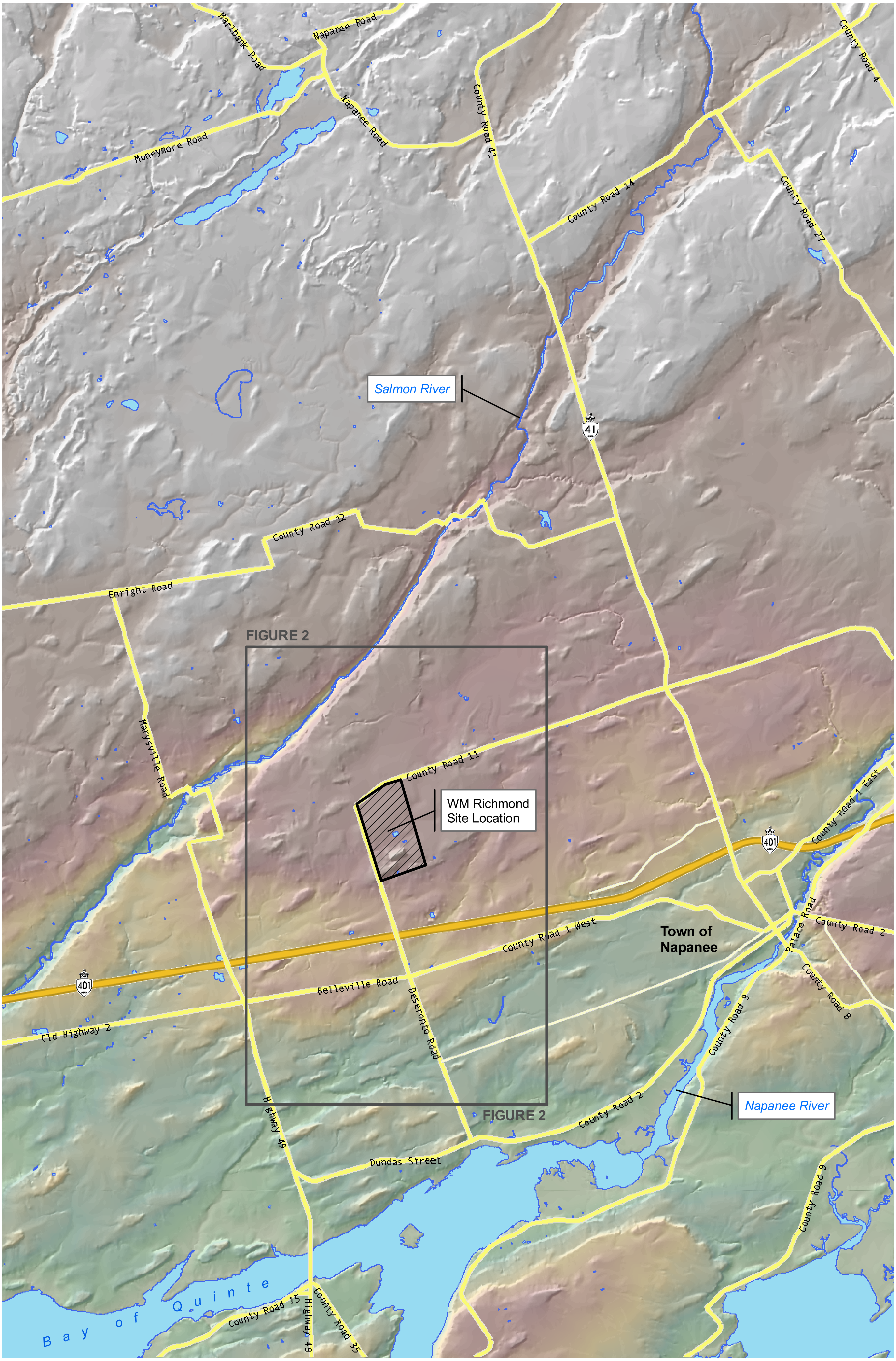
The Richmond Landfill site is underlain by limestone of the Simcoe Group, including (from youngest to oldest) the following Formations: Verulam, Bobcaygeon (Upper and Lower Members), Gull River and Shadow Lake. While the total thickness of the Verulam Formation is estimated at approximately 90 m, only 2 m was encountered in drilling beneath the Richmond site. The total thickness of the Bobcaygeon Formation beneath the site is estimated at between 11 and 15 m, while the thickness of the Gull River beneath the site is estimated at approximately 75 m. The Shadow Lake Formation was encountered in one of the deep boreholes at the site (M69-1). Based on the depth to this unit, the total thickness of the paleozoic limestone beds in the immediate vicinity of the site is on the order of 90 m.

The results of bedrock coring at several locations at the site to a maximum depth of about 60 m indicates that bedrock fracturing consists predominantly of bedding plane joints. Many of the fractures observed in the rock core were infilled with calcite indicating some degree of water transport in the past. Fracturing becomes greatly diminished in frequency below a depth of approximately 10 m, where the bedrock is relatively massive, with the exception of a vertical to subvertical joint system which has likely developed in response to the faulting history of the area. Observations of outcrop along the Salmon River section suggest the spacing of these sub-vertical jointing is on the order of 10’s of metres.

The jointing system appears to consist predominantly of two sets of joints oriented at approximately 75 degrees to one another – a primary joint system oriented at 210 degrees (parallel to the Salmon and Napanee Rivers) and a secondary one at about 285 degrees. These joint systems do not appear to correlate with bedding dip or strike, but appear related to normal faulting in the area. The Richmond landfill site is located between two normal faults; the Salmon River and Napanee River faults

Closing Remarks

We trust that the information provided in this document is sufficient to provide an overview of the geological and structural setting at the Richmond Landfill site and vicinity. Please do not hesitate to contact me should you require any additional information.



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RICHMOND LANDFILL

Figure 1:
Regional Topography

LEGEND

Water bodies

Topography (m)

High : 180

Low : 50

Project : K-B5691-6
Data Source: WM Canada, WESA, HPA Ltd. OMNR
Date: December 11, 2008

0 250 500 1,000 1,500 2,000
Meters

Prepared by:
WESA Geomatics

Units:
UTM NAD 83 Zone 18

Scale: 1:85 000

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Figure 2:
Aerial Photo and Drainage Features

LEGEND

Water bodies

Streams

Project : K-B5691-6
Data Source: WM Canada, WESA, HPA Ltd. OMNR
Date: December 11, 2008

0 75 150 300 450 600
Meters

Prepared by:
WESA Geomatics

Units:
UTM NAD 83 Zone 18

Scale: 1:30 000

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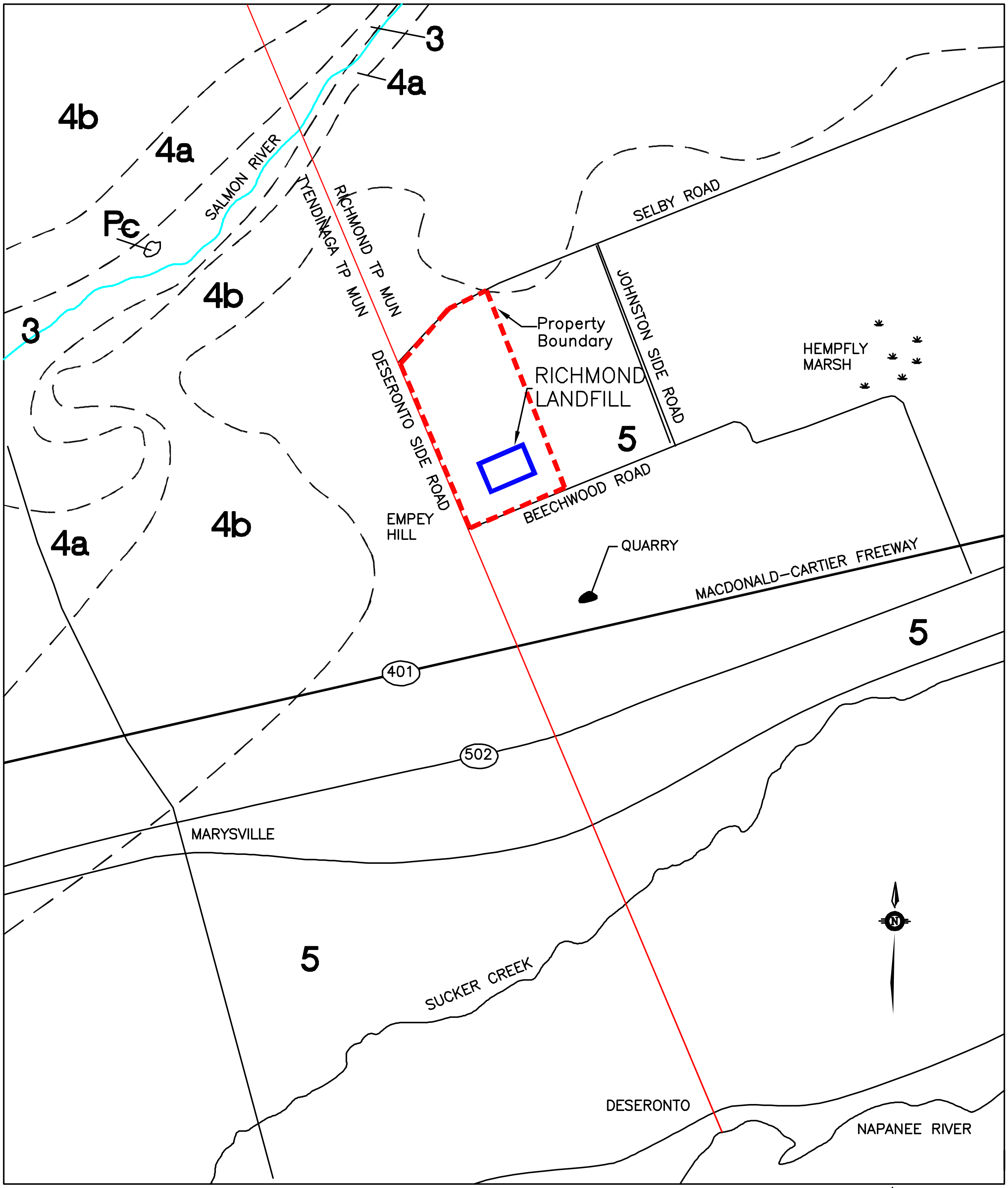

5	VERULAM FORMATION – Interbedded limestone and shale
4b	BOBCAYGEON FORMATION (Upper Member) – Crystalline and bioclastic limestone
4a	BOBCAYGEON FORMATION (Lower Member) – Crystalline limestone and calcarenite
3	GULL RIVER FORMATION – Lithographic and sublithographic limestone
Pє	PRECAMBRIAN ROCK (Undifferentiated)
— — —	GEOLOGICAL CONTACT (Inferred)

PROJECT NO. A756	DRAWN BY: CMR/BJL	DESIGNED BY: BOC
DATE: MAR 24/99	CHECKED BY: BOC	
SCALE: 1:50,000 (APPROX)	CAD FILE NO. A756-RGM	

FIGURE: 3

REGIONAL GEOLOGY MAP

RICHMOND LANDFILL, NAPANEE, ON

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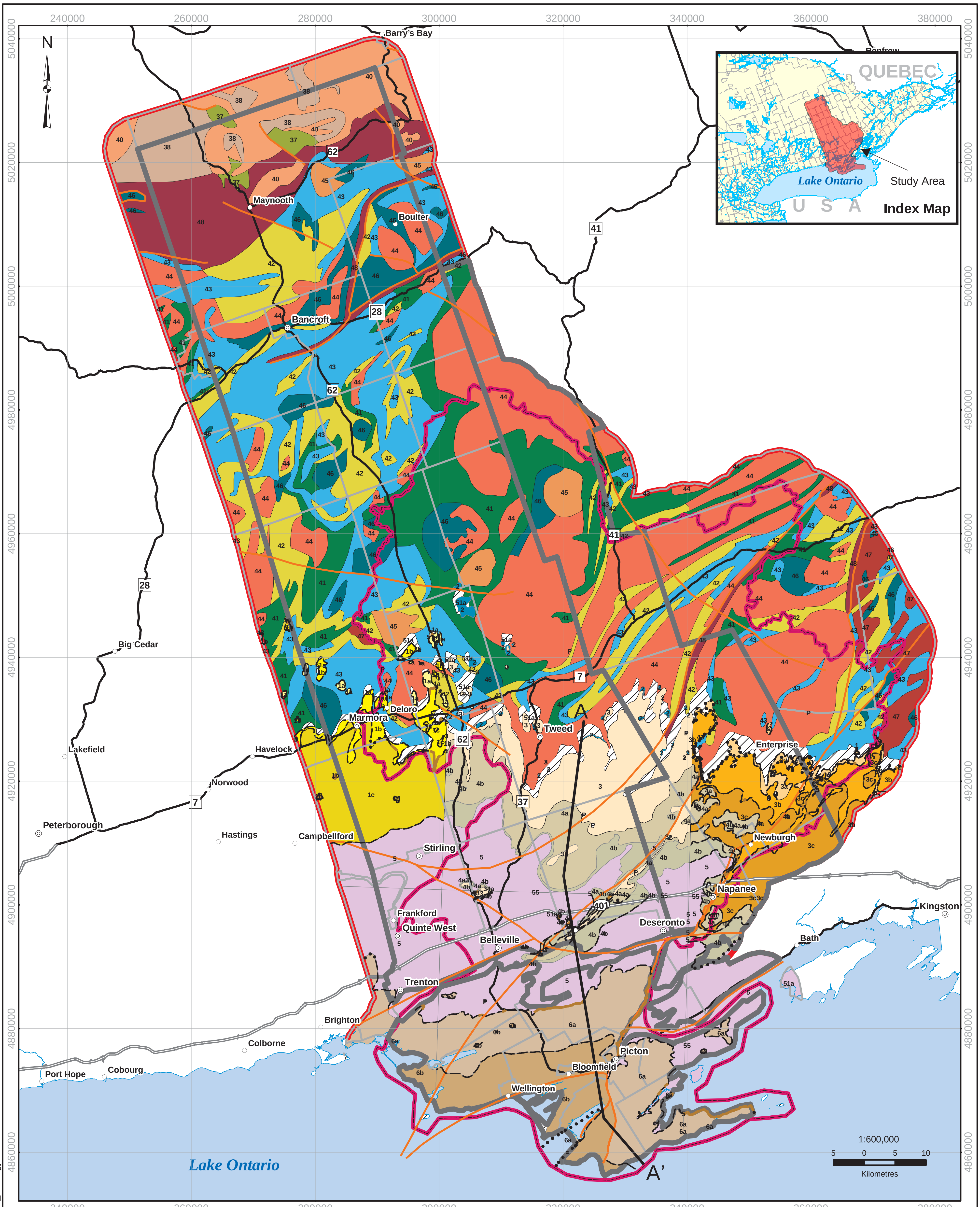

UTM Zone 18, NAD 83

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Digital Mapping Sources:
Base Mapping Features - CANMAP v5.0,
Prince Edward Municipal Mapping, MOE NRVIS data,
Various MNDM and GSC Maps

Disclaimer: The information conveyed by this map is regional in nature and is not suitable for use in site specific evaluations. The map should only by interpreted in conjunction with the accompanying written report.

Date: August 2004

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Agricultural Watersheds Associates

Legend

- Major Population Centres
- Communities
- Expressways
- Highways
- Counties
- Municipalities
- Study Area Boundary
- Fault - Approximate Location
- Geological Boundary - position approximate
- Geological Boundary - position interpreted
- Geological Boundary - observed
- Quinte Conservation Watershed
- Lakes
- Section Line

1: 50 000 Paleozoic Geology

- 1 Potsdam Formation: evenly textured sandstone
- 1a Shadow Lake Formation: red and green arkosic sandstone, siltstone and shale
- 1b Gull River Formation: pale grey and brown sublithographic to litographic limestone: minor dolostone
- 1c Bobcaygeon Formation: Bioclastic limestone, nodular limestone
- 1d Verulam Formation: interbedded limestone and shale
- 2 Shadow Lake Formation: arkosic sandstone, siltstone, and shale
- 3 Gull River Formation: lithographic to sublithographic limestone
- 3a Gull River Formation (lower member): brown lithographic to finely crystalline limestone
- 3b Gull River Formation (middle member): buff and green siltstone, dolomitic siltstone, and brown, lithographic limestone
- 3c Gull River Formation (upper member): brown, lithographic and sublithographic limestone
- 4a Bobcaygeon Formation (lower member): crystalline limestone and calcerenite
- 4b Bobcaygeon Formation (upper member): crystalline limestone and calcarenite
- 5 Verulam Formation: interbedded limestone and shale
- 6a Lindsay Formation (lower member): crystalline limestone with shaly partings
- 6b Lindsay Formation (upper member): nodular limestone and shale

1 : 250 000 Precambrian Geology

- 37 Mafic rocks
- 38 Migmatitic rocks and gneisses of uncertain protolith
- 40 Felsic igneous rocks
- 41 Mafic to felsic metavolcanic rocks
- 42 Clastic metasedimentary rocks
- 43 Carbonate metasedimentary rocks
- 44 Early felsic plutonic rocks
- 45 Alkalic plutonic rocks
- 46 Mafic to ultramafic plutonic rocks
- 47 Late felsic plutonic rocks
- 48 Tectonite unit
- 51a Unknown, data not reconciled between different map scales

Generalized Bedrock Geology
Quinte Regional Groundwater Study

Map 3.1