December 2014

ENVIRONMENTAL ASSESSMENT OF THE PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

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Geology, Hydrogeology and Geotechnical Report

VOLUME IV

Design and Operations Reports

December 2014

VOLUME III

Geology, Hydrogeology and Geotechnical Report
Capital Region Resource Recovery Centre

REPORT

Report Number: 12-1125-0045/4500/vol III

Executive Summary

This report summarizes the results of the subsurface investigation, hydrogeological assessment and geotechnical assessment of the Capital Region Resource Recovery Centre Site (Site) to provide an evaluation of the use of the Site for the proposed diversion facilities and associated landfill for disposal of residual wastes. The Site is located on the east side of Boundary Road, just southeast of the Highway 417/Boundary Road interchange, on Lots 22 through 25, Concession XI, in the former Township of Cumberland (now part of the City of Ottawa). The property is east of an existing industrial park, north of Devine Road and west of Frontier Road and totals approximately 192 hectares (475 acres) in area.

A subsurface investigation was completed to characterize the overburden and bedrock beneath the Site, and to gather the necessary data to complete the required hydrogeological and geotechnical assessments. The field program involved the drilling of at least one, and as many as seven, boreholes at 25 investigation locations across the Site. The activities undertaken as part of the subsurface investigation included the following:

- Cone Penetration Testing at all 25 investigation locations;
- Deep borehole drilling program at seven investigation locations and a shallow borehole drilling program at 18 investigation locations;
- Detailed geological logging of continuous (direct push) overburden and bedrock samples collected during the borehole drilling program;
- Geotechnical laboratory testing on selected samples collected during the borehole drilling program;
- Installation of 66 monitoring wells within selected on-Site boreholes to allow for the measurement of groundwater levels, horizontal hydraulic conductivity testing, and to allow for the collection of groundwater samples;
- Groundwater level monitoring program to provide information on hydraulic gradients and the groundwater flow direction(s) at the Site;
- A groundwater and surface water sampling program to establish background water quality in the vicinity of the Site; and,
- Vertical seismic profile data was collected at two locations to calculate a detailed vertical seismic velocity profile of the subsurface at the Site.

Based on the results of the subsurface investigation, the subsurface conditions across the Site consist of about 0.05 to 0.3 metres of topsoil/peat underlain by about 0.3 to 2.7 metres of surficial sand and silt, overlying between about 26 to 37 metres of silty clay. The upper 0.1 to 1.3 metres of the clay deposit at most locations has been weathered to a red brown crust and has a stiff consistency. Within the upper portion of the underlying unweathered silty clay, at a depth of about 4 to 6 metres below ground surface, a 0.1-metre to 0.6-metre thick continuous silty layer was identified in all boreholes completed at the Site. The unweathered silty clay generally has a soft consistency to about 9 to 10 metres depth, followed by a firm consistency to about 15 to 18 metres depth, and is stiff to very stiff below that. The silty clay is underlain by loose to very dense glacial till that ranges from about 2 to 9 metres in thickness. The bedrock surface (Carlsbad Formation limestone and shale) was encountered beneath the glacial till deposit at depths between about 33 and 41 metres.

Laboratory permeability tests were conducted on three Shelby tube samples to provide information on the vertical hydraulic conductivity of the silty clay at the Site. The laboratory results of the hydraulic conductivity testing indicate the silty clay at the Site has a consistently low permeability at the various depths sampled (i.e., less than 1 x 10^{-9} metres per second). Assuming the silty clay has a horizontal to vertical anisotropy of 10:1, the horizontal hydraulic conductivity of the formation ranges from 7 x 10^{-9} m/sec to 2 x 10^{-8} m/sec (low permeability).

Based on the results of the *in-situ* hydraulic conductivity testing completed at the Site, the following ranges in horizontal hydraulic conductivities were observed in the following overburden and upper bedrock formations:

- Surficial silty sand: 9 x 10^{-8} m/sec to 2 x 10^{-5} m/sec (moderate hydraulic conductivity);
- Silty layer within shallow clay: 3 x 10^{-8} m/sec to 3 x 10^{-6} m/sec (moderate hydraulic conductivity);
- Glacial till: 8 x 10^{-9} m/sec to 2 x 10^{-4} m/sec (variably low to high hydraulic conductivity); and,
- Upper bedrock: 2 x 10^{-8} m/sec to 2 x 10^{-5} m/sec (low to moderate hydraulic conductivity).

The average horizontal gradients for the formations monitored at the Site are very low and ranged between 0.0006 and 0.0008, and the range in average linear groundwater velocity for the formations were: <0.01 to 1.8 metres per year for the surficial silty sand, <0.01 to 0.2 metres per year in the shallow clay with silty layer, <0.01 metres per year in the silty clay, <0.01 to 9 metres per year in the glacial till, and <0.01 to 4.4 metres per year in the upper bedrock zone.

Within the vicinity of the Site, the shallow groundwater flow within the surficial silty sand layer is influenced by local topography and the position of local surface water features, and is interpreted to be primarily horizontal. Within the marine clay deposits (at surface and at depth), there is minimal groundwater flow, and the groundwater flow direction is typically vertical. Based on the groundwater levels measured at the Site, the interpreted groundwater flow direction within the surficial silty sand, silty layer in the silty clay, silty clay, glacial till and upper bedrock zone is consistently towards the east or northeast. Based on the monthly and daily groundwater elevation data collected at the Site, vertical gradients are typically downward (recharge conditions) or absent between the surficial silty sand, the silty layer, silty clay, glacial till and upper bedrock formations at most monitoring locations.

Most residents/businesses in the vicinity of the Site use shallow dug wells to provide their water supply. Based on the results of a dug well assessment and testing program completed at two dug wells on the Site it was shown that: the dug wells obtain water primarily from the surficial silty sand layer; they are recharged locally (i.e., from silty sand close to the well); they can sustain a pumping rate of approximately four Litres per minute; and, under typical use, dug wells have a very localized radius of influence of less than 10 metres.

A groundwater and surface water quality monitoring program was undertaken to establish background water quality in the vicinity of the Site. Three rounds of samples were taken from monitoring wells completed in the overburden formations and upper bedrock at the Site. Groundwater samples were also collected from three dug wells in the vicinity of the Site. Based on the available information, groundwater quality at the Site varies from fresh to brackish and deteriorates with depth. The results of the water supply (dug wells) sampling program indicates that most parameters analyzed met their respective Ontario Drinking Water Quality Standards.

The surface water sampling program involved monitoring water quality from a total of nine surface water locations. Six of the surface water locations are situated within the Site, and three surface water stations are located east and downgradient of the Site. The surface water monitoring program included up to five sampling events completed on a seasonal basis between December 2012 and December 2013. The results of the background surface water quality sampling indicate that dissolved oxygen, total phosphorus and iron were the parameters found to typically exceed their respective Provincial Water Quality Objectives.

Structurally, the Site is located near the southeast end of the Ottawa-Bonnechere graben. The Ottawa-Bonnechere graben extends for approximately 700 kilometres into the Canadian Shield from the Sutton Mountains salient of the central Appalachian orogeny. The graben extends eastward beneath the Appalachian thrust sheets for approximately 30 kilometres. The Ottawa-Bonnechere graben is within the larger Western Quebec Seismic Zone.

The results of the geological evaluation have confirmed that the primary fault feature within the Local Study area is the Gloucester and Russell-Rigaud Fault system. The Gloucester Fault is comprised of a series of normal fault slices locally projected to occur within a zone approximately 0.75 kilometres in width where it passes beneath the community of Russell. The combined vertical offset associated with this fault zone is approximately 500 metres downward on the north side, which can be seen by the projected offset of the Oxford/March Formations across the fault zone. Small scale secondary faults associated with offsets in the range of several metres to several tens of metres are comparatively common throughout the Ottawa Valley, occurring within the intervening areas between primary faults.

An assessment of the potential for fault rupture at the Site was undertaken. Fault rupture at the ground surface is a potential geological hazard because the surface fault rupture causes localized differential displacements that can adversely affect engineered structures and facilities. A key layer for the evaluation of the potential for past surface fault rupture at this Site is the 0.1-metre to 0.6-metre thick silty layer about 4 to 6 metres below ground surface. This marker bed within the upper part of the silty clay deposit is sub-horizontal and reasonably interpreted to be continuous across the Site. The largely consistent elevation and lateral continuity indicates that this layer has not been offset in any significant way by vertical fault displacements at the CRRRC Site. It was reasonably concluded that there has been no surface fault rupture at the CRRRC Site since at least the deposition of the silty layer (i.e., in the past 8,000 to 10,000 years), and that the probability of future fault movement resulting in large differential displacements at the surface or shallow subsurface at or in the vicinity of the CRRRC Site is negligible.

Using the information gathered during the subsurface investigation, a geotechnical assessment of the proposed Site design was undertaken. The assessment focused on the landfill geometry and performance. The assessment included a seismic assessment, stability analyses and settlement analyses. The seismic assessment included dynamic analyses to investigate the seismic stability of the proposed landfill configuration when subjected to strong earthquake shaking. Seismic design guidelines established for solid waste landfills in the USA require that such facilities be designed to resist ground motions with a 2,475-year return period, which has been considered for the analysis of this landfill. The results of the seismic assessment indicate the proposed landfill configuration is stable under the design seismic loading conditions.

The stability and settlement of the proposed landfill are controlled by the underlying silty clay material. The proposed design has an adequate factor of safety against slope instability. The calculated range of settlements over time, based on the combination of primary consolidation and secondary compression, indicate the total settlements under the highest portions of the landfill are expected to be in the order of 6 to 8 metres (approximately 100 years from the start of consolidation).

A hydrogeological conceptual model was developed based on the geological and hydrogeological data gathered as part of the subsurface investigation completed at the Site, as well as data available from previous work completed in the vicinity of the Site. A three-dimensional numerical groundwater flow model was constructed based on the conceptual model to provide a quantitative evaluation of hydraulic head drawdown, groundwater flow paths, groundwater seepage rates, and groundwater travel times resulting from the proposed development of the Site. Groundwater drawdown provides an indication of the extent to which the landfill could potentially affect groundwater quantity and off-Site dug well supply. Based on the modelling results, the simulated drawdown does not extend beyond the property boundary for any of the modelled scenarios, and therefore impact on the groundwater quantity (and off-Site dug well supply) outside of the property boundary is not predicted as a result of the proposed Site development.

Modelling of long-term groundwater quality impacts for new or expanding landfill sites is required under Ontario Regulation 232/98 to demonstrate that the proposed design will meet the requirements of Ministry of the Environment Guideline B-7 (Reasonable Use). Contaminant transport modelling for the proposed landfill was undertaken using POLLUTE to evaluate potential impacts on the groundwater. The results of the contaminant transport modelling indicate all parameters modelled meet the Reasonable Use performance objectives. Analyses also show that should the leachate collection system fail after 20 years beyond the mid-point of landfilling or 20 years beyond year 10 after filling commenced, the thickness and low hydraulic conductivity of the natural silty clay deposit would provide the required off-Site groundwater protection. Nevertheless, the leachate collection system while functioning will help ensure the protection of groundwater within the surficial silty sand layer by reducing leachate mounding on the proposed geosythetic clay liner (GCL) perimeter barrier. In addition, a leak detection and secondary collection system (LDSCS) will be installed within the surficial silty sand layer outside the GCL perimeter barrier. Monitoring of the LDSCS and leachate levels within the landfill will be ongoing during operations and post-closure, and determine the need for contingency measures to prevent leakage, seeps and breakouts that could potentially cause adverse impacts.

In terms of the engineering significance or potential effects of surface or subsurface displacements from potential future fault movement on the design and performance of the proposed CRRRC landfill, both the landfill mass itself and the proposed leachate containment and collection system (and its components), are very capable of withstanding significant differential displacements. There is no constructed or manufactured liner system at the base of the landfill as designed; rather, the containment of landfill leachate relies on the natural containment properties of the 30 metres of low permeability silty clay underlying the Site. The proposed leachate containment and collection system has been designed to withstand relatively large differential movements and continue to perform its intended function. For example, this containment and collection system has been designed to function when experiencing the predicted movements associated with long term consolidation of the clay deposit beneath the landfill, i.e., total settlements of 6 to 8 metres under the central portion of the landfill. The containment and collection system has also been designed to accommodate lateral displacements of up to 350 mm under seismic loading conditions. The groundwater analyses show that even if there was an early failure of the leachate collection system, then the thickness and low hydraulic conductivity of the natural silty clay deposit would provide the required off-Site groundwater protection. For these reasons, the effects of small-scale surface or subsurface displacements from fault displacement are, therefore, inconsequential for the engineering design and performance of the landfill component of the CRRRC.

A geotechnical monitoring program will be implemented for the purposes of confirming the performance/behaviour of the underlying foundation soils, and to provide information to optimize the design and/or operation of the landfill, as construction and filling progress. Groundwater, leachate and surface water monitoring programs have been proposed to monitor background water quality, leachate quality and water quality hydraulically downgradient of the landfill and other on-Site facilities. The monitoring programs have been designed to act as an early warning mechanism for detection of contaminant migration in groundwater or surface water before it reaches the Site boundaries. The proposed monitoring programs also include trigger mechanisms. The objectives of trigger mechanisms at the Site are to utilize the results of the ongoing surface water and groundwater monitoring programs to assess Site compliance and to trigger implementation of the contingency plans, if necessary.

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1.0 INTRODUCTION

This report summarizes the results of the subsurface investigation, hydrogeological assessment and geotechnical assessment of the Capital Region Resource Recovery Centre (CRRRC) Site (Site) located in the eastern portion of the City of Ottawa. The location of the CRRRC Site was selected following a Comparative Evaluation of Alternative Sites that considered the protection of groundwater and included an assessment of the results of the preliminary geology, hydrogeology and geotechnical investigations completed at two potential Sites.

A subsurface investigation was completed by Golder Associates Ltd. (Golder) in accordance with the approved environmental assessment work plans and conformed to the scope of studies contained in the approved Terms of Reference. The subsurface investigation was undertaken to obtain Site-specific geological, hydrogeological and geotechnical information to a level of detail suitable for the purpose of supporting applications for approval of on-Site diversion and on-Site residual disposal components under the Ontario *Environmental Assessment Act* and *Environmental Protection Act*/*Ontario Water Resources Act*.

1.1 Site Description

The general location of the proposed CRRRC Site is shown on Figure 1-1. The Site is located on the east side of Boundary Road, just southeast of the Highway 417/Boundary Road interchange, on Lots 22 through 25, Concession XI, in the former Township of Cumberland. The property is east of an existing industrial park, north of Devine Road and west of Frontier Road and totals approximately 192 hectares (475 acres) in area.

The land use surrounding the Site is primarily a mixture of commercial/industrial and agricultural. The agricultural land use is found immediately east of the Site, as well as to the southeast, south and southwest; however, areas of undeveloped (heavily vegetated) land generally exists between the Site and the agricultural lands in these directions. The industrial land use is found to the west and northwest of the Site. Residential development in the vicinity of the Site is limited to some homes mixed in with the commercial/industrial uses along Boundary Road.

1.2 Proposed Site Development Plan

Taggart Miller Environmental Services (Taggart Miller) is proposing the following diversion facilities/operations for the CRRRC:

- Material Recovery Facility (MRF);
- Construction and Demolition (C&D) processing facility;
- Organics processing facility;
- PHC contaminated soil treatment;
- Surplus soil management;
- Drop off for separated materials or for separation of materials; and,
- Leaf and yard materials composting (if there is enough material available).

There would also be a landfill for disposal of residual wastes.

1.3 Organization of Report

This document is referred to as Volume III, Geology, Hydrogeology and Geotechnical Report and contains 15 chapters as follows:

- Chapter 1 – Provides an introduction to the report, relevant background information about the site and a brief description of the proposed site development plan;
- Chapter 2 – Describes the methodology used for the subsurface investigation and hydrogeological assessment completed at the Site;
- Chapter 3 – Describes the geological setting of the Site at the regional, local and site scales;
- Chapter 4 – Describes the regional tectonic setting of the Site;
- Chapter 5 – Describes the local topography and existing surface water drainage in the vicinity of the site;
- Chapter 6 – Describes the site subsurface conditions and is based on the result of the subsurface investigation completed at the Site;
- Chapter 7 – Describes the local and site hydrogeological conditions and is based on available published information and detailed site-specific hydrogeological data collected as part of the hydrogeological monitoring completed at the Site. The site-specific hydrogeological data includes groundwater levels, groundwater flow directions, hydraulic gradients and conductivity, groundwater flux and average linear groundwater velocity;
- Chapter 8 – Describes the background groundwater and surface water quality in the vicinity of the Site;
- Chapter 9 – Presents an evaluation of the potential geological impacts associated with fault rupture and subsurface settlement from earthquake ground shaking;
- Chapter 10 – Describes the proposed site design and facilities to be located at the Site;
- Chapter 11 – Provides geotechnical considerations of the site design including a stability assessment, seismic assessment and settlement assessment, and presents a proposed geotechnical monitoring program;
- Chapter 12 – Presents a hydrogeological conceptual model for the Site, along with the results of the groundwater flow modelling and contaminant transport modelling;
- Chapter 13 – Presents the proposed groundwater and surface water monitoring programs and trigger mechanisms;
- Chapter 14 – Discusses proposed contingency measures in the event that the groundwater and/or surface water monitoring programs identify an impact on groundwater and/or surface water which was not predicted; and,
- Chapter 15 – Discusses the limitations and use of the report.

1.4 List of Contributing Authors

The following provides a list of authors who contributed to the Geology, Hydrogeology & Geotechnical Report for the CRRRC Site.

Geology:

R. Blair, M.Sc., P.Geo., Senior Geologist, Principal (Golder Associates Ltd. – Canada)

Seismicity:

A. Hull, Ph.D., C.E.G., Seismic Hazard Protection Leader, Principal (Golder Associates Inc. – United States of America)

Professor G. Atkinson, Ph.D., P.Geo., Engineering Seismologist (Independent Advisor)

Professor L. Godin, Ph.D., Structural Geologist (Independent Advisor)

Geotechnical:

M. Cunningham, M.Sc., P.Eng., Senior Geotechnical Engineer, Principal (Golder Associates Ltd. – Canada)

S. Trickey, M.Sc., P.Eng., Geotechnical Engineer (Golder Associates Ltd. – Canada)

A. Walker, M.Sc., P.Eng., Senior Geotechnical Engineer, Principal (Golder Associates Inc. – United States of America)

U. Atukorala, Ph.D., P.Eng., Senior Geotechnical Engineer, Principal (Golder Associates Ltd. – Canada)

V. Fernando, M.E.Sc., P.Eng., Senior Geotechnical Engineer, Associate (Golder Associates Ltd. – Canada)

M. Seid-Karbasi, Ph.D., P.Eng., Geotechnical Engineer (Golder Associates Ltd. – Canada)

Hydrogeology:

K. Marentette, M.Sc., P.Geo., Senior Hydrogeologist, Principal (Golder Associates Ltd. – Canada)

J. Oxtobee, M.Sc., P.Geo., Senior Hydrogeologist, Associate (Golder Associates Ltd. – Canada)

D. Holtze, M.Sc., P.Geo., Hydrogeologist (Golder Associates Ltd. – Canada)

N. Bishop, M.Sc., P.Eng., Geological Engineer (Golder Associates Ltd. – Canada)

M. Mailloux, M.Sc., Ing., Senior Hydrogeologist, Associate (Golder Associates Ltd. – Canada)

M. Bunn, Ph.D., P.Geo., Hydrogeologist (Golder Associates Ltd. – Canada)

Contaminant Transport:

T. Edmond, M.E.Sc., P.Eng., Senior Geo-Environmental Engineer, Associate (Golder Associates Ltd. – Canada)

M. Farnel, P.Eng., Geo-Environmental Engineer (Golder Associates Ltd. – Canada)

Senior Reviewer:

P. Smolkin, P.Eng., Senior Geo-Environmental Engineer, Principal (Golder Associates Ltd. – Canada)

2.0 SITE INVESTIGATION METHODOLOGY

The following section summarizes the Site investigation methodology applied during the subsurface investigation and hydrogeological assessment completed at the CRRRC Site. The field program involved the drilling of at least one borehole at 25 investigation locations across the Site. The investigation locations are identified as 12-1 through 12-4 and 13-5 through 13-25 (see locations on Figure 2-1). The following sections describe the testing completed at the investigation locations.

2.1 Cone Penetration Testing

A minimum of one Cone Penetration Test (CPT) was advanced at each of the 25 investigation locations. The CPT consists of a probe with a cone shaped tip that is equipped with electronic sensing elements to continuously measure tip resistance, local side friction on a sleeve behind the tip, and porewater pressure. The cone is pushed at a constant rate into the ground using a drill rig. A continuous stratigraphic profile together with engineering properties, such as strength, stress history and density, can be interpreted from the results of the CPT. The CPTs were advanced through the silty clay to depths up to about 38 metres (i.e., to the top of the underlying glacial till).

During advancement of seven of the CPTs, porewater pressure dissipation tests were carried out at various depths in the silty clay profile by temporarily stopping the advance and recording the pore pressure changes over periods of up to about 1 hour (but as short as 8 minutes). That dissipation data can be used to assess consolidation properties of the deposit. Either 3 or 4 dissipation tests were carried out in each of these CPTs, at depths ranging between 5.2 and 28.1 metres.

2.2 Borehole Drilling Program

2.2.1 Deep Borehole Investigation Locations: 12-1 through 12-4 and 13-5 through 13-7

Investigation of the full overburden sequence and into the underlying upper bedrock zone was completed at the first seven investigation locations identified as 12-1 through 12-4 and 13-5 through 13-7 (see locations on Figure 2-1). Multiple boreholes were completed at each location to allow for the required geotechnical testing and installation of monitoring wells within the bedrock, glacial till, silty clay and surficial silty sand. The boreholes were advanced using a track-mounted drill rig supplied and operated by Marathon Drilling Company Ltd. of Ottawa, Ontario, with the exception of the direct push boreholes, which were advanced using a track-mounted Geoprobe drill rig supplied and operated by the Strata Drilling Group (Strata) of Carleton Place, Ontario.

The following provides a general overview of the testing completed as part of the deep borehole investigation:

- Nilcon Vane Testing – Nilcon *in-situ* vane boreholes were completed at the seven deep investigation locations across the Site. Soil sampling and standard penetration tests were typically first carried out in the surficial silty sand and/or upper silty clay to depths of between about 1.2 and 2.1 metres, to reach the native unweathered silty clay. Below that depth, the boreholes were advanced using an electric Nilcon *in-situ* vane testing apparatus, with measurements taken at either 0.5 or 1.0 metre depth intervals. This vane testing was carried out under conditions of a constant rate of strain/rotation. The undrained shear strength of remoulded silty clay was also typically measured (to assess sensitivity of the clay) at approximately one of every three to five test intervals. The boreholes for Nilcon vane testing were advanced to depths between approximately

27 and 38 metres below the existing ground surface, except for at location 13-7 where Nilcon vane testing focused on the upper portion of the silty clay and was completed to a depth of 9 metres.

- During borehole drilling, standard penetration tests and ‘split-barrel’ soil sampling were carried in the surficial silty sand and in portions of the lower silty clay and/or glacial till.
- 73-millimetre diameter thin-walled Shelby tube samples of the silty clay were obtained using a fixed piston sampler at locations 12-1 through 12-4, 13-6 and 13-7. Typically, the Shelby tube samples were collected from boreholes completed for the installation of monitoring wells; however, at location 13-7, two additional boreholes were drilled specifically for the collection of additional Shelby tube samples.
- One borehole at each deep investigation location was extended between approximately four and six metres into the upper bedrock using rotary diamond drilling equipment while retrieving NQ or HQ size bedrock core. At location 12-1, a second borehole was extended into the bedrock to be used for vertical seismic profile (VSP) casing installation (and subsequent testing). At locations 12-2-3, 12-3-3 and 12-4-3, a single borehole for both bedrock groundwater monitoring well installation and VSP casing installation was completed.
- Deep, continuous direct push sampling was carried out at five of the deep investigation locations (12-1 through 12-4 and 13-6). The direct push sampling system consists of an outer casing that houses either a 53 or 38-millimetre diameter plastic sleeve that is vibrated into the ground in approximately 1.5-metre lengths. The direct push sampling at the deep investigation locations was carried out through the surficial silty sand, underlying silty clay and into the glacial till (where possible) to depths between about 30.3 and 36.0 metres below the existing ground surface. The direct push sampling allowed for direct observation of a continuous soil profile from ground surface into the top of the glacial till.

The borehole drilling for the deep investigation locations was coordinated and observed by a Golder technician or engineer who located the boreholes, monitored the drilling operations, logged the boreholes, monitored the *in-situ* testing, and took custody of the soil and rock core samples retrieved. Upon completion of the drilling operations, samples of the soils and rock core encountered in the boreholes were transported to Golder’s laboratory for examination by the project engineer or geologist.

In order to provide better coverage of the western part of the Site in terms of properties of the clay deposit, some of the subsurface investigation components proposed for location 13-7 (located in the south-central portion of the Site) were completed at location 13-6 (located in the central portion along the western boundary of the Site). The investigation components transferred to 13-6 included the deep continuous direct push sampling and the installation of a deep silty clay monitoring well. In addition, Shelby tube samples were collected at locations 13-6 and 13-7. The collection of Shelby tube samples was not originally proposed at location 13-6. This minor variation to the work plan in the approved Terms of Reference was discussed with the Ministry of the Environment and Climate Change (MOECC).

A summary of the drilling program carried out at locations 12-1 through 12-4 and 13-5 through 13-7 is provided in Table 2-1 below. The summary includes details on the testing completed in each borehole, and identifies the monitoring intervals installed within the various boreholes at each location.

Table 2-1: Summary of Deep Borehole Investigation: Locations 12-1 through 12-4 and 13-5 through 13-7

Description of Borehole Type	Borehole Location						
	12-1	**12-2**	**12-3**	**12-4**	**13-5**	**13-6**	**13-7**
CPT Confirmation CPT	12-1-1 12-1-8	12-2-1 12-2-8	12-3-1” 12-3-8	12-4-1 12-4-8	13-5-1	13-6-1	13-7-1
Nilcon Vane Borehole	12-1-2	12-2-2	12-3-2	12-4-2	13-5-2	13-6-2	13-7-6
Bedrock Monitoring Well and/or VSP Installation	12-1-3 (VSP) 12-1-3-1 (BR)	12-2-3 (VSP/BR)	12-3-3 (VSP/BR)	12-4-3 (VSP/BR)	13-5-3 (BR)	13-6-3 (BR)	13-7-2 (BR)
Glacial Till Monitoring Well	12-1-4A	- -	12-3-4A	12-4-4A	13-5-4A	13-6-4A	13-7-3
Deep Silty Clay Monitoring Well	12-1-4B	12-2-4	12-3-4B	12-4-4B	- -	13-6-4B	- -
Mid Silty Clay Monitoring Well	12-1-5A	12-2-5A	12-3-5A	12-4-5A	13-5-4B	13-6-5A	13-7-4-1
Shallow Silty Clay Monitoring Well (typically spanning silty layer)	12-1-5B	12-2-5B	12-3-5B	12-4-5B	13-5-5	13-6-5B	13-7-4-2
Surficial Silty Sand, Silt and/or Weathered Silty Clay Monitoring Well	12-1-6	12-2-6	13-3-6	12-4-6	13-5-6	13-6-6	13-7-5
Direct Push Borehole	12-1-7	12-2-7	12-3-7	12-4-7	- -	13-6-7	- -
Shelby Tube Sample Borehole	12-1-3	12-2-3	12-3-3	12-4-3	- -	13-6-3	13-7-7 13-7-8

Notes: VSP – Vertical Seismic Profile; BR – Bedrock, - - no monitoring well installed

Details of the subsurface materials encountered during the deep borehole investigation program for locations 12-1 through 12-4 and 13-5 through 13-7 are provided on the borehole records in Appendix A.

In addition to the deep subsurface investigation program describe above, it was proposed to include *in-situ* (down hole) measurements of the maximum horizontal stress in the bedrock at two locations. The use of a USBM gauge tool was the proposed method. Once the depth to bedrock at the Site was confirmed by the drilling program to be greater than 30 metres and the condition of the bedrock was assessed by core drilling, the feasibility of using the USBM gauge was further assessed. Experience has shown that this tool is unlikely to provide useful horizontal stress measurements at this depth, and the bedrock characteristics are not favourable for overcoring. Consideration was then given to using a bedrock hydro-fracturing technique, but detailed examination of bedrock core recovered from the boreholes again showed that obtaining meaningful results was highly unlikely. The potential to use an advanced bi-axial overcoring stress measurement system was also assessed and found to have a low chance of success. As a result, the measurement of *in-situ* maximum horizontal stress could not be completed at the Site. This minor variation to the approved work plan in the Terms of Reference was discussed with the MOECC.

2.2.2 Shallow Borehole Investigation Locations: 13-8 through 13-25

Shallow continuous direct push sampling using a track-mounted Geoprobe drill rig supplied and operated by Strata was carried out at 18 investigation locations identified as 13-8 through 13-25 (see locations on Figure 2-1). The shallow overburden investigation focused on the surficial silty sand and/or weathered crust at all locations (i.e., approximately upper 1.5 metres of material), and at half of the locations a second shallow borehole was completed through the upper approximately 7.5 metres of overburden.

The purpose of the shallow direct push sampling was to confirm the thickness of the surficial silty sand unit (where present), to look for potential sand or silt layers within the upper portion of the silty clay, and to permit the installation of monitoring wells within the surficial silty sand layer and the upper portion of the silty clay.

The shallow direct push drilling was coordinated and observed by a Golder technician or engineer who located the boreholes, monitored the drilling operations and took custody of the soil samples retrieved. Upon completion of the drilling operations, soil cores collected from the direct push locations were transported to Golder's laboratory for detailed examination by the project engineer or geologist.

A summary of the drilling program completed at locations 13-8 through 13-25 is provided in Table 2-2 below. The summary also identifies the monitoring intervals installed at the direct push locations.

Table 2-2: Summary of Shallow Borehole Investigation: Locations 13-8 through 13-25

Borehole Location	Description of Borehole Type		
	CPT	Surficial Silty Sand, Silt and/or Weathered Silty Clay Monitoring Well	Shallow Silty Clay (spanning Silty Layer) Monitoring Well
13-8	13-8-1	13-8-2	13-8-3
13-9	13-9-1	13-9-2	13-9-3
13-10	13-10-1	13-10-2	13-10-3
13-11	13-11-1	13-11-2	
13-12	13-12-1	13-12-2	13-12-3
13-13	13-13-1	13-13-2	
13-14	13-14-1	13-14-2	
13-15	13-15-1	13-15-2	13-15-3
13-16	13-16-1	13-16-2	
13-17	13-17-1	13-17-2	13-17-3
13-18	13-18-1	13-18-2	13-18-3
13-19	13-19-1	13-19-2	
13-20	13-20-1	13-20-2	
13-21	13-21-1	13-21-2	
13-22	13-22-1	13-22-2	
13-23	13-23-1	13-23-2	13-23-3
13-24	13-24-1	13-24-2	
13-25	13-25-1	13-25-2	13-25-3

Details of the subsurface materials encountered during the shallow direct push drilling program are provided on the borehole records in Appendix A.

2.3 Detailed Geological Logging

The continuous soil samples collected as part of the direct push drilling program were returned to Golder's office for detailed logging. The materials present within the continuous soil samples were logged, and particular attention was paid to identifying any sand or silt layers present within the silty clay. In addition, the soil cores were examined for evidence of sediment disturbance such as deformed, tilted or sheared bedding patterns, or evidence of sand liquefaction and flow. The geologic descriptions of the overburden materials encountered at the Site are included on the borehole records provided in Appendix A. Photographs of the direct push soil samples are provided in Appendix I.

The bedrock recovered from locations 12-1 through 12-4 and 13-5 through 13-7 was lithologically logged on a bed-by-bed basis. The logging included a systematic description of the core including: weathered state; structure; colour; grain size; bedding; texture; material type; and, the location of open bedding planes/voids. The geologic descriptions of the bedrock encountered at the Site are included on the drillhole records provided in Appendix A. Photographs of the bedrock core samples are provided in Appendix J.

2.4 Geotechnical Laboratory Testing

Geotechnical laboratory testing including water content determinations, Atterberg limit testing, grain size distribution testing and hydraulic conductivity testing was carried out on selected soil samples. In addition, 17 selected Shelby tube samples were submitted for laboratory oedometer consolidation testing to assess the consolidation characteristics of the silty clay. Longer-term sustained load testing (i.e., secondary compression testing) was also carried out on 2 of the 17 Shelby tube samples. The testing was completed at stress levels in the order of the anticipated final stress level at the sample depth to evaluate the secondary compression (i.e., 'creep') behaviour of the soil.

2.5 Monitoring Well Installation and Elevation Surveying Program

Groundwater monitoring wells were constructed within selected on-Site boreholes to allow for the measurement of groundwater levels, horizontal hydraulic conductivity, and to allow for the collection of groundwater quality samples.

2.5.1 Bedrock and VSP Monitoring Well Installations

Single bedrock monitoring wells were installed at boreholes 12-2-3, 12-3-3, 12-4-3, 13-5-3, 13-6-3 and 13-7-2. At boreholes 12-2-3, 12-3-3 and 12-4-3, the bedrock installation was completed in a manner (i.e., appropriate diameter and grouting technique) to allow the bedrock installation to be used for VSP testing. The VSP casing and bedrock monitoring well at location 12-1 were installed in two separate boreholes (i.e., 12-1-3 and 12-1-3-1, respectively) due to construction difficulties encountered at this location The VSP installation at 12-1-3 was constructed of 0.076-metre diameter PVC solid risers. The installations in 12-2-3, 12-3-3 and 12-4-3 were constructed of 0.063-metre diameter, threaded, PVC slot #10 screen and solid risers. Bedrock monitoring wells at 12-1-3-1 and 13-6-3 were constructed of 0.050-metre diameter, threaded, PVC slot #10 screen and solid risers, while monitoring wells in 13-5-3 and 13-7-2 were constructed of 0.032-metre diameter, threaded, PVC slot #10 screen and solid risers. Silica sand backfill was placed in the boreholes around the screened portion within the bedrock and then a combination of peltonite and bentonite-cement grout was used to seal the boreholes up to the ground surface. The monitoring well installation details for the bedrock and VSP installations are provided on the borehole records in Appendix A.

The bedrock monitoring wells were developed following their installation in preparation for undertaking hydraulic conductivity testing, groundwater level measurements and groundwater quality sampling.

2.5.2 Overburden Monitoring Well Installations

Within the overburden soils, multi-level groundwater monitoring wells were installed within the glacial till and at various depths with the silty clay at boreholes 12-1-4, 12-1-5, 12-2-5, 12-3-4, 12-3-5, 12-4-4, 12-4-5, 13-5-4, 13-6-4 and 13-6-5. Where multi-level wells were installed in a single borehole, the deepest monitoring well installation at each borehole is designated as monitoring well “A”, with the shallower monitoring well at each borehole designated as “B”.

Single monitoring wells were installed within the surficial silty sand deposits at 12-1-6, 12-2-6, 12-3-6, 12-4-6, 13-5-6, 13-6-6, 13-7-5, 13-8-2, 13-9-2, 13-10-2, 13-11-2, 13-12-2, 13-13-2, 13-14-2, 13-15-2, 13-16-2, 13-17-2, 13-18-2, 13-19-2, 13-20-2, 13-21-2, 13-22-2, 13-23-2, 13-24-2 and 13-25-2. Single monitoring wells were installed within the shallow silty clay spanning a silty layer at 13-7-4-2, 13-8-3, 13-9-3, 13-10-3, 13-12-3, 13-15-3, 13-17-3, 13-18-3, 13-21-3, 13-23-3 and 13-25-3. Additional single monitoring wells were installed at 12-2-4 (deep silty clay), 13-7-3 (glacial till) and 13-7-4-1 (mid-silty clay).

The monitoring wells were installed at specific depths to allow for the measurement of groundwater levels and to obtain estimates of horizontal hydraulic conductivity and gradients within the various soils and bedrock encountered at the Site. The preferred locations for the screened intervals of the monitoring wells were determined based on observations during the drilling program. These monitoring wells were constructed of either 0.025-metre, 0.032-metre, 0.038-metre or 0.050-metre diameter, threaded, PVC slot #10 screen and solid risers. Silica sand backfill was placed in the boreholes around the screened portions of the monitors. A combination of bentonite, peltonite and/or bentonite-cement grout was used to provide seals between the screened intervals and to seal the borehole up to ground surface. The monitoring well installation details for the overburden installations are provided on the borehole records in Appendix A, and a summary of the monitoring well completion details are provided on Table L-1 in Appendix L.

The overburden monitoring wells were developed following their installation in preparation for undertaking hydraulic conductivity testing, groundwater level measurements, and groundwater quality sampling at selected locations.

2.5.3 Elevation Survey Program

Each monitoring well is protected at surface by a steel casing with a lockable cap. Following the borehole drilling and installation of monitoring wells, a survey of the horizontal coordinates and the elevation of the ground surface and top of the PVC pipe(s) was completed by Golder. In addition, the ground surface and horizontal coordinates for the CPT and Nilcon vane holes were also surveyed by Golder. The horizontal coordinates were surveyed relative to Universal Transverse Mercator (UTM) NAD 83, Zone 18, and the elevations were surveyed to Geodetic datum.

The coordinates and ground surface elevations for each borehole location is provided on the borehole records in Appendix A.

2.6 Groundwater and Surface Water Testing Program

2.6.1 Groundwater Level Monitoring

A groundwater level monitoring program was conducted to provide information on hydraulic gradients and the groundwater flow direction(s) at the CRRRC Site. The depth to groundwater was measured relative to the surveyed top of PVC pipes for the monitoring wells. The groundwater elevations in the monitoring wells were calculated by subtracting the measured depth to water from the top of pipe reference elevations. Groundwater level monitoring was conducted in January and February 2013 (12-1, 12-2 and 12-3 only) and on monthly basis at all on-Site wells between April 2013 and December 2013 using manual measurements. In addition, dataloggers were installed in select monitoring wells screened within the surficial silty sand (12-1-6, 12-3-6 and 13-6-6), the silty layer within the shallow silty clay (12-1-5B, 12-3-5B and 13-6-5B), glacial till (12-1-4A, 12-3-4A and 13-6-4A) and upper bedrock (12-1-3-1, 12-3-3 and 13-6-3) units in April 2013 in order to monitor daily groundwater levels at the Site. The dataloggers were programmed to record three groundwater levels per day at each location.

2.6.2 Groundwater Sampling

The groundwater quality sampling program at the CRRRC Site was divided into two programs, which included the on-Site monitoring well sampling program and the residential water supply well sampling program.

2.6.2.1 On-Site Groundwater Sampling Program

2.6.2.1.1 Background Groundwater Quality Monitoring

The on-Site monitoring well water quality sampling program involved collecting groundwater samples from the depth-specific monitoring wells installed at locations 12-1 through 12-4 and 13-5 through 13-7. The primary objective of the groundwater quality monitoring program is to define existing background groundwater quality at the CRRRC Site. The groundwater samples were analyzed for the parameters specified in *Ontario Regulation* (O.Reg.) 232/98 (except for total suspended solids), which relates to the construction and expansion of landfill sites. All samples were entered on Chain of Custody forms and delivered to Maxxam Analytics Inc. (Maxxam) for the required analysis.

2.6.2.1.2 Isotopic Analysis of Groundwater

Groundwater samples from monitoring wells 12-2-6 (surficial silty sand), 13-7-4-2 (weathered crust at surface) and 13-7-5 (shallow silty clay with silty layer) were analysed for tritium and helium-3 to assist in estimating the groundwater residence time (i.e., age of groundwater) in specific shallow water bearing zones within the shallow overburden (i.e., upper seven metres). This groundwater dating method relies on the presence of tritium in the groundwater samples (helium-3 is a daughter product of the decay of tritium); as such, samples were not collected from the deeper portions of the silty clay, the glacial till and the upper bedrock where tritium is unlikely to be present.

The groundwater samples for tritium were collected after a minimum of three well volumes had been purged from the monitoring interval. Dedicated sampling equipment consisting of Waterra® tubing and foot valves was used to avoid cross-contamination of wells/samples. The tritium samples were collected in one litre plastic bottles as requested by the Environmental Isotope Lab at the University of Waterloo.

The samples for helium-3 were collected using diffusion samplers prepared and provided by the MAPL Noblegas Laboratory at the University of Ottawa. The diffusion samplers consist of a diffusion membrane and two copper tube reservoirs. The diffusion samplers were deployed within the three screened intervals of the monitoring wells, and left in place for 12 days to allow the concentration of gasses in the air in the copper reservoir to equilibrate with the concentration of gases in the groundwater in the test interval. When the sampler was removed from the well, the ends of the copper reservoirs were clamped to isolate the air sample. The concentration of helium-3 in the collected sample was then determined by the lab using a magnetic sector mass spectrometer.

The results of the tritium analysis completed by the Environmental Isotope Lab at the University of Waterloo were then provided to the MAPL Noblegas Laboratory at the University of Ottawa, and the age of the groundwater in each interval was estimated using the procedure described below.

The concentration of tritium in the groundwater is measured in the lab. The measured helium-3 in the air sample (collected from the diffusion sampler) is corrected by the lab to account for atmospheric helium-3 that is dissolved at the time of recharge. Any helium-3 above the concentration expected to dissolve from the atmosphere is assumed to be from the decay of tritium. This concentration is referred to as the tritiogenic helium-3.

The estimated concentration of tritiogenic helium-3 is used with the measured concentration of tritium to estimate the groundwater residence time according to the following equation:

$$t = T_{1/2}/\ln 2 \text{ x } \ln(1+{}^{3}He_{tri}/{}^{3}H)$$

Where:

t = groundwater residence time;

$T_{1/2}$ = half life of ^{3}H (12.43 years);

$^{3}He_{tri}$ = tritiogenic ^{3}He (helium from the decay of ^{3}H); and

^{3}H = measured ^{3}H concentration in groundwater.

2.6.2.2 Residential Well Sampling Program

The residential well sampling program involved collecting groundwater samples from supply wells in the immediate vicinity of the CRRRC Site to characterize background groundwater quality for typical organic and inorganic landfill leachate parameters. The parameters analyzed for the residential wells were the same as the on-Site monitoring wells. Prior to sampling, Golder staff completed a survey with the homeowners to gather information about their water supply (i.e., well type, depth, location, satisfaction with water quality and quantity, etc.). If the water supply is treated (i.e., water softener), the water sample was collected from an untreated location, or the treatment system was bypassed. All samples were entered on Chain of Custody forms and delivered to Maxxam for the required analysis.

2.6.3 Background Surface Water Quality Monitoring

The background surface water quality sampling program involved collecting samples from on-Site surface water stations BSW1, BSW2, BSW3, BSW4, BSW5 and BSW9 and downgradient off-Site locations BSW6, BSW7 and BSW8. The primary objective of the surface water quality monitoring program is to define existing background surface water quality at, and in the vicinity of, the CRRRC Site. The surface water sampling locations are shown on Figure 2-2. The surface water monitoring program comprised up to five sampling sessions completed in December 2012 (winter), May 2013 (spring), July 2013 (summer), October or early-November 2013 (fall) and late-November or December 2013 (winter). Surface water stations BSW1 through BSW7 were established in December 2012 and five monitoring sessions were completed at each location. BSW8 and BSW9 were added to the monitoring program in spring and fall 2013, respectively. Four monitoring sessions were completed at BSW8 and two monitoring session were completed at BSW9. The surface water samples were analyzed for the parameters specified in O.Reg. 232/98, which relates to the construction and expansion of landfill sites. All samples were entered on Chain of Custody forms and delivered to Maxxam for the required analysis.

2.6.4 Quality Assurance/Quality Control

A blind duplicate groundwater and/or surface water sample was analyzed as part of the quality assurance/quality control (QA/QC) protocol during the winter 2012 (surface water), summer (groundwater and surface water) and fall 2013 (groundwater and surface water) sessions. In addition, the analytical laboratory performs equipment blanks as a method of internal QA/QC verification.

2.7 Hydraulic Conductivity Testing

2.7.1 Laboratory Permeability Tests

Laboratory permeability tests were conducted on three Shelby tube samples to provide information on the (*ex-situ*) vertical hydraulic conductivity of the silty clay at the CRRRC Site. The constant head permeability test was completed as per the standard test method described in American Society for Testing and Materials 5084 (ASTM-D5084), and consisted of monitoring the volumetric flow rate of water through an undisturbed sample of known volume using hydraulic head and the volume of outflow as a function of time.

2.7.2 Slug Testing

Well response tests were carried out in selected monitoring wells installed at the Site. The well response testing was undertaken to provide information on the *in-situ* horizontal hydraulic conductivity of the overburden and bedrock adjacent to the monitoring well intervals. The falling-head/rising-head tests consisted of inserting or removing a slug of known volume into each of the monitoring wells, followed by monitoring the groundwater level dissipation/recovery within the monitor. Before the start of the hydraulic testing, static water levels were measured at all locations. Each hydraulic test was deemed complete when the monitoring well recovered to approximately 95% of the original static water level, or after two hours of monitoring for locations having slow recovery.

The intervals for response testing were defined as the sand pack interval (i.e., the zone filled with sand surrounding the screens) between the bentonite seals. The water level recovery data were analyzed using the Bouwer and Rice method (Bouwer and Rice, 1976) or Butler (1998) to provide an estimate of the horizontal hydraulic conductivity.

2.8 Geophysical Testing

VSP testing was carried out within boreholes 12-2-3 and 12-3-3. For the VSP method, seismic energy is generated at the ground surface by an active seismic source and recorded by a geophone located in a nearby borehole at a known depth. The methodology can be applied using an active seismic source that produces either compression or shear waves. The time required for the energy to travel from the source to the receiver (geophone) provides a measurement of the average compression or shear-wave seismic velocity of the medium between the source and the receiver. Data obtained from different geophone depths are used to calculate a detailed vertical seismic velocity profile of the subsurface in the immediate vicinity of the test borehole.

3.0 GEOLOGICAL SETTING

The geology of the CRRRC Site has been assessed based on a regional, local and Site scale as discussed in the following sections, placing it within the overall context of the Ottawa Valley area geology and taking into consideration the Site-specific investigations that have been carried out. Selected geological literature (Sanford and Arnott, 2010, Bleeker et al, 2011) for the area was reviewed along with geological mapping produced by the Geological Survey of Canada (GSC) and the Ontario Geological Survey (OGS), as well as Site-specific investigations carried out by Golder, the Ministry of Transportation of Ontario and other consultants. Information was obtained on deep gas exploration wells from the Ministry of Natural Resources and Forestry (MNRF) Oil, Gas and Salt Resource Library. The MOECC Water Well Information System (WWIS) (MOE, 2013) was reviewed and records of cored boreholes were collected.

Additional detailed information on the Site subsurface conditions is provided in Section 6.0, and on the regional and Site hydrogeological conditions in Section 7.0.

3.1 Regional Geological Conditions

3.1.1 Regional Bedrock Geology

The regional bedrock geology of the Ottawa Valley area is shown on Figure 3-1 taken from Sanford and Arnott, 2010 (Geological Survey of Canada Bulletin 597). The area is underlain by a Paleozoic sedimentary sequence extending from basal quartz sandstone and conglomerate deposits of the Cambrian Period and limestone, dolostone and shale sequences of the Ordovician Period. This area underlain by Paleozoic strata is referred to as the Ottawa Embayment and lies unconformably upon Precambrian basement rocks of Grenville age (approximately 1.2 billion years and older). The Ottawa embayment is structurally bounded by Precambrian rock of the Frontenac Arch to the southwest and west, the Laurentian Arch to the north, the Oka-Beauharnois Arch to the east and the Adirondack Dome to the south as shown on Figure 3-1. These arches have been structurally active areas of uplift at various times during the Paleozoic and Mesozoic Eras (approximately 600 to 100 million years ago) as part of the Ottawa Valley-Nippissing Graben structure, which has affected the sedimentation and structure of the overlying Paleozoic sequences within the embayment.

The Ottawa Valley-Nippissing Graben consists of extensional block fault structures extend from the St Lawrence River north westward through the Ottawa Valley including Lake Timiskaming and the Lake Nippissing valleys. Faulting within the graben commenced in the late Precambrian period (about 600 million years ago) and stratigraphic information indicates that it was active through the Cambrian period associated with the clastic deposition of the basal Covey Hill Formation quartz sandstone and conglomerate. Mid- to late-Ordovician limestone and shale strata were deposited in relatively quiescent environments. Formerly overlying Silurian and Devonian Era (younger) strata have been eroded from the area. The Mesozoic Era saw renewed geological activity including intrusion of alkaline dykes and the Cretaceous age Monteregian calc-alkaline igneous intrusions of the Montreal-St. Lawrence valley area including the Mount Royal, Oka and Saint Andre Est igneous complexes. The major period of faulting within the Ottawa Valley culminated during the Cretaceous Period (145 to 66 million years ago) associated with the dominant period of igneous intrusive activity (Beeker et al, 2011).

The Paleozoic carbonate and shale sedimentation occurred in near flat-lying conditions. Ottawa Valley Graben faulting and uplift associated with the Precambrian arches subsequently gently folded the Paleozoic sequence forming a broad syncline with numerous extensional fault offsets. The locations of the major faults are shown in plan view on Figure 3-1, and the location and amount of vertical displacement along these faults are shown in the cross-sections on Figure 3-2. Displacement along these normal fault structures varies from a few tens of metres to several hundreds of metres and deformational dragging along the fault contacts locally resulted in steeper fold deformation of the bedrock strata. Small scale faults associated with offsets in the range of several metres to several tens of metres are comparatively common throughout the Ottawa Valley, occurring within the intervening areas between the more dominant primary faults such as the Gloucester-Russell, Eardley and Hazeldean Faults. Secondary faults of this nature are typically encountered within the Paleozoic sequence within the Ottawa area. The encountered fault features form comparatively sharp planes associated with localized angular brecciation of wall rock re-cemented in white coarse-grained calcite crystallization. The calcite is also associated with minor pyrite and tremolite mineralization indicating hydrothermal conditions at the time of faulting while the strata was still deeply buried beneath overlying strata, which has since been removed by erosion. The fault planes have been observed to be generally intact in nature (tight) unless opened by penetrative weathering near surface.

Rimando and Benn (2005) studied the origin and development of faults exposed within the Paleozoic rocks of the Ottawa-Bonnechere Graben, including the Queenston Formation shale and underlying interbedded limestone and shale of the Carlsbad Formation. These bedrock formations underlie the CRRRC Site (see Figure 3-1, Figure 3-7 and Figure 3-11).

Rimando and Benn (2005) identified three main periods of deformation events (D_1, D_2 and D_3) represented as in the orientation and slip sense of fault sets in the bedrock units exposed in surface outcrops. Each deformation event is associated with different types of faults, listed below from oldest to youngest:

- D_1 – three families of faults including sinistral and dextral strike-slip faults with north-northwest and northwest strikes, respectively, and northwest-striking normal faults. This oldest generation of faults formed in response to a horizontal maximum principal compressive stress (σ1) oriented northwest. The faults are kinematically consistent with the compression direction associated with the Iapetus Ocean.
- D_2 – mostly normal faults with subordinate sinistral and dextral strike-slip faults oriented northwest and west-northwest; normal faults striking west-northwest to west-southwest; and minor thrust faults. Fault patterns indicate a west-northwest-oriented σ1. This stress orientation coincides with emplacement of Cretaceous carbonatite dikes.
- D_3 – dextral and sinistral strike-slip faults; northeast-striking normal faults and minor thrust faults with a southwest-oriented σ1 consistent with the post-Cretaceous stress field for eastern North America.

Rimando and Benn (2005) related each deformation event to the regional stress field developed from major, continental-scale tectonic events such as closing of the Paleozoic Iapetus Ocean toward the end of the Hadrynian approximately 850 to 542 million years ago (D_1) Mesozoic opening of the Atlantic Ocean and associated dyke intrusion about 120 million years ago (D_2); and post-Cretaceous westward drift of the North American plate 66 million years to the present day (D_3). Structural analysis indicates that these faults developed and underwent much of their total displacement more than about 66 million years ago, when the bedrock was in a different stress regime compared to that of the present day.

Major faults that affect the CRRRC study area include the northwest-southeast trending Gloucester Fault and the northeasterly trending Russell-Rigaud Fault branching off from the Gloucester Fault near the Village of Russell (Figure 3-1). These faults have preserved the Billings-Carlsbad-Queenston Formation shale sequences on the north down-dropped side of the faults. The small area of Queenston Formation red shale preserved between the CRRRC Site and Village of Russell represents the youngest strata and hence thickest area of Paleozoic sequence within the Ottawa Valley, up to approximately 850 metres above the Precambrian basement rock (Figure 3-2). Bedrock surface topographic relief associated with faulting has locally developed due to erosion associated with hardness contrasts such as between the harder Precambrian igneous terrain and the softer limestone or between limestone and shale. This is quite evident along the north side of the Ottawa Valley where the Precambrian igneous terrain of the Laurentian Arch rises steeply 100 metres to 150 metres above the Paleozoic terrain to the south along the Eardley Fault located across the river from Ottawa, and to a lesser degree with the Hazeldean Fault west of Ottawa (Figure 3-1).

3.1.2 Regional Surficial Geology

The regional scale surficial geology of the Ottawa Valley is shown on Figure 3-3 taken from the Ontario Ministry of Northern Development and Mines (Map 2556 – Quaternary Geology of Ontario – Southern Sheet). The valley terrain is largely flat associated with the extensive deposition of marine clay during the post-glacial period when the Champlain Sea inundated the area directly following the retreat of the glaciers. The clay soils infilled the former glaciated topography and built up an aerially extensive deposit whose thickness presently varies from a few metres to greater than 30 metres to 50 metres.

The clay thins or is absent within areas where the underlying glacial till deposits formed more prominent relief. The glacial till typically overlies bedrock and bedrock outcrops occur infrequently. Areas of glaciomarine sand and gravel beach deposits developed above the clay deposit during the retreat of the Champlain Sea from the valley, and the subsequent Ottawa River followed former meander channels associated with fluvial granular deposits. The river cut down into the underlying clay as the area continued to isostatically uplift during the post-glacial period until the present Ottawa River course was established. Relatively extensive areas of organic bog deposits have developed due to the flat, poorly drained terrain associated with the marine clays and former river channels.

3.2 Local Geological Conditions

3.2.1 Local Bedrock Geology

The bedrock geological conditions within the local study area around the CRRRC Site are shown on Figures 3-5, 3-6 and 3-7. The local study area includes the CRRRC Site and approximately 12 kilometres towards the east, 9.5 kilometres towards the south, 10.5 kilometres towards the west, and 5 kilometres towards the north. For general context, the extent of the local study area is shown on the regional bedrock geology map (Figure 3-1).

The local study area is overburden covered and bedrock outcrop is limited to a few comparatively isolated areas of shale outcrop at the Russell Shale Quarry approximately 5 kilometres to the southeast of the CRRRC Site and isolated limestone outcrops along the southern edge of the map area, typically south of the Gloucester Fault. An assessment of the bedrock geological conditions within this area was carried out by Golder through a review of the 1:50,000 scale Ontario OGS bedrock mapping (OGS Map P.2717 Paleozoic Geology Russell – Thurso Area, Southern Ontario dated 1985), a review of available site-specific investigation borehole and water well information.

The information included 1,176 MOECC water well records, 70 site-specific investigation cored boreholes drilled by Golder, Ministry of Transportation and other consultants, one deep core hole drilled by the GSC (GSC #2).

The OGS Russell-Thurso Area geology map identified 25 deep gas exploration wells within the local study area and the deep GSC #2 core hole that vary in depth between 300 metres and 890 metres. Ten of the gas exploration wells were completed in the Precambrian basement. The OGS map designated the wells RU-1 to RU-26 and that nomenclature has been retained in this document. The wells also have well names and Well IDs specified on the well cards, providing three references per well as summarized in Table A-1 of Appendix A. The locations of the wells designated RU-01 to RU-26 (GSC #2 = RU-24) are shown on Figure 3-4. The records for the 26 wells were obtained from the MNRF Oil, Gas and Salt Resource Library in London, Ontario. The records obtained included scanned copies of the well card summary sheets including generalized stratigraphy and well completion details, and scanned copies of the original natural gamma and neutron borehole geophysical records. Digitized copies of the natural gamma and neutron logs were also acquired. The majority of the exploration gas wells (23) were drilled by Consumers Gas between 1967 and 1969 and located within approximately 8 km northwest of the community of Russell. The exploration wells were drilled to assess the natural gas production potential within this deep part of the Paleozoic basin. No wells were put into production. Two wells (RU-25 and RU-26) were drilled by the Standard Oil Company in 1910 and 1911 according to the well card records. These two holes were geophysically logged by Consumers Gas in 1968. They are located approximately three kilometres to the east and three kilometres to the north of the CRRRC site, while the GSC #2 core hole is located approximately three kilometres to the southeast of the Site. The exploration gas wells were all plugged and abandoned between 1968 and 1971 in accordance with the MNRF regulations for abandonment of oil and gas wells. The GSC #2 hole was plugged and abandoned in 1966.

The location coordinates of the gas exploration wells are provided on the MNRF well cards in degrees, minutes and seconds of latitude and longitude. The well cards also include offsets from the Concession/Lot boundaries. It was noted that some of the indicated locations were at variance to the locations shown on the OGS Russell-Thurso geology map; for example, RU-24 (GSC #2) locates approximately 1.5 kilometres north of the location shown on the OGS geology map based on the well card location, which has been used in this study.

The digital records for natural gamma and neutron logs were used to interpret the stratigraphy encountered in the exploration gas wells, including the depths to the top of formations and the elevations of the formation tops as summarized on Tables A-2 and A-3 in Appendix A. The interpretation was carried out formation by formation based upon Golder's considerable experience with the interpretation of geophysical records for core holes throughout the Ottawa Valley. The gas well geophysical records vary somewhat in signal intensity between holes, likely reflecting different tools and logging rates. Casing effects on dampening gamma and neutron signals were also evident in wells RU-2, RU-7, RU-10, RU-24 and RU-25 (Figure 3-7). Overall the available records have enabled a comparatively detailed interpretation of the subsurface stratigraphy as discussed further in Section 3.2.1.3. The detailed stratigraphic interpretation has enabled the identification of faults based on formational displacements as discussed in Section 3.2.1.4.

Seven gas exploration wells (RU-2, RU-5, RU-7, RU-10, RU-23, RU-25 and RU-26) and the deep GSC #2 (RU-24) core hole were used to construct a north-south structural geological section though the local study area (Figure 3-7) extending from ground surface to the Precambrian basement encountered at depths between 700 metres and 850 metres. More detailed records of the borehole geophysics with the stratigraphic interpretation are provided on Figures A-1, A-2 and A-3 of Appendix A.

3.2.1.1 Bedrock Surface Topography

The combined file of site-specific investigation boreholes and MOECC water well information (1,274 data points) and 26 exploration gas wells was used to interpret the bedrock surface topography beneath the local study area as shown on Figure 3-5. The bedrock surface varies over a vertical range of approximately 90 metres within the local study area. In the southwestern corner of the area where bedrock is at or near surface, bedrock occurs at elevations of approximately 75 metres above sea level (m ASL) to 105 m ASL. In the northwestern corner of the local study area where the ground surface is between approximately 65 m ASL to 75 m ASL, the bedrock elevation occurs at approximately 15 m ASL to 25 m ASL. The areas of higher bedrock topography typically coincide with more erosional resistant limestone and dolostone bedrock along or south of the Gloucester Fault while the low areas tend to be underlain by less resistant shaley strata. Beneath the CRRRC Site, the shale bedrock surface occurs at an elevation of approximately 40 m ASL to 45 m ASL compared to ground surface between 75 to76 m ASL.

A buried bedrock ridge trending north-northeast occurs approximately six kilometres east of the Site where the bedrock surface rises approximately 20 metres to between elevations of approximately 60 to 80 m ASL, which coincides with a low topographic ridge at ground surface. The Russell Quarry occurs along this ridge where the Queenston shale is locally exposed at surface.

3.2.1.2 Local Bedrock Geology Map

The interpretation of the geology of the bedrock surface and locations of the Gloucester and Russell-Rigaud Faults is provided on Figure 3-6. The Gloucester and Russell-Rigaud Faults are stratigraphically definable primary faults that pass through the southern portion of the local study area. These faults separate the Upper Ordovician shales of the Queenston and Carlsbad Formations to the north of the faults from the Middle and Lower Ordovician limestone of the Bobcaygeon and Gull River Formations and dolostone of the older Oxford Formation to the south. The total vertical displacement associated with the Gloucester Fault is approximately 500 m (Figure 3-7).

The position of the Gloucester Fault shown on Figure 3-6 approximately coincides with a 5 metre to 20 metres change in bedrock surface elevation as shown on Figure 3-5, the shales to the north of the fault being less resistant to erosion and occurring at lower elevations than the limestone and dolostone south of the fault. There are additional secondary faults with displacements in the range of a few metres to tens of metres that occur beneath the local study area, but there is little stratigraphic information to define their potential positions. Faults of this nature can be recognized by reference to 6 of the 26 gas exploration wells (RU-4, RU-7, RU-8, RU-11, RU-14 and RU-17) based on stratigraphic interpretation of the borehole geophysics.

The lateral extent of the bedrock formations beneath the local study area as shown on Figure 3-6 has taken into consideration the OGS mapping and the available site-specific investigation borehole information. In addition, the MOECC WWIS (MOE, 2013) provided well driller's brief descriptions of the bedrock encountered during drilling domestic water wells. The wells/boreholes shown on Figure 3-6 are colour coded to take the bedrock descriptions into consideration. Red-coloured bedrock (Queenston shale) was consistently described, while areas underlain by the Carlsbad Formation were variously described by water well drillers as grey to black shale or limestone. The driller's reference to limestone in the same areas may reflect the presence of limestone layers interbedded in the shale that caught the driller's attention.

Through taking the water wells, site-specific investigation boreholes and gas wells into consideration, the general area underlain by the Queenston Formation shale, the uppermost and youngest Paleozoic sequence in the Ottawa Valley, has been defined as shown on Figure 3-6. This area differs from that shown on the published bedrock geology map of the area (OGS Map P.2717) and the Sanford GSC map (Figure 3-1) by being significantly reduced in extent to the east and greater in extent to the west based upon the benefit of the additional information on bedrock from the boreholes compiled for this study. The OGS interpretation indicated that the extent of the Queenston shale was fault bounded representing a down-dropped block. However the results of work carried out for this investigation indicate that the main body of the shale occurs as a conformable sequence within a broad synclinal basin (Figure 3-7). The OGS mapping recognized slivers of the Queenston Formation apparently encountered by water well drillers within the Gloucester-Russell fault zone where they are preserved as down-dropped blocks (Figure 3-6).

The MNRF well cards for gas exploration wells RU-07, RU-08 and RU-17 located near the Village of Russell report Queenston shale at the bedrock surface without definition of the underlying Carlsbad-Billings sequence. The MNRF well cards for gas exploration wells RU-1, RU-2 and RU-4 also indicate the presence of Queenston Formation shale at the bedrock surface where the well cards define a comparatively consistent thickness to the formation. However, examination of the geophysical records for these wells indicates that there is insufficient stratigraphic thickness in the Carlsbad/Billings shale sequences above the Trenton Group limestone to accommodate the Queenston shale at these well locations when compared to the record for RU-24 (GSC #2). In RU-24 approximately 235 metres of Carlsbad and Billings Formation shale occurs between the Queenston shale contact and the underlying Trenton Group limestone. Accordingly, these specific exploration well records are not considered representative with respect to the occurrence of the Queenston Formation.

The RU-6 well card reports Queenston Formation at the bedrock surface but did not define a thickness. There is approximately 306 metres of shale sequence in this well. When compared to RU-24, the projected Queenston shale contact in RU-6 would occur at a depth of approximately 73 metres. This represents the thickest intersection of Queenston shale in the area.

The red shale of the Queenston Formation is locally exposed within the Russell Shale Quarry where previous site-specific investigation core drilling by Golder identified up to 35 metres of Queenston Formation red shale/mudstone overlying the grey shale and limestone of the Carlsbad Formation. The transition from the Queenston Formation to the Carlsbad Formation shale was found to be marked by a laterally continuous fine grained, non-porous limestone layer with minor shale interbeds forming the caprock on the Carlsbad Formation. This limestone caprock varies in thickness from approximately 6.4 metres to 8.3 metres at the Russell Shale Quarry. A five metre thick section of the same limestone caprock with approximately 10% interbedded shale and calcareous shale was encountered in borehole BH12-2-3 at the southwest end of the CRRRC Site, indicating that this limestone caprock is a comparatively continuous stratigraphic horizon associated with the Queenston Formation/Carlsbad Formation contact. The caprock also underlies the eastern slope of the north-northeast trending bedrock ridge in the Russell Shale Quarry area, which is likely in part responsible for this erosional resistant bedrock topographic feature.

At the Russell Shale Quarry site, elevation contours of the Carlsbad limestone caprock/Queenston Formation contact horizon indicate a gentle synclinal fold as shown on Figure 3-8. The axis of the fold gently plunges westward at approximately 1.0% to 1.5% with inward sloping north and south limbs at approximately 2% to 3%. This fold is likely a localized sympathetic fold within the overall gentle synclinal structure represented by the Queenston shale sub-crop (the interpreted extent of which is shown on Figure 3-6), and indicates the scale of fold related bedding dip that can locally occur.

3.2.1.3 Bedrock Stratigraphic Sequence

The subsurface stratigraphy and structure beneath the local study area is shown in cross-section on Figure 3-7. This cross-section has been largely developed from interpretation of the stratigraphic sequence encountered by the deep gas exploration wells and the comparatively shallow site-specific investigation core holes. The section reflects the approximately 700 metres to 850 metres thick Paleozoic sequence unconformably overlying the Precambrian basement. The natural gamma and neutron geophysical records for the gas wells are shown on the section to indicate the positions of the major formation contacts. For example, the contact between the Billings Formation shale and the underlying Eastview Member of the Lindsay Formation limestone provides a pronounced regression in the natural gamma and neutron signal for correlation purposes. Detailed records of the interpreted geophysical signatures are provided on Figures A-1 to A-3 in Appendix A.

Shale Sequence

As indicated on Figure 3-7, the Upper Ordovician shale sequence that forms the bedrock surface north of the Gloucester Fault includes the red shale of the Queenston Formation, the underlying dark grey shale and secondary interbedded limestone of the Carlsbad Formation and the Billings Formation dark grey to black shale. The thickness of this shale sequence shown in the section varies between approximately 200 metres and 260 metres overlying limestone of the Trenton Group. The thickness variation reflects the depth of bedrock surface erosion and the very gentle dip of the strata. A few kilometres further west at well RU-6 (see location on Figure 3-4) the combined shale sequence thickens to approximately 306 metres.

The Queenston Formation red shale intersection in the RU-24 (GSC #2) core hole was approximately 25 metres as indicated by Dix and Jolicoeur (2011), while previous Golder borehole drilling at the Russell Quarry site encountered 35 metres of shale. As discussed above, the Queenston shale is directly underlain by the 6- to 8-metre thick limestone caprock of the Carlsbad Formation.

The Carlsbad Formation underlying the limestone caprock at both the Russell Quarry and CRRRC Site is comprised of thinly interbedded dark grey to black slake-susceptible shale with interbeds of calcareous shale, shaley limestone and individual beds of micritic to bioclastic limestone varying between approximately 2 and 20 centimetres thick. Some calcareous beds are cross laminated. The exposed shale tends to weather to a medium grey colour. At the CRRRC Site the percentage of shale and calcareous shale encountered in the cored boreholes was measured and found to vary between approximately 47% and 86% of the sequence, with the balance being interbedded shaley limestone and limestone. Siltstone is often used to describe some of these hard beds but they are all calcareous and readily scratched by knife indicating they are micritic to detrital carbonate beds rather than siliceous clastic beds.

The Carlsbad Formation has a distinct positive gamma spike and negative neutron spike at a depth of approximately 100 metres below the Queenston/Carlsbad contact in the RU-24 core hole as shown on Figure 3-7 (for detail see Figure A3 in Appendix A). This same spike is approximately 130 to 140 metres above the Billings/Eastview contact and was identified within the geophysical signatures of all the gas exploration wells where it provides a distinct stratigraphic marker bed. This thin horizon is reported to be a bentonitic clay layer consistent with an ancient volcanic ash layer (Dix and Jolicoeur, 2011). In exploration gas wells RU-7, RU-8, RU-11, RU-14 and RU-17(all located in the cluster of gas wells just north of the Village of Russell) the shale thickness between the bentonite layer and the Eastview Member varied between approximately 104 and 114 metres indicating the effects of vertical fault offsets in the respective boreholes.

The Billings Formation was not encountered in any of the local site investigations but has been extensively drilled by Golder in the urban Ottawa area as part of sewer and transit tunnel alignment investigations where up to 53 metres of Billings Formation shale sequence has been encountered. The formation consists of black slake-susceptible non-calcareous, bituminous shale. The formation's non-calcareous nature and general absence of hard carbonate interbeds differs significantly from that of the overlying Carlsbad Formation. The basal 10 to 20 metres of the Billings Formation is associated with an elevated natural gamma signature as shown on Figure 3-7, which is also associated with elevated total organic carbon concentrations in the range of 2% to 3% (Dix and Jolicoeur, 2011). The organic carbon content imparts the dark black colouration to the shale, which weathers brownish when exposed. Minor pyrite occurs along bedding partings while occasional thin (5 to 10 centimetres) limestone/siltstone beds occur at intervals of approximately 10 to 15 metres within the lower 53 metres of the section encountered in boreholes drilled in the urban Ottawa area. These thin beds are typically associated with negative natural gamma spikes.

The upward formational change from the Billings Formation to the Carlsbad Formation is transitional noted by the increased frequency of limestone beds. The OGS Russell-Thurso map sheet (map P.2717) reported a Billings shale thickness of approximately 54 metres in the RU-24 core hole. The available geophysical borehole records or the gas exploration wells were not considered to be sufficiently detailed to provide a clear distinction of the contact between the Carlsbad and Billings Formations. Therefore, the Carlsbad and Billings Formations are presented as one combined unit on Figure 3-7 with a thickness of approximately 235 metres.

Previous structural interpretation by Dix and Jolicoeur (2011) based upon limited borehole information (GSC #2/RU-24 and Consumers Gas wells 12417/RU-2 and 1772/RU-25) has suggested that correlation between these three boreholes indicates a localized sin-depositional graben fault feature with approximately 10 metres of offset. This correlation is based mainly upon their core logging of GSC #2/RU-24 borehole compared to the coarsely defined geophysical records of 12417/RU-2 and 1772/RU-25. Based on the geological information compiled and interpreted as presented in this report, the correlation is considered subjective, such that hypothesizing the presence of sin-depositional faulting may not be necessary to interpret the bedrock structure. As shown on Figure 3-7, the boreholes are 2.5 to 3.5 kilometres apart and there is essentially no thickness difference in the intervals between the base of the shale and the bentonite layer. Regardless, post-depositional faults on the scale of several metres to several tens of metres are relatively common throughout the region.

Trenton and Black River Groups

The shale sequence overlies approximately 200 to 215 metres of limestone of the Trenton and Black River Groups. The Trenton group includes the Lindsay and underlying Verulam Formations, which have a comparatively consistent combined thickness of 72 to 74 metres where not influenced by fault offsets (see Figure 3-7). The Eastview Member (former Eastview Formation) of the Lindsay Formation forms the top of the sequence directly beneath the Billings shale. Based on the gas well correlations, the member has a thickness of approximately 10 metres. It is comprised of thinly interbedded dark brownish black bituminous shale and dark brownish grey nodular micritic limestone with fossiliferous debris. The geophysical signature shows a distinct transition from the Lower Lindsay Formation to the Billings Formation (Figure 3-7). The Lower Lindsay Formation consists of medium to dark brownish grey medium thickly bedded micritic to calcarenitic nodular limestone.

The Verulam Formation consists of medium brownish grey thinly to medium bedded shaley calcarenitic limestone with interbeds of nodular limestone, minor thin lithoclastic calcarenite limestone beds and numerous dark gray to black very thin to thin interbeds shale. The formation is transitional from the overlying Lindsay Formation and the contact is considered to be the first shale bed typically identifiable in the natural gamma and neutron geophysical logs, subject to the log quality.

The Black River Group is comprised of the Bobcaygeon Formation and the underlying Gull River Formation. The Bobcaygeon Formation consists of light to medium brownish grey, medium to thickly bedded calcarenitic limestone and interbedded units of argillaceous nodular limestone and shaley limestone. The formation has an average thickness of approximately 92 metres based upon the interpretation of the gas well geophysics. It is associated with a comparatively distinctive geophysical signature, the top contact marked by a drop in gamma and increase in neutron response associated with the transition into a shale free calcarenite. The base of the formation is considered to be the first appearance of faintly to moderately porous dolostone marking the top of the Gull River Formation. This contact is associated with a positive gamma response and negative neutron response. The Bobcaygeon Formation is a clear geophysical marker horizon as shown on Figure 3-7.

The Gull River Formation is approximately 30 to 40 metres thick with the difference largely reflecting the transition into the underlying Rockcliffe Formation. The Gull River Formation is comprised of medium grey, micritic to lithographic limestone, argillaceous to calcareous dolostone and medium to very thickly bedded dolostone, minor interbedded black shale, shaley dolostone, dolomitic siltstone and partly bioturbated quartz sandstone. The top half of the sequence is largely limestone while the lower half is interbedded limestone and dolostone with sandstone interbeds

Rockcliffe Formation

The Rockcliffe Formation is a largely clastic sequence that varies in thickness between approximately 45 metres to 75 metres that can be subdivided into an upper and lower member associated with fairly distinct geophysical signatures. The Upper Member (15-18 metres) is comprised of medium to thick interbedded dolostone and calcareous dolostone, dark grey to black shale, medium grey, argillaceous limestone, and minor light grey calcareous cemented quartz sandstone. The Lower Member (45-60 metres) is composed of light whitish grey, laminar textured to ripple and cross bedded, thin to thick bedded silica cemented quartz sandstone, with minor interbeds of shale.

Oxford and March Formations

The Oxford Formation and the underlying March Formation are dolostone sequences where the thinner March Formation is transitional from the Oxford dolostone noted in core by gradational increase in carbonate cemented quartz sand grains. The geophysical transition from the overlying Rockcliffe Formation is sharply noted by a drop in gamma and increase in neutron responses. There is no distinct geophysical contrast between the Oxford and March Formations and they have been combined as a single unit for the purposes of Figure 3-7. The formations are comprised of fine grained, micritic dolostone, calcareous dolostone, argillaceous nodular dolostone, subordinate beds of lithoclastic dolostone, dark grey to black shale laminations in upper half (Oxford Formation), grading down to sandy dolostone to dolomitic sandstone and carbonate cemented quartz sandstone (March Formation). The thickness of this sequence varies from approximately 110 metres to 125 metres of which the basal 10 to15 metres could be the March Formation.

Nepean Formation

A contact depth for the base of this sequence (top of Nepean Formation) was provided in the MNRF well cards for the gas wells. The contact is associated with an increase in both gamma and neutron responses reflecting an underlying rock unit approximately 35 to 40 metres thick, interpreted to be a calcareous sandstone phase at the top of the Nepean Formation (Nepean Formation Unit 2B on Figure 3-7).

This unit is underlain by a sharp decrease in gamma response consistent with light grey, laminar to cross bedded, silica cemented quartz sandstone typical of the Nepean Formation. The sandstone includes widely spaced interbeds of grey shale and shaley siltstone with individual beds of quartz pebbles and cobbles set in a coarse grained quartz sandstone matrix. This sequence varies in thickness between approximately 100 and 140 metres based on the gas well geophysical interpretation likely reflecting variations in the topography of the underlying Precambrian surface (Nepean Formation Unit 2A on Figure 3-7). The comparatively thin (10 metre) Covey Hill Formation at the base of the Nepean Formation (where present) has not been subdivided.

Precambrian Basement

The Precambrian basement is comprised of undifferentiated igneous and metamorphic rock sequences of the Grenville Province including marble, biotite gneiss and granitic suites.

3.2.1.4 Fault Structures

The results of the geological evaluation have confirmed that the primary fault feature within the Local Study area is the Gloucester and Russell-Rigaud Fault system. As shown on Figure 3-7, the Gloucester Fault is comprised of a series of normal fault slices locally projected to occur within a zone approximately 0.75 kilometres in width where it passes beneath the community of Russell. The combined vertical offset associated with this fault zone is approximately 500 metres downward on the north side, which can be seen by the projected offset of the Oxford/March Formations across the fault zone. The fault zone depicted on Figure 3-7 reflects three individual vertical faults based on projections from sparse formation outcrops at surface. However, the zone is likely comprised of numerous vertical fault slices of varying displacements that collectively make up the total observed formational offset.

The geophysical interpretation of the stratigraphy encountered in the gas exploration well identified secondary faults intersecting wells RU-4, RU-7, RU-8, RU-11, RU-14 and RU-17 where displacement was measurable based upon the stratigraphic offsets in the boreholes.

In gas well RU-7, there is approximately 60 metres of vertical displacement associated with a reduction in the thickness of the Carlsbad/Billings sequence, complete displacement of the Lindsay Formation and upper 10 metres of the Verulam Formation, as indicated in section on Figure 3-7. The lower strata extending from the base of the Verulam Formation downward project directly from RU-10, while the upper sequence is displaced and RU-23 is stratigraphically down dropped relative to RU-7. This indicates that the fault passing through RU-7 is down thrown on the south side and probably parallels the local northeast-southwest trend of the adjacent Gloucester-Russell fault zone reflecting a localized downthrown post-depositional graben feature. There are likely other smaller scale faults within this interval as indicated by the projection of the Carlsbad bentonite layer between gas wells RU-7 and RU-23 (Figure 3-7).

Further west at gas well RU-17 (see location on Figure 3-4), the Carlsbad/Billings shale sequence between the bentonite layer and the top of the Eastview Member is approximately 110 metres thick compared to a typical undisturbed thickness of approximately 140 metres, indicating a displacement of 30 metres likely passing through the borehole approximately 10 metres above the Billings/Eastview contact based upon the foreshortened basal Billings geophysical signature.

Gas well RU-11 (see location on Figure 3-4) also has a foreshortening of the Carlsbad/Billings shale sequence between the bentonite layer and the top of the Eastview Member of approximately 35 metres.

Gas well RU-14 directly west of RU-11 has a foreshortening of the Carlsbad/Billings shale sequence between the bentonite layer and the top of the Eastview Member of approximately 26 metres and complete displacement of the Eastview Member and a portion of the underlying Lower Lindsay Formation of 16 metres totalling 42 metres, similar to the displacement in RU-11.

Gas well RU-8, located approximately 650 m south of RU-11 and RU-14 has a foreshortening of the Carlsbad/Billings shale sequence between the bentonite layer and the top of the Eastview Member of approximately 20 to 22 metres. To the northwest at gas well RU-4 (see location on Figure 3-4), there is a minor offset of approximately 10 m associated with foreshortening of the Carlsbad/Billings shale sequence between the bentonite layer and the top of the Eastview Member.

Further structural insight can be gained through a comparison of the formation contact elevations of the gas wells summarized in Table A-3 of Appendix A and the gas well locations shown on Figure 3-4. For example, slope of the contact of the top of the Eastview Member between gas well RU-22 and RU-12 is approximately 2% northward, similar to the local observations of formation slope at the Russell Quarry. There is an offset of approximately 28 to 30 metres between RU-22 and RU-17 to the south, consistent with the offset observed in RU-17 indicating downward displacement on the south side of the fault similar to RU-7. To the west, the projected displacement between RU-14 and RU-8 is approximately 60 metres. These relationships indicate an east-west trending fault or series of parallel faults related to the Gloucester Fault Zone passing between these boreholes with displacements of up to 60 metres down-thrown on the south side of the faults as indicated on Figure 3-7. North of these boreholes the formation contact slopes are comparatively constant and there is little indication of faulting.

The stratigraphic projection shown on Figure 3-7 extending northward beneath the CRRRC Site appears very consistent with no direct indication of discernable fault displacements. Smaller displacement faults (<10 metres) could however be present.

3.2.2 Local Surficial Geology

The thickness of the surficial deposits overlying the bedrock within the local study area is shown on Figure 3-9. This figure represents a subtraction of the bedrock surface shown on Figure 3-5 from the ground surface topography, essentially reflecting an inverse image. As shown, the areas underlain by shale north of the Gloucester Fault have approximately 20 metres to 60 metres of surficial deposits. The north-northeast trending buried bedrock ridge within this area locally has thinner surficial deposits of approximately 0 metres to 10 metres. The deposits are similarly thin (5 metres or less) within the area to the southwest of the Gloucester Fault underlain by Oxford Formation dolostone. The CRRRC Site is underlain by up to approximately 40 metres of soil, representing one of the thicker areas of surficial deposits within the local study area.

GSC mapping of the surficial deposits is shown on Figure 3-10. Much of the area is underlain by deposits of offshore marine silts and clays associated with the former Champlain Sea. The Champlain Sea deposits are thickest within those areas of lower bedrock surface topography. The marine clay deposit overlies glacial till deposits above the bedrock. The till deposits locally come to surface along the north-northeast trending buried bedrock ridge and within the areas of thin overburden above the dolostone bedrock strata to the southwest of the Gloucester Fault. The relationship between the basal till and overlying deposits is shown on Section D-D' Figure 3-11. The till is comparatively thin (2 metres to 9 metres) and follows the bedrock topography. The marine clay deposits have filled in the low areas, and are generally overlain by thin sandy soils.

A buried esker deposit of sand and gravel (Vars-Winchester Esker) occurs directly east of and roughly parallels the trend of the north-northeast trending buried bedrock ridge (Figure 3-11), and is about 8 kilometres east of the CRRRC Site. This esker forms an aquifer beneath the clayey marine deposits. This aquifer is structurally and hydraulically isolated from the CRRRC Site by the thick clay deposits and the buried bedrock ridge as illustrated on Figure 3-11.

The clayey marine deposits are locally overlain by a thin layer of sand and silt of near shore deltaic or estuary derivation that was deposited during the retreat of the Champlain Sea from the area. A former channel of the Ottawa River passes through the area directly north of Highway 417. The channel cut linear terrace faces into the marine clays and deposited stratified silts, sands and gravels along the channel bed. Following the retreat of the Ottawa River to its present channel, organic bog deposits accumulated in the low areas such as the extensive Mer Bleue Bog to the north/northwest of the CRRRC Site (see location on Figure 3-10).

3.3 CRRRC Site Geological Conditions

3.3.1 Site Bedrock Geology

The CRRRC Site was investigated by drilling at 25 locations during 2012 and 2013 (the methodology and results of the drilling program are described in detail in Section 2.0 and Section 6.0, respectively). Eight of the boreholes were drilled to bedrock and the rock was cored to depths of approximately 4 metres to 6 metres below the bedrock surface. The bedrock boreholes included BH12-1-3, BH12-1-3-1, BH12-2-3, BH12-3-3, BH12-4-3, BH13-5-3, BH13-6-3 and BH13-7-2, and the borehole locations are shown on Figure 3-12. The bedrock encountered in these boreholes was lithologically logged on a bed-by-bed basis and the individual borehole records are provided in Appendix A. Ten groundwater boreholes were previously drilled on the Site by Water & Earth Sciences Associates (WESA) in 1986-87, but only Test Hole #10 was completed into bedrock.

The location of Test Hole #10 drilled approximately 650 metres east of the southeast corner of the CRRRC Site is shown on Figure 3-12.

The bedrock surface elevation beneath the Site was interpreted from the on-Site boreholes that intersected the bedrock and from adjacent boreholes and water wells as shown on Figure 3-12 Panel A. The bedrock topography forms an irregular bowl shape beneath the Site varying in elevation between approximately 36 m ASL and 46 m ASL compared to a ground surface elevation of approximately 76 m ASL to 77.5 m ASL.

The boreholes cored into bedrock beneath the CRRRC Site all encountered the Carlsbad Formation (Figure 3-12 Panel B). The majority of the Site is underlain by the shaley member of the formation consisting of dark grey, very thinly to thinly interbedded shale and calcareous shale with thin to medium interbeds of argillaceous to shaley limestone and occasional beds of bioclastic limestone typical of the Carlsbad sequence beneath the limestone cap. A comparison of the core logs indicated that the interbeds of limestone could not be correlated between the cored boreholes. The shale and calcareous shale beds comprised approximately 47% to 86% of the bedrock investigated in the 8 core holes, averaging 71%. The shale tended to slake on exposure to wetting and drying.

The limestone caprock layer marking the top of the Carlsbad Formation was encountered at the south end of the CRRRC Site in BH12-2-3 where 5 metres of thinly to medium bedded limestone with approximately 10% shale interbeds was intersected. The limestone caprock was also encountered in the previously drilled Test Hole #10 directly east of the Site, while the red shale of the Queenston Formation was encountered in a water well directly southwest of the Site. Based on these strata intersections, a bedrock geology plan of the Site was constructed as shown on Figure 3-12 Panel B.

The geology plan indicates that the typically 6 metres to 8 metres thick caprock and associated formations dip very gently toward the south in the range of 1% to 2%.

3.3.2 Site Surficial Geology

As indicated on Figure 3-13 Panel A, the CRRRC Site is underlain by approximately 32 metres to 40 metres of surficial deposits; the thickest section is beneath the eastern side of the Site. The soil thickness directly mirrors the bedrock topography considering that the ground surface within the Site is essentially flat.

The majority of the boreholes drilled on-Site encountered a 1 metre to 2 metres thick veneer of silty sand at the surface overlying marine silty clay, while a few of the boreholes encountered the underlying marine silty clay at surface (Figure 3-13 Panel B). Two cross-sections illustrating the subsurface soil stratigraphy are provided on Sections E-E’ and F-F’ on Figures 3-14 and 3-15, respectively. The silty clay is the dominant soil horizon overlying a comparatively thin glacial till layer above the bedrock. A thin (0.1 metres to 0.6 metres), near flat lying layer of sandy silt to silty sand, trace clay (described as the ‘silty layer’) was encountered at a consistent depth of approximately 4 metres to 6 metres below ground surface (Figures 3-14 and 3-15) and was reasonably interpreted to be continuous beneath the Site and assumed to extend off-Site.

The thicknesses of the various soil horizons are shown by isopachs on Figures 3-16 and 3-17. The surficial layer of silty sand varies from not present (0 metres) to a maximum of 2.7 metres in a localized area (Figure 3-16 Panel A), while the underlying marine silty clay varies from approximately 25 metres along the northern edge of the Site to approximately 32 metres to 34 metres in the southwest corner and beneath the east side of the Site (Figure 3-16 Panel B). This trend generally reflects the inverse of the bedrock surface topography.

The silty layer within the upper portion of the silty clay deposit thins to the north and south of the Site and appears to be thickest in a diagonal band passing from northwest to southeast through the central part of the Site where it locally thickens to approximately 0.4 metres to 0.6 metres, possibly reflecting a local erosional pattern in the surface of the clay deposit (Figure 3-17 Panel A).

The thickness contours of the basal glacial till unit vary from 4 metres to 8 metres and reflect a relatively uniform layer given the large scale of the Site (Figure 3-17 Panel B).

4.0 REGIONAL TECTONICS

The CRRRC Site lies in a structurally complex geological setting resulting from a number of regional-scale tectonic events spanning more than one billion years. Structurally, the CRRRC Site is located near the southeast end of the Ottawa-Bonnechere graben. The Ottawa-Bonnechere graben extends for approximately 700 kilometres into the Canadian Shield from the Sutton Mountains salient of the central Appalachian orogeny. The graben extends eastward beneath the Appalachian thrust sheets for approximately 30 kilometres. Rimando and Benn (2005) argue that the Ottawa-Bonnechere graben is a failed arm along the triple junction of the St. Lawrence rift.

4.1 Seismicity

The Ottawa-Bonnechere graben is within the larger Western Quebec Seismic Zone (WQSZ) that extends from the Timiskaming region of Quebec to the Adirondack Highlands of upstate New York. The CRRRC Site is located at the southeastern end of the WQSZ – one of five seismic zones in southeastern Canada. These seismic zones have an historic record of relatively frequent small to moderate-magnitude earthquakes over about the last 250 years (Lamontagne et al. 2007). The WQSZ can be divided into two regions. One region extends along the Ottawa River from Timiskaming to Ottawa with earthquakes associated with a zone of normal faulting along the Ottawa River. Another region extends from Montreal to Baskatong Reservoir about 200 kilometres north of Ottawa. Adam and Basham (1989) suggest that earthquakes occur on crustal fractures that formed as North America rode over a mantle hotspot between about 140 and 120 million year ago. These two seismic zones merge near the St. Lawrence River.

Circumstantial evidence of large regional earthquakes in the Holocene Epoch (last 11,000 years) has been inferred from the clustering of ages of landslides in the Ottawa Valley by Aylsworth et al. (2000). Interpretation of information east of Ottawa suggests that large pre-historic earthquakes may have occurred about 4,550 and 7,060 radiocarbon years before present (years BP). About 45 kilometres northwest of Ottawa, in southwestern Quebec, a large earthquake event about 1,000 years BP is interpreted to also have caused a large landslide along the Quyon River channel; dating is similar for a number of other landsides along the Quyon River and the north side of the Ottawa River channel northwest of Ottawa (Brooks, 2013).

Shaking from these earthquakes and probably some historic earthquakes is inferred to have deformed bedding within near-surface sediments, generated differential settlement and resulted in the formation of irregular topography within the surficial deposits. While the widespread occurrence of large landslides in eastern Ontario/western Quebec on at least three occasions in the Holocene Epoch suggests widespread earthquake-related shaking, no evidence for fault movement / rupture at the ground surface has been found to be associated with these prehistoric earthquakes and more recent local large earthquakes.

The historical record of earthquake occurrence in the region has been evaluated from pre-instrumental and instrumental records extending from the late 17th century to the present day. For this analysis, the records were compiled from the following earthquake catalogs:

- National earthquake database (NEDB) maintained by the Department of Natural Resources of Canada (NRCAN), which contains instrumental data from 1987 to 2009;
- Composite Canadian Seismicity Catalog (CCSC) spanning from late 1534 to 2010;
- Global Centroid Moment Tensor catalog (CMT), which contains records of events from 1977 to present day;

- US Comprehensive Catalog (ComCat), currently containing records from 1973 to present;
- Advanced National Seismic System (ANSS); and,
- National Oceanic and Atmospheric Administration (NOAA) and the National Geophysical Data Center (NGDC).

These records reveal that at least 289 earthquakes (duplicates removed) of moment magnitude (M) ≥ 3.0 have epicenters located within about 200 kilometres of the CRRRC Site (Figure 4-1). Ten of these earthquakes were of M≥ 6.0, 29 have recorded M≥5.0, and the remaining 250 were of M≤ 4.0. Approximately 72% of the recorded earthquakes occurred at distances greater than 100 kilometres from the CRRRC Site. Table 4-1 lists major historical earthquakes with M ≥ 5.0 within about 200 kilometres of the CRRRC Site.

The largest earthquake recorded close to the CRRRC Site was the 1944 Cornwall-Massena earthquake that occurred on September 5, 1944 (Table 4-1). The epicenter of the M 5.8 Cornwall-Massena earthquake was located on the Saint Lawrence rift system between Massena, New York and Cornwall, Ontario about 66 kilometres from the Site.

Table 4-1: Major Historical Earthquakes (M ≥ 5.0) with Epicentres located within about 200 kilometres of the CRRRC Site

Year	Month	Day	Latitude (°N)	Longitude (°W)	Depth (km)	Moment magnitude (M)	Distance to the CRRRC Site (km)
1944	9	5	44.96	74.77	18	5.8	66
1732	9	16	45.50	73.60	- -	5.4	144
1661	2	10	45.50	73.00	- -	5.4	190
1914	2	10	46.00	75.00	- -	5.1	81
1893	11	27	45.50	73.30	- -	5.1	167
2010	6	23	45.88	75.48	22	5.0	60
2002	4	20	44.53	73.73	12	5.0	161
1983	10	7	43.94	74.25	9	5.0	181

Notes:
- - depth information not available
km – kilometres
M – moment magnitude

The occurrence of historical earthquakes and numerous micro-seismic events and adjoining areas suggests that some of the faults in the Ottawa-Bonnechere graben and other fractures may be seismically active. Although some earthquake activity appears to be localized along the Ottawa-Bonnechere graben, the irregular pattern of earthquake locations suggests that the main mapped geological structures of the graben probably do not control the seismicity distribution. Rather, the well-developed regional fracture pattern of northwest faults and fractures and a less well developed northeast-striking set of faults may exercise the major control on the distribution of instrumental earthquakes (Kumarapeli, 1987).

4.2 Present Day State of Stress

Studies of the present-day regional stress field by Hurd and Zoback (2012) suggest that the horizontal stresses become increasingly compressive with respect to the vertical stress moving from the south-central to the northeast United States and southeastern Canada (Figure 4-2). Hurd and Zoback speculate that the stress field may have developed from: 1) the superposition of stresses from the unloading of the massive Pleistocene ice sheet over about the last 15,000 years; 2) negative buoyancy effects associated with the relatively high density in the mantle lithosphere that pulls down on the crust and increases compressional forces; or 3) the orientation of paleotectonic rift structures with respect to modern day stress fields.

Figure 4-3 shows the orientation of the present day stress field near the CRRRC Site. The stress field orientation was developed from the variety of data sources included in the World Stress Map database. In Eastern Canada, and the Northeastern United States, these are primarily borehole breakouts and earthquake focal mechanisms (Baird et al. 2009).

Interpretation of stresses was made by Adams and Fenton (1994) from horizontal offsets of up to 25 millimetres of closely-spaced drillholes in and around the Ottawa area. They observed drillhole offsets of up to 25 millimetres at three locations: Baskatong, Quebec, Hull, Quebec and Carling Avenue, Ottawa. However, other excavation sites showed no evidence of borehole or other reference feature offset. The offsets were relatively small, not associated with known earthquakes and were interpreted by Adams and Fenton (1994) to have a probable cause related to near-surface stress relief rather than major seismogenic tectonic stresses.

5.0 TOPOGRAPHY AND SURFACE DRAINAGE

5.1 Local Topography

The surface topography in the vicinity of the CRRRC Site is shown on Figure 5-1. The topography is generally highest to the west and southwest of the Site, where ground surface elevations are as high as 105 m ASL. A local topographic high of 90 m ASL is found to the southwest of the Site along a north-south trending ridge. The topography is lowest in the north (65 m ASL), northeast (64 m ASL) and southeast (68 m ASL) portions of the area shown on Figure 5-1. Locally lower elevations resulting from erosion are found within the surface water features in the vicinity of the CRRRC Site. Major surface water features within the vicinity of the CRRRC Site (i.e., the Castor River and Bear Brook Creek) generally drain in an easterly direction following the general topographic slope.

At the CRRRC Site, the topography is flat, and varies between 76 m ASL on the east side of the Site, to 77.5 m ASL in the southwest portion of the Site.

5.2 Surface Water Drainage

5.2.1 Natural Watercourses

There are four main natural watercourses within five kilometres of the CRRRC Site. Bear Brook Creek is 3.4 kilometres to the northwest of the property boundaries, and Shaw's Creek is 1.6 kilometres to the east. Bear Brook Creek is a major tributary of the South Nation River. The North Castor River is 4.7 kilometres to the southwest of the property, while Black Creek is approximately 2.5 kilometres to the southeast. Both the North Castor River and Black Creek are part of the Castor River subwatershed and, as such, are isolated by the subwatershed boundary from receiving potential drainage from the CRRRC Site. The approximate boundary between the Bear Brook Creek subwatershed and the Castor River subwatershed is shown on Figure 5-2.

The communities of Edwards, Carlsbad Springs, Bearbrook, Cheney and Bourget are located along tributaries or sections of Bear Brook Creek. There are no municipal surface water intakes, with these communities primarily relying on groundwater or municipal systems for their water supply (South Nation Conservation Authority, 2012). The two closest of these communities are Edwards and Carlsbad Springs, located about two kilometres west and just over three kilometres north, respectively, from the Site. The other three communities are more than 10 kilometres east of Carlsbad Springs.

Water quality monitoring information for Bear Brook Creek is available from the City of Ottawa Water Environment Protection Program (WEPP). Water level information is available from the hydrometric data (HYDAT). The City of Ottawa WEPP sampled in various locations of the Bear Brook Creek Watershed, including a location near Carlsbad Springs, just north of the CRRRC Site (see location on Figure 5-2). The HYDAT station (No. 02LB008) within Bear Brook Creek is located near Bourget approximately 20 kilometres east of the CRRRC Site (east of the map area shown on Figure 5-2).

The water quality in Bear Brook Creek is reflective of the rural, agricultural population in its vicinity. According to the City of Ottawa Water Environment Protection Program (WEPP) 2008 to 2014 data for Bear Brook Creek (City of Ottawa, 2014), 0% to 44% of the phosphorus, E.*coli* and copper in water quality samples meet provincial and federal targets and 95% to 100% of zinc samples meet provincial and federal targets.

The average daily discharge at HYDAT station 02LB008 for 2001 to 2010 is 7.42 cubic metres per second (m^3/sec). This represents seven years of data as the records were incomplete for 2001, 2004 and 2007.

5.2.2 Constructed Watercourses

Watercourses in the form of ditches and drains are present on the CRRRC Site. In general, these are extensions of municipal drains in the vicinity of the property, or of municipal drains and their branches that originate from the property. Refer to Figure 2-2 for the location of constructed watercourses within the vicinity of the CRRRC Site.

The constructed watercourses that are on or near the CRRRC Site are as follows:

- DD1 – Originates within the CRRRC Site. It is an extension of the Regimbald Municipal Drain and is on a west to east orientation. It is located on the northern portion of the Site;
- Simpson Municipal Drain – Crosses the Site, entering from the west and exiting on the east. The municipal drain is on a west to east alignment and travels approximately 1.8 kilometres from the east boundary of the property, eastward under Highway 417 before turning southeast, continues as Shaw’s Creek which eventually feeds Bear Brook Creek. The streamflow distance from the Simpson Municipal Drain at the CRRRC Site east boundary to Bear Brook Creek is approximately 11.4 kilometres;
- DD2 – Originates within the CRRRC Site and is on a west-east orientation. It is an extension of the Frank Johnston Municipal Drain, which drains into the Wilson Johnson Municipal Drain prior to discharge to Shaw’s Creek. DD2 is located on the southern half of the CRRRC Site. Surface drainage from the Site boundary will travel approximately 1.3 kilometres before reaching the municipal drain system, which travels another 820 metres, crosses under Highway 417 and joins the Simpson Municipal Drain at Shaw’s Creek. The streamflow distance from the CRRRC Site boundary to Shaw’s Creek is approximately 2.1 kilometres;
- DD3 – Is a manmade surface water feature, approximately 800 metres in length, surrounding three sides of the former scrapyard property on the west central side of the Site. DD3 is an isolated incised constructed channel that may have a tenuous connection with DD2 during periods of high water; and,
- Regimbald Municipal Drain – Another extension of the Regimbald Municipal Drain is located near the northwest boundary of the Site on the north side of Highway 417. Initially aligned in a southeast to northwest direction, it then runs east, and flows southeast to join the Simpson Municipal Drain. Little or no drainage from the Site flows to this extension of the Regimbald Municipal Drain.

As noted above, all drainage discharge from the CRRRC Site eventually combines in the Simpson Municipal Drain, continues as Shaw’s Creek and eventually discharges to Bear Brook Creek.

The Bear River Municipal Drain is located approximately 1.4 kilometres to the west of the Site. It is a municipal drain with permanent flow that makes its way north for approximately 5.1 kilometres and discharges into Bear Brook Creek. The Bear River Municipal Drain does not receive drainage directly from the CRRRC Site.

Municipal drain details from the Fisheries and Oceans Canada (DFO) Drain Classification Database are presented in Table 5-1.

Table 5-1: Municipal Drain Details for the CRRRC Site

Municipal Drain Name	Flow	DFO Classification Type
Regimbald	Intermittent	F
Simpson	Intermittent	F
Wilson Johnston	Intermittent	F
Bear River	Permanent	B

All municipal drains on the CRRRC Site are intermittent and DFO Class F. However, the Bear River Municipal Drain has permanent flow and is DFO Class B; as described above, this does not receive drainage from the Site.

5.2.3 Existing Surface Water Outlet Points

Three drainage areas were delineated for the CRRRC Site and are presented on Figure 5-3.

Surface water generally flows into ditches and channels or sheet flows to three outlets:

- Surface drainage from the northeast portion of the Site is collected by DD1, and directed to the Regimbald Municipal Drain on the northeast border of the property.
- The central portion of the CRRRC Site is drained by the Simpson Municipal Drain, which exits out the east border and is eventually joined by the drainage from the northeast portion.
- The south portion of the Site drains to DD2, exits out the east property boundary and continues to flow until it reaches the Wilson Johnston Municipal Drain, which connects with the Simpson Municipal Drain at Shaw’s Creek.

6.0 SITE SUBSURFACE CONDITIONS

The following provides the results of the Site subsurface investigation:

- The subsurface conditions encountered in the boreholes along with the results of the Nilcon vane testing and direct push sampling are shown on the Record of Borehole and Drillhole sheets in Appendix A. The results of the water content and Atterberg limit testing are also indicated on the Record of Borehole sheets.
- The CPT profiles for normalized cone resistance, sleeve friction, and porewater pressure during pushing together with an interpreted profile of the stratigraphy are presented in Appendix B.
- The results of grain size distribution testing carried out on the surficial silty sand, silty layer within the silty clay, deep sandy silt and glacial till are provided in Appendix C.
- A summary of the measured undrained shear strength from the Nilcon vane testing as well as undrained shear strength profiles interpreted from the CPTs are provided in Appendix D.
- A summary of the sensitivity of the silty clay is provided in Appendix E.
- Plasticity charts for the weathered and unweathered silty clay, consolidation test results and secondary compression test results are provided in Appendix F.
- Summaries of the measured/interpreted coefficients of vertical and horizontal consolidation from the laboratory oedometer consolidation tests and the porewater pressure dissipation tests from the CPTs are provided in Appendix G.
- A graphical summary of selected engineering properties is provided in Appendix H.
- Photographs of the direct push soil samples are provided in Appendix I.
- Photographs of the bedrock core samples are provided in Appendix J.
- The results of the geophysical VSP testing are provided in a memorandum in Appendix K.

The following presents a summary of the subsurface conditions encountered within the on-Site boreholes.

6.1 Topsoil/Peat

Between 0.05 metres and 0.3 metres of topsoil/peat is encountered at ground surface at all of the borehole locations.

6.2 Surficial Silty Sand and Silt

The topsoil is underlain by between 0 to 2.7 metres of sand, silty sand, and/or sandy silt with trace to some clay. Standard penetration tests carried out within the sandy soils resulted in ‘N’ values of between 2 and 12 blows per 0.3 metres of penetration indicating a very loose to compact state of packing.

The measured natural water contents in the surficial silty sand soils at locations 12-1 and 12-3 were about 19% and 23%. The results of grain size distribution testing on 13 samples of this material are shown on Figure C1 in Appendix C.

Layers of weathered silty clay were encountered within the surficial silty sand soils at borehole locations 13-6 and 13-17, with thicknesses between about 0.1 and 0.4 metres. A layer of clayey silt with some sand was encountered within the surficial silty sand soils at location 13-8 with a thickness of about 0.1 metres.

6.3 Silty Clay

The surficial silty sand soils are underlain by a thick deposit of silty clay. The silty clay was fully penetrated to depths between approximately 27 and 36 metres below the existing ground surface at the first seven investigation locations (i.e., 12-1 through 12-4 and 13-5 through 13-7).

The upper 0.1 to 1.3 metres of the silty clay at 18 of the 25 investigation locations has been weathered to a red brown crust (referred to as ‘weathered crust’). Layers and seams of silty sand, sand and clayey silt were also encountered within the weathered portion of the silty clay. Standard penetration tests carried out in the weathered material gave ‘N’ values of between 2 and 4 blows per 0.3 metres of penetration indicating a stiff consistency (based on local experience with the correlation to undrained shear strength).

The results of Atterberg limit testing on several samples of the weathered silty clay indicate plasticity index values ranging from about 16% to 46%, and liquid limit values ranging from about 32% to 69%, which generally indicates a silty clay to clay of medium to high plasticity. These values are summarized on Figure F1 in Appendix F. One result did plot within the lower plasticity region of the plasticity chart. The measured natural water contents of several samples of the weathered crust ranged from about 21% to 46%. These values are generally below the measured liquid limits.

The silty clay below the surficial silty sand and silt or weathered crust (where present) is unweathered. The results of *in-situ* Nilcon vane testing in this unweathered material gave undrained shear strengths ranging from about 4 kilopascals (kPa) (a single measurement) to greater than 100 kPa, generally increasing with depth. These results indicate a generally soft consistency to about 9 to 10 metres depth, followed by a firm consistency to about 15 to 18 metres depth, followed by stiff to very stiff for the remainder of the deposit. The results of the Nilcon vane testing are summarized on the Record of Borehole sheets as well as provided on Figure D6 in Appendix D.

Undrained shear strength profiles of the silty clay have also been evaluated from the results of the CPTs, using the following equation:

$$S_u = (q_t - \sigma_{vo}) / N_{kt}$$

Where: S_u = Calculated undrained shear strength (kPa);

q_t = Measured net tip resistance (kPa);

σ_{vo} = Calculated total vertical stress (kPa);

N_{kt} = Correlation factor, which ranges from 11 to 15 for this Site.

The undrained shear strength profiles for the silty clay, interpreted from the results of the CPTs, as described above, are summarized on Figures D1 to D5 in Appendix D. The CPT results indicate undrained shear strengths that are generally consistent with the *in-situ* Nilcon vane testing results.

The measured sensitivity of the unweathered silty clay deposit, as indicated from the Nilcon vane tests, ranges from about 1 to 17, but is more generally in the range of 4 to 14, indicating a medium sensitive to extrasensitive soil. These values are summarized on Figure E1 in Appendix E.

The results of Atterberg limit testing carried out on several samples of the unweathered silty clay gave plasticity index values generally ranging from about 27% to 58% and liquid limits values from about 46% to 84%. These results indicate a relatively high plasticity soil. The results of one sample from location 12-1-3 indicated particularly high values, with a plasticity index of 80% and a liquid limit of 114%. These values are summarized on Figure F2 in Appendix F.

The measured water contents of the samples of the unweathered silty clay material were between about 20% and 90%. However, more generally, the following observations are made:

- The water content above about 20 metre depth is typically in the range of 65% to 85%; and,
- The water content below about 20 metre depth is generally slightly less, being typically in the range of 60% to 70%.

The natural water content is also generally at or above the measured liquid limit.

Laboratory oedometer consolidation tests were carried out on 17 thin-walled Shelby tube samples of the unweathered silty clay. The results of that testing are provided on Figures F3 to F19 in Appendix F and are summarized in Table 6-1 below.

Table 6-1: Summary of Oedometer Consolidation Tests

Borehole Location/Sample Number	Sample Depth/Elevation (m)	Unit Weight (kN/m^3)	σ'_p (kPa)	C_c	C_r	e_0
12-1-3 / 1	2.5 / 73.5	15.7	55	1.59	0.010	1.98
12-1-3 / 4	13.3 / 62.7	15.0	180	4.23	0.008	2.47
12-1-3 / 5	18.7 / 57.3	15.3	170	1.70	0.024	2.35
12-2-3 / 1	4.5 / 72.4	14.7	55	2.57	0.032	2.47
12-2-3 / 2	8.5 / 68.4	15.0	110	3.06	0.017	2.35
12-2-3 / 6	24.0 / 52.9	16.1	260	1.40	0.015	1.81
12-3-3 / 6	29.4 / 46.8	16.3	270	1.10	0.018	1.71
12-3-5 / 1	5.7 / 70.5	14.8	85	3.71	0.015	2.46
12-3-5 / 2	15.7 / 60.5	15.9	185	1.58	0.025	1.93
12-4-3 / 1	3.3 / 72.6	16.0	60	1.31	0.015	1.73
12-4-3 / 3	11.1 / 64.8	16.0	115	1.58	0.009	1.80
12-4-3 / 6	26.2 / 49.7	16.4	285	1.32	0.017	1.63
13-6-3 / 3	10.0 / 66.7	15.1	110	3.41	0.010	2.29
13-6-3 / 4	18.4 / 58.3	15.4	210	2.80	0.011	2.08
13-6-5 / 1	6.4 / 70.2	14.8	80	2.30	0.025	2.44

Notes:
kN/m^3 – kilonewtons per cubic metre
σ'_p – Apparent preconsolidation pressure; C_r –Recompression index; C_c – Compression index; e_o – Initial void ratio

Longer term (i.e., sustained load) laboratory oedometer consolidation tests were carried out on 2 of the 17 thin-walled Shelby tube samples of the unweathered silty clay, one from each of boreholes 12-1-3 (sample 2) and 12-3-5 (sample 1), stressed to about the anticipated final effective stress level at the depths of the samples (i.e., once the landfill weight is applied), to evaluate the secondary compression (i.e., creep) characteristics of the deposit. The results of the secondary compression tests are provided on Figures 20 to 21 in Appendix F and are summarized in Table 6-2 below.

Table 6-2: Summary of Secondary Compression Oedometer Consolidation Tests

Borehole Location/Sample Number	Sample Depth/Elevation (m)	Unit Weight (kN/m^3)	σ'_p (kPa)	C_c	C_α	e_0
12-1-3 / 2	6.4 / 69.6	16.6	45	0.69	0.011	1.50
12-3-5 / 1	5.6 / 70.6	14.9	70	2.04	0.019	2.44

Notes:
kN/m^3 – kilonewtons per cubic metre; kPa – kilopascals
σ'_p – Apparent preconsolidation pressure; C_α – Secondary compression index; C_c – Compression index; e_o – Initial void ratio

It should be noted that a higher load increment ratio ('LIR' – which is the ratio of the magnitude of the each load increment to the magnitude of the previous total load) was used when loading these samples to the design stress level, versus the general consolidation testing program, which could impact on the accuracy of the interpreted preconsolidation pressure. An LIR of about 1.0 was used for these tests.

The vertical coefficient of consolidation values (c_v) interpreted from the results of the laboratory oedometer consolidation tests are shown on Figure G1 in Appendix G. It should be noted that most of the oedometer consolidation tests were carried out using a relatively low LIR, which assists with defining the preconsolidation pressure for a sensitive and structured clay, such as present at this Site, but can yield unrepresentative c_v values. However, the calculated c_v values for the two sustained load (i.e., secondary compression) tests are also shown on this figure, and they were carried out using a higher and more conventional LIR.

The *horizontal* coefficient of consolidation (c_h) values were evaluated from the porewater pressure dissipation tests carried out using the CPT unit at seven of the investigation locations. The results of the dissipation tests are summarized Table 6-3 below and provided in Appendix G.

Table 6-3: Summary of Porewater Pressure Dissipation Tests

Location (CPT)	Test Depth/Elevation (m ASL)	C_h (m^2/sec)	M (MPa)	K_h (m/sec)
12-1-1	7.7 / 68.3	2.61×10^{-7}	0.88	2.91×10^{-9}
12-1-1	12.7 / 63.3	2.93×10^{-7}	2.32	1.24×10^{-9}
12-1-1	18.6 / 57.4	7.81×10^{-7}	3.71	2.06×10^{-9}
12-1-1	23.6 / 52.4	1.30×10^{-6}	3.64	3.51×10^{-9}
12-2-1	9.3 / 67.7	4.20×10^{-7}	1.57	2.62×10^{-9}
12-2-1	14.9 / 62.1	5.33×10^{-7}	2.99	1.75×10^{-9}
12-2-1	19.7 / 57.3	8.43×10^{-7}	3.68	2.24×10^{-9}
12-2-1	23.9 / 53.1	1.63×10^{-6}	7.50	2.13×10^{-9}
12-3-1	9.9 / 66.3	3.18×10^{-7}	2.51	1.24×10^{-9}
12-3-1	14.8 / 61.3	6.95×10^{-7}	5.09	1.34×10^{-9}
12-3-1	19.8 / 56.3	9.52×10^{-7}	6.55	1.43×10^{-9}
12-3-1	24.9 / 51.3	2.06×10^{-6}	9.57	2.11×10^{-9}
12-4-1	5.2 / 70.6	6.19×10^{-7}	0.43	1.43×10^{-8}
12-4-1	10.1 / 65.8	3.53×10^{-7}	2.26	1.53×10^{-9}
12-4-1	16.1 / 59.7	1.02×10^{-6}	3.27	3.06×10^{-9}
12-4-1	23.2 / 52.7	9.55×10^{-7}	4.84	1.93×10^{-9}
13-5-1	8.1 / 68.2	3.75×10^{-7}	1.13	3.24×10^{-9}
13-5-1	14.7 / 61.7	8.19×10^{-7}	2.46	3.26×10^{-9}
13-5-1	20.7 / 55.6	1.15×10^{-6}	3.97	2.85×10^{-9}
13-5-1	27.35 / 49.0	1.70×10^{-6}	6.90	2.41×10^{-9}
13-6-1	7.1 / 69.8	2.97×10^{-5}	1.61	1.81×10^{-7}
13-6-1	14.0 / 62.8	6.04×10^{-7}	3.35	1.77×10^{-9}
13-6-1	21.1 / 55.8	1.29×10^{-6}	3.31	3.82×10^{-9}
13-6-1	28.1 / 48.8	1.87×10^{-6}	4.97	3.70×10^{-9}
13-7-1	7.0 / 69.3	1.98×10^{-7}	0.36	5.37×10^{-9}
13-7-1	14.1 / 62.2	7.11×10^{-7}	1.45	4.80×10^{-9}
13-7-1	21.0 / 55.3	9.50×10^{-7}	3.07	3.03×10^{-9}

Notes:
MPa – Mega Pascals
C_h – Coefficient of consolidation in the horizontal direction; k_h – Soil permeability
M – One-dimensional constrained modulus of compressibility

The above coefficient of horizontal consolidation (c_h) values are also summarized on Figure G2 in Appendix G.

A continuous layer of sandy silt to silty sand, trace clay was encountered within the upper portion of the silty clay at depths between about 4 and 6 metres (referred to as the silty layer). This layer was observed both within the sampled boreholes as well as from the results of the CPTs and varies in thickness from about 0.1 metres to 0.6 metres.

The results of grain size distribution testing carried out on 10 samples of this silty layer material are shown on Figure C2 in Appendix C and indicate that the layer consists of sandy silt or silt with trace clay.

Other discontinuous seams/layers of mainly silt were encountered at various depths within the silty clay deposit. In particular, a deep sandy silt layer was encountered at about 34.5 metres depth within the silty clay deposit just above the glacial till at borehole 12-1-7. The results of grain size distribution testing on one sample of the approximately 1.3 metre thick deep sandy silt layer are shown on Figure C3 in Appendix C. A similar approximately 0.5 metre thick deep silty sand/sandy silt layer was also encountered within the silty clay deposit at location 12-2 at about 33.8 metres depth, just above the glacial till.

6.4 Glacial Till

The silty clay is underlain by a deposit of glacial till. Based on the retrieved samples and observations of the sampler/drilling resistance, the glacial till is considered to generally consist of a heterogeneous mixture of gravel, cobbles and boulders in a matrix of sand and silt with a trace to some clay. This deposit was fully penetrated to depths between about 33.4 and 40.8 metres below the existing ground surface. Where penetrated, the thickness ranges from about 2 to 9 metres.

Standard penetration tests carried out within the glacial till resulted in ‘N’ values of between 6 and greater than 100 blows per 0.3 metres of penetration indicating a loose to very dense state of packing. However, the higher standard penetration test ‘N’ values encountered in the glacial till likely reflect the presence of cobbles and boulders in the deposit. In borehole 13-6, diamond drilling techniques were required to penetrate through the boulders in the glacial till deposit.

The measured natural water contents of the glacial till at locations 12-1 and 12-3 were about 9% and 10%. The results of grain size distribution testing carried out on two samples of this deposit are shown on Figure C4 in Appendix C. However, it should be noted that the samples were retrieved using a 35-millimetre inside diameter sampler and therefore the results don’t reflect the boulder, cobble or full gravel content.

Naturally occurring gas was encountered within the glacial till layer during drilling at locations 12-4, 13-5 and 13-6.

6.5 Bedrock

Coring of the bedrock was carried out at the first seven investigation locations (i.e., 12-1 through 12-4 and 13-5 through 13-7). The following table provides details of the cored boreholes.

Table 6-4: Summary of Cored Bedrock Boreholes

Borehole Location	Date Drilled	Ground Surface Elevation (m ASL)	Depth to Bedrock (metres)	Bedrock Surface Elevation (m ASL)	Total Depth Cored (metres)
12-1-3	November 15 to 19, 2012	76.01	40.61	35.40	5.86
12-1-3-1	November 23, 2012	76.10	39.78	36.32	5.59
12-2-3	January 11 and 14, 2013	76.94	36.74	40.20	5.21
12-3-3	December 3 to 5, 2012	76.22	39.84	36.38	5.58
12-4-3	January 31 to February 15, 2013	75.92	37.80	38.12	5.81
13-5-3	June 14 to 18, 2013	76.51	34.23	42.28	6.10
13-6-3	March 11 to 15, 2013	76.69	40.79	35.90	4.26
13-7-2	June 10 to 13, 2013	76.35	33.37	42.98	6.10

The boreholes cored into bedrock beneath the CRRRC Site all encountered the Carlsbad Formation. The majority of the Site is underlain by the shaley member of the formation consisting of dark grey, very thinly to thinly interbedded shale and calcareous shale with thin to medium interbeds of argillaceous to shaley limestone and occasional beds of bioclastic limestone typical of the Carlsbad sequence beneath the limestone cap. The shale and calcareous shale beds comprised approximately 47% to 86% of the bedrock investigated in the 8 core holes, averaging 71%.

The limestone caprock layer marking the top of the Carlsbad Formation was encountered at the south end of the CRRRC Site in BH12-2-3 where five metres of thinly to medium bedded limestone with approximately 10% shale interbeds was intersected.

The Rock Quality Designation (RQD) values measured on recovered bedrock core samples typically range from about 59% to 100%, indicating a fair to excellent quality rock. However, two lower RQD values of 12% and 29% were measured within the upper portion of the bedrock at borehole locations 12-3-3 and 12-2-3, respectively, indicating poorer quality bedrock.

6.6 Geophysical Testing

The results of the geophysical VSP testing that was carried out within boreholes 12-2-3 and 12-3-3 are provided in the memorandum in Appendix K. The results indicate a measured average shear-wave velocity from ground surface to a depth of 30 metres of 117 m/sec for borehole 12-2-3 and 112 m/sec for borehole 12-3-3. These results show the Boundary Road Site to be Class E as it relates to seismic design as set out in the National Building Code of Canada (NRC, 2010) and the Ontario Building Code (MMAH, 2012). This agrees with the seismic site class map of the Ottawa area (Hunter et. al., 2012)

6.7 Additional Borehole Investigations

Following the initial Site investigation, additional boreholes were completed as part of supplementary investigations. Two boreholes were drilled in the vicinity of the proposed Site entrance off of Boundary Road. The boreholes are identified at A13-1 and A13-2, and the borehole locations are shown on Figure 2-1. Boreholes A13-1 and A13-2 provided investigation of the geology in the northwestern extent of the property, and permitted the installation of monitoring wells for the collection of additional groundwater levels in the surficial silty sand. Following the installation of the monitoring wells in A13-1 and A13-2, these locations were added to the monthly groundwater level monitoring program for the Site. The geological conditions encountered at locations A13-1 and A13-2, as well as the monitoring well completion details are provided on the borehole records in Appendix A (following the Site investigation borehole logs).

Ten additional boreholes were drilled as part of a dug well assessment completed at the Site. The boreholes were drilled to confirm the geological conditions in the vicinity of two on-Site dug wells and to permit the installation of groundwater monitoring wells. The first dug well is located in the northeastern portion of the Site along Frontier Road and is identified as Frontier-1 on Figure 2-1. The second dug well is located near the western Site boundary in the central part of the Site. The second dug well is identified as Boundary-2 on Figure 2-1.

The boreholes drilled as part of the dug well assessment are identified as B13-1 through B13-10, and the borehole locations are shown on Figure 2-1. Two of the boreholes (B13-1 and B13-2) were drilled in the vicinity of Frontier-1. The monitoring wells installed within these boreholes allowed for the observation of groundwater levels in the shallow overburden during typical operation of a dug well (i.e., the residence where this dug well is located is still occupied). Boreholes B13-3 through B13-10 were drilled in the vicinity of Boundary-2. The monitoring wells installed within these boreholes allowed for the observations of groundwater levels in the shallow overburden during a pumping test completed using Boundary-2. The geological conditions encountered at locations B13-1 through B13-10, as well as the monitoring well completion details are provided on the borehole records in Appendix A (following the Site investigation borehole logs). The results of the dug well assessment are discussed in a separate technical memorandum provided in Appendix M.

A review of the borehole logs for locations A13-1, A13-2 and B13-1 through B13-10 indicates the native geological materials encountered are consistent with those observed during the original Site investigation (i.e., at locations 12-1 through 12-4 and 13-5 through 13-25 shown on Figure 2-1), although some locations have more fill material.

7.0 HYDROGEOLOGY CONDITIONS

7.1 Local Hydrogeology

In the vicinity of the CRRRC Site, the shallow groundwater flow within the surficial silty sand layer is influenced by local topography and the position of local surface water features, and is interpreted to be primarily horizontal. Within the marine clay deposits (at surface and at depth), there is minimal groundwater flow, and the groundwater flow direction is typically vertical. At depth, the groundwater flow direction within the basal till/bedrock contact zone and within the upper portion of the bedrock is towards the east and northeast (Raisin Region-South Nation Source Protection Region, 2012; WESA, 2010, WESA and Earthfx, 2006; Golder 2004).

Within the shallow groundwater flow system (surficial silty sand), groundwater recharge and discharge tends to occur locally, with recharge occurring within topographically higher areas with coarser grained materials, and discharge likely occurring tens of metres to a few kilometres downgradient in ditches and small streams. Within the vicinity of the CRRRC Site, the natural recharge/discharge cycle may be short-circuited by the interception of tile drains followed by direct discharge to nearby surface watercourses (Raisin Region-South Nation Source Protection Region, 2012). Most of the water that recharges into the surficial overburden discharges locally to surface water features and does not flow to the deeper basal till/bedrock groundwater system. The recharge to the deeper bedrock/till flow system is not expected be local, and likely occurs in upgradient areas where the till/bedrock are closer to ground surface and overlain by coarse grained material.

Based on a review of the City of Ottawa Official Plan, and the Source Water Protection work completed for the Rideau Valley Source Protection Area and the South Nation Source Protection Area, the CRRRC Site is not located within a groundwater protection zone, or within a significant groundwater recharge area.

Within the vicinity of the CRRRC Site, water supply to residences, farms and commercial/industrial properties is provided by private wells. Approximately eight kilometres to the east of the CRRRC Site, the communities of Vars and Limoges obtain their water supply from communal wells completed in a north-south trending buried sand and gravel esker (Vars-Winchester Esker).

In the area surrounding, but some distance from the CRRRC Site, drilled wells for private water supply obtain their water from the basal till/bedrock contact zone or from within the upper portion of the bedrock. The yield of water from this zone is often adequate for domestic use, with well yields reported to typically range from 15 to 25 L/min, and up to 45 to 65 L/min in certain wells (MOE, 2013). In the immediate vicinity of the CRRRC Site, there are few wells registered in the MOECC WWIS (i.e., few drilled water supply wells). The groundwater quality from the till/bedrock contact zone and within the bedrock in the immediate vicinity of the CRRRC Site is reported as salty, sulphurous or mineralized; the presence of methane gas in the groundwater is also reported (WESA, 1986). For this reason, it is understood that most residents/businesses in the vicinity of the CRRRC Site use shallow dug wells to provide a water supply from the surficial silty sand layer.

The groundwater quality issues in the basal till/bedrock contact zone are known to exist as far as three or four kilometres to the north of the CRRRC Site in the area of Carlsbad Springs and also to the west of the Site. The City of Ottawa extended the municipal water supply to a portion of the Carlsbad Springs area to address these water supply issues. Further to the southwest and southeast, drilled wells are also completed in the basal till/bedrock contact zone and the groundwater quality is reported as fresh (Charron, 1978; WESA, 1986; WESA and Earthfx, 2006).

In October and November 2013, Golder undertook a dug well assessment to confirm how dug wells in the vicinity of the Site function. A technical memorandum describing the dug well assessment is provided in Appendix M. The following summarizes the findings relating to dug well water supply in the vicinity of the Site:

- The dug wells obtain water primarily from the surficial silty sand layer;
- The dug wells are recharged locally (i.e., from the silty sand close to the well);
- The sustainable pumping rate is approximately 4 L/min; and,
- Under typical use, the radius of influence of a dug well (i.e., area of drawdown associated with the water taking) is interpreted to be less than 10 metres. That is, the dug wells are recharged locally (i.e., from the silty sand close to the well).

7.2 Site Hydrogeology

7.2.1 Groundwater Level Data and Flow Directions

The groundwater level monitoring program for on-Site monitoring wells was conducted to further characterize the long-term hydrogeological conditions present at the CRRRC Site. Groundwater levels were collected at the on-Site monitoring wells in January and February 2013 (12-1, 12-2 and 12-3 only) and monthly from April to December 2013. During the January and February 2013, some of the monitoring wells were frozen and water levels could not be obtained. The available monthly groundwater levels are presented in Table L-2 in Appendix L and on Figures L1, L3, L5, L6, L7 and L9. Groundwater levels were also measured three times per day using dataloggers in monitoring wells completed in the surficial silty sand layer, the silty layer, glacial till and upper bedrock zone at locations 12-1, 12-3 and 13-6. The daily groundwater elevation data is presented by stratigraphic unit on Figures L2, L4, L8 and L10 and by location (i.e., 12-1, 12-3 and 13-6) on Figures L11 to L13.

An estimate of the groundwater flow direction for the surficial silty sand, the silty layer, silty clay, glacial till and upper bedrock units at the CRRRC Site was obtained using appropriately positioned (vertically) on-Site monitoring intervals. A representative set of groundwater levels collected on October 16, 2013 were used to generate the groundwater contours and interpret the groundwater flow direction in each stratigraphic unit as shown on Figures 7-1 through to 7-5.

7.2.1.1 Surficial Silty Sand Layer

The groundwater flow direction in the surficial silty sand was estimated using groundwater level data from 27 monitoring wells. Based on a review of the available monthly groundwater levels, the groundwater flow direction in the surficial silty sand is interpreted to be consistently towards the east at the CRRRC Site as shown on Figure 7-1. Groundwater levels across the CRRRC Site were generally consistent throughout the groundwater monitoring program based on monthly manual measurements, with the exception of the August 15, 2013 monitoring session (see Figure L1). In August 2013, groundwater levels in the majority of surficial silty sand monitoring wells decreased by 0.1 to 0.8 metres. Groundwater levels in the surficial silty sand monitors recovered following the September 2013 monitoring session, with the exception of 13-17-2.

The available datalogger data provided on Figure L2 indicates that groundwater levels in monitoring wells 12-1-6, 12-3-6 and 13-6-6 completed in the surficial silty sand show rapid fluctuation, which is interpreted to be a result of local precipitation events followed by dry periods. The groundwater level fluctuations observed in the surficial silty sand are more pronounced during the summer months (i.e., June through August). Groundwater elevations in the surficial silty sand measure on average 0.4 metres below ground surface across the CRRRC Site, and range from 0.1 metres above ground surface (12-4-6) to more than 1.5 metres below ground surface at monitoring well 13-21-2 (location was dry during the August and September monitoring sessions). The overall range in groundwater elevations observed within the surficial silty sand was between 75.0 m ASL and 76.8 m ASL.

7.2.1.2 Silty Layer

The groundwater flow direction in the silty layer was estimated using groundwater level data from 16 monitoring wells. Based on a review of the available monthly groundwater levels, the groundwater flow direction in the silty layer is interpreted to be consistently towards the east at the CRRRC Site as shown on Figure 7-2. Groundwater levels in the silty layer measured between 0 and 1.0 metres below ground surface (75.3 m ASL and 76.7 m ASL) throughout the monitoring program (see Figure L3). In general, groundwater levels within the silty layer show seasonal variability and decreased between 0.1 and 0.5 metres throughout the summer months, followed by an increase in the fall. The available datalogger data on Figure L4 for locations 12-1-5B, 12-3-5B and 13-6-5B completed in the silty layer indicate that groundwater levels are generally consistent, and do not show the same rapid fluctuations observed in the surficial silty sand.

7.2.1.3 Silty Clay

The horizontal direction of the groundwater flow gradient in the silty clay was estimated using groundwater level data from monitoring wells 12-1-5A, 12-2-5A, 12-3-5A, 12-4-5A, 13-5-4B, 13-6-5A and 13-7-4A (i.e., the middle silty clay monitoring wells). Based on a review of the available monthly groundwater levels, the potential direction in the silty clay is interpreted to be consistently towards the east at the CRRRC Site as shown on Figure 7-3. Groundwater levels in the middle silty clay measured between 0.4 and 1.9 metres below ground surface (74.6 m ASL and 76.2 m ASL), and were generally consistent or decreased slightly during the summer months followed by a slight increase in the fall (see Figure L5).

Groundwater levels in the deep silty clay measured between 0.2 metres above ground surface to 1.9 metres below ground surface (74.5 m ASL and 76.8 m ASL) and were generally consistent throughout the monitoring program, with the exception of monitor 12-2-4 and 13-6-4B (see Figure L-6). The water levels observed at monitor 12-2-4 display a more pronounced increase during the fall (i.e., between September and December 2013) than was observed at the remaining deep silty clay monitors. Water levels observed at monitor 13-6-4B declined consistently by approximately 0.4 metres between May and December 2013.

7.2.1.4 Glacial Till

The groundwater flow direction in the glacial till was estimated using groundwater level data from monitoring wells 12-1-4A, 12-3-4A, 12-4-4A, 13-5-4A, 13-6-4A and 13-7-3. Based on a review of the available monthly groundwater levels, the groundwater flow direction in the glacial till is interpreted to be consistently towards the east/northeast at the CRRRC Site as shown on Figure 7-4. Groundwater levels within the glacial till layer measured between 1.3 and 1.9 metres below ground surface (74.4 m ASL and 75.1 m ASL) and were generally consistent throughout the monitoring program (less than 0.3 metres observed difference at any given glacial till monitor) as shown in Figure L7. The available datalogger data for locations 12-1-4A, 12-3-4A and 13-6-4A completed in the glacial till show minor fluctuation in groundwater levels that are not observed in the less frequent monthly measurements (see Figure L8).

7.2.1.5 Upper Bedrock Zone

The groundwater flow direction in the upper bedrock zone was estimated using data from monitoring wells 12-1-3-1, 12-2-3, 12-3-3, 12-4-3, 13-5-3, 13-6-3 and 13-7-2. Based on a review of available groundwater levels, the groundwater flow direction in the upper bedrock is interpreted to be consistently towards the northeast in the southern and central portions of the CRRRC Site as shown on Figure 7-5. Although based on limited data, the groundwater flow direction in the bedrock in the northern portion of the Site is occasionally towards the southeast based on the July, October and November 2013 monitoring sessions. During these times, the upper bedrock groundwater from the southern and central portions of the Site and the northern portion of the Site are interpreted to exit the Site along the central portion of the eastern property boundary. For the remainder of the monitoring sessions, the groundwater flow in the upper bedrock is interpreted to be towards the northeast across the entire Site.

Groundwater levels in the upper bedrock zone shown on Figure L9 ranged between 1.4 and 2.0 metres below ground surface across the CRRRC Site (74.2 m ASL and 75.3 m ASL) and were generally consistent throughout the monitoring program (less than 0.3 metre change at any given bedrock monitor). The available datalogger data provided on Figure L10 for locations 12-1-3-1, 12-3-3 and 13-6-3 completed in the upper bedrock zone show minor fluctuations in groundwater levels, similar to those observed in the glacial till.

7.2.2 Hydraulic Gradients

7.2.2.1 Vertical Component

Based on the monthly and daily groundwater elevation data collected to date, vertical gradients at the Site are typically either downward (recharge conditions) or absent between the surficial silty sand, the silty layer, silty clay, glacial till and upper bedrock formations at most monitoring locations.

Periodic reversals of gradient have been observed between the surficial silty sand and the silty layer based on continuous groundwater elevation data in monitoring wells 12-1, 12-3 and 13-6 (see Figures L11, L12 and L13). The daily groundwater level data indicates the direction of the vertical gradients observed between the surficial silty sand and the silty layer at 12-1 and 13-6 are subject to seasonal variations. In general, downward vertical gradients were consistently observed during the spring and fall (wet period), while upward gradients were present during the summer months (dry period) at these two locations (see Figures L11 and L13). The vertical gradients observed within the surficial silty sand and the silty layer at 12-3 were variable in direction and magnitude throughout the monitoring program. In general, downward gradients between the surficial silty sand and the silty layer dominate at 12-3, with the magnitude of the downward gradients increasing during drier periods (see Figure L12).

As shown on Figures L11, L12 and L13, there is a consistent downward gradient between the silty layer and the glacial till beneath the silty clay deposit. A slight downward gradient is observed between the glacial till and upper bedrock zone at locations 12-3 and 13-6, and a slight upward gradient is observed at location 12-1. In general, the daily groundwater level data indicates that the groundwater levels in the glacial till and upper bedrock zone show the same variations (frequency and magnitude), indicating they are likely well connected from a hydrogeological perspective.

7.2.2.2 *Horizontal Component*

The horizontal gradient for each stratigraphic layer was estimated during monitoring session completed at the CRRRC Site. The range in horizontal gradients estimated for each stratigraphic layer is presented in Table 7-1, along with the monitoring well locations used to estimate the horizontal gradient.

Table 7-1: Horizontal Gradients at CRRRC Site

Formation Monitored	Groundwater Flow between Monitoring Wells	Horizontal Gradient Range	Average Horizontal Gradient
Surficial Silty Sand	13-18-2 and 13-17-2	0.0005 to 0.0010	0.0008
Shallow Clay with Silty Layer	13-18-3 and 13-17-3	0.0005 to 0.0008	0.0007
Silty Clay	13-7-4A and 12-1-5A	0.0006 to 0.0009	0.0006
Glacial Till	13-6-4A and 12-4-4A	0.0004 to 0.0007	0.0006
Upper Bedrock Zone	13-6-3 and 12-4-3	0.0006 to 0.0009	0.0007

7.2.3 Vertical Hydraulic Conductivity

Laboratory permeability tests were conducted on three Shelby tube samples to provide information on the (*ex-situ*) vertical hydraulic conductivity of the silty clay at the CRRRC Site. The laboratory analysis sheets are provided in Appendix N. The results of the laboratory hydraulic conductivity testing are summarized in Table 7-2. The borehole location and sample interval are also provided.

Table 7-2: Vertical Hydraulic Conductivity Testing Results

Location	Sample Interval (mbgs)	Hydraulic Conductivity (m/sec)	Formation Monitored
12-1-3	21.3 to 21.8	7×10^{-10}	Silty Clay
12-2-3	11.4 to 12.0	9×10^{-10}	Silty Clay
12-3-3	2.1 to 2.7	2×10^{-9}	Silty Clay

Note: mbgs – metres below ground surface

Based on the laboratory testing, the range in vertical hydraulic conductivity of the silty clay is 2×10^{-9} to 7×10^{-10} m/sec. The results of the vertical hydraulic conductivity testing indicate the silty clay has a consistently low permeability at the various depths sampled. Based on the hydraulic conductivity of the silty clay, the formation is referred to as an aquitard and serves as a confining stratigraphic unit to the underlying glacial till and upper bedrock. Groundwater flow is assumed to predominantly occur in the vertical direction within the silty clay aquitard, and based on estimates of the vertical hydraulic conductivity there is expected to be minimal groundwater flow in this material.

7.2.4 Horizontal Hydraulic Conductivity

Well response tests were carried out in 37 monitoring intervals installed within the on-Site boreholes using the rising-head and/or falling head methods. The results of the *in-situ* hydraulic conductivity testing are summarized in Table 7-3 and the horizontal hydraulic conductivity analysis sheets are provided in Appendix N. The depth of the screened interval and comments relating to the interval tested are also provided in Appendix N.

Table 7-3: Horizontal Hydraulic Conductivity Testing Results

Formation Monitored	Location	Screened Interval* (mbgs)	Hydraulic Conductivity (m/sec)	Comments
Surficial Silty Sand	12-1-6	0.3 to 1.5	9 x 10^{-8}	--
	12-2-6	0.4 to 2.3	2 x 10^{-5}	--
	12-3-6	0.3 to 1.5	5 x 10^{-6}	--
	12-4-6	0.3 to 1.6	3 x 10^{-6}	--
	13-5-6	0.3 to 1.5	9 x 10^{-6}	--
	13-6-6	0.6 to 1.6	8 x 10^{-6}	--
	13-7-5	0.5 to 1.7	2 x 10^{-6}	--
	13-8-2	0.3 to 1.5	1 x 10^{-6}	--
	13-10-2	0.3 to 1.5	2 x 10^{-6}	--
	13-12-2	0.3 to 1.5	4 x 10^{-6}	--
	13-17-2	0.3 to 1.5	1 x 10^{-6}	--
	13-18-2	0.3 to 1.5	1 x 10^{-5}	--
	13-21-2	0.3 to 1.5	3 x 10^{-6}	--
	13-24-2	0.3 to 1.5	2 x 10^{-6}	--
Silty Layer within Shallow Clay	12-1-5B	4.0 to 6.0	5 x 10^{-7}	silty seam between 4.8 and 5.0 mbgs
	12-2-5B	3.8 to 7.6	2 x 10^{-6}	silty seam between 6.3 and 6.6 mbgs
	12-3-5B	4.0 to 6.1	7 x 10^{-7}	silty seam between 4.6 and 4.9 mbgs
	12-4-5B	3.5 to 6.0	3 x 10^{-6}	silty seam between 4.7 and 5.0 mbgs
	13-5-5	4.0 to 6.1	1 x 10^{-6}	silty seam between 4.3 and 4.9 mbgs
	13-6-5B	4.6 to 7.3	2 x 10^{-6}	silty seam between 5.2 and 5.6 mbgs
	13-7-4-2	4.4 to 6.4	7 x 10^{-7}	silty seam between 5.8 and 5.9 mbgs
	13-8-3	4.0 to 7.0	3 x 10^{-8}	silty seam between 4.4 and 4.7 mbgs
	13-10-3	4.0 to 7.0	1 x 10^{-6}	silty seam between 5.87 and 6.15 mbgs
	13-12-3	4.0 to 7.0	1 x 10^{-6}	silt seam between 4.8 and 5.4 mbgs
	13-17-3	4.0 to 7.0	1 x 10^{-6}	silty seam between 4.4 and 5.0 mbgs
	13-18-3	4.0 to 7.0	8 x 10^{-7}	sandy silt seam between 5.7 and 6.2 mbgs
Glacial Till	12-1-4A	36.0 to 39.5	3 x 10^{-6}	--
	12-3-4A	35.1 to 38.7	2 x 10^{-6}	--
	12-4-4A	34.8 to 36.7	2 x 10^{-4}	--
	13-5-4A	28.7 to 31.1	2 x 10^{-6}	--
	13-6-4A	33.0 to 35.6	6 x 10^{-7}	--
	13-7-3	28.0 to 30.3	8 x 10^{-9}	--
Upper Bedrock (Carlsbad)	12-1-3-1	40.1 to 45.4	2 x 10^{-7}	--
	12-2-3	37.0 to 42.0	2 x 10^{-5}	--
	12-3-3	40.1 to 45.4	3 x 10^{-6}	--
	12-4-3	38.5 to 43.6	2 x 10^{-8}	--
	13-5-3	35.3 to 40.3	5 x 10^{-6}	
	13-6-3	41.7 to 44.7	2 x 10^{-7}	--
	13-7-2	34.6 to 39.5	2 x 10^{-7}	--

Notes: * The screened interval refers to the entire sand pack area – not just the length of the slotted screen
mbgs – metres below ground surface

Based on the results of the *in-situ* hydraulic conductivity testing completed at the Site (falling and/or rising head tests), the following ranges in horizontal hydraulic conductivities were observed in the following overburden and upper bedrock formations:

- Surficial silty sand: 9 x 10^{-8} m/sec to 2 x 10^{-5} m/sec (moderate hydraulic conductivity);
- Silty layer within shallow clay: 3 x 10^{-8} m/sec to 3 x 10^{-6} m/sec (moderate hydraulic conductivity);
- Glacial till: 8 x 10^{-9} m/sec to 2 x 10^{-4} m/sec (variably low to high hydraulic conductivity); and,
- Upper bedrock: 2 x 10^{-8} m/sec to 2 x 10^{-5} m/sec (low to moderate hydraulic conductivity).

No *in-situ* hydraulic conductivity testing was completed in the unweathered silty clay unit because this unit does not lend itself to these *in-situ* testing methods. Assuming the silty clay has a horizontal to vertical anisotropy of 10:1, the horizontal hydraulic conductivity of the formation ranges from 7 x 10^{-9} m/sec to 2 x 10^{-8} m/sec (low permeability).

7.2.5 Groundwater Flux

The groundwater flux or specific discharge, q, is the volumetric flow rate of groundwater per unit area per unit time and is calculated from Darcy's equation, as follows:

$$q = -Ki$$

Where: *q* = groundwater flux (m/sec)

K = horizontal hydraulic conductivity (m/sec)

i = horizontal hydraulic gradient in direction of groundwater flux (m/m)

The groundwater flux was calculated for the surficial silty sand, the silty layer, silty clay, glacial till and upper bedrock zone using estimates of the horizontal hydraulic gradients for each unit previously discussed in Section 7.2.2.2.

Using an average horizontal gradient of 0.0008 for the surficial silty sand between monitoring wells 13-18-2 and 13-17-2 and the range in horizontal hydraulic conductivity for the formation (9 x 10^{-8} m/sec to 2 x 10^{-5} m/sec), the groundwater flux across the CRRRC Site within the surficial silty sand is calculated to be 7 x10^{-11} m/sec to 2 x 10^{-8} m/sec.

Using the average horizontal gradient of 0.0007 for the shallow clay with silty layer between monitoring wells 13-18-3 and 13-17-3 and the range in horizontal hydraulic conductivity for the formation (3 x 10^{-8} m/sec to 3 x 10^{-6} m/sec), the groundwater flux across the CRRRC Site within the shallow clay with silty layer is calculated to be 2 x10^{-11} m/sec to 2 x 10^{-9} m/sec.

Using the average horizontal gradient of 0.0006 for the middle portion of the silty clay layer between monitoring wells 13-7-4A and 12-1-5A and the range in horizontal hydraulic conductivity for the formation (7 x 10^{-9} m/sec to 2 x 10^{-8} m/sec), the groundwater flux across the CRRRC Site within the middle silty clay layer is calculated to be 4 x10^{-12} m/sec to 1 x 10^{-11} m/sec.

Using the average horizontal gradient of 0.0006 for the glacial till between monitoring wells 13-6-4A and 12-4-4A and the range in horizontal hydraulic conductivity for the formation (8×10^{-9} m/sec to 2×10^{-4} m/sec), the groundwater flux across the CRRRC Site within the glacial till is calculated to be 5×10^{-12} m/sec and 1×10^{-7} m/sec.

Using the average horizontal gradient of 0.0007 for the upper bedrock between monitoring wells 13-6-3 and 12-4-3 and the range in horizontal hydraulic conductivity for the formation (2×10^{-8} m/sec and 2×10^{-5} m/sec), the corresponding groundwater flux across the CRRRC Site within the bedrock is calculated to be 1×10^{-11} m/sec and 1×10^{-8} m/sec.

7.2.6 Average Linear Groundwater Velocity

The average linear groundwater velocity (seepage velocity), $\bar{v}$, is directly proportional to the groundwater flux and inversely proportional to formation porosity. The average linear groundwater velocity is calculated using the equation:

$$\bar{v} = \frac{Ki}{n}$$

Where: $\bar{v}$ = Average linear groundwater velocity (units of length per time);

n = Formation porosity (dimensionless);

K = Horizontal hydraulic conductivity (units of length per time); and,

i = Horizontal hydraulic gradient in direction of $\bar{v}$ (dimensionless).

For unconsolidated deposits such as silts and sands, typical porosity values can range from 25% to 50% and 0% to 20% for limestone bedrock (Freeze and Cherry, 1979). Average porosity values of 35% for the surficial silty sand, shallow clay with silty layer and glacial till units and 10% for the upper bedrock zone are assumed for the estimation of average linear groundwater velocities in the vicinity of the CRRRC Site. For the silty clay at the site, an average porosity of 0.54 was used for estimating of the average linear groundwater velocity; this average porosity of the silty clay was calculated using the final void ratios measured on oedometer test samples.

The range in average linear groundwater velocities within each formation monitored is provided in Table 7-4 below:

Table 7-4: Summary of Average Linear Groundwater Velocities across the CRRRC Site

Formation Monitored	Groundwater Flow between Monitoring Wells	Average Linear Groundwater Velocity Range at the CRRRC Site (m/year)
Surficial Silty Sand	13-18-2 and 13-17-2	<0.01 to 1.8
Shallow Clay with Silty Layer	13-18-3 and 13-17-3	<0.01 to 0.2
Silty Clay	13-7-4A and 12-1-5A	<0.01
Glacial Till	13-6-4A and 12-4-4A	<0.01 to 9
Upper Bedrock Zone	13-6-3 and 12-4-3	<0.01 to 4.4

7.2.7 Groundwater Residence Time

Groundwater samples from monitoring wells 12-2-6 (surficial silty sand), 13-7-4-2 (weathered crust at surface) and 13-7-5 (shallow silty clay with silty layer) were analysed for tritium and helium-3 to assist in estimating the groundwater residence time (i.e., age of groundwater). The tritium results provided by the University of Waterloo are presented in Table 7-5 below:

Table 7-5: Tritium Results

Sample Location	Formation Sampled	Tritium Concentration (tritium units)
12-2-6	Surficial Silty Sand	11.4
13-7-5	Weathered Silty Clay at Surface	9.9
13-7-4-2	Shallow Clay with Silty Layer	1.1

The tritium results indicate that the relative age of the groundwater within the surficial silty sand layer and the at-surface weathered silty clay is similar. The lower tritium concentration in the shallow clay with silty layer at a depth of about 5 to 6 metres below ground surface indicates that the groundwater within this layer is older than in the surficial silty sand layer and the at-surface weathered silty clay. These results are consistent with the understanding of the groundwater flow system at the Site. The surficial sand layer and at-surface weathered silty clay are interpreted to be recharged locally with young water (precipitation), while the shallow clay with silty layer is separated from the ground surface by several metres of intact silty clay resulting in longer local recharge times, or off-Site recharge.

The samples for helium-3 were collected using diffusion samplers and analyzed by the MAPL Noblegas Laboratory at the University of Ottawa. Following the helium-3 analysis, the laboratory indicated that the results were inconclusive due to an excess of helium-4 in the samples, which is interpreted to be from a geologic source. The source of the helium-4 would also contribute a small amount of helium-3. As such, the laboratory interpreted that the helium-3 measured in the samples may represent a combination of helium-3 from the decay of tritium as well as from the geologic source. As a result, the concentration of tritiogenic helium-3 (from the decay of tritium) could not be determined, and specific ages could not be assigned to the groundwater within the units tested.

8.0 BACKGROUND GROUNDWATER AND SURFACE WATER QUALITY

8.1 Monitoring Well Program

The background groundwater quality program involved collecting samples from selected on-Site monitoring wells installed at locations 12-1 through 12-4 and 13-5 through 13-7 (standpipe locations 12-1-4B, 12-1-5A, 12-2-4, 12-2-5A, 12-3-4B, 12-3-5A, 12-4-4B, 12-4-5A, 13-5-4B, 13-6-4B, 13-6-5A and 13-7-4-1 completed in the mid- and deep silty clay were not included in the groundwater monitoring program). Four rounds of groundwater quality sampling were completed for this assessment at locations 12-1, 12-2 and 12-3 (winter, spring, summer and fall 2013) and three rounds at locations 12-4, 13-5, 13-6 and 13-7 (spring, summer and fall 2013), with the exception of monitoring well 13-7-2, which was installed in June 2013 (summer and fall 2013 only).

The groundwater samples were analyzed for the parameters specified in O.Reg. 232/98 (except for total suspended solids), which lists generic parameters that should be monitored at landfill sites. Total suspended solids were not measured in the samples collected from the monitoring wells because the analysis would be measuring material in the well that has accumulated, and was then re-suspended during the sampling process. All groundwater samples collected were odourless, very light brown to dark brown in colour and had little to high sediment loading. The high sediment loading was primarily found in the groundwater samples from monitors installed in the surficial silty sand and the silty layer.

The groundwater quality results for the on-Site monitoring wells are presented in Table O-1 in Appendix O-I. Based on the results of the groundwater quality sampling program, groundwater quality was variable across the CRRRC Site. Table 8-1 provides a list of the parameters at monitoring wells that were consistently elevated (two or more occasions) compared to the Ontario Drinking Water Quality Standards (ODWQS; MOE, 2006).

Table 8-1: Parameters Consistently Exceeding ODWQS in On-Site Monitoring Wells

Formation Monitored	Locations	Parameters Consistently Exceeding ODWQS
Surficial Silty Sand	12-1-6	DOC, manganese, sodium, TDS
	12-2-6	manganese
	12-3-6, 13-7-5	manganese, sodium, TDS
	12-4-6	DOC, manganese, TDS
	13-5-6	[none]
	13-6-6	manganese, TDS
Silty layer within Shallow Clay	12-1-5B, 12-2-5B, 12-3-5B, 12-4-5B, 13-6-5B, 13-7-4-2	chloride, DOC, manganese, sodium, TDS
	13-5-5	manganese, TDS
Glacial Till	12-1-4A, 12-3-4A, 13-5-4A, 13-7-3	barium, chloride, DOC, manganese, sodium, TDS
	12-4-4A	chloride, DOC, sodium, TDS
	13-6-4A	chloride, DOC, manganese, sodium, TDS
Upper Bedrock Zone	12-1-3-1	barium, chloride, DOC, manganese, methane, sodium, TDS
	12-2-3	chloride, DOC, sodium, TDS
	12-3-3, 12-4-3, 12-5-3	barium, chloride, DOC, methane, sodium, TDS
	13-6-3	barium, chloride, manganese, sodium, TDS
	13-7-2	Barium, chloride, manganese, methane, sodium, TDS

Notes: BOD – biochemical oxygen demand; COD – chemical oxygen demand; TDS – total dissolved solids; and TKN – total kjeldahl nitrogen

Elevated concentrations of total phosphorus observed at all seven monitoring wells screened within the silty layer (12-1-5B, 12-2-5B, 12-3-5B, 12-4-5B, 13-5-5, 13-6-5B and 13-7-4-2) and monitoring wells 12-2-6, 13-5-6, 13-6-6 and 13-7-5 screened within the surficial silty sand are likely attributed to the samples having high sediment loadings. A minimum of 5 purge volumes were removed as part of the monitoring well development program prior to groundwater sampling; however, the sediment loading remained high in these samples.

The elevated concentrations measured at monitoring wells presented in Table 8-1 are interpreted to be naturally occurring. Volatile organic compounds (VOCs) including 1,4-dichlorobenzene, benzene, toluene and/or vinyl chloride were detected in trace amounts in groundwater samples collected from monitoring wells screened within the surficial silty sand (13-7-5), the silty layer (12-2-5B, 12-3-5B, 12-4-5B, 13-5-5, 13-6-5B and 13-7-4-2), glacial till (12-4-4) and upper bedrock zone (12-2-3, 12-3-3, 12-4-3 and 13-6-3). VOCs were detected in the first monitoring session only for these locations, with the exception of groundwater samples collected from the silty layer monitoring well 12-3-5B where benzene, toluene and vinyl chloride were consistently detected during consecutive sampling events (winter, summer and fall 2013), and upper bedrock monitoring well 12-2-3 where benzene was detected in the fall 2013 session only. All detections of VOCs were below the applicable ODWQS.

Based on the available information, groundwater quality at the CRRRC Site varies from fresh to brackish and deteriorates with depth. The groundwater within the surficial silty sand and the silty layer typically exceed the ODWQS for TDS and manganese, and occasionally for DOC. Within the glacial till and upper bedrock, elevated concentrations of barium, chloride, sodium and TDS and occasionally manganese are observed compared to the applicable ODWQS. Groundwater quality samples collected in the upper bedrock were also analyzed for dissolved methane, which consistently exceeded the ODWQS at monitoring wells 12-1-3-1, 12-3-3, 12-4-3, 13-5-3 and 13-7-2.

QA/QC results for all duplicate groundwater samples and analytical laboratory equipment blanks were within acceptable tolerance limits.

8.2 Residential Well Program

The residential well sampling program involved collecting groundwater samples from accessible supply wells in the immediate vicinity of the CRRRC Site to characterize background groundwater quality for typical organic and inorganic parameters. Prior to sampling, Golder staff completed a survey with the homeowners to gather information about their water supply. Copies of the completed surveys are provided in Appendix O-II.

Two residential water supply wells and one commercial water supply well were sampled between January 17 and 18, 2013. Residential water supply wells are situated along Frontier Road (two: Frontier-1 and Frontier-2) within the northeast limits of the CRRRC Site, and one commercial supply well (Boundary-1) is situated west of the CRRRC Site. The wells located along Frontier Road are as shown in Figure 8-1. The water supply well survey completed at location Boundary-1 identified the supply well operates at a commercial property and is primarily used for washing equipment. All water supply wells sampled during this program are completed to an approximate depth of 3.7 to 6.1 metres (unknown well depth at Frontier-2) in the overburden and consist of dug wells.

The groundwater quality results for the residential and commercial water supply wells are provided in Table O-2 in Appendix O-II. The results of the water supply sampling program indicate that most parameters analyzed were below the respective ODWQS. Parameters exceeding the ODWQS include DOC and manganese at all three water supply locations, along with TDS and iron at the commercial water supply well only (Boundary-1).

The results of the residential water supply wells sampling program indicate that groundwater quality at the private well locations is comparable to the groundwater quality observed at monitoring wells screened within the surficial silty sand at the Site, with the exception of chloride, COD, total phosphorus, sodium, TDS and TKN that are generally observed at higher concentrations in the CRRRC Site monitoring wells.

8.3 Surface Water Program

The surface water sampling program involved monitoring water quality from a total of nine surface water locations BSW1 through BSW9 (see Figure 2-2). Surface water stations BSW1 through BSW7 were established in December 2012, and surface water stations BSW8 and BSW9 were added to the monitoring program in spring and fall 2013, respectively.

A total of six surface water stations (BSW1, BSW2, BSW3, BSW4, BSW5 and BSW9) are situated within the CRRRC Site, and three surface water stations (BSW6, BSW7 and BSW8) are located east and downgradient of the CRRRC Site.

The surface water stations are as follows:

- BSW1 – discharge of DD2;
- BSW2 – discharge of Simpson Municipal Drain at CRRRC Site boundary;
- BSW3 – discharge at DD1;
- BSW4 – upstream, beginning of Simpson Municipal Drain as it enters CRRRC Site;
- BSW5 – upstream, beginning of DD2;
- BSW-6 – Shaw Creek at Sand Road (downgradient of CRRRC Site);
- BSW-7 – Shaw Creek at Frank Kenny Road (downgradient of CRRRC Site);
- BSW-8 – drainage ditch at Frank Johnson Municipal Drain (downgradient of CRRRC Site prior to discharge to Wilson Johnson Municipal Drain); and,
- BSW-9 – ditch near western property boundary in central portion of Site (DD3).

Surface water sampling was conducted to establish background surface water quality at the CRRRC Site and downgradient of the Site. The surface water monitoring program for this assessment includes up to five sampling events completed on a seasonal basis (December 2012 (winter), May 2013 (spring), July 2013 (summer), October or early-November 2013 (fall) and late-November or December 2013 (winter) between December 2012 and December 2013. Surface water sampling was completed at locations BSW1 through BSW7 on all five occasions, four sessions at BSW8 (spring, summer, fall and winter 2013) and two at BSW9 (fall and winter 2013). The results of the baseline surface water quality program are presented in Appendix P.

Table 8-2 provides a list of the parameters at surface water stations that did not meet Provincial Water Quality Objectives on three or more occasions at BSW1 through BSW7 (five sessions) and two or more occasions at BSW8 and BSW9 (four and two sessions, respectively) (PWQO; MOE, 1994a).

Table 8-2: Parameters Consistently Not Meeting PWQO

Surface Water Location	Surface Water Feature	Parameters Consistently Not Meeting PWQO
BSW1	DD2	dissolved oxygen, total phosphorus, iron
BSW2	Simpson Drain	dissolved oxygen, total phosphorus, iron
BSW3	DD1	dissolved oxygen, total phosphorus, iron
BSW4	Simpson Drain	dissolved oxygen, total phosphorus, iron
BSW5	DD2	dissolved oxygen, total phosphorus, iron
BSW6	Shaw's Creek	total phosphorus, iron
BSW7	Shaw's Creek	total phosphorus, iron
BSW8	Frank Johnston Drain	dissolved oxygen, total phosphorus
BSW9	DD3	phenols*

Note: * based on two sampling events only.

BSW5 was dry during the winter 2012 sampling session and was not sampled. Concentrations of copper exceeded the PWQO at surface water location BSW3 during the winter 2012 sampling session only. An exceedance of the chromium PWQO occurred one time at location BSW4 during the November 2013 sampling session. Concentrations of phenols (total recoverable phenolics) were consistently below or at the detection limit at all surface water monitoring locations throughout the sampling program with the exception of the fall and winter 2013 monitoring events. During the fall 2013 sampling event, concentrations of phenols exceeded the PWQO at all locations with the exception of BSW8. An additional winter 2013 sampling session was added to the monitoring program to confirm these results. Concentrations of phenols exceeded the PWQO at locations BSW1, BSW2, BSW3, BSW5 and BSW8 only during the winter 2013 session. The observed elevated concentrations of phenols in the surface water during the fall and winter 2013 sampling events may be attributed to decomposing plant material as concentrations of phenols at all surface water locations declined during the winter 2013 confirmation sampling session with the exception of BSW8. An exceedance of the phosphorus PWQO occurred one time at location BSW9 during the December 11, 2013 sampling session.

QA/QC results for analytical laboratory equipment blanks and the duplicate surface water samples were within acceptable tolerance limits, with the exception of duplicate concentrations of TSS (1 and 27 mg/L) at BSW1 during the winter 2012 monitoring session. The reason for this deviation is unknown as the surface water samples collected from DD2 were generally clear and sediment-free. Based on the available surface water quality data at BSW1, the analytical results discussed above are interpreted to be representative of the surface water quality.

9.0 EVALUATION OF POTENTIAL GEOLOGICAL IMPACTS

9.1 Fault Rupture

At a number of localities in southern Ontario geologists have observed vertical offsets in glacial deposits and in some cases the underlying basement rock (e.g., Mohajer et al. 1992) associated with faults. One of the most extensively studied locations is at Rouge River east of Toronto and about 3 to 5 kilometres north of Lake Ontario (e.g., Mohajer et al., 1992; Adams et al., 1993; Wallach, 1994; Godin et al., 2002). The faults observed at Rouge River have been regarded as an example of Late Quaternary (last 130,000 years to present) co-seismic fault movements associated with major geophysical lineaments by Mohajer et al., (1992) and Wallach (1994). By contrast, Adams et al. (1993) and Godin et al. (2002) have more recently suggested that these normal faults have developed in response to localized pre-Holocene (last 11,700 years) glacial ice movements that are not associated with crustal faulting.

Godin et al. (2002) concluded from the results of their detailed analysis and re-interpretation that the deformation features preserved in glacial sediments at Rouge River were generated by glacial processes. They consider that the normal faults preserved in glacial sediments and in outcrops of the underlying Ordovician bedrock were generated by regional and local ice flow. Because borehole data show that the surficial faults do not penetrate beyond a depth of about 20 metres within the bedrock, i.e., they are relatively shallow, the faulting at Rouge River is considered by them to not be generated by deep seated tectonic stress and co-seismic faulting (Godin et al., 2002).

Review of published geologic and seismic information for the region surrounding Ottawa-Gatineau carried out as part of the CRRRC studies found no evidence that mapped bedrock faults have ruptured to the ground surface since the retreat of glacial ice and the Champlain Sea from the Ottawa valley. While there are expected to be high surface stresses at some locations (e.g., Adams and Fenton 1994), there is no clear association between surficial stress relief and the generation of large local earthquakes. Studies to date, i.e., Aylsworth et al. (2000) indicate that even when larger earthquakes have occurred in the recent past, they may not be of sufficient magnitude (energy) to generate movement or displacement within the bedrock fault to propagate rupture to the ground surface. Furthermore, where evidence of surface faults has been found in local bedrock outcrops, it can usually be explained as resulting from local ice deformation or landslides rather than by the rupture of a major through-going surface or near surface tectonic fault. This conclusion does not preclude the possibility that vertical and/or horizontal fault movements have occurred in the region but are as yet undetected. Based on available information, however, there is no indication of surface ruptures from historical earthquakes at the proposed CRRRC Site or its immediate vicinity.

Joints and faults within the Ottawa-Bonnechere Graben often contain calcite, indicating that they have been cemented after the formation and lithification of the basement rocks (Rimando and Benn 2005; Adams and Fenton 1994). Unpublished dates from near-surface (2 metres below ground surface) calcite within multiphase, joint-controlled veins in the Ordovician limestone (Pat Smith, University of Toronto, personal communication) indicate ages of about 100 million years ago and about 50 million years ago for the time of calcite cementation. These ages for episodes of calcite vein filling coincide approximately with the relative age of the youngest of the three deformation phases with the Paleozoic rocks identified by Rimando and Benn (2005), as described in Section 3.1.1. The presence of calcite within most of the fault planes and their early Paleogene (40 to 65 million years ago) and older crystallization ages suggests that there has been no Quaternary movement (including the Holocene Epoch of the past 11,700 years) along calcite-bearing faults and joints in the bedrock in the vicinity of the CRRRC Site.

9.2 Assessment of Potential for Fault Rupture at CRRRC Site

Fault rupture at the ground surface is a potential geological hazard because the surface fault rupture could cause localized differential displacements that can adversely affect engineered structures and facilities. A fault is a planar fracture in the Earth along which displacement occurs in response to stresses that accumulate in crustal rocks. Faults can have both vertical and horizontal displacements, although one type of movement is usually dominant. Faults with larger total displacements (100's of metres) have moved repeatedly along the same plane.

To identify the potential for fault rupture at the ground surface of a site, the important faults are those that are accumulating strain in the present-day tectonic strain field. Empirical studies indicate that only the larger faults generate displacements at the ground surface, and it is these larger faults that can present a significant hazard to engineered structures. For example, most surface fault ruptures occur in geologically active areas, have single-event horizontal and/or vertical surface displacements that range from about 100 millimetres to 10 metres, and are associated with moderate to large earthquakes (moment magnitude $M \geq 6$). Further, these surface rupturing faults usually show repeated displacements in the same location over thousands to millions of years.

The identification of "active" faults and/or lineaments that could intersect the footprint of the CRRRC is based in tectonic geomorphology – the interactions between tectonic and surface processes that shape the landscape. Tectonic geomorphic processes operate in regions of ongoing deformation, and at time scales ranging from days to millions of years. An understanding of the geomorphic characteristics and landforms generated by movement at active faults is critical for the evaluation of the fault rupture potential at the CRRRC Site. Fault rupture produces distinctive tectonic geomorphology and landforms such as linear valleys, aligned offset stream channels, linear scarps, aligned linear ridges, faceted ridge spurs and linear vegetation patterns. If these distinctive tectonic geomorphologic landforms can be recognized at the CRRRC Site, then the presence, location, nature, type and activity of the fault or lineament may be evaluated.

Similarly, abrupt offsets or a change in orientation of subsurface geologic layers often indicates that near-surface faults are present at a site. Thus, if tectonic geomorphic features and/or the subsurface layers at the CRRRC Site show abrupt elevation changes, then a fault may be indicated.

Golder's analysis of topography and interpretation of aerial imagery of the CRRRC Site indicate that the Site is essentially horizontal at an elevation of about 76 to 77.5 m ASL. Neither topographic interpretation nor imagery analysis revealed the existence of tectonic geomorphic features crossing the Site. While that lack of tectonic geomorphology indicates no recently active fault features, it remains possible that anthropogenic modification or localized erosion may have removed diagnostic surface fault features.

Figure 3-11 provides a generalized west-east cross-section through the CRRRC Site, and Figures 3-14 and 3-15 are more detailed west-east and north-south cross-sections, respectively. A key layer for the evaluation of the potential for past surface fault rupture at this Site is the 0.1-metre to 0.6-metre thick silty layer (Figure 3-17) at a depth of about 4 to 6 metres below ground surface. This relatively thin silty layer represents a short duration change in the sedimentary depositional environment in the Champlain Sea about 10,000 years ago, perhaps because of a minor change in water depth/sea level or sediment source. This marker bed within the upper part of the silty clay deposit is sub-horizontal; the bottom elevation of the silty layer varies between about elevation 70.5 and 71.5 m ASL, while the top surface elevation varies between about elevation 71 and 72 m ASL. Because the silty layer was encountered and identified in all 25 borehole locations advanced in a grid pattern beneath the Site, it is reasonable to interpret that the silty layer is continuous across the CRRRC Site (as illustrated on Figures 3-14, 13.5 and 3-17). The largely consistent elevation and lateral continuity indicates that this layer has not been offset in any significant way by vertical fault displacements at the CRRRC Site. It is reasonable to conclude, therefore, that there has been no surface fault rupture at the CRRRC Site since at least the deposition of the silty layer (i.e., in the past 8,000 to 10,000 years). Furthermore, the evidence from the surrounding geological structure indicates that recent fault movements are unlikely to have occurred within the bedrock underlying the Site and surrounding area.

Considering the regional, local and Site geological conditions within the CRRRC Site and surrounding area, and the nature of “active” faults as described above, it is reasonable to conclude that the probability of future fault movement resulting in large differential displacements at the surface or shallow subsurface at or in the vicinity of the CRRRC Site is negligible. For the reasons discussed in Section 11.4, even if smaller scale differential displacements were to occur, they are of no engineering significance for the development of the CRRRC Site.

9.3 Assessment of Potential Subsurface Settlement from Earthquake Ground Shaking

The GSC has studied the effects of possible prehistoric (Holocene) earthquakes on the marine clay deposits in eastern Ontario. Published information on this topic has been reviewed and integrated with Site-specific investigation of the clay deposit that underlies the CRRRC Site. The purpose of the review has been to assess if the clay deposit beneath or in the area of the Site is likely to have been disturbed by earthquake shaking in eastern Ontario. Much of the following has been taken from Aylsworth and Lawrence (2003), noting that there have been a number of related articles published on this topic.

Following the deposition of the marine clay soils in eastern Ontario about 10,000 years ago, a number of channels (called Paleo-channels) were cut into the clay deposit between about 10,000 and 8,000 years ago by flowing water prior to the development of the present-day alignment of the Ottawa River channel. As shown on Figure 9-1, four wide channels formed across eastern Ontario. Three channels were oriented northwest to southeast and one connecting these three oriented west to east. By about 8,000 years ago, the Ottawa River established itself in its current course, abandoning these deep, former channels. The western end of one the channels is presently occupied in part by the Mer Bleue to the northwest of Carlsbad Springs. The general location of the CRRRC Site relative to the location of the Paleo-channels is shown on Figure 9-1. The location of the Site is beyond (south of) the area of Paleo-channels.

Analysis of aerial photos and field observations indicate past landslide activity along the margins of the Paleo-channels as shown on Figure 9-1. Radiocarbon dating of organic materials buried by a number of landslides indicates a common date of about 4,550 years BP. Aylsworth et al (2000) and Aylsworth and Lawrence (2003) interpreted the age concordance of the large landslide to indicate that they were triggered by a large earthquake event about 4,550 years BP. They estimated the earthquake to have a M greater than 6.2, and probably at least M 6.5.

There are also three large areas of flat-lying low-relief terrain underlain by marine clay soils, located beyond the Paleo-channels that have been found to be highly disturbed. These are located at Treadwell, Wendover and Lefaivre, about 30 to 50 kilometres northeast of the Site, and are labelled A, B and C on Figure 9-1. Based on field studies, Aylsworth et al (2000) interpreted this disturbance as further evidence of a large earthquake of at least M 6.5 about 7,060 years BP.

Evidence of disturbance by earthquake shaking is indicated by an irregular, hummocky ground surface in an area that is otherwise flat and underlain by sub-horizontal sediment layers. Layering of the sand and clay soils that underlie the hummocky ground is deformed and in some cases faulted. There is also evidence of sand liquefaction and its upward flow through overlying clay layers. Subsurface investigations of these disturbed areas have included geophysical imaging, test trenching and borehole drilling and sampling programs, and description of the continuous soil cores where the presence of deformation of the subsurface materials was evident.

Key evidence cited by Aylsworth et al (2000) and Alysworth and Lawrence (2003) to explain why these three areas experienced disturbance and other areas did not are: 1) the clay deposit is very thick, greater than 100 metres; 2) uncommonly thick layers of liquefiable sand (greater than 10 metres to 20 metres thick) are present within the clay deposit; and 3) the areas are located within deep, locally steep-sided bedrock basins that could amplify earthquake ground shaking. The investigation work in the zone immediately adjacent to the disturbed area showed that where the clay deposit is only 38 metres thick and no thick sand layers were present (i.e., conditions similar to that underlying the CRRRC Site) there was no evidence of sedimentary deformation or disturbance.

The CRRRC Site is located in an area of flat-lying terrain without topographic irregularities, and the Site is not in an area inferred to have been disturbed by past earthquakes or landslides. The silty clay underlying the Site is about 30 to 35 metres thick, anomalously thick sand layers are not present within or underlying the clay deposit; and the Site is not located within a deep bedrock depression. That is, none of the factors identified by Aylsworth et al. (2000) are present at the CRRRC Site.

Although these Site-specific subsurface conditions strongly suggest the absence of amplified earthquake shaking and soft sediment deformation, the soils underlying the Site were also evaluated for any evidence of disturbance. The evaluation was completed from examination of continuous soil cores for evidence of deformed, tilted or sheared bedding patterns indicative of sand liquefaction and flow. Evidence of sediment disturbance was not observed.

As described above, subsurface investigation of the CRRRC Site identified a continuous silty layer within the upper part of the silty clay deposit. This silty layer is a marker bed throughout the subsurface (Figures 3-14 and 3-15) deposited about 10,000 years ago. The presence of a flat-lying surface topography and the lower horizontal subsurface silty layer supports the conclusion that any strong earthquake shaking during the past 10,000 to 8,000 years has not resulted in liquefaction or other disturbance of the Holocene stratigraphy beneath the Site.

In summary, based on the available regional and Site-specific information, the large pre-historic earthquakes (4,550 and 7,060 years BP) inferred by Aylsworth et al (2000) and Aylsworth and Lawrence (2003) have not resulted in large scale deformation of the silty clay deposit that underlies the Site. There is no evidence of deformation or displacement in the continuous samples recovered from the Site boreholes completed as part of the EA/EPA investigation. While it is possible that there has been smaller-scale deformation that is not apparent from the Site investigation program, differential settlement associated with strong earthquake shaking (liquefaction), is not considered to be a hazard at the CRRRC Site, nor for the reasons discussed in Section 11.4 to be of engineering significance in any event.

10.0 DESCRIPTION OF SITE DESIGN

The following sections describe the overall design of the CRRRC Site and its facilities. The proposed Site development plan is shown on Figure 10-1. The Design and Operations Report included in this submission package describes the following features in greater detail.

10.1 Site Access, Entrance Facilities and Roads

Primary access to the Site will be provided from Boundary Road. The 30 metre wide access road allowance will accommodate the in-bound, out-bound and queuing lanes, appropriate geometry to accommodate turning at Boundary Road, and roadside drainage. A secondary Site access/exit will be provided at the northern end of Frontier Road for infrequent use by vehicles associated with Site operations, maintenance or emergency.

The administration building located just north of the primary access road will have an approximate footprint of 200 square metres (m^2). The administration building will house office functions for the CRRRC. Staff and visitor access to the building will be provided via a separate lane off the main access road prior to the in-bound scales. A paved parking and apron area will be provided around the administration building.

Ancillary facilities at the CRRRC include a maintenance garage (and associated employee parking lot), secondary scales along the internal access/exit road to/from the landfill, and a truck tire wash located along the exit road from the landfill.

All on-Site roads north of the Simpson Drain are paved, with the exception of the road running along the east side of the Site connecting the landfill to the maintenance garage; this road will remain gravel surfaced for use by equipment associated with landfill operations such as compactors, dozers, etc.

10.2 Small Load Drop-Off

A small load drop-off is located north of the administration building. Figure 10-1 shows a maximum number of receiving bunkers.

10.3 C&D Processing Facility

C&D material recycling will be carried out to recover waste materials received from construction and demolition projects. The proposed C&D processing facility will be housed in a building with a footprint of approximately 13,000 m^2 and will have the capacity to process approximately 50 tonnes per hour of material. The main recovered products from the processing of C&D refuse material will consist of shredded wood, ferrous and non-ferrous metals, mixed aggregate, shingles, cardboard and drywall, and process fines. Recovered materials will be sent to off-Site markets, recovered materials will be re-used on-Site, and rejected materials will be hauled to the on-Site landfill.

10.4 Material Recovery Facility

The Material Recovery Facility (MRF) will process and recover industrial, commercial and institutional (IC&I) materials, and is designed to handle both mixed materials and source separated loads. The proposed MRF will have the capacity to process approximately 50 tonnes per hour of material. The MRF operation will be housed in a building with a footprint of approximately 13,000 m^2. The recovered materials will generally consist of cardboard, paper, glass, plastics, ferrous and non-ferrous metals, wood and other fibres. The recovered materials will be hauled off-Site to end markets and the rejected materials that cannot be diverted will hauled for disposal in the on-Site landfill.

10.5 Organics Processing Facility and Compost Processing and Storage Pad

The organics processing facility will be constructed to remove the organics component from those portions of the IC&I waste stream that contain a sufficient amount of organics. Processing of both the organics contained within the highly variable mixed IC&I waste stream and source separated organics will be carried out within the facility. The organics processing facility will consist of four main components:

- Receiving and storage building and biofilter;
- Primary anaerobic digester cells;
- Secondary digester and collected gas flaring and/or electrical generating facility; and,
- Compost pad.

It is initially proposed that the organics processing facility be constructed and operated at a demonstration scale, as this combination of processes has not been previously approved for full scale operation. In order to provide diversion of organics during this initial period of Site operation, it is proposed to take source-separated organics from IC&I sources and pre-process them (size reduction and removal of physical contaminants via hydraulic squeezing) within the on-Site organics receiving building, and then take the resulting organics slurry by tanker to approved off-Site farm digesters for processing. It is estimated that this initial operation could divert up to 20,000 tonnes per year of organics. This building, which is anticipated to serve for both the shorter term pre-processing and the full scale receiving and storage, will have a footprint area of about 3,000 m^2 and a height of about 12 metres.

Although subject to modification depending on the results of the demonstration scale project, it is anticipated that the BioPower primary reactor digester will consist of contained and covered cells that are excavated to shallow depth below grade and have a height of about 6.5 to 7 metres, and require a land area of about 5 hectares. This sizing is expected to handle about 50,000 tonnes per year of organics.

The secondary reactor building (having dimensions of about 20 by 30 metres, about 10 metres in height) will receive collected liquor from the primary reactor and receiving building where the liquor will be digested anaerobically and converted to biogas consisting primarily of methane and carbon dioxide. The biogas will be sent to an enclosed flare and/or an electrical generation plant where it will be combusted (in combination with collected landfill gas) and the combustion air treated prior to release. In the initial period of Site operation, all collected gas will be flared. If there is enough gas generated and the economics are favourable, an electrical generation plant would be utilized to generate electricity for export to the grid. The compost storage and processing pad, to be used for final curing of the digested product from the organics processing, for aerobic windrow/trapezoidal composting of leaf and yard materials, and wood grinding and chipping, will be paved and is anticipated to require an area of approximately 3.5 hectares. It is also possible that an aerated pile composting process may be utilized on the pad for the digested product or leaf and yard materials, wherein air is introduced to the material to be composted in order to sustain elevated oxygen content within the material and thereby further assist/accelerate the pathogen kill and composting process.

10.6 Petroleum Hydrocarbon Contaminated Soil Treatment

The initial stages of the treatment system for petroleum hydrocarbon (PHC) contaminated soil will be developed as part of the initial Site development. The initial treatment system will consist of two biopile cells connected to a single treatment unit that controls air extraction rate, moisture and nutrients and the biopiles. Nutrient addition is optional because the main purpose of the initial treatment system approach is to aerate the soil to promote volatilization of the lighter PHCs.

The proposed future treatment system consists of six biopiles in addition to the two biopiles to be developed as part of the initial stages of the treatment system, as required based on MOECC treatment requirements of PHC soil. A PHC soil storage building has also been proposed for the future development of the treatment system.

Incoming PHC impacted soil may first require the removal of oversize materials (i.e., concrete, cobbles, boulders), and then storage on a concrete pad until at least one of the biopiles is ready to be filled. The soil stored on the pad will be covered with a woven coated reinforced polyethylene liner (tarp). The PHC impacted soil will be placed in the biopiles up to a maximum total height of 2.5 metres using a loader after being mixed with nutrients (optional) and a bulking agent (wood chips or straw, up to 10% of soil volume). The cell base would be provided with a geomembrane liner to contain the liquid produced from the process. Piping would be provided in the base to both collect liquid and to add and remove air from the soil; an irrigation piping system would be installed at the top of the soil to supply water, to provide amendments and nutrients, and recirculate the collected liquid. A central treatment unit would be provided to regulate and optimize the conditions within the biopile to achieve the pre-treatment or treatment.

10.7 Surplus Soil Management

The surplus soil management area is located in the west central portion of the Site area north of the Simpson Drain. The ongoing operation in this area, as well as other areas of the Site where surplus uncontaminated soil may be temporarily stored until such time that it is required for re-use, will consist of the dumping and dozing of incoming soil into a stockpile(s), and removal of this soil for re-use on-Site. Uncontaminated soil is comprised of native (undisturbed) earth materials (from undeveloped land) or native earth materials/fill materials that are unimpacted by development or human activity, or altered earth/fill material whose quality meets the applicable table in O. Reg. 153/04 (MOE, 2004). It is anticipated that the temporary stockpiles could be up to about 5 metres in height. Other undeveloped areas of the Site could also be used for this purpose to suit Site operations. The operational details of surplus uncontaminated soil management will change frequently depending on the quantities and types of materials that are available to be brought to the Site, and the Site requirements for materials for construction and operational purposes.

In addition to PHC contaminated soils, the CRRRC will also receive other types of non-hazardous contaminated soil (or rock). Contaminated soil, with the exception of PHC contaminated soil directed to treatment, will be managed within the landfill, either as waste or re-used as daily cover.

10.8 Landfill

The landfill component of the CRRRC will support the diversion operations for a planning period of 30 years. This is based on a five year ramp up of waste receipts to a maximum of 450,000 tonnes per year and achieving an overall diversion rate of 43% to 57%. The total landfill footprint could cover approximately 84 hectares. The landfill base will be excavated 1.5 to 2.5 metres below the existing ground level and will be surrounded with a perimeter containment berm. The perimeter berm will be constructed to about a 3.5 metre height using the excavated soils and/or similar types of imported materials. The perimeter berm will have a top platform width of about 36 metres to provide adequate overall landfill stability, with 7 horizontal: 1 vertical (7H:1V) sideslopes. The berm will also accommodate a perimeter road, header piping for leachate and landfill gas and other service lines, and provide conveyance of runoff to the stormwater management system. An approximately 20 metre wide bench will be provided between the exterior toe of the perimeter berm and adjacent facilities within the buffer, providing both access and working area around the landfill.

To provide adequate stability for the landfill overlying the clay deposit, the landfill design has 14H:1V sideslopes above the perimeter berm up to about elevation 89 m ASL or approximately 12 to 13 metres above ground surface, and then a 20H:1V slope up to a central peak or ridge area. The maximum height of the designed final landfill contours is about 25 metres above existing ground level. This corresponds to an airspace volume of approximately 10,170,000 cubic metres (m^3) for waste and daily cover. An allowance for a one metre thick final soil cover has been provided, although the final soil cover is likely to have a total thickness of 0.75 metres. Final cover construction will take place after filling in a part of the landfill is complete.

For leachate containment, a Site-specific design approach will be followed. The natural low permeability silty clay deposit will provide the low permeability bottom liner for the landfill. The perimeter berm will incorporate a constructed low permeability hydraulic barrier (a geosynthetic clay liner or GCL) extending the full height of the berm and down through the surficial silty sand layer or weathered clay zone and keyed into the upper portion of the underlying silty clay. This would cut off the potential pathway for off-Site leachate migration via the berm fill and surficial silty sand layer. A leachate detection and secondary containment system (LDSCS) will be positioned beneath the perimeter berm on the hydraulically downgradient (eastern) side of the landfill. The LDSCS, which will be a granular filled trench completed in the surficial silty sand layer, will allow for the monitoring of the performance of the landfill's leachate containment system (the natural clay deposit, the LCS, and perimeter berm with the GCL) and provide secondary containment in the unlikely event that leachate enters the surficial silty sand layer outside of the landfill footprint.

The design of the landfill base recognizes that consolidation settlement of the silty clay deposit will occur due to the weight of the waste, and that the largest settlements will be below the central portion of the landfill where the waste thickness is greatest as described in the following section of this report. As such, the landfill base will be shaped to provide drainage of leachate from the perimeter of the landfill towards the centre; the leachate will be conveyed through a system of perforated and non-perforated leachate piping and a granular drainage blanket. Leachate sumps (manholes) will be provided within the landfill; they will be located at the lowest points of the base grading, both when constructed initially and allowing for the longer term consolidation of the clay as the waste is placed. The leachate collection system design will accommodate the expected settlement. As the settlement of the clay occurs, the slope of the base and piping will increase from that originally constructed, thereby enhancing the transmission of leachate to the interior leachate sumps. Leachate removal from each sump will be by means of submersible pumps and via piping to a forcemain that will convey the collected leachate for treatment. The layout of the base is shown on Figure 10-2. Cleanout access for inspection and flushing/cleaning of the leachate collection piping system will be provided, both from the exterior of the landfill and by cleanouts provided from within the landfill.

The proposed landfill gas management (LFG) system will be designed in accordance with the requirements of O.Reg. 232/98. The approach at the Site recognizes the diversion of IC&I organics from disposal to the extent practical, and as such the anticipated reduction in potential odour emissions associated with decomposition of organics within the landfill. The proposed active LFG collection system will consist of horizontal collector piping installed in two layers within the waste as the waste is placed, and, header piping around the landfill perimeter and extending to the condensate management facilities, a vacuum extraction plant and an enclosed flare. The proposed LFG collection system will conform to the most recent version of B149.6-11 *Code for Digester Gas and Landfill Gas Installations*, which has been adopted by the Technical Safety and Standards Authority for use in Ontario as of December 2012. The LFG collection system will also be designed for the predicted clay foundation settlement.

Due to the presence of clay soils beneath and in a large area beyond the Site, the presence of a high groundwater table in the area, and the proposed low permeability barrier through the surficial silty sand layer around the landfill perimeter, the potential for off-Site migration of landfill gas through the subsurface is negligible. In addition, there is a minimum 100 metre wide buffer between the landfill footprint and the Site property boundaries; and there are ditches and drains that would interrupt the movement any landfill gas in the unlikely event that it had migrated away from the landfill through the thin unsaturated zone.

The proposed Site development provides for on-Site buffer lands. A buffer area 125 metres wide would be adjacent to the east side, the east half of the south side, and the northwest corner of the landfill. Around the remainder of the landfill the perimeter buffer would be 100 metres, as per the O.Reg. 232/98.

10.9 Stormwater Management

Design of drainage requirements from the landfill (as required by O.Reg. 232/98) and from the diversion areas was carried out and the proposed stormwater management system is shown on Figure 10-1. The approach to system design is to closely match post-development flows to pre-development flows by providing the required retention time in on-Site ponds, and by doing so also provide total suspended solids removal. The approach also divides up the Site into three drainage areas that are similar in size to the three pre-development drainage area leading to the three surface water discharge locations from the Site. The three discharge locations, which all flow eastward and enter Shaw’s Creek, are to the Regimbald Municipal Drain to the northeast, to the Simpson Municipal Drain in the central portion, and in the southern portion to the Wilson-Johnston Municipal Drain via an existing ditch. The system consists of Site grading, ditching and culverts leading to five linear stormwater ponds or pairs of ponds.

10.10 Screening Berms

Constructed screening will be required at the northeast and southeast corner areas and along a portion of the west central Site boundary. The constructed earth screening berms would have 3H:1V side slopes, a 2 metre top width and be 2 metres high with trees transplanted on them. In other areas screening could be provided by leaving an adequate width (15 to 20 metres) of existing tree cover around the perimeter of the property. It is noted that a portion of the constructed screening proposed at the northeast corner could be replaced by transplanting trees in the gap in the existing tree line at the north end of the Frontier Road cul-de-sac; this would also effectively screen the view of the Site for persons travelling along Highway 417.

11.0 GEOTECHNICAL CONSIDERATIONS OF SITE DESIGN

This section discusses some of the geotechnical design aspects of CRRRC project, with a focus on the landfill geometry and performance. The geotechnical design aspects of secondary Site components (e.g., pavement designs for roadways, detailed design of building foundations, screening berm construction, etc.) will be addressed subsequently as part of the City site plan and building permit application process.

In general, the subsurface conditions across the Site consist of about 0.05 to 0.3 metres of topsoil/peat underlain by about 0.3 to 2.7 metres of surficial sand and silt, overlying between about 26 to 37 metres of sensitive silty clay. The upper 0.1 to 1.3 metres of the clay deposit at most locations has been weathered to a red brown crust and has a stiff consistency. The underlying silty clay generally has a soft consistency to about 9 to 10 metres depth, followed by a firm consistency to about 15 to 18 metres depth, and is stiff to very stiff below that. The silty clay is underlain by loose to very dense glacial till that ranges from about 2 to 9 metres in thickness. The bedrock surface was encountered beneath the glacial till deposit at depths between about 33 and 41 metres.

The following sections provide a summary of the results of the slope stability and settlement analyses carried out for the Site, along with recommendations for Site design.

11.1 Stability Analyses

The presence of the thick deposit of soft silty clay beneath the Site presents a constraint on the landfill geometry.

Various potential waste slope geometries were initially evaluated, in order to optimize the Site design. The currently proposed arrangement (as described in Section 10.0 and below) was ultimately selected as being preferred. Only the proposed Site development landfill arrangement is discussed.

The use of 3.5 metre high perimeter berms, with a crest width of 36 metres, was identified by the analyses as being a key component of the design, from the perspectives of optimising the landfill capacity and achieving the required factor of safety.

Stability analyses have been carried out for the various slope geometries that will exist around the perimeter of the landfill, including the arrangements of the perimeter berms and the adjacent features. The analyses identified that the critical locations/slopes are those on the eastern and northern sides, where shallow excavations will be needed parallel to the slope toe, to accommodate surface water drainage elements. The resulting proposed landfill sideslope geometry along these slopes is described as follows (downward, from peak to toe):

- **The eastern side of the landfill adjacent to the linear storm water management pond:**
    - A maximum peak height of the landfill of about 25 metres above the existing ground surface.
    - A slope down from the peak at 20H:1V (horizontal to vertical inclination) to a height of 13.5 metres above the existing ground surface.
    - A further slope down at 14H:1V to the top of the perimeter berm.
    - A perimeter berm which is 3.5 metres high (relative to the existing/native ground surface) and with a crest width of 36 metres (from the edge of the waste to the crest of the external berm sideslope).
    - An ‘outer’ berm sideslope inclined at 7H:1V, extending down to the native/existing ground surface.

  - About a 23 metre set-back distance from the toe of the perimeter berm to the crest of the linear storm water management pond.
  - A 3H:1V and 2-metre high slope down to the floor of the storm water management pond (i.e., reaching to a maximum depth of 2 metres below the existing/native ground surface).
- **The northern end of the landfill adjacent to the Simpson Drain:**
  - A maximum peak height of the landfill of about 25 metres above the existing ground surface.
  - A slope down from the peak at 20H:1V to a height of 13.5 metres above the existing ground surface.
  - A further slope down at 14H:1V to the top of the perimeter containment berm.
  - A perimeter berm which is 3.5 metres high (relative to the existing/native ground surface) and with a crest width of 36 metres (from the edge of the waste to the crest of the external berm side slope).
  - An ‘outer’ berm side-slope at 7H:1V, extending down to the native/existing ground surface.
  - About a 20 metre set-back distance (minimum) from the toe of the perimeter berm to the crest of the Simpson Drain (which is up to two metres deep relative to the existing/native ground surface).

Two other temporary conditions were also identified as being critical to the design and the following geometries were proposed and analyzed:

- **Internal Perimeter Berm/Excavation Stability:** An *internal* perimeter berm/excavation slope that is inclined at no steeper than 7H:1V from the top of the perimeter berm to the subgrade level of the landfill (based on the ‘internal’ stability for the creation of that excavation beside the berm).
- **Interim Waste Slope:** A typical interim waste slope geometry between adjacent phases which consists of a 14H:1V inclination from a height of about 13.5 metres above the original ground surface down to the subgrade level of the landfill (based on the stability of the proposed temporary slopes during waste placement, in accordance with the proposed phasing).

The stability analyses were carried out using the SLOPE/W commercial software, which uses Limit Equilibrium methods to calculate a factor of safety against shearing of the soil and resulting instability. The Morgenstern-Price method was used to compute the factor of safety. The factor of safety is defined as the ratio of the magnitude of the forces/moments tending to resist failure to the magnitude of the forces/moments tending to cause failure. Theoretically, a slope with a factor of safety of less than 1.0 will fail and one with a factor of safety of 1.0 or greater will stand. However, because the modelling is not exact and natural variations exist for all of the parameters affecting slope stability, a higher factor of safety is typically required. The following minimum target factors of safety were identified for these analyses:

- Overall Landfill/Waste Slope: 1.4;
- Internal Perimeter Berm/Excavation: 1.3; and,
- Interim Waste Slope: 1.4.

The analyses were carried out for undrained conditions (i.e., short-term conditions, where the full excess porewater pressures are generated in the silty clay due to the applied stress from the full height of waste). This condition is considered to be a conservative assessment, because the actual waste placement will take place over several decades, allowing for some pressure dissipation. Therefore, conditions in the underlying silty clay would actually be intermediate between truly undrained or completely drained (i.e., where the waste is placed sufficiently slowly that excess porewater pressures are not generated in the clay). However, given the uncertainties regarding the actual rate of filling, and to allow flexibility on the rate and location of waste placement, undrained conditions were conservatively selected as the design criteria. This undrained condition would be analogous to the landfill being completely filled and the cover soil placed semi-instantaneously (or over a very short period of time).

The soil parameters used for the analyses were interpreted from the subsurface information collected from the extensive geotechnical investigation carried out for the Site as described in Section 2.0 (methodology) and Section 6.0 (results). Because undrained conditions were analyzed, total stress parameters were used for the silty clay. The selected parameters are summarized in Table 11-1:

Table 11-1: Summary of Soil Parameters

Material	Unit Weight (KN/m^3)	Undrained Shear Strength (kPa)	Friction Angle (degrees)
Final Cover	19	0	25
Waste	12	0	30
Saturated Waste	16	0	30
Drainage Layer	18	0	30
Perimeter Berm Fill	18	0	28
Surficial Soils (0 to 1.5 metres below original ground surface)	19	0	28
Upper Clay A (1.5 to 3.5 metres below original ground surface)	15	10	0
Upper Clay B1 (3.5 to 6.0 metres below original ground surface)	15	12	0
Upper Clay B2 (6.0 to 7.0 metres below original ground surface)	15	11	0
Upper Clay C (7.0 to 15.0 metres below original ground surface)	15	Increasing from 11 to 29	0
Upper Clay D (15.0 to 20.0 metres below original ground surface)	15	Increasing from 29 to 52	0
Lower Clay A (20.0 to 25.0 metres below original ground surface)	16	52	0
Lower Clay B (25.0 to 35.8 metres below original ground surface)	16	Increasing from 58 to 116	0
Glacial Till	Impenetrable		
Bedrock	Impenetrable		

Notes: kN/m^3 – kilonewtons per cubic metre; kPa – kilopascals

The values of the 'mobilized' undrained shear strength of the silty clay indicated in the above table were selected based on the *in-situ* vane testing results, the plasticity index values indicated from the laboratory testing program, the assessed preconsolidation pressures, and the CPT results.

Several different shearing geometries (i.e., potential failure surfaces) were assessed, including rotational, sliding, and composite failures. The critical failure surface was generally found to consist of a sliding/translational failure through the upper unweathered clay layer between 6.0 and 7.0 metres depth (i.e., just above the zone of significant strength increase with depth).

11.1.1 Static Slope Stability Results

A summary of the static slope stability results is presented in Table 11-2:

Table 11-2: Summary of Static Slope Stability Results

Critical Slope Cross Section	Calculated Static Factor of Safety
The eastern side of the landfill adjacent to the storm water management pond	1.4
The northern end of the landfill adjacent to the Simpson Drain	1.4
Interim waste slope	1.5
Internal Perimeter Berm/Excavation	1.3

The analysis results for the first 3 cases in the above table are shown graphically on Figures 11-1 to 11-3, respectively. Each pair of figures presents the information using a normal scale (Figure A) to show the landfill in context and with the vertical scale exaggerated three times (Figure B) to allow the descriptions for the layers to be legible.

Based on the above results, it is considered that the proposed waste slope geometries and berm/excavation geometries have an acceptable static factor of safety against slope instability (i.e., the proposed design meets the design criteria).

It should be noted that the landfill geometry used in the analyses, and described above, is the theoretical geometry without accounting for subgrade settlements. As discussed subsequently in Section 11.3 of this report, the subgrade settlements due to consolidation of the underlying silty clay will be time-dependant (taking many years/decades to occur). It is expected that the subgrade surface will be settling while waste is placed. Therefore, it would not likely be technically feasible to actually fill to the theoretical slope/cover elevations considered in these analyses. It will therefore be necessary to monitor the subgrade settlements (see Section 11.5 for the proposed geotechnical monitoring program).

The stability analyses are also dependent on the unit weight of the waste and, in view of the low shear strength of the underlying clay, it will be important to also carry out monitoring to evaluate the unit weight of the as-placed waste to assess the overall waste *weight* (i.e., stress imposed on the subgrade) compared to the weight considered in the stability analyses.

It may also be feasible to re-evaluate on an ongoing basis the actual permissible finished slope/cover geometry (not to exceed the final design elevation contours) based on the strength gain that will occur as the underlying clay consolidates and compresses. To do so, it will be necessary to monitor the landfill subgrade settlements (as a measure of the degree of consolidation), the rate of excess porewater pressure dissipation in the silty clay deposit, and the rate and magnitude of the lateral deformation of the silty clay beneath the perimeter berms.

To evaluate landfill capacity at this stage of the project, the geometry/volume defined by the stability analysis was used (i.e., the theoretical volume corresponding to the final waste elevations described above, in the absence of subgrade settlements).

The construction of the perimeter berms will require control on the material type used for the berm fill (specifically its unit weight) and on the level of compaction achieved, because the berm improves the stability of the landfill slope due to its overall *weight*. The stability analyses were based on a unit weight for the berm fill of 18 kN/m^3. A lower in-place unit weight for the fill would reduce the factor of safety against instability of the overall waste slope. Conversely, a significantly higher unit weight could reduce the factor of safety against localized instability of the berm itself, in particular along the east and north sides of the landfill where adjacent shallow excavations will be required for a storm water management pond and the Simpson Drain. As a preliminary guideline, the berm fill should be restricted to an in-place unit weight between about 17.5 and 18.5 kN/m^3.

11.1.2 Static Stability Guidelines for Related Site Features

In addition to the analysis results described above in relation to the landfill, static slope stability analyses were also carried out for various other features on the Site, such as fire, leachate, and storm water management ponds, and the Primary Reactor cells to be used in the organic processing compost facility. These features are considered to have adequate factors of safety provided the following guidelines are adhered to:

- Side slopes for fire, leachate, and those storm water management ponds not adjacent to the landfill should be sloped at 4H:1V. However, this guideline assumes that any grade raise fill or berm fill placed adjacent to the ponds will not be initially constructed within 15 metres of the crest of the slopes (i.e., a delay of approximately six months will be required between the pond excavation being made and the fill being placed).
- Any ponds placed adjacent to (i.e., north of) the Simpson Drain should be offset at least 10 metres from the crest of the exterior slope of the Drain (crest-to-crest distance).
- The external side slopes of the Primary Reactor cells should be sloped at 5.25H:1V for a maximum compost thickness of 6.5 - 7.0 metres and width of 70 metres.
- Any ponds placed adjacent to the Primary Reactor cells should be offset by at least 20 metres from the toe of the Reactor.

11.2 Seismic Assessment

Dynamic analyses were also carried out to investigate the seismic stability of the proposed landfill configuration when subjected to strong earthquake shaking. A summary of the analyses and results is provided in this section of the report. A memorandum with further details on the methodology used to assess the seismic stability and earthquake-induced deformations of the waste materials and the underlying foundations, and the results of the analyses, is provided in Appendix Q.

Seismic design guidelines established for solid waste landfills in the USA require that such facilities be designed to resist ground motions with a 2,475-year return period, which has been considered for the analysis of this landfill.

The corresponding seismic ground motion parameters for the Site have been evaluated using the seismic hazard models and seismogenic zones developed on a regional basis by Natural Resources Canada for use in the National Building Code of Canada.

The de-aggregated hazard for the Site indicates that the earthquake characteristics correspond to “mean” earthquake magnitudes ranging between M6 and M7 with associated distances between 25 kilometres and 72 kilometres.

Bedrock acceleration time-histories that correspond to those earthquake magnitudes were then selected from available synthetic earthquake records for Eastern Canada.

A total of six M7 earthquake records were selected and they were linearly scaled to match the response spectrum for the Site over the period range corresponding to the expected fundamental period of the soils underlying the Site. The duration of strong shaking of the selected time-histories varies between 10 and 15 seconds.

Non-linear dynamic time-history analyses were then carried out to assess the seismic stability and deformations of the CRRRC landfill at the closure condition. The seismic ground motions were propagated from the bedrock upwards towards the ground surface using ground response analysis models.

The analyses considered conditions at the end of filling. Over time, the self-weight loads imposed by the landfill materials will induce consolidation settlements in the underlying clayey soils, which will increase the strength and stiffness of the clay foundation soils. However, at the end of filling, the analyses indicate that, beneath the ‘youngest’ portions of the landfill (i.e., Phases 6, 7, and 8) there will only have been fairly limited consolidation and therefore no significant strength gain. The ‘end of filling’ time is therefore considered to be a conservative condition for which to check the seismic stability.

The analyses were carried out using the computer code FLAC^{2D} *V6* (*Itasca,* 2008), which is a commercially available finite difference code with the capability to analyse the coupled stress-flow-deformation response of earth structures that can undergo large deformations under static and dynamic loading conditions.

The dynamic analyses were carried out considering two-dimensional plane strain conditions.

The analyses were conducted using the total-stress approach, with undrained shear strength parameters assigned to the clayey foundation soils. The shear strength profile for the clayey soils comprising the foundation under as-is conditions was established based on the SHANSEP concept. Laboratory cyclic simple shear tests carried out on undisturbed soil samples obtained from similar deposits in the Ottawa region indicate only nominal strain softening as a result of the application of up to 10 uniform cycles of shear loading (consistent with the anticipated shaking duration) that correspond to the projected intensity of Site-specific cyclic loading.

The computed seismic loading-induced lateral movements of the landfill for all six of the analyzed time histories are less than 340 millimetres. The calculated earthquake-induced deformations of the landfill are the result of deformations occurring in the upper clay layers directly below the landfill.

These results are indicative of a stable landfill under the design seismic loading conditions.

Further details on the analyses and results are provided in Appendix Q. In summary, the results indicate the following:

1) The landfill configuration is stable under the design seismic loading conditions;

2) The zones closest to the landfill toe undergo permanent lateral displacements of less than 340 millimetres during shaking (for 2,475-year return period ground motions). The resultant permanent ground movements at the corners of the landfill may be larger by about 40% due to three-dimensional loading effects, reaching values close to 500 millimetres;

3) The landfill lateral displacements are mainly controlled by the response of the soft clayey foundation soils directly below the waste materials and in the upper 20 metres; and,

4) Because the ongoing consolidation of the clay deposit beneath the waste will result in increased shear strength and corresponding increased resistance to the effects of earthquake shaking, the stability of the landfill will improve and the potential displacements will decrease with time after filling is complete.

11.3 Settlement Analyses

The development of the landfill (i.e., the placement of up to 25 metres of waste) will induce time-dependant consolidation of the underlying clay soil deposit. Due to the low hydraulic conductivity of the silty clay, the settlements will be time-dependant in nature and will occur over many years/decades.

The settlement estimates discussed in this section of the report represent the settlement of the landfill subgrade (i.e., at the base elevations of the waste), due to consolidation of the underlying silty clay deposit. There would be additional settlements of the landfill surface/cover, due to compression of the waste itself.

In order to estimate the magnitude of settlement of the silty clay underlying the landfill, analyses were carried out using the commercially-available ‘Settle-3D’ software.

The calculated ultimate effective stress levels in the silty clay will exceed the deposit’s preconsolidation pressure. The consolidation settlements will therefore occur in the ‘virgin’ compression range and will be significant in magnitude.

Porewater will need to be expelled for these settlements to occur. Therefore, due to the low hydraulic conductivity of the silty clay, the settlements will be time-dependant in nature and will occur over many years/decades.

Two key parameters in the evaluation of the magnitude and rate of consolidation settlement are:

- The preconsolidation pressure (σ'_p) of the silty clay, which is effectively its 'yield strength' and varies with depth (increasing in approximate correlation with the undrained shear strength); and,
- The coefficient of consolidation (c_v), which is related to the soil's hydraulic conductivity (and the ability to expel porewater), and which decreases as the clay consolidates.

The vertical profile of the preconsolidation pressure, through the soil deposit, has been selected based on the results of the laboratory oedometer consolidation testing. However, because the undrained shear strength is generally expected to correlate with the preconsolidation pressure (as evidenced by the data on Figure H1 in Appendix H), and there is significantly more data available on the undrained shear strength than there is for the preconsolidation pressure, consideration has also been given to the undrained shear strength profile in making the selection of the preconsolidation pressure profile with depth used in the settlement analyses.

The c_v has been interpreted from the results of the laboratory oedometer consolidation testing (with emphasis on the c_v data for those tests carried out with greater load increment ratios), as well as from the results of the porewater pressure dissipation tests carried out as part of the CPT program (see Appendix G). In addition, because there is considerable published evidence that the coefficient of consolidation as measured by these methods is often not consistent with actual/measured settlement performance, consideration has been given to published values of the coefficient of consolidation for Champlain Sea clay, as determined from the results of monitoring of the settlements of other embankments in eastern Ontario and western Quebec.

With the above approach, there is considerable variation in the values that could be selected for both parameters. A range of values/profiles for both parameters was therefore considered, and several combinations of the two used in the analyses. This methodology results in a range of the calculated possible settlements over time.

It was also considered in the analyses that the upper portion of the clay deposit, to a depth of about 20 metres, appears to have a higher compression index, slightly lower unit weight, and higher void ratio than the deeper clay. Different properties were therefore assigned in the model to the upper 20 metres of silty clay versus the deeper portion of the deposit.

It is noted that the properties of the silty clay deposit that affect its compressibility appear to be relatively uniform across this large Site (i.e., the silty clay properties are fairly homogenous in terms of horizontal variation). Therefore, only a single soil 'model' was developed to represent the conditions at this Site.

The initial effective stress profile used in the model, with depth, also considered that there appears to be a slightly downward hydraulic gradient through the silty clay deposit.

A one-way 'drainage' condition (upward) was selected for the analyses as being most representative of the anticipated behaviour during consolidation, for the groundwater flow associated with dissipation of the excess porewater pressures. This selection was based on the significant thickness of the deposit and considering that most of the settlements are calculated to occur within the upper portion. It should also be noted that the analysis software can only consider one-dimensional flow (i.e., up, or up and down). However, considering the significant horizontal dimension of the landfill, this drainage condition is considered to be a reasonable approximation of the real conditions, at least for the areas not directly along the perimeter of the footprint (where horizontal groundwater consolidation flow could occur), and is therefore reasonable for the most heavily loaded areas.

A waste unit weight of 12 kN/m^3 was used in the analyses, based on the type of waste to be placed in the landfill (including daily cover soil) and using published unit weight values. The lower one metre of material (waste and drainage materials) above the subgrade was considered to be saturated (and therefore heavier), based on a conservative assessment of the potential leachate level.

Based on the above, the ‘net’ applied stress on the subgrade under the highest portion of the landfill, based on the excavated soil to reach subgrade level, the waste height to be placed, and the cover material and drainage layers, is estimated at about 300 kPa.

The results of the analyses indicate that, under the highest portions of the landfill, the settlements resulting from *primary consolidation* of the deposit are expected to be in the order of 6 to 8 metres, by a time of about 100 years from the start of consolidation.

In the longer term, the settlements would increase beyond this estimate due to secondary compression of the deposit. The secondary compression index used to calculate these potential additional settlements was conservatively selected based on generally-accepted published correlations with the compression index. The results of the two long-term/sustained consolidation tests indicated secondary compression index values that were much less than would typically be expected, given the other properties of the silty clay deposit, and therefore the higher values based on published correlations were used. The resulting analysis results could therefore potentially over-estimate the secondary compression component of the overall settlements.

Based on the above methodology, the calculated range of settlements over time, based on the combination of primary consolidation and secondary compression, are shown on Figure 11-4.

The landfill subgrade settlements will also vary across the footprint, due to the variation in the landfill waste thickness. For example, the calculated range of settlements under a 13.5 metre waste height (i.e., beneath the transition level between the 14H:1V and 20H:1V side-slopes), over a 100 year time frame, are shown on Figure 11-5. These settlements are expected to range from about 3.5 to 5 metres in magnitude (combined primary consolidation and secondary compression).

The Settle-3D model was therefore developed to approximately correspond to the semi-rectangular landfill footprint and varying waste height. The resulting analyses indicate that the vertical stress increases generated in the underlying silty clay very closely correspond to the imposed stress directly above each location. There does not appear to be significant vertical dissipation of stress, or 3-dimensional effects, to the state of vertical stress. This result is considered to be attributed to the fact that the horizontal dimensions of the landfill are much larger than the thickness of the clay layer. As such, an essentially 1-dimensional assessment of the incremental vertical stresses beneath the landfill footprint is feasible for this project. Based on this assessment, the calculated range of settlements under waste heights varying up to the maximum proposed waste height, at a time of 100 years following that start of consolidation, are shown on Figure 11-6. These results can be used to evaluate the potential differential settlements of the subgrade (and drainage system) beneath different points in the landfill footprint.

In regards to these results, the following should be noted:

- The settlement calculations shown on Figure 11-6 may be of reduced accuracy in the area directly along the toe/perimeter of the landfill, where the one-dimensional assessment may be less representative; the settlements in those areas would potentially be slightly less than those indicated on Figure 11-6.
- The analyses are based on the simplification of the landfill being constructed essentially instantaneously and the settlements occurring thereafter. In actuality, the waste placement will occur over many years and therefore some of the settlements will occur during waste placement. The reference time for the settlement results provided on Figures 11-4 to 11-6 is therefore actually an intermediate time between the start and end of filling. Once the rate of filling has been defined (over time and by area of the landfill), these analyses could be refined.

As discussed in Section 11.1.1, the completed landfill geometry (i.e., the elevation of the ‘finished’ landfill surface and sideslopes) will need to account for subgrade settlements. Because the subgrade surface will be settling while waste is placed, it will not, therefore, likely be technically feasible to actually fill to the theoretical slope/cover geometry. Based on monitoring and the associated gain in strength of the clay as it consolidates, the appropriate final waste thickness (not to exceed the final elevation contours assumed for purposes of this study) will be determined in consultation with the MOECC prior to placement of the waste in the uppermost phases of the landfill. Subgrade settlements will be monitored (see Section 11.5).

11.4 Potential Geological and Geotechnical Related Effects on Landfill Design and Performance

The evaluation of potential geological impacts is provided in Section 9.0, while the geotechnical considerations are described in Sections 11.1, 11.2 and 11.3. The geological assessment concluded, based on available information, that there is no evidence of surface fault ruptures from historical earthquakes at the proposed CRRRC Site or its immediate vicinity. The assessment further concluded that there is negligible hazard at the CRRRC Site of future fault movement resulting in large scale differential displacements at the surface or shallow subsurface and that there is also little potential for differential settlement associated with strong earthquake shaking (liquefaction) at the CRRRC Site.

In any event, in terms of the engineering significance or potential effects of surface or subsurface displacements from potential future fault movement on the design and performance of the proposed CRRRC landfill, both the landfill mass itself and the proposed leachate containment and collection system (and its components), are very capable of withstanding significant differential displacements. There is no constructed or manufactured liner system at the base of the landfill as designed; rather, the containment of landfill leachate relies on the natural containment properties of the 30 metres of low permeability silty clay underlying the Site. The proposed leachate containment and collection system has been designed to withstand relatively large differential movements and continue to perform its intended function. For example, this containment and collection system has been designed to function when experiencing the predicted movements associated with long term consolidation of the clay deposit beneath the landfill, i.e., total settlements of 6 to 8 metres under the central portion of the landfill. The containment and collection system has also been designed to accommodate lateral displacements of up to 350 mm under seismic loading conditions. The effects of small-scale surface or subsurface displacements from fault displacement are, therefore, inconsequential for the engineering design and performance of the landfill component of the CRRRC.

11.5 Geotechnical Monitoring Program

It is recommended that a geotechnical monitoring program be implemented for the purposes of:

- Confirming that the performance/behaviour of the underlying foundation soils is consistent with those expected based on the geotechnical investigation program and analyses, to thereby confirm the applicability of the design recommendations provided; and,
- Providing information to optimize the design and/or operation of the landfill, as construction and filling progress.

The following monitoring measures are therefore recommended:

- The subgrade settlements should be monitored by means of surveying of the elevations of the leachate collection system manholes. If better definition of the settlement pattern is determined to be helpful (i.e., at a better horizontal resolution than can be achieved using only surveying of the manholes), then the feasibility of also monitoring the settlements by means of instrumentation placed on the landfill subgrade (such as with a grid of vibrating wire settlement monitors) could also be considered.
- The unit weight of the as-placed waste should be evaluated on a periodic basis (e.g., semi-annually) by means of weigh-scale records and air-space utilization surveys, and also using the subgrade settlement surveys.
- The lateral displacements of the silty clay beneath the perimeter berm of the landfill should be monitoring by means of the following:
    - Inclinometers should be used to measure the horizontal deformation profile in the silty clay with depth, using casings installed from the surface of the perimeter berm and anchored into the bedrock. Based on the anticipated performance, at least one inclinometer casing should be installed per side/face of the landfill. Note: Specialized telescoping casings will need to be used to avoid having the casing deformed by downdrag forces resulting from consolidation and settlement of the silty clay beneath the perimeter berms. The casing grout will also need to be designed to be compatible in physical behaviour with the surrounding soft soil.
    - Surface survey point/monuments should be installed along the surface of the perimeter berm and at the toe of the perimeter berm, which can be used to monitor the surface deformations (both horizontal and vertical). The monitoring of these can be carried out using conventional survey equipment/methods. Monitors should be installed every 200 metres along the perimeter of the landfill.

It is also recommended that the rate of porewater pressure dissipation in the underlying clay be monitored by means of vibrating wire piezometers installed at the time of landfill cell construction at various depths in the upper portion of the silty clay deposit. As discussed in Section 11.1.1, this data, in conjunction with the monitoring of the lateral deformations of the silty clay beneath the perimeter berms and monitoring of the landfill subgrade settlements should permit ongoing evaluation of the actual permissible finished slope/cover geometry, based on the strength gain that will occur as the underlying clay consolidates and compresses. Additional laboratory triaxial testing would be needed to provide the necessary soil parameters for these analyses. For the installation of these piezometers, it would not be planned to fully penetrate the silty clay layer (i.e., they would only be installed in the upper portion of the deposit) and the boreholes would be fully grouted; a path for preferential leachate migration to the underlying more permeable strata would not be created.

11.6 Buildings and Site Grading

As discussed previously, the focus of this overall section of the report has been the geotechnical design aspects of the landfill geometry. The following preliminary/general comments are provided for other Site components:

- Given the limited capacity of the underlying soils to support additional load/stress without experiencing significant compression, the overall grade raise on the Site (as required for Site drainage purposes) would ideally be restricted to a low value. A grade raise of no more than about 0.6 metres would likely be required if the general ground settlements are to be limited to very low values. However, it is understood that this level of grade raise is unlikely to be feasible. It is expected that, for grade raises of up to about one metre in magnitude, the settlements would be limited to values which could feasibly be accommodated by on-going Site maintenance. Grade raises of more than about one metre may require mitigating measures and/or perpetual and costly maintenance. A particular issue would be the differential settlements around pile-supported buildings (see next item); the settlements at the entrance thresholds could impede equipment movements. One option that could be considered would be to preload portions of the Site and to thereby have some of the settlement occur prior to the Site being developed. Consideration could also be given to a test filling program, to monitor actual settlements, and thereby refine the theoretical predictions that have been made using the *in-situ* and laboratory testing data.
- The overall Site development will include the construction of several buildings. Given the limited capacity of the silty clay deposit to support foundation loads, it is expected that the buildings will need to be supported on deep foundations, such as driven steel piles which derive their support from end-bearing on the bedrock. It is also expected that, given the anticipated grade raises (which are likely to exceed 0.6 metres), and the potentially significant floor loading, it will probably be necessary to provide the buildings (or at least some buildings) with structural floor slabs, which are supported on deep foundations.
- Shorter/lighter buildings could potentially be supported on helical pier foundations, which are supported below the softest portions of the clay deposit.
- Based on Site-specific shear wave velocity profiling completed at the this Site, the average shear wave velocity of the upper 30 metres of overburden soils has been established as less than 180 m/sec. A Site Class E would likely apply for the seismic design of buildings at this Site.

The feasibility of a larger-scale ground improvement program could also be evaluated for this Site. The use of light weight fill materials, such as expanded polystyrene Geofoam blocks, could also be considered in some applications/locations on this Site, to lessen the applied load on the clay and reduce the expected settlements.

12.0 GROUNDWATER MODELLING AND ASSESSMENT OF LONG-TERM GROUNDWATER IMPACTS

Groundwater and contaminant transport modelling were completed to simulate post-development conditions considering the planned Site development. Predictive simulations of groundwater quantity were completed using a three-dimensional (3-D) numerical groundwater flow model, while predictive simulations of contaminant transport and groundwater quality were completed using a one-dimensional (1-D) analytical contaminant transport model. The objective of the groundwater modelling studies described below was to quantitatively evaluate the potential effects of the Site on groundwater quantity and quality.

12.1 Hydrogeological Conceptual Model

12.1.1 Site Geological Setting

A detailed description of the local and regional geological setting for the Site is described in detail in Section 3.0. The following sections summarize the components of the Site geological setting pertinent to the development of the hydrogeological conceptual model.

The region within which the CRRRC Site is situated is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the Champlain Sea basin. These deposits overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock consisting of shales, dolostones and limestones.

Overburden materials tend to fill depressions in the bedrock surface in the area, and reach thicknesses of up to 20 metres to 60 metres. Approximately six kilometres to the east of the Site the overburden thins due to a north-northeast trending buried bedrock ridge. Glacial till deposits are present at surface over the ridge as shown on Figure 3-11 (Cross-Section D-D’).

The Vars-Winchester buried esker (a buried deposit of sand and gravel) occurs a few kilometres east of the ridge, and roughly parallels the north-northeast trend of the buried bedrock ridge (Figure 3-11). The esker is about eight kilometres east of the Site and is separated from the Site by the bedrock ridge, and the surrounding thick clay deposits.

12.1.2 Hydrostratigraphy

The hydrostratigraphic units which underlie the Site were characterized through a series of geotechnical and hydrogeological investigations as described in Section 2.0. Based on these investigations, seven hydrostratigraphic units are identified as follows:

- **Surficial silty sand**: Silty sand was observed at surface in all but four of the borehole locations completed as part of the subsurface investigation at the Site. Where present on the Site, the sand was found to vary in thickness between 0.3 metres and 2.7 metres, with an average thickness of approximately one metre. An isopach map of this unit is presented on Figure 3-16 Panel A. Horizontal hydraulic conductivity of the surficial silty sand unit was found to vary between 9 x 10^{-8} m/sec to 2 x 10^{-5} m/sec, with a geometric mean value of 2.5 x 10^{-6} m/sec (Section 7.2.4). Residential wells in the area are dug wells, and draw water from this unit.

- **Weathered clay**: A thick and continuous silty clay unit was observed to underlie the surficial silty sand unit (or outcrop at surface where sand is absent). At most borehole locations, the upper portion of the silty clay was weathered. The weathered portion varies in thickness between 0.1 metres and 1.3 metres, with an average thickness of 0.43 metres. The thickness of the weathered clay unit was found to be inversely proportional to the thickness of the overlying surficial silty sand unit, with the weathered clay unit being thickest where clay is present at the surface.

- **Silty clay**: The total thickness of the silty clay unit (including the weathered clay) ranges from approximately 19 metres to 35 metres, with a minimum of about 25 metres below the Site (Figure 3-16, Panel B). As discussed above the upper 0.1 metres to 1.3 metres of this unit has been weathered. The silty clay unit was found to contain occasional silt and silty sand seams. The vertical hydraulic conductivity of this unit was found to range from 1.2 x 10^{-11} to 1.8 x 10^{-9} m/sec, with a geometric mean value of 1.0 x 10^{-9} m/sec based on the results of laboratory testing (Section 7.2.3). Given the low vertical hydraulic conductivity of this unit, it is interpreted to behave as an aquitard, with primarily vertical groundwater flow occurring through this unit, between the surficial silty sand, and the glacial till below. Given the relatively low hydraulic conductivity of this unit, groundwater flow volumes through the silty clay would be low. As discussed below, a thin but continuous layer of sand silt to silty sand, trace clay is present within the silty clay unit (referred to as the silty layer). For discussion purposes, the terms upper and lower are added as descriptors when referring to the silty clay above and below the silty layer, respectively. These terms are used for spatial reference only, and are not meant to imply a change in the hydraulic properties of the unit.

- **Silty layer**: A continuous but thin layer of silty soil was observed within the upper portion of the silty clay unit at all of the borehole locations at the Site. The thickness of this unit was found to vary from 0.1 metres to 0.6 metres with an average thickness of 0.3 metres (Figure 3-17, Panel A). This unit was typically found between three and four metres below the top of the clay unit (average depth of 3.95 metres below the top of the weathered clay unit). The horizontal hydraulic conductivity of this unit ranges from 3 x 10^{-8} m/sec to 3 x 10^{-6} m/sec, with a geometric mean value of 8 x 10^{-7} m/sec (Section 7.2.4). As the hydraulic conductivity of this layer is higher than the silty clay above and below, horizontal flow may occur through this layer; however, given the relatively small thickness of this layer, groundwater flow volumes in this unit would be low.

- **Glacial till:** The thickness of this unit was found to vary between two metres and nine metres in boreholes at the Site (Figure 3-17 Panel B). The horizontal hydraulic conductivity of this unit varies from 8 x 10^{-9} m/sec to 2 x 10^{-4} m/sec with a geometric mean value of 1.5 x 10^{-6} m/sec (Section 7.2.4). There are few drilled residential wells in the area; however, those that do exist take their water from the contact between the glacial till unit and the underlying bedrock. In general, this contact aquifer produces enough water for domestic supply; however, the water produced is generally not potable.

- **Queenston Formation**: Although not observed in boreholes at the Site, mapping of local geology indicates the presence of the Queenston shale as the upper bedrock unit to the south of the Site (see Section 3.1.1, Figure 3-6). Horizontal hydraulic conductivity of this unit ranges from 3.6 x 10^{-9} m/sec to 3.0 x 10^{-6} m/sec (Golder, 2013), with a geometric mean value of 5.5 x 10^{-7} m/sec.

- **Carlsbad Formation**: Bedrock observed in boreholes extended to bedrock at the Site generally consists of fresh, very thinly to thinly bedded, dark grey to black, interbedded shale, calcareous shale, shaley to argillaceous limestone and limestone bedrock of the Carlsbad Formation. This formation is inferred to be more than 150 metres thick below the Site (Figure 3-7). The horizontal hydraulic conductivity of the upper four to six metres of the Carlsbad bedrock varies from 2 x 10^{-8} m/sec to 2 x 10^{-5} m/sec, with a geometric mean value of 7 x 10^{-7} m/sec (Section 7.2.4).

A hydrostratigraphic model of the South Nation watershed (that includes the CRRRC Site) was developed by the GSC (Logan et al., 2009). This model defines the top surface elevation of eight hydrostratigraphic units based on the analysis of various data sources. The defined units include: recent deposits, organic deposits, basin sand, basin mud, glaciofluvial sediment, sandy silt till, sub-till sediment, and Paleozoic bedrock. These surfaces are generally consistent with the local cross-section shown on Figure 3-11. Locally, the surficial silty sand unit is discontinuous and is present in distinct areas to the north of Highway 417, to the southwest of the Site near the headwater of the Castor River, and in small areas overlying the bedrock ridge. Where present, the sands range in thickness from less than 0.1 metres to 15 metres. Locally, the thickness of the silty clay unit varies between 20 metres and 40 metres. This unit is thinner (i.e., less than 20 metres) where rivers and creeks (such as the Bear Brook Creek) have incised the clay, and is not present above the bedrock ridge to the east of the Site. The till and sub-till sediments form a unit that varies in thickness between 1 metre and 15 metres.

12.1.3 Groundwater Flow Directions and Hydraulic Gradients

Groundwater flow directions and hydraulic gradients observed at the Site are discussed in detail in Sections 7.2.1 and 7.2.2. Horizontal groundwater flow in the surficial silty sand, the silty layer, silty clay, glacial till and upper bedrock were observed to be towards the east/northeast direction. Local groundwater contours are shown on Figures 7-1 through 7-4. Average horizontal hydraulic gradients in the surficial silty sand, silty clay, glacial till, and upper bedrock are very low and range from 0.0006 to 0.0008 m/sec. The vertical hydraulic gradients at the Site are generally downwards.

Locally, the shallow groundwater flow in the overburden units is interpreted to be towards rivers, creeks, drains, and, where present, tile drainage systems (WESA, 2010). Surface water features in the area that may influence shallow groundwater flow include: Bear Brook Creek and Regimbald Municipal Drain to the north of the Site, the Castor River to the south of the Site, the Bear River and Rochon Municipal Drains to the east of the Site, and the Simpson Municipal Drain, which runs west to east through the Site. Deep regional bedrock groundwater flow is generally interpreted to be to the north or northeast towards the Ottawa River (WESA, 2010).

12.1.4 Effect of Clay Consolidation on Groundwater Flow

As discussed in Section 11.3 the additional stresses to the underlying soils imposed by the landfill can induce time-dependent drainage of porewater from the underlying soils, resulting in consolidation. The silty clay deposit underlying the Site is expected to experience consolidation and subsequent settlement. The following consolidation processes and effects may influence groundwater flow at the Site:

- During the period in which porewater is draining from the silty clay, there will be persistent excess porewater pressure in the silty clay. As a result of these excess porewater pressures, upward vertical hydraulic gradients may be generated. A plot of hydraulic head variations with depth under a load equivalent to 20 metres of waste is shown on Figure 12.1 for various times in the consolidation process.

These results are based on the results of the Settle-3D modelling described in Section 11.3. These schematics are shown considering observed vertical hydraulic gradients at the Site. These results suggest that consolidation of the silty clay unit may result in upward hydraulic gradients below the landfill that persist for between 25 and 50 years following the placement of the waste, creating a barrier to downward seepage during this period.

- The consolidation of the silty clay deposits will result in settlement of the overlying stratigraphic layers. This settlement is highest where the waste is thickest, and reaches zero at the toe of the berm. Due to this differential settlement, the stratigraphic layers will shift towards a bowl structure. This differential deformation will act as a structural trap to leachate generated at the Site.
- The reduction in volume of the clay with consolidation is associated with the realignment of clay minerals towards a more horizontal orientation, and a subsequent reduction in vertical hydraulic conductivity. It is assumed that this reduction may be by as much as one order of magnitude for the fully consolidated clay based on the results of oedometer consolidation testing completed as a component of this study (Section 6.3).

12.2 Three-Dimensional Numerical Groundwater Flow Model

A 3-D numerical groundwater flow model was constructed to provide a quantitative evaluation of hydraulic head drawdown, groundwater flow paths, groundwater seepage rates, and groundwater travel times resulting from the proposed development of the CRRRC Site. The groundwater flow model was developed using FEFLOW (Finite Element subsurface FLOW system) Version 6.1, WASY Ltd. (www.wasy.de). FEFLOW is capable of representing groundwater flow, contaminant mass transport and heat transfer using finite elements. The objective of this modelling study was to evaluate potential effects of the Site on groundwater quantity. Potential effects on groundwater quality are evaluated separately (see Section 12.3).

12.2.1 Model Construction and Grid Discretization

The model domain is bounded by the Bear River municipal drain in the west, Bear Brook Creek in the north, and the North Castor/Castor River in the south. The bedrock ridge was used to define the eastern boundary of the model domain. As discussed above, the ridge acts as a structural barrier for flow in the overburden to the east (towards the Vars-Winchester Esker). It is also noted that, as the ridge is a topographically high point in the area, it also acts as a recharge area. The modelled domain is shown on Figure 12-2.

The 3-D mesh was generated from a vertical extension of a two-dimensional (2-D) mesh to all hydrostratigraphic units. The 2-D mesh is made of 35,017 nodes forming 69,637 triangular finite elements. The 3-D mesh was generated by an extension of the 2-D mesh from the ground level to the base of the model domain while using the geodetic elevations of hydrostratigraphic unit contacts. The resulting mesh was subdivided into 17 layers (18 numerical slices) made of 630,306 nodes and forming 1,183,829 triangular prism shape finite elements for the predictive simulations.

The hydrostratigraphic layers, and surfaces used to define them are summarized as follows:

- **Layers 1 and 2:** These layers represent the surficial geology as shown on Figure 3-10. Borehole observations at the Site have shown that the surficial silty sand unit is present over a larger area than indicated by surficial mapping. As limited borehole observation data is available outside of the Site boundaries, this silty sand unit was extended to the east and west of the Site towards the Regimbald Municipal Drain, to provide a conservative representation of any potential connection between the drain and the Site. The top surface of Layer 1 was defined by local topographic and survey data. The bottom surface of Layer 2 was locally defined within the Site using borehole observations, and defined throughout the remainder of the model domain using the basin mud surface from the South Raisin Hydrostratigraphic model (Logan et al., 2009). The combined thickness of Layers 1 and 2 varies from 1 to 2 metres in the area of CRRRC site. The surficial silty sand unit is present in these layers only.
- **Layers 3 and 4:** These layers represent the weathered clay unit, with a uniform combined thickness of 0.5 metres. The properties of the till unit were assigned to these layers in the area where glacial till is present at the surface (i.e., where the clay unit pinches out).
- **Layers 5 and 6:** These layers represent the upper silty clay unit. The base of this layer is defined as the top of the silty layer. The combined thickness of these layers ranges from 1 metre to 5.7 metres within the Site boundaries, and was fixed at a uniform value of 3.45 metres elsewhere within the model domain. The properties of the till unit were assigned to these layers in the area where glacial till is present at the surface.
- **Layers 7 and 8:** These layers represent the silty layer. The combined thickness of these layers ranges from 0.1 metres to 0.6 metres within the Site boundaries, and was fixed at a uniform value of 0.3 metres elsewhere in the model domain. The properties of the till unit were assigned to these layers in the area where glacial till is present at the surface.
- **Layers 9 and 10:** These layers represent the lower silty clay unit, and are bounded on the top by the silty layer and on the bottom by the glacial till unit. The properties of the till unit were assigned to these layers in the area where glacial till unit is present at the surface.
- **Layers 11 and 12:** These layers represent the glacial till unit, which is assumed to be continuous throughout the model domain. The top surface of Layer 11 is defined on the Site using the borehole information described above, and defined elsewhere in the model using the glacial till and sub-till sediment surfaces from the South Raisin Hydrostratigraphic model (Logan et al., 2009). The combined thickness of these layers varies from 1 metre to 11.2 metres.
- **Layer 13 and 14:** These layers represent the Paleozoic bedrock units. The top surface Layer 13 was defined using the bedrock surface elevation discussed in Section 3.2.1. Layer 13 was assigned a uniform thickness of 50 metres, while Layer 14 was assigned a uniform thickness of 100 metres.

12.2.2 Boundary Conditions

The boundary conditions specified in the model are illustrated on Figure 12-3 and include the following:

- The eastern boundary of the model domain was assigned using a combination of no flow and specified head boundaries. A no flow boundary was assigned along the bedrock ridge to represent the water table mounding observed in the WESA (2010) study. At the northern and southern ends of the ridge, specified head boundaries were assigned along mapped surface water features. The interpreted boundary conditions are in agreement with the piezometric surfaces developed as a component of regional groundwater modelling completed by WESA (2010).
- Specified head boundaries were assigned to the main rivers, creeks and drains within the model domain. Assigned heads correspond to ground surface elevations.
- Seepage boundaries at the Simpson Drain and DD2.

Recharge was estimated through the calibration of the numerical model. Calibrated values are summarized in Table 12-1. These values represent between 0.5% and 2% of mean precipitation.

Table 12-1: Calibrated Recharge Rates

Surficial Unit	Recharge (mm/year)
Silty Sand	20
Weathered Clay	5
Glacial Till	15

12.2.3 Material Properties

The simulated hydraulic conductivity distribution for the various units is shown on Figure 12-4. The hydraulic parameters assigned to the various units are summarized in Table 12-2.

Table 12-2: Summary of Hydraulic Parameters Assigned in the Calibrated Numerical Model

Unit	Horizontal Hydraulic Conductivity (m/sec)	Anisotropy (K_H:K_v)	Specific Storage (m^{-1})	Specific Yield (-)
Surficial Silty Sand	2.0×10^{-5}	1:1	2.0×10^{-4}	0.2
Weathered Clay	1.0×10^{-7}	10:1	2.0×10^{-3}	0.05
Unweathered Clay	1.0×10^{-8}	10:1	2.0×10^{-3}	0.05
Silty Layer	8.0×10^{-7}	1:1	2.0×10^{-4}	0.1
Glacial Till	1.5×10^{-6}	1:1	2.0×10^{-4}	0.1
Queenston Shale Bedrock Formation	5.5×10^{-7}	1:1	3.0×10^{-6}	0.01
Carlsbad Bedrock Formation	7.0×10^{-7}	1:1	3.0×10^{-6}	0.01

Hydraulic conductivity values presented above were assigned based on hydraulic testing completed at the Site (Section 7.2.4), and calibration of the numerical model. Storage parameters were selected from literature values (Anderson and Woessner, 1992).

12.2.4 Model Calibration

The calibration of the groundwater flow model was evaluated by comparing the simulated steady-state groundwater elevations to measured groundwater elevations. The calibration dataset consisted of average groundwater elevations observed at the Site (between January and October 2013), and was supplemented using available data from the MOECC WWIS (MOE, 2013), and data from other Golder projects within the model domain.

As standard practice, a groundwater flow model is considered calibrated when the root mean square error (RMS) is within 5 to 10% of the total head variation over the domain (Anderson and Woessner, 1992). The RMS error for the calibrated model is 3.1 metres. With a total head variation of 25.8 metres over the domain, the calibrated RMS value slightly exceeds the suggested target.

The relationship between observed and simulated hydraulic head values is shown on Figure 12-5. This figure shows that the majority of the points fall along the line marking simulated hydraulic heads equal to observed hydraulic heads, indicating that the calibrated model properly simulates groundwater flow within the modelled domain.

Within the Site boundaries, the calibrated model replicates the observed groundwater flow directions, and hydraulic gradients in each of the hydrostratigraphic units. Simulated hydraulic heads are within 0.8 metres of the observed hydraulic heads at the Site, with an average residual of 0.2 metres. The hydraulic head residual for monitoring wells on the Site falls within the range of seasonal variability, indicating that the model is locally well calibrated.

12.2.5 Predictive Simulations

Predictive simulations of the post-development Site conditions were completed considering potential scenarios. Simulations were completed to represent steady-state conditions with an operating leachate collection system, and steady-state conditions following failure of the leachate collection system. Failure of the leachate collection system is not expected to occur until more than 100 years after the closure of the Site. Simulations were also completed to represent the steady-state conditions following the structural deformation of the stratigraphic layers resulting from consolidation of the silty clay unit. Consolidation was taken to be complete within 50 years following closure of the Site. Post-development conditions at the Site were represented by making the following changes to the calibrated model described above:

- Three additional slices were added to the model to represent the post-development infrastructure at the Site. The top slice represents the design surface of the landfill area and the perimeter berms. The second slice represents the interior side slopes of the perimeter berm, and the top of the drainage layer. The third slice was placed a distance of 0.6 metres below the second slice, representing the approximate thickness of the drainage layer. Within the Site boundaries, Slice 7 was adjusted to a distance of 0.25 metres below Slice 3 to represent the perimeter GCL hydraulic barrier to be constructed to provide cut-off for the perimeter berm fill, surficial sand and weathered clay. Where the fill area is not lined, Slice 7 was placed 0.5 metres below Slice 3 to represent the approximate thickness of the remaining surficial units underlying the leachate collection system. Slices 4, 5, and 6 are intermediate slices.
- The seepages boundaries representing the DD2 drain (location shown on Figure 2-2) within the landfill footprint were removed, and specified head boundaries were assigned to represent the leachate collection system at an elevation of 0.3 metres above the base of the drainage layer. Specified head boundaries

were assigned at 0.5 metres below the top of the perimeter berm to represent the planned ditch network at the edge of the berm. Seepage boundaries were assigned along the sideslopes and base of the waste and the berm.

- Recharge rates to the waste during operations and closure were assigned values of 289.6 and 269.6 millimetres per year, respectively, based on HELP model results (Section 12.3.4). Recharge on the berm was assigned a value of 5 millimetres per year. Recharge on the portion of the Site to the north of the Simpson Drain was assigned a value of 0 millimetres per year to represent the planned development in that area.

Material properties of the various post-development infrastructure components are summarized in Table 12-3.

Table 12-3: Summary of Hydraulic Parameters Assigned in the Post-development Numerical Model

Unit	Horizontal Hydraulic Conductivity (m/sec)	Anisotropy (K_H:K_v)	Specific Storage (m^{-1})	Specific Yield (-)
Waste (Operations)	1.0×10^{-5}	1:1	2.0×10^{-3}	0.1
Waste (Closure)	1.2×10^{-5}	1:1	2.0×10^{-3}	0.1
Drainage Layer	1.0×10^{-4}	1:1	2.0×10^{-4}	0.3
GCL Hydraulic Barrier	3.0×10^{-10}	1:1	2.0×10^{-3}	0.0001
Berm	1.0×10^{-7}	1:1	2.0×10^{-3}	0.05
Consolidated Weathered Clay	1.0×10^{-7}	100:1	2.0×10^{-3}	0.05
Consolidated Unweathered Clay	1.0×10^{-8}	100:1	2.0×10^{-3}	0.05

Note: Hydraulic conductivity of the waste is increased slightly at closure to represent the addition of a permeable cover

The hydraulic conductivity of the waste during the closure period is slightly higher than in operations to account for the addition of a permeable cover. The GCL hydraulic barrier will be approximately 0.95 centimetres thick with a hydraulic conductivity of approximately 1×10^{-11} m/sec. The hydraulic conductivity assigned for the GCL in the model is considered equivalent to the GCL hydraulic conductivity for the 0.25 metres thickness modelled. A cross-section showing the post-development hydrostratigraphic model layers is included on Figure 12-6.

The consolidation of the upper and lower silty clay units was represented in the model using the results of the settlement modelling discussed in Section 11.3. Consolidation affected only the clay units (Model Layers 8, 9, 12 and 13), while the overlying non-consolidated stratigraphic layers were translated downward by the same degree as the underlying layers. The settlement of the waste was not included in this analysis. The vertical hydraulic conductivity of the fully consolidated layers was decreased by one order of magnitude based on the results of oedometer consolidation testing completed as a component of this study (Section 6.3). A cross-section showing the post-consolidation model layers is shown on Figure 12-7. It is noted that this settlement representation is a simplified and steady state approximation of the consolidation process, and is only representative of structural changes once consolidation has been completed. The hydraulic effects of the consolidation process on excess porewater pressure development were not represented. As a result, the groundwater model presents a conservative approximation of the potential for groundwater seepage off-Site. As discussed in Section 12.1.4, during consolidation, excess porewater pressures will generate upward hydraulic gradients, resulting in a hydraulic barrier for downward vertical seepage from the landfill.

12.2.6 Results

The predictive model was used to estimate pseudo-steady state seepage rates and groundwater levels for the following scenarios:

- **Predictive Scenario (PS1):** Operating leachate collection system, pre-settlement, operational conditions;
- **Predictive Scenario (PS2):** Operating leachate collection system, post-settlement, closure conditions; and,
- **Predictive Scenario (PS3):** Failed leachate collection system, post-settlement, closure conditions.

Groundwater drawdown provides an indication of the extent to which the landfill could potentially affect off-Site groundwater quantity. Groundwater drawdown was calculated for each pre-failure scenario relative to the calibrated pre-development conditions. Groundwater drawdown will be most significant while the leachate collection system is in operation; as such, scenarios PS1 and PS2 represent the greatest potential for groundwater lowering. Figure 12-8 and Figure 12-9 show the drawdown iso-contours at steady state for PS1 and PS2, respectively. As shown on the figures, the simulated drawdown does not extend beyond the property boundary for any of the scenarios. Therefore the proposed Site development is not predicted to have any measurable impact on groundwater quantity (and off-Site dug well supply) outside of the property boundary. It is noted that the drawdown to the north of the Simpson Drain, within the property boundary, is due to the reduction in recharge resulting from the development of that portion of the Site.

As discussed in Section 12.3.7, failure of the leachate collection system would result in mounding of groundwater within the landfill component. The effect of this mounding on groundwater elevations is shown on Figure 12-10 for PS3. The predicted effect of the Site on groundwater levels post-failure does not extend beyond the property boundary.

Hydraulic head contours for the silty layer and the glacial till / bedrock contact are shown on Figure 12-11 for the PS3 scenario. These results show that groundwater seepage in the silty layer will flow radially away from the Site until it enters the local flow regime. Groundwater seepage in the glacial till / bedrock contact will be as under existing pre-development conditions and generally flow towards the northeast.

The travel time for particles released under steady-state conditions following failure of the leachate collection system, and representative of the first arrival of a conservative tracer at the glacial till/bedrock contact is on the order of 500 years.

12.3 Assessment of Long-Term Groundwater Impacts

12.3.1 Regulatory Objectives

Modelling of long-term groundwater quality impacts for new or expanding landfill sites is required under O.Reg. 232/98 (MOE, 1998a) to demonstrate that the proposed design will meet the requirements of MOECC Guideline B-7 (MOE, 1994b).

The Reasonable Use Guideline B-7 (MOE, 1994b) establishes a quantitative benchmark for protecting off-Site groundwater quality for drinking water purposes. The Reasonable Use Guideline makes the following statement regarding groundwater impact at the landfill property boundary:

> *"In the case of drinking water, the quality must not be degraded by an amount in excess of 50% of the difference between background and the Ontario Drinking Water Objectives for non-health related parameters and in excess of 25% of the difference between background and the Ontario Drinking Water Objectives for health related parameters. Background is considered to be the quality of the groundwater prior to any man-made contamination."*

In terms of any engineered facilities the *Landfill Standards: A Guideline on the Regulatory and Approval Requirements for New or Expanding Landfilling Sites* (Landfill Standards) (MOE, 1998b, revised January 2012), a document which provides help in understanding O.Reg. 232/98, makes the following statement regarding the basis for evaluation of the acceptability of proposed engineered facilities at landfills:

> *"An engineered facility which is to be constructed at a landfilling site for purposes of controlling leachate, groundwater, surface water or landfill gas should be designed such that: the service life of the engineered facility exceeds the period of time during which contaminants may be generated by the site and need to be controlled by the engineered facility to prevent an unacceptable impact; or the engineered facility can be replaced, or an alternative engineered facility can be constructed, as necessary to enable the combined service lives of the engineered facilities to exceed the period of time during which contaminants may be generated by the site and need to be controlled by the engineered facility to prevent an unacceptable impact."*

12.3.2 Geological/Hydrogeological Conditions Modelled Beneath the Landfill

The geological/hydrogeological conditions modelled are based on the stratigraphic Section E-E' shown on Figure 3-14. As described in Section 10.8, the landfill component of the CRRRC will be surrounded by a constructed hydraulic barrier consisting of a geosynthetic clay liner (GCL) keyed into the silty clay which will cut off the horizontal flow to the surficial silty sand and perimeter berm fill. While the silty layer does not convey a substantial amount of water, it was conservatively used to represent the groundwater resource that is the most susceptible to landfill leachate impacts.

For the purpose of the contaminant transport modelling, Section E-E' was simplified as shown on Figure 12-14 with two distinct silty clay layers of uniform thickness separated by a 0.3 metre silty layer. The depth of the base of the landfill varies from 1.5 metres to 2.5 metres below the original ground surface. As a result of the difference in base elevation, in some areas below the landfill there will be pockets of the surficial silty sand. The silty sand below the landfill will be cut-off from the surrounding surficial silty sand with a GCL hydraulic barrier as described in Section 10.8. To be conservative, the thickness of the surficial silty sand was taken to be 0.5 metres everywhere below the landfill. For the purposes of the contaminant transport model, the surficial silty sand and upper silty clay were modelled as one layer (with a weighted hydraulic conductivity as discussed later). The silty layer was modelled as a horizontal "sink" at the top of the lower silty clay. During operation of the landfill the average thickness of the silty clay deposits below the landfill are 3.3 metres and 23.3 metres for the silty clay above the silty layer and below the silty layer, respectively. The top 3 metres of the glacial till deposit (assumed mixing zone of landfill contaminants within the glacial till deposit) underlies the silty clay in the conditions modelled.

As discussed in Section 11.3, the silty clay beneath the landfill will settle over time. The amount of settlement depends on the length of loading time as well as the thickness of the waste in the landfill. An average landfill waste thickness of 12 metres was used (based on a volume of 10.1 million m^3 and a footprint area of 84 hectares). The elevations of the base of the landfill and the silty layer were adjusted over time using the upper bound predicted settlement for the average waste thickness as shown on Figure 12-14. The following assumptions were made for the model related to settlement:

- The surficial silty sand below the landfill will be an average of 0.5 metres thick;
- The silty layer will remain 0.3 metres thick;
- The top of the glacial till will remain at the same elevation; and,
- The average thickness of the upper silty clay below the landfill after 100 years of settlement was conservatively used to represent the thickness of the upper silty clay in the model from year 0.

The soil types, layer thicknesses and water levels shown on Figure 12-14 are representative of the conditions throughout the proposed landfill area.

Modelling input values for hydraulic conductivity (K), porosity (n), dry density and fraction organic carbon (foc) content of each soil layer are presented on Figure 12-14. The vertical hydraulic conductivity values shown for the surficial silty sand and glacial till were conservatively assumed to be equal to the geometric mean horizontal hydraulic conductivity determined from in-situ rising head tests (refer to Table 7-3). The results of the permeability testing completed on a sample from the upper silty clay (refer to Table 7-2) was used to represent the existing hydraulic conductivity for the upper silty clay. The average results of the permeability tests completed on two samples from the lower silty clay (Table 7-2) were used to represent the existing hydraulic conductivity of the lower silty clay. To account for the compression of the silty clay layers, the hydraulic conductivities were decreased by an order of magnitude considering settlement at 50 years from the start of filling. For the contaminant model, a weighted hydraulic conductivity of the surficial silty sand and upper silty clay were used for the upper silty clay layer. The horizontal hydraulic gradient in the silty layer and the glacial till was taken as 0.0009 (slightly high than interpreted from the groundwater data for the silty layer).

The average porosity (n) of 0.54 for the silty clay was calculated using the final void ratios (e) measured on oedometer test samples from boreholes completed south of the Simpson Drain (i.e., in the area of the landfill). The formula used to calculate the porosity is as follows:

$$n = e/(1 + e)$$

The porosity of the glacial till was assumed as a typical value of 0.35.

The fraction organic carbon content of the silty clay was calculated to be 0.145%, which is the average of two fraction organic carbon analyses completed on a sample obtained from 2.1 to 2.7 metres below ground from borehole 12-3-3. Fraction organic carbon was also measured in the lower silty clay at 0.40% and 0.36% at borehole 12-1-3 and borehole BH12-02-3, respectively. To be conservative, the lower fraction organic carbon value of 0.145% was applied to both the upper and lower silty clay.

Based on groundwater level monitoring carried out, the primary groundwater flow path within the silty layer is interpreted to be consistently to the east. A horizontal hydraulic gradient of 0.0009 was used for the silty layer. The contaminant dispersivity for this flow path was taken as 0.3 metres. The distance from the downgradient (east) side of the landfill to the east property boundary is about 125 metres.

12.3.3 Landfill Modelling Approach

The contaminant transport modelling for the proposed landfill was carried out using POLLUTE (Rowe, et al., 1994). POLLUTE is a one-dimensional, analytical contaminant transport model, which can account for contaminant migration from a landfill situated on a multi-layered soil deposit. The model predicts concentrations in the aquifer unit at the down-gradient edge of a landfill.

The contaminant transport processes accounted for by the model include: molecular diffusion, mechanical dispersion, advection, adsorption onto soil solids and bio-chemical decay in the landfill and underlying soil layers. For the hydrogeological conditions at the CRRRC landfill, advection/dispersion and bio-chemical decay are the primary transport processes in the sandy silt and till layers, whereas diffusion is the primary transport process in the upper and lower silty clay layers, with the advection, adsorption and bio-chemical decay playing lesser roles.

The boundary condition used for contaminant source concentrations in the landfill is that of a depleting contaminant concentration with time from an initial representative peak value that occurs at the closure of the landfill component. The depletion in concentration once the area being landfilled is completed is due to bio-chemical decay and wash-out by moisture infiltration/percolation through the waste mass. The rate of concentration decrease with time is a function of the bio-chemical decay half-life, the representative peak leachate concentration, the contaminant mass inventory in the landfill and the moisture infiltration rate through the landfill cover. POLLUTE does not account for volatilization of VOCs and, as such, is conservative in this respect.

The model and approach used to evaluate groundwater quality impacts was extended for 1,000 years beyond the time that waste filling was assumed to commence.

12.3.4 Landfill Leachate Generation Rates

The long-term (steady-state) leachate generation rate for the landfill was calculated using the Hydrologic Evaluation of Landfill Performance (HELP) Model, assuming a landfill cover system consisting of a 0.6 metre thick layer of imported sandy silt to silty sand (or similar material) overlain by a 0.15 metre thick layer of soil capable of sustaining vegetation. The average annual infiltration rate through daily/intermediate cover was also evaluated using the HELP Model. The HELP model is a quasi-two dimensional hydrologic model designed by the U.S. Army Corps of Engineers for the U.S. EPA and is widely accepted for prediction of landfill surface run-off, evapotranspiration, leachate collection and leakage. The HELP model method of solution, assumptions and limitations can be found in the model documentation (Schroeder et al., 1994).

The climatological data used in the HELP Model were synthetically generated using mean monthly precipitation, wind speed and temperature data for the Ottawa MacDonald Cartier International Airport (Environment Canada, 2010) and precipitation / temperature variability coefficients for Syracuse, New York (Note: Syracuse data are included in the HELP Model data base). Values used for the key input parameters for the soil cover and refuse are summarized in Table 12-4.

a) Layer Data

Table 12-4: Input Parameters for Modelling Leachate Generation Rate Using HELP Model

Layer	Thickness (metres)	Total Porosity (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
Vegetated Soil	0.15	0.437*	1.7 x 10^{-3*}
Cover Soil	0.6	0.437*	1.7 x 10^{-3*}
Refuse	12	0.168*	1.0 x 10^{-3}*

Note: * HELP Model default value for material type

b) General Data

Average Annual Total Precipitation = 993.5 mm/year (based on 1971 to 2000 Climate Normals for the MacDonald Cartier Ottawa International Airport)

Surface Slope of Final Cover = 5%

SCS Runoff Curve Number = 56 (based on sandy silt soil with a fair stand of grass)

Evaporative Zone Depth for Final Cover = 50 cm

Leaf Area Index = 2.0

The long-term (steady-state) average annual infiltration rate through daily/intermediate cover as predicted by the HELP model is 289.5 millimetres per year. Assuming a landfill final cover system comprised of silty sand or sandy silt soil final cover, the resulting long-term (steady-state) average leachate generation rate is 269.5 millimetres per year.

12.3.5 Landfill Key Contaminants and Associated Transport Parameters

In accordance with O.Reg. 232/98 (MOE, 1998a), the key leachate contaminants modelled for municipal solid waste to address long-term compliance with MOECC Guideline B-7 (MOE, 1994b) are: benzene, cadmium, chloride, lead, 1,4-dichlorobenzene, dichloromethane, toluene and vinyl chloride. Although it is not proposed that the CRRRC receive residential waste[1], and much of the organic component of the waste/residual stream should be able to be diverted from landfill (thus reducing some parameter concentrations in the leachate), utilizing these leachate contaminants and their proposed source concentrations is a conservative approach to impact assessment. In addition to the key leachate contaminants associated with municipal solid waste, boron was also used in consultation with the MOECC based on boron being a typical leachate indicator for IC&I waste.

Modelling input parameters required for each key landfill leachate contaminant are the representative peak leachate source concentration, mass inventory in the landfill (i.e., contaminant mass as a proportion of total mass of waste), half-life in the groundwater flow system, soil diffusion coefficient and soil adsorption coefficient. As shown on Table 12-5, the input for representative peak leachate source concentration, mass inventory and half-life are conservatively the same as the values recommended in Table 1 of O.Reg. 232/98, which are based on historical leachate quality monitoring for a number of municipal solid waste landfill sites in Ontario. Again, as

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[1] Recyclables from multi-residential developments will be received at the CRRRC if available.

the CRRRC will not receive municipal solid waste and will be incorporating a significant organics processing operation, use of these default values likely overstates actual source concentrations. The peak leachate source concentration for the IC&I waste key contaminant, boron, was obtained from peak leachate concentrations in a landfill accepting similar waste to the CRRRC landfill, while the mass inventory and half-life values were assumed based on literature values. The soil adsorption coefficients for the organic contaminants were calculated using literature values for soil/organic carbon partition coefficient (i.e., K_{oc}) and a laboratory fraction organic carbon (foc) for the upper silty clay deposit, as outlined in Table 12-5. Soil adsorption coefficients for the metals (i.e., boron, cadmium and lead) were assumed based on literature values for similar soil types.

The source concentrations of the key contaminants were generally increased to the representative peak leachate source concentration during the time that the landfill is being filled and then allowed to deplete. The background groundwater quality of the silty layer was obtained for all parameters from the median of two groundwater sampling events from seven monitoring wells on the Site.

Table 12-5: Key Contaminants and Associated Soil Transport Parameters – Silty Layer

Key Contaminant	Representative Peak Leachate Source Concentration [1] (mg/L)	Mass Proportion of Total (Wet) Mass of Waste [1] (mg/kg)	Half-Life (years)	Soil Adsorption Coefficient (mL/g)	Soil Diffusion Coefficient [6] (m^2/year)	Background Concentration [8] (mg/L)	Ontario Drinking Water Quality Objective (mg/L)
Chloride	1,500	1,800	Infinite[1]	0	0.019	890	250 (A)
Boron	17 [2]	20.4 [3]	Infinite	1 [7]	0.019	0.225	5 (H)
Cadmium	0.05	0.035	Infinite[1]	35 [5]	0.019	0.00005	0.005 (H)
Lead	0.6	0.42	Infinite[1]	1000 [5]	0.019	0.00025	0.01 (H)
Benzene	0.02	0.014	25[1]	1.250[4]	0.019	0.0001	0.005 (H)
1,4-Dichlorobenzene	0.01	0.007	50[1]	4.06[4]	0.019	0.00015	0.005 (H)
Dichloromethane	3.3	2.3	10[1]	0.5[4]	0.019	0.0005	0.05 (H)
Toluene	1	0.7	15[1]	2.828[4]	0.019	0.0003	0.024 (A)
Vinyl Chloride	0.055	0.039	25[1]	0.544[4]	0.019	0.0002	0.002 (H)

Notes:

[1] Values taken from Table 1 of O.Reg. 232/98 for municipal solid waste, except where stated.

[2] Based on maximum boron concentration in leachate recorded from a landfill that receives a similar waste type to the CRRRC landfill.

[3] Mass proportion directly related to chloride mass proportion divided by the chloride peak and multiplied by the peak of the parameter of interest (Rowe et. al., 1994a).

[4] Based on a fraction organic carbon content (foc) of 0.145% for the upper silty clay deposit and soil/organic carbon partition coefficients (Koc) of 862 mL/g for benzene, 345 mL/g for dichloromethane, 375 mL/g for vinyl chloride, 1,950 mL/g for toluene and 2,800 mL/g for 1,4-dichlorobenzene (Ref. Rowe et.al., 1994a).

[5] Rowe et.al., 1994a

[6] Assumed diffusion coefficient based on literature values for similar soils.

[7] Battelle Memorial Institute, 1989.

[8] Background based on median of groundwater concentrations in the silty layer within the clay deposit measured between January and July 2013.

(A) Denotes aesthetic drinking water objective

(H) Denotes health related drinking water objective

12.3.6 Service Life of Landfill Leachate Control System Components

The service life of the granular drainage layer is defined as the time at which the pores between the stone particles become clogged with bacteria and chemical precipitates (mainly calcium carbonate) to the extent that leachate can no longer be effectively collected, resulting in the development of a leachate mound above the base of the landfill.

As described in Section 10.8, a granular drainage blanket will be constructed below the waste and, together with a piping system, will convey the leachate to sumps where it will be removed from the landfill for treatment. It is proposed that the design for the granular drainage layer meet the requirements of Schedule 1 provided in O.Reg. 232/98. Based on this regulation, the service life of a leachate collection system that meets the requirements in Schedule 1 can be taken as 100 years, starting from either year 10 or the mid-point of the landfilling period, whichever is less.

The proposed sideslope liner system at the CRRRC landfill incorporates a GCL hydraulic barrier to prevent leachate from entering the surficial silty sand/weathered crust zone or overlying perimeter berm fill. This role of the GCL requires that its hydraulic conductivity remain very low, at values less than 3×10^{-10} m/s.

For a GCL that is properly installed in accordance with the manufacturer's procedures, the primary mechanisms that may limit its service life as a hydraulic barrier in a waste containment facility are cation exchange reactions and clay mineral breakdown on exposure to leachate. No natural weathering/breakdown of the bentonite clay component is expected as bentonite is already at the end-point of the soil weathering cycle.

Cation exchange reactions involve replacement of monovalent sodium ions adsorbed on the negatively charged bentonite clay particle surfaces with divalent calcium ions from the water / leachate that is in contact with the GCL. This in turn produces a more flocculated orientation of the clay minerals with larger interstitial pore spaces. The larger pore spaces increase the hydraulic conductivity of the GCL. With little or no surcharge on the GCL (e.g., <10 kPa), the increase in hydraulic conductivity can be more than one order of magnitude (Bishop, 1995). Egloffstein (2001) indicates that a minimum effective stress of 15 kPa (and preferably 20 kPa) is required for self-healing of the GCL clay fabric against cation exchange reactions. For the proposed CRRRC landfill, the estimated effective confining stresses acting on the sideslope GCL are larger than 20 kPa, with values of approximately 75 kPa at mid-slope and 105 kPa at the toe of slope. Therefore, based on the above results, self-healing of the sideslope GCL is expected to limit the potential increase in hydraulic conductivity such that the GCL will continue to perform adequately as a hydraulic barrier.

The mechanism of breakdown of the bentonite clay mineral on exposure to leachate is relevant only for high pH leachate (e.g., pH=12) and involves dissolution of silicon and aluminum, which are the primary elements forming the bentonite clay mineral structure. For the CRRRC landfill, the leachate pH is expected to be in the 5.2 to 8.0 range. At this pH range, silicon and aluminum solubility is very low and dissolution from the bentonite clay is expected to be insignificant.

In addition, the design of the base grades and leachate collection system for the proposed CRRRC landfill will direct the leachate away from the perimeter of the landfill and towards the manholes in the central portion for removal to treatment. As such, the leachate will not remain in sustained contact with the perimeter GCL.

The service life of the sideslope GCL as a hydraulic barrier around the perimeter of the proposed CRRRC landfill is expected to be comparable to the 1,000 year service life reported for a compacted clay liner in O. Reg. 232/98.

12.3.7 Landfill Leachate Mound Height

The average leachate head above the base of the landfill, which is underlain by the thick low permeability clay deposit that serves as a natural liner, was assumed to remain constant at 0.3 metres up to the point at which the leachate drainage layer fails. After leachate drainage layer failure, a leachate mound then begins to develop in these areas.

The average leachate mound height relative to perimeter ground surface elevation (h) after failure of the leachate collection system was calculated iteratively using the Harr Equation. An example is provided below.

$$\overline{h} = 0.393 x L x \sqrt{\frac{q_{net}}{k_{waste}}}$$

Where:

$\overline{h}$ = average leachate mound height (m) relative to perimeter ground surface elevation

L = minimum dimension of the landfill (perpendicular to the direction of groundwater flow)

= 350 metres

k_{waste} = hydraulic conductivity of the waste at the bottom of the landfill

= 315 m/year

q_{net} = portion of the cover infiltration rate (q_{inf}) contributing to the development of a leachate mound

= $q_{inf} – v_a$

q_{inf} = 0.2695 m/year

The Darcy flux (v_a) after failure of the leachate collection system was obtained from the 3-D groundwater flow modelling discussed in Section 12.2 of this report.

The calculation considers leachate drainage by seepage into the underlying soil layers and by outward seepage along the toe of the landfill at the perimeter berm (where the mound is higher than perimeter berm elevation).

The calculated average mound height was 4.0 metres (elevation 83.9 m ASL) above the top of the perimeter berm.

12.3.8 Vertical Leakage Rates

Table 12-6: Average Darcy Fluxes

Time (years)	Average Leachate Head on Silty Clay	Average Vertical Darcy Flux Between the Landfill and Upper Silty Clay, Va_1	Average Horizontal Darcy Flux in the Silty Layer [1]	Average Vertical Darcy Flux Through Lower Silty Clay, Va_2	Average Horizontal Darcy Flux in Glacial Till, Vb
0 – 20	0.3 metres	3×10^{-3} m/year ↑	0 m/year [4]	1.3×10^{-4} m/year ↓	0.11 m/year
20 – 30	0.3 metres	3×10^{-3} m/year ↑	0 m/year [4]	1.3×10^{-4} m/year ↓	0.11 m/year
30 – 70	0.3 metres	1.5×10^{-2} m/year ↑	0 m/year [4]	1.4×10^{-4} m/year ↓	0.12 m/year
70 – 100	0.3 metres	2×10^{-2} m/year ↑	0 m/year [4]	1.5×10^{-4} m/year ↓	0.115 m/year
100 – 104	3.7 metres	1.5×10^{-2} m/year ↑	0 m/year [4]	6×10^{-4} m/year ↓	0.28 m/year
104 – 108	7.0 metres	9×10^{-3} m/year ↑	0 m/year [4]	1×10^{-3} m/year ↓	0.45 m/year
108 – 112	10.4 metres	4×10^{-3} m/year ↑	0 m/year [4]	1.5×10^{-3} m/year ↓	0.61 m/year
112 – 1,112	13.7 metres	1.93×10^{-3} m/year ↓ [3]	0.2 m/year [2]	2×10^{-3} m/year ↓ [2]	0.78 m/year

Notes:

[1] The horizontal Darcy flux was set to 0 m/year while the average vertical Darcy flux through the upper silty clay is upwards.

[2] Predicted from groundwater flow modelling discussed in Section 12.2 of this report.

[3] Calculated by continuity of flow with the average rate of removal through the 0.3 metre silty layer and the average vertical Darcy Flux through the lower silty clay over the 1,160 metre length of the landfill in the direction of groundwater flow.

[4] Horizontal Darcy Flux is not applicable due to upward flux between the landfill and upper silty clay and is set to 0 m/year for modelling purposes.

The hydraulic effects of the consolidation process on excess porewater pressure development were not represented. As a result, the vertical fluxes provided in the Table 12-6 above present a conservative approximation.

12.3.9 Results of Contaminant Transport Modelling

The results of the hydrogeologic/contaminant transport modelling are described below. An example of the POLLUTE output file is provided in Appendix R. Figure 12-15 shows the predicted key leachate contaminant parameter concentration variations with time at the downgradient edge of the landfill.

The results of the modelling for all key landfill leachate contaminant parameters are summarized in Table 12-7 and indicate essentially zero predicted impact on the silty layer at the downgradient edge of the landfill. For all parameters, the Reasonable Use Criteria for the silty layer (indicated in Table 12-7) are satisfied, noting that chloride naturally exceeds the ODWQS for chloride.

The negligible predicted impact for the organic contaminants (i.e., benzene, 1,4-dichlorobenzene, dichloromethane, toluene and vinyl chloride) on the silty layer relates primarily to biodegradation, mass removal through leachate collection and the very slow (diffusion controlled) rate of transport into the underlying silty clay deposit.

For boron, chloride, lead and cadmium, the negligible impact is due to the same processes noted above except that biodegradation does not apply for these parameters.

Table 12-7: Predicted Concentrations of Key Leachate Contaminants in the Silty Layer from the CRRRC Landfill

Contaminant	Background Median Concentration in Silty Layer (mg/L)[1]	Ontario Drinking Water Quality Standards [2] (mg/L)	Reasonable Use Criteria [3] (mg/L)	Predicted Peak Concentration* (mg/L)	Predicted Peak Plus Background Concentration* (mg/L)	Time of Peak Concentration** (years)
Boron	0.225	5 (H)	1.42	0.166	0.39	272
Chloride	890	250 (A)	N/A	16	906	272
Cadmium	0.00005	0.005 (H)	0.001	0.00004	0.00009	>1000
Lead	0.00025	0.01 (H)	0.003	0	0.00025	>1000
Benzene	0.0001	0.005 (H)	0.001	0	0.0001	162
1,4-Dichlorobenzene	0.00015	0.005 (H)	0.001	0	0.00015	272
Dichloromethane	0.0005	0.05 (H)	0.01	0	0.0005	122
Toluene	0.0003	0.024 (A)	0.01	0	0.0003	172
Vinyl Chloride	0.0002	0.002 (H)	0.0007	0	0.0002	142

Notes:

(H) Health-related objective.

(A) Aesthetic objective.

N/A Reasonable Use concentration cannot be calculated since the background concentration exceeds the ODWQS.

[1] Based on the median results of groundwater samples taken from groundwater monitoring wells BH12-1-5B, BH12-2-5B, BH12-3-5B, BH12-4-5B, BH13-5-5, BH13-6-5B and BH13-7-4-2 between January and July 2013.

[2] Ref. Ontario Drinking Water Quality Standards (MOE, 2003).

[3] Reasonable Use Criteria = Background Concentration + X (ODWQS Criteria - Background Concentration):
where X = 0.25 for health related drinking water parameters
= 0.50 for aesthetic related drinking water parameters

* Based on a 1,000 year contaminant transport modelling time frame, has been added to the background concentration.

** Relative to year 10 of the landfilling period.

12.3.10 Landfill Contaminating Lifespan

The contaminating lifespan for the proposed landfill component of the CRRRC corresponds to the time at which contaminant concentrations in the landfill have decreased to the extent that the landfill would no longer require the engineered system components to protect off-Site groundwater quality, but can rely on the natural containment provided by the silty clay deposit to do so.

To ensure protection of off-Site groundwater and compliance with MOECC requirements, the design of the proposed CRRRC landfill component relies primarily on: 1) the perimeter GCL hydraulic barrier and operation of the leachate collection system for protection of groundwater quality within the on-Site surficial silty sand layer, and 2) the natural silty clay deposit augmented by the leachate collection system for protection of the groundwater within the on-Site silty layer located several metres below the base of the landfill.

In addition to the above modelling, sensitivity analyses were carried out to assess a number of scenarios related to the potential impact to the subsurface silty layer: all contaminants going to the silty layer; settlement of the underlying clay deposit; and early failure of the leachate collection system beneath the landfill. The sensitivity analyses are reported in Section 12.3.10.1. Under these scenarios, the Site is still predicted to remain in compliance with the Reasonable Use Criteria (MOE, 1994b). All of these analyses show that should the leachate collection system fail after 20 years beyond the mid-point of landfilling or 20 years beyond year 10 after filling commenced, the thickness and low hydraulic conductivity of the natural silty clay deposit would provide the required off-Site groundwater protection. Nevertheless, the leachate collection system while functioning still helps ensure the protection of groundwater within the surficial silty sand layer by reducing leachate mounding on the GCL barrier. Monitoring of leachate levels within the landfill will be ongoing during operations and post-closure, and determine the need for contingency measures to prevent seeps and breakouts that could potentially impact surface water.

As described in Section 10.8, the design of the leachate collection system is such that leachate movement is towards sumps in the centre portion of the landfill, away from the perimeter of the landfill. The consolidation of the clay under the weight of the landfill will enhance this flow even more over time. As such, a significant mound of leachate will have to build up within the landfill before there is a leachate head against the perimeter of the landfill and the GCL, which would be the condition required for leachate to potentially diffuse through the GCL hydraulic barrier and into the surficial silty sand layer. Should leachate diffusion through the GCL barrier occur it would be detected by the monitoring program and there are a number of contingency measures available to ensure protection of off-Site groundwater in the surficial silty sand layer in such circumstances as described in Section 14.1.

In conclusion, the assumed service lives of both the leachate collection system (100 years) and the GCL (greater than 1,000 years) exceed the contaminating lifespan of the landfill.

12.3.10.1 Sensitivity Analyses

A sensitivity analysis involves changing a particular parameter to determine what effect it has on contaminant impact. Within the POLLUTE model and solutions, numerous input values are required. These input values were based on the Landfill Standards' recommendations, site specific data and literature values. In all instances where multiple values were available, best and typically conservative estimates were used.

In general, when values are provided by the Landfill Standards these values are used unless there are Site-specific data that would be more appropriate. Sensitivity analysis is not generally conducted on MOECC-provided input parameters. Some parameters, whether from literature or site-specific data, have a limited range or are known to have a limited effect on the output of results from the various models and solutions. However, it is useful to conduct sensitivity analyses on some parameters that may have a wider range and/or are known to have an impact on model results. The sensitivity study was undertaken using the parameter boron. Boron is the most sensitive parameter for the Site because it has no decay, has the smallest adsorption coefficient and is not naturally occurring in high concentrations. The sensitivity analyses conducted for the proposed landfill component of the CRRRC are discussed below.

12.3.10.2 All Contaminants Going to the Silty Layer

The contaminant transport model considers that some of the leachate will continue downward through the lower silty clay towards the glacial till. This reduces somewhat the concentration of the key contaminant in the silty layer. A sensitivity analysis was run in which it was assumed that the silty layer was able to take all of the predicted downward groundwater flow in the upper silty clay below the landfill. For this scenario, the concentration of boron at the downgradient edge of the landfill was 0.7 milligrams per Litre (mg/L) compared to 0.16 mg/L when some groundwater flow into the lower silty clay was modelled. The peak boron concentration of 0.7 mg/L added to the background boron concentration is 0.9 mg/L, roughly 60% of the Reasonable Use Criteria of 1.4 mg/L. Therefore, the sensitivity analysis results indicate that even with all of the groundwater flow going to the silty layer (which is physically not possible), the Site is still predicted to remain in compliance with the Reasonable Use Criteria.

12.3.10.3 Settlement

The geotechnical analysis at the Site indicates that significant clay consolidation can be expected beneath the landfill, with the largest settlement at the centre of the landfill. The contaminant transport model accounted for this predicted settlement, which also results in an increase in flux into the landfill. A sensitivity analysis was run on contaminant impact to the silty layer assuming no settlement beneath the landfill. The clay was not consolidated and the hydraulic conductivity of the silty clay was not reduced by an order of magnitude. In addition, this sensitivity analysis was combined with the conservative assumption analyzed in the previous section with all of the flow going to the silty layer. Due to the increased clay thickness and hydraulic conductivity, it was also necessary to re-calculate the Darcy fluxes. The peak concentration of boron in the silty layer at the downgradient edge of the landfill is predicted to be 0.45 mg/L compared to 0.16 mg/L when settlement was modelled. The peak boron concentration of 0.45 mg/L added to the background boron concentration is 0.67 mg/L, less than half of the Reasonable Use Criteria of 1.4 mg/L. The sensitivity results indicate that without the settlement and the associated increased flux into the landfill, the Site is still expected to remain in compliance with the Reasonable Use Criteria.

12.3.10.4 Early Failure of the Leachate Collection System Beneath the Waste

The leachate collection system beneath the waste has been designed with mechanisms to accommodate the large settlements expected at the Site. The design of the leachate collection system will have slip couplings on the leachate collection pipe joints to accommodate pipe movement when settlement occurs. Also, the sumps are located in areas of the greatest thickness of waste, which is where the greatest settlement is predicted to occur. As such, the base slopes of the granular blanket and the pipes will increase over time towards the sumps. Nevertheless, the implications of a failure of the leachate collection system beneath the waste sooner than 100 years from the start of the model was considered. The sensitivity study was again undertaken using the parameter boron.

Results of the sensitivity analyses are provided in Table 12-8 as follows:

Table 12-8: Early Failure of Leachate Collection System

Time of Leachate Collection System Failure (years)	Predicted Peak Concentration of Boron (mg/L)	Predicted Peak Concentration of Boron with Background Concentration[1] (mg/L)	Reasonable Use Criteria[2] (mg/L)
100	0.166	0.39	1.42
30	0.777	1.002	1.42
20	0.865	1.090	1.42

Notes:

[1] Background concentration based on the median results of groundwater samples taken from groundwater monitoring wells BH12-1-5B, BH12-2-5B, BH12-3-5B, BH12-4-5B, BH13-5-5, BH13-6-5B and BH13-7-4-2 (completed in the silty layer) between January and July 2013.

[2] Reasonable Use Criteria = Background Concentration + X (ODWQS Criteria - Background Concentration):
where X = 0.25 for health-related drinking water parameters
= 0.50 for aesthetic-related drinking water parameters

The expected boron background concentration in the silty layer is 0.225 mg/L. When the leachate collection system functions for 100 years, the predicted peak concentration of boron in the silty layer (after addition of the background concentration) is 0.39 mg/L. Even if it is assumed that the leachate collection system fails after 20 years, the impact to the silty layer is 1.09 mg/L at the downgradient edge of the landfill footprint, less than the Reasonable Use Criteria of 1.42 mg/L. This sensitivity analysis demonstrates that even with significantly earlier failure of the leachate collection system, the Site is still expected to remain in compliance with the Reasonable Use Criteria.

12.4 Summary

The following conclusions can be derived from the modelling analyses described above.

- Results of the 3-D numerical groundwater flow model show that groundwater levels (in the surficial silty sand and other strata) will not be affected beyond the property boundary;
- The results of the steady state groundwater model show that, post-failure of the leachate collection system, between 94% and 99% of the leachate generated at the Site will be collected in on-Site ditches, and will not leave the Site. Of the groundwater that seeps past the property boundaries, approximately 0.10% to 0.14% will be through the silty layer, while between 0.8% and 4.9% will be through the silty clay towards the glacial till/bedrock contact zone;

- The results of the hydrogeologic/contaminant transport modelling indicate essentially zero predicted impact on the silty layer at the downgradient edge of the landfill. For all parameters, the Reasonable Use Criteria for the silty layer are satisfied, noting that chloride naturally exceeds the ODWQS;
- The results of the hydrogeologic/contaminant transport modelling indicate that the contaminating lifespan of the landfill is 20 years from year 10 after filling commences (i.e. at closure of the landfill based on a 30 year planning period), which is less than the service lives of both the leachate collection system (100 years) and the GCL (greater than 1,000 years); and
- The groundwater analyses show that even if there was an early failure of the leachate collection system, then the thickness and low hydraulic conductivity of the natural silty clay deposit would provide the required off-Site groundwater protection. For this reason, as described in section 11.4, the effects of small-scale surface or subsurface displacements from local fault movement, in the very unlikely event that it occurs during the contaminating lifespan of the landfill, are inconsequential for engineering design or performance of the landfill.

13.0 GROUNDWATER AND SURFACE WATER MONITORING PROGRAMS AND TRIGGER MECHANISMS

13.1 Objectives of Monitoring Program

The objectives of the groundwater, leachate and surface water program are to monitor background water quality, leachate quality and water quality hydraulically downgradient of the landfill and other on-Site facilities. The proposed Site monitoring programs have been developed to adhere to the *Landfill Standards* (MOE, 1998b, revised January 2012).

13.2 Groundwater Monitoring Program

13.2.1 Monitoring Locations

The proposed groundwater monitoring program for the Site is described in the sections below. The groundwater monitoring program has been split into a monitoring program for the processing and treatment facilities north of the Simpson Drain and a monitoring program for the landfill south of the Simpson Drain as summarized in Table 13-1 and Table 13-2, respectively. The groundwater monitoring programs proposed for the CRRRC include maintaining the existing monitoring wells (where possible) and adding additional monitoring well locations to ensure adequate coverage of the Site is attained. The existing and proposed monitoring locations are shown on Figure 13-1.

The groundwater monitoring wells at locations 13-9 and 13-10 are proposed to be converted to flushmount groundwater monitoring wells as they are in high traffic areas. A new multi-level monitoring well (P1-9) is proposed to be installed at the eastern (exterior) toe of the landfill perimeter berm to replace monitoring well 12-1 (not shown on Figure 13-1), which will have to be decommissioned to allow construction of the stormwater management pond. A new multi-level monitoring well (V) is proposed to be installed south of the leachate treatment equalization pond or tank(s) to replace monitoring well 12-4 (not shown on Figure 13-1), which will have to be decommissioned to allow construction of the leachate treatment equalization pond. Borehole P1-9 will have monitoring wells screening the surficial sand/weathered clay, the silty layer in the silty clay deposit (referred to as the silty layer), glacial till and upper bedrock. Groundwater will also be sampled from four manholes (MH1, MH2, MH3 and MH4) located at the low points of the LDSCS that will be positioned below the perimeter berm, within the surficial silty sand layer. The LDSCS will be the first line of monitoring to show changes in groundwater quality if the GCL hydraulic barrier is not performing as expected. In addition to the LDSCS, 16 new boreholes are proposed to be drilled along the eastern toe of the landfill perimeter berm (P1-1, P1-2, P1-3, P1-4, P1-5, P1-6, P1-7, P1-8, P1-10, P2-1, P2-2, P2-3, P2-4, P2-5, P2-6, P2-7) and will have monitoring wells completed in the surficial silty sand/weathered clay and the silty layer at each location. These sentinel monitoring wells are immediately downgradient of the LDSCS, but far enough from the property boundary (approximately 60 metres) to allow for additional monitoring wells to be installed at the property boundary should impacts be observed in the sentinel monitoring wells. The LDSCS and the 16 sentinel monitoring wells are on the exterior side of the landfill closest to a property boundary for approximately the first 10 years of landfill operations. Based on groundwater quality data and groundwater elevations collected during landfill operations, the need for progressive installation of additional groundwater monitoring wells around the external side of other phases of the landfill will be determined as landfilling progresses. The P1 series of wells will be installed one year prior to the start of operation of Phase 1, while the P2 series of wells will be installed one year prior to the start of operation of Phase 2. New boreholes M and N are proposed to be drilled between the north side of the landfill perimeter berm toe and the Simpson Drain.

New monitoring wells completed in the surficial silty sand/weathered clay and the silty layer are proposed for the process and treatment facility area north of the Simpson Drain. Monitoring wells O, P, Q, R, S, T and U are proposed for areas adjacent to facilities north of the Simpson Drain as described in Table 13-1.

Table 13-1: Proposed Groundwater Monitoring Program for the Process and Treatment Facilities

Activity	Geological Unit	Monitoring Well	Description
Off-Site Activities	Surficial Silty Sand/Weathered Clay	13-5-6	Observe potential groundwater impacts from off-Site activities
		13-12-2	
	Silty Layer in Silty Clay	13-5-5	
		13-12-3	
	Glacial Till Deposit	13-5-4A	
	Upper Bedrock	13-5-3	
C&D, MRF	Surficial Silty Sand/Weathered Clay	12-3-6	Downgradient Property Boundary
	Silty Layer in Silty Clay	12-3-5B	
	Glacial Till Deposit	12-3-4A	
	Upper Bedrock	12-3-3	
Leachate Treatment**	Surficial Silty Sand/Weathered Clay	V-B*	Leachate Treatment Equalization Pond or Tank(s)
		T-B	Leachate Treatment (Treated Effluent Ponds or Tanks) (upgradient)/ (Leachate Equalization Pond or Tank(s)) (downgradient)
		U-B	Sludge Dewatering/Leachate Treatment Equalization Pond or Tank(s)
		S-B	Leachate Treatment (Treated Effluent Ponds or Tanks) (downgradient)
	Silty Layer in Silty Clay	V-A*	Leachate Treatment Equalization Pond or Tank(s)
		T-A	Leachate Treatment (Treated Effluent Ponds or Tanks) (upgradient) / (Leachate Equalization Pond or Tank(s)) (downgradient)
		U-A	Sludge Dewatering/Leachate Treatment Equalization Pond or Tank(s)
		S-A	Leachate Treatment (Treated Effluent Ponds or Tanks)
Organics Processing Facility	Surficial Silty Sand/Weathered Clay	13-10-2	Organics Pre-Processing / Compost Processing and Storage Pad
		13-13-2	Downgradient Property Boundary – Organics Processing Facility
		P-B	Compost Processing and Storage Pad
		Q-B	Organics Processing Facility Area
	Silty Layer in Silty Clay	13-10-3	Organics Pre-Processing / Compost Processing and Storage Pad

Activity	Geological Unit	Monitoring Well	Description
		13-13-3	Downgradient Property Boundary – Organics Processing Facility
		P-A	Compost Processing and Storage Pad
		Q-A	Organics Processing Facility Area
Soil Treatment Area	Surficial Silty Sand/Weathered Clay	R-B	Soil Treatment Area
		O-B	
	Silty Layer in Silty Clay	R-A	
		O-A	

Notes: * Existing groundwater monitoring well series V replaces monitoring wells completed in the surficial silty sand and silty layer of monitoring well series 12-4, which is very close to the leachate treatment equalization pond or tank(s). It is intended that the full monitoring well series 12-4 (monitoring wells completed in the bedrock, glacial till, surficial silty sand and silty layer) will be decommissioned as per O.Reg. 903 (MOE, 2011). However, if during final design and construction it is determined that monitoring well series 12-4 can be kept, they will be. If the 12-4 monitoring wells completed in the surficial silty sand and silty clay do not have to be decommissioned, then they will be used in place of monitoring well series V.

** If tank(s) are used instead of ponds not all of these monitoring wells may be required.

The groundwater monitoring wells proposed for the landfill monitoring program are summarized in Table 13-2.

Table 13-2: Proposed Groundwater Monitoring Program for the Landfill

Geological Unit	Monitoring Well	Purpose
Surficial Silty Sand/Weathered Clay	12-2-6	Background Control Well
	13-6-6	Adjacent
	13-7-5	Background Conditions
	13-17-2	Downgradient Property Boundary - Compliance
	13-24-2	Adjacent
	13-25-2	Downgradient Property Boundary - Compliance
	M-B	Adjacent – Simpson Drain
	N-B	Adjacent – Simpson Drain
	MH1	LDSCS
	MH2	LDSCS
	MH3	LDSCS
	MH4	LDSCS
	P1-1B	Immediately Downgradient - Sentinel
	P1-2B	Immediately Downgradient - Sentinel
	P1-3B	Immediately Downgradient - Sentinel

Geological Unit	Monitoring Well	Purpose
	P1-4B	Immediately Downgradient - Sentinel
	P1-5B	Immediately Downgradient - Sentinel
	P1-6B	Immediately Downgradient - Sentinel
	P1-7B	Immediately Downgradient - Sentinel
	P1-8B	Immediately Downgradient - Sentinel
	P1-9D	Immediately Downgradient - Compliance
	P1-10B	Immediately Downgradient - Sentinel
	P2-1B	Immediately Downgradient - Sentinel
	P2-2B	Immediately Downgradient - Sentinel
	P2-3B	Immediately Downgradient - Sentinel
	P2-4B	Immediately Downgradient - Sentinel
	P2-5B	Immediately Downgradient - Sentinel
	P2-6B	Immediately Downgradient - Sentinel
	P2-7-B	Immediately Downgradient - Sentinel
Silty Layer in Silty Clay	12-2-5B	Background Control Well
	13-6-5B	Adjacent
	13-7-4-2	Background Conditions
	13-17-3	Downgradient Property Boundary - Compliance
	13-25-3	Downgradient Property Boundary - Compliance
	M-A	Adjacent – Simpson Drain
	N-A	Adjacent – Simpson Drain
	P1-1A	Immediately Downgradient - Sentinel
	P1-2A	Immediately Downgradient - Sentinel
	P1-3A	Immediately Downgradient - Sentinel

Geological Unit	Monitoring Well	Purpose
	P1-4A	Immediately Downgradient - Sentinel
	P1-5A	Immediately Downgradient - Sentinel
	P1-6A	Immediately Downgradient - Sentinel
	P1-7A	Immediately Downgradient - Sentinel
	P1-8A	Immediately Downgradient - Sentinel
	P1-9C	Immediately Downgradient - Compliance
	P1-10A	Immediately Downgradient - Sentinel
	P2-1A	Immediately Downgradient - Sentinel
	P2-2A	Immediately Downgradient - Sentinel
	P2-3A	Immediately Downgradient - Sentinel
	P2-4A	Immediately Downgradient - Sentinel
	P2-5A	Immediately Downgradient - Sentinel
	P2-6A	Immediately Downgradient - Sentinel
	P2-7A	Immediately Downgradient - Sentinel
Glacial Till Deposit	13-6-4A	Adjacent
	13-7-3	Background Conditions
	P1-9B	Immediately Downgradient - Compliance
Upper Bedrock	12-2-3	Background Control Well
	13-6-3	Adjacent
	13-7-2	Background Conditions
	P1-9A	Immediately Downgradient - Compliance

In addition to on-Site groundwater monitoring wells, water wells within 500 metres of the Site will be sampled, with consent from the owner, one time prior to starting operations at the facility.

Groundwater levels will be measured in the LDSCS manholes and all on-Site functional groundwater monitoring wells, including those not listed in groundwater quality monitoring program. If a monitoring well not included in the groundwater quality monitoring program is damaged or has to be removed because of Site development (such as monitoring wells 13-14, 13-15, 13-16, 13-19 and 13-20), it will be decommissioned in accordance with O.Reg 903 (MOE, 2011).

13.2.2 Monitoring Frequency

The on-Site groundwater quality monitoring sessions and groundwater level monitoring will be conducted during the spring, summer and fall of the year at monitoring wells and manholes, except as noted below, as recommended in the *Landfill Standards* (MOE, 1998b, revised January 2012). Groundwater levels will be measured in the LDSCS manholes on a quarterly basis. The groundwater quality from the sentinel monitoring wells (the P1 and P2 series of wells, excluding P1-9) will be monitored in the spring and fall only. Monitoring frequency will be revisited with MOECC over time. It is recommended that the groundwater monitoring program begin one year prior to the start of operation so that two to three monitoring sessions can be completed to obtain baseline data, with the exception of the P2 series of wells that will commence one year prior to the start of operation in Phase 2.

13.2.3 Parameters

As per the *Landfill Standards* (MOE, 1998b, revised January 2012), there is a different recommended list of parameters to be analyzed in the spring, summer and fall. Groundwater samples collected from the groundwater monitoring wells are proposed to be analyzed for the parameters listed in Column 2, Schedule 5 of the *Landfill Standards* during the spring and summer and Column 1, Schedule 5 of *Landfill Standards* in the fall, plus a few additions as requested by the MOECC. The *Landfill Standards* parameters apply to all of the groundwater monitoring wells in the program. In addition, facility specific parameters are recommended for groundwater monitoring wells near the organics processing facility and the soil treatment area. Table 13-3 below outlines the proposed monitoring parameters for groundwater.

Table 13-3: Proposed Groundwater Monitoring Parameters

Parameter	Spring & Summer [1, 2]	Fall[1, 2]
Alkalinity ($CaCO_3$)	X	X
Ammonia	X	X
Calcium	X	X
Chloride	X	X
Conductivity (Laboratory)	X	X
Hardness	X	X
Magnesium	X	X
Total Phosphorous		X
Potassium	X	X
Sodium	X	X

Parameter	Spring & Summer [1, 2]	Fall[1, 2]
Sulphate	X	X
Nitrate nitrogen	X	X
Nitrite nitrogen		X
Total Kjeldahl nitrogen	X	X
pH (laboratory tested)	X	X
Total Dissolved Solids	X	X
Metals		
Arsenic		X
Barium	X	X
Boron	X	X
Cadmium		X
Chromium		X
Copper		X
Iron	X	X
Lead		X
Manganese	X	X
Mercury		X
Zinc		X
Bulk Organics		
Phenols		X
COD	X	X
DOC	X	X
Volatile Organics		
Complete VOC scan (including 1,4 –dioxane)		X
Field Measured Parameters		
pH	X	X
Conductivity	X	X
Temperature	X	X

Notes:

1 In addition to the listed parameters, groundwater monitors 13-10, 13-13, P and Q (in the vicinity of the organics processing facility) will be analyzed for tannins and lignins.

2 In addition to the listed parameters, groundwater monitors R and O (in the vicinity of the soil treatment area) will be analyzed for ethylbenzene, xylenes and petroleum hydrocarbons fractions 1 through 4.

The groundwater samples collected from the monitoring wells would be submitted to a private laboratory for analysis of parameters indicated in Table 13-3.

An appropriate number of field duplicates (i.e., approximately one duplicate for every 10 samples collected) would be prepared during each monitoring session as part of the QA/QC program. In addition, one field and trip blank will be prepared for the fall sampling event for evaluation of 1,4-dichlorobenzene, benzene, methylene chloride, toluene, vinyl chloride, ethylbenzene and xylenes.

13.2.4 Monitoring System Maintenance

During each monitoring event all existing monitors will be visually inspected and groundwater levels will be obtained. Changes in the physical condition of each well will be noted and minor repairs undertaken. Groundwater monitors that are shown to be damaged beyond repair or whose integrity is in doubt for further monitoring will be abandoned in accordance with O.Reg. 903 (MOE, 2011) and replaced, if necessary.

13.3 Surface Water Quality Monitoring Program

13.3.1 Monitoring Locations

The proposed surface water monitoring program for the Site is described in the sections below and is summarized in Table 13-4. The proposed monitoring locations are shown on Figure 13-1.

Table 13-4: Proposed Surface Water Monitoring Stations

Water System	Monitoring Sites*	Description
Surface Water	BSW1	Discharge adjacent to landfill
	BSW2	Discharge for Simpson Drain
	BSW3	Discharge from northern portion of Site
	BSW4	Control location in the Simpson Drain

Notes: * Regimbald Drain (upstream of Simpson Drain) and Wilson-Johnston Drain at Devine Road will be sampled during baseline monitoring starting in 2014 provided permission to access the locations can be obtained and they are practically accessible. These locations will be removed from the program once the Site becomes operational.

13.3.2 Monitoring Frequency

The surface water quality monitoring sessions will be conducted during the spring, summer and fall of the year plus a monitoring session after a large rainfall event as recommended in the *Landfill Standards* (MOE, 1998b, revised January 2012). Surface water sampling that was undertaken as part of the existing conditions work can be used as baseline information for the proposed surface water monitoring program. It is recommended that monitoring events begin in 2014 to observe any changes in the baseline data.

13.3.3 Parameters

As per the *Landfill Standards* (MOE, 1998b, revised January 2012), there is a different recommended list of parameters to be analyzed in the spring, summer and fall. Surface water samples collected from the surface water monitoring locations are proposed to be analyzed for the parameters listed in Column 4, Schedule 5 of the *Landfill Standards* during the spring and summer and Column 3, Schedule 5 of *Landfill Standards* in the fall. In addition, facility specific parameters are recommended for surface water monitoring locations north of the Simpson Drain. Table 13-5 below outlines the proposed monitoring parameters for surface water.

Table 13-5: Proposed Surface Water Monitoring Program Parameters

Parameter	Spring & Summer [1,2]	Fall[1,2]
Alkalinity ($CaCO_3$)	X	X
Ammonia	X	X
Chloride	X	X
Conductivity (Laboratory)	X	X
Total Phosphorous	X	X
Sulphate	X	X
Nitrate nitrogen	X	X
Nitrite nitrogen	X	X
Total Kjeldahl nitrogen	X	X
pH (laboratory tested)	X	X
Total Dissolved Solids	X	X
Metals		
Arsenic		X
Barium		X
Boron		X
Cadmium		X
Chromium		X
Copper		X
Iron	X	X
Lead		X
Mercury		X
Zinc		X
Bulk Organics		
Phenols	X	X
BOD_5	X	X
COD	X	X
Field Measured Parameters		
pH	X	X
Conductivity	X	X
Temperature	X	X
Dissolved Oxygen	X	X
Flow	X	X

Notes:

[1] Unionized ammonia nitrogen calculated for surface water based on field measured pH and temperature.

[2] In addition to the listed parameters, surface water stations BSW2, BSW3 and BSW4 will be analyzed for tannins and lignins, benzene, toluene, ethylbenzene, xylene and petroleum hydrocarbons fractions 1 through 4.

The surface water samples collected from the surface water stations would be submitted to a private laboratory for analysis of the parameters listed in Table 13-5.

An appropriate number of field duplicates (i.e., approximately one duplicate for every monitoring session) would be prepared during each monitoring session as part of the QA/QC program.

13.4 Leachate Monitoring Program

13.4.1 Monitoring Locations

The proposed leachate monitoring program for the Site is described in the sections below. It is proposed that a leachate sample is collected from the leachate treatment facility prior to treatment and from monitoring wells LW-1, LW-2 and LW-3 that will be completed within the leachate collection system. The proposed leachate monitoring well locations are shown on Figure 13-1. The leachate monitoring wells will be constructed as the landfill progresses and therefore will only be included in the monitoring program once constructed.

13.4.2 Monitoring Frequency

The leachate quality monitoring sessions will be conducted during the spring, summer and fall of the year as recommended in the *Landfill Standards* (MOE, 1998b, revised January 2012). Leachate collection, and hence leachate quality monitoring, is expected to terminate at some point post-closure when residual leachate quality permits.

13.4.3 Parameters

As per the *Landfill Standards* (MOE, 1998b, revised January 2012), there is a different recommended list of parameters to be analyzed in the spring, summer and fall. Leachate samples are proposed to be analyzed for the parameters listed in Column 2, Schedule 5 of the *Landfill Standards* during the spring and summer and Column 1, Schedule 5 of *Landfill Standards* in the fall, plus a few additions as recommended by the MOECC. Table 13-6 below outlines the proposed monitoring parameters for leachate.

Table 13-6: Proposed Leachate Monitoring Parameters

Parameter	Spring & Summer	Fall
Alkalinity ($CaCO_3$)	X	X
Ammonia	X	X
Calcium	X	X
Chloride	X	X
Conductivity (Laboratory)	X	X
Hardness	X	X
Magnesium	X	X
Total Phosphorous		X
Potassium	X	X
Sodium	X	X
Sulphate	X	X
Nitrate nitrogen	X	X
Nitrite nitrogen		X

Parameter	Spring & Summer	Fall
Total Kjeldahl nitrogen	X	X
pH (laboratory tested)	X	X
Total Dissolved Solids	X	X
Total Suspended Solids	X	X
Metals		
Arsenic		X
Barium	X	X
Boron	X	X
Cadmium		X
Chromium		X
Copper		X
Iron	X	X
Lead		X
Manganese	X	X
Mercury		X
Zinc		X
Bulk Organics		
Phenols		X
BOD_5	X	X
COD	X	X
DOC	X	X
Volatile Organics		
Complete VOC scan (including 1,4 –dioxane)		X
Field Measured Parameters		
pH	X	X
Conductivity	X	X
Temperature	X	X

The leachate samples would be submitted to a private laboratory for analysis of parameters indicated in Table 13-6.

13.4.4 Leachate Level Measurement

During each monitoring event, leachate levels will be measured in the cleanout at any constructed manhole sumps in the landfill as well as in the leachate monitoring wells. The leachate measurements will assist in understanding the amount of leachate mounding within the leachate collection system.

13.5 Future Modifications to Monitoring Program

Each annual monitoring report would include a re-evaluation of the groundwater and surface water monitoring requirements at the Site. In the event that the monitoring program presented above requires modification so as to adequately monitor the future performance of the Site, or such modification (i.e., reduction in frequency) is otherwise appropriate, the proposed modifications for the subsequent year would be discussed with the MOECC to obtain their approval for the changes prior to implementation. As the groundwater velocity in all units is low at the Site, it is anticipated that a recommendation for reduced groundwater monitoring frequency would be made after several years of demonstrated performance.

Groundwater monitoring wells at location 13-7 will be decommissioned in accordance with O.Reg. 903 (MOE, 2011) and removed from the groundwater monitoring program as landfilling progresses into that area.

13.6 Objectives of Trigger Mechanism

The objectives of trigger mechanisms at the Site are to utilize the results of the ongoing surface water and groundwater monitoring programs to assess Site compliance and to trigger implementation of the contingency plans, when and if necessary. The purposes of the trigger mechanisms are to prevent leachate-impacted groundwater exceeding the MOECC *Guideline B-7: Incorporation of the Reasonable Use Concept into MOE Groundwater Management* (Guideline B-7) (MOE, 1994b) from migrating beyond the Site boundaries, and to prevent adverse impact on surface water quality.

13.7 Compliance Evaluation Parameters and Trigger Concentrations

13.7.1 Preamble

A *Leachate Indicator Parameter* for a landfill site is defined as being a parameter which is useful in determining the presence/absence of landfill leachate impact on water resources; assessing the degree of leachate impact on water resources; and, is useful in determining the extent of leachate impact near the landfill site. Because there is no existing site-specific leachate quality to determine the *Leachate Indicator Parameter* list for the CRRRC, the *Leachate Indicator Parameters* for groundwater will be a combination of those listed in Column 2 and Column 4 of Schedule 5 of the *Landfill Standards* (MOE, 1998b, revised January 2012) with some modifications. Hardness will be used for groundwater as opposed to calcium and magnesium because there is an operational guideline ODWQS for hardness but not for calcium and magnesium. Hardness will only be a *Leachate Indicator Parameter* for groundwater. Also, unionized ammonia, BOD and TSS will be *Leachate Indicator Parameters* for surface water and not groundwater, and DOC and sodium will be *Leachate Indicator Parameters* for groundwater and not surface water. Benzene, toluene, ethylbenzene and xylenes will also be added to the Leachate Indicator Parameter list for surface water to detect potential impacts to surface water from the soil treatment facility. The following is a list of *Leachate Indicator Parameters* for the Site: alkalinity, ammonia (unionized ammonia for surface water), barium, boron, chloride, BOD (surface water only), COD, DOC (groundwater only), hardness (groundwater only), iron, nitrate, nitrite, TKN, total phosphorus, phenols, sodium (groundwater only), sulphate, TDS, TSS (surface water only), benzene (surface water only), toluene (surface water only), ethylbenzene (surface water only) and xylenes (surface water only). The Site compliance will be evaluated in the surficial silty sand, the silty layer, the glacial till and the upper bedrock.

Compliance Evaluation Parameters are defined as the site-specific *Leachate Indicator Parameters* which have established Provincial Water Quality Objectives (surface water) or Ontario Drinking Water Quality Standards (groundwater). Note that if the upper tolerance limit of a groundwater parameter exceeds the ODWQS, then the parameter is not considered a compliance evaluation parameter for groundwater within that unit.

A *Reasonable Use Performance Objective* refers to the maximum allowable concentration for a *Compliance Evaluation Parameter* in groundwater at the point of compliance under MOECC Guideline B-7. It is a specified calculation using the median for each parameter based on the existing background data.

A *Surface Water Compliance Concentration* generally refers to the higher of either the upper tolerance limit or the Provincial Water Quality Objectives for each *Compliance Evaluation Parameter* based on the existing background data. Under the tolerance interval approach, the natural variation in background surface water quality is recognized and the surface water compliance concentrations are not lower than the corresponding tolerance limits for the *Compliance Evaluation Parameters*.

A *Trigger Concentration* is an agreed upon threshold of the *Leachate Indicator Parameters*.

It is noted that future *Compliance Evaluation Parameters* may differ from those discussed herein, in consultation with MOECC, due to the addition or deletion of site-specific *Leachate Indicator Parameters*, changes to background groundwater concentrations as future monitoring programs are added to the database, or changes to the ODWQS and/or PWQO in the future.

13.7.2 Groundwater

The background groundwater quality and upper tolerance limits for each of the *Leachate Indicator Parameters* for the surficial silty sand, the silty layer, the glacial till and the upper bedrock are presented in Table 13-7 to Table 13-10 below:

Table 13-7: Groundwater Quality for Leachate Indicator Parameters in the Surficial Silty Sand

Leachate Indicator Parameters	**ODWQS[2] (mg/L)**	**Surficial Silty Sand Deposit[1]**		
		Background Range (mg/L)	**Upper Tolerance Limit (mg/L)**	**Median (mg/L)**
Alkalinity	- -	140 – 660	705	340
Ammonia	- -	0.03 – 0.52	0.5	0.17
Barium	1(H)	0.03 – 0.36	0.3	0.07
Boron	5 (H)	<0.01 – 0.07	0.1	0.03
Chloride	250(AO)	30 – 950	1,023	185
COD	- -	13 – 270	236	48
DOC	5 (AO)	2 – 32	24.6	4.3
Hardness	- -	204 – 830	844	415
Iron	0.3 (AO)	<0.1 – 0.16	0.1	<0.1
Nitrate	10(H)	<0.1 – 5.9	4.7	<0.1
Nitrite	1(H)	<0.01 – 0.024	0.021	<0.01
TKN	- -	0.73 – 6.8	7.4	2.8
Sodium	200 (AO)	23 – 540	629	195
Total Phosphorus	- -	0.5 – 27	32.1	5.5
Phenols	- -	<0.001 – 0.004	0.003	<0.001
Sulphate	500 (AO)	25 – 160	176	74
TDS	500 (AO)	150 – 2,320	2,569	781

Notes:

mg/L - milligrams per Litre.

ODWQS - Ontario Drinking Water Quality Standards (2003).

[1] Background groundwater quality based on 2013 groundwater quality from monitoring wells 12-1-6, 12-2-6, 12-3-6, 12-4-6, 13-5-6, 13-6-6 and 13-7-5.

[2] ODWQS values presented relate specifically to non-health related parameters (i.e., aesthetic parameters) and health-related parameters for which a maximum acceptable concentration (MAC) or interim maximum acceptable concentration (IMAC) has been established.

(H) Health-related parameter.

(AO) Aesthetic objective parameter.

- - No ODWQS for health-related or aesthetic objective parameters

Table 13-8: Groundwater Quality for Leachate Indicator Parameters in the Silty Layer

Leachate Indicator Parameters	ODWQS[2] (mg/L)	Silty Layer[1]		
		Background Range (mg/L)	Upper Tolerance Limit (mg/L)	Median (mg/L)
Alkalinity	- -	200 – 750	909	575
Ammonia	- -	1.0 – 3.4	3.3	1.7
Barium	1(H)	0.04 – 0.24	0.29	0.16
Boron	5 (H)	0.13 – 0.34	0.38	0.23
Chloride	250(AO)	200 – 1,600	2026	930
COD	- -	22 – 740	640	96
DOC	5 (AO)	3.7 – 45	33.3	6.1
Hardness	- -	257 – 752	867	393
Iron	0.3 (AO)	<0.1 – 0.37	0.34	<0.1
Nitrate	10(H)	<0.1	<0.1	<0.1
Nitrite	1(H)	<0.01 – 0.31	0.2	<0.01
TKN	- -	2.8 – 19	18.4	5.9
Sodium	200 (AO)	240 – 1,200	1,403	720
Total Phosphorus	- -	13 – 130	143	25
Phenols	- -	<0.001 – 0.002	0.002	<0.001
Sulphate	500 (AO)	<1 – 130	114	11.5
TDS	500 (AO)	834 – 3,460	4,048	2,085

Notes:

mg/L - milligrams per Litre.

ODWQS - Ontario Drinking Water Quality Standards (2003).

1 Background groundwater quality based on 2013 groundwater quality from monitoring wells 12-1-5B, 12-2-5B, 12-3-5B, 12-4-5B, 13-5-5, 13-6-5B and 13-7-4-2.

2 ODWQS values presented relate specifically to non-health related parameters (i.e., aesthetic parameters) and health-related parameters for which a maximum acceptable concentration (MAC) or interim maximum acceptable concentration (IMAC) has been established.

(H) Health-related parameter.

(AO) Aesthetic objective parameter.

- - No ODWQS for health-related or aesthetic objective parameters

Table 13-9: Groundwater Quality for Leachate Indicator Parameters in the Glacial Till Deposit

Leachate Indicator Parameters	ODWQS[2] (mg/L)	Glacial Till Deposit[1]		
		Background Range (mg/L)	Upper Tolerance Limit (mg/L)	Median (mg/L)
Alkalinity	- -	340 – 860	961	600
Ammonia	- -	2.7 – 12	14.9	6.7
Barium	1(H)	0.5 – 17	24.1	4.3
Boron	5 (H)	0.8 – 1.8	2.2	1.4
Chloride	250(AO)	2,300 – 7,500	9,555	5,600
COD	- -	48 – 210	244	110
DOC	5 (AO)	7.6 – 16	17.9	9.7
Hardness	- -	286 – 1,564	1,956	909
Iron	0.3 (AO)	<0.1 – 1.5	1.6	0.25
Nitrate	10(H)	<0.1	0.1	<0.1
Nitrite	1(H)	<0.01 – 0.025	0.02	<0.01
TKN	- -	4.7 – 14	15.2	8.3
Sodium	200 (AO)	1,800 – 4,900	5,972	3,500
Total Phosphorus	- -	0.11 – 11	14.2	3.3
Phenols	- -	<0.001 – 0.01	0.01	<0.001
Sulphate	500 (AO)	2 – 84	85	11
TDS	500 (AO)	4,540 – 12,900	16,267	9,900

Notes:

mg/L - milligrams per Litre.

ODWQS - Ontario Drinking Water Quality Standards (2003).

1 Background groundwater quality based on 2013 groundwater quality from monitoring wells 12-1-4A, 12-3-4A, 12-4-4A, 13-5-4A, 13-6-4A and 13-7-3.

2 ODWQS values presented relate specifically to non-health related parameters (i.e., aesthetic parameters) and health-related parameters for which a maximum acceptable concentration (MAC) or interim maximum acceptable concentration (IMAC) has been established.

(H) Health-related parameter.

(AO) Aesthetic objective parameter.

- - No ODWQS for health-related or aesthetic objective parameters

Table 13-10: Groundwater Quality for Leachate Indicator Parameters in the Upper Bedrock

Leachate Indicator Parameters	ODWQS[2] (mg/L)	Upper Bedrock[1]		
		Background Range (mg/L)	Upper Tolerance Limit (mg/L)	Median (mg/L)
Alkalinity	- -	47 – 710	1,079	535
Ammonia	- -	5.8 – 28	26.4	8.3
Barium	1(H)	0.09 – 17	29	15
Boron	5 (H)	0.3 – 1.9	2.7	1.6
Chloride	250(AO)	2,800 – 9,600	12,034	6,950
COD	- -	45 – 210	218	105
DOC	5 (AO)	3.7 – 47	36	7.1
Hardness	- -	384 – 3,310	3,878	1,330
Iron	0.3 (AO)	<0.1 – 1.2	1.1	0.5
Nitrate	10(H)	<0.1	0.1	<0.1
Nitrite	1(H)	<0.01 – 0.5	0.04	<0.01
TKN	- -	6.7 – 28	26	9
Sodium	200 (AO)	2,000 – 5,400	6,843	4,300
Total Phosphorus	- -	0.06 – 3	3.2	0.2
Phenols	- -	<0.001 – 0.4	0.03	0.003
Sulphate	500 (AO)	<1 – 260	308	23
TDS	500 (AO)	5,560 – 19,700	22,335	12,150

Notes:
mg/L - milligrams per Litre.
ODWQS - Ontario Drinking Water Quality Standards (2003).
1 Background groundwater quality based on 2013 groundwater quality from monitoring wells 12-1-3.1, 12-2-3, 12-3-3, 12-4-3, 13-5-3, 13-6-3 and 13-7-2.
2 ODWQS values presented relate specifically to non-health related parameters (i.e., aesthetic parameters) and health-related parameters for which a maximum acceptable concentration (MAC) or interim maximum acceptable concentration (IMAC) has been established.
(H) Health-related parameter.
(AO) Aesthetic objective parameter.
- - No ODWQS for health-related or aesthetic objective parameters

The upper tolerance limits represent the maximum parameter concentrations that can be expected in the background groundwater in the surficial silty sand, the silty layer, glacial till and upper bedrock near the Site based on statistical analysis. The median from the background groundwater quality data set is used to derive the revised *Reasonable Use Performance Objectives* (if possible) and corresponding *Trigger Concentrations* for the *Compliance Evaluation Parameters,* with the exception where the upper tolerance limit exceeds the ODWQS, then the parameter is excluded as a *Compliance Evaluation Parameter*. For the parameters that have upper tolerance limit concentrations above the ODWQS (referred to as *Other Evaluation Parameters*), the *Trigger Concentration* will be based on the background range of each of those parameters within the corresponding stratigraphic unit. The background range will be derived from the maximum and minimum data obtained from 2013 to present in each stratigraphic unit and at any future wells installed. The background ranges will be updated annually using the most recent data. An exceedance of the background range is considered an exceedance of the trigger mechanism and is discussed further below.

Based on the calculated statistical median and upper tolerance limits for the background groundwater quality data in the surficial silty sand, the silty layer, the glacial till and the upper bedrock, the current *Reasonable Use Performance Objectives* and the current *Trigger Concentrations* are presented in the following tables.

Table 13-11: Groundwater Reasonable Use Performance Objectives and Trigger Concentrations for Surficial Silty Sand

Compliance Evaluation Parameters	Median (mg/L)	Reasonable Use Performance Objective (mg/L)	Trigger Concentration (mg/L)
Barium	0.07	0.31	0.23
Boron	0.03	1.28	0.96
Iron	<0.1	0.18	0.13
Nitrate	<0.1	2.5	1.9
Nitrite	<0.01	0.25	0.19
Sulphate	74	287	215
Other Evaluation Parameter	**Median (mg/L)**	**Reasonable Use Performance Objective (mg/L)**	**Trigger Concentration (mg/L)**
Chloride	185	--	950*
DOC	4.3	--	32*
Sodium	195	--	540*
TDS	781	--	2,320*

Note: mg/L - milligrams per Litre
* Maximum background concentration in the surficial silty sand

Table 13-12: Groundwater Reasonable Use Performance Objectives and Trigger Concentrations for the Silty Layer

Compliance Evaluation Parameters	Median (mg/L)	Reasonable Use Performance Objective (mg/L)	Trigger Concentration (mg/L)
Barium	0.16	0.37	0.28
Boron	0.23	1.4	1.1
Nitrate	<0.1	2.5	1.9
Nitrite	<0.01	0.25	0.19
Sulphate	11.5	256	192
Other Evaluation Parameter	**Median (mg/L)**	**Reasonable Use Performance Objective (mg/L)**	**Trigger Concentration (mg/L)**
Chloride	930	--	1,600*
DOC	6.1	--	45*
Iron	<0.1	--	0.37*
Sodium	720	--	1,200*
TDS	2,085	--	3,460*

Note: mg/L - milligrams per Litre.
* Maximum background concentration in the silty layer

Table 13-13: Groundwater Reasonable Use Performance Objectives and Trigger Concentrations for the Glacial Till

Compliance Evaluation Parameters	Median (mg/L)	Reasonable Use Performance Objective (mg/L)	Trigger Concentration (mg/L)
Boron	1.4	2.3	1.7
Nitrate	<0.1	2.5	1.9
Nitrite	<0.01	0.25	0.19
Sulphate	11	256	192
Other Evaluation Parameter	**Median (mg/L)**	**Reasonable Use Performance Objective (mg/L)**	**Trigger Concentration (mg/L)**
Barium	4.3	--	17*
Chloride	5,600	--	7,500*
DOC	9.7	--	16*
Iron	0.25	--	1.5*
Sodium	3,500	--	4,900*
TDS	9,900	--	12,900*

Note: mg/L - milligrams per Litre.
* Maximum background concentration in the glacial till

Table 13-14: Groundwater Reasonable Use Performance Objectives and Trigger Concentrations for the Upper Bedrock

Compliance Evaluation Parameters	Median (mg/L)	Reasonable Use Performance Objective (mg/L)	Trigger Concentration (mg/L)
Boron	1.6	2.5	1.8
Nitrate	<0.1	2.5	1.9
Nitrite	<0.01	0.25	0.19
Sulphate	23	261	196
Other Evaluation Parameter	**Median (mg/L)**	**Reasonable Use Performance Objective (mg/L)**	**Trigger Concentration (mg/L)**
Barium	15	--	17*
Chloride	6,950	--	9,600*
DOC	7.1	--	47*
Iron	0.5	--	1.2*
Sodium	4,300	--	5,400*
TDS	12,150	--	19,700*

Note: mg/L - milligrams per Litre.
* Maximum background concentration in the upper bedrock

The calculated maximum allowable boundary concentrations for these parameters under MOECC Guideline B-7 and the trigger concentrations will be modified, as required, based on additional background groundwater quality data which will be obtained during future monitoring programs.

13.7.3 Surface Water

The background surface water quality and upper tolerance limits for each of the *Leachate Indicator Parameters* are presented below:

Table 13-15: Surface Water Quality for Leachate Indicator Parameters

Leachate Indicator Parameters	PWQO (ug/L)	Surface Water[1]	
		Background Range (µg/L)	Upper Tolerance Limit (µg/L)
Alkalinity	127,500[2]	54,000 – 250,000	11,506 [3]
Unionized Ammonia	20	0.03 – 7.1	5
Barium	--	18 – 83	89
Boron	200	<10 – 65	67
Chloride	- -	30,000 – 440,000	442.900
COD	- -	18,000 – 170,000	171,400
BOD	- -	<2,000 – 38,000	23,725
Iron	300	<100 – 3,100	3,100
Nitrate	- -	<100 – 1,200	845
Nitrite	- -	<10 – 58	55
TKN	- -	660 – 3,400	3,200
Total Phosphorus	30	17 – 140	159
Phenols	- -	<1 – 55	40
Sulphate	- -	<5,000 – 200,000	189,300
TDS	- -	170,000 – 1,070,000	1,199,200
TSS	- -	500 – 8,000	10,500

Notes:

µg/L – micrograms per Litre.

PWQO – Provincial Water Quality Objectives (1994, re-print 1999).

[1] Background surface water quality based on BSW1, BSW2, BSW3, BSW4 (2013).

[2] Alkalinity should not be decreased by more than 25% of the natural concentration. This value was calculated as 75% of the median background concentration.

[3] Lower tolerance limit.

- - No PWQO.

The upper tolerance limits represent the maximum parameter concentrations that can be expected in the background surface water near the Site.

The compliance concentrations based on the higher of the upper tolerance limits or PWQO for the background surface water quality data are presented in Table 13-16.

Table 13-16: Surface Water Compliance and Trigger Concentrations

Compliance Evaluation Parameters	Compliance Concentrations (µg/L)	Trigger Concentrations (µg/L)
Alkalinity	>11,056*	<13,820
Boron	<200	>150
Iron	<3,093	>2,320
Total Phosphorus	<159	>119
Unionized Ammonia	<20	>15
Benzene	<100 [1]	>75
Toluene	<0.8 [1]	>0.6
Ethylbenzene	<8 [1]	>6
Xylene, m-	<2 [1]	>1.5
Xylene, o-	<40 [1]	>30
Xylene, p-	<30 [1]	>22.5

Notes:
µg/L - micrograms per Litre
* In the case of alkalinity the compliance concentration is the lesser of the lower tolerance limit or the PWQO
[1] Interim PWQO

The trigger concentrations are 75% of the compliance concentrations or in the case of alkalinity 125% of the compliance concentration. The calculated trigger concentrations will be modified, as required, based on additional background surface water quality data which will be obtained during future monitoring programs.

13.8 Trigger Formats

13.8.1 Groundwater Trigger

The trigger parameters are barium, boron, chloride, DOC, iron, nitrate, nitrite, sodium, sulphate and TDS. The trigger concentrations will be those calculated using 75% of the MOECC Guideline B-7 value or the maximum background concentration for those parameters where the upper tolerance limit is greater than the ODWQS. The calculated trigger concentrations will be based on all the background data which exists at the time of each comparison with the trigger criteria. These trigger concentrations may vary over time as background concentrations from future monitoring programs are added to the data base.

The groundwater trigger will be considered to have been exceeded when one or more of the above trigger parameters exceed the maximum trigger concentration during two consecutive monitoring sessions (not including non-compliance verification re-sampling).

Any observed exceedances of the trigger concentrations will be verified by re-sampling for the parameter(s) of concern within one month of the original sampling session at which time non-compliance was measured. The time frame of one month is to allow time for the initial chemical analyses to be performed, received from the analytical laboratory and interpreted by the proponent. If the non-compliance is not confirmed by the follow-up sample, then the initial non-compliance will be considered anomalous and will be discounted. The historical trends in the *Compliance Evaluation Parameter* concentrations at the points of compliance would also be used in concluding that monitoring results are anomalous.

If exceedances of the trigger concentrations are confirmed at the trigger location (i.e., confirmed non-compliance or trigger concentration exceedance during two consecutive monitoring sessions), a three-step process will be initiated for the purpose of determining whether implementation of the contingency plan is warranted. The three-step process is as follows:

Step 1 - Assess the concentrations reported for other *Leachate Indicator Parameters* at the monitoring location. If more than one *Leachate Indicator Parameter* experiences an increase, assess two subsequent sampling sessions to determine if the parameters continue to increase. If an exceedance is followed by two subsequent increasing monitoring sessions, assess whether the non-compliance or trigger concentration exceedance is due to leachate, or whether it is partially or wholly explicable by other factors. This will be achieved by considering trends in *Leachate Indicator Parameter* concentrations at all relevant monitoring locations or could include an expanded suite of monitoring parameters and/or an increased sampling frequency (if warranted depending on the on-going monitoring results and/or an increased sampling frequency). This step would be completed within two months of receipt of laboratory analyses that indicated a confirmed exceedance;

Step 2 - If the conclusion of Step 1 is affirmative, then an assessment of the results of Step 1 would be conducted to decide whether implementation of the contingency plan is warranted. The MOECC would be consulted with respect to this decision. This step would be completed within three months of the completion of Step 1; and,

Step 3 - If the conclusion of Step 2 is affirmative, then the groundwater contingency plan would be implemented. A detailed evaluation of contingency options would be completed and a suitable contingency option would be selected within six months of Step 2 being affirmative. Following the selection of a suitable contingency option, a schedule would be submitted to the MOECC outlining the anticipated timing of design, approval and construction of the selected contingency option.

13.8.2 Surface Water Trigger

The trigger parameters are alkalinity, boron, iron, total phosphorus, unionized ammonia, benzene, toluene, ethylbenzene and xylenes. The trigger concentrations will be based on 75% of either the upper tolerance limit for all background data or the PWQO that exists at the time of each comparison with the trigger concentration, whichever is higher. The exception would be alkalinity, which would be 125% of either the lower tolerance limit for all background data or the PWQO that exists at the time of each comparison with the trigger concentration, whichever is lower. These trigger concentrations may vary over time as background concentrations from future monitoring programs are added to the data base.

The surface water trigger will be considered to have been exceeded when one or more of the above trigger parameters exceeds the maximum allowable concentration (i.e., trigger concentrations) during two consecutive monitoring sessions (not including non-compliance verification re-sampling). The exception would be alkalinity, which will be considered to not meet compliance when it is below the lowest allowable concentration (i.e., trigger concentration) during two consecutive monitoring sessions (not including non-compliance verification re-sampling).

Any observed non-compliance will be verified by re-sampling for the parameter(s) of concern within one month of the initial sampling session. The time frame of one month is to allow time for the initial chemical analyses to be performed, received from the analytical laboratory and interpreted by the proponent. If the non-compliance is not confirmed by the follow-up sample, then the initial non-compliance will be considered anomalous and will be discounted. The historical trends in the *Compliance Evaluation Parameter* concentrations at the point of compliance would also be used in assuming whether or not these monitoring results are anomalous.

If non-compliance is confirmed at the trigger location (i.e., confirmed non-compliance during two consecutive monitoring sessions), a three-step process will be initiated for the purpose of determining whether implementation of the contingency plan is warranted. The three-step process is as follows:

Step 1 - Assess whether the non-compliance is due to leachate, or whether it is partially or wholly explicable by other factors. This will be achieved by considering trends in *Leachate Indicator Parameter* concentrations at all relevant monitoring locations or could include an expanded suite of monitoring parameters and/or an increased sampling frequency. This step would be completed within two months of receipt of laboratory analyses indicated a confirmed exceedance. If additional monitoring (e.g., expanded suite of parameters) is required, then this step would be completed within five months of receipt of laboratory analyses indicating a confirmed exceedance. Five months is a maximum time to allow for seasonality of sampling;

Step 2 - If the conclusion of Step 1 is affirmative, then a discussion of the results of Step 1 would be conducted to decide whether implementation of the contingency plan is warranted. The MOECC would be consulted with respect to this decision. This step would be completed within three months of the completion of Step 1; and,

Step 3 - If the conclusion of Step 2 is affirmative, then the surface water contingency plan would be implemented. A detailed evaluation of contingency options would be completed and a suitable contingency option would be selected within six months of Step 2 being affirmative. Following the selection of a suitable contingency option, a schedule would be submitted to the MOECC outlining the anticipated timing of design, approval and construction of the selected contingency option.

13.9 Trigger Locations

For the purpose of establishing distinct trigger mechanisms for this Site, each of the four Site boundaries are discussed separately in the following subsections. These Site boundaries, together with their associated trigger mechanisms (when appropriate), are as follows, with rationale provided in Subsections 13.9.1 and 13.9.2.

13.9.1 North, West and South Boundaries

Because the interpreted direction of groundwater flow and the direction of surface water flow are ultimately towards the eastern property boundary, there is a buffer zone, and there are leachate collection system components, no trigger mechanisms are required for these three boundaries during the first 10 years of landfill operation. Based on groundwater quality data and groundwater elevations collected during landfill operations, the need for additional compliance locations on the north, west and south sides of the landfill will be determined as landfilling progresses.

13.9.2 East Boundary

At the down-gradient property boundary, groundwater quality is monitored at five nests of groundwater monitoring wells. These wells are located at the northeast corner of the Site near the Site processing and treatment facilities (monitoring well nests 12-3, 13-13, S), northeast corner of the landfill (monitoring well nests 13-17), and at the southeast corner of the landfill (monitoring well nests 13-25) as shown on Figure 13-1. These groundwater monitoring wells are referred to as compliance wells. In addition, the monitoring well nest P1-9, located midway along the landfill's eastern boundary and located approximately 60 metres from the down-gradient property boundary, has also been considered a compliance well as it has monitoring wells screened in the 4 stratigraphic units at the Site, Along with the compliance locations, the sentinel groundwater monitoring wells along the eastern boundary of the landfill (P1-1, P1-2, P1-3, P1-4, P1-5, P1-6, P1-7, P1-8, P1-10, P2-1, P2-2, P2-3, P2-4, P2-5, P2-6, P2-7) will also be included as trigger locations.

The surface water stations BSW1, BSW2 and BSW3 represent the surface water discharge points from the Site and will be the compliance surface water stations.

13.9.2.1 Surficial Silty Sand

The down-gradient surficial silty sand trigger locations include monitoring wells 12-3-6, 13-13-2, S-B, P1-1B, P1-2B, P1-3B, P1-4B, P1-5B, 13-17-2, P1-6B, P1-7B, P1-8B, P1-9D, P1-10B, P2-1B, P2-2B, P2-3B, P2-4B, P2-5B, P2-6B, P2-7B and 13-25-2. Of these locations, monitoring wells 12-3-6, 13-13-2, S-B, 13-17-2, P1-9D and 13-25-2 are compliance locations.

13.9.2.2 Silty Layer

The down-gradient silty layer trigger locations include monitors 12-3-5B, S-A, 13-13-3, P1-1A, P1-2A, P1-3A, P1-4A, P1-5A, 13-17-3, P1-6A, P1-7A, P1-8A, P1-9C, P1-10A, P2-1A, P2-2A, P2-3A, P2-4A, P2-5A, P2-6A, P2-7A and 13-25-3. Of these locations, monitoring wells 12-3-5B, 13-13-3, S-A, 13-17-3, P1-9C and 13-25-3 are compliance locations.

13.9.2.3 Glacial Till

The down-gradient glacial till trigger locations include monitors 12-3-4A and P1-9B. Both of these locations are compliance locations.

13.9.2.4 Bedrock

The down-gradient bedrock trigger locations include monitors 12-3-3 and P1-9A. Both of these locations are compliance locations.

13.10 Modification to Trigger Mechanism

If, depending on observations and ongoing Site monitoring results, there is a need in the future to modify the trigger mechanisms, a formal application would be made by the CRRRC to the MOECC District Manager requesting the necessary changes.

14.0 GROUNDWATER AND SURFACE WATER CONTINGENCY MEASURE

The findings of the predictive modelling indicate that the CRRRC landfill will not adversely affect groundwater and surface water. However, in the event that the results of the proposed monitoring program demonstrate unacceptable levels of contaminants in the groundwater at the points of compliance, or unexpected impacts to surface water, remedial actions will be implemented as required, in consultation with the MOECC. The contingency measures presented in this section are considered the most feasible options to reduce landfill leachate impacts to groundwater and surface water resources at the Site.

14.1 Groundwater

In the event that monitoring results suggest leachate is unexpectedly getting into the groundwater system on-Site, the following contingency measures could be implemented. The intercepted leachate-impacted groundwater collected from the surficial silty sand layer in the LDSCS could be pumped for treatment and act as the secondary containment system for the landfill. At this time, additional groundwater monitoring wells could be installed between the sentinel monitoring wells (P1 series and P2 series) and the property boundary to evaluate site compliance.

Alternatively, or additionally, a series of purge wells through the cover of the landfill and into the granular blanket of the leachate collection system could be installed and leachate removal by pumping to leachate treatment. Typically, this type of a contingency is triggered by premature failure of the leachate collection system, such that a mound is formed within the landfill. The benefit of having purge wells installed in the leachate collection system is that leachate is contained within the landfill and collected prior to getting diluted with non-leachate-impacted groundwater. Details regarding purge well installation, such as the number and spacing, would be determined based on the area and level of leachate mound control required.

If, despite the presence of the LDSCS, it is necessary to cut off flow through any or all of the perimeter berm, surficial silty sand layer or silty layer, a low permeability cut-off barrier could be constructed. Options available for the barrier include a soil-bentonite wall constructed using the slurry trench method or an interlocking sheet pile wall (steel or PVC sheet piling). This would contain the groundwater within/close to the landfill on-Site, which would then continue to be removed from the leachate collection system.

MOECC approval to implement the contingency measures would be obtained.

In the event that the liner systems associated with ponds in the leachate pre-treatment facility and primary reactor cells in the organics processing facility are compromised, materials would be removed and the liner repaired or replaced.

14.2 Surface Water

In the event that leachate-impacted water was to reach either stormwater management ponds or ditches, the source of the impact would be determined and then intercepted, as required. If necessary, the affected pond and/or ditches could then be emptied through a temporary pumping operation and the pumped water could be combined with the leachate and directed to the leachate treatment facility.

15.0 LIMITATIONS AND USE OF REPORT

This report was prepared for the exclusive use of Taggart Miller Environmental Services, and is intended to support applications under the *Environmental Assessment Act*, *Environmental Protection Act*, and *Ontario Water Resources Act*. The report, which specifically includes all tables, figures and appendices, is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this report. Each of these reports must be read and understood collectively, and can only be relied upon in their totality.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The assessment of environmental conditions and possible hazards at this Site has been made using the results of physical measurements and chemical analyses of liquids from a limited number of monitoring locations. The Site conditions between sampling locations have been inferred based on conditions observed at the effluent sampling location. Conditions may vary from these sampled locations.

The services performed, as described in this report, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Noting the intended use of this report, any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

GOLDER ASSOCIATES LTD.

J.P.A. Oxtobee, M.Sc., P.Geo. Senior Hydrogeologist, Associate	M. Cunningham, M.Sc., P.Eng. Senior Geotechnical Engineer, Principal

JPAO/MIC/sg

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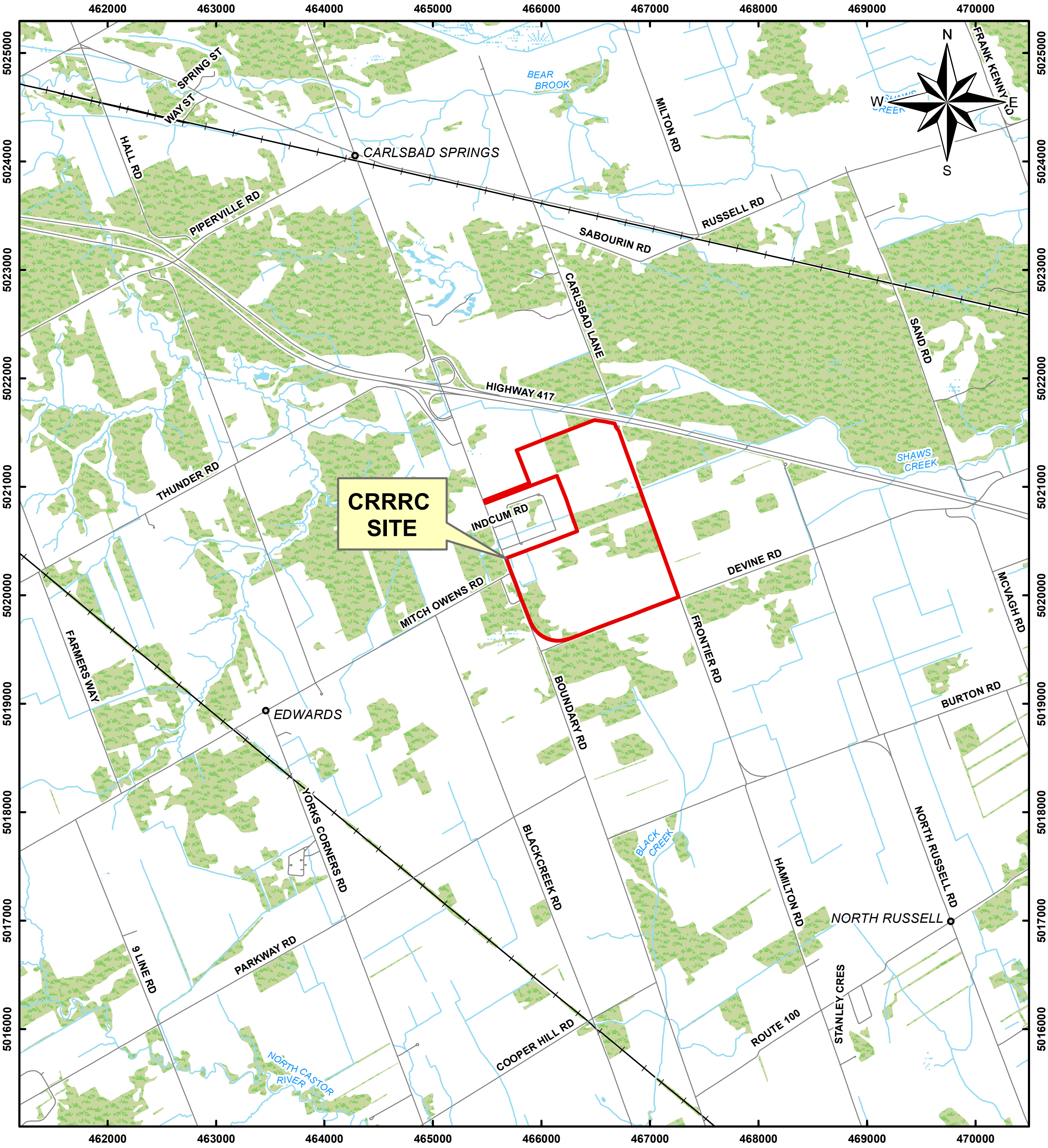

1,000 500 0 1,000

SCALE 1:50,000 METRES

LEGEND

🟥 PROPERTY BOUNDARY

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCES

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2011.
DATUM: NAD 83, COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

KEY PLAN

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4000
DESIGN	JPAO	DEC. 2013	SCALE AS SHOWN REV. 0.0
GIS	BR	DEC. 2013	FIGURE 1-1
CHECK	PLE	AUG. 2014	
REVIEW	PAS	AUG. 2014	

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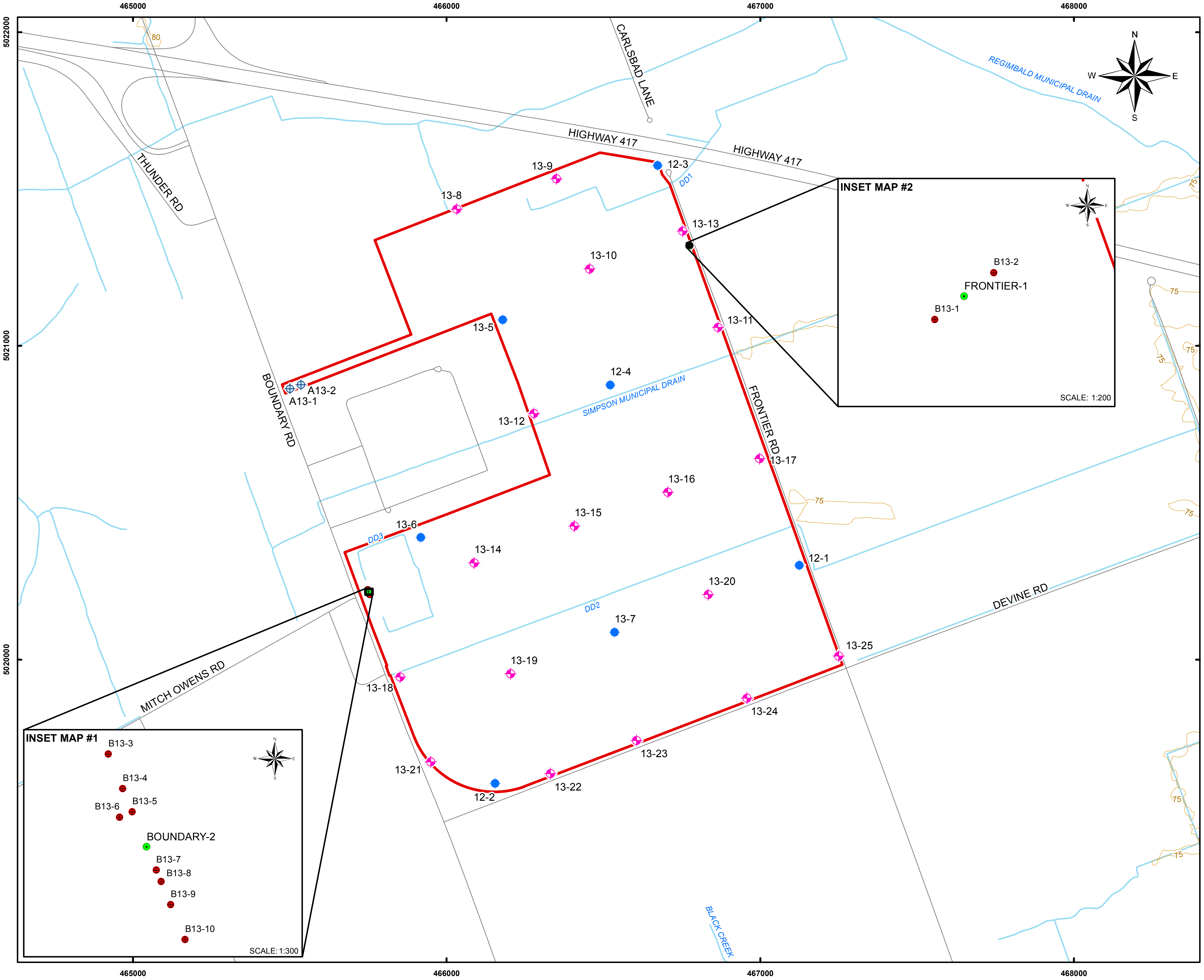

LEGEND

●	DEEP INVESTIGATION LOCATION
⊕	SHALLOW INVESTIGATION LOCATION
⊕	GOLDER SUPPLEMENTAL MONITORING WELL LOCATION
⊗	GOLDER DUG WELL ASSESSMENT MONITORING LOCATION
●	PRIVATE DUG WELL
—	ROAD
—	CONTOUR LINE, (5m)
—	SURFACE WATER FEATURE
🟦	WATER AREA
🟥	PROPERTY BOUNDARY

200 100 0 200

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

SITE PLAN

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	DEC. 2013	FIGURE 2-1	
GIS	BR	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Golder Associates

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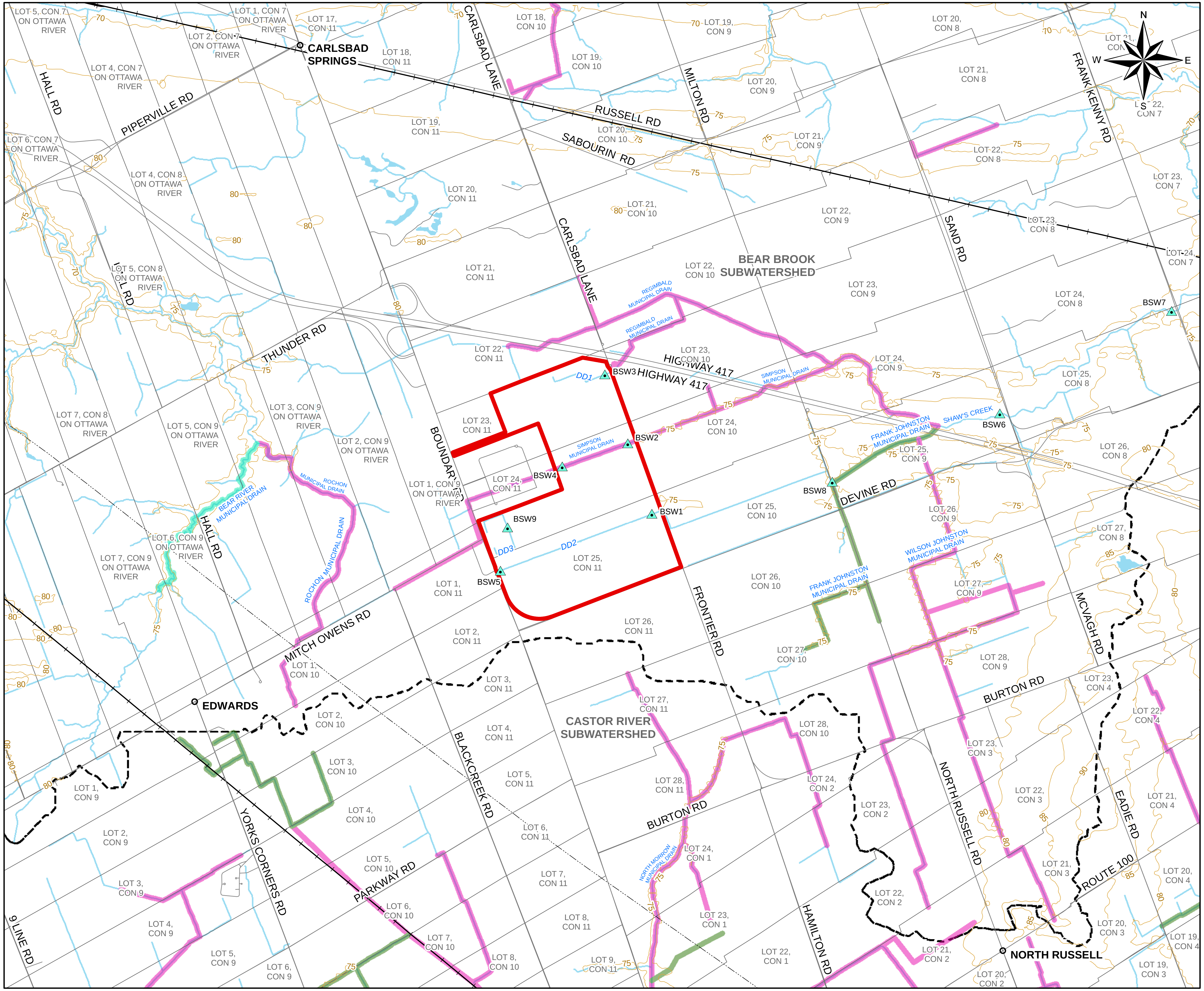

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LEGEND

- ○ POPULATED PLACENAME
- ▲ SURFACE WATER SAMPLING LOCATION
- — ROAD
- —+— RAIL ROAD
- — CONTOUR LINE, (5m)
- -·-·- UTILITY LINE
- 🟩 MUNICIPAL DRAIN, CLASS B
- 🟪 MUNICIPAL DRAIN, CLASS F
- 🟩 MUNICIPAL DRAIN, NO CLASSIFICATION
- — SURFACE WATER FEATURE
- 🟦 WATER AREA
- ⬚ SUBWATERSHED DIVIDE
- ☐ LOT/CONCESSION
- 🟥 PROPERTY BOUNDARY

600 300 0 600

SCALE 1:30,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

MUNICIPAL DRAIN CLASSIFICATIONS PROVIDED BY DEPARTMENT OF FISHERIES AND OCEANS (DFO).
LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

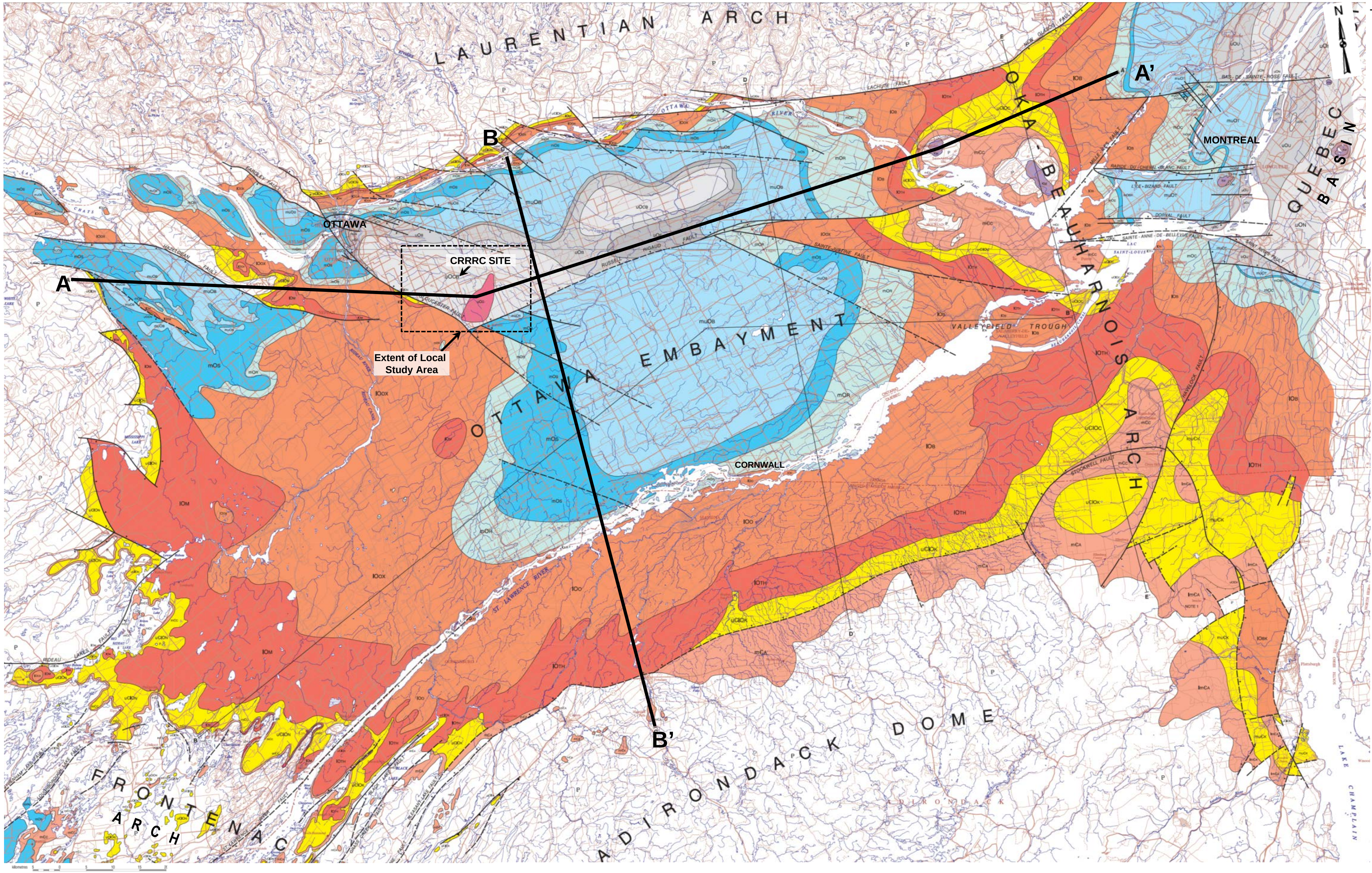
CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

SURFACE WATER MONITORING LOCATIONS
AND CONSTRUCTED SURFACE WATER FEATURES

Golder Associates

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	DEC. 2013	FIGURE 2-2	
GIS	BR	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		



LEGEND

MESOZOIC
LOWER CRETACEOUS

KM	*Monteregian intrusives*

PALEOZOIC
ORDOVICIAN

OM	*Metamorphosed shale, siltstone, sandstone, and limestone*

UPPER ORDOVICIAN

uOQ	*Queenston and Russell formations: red shale, interbedded grey shale and dolostone*
uOCB	*Carlsbad Formation: grey and blue-grey shale*
uON	*Nicolet Formation: grey shale*
uOB	*Billings Formation: black shale*
uOU	*Utica Shale: dark grey to black shale*
uOE	*Eastview Formation: black petroliferous limestone*

MIDDLE AND UPPER ORDOVICIAN

muOB	*Bobcaygeon, Verulam, and Lindsay formations (Trenton Group equivalent)*
muOT	*Trenton Group: brown and grey limestone and minor shale*

MIDDLE ORDOVICIAN

mOS	*Shadow Lake and Gull River formations (Black River Group equivalent)*
mOBR	*Black River Group: dove-grey limestone, dolostone, and minor shale*
mOR	*Rockcliffe and St. Martin formations (Chazy Group equivalent)*
mOC	*Chazy Group: grey-green shale, siltstone, sandstone, and grey shaly limestone*

LOWER ORDOVICIAN

lOOX	*Oxford Formation: dark grey to brown dolostone and dolomitic limestone, minor sandstone interbeds*
lOO	*Ogdensburg Formation: dark grey to brown dolostone and dolomitic limestone, minor sandstone interbeds*
lOB	*Beauharnois Formation: dark grey to brown dolostone and dolomitic limestone, minor sandstone interbeds*
lOBK	*Beekmantown Group: dark grey to brown dolostone and dolomitic limestone, minor sandstone interbeds*
lOM	*March Formation: medium to dark grey dolostone and dolomitic limestone with interbeds of light grey to white sandstone*
lOTH	*Theresa Formation: medium to dark grey dolostone and dolomitic limestone with interbeds of light grey to white sandstone*

MIDDLE AND UPPER CAMBRIAN AND LOWER ORDOVICIAN

u€lON	*Nepean Formation: light grey to white sandstone (quartz arenite)*
u€lOC	*Cairnside Formation: light grey to white sandstone (quartz arenite)*
u€lOK mu€K	*Keeseville Formation: light grey to white sandstone (quartz arenite)*

LOWER AND MIDDLE CAMBRIAN

m€C	*Covey Hill Formation: red, salmon-pink to light grey sandstone, and red, pink, to grey feldspathic conglomerate*
m€A lm€A	*Ausable Formation: red, salmon-pink to light grey sandstone, and red, pink, to grey feldspathic conglomerate, and minor carbonate*

PRECAMBRIAN
UPPER PROTEROZOIC

uPA	*Abbey Dawn Formation: light to dark grey quartzite-cobble and -boulder conglomerate*

PROTEROZOIC, undivided

P	*Basement rocks to Central Division of St. Lawrence Platform*

Geological boundary (defined and approximate)

Normal fault (defined, approximate; solid circles indicate downthrown side)

Uncertain fault (defined, approximate)

Thrust fault

Approximate outcrop distribution of the Jericho Member of the Ausable Formation in northeastern New York State NOTE 1

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

FROM SANFORD, B.V. AND RWC ARNOT. 2010. STRATIGRAPHIC AND STRUCTURAL FRAMEWORK OF THE POTSDAM GROUP IN EASTERN ONTARIO, WESTERN QUEBEC AND NORTHERN NEW YORK STATE. GEOLOGICAL SURVEY OF CANADA BULLETIN 597, 1:250,000 SCALE, 83 PP. OTTAWA: GSC.

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

REGIONAL BEDROCK GEOLOGY

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV 2013	FIGURE 3-1	
GIS	NB	15 NOV 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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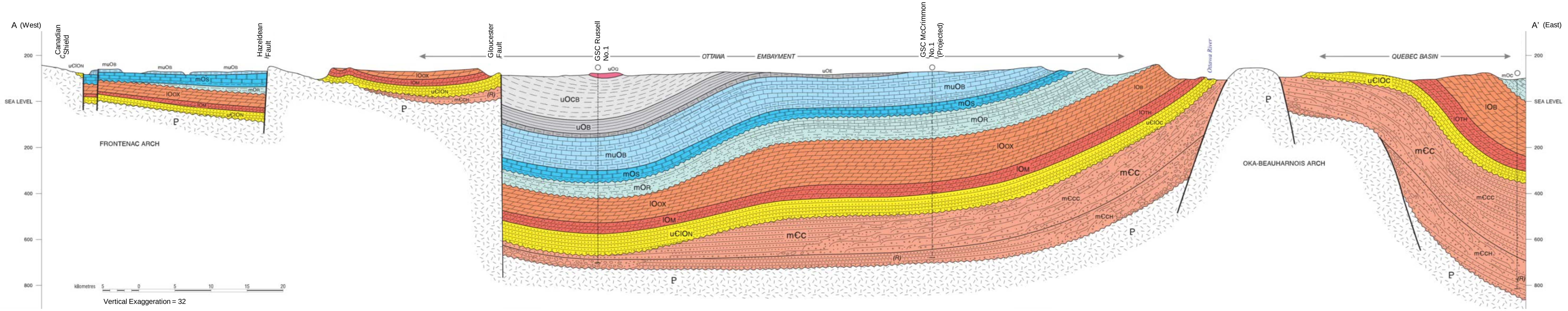


LEGEND

UPPER ORDOVICIAN

uOQ	*Queenston Formation*
uOCB	*Carlsbad Formation*
uOB	*Billings Formation*
uOE	*Eastview Formation*

MIDDLE AND UPPER ORDOVICIAN

muOB	*Bobcaygeon, Verulam, and Lindsay formations (Trenton Group equivalent)*

MIDDLE ORDOVICIAN

mOS	*Shadow Lake and Gull River formations (Black River Group equivalent)*
mOR	*Rockcliffe and St. Martin formations (Chazy Group equivalent)*
mOC	*Chazy Group*

LOWER ORDOVICIAN

lOOX	*Oxford Formation*
lOO	*Ogdensburg Formation*
lOB	*Beauharnois Formation*
lOM	*March Formation*
lOTH	*Theresa Formation*

MIDDLE AND UPPER CAMBRIAN AND LOWER ORDOVICIAN

uЄlON	*Nepean Formation*
uЄlOC	*Cairnside Formation*
uЄlOK muЄK	*Keeseville Formation*

MIDDLE CAMBRIAN

Covey Hill Formation (mЄC)

mЄCE	*Edwardsville Member*
mЄCC	*Chippewa Bay Member*
mЄCH	*Hannawa Falls Member*

Ausable Formation (mЄA)

mЄAE	*Edwardsville Member*
mЄAC	*Chippewa Bay Member*
mЄAH	*Hannawa Falls Member*

PRECAMBRIAN

PROTEROZOIC, undivided

P	*Basement rocks to Central Division of St. Lawrence Platform*

Grey and red (R) shale

Black shale

Shale/sandstone interbedded

Petroliferous limestone

Grey to brown limestone, and argillaceous limestone

Dove-grey lithographic limestone

Grey and brown interbedded dolostone and sandstone

Grey and brown dolostone

Grey, white, pink, and red (R) sandstone

Grey, pink, and red (R) quartz-pebble conglomerate

Grey, pink, and red (R) quartz-fledspar-pebble conglomerate
(symbol denotes probable direction of fluvial transport)

Grey, pink, and red (R) quartz-feldspar-cobble and -boulder conglomerate

Igneous and metamorphic rocks, undivided

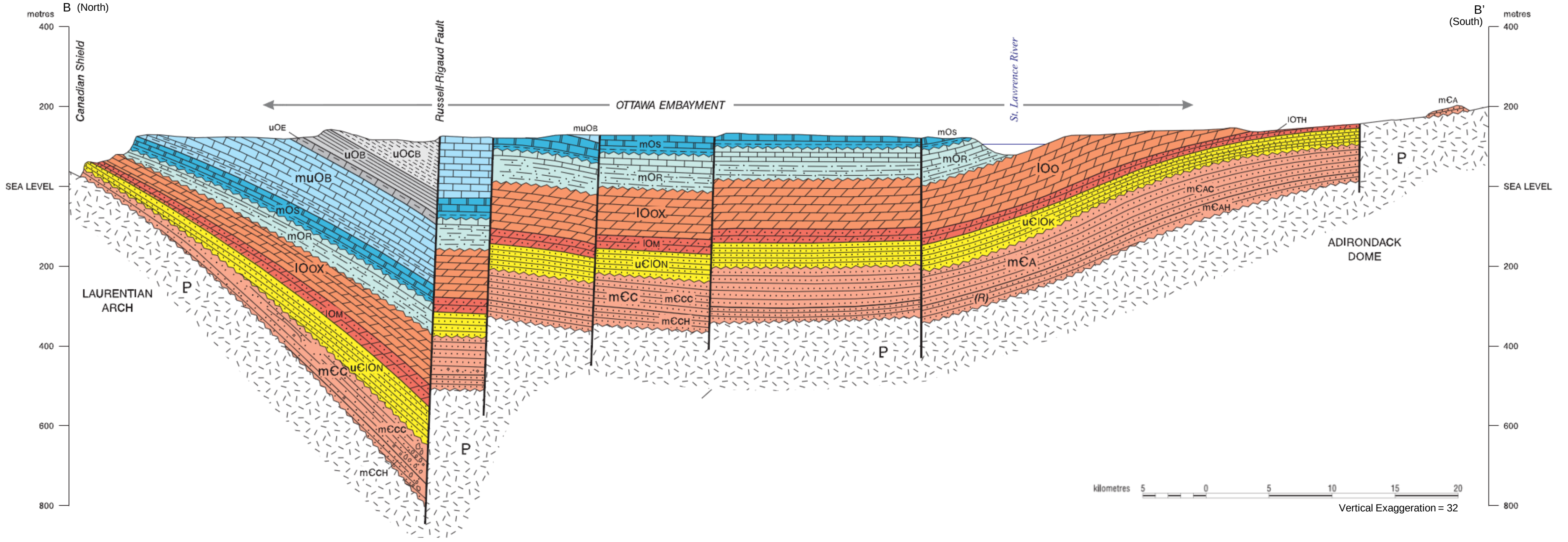
Geological boundary ....

Unconformity ....

Fault ....

Borehole information .... ○ ------------┤

Borehole information (projected). .... ○ – – – – – –┤



NOTE

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REFERENCE

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PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

REGIONAL BEDROCK GEOLOGY
CROSS-SECTIONS A-A' AND B-B'

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013	FIGURE 3-2	
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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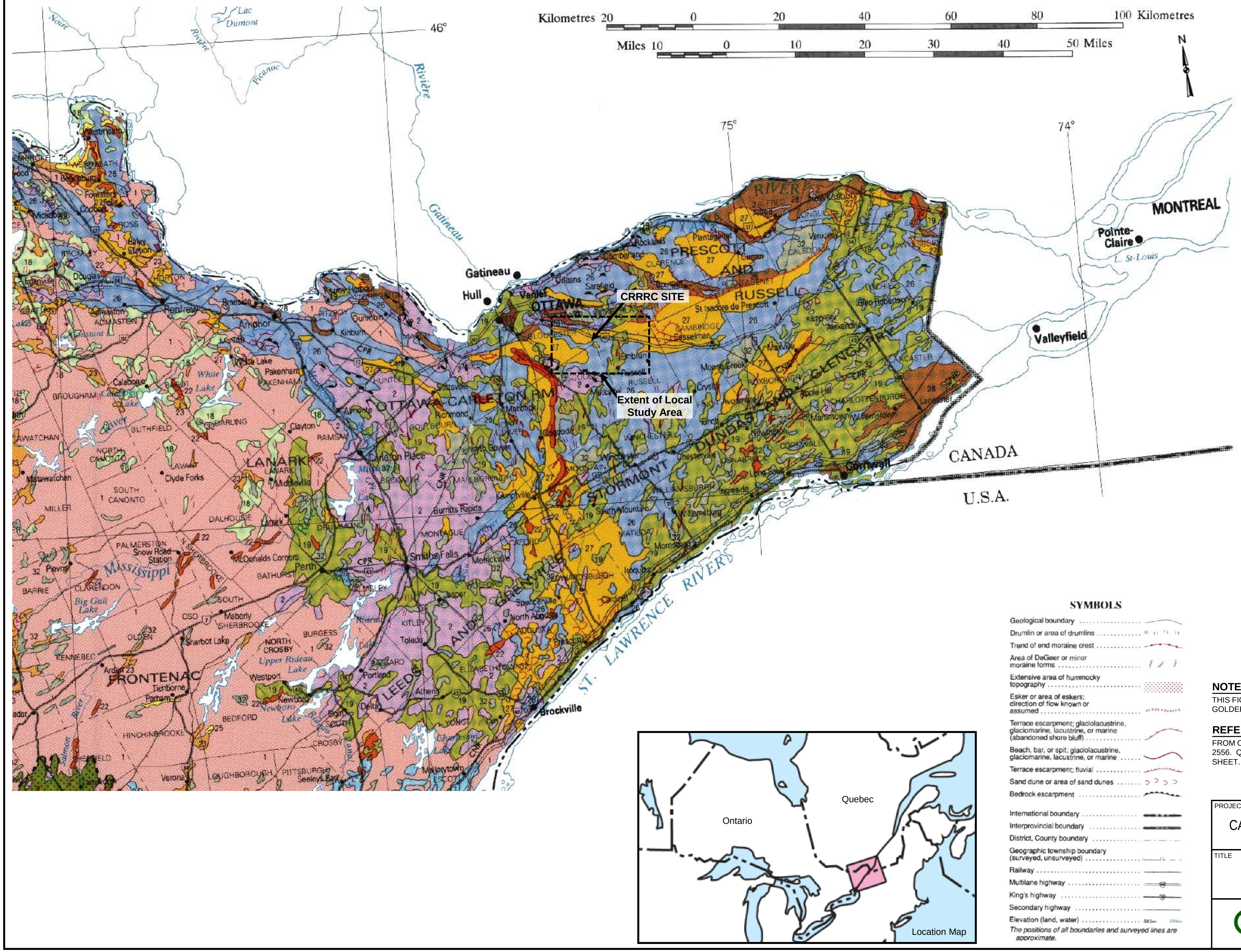

SYMBOLS

Geological boundary
Drumlin or area of drumlins
Trend of end moraine crest
Area of DeGeer or minor moraine forms
Extensive area of hummocky topography
Esker or area of eskers; direction of flow known or assumed
Terrace escarpment; glaciolacustrine, glaciomarine, lacustrine, or marine (abandoned shore bluff)
Beach, bar, or spit; glaciolacustrine, glaciomarine, lacustrine, or marine
Terrace escarpment; fluvial
Sand dune or area of sand dunes
Bedrock escarpment

International boundary
Interprovincial boundary
District, County boundary
Geographic township boundary (surveyed, unsurveyed)
Railway
Multilane highway
King's highway
Secondary highway
Elevation (land, water) 585m 184m

The positions of all boundaries and surveyed lines are approximate.

LEGEND

PHANEROZOIC
CENOZOIC
QUATERNARY
RECENT

32	**Organic deposits:** peat, muck and marl
31	**Fluvial deposits:** gravel, sand, silt and clay; deposited on modern flood plains
30	**Lacustrine deposits:** sand, gravelly sand and gravel; nearshore and beach deposits
29	**Lacustrine deposits:** silt and clay; basin or quiet water deposits

PLEISTOCENE

28	**Fluvial deposits:** gravel, sand, silt and clay; deposited on abandoned flood plains, terrace remnants
27	**Glaciomarine and marine deposits:** sand, gravelly sand and gravel; nearshore and beach deposits
26	**Glaciomarine and marine deposits:** silt and clay; basin and quiet water deposits
25	**Glaciolacustrine deposits:** sand, gravelly sand and gravel; nearshore and beach deposits
24	**Glaciolacustrine deposits:** silt and clay, minor sand; basin and quiet water deposits
23	**Glaciofluvial outwash deposits:** gravel and sand; includes proglacial river and del-
19	**Till:** undifferentiated, predominantly sandy silt to silt matrix, commonly rich in clasts, often high in total matrix carbonate content
18	**Till:** undifferentiated, predominantly sand to silty sand matrix, high content of clasts, often low in matrix carbonate content

PALEOZOIC

2	**Bedrock:** undifferentiated carbonate and clastic sedimentary rock, exposed at surface or covered by a discontinuous, thin layer of drift

PRECAMBRIAN

1	**Bedrock:** undifferentiated igneous and metamorphic rock, exposed at surface or covered by a discontinuous, thin layer of drift

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

FROM ONTARIO MINISTRY OF NORTHERN DEVELOPMENT AND MINES. MAP 2556. QUARTERNARY GEOLOGY OF SOUTHERN ONTARIO – SOUTHERN SHEET. 1991. © QUEEN'S PRINTER.

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
REGIONAL SURFICIAL GEOLOGY

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013		
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Golder Associates
Ottawa, Ontario

FIGURE 3-3

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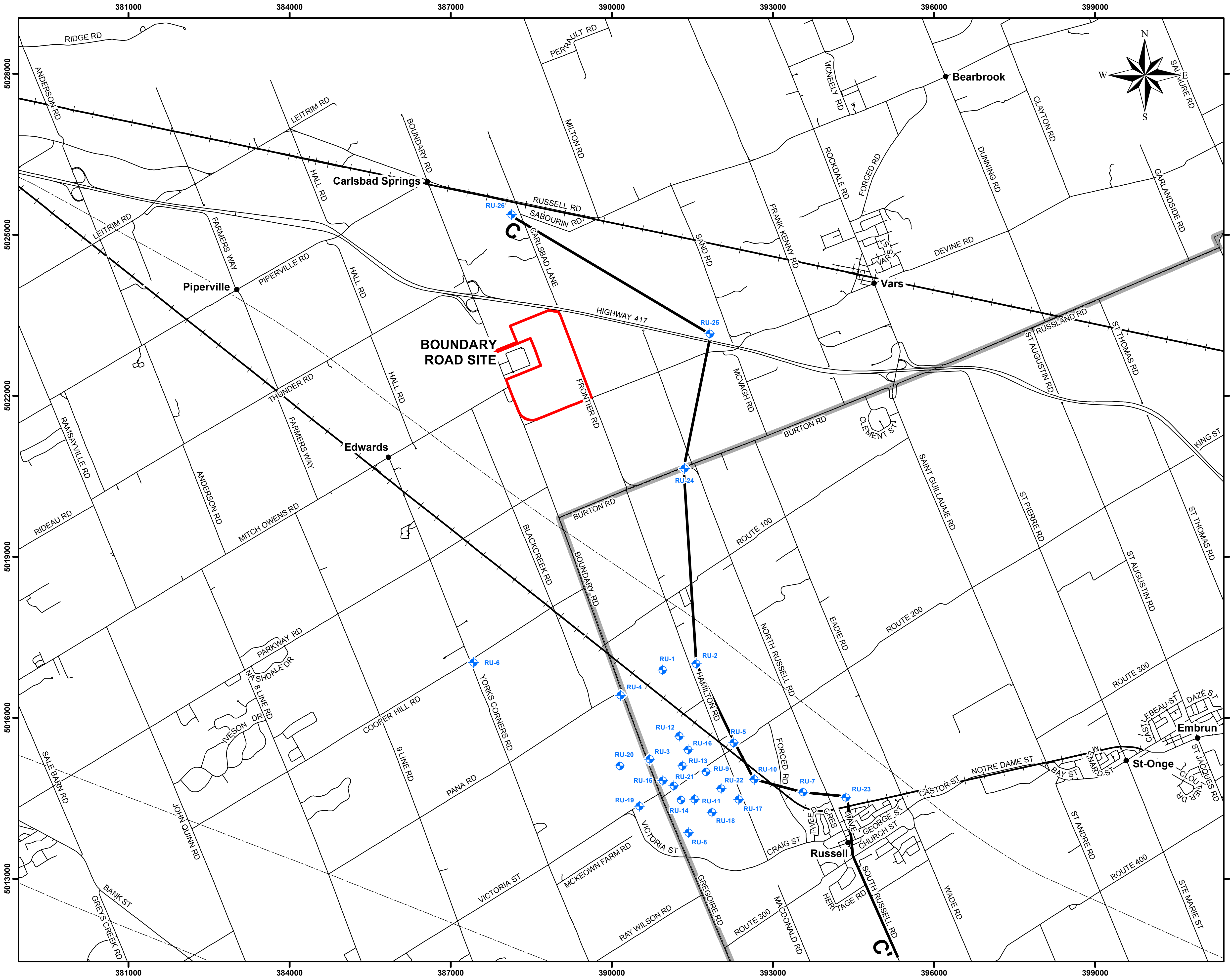

LEGEND

DEEP GAS EXPLORATION WELL LOCATION
POPULATED PLACE NAME
CROSS-SECTION C-C'
ROADWAY
RAIL
UTILITY
TOWNSHIP OF RUSSELL BOUNDARY
CITY OF OTTAWA BOUNDARY

1 0.5 0 1 2 3
SCALE 1:70,000 KILOMETRES

NOTE

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REFERENCE

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PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9

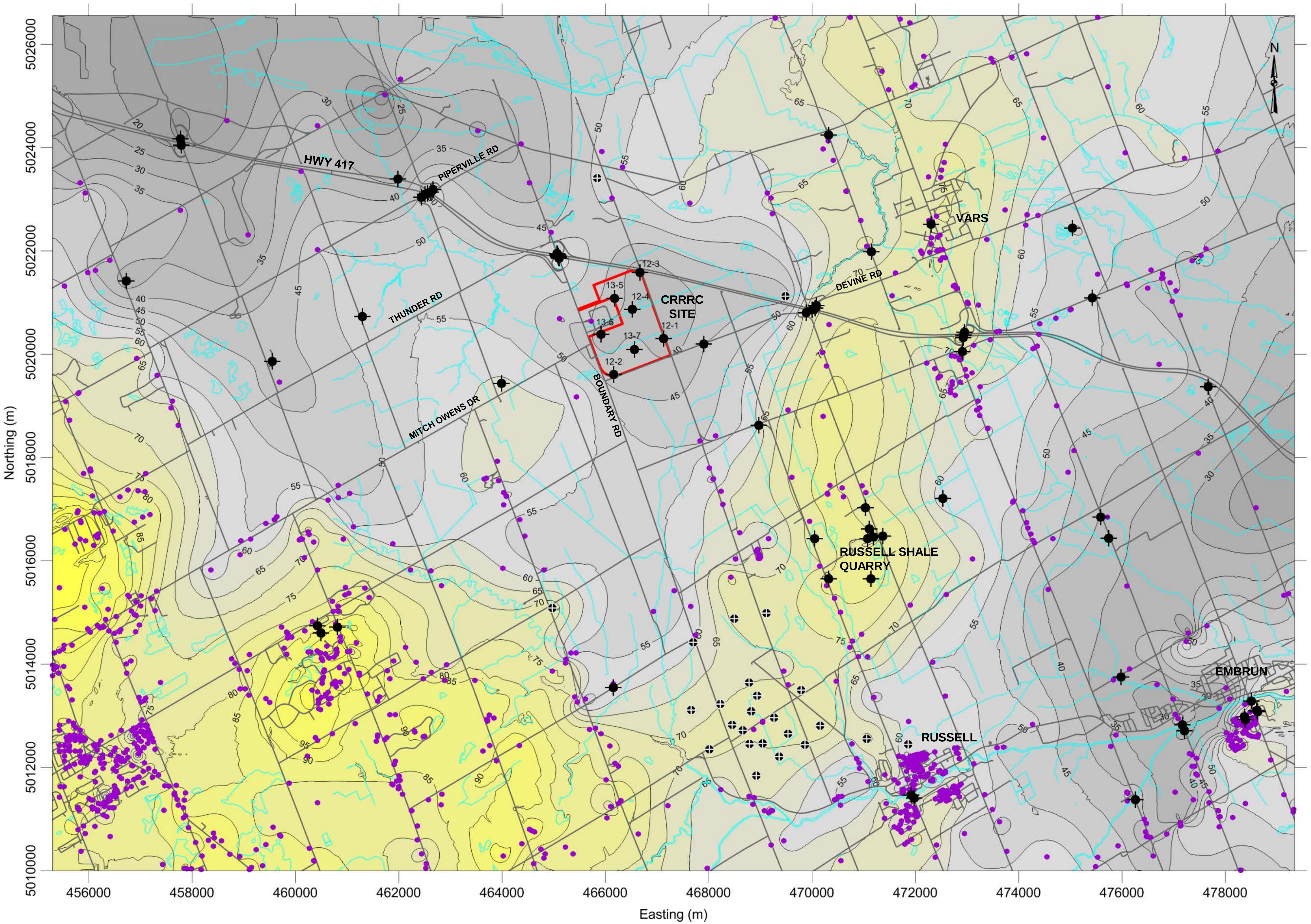
PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
GAS EXPLORATION WELL LOCATIONS

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	PLE	DEC. 2013	**FIGURE 3-4**	
GIS	BR	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Reporting\Phase4000\GHandG\1211250045-4000-3-4-GasExplorationWellLocations.mxd



LEGEND

- ✚ CORED BOREHOLE LOCATION
- ● WATER WELL LOCATION
- ⊕ OIL AND GAS EXPLORATION WELL LOCATION

- WATERBODIES
- ROADS
- PROPERTY BOUNDARY

BEDROCK SURFACE COLOUR SCALE
(mASL)

105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5

1000 0 1000
METRES
SCALE 1:85,000 (APPROX.)

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
ELEVATION CONTOUR INTERVAL = 5m
CONTOUR DATUM IS mASL

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010)

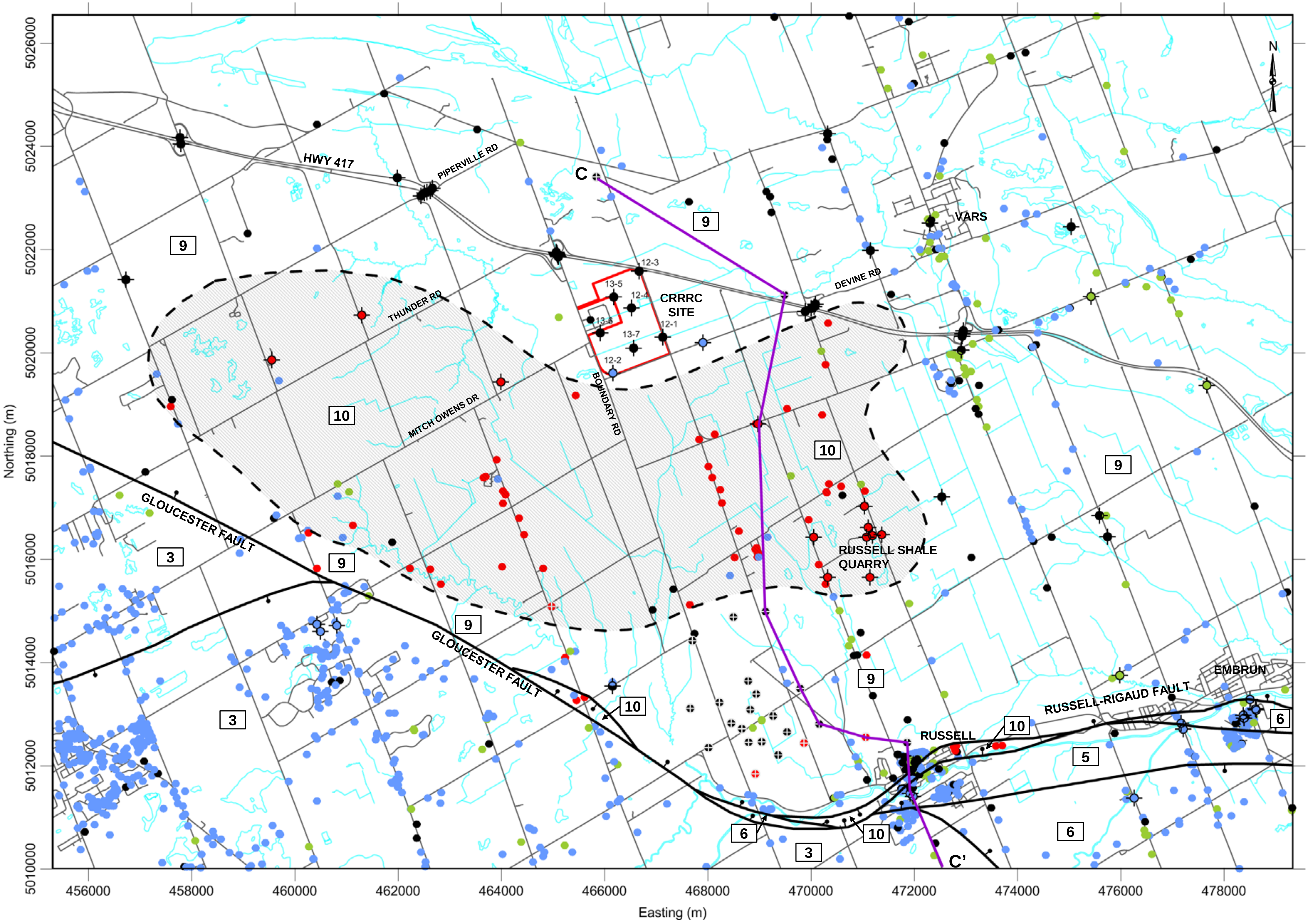
PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
LOCAL BEDROCK SURFACE ELEVATION MAP

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013	FIGURE 3-5	
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

N:\Active\2012\1125 - Environmental and Civil Engineering\12-1125-0045 CRRRC EA Eastern ON\Phase 4000_EA_Documentation\Vol 3 - G H&G\Geology Figures\ppt



LEGEND

UPPERMOST BEDROCK FORMATION DESCRIPTION:

🟥	RED BEDROCK (ALL FORMATIONS)
⬛	GREY OR BLACK SHALE
🟦	LIMESTONE (ALL COLOURS)
🟩	OTHER DESCRIPTIONS
—	WATERBODIES
—	ROADS
┴	INTERPRETED FAULT – DOWNTHROWN SIDE INDICATED BY STICK AND BALL
- - -	STRATIGRAPHIC CONTACT
▨	INTERPRETED EXTENT OF QUEENSTON FORMATION
—	PROPERTY BOUNDARY
⊕	CORED BOREHOLE LOCATION
●	WATER WELL LOCATION
⊕	OIL AND GAS EXPLORATION WELL LOCATION
—	CROSS-SECTION C-C' (FIGURE 3-7)

STRATIGRAPHY

10	QUEENSTON FORMATION RED SHALE AND MUDSTONE
9	CARLSBAD/BILLINGS FORMATION DARK GREY SHALE, MINOR LIMESTONE
6	BOBCAYGEON FORMATION BROWNISH GREY CRYSTALLINE LIMESTONE
5	GULL RIVER FORMATION LIGHT GREY VERY FINE GRAINED LIMESTONE
3	OXFORD/MARCH FORMATION GREY DOLOSTONE

1000 0 1000

METRES

SCALE 1:85,000 (APPROX.)

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010)

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

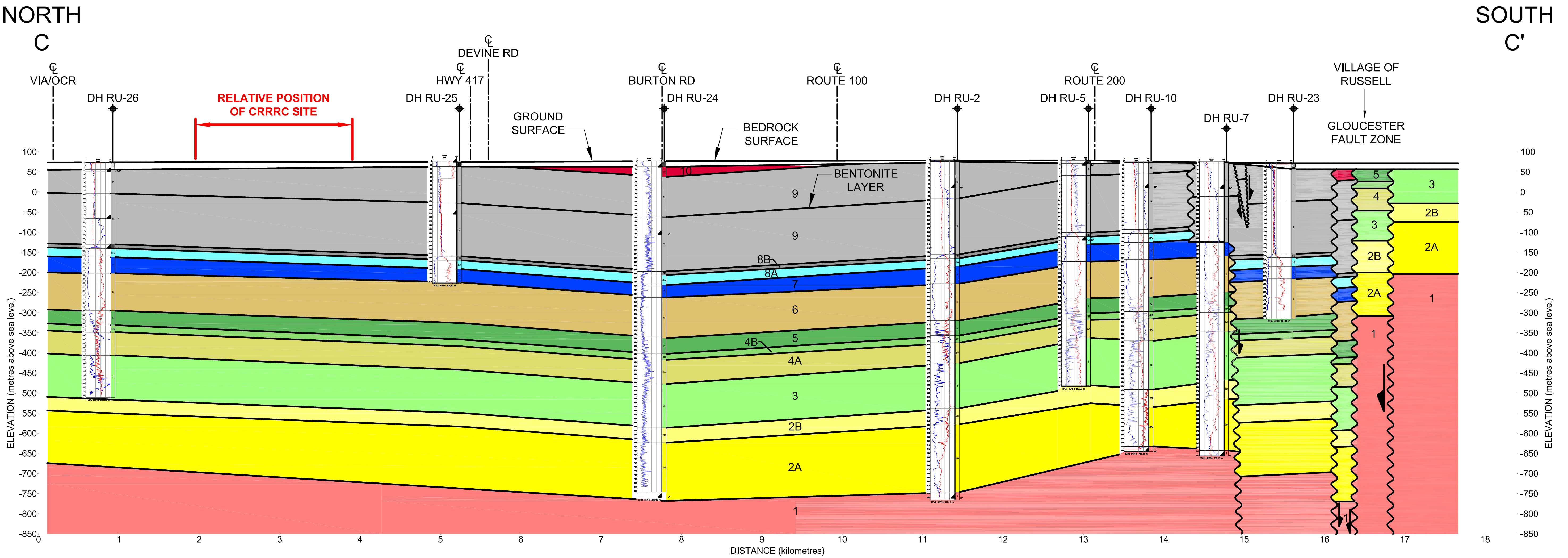
INTERPRETED LOCAL BEDROCK GEOLOGY MAP

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013		
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

FIGURE 3-6

N:\Active\2012\1125 - Environmental and Civil Engineering\12-1125-0045 CRRRC EA Eastern ON\Phase 4000_EA_Documentation\Vol 3 - G H&G\Geology Figures\ppt



BOREHOLE GEOPHYSICAL RECORDS

NATURAL GAMMA LOG

NEUTRON LOG

DEPTH OF DRILL CASING

HORIZONTAL

1600 0 1600 3200

SCALE 1:50000 METRES

VERTICAL

320 0 320 640

SCALE 1:10000 METRES

NOTE:
VERTICAL SCALE EXAGGERATED 5 TIMES THE
HORIZONTAL SCALE FOR PRESENTATION PURPOSES

BEDROCK GEOLOGY

10 QUEENSTON FORMATION

Dark reddish brown calcareous mudstone with interbeds of greenish grey siltstone and mudstone.

9 CARLSBAD/BILLINGS FORMATIONS

Dark grey shale interbedded with micritic limestone interbeds (Carlsbad Fm) grading down to dark grey to dark brownish black bituminous shale with minor laminations to very thin interbeds of calcareous siltstone and dolomitic limestone (Billings Fm).

8B UPPER LINDSAY FORMATION (EASTVIEW MEMBER)

Interbedded dark brownish black bituminous shale and dark brownish grey nodular micritic limestone.

8A LOWER LINDSAY FORMATION

Medium to dark brownish grey thickly bedded micritic to calcarenitic nodular limestone.

7 VERULAM FORMATION

Medium brownish grey thinly to medium bedded shaley calcarenitic limestone with interbeds of nodular limestone, minor thin lithoclastic calcarenite limestone beds and numerous dark grey to black very thin to thinly interbeds shale.

6 BOBCAYGEON FORMATION

Light to medium brownish grey, medium to thickly bedded calcarenitic limestone and interbedded units of argillaceous nodular limestone and shaley limestone.

5 GULL RIVER FORMATION

Medium grey, micritic to lithographic limestone, argillaceous to calcareous dolostone and medium to very thickly bedded dolostone, minor interbedded black shale, shaley dolostone, dolomitic siltstone and partly bioturbated quartz sandstone.

4B UPPER ROCKCLIFFE FORMATION

Interbedded sequence composed of medium to thick beds of dolostone and calcareous dolostone, dark grey to black shale, medium grey, argillaceous limestone, minor light grey, calcareous cemented quartz sandstone.

4A LOWER ROCKCLIFFE FORMATION

Light whitish grey, laminar textured to rippled and cross bedded, thin to thick bedded silica cemented quartz sandstone, minor interbeds of shale.

3 OXFORD/MARCH FORMATIONS

Fine grained, micritic dolostone, calcareous dolostone, argillaceous nodular dolostone, subordinate beds lithoclastic dolostone, dark grey to black shale laminations in upper half (Oxford Fm), grading down to sandy dolostone to dolomitic sandstone and carbonate cemented quartz sandstone.

2 NEPEAN FORMATION

Light grey, laminar to cross bedded, silica cemented quartz sandstone. Includes widely spaced interbeds of grey shale and shaley siltstone with individual beds of quartz pebbles and cobbles set in a coarse grained quartz sandstone matrix. 2A Golder pick for top contact of Nepean Fm marking transition into silica sandstone sequence, 2B MNR Well Card pick for top of Nepean Fm (possible dolomitic sandstone of March Fm). Includes un-subdivided Covey Hill Fm sandstone and conglomerate at base if present.

1 PRECAMBRIAN BASEMENT

Quartz feldspar biotite gneiss or dolomitic marble typically weathered near the unconformable surface with either the overlying Covey Hill Formation quartz pebble cobble conglomerate or the Nepean Formation sandstone.

LEGEND

✦ BOREHOLE LOCATION

NOTES

1. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
2. FOR LOCATION OF SECTION C-C' SEE FIGURE 3-6
3. FOR DETAILS OF BOREHOLE GEOPHYSICAL RECORDS SEE FIGURES A1 to A3 IN APPENDIX A

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW
△						

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

LOCAL STRUCTURAL GEOLOGIC CROSS-SECTION C-C'

Golder Associates
Ottawa, Ontario, Canada

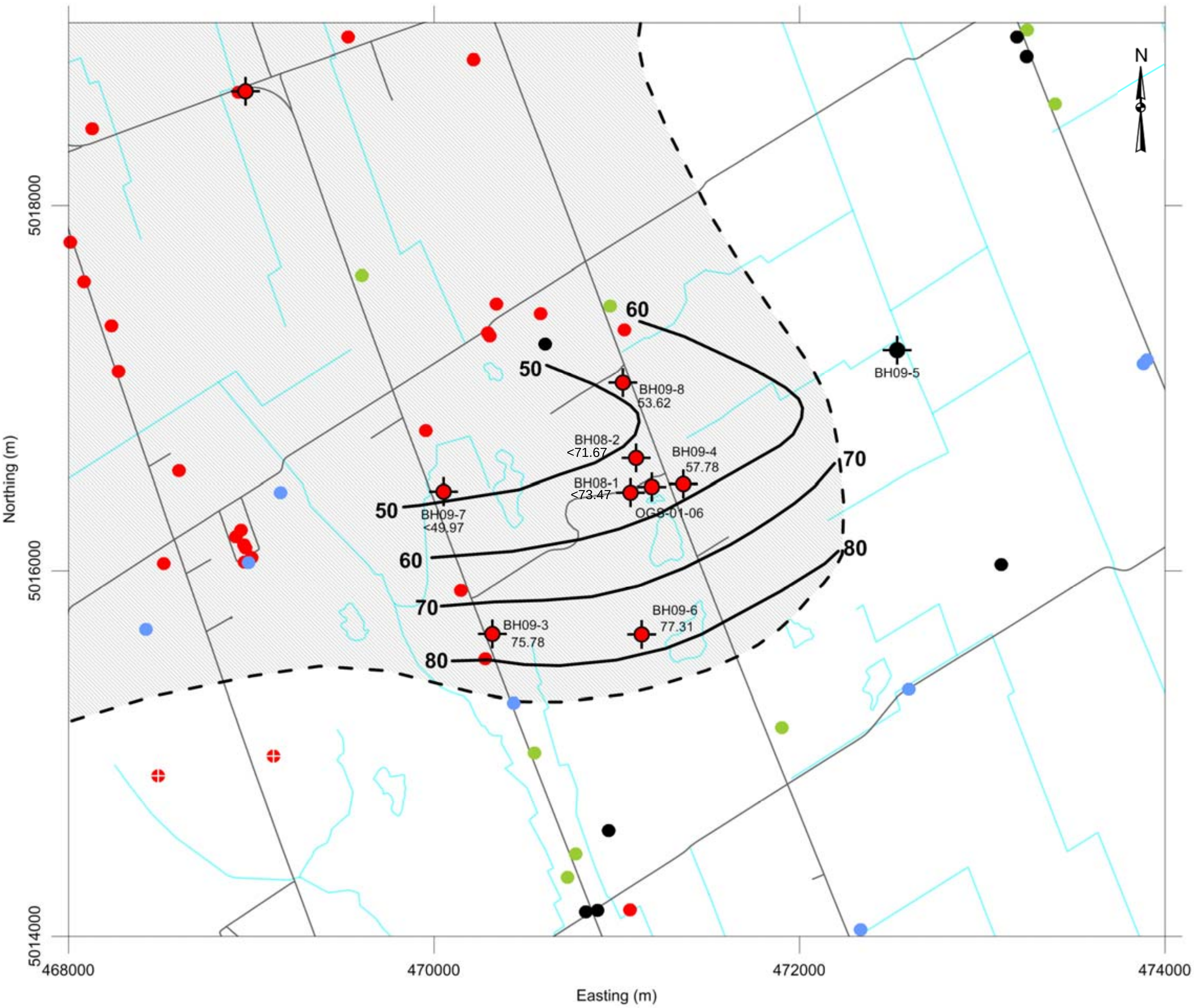
PROJECT No.		12-1125-0045
DESIGN	JPAO	Sept. 2013
CAD	JM/JFC	Feb. 2014
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

FILE No. 1211250045-4000-3-7.dwg

SCALE AS SHOWN REV.

FIGURE 3-7

PLOT DATE: June 26, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase 4000\1211250045-4000-3-7.dwg



LEGEND

UPPERMOST BEDROCK FORMATION DESCRIPTION:

⌖ ● ⊕	RED BEDROCK (ALL FORMATIONS)
⌖ ● ⊕	GREY OR BLACK SHALE
⌖ ● ⊕	LIMESTONE (ALL COLOURS)
⌖ ● ⊕	OTHER DESCRIPTIONS
—	WATERBODIES
—	ROADS
⌖ BH09-3 75.78	BOREHOLE LOCATION AND ELEVATION OF QUEENSTON-CARLSBAD CONTACT (mASL) AT RUSSELL QUARRY

- -	STRATIGRAPHIC CONTACT
▨	INTERPRETED EXTENT OF QUEENSTON FORMATION
—	PROPERTY BOUNDARY
⌖	CORED BOREHOLE LOCATION
●	WATER WELL LOCATION
⊕	OIL AND GAS EXPLORATION WELL LOCATION
—	INTERPRETED CONTOUR OF QUEENSTON-CARLSBAD CONTACT (mASL)

500 0 500

METRES

SCALE 1:17,000 (APPROX.)

NOTES

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING REPORT
THE LOCATION OF OGS-01-06 IS SUSPECT AND THERE IS NO ELEVATION DATA AVAILABLE FOR THIS BOREHOLE

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2011. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

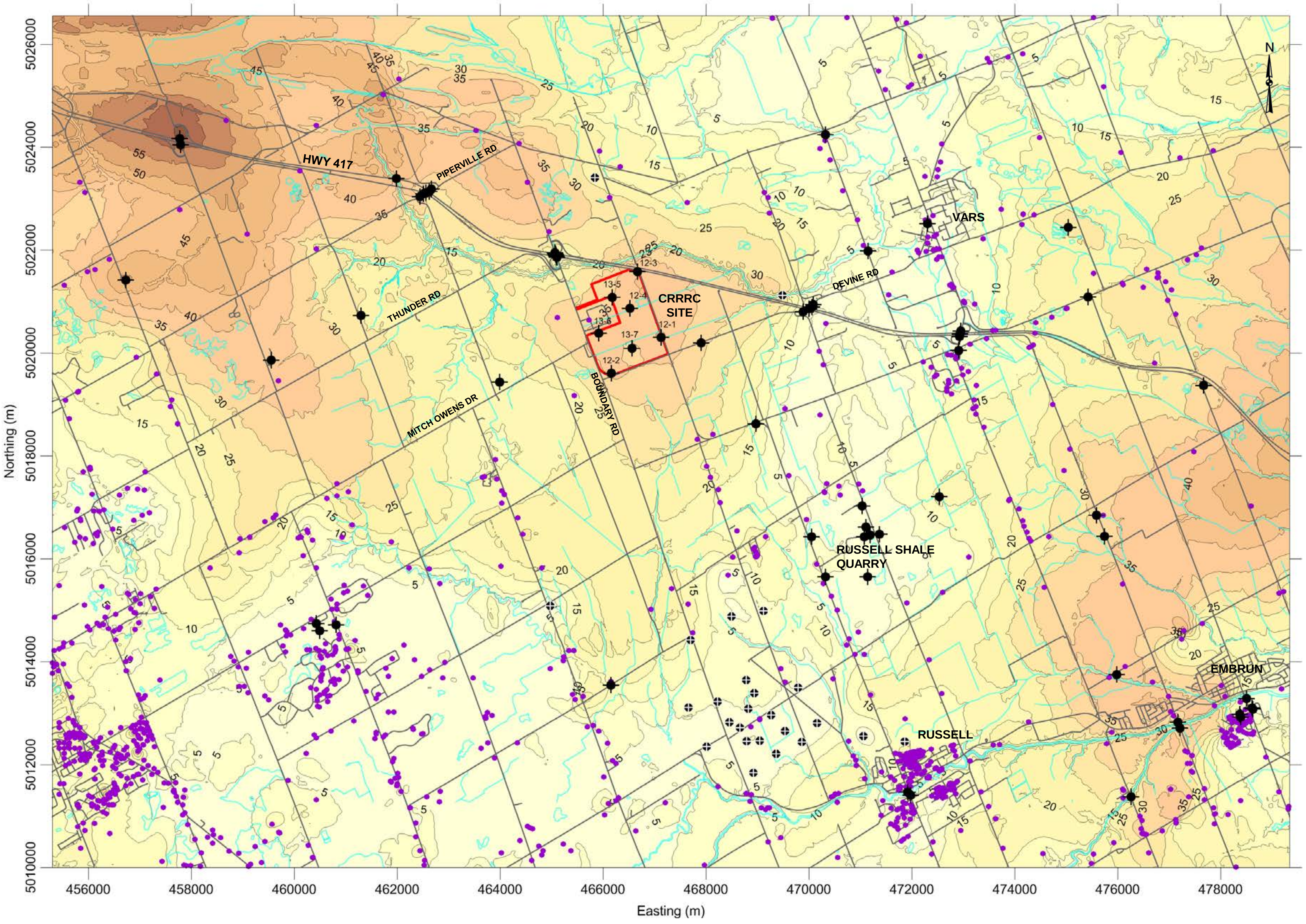
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

ELEVATION OF QUEENSTON FORMATION
BASAL CONTACT AT RUSSELL QUARRY

Golder Associates

PROJECT No. 12-1125-0045		PHASE No. 4500	
DESIGN	NB	16 JAN. 2014	SCALE AS SHOWN	REV.0
GIS	--	--	
CHECK	PLE	AUG. 2014	FIGURE 3-8
REVIEW	PAS	AUG. 2014	



LEGEND

- ✚ CORED BOREHOLE LOCATION
- ● WATER WELL LOCATION
- ⊕ OIL AND GAS EXPLORATION WELL LOCATION

- WATERBODIES
- ROADS
- PROPERTY BOUNDARY

OVERBURDEN THICKNESS COLOUR SCALE
(m)

75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

1000 0 1000
METRES
SCALE 1:85,000 (APPROX.)

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
ELEVATION CONTOUR INTERVAL = 5m

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010)

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
LOCAL OVERBURDEN
THICKNESS MAP

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013	FIGURE 3-9	
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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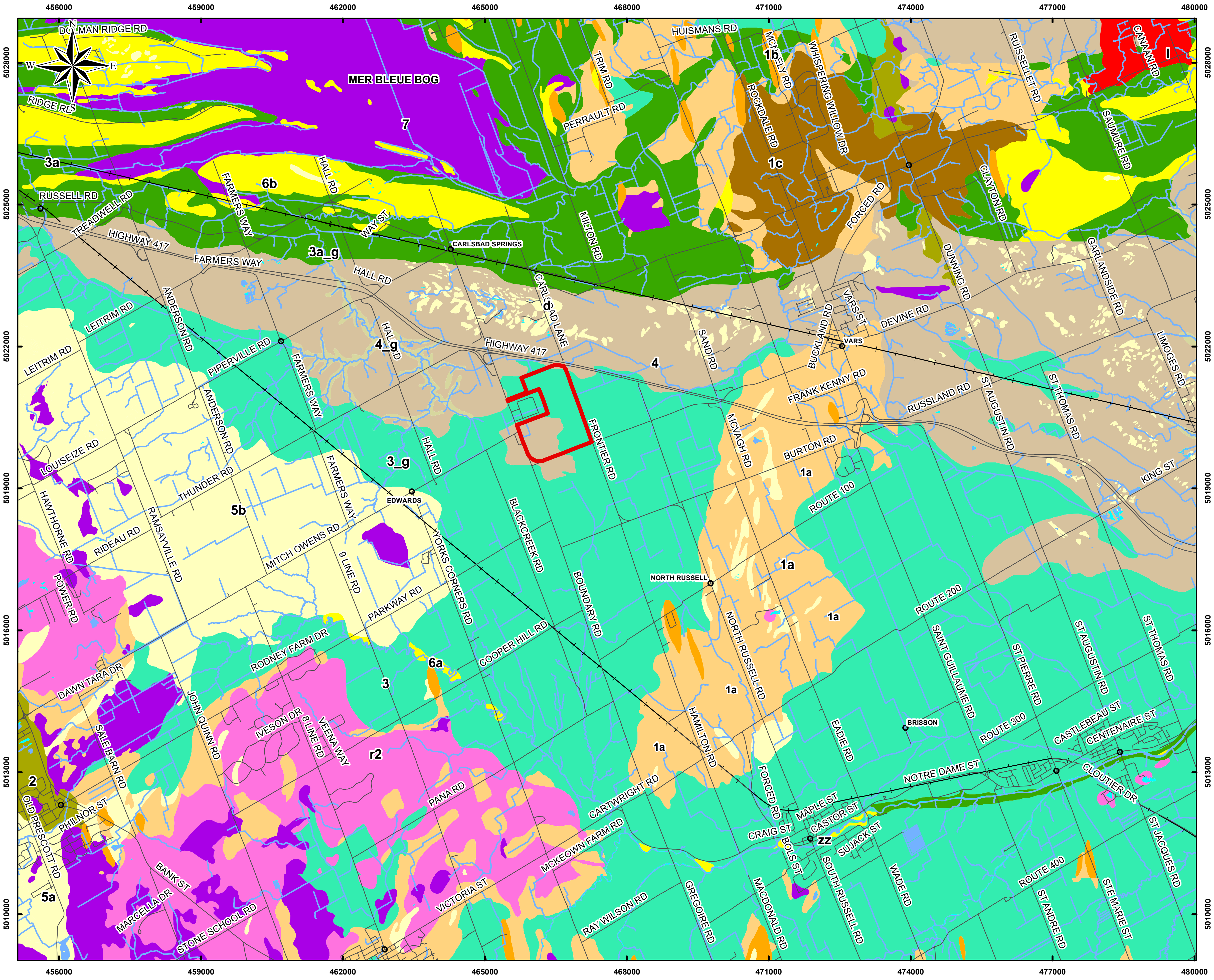

LEGEND

○ POPULATED PLACENAME

— ROAD

—+— RAILWAY

— SURFACE WATER FEATURE

▭ PROPERTY BOUNDARY

SURFICIAL GEOLOGY

1a	TILL, PLAIN WITH LOCAL RELIEF <5m
1b	TILL, DRUMLINIZED
1c	TILL, HUMMOCKY TO ROLLING WITH LOCAL RELIEF 5 TO 10 m
2	ICE CONTACT STRATIFIED DRIFT: GRAVEL & SAND
3	OFFSHORE MARINE DEPOSITS: CLAY, SILTY CLAY & SILT
3_g	OFFSHORE MARINE DEPOSITS: CLAY, SILTY CLAY & SILT (GULLIES & RAVINES)
3a	OFFSHORE MARINE DEPOSITS: CLAY & SILT UNDERLYING EROSIONAL TERRACES
3a_g	OFFSHORE MARINE DEPOSITS: CLAY & SILT UNDERLYING EROSIONAL TERRACES (GULLIES & RAVINES)
4	DELTAIC AND ESTUARY DEPOSITS: MEDIUM TO FINE GRAINED SAND
4_g	DELTAIC AND ESTUARY DEPOSITS: MEDIUM TO FINE GRAINED SAND (GULLIES & RAVINES)
5a	NEARSHORE SEDIMENTS: GRAVEL, SAND & BOULDERS
5b	NEARSHORE SEDIMENTS: FINE TO MEDIUM GRAINED SAND
6a	ALLUVIAL DEPOSITS: SILTY SAND, SILT, SAND & CLAY
6a_g	ALLUVIAL DEPOSITS: SILTY SAND, SILT, SAND & CLAY (GULLIES & RAVINES)
6b	ALLUVIAL DEPOSITS: MEDIUM GRAINED STRATIFIED SAND WITH SOME SILT
6b_g	ALLUVIAL DEPOSITS: MEDIUM GRAINED STRATIFIED SAND WITH SOME SILT (GULLIES & RAVINES)
7	ORGANIC DEPOSITS: MUCK & PEAT
d	DUNE
d_g	DUNE (GULLIES & RAVINES)
l	LANDSLIDE AREA
l_g	LANDSLIDE AREA (GULLIES & RAVINES)
r1	BEDROCK: INTRUSIVE & METAMORPHIC
r2	BEDROCK: LIMESTONE, DOLOMITE, SANDSTONE & LOCAL SHALE
r2_g	BEDROCK: LIMESTONE, DOLOMITE, SANDSTONE & LOCAL SHALE (GULLIES & RAVINES)

2,000 1,000 0 2,000

SCALE 1:80,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

BELANGER, J. R., URBAN GEOLOGY OF THE NATIONAL CAPITAL AREA. GEOLOGICAL SURVEY OF CANADA, OPEN FILE D3256, 2001 © QUEEN'S PRINTER OF ONTARIO.
LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT
CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE
LOCAL SURFICIAL GEOLOGY

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	DEC. 2013	**FIGURE 3-10**	
GIS	BR/PM	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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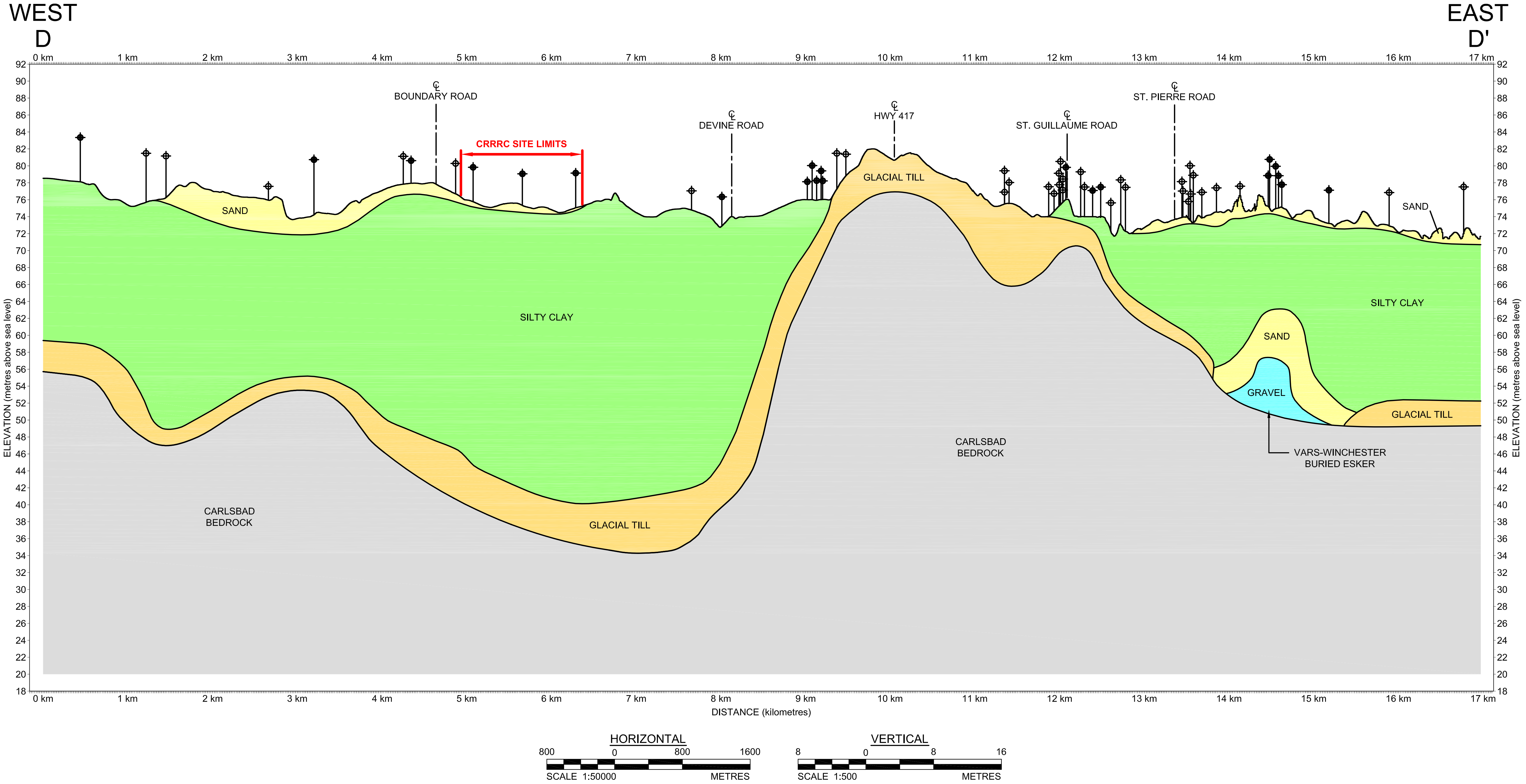
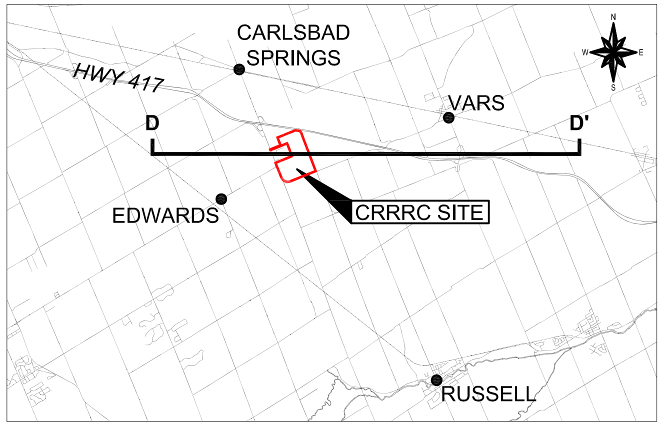


NOTE:
VERTICAL SCALE EXAGGERATED 100 TIMES THE HORIZONTAL SCALE FOR PRESENTATION PURPOSES



KEY MAP
1:300,000

LEGEND

- ✦ BOREHOLE LOCATION
- ⌖ MINISTRY OF THE ENVIRONMENT AND CLIMATE CHANGE WATER WELL RECORD LOCATION

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
LOCAL GEOLOGIC CROSS-SECTION D-D'

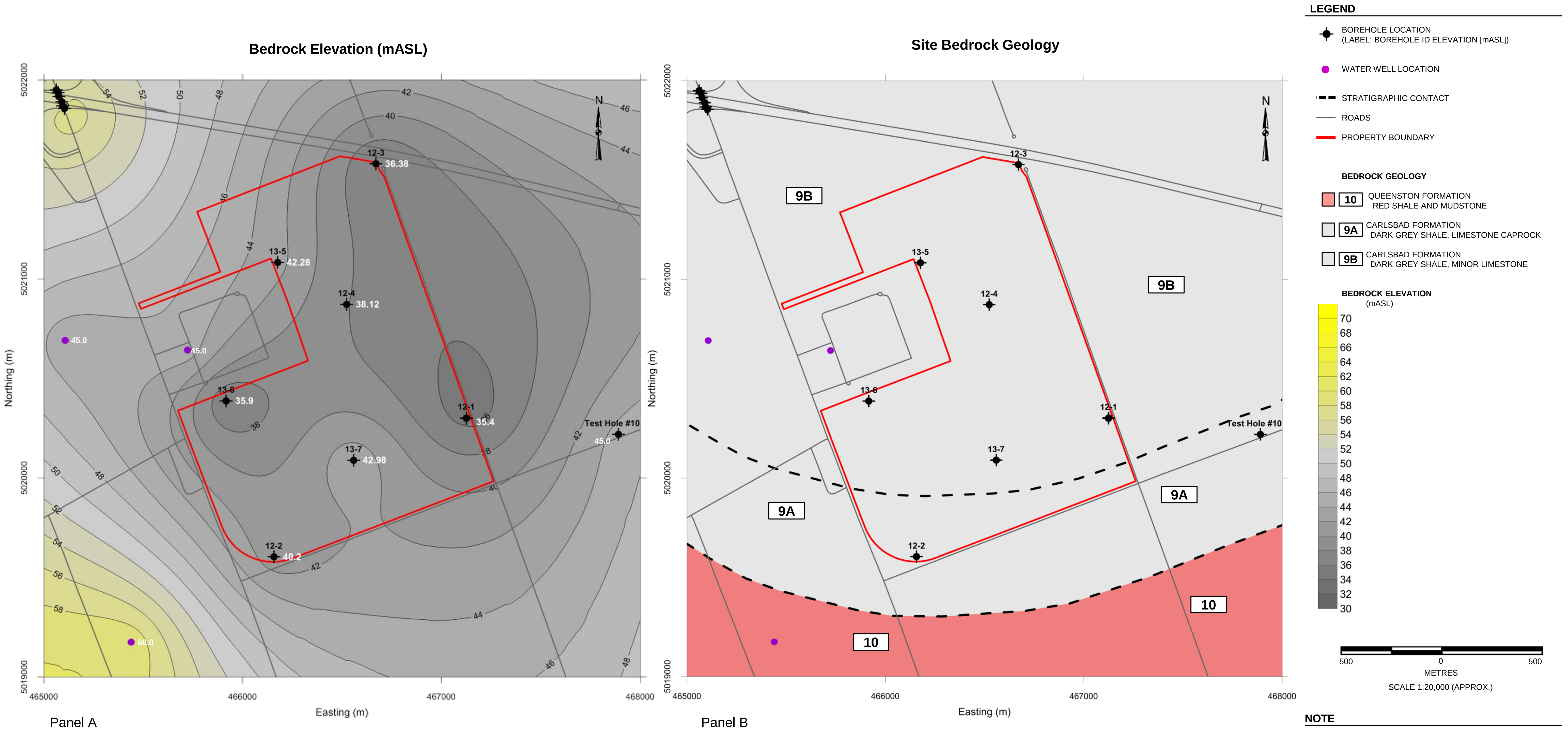
Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045
DESIGN	JPAO	June 2013
CAD	JM	Nov. 2013
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

FILE No. 1211250045-4000-3-11.dwg
SCALE AS SHOWN REV.

FIGURE 3-11

PLOT DATE: October 7, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase 4000\1211250045-4000-3-11.dwg



NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
TEST HOLE LOCATIONS FROM WESA (1986) AND WESA (1987)

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010).

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

SITE BEDROCK SURFACE ELEVATION
AND BEDROCK GEOLOGY MAPS

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013		
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

FIGURE 3-12

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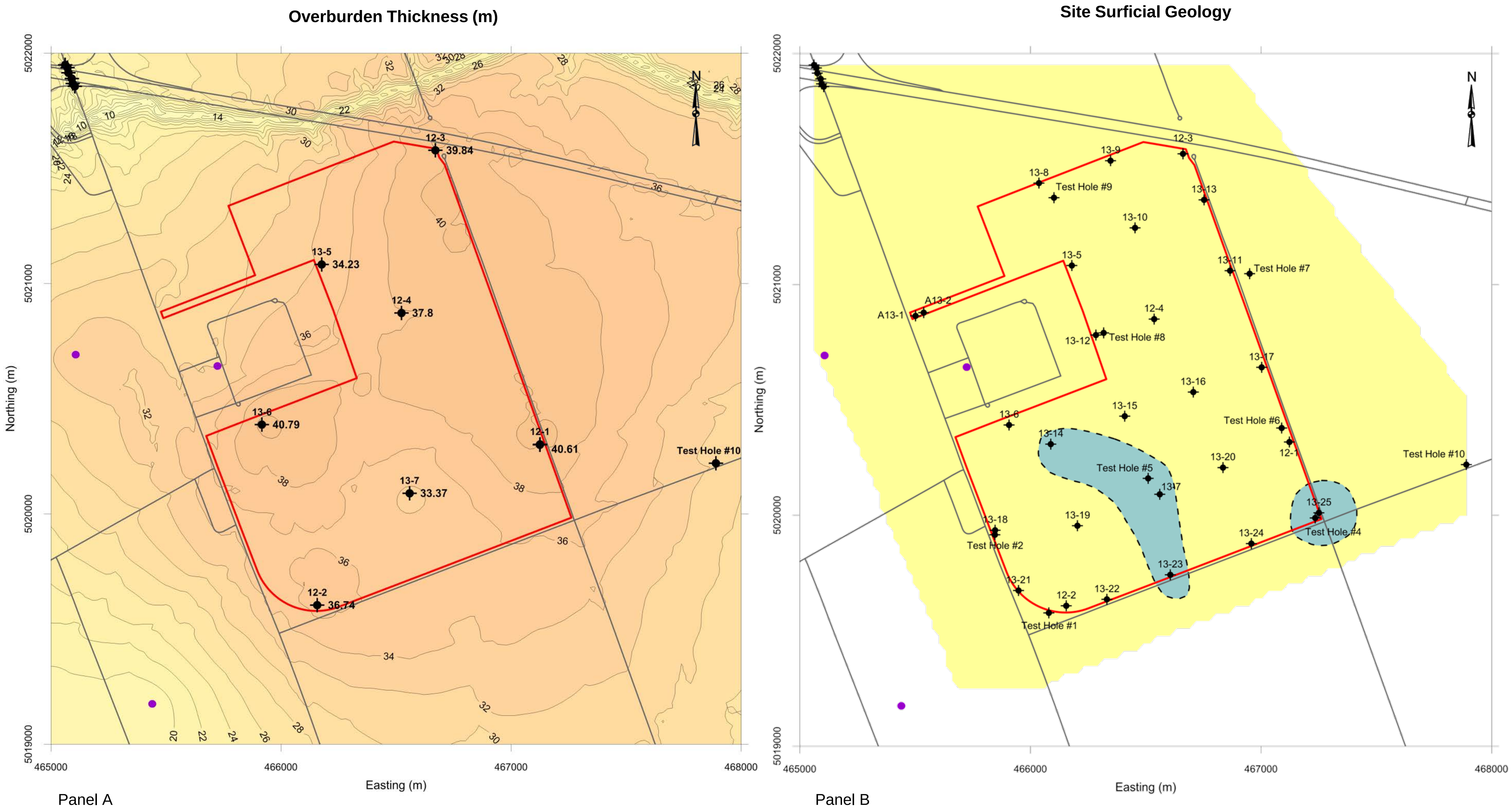

LEGEND

- ✦ BOREHOLE LOCATION (LABEL: BOREHOLE ID AND FORMATION THICKNESS [m])
- ● WATER WELL LOCATION
- - - STRATIGRAPHIC CONTACT
- — ROADS
- — PROPERTY BOUNDARY

SURFICIAL GEOLOGY

- ▭ SILTY SAND
- ▭ SILTY CLAY

OVERBURDEN THICKNESS
(m)

75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

500 0 500
METRES
SCALE 1:20,000 (APPROX.)

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
TEST HOLE LOCATIONS FROM WESA (1986) AND WESA (1987)

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010).

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
SITE OVERBURDEN THICKNESS AND SURFICIAL GEOLOGY MAPS

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013	FIGURE 3-13	
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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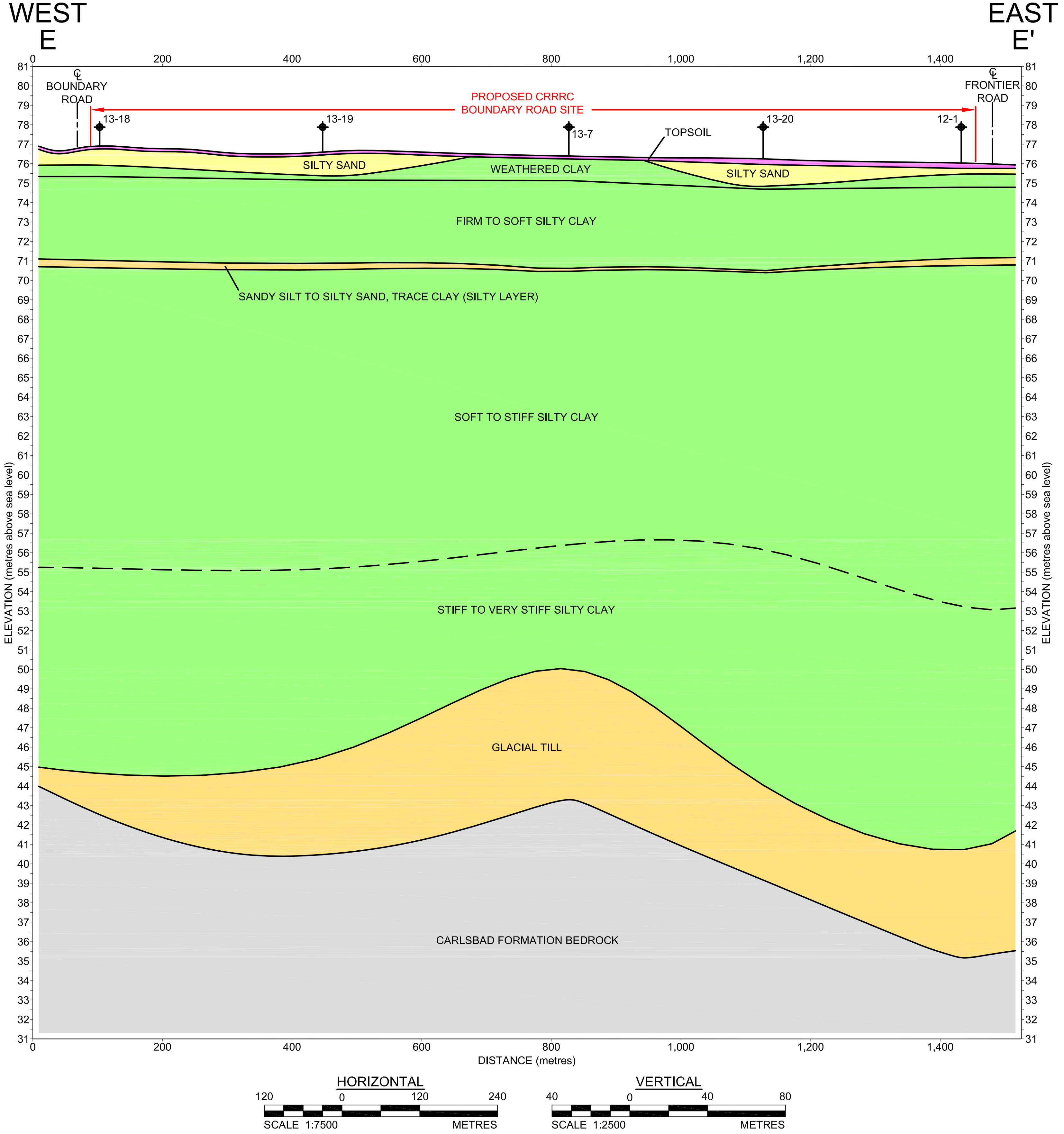
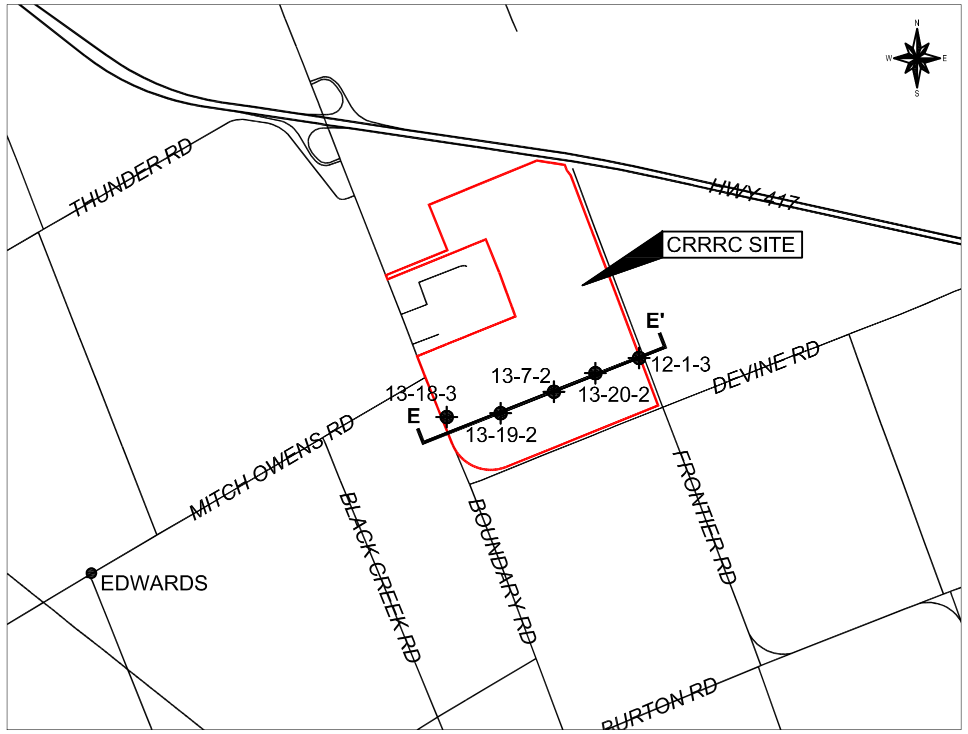


NOTE:
VERTICAL SCALE EXAGGERATED 100 TIMES THE HORIZONTAL SCALE FOR PRESENTATION PURPOSES



KEY MAP
1:50,000

LEGEND

✦ BOREHOLE LOCATION

NOTES

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW
△						

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
SITE CROSS-SECTION E-E'

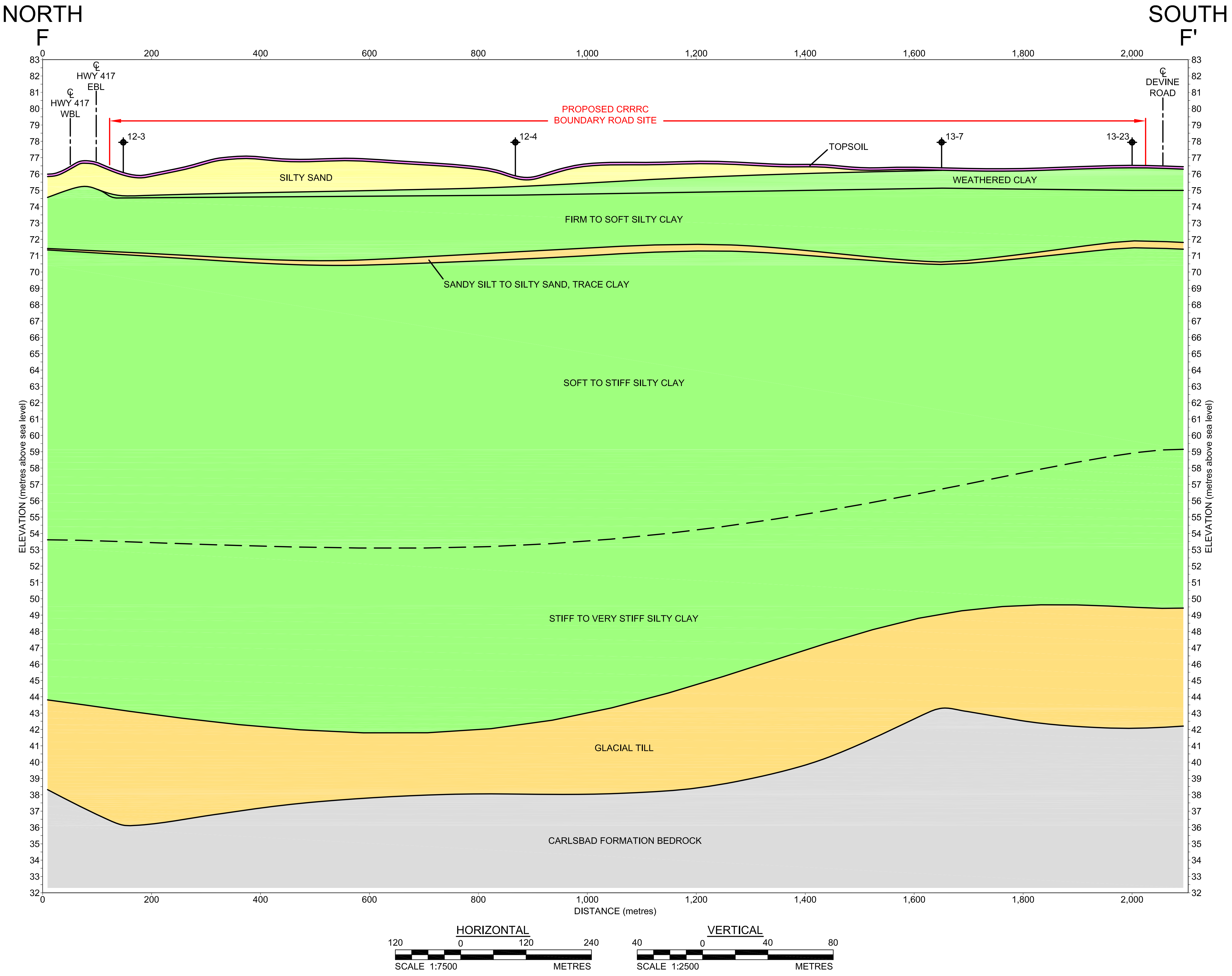
Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045
DESIGN	SAT	Oct. 2013
CAD	JM	Nov. 2013
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

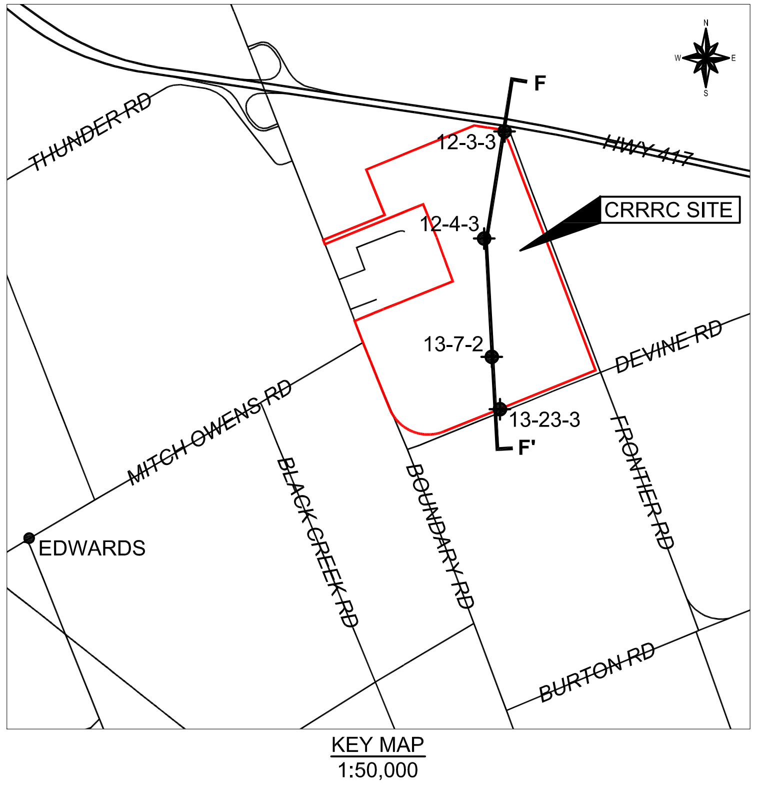
FILE No. 1211250045-4000-3-14.dwg
SCALE AS SHOWN REV.

FIGURE 3-14

PLOT DATE: June 26, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase 4000\1211250045-4000-3-14.dwg



NOTE:
VERTICAL SCALE EXAGGERATED 100 TIMES THE HORIZONTAL SCALE FOR PRESENTATION PURPOSES



KEY MAP
1:50,000

LEGEND

✦ BOREHOLE LOCATION

NOTES

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

SITE CROSS-SECTION F-F'

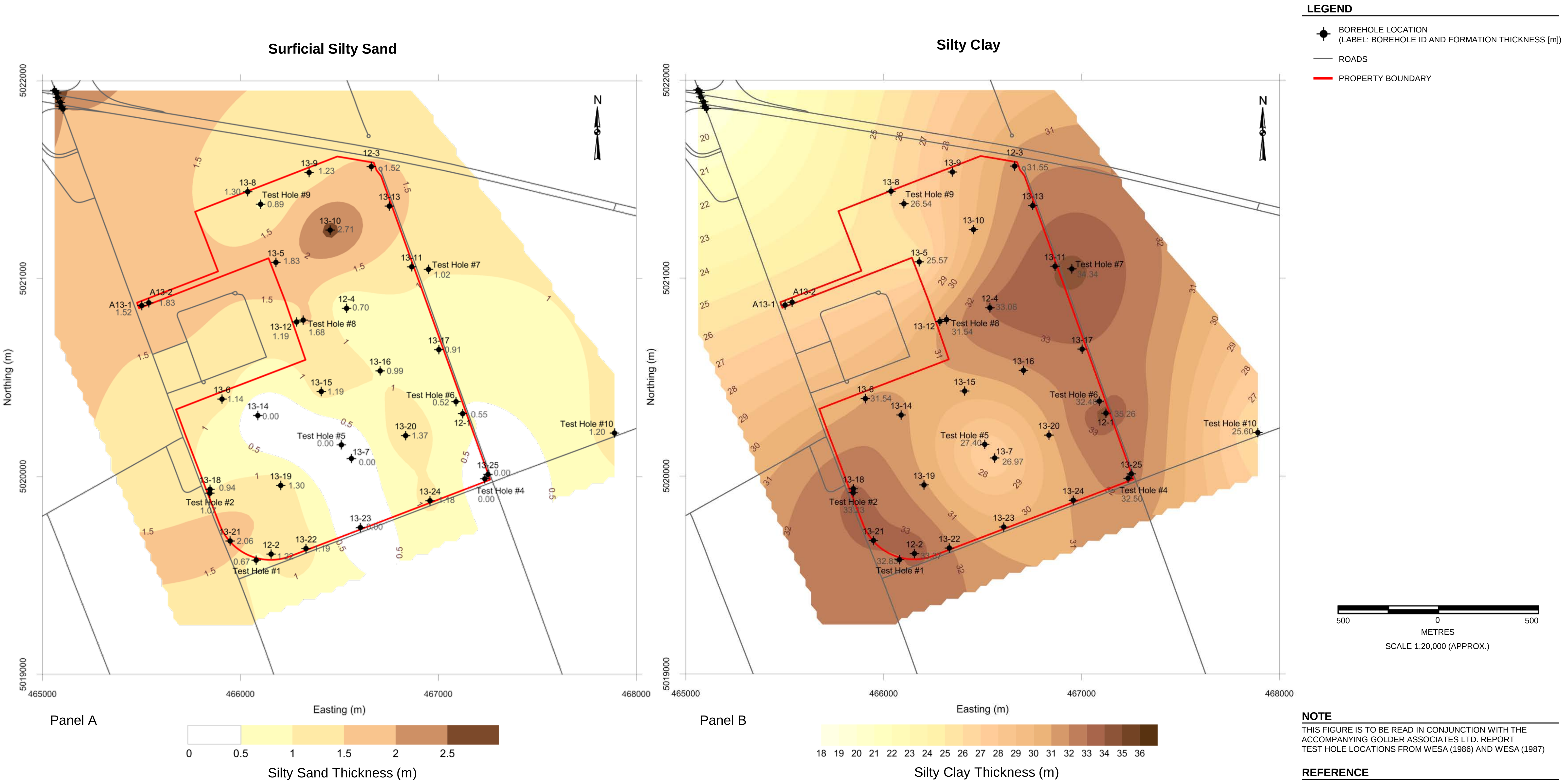
Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045
DESIGN	SAT	Oct. 2013
CAD	JM	Nov. 2013
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

FILE No. 1211250045-4000-3-15.dwg
SCALE AS SHOWN REV.

FIGURE 3-15

PLOT DATE: June 26, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase 4000\1211250045-4000-3-15.dwg



NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
TEST HOLE LOCATIONS FROM WESA (1986) AND WESA (1987)

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010).

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
SITE SURFICIAL GEOLOGY ISOPACH MAPS
(SURFICIAL SILTY SAND AND SILTY CLAY)

Golder Associates Ottawa, Ontario	PROJECT No. 12-1125-0045			SCALE AS SHOWN / REV.0
	DESIGN	NB	15 NOV. 2013	FIGURE 3-16
	GIS	NB	15 NOV. 2013	
	CHECK	PLE	AUG. 2014	
	REVIEW	PAS	AUG. 2014	

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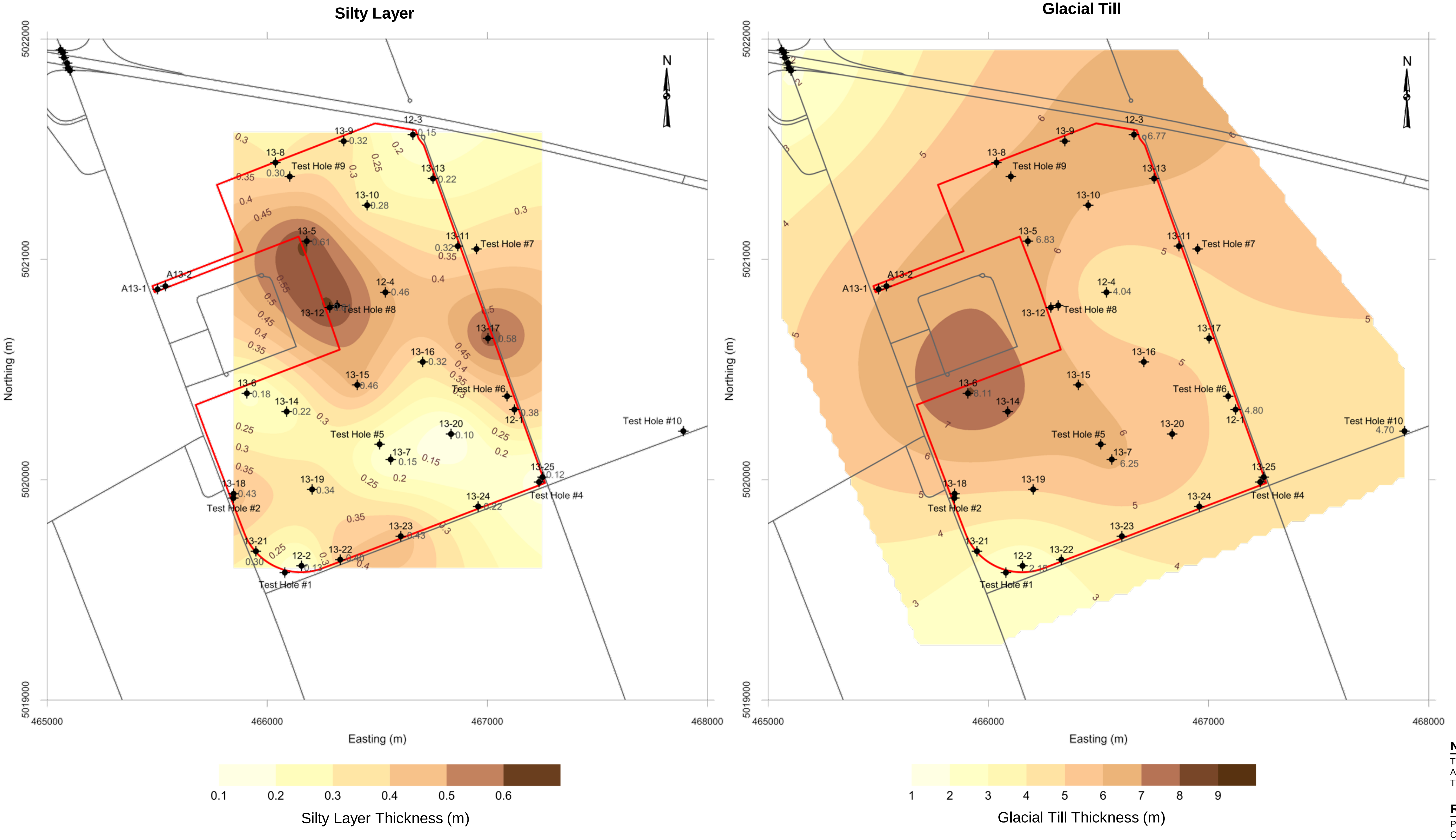


LEGEND

BOREHOLE LOCATION
(LABEL: BOREHOLE ID AND FORMATION THICKNESS [m])

ROADS

PROPERTY BOUNDARY

500 0 500
METRES
SCALE 1:20,000 (APPROX.)

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
TEST HOLE LOCATIONS FROM WESA (1986) AND WESA (1987)

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 18
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010).

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

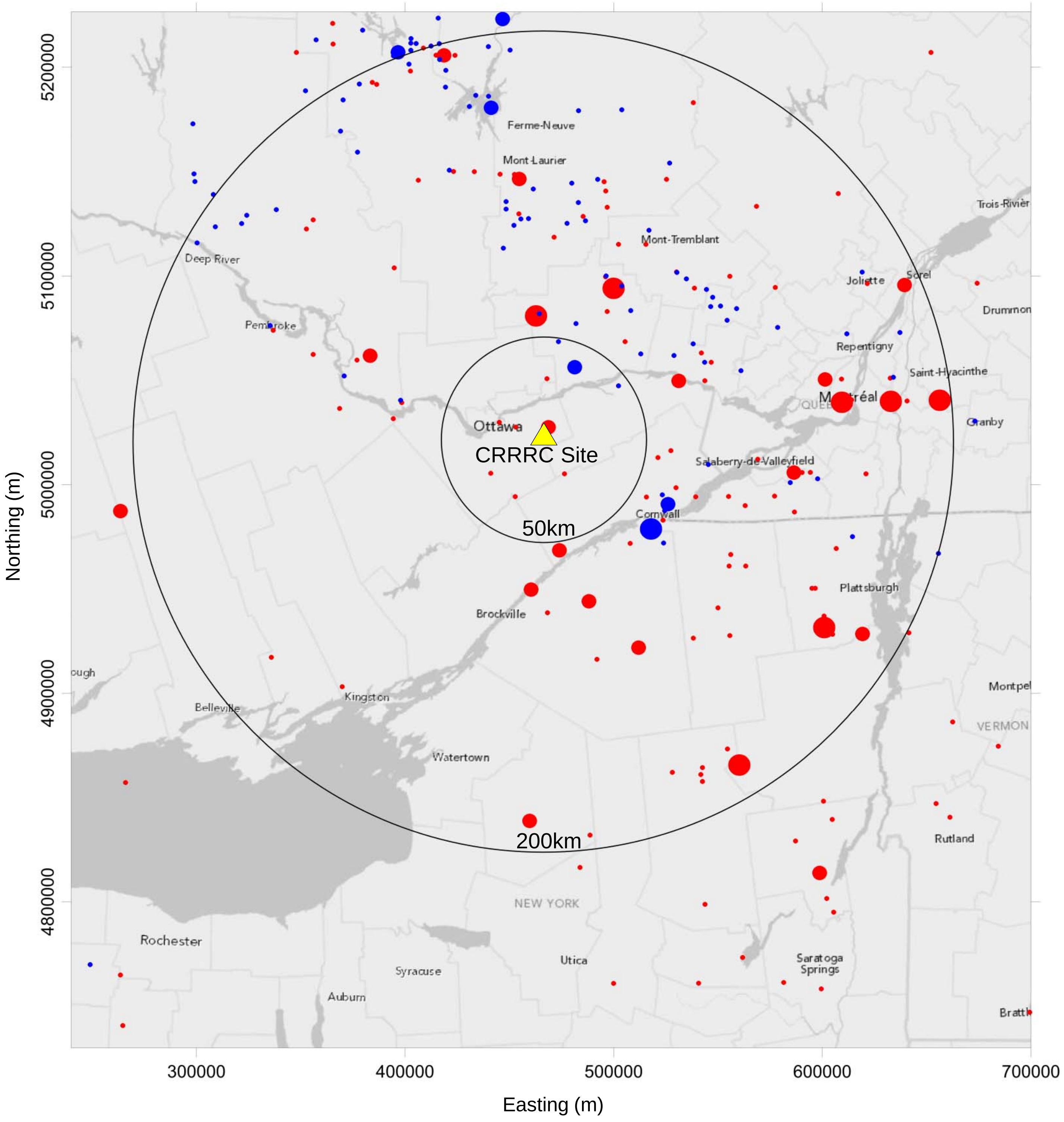
TITLE
SITE SURFICIAL GEOLOGY ISOPACH MAPS
(SILTY LAYER AND GLACIAL TILL)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013		
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

FIGURE 3-17

N:\Active\2012\1125 - Environmental and Civil Engineering\12-1125-0045 CRRRC EA Eastern ON\Phase 4000_EA_Documentation\Vol 3 - G H&G\Geology Figures\ppt



LEGEND

MAGNITUDE

● 5 < Mw < 6

● 4 < Mw < 5

• 3 < Mw < 4

DEPTH

🔴 < = 15 km

🔵 > 15 km

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

SEISMICITY NEAR THE CRRRC SITE

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4500	
DESIGN	CV	27 NOV. 2013	SCALE AS SHOWN	REV.0
GIS	NB	27 NOV. 2013	FIGURE 4-1	
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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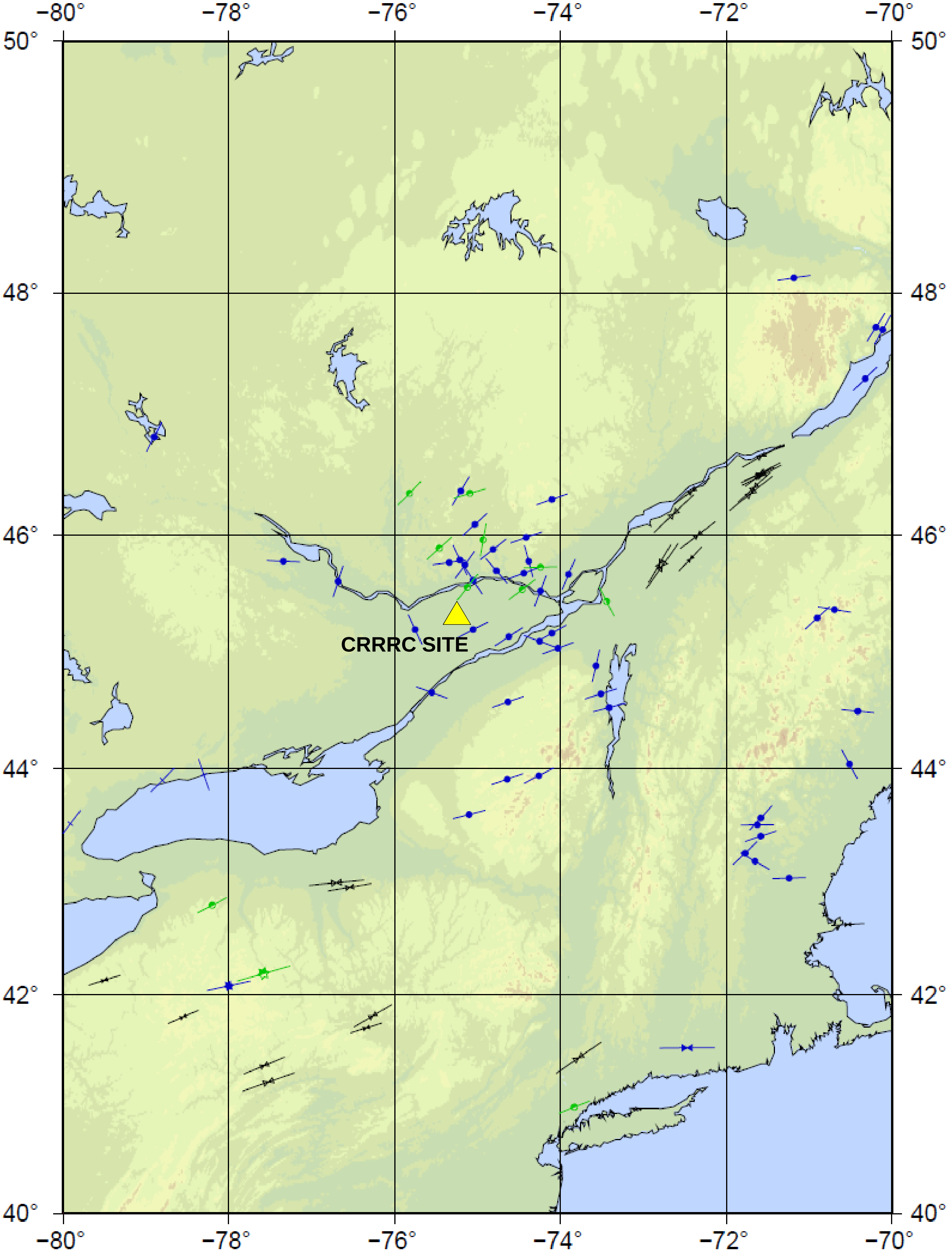

LEGEND

focal mechanism
breakouts
hydro. fractures

Quality:

A ———
B ——
C —

Regime:

● SS ● TF ⊘ U

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

SS = STRIKE-SLIP FAULT; TF = THRUST FAULT; U = UNKNOWN REGIME

REFERENCE

SOURCE: WORLD STRESS MAP REL. 2008
HELMHOLTZ CENTRE POTSDAM
GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

ORIENTATION OF THE STRESS FIELD
NEAR THE CRRRC SITE

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4500	
DESIGN	CV	27 NOV. 2013	SCALE AS SHOWN	REV.0
GIS	NB	27 NOV. 2013	FIGURE 4-2	
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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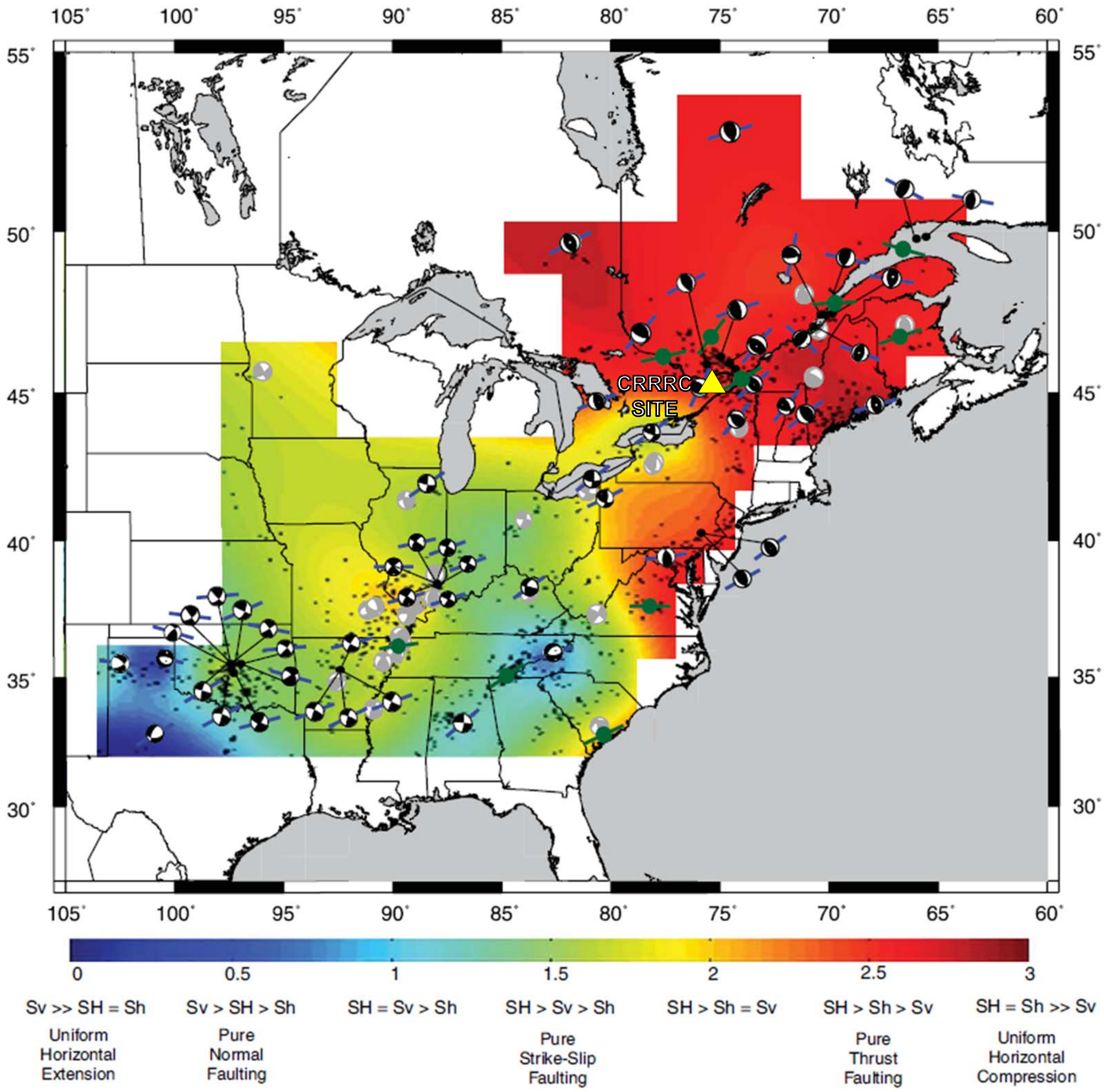

LEGEND

FOCAL MECHANISM SHOWING S_{HMAX} ORIENTATION (HURD AND ZOBACK STUDY)
FOCAL MECHANISM SHOWING S_{HMAX} ORIENTATION (EARLIER STUDIES)
STRESS INVERSIONS
● BACKGROUND SEISMICITY FROM USG/NEIC CATALOG (1973 – 2010)

STRIKE-SLIP
THRUST
NORMAL

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

SOURCE: HURD, O., AND ZOBACK, M.D. (2012). INTERPLATE EARTHQUAKES, REGIONAL STRESS AND FAULT MECHANICS IN THE CENTRAL AND EASTERN U.S. AND SOUTHEASTERN CANADA. TECTONOPHYSICS, 581, 182-192.

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

REGIONAL STRESS MAP

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4500	
DESIGN	CV	27 NOV. 2013	SCALE AS SHOWN	REV.0
GIS	NB	27 NOV. 2013	FIGURE 4-3	
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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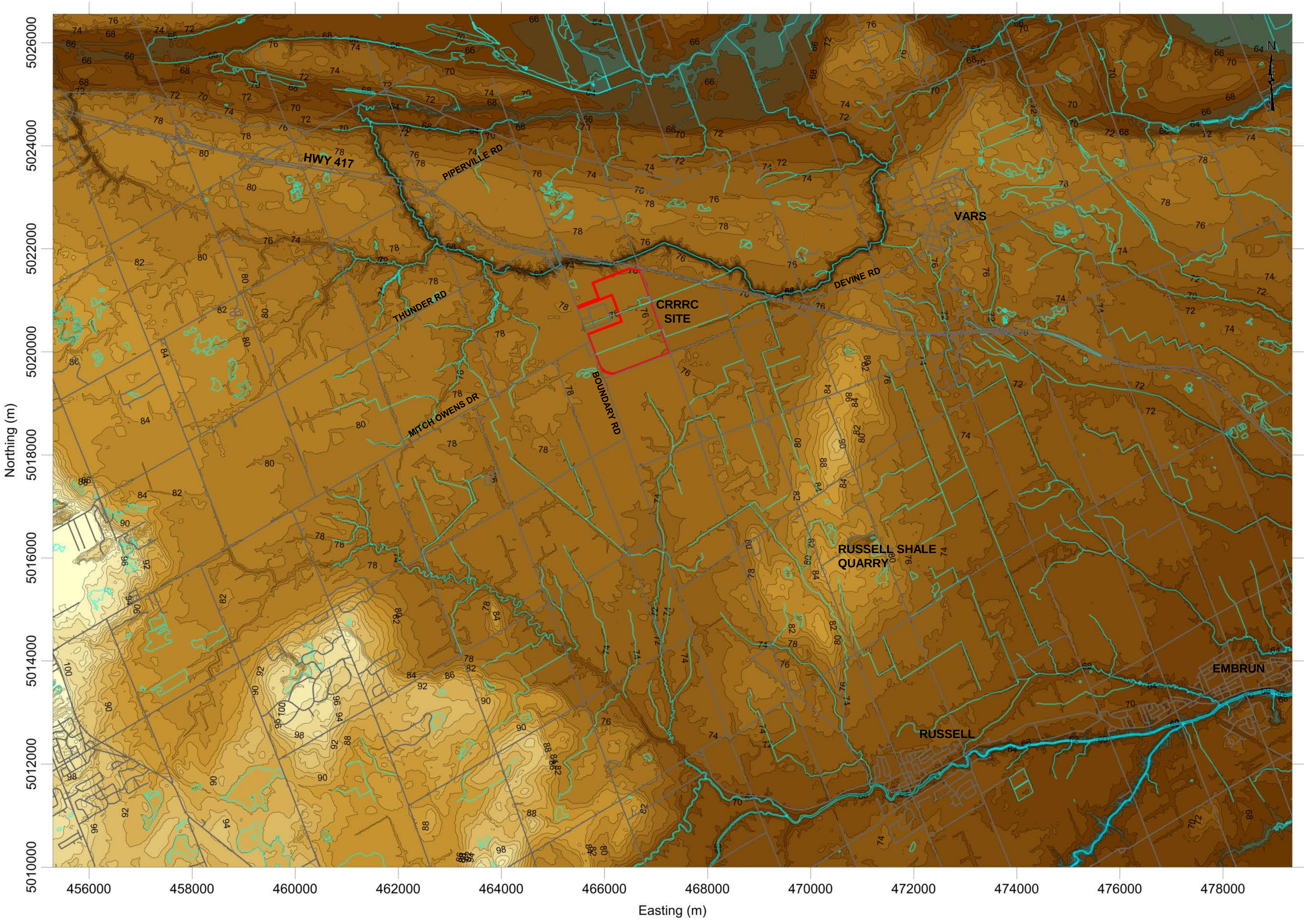

LEGEND

- WATERBODIES
- ROADS
- PROPERTY BOUNDARY

TOPOGRAPHY COLOUR SCALE (mASL)

106
104
102
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54

1000 0 1000
METRES
SCALE 1:85,000 (APPROX.)

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT
ELEVATION CONTOUR INTERVAL = 2m
CONTOUR DATUM IS mASL

REFERENCE

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18.
BASE MAPPING FROM ONTARIO MINISTRY OF NATURAL RESOURCES (2010).

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

TOPOGRAPHY

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV. 2013	FIGURE 5-1	
GIS	NB	15 NOV. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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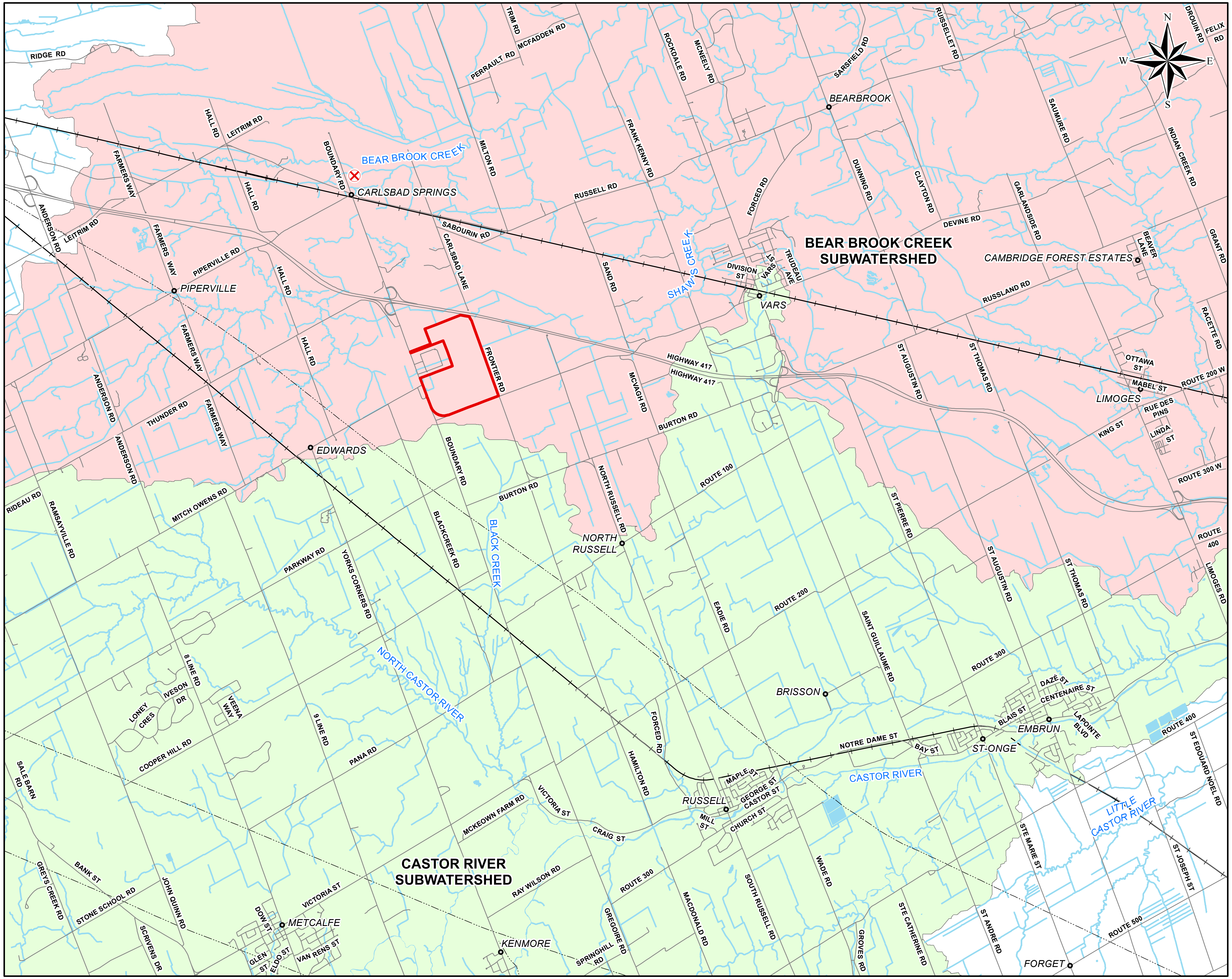

LEGEND

- ⊗ CITY OF OTTAWA WEPP SAMPLING STATION
- ● POPULATED PLACE NAME
- — ROAD
- —+— RAILWAY
- -··- UTILITY LINE
- — SURFACE WATER FEATURE
- ▨ WATER AREA
- ☐ PROPERTY BOUNDARY
- 🟥 BEAR BROOK CREEK SUBWATERSHED
- 🟩 CASTOR RIVER SUBWATERSHED

1,600 800 0 1,600

SCALE 1:80,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, ©QUEENS PRINTER 2012.

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

SURFACE WATER SUBWATERSHEDS

Golder Associates

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0.0
DESIGN	JPAO	DEC. 2013	FIGURE 5-2	
GIS	BR	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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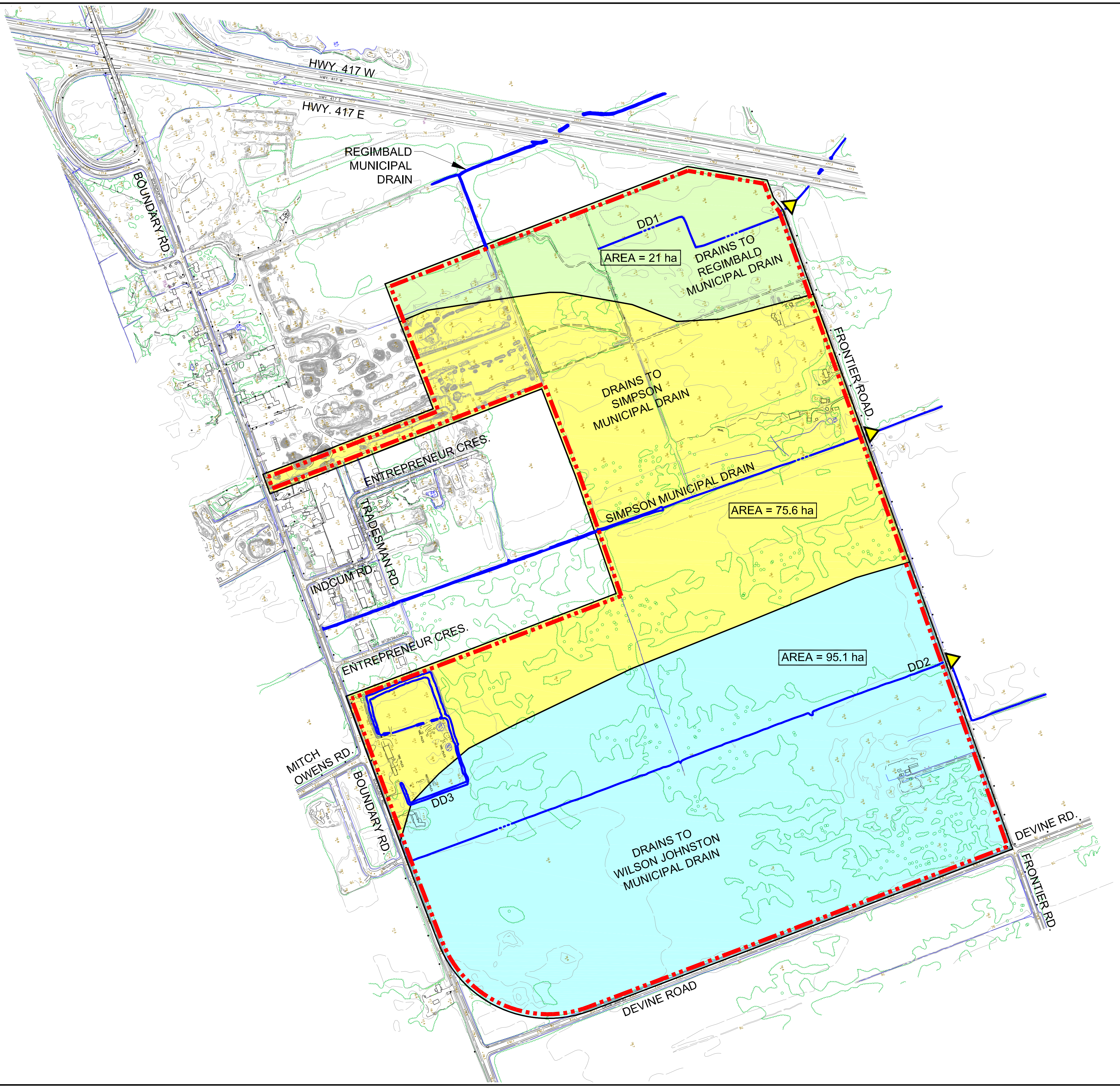


N
W E
S

LEGEND:

🟥 PROPERTY BOUNDARY

— SURFACE WATER FEATURE

△ OUTLET

NOTE

1. THIS FIGURE SHOULD BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCES:

1. BASE DRAWING PROVIDED IN A DIGITAL FORMAT BY BASE MAPPING CO. LTD., CONTRACT No. 2517-12, PHOTO DATE: NOVEMBER 7, 2012, DATE RECEIVED: JANUARY 9, 2013.
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

200 0 200 400

SCALE 1:10,000 METRES

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

EXISTING SITE DRAINAGE

Golder Associates
Ottawa, Ontario, Canada

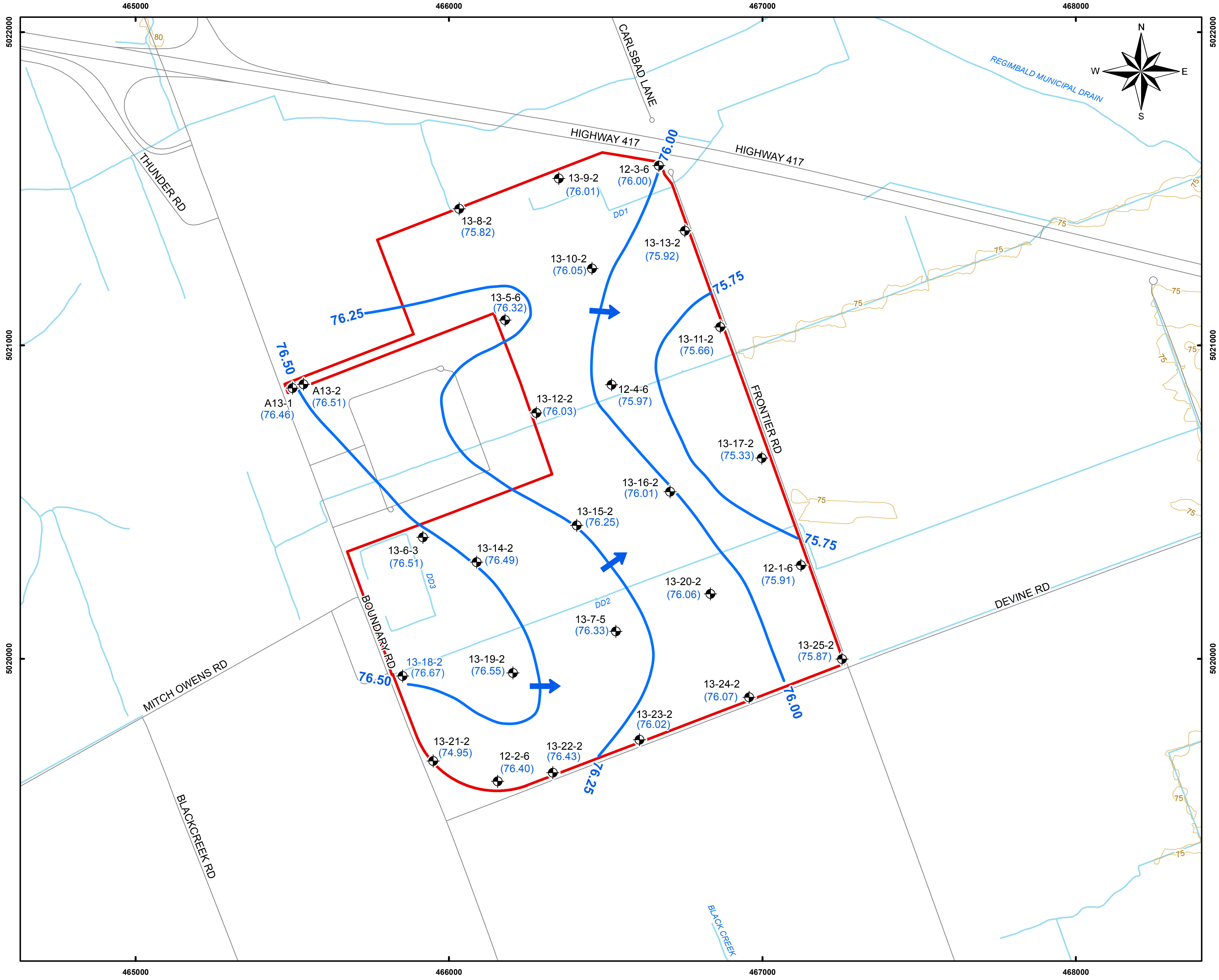
PROJECT No.		12-1125-0045
DESIGN	D.H.	22 Jan. 2013
CAD	M.L.F.	23 Jan. 2013
CHECK	P.L.E.	Aug. 2014
REVIEW	P.A.S.	Aug. 2014

FILE No.1211250045-V3-5-3.dwg

SCALE AS SHOWN REV. 0

FIGURE 5-3

PLOT DATE: June 26, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Vol 3 (Report Figures)\1211250045-V3-5-3.dwg



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LEGEND

(75.61)	GROUNDWATER ELEVATION ON OCTOBER 16, 2013 (METRES ABOVE SEA LEVEL)
━	GROUNDWATER ELEVATION CONTOUR (METRES ABOVE SEA LEVEL)
➡	INTERPRETED GROUNDWATER FLOW DIRECTION
⊕	MONITORING WELL LOCATION
─	ROAD
─	CONTOUR LINE, (5m)
─	SURFACE WATER FEATURE
▬	WATER AREA
☐	PROPERTY BOUNDARY

200 100 0 200

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

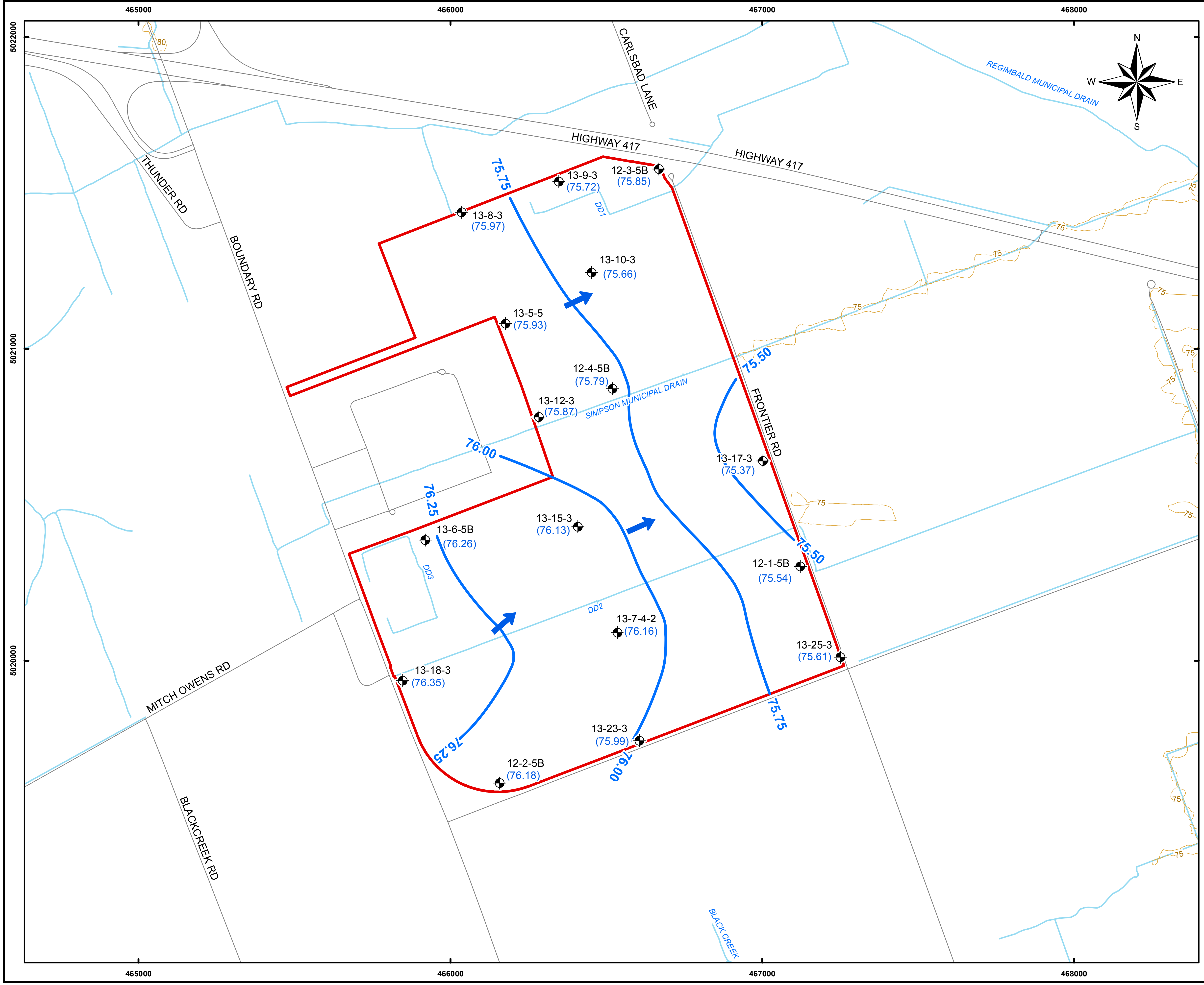
PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

SURFICIAL SILTY SAND GROUNDWATER FLOW

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	DH	DEC. 2013	**FIGURE 7-1**	
GIS	BR/PM	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		



LEGEND

(75.61)	GROUNDWATER ELEVATION ON OCTOBER 16, 2013 (METRES ABOVE SEA LEVEL)
─	GROUNDWATER ELEVATION CONTOUR (METRES ABOVE SEA LEVEL)
➡	INTERPRETED GROUNWATER FLOW DIRECTION
⊕	MONITORING WELL LOCATION
─	CONTOUR LINE, (5m)
─	SURFACE WATER FEATURE
■	WATER AREA
▭	PROPERTY BOUNDARY

200 100 0 200

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

SILTY LAYER GROUNDWATER FLOW

Golder Associates

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	DH	NOV. 2013	FIGURE 7-2	
GIS	BR/PM	DEC. 2014		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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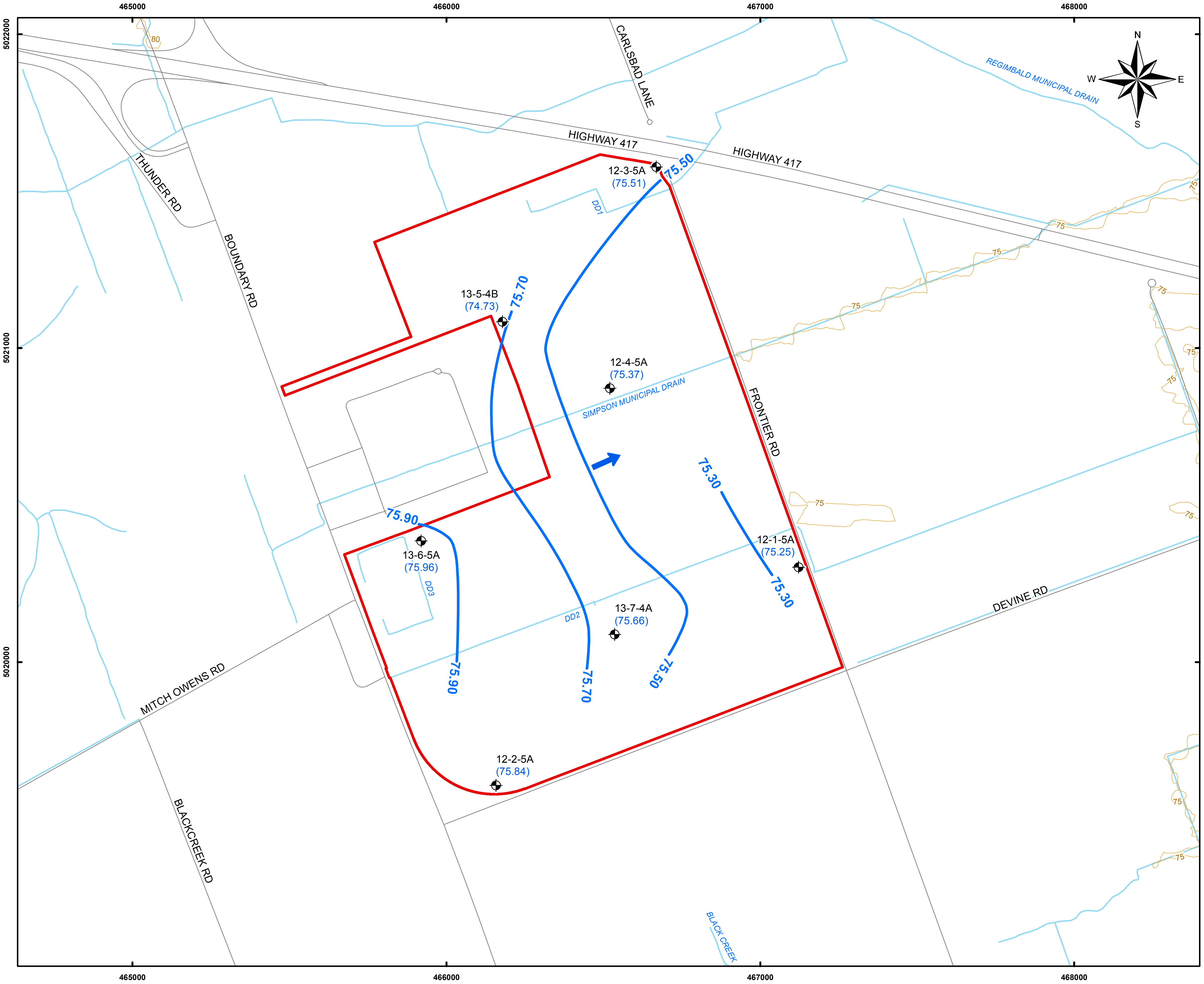

LEGEND

(75.61)	GROUNDWATER ELEVATION ON OCTOBER 16, 2013 (METRES ABOVE SEA LEVEL)
—	GROUNDWATER ELEVATION CONTOUR (METRES ABOVE SEA LEVEL)
➡	INTERPRETED GROUNDWATER FLOW DIRECTION
⊕	MONITORING WELL LOCATION
—	CONTOUR LINE, (5m)
—	SURFACE WATER FEATURE
▬	WATER AREA
▭	PROPERTY BOUNDARY

200 100 0 200

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

MIDDLE SILTY CLAY GROUNDWATER FLOW

Golder Associates

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	DH	NOV. 2013	**FIGURE 7-3**	
GIS	BR/PM	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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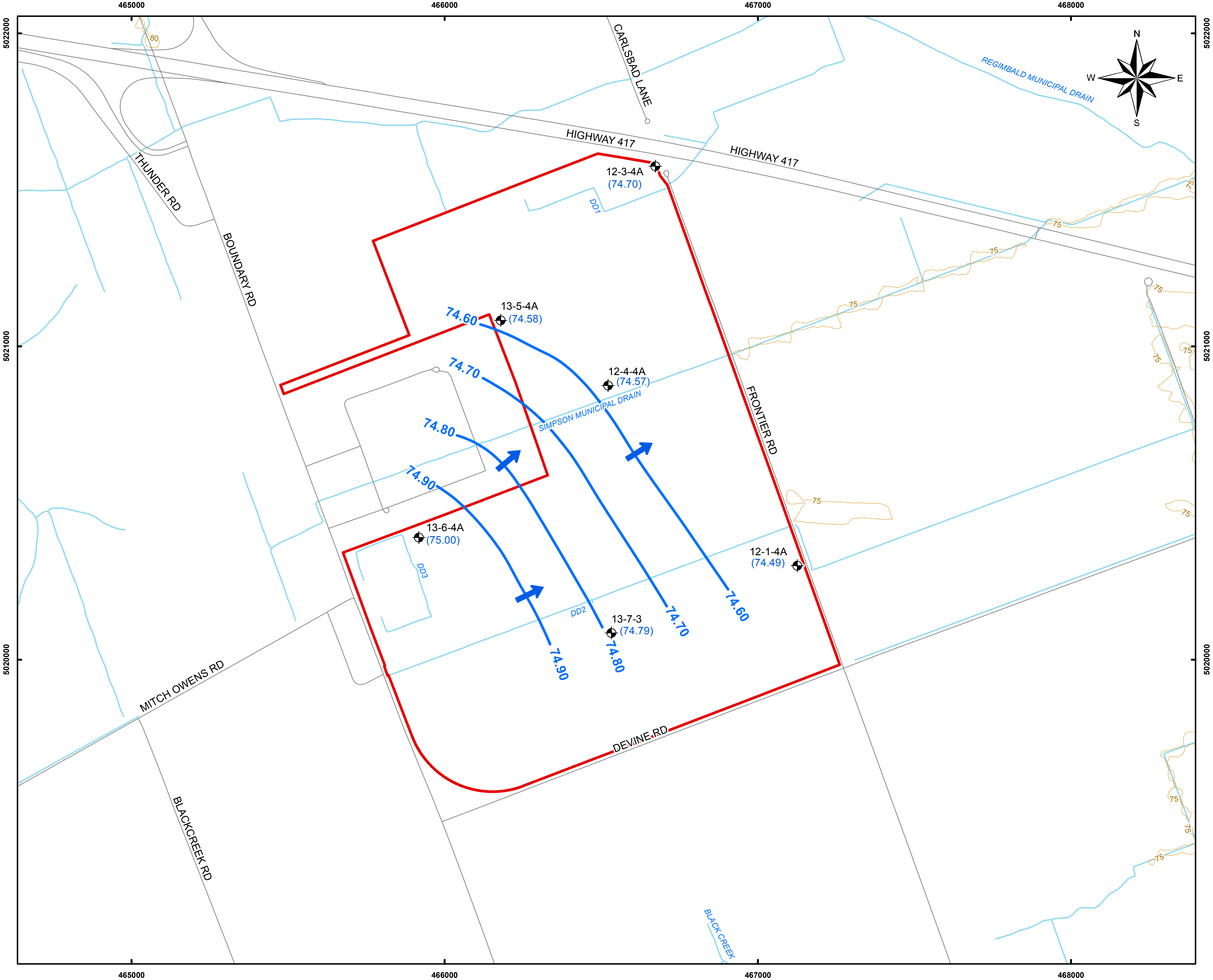

LEGEND

(75.61) GROUNDWATER ELEVATION ON OCTOBER 16, 2013 (METRES ABOVE SEA LEVEL)

— GROUNDWATER ELEVATION CONTOUR (METRES ABOVE SEA LEVEL)

➡ INTERPRETED GROUNWATER FLOW DIRECTION

⊕ MONITORING WELL LOCATION

— CONTOUR LINE, (5m)

— SURFACE WATER FEATURE

▬ WATER AREA

▭ PROPERTY BOUNDARY

200 100 0 200

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

GLACIAL TILL GROUNDWATER FLOW

Golder Associates

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	DH	2013-11-22	FIGURE 7-4	
GIS	BR/PM	2013-12-11		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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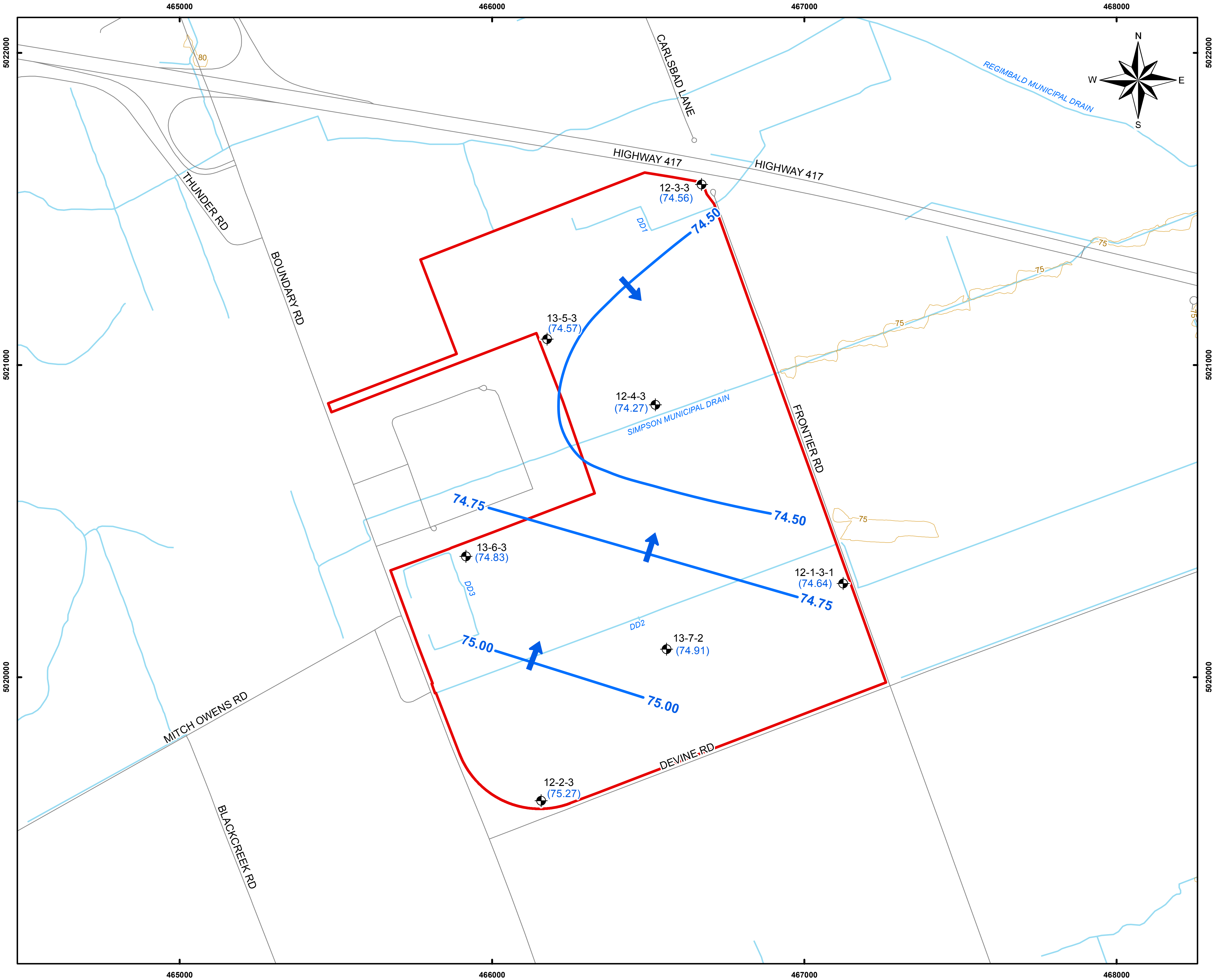

LEGEND

(75.61)	GROUNDWATER ELEVATION ON OCTOBER 16, 2013 (METRES ABOVE SEA LEVEL)
—	GROUNDWATER ELEVATION CONTOUR (METRES ABOVE SEA LEVEL)
➡	INTERPRETED GROUNWATER FLOW DIRECTION
⊕	MONITORING WELL LOCATION
—	ROAD
—	CONTOUR LINE, (5m)
—	SURFACE WATER FEATURE
▨	WATER AREA
☐	PROPERTY BOUNDARY

200 100 0 200

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

UPPER BEDROCK GROUNDWATER FLOW

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	DH	NOV. 2013	FIGURE 7-5	
GIS	BR/PM	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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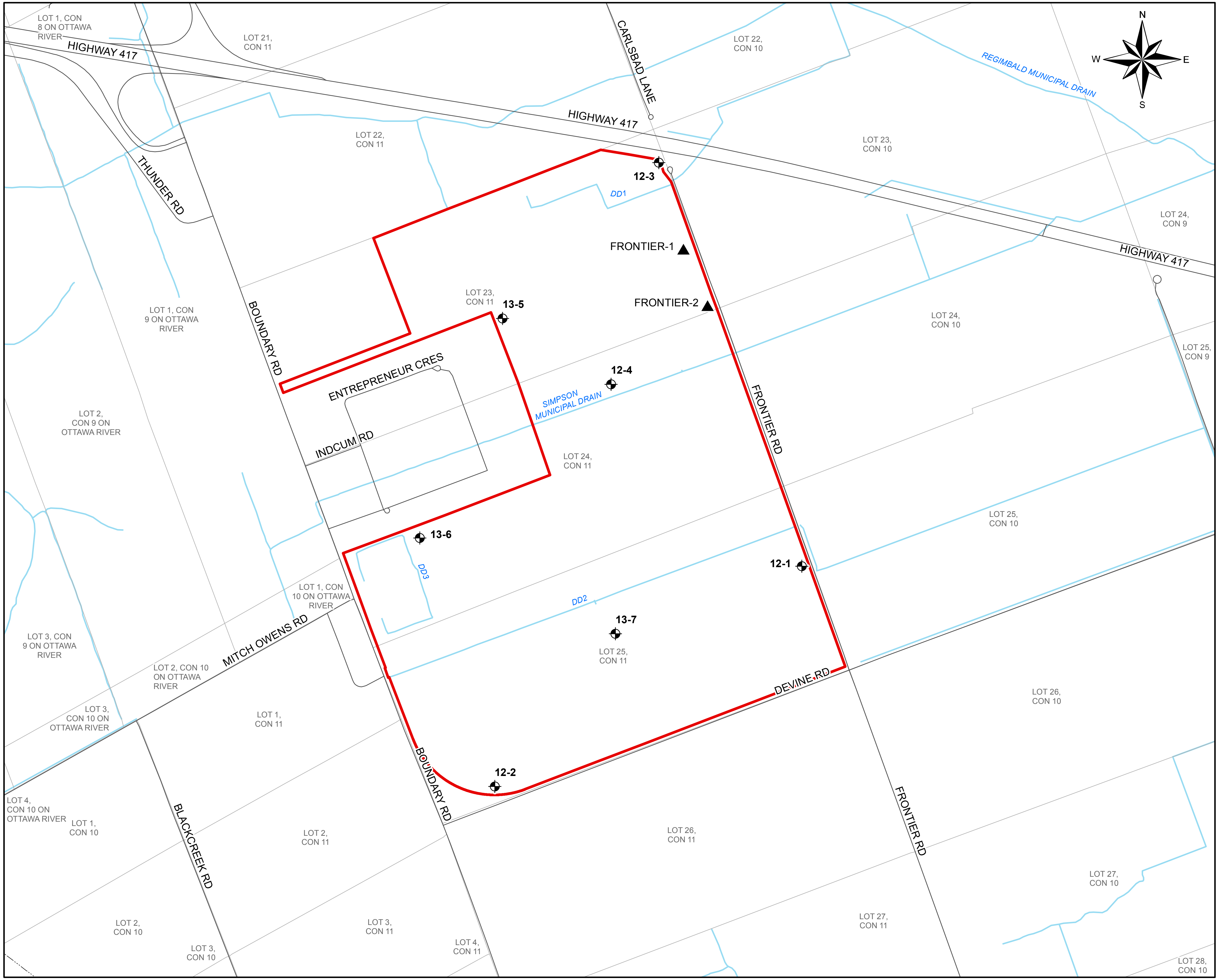

LEGEND

⌖ ON-SITE GROUNDWATER MONITORING WELL

WATER SUPPLY WELL LOCATION

▲ RESIDENTIAL WATER SUPPLY WELL

— ROAD

┼ RAIL ROAD

-·- UTILITY LINE

— SURFACE WATER FEATURE

🟦 WATER AREA

☐ LOT/CONCESSION

🟥 PROPERTY BOUNDARY

300 150 0 300

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

TITLE

GROUNDWATER QUALITY MONITORING
LOCATIONS

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	DH	DEC. 2013	FIGURE 8-1	
GIS	BR	DEC. 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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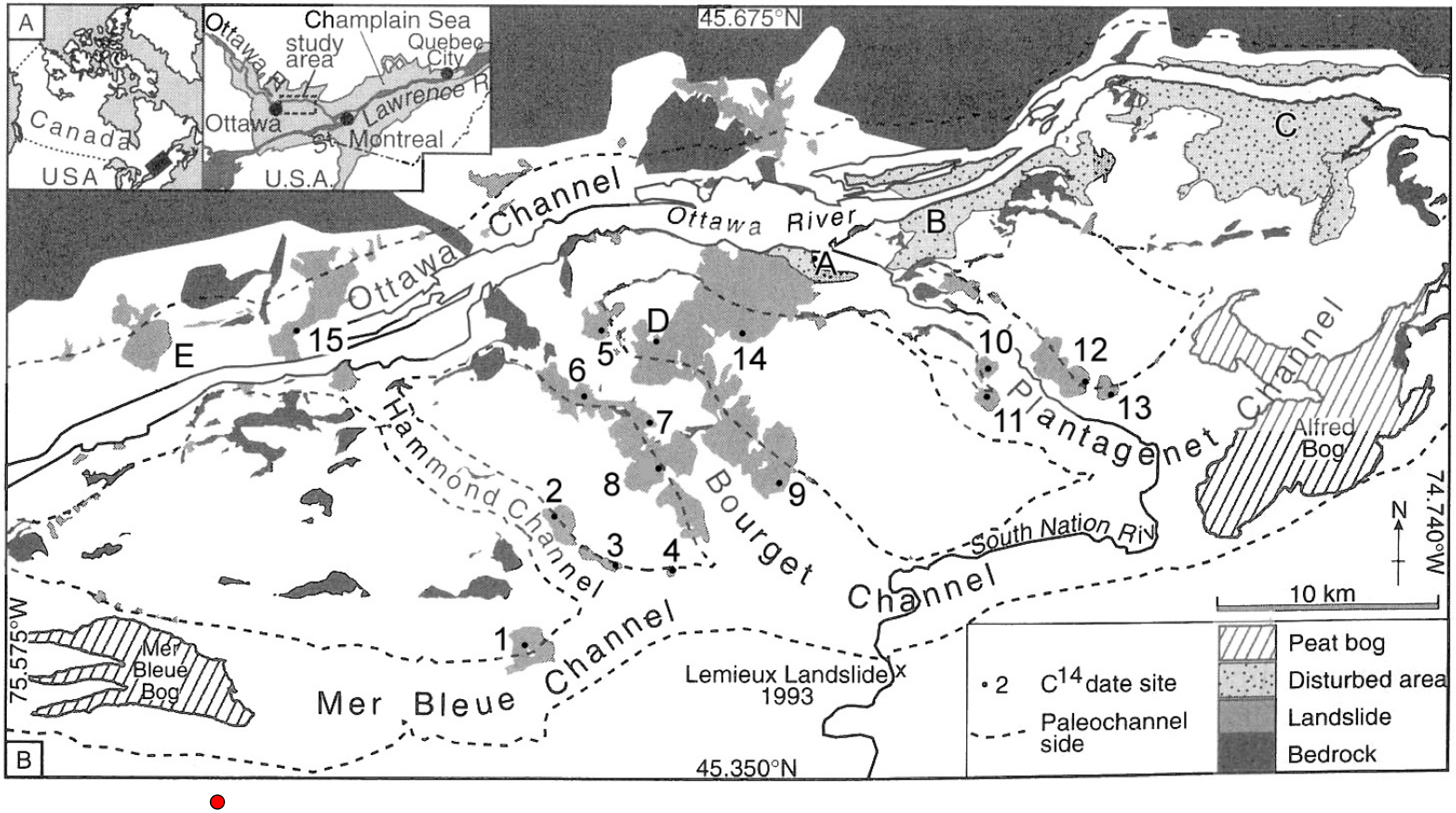

APPROXIMATE LOCATION
OF THE CRRRC SITE

NOTE

PANEL A): LOCATION OF THE CHAMPLAIN SEA BASIN IN EASTERN CANADA
PANEL B): MAP OF STUDY AREAS SHOWING PALEOCHANNELS, PALEO-LANDSLIDES, AND AREAS OF EARTHQUAKE-INDUCED DISTURBANCE.
THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

TAKEN FROM BROOKS, G.R. et al., 2013. A COMPILATION OF RADIOCARBON DATES RELATING TO THE AGE OF SENSITIVE CLAY LANDSLIDES IN THE OTTAWA VALLEY, ONTARIO-QUEBEC GEOLOGICAL SURVEY OF CANADA OPEN FILE 7432.

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

PALEO-CHANNELS

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	NB	15 NOV 2013	FIGURE 9-1	
GIS	NB	15 NOV 2013		
CHECK	PLE	AUG. 2014		
REVIEW	PAS	AUG. 2014		

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PLOT DATE: October 9, 2014
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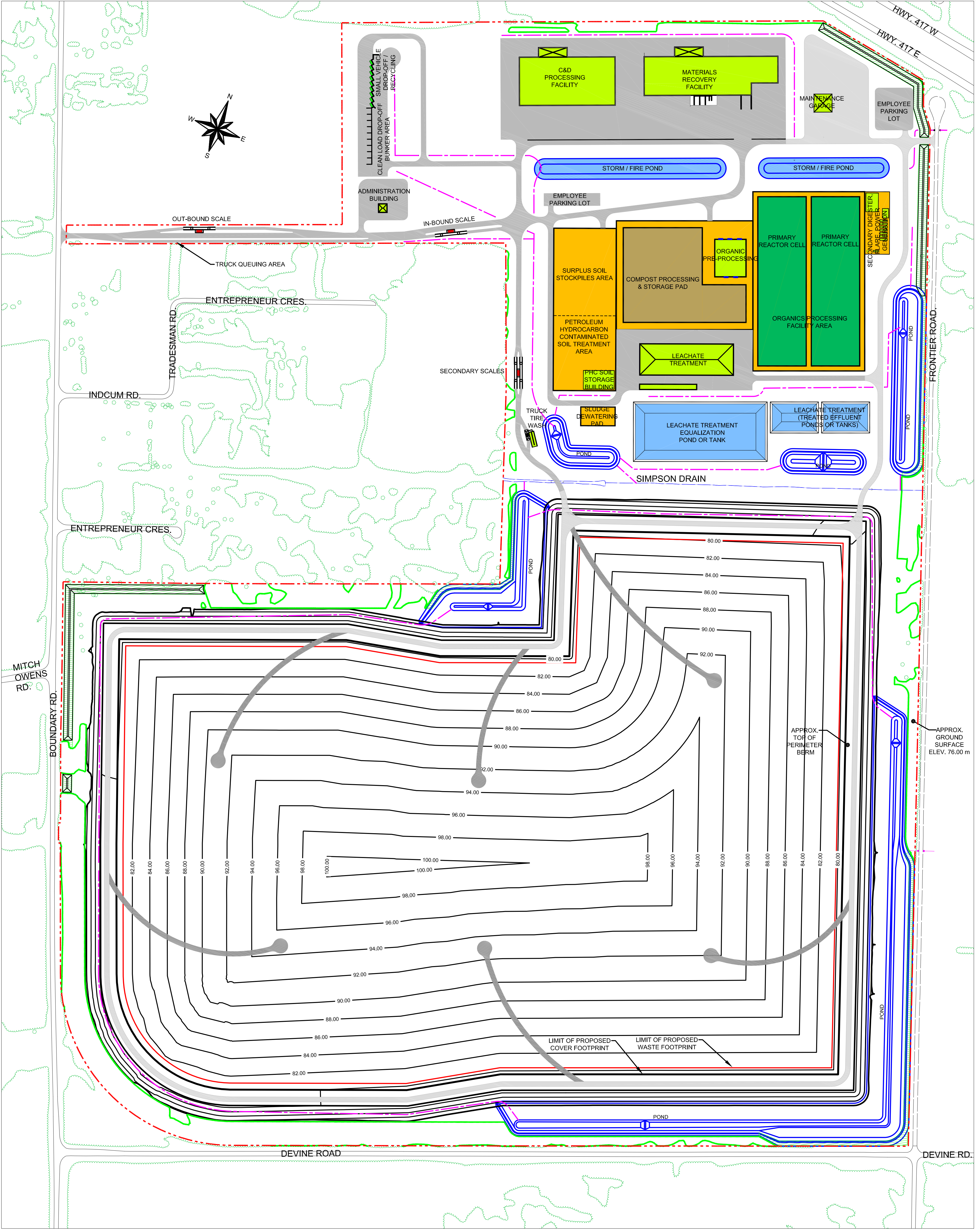


LEGEND

🟩	PROPOSED FACILITY BUILDING		EXISTING VEGETATION SCREENING		TEMPORARY ACCESS ROAD
🟧	OUTDOOR DIVERSION AREA		CONSTRUCTED SCREENING FEATURE		STORMWATER DITCH
	PAVED ROAD (ASPHALT)		PERIMETER BERM CONTOURS (interval 1 m)		
	GRAVEL ROAD		STORMWATER MANAGEMENT PONDS		
	PROPERTY BOUNDARY	84.00 86.00	LANDFILL FINAL CONTOURS (interval 2 m)		

120 0 120 240
SCALE 1:6,000 METRES

Golder Associates
Ottawa, Ontario, Canada

SCALE	AS SHOWN
DATE	7 Nov. 2013
DESIGN	M.L.F.
CAD	M.L.F.
CHECK	P.L.E.
REVIEW	P.A.S.

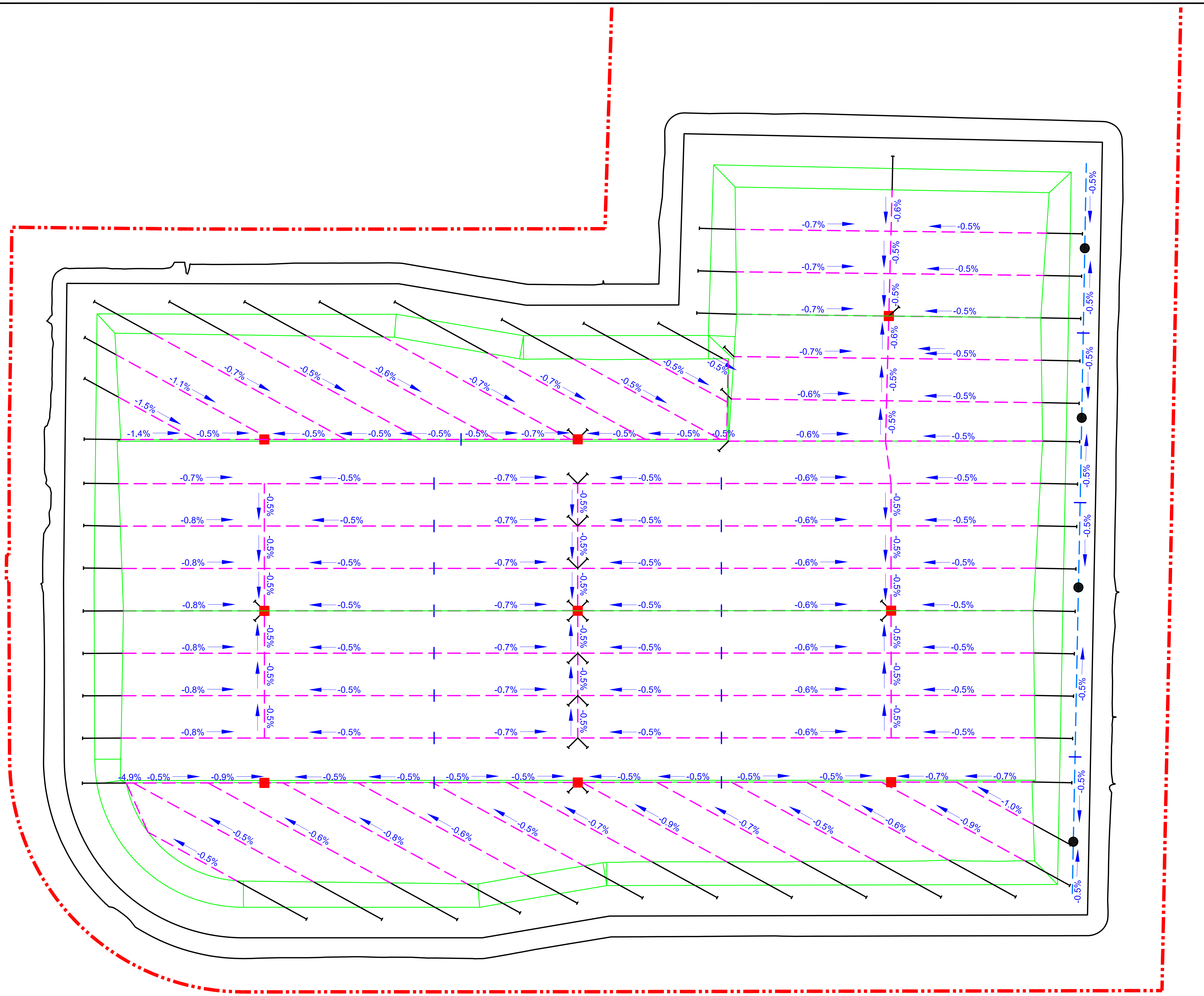
FILE No. 1211250045-V3-10-1.dwg
PROJECT No. 12-1125-0045 REV.

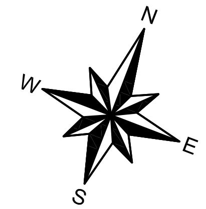
TITLE

SITE DEVELOPMENT PLAN

CAPITAL REGION RESOURCE RECOVERY CENTRE

FIGURE
10-1





LEGEND:

▬ ▪ ▪ ▬	PROPERTY BOUNDARY
← -0.5%	LEACHATE COLLECTION PIPE SLOPE (initial)
🟥	LEACHATE MANHOLE (nts)
─	CLEAN OUT LOCATION (nts)
- - + - -	PIPE GRADE BREAK POINT
- - - -	LEACHATE COLLECTION PIPE
─	MAIN SUBGRADE SLOPE BREAK POINTS
─	PERIMETER BERM SLOPE BREAK POINTS
●	LEACHATE DETECTION AND SECONDARY CONTAINMENT SYSTEM MANHOLE (nts)
— — —	LEACHATE DETECTION AND SECONDARY CONTAINMENT SYSTEM COLLECTION PIPE

REFERENCES:

1. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
   COORDINATE SYSTEM: UTM ZONE 18

NOT FOR CONSTRUCTION

100 0 100 200
SCALE 1:5,000 METRES

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

LEACHATE COLLECTION AND LDSCS PIPING LAYOUT PLAN

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045
DESIGN	M.K.F.	15 Oct. 2013
CAD	M.L.F.	15 Oct. 2013
CHECK	M.K.F.	Aug. 2014
REVIEW	P.A.S.B.	Aug. 2014

FILE No. 1211250045-V3-10-2.DWG
SCALE AS SHOWN REV. 0
DRAWING No.

Figure 10-2

PLOT DATE: November 17, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Vol 3 (Report Figures)\1211250045-V3-10-2.DWG

File Name: 12-45 UCC IP 23 OFDT.gsz
Revision Number: 203
Name: 12-1125-0045 Boundary Road Site
Date: 03/09/2013
Time: 2:44:00 PM
Method: Morgenstern-Price
Direction of movement: Right to Left
PWP Conditions Source: Piezometric Line

Name: Berm Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Cover
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: Waste
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Saturated Waste
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Drainage Layer
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Upper Clay A
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 10 kPa

Name: Upper Clay B1
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 12 kPa

Name: Upper Clay B2
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 11 kPa

Name: Upper Clay C
Model: Bedrock (Impenetrable)

Name: Upper Clay D
Model: Bedrock (Impenetrable)

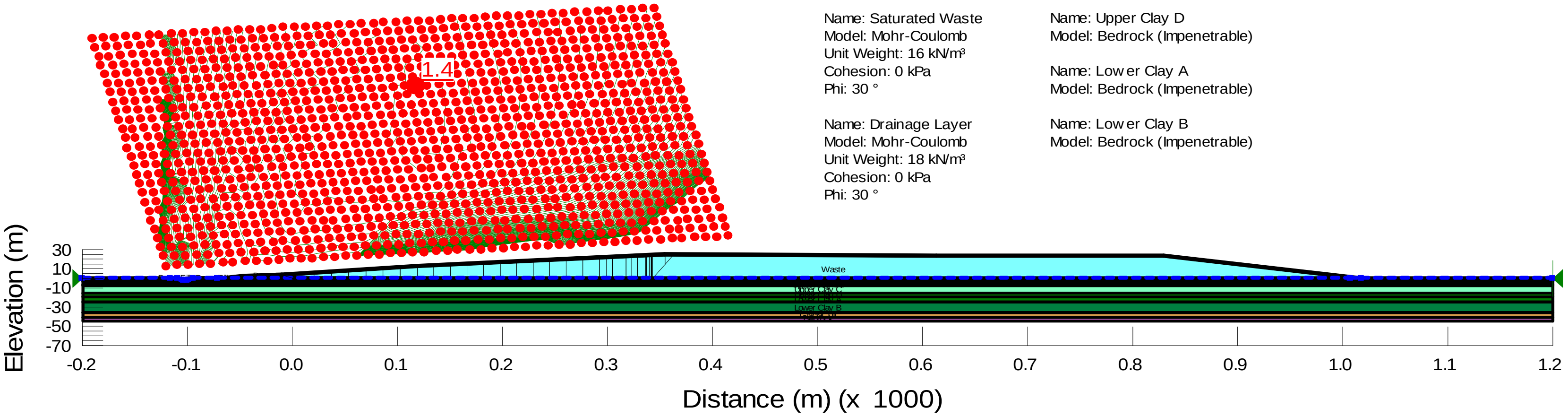
Name: Lower Clay A
Model: Bedrock (Impenetrable)

Name: Lower Clay B
Model: Bedrock (Impenetrable)

Name: Surficial Soils
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Glacial Till
Model: Bedrock (Impenetrable)

Name: Bedrock
Model: Bedrock (Impenetrable)



Golder Associates

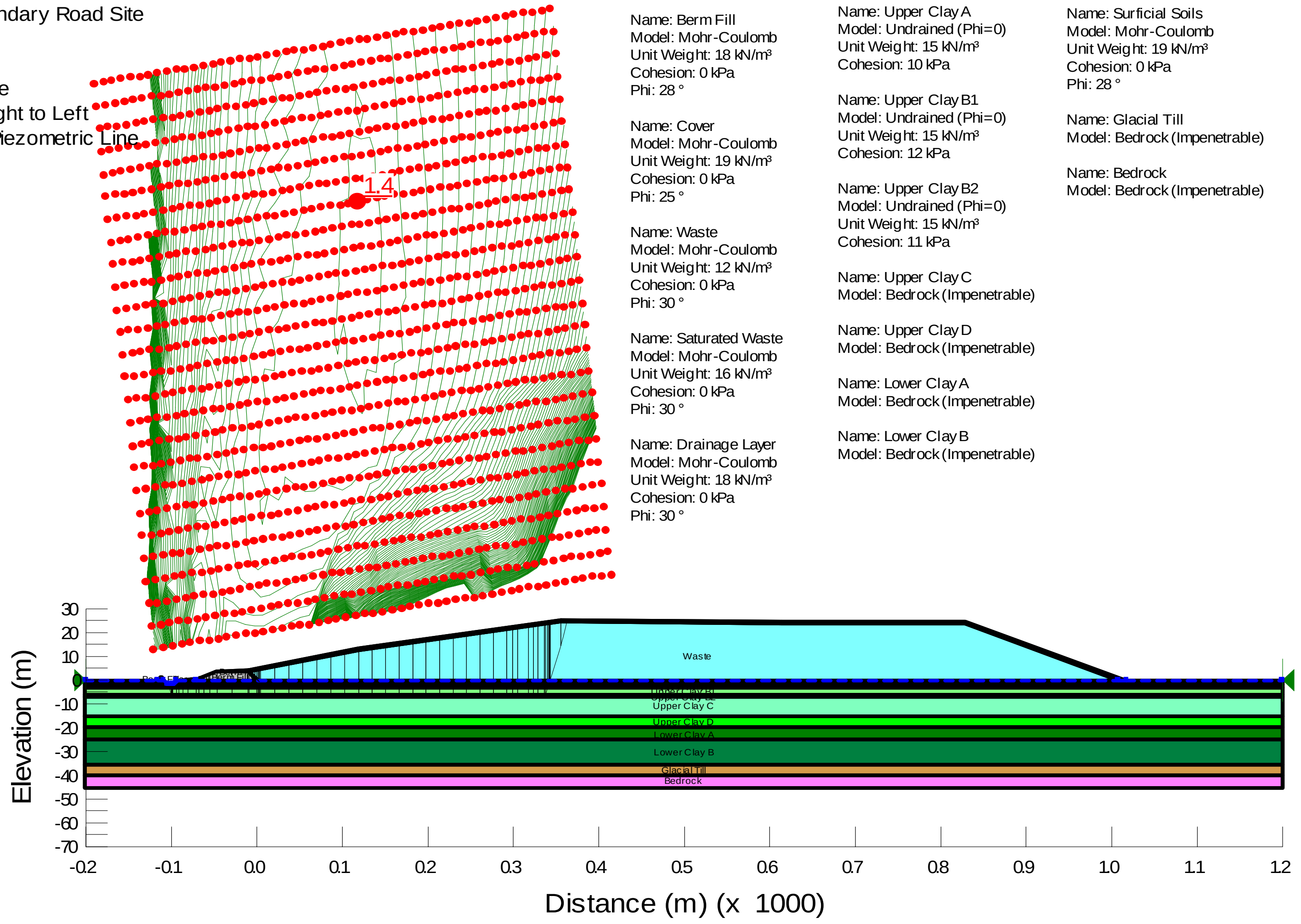
STABILITY ANALYSIS - EASTERN SIDE OF LANDFILL ADJACENT TO SWMP

CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2014
Checked:	PLE
Review:	PAS

Figure 11-1A

File Name: 12-45 UCC IP 23 OFDT.gsz
Revision Number: 203
Name: 12-1125-0045 Boundary Road Site
Date: 03/09/2013
Time: 2:44:00 PM
Method: Morgenstern-Price
Direction of movement: Right to Left
PWP Conditions Source: Piezometric Line



Name: Berm Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Cover
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: Waste
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Saturated Waste
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Drainage Layer
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Upper Clay A
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 10 kPa

Name: Upper Clay B1
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 12 kPa

Name: Upper Clay B2
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 11 kPa

Name: Upper Clay C
Model: Bedrock (Impenetrable)

Name: Upper Clay D
Model: Bedrock (Impenetrable)

Name: Lower Clay A
Model: Bedrock (Impenetrable)

Name: Lower Clay B
Model: Bedrock (Impenetrable)

Name: Surficial Soils
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Glacial Till
Model: Bedrock (Impenetrable)

Name: Bedrock
Model: Bedrock (Impenetrable)

Golder Associates

STABILITY ANALYSIS - EASTERN SIDE OF LANDFILL ADJACENT TO SWMP

CAPITAL REGION RESOURCE RECOVERY CENTRE
(3 x VERTICAL EXAGGERATION)

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2014
Checked:	PLE
Review:	PAS

Figure 11-1B

File Name: 12-45 UCC IP 20 SB SMP DR S1.gsz
Revision Number: 207
Name: 12-1125-0045 Boundary Road Site
Date: 28/08/2013
Time: 2:50:30 PM
Method: Morgenstern-Price
Direction of movement: Right to Left
PWP Conditions Source: Piezometric Line

Name: Berm Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Cover
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: Waste
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Saturated Waste
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Drainage Layer
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Upper Clay A
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 10 kPa

Name: Upper Clay B1
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 12 kPa

Name: Upper Clay B2
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 11 kPa

Name: Upper Clay C
Model: Bedrock (Impenetrable)

Name: Upper Clay D
Model: Bedrock (Impenetrable)

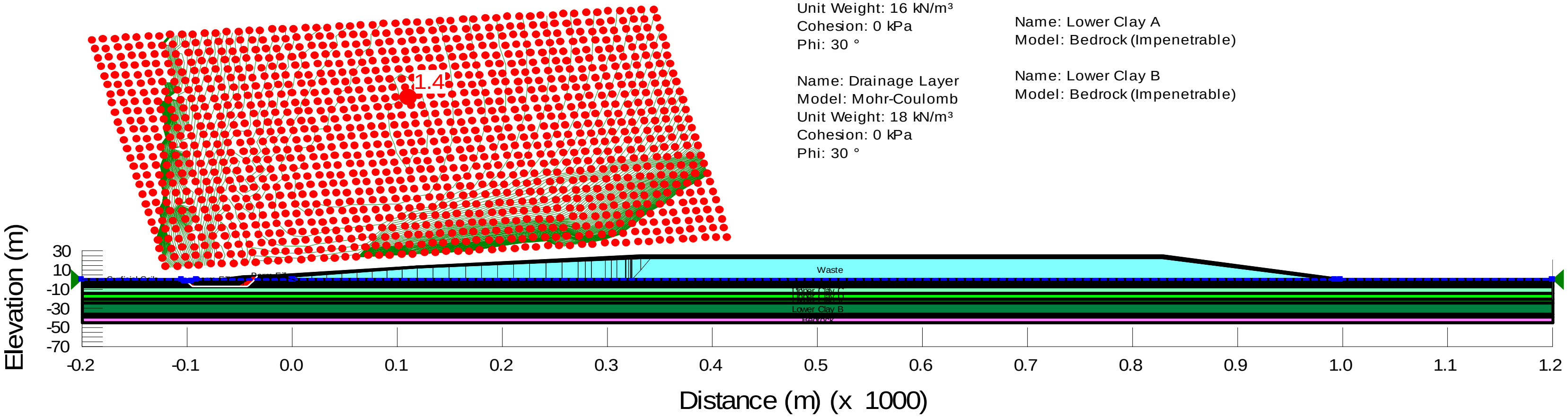
Name: Lower Clay A
Model: Bedrock (Impenetrable)

Name: Lower Clay B
Model: Bedrock (Impenetrable)

Name: Surficial Soils
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Glacial Till
Model: Bedrock (Impenetrable)

Name: Bedrock
Model: Bedrock (Impenetrable)



STABILITY ANALYSIS - NORTHERN END OF LANDFILL ADJACENT TO SIMPSON DRAIN

CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2014
Checked:	PLE
Review:	PAS

Figure 11-2A

File Name: 12-45 UCC IP 20 SB SMP DR S1.gsz
Revision Number: 207
Name: 12-1125-0045 Boundary Road Site
Date: 28/08/2013
Time: 2:50:30 PM
Method: Morgenstern-Price
Direction of movement: Right to Left
PWP Conditions Source: Piezometric Line

Name: Berm Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Cover
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: Waste
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Saturated Waste
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Drainage Layer
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Upper Clay A
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 10 kPa

Name: Upper Clay B1
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 12 kPa

Name: Upper Clay B2
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 11 kPa

Name: Upper Clay C
Model: Bedrock (Impenetrable)

Name: Upper Clay D
Model: Bedrock (Impenetrable)

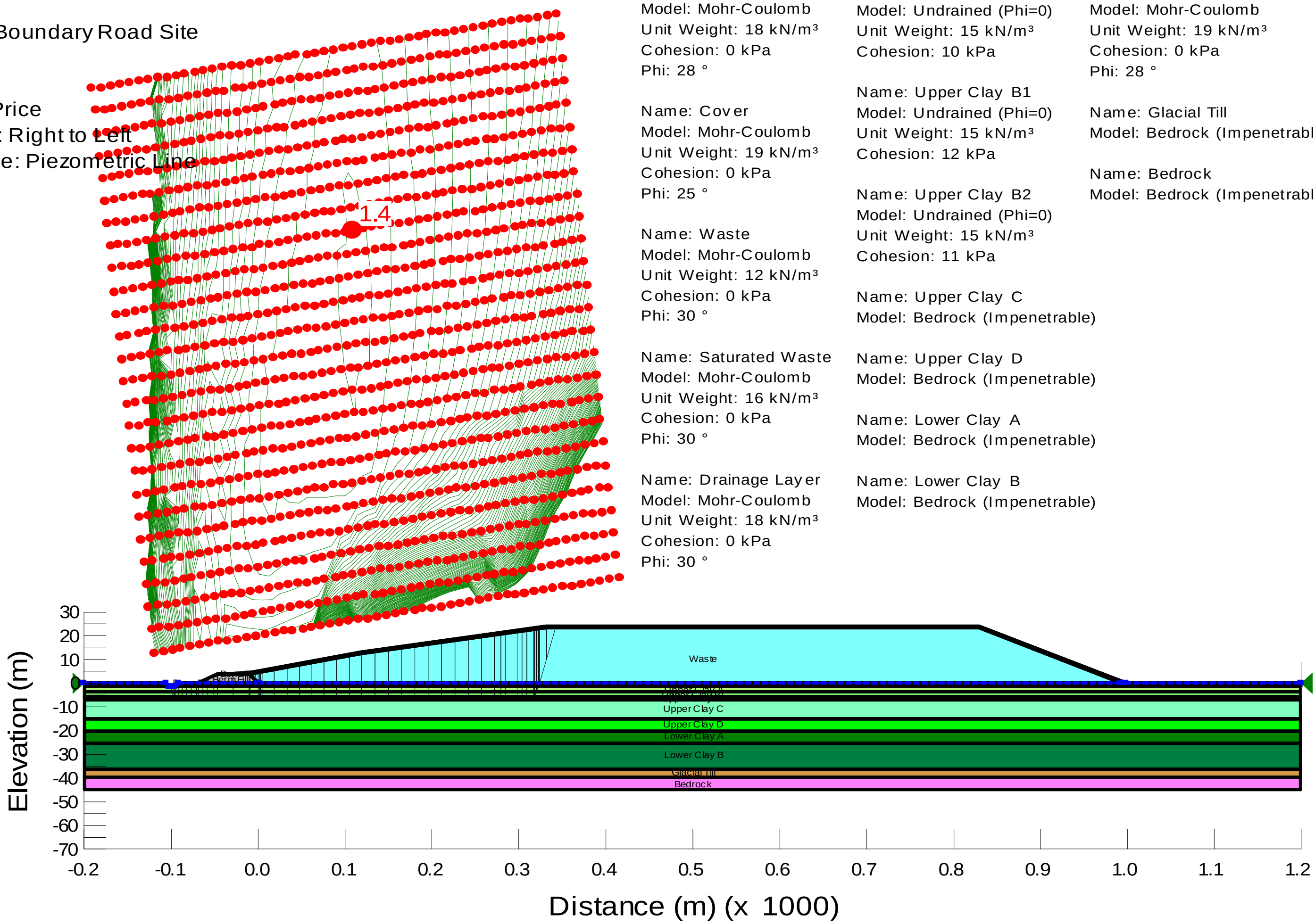
Name: Lower Clay A
Model: Bedrock (Impenetrable)

Name: Lower Clay B
Model: Bedrock (Impenetrable)

Name: Surficial Soils
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Glacial Till
Model: Bedrock (Impenetrable

Name: Bedrock
Model: Bedrock (Impenetrable



Golder Associates

STABILITY ANALYSIS - NORTHERN END OF LANDFILL ADJACENT TO SIMPSON DRAIN

CAPITAL REGION RESOURCE RECOVERY CENTRE
(3 x VERTICAL EXAGGERATION)

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2014
Checked:	PLE
Review:	PAS

Figure 11-2B

File Name: 12-45 UCC IP 14H 1V INT.gsz
Revision Number: 179
Name: 12-1125-0045 Boundary Road Site
Date: 04/09/2013
Time: 2:11:56 PM
Method: Morgenstern-Price
Direction of movement: Left to Right
PWP Conditions Source: Piezometric Line

Name: Berm Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Cover
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: Waste
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Saturated Waste
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Drainage Layer
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Upper Clay A
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 10 kPa

Name: Upper Clay B1
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 12 kPa

Name: Upper Clay B2
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 11 kPa

Name: Upper Clay C
Model: Bedrock (Impenetrable)

Name: Upper Clay D
Model: Bedrock (Impenetrable)

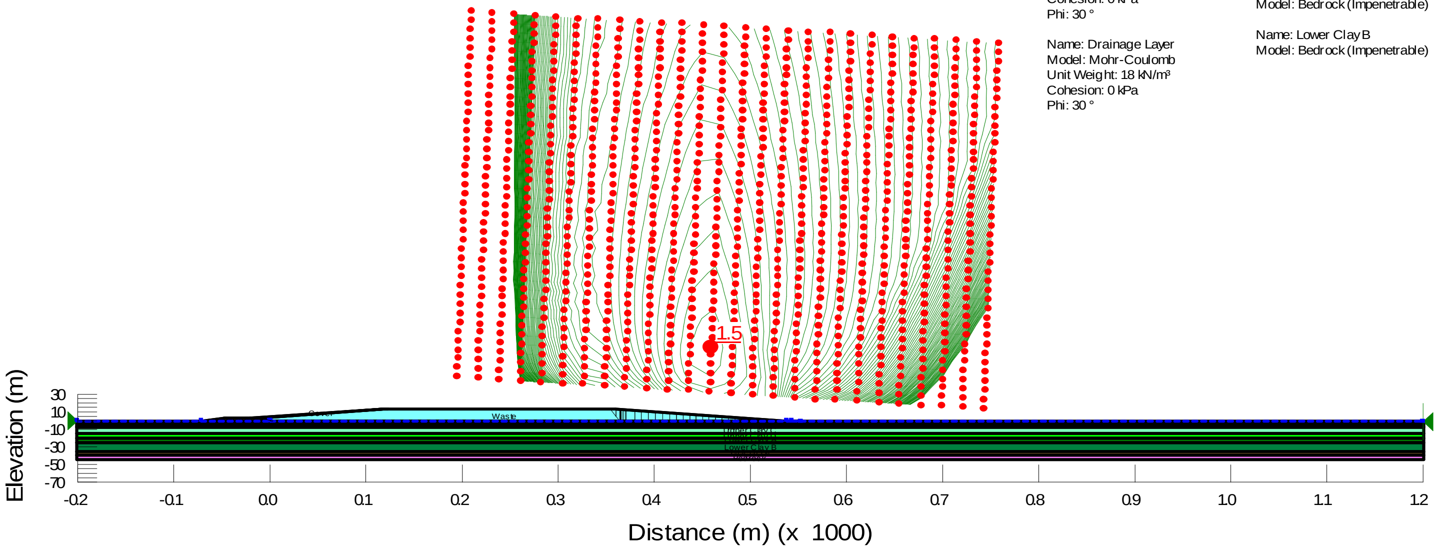
Name: Lower Clay A
Model: Bedrock (Impenetrable)

Name: Lower Clay B
Model: Bedrock (Impenetrable)

Name: Surficial Soils
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Glacial Till
Model: Bedrock (Impenetrable)

Name: Bedrock
Model: Bedrock (Impenetrable)



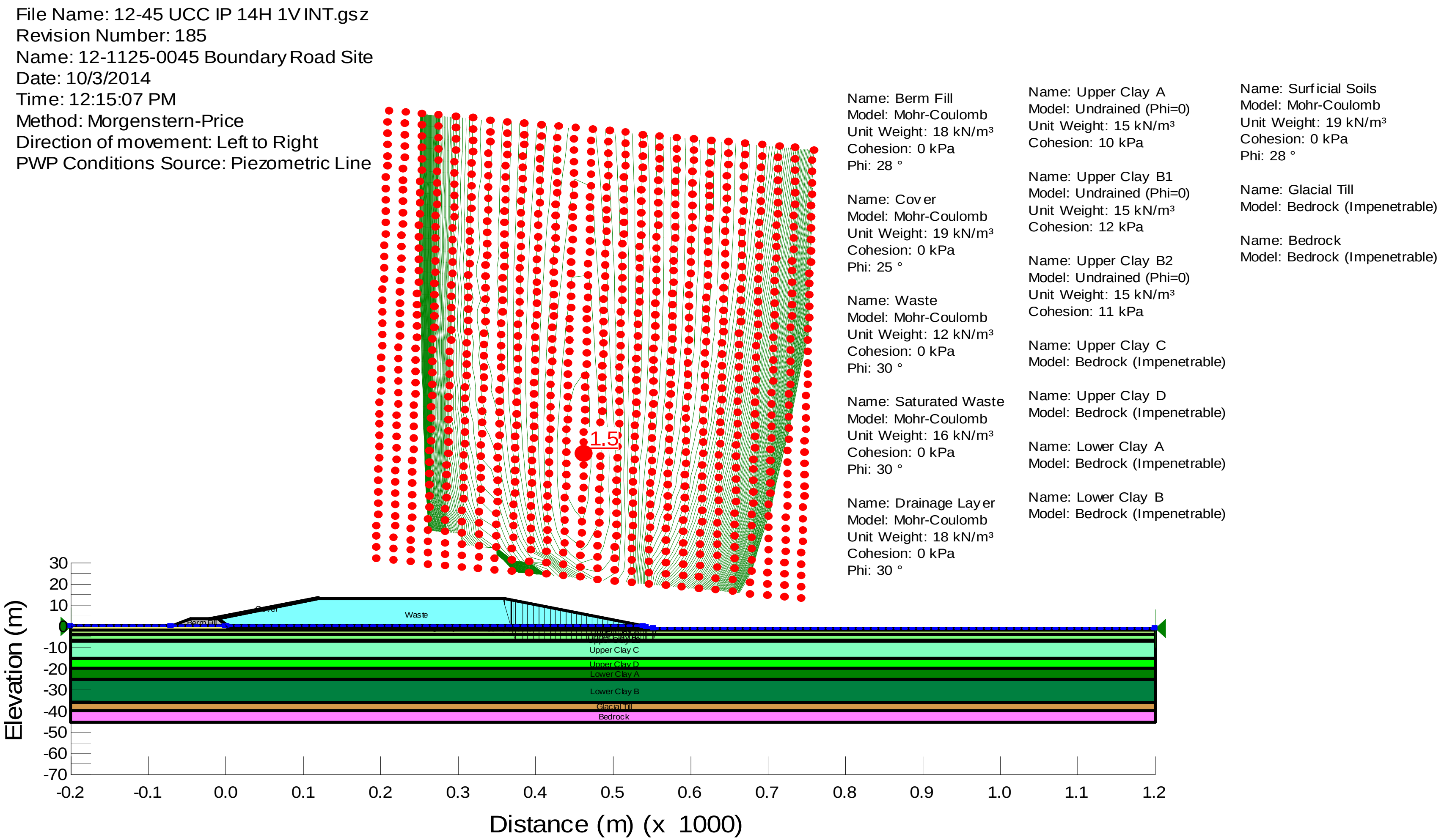
Golder Associates

STABILITY ANALYSIS - INTERIM WASTE SLOPE

CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2014
Checked:	PLE
Review:	PAS

Figure 11-3A



File Name: 12-45 UCC IP 14H 1V INT.gsz
Revision Number: 185
Name: 12-1125-0045 Boundary Road Site
Date: 10/3/2014
Time: 12:15:07 PM
Method: Morgenstern-Price
Direction of movement: Left to Right
PWP Conditions Source: Piezometric Line

Name: Berm Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Cover
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 25 °

Name: Waste
Model: Mohr-Coulomb
Unit Weight: 12 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Saturated Waste
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Drainage Layer
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 30 °

Name: Upper Clay A
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 10 kPa

Name: Upper Clay B1
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 12 kPa

Name: Upper Clay B2
Model: Undrained (Phi=0)
Unit Weight: 15 kN/m³
Cohesion: 11 kPa

Name: Upper Clay C
Model: Bedrock (Impenetrable)

Name: Upper Clay D
Model: Bedrock (Impenetrable)

Name: Lower Clay A
Model: Bedrock (Impenetrable)

Name: Lower Clay B
Model: Bedrock (Impenetrable)

Name: Surficial Soils
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 28 °

Name: Glacial Till
Model: Bedrock (Impenetrable)

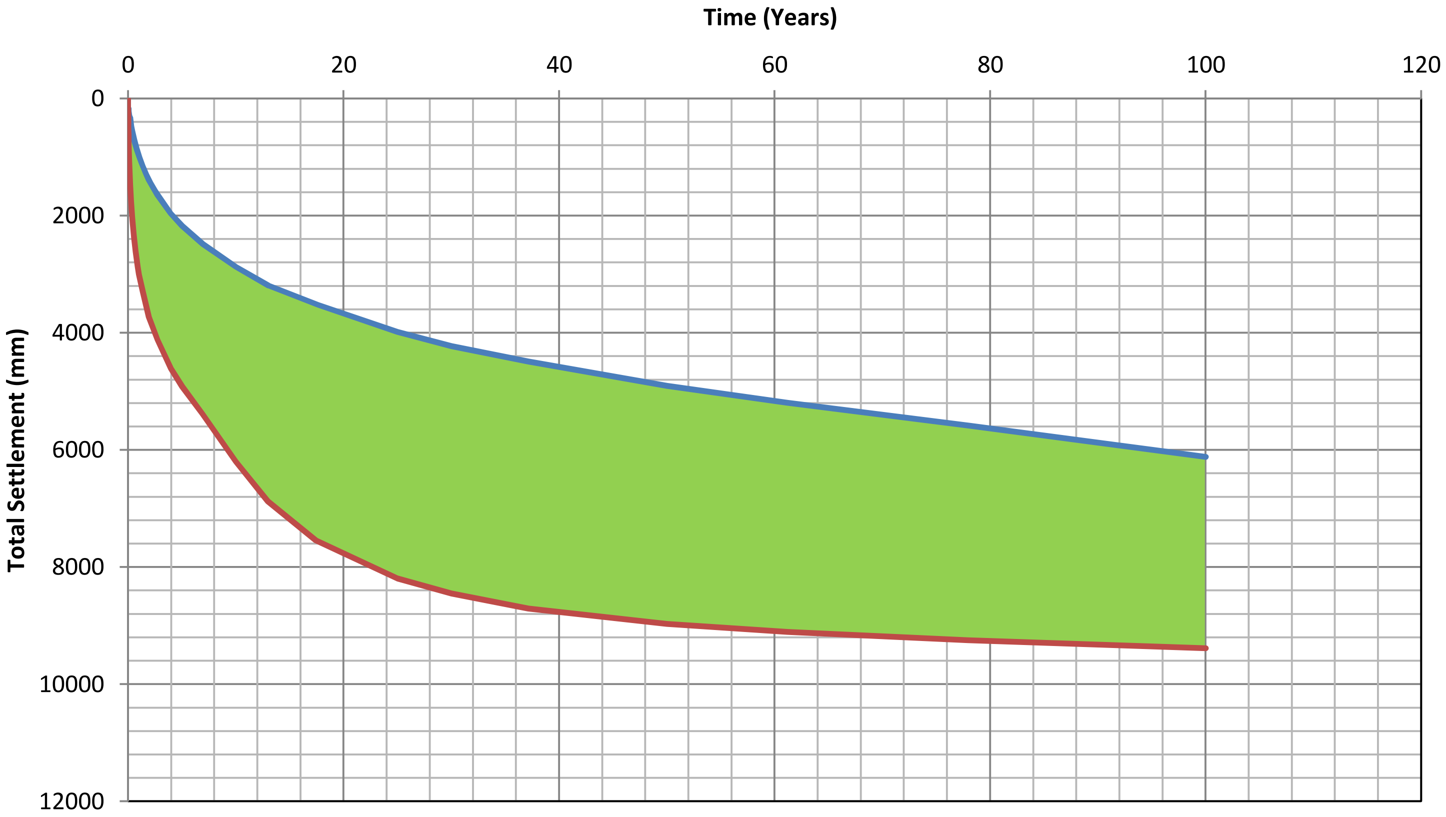
Name: Bedrock
Model: Bedrock (Impenetrable)

Golder Associates

STABILITY ANALYSIS - INTERIM WASTE SLOPE
CAPITAL REGION RESOURCE RECOVERY CENTRE
(3 x VERTICAL EXAGGERATION)

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2014
Checked:	PLE
Review:	PAS

Figure 11-3B



Golder Associates

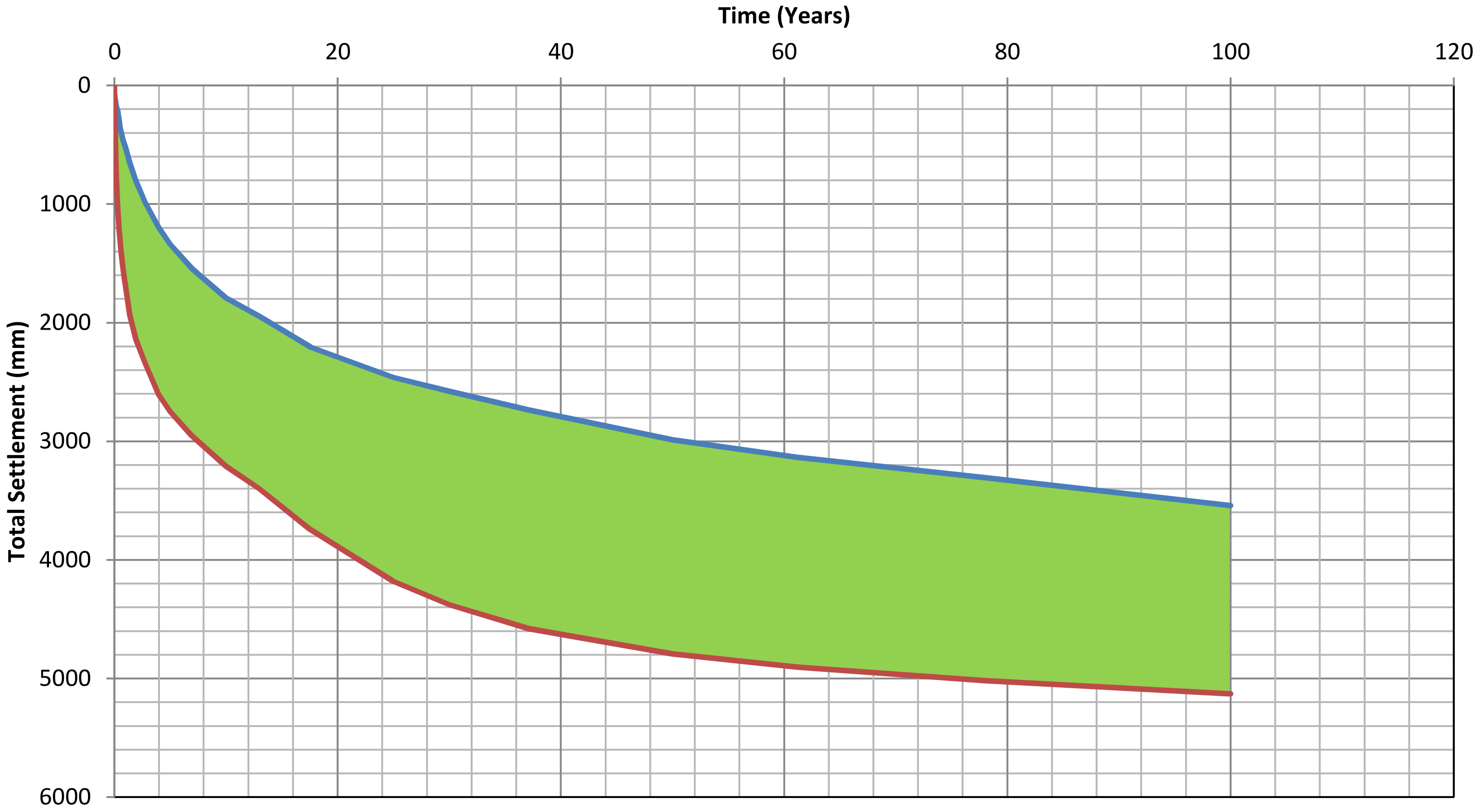
CALCULATED RANGE OF TOTAL SETTLEMENT

SETTLEMENT VERSUS TIME - 25-METRE HIGH LANDFILL

CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	CK
Date:	Nov. 2013
Checked:	PLE
Review:	PAS

Figure 11-4



Golder Associates

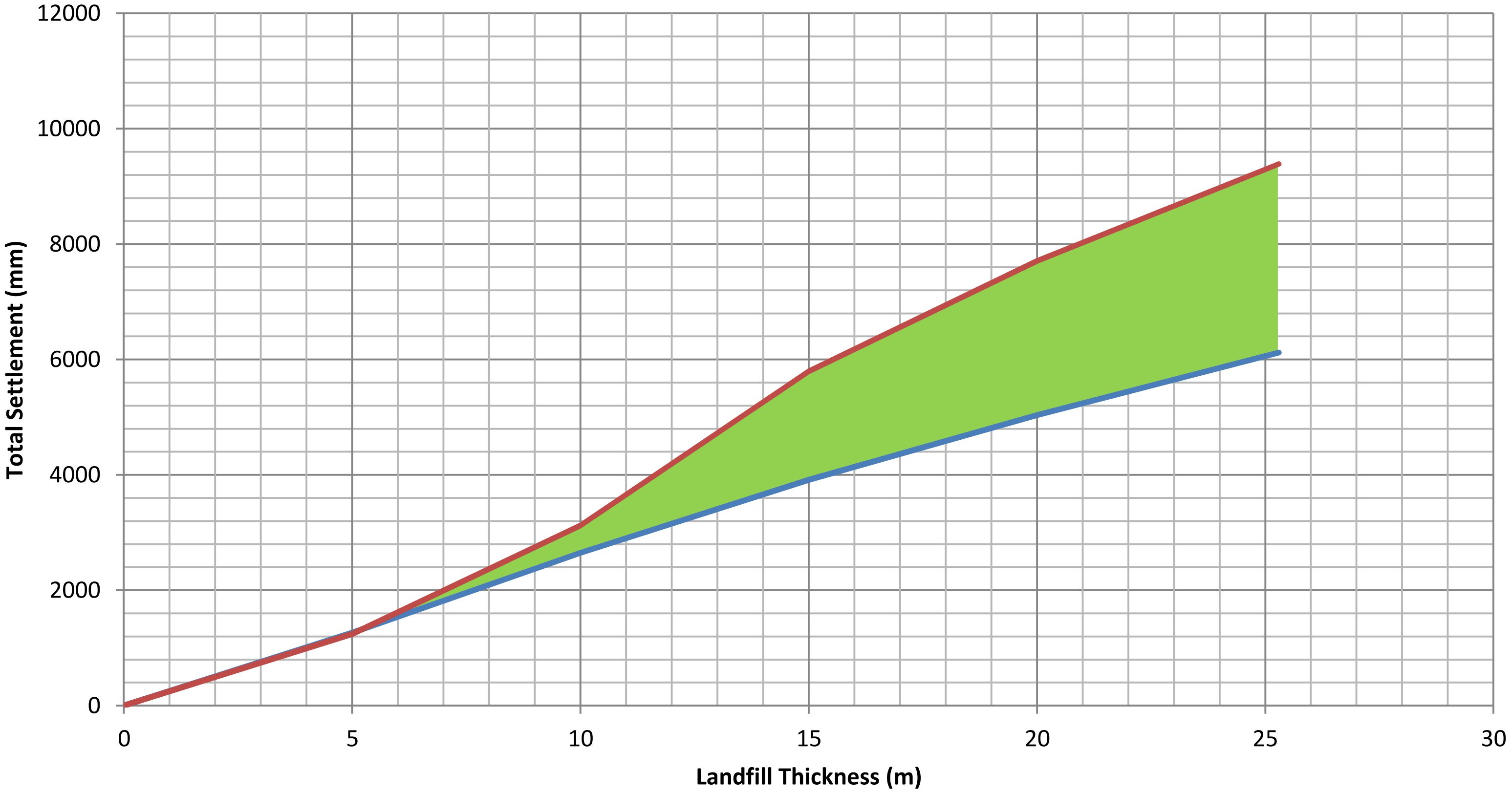
CALCULATED RANGE OF TOTAL SETTLEMENT

SETTLEMENT VERSUS TIME - 13.5-METRE HIGH LANDFILL

CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	CK
Date:	Nov. 2013
Checked:	PLE
Review:	PAS

Figure 11-5



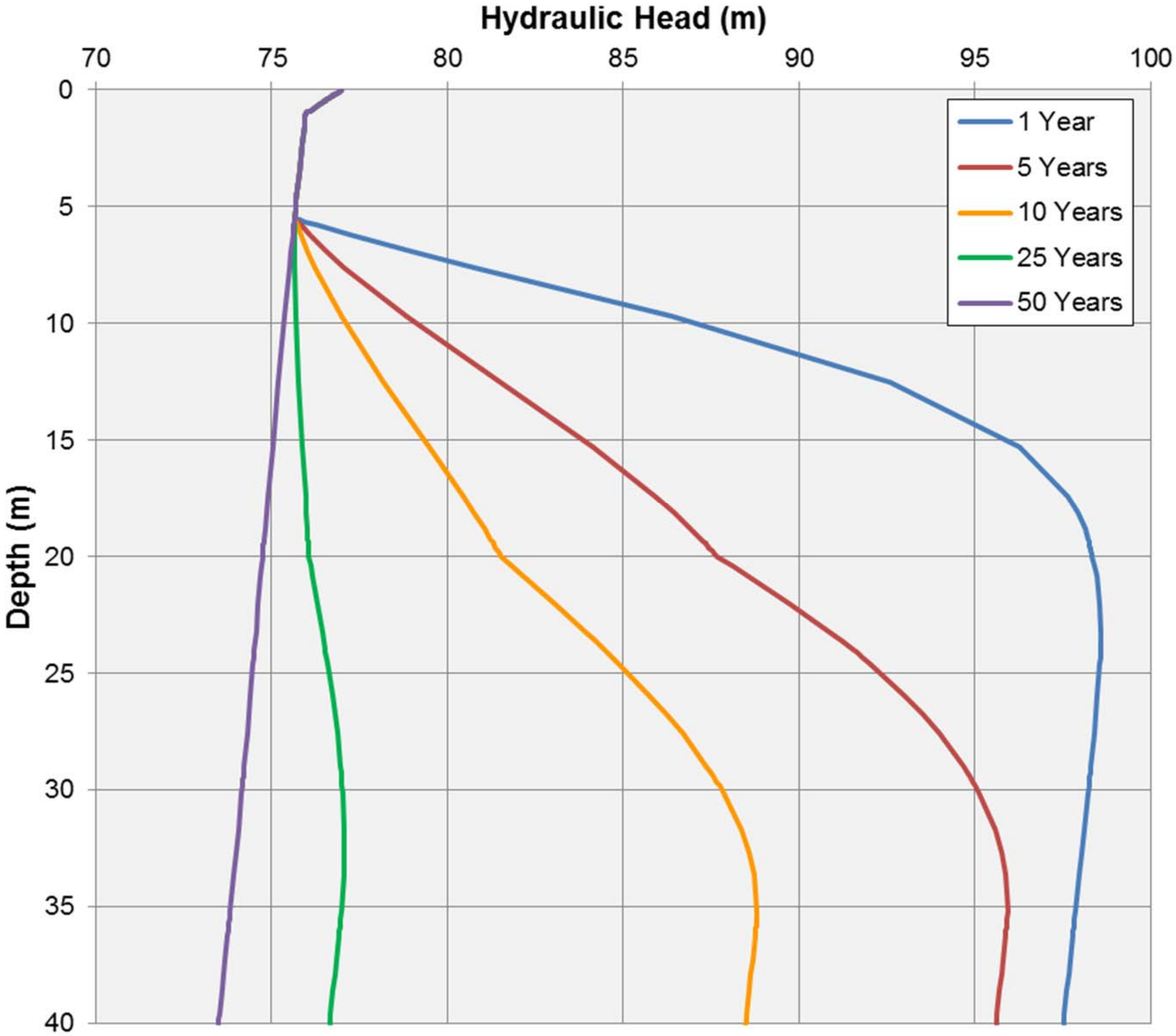
CALCULATED RANGE OF TOTAL SETTLEMENT

TOTAL SETTLEMENT VERSUS LANDFILL THICKNESS - 100 YEARS

CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	CK
Date:	Nov. 2013
Checked:	PLE
Review:	PAS

Figure 11-6



NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

HYDRAULIC HEAD PROFILES GENERATED BASED ON SETTLE-3D MODEL RESULTS AND OBSERVED VERTICAL GRADIENTS

SETTLE-3D MODEL ACCOUNTS FOR LEACHATE COLLECTION SYSTEM AT 0.3 METRES DEPTH AND ALLOWS DRAINAGE OF THE UPPER CLAY THROUGH THE SILTY LAYER

PROJECT

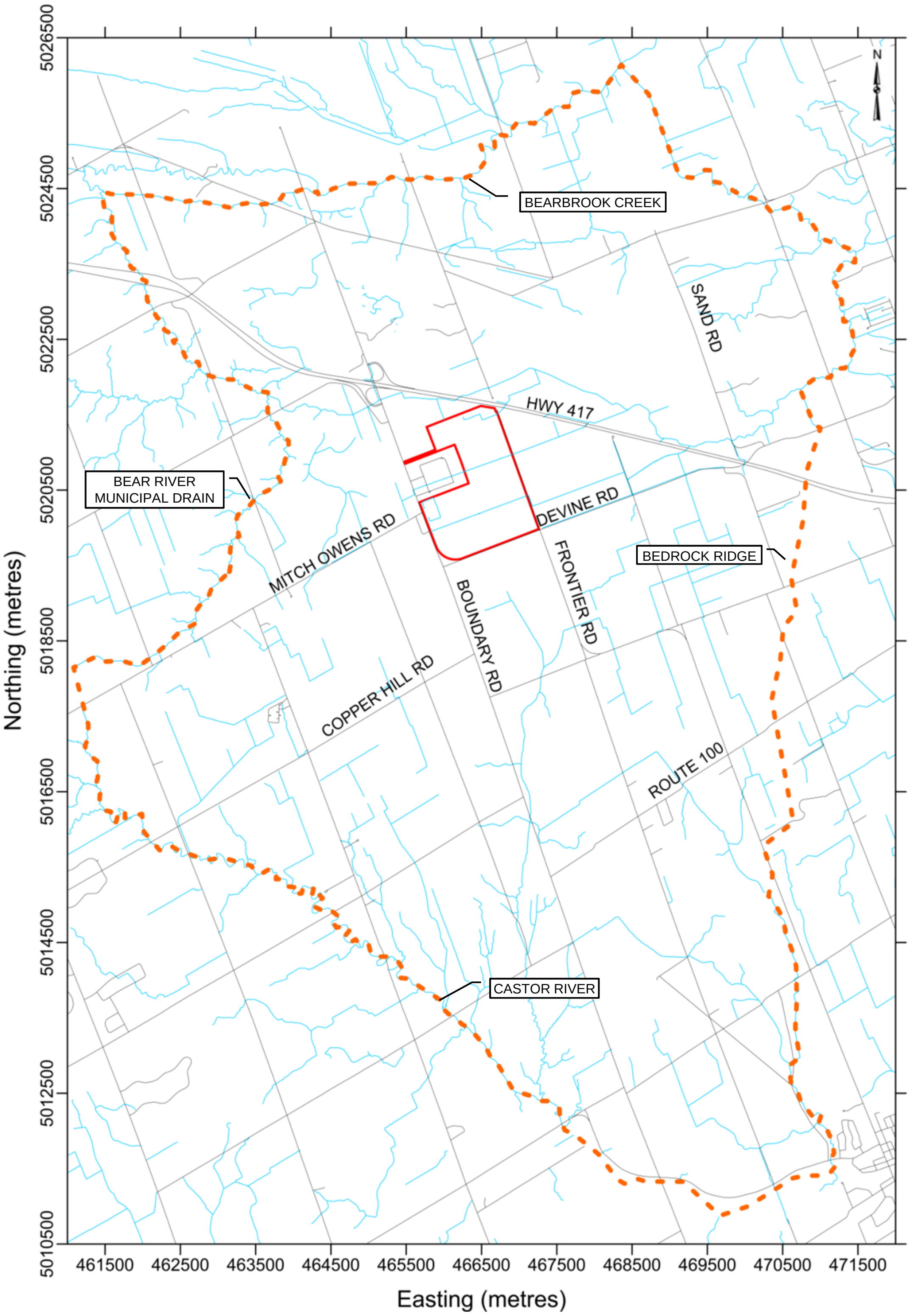
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Hydraulic Head Development During Consolidation

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4500	
DESIGN	MIB	Nov. 2013	SCALE AS SHOWN	REV.0
GIS	--	--	FIGURE 12-1	
CHECK	PLE	Aug. 2014		
REVIEW	PAS	Aug. 2014		



LEGEND

━ WATERBODIES

━ ROADS

━ PROPERTY BOUNDARY

╍ MODEL DOMAIN

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2011. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

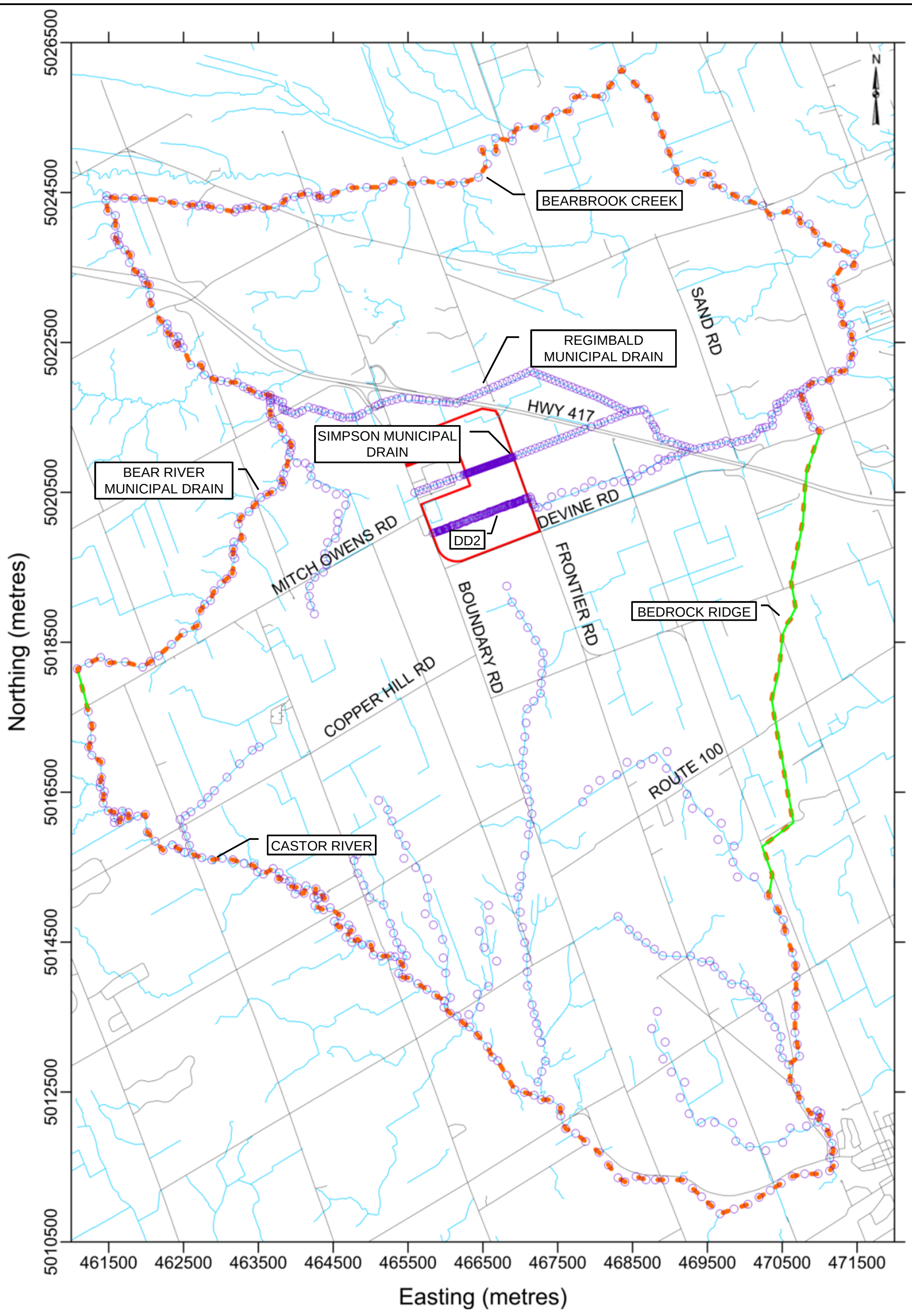
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

3-D Numerical Groundwater Model Domain

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4500
DESIGN	MIB	Nov. 2013	SCALE AS SHOWN REV.0
GIS	--	--	FIGURE 12-2
CHECK	PLE	Aug. 2014	
REVIEW	PAS	Aug. 2014	



LEGEND

🟦	WATERBODIES
▬	ROADS
🟥	PROPERTY BOUNDARY
▬ ▬	MODEL DOMAIN
○○○○	SPECIFIED HEAD OR SEEPAGE BOUNDARY
🟩	NO FLOW BOUNDARY

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2011. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

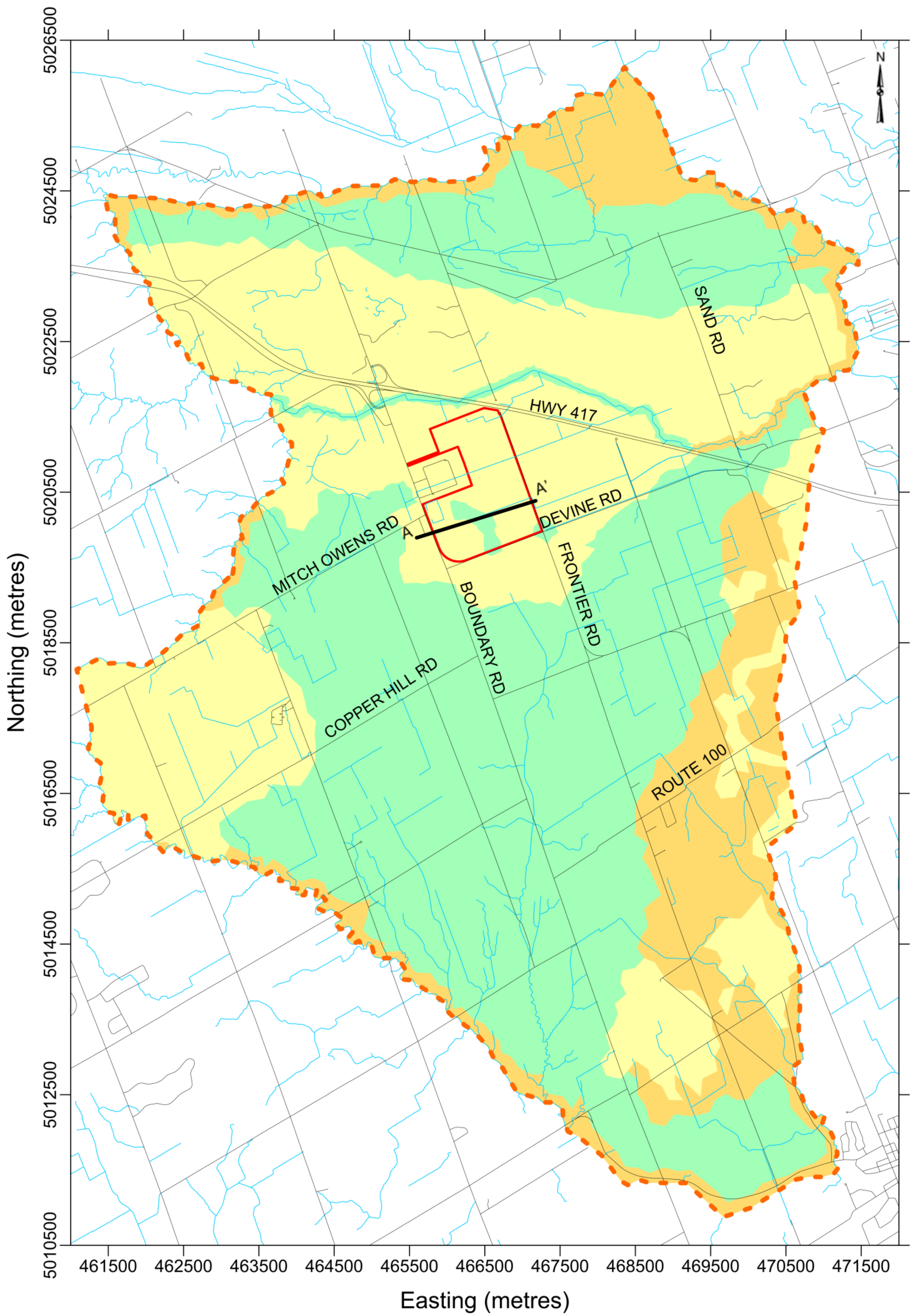
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

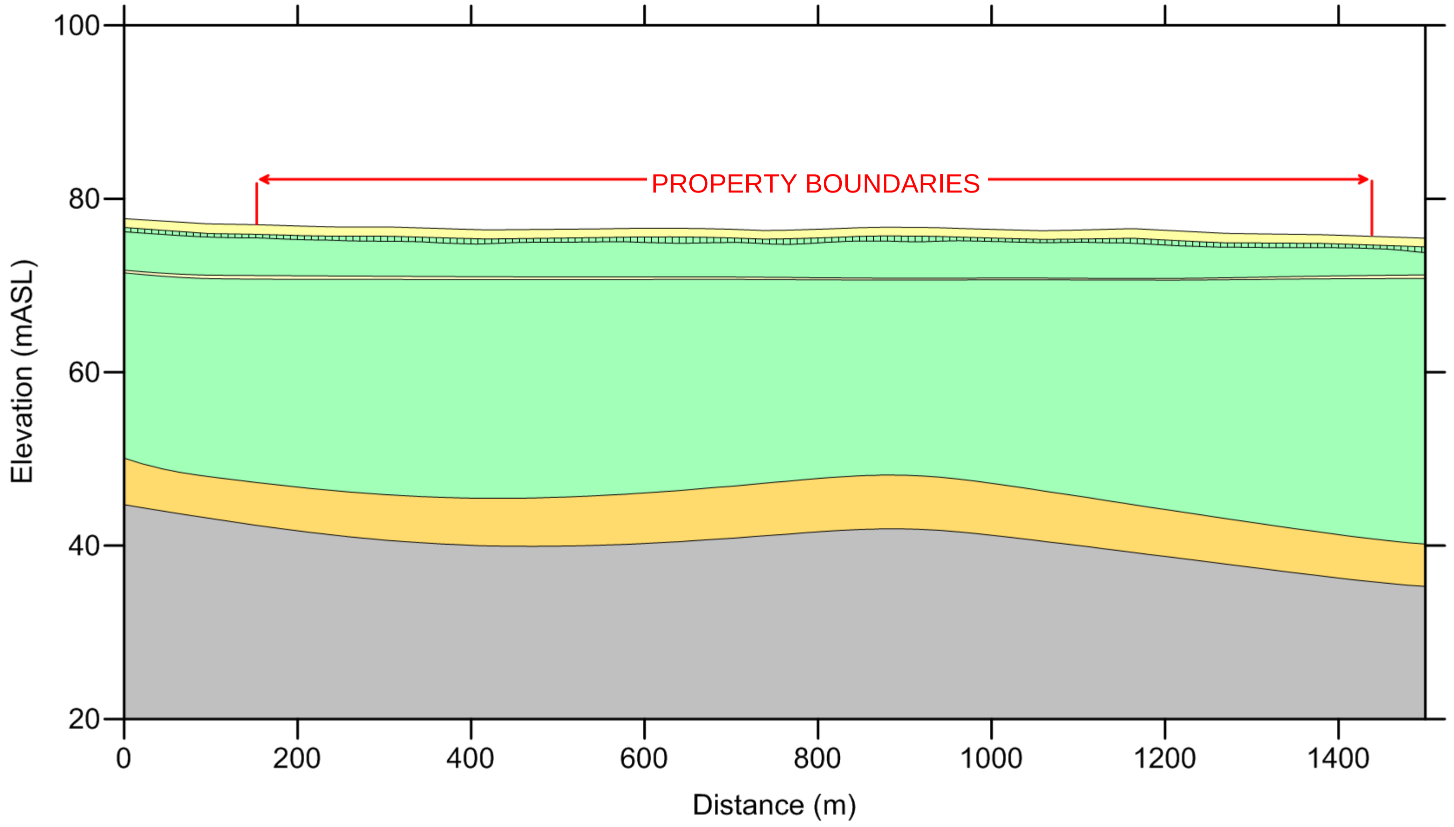
Boundary Conditions
3-D Numerical Groundwater Model

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4500	
DESIGN	MIB	Nov. 2013	SCALE AS SHOWN	REV.0
GIS	--	--	FIGURE 12-3	
CHECK	PLE	Aug. 2014		
REVIEW	PAS	Aug. 2014		



PLAN VIEW (SLICE 1)
Scale as Shown



CROSS-SECTION A-A'
Scale as Shown

SUMMARY OF HYDRAULIC PARAMETERS

Unit	Horizontal Hydraulic Conductivity (m/sec)	Anisotropy (K_H:K_V)	Specific Storage (m^{-1})	Specific Yield (-)
Surficial Silty Sand	2.0×10^{-5}	1:1	2.0×10^{-4}	0.2
Weathered Clay	1.0×10^{-7}	10:1	2.0×10^{-3}	0.05
Unweathered Clay	1.0×10^{-8}	10:1	2.0×10^{-3}	0.05
Silty Layer	8.0×10^{-7}	1:1	2.0×10^{-4}	0.1
Glacial Till	1.5×10^{-6}	1:1	2.0×10^{-4}	0.1
Queenston Shale Bedrock Formation	5.5×10^{-7}	1:1	3.0×10^{-6}	0.01
Carlsbad Bedrock Formation	7.0×10^{-7}	1:1	3.0×10^{-6}	0.01

LEGEND

―	WATERBODIES
―	ROADS
―	PROPERTY BOUNDARY
- - -	MODEL DOMAIN
🟨	SURFICIAL SILTY SAND
🟩	SILTY CLAY
🟧	GLACIAL TILL
⬜	CARLSBAD BEDROCK FORMATION

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

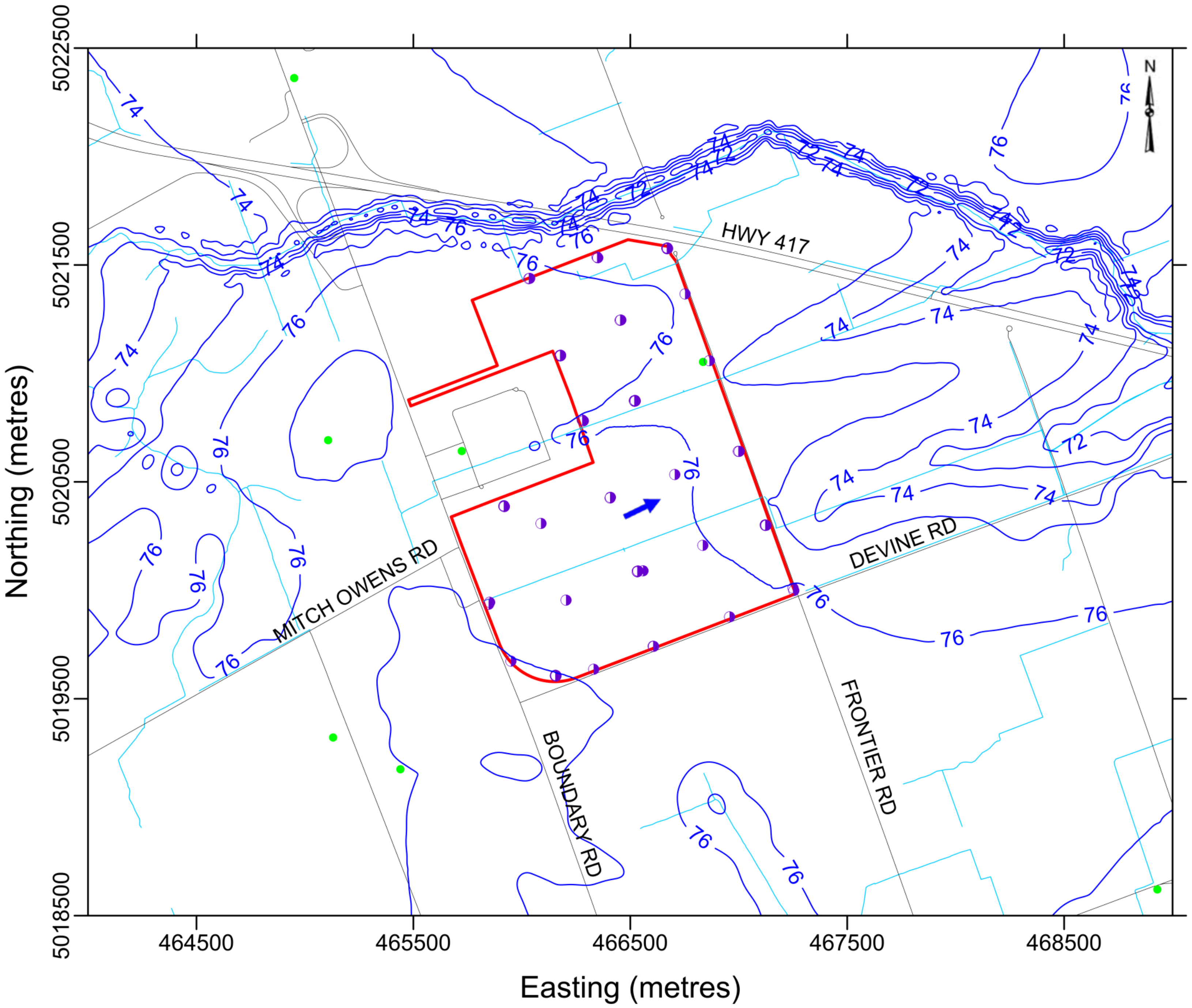
LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2011. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

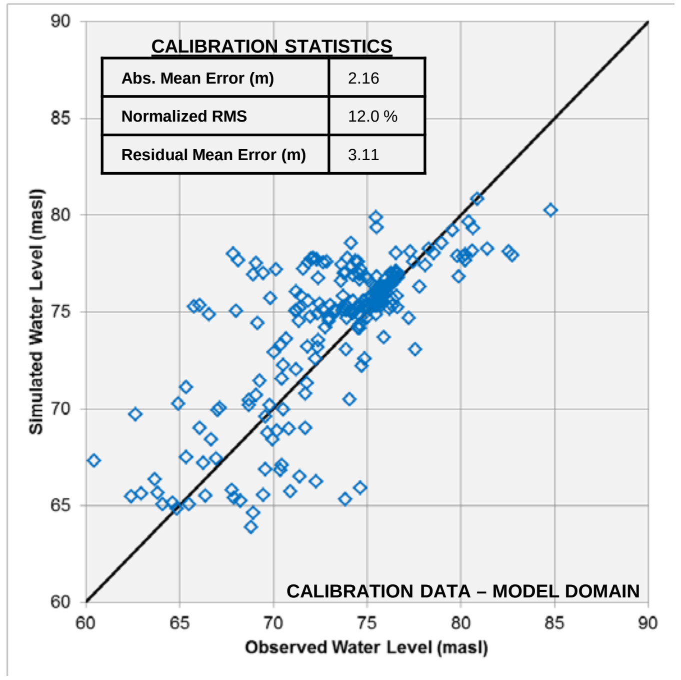
PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

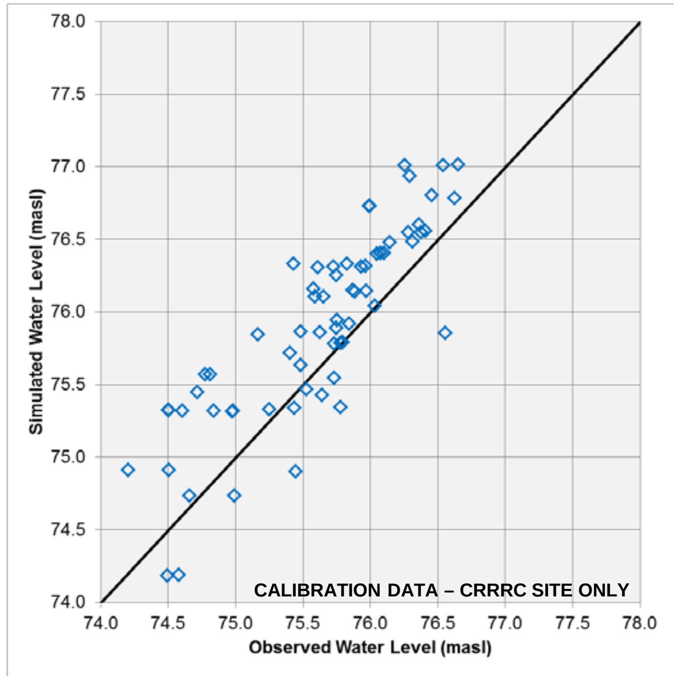
TITLE
Hydraulic Conductivity Distribution
3-D Numerical Groundwater Model

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	MIB	Nov. 2013	FIGURE 12-4	
GIS	----	----		
CHECK	PLE	Aug. 2014		
REVIEW	PAS	Aug. 2014		







LEGEND

—	WATERBODIES
—	ROADS
—	PROPERTY BOUNDARY
—75—	GROUNDWATER ELEVATION (metres ABOVE SEA LEVEL) (2 metre contour interval)
➡	INTERPRETED GROUNDWATER FLOW DIRECTION
◑	MONITORING LOCATION (CURRENT STUDY)
●	WATER WELL LOCATION

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

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PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

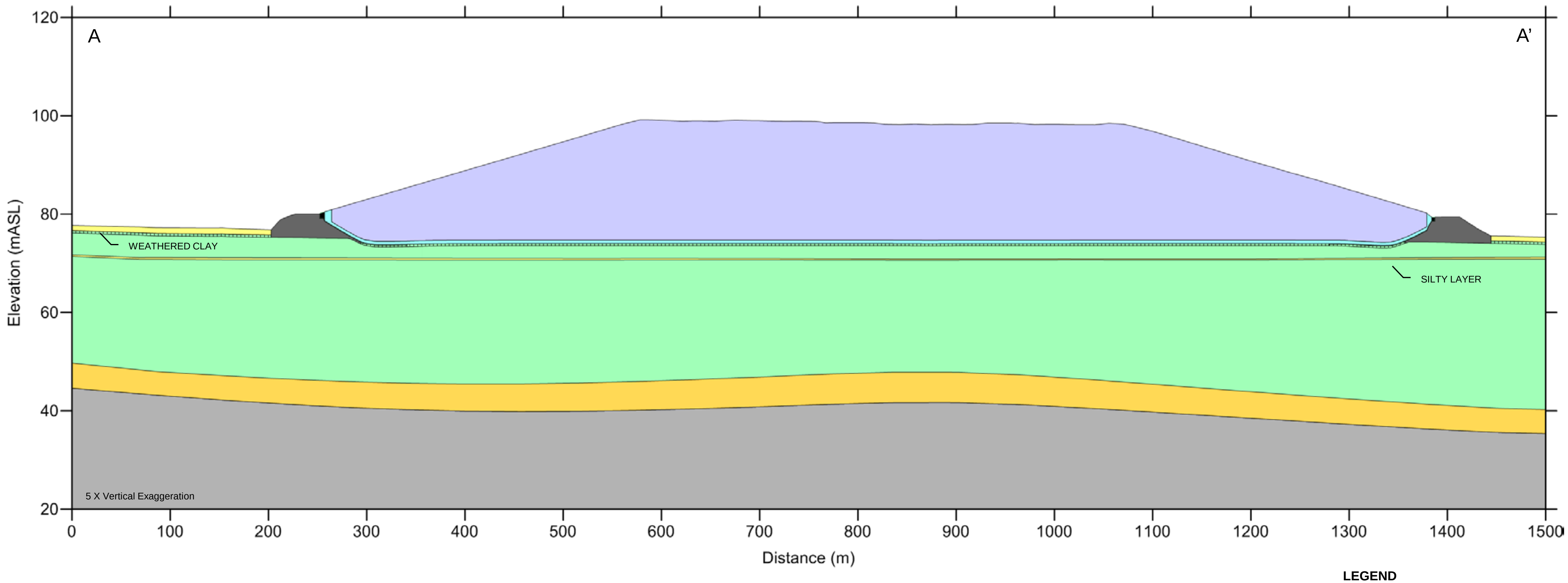
TITLE
Comparison of Simulated and Measured
Groundwater Elevations

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045		
DESIGN	MIB	Nov. 2013
GIS	----	----
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

SCALE AS SHOWN
REV.0

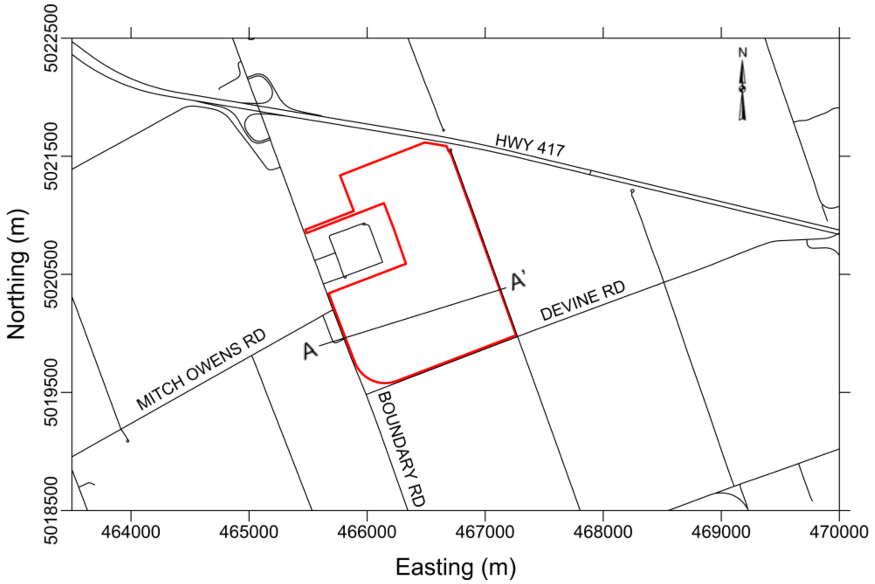
FIGURE 12-5



CROSS-SECTION A-A'
Scale as Shown

LEGEND

- — WATERBODIES
- — ROADS
- — PROPERTY BOUNDARY
- 🟨 SURFICIAL SILTY SAND
- 🟩 SILTY CLAY
- 🟧 GLACIAL TILL
- ⬛ CARLSBAD BEDROCK FORMATION
- 🟪 WASTE
- 🟦 DRAINAGE LAYER
- — GCL



KEY MAP
Scale as Shown

SUMMARY OF HYDRAULIC PARAMETERS

Unit	Horizontal Hydraulic Conductivity (m/sec)	Anisotropy (K_H:K_V)	Specific Storage (m^{-1})	Specific Yield (-)
Surficial Silty Sand	2.0×10^{-5}	1:1	2.0×10^{-4}	0.2
Weathered Clay	1.0×10^{-7}	10:1	2.0×10^{-3}	0.05
Unweathered Clay	1.0×10^{-8}	10:1	2.0×10^{-3}	0.05
Silty Layer	8.0×10^{-7}	1:1	2.0×10^{-4}	0.1
Glacial Till	1.5×10^{-6}	1:1	2.0×10^{-4}	0.1
Queenston Shale Bedrock Formation	5.5×10^{-7}	1:1	3.0×10^{-6}	0.01
Carlsbad Bedrock Formation	7.0×10^{-7}	1:1	3.0×10^{-6}	0.01
Waste (Operations)	1.0×10^{-5}	1:1	2.0×10^{-3}	0.1
Waste (Closure)	1.2×10^{-5}	1:1	2.0×10^{-3}	0.1
Drainage Layer	1.0×10^{-4}	1:1	2.0×10^{-4}	0.3
GCL	3.0×10^{-10}	1:1	2.0×10^{-3}	0.0001
Berm	1.0×10^{-7}	1:1	2.0×10^{-3}	0.05

NOTE

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REFERENCE

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PROJECT

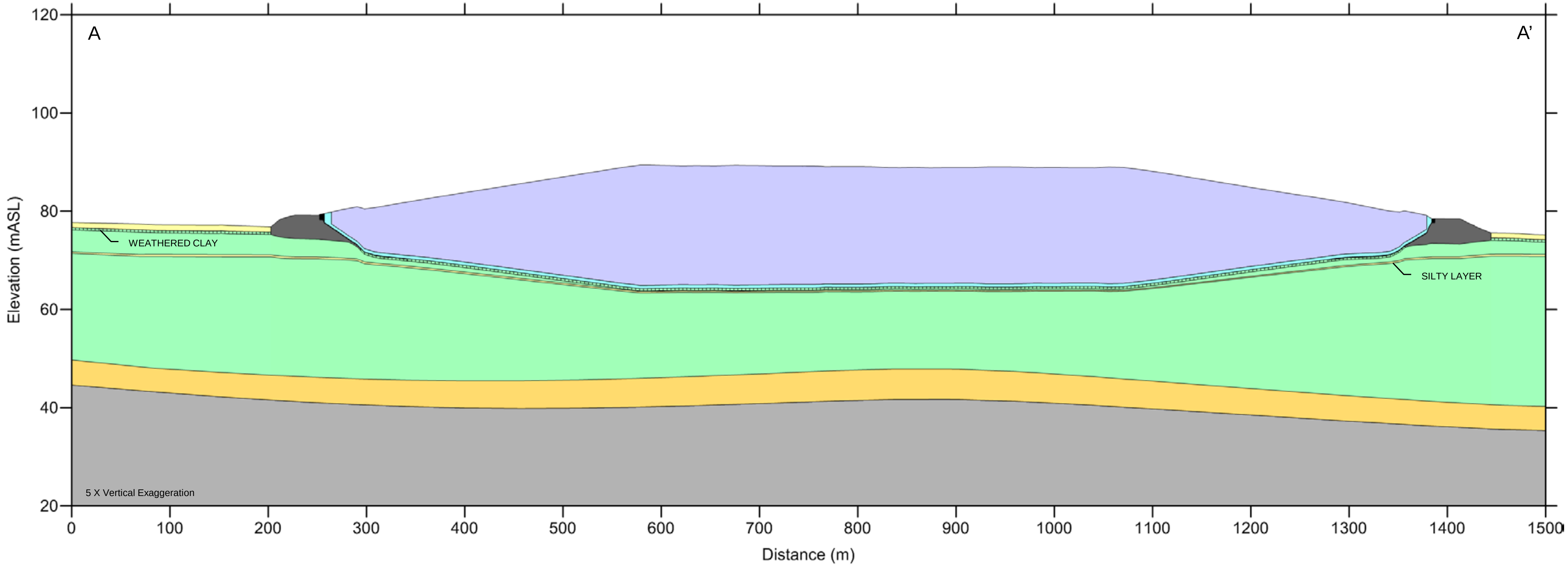
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Simulated Post-Development Cross-Section

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	MIB	Nov. 2013	FIGURE 12-6	
GIS	----	----		
CHECK	PLE	Aug. 2014		
REVIEW	PAS	Aug. 2014		



CROSS-SECTION A-A'
Scale as Shown

LEGEND

— WATERBODIES
— ROADS
— PROPERTY BOUNDARY
🟨 SURFICIAL SILTY SAND
🟩 SILTY CLAY
🟧 GLACIAL TILL
⬛ CARLSBAD BEDROCK FORMATION
🟪 WASTE
🟦 DRAINAGE LAYER
— GCL

NOTE

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REFERENCE

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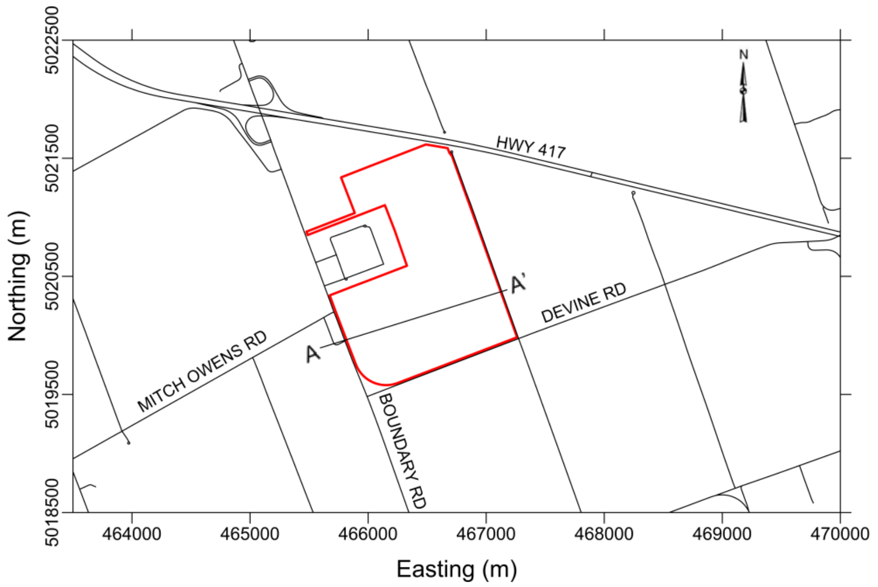


KEY MAP
Scale as Shown

SUMMARY OF HYDRAULIC PARAMETERS

Unit	Horizontal Hydraulic Conductivity (m/sec)	Anisotropy (K_H:K_V)	Specific Storage (m^{-1})	Specific Yield (-)
Surficial Silty Sand	2.0×10^{-5}	1:1	2.0×10^{-4}	0.2
Weathered Clay	1.0×10^{-7}	100:1(1)	2.0×10^{-3}	0.05
Unweathered Clay	1.0×10^{-8}	100:1(1)	2.0×10^{-3}	0.05
Silty Layer	8.0×10^{-7}	1:1	2.0×10^{-4}	0.1
Glacial Till	1.5×10^{-6}	1:1	2.0×10^{-4}	0.1
Queenston Shale Bedrock Formation	5.5×10^{-7}	1:1	3.0×10^{-6}	0.01
Carlsbad Bedrock Formation	7.0×10^{-7}	1:1	3.0×10^{-6}	0.01
Waste (Operations)	1.0×10^{-5}	1:1	2.0×10^{-3}	0.1
Waste (Closure)	1.2×10^{-5}	1:1	2.0×10^{-3}	0.1
Drainage Layer	1.0×10^{-4}	1:1	2.0×10^{-4}	0.3
GCL	3.0×10^{-10}	1:1	2.0×10^{-3}	0.0001
Berm	1.0×10^{-7}	1:1	2.0×10^{-3}	0.05

1: 100:1 Anisotropy applied to consolidated clay, 10:1 Anisotropy applied to unconsolidated clay

PROJECT

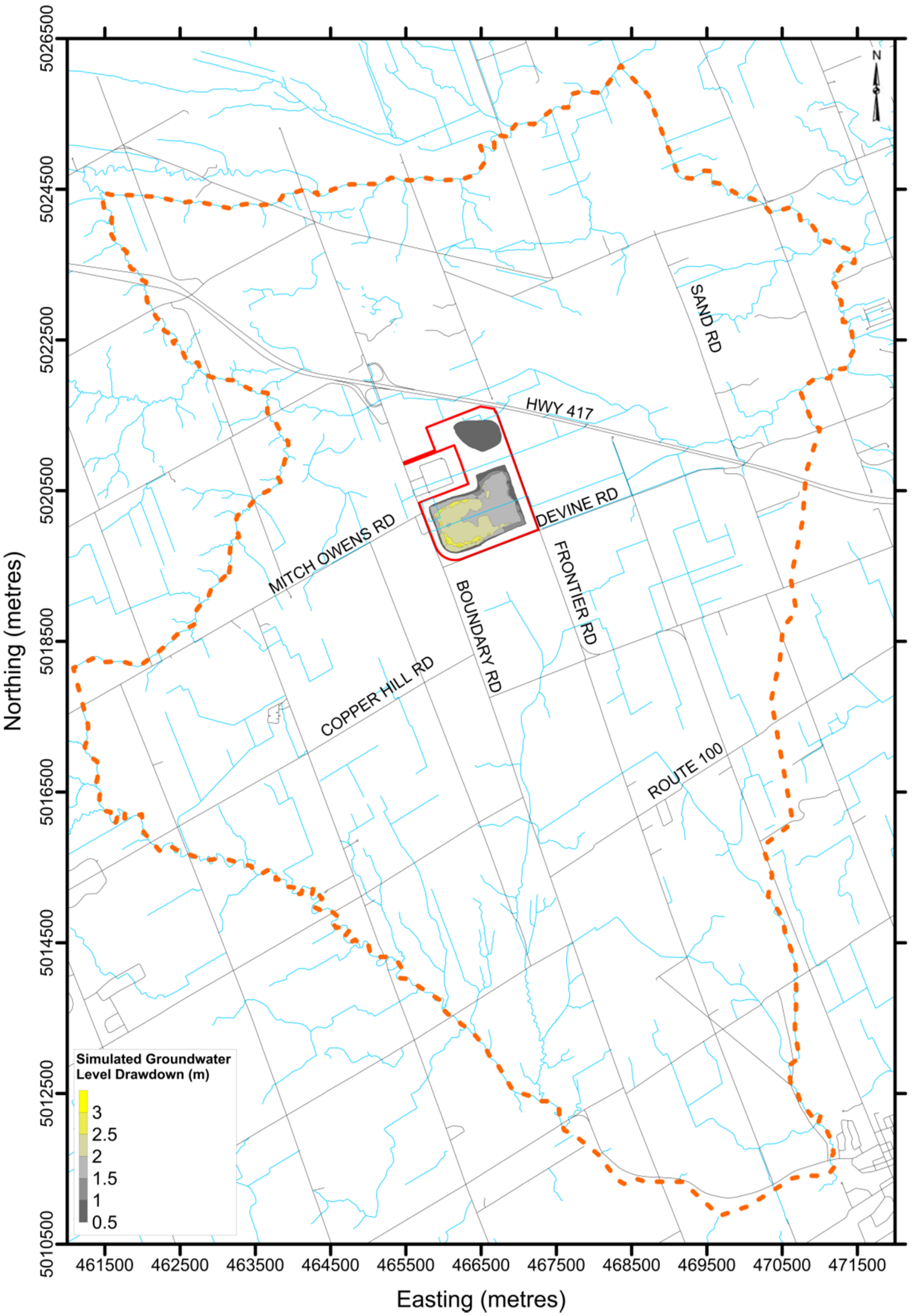
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Simulated Post-Development Post-Settlement Cross-Section

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	MIB	Nov. 2013	FIGURE 12-7	
GIS	----	----		
CHECK	PLE	Aug. 2014		
REVIEW	PAS	Aug. 2014		



LEGEND

WATERBODIES

ROADS

PROPERTY BOUNDARY

MODEL DOMAIN

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2011. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

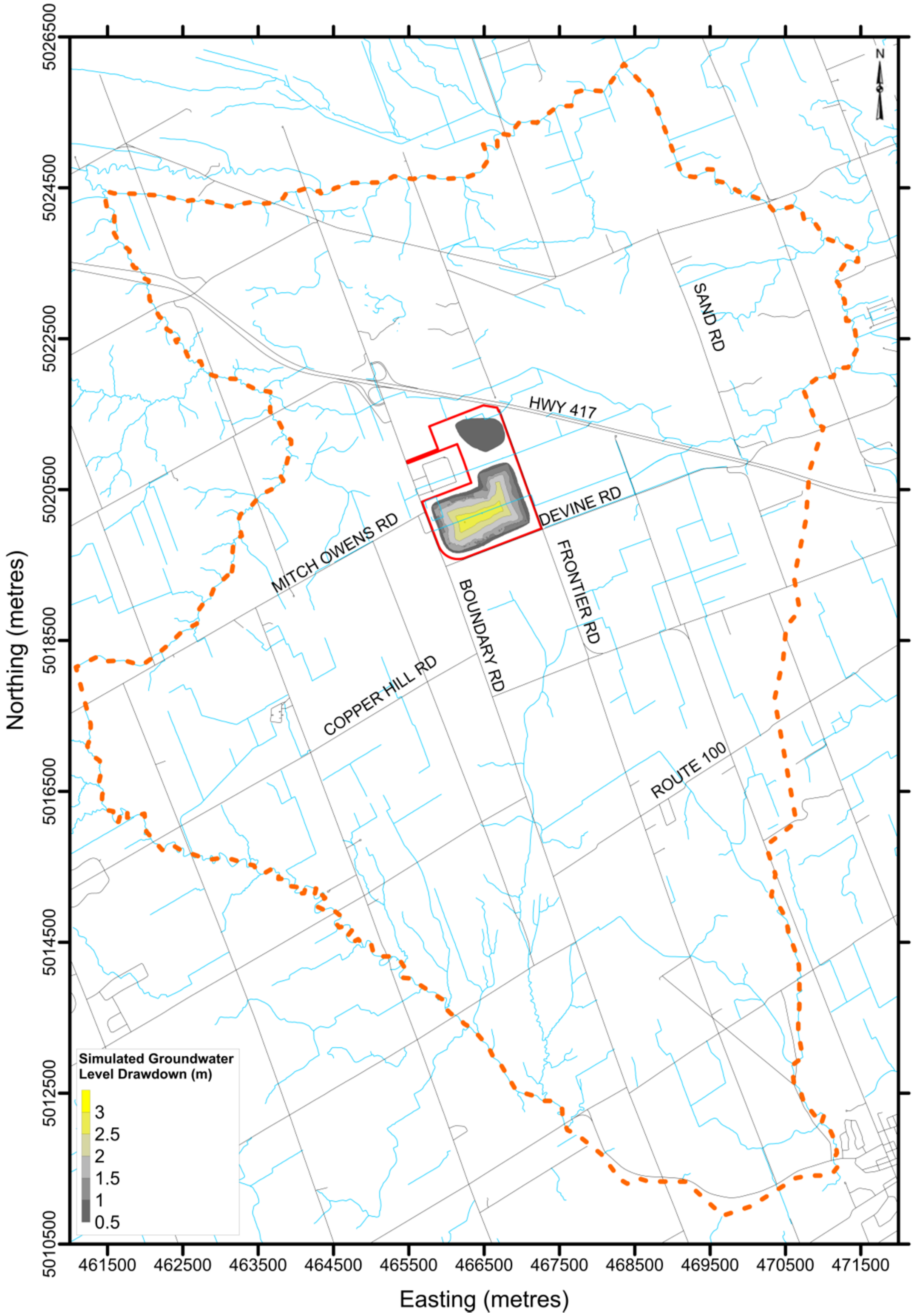
PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Simulated Pre-Failure Groundwater Drawdown (PS1: pre-settlement)

PROJECT No. 12-1125-0045			PHASE No. 4500	
DESIGN	MIB	Nov. 2013	SCALE AS SHOWN	REV.0
GIS	--	--	FIGURE 12-8	
CHECK	PLE	Aug. 2014		
REVIEW	PAS	Aug. 2014		



LEGEND

━	WATERBODIES
━	ROADS
━	PROPERTY BOUNDARY
╍	MODEL DOMAIN

NOTE

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REFERENCE

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PROJECT

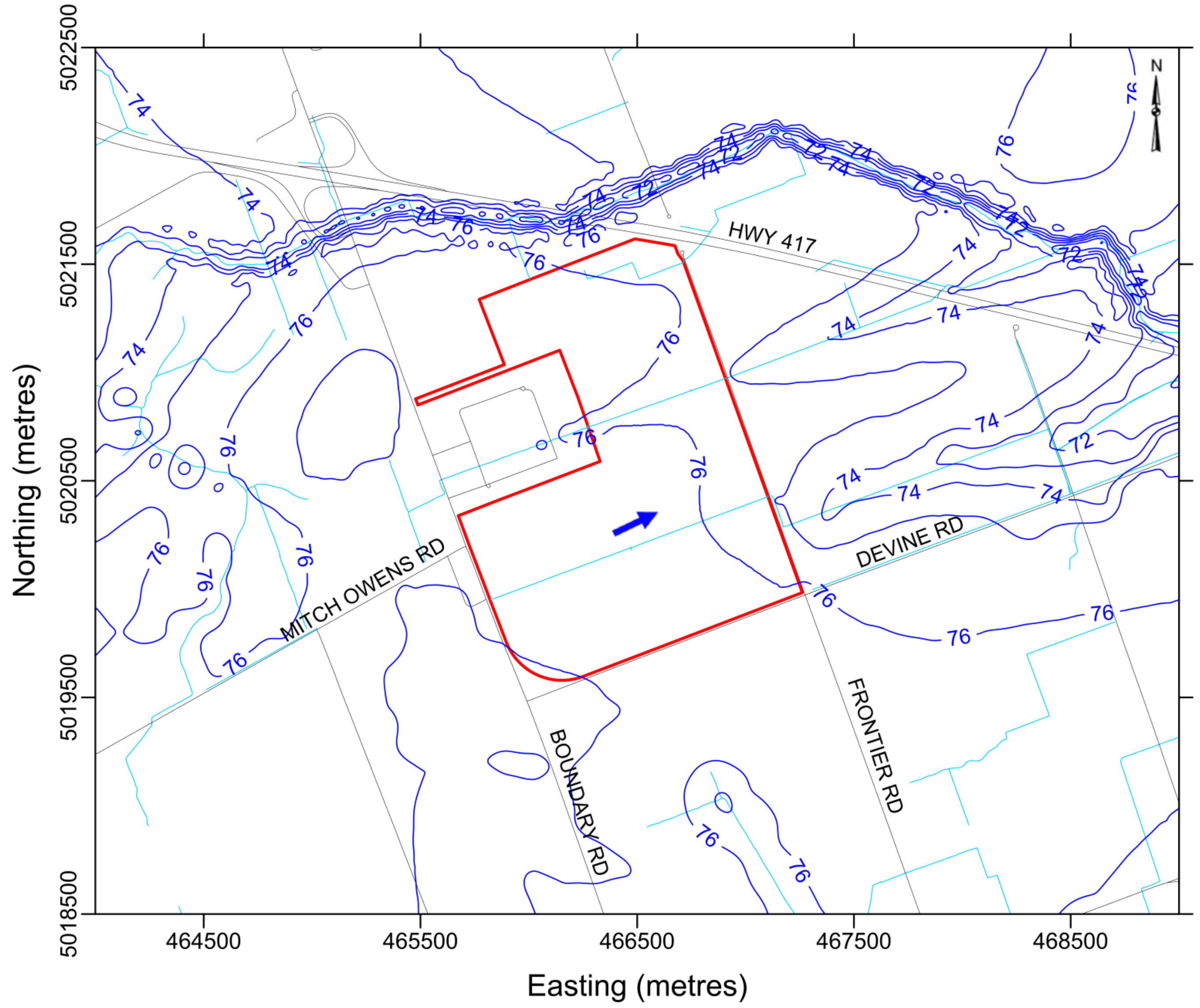
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

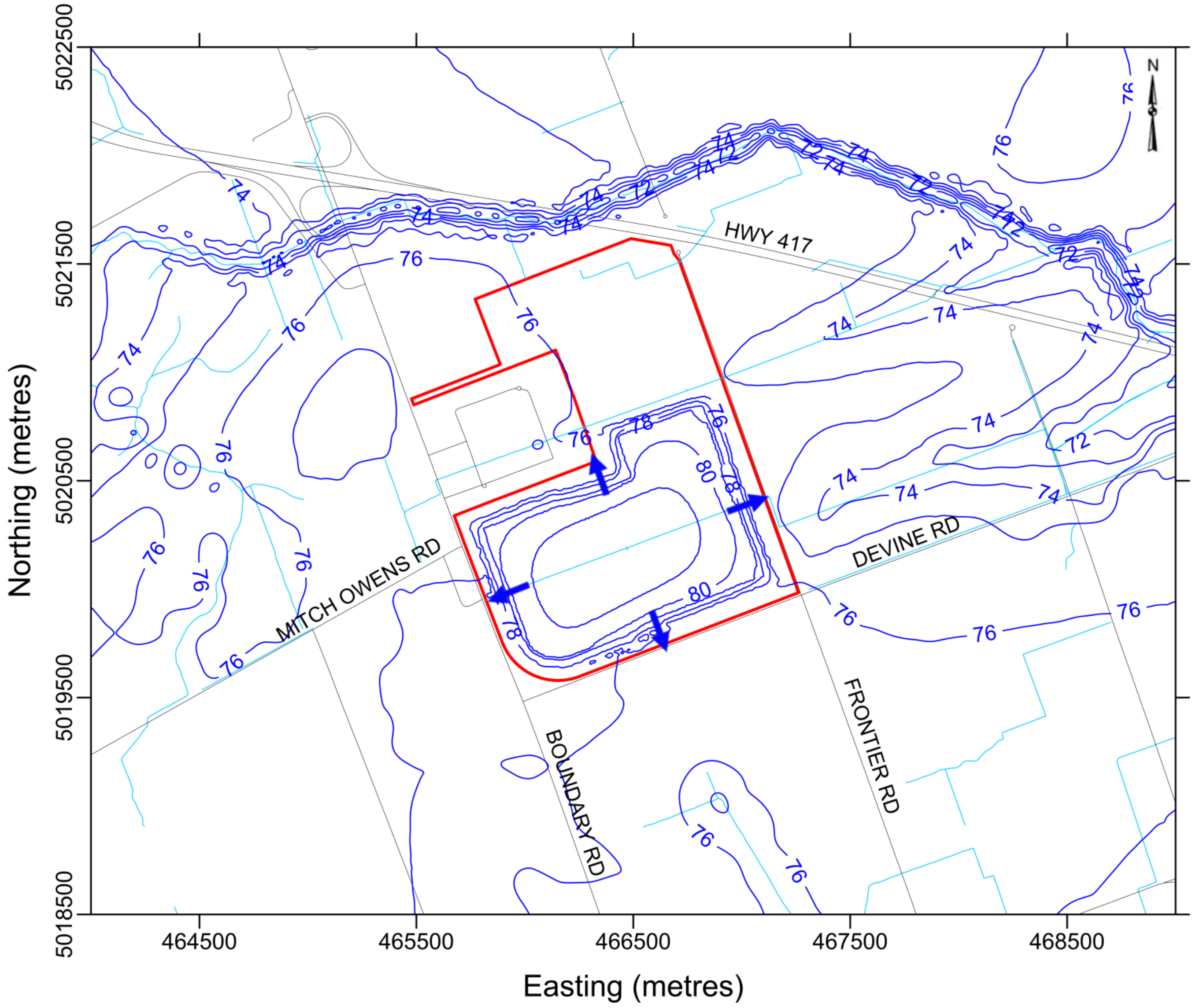
Simulated Pre-Failure Groundwater Drawdown (PS2: post-settlement)

Golder Associates

PROJECT No. 12-1125-0045			PHASE No. 4500	
DESIGN	MIB	Nov. 2013	SCALE AS SHOWN	REV.0
GIS	--	--	FIGURE 12-9	
CHECK	PLE	Aug. 2014		
REVIEW	PAS	Aug. 2014		



CALIBRATED PRE-DEVELOPMENT CONDITIONS
SLICE 3: SURFICIAL SILTY SAND AND CLAY



STEADY-STATE POST-FAILURE CONDITIONS
SLICE 3: SURFICIAL SILTY SAND AND CLAY

NOTE

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REFERENCE

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LEGEND

—	WATERBODIES
—	ROADS
—	PROPERTY BOUNDARY
—75—	GROUNDWATER ELEVATION (metres ABOVE SEA LEVEL) (1 metre contour interval)
➡	INTERPRETED GROUNDWATER FLOW DIRECTION

PROJECT

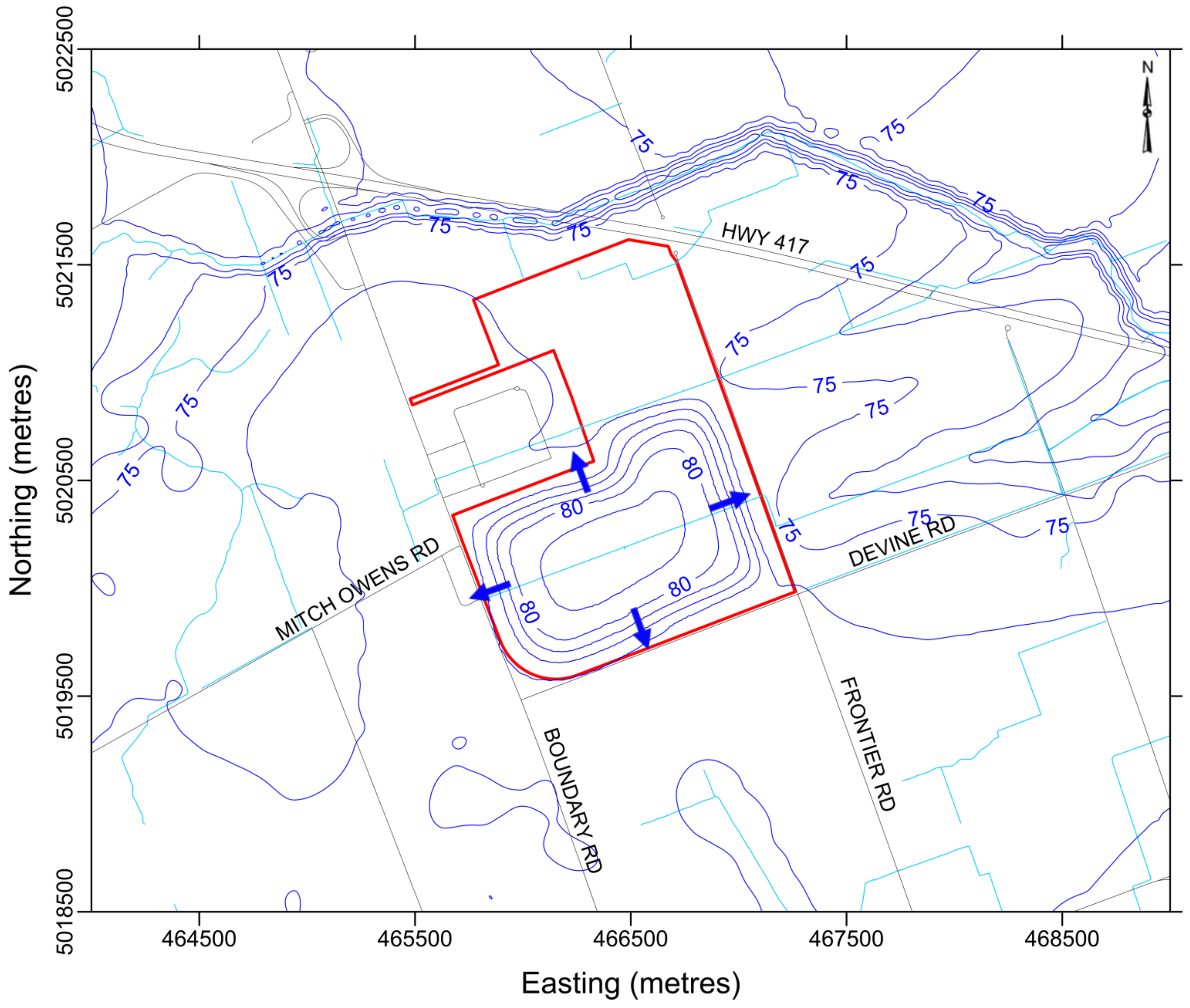
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

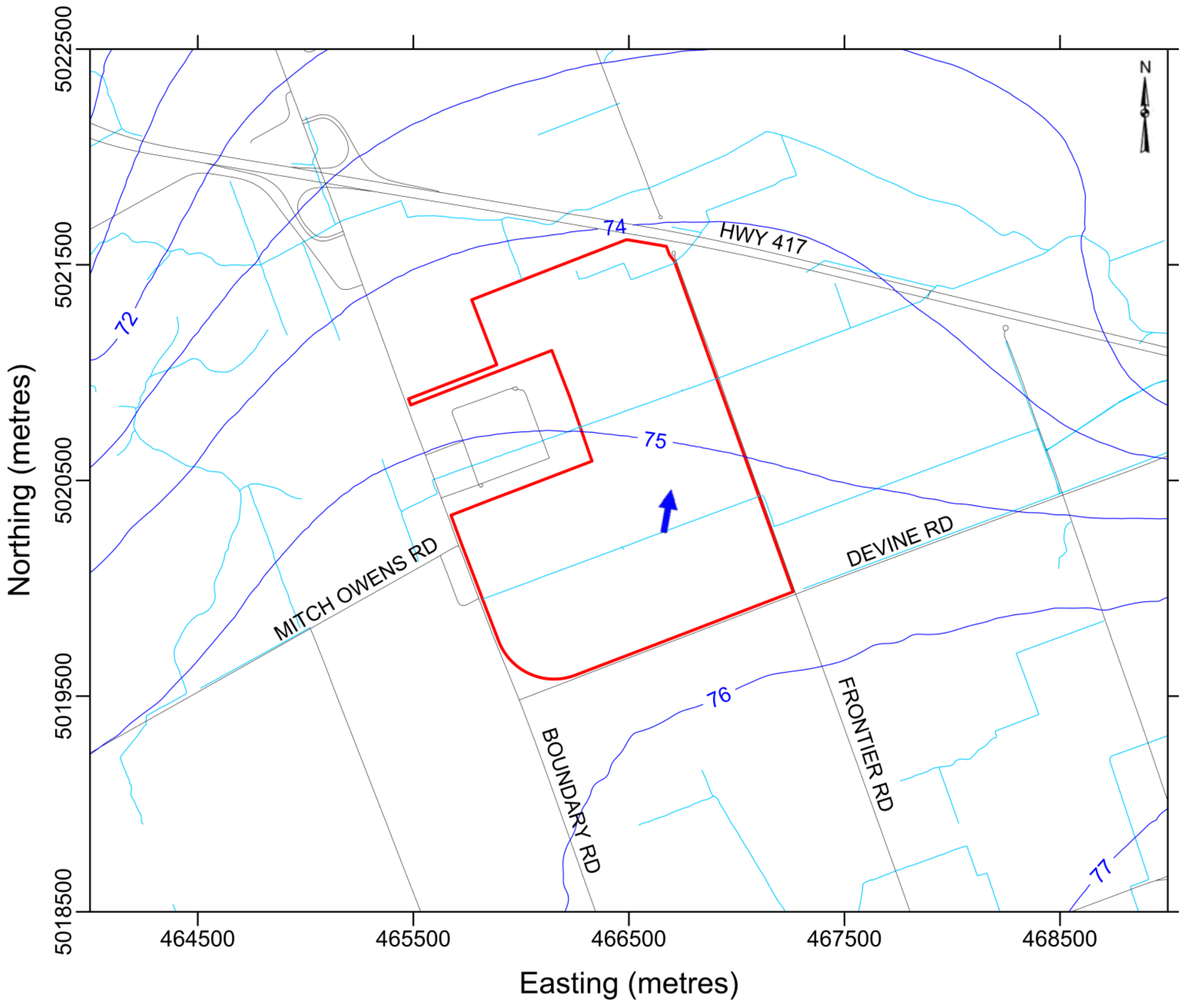
Simulated Post-Failure Groundwater
Elevation (PS3: post-settlement)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	MIB	Nov. 2013	FIGURE 12-10	
GIS	----	----		
CHECK	PLE	Aug. 2014		
REVIEW	PAS	Aug. 2014		



SLICE 11: SILTY LAYER



SLICE 16: GLACIAL TILL / BEDROCK CONTACT

NOTE

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REFERENCE

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LEGEND

- WATERBODIES
- ROADS
- PROPERTY BOUNDARY
- —75— SIMULATED HYDRAULIC HEAD (metres) (one metre contour interval)
- ➡ INTERPRETED GROUNDWATER FLOW DIRECTION

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

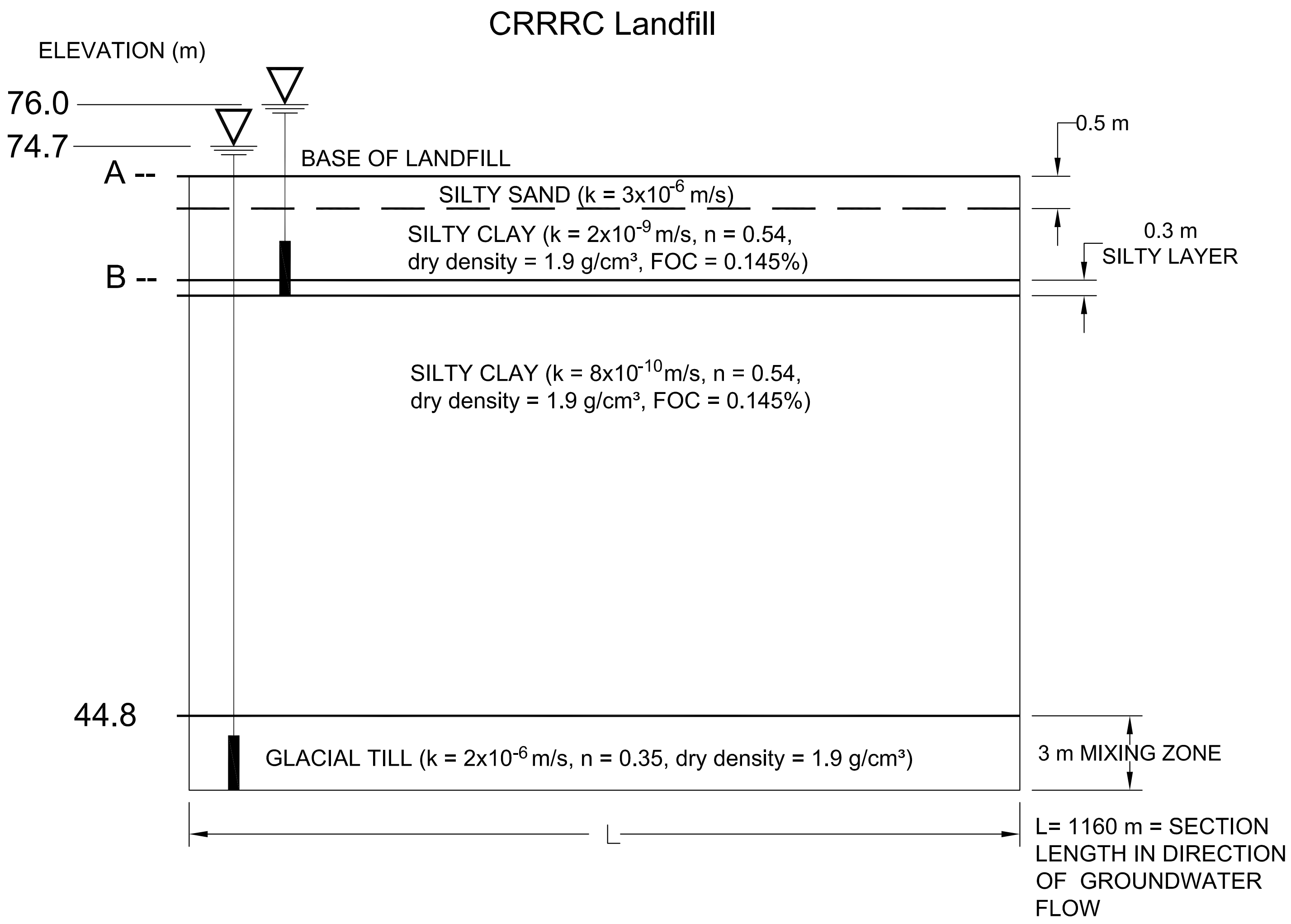
Simulated Post-Failure Hydraulic Head
(PS3: post-settlement)

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045
SCALE AS SHOWN
REV.0

DESIGN	MIB	Nov. 2013
GIS	----	----
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

FIGURE 12-11



Years Past Closure	A (m ASL)	B (m ASL)
0 YEARS (CLOSURE)	74.4	71.1
10 YEARS	71.5	69.4
50 YEARS	70.4	68.3
80 YEARS * (FAILURE OF LEACHATE COLLECTION SYSTEM)	70.2	68.1

* Used 100 year settlement numbers at this time to be conservative

NOTES:

1. THIS DRAWING / FIGURE IS TO BE READ IN CONJUNCTION WITH GOLDER ASSOCIATES LTD. REPORT.

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW
△						

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

SIMPLIFIED CROSS-SECTIONS FOR CONTAMINANT TRANSPORT MODEL

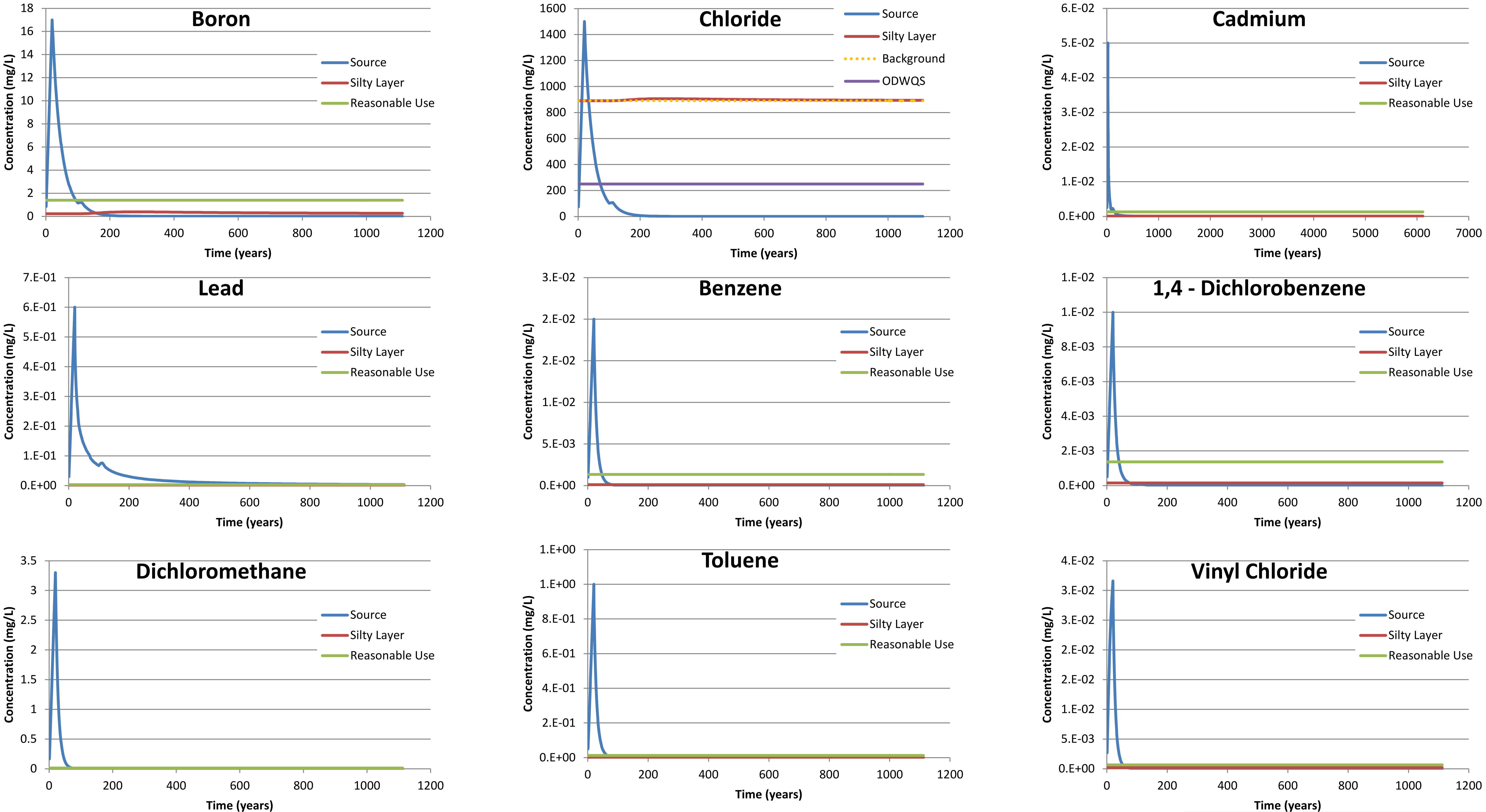
Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045
DESIGN	M.K.F.	27 Nov. 2013
CAD	M.L.F.	27 Nov. 2013
CHECK	P.L.E.	Aug. 2014
REVIEW	P.A.S.	Aug. 2014

FILE No. 1211250045-V3-12-12.DWG
SCALE N.T.S. REV. 0
DRAWING No.

Figure 12-12

PLOT DATE: June 26, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Vol 3 (Report Figures)\1211250045-V3-12-12.DWG



NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

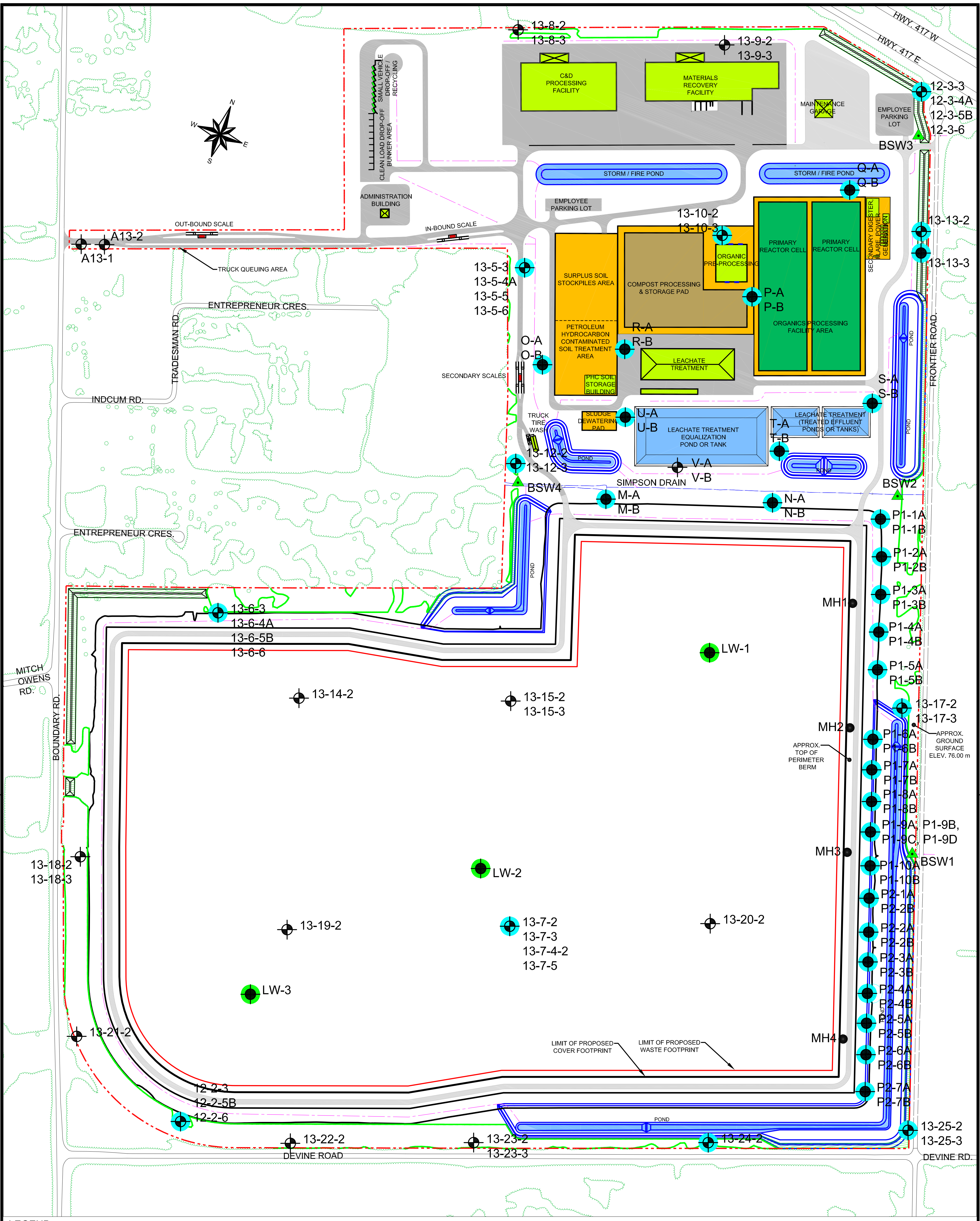
TITLE

Results of Contaminant Transport Model

Golder Associates
Ottawa, Ontario

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV.0
DESIGN	MKF	Nov. 23/2013	FIGURE 12-13	
GIS	MKF	Nov. 23/2013		
CHECK	PLE	Aug. 2014		
REVIEW	MKF	Aug. 2014		

PLOT DATE: November 4, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Vol 3 (Report Figures)\1211250045-V3-13-1.dwg



LEGEND

🟩 PROPOSED FACILITY BUILDING

🟧 OUTDOOR DIVERSION AREA

▬ PAVED ROAD (ASPHALT)

▬ GRAVEL ROAD

- · - · PROPERTY BOUNDARY

▭ EXISTING VEGETATION SCREENING

▨ CONSTRUCTED SCREENING FEATURE

— PERIMETER BERM CONTOURS (interval 1 m)

▭ STORMWATER MANAGEMENT PONDS

⊕ EXISTING GROUNDWATER MONITORING WELL (SAMPLING PROGRAM)

⊕ EXISTING GROUNDWATER MONITORING WELL (WATER LEVELS ONLY)

⊕ PROPOSED GROUNDWATER MONITORING WELL

▲ SURFACE WATER SAMPLING STATION

⊕ PROPOSED LEACHATE MONITORING WELL

● LEACHATE DETECTION AND SECONDARY CONTAINMENT SYSTEM MANHOLE

120 0 120 240

SCALE 1:6,000 METRES

Golder Associates
Ottawa, Ontario, Canada

SCALE	AS SHOWN
DATE	7 Nov. 2013
DESIGN	M.L.F.
CAD	M.L.F.
CHECK	P.L.E.
REVIEW	P.A.S.

FILE No. 1211250045-V3-13-1.dwg

PROJECT No. 12-1125-0045 REV.

TITLE

PROPOSED GROUNDWATER AND SURFACE WATER MONITORING LOCATIONS

CAPITAL REGION RESOURCE RECOVERY CENTRE

FIGURE 13-1

APPENDIX A

Borehole Records

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures, and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open-ended, driven or pushed tube samplers
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample
DT	Dual tube sample
DD	Diamond drilling

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split spoon sampler for a distance of 300 mm (12 in.).

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive an uncased 50 mm (2 in.) diameter, 60^0 cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60^0 conical tip and a projected end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	**N** Blows/300 mm Or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

	C_u or S_u	
Consistency		
	kPa	Psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	Over 200	Over 4,000

IV. SOIL TESTS

w	Water content
w_p or PL	Plastic limited
w_1 or LL	Liquid limit
C	Consolidaiton (oedometer) test
CHEM	Chemical analysis (refer to text)
CID	Consolidated isotropically drained triaxial test[1]
CIU	Consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	Relative density
DS	Direct shear test
Gs	Specific gravity
M	Sieve analysis for particle size
MH	Combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	Organic content test
SO_4	Concentration of water-soluble sulphates
UC	Unconfined compression test
UU	Unconsolidated undrained triaxial test
V	Field vane test (LV-laboratory vane test)
γ	Unit weight

Note: [1] Tests which are anisotropically consolidated prior shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$ x or log x	logarithm of x to base 10
g	acceleration due to gravity
t	time
FOS	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma'$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson’s ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial vertical effective overburden stress
$\sigma_1\sigma_2\sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3) / 3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_1 or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity Index = $(w_1 - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_c	consistency index = $(w_1 - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (overconsolidated range)
C_s	swelling index
C_α	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	overconsolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p or τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u or s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3) / 2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3) / 2$
q	$(\sigma_1 - \sigma_3) / 2$ or $(\sigma'_1 - \sigma'_3) / 2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:

[1] $\tau = c' + \sigma' \tan \phi'$

[2] shear strength = (compressive strength) / 2

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-2

SHEET 1 OF 2

LOCATION: N 5020298.57 ;E 467132.84

BORING DATE: November 13-14, 2012

DATUM: Geodetic

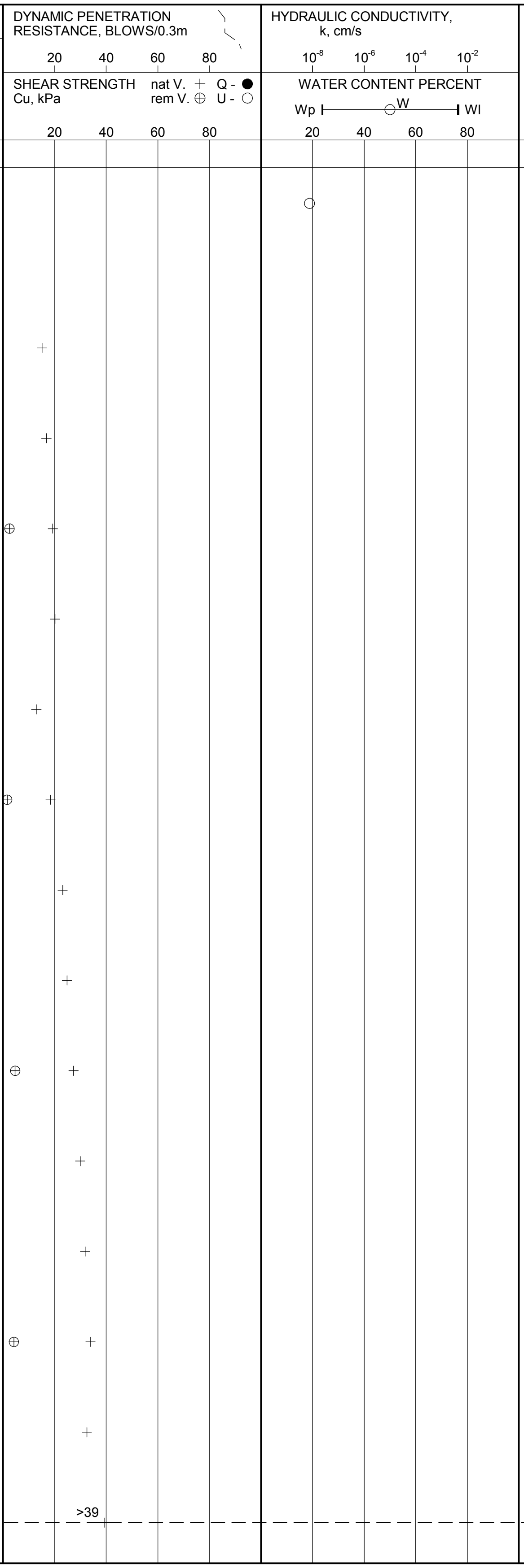
INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem) (0 to approx. 1.8 m); Electric Nilcon (below)

DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
GROUND SURFACE	75.95				
TOPSOIL	0.00				
Very loose brown SILTY SAND to SAND, some silt and clay	0.25	1	50 DO	3	MH
Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	75.40 0.55	2	50 DO	4	
Grey brown SAND, some silt, trace clay	74.88				
Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	1.22	3	50 DO	1	
Soft grey to red grey SILTY CLAY					
Grey CLAYEY SILT, some sand	73.89				
Soft grey to red grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 3.72 m to 3.76 m	2.15				
Grey SANDY SILT, with black staining	71.20 4.75				
Grey SILT, some clay	4.99				
Soft to firm red grey CLAY to SILTY CLAY, with black staining and sandy silt and sand seams - Grey sandy silt layer from 5.28 m to 5.32 m - Grey silt layer from 7.16 m to 7.24 m - Grey clayey silt layer from 8.94 m to 9.07 m	5.13				
Stiff grey and red CLAY to SILTY CLAY, with black staining	63.76 12.19				



PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 – 15

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-2

SHEET 2 OF 2

LOCATION: N 5020298.57 ;E 467132.84

INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 13-14, 2012

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		--- CONTINUED FROM PREVIOUS PAGE ---					
15	Electric Nilcon	Stiff grey and red CLAY to SILTY CLAY, with black staining	▨				
23		Stiff to very stiff grey CLAY to SILTY CLAY, with black staining	▨	53.09 22.86			
27		End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Vane pushed to 27 m depth. Rod friction too high to carry out test.		48.95 27.00			

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

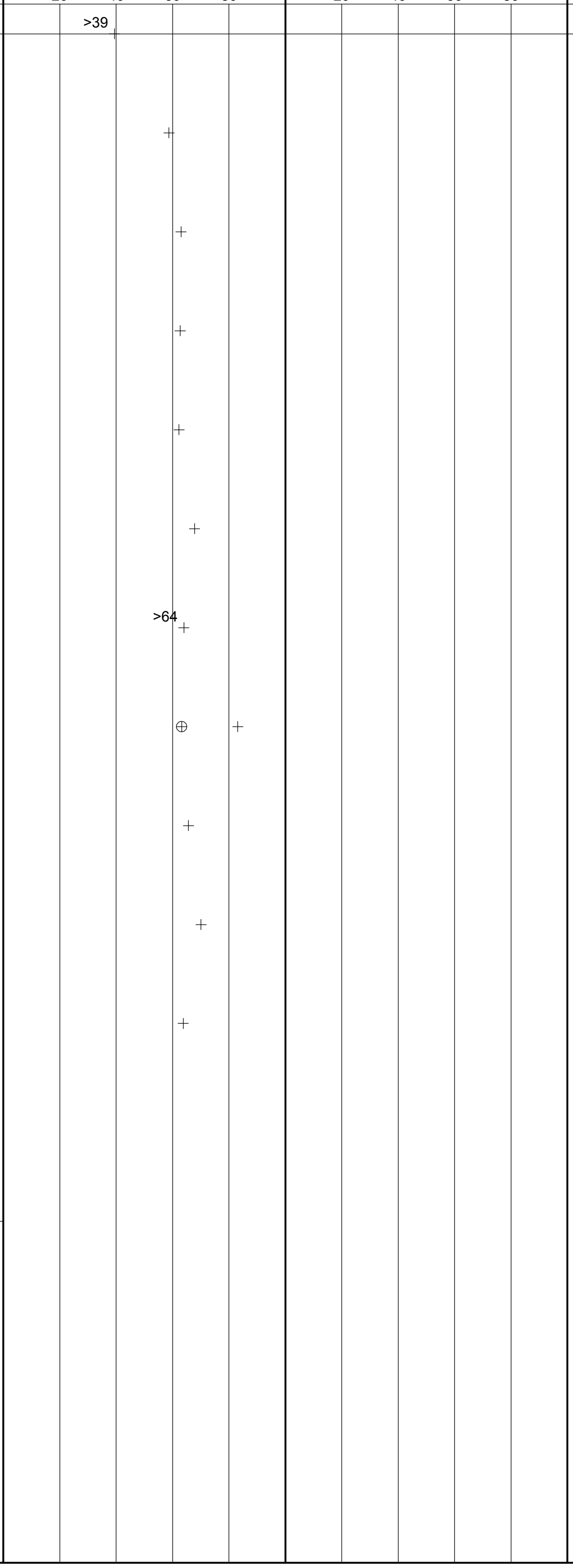
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-3

SHEET 1 OF 3

LOCATION: N 5020302.44 ;E 467125.21

BORING DATE: November 15-19, 2012

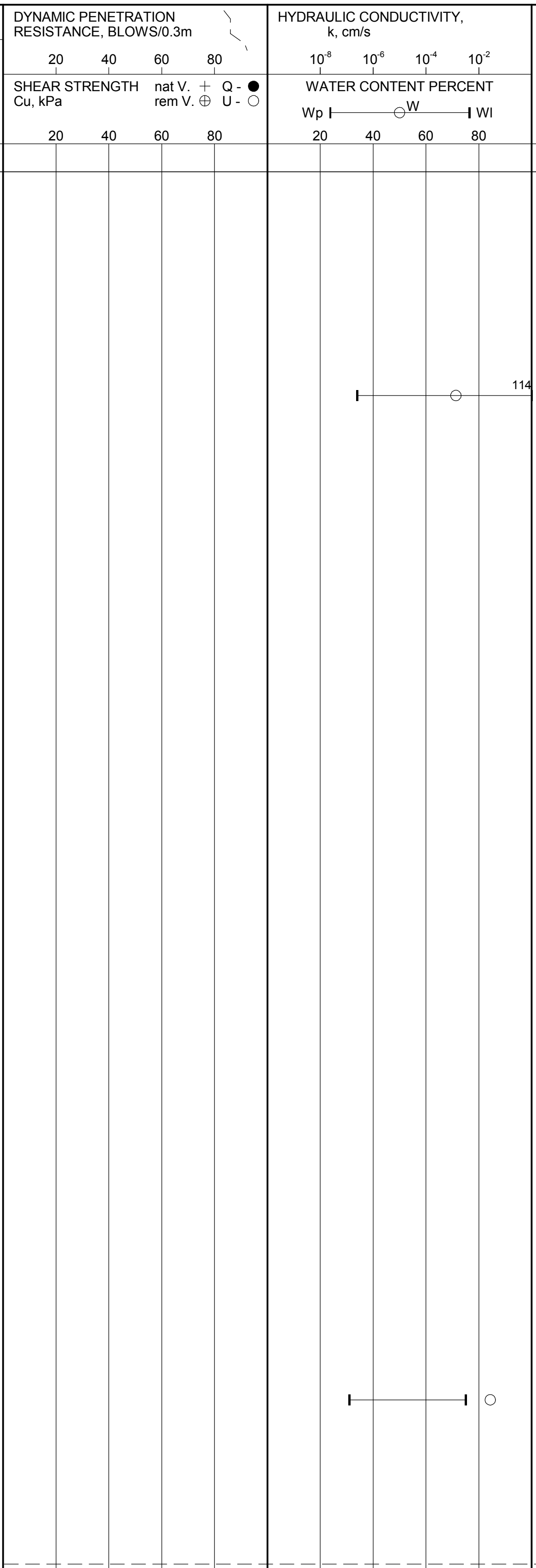
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.01					
0	Wash Boring HW Casing	TOPSOIL	0.00					Protective Casing
		Very loose brown SILTY SAND to SAND, some silt and clay	0.25					
		Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	75.46 0.55					
1		Grey brown SAND, some silt, trace clay	74.94					
		Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	1.22					
		Soft grey to red grey SILTY CLAY						
2		Grey CLAYEY SILT, some sand	73.95					
		Soft grey to red grey CLAY to SILTY CLAY, with silt seams	2.15	1	73 TP	PH		
4		- Grey silt layer from 3.72 m to 3.76 m						
		Grey SANDY SILT, with black staining	71.26 4.75					
5		Grey SILT, some clay	4.99					
		Soft to firm red grey CLAY to SILTY CLAY, with black staining and sandy silt and sand seams - Grey sandy silt layer from 5.28 m to 5.32 m	5.13					
6				2	73 TP	PH		
7		- Grey silt layer from 7.16 m to 7.24 m						76 mm Diam. PVC Casing Bentonite-Cement Grout
9		- Grey clayey silt layer from 8.94 m to 9.07 m		3	73 TP	PH		
12		Stiff grey and red CLAY to SILTY CLAY, with black staining	63.82 12.19					
13				4	73 TP	PH		
15		*CONTINUED NEXT PAGE*						



DEPTH SCALE

1 : 75

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-3

SHEET 2 OF 3

LOCATION: N 5020302.44 ;E 467125.21

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: November 15-19, 2012

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. DEPTH (m)
15	Wash Boring HW Casing	Stiff grey and red CLAY to SILTY CLAY, with black staining	
23		Stiff to very stiff grey CLAY to SILTY CLAY, with black staining	53.15 22.86
30		CONTINUED NEXT PAGE	

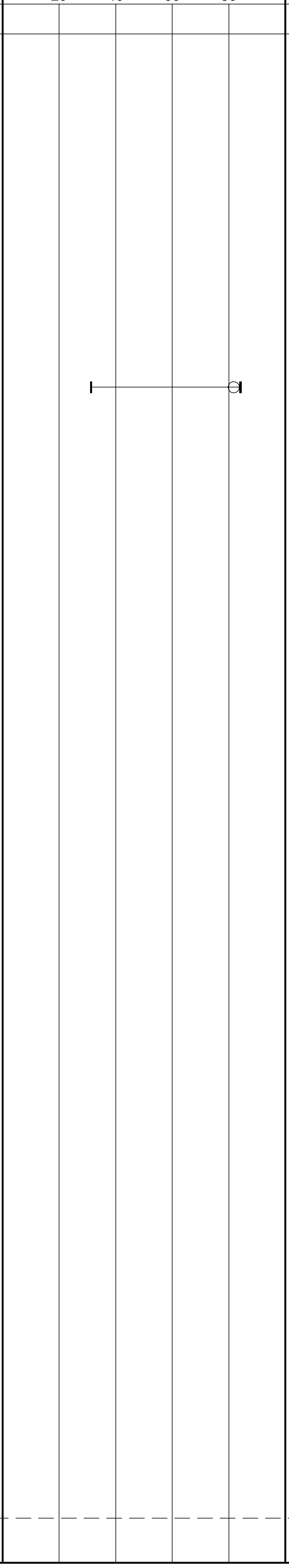
NUMBER	TYPE	BLOWS/0.3m
5	73 TP	PH
6	73 TP	PH
7	50 DO	WH
8	50 DO	WR
9	50 DO	WR
10	50 DO	WR
11	50 DO	WR
12	50 DO	WR
13	50 DO	WR
14	50 DO	WR

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl 20 40 60 80



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

76 mm Diam. PVC Casing

Bentonite-Cement Grout

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-3

SHEET 3 OF 3

LOCATION: N 5020302.44 ;E 467125.21

BORING DATE: November 15-19, 2012

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---								
30	Wash Boring HW Casing	Stiff to very stiff grey CLAY to SILTY CLAY, with black staining		14	50 DO	WR				
				15	50 DO	WR				
31				16	50 DO	WR				
32				17	50 DO	WR				
33				18	50 DO	WR				
				19	50 DO	WR				
34				20	50 DO	WR				
35				21	50 DO	WR				
			40.20 35.81							
36		Dense to very dense grey SILTY SAND, some gravel, trace clay, with cobbles and boulders (GLACIAL TILL)		22	50 DO	52				
37				23	50 DO	67				
				24	50 DO	36		○	MH	76 mm Diam. PVC Casing Bentonite-Cement Grout
38				25	50 DO	33				
				26	50 DO	>50				
				27	HQ RC	DD				
39				28	50 DO	>50				
40			35.40							
41		Borehole continued on RECORD OF DRILLHOLE 12-1-3 Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Different stratigraphy relative to borehole 12-1-7.								
42										
43										
44										
45										

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-1-3

SHEET 1 OF 3

LOCATION: N 5020302.44 ;E 467125.21

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 15-19, 2012

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

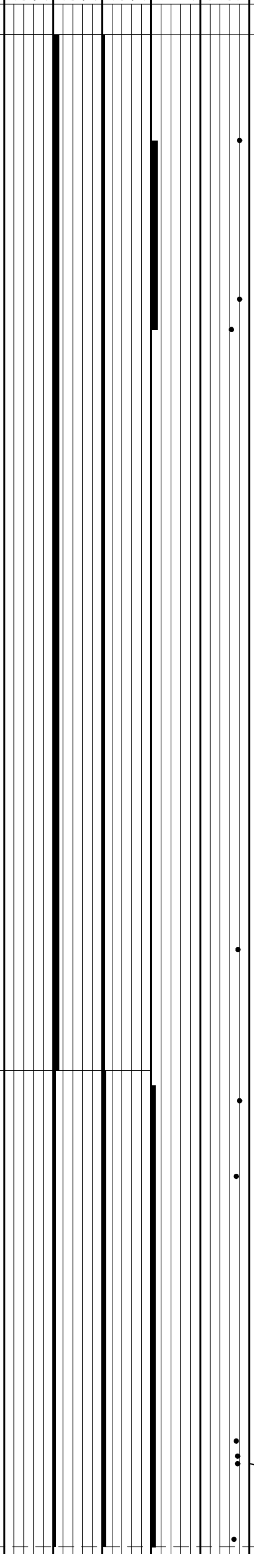
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % (80 60 40 20)	RECOVERY SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER 0.25m (5 10 15 20)	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	NOTES
		BEDROCK SURFACE		35.40														



DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	TYPE AND SURFACE DESCRIPTION	NOTES
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 40.61 m to 46.47 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.	40.61			76 mm Diam. PVC Casing Bentonite-Cement Grout
			35.26 40.75		JN,,	
					JN,,	
41					JN,,	
				1		
			34.27 41.74			
			41.76		JN,,	
			34.10 41.91			
			41.94			
42					JN,,	
			33.91 42.10		JN,,	
			33.83 42.18			
				2		
			33.58 42.43			
			33.54 42.47		VN,,	
			33.50 42.51		JN,, JN,,	
			33.44 42.57		JN,,	

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-1-3

SHEET 2 OF 3

LOCATION: N 5020302.44 ;E 467125.21

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 15-19, 2012
DRILL RIG: CME 850
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

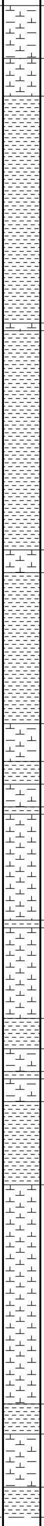
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY: TOTAL CORE % (80 60 40 20), SOLID CORE % (80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX PER 0.25m (5 10 15 20) | DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION, Jcon, Jr, Ja | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}) | WEATHERING INDEX (W1 W2 W3 W4 W5 W6) | NOTES

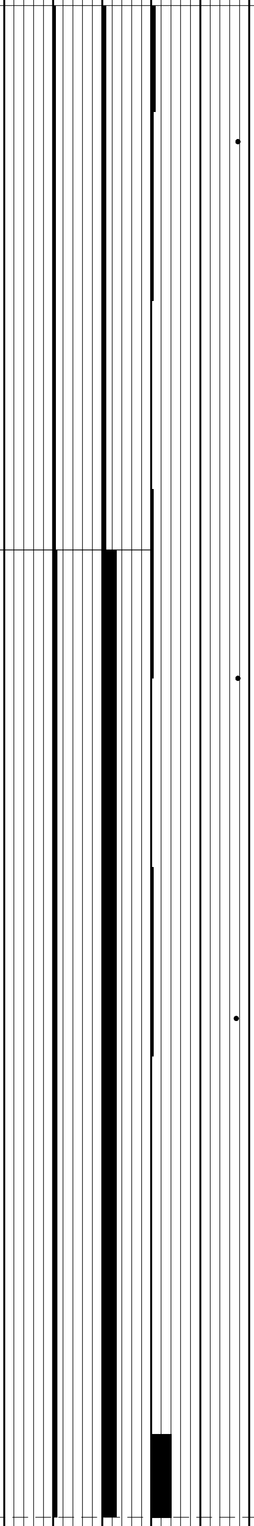
--- CONTINUED FROM PREVIOUS PAGE ---

Drilling record: Rotary Drill, HQ Core

CARLSBAD FORMATION, 40.61 m to 46.47 m Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.



DEPTH SCALE METRES	ELEV.	DEPTH (m)	RUN No.	DISCONTINUITY DATA
	33.33	42.68		
	33.28	42.73		
				JN,,
			2	
43	32.98	43.04		
	32.68	43.33		
		43.36		
				JN,,
	32.45	43.56		
	32.40	43.61		
		43.64		
		43.68		
	32.19	43.83		
				JN,,
	32.06	43.95	3	
	32.02	43.99		
44		44.03		
		44.06		
	31.84	44.17		
	31.55	44.46		
	31.51	44.50		
	31.44	44.57		



NOTES:

76 mm Diam. PVC Casing

Bentonite-Cement Grout

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DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DG
CHECKED: SAT

CRRRC-ROCK 1211250045.GPJ GAL-MISS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-1-3

SHEET 3 OF 3

LOCATION: N 5020302.44 ;E 467125.21

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 15-19, 2012

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

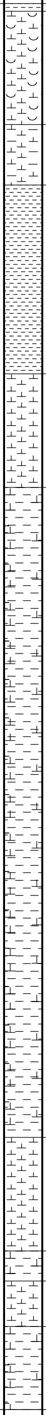
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

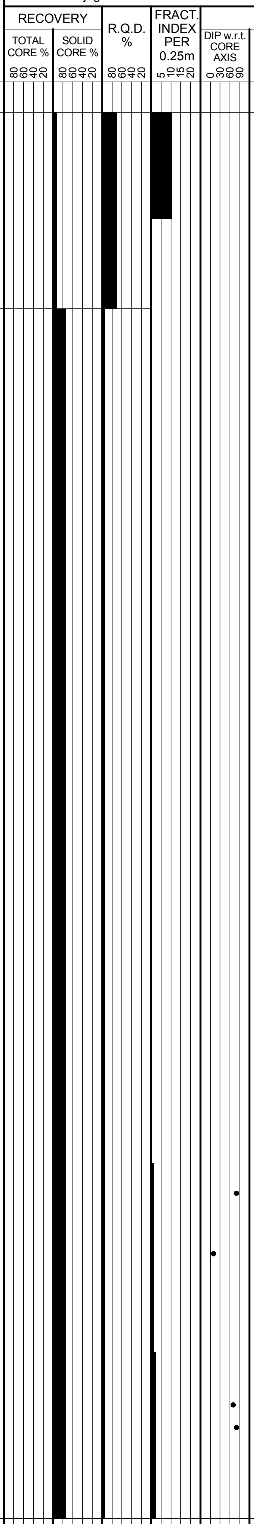
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---				
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 40.61 m to 46.47 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.	31.39 44.62	3		76 mm Diam. PVC Casing Bentonite-Cement Grout
			31.24 44.77			
			31.16 44.85			
45						
			30.91 45.10			
			30.76 45.25	4		
46					JN,,	
			29.90 46.11		VN,,	
			29.75 46.26			
			29.71 46.30		JN,, JN,,	
			29.65 46.36			
			29.54 46.47			
		End of Drillhole				





FLUSH RETURN

Jcon Jr Ja

HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WEATHERING INDEX W1 W2 W3 W4 W5 W6

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-3-1

SHEET 1 OF 3

LOCATION: N 5020300.53 ;E 467124.43

INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 23, 2012

DATUM: Geodetic

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES: NUMBER, TYPE, BLOWS/0.3m | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 | SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80 | HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} | WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80 | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

BORING METHOD: Rotary Drill, HQ Core

DESCRIPTION	ELEV.	DEPTH (m)
GROUND SURFACE	76.10	
TOPSOIL		0.00
Very loose brown SILTY SAND to SAND, some silt and clay		0.25
Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	75.55	0.55
Grey brown SAND, some silt, trace clay	75.03	
Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)		1.22
Soft grey to red grey SILTY CLAY		
Grey CLAYEY SILT, some sand	74.04	
Soft grey to red grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 3.72 m to 3.76 m		2.15
Grey SANDY SILT, with black staining	71.35	4.75
Grey SILT, some clay		4.99
Soft to firm red grey CLAY to SILTY CLAY, with black staining and sandy silt and sand seams - Grey sandy silt layer from 5.28 m to 5.32 m - Grey silt layer from 7.16 m to 7.24 m - Grey clayey silt layer from 8.94 m to 9.07 m		5.13
Stiff grey and red CLAY to SILTY CLAY, with black staining	63.91	12.19

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

MON. WELL

Protective Casing

Bentonite-Cement Grout

CONTINUED NEXT PAGE

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-3-1

SHEET 2 OF 3

LOCATION: N 5020300.53 ;E 467124.43

INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 23, 2012

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ├──○W──┤ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
15	Rotary Drill HQ Core	Stiff grey and red CLAY to SILTY CLAY, with black staining	▨								
16			▨								
17			▨								
18			▨								
19			▨								
20			▨								
21			▨								
22			▨							Bentonite-Cement Grout
23		Stiff to very stiff grey CLAY to SILTY CLAY, with black staining	▨	53.24 22.86							
24			▨								
25			▨								
26			▨								
27			▨								
28			▨								
29			▨								
30											
		CONTINUED NEXT PAGE									

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-3-1

SHEET 3 OF 3

LOCATION: N 5020300.53 ;E 467124.43

INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 23, 2012

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
30	Rotary Drill HQ Core	Stiff to very stiff grey CLAY to SILTY CLAY, with black staining	▨								
35				40.29 35.81							Bentonite-Cement Grout
36		Dense to very dense grey SILTY SAND, some gravel, trace clay, with cobbles and boulders (GLACIAL TILL)									
39				36.32							
40		Borehole continued on RECORD OF DRILLHOLE 12-1-3.1 Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Different stratigraphy relative to borehole 12-1-7.									

Depth scale marks: 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-1-3-1

SHEET 1 OF 3

LOCATION: N 5020300.53 ;E 467124.43

DRILLING DATE: November 23, 2012

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

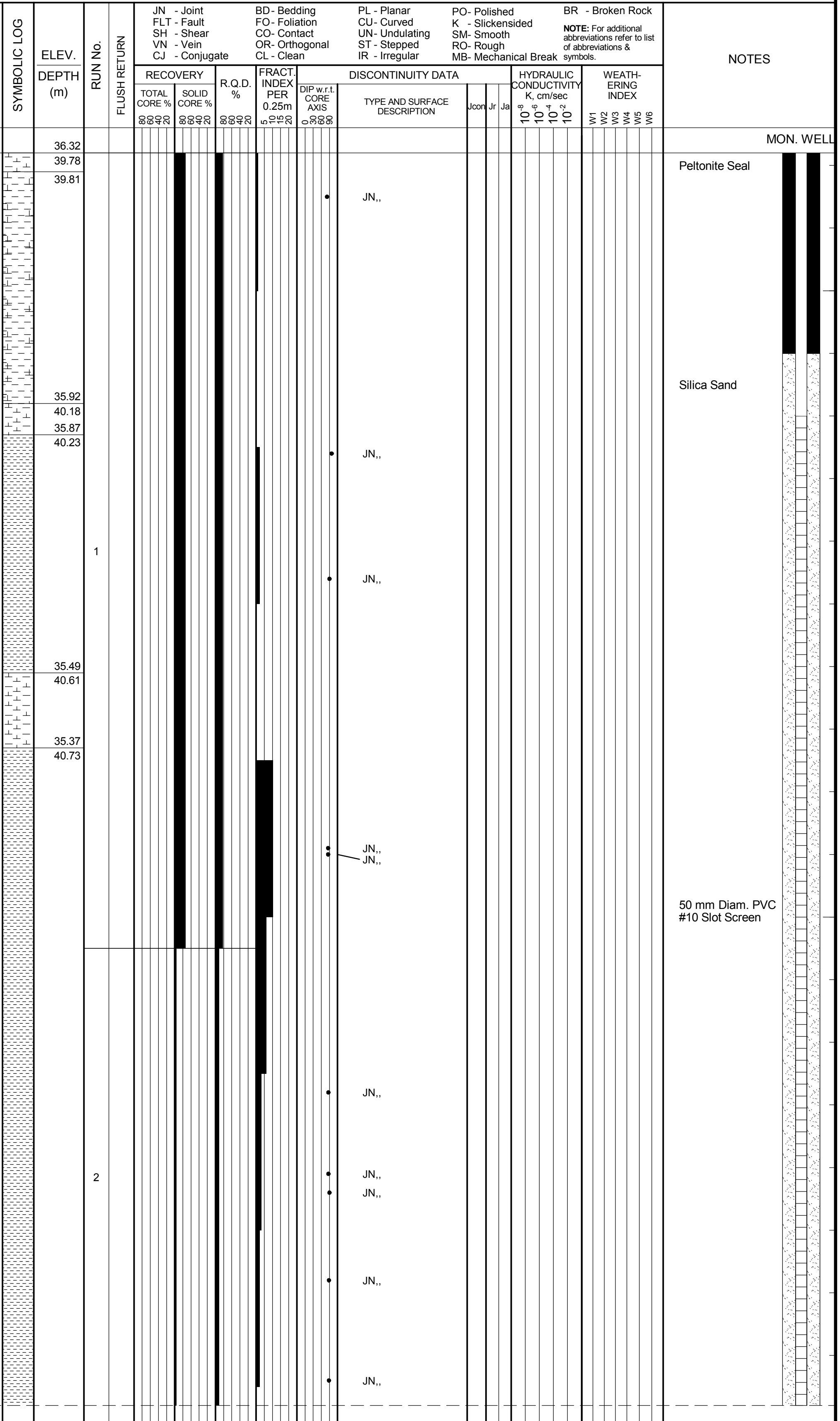
DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES
		BEDROCK SURFACE	36.32			MON. WELL
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 39.78 m to 45.37 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.	39.78 39.81		JN,,	Peltonite Seal
40						
			35.92 40.18 35.87 40.23			Silica Sand
					JN,,	
				1	JN,,	
			35.49 40.61 35.37 40.73			
					JN,, JN,,	
41						50 mm Diam. PVC #10 Slot Screen
					JN,,	
				2	JN,, JN,,	
					JN,,	
					JN,,	



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DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-1-3-1

SHEET 2 OF 3

LOCATION: N 5020300.53 ;E 467124.43

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 23, 2012

DRILL RIG: CME 850

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---				MON. WELL
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 39.78 m to 45.37 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.				
42						
				2		
			33.59 42.51			
			33.55 42.55		JN,,	
			33.49 42.61			
			33.40 42.70			
			33.34 42.76			50 mm Diam. PVC #10 Slot Screen
			33.23 42.87			
			33.14 42.96			
43						
			33.05 43.05		JN,,	
			33.01 43.09			
				3		
			32.86 43.24			
			32.73 43.37			
			32.55 43.55			
			32.40 43.70		JN,,	
		CONTINUED NEXT PAGE				

Column headings: FLUSH RETURN; SYMBOLIC LOG; RECOVERY TOTAL CORE % 80 60 40 20, SOLID CORE % 80 60 40 20; R.Q.D. % 80 60 40 20; FRACT. INDEX PER 0.25m 5 10 15 20; DIP w.r.t. CORE AXIS 0 30 60 90; Jcon Jr Ja; HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WEATH-ERING INDEX W1 W2 W3 W4 W5 W6

DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-1-3-1

SHEET 3 OF 3

LOCATION: N 5020300.53 ;E 467124.43

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 23, 2012

DRILL RIG: CME 850

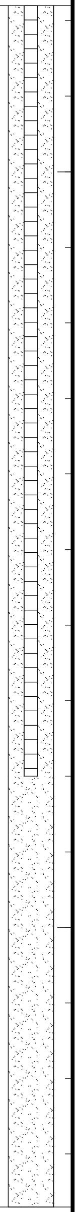
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SH - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	RO - Rough	
CJ - Conjugate	CL - Clean	IR - Irregular	MB - Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---				MON. WELL
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 39.78 m to 45.37 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.	32.23 43.87 43.90 32.15 43.95	3	JN,,	
44			32.08 44.02 32.03 44.07			
						50 mm Diam. PVC #10 Slot Screen
					JN,,	
				4		
					JN,,	
45						Silica Sand
			30.85 45.25 30.75 30.73 45.35			
		End of Drillhole	45.37			

Other column headings: SYMBOLIC LOG; FLUSH RETURN; RECOVERY (TOTAL CORE %, SOLID CORE % — 80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.25m (5 10 15 20); DIP w.r.t. CORE AXIS (0 30 60 90); Jcon; Jr; Ja; HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WEATH-ERING INDEX (W1 W2 W3 W4 W5 W6).



DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-4

SHEET 1 OF 3

LOCATION: N 5020299.81 ;E 467126.00

INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 26, 2012

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m				
		GROUND SURFACE		76.08							'B' 'A'
0	Wash Boring HW Casing	TOPSOIL		0.00							Protective Casing Bentonite Seal
		Very loose brown SILTY SAND to SAND, some silt and clay		0.25 75.53							
1		Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)		0.55 75.01							
		Grey brown SAND, some silt, trace clay									
		Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)		1.22							
2		Soft grey to red grey SILTY CLAY		74.02							
		Grey CLAYEY SILT, some sand		2.15							
3		Soft grey to red grey CLAY to SILTY CLAY, with silt seams									
4		- Grey silt layer from 3.72 m to 3.76 m		71.33							
		Grey SANDY SILT, with black staining		4.75							
5		Grey SILT, some clay		4.99							
6		Soft to firm red grey CLAY to SILTY CLAY, with black staining and sandy silt and sand seams - Grey sandy silt layer from 5.28 m to 5.32 m		5.13							
7		- Grey silt layer from 7.16 m to 7.24 m									
8											Bentonite-Cement Grout
9		- Grey clayey silt layer from 8.94 m to 9.07 m									
10											
11											
12				63.89							
		Stiff grey and red CLAY to SILTY CLAY, with black staining		12.19							
13											
14											
15											

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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-4

SHEET 2 OF 3

LOCATION: N 5020299.81 ;E 467126.00

BORING DATE: November 26, 2012

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									'B' 'A'
15	Wash Boring HW Casing	Stiff grey and red CLAY to SILTY CLAY, with black staining									
20											Bentonite-Cement Grout
23		Stiff to very stiff grey CLAY to SILTY CLAY, with black staining		53.22 22.86							
26											Peltonite
28											Silica Sand
29											25 mm Diam. PVC #10 Slot Screen 'B'
30		*CONTINUED NEXT PAGE*									

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-4

SHEET 3 OF 3

LOCATION: N 5020299.81 ;E 467126.00
INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 26, 2012

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION 'B' 'A'
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Wash Boring HW Casing	Stiff to very stiff grey CLAY to SILTY CLAY, with black staining	▨								Silica Sand
31–35											Bentonite Seal Peltonite
36		Dense to very dense grey SILTY SAND, some gravel, trace clay, with cobbles and boulders (GLACIAL TILL)		40.27 35.81							Silica Sand
37–39											32 mm Diam. PVC #10 Slot Screen 'A' Silica Sand Peltonite
40		End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Different stratigraphy relative to borehole 12-1-7.		36.18 39.90							
41											
42											
43											
44											
45											

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-5

SHEET 1 OF 2

LOCATION: N 5020301.64 ;E 467122.27

INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 19, 2012

DATUM: Geodetic

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}); WATER CONTENT PERCENT Wp —○W— Wl (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	76.06
TOPSOIL	0.00
Very loose brown SILTY SAND to SAND, some silt and clay	0.25
Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	75.51 0.55
Grey brown SAND, some silt, trace clay	74.99
Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	1.22
Soft grey to red grey SILTY CLAY	
Grey CLAYEY SILT, some sand	74.00
Soft grey to red grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 3.72 m to 3.76 m	2.15
Grey SANDY SILT, with black staining	71.31 4.75
Grey SILT, some clay	4.99
Soft to firm red grey CLAY to SILTY CLAY, with black staining and sandy silt and sand seams - Grey sandy silt layer from 5.28 m to 5.32 m - Grey silt layer from 7.16 m to 7.24 m - Grey clayey silt layer from 8.94 m to 9.07 m	5.13
Stiff grey and red CLAY to SILTY CLAY, with black staining	63.87 12.19

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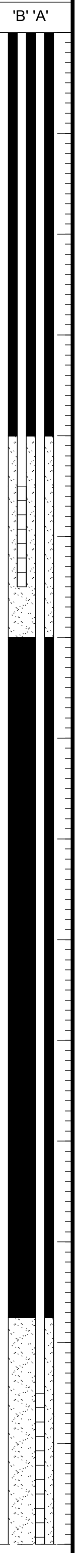


Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen 'B'

Silica Sand

Bentonite Seal

Silica Sand

25 mm Diam. PVC #10 Slot Screen 'A'

DEPTH SCALE 1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-5

SHEET 2 OF 2

LOCATION: N 5020301.64 ;E 467122.27

INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 19, 2012

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									'B' 'A'
15			▨	60.81 15.25							Silica Sand
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-6

SHEET 1 OF 1

LOCATION: N 5020298.76 ;E 467123.21

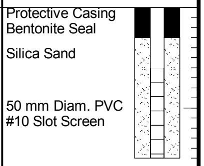
INCLINATION: -90° AZIMUTH: ---

BORING DATE: November 19, 2012

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.06							MON. WELL
0	Power Auger 200 mm Diam. (HS)	TOPSOIL		0.00							
		Very loose brown SILTY SAND to SAND, some silt and clay		0.25 75.51							
		Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)		0.55 74.99							
1		Grey brown SAND, some silt, trace clay									
		Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)		1.22 74.56 1.50							
		Soft grey to red grey SILTY CLAY									
2		End of Borehole									

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-7

SHEET 1 OF 3

LOCATION: N 5020317.39 ;E 467122.99

INCLINATION: -90° AZIMUTH: ---

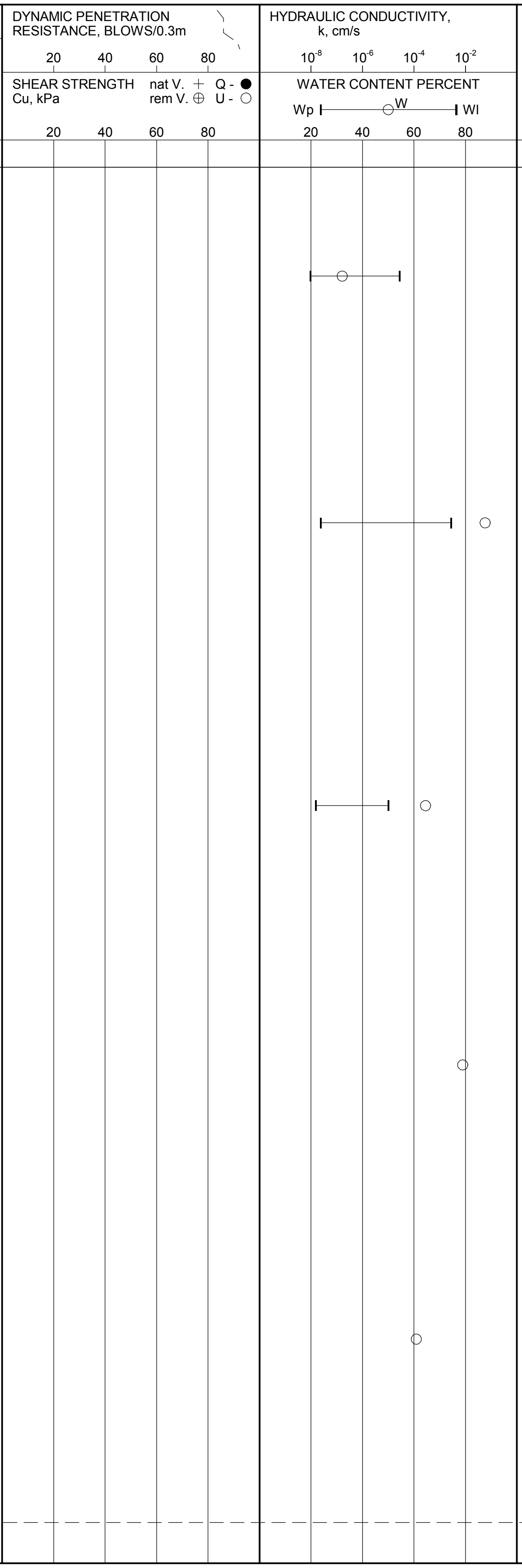
BORING DATE: April 4, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe, 90 mm Diam. (Driveable Casing)

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	75.89
TOPSOIL	0.00
Very loose brown SILTY SAND to SAND, some silt and clay	0.25
Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	75.34 0.55
Grey brown SAND, some silt, trace clay	74.82
Stiff red brown SILTY CLAY, with sand seams (Weathered Crust)	1.22
Soft grey to red grey SILTY CLAY	
Grey CLAYEY SILT, some sand	73.83
Soft grey to red grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 3.72 m to 3.76 m	2.15
Grey SANDY SILT, with black staining	71.14 4.75
Grey SILT, some clay	4.99
Soft to firm red grey CLAY to SILTY CLAY, with black staining and sandy silt and sand seams - Grey sandy silt layer from 5.28 m to 5.32 m - Grey silt layer from 7.16 m to 7.24 m - Grey clayey silt layer from 8.94 m to 9.07 m	5.13
Stiff grey and red CLAY to SILTY CLAY, with black staining	63.70 12.19

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	53 mm TUBE	-	MH
2	53 mm TUBE	-	
3	53 mm TUBE	-	
4	53 mm TUBE	-	MH
5	53 mm TUBE	-	
6	53 mm TUBE	-	
7	53 mm TUBE	-	
8	53 mm TUBE	-	
9	53 mm TUBE	-	
10	53 mm TUBE	-	



PIEZOMETER OR STANDPIPE INSTALLATION

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-7

SHEET 2 OF 3

LOCATION: N 5020317.39 ;E 467122.99

INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 4, 2013

DATUM: Geodetic

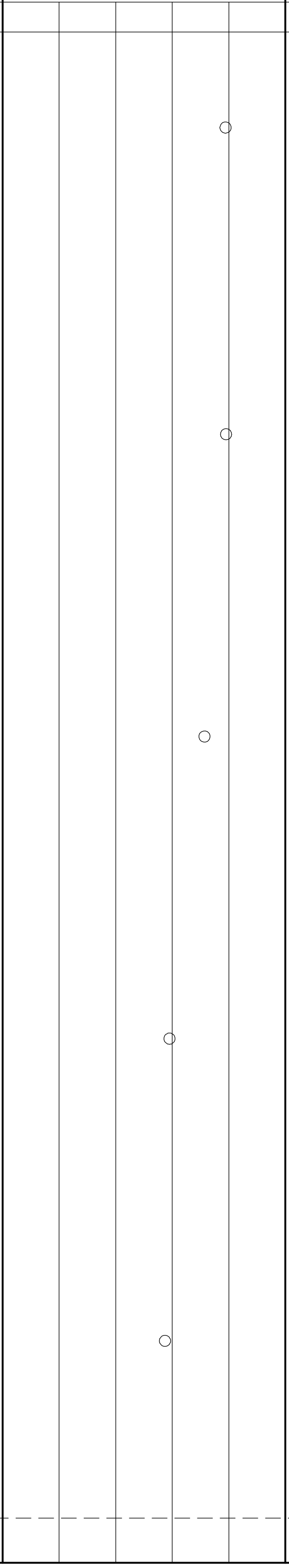
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m
		--- *CONTINUED FROM PREVIOUS PAGE* ---					
15	Geoprobe 90 mm Diam. (Driveable Casing)	Stiff grey and red CLAY to SILTY CLAY, with black staining	▨		10		-
16			▨		11	53 mm TUBE	-
17			▨		12	53 mm TUBE	-
19			▨		13	53 mm TUBE	-
20			▨		14	53 mm TUBE	-
22			▨		15	53 mm TUBE	-
23		Stiff to very stiff grey CLAY to SILTY CLAY, with black staining	▨	53.03 22.86	16	53 mm TUBE	-
25			▨		17	53 mm TUBE	-
26			▨		18	53 mm TUBE	-
28			▨		19	53 mm TUBE	-
29			▨		20	53 mm TUBE	-
30		*CONTINUED NEXT PAGE*					

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○; 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; 20 40 60 80



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-1-7

SHEET 3 OF 3

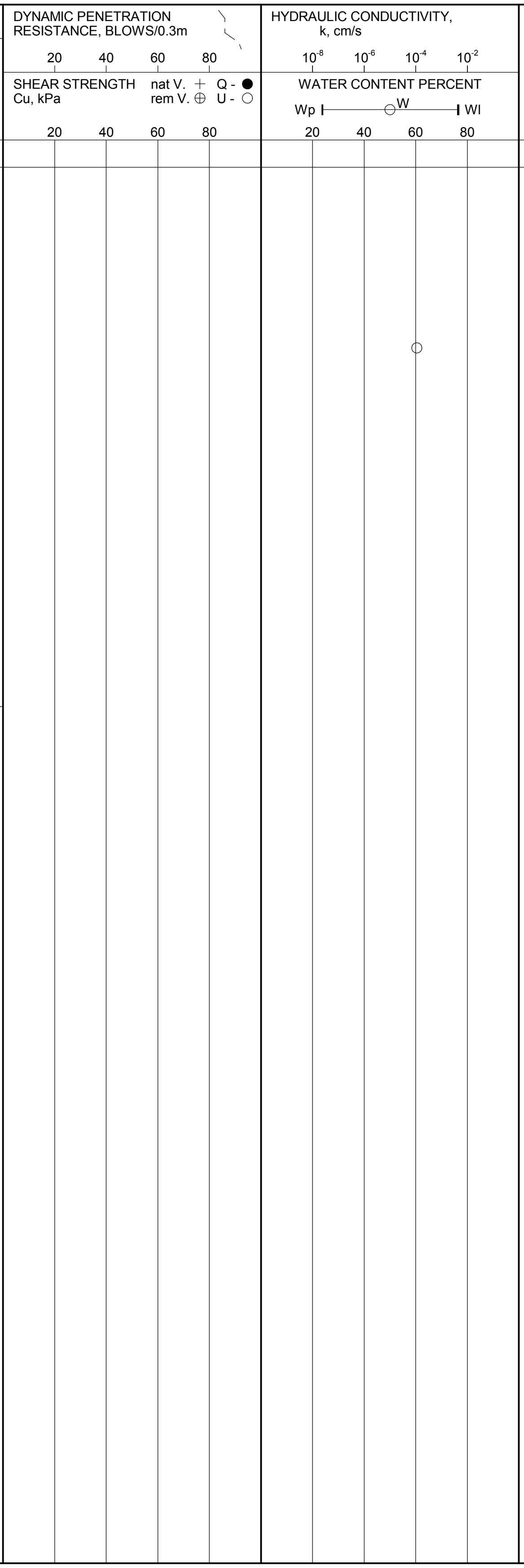
LOCATION: N 5020317.39 ;E 467122.99

INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 4, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---							
30	Geoprobe 90 mm Diam. (Driveable Casing)	Stiff to very stiff grey CLAY to SILTY CLAY, with black staining	▨		20		-		
31					21	53 mm TUBE	-		
32					22	53 mm TUBE	-		
33					23	53 mm TUBE	-		
34				41.40 34.49					
35		Grey SANDY SILT, trace clay		40.13	24	38 mm TUBE	-		
36		Grey SILTY CLAY		35.76					
		Grey SILTY SAND, some gravel, trace clay (GLACIAL TILL)		35.97					
		End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Different stratigraphy relative to borehole 12-1-3.							
37									
38									
39									
40									
41									
42									
43									
44									
45									



DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-2

SHEET 1 OF 2

LOCATION: N 5019601.24 ;E 466150.44
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: December 19, 2012

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

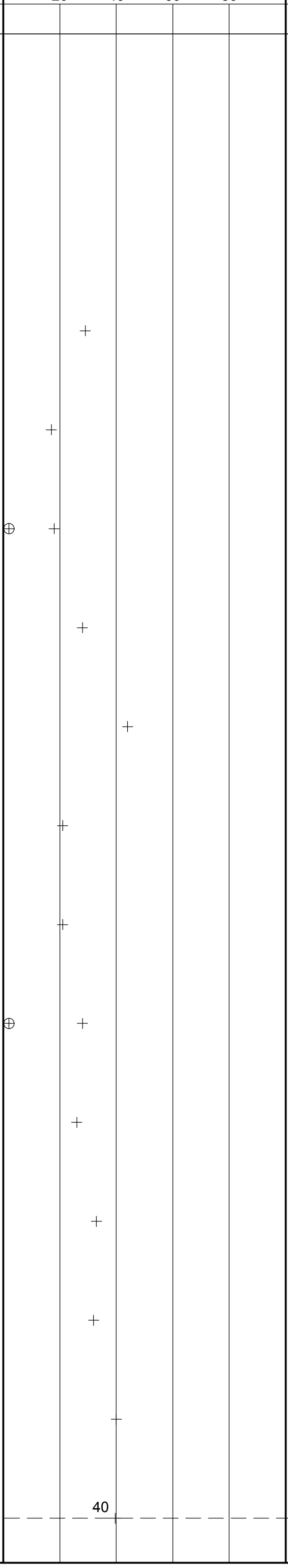
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE	77.12			
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL/PEAT	0.00			
		Very loose to loose grey brown SILTY SAND	0.23	1	50 DO	2
1				2	50 DO	6
		Red brown SILTY CLAY, with sand seams (Weathered Crust)	75.90 1.22			
		CLAY to SILTY CLAY	1.37	3	50 DO	WH
2	Electric Nilcon	Grey brown SANDY SILT, trace to some clay	75.01 2.11			
		Firm red grey SILTY CLAY, with sand seams - Sand layer from 2.41 m to 2.46 m	2.29			
3		Grey SAND, some silt, trace clay, with black staining	74.32 2.80			
		Soft to firm red grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 4.47 m to 4.50 m - Silt layer from 6.53 m to 6.61 m - Silt layer from 6.65 m to 6.68 m	3.02			
7		SILTY SAND, trace clay, with black staining	70.19 7.03			
		Grey CLAYEY SILT	69.73 7.39			
8		Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams				
15		*CONTINUED NEXT PAGE*				

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○: 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl: 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE
1 : 75

LOGGED: DG
CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-2

SHEET 2 OF 2

LOCATION: N 5019601.24 ;E 466150.44

BORING DATE: December 19, 2012

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

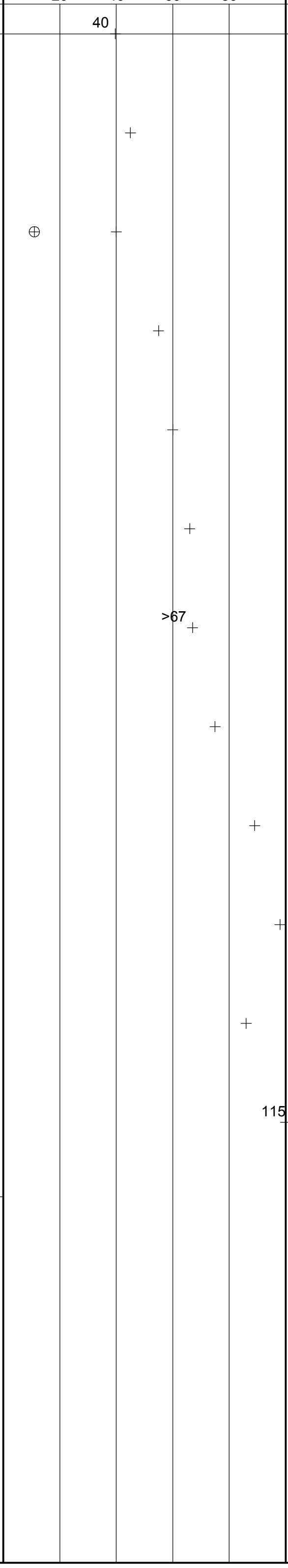
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---							
15	Electric Nilcon	Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	▨						
		Firm to stiff grey CLAY to SILTY CLAY, with black staining	▨	60.51 16.61					
		Very stiff dark grey CLAY to SILTY CLAY, with black staining	▨	51.36 25.76					
		End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Vane pushed to 26.75 m depth.		50.37 26.75					

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl : 20 40 60 80



DEPTH SCALE

1 : 75

LOGGED: DG

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-3

SHEET 1 OF 3

LOCATION: N 5019604.15 ;E 466157.12

INCLINATION: -90° AZIMUTH: ---

BORING DATE: January 7-14, 2013

DATUM: Geodetic

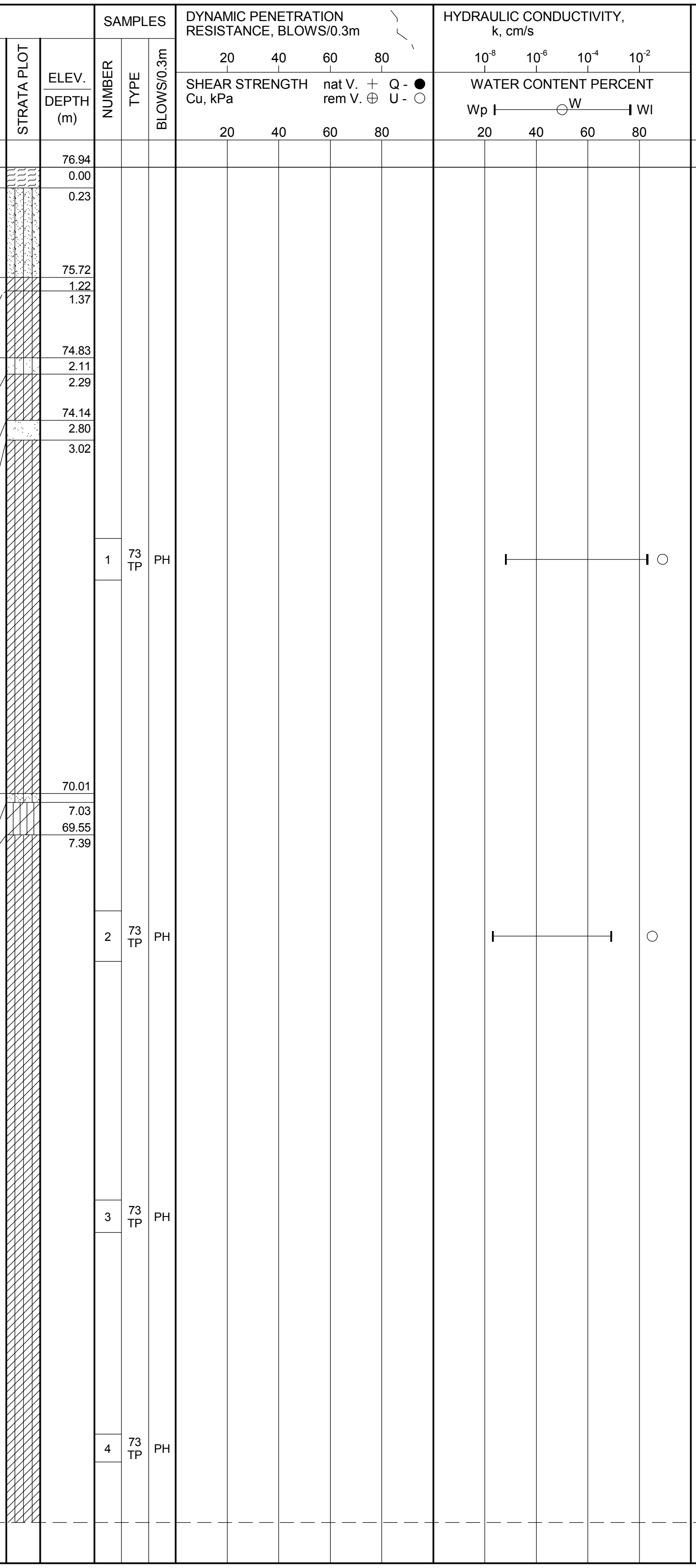
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

Boring method: Wash Boring, HW Casing (0 to 15 m)

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	76.94
TOPSOIL/PEAT	0.00
Very loose to loose grey brown SILTY SAND	0.23
Red brown SILTY CLAY, with sand seams (Weathered Crust)	75.72 1.22
CLAY to SILTY CLAY	1.37
Grey brown SANDY SILT, trace to some clay	74.83 2.11
Firm red grey SILTY CLAY, with sand seams - Sand layer from 2.41 m to 2.46 m	2.29
Grey SAND, some silt, trace clay, with black staining	74.14 2.80
Soft to firm red grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 4.47 m to 4.50 m - Silt layer from 6.53 m to 6.61 m - Silt layer from 6.65 m to 6.68 m	3.02
SILTY SAND, trace clay, with black staining	70.01 7.03
Grey CLAYEY SILT	69.55 7.39
Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	

NUMBER	TYPE	BLOWS/0.3m
1	73 TP	PH
2	73 TP	PH
3	73 TP	PH
4	73 TP	PH



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION: MON. WELL

Protective Casing

Bentonite-Cement Grout

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-3

SHEET 2 OF 3

LOCATION: N 5019604.15 ;E 466157.12

BORING DATE: January 7-14, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

--- *CONTINUED FROM PREVIOUS PAGE* ---

DEPTH (m)	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)
15	Wash Boring HW Casing	Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	▨	
16.61		Firm to stiff grey CLAY to SILTY CLAY, with black staining	▨	60.33 16.61
25.76		Very stiff dark grey CLAY to SILTY CLAY, with black staining	▨	51.18 25.76

NUMBER	TYPE	BLOWS/0.3m
5	73 TP	PH
6	73 TP	PH
7	50 DO	4

MON. WELL

Bentonite-Cement Grout

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-3

SHEET 3 OF 3

LOCATION: N 5019604.15 ;E 466157.12

BORING DATE: January 7-14, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---								MON. WELL
30	Wash Boring HW Casing	Very stiff dark grey CLAY to SILTY CLAY, with black staining								
31				8	73 TP	PH				
33										Bentonite-Cement Grout
				9	50 DO	2				
			43.16 33.78							
34		Grey brown SILTY SAND								
		Grey SANDY SILT	33.91 42.65							
		Dark grey and brown SILTY CLAY	34.29 42.35							
		Compact to very dense grey SAND and SILT, some gravel, trace clay (GLACIAL TILL)	34.59	10	50 DO	71				
35				11	50 DO	16				
36				12	50 DO	73				Peltonite
			40.20							
37		Borehole continued on RECORD OF DRILLHOLE 12-2-3 Note: Soil stratigraphy inferred from various soil sampling methods and CPT.								
38										
39										
40										
41										
42										
43										
44										
45										

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-2-3

SHEET 1 OF 3

LOCATION: N 5019604.15 ;E 466157.12

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: January 7-14, 2013

DRILL RIG: CME 55

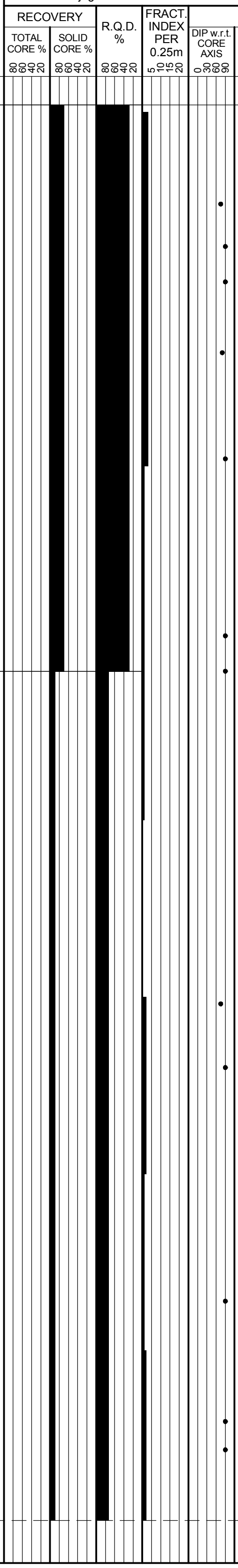
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

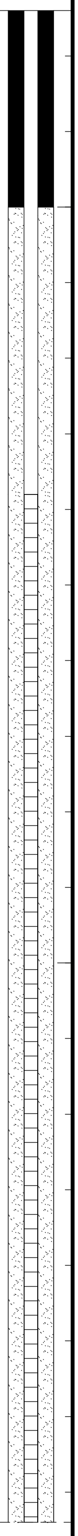
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	NOTES
		BEDROCK SURFACE	40.20			MON. WELL
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 36.74 m to 41.95 m** Fresh, medium grey, fine to medium grained crystalline, non-porous, thinly to medium bedded **LIMESTONE** with fine argillaceous partings, occasional bioclastic and lithoclastic beds and black slake susceptible shale partings 0.5-5.0 cm thick. Shale and calcareous shale comprises approximately 10% of section.	36.74	1		
			40.07 36.87		JN,,	Peltonite
					BD,,	
37					BD,,	
					BD,,	
			39.77 37.17			
			37.20			Silica Sand
					BD,,	
			39.44 37.51		BD,,	
				2	BD,,	
			39.24 37.70			
			39.17 37.77			
			39.03 37.91			
38			38.94 38.01		JN,,	63 mm Diam. PVC #10 Slot Screen
			38.83 38.11		BD,,	
					JN,,	
			38.44 38.50			
					BD,,	
					BD,,	



Jcon Jr Ja

HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WEATHERING INDEX W1 W2 W3 W4 W5 W6



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DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-2-3

SHEET 2 OF 3

LOCATION: N 5019604.15 ;E 466157.12

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: January 7-14, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

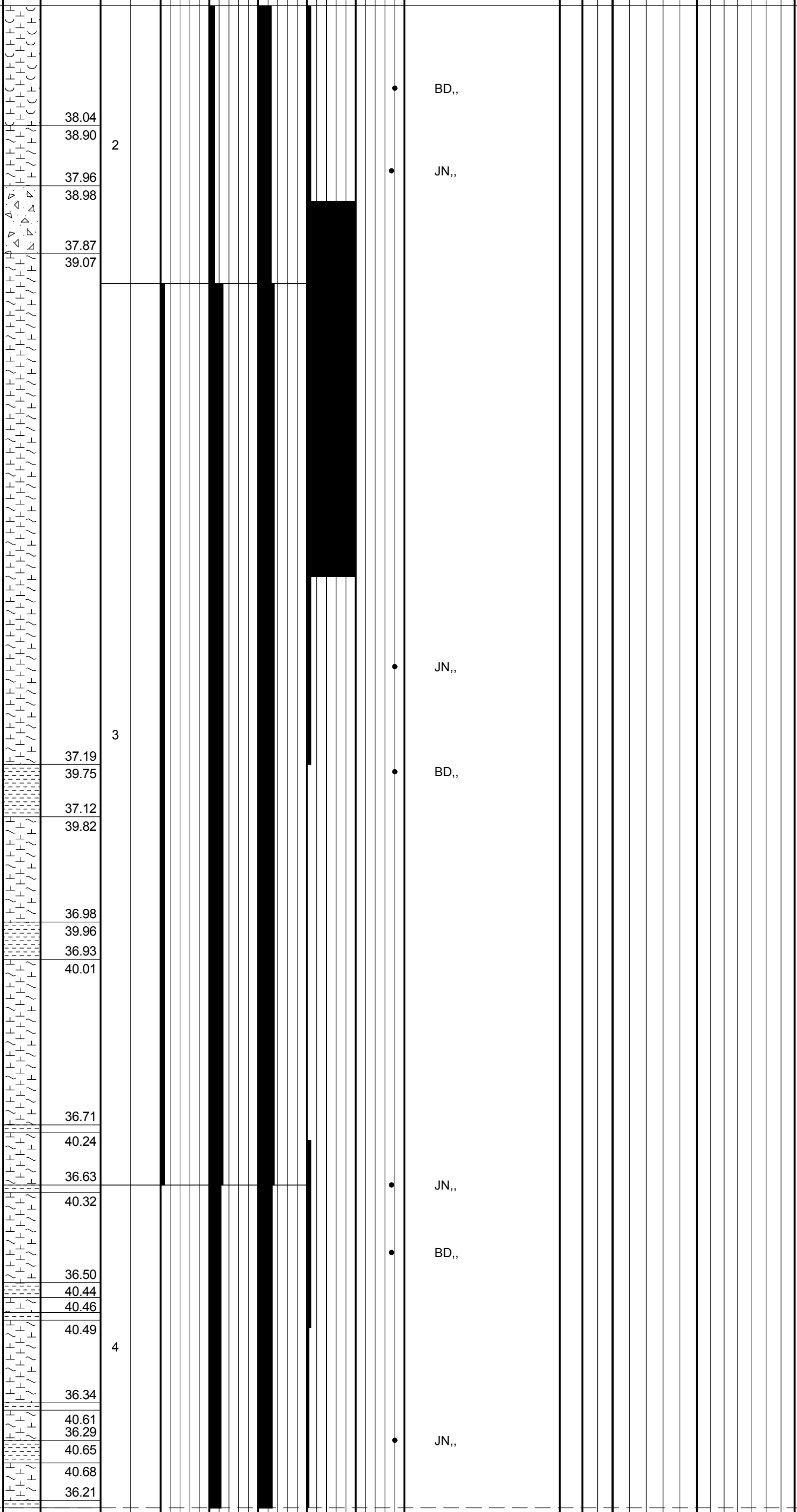
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % / SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.25m	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon Jr Ja	HYDRAULIC CONDUCTIVITY K, cm/sec	WEATHERING INDEX	NOTES

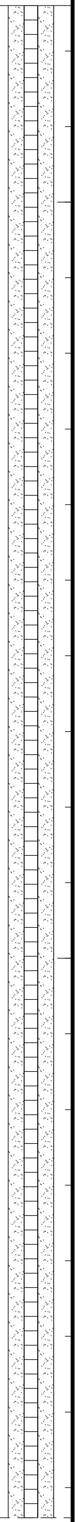
--- CONTINUED FROM PREVIOUS PAGE ---

Drilling record: Rotary Drill, HQ Core

CARLSBAD FORMATION, 36.74 m to 41.95 m Fresh, medium grey, fine to medium grained crystalline, non-porous, thinly to medium bedded **LIMESTONE** with fine argillaceous partings, occasional bioclastic and lithoclastic beds and black slake susceptible shale partings 0.5-5.0 cm thick. Shale and calcareous shale comprises approximately 10% of section.



MON. WELL



63 mm Diam. PVC
#10 Slot Screen

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-2-3

SHEET 3 OF 3

LOCATION: N 5019604.15 ;E 466157.12

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: January 7-14, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate
BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Clean
PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular
PO - Polished, K - Slickensided, SM - Smooth, RO - Rough, MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

Columns: DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE % 80 60 40 20; SOLID CORE % 80 60 40 20) | R.Q.D. % 80 60 40 20 | FRACT. INDEX PER 0.25m 5 10 15 20 | DISCONTINUITY DATA (DIP w.r.t. CORE AXIS 0 30 60 90; TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2} | WEATHERING INDEX W1 W2 W3 W4 W5 W6 | NOTES

--- CONTINUED FROM PREVIOUS PAGE ---

MON. WELL

Depth scale: 41, 42

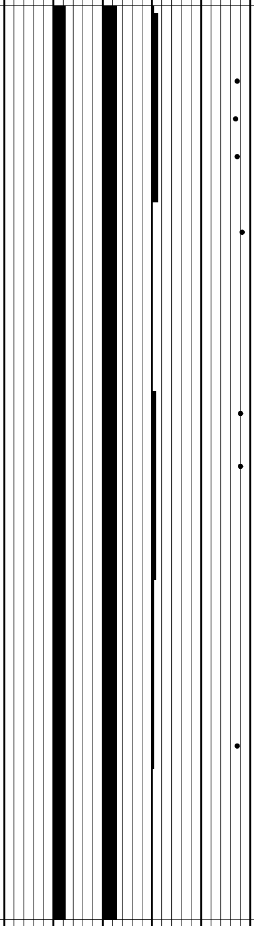
Drilling record: Rotary Drill, HQ Core

CARLSBAD FORMATION, 36.74 m to 41.95 m Fresh, medium grey, fine to medium grained crystalline, non-porous, thinly to medium bedded **LIMESTONE** with fine argillaceous partings, occasional bioclastic and lithoclastic beds and black slake susceptible shale partings 0.5-5.0 cm thick. Shale and calcareous shale comprises approximately 10% of section.

ELEV.	DEPTH (m)	Discontinuity type and surface description
	40.74	BD,,
36.05	40.89	BD,,
36.01	40.93	BD,,
35.95	40.99	VN,,
35.76	41.18	
35.72	41.22	
35.67	41.27	BD,,
35.59	41.35	BD,,
35.54	41.40	
35.42	41.52	
35.29	41.65	
35.23	41.71	BD,,
35.19	41.75	
35.08	41.86	
35.04	41.90	
34.99	41.95	

RUN No.: 4

End of Drillhole



NOTES: 63 mm Diam. PVC #10 Slot Screen

DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DG
CHECKED: SAT

CRRC-ROCK 1211250045.GPJ GAL-MISS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-4

SHEET 1 OF 3

LOCATION: N 5019605.34 ;E 466154.28
INCLINATION: -90° AZIMUTH: ---

BORING DATE: January 15-17, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		77.09							MON. WELL
0	Wash Boring HW Casing	TOPSOIL/PEAT		0.00							Protective Casing
		Very loose to loose grey brown SILTY SAND		0.23							Bentonite Seal
1		Red brown SILTY CLAY, with sand seams (Weathered Crust)		75.87 1.22							
		CLAY to SILTY CLAY		1.37							
2		Grey brown SANDY SILT, trace to some clay		74.98 2.11							
		Firm red grey SILTY CLAY, with sand seams - Sand layer from 2.41 m to 2.46 m		2.29							
3		Grey SAND, some silt, trace clay, with black staining		74.29 2.80							
		Soft to firm red grey CLAY to SILTY CLAY, with silt seams		3.02							
4		- Grey silt layer from 4.47 m to 4.50 m									
5											
6		- Silt layer from 6.53 m to 6.61 m - Silt layer from 6.65 m to 6.68 m									
7		SILTY SAND, trace clay, with black staining		70.16 7.03							
		Grey CLAYEY SILT		69.70 7.39							
8		Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams									Bentonite-Cement Grout
9											
10											
11											
12											
13											
14											
15											

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CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-4

SHEET 2 OF 3

LOCATION: N 5019605.34 ;E 466154.28
INCLINATION: -90° AZIMUTH: ---

BORING DATE: January 15-17, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---						MON. WELL
15	Wash Boring HW Casing	Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams						
16.61		Firm to stiff grey CLAY to SILTY CLAY, with black staining	60.48 16.61					
22								Bentonite-Cement Grout
25.76		Very stiff dark grey CLAY to SILTY CLAY, with black staining	51.33 25.76					
29.3								Bentonite Seal
30		*CONTINUED NEXT PAGE*						

Depth scale: 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-4

SHEET 3 OF 3

LOCATION: N 5019605.34 ;E 466154.28

INCLINATION: -90° AZIMUTH: ---

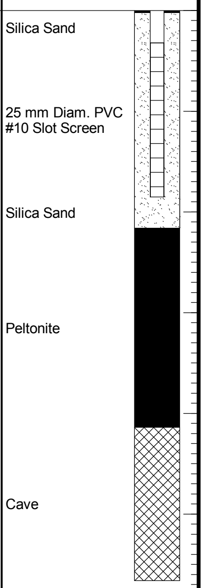
BORING DATE: January 15-17, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING
		--- CONTINUED FROM PREVIOUS PAGE ---							
30	Wash Boring HW Casing	Very stiff dark grey CLAY to SILTY CLAY, with black staining							
31									
32									
33									
		Grey brown SILTY SAND	43.31 33.78						
34		Grey SANDY SILT	33.91						
		Dark grey and brown SILTY CLAY	42.80 34.29						
		Compact to very dense grey SAND and SILT, some gravel, trace clay (GLACIAL TILL)	42.50 34.59						
35									
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	41.43 35.66						
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-5

SHEET 1 OF 2

LOCATION: N 5019606.89 ;E 466157.75
INCLINATION: -90° AZIMUTH: ---

BORING DATE: January 17-18, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

BORING METHOD: Wash Boring, HW Casing

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	76.99
TOPSOIL/PEAT	0.00
Very loose to loose grey brown SILTY SAND	0.23
Red brown SILTY CLAY, with sand seams (Weathered Crust)	75.77 1.22
CLAY to SILTY CLAY	1.37
Grey brown SANDY SILT, trace to some clay	74.88 2.11
Firm red grey SILTY CLAY, with sand seams - Sand layer from 2.41 m to 2.46 m	2.29
Grey SAND, some silt, trace clay, with black staining	74.19 2.80
Soft to firm red grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 4.47 m to 4.50 m - Silt layer from 6.53 m to 6.61 m - Silt layer from 6.65 m to 6.68 m	3.02
SILTY SAND, trace clay, with black staining	70.06 7.03
Grey CLAYEY SILT	69.60 7.39
Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	

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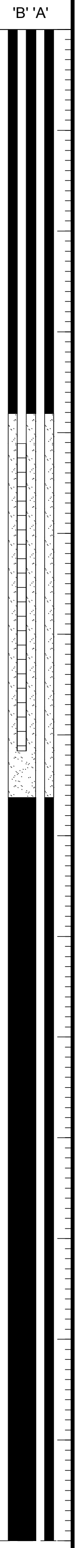
PIEZOMETER OR STANDPIPE INSTALLATION



Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen 'B'

Silica Sand

Bentonite Seal

DEPTH SCALE
1 : 75

LOGGED: DG
CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-5

SHEET 2 OF 2

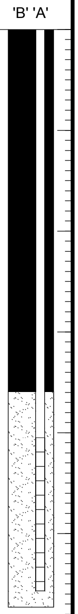
LOCATION: N 5019606.89 ;E 466157.75

INCLINATION: -90° AZIMUTH: ---

BORING DATE: January 17-18, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									'B' 'A'
15	Wash Boring HW Casing	Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	▨								
		Firm to stiff grey CLAY to SILTY CLAY, with black staining	▨	60.38 16.61							Bentonite Seal
											Silica Sand
											25 mm Diam. PVC #10 Slot Screen 'A'
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		56.26 20.73							



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-6

SHEET 1 OF 1

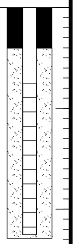
LOCATION: N 5019607.98 ;E 466154.98

INCLINATION: -90° AZIMUTH: ---

BORING DATE: January 19, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		77.13							MON. WELL
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL/PEAT		0.00							Protective Casing Bentonite Seal
1		Very loose to loose grey brown SILTY SAND		0.23							Silica Sand
		Red brown SILTY CLAY, with sand seams (Weathered Crust)		75.91 1.22							50 mm Diam. PVC #10 Slot Screen
2		CLAY to SILTY CLAY		1.37							
		Grey brown SANDY SILT, trace to some clay		75.02 2.11							
		End of Borehole		2.29							
3		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
4 5 6 7 8 9 10 11 12 13 14 15											



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-7

SHEET 1 OF 3

LOCATION: N 5019597.15 ;E 466156.16

INCLINATION: -90° AZIMUTH: ---

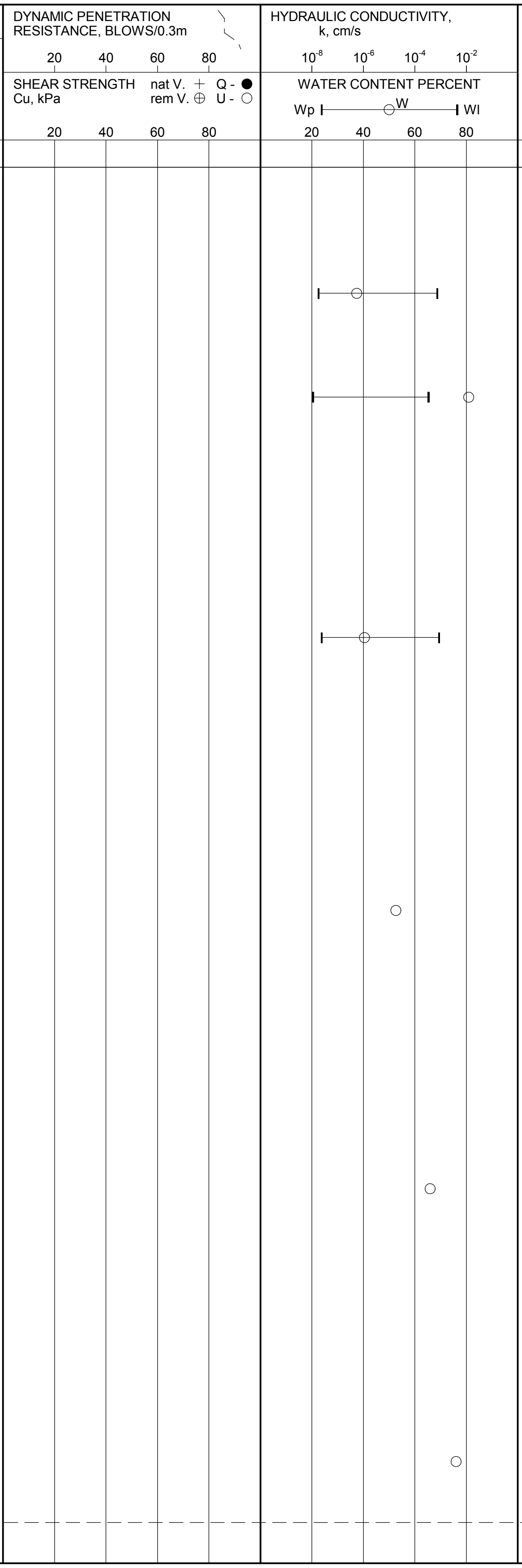
BORING DATE: March 15, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe

DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	ADDITIONAL LAB. TESTING
GROUND SURFACE		76.92	
TOPSOIL/PEAT		0.00	
Very loose to loose grey brown SILTY SAND		0.23	
Red brown SILTY CLAY, with sand seams (Weathered Crust)		75.70 1.22	
CLAY to SILTY CLAY		1.37	
Grey brown SANDY SILT, trace to some clay		74.81 2.11	MH
Firm red grey SILTY CLAY, with sand seams - Sand layer from 2.41 m to 2.46 m		2.29	
Grey SAND, some silt, trace clay, with black staining		74.12 2.80	MH
Soft to firm red grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 4.47 m to 4.50 m - Silt layer from 6.53 m to 6.61 m - Silt layer from 6.65 m to 6.68 m		3.02	
SILTY SAND, trace clay, with black staining		69.99	MH
Grey CLAYEY SILT		7.03	
Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams		69.53 7.39	

NUMBER	TYPE	BLOWS/0.3m
1	53 mm TUBE	-
2	53 mm TUBE	-
3	53 mm TUBE	-
4	53 mm TUBE	-
5	53 mm TUBE	-
6	53 mm TUBE	-
7	53 mm TUBE	-
8	53 mm TUBE	-
9	53 mm TUBE	-
10	53 mm TUBE	-



PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-7

SHEET 2 OF 3

LOCATION: N 5019597.15 ;E 466156.16

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 15, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe

--- CONTINUED FROM PREVIOUS PAGE ---

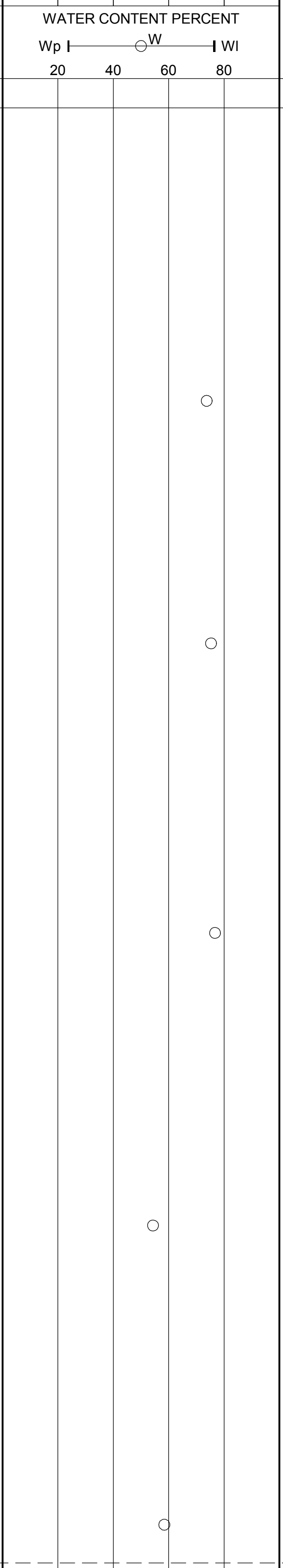
DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
15	Soft to firm red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	
16.61	Firm to stiff grey CLAY to SILTY CLAY, with black staining	60.31 16.61
25.76	Very stiff dark grey CLAY to SILTY CLAY, with black staining	51.16 25.76

SAMPLE NUMBER	TYPE	BLOWS/0.3m
11	53 mm TUBE	-
12	53 mm TUBE	-
13	53 mm TUBE	-
14	53 mm TUBE	-
15	53 mm TUBE	-
16	53 mm TUBE	-
17	53 mm TUBE	-
18	53 mm TUBE	-
19	53 mm TUBE	-
20	53 mm TUBE	-

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

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DEPTH SCALE

1 : 75

LOGGED: KE

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-2-7

SHEET 3 OF 3

LOCATION: N 5019597.15 ;E 466156.16
INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 15, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80
ADDITIONAL LAB. TESTING
PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)
		--- CONTINUED FROM PREVIOUS PAGE ---	
30	Geoprobe	Very stiff dark grey CLAY to SILTY CLAY, with black staining	
34		Grey brown SILTY SAND	43.14 33.78
		Grey SANDY SILT	33.91
		Dark grey and brown SILTY CLAY	42.63 34.29
35		Compact to very dense grey SAND and SILT, some gravel, trace clay (GLACIAL TILL)	42.10 34.82
36		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	41.11 35.81

SAMPLES NUMBER	TYPE	BLOWS/0.3m
20		-
21	53 mm TUBE	-
22	53 mm TUBE	-
23	38 mm TUBE	-
24	38 mm TUBE	-

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: KE
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-2

SHEET 1 OF 3

LOCATION: N 5021570.68 ;E 466665.61

INCLINATION: -90° AZIMUTH: ---

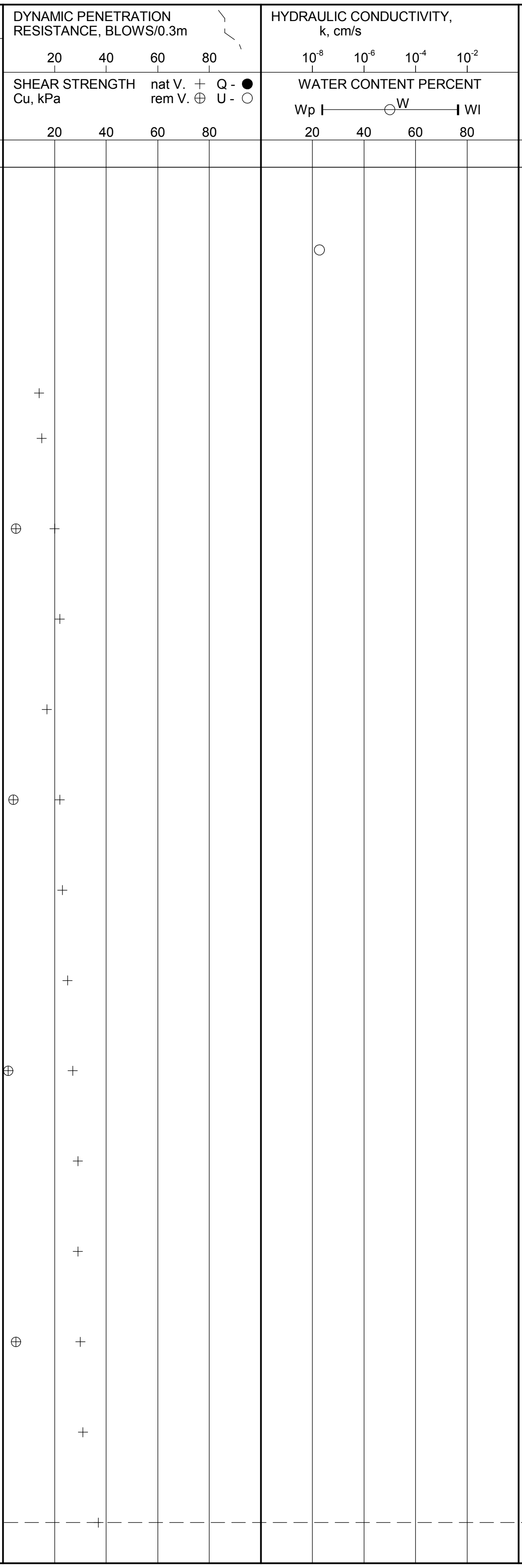
SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: November 27-28, 2012

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
		GROUND SURFACE	76.24				
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL	0.00				
		Loose to compact grey brown to grey SILTY SAND, trace clay	0.20	1	50 DO	9	
1				2	50 DO	10	MH
		Grey SANDY SILT, trace clay	75.10 1.14				
		Soft grey and red brown CLAY to SILTY CLAY, with silt seams	74.72 1.52	3	50 DO	WH	
2							
3	Electric Nilcon						
4							
5		Grey SILT, trace clay	71.36 4.88				
		Grey SILTY SAND	5.03				
		Soft grey and red brown CLAY to SILTY CLAY, with black staining and silt seams	5.15				
6							
		Grey SILT	69.84 6.46				
		Soft grey and red brown CLAY to SILTY CLAY, with black staining	69.35				
7		Grey SILT	6.95				
		Soft grey and red brown CLAY to SILTY CLAY, with black staining and clayey silt seams					
8							
		Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	67.65 8.59				
9							
10							
11							
12							
13							
14							
15							



PIEZOMETER OR STANDPIPE INSTALLATION

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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-2

SHEET 2 OF 3

LOCATION: N 5021570.68 ;E 466665.61

BORING DATE: November 27-28, 2012

DATUM: Geodetic

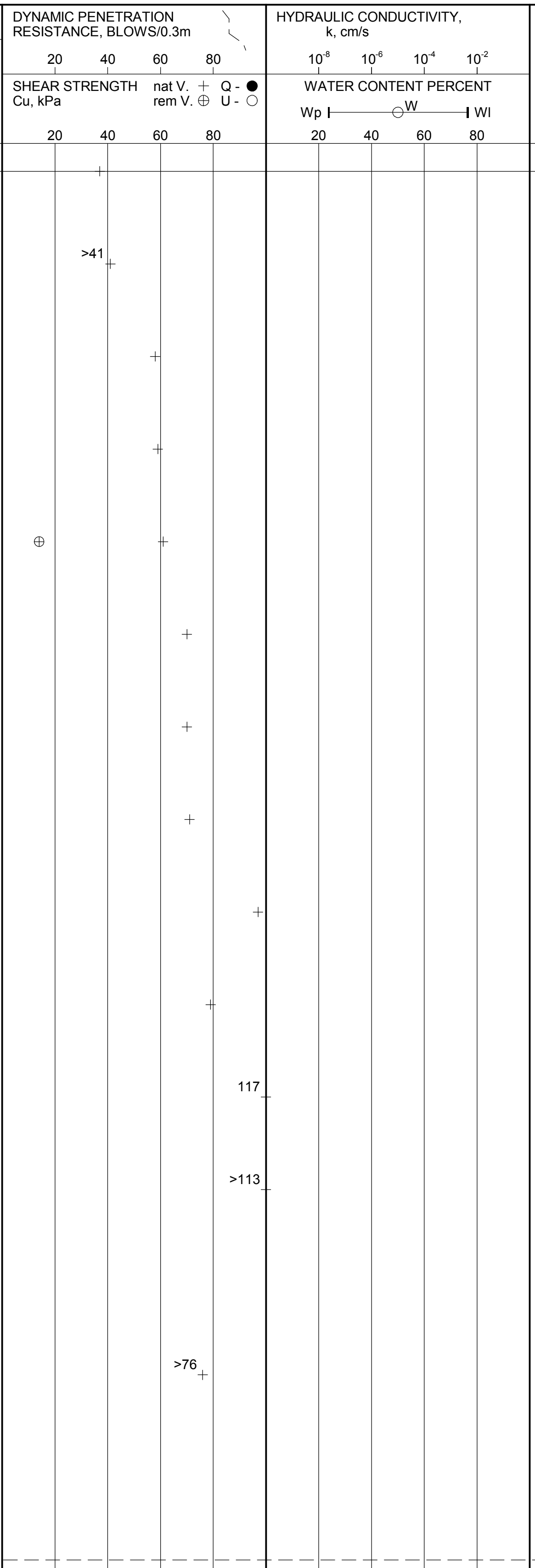
INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Electric Nilcon

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	--- CONTINUED FROM PREVIOUS PAGE ---						
15	Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining						
22	Stiff grey and red brown CLAY to SILTY CLAY, with black staining	53.63 22.61					
25	Grey CLAYEY SILT, some sand	50.58 25.66					
26	Very stiff grey CLAY to SILTY CLAY, with black staining	50.24 26.00					
27	Grey SILTY fine SAND	49.05 27.30					
	Grey SANDY SILT, some clay						
	Very stiff grey CLAY to SILTY CLAY, with black staining						
30							



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DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-2

SHEET 3 OF 3

LOCATION: N 5021570.68 ;E 466665.61

BORING DATE: November 27-28, 2012

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa nat V. + rem V. ⊕ Q - ● U - ○ 20 40 60 80	WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80		
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Electric Nilcon	Brown SILTY SAND	▨	45.94 30.33							
31		Very stiff grey CLAY to SILTY CLAY, with black staining	▨	45.11 31.13				>76 +			
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-3

SHEET 1 OF 3

LOCATION: N 5021578.47 ;E 466670.90

BORING DATE: December 3-5, 2012

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.22				
0	Wash Boring HW Casing	TOPSOIL	0.00				Protective Casing Bentonite Seal
		Loose to compact grey brown to grey SILTY SAND, trace clay	0.20				
1		Grey SANDY SILT, trace clay	75.08 1.14				
		Soft grey and red brown CLAY to SILTY CLAY, with silt seams	74.70 1.52				
2				1	73 TP	PH	
3							
4							
5		Grey SILT, trace clay	71.34 4.88				
		Grey SILTY SAND	5.03				
		Soft grey and red brown CLAY to SILTY CLAY, with black staining and silt seams	5.15				
6				2	73 TP	PH	
		Grey SILT	69.82 6.46				
		Soft grey and red brown CLAY to SILTY CLAY, with black staining	69.33				
7		Grey SILT	6.95				
		Soft grey and red brown CLAY to SILTY CLAY, with black staining and clayey silt seams					Bentonite-Cement Grout
8		Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	67.63 8.59				
9							
10							
11							
12				3	73 TP	PH	
13							
14							
15							

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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-3

SHEET 2 OF 3

LOCATION: N 5021578.47 ;E 466670.90
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: December 3-5, 2012

DATUM: Geodetic

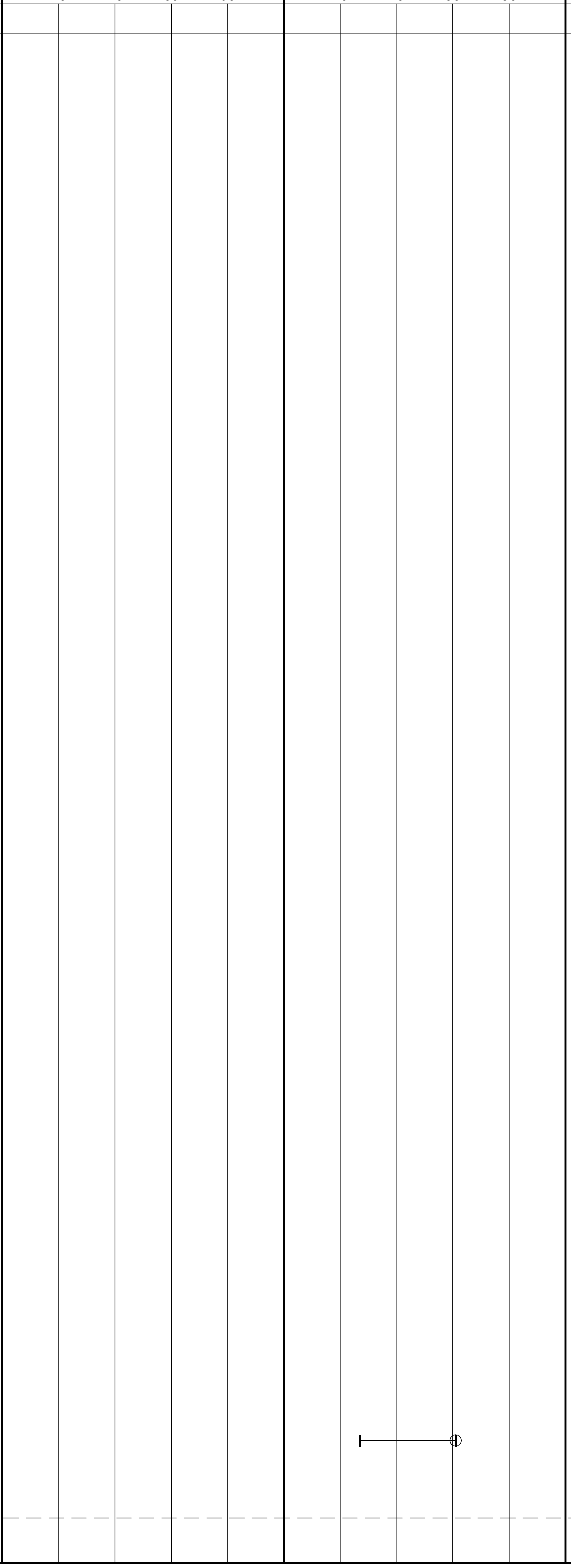
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

--- CONTINUED FROM PREVIOUS PAGE ---

Boring method: Wash Boring, HW Casing

DESCRIPTION	ELEV. / DEPTH (m)
Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	
Stiff grey and red brown CLAY to SILTY CLAY, with black staining	53.61 22.61
Grey CLAYEY SILT, some sand	50.56 25.66
Very stiff grey CLAY to SILTY CLAY, with black staining	50.22 26.00
Grey SILTY fine SAND	49.03 27.30
Grey SANDY SILT, some clay	
Very stiff grey CLAY to SILTY CLAY, with black staining	

NUMBER	TYPE	BLOWS/0.3m
4	73 TP	PH
5	73 TP	PH
6	73 TP	PH



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION: Bentonite-Cement Grout

DEPTH SCALE METRES: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

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DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-3

SHEET 3 OF 3

LOCATION: N 5021578.47 ;E 466670.90
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: December 3-5, 2012

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

--- *CONTINUED FROM PREVIOUS PAGE* ---

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. / DEPTH (m)
30.33	Wash Boring HW Casing	Brown SILTY SAND	45.92 30.33
		Very stiff grey CLAY to SILTY CLAY, with black staining	
31.85		Very stiff grey SILTY CLAY, some sand	44.37 31.85
32.10		Very stiff grey and red CLAY to SILTY CLAY	32.10
33.07		Compact to very dense grey SILTY SAND to SANDY SILT, some gravel, trace to some clay, with cobbles and boulders (GLACIAL TILL)	43.15 33.07
34	Rotary Drill HQ Core		
			36.38
		Borehole continued on RECORD OF DRILLHOLE 12-3-3	

NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
7	50 DO	6	
8	50 DO	20	
9	50 DO	21	
10	50 DO	44	
11	50 DO	55	
12	50 DO	97	
13	50 DO	88	MH
14	50 DO	>50	
15	50 DO	90	
16	50 DO	90	

PIEZOMETER OR STANDPIPE INSTALLATION:
- Bentonite-Cement Grout
- Peltonite

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-3-3

SHEET 1 OF 3

LOCATION: N 5021578.47 ;E 466670.90

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: December 3-5, 2012

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Clean	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth RO - Rough MB - Mechanical Break	BR - Broken Rock	NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES
		BEDROCK SURFACE	36.38			
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 39.84 m to 45.42 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.	39.84 39.86			Peltonite
40			36.23 39.99		JN,, JN,, JN,,	
			36.06 40.16			
			35.93 40.29		JN,,	Silica Sand
				1	VN,,	
41			35.09 41.13			
			34.98 41.24	2	VN,,	63 mm Diam. PVC #10 Slot Screen

Column headings also printed: SYMBOLIC LOG; FLUSH RETURN; RECOVERY (TOTAL CORE %, SOLID CORE % — 80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.25m (5 10 15 20); DIP w.r.t. CORE AXIS (0 30 60 90); Jcon Jr Ja; HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WEATHERING INDEX (W1 W2 W3 W4 W5 W6)

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-3-3

SHEET 2 OF 3

LOCATION: N 5021578.47 ;E 466670.90

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: December 3-5, 2012

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SH - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	RO - Rough	
CJ - Conjugate	CL - Clean	IR - Irregular	MB - Mechanical Break	

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY: TOTAL CORE % (80 60 40 20), SOLID CORE % (80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX PER 0.25m (5 10 15 20) | DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90), TYPE AND SURFACE DESCRIPTION, Jcon, Jr, Ja | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}) | WEATH-ERING INDEX (W1 W2 W3 W4 W5 W6) | NOTES

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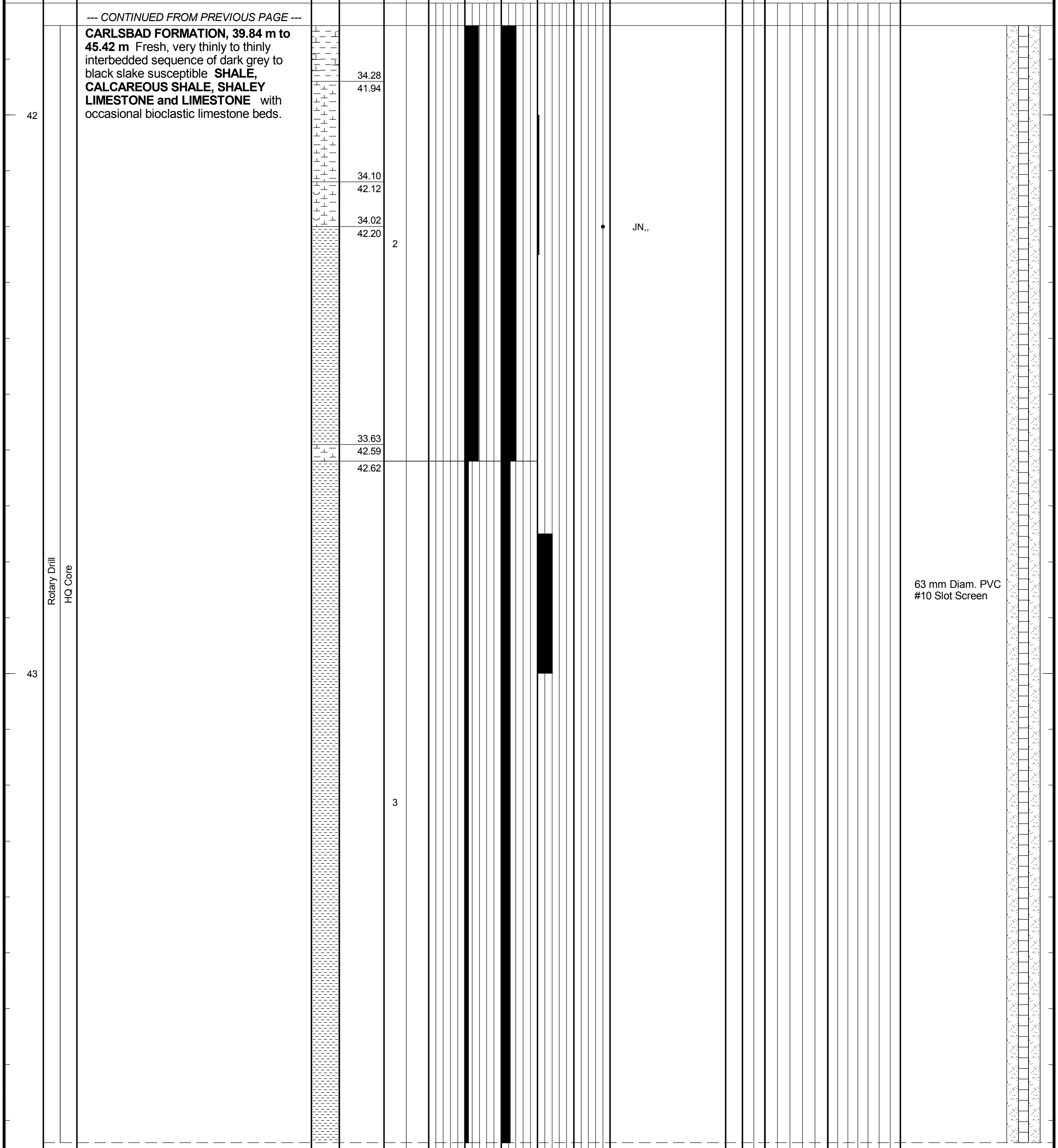


CARLSBAD FORMATION, 39.84 m to 45.42 m Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.

63 mm Diam. PVC
#10 Slot Screen

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-3-3

SHEET 3 OF 3

LOCATION: N 5021578.47 ;E 466670.90

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: December 3-5, 2012

DRILL RIG: CME 55

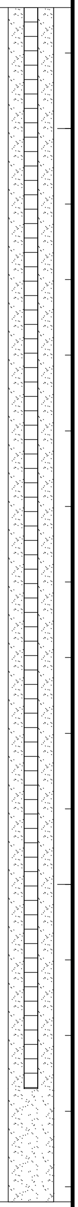
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---				
44	Rotary Drill HQ Core	**CARLSBAD FORMATION, 39.84 m to 45.42 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.	32.07 44.15 44.17	3		
					VN,,	
			31.69 44.53 31.63 44.59 31.54 44.68 31.50 44.72	4		63 mm Diam. PVC #10 Slot Screen
45			31.06 45.16 30.85 45.37 30.80			Silica Sand
		End of Drillhole	45.42			



DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-4

SHEET 1 OF 3

LOCATION: N 5021576.05 ;E 466672.49

INCLINATION: -90° AZIMUTH: ---

BORING DATE: December 11-14, 2012

DATUM: Geodetic

BORING METHOD: Wash Boring, HW Casing

SAMPLES: NUMBER | TYPE | BLOWS/0.3m

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ — 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp —○W— Wl — 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DESCRIPTION	ELEV.	DEPTH (m)
GROUND SURFACE	76.23	
TOPSOIL		0.00
Loose to compact grey brown to grey SILTY SAND, trace clay		0.20
Grey SANDY SILT, trace clay	75.09	1.14
Soft grey and red brown CLAY to SILTY CLAY, with silt seams	74.71	1.52
Grey SILT, trace clay	71.35	4.88
Grey SILTY SAND		5.03
Soft grey and red brown CLAY to SILTY CLAY, with black staining and silt seams		5.15
Grey SILT	69.83	6.46
Soft grey and red brown CLAY to SILTY CLAY, with black staining		
Grey SILT	69.34	6.95
Soft grey and red brown CLAY to SILTY CLAY, with black staining and clayey silt seams		
Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	67.64	8.59

'B' 'A'

Protective Casing

Bentonite-Cement Grout

DEPTH SCALE (METRES): 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

CONTINUED NEXT PAGE

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-4

SHEET 2 OF 3

LOCATION: N 5021576.05 ;E 466672.49

INCLINATION: -90° AZIMUTH: ---

BORING DATE: December 11-14, 2012

DATUM: Geodetic

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80) | SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

Depth scale: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

Boring method: Wash Boring; HW Casing

DESCRIPTION	ELEV. DEPTH (m)
--- CONTINUED FROM PREVIOUS PAGE ---	
Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	
Stiff grey and red brown CLAY to SILTY CLAY, with black staining	53.62 22.61
Grey CLAYEY SILT, some sand	50.57 25.66
Very stiff grey CLAY to SILTY CLAY, with black staining	50.23 26.00
Grey SILTY fine SAND	49.04 27.30
Grey SANDY SILT, some clay	
Very stiff grey CLAY to SILTY CLAY, with black staining	
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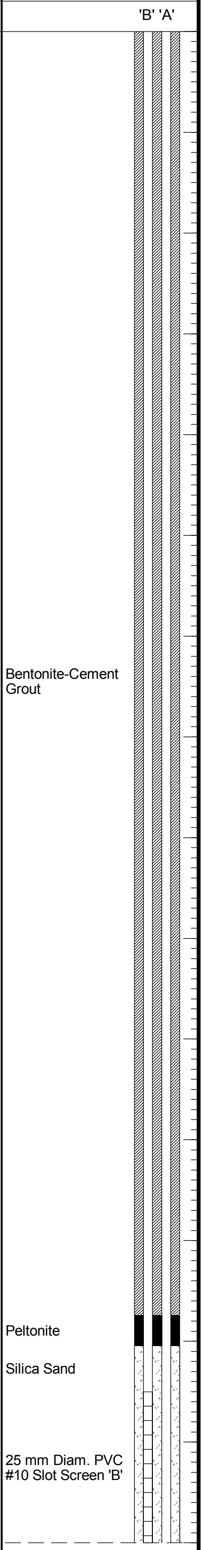


DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-4

SHEET 3 OF 3

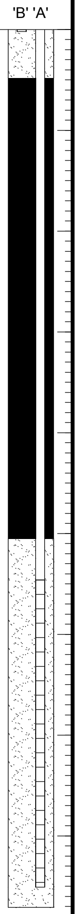
LOCATION: N 5021576.05 ;E 466672.49

INCLINATION: -90° AZIMUTH: ---

BORING DATE: December 11-14, 2012

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- *CONTINUED FROM PREVIOUS PAGE* ---									'B' 'A'
30	Wash Boring HW Casing	Brown SILTY SAND		45.93 30.33							Silica Sand
		Very stiff grey CLAY to SILTY CLAY, with black staining									
31											
32		Very stiff grey SILTY CLAY, some sand		44.38 31.85							
		Very stiff grey and red CLAY to SILTY CLAY		32.10							Peltonite
33		Compact to very dense grey SILTY SAND to SANDY SILT, some gravel, trace to some clay, with cobbles and boulders (GLACIAL TILL)		43.16 33.07							
34											
35											Silica Sand
36											
37											38 mm Diam. PVC #10 Slot Screen 'A'
38											Silica Sand
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		37.52 38.71							
39											
40											
41											
42											
43											
44											
45											



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-5

SHEET 1 OF 2

LOCATION: N 5021577.15 ;E 466668.45

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: December 7, 2012

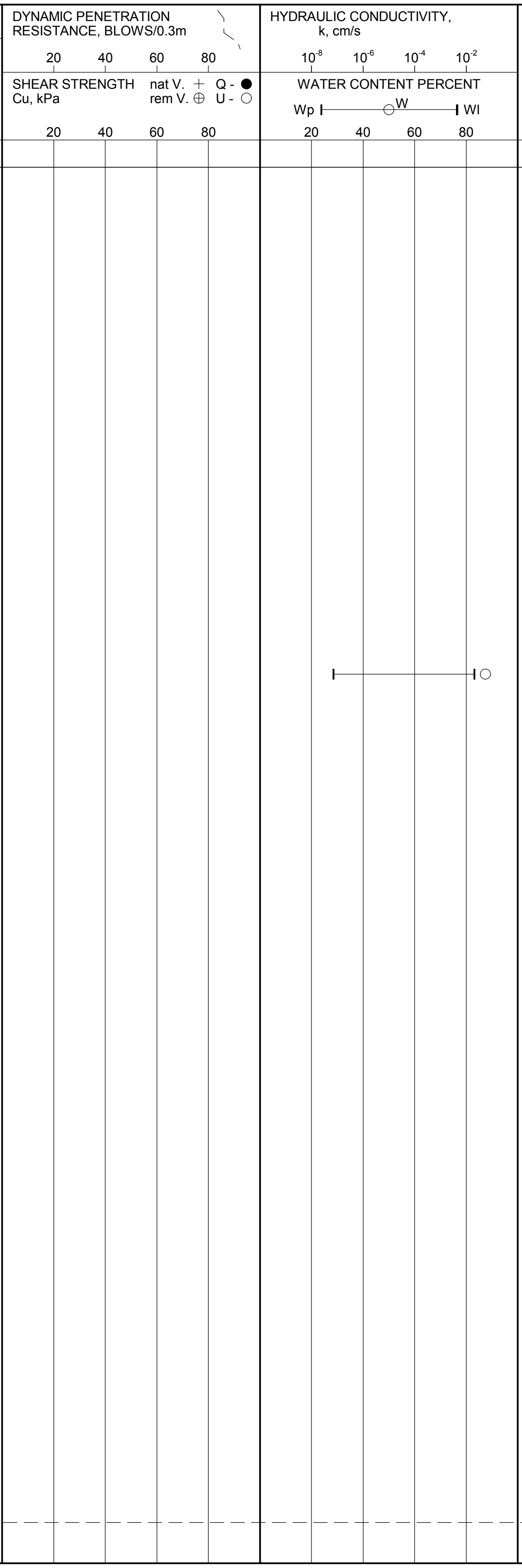
DATUM: Geodetic

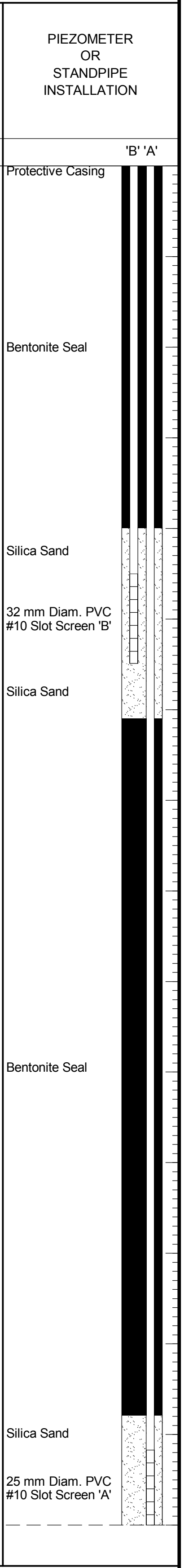
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	76.23
TOPSOIL	0.00
Loose to compact grey brown to grey SILTY SAND, trace clay	0.20
Grey SANDY SILT, trace clay	75.09 1.14
Soft grey and red brown CLAY to SILTY CLAY, with silt seams	74.71 1.52
Grey SILT, trace clay	71.35 4.88
Grey SILTY SAND	5.03
Soft grey and red brown CLAY to SILTY CLAY, with black staining and silt seams	5.15
Grey SILT	69.83 6.46
Soft grey and red brown CLAY to SILTY CLAY, with black staining	
Grey SILT	69.34 6.95
Soft grey and red brown CLAY to SILTY CLAY, with black staining and clayey silt seams	
Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	67.64 8.59

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	73 TP	PH	





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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-5

SHEET 2 OF 2

LOCATION: N 5021577.15 ;E 466668.45

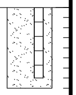
BORING DATE: December 7, 2012

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									'B' 'A'
15	Power Auger	Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	▨	60.43	2	73 TP	PH				25 mm Diam. PVC #10 Slot Screen 'A' Silica Sand
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		15.80							
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-6

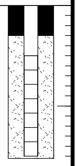
SHEET 1 OF 1

LOCATION: N 5021574.40 ;E 466669.89

INCLINATION: -90° AZIMUTH: ---

BORING DATE: December 7, 2012

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.27							MON. WELL
0		TOPSOIL		0.00							 Protective Casing Bentonite Seal
	Power Auger 200 mm Diam. (HS)	Loose to compact grey brown to grey SILTY SAND, trace clay		0.20							Silica Sand
1		Grey SANDY SILT, trace clay		75.13 1.14							50 mm Diam. PVC #10 Slot Screen
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		74.75 1.52							
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											

DEPTH SCALE

1 : 75

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-7

SHEET 1 OF 3

LOCATION: N 5021565.88 ;E 466661.37
INCLINATION: -90° AZIMUTH: ---

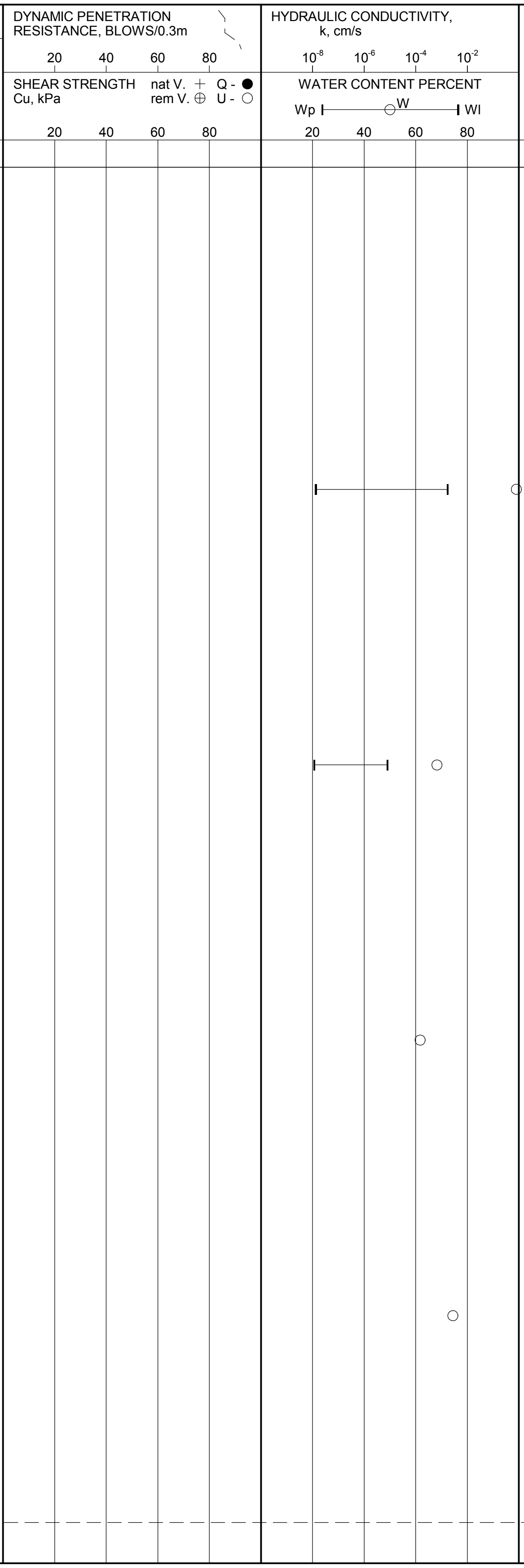
BORING DATE: March 11, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	76.09
TOPSOIL	0.00
Loose to compact grey brown to grey SILTY SAND, trace clay	0.20
Grey SANDY SILT, trace clay	74.95 1.14
Soft grey and red brown CLAY to SILTY CLAY, with silt seams	74.57 1.52
Grey SILT, trace clay	71.21 4.88
Grey SILTY SAND	5.03
Soft grey and red brown CLAY to SILTY CLAY, with black staining and silt seams	5.15
Grey SILT	69.69 6.46
Soft grey and red brown CLAY to SILTY CLAY, with black staining	
Grey SILT	69.20 6.95
Soft grey and red brown CLAY to SILTY CLAY, with black staining and clayey silt seams	
Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	67.50 8.59

SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	53 mm TUBE	-	MH
2	53 mm TUBE	-	MH MH
3	53 mm TUBE	-	
4	53 mm TUBE	-	MH
5	53 mm TUBE	-	
6	53 mm TUBE	-	
7	53 mm TUBE	-	
8	53 mm TUBE	-	
9	53 mm TUBE	-	
10	53 mm TUBE	-	



PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: KE
CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-7

SHEET 2 OF 3

LOCATION: N 5021565.88 ;E 466661.37

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 11, 2013

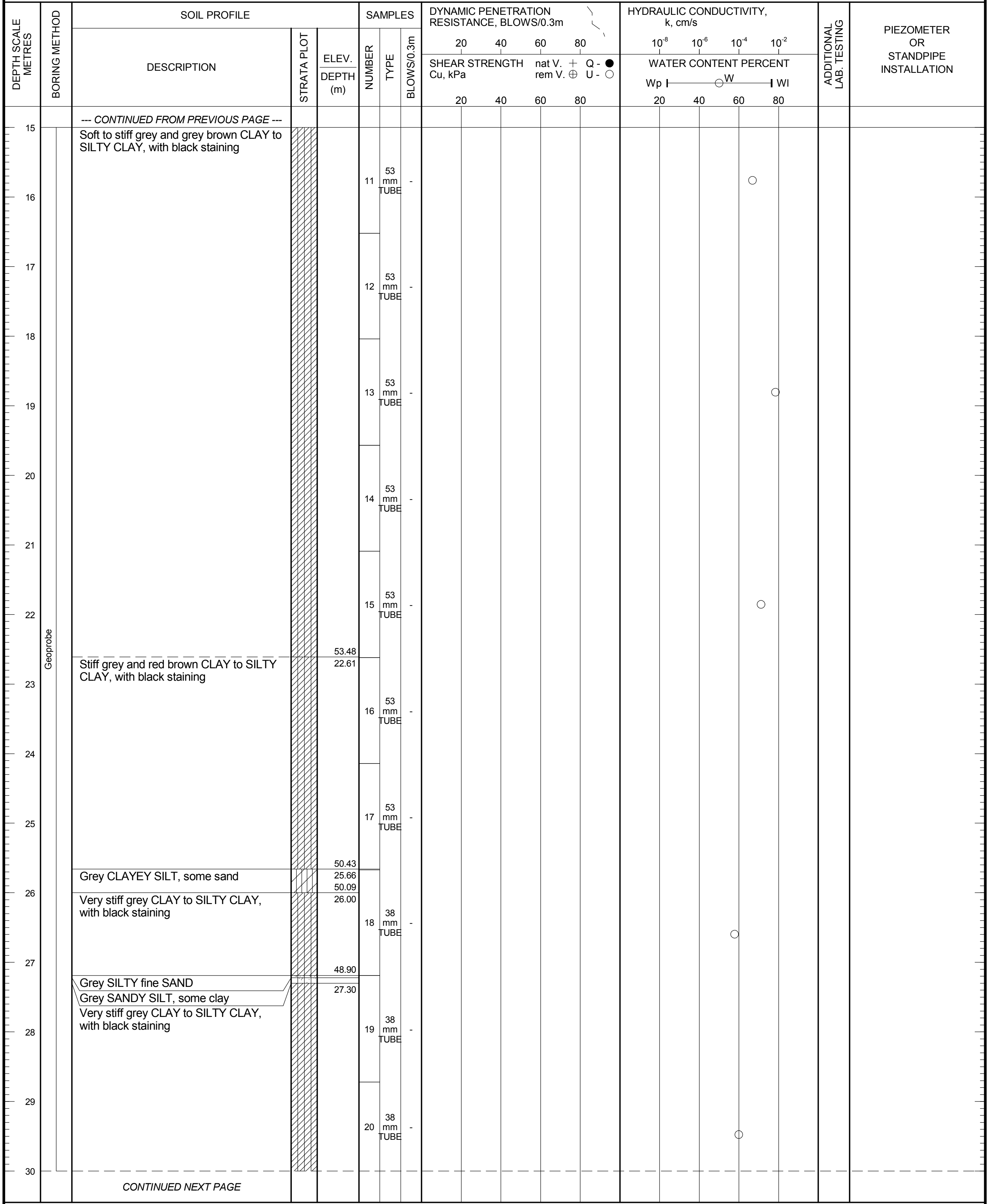
DATUM: Geodetic

BORING METHOD: Geoprobe

--- CONTINUED FROM PREVIOUS PAGE ---

DESCRIPTION	ELEV. / DEPTH (m)
Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	
Stiff grey and red brown CLAY to SILTY CLAY, with black staining	53.48 22.61
Grey CLAYEY SILT, some sand	50.43 25.66
Very stiff grey CLAY to SILTY CLAY, with black staining	50.09 26.00
Grey SILTY fine SAND Grey SANDY SILT, some clay Very stiff grey CLAY to SILTY CLAY, with black staining	48.90 27.30

NUMBER	TYPE	BLOWS/0.3m
11	53 mm TUBE	-
12	53 mm TUBE	-
13	53 mm TUBE	-
14	53 mm TUBE	-
15	53 mm TUBE	-
16	53 mm TUBE	-
17	53 mm TUBE	-
18	38 mm TUBE	-
19	38 mm TUBE	-
20	38 mm TUBE	-



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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-7

SHEET 3 OF 3

LOCATION: N 5021565.88 ;E 466661.37

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 11, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Geoprobe				20		-				
		Brown SILTY SAND		45.79 30.33							
31		Very stiff grey CLAY to SILTY CLAY, with black staining			21	38 mm TUBE	-				
		Very stiff grey SILTY CLAY, some sand		44.24 31.85							
32		Very stiff grey and red CLAY to SILTY CLAY		32.10	22	38 mm TUBE	-		○		
33		Compact to very dense grey SILTY SAND to SANDY SILT, some gravel, trace to some clay, with cobbles and boulders (GLACIAL TILL)		43.02 33.07							
		End of Borehole		33.28							
34		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE

1 : 75

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-3-7-1

SHEET 1 OF 1

LOCATION: N 5021565.89 ;E 466667.46

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 11, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m
		GROUND SURFACE	76.06			
0	Geoprobe	TOPSOIL	0.00			
		Loose to compact grey brown to grey SILTY SAND, trace clay	0.20	1	53 mm TUBE	-
1		Grey SANDY SILT, trace clay	74.92 1.14			
		Soft grey and red brown CLAY to SILTY CLAY, with silt seams	74.54 1.52	2	53 mm TUBE	-
2						
3				3	53 mm TUBE	-
4						
5		Grey SILT, trace clay	71.18 4.88			
		Grey SILTY SAND	5.03	4	53 mm TUBE	-
		Soft grey and red brown CLAY to SILTY CLAY, with black staining and silt seams	5.15			
6		Grey SILT	69.66 6.46			
		Soft grey and red brown CLAY to SILTY CLAY, with black staining		5	53 mm TUBE	-
7		Grey SILT	69.17 6.95			
		Soft grey and red brown CLAY to SILTY CLAY, with black staining and clayey silt seams				
8				6	53 mm TUBE	-
		Soft to stiff grey and grey brown CLAY to SILTY CLAY, with black staining	67.47 8.59			
9		End of Borehole	67.15 8.91			

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: WAM
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-2

SHEET 1 OF 3

LOCATION: N 5020868.09 ;E 466519.28

BORING DATE: January 23-28, 2013

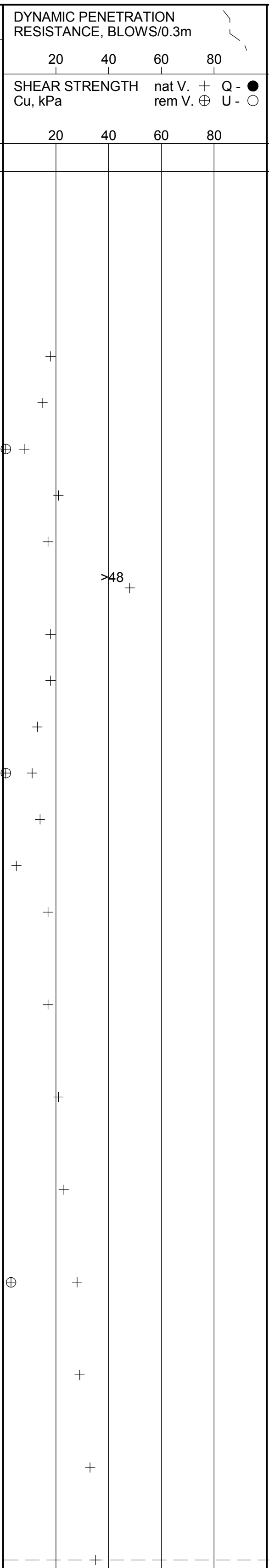
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE	75.92			
0	Power Auger 200 mm Diam. (HS)	TOPSOIL	0.00			
		Grey brown SANDY SILT, trace clay, with black staining	75.62 0.30	1	50 DO	
1		Red brown SILTY CLAY, with silty sand seams (Weathered Crust)	75.22 0.70	2	50 DO	
	Electric Nilcon	Soft red grey CLAY to SILTY CLAY, with silty sand and silt seams	74.70 1.22			
3		Red grey and grey CLAY to SILTY CLAY, with silt seams	72.95 2.97			
		Grey SILTY SAND, trace clay, with black staining	71.20 4.72			
5		Grey SILT, some sand	4.95			
		Soft red grey and grey CLAY to SILTY CLAY, with black staining and silt seams	5.18			
7		Grey SILT, some sand	68.76			
		Soft to firm red grey and grey CLAY to SILTY CLAY, with black staining	7.26			
13		Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	62.36 13.56			
15						



HYDRAULIC CONDUCTIVITY, k, cm/s	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80		

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-2

SHEET 2 OF 3

LOCATION: N 5020868.09 ;E 466519.28

BORING DATE: January 23-28, 2013

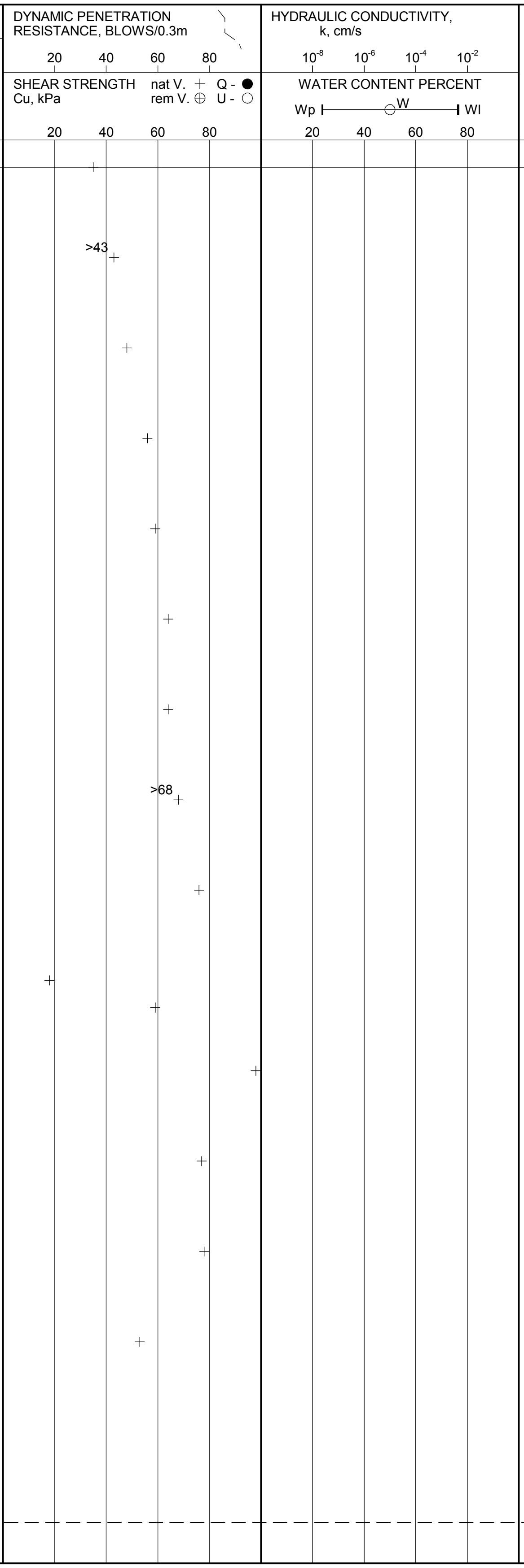
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---							
15	Electric Nilcon	Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	▨						
22.76		Stiff grey to dark grey CLAY to SILTY CLAY, with black staining	▨	53.16 22.76					
30		*CONTINUED NEXT PAGE*							



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-2

SHEET 3 OF 3

LOCATION: N 5020868.09 ;E 466519.28

BORING DATE: January 23-28, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
30 31 32 33	Electric Nilcon	Stiff grey to dark grey CLAY to SILTY CLAY, with black staining	▨	42.12							
34 35 36 37 38 39 40 41 42 43 44 45		End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Vane pushed to 33.8 m depth.		33.80							

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-3

SHEET 1 OF 3

LOCATION: N 5020872.72 ;E 466523.18

BORING DATE: January 31 - February 15, 2013

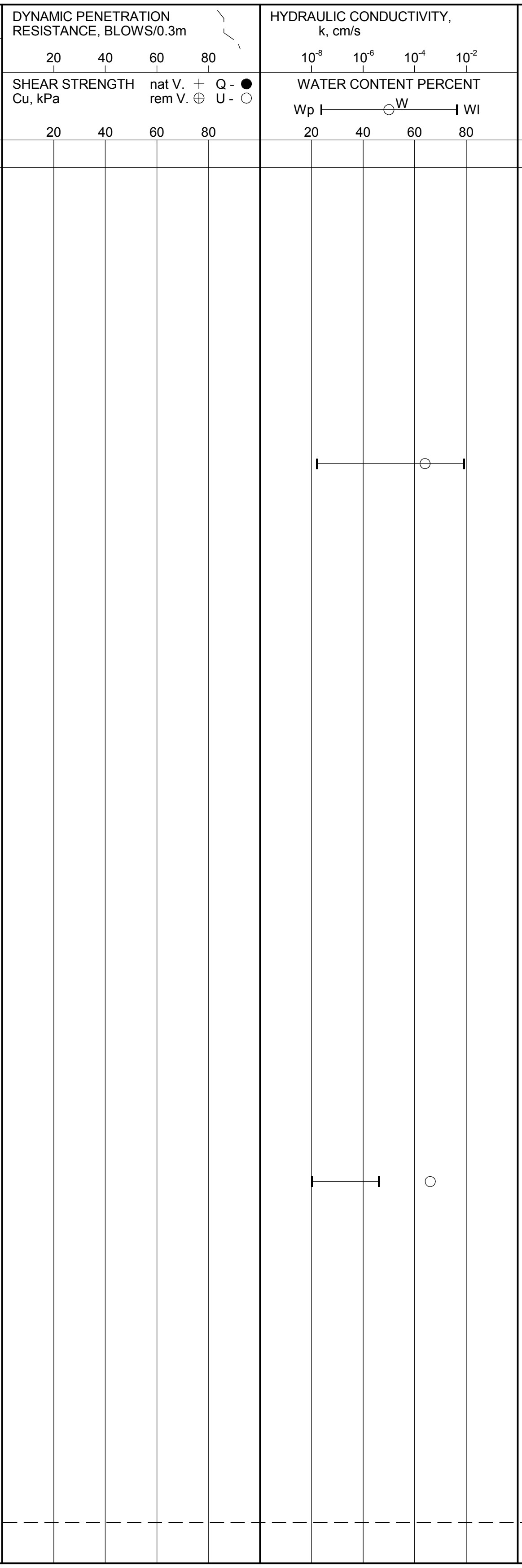
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	75.92					
0	Wash Boring HW Casing	TOPSOIL	0.00					Protective Casing
		Grey brown SANDY SILT, trace clay, with black staining	75.62 0.30					Bentonite Seal
1		Red brown SILTY CLAY, with silty sand seams (Weathered Crust)	75.22 0.70					
		Soft red grey CLAY to SILTY CLAY, with silty sand and silt seams	74.70 1.22					
3		Red grey and grey CLAY to SILTY CLAY, with silt seams	72.95 2.97	1	73 TP	PH		
		Grey SILTY SAND, trace clay, with black staining	71.20 4.72					
5		Grey SILT, some sand	4.95					
		Soft red grey and grey CLAY to SILTY CLAY, with black staining and silt seams	5.18					
7		Grey SILT, some sand	68.76	2	73 TP	PH		
		Soft to firm red grey and grey CLAY to SILTY CLAY, with black staining	7.26					Bentonite-Cement Grout
11				3	73 TP	PH		
13		Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	62.36 13.56					
15		*CONTINUED NEXT PAGE*						



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-3

SHEET 2 OF 3

LOCATION: N 5020872.72 ;E 466523.18

BORING DATE: January 31 - February 15, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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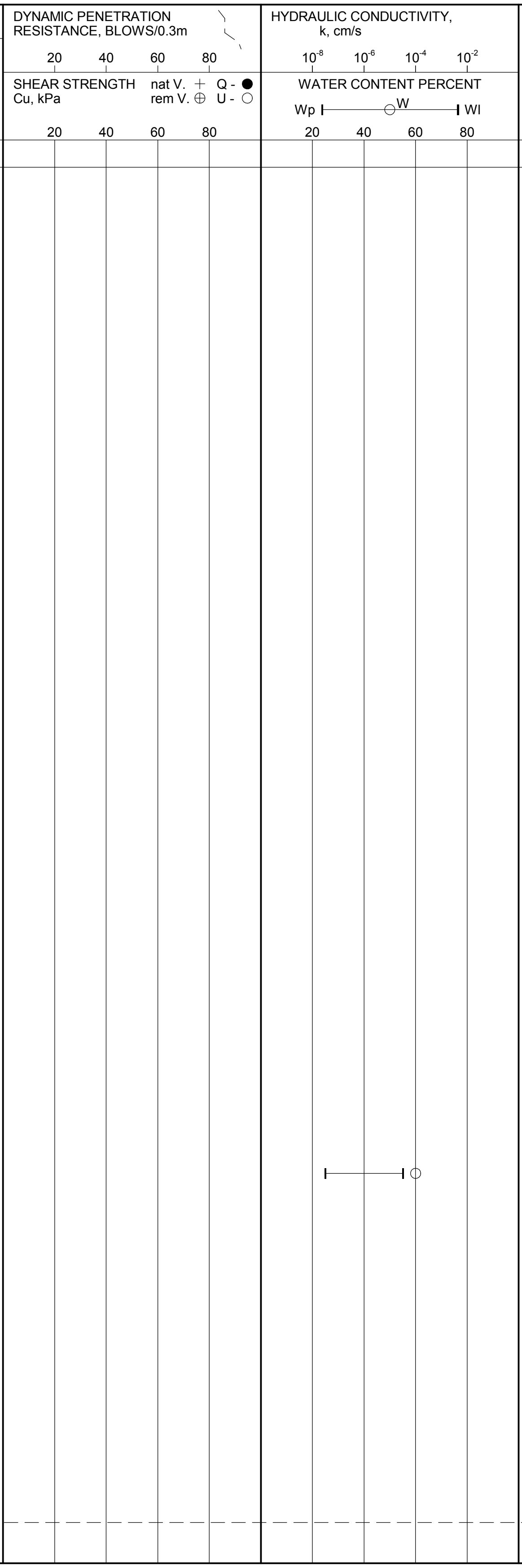
DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
15	Wash Boring HW Casing	Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	▨						
17.5					4	73 TP	PH		
18.4					5	73 TP	PH		
22.76		Stiff grey to dark grey CLAY to SILTY CLAY, with black staining	▨	53.16 22.76					Bentonite-Cement Grout
26					6	73 TP	WR		
30									



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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-3

SHEET 3 OF 3

LOCATION: N 5020872.72 ;E 466523.18

BORING DATE: January 31 - February 15, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Wash Boring HW Casing	Stiff grey to dark grey CLAY to SILTY CLAY, with black staining									
31					7	73 TP	WR				
32											
33					8	50 DO	11				
34		Dense grey SILTY SAND, some gravel, trace clay (GLACIAL TILL)		42.16 33.76	9	50 DO	60				Bentonite-Cement Grout
35											
36											
37				38.12							
38		Borehole continued on RECORD OF DRILLHOLE 12-4-3 Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Soil stratigraphy from 0.0 m to 33.8 m based on 12-4-2									
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-4-3

SHEET 1 OF 3

LOCATION: N 5020872.72 ;E 466523.18

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: January 31 - February 15, 2013

DRILL RIG: CME 55

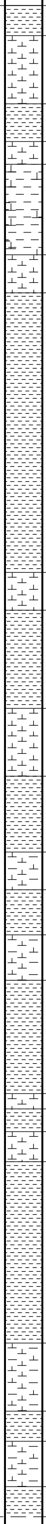
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.
		BEDROCK SURFACE	38.12	
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 37.80 m to 43.61 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.	37.80 38.08	
			37.84	
			37.99	
			37.93	
			37.94	
			37.98	
38			38.01	
			37.79	
			38.13	
			37.74	
			38.18	1
			37.37	
			38.55	
			37.32	
			38.60	
			37.19	
			38.73	
			37.10	
			38.82	
			37.00	
			38.92	
			36.95	
39			38.97	
			36.89	
			39.03	
			36.83	
			39.09	
			36.68	
			39.24	
			39.26	
			39.29 36.59	
			39.33	2
			36.35	
			39.57	
			36.26	
			39.66 36.22	
			39.70	
			36.16	
			39.76	



SYMBOLIC LOG

FLUSH RETURN

RECOVERY: TOTAL CORE % / SOLID CORE % (80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.25m (5 10 15 20); DIP w.r.t. CORE AXIS (0 30 60 90)

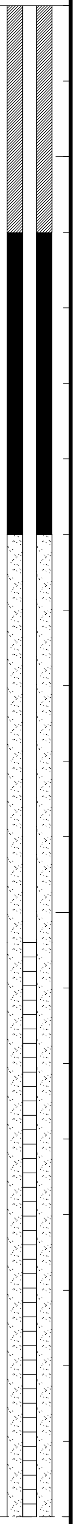
HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2})

WEATH-ERING INDEX (W1 W2 W3 W4 W5 W6)

DISCONTINUITY DATA

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
BD,PL,SM	12	1	1
BD,IR,SM	16	1.5	1
BD,PL,SM	12	1	1
BD,PL,SM	12	1	1

NOTES



Bentonite-Cement Grout

Bentonite Seal

Silica Sand

63 mm Diam. PVC #10 Slot Screen

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-4-3

SHEET 2 OF 3

LOCATION: N 5020872.72 ;E 466523.18

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: January 31 - February 15, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

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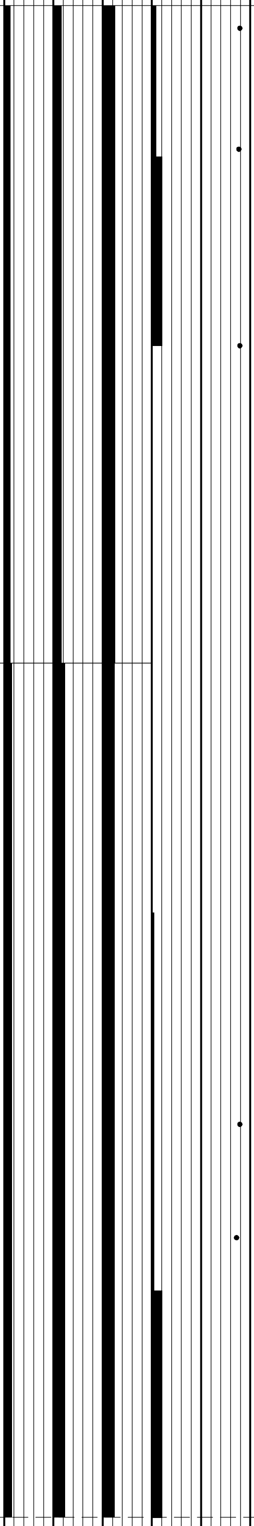
CARLSBAD FORMATION, 37.80 m to 43.61 m Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.

DRILLING RECORD: Rotary Drill, HQ Core

DEPTH SCALE METRES	ELEV. / DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
	36.06 39.86		BD,PL,SM	12	1	1	
	36.01 39.91						
	39.94						
40	35.92 40.00		JN,PL,SM	12	1	1	
		2	JN,PL,SM	12	1	1	
	35.25 40.67						
	40.70						63 mm Diam. PVC #10 Slot Screen
41							
	34.84 41.08						
	34.78 41.14						
	41.17						
	34.70 41.22	3					
	41.24						
	34.62 41.30		BD,PL,SM	12	1	1	
			BD,CU,SM	12	2	1	
	34.29 41.63						
	34.21 41.71						
	41.74						



HYDRAULIC CONDUCTIVITY K, cm/sec: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WEATHERING INDEX: W1 W2 W3 W4 W5 W6

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 12-4-3

SHEET 3 OF 3

LOCATION: N 5020872.72 ;E 466523.18

DRILLING DATE: January 31 - February 15, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SH - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	RO - Rough	
CJ - Conjugate	CL - Clean	IR - Irregular	MB - Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---							
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 37.80 m to 43.61 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds.	34.07 41.85						
			34.00 41.92						
42			33.87 42.05	3					
					BD,PL,SM	12	1	1	
			33.54 42.38						
			33.50 42.42						
			33.21 42.71						63 mm Diam. PVC #10 Slot Screen
			33.14 42.78						
			33.08 42.84						
			42.87						
			42.90						
43				4					
			32.86 43.06						
			32.72 43.20						
			32.68 43.24						
			32.55 43.37						
			43.40		BD,PL,SM	12	1	1	
			32.31						
		End of Drillhole	43.61						

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-4

SHEET 1 OF 3

LOCATION: N 5020875.53 ;E 466521.56

BORING DATE: February 22-25, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES: NUMBER, TYPE, BLOWS/0.3m | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80 | SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○: 20 40 60 80 | HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2} | WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl: 20 40 60 80 | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

BORING METHOD: Wash Boring, HW Casing

DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	75.88
TOPSOIL	0.00
Grey brown SANDY SILT, trace clay, with black staining	75.58 0.30
Red brown SILTY CLAY, with silty sand seams (Weathered Crust)	75.18 0.70
Soft red grey CLAY to SILTY CLAY, with silty sand and silt seams	74.66 1.22
Red grey and grey CLAY to SILTY CLAY, with silt seams	72.91 2.97
Grey SILTY SAND, trace clay, with black staining	71.16 4.72
Grey SILT, some sand	4.95
Soft red grey and grey CLAY to SILTY CLAY, with black staining and silt seams	5.18
Grey SILT, some sand	68.72
Soft to firm red grey and grey CLAY to SILTY CLAY, with black staining	7.26
Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	62.32 13.56

CONTINUED NEXT PAGE

PIEZOMETER OR STANDPIPE INSTALLATION: 'B' 'A'

Protective Casing

Bentonite Seal

Bentonite-Cement Grout

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG/DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-4

SHEET 2 OF 3

LOCATION: N 5020875.53 ;E 466521.56

INCLINATION: -90° AZIMUTH: ---

BORING DATE: February 22-25, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- *CONTINUED FROM PREVIOUS PAGE* ---									'B' 'A'
15	Wash Boring HW Casing	Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	▨								
16											
17											
18											
19											
20											Bentonite-Cement Grout
21											
22											
23		Stiff grey to dark grey CLAY to SILTY CLAY, with black staining	▨	53.12 22.76							
24											
25											Bentonite Seal
26											Silica Sand
27											25 mm Diam. PVC #10 Slot Screen 'B'
28											Silica Sand
29											Bentonite Seal
30		*CONTINUED NEXT PAGE*									

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG/DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-4

SHEET 3 OF 3

LOCATION: N 5020875.53 ;E 466521.56

INCLINATION: -90° AZIMUTH: ---

BORING DATE: February 22-25, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- *CONTINUED FROM PREVIOUS PAGE* ---									'B' 'A'
30	Wash Boring HW Casing	Stiff grey to dark grey CLAY to SILTY CLAY, with black staining	▨								Bentonite Seal
34		Dense grey SILTY SAND, some gravel, trace clay (GLACIAL TILL)		42.12 33.76							Silica Sand 32 mm Diam. PVC #10 Slot Screen 'A'
37		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		39.23 36.65							

Depth scale: 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG/DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-5

SHEET 1 OF 2

LOCATION: N 5020871.62 ;E 466520.35

INCLINATION: -90° AZIMUTH: ---

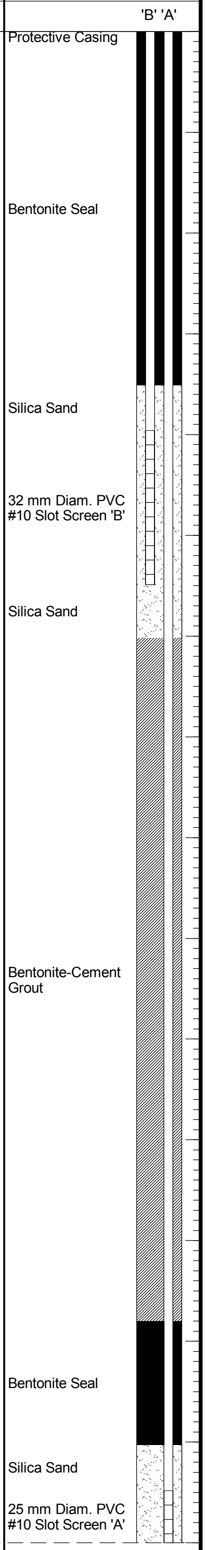
BORING DATE: February 26, 2013

DATUM: Geodetic

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80) | SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○) (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WATER CONTENT PERCENT (Wp ⊢ ○W ⊣ Wl) (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

BORING METHOD: Wash Boring, HW Casing

DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	75.90
TOPSOIL	0.00
Grey brown SANDY SILT, trace clay, with black staining	75.60 0.30
Red brown SILTY CLAY, with silty sand seams (Weathered Crust)	75.20 0.70
Soft red grey CLAY to SILTY CLAY, with silty sand and silt seams	74.68 1.22
Red grey and grey CLAY to SILTY CLAY, with silt seams	72.93 2.97
Grey SILTY SAND, trace clay, with black staining	71.18 4.72
Grey SILT, some sand	4.95
Soft red grey and grey CLAY to SILTY CLAY, with black staining and silt seams	5.18
Grey SILT, some sand	68.74
Soft to firm red grey and grey CLAY to SILTY CLAY, with black staining	7.26
Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	62.34 13.56



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DEPTH SCALE
1 : 75

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-5

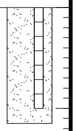
SHEET 2 OF 2

LOCATION: N 5020871.62 ;E 466520.35
INCLINATION: -90° AZIMUTH: ---

BORING DATE: February 26, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									'B' 'A'
15	Wash Boring HW Casing	Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	▨								25 mm Diam. PVC #10 Slot Screen 'A'
16				59.75 16.15							Silica Sand
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											



DEPTH SCALE
1 : 75

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-6

SHEET 1 OF 1

LOCATION: N 5020874.33 ;E 466518.97

INCLINATION: -90° AZIMUTH: ---

BORING DATE: February 27, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

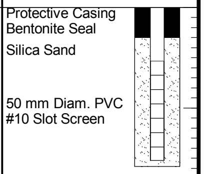
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ├──○W──┤ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION: MON. WELL

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE	75.89			
0	Wash Boring HW Casing	TOPSOIL	0.00			
		Grey brown SANDY SILT, trace clay, with black staining	75.59 0.30			
1		Red brown SILTY CLAY, with silty sand seams (Weathered Crust)	75.19 0.70			
		Soft red grey CLAY to SILTY CLAY, with silty sand and silt seams	74.67 1.22			
		End of Borehole	74.31 1.58			
2		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.				
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-7

SHEET 1 OF 3

LOCATION: N 5020849.96 ;E 466535.91

INCLINATION: -90° AZIMUTH: ---

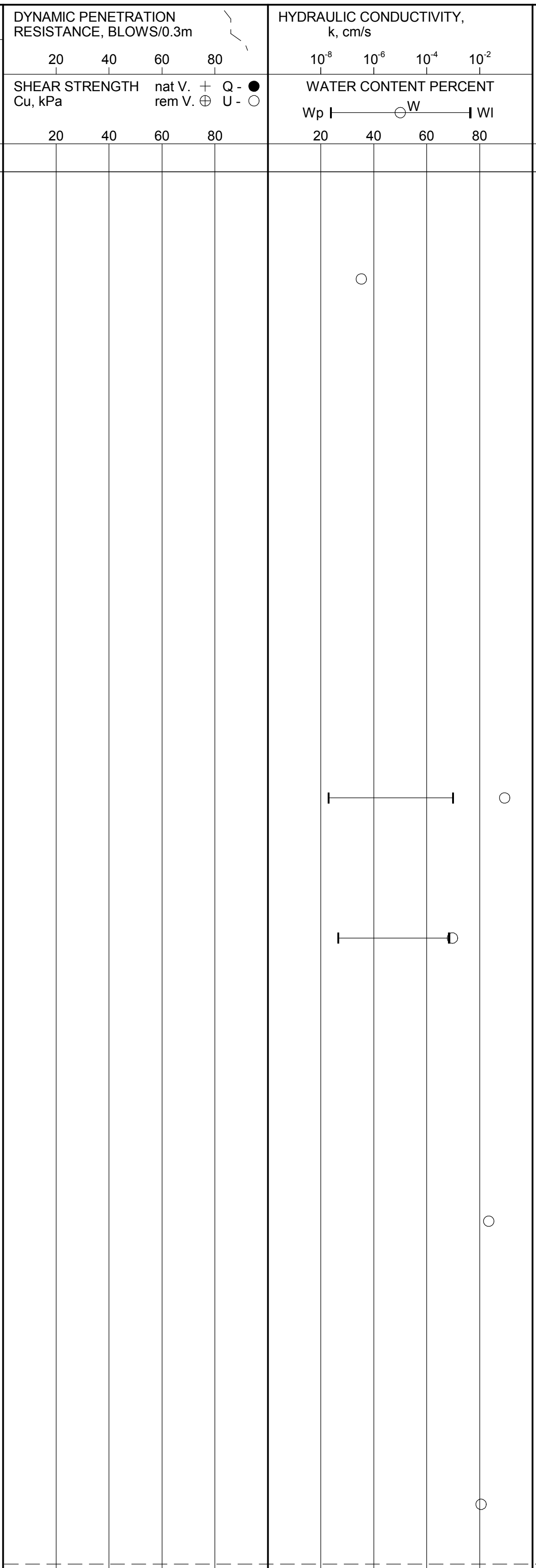
BORING DATE: April 2-3, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	75.95
TOPSOIL	0.00
Grey brown SANDY SILT, trace clay, with black staining	75.65 0.30
Red brown SILTY CLAY, with silty sand seams (Weathered Crust)	75.25 0.70
Soft red grey CLAY to SILTY CLAY, with silty sand and silt seams	74.73 1.22
Red grey and grey CLAY to SILTY CLAY, with silt seams	72.98 2.97
Grey SILTY SAND, trace clay, with black staining	71.23 4.72
Grey SILT, some sand	4.95
Soft red grey and grey CLAY to SILTY CLAY, with black staining and silt seams	5.18
Grey SILT, some sand	68.79
Soft to firm red grey and grey CLAY to SILTY CLAY, with black staining	7.26
Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	62.39 13.56

SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	53 mm TUBE	-	MH
2	53 mm TUBE	-	
3	53 mm TUBE	-	
4	53 mm TUBE	-	MH
5	53 mm TUBE	-	
6	53 mm TUBE	-	
7	53 mm TUBE	-	
8	53 mm TUBE	-	
9	53 mm TUBE	-	
10	53 mm TUBE	-	



PIEZOMETER OR STANDPIPE INSTALLATION

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DEPTH SCALE

1 : 75

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-7

LOCATION: N 5020849.96 ;E 466535.91
INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 2-3, 2013

DATUM: Geodetic

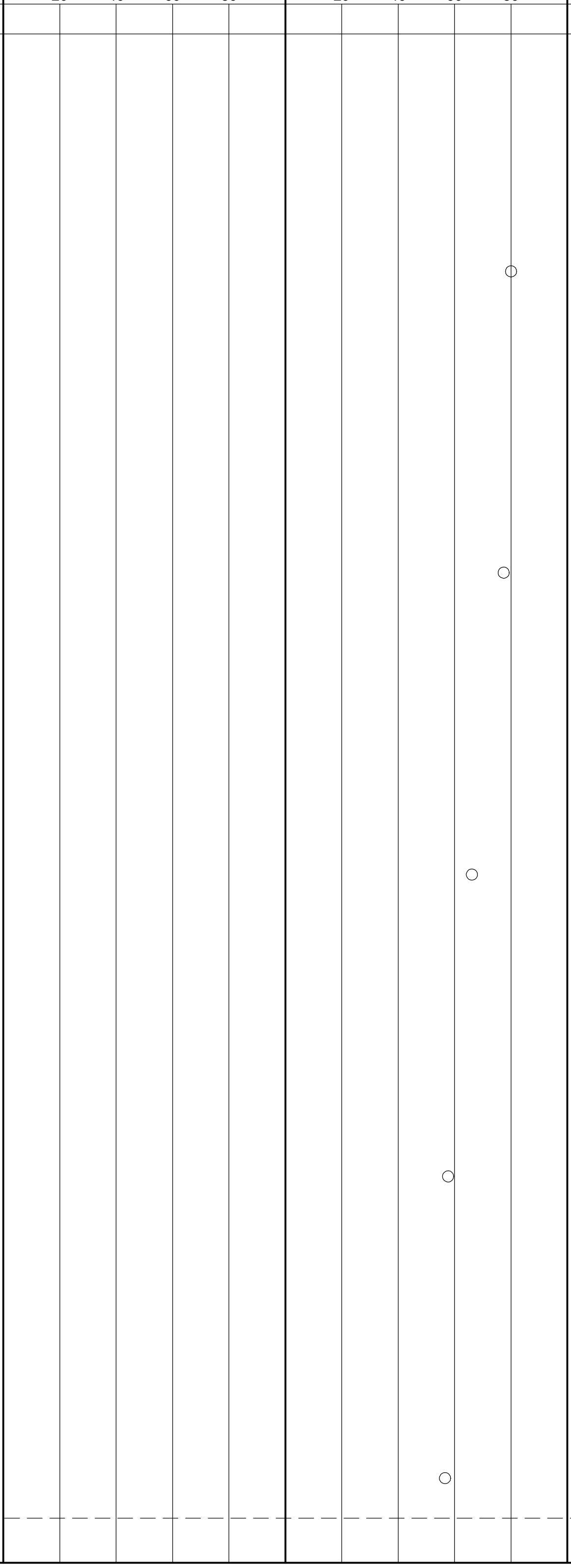
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ├──○W──┤ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		--- CONTINUED FROM PREVIOUS PAGE ---					
15	Geoprobe	Firm to stiff grey and red CLAY to SILTY CLAY, with black staining	▨				
16					11	53 mm TUBE	-
17					12	53 mm TUBE	-
18							
19					13	53 mm TUBE	-
20					14	53 mm TUBE	-
21							
22					15	53 mm TUBE	-
		Stiff grey to dark grey CLAY to SILTY CLAY, with black staining	▨	53.19 22.76			
23					16	53 mm TUBE	-
24							
25					17	53 mm TUBE	-
26					18	53 mm TUBE	-
27							
28					19	53 mm TUBE	-
29					20	53 mm TUBE	-
30							



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DEPTH SCALE
1 : 75

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 12-4-7

SHEET 3 OF 3

LOCATION: N 5020849.96 ;E 466535.91

BORING DATE: April 2-3, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m				
		--- CONTINUED FROM PREVIOUS PAGE ---									
30			▨	45.62 30.33	20		-				
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-2

SHEET 1 OF 3

LOCATION: N 5021087.76 ;E 466180.49

INCLINATION: -90° AZIMUTH: ---

BORING DATE: February 28 - March 1, 2013

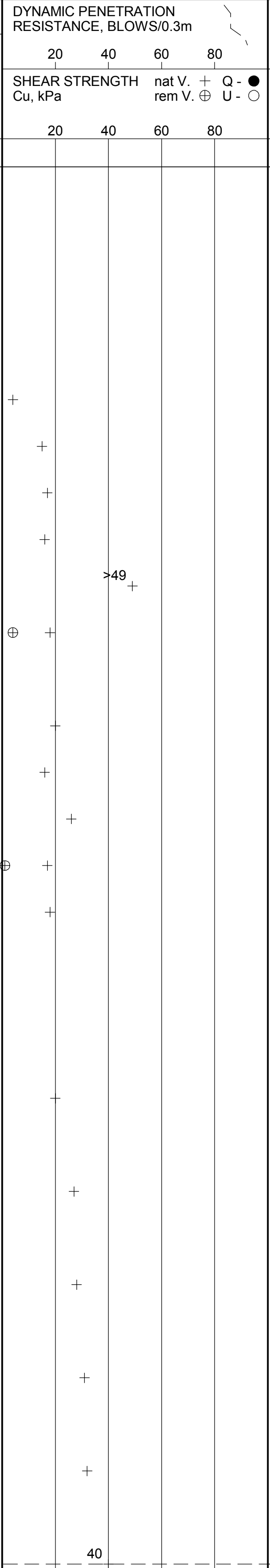
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
	GROUND SURFACE	76.43
Power Auger 200 mm Diam. (HS)	TOPSOIL	0.00
	Loose brown to grey brown SAND, some silt	76.13 0.30
Electric Nilcon	Soft CLAY to SILTY CLAY	74.60 1.83
	Compact grey SAND	72.16 4.27
	Soft CLAY to SILTY CLAY	71.55 4.88
	Firm CLAY to SILTY CLAY	65.43 11.00

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	50 DO	5
2	50 DO	10
3	50 DO	6



HYDRAULIC CONDUCTIVITY, k, cm/s — 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT — Wp ⊢—○W—⊣ Wl — 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

LOGGED: DG

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-2

SHEET 2 OF 3

LOCATION: N 5021087.76 ;E 466180.49

BORING DATE: February 28 - March 1, 2013

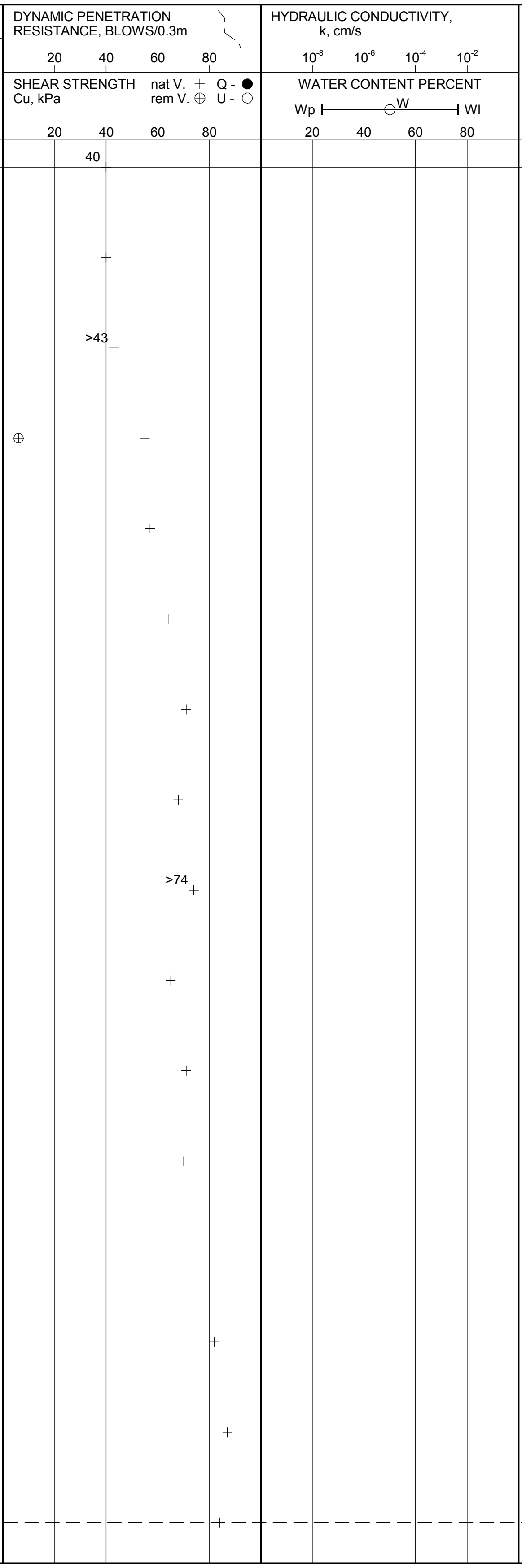
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---							
15	Electric Nilcon	Firm CLAY to SILTY CLAY	▨						
18		Stiff CLAY to SILTY CLAY	▨	58.43 18.00					
30		*CONTINUED NEXT PAGE*							



CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-2

SHEET 3 OF 3

LOCATION: N 5021087.76 ;E 466180.49

BORING DATE: February 28 - March 1, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Electric Nilcon	Stiff CLAY to SILTY CLAY	▨								
31											
32											
33											
34											
35											
36											
37											
38				38.23							
		End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Vane pushed to 38.20 m depth. 3. Different stratigraphy relative to boreholes 13-5-3 and 13-5-4.		38.20							
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-3

SHEET 1 OF 3

LOCATION: N 5021083.24 ;E 466176.27

BORING DATE: June 14-18, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Wash Boring, NW Casing

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	76.51
TOPSOIL	0.00
Loose brown to grey brown SAND, some silt	76.21 0.30
Soft CLAY to SILTY CLAY	74.68 1.83
Compact grey SAND	72.24 4.27
Soft CLAY to SILTY CLAY	71.63 4.88
Firm CLAY to SILTY CLAY	65.51 11.00

SAMPLES: NUMBER, TYPE, BLOWS/0.3m

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20, 40, 60, 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20, 40, 60, 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl : 20, 40, 60, 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION: MON. WELL

PIEZOMETER OR STANDPIPE INSTALLATION	Depth (m)
Protective Casing	0
Bentonite Seal	0 – 4.27
Bentonite-Cement Grout	4.27 – 15

DEPTH SCALE METRES: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

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DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-3

SHEET 2 OF 3

LOCATION: N 5021083.24 ;E 466176.27
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: June 14-18, 2013

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
15	Wash Boring NW Casing	*--- CONTINUED FROM PREVIOUS PAGE ---* Firm CLAY to SILTY CLAY						MON. WELL
18		Stiff CLAY to SILTY CLAY	58.51 18.00					
22								Bentonite-Cement Grout
27		Compact to very dense grey SILTY SAND and SANDY SILT, some gravel, trace clay (GLACIAL TILL)	49.11 27.40	1	50 DO	>100		
30		*CONTINUED NEXT PAGE*						

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DWM
CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-3

SHEET 3 OF 3

LOCATION: N 5021083.24 ;E 466176.27

BORING DATE: June 14-18, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---								MON. WELL
30	Wash Boring NW Casing	Compact to very dense grey SILTY SAND and SANDY SILT, some gravel, trace clay (GLACIAL TILL)								
				2	50 DO	70				
31										
				3	50 DO	94				
32										Bentonite-Cement Grout
33				4	50 DO	80				
34			42.45							
		COBBLES	34.06							Peltonite
		Borehole continued on RECORD OF DRILLHOLE 12-5-3 Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Different stratigraphy relative to borehole 13-5-2.								
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-5-3

SHEET 1 OF 4

LOCATION: N 5021083.24 ;E 466176.27

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 14-18, 2013
DRILL RIG: CME 55
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		BEDROCK SURFACE	42.28							MON. WELL
	Rotary Drill NQ Core	**CARLSBAD FORMATION, 34.23 m to 40.33 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY to ARGILLACEOUS LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds (35.85-.91 m and 37.59-.82 m). Shale and calcareous shale comprises approximately 78% of section.	34.23							
			42.22 34.29							
						JN,CU,SM	16	2	1	
				1	100					
						BD,PL,SM	12	1	1	
			41.83 34.68							
										Peltonite
			41.73 34.78							
			41.56 34.95							
			34.97							
35										
			41.46 35.06							
			41.17 35.34							
			35.37			BD,PL,SM	12	1	1	
										Silica Sand
				2	100					
			40.83 35.68							
			40.76 35.75			BD,CU,SM	16	2	1	
			35.77							
			35.79			FR,,				
			40.66 35.85							
			40.60 35.91							32 mm Diam. PVC #10 Slot Screen
36						BD,PL,SM	12	1	2	
						BD,CU,SM	12	2	2	
			40.41 36.10							
			40.36 36.15							
			40.29							

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DWM
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-5-3

SHEET 2 OF 4

LOCATION: N 5021083.24 ;E 466176.27
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 14-18, 2013
DRILL RIG: CME 55
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % (80 60 40 20)	RECOVERY SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER 0.25m (5 10 15 20)	DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	NOTES
		--- *CONTINUED FROM PREVIOUS PAGE* ---																MON. WELL
	Rotary Drill NQ Core	**CARLSBAD FORMATION, 34.23 m to 40.33 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY to ARGILLACEOUS LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds (35.85-.91 m and 37.59-.82 m). Shale and calcareous shale comprises approximately 78% of section.		36.22 40.23 36.28	2	100												
				39.97 36.54 36.57														
											●	BD,PL,SM	16	1	2			
				39.84 36.67 36.69														
				39.75 36.76 39.71 36.80							●	BD,PL,SM	12	1	1			
				39.62 36.89 36.91 36.94														
37				39.47 37.04 37.07 37.09 37.11	3	100												
											●	BD,PL,SM	12	1	1			
																		32 mm Diam. PVC #10 Slot Screen
											●	BD,CU,SM	16	2	1			
				39.06 37.45 38.99 37.52 38.92 37.59														
				38.69 37.82	4	100												
38																		
		CONTINUED NEXT PAGE																

DEPTH SCALE
1 : 10

LOGGED: DWM
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-5-3

SHEET 3 OF 4

LOCATION: N 5021083.24 ;E 466176.27

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 14-18, 2013
DRILL RIG: CME 55
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock
NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY: TOTAL CORE % (80 60 40 20), SOLID CORE % (80 60 40 20) | R.Q.D. % (80 60 40 20) | FRACT. INDEX PER 0.25m (5 10 15 20) | DIP w.r.t. CORE AXIS (0 30 60 90) | DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION, Jcon, Jr, Ja | HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}) | WEATHERING INDEX (W1 W2 W3 W4 W5 W6) | NOTES

--- *CONTINUED FROM PREVIOUS PAGE* ---

MON. WELL

CARLSBAD FORMATION, 34.23 m to 40.33 m Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY to ARGILLACEOUS LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds (35.85-.91 m and 37.59-.82 m). Shale and calcareous shale comprises approximately 78% of section.

Drilling record: Rotary Drill, NQ Core

ELEV.	DEPTH (m)
37.76	38.75
37.71	38.80
37.44	39.07
37.38	39.13
37.21	39.30
37.17	39.34
36.93	39.58
36.83	39.69
	39.71
	39.73
36.66	39.85

RUN No.	FLUSH RETURN
4	100
5	100

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
BD,PL,SM	16	1	2
BD,PL,SM	16	1	2
BD,CU,SM	16	2	2
BD,PL,SM	12	1	1

Depth scale: 39, 40

NOTES: 32 mm Diam. PVC #10 Slot Screen

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 10

Golder Associates

LOGGED: DWM
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-5-3

SHEET 4 OF 4

LOCATION: N 5021083.24 ;E 466176.27

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 14-18, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular
PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25m 5 10 15 20	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}	WEATHERING INDEX W1 W2 W3 W4 W5 W6	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---																MON. WELL
	Rotary Drill NQ Core			36.23 40.28 40.30 36.18	5	100												Silica Sand
		End of Drillhole		40.33														
41																		
42																		

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DWM

CHECKED: SAT

CRRRC-ROCK 1211250045.GPJ GAL-MISS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-4

SHEET 1 OF 3

LOCATION: N 5021083.81 ;E 466178.65

BORING DATE: March 4-5, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m
		GROUND SURFACE	76.43			
0	Wash Boring HW Casing	TOPSOIL	0.00			
		Loose brown to grey brown SILTY SAND	76.13 0.30			
2		Grey SILTY CLAY, with black staining	74.60 1.83			
4		Compact grey SAND	72.16 4.27	1	50 DO	14
5		Grey SILTY CLAY, with black staining	71.55 4.88			
9				2	50 DO	WR
15						

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

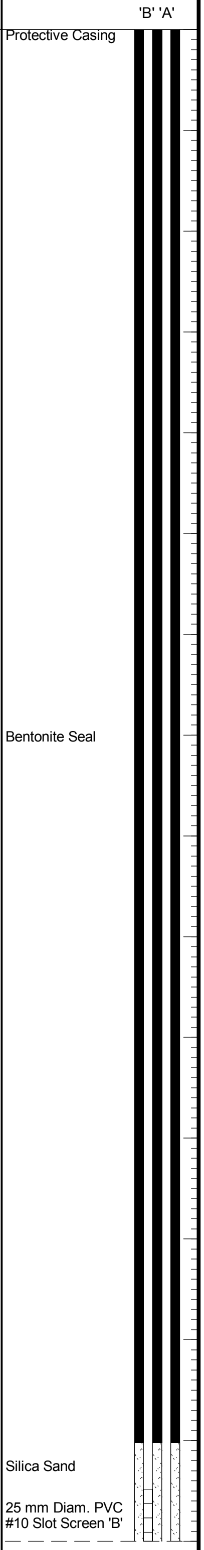
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-4

SHEET 2 OF 3

LOCATION: N 5021083.81 ;E 466178.65

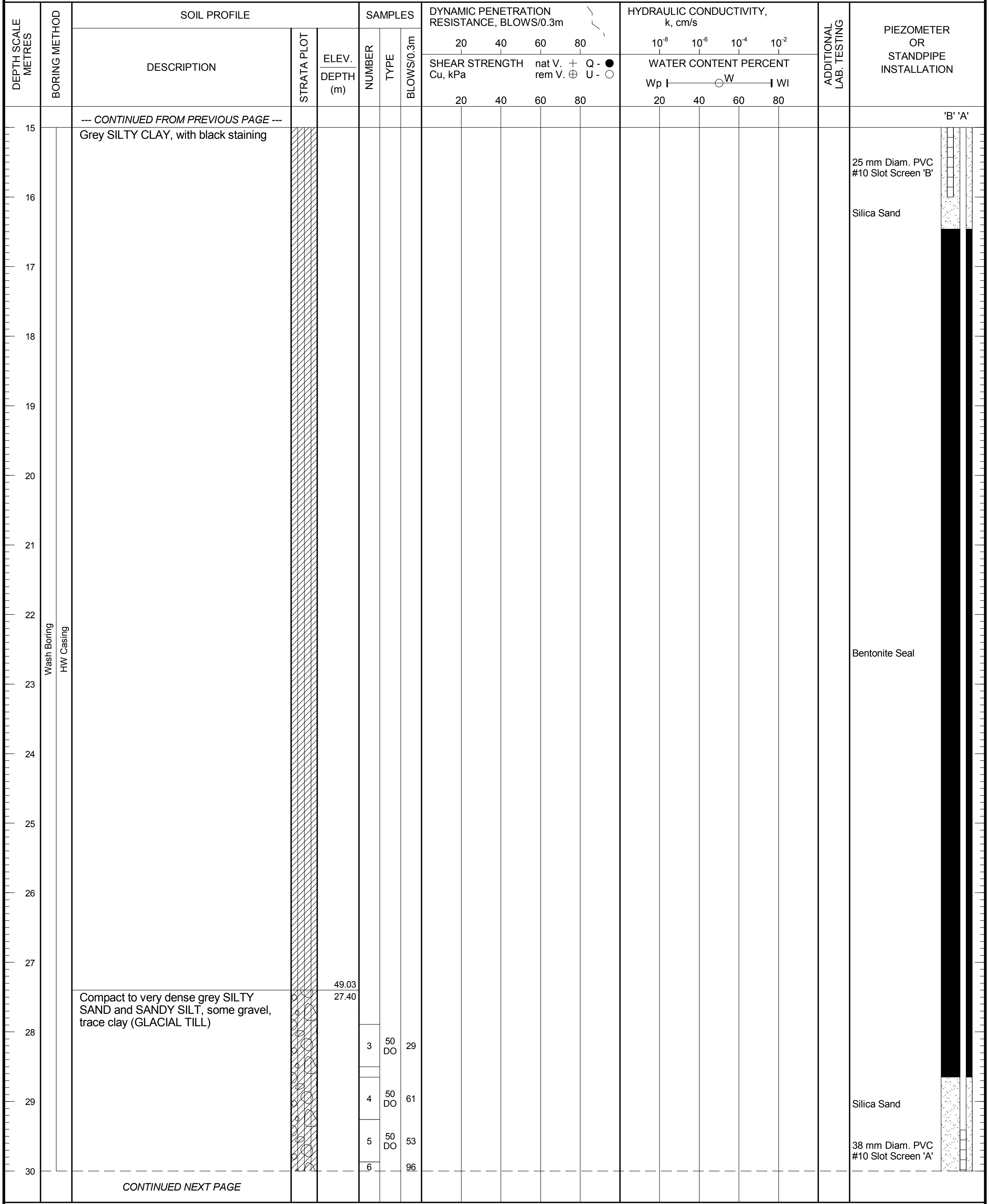
BORING DATE: March 4-5, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm



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Description	Elev. / Depth (m)	Number	Type	Blows/0.3m
Grey SILTY CLAY, with black staining				
Compact to very dense grey SILTY SAND and SANDY SILT, some gravel, trace clay (GLACIAL TILL)	49.03 27.40			
		3	50 DO	29
		4	50 DO	61
		5	50 DO	53
		6		96

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-4

SHEET 3 OF 3

LOCATION: N 5021083.81 ;E 466178.65

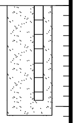
BORING DATE: March 4-5, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ├──○W──┤ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									'B' 'A'
30	Wash Boring HW Casing	Compact to very dense grey SILTY SAND and SANDY SILT, some gravel, trace clay (GLACIAL TILL)		45.34	6	50 DO	96				 38 mm Diam. PVC #10 Slot Screen 'A'
31		End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Different stratigraphy relative to borehole 13-5-2.		31.09							
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE

1 : 75

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-5

SHEET 1 OF 1

LOCATION: N 5021081.04 ;E 466176.45

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 6, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.38							MON. WELL
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL		0.00							Protective Casing
1		Loose brown to grey brown SILTY SAND		76.08 0.30							
2 3 4		Grey SILTY CLAY, with black staining		74.55 1.83							Bentonite Seal
		Compact grey SAND		72.11 4.27							Silica Sand
5		Grey SILTY CLAY, with black staining		71.50 4.88							50 mm Diam. PVC #10 Slot Screen
6		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		70.28 6.10							Silica Sand
7											
8											
9											
10											
11											
12											
13											
14											
15											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-5-6

SHEET 1 OF 1

LOCATION: N 5021081.45 ;E 466178.88

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 6, 2013

DATUM: Geodetic

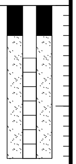
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.45					MON. WELL
0	Power Auger 200 mm Diam. (HS)	TOPSOIL	0.00					Protective Casing Bentonite Seal
		Loose brown to grey brown SILTY SAND	76.15 0.30					Silica Sand 50 mm Diam. PVC #10 Slot Screen
1.52		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	74.93 1.52					



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-2

SHEET 1 OF 3

LOCATION: N 5020391.84 ;E 465914.72

BORING DATE: March 4-5, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE	76.78			
0	Power Auger 200 mm Diam. (HS)	TOPSOIL	0.00			
		Compact to loose grey brown SILTY SAND	0.15	1	50 DO	12
				2	50 DO	8
1		Red brown SILTY CLAY (Weathered Crust) - Silty sand layers from 1.19 m to 1.27 m and 1.37 m to 1.44 m	75.64 1.14	3	50 DO	4
		Grey brown SAND, some silt, trace black staining	75.20 1.58			
2	Electric Nilcon	Soft red grey and grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 2.92 m to 3.00 m - Grey silt layer from 4.50 m to 4.55 m	74.80 1.98			
5		Grey SILTY SAND, with black staining	71.57 5.21			
		Grey SANDY SILT, trace clay	5.39			
		Soft red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	5.59			
9		Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	67.64 9.14			
15						

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DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

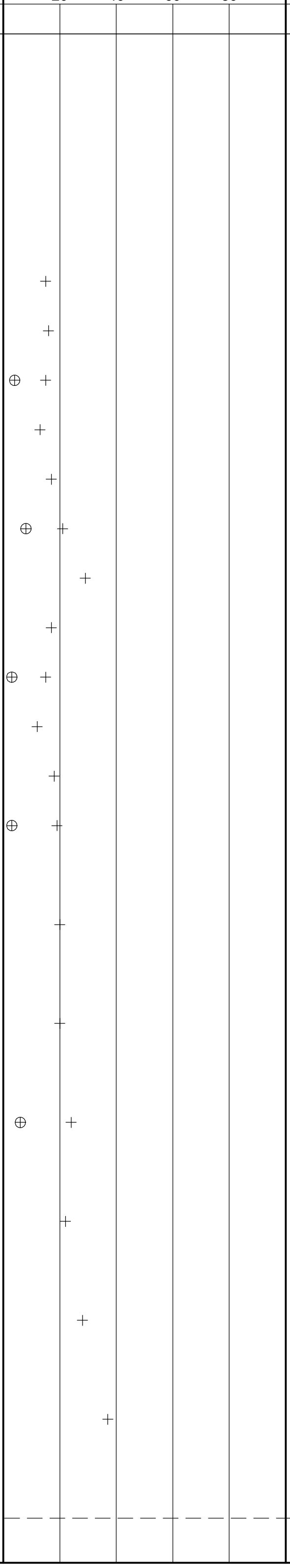
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-2

SHEET 2 OF 3

LOCATION: N 5020391.84 ;E 465914.72

BORING DATE: March 4-5, 2013

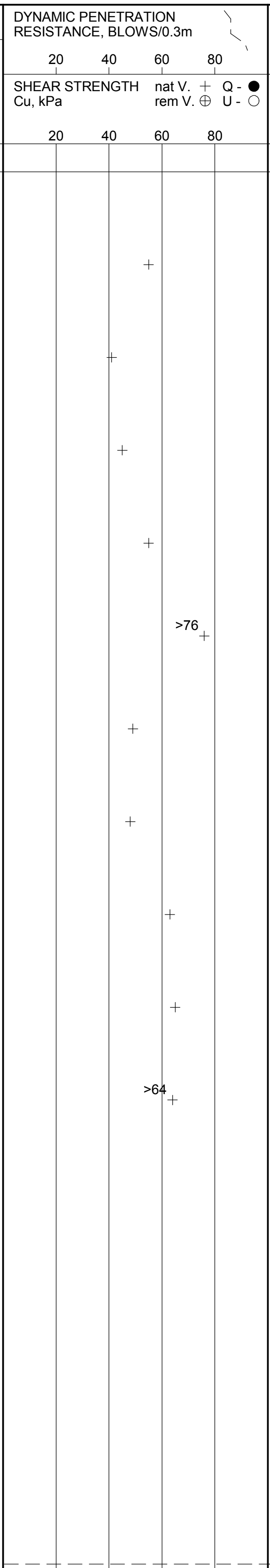
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---							
15	Electric Nilcon	Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	▨						
24		Stiff grey CLAY to SILTY CLAY	▨	52.40 24.38					
30				46.91					
		CONTINUED NEXT PAGE							



HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; 20 40 60 80

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-2

SHEET 3 OF 3

LOCATION: N 5020391.84 ;E 465914.72

BORING DATE: March 4-5, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Electric Nilcon	Grey SILTY CLAY to CLAYEY SILT		46.60 29.87							
		Stiff grey SILTY CLAY, trace sand and gravel		30.18							
31				45.39							
		Red grey SILTY CLAY, some sand, trace gravel		31.39 45.03							
32		SILTY SAND, some clay, trace gravel (GLACIAL TILL)		31.75 44.28							
		End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT. 2. Vane pushed to 32.50 m depth.		32.50							
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-3

SHEET 1 OF 3

LOCATION: N 5020387.62 ;E 465916.79

BORING DATE: March 11-15, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.69							MON. WELL
0	Wash Boring HW Casing	TOPSOIL	0.00							Protective Casing
		Compact to loose grey brown SILTY SAND	0.15							
1		Red brown SILTY CLAY (Weathered Crust) - Silty sand layers from 1.19 m to 1.27 m and 1.37 m to 1.44 m	75.55 1.14							
		Grey brown SAND, some silt, trace black staining	75.11 1.58							
2		Soft red grey and grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 2.92 m to 3.00 m - Grey silt layer from 4.50 m to 4.55 m	74.71 1.98							
4				1	73 TP	PH				
5				2	73 TP	PH				
		Grey SILTY SAND, with black staining	71.48 5.21							
		Grey SANDY SILT, trace clay	5.39							
6		Soft red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	5.59							Grout
9		Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	67.55 9.14							
10				3	73 TP	PH				
15										

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG/DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-3

SHEET 2 OF 3

LOCATION: N 5020387.62 ;E 465916.79

INCLINATION: -90° AZIMUTH: ---

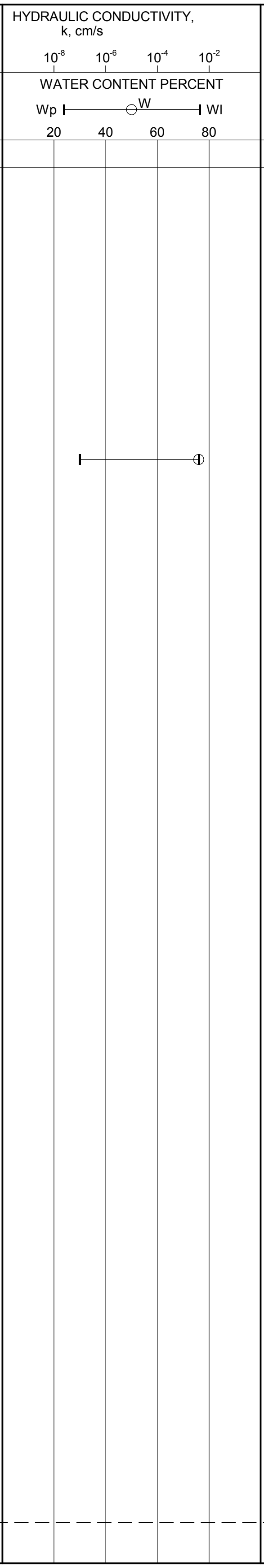
BORING DATE: March 11-15, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WEL
15	Wash Boring HW Casing	Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	▨								
18					4	73 TP	PH				
21					5	73 TP	PH				
22											Grout
24		Stiff grey CLAY to SILTY CLAY	▨	52.31 24.38							
27					6	73 TP	PH				
30				46.82							
		CONTINUED NEXT PAGE									



DEPTH SCALE

1 : 75

LOGGED: DG/DWM

CHECKED: SAT

RECORD OF BOREHOLE: 13-6-3

PROJECT: 12-1125-0045
SHEET 3 OF 3

LOCATION: N 5020387.62 ;E 465916.79
BORING DATE: March 11-15, 2013
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm
PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		--- *CONTINUED FROM PREVIOUS PAGE* ---					MON. WELL
30	Wash Boring HW Casing	Grey SILTY CLAY to CLAYEY SILT	[illegible]				
		Stiff grey SILTY CLAY, trace sand and gravel	30.18	7	73 TP	PH	
31			45.30				
		Red grey SILTY CLAY, some sand, trace gravel	31.39 44.94				
32		SILTY SAND, some clay, trace gravel (GLACIAL TILL)	31.75 44.33				
		BOULDER	32.36 44.01	8	50 DO	>50	
33		Very dense grey SILTY SAND, some gravel, trace clay (GLACIAL TILL)	32.68	9	50 DO	56	
				10	50 DO	78	
34			42.10	11	50 DO	74	
		Dense grey SANDY SILT, some gravel, trace clay (GLACIAL TILL)	34.59 41.49	12	50 DO	46	
35		Compact grey CLAYEY SILT, some sand and gravel (GLACIAL TILL)	35.20				Grout
				13	50 DO	22	
36			40.11	14	50 DO	90	
		BOULDER	36.58				
37		Very dense grey CLAYEY SILT and SANDY SILT, some gravel (GLACIAL TILL)	36.75	15	NQ RC	DD	
38				16	50 DO	92	
				17	50 DO	>100	
39				18	50 DO	>100	
				19	50 DO	>100	
40				20	50 DO	72	
				21	50 DO	>100	
			35.90				Bentonite Seal
41		Borehole continued on RECORD OF DRILLHOLE 12-6-3 Note: Soil stratigraphy inferred from various soil sampling methods and CPT.					
42							
43							
44							
45							

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG/DWM
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-6-3

SHEET 1 OF 3

LOCATION: N 5020387.62 ;E 465916.79

DRILLING DATE: March 11-15, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SH - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	RO - Rough	
CJ - Conjugate	CL - Clean	IR - Irregular	MB - Mechanical Break	

Column headings: DEPTH SCALE METRES; DRILLING RECORD; DESCRIPTION; SYMBOLIC LOG; ELEV. DEPTH (m); RUN No.; FLUSH RETURN; RECOVERY (TOTAL CORE % 80 60 40 20; SOLID CORE % 80 60 40 20); R.Q.D. % 80 60 40 20; FRACT. INDEX PER 0.25m 5 10 15 20; DIP w.r.t. CORE AXIS 0 30 60 90; DISCONTINUITY DATA (TYPE AND SURFACE DESCRIPTION; Jcon; Jr; Ja); HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WEATHERING INDEX W1 W2 W3 W4 W5 W6; NOTES

BEDROCK SURFACE — 35.90

CARLSBAD FORMATION, 40.79 m to 45.05 m Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds. Bioturbated (burrow casts) beds occur at 43.20-.22 m and 43.41-.44 m. Shale and calcareous shale comprises approximately 47% of section.

Drilling record: Rotary Drill, HQ Core

Depth scale: 41, 42

ELEV.	DEPTH (m)
35.90	
	40.79
35.72	40.97
35.55	41.14
35.25	41.44
35.17	41.52
35.08	41.61
35.04	41.65
34.98	41.71
34.92	41.77
34.43	42.26
34.37	42.33
	42.36
34.17	42.52
34.09	42.60
34.05	42.64

RUN No.	FLUSH RETURN
1	100
2	100

TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja
BD,PL,SM	12	1	1
BD,PL,SM	12	1	1
BD,PL,SM	12	1	1
FR,PL,SM	12	1	4
BD,PL,SM	12	1	1
BD,PL,SM	12	1	1
FR,ST,Ro	22	3	1

NOTES:

MON. WELL

Bentonite Seal

Silica Sand

50 mm Diam. PVC #10 Slot Screen

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG/DWM

CHECKED: SAT

CRRRC-ROCK 1211250045.GPJ GAL-MISS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-6-3

SHEET 2 OF 3

LOCATION: N 5020387.62 ;E 465916.79

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 11-15, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---								MON. WELL
	Rotary Drill HQ Core	**CARLSBAD FORMATION, 40.79 m to 45.05 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds. Bioturbated (burrow casts) beds occur at 43.20-.22 m and 43.41-.44 m. Shale and calcareous shale comprises approximately 47% of section.	33.86 42.83			BD,PL,SM	12	1	1	
43			33.65 43.04							
			33.59 43.10							
			33.52 43.17			BD,PL,SM	12	1	1	
			43.20							
			43.22	2	100					
			33.28 43.41							
			43.44							
			33.10 43.59							
			33.01 43.68			BD,PL,SM	12	1	1	50 mm Diam. PVC #10 Slot Screen
44			32.74 43.95							
			32.60 44.09			BD,CU,SM	16	1.5	1	
			32.50 44.19							
			32.42 44.27			BD,CU,SM	16	1.5	1	
			44.30	3	100					
			32.29 44.40							
						BD,PL,SM	12	1	1	
						BD,PL,SM	12	1	1	Silica Sand
		CONTINUED NEXT PAGE								

RECOVERY: TOTAL CORE % / SOLID CORE % — R.Q.D. % — FRACT. INDEX PER 0.25m — DIP w.r.t. CORE AXIS — HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}) — WEATHERING INDEX (W1 W2 W3 W4 W5 W6) — SYMBOLIC LOG

DEPTH SCALE

1 : 10

LOGGED: DG/DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-6-3

SHEET 3 OF 3

LOCATION: N 5020387.62 ;E 465916.79

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 11-15, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % (80 60 40 20)	RECOVERY SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER 0.25m (5 10 15 20)	DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	NOTES	MON. WELL
		--- CONTINUED FROM PREVIOUS PAGE ---																
	Rotary Drill HQ Core		31.89 44.80	3	100												Silica Sand	
			31.82 44.87							•	BD,PL,SM	12	1	1				
			44.89							•	BD,PL,SM	12	1	1				
										•	BD,PL,SM	12	1	1				
45										•	BD,PL,SM	12	1	1				
			31.64															
		End of Drillhole	45.05															
46																		

CRRRC-ROCK 1211250045.GPJ GAL-MISS.GDT 09/04/14 JM

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DG/DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-4

SHEET 1 OF 3

LOCATION: N 5020389.92 ;E 465917.77

BORING DATE: March 20-22, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES: 0 to 15

BORING METHOD: Wash Boring, HW Casing

SAMPLES: NUMBER, TYPE, BLOWS/0.3m

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20, 40, 60, 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80)

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl (20, 40, 60, 80)

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION: 'B' 'A'

SOIL PROFILE DESCRIPTION	ELEV.	DEPTH (m)
GROUND SURFACE	76.69	
TOPSOIL		0.00
Compact to loose grey brown SILTY SAND		0.15
Red brown SILTY CLAY (Weathered Crust) - Silty sand layers from 1.19 m to 1.27 m and 1.37 m to 1.44 m	75.55	1.14
Grey brown SAND, some silt, trace black staining	75.11	1.58
Soft red grey and grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 2.92 m to 3.00 m - Grey silt layer from 4.50 m to 4.55 m	74.71	1.98
Grey SILTY SAND, with black staining	71.48	5.21
Grey SANDY SILT, trace clay		5.39
Soft red grey to grey CLAY to SILTY CLAY, with black staining and silt seams		5.59
Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	67.55	9.14

Piezometer installation: Protective Casing; Bentonite Seal; Grout

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-4

SHEET 2 OF 3

LOCATION: N 5020389.92 ;E 465917.77

BORING DATE: March 20-22, 2013

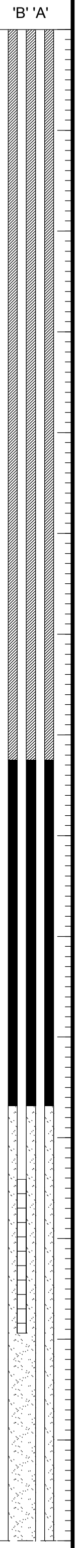
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									'B' 'A'
15	Wash Boring HW Casing	Soft to stiff grey and red CLAY to SILTY CLAY, with black staining									
16											
17											
18											Grout
19											
20											
21											
22											
23											
24											Peltonite
		Stiff grey CLAY to SILTY CLAY		52.31 24.38							
25											
26											Silica Sand
27											25 mm Diam. PVC #10 Slot Screen 'B'
28											Silica Sand
29											Silica Sand and Bentonite mix
				46.82							
30											
		CONTINUED NEXT PAGE									



DEPTH SCALE

1 : 75

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-4

SHEET 3 OF 3

LOCATION: N 5020389.92 ;E 465917.77

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 20-22, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80) | SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}) | WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

--- CONTINUED FROM PREVIOUS PAGE ---

Boring method: Wash Boring, HW Casing

DESCRIPTION	ELEV. DEPTH (m)
Grey SILTY CLAY to CLAYEY SILT	[illegible]
Stiff grey SILTY CLAY, trace sand and gravel	30.18
	45.30
Red grey SILTY CLAY, some sand, trace gravel	31.39 44.94
SILTY SAND, some clay, trace gravel (GLACIAL TILL)	31.75
	44.33
BOULDER	32.36 44.01
Very dense grey SILTY SAND, some gravel, trace clay (GLACIAL TILL)	32.68
	42.10
Dense grey SANDY SILT, some gravel, trace clay (GLACIAL TILL)	34.59
	41.49
Compact grey CLAYEY SILT, some sand and gravel (GLACIAL TILL)	35.20 41.11
End of Borehole	35.58

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.

Piezometer installation: 'B' 'A'

- Silica Sand and Bentonite mix
- Peltonite
- Silica Sand
- 32 mm Diam. PVC #10 Slot Screen 'A'
- Silica Sand

Depth scale: 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-5

SHEET 1 OF 2

LOCATION: N 5020386.28 ;E 465919.77

BORING DATE: March 22-23, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Wash Boring, HW Casing

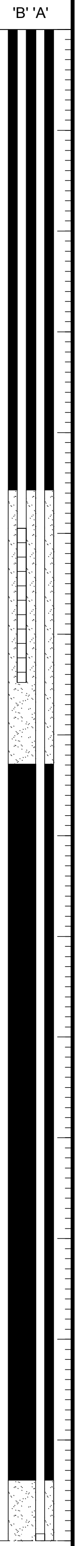
SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	76.60
TOPSOIL	0.00
Compact to loose grey brown SILTY SAND	0.15
Red brown SILTY CLAY (Weathered Crust) - Silty sand layers from 1.19 m to 1.27 m and 1.37 m to 1.44 m	75.46 1.14
Grey brown SAND, some silt, trace black staining	75.02 1.58
Soft red grey and grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 2.92 m to 3.00 m - Grey silt layer from 4.50 m to 4.55 m	74.62 1.98
Grey SILTY SAND, with black staining	71.39 5.21
Grey SANDY SILT, trace clay	5.39
Soft red grey to grey CLAY to SILTY CLAY, with black staining and silt seams	5.59
Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	67.46 9.14

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	73 TP	PH
2	73 TP	PH

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 75

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-5

SHEET 2 OF 2

LOCATION: N 5020386.28 ;E 465919.77

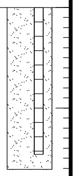
BORING DATE: March 22-23, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢ W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									'B' 'A'
15 16	Wash Boring HW Casing	Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	▨	59.99 16.61							 25 mm Diam. PVC #10 Slot Screen 'A' Silica Sand
17 18 19 20 21 22 23 24 25 26 27 28 29 30		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-6

SHEET 1 OF 1

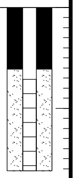
LOCATION: N 5020388.96 ;E 465920.63
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: March 23, 2013

DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.64							MON. WELL
0	Wash Boring HW Casing	TOPSOIL		0.00							Protective Casing
		Compact to loose grey brown SILTY SAND		0.15							Bentonite Seal Silica Sand
1		Red brown SILTY CLAY (Weathered Crust) - Silty sand layers from 1.19 m to 1.27 m and 1.37 m to 1.44 m		75.50 1.14							50 mm Diam. PVC #10 Slot Screen
		Grey brown SAND, some silt, trace black staining		75.06 1.62							
2		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									



DEPTH SCALE
1 : 75

LOGGED: DWM
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-7

SHEET 1 OF 3

LOCATION: N 5020391.49 ;E 465907.36

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 27, 2013

DATUM: Geodetic

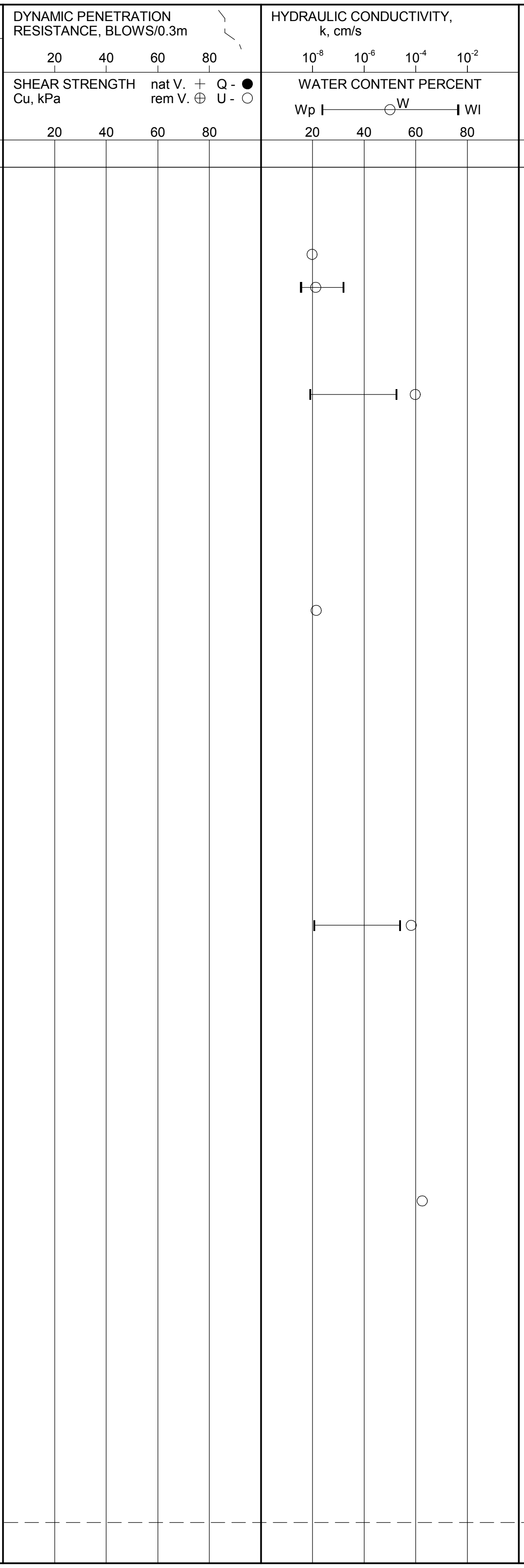
BORING METHOD: Geoprobe

DESCRIPTION	ELEV.	DEPTH (m)
GROUND SURFACE	76.91	
TOPSOIL		0.00
Compact to loose grey brown SILTY SAND		0.15
Red brown SILTY CLAY (Weathered Crust) - Silty sand layers from 1.19 m to 1.27 m and 1.37 m to 1.44 m	75.77	1.14
Grey brown SAND, some silt, trace black staining	75.33	1.58
Soft red grey and grey CLAY to SILTY CLAY, with silt seams - Grey silt layer from 2.92 m to 3.00 m - Grey silt layer from 4.50 m to 4.55 m	74.93	1.98
Grey SILTY SAND, with black staining	71.70	5.21
Grey SANDY SILT, trace clay		5.39
Soft red grey to grey CLAY to SILTY CLAY, with black staining and silt seams		5.59
Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	67.77	9.14

NUMBER	TYPE	BLOWS/0.3m
1	38 mm TUBE	-
2	38 mm TUBE	-
3	38 mm TUBE	-
4	38 mm TUBE	-
5	38 mm TUBE	-
6	38 mm TUBE	-
7	38 mm TUBE	-
8	38 mm TUBE	-
9	38 mm TUBE	-
10	38 mm TUBE	-

ADDITIONAL LAB. TESTING: MH (approx. 1.8 m); MH (approx. 5.4 m)

PIEZOMETER OR STANDPIPE INSTALLATION



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DEPTH SCALE

1 : 75

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-7

SHEET 2 OF 3

LOCATION: N 5020391.49 ;E 465907.36

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 27, 2013

DATUM: Geodetic

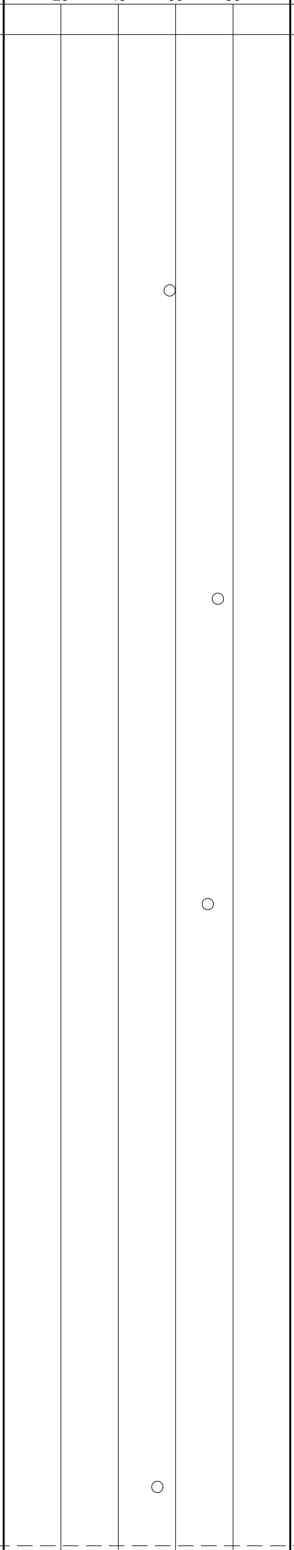
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---							
15		Soft to stiff grey and red CLAY to SILTY CLAY, with black staining	▨		10		-		
16			▨		11	53 mm TUBE	-		
17			▨		12	53 mm TUBE	-		
18			▨						
19			▨		13	53 mm TUBE	-		
20			▨		14	53 mm TUBE	-		
21			▨						
22	Geoprobe		▨		15	53 mm TUBE	-		
23			▨		16	53 mm TUBE	-		
24			▨						
		Stiff grey CLAY to SILTY CLAY	▨	52.53 24.38					
25			▨		17	53 mm TUBE	-		
26			▨		18	53 mm TUBE	-		
27			▨						
28			▨		19	53 mm TUBE	-		
29			▨		20	53 mm TUBE	-		
				47.04					
30		*CONTINUED NEXT PAGE*							

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ ; 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl ; 20 40 60 80



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-6-7

SHEET 3 OF 3

LOCATION: N 5020391.49 ;E 465907.36
INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 27, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
30	Geoprobe	Grey SILTY CLAY to CLAYEY SILT		46.73	20		-				
		Stiff grey SILTY CLAY, trace sand and gravel		30.18	21	53 mm TUBE	-				
31		Red grey SILTY CLAY, some sand, trace gravel		45.52 31.39	22	53 mm TUBE	-				
		SILTY SAND, some clay, trace gravel (GLACIAL TILL)		45.16 31.75							
32		End of Borehole Casing Refusal Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		44.86 32.05							
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: KE
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-2

SHEET 1 OF 3

LOCATION: N 5020089.80 ;E 466558.56

BORING DATE: June 10-13, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.35							MON. WELL
0	Wash Boring NW Casing	TOPSOIL	0.00							Protective Casing
		Brown SILTY CLAY, with silty sand seams (Weathered Crust)	0.15							
1		Firm to soft red grey CLAY to SILTY CLAY, with silty sand seams	75.13 1.22							Bentonite Seal
5		Grey SILTY SAND	70.56 5.79							
6		Soft grey CLAY to SILTY CLAY, with silty sand seams	5.94							
9		Grey CLAY to SILTY CLAY, with silty sand seams	67.35 9.00							Bentonite-Cement Grout
15										

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-2

SHEET 2 OF 3

LOCATION: N 5020089.80 ;E 466558.56

BORING DATE: June 10-13, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
15	Wash Boring NW Casing	Grey CLAY to SILTY CLAY, with silty sand seams	▨								Bentonite-Cement Grout
27		Compact to very dense grey SILTY SAND, trace to some clay, trace gravel (GLACIAL TILL)		49.23 27.12							
30		*CONTINUED NEXT PAGE*									

Depth scale: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-2

SHEET 3 OF 3

LOCATION: N 5020089.80 ;E 466558.56

BORING DATE: June 10-13, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
30	Wash Boring NW Casing	Compact to very dense grey SILTY SAND, trace to some clay, trace gravel (GLACIAL TILL)									
31					1	50 DO	>100				Bentonite-Cement Grout
32		- Sand and gravel layer at depth			2	50 DO	>100				
					3	50 DO	>100				
33				42.98							
		Borehole continued on RECORD OF DRILLHOLE 12-7-2 Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-7-2

SHEET 1 OF 4

LOCATION: N 5020089.80 ;E 466558.56

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 10-13, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	NOTES
		BEDROCK SURFACE	42.98							MON. WELL
	Rotary Drill NQ Core	**CARLSBAD FORMATION, 33.37 m to 39.47 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY to ARGILLACEOUS LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds (33.37-.79 m and 36.76-.82 m). Shale, calcareous shale and shaley limestone comprises approximately 74% of section.	33.37							Bentonite-Cement Grout
			42.56 33.79							
						BD,PL,SM	16	1	1	
34			42.35 34.00							
			42.28 34.07							Peltonite
						BD,CU,SM				
			42.02 34.33 34.35	1	100	BD,PL,SM	16	1	1	
			41.85 34.50							
			41.79 34.56							
			41.66 34.69			BD,PL,SM	16	1	1	
										Silica Sand
35			41.33 35.02							
			41.26 35.09			BD,PL,SM	16	1	1	
			41.22 35.13	2	100					32 mm Diam. PVC #10 Slot Screen
			41.15 35.20							
			35.23			BD,PL,SM	16	1	1	

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-7-2

SHEET 2 OF 4

LOCATION: N 5020089.80 ;E 466558.56

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 10-13, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
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OR - Orthogonal
CL - Clean

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25m 5 10 15 20	DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}	WEATHERING INDEX W1 W2 W3 W4 W5 W6	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---																MON. WELL
	Rotary Drill NQ Core	**CARLSBAD FORMATION, 33.37 m to 39.47 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY to ARGILLACEOUS LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds (33.37-.79 m and 36.76-.82 m). Shale, calcareous shale and shaley limestone comprises approximately 74% of section.		40.59 35.76 40.55 35.80 40.45 35.90 35.93 40.36 35.99	2	100												
36				40.18 36.17							•	BD,PL,SM	12	1	2			
				40.10 36.25							•	BD,PL,SM	16	1	1			32 mm Diam. PVC #10 Slot Screen
				39.99 36.36 36.38														
				39.66 36.69							•	BD,PL,SM	12	1	2			
				39.59 36.76							•	BD,PL,SM	12	1	2			
				39.53 36.82	3	100												
37											•	BD,PL,SM	16	1	1			
		CONTINUED NEXT PAGE																

DEPTH SCALE

1 : 10

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-7-2

SHEET 3 OF 4

LOCATION: N 5020089.80 ;E 466558.56

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 10-13, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate
BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean
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NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25m 5 10 15 20	DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}	WEATHERING INDEX W1 W2 W3 W4 W5 W6	NOTES
		--- *CONTINUED FROM PREVIOUS PAGE* ---																MON. WELL
	Rotary Drill NQ Core	**CARLSBAD FORMATION, 33.37 m to 39.47 m** Fresh, very thinly to thinly interbedded sequence of dark grey to black slake susceptible **SHALE, CALCAREOUS SHALE, SHALEY to ARGILLACEOUS LIMESTONE and LIMESTONE** with occasional bioclastic limestone beds (33.37-.79 m and 36.76-.82 m). Shale, calcareous shale and shaley limestone comprises approximately 74% of section.										BD,PL,SM	16	1	1			
				38.85 37.50														
				38.79 37.56														
				38.71 37.64														
				37.67	3	100												
				38.53 37.82														
				37.85														
38				38.37 37.98														
				38.32 38.03														
																		32 mm Diam. PVC #10 Slot Screen
				37.74 38.61														
				37.68 38.67	4	100						BD,PL,SM	16	1	1			
				37.57 38.78								BD,CU,SM	20	2	1			
				38.81														
39				37.39 38.96 37.35 39.00								BD,CU,SM	16	2	1			
				37.17 39.18								BD,CU,SM	16	2	1			
				37.05 39.30 39.32 39.34														
		CONTINUED NEXT PAGE																

DEPTH SCALE

1 : 10

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF DRILLHOLE: 13-7-2

SHEET 4 OF 4

LOCATION: N 5020089.80 ;E 466558.56

DRILLING DATE: June 10-13, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

JN - Joint
FLT - Fault
SH - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Clean

PL - Planar
CU - Curved
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ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
RO - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25m 5 10 15 20	DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-8} 10^{-6} 10^{-4} 10^{-2}	WEATHERING INDEX W1 W2 W3 W4 W5 W6	NOTES MON. WELL
		--- *CONTINUED FROM PREVIOUS PAGE* ---																
	Rotary Drill NQ Core			36.88	4	100												32 mm Diam. PVC #10 Slot Screen
		End of Drillhole		39.47														
40																		
41																		

DEPTH SCALE

1 : 10

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-3

SHEET 1 OF 3

LOCATION: N 5020084.85 ;E 466532.44

BORING DATE: March 28, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.35							MON. WELL
0	Wash Boring HW Casing	TOPSOIL		0.00							Protective Casing
		Brown SILTY CLAY, with silty sand seams (Weathered Crust)		0.15							
1		Firm to soft red grey CLAY to SILTY CLAY, with silty sand seams		75.13 1.22							
5		Grey SILTY SAND		70.56 5.79							
6		Soft grey CLAY to SILTY CLAY, with silty sand seams		5.94							Bentonite-Cement Grout
9		Grey CLAY to SILTY CLAY, with silty sand seams		67.35 9.00							
15											

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-3

SHEET 2 OF 3

LOCATION: N 5020084.85 ;E 466532.44

BORING DATE: March 28, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
15	Wash Boring HW Casing	Grey CLAY to SILTY CLAY, with silty sand seams	▨								Bentonite-Cement Grout
27		Compact to very dense grey SILTY SAND, trace to some clay, trace gravel (GLACIAL TILL)		49.23 27.12	1	50 DO	20				Peltonite Seal
28					2	50 DO	38				Silica Sand
29											32 mm Diam. PVC #10 Slot Screen
30		*CONTINUED NEXT PAGE*									

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-3

SHEET 3 OF 3

LOCATION: N 5020084.85 ;E 466532.44

BORING DATE: March 28, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
30		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	▨	46.08 30.27							
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-4-1

SHEET 1 OF 2

LOCATION: N 5020087.64 ;E 466535.51
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm

BORING DATE: March 26, 2013

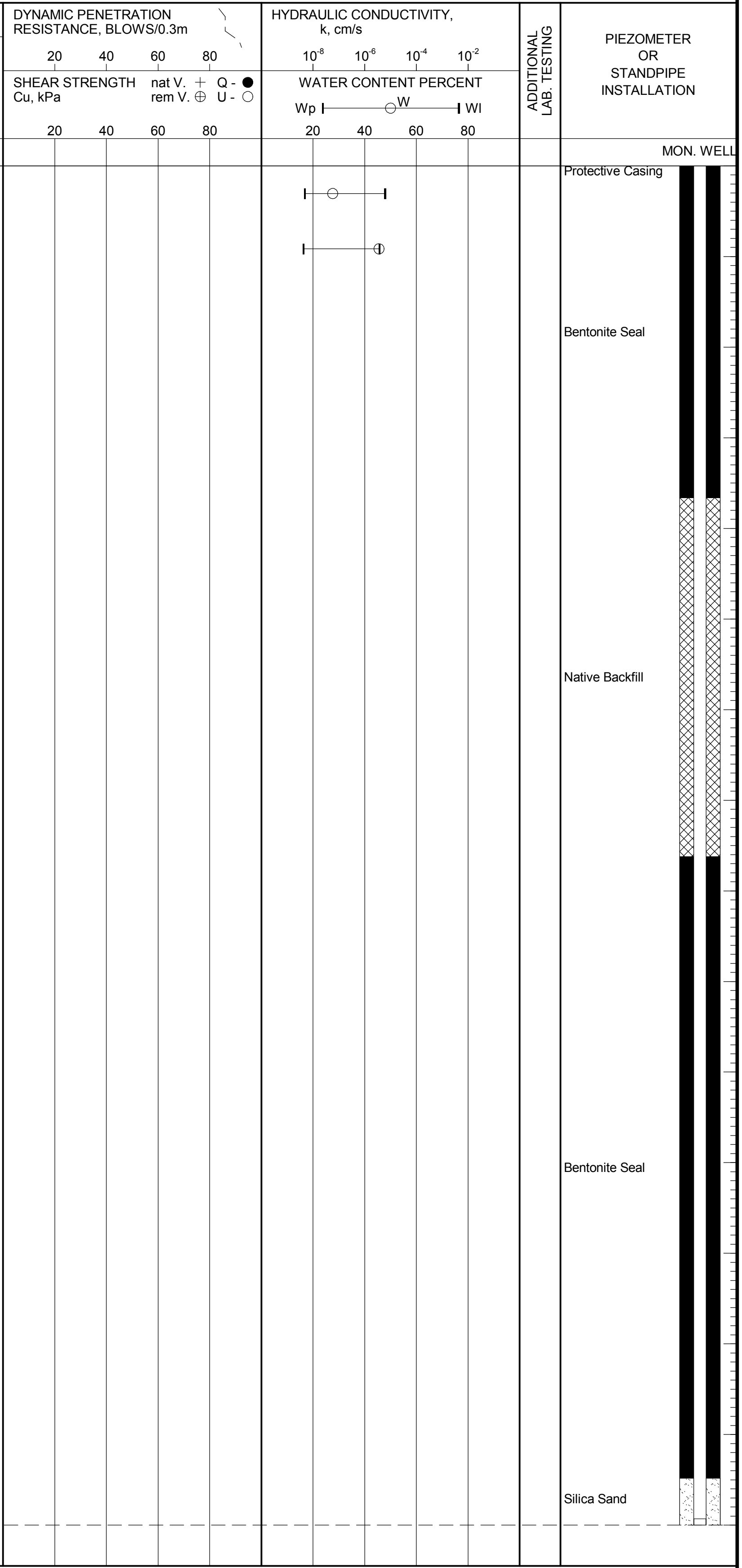
DATUM: Geodetic

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	76.38
TOPSOIL	0.00
Brown SILTY CLAY, with silty sand seams (Weathered Crust)	0.15
Firm to soft red grey CLAY to SILTY CLAY, with silty sand seams	75.16 1.22
Grey SILTY SAND	70.59 5.79
Soft grey CLAY to SILTY CLAY, with silty sand seams	5.94
Grey CLAY to SILTY CLAY, with silty sand seams	67.38 9.00

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	50 DO	2
2	50 DO	4
3	50 DO	1
4	50 DO	1
5	50 DO	WR
6	50 DO	1
7	50 DO	WR



DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 75

LOGGED: DWM
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-4-1

SHEET 2 OF 2

LOCATION: N 5020087.64 ;E 466535.51

BORING DATE: March 26, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									MON. WELL
15	Power Auger 200 mm Diam. (Hollow Stem)	Grey CLAY to SILTY CLAY, with silty sand seams	▨	59.62							25 mm Diam. PVC #10 Slot Screen Silica Sand
16											
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		16.76							
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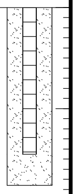


DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-4-2

SHEET 1 OF 1

LOCATION: N 5020089.23 ;E 466535.48

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 27, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. DEPTH (m)
		GROUND SURFACE	76.33
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL	0.00
		Brown SILTY CLAY, with silty sand seams (Weathered Crust)	0.15
1		Firm to soft red grey CLAY to SILTY CLAY, with silty sand seams	75.11 1.22
		Grey SILTY SAND	70.54 5.79
6		Soft grey CLAY to SILTY CLAY, with silty sand seams	5.94
		End of Borehole	69.93 6.40

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.

SAMPLES: NUMBER | TYPE | BLOWS/0.3m

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

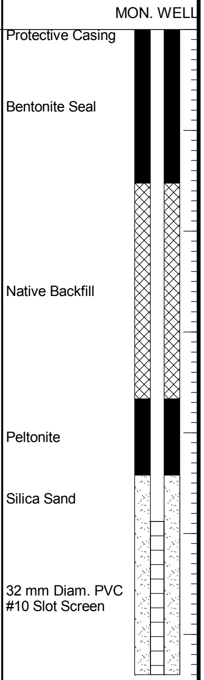
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE 1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-5

SHEET 1 OF 1

LOCATION: N 5020087.56 ;E 466532.35

BORING DATE: March 27, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.35							MON. WELL
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL		0.00							Protective Casing Bentonite Seal
		Brown SILTY CLAY, with silty sand seams (Weathered Crust)		0.15							Silica Sand
1		Firm to soft red grey CLAY to SILTY CLAY, with silty sand seams		75.13 1.22							50 mm Diam. PVC #10 Slot Screen
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		74.67 1.68							
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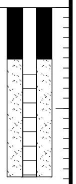


DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-6

SHEET 1 OF 1

LOCATION: N 5020088.20 ;E 466562.16

INCLINATION: -90° AZIMUTH: ---

BORING DATE: June 6, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.31					
0	Power Auger (Hollow Stem)	TOPSOIL		0.00					
		Brown SILTY CLAY, with silty sand seams (Weathered Crust)		0.15					
1	Electric Nilcon	Firm to soft red grey CLAY to SILTY CLAY, with silty sand seams		75.09 1.22					
		Grey SILTY SAND		70.52 5.79					
6		Soft grey CLAY to SILTY CLAY, with silty sand seams		5.94					
9		End of Borehole		67.31 9.00					

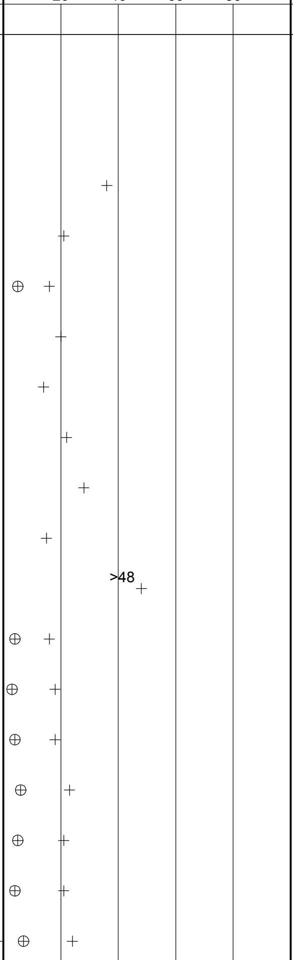
Note:
1. Soil stratigraphy inferred from various soil sampling methods and CPT.
2. Vane pushed to 9.0 m depth.

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m — 20 40 60 80

SHEAR STRENGTH Cu, kPa — nat V. + Q - ● rem V. ⊕ U - ○ — 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s — 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT — Wp ⊢—○W—⊣ Wl — 20 40 60 80



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG/DWM

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-7

SHEET 1 OF 1

LOCATION: N 5020086.62 ;E 466563.26

BORING DATE: June 7, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
		GROUND SURFACE		76.32
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL		0.00
		Brown SILTY CLAY, with silty sand seams (Weathered Crust)		0.15
1		Firm to soft red grey CLAY to SILTY CLAY, with silty sand seams		75.10 1.22
5		Grey SILTY SAND		70.53 5.79
6		Soft grey CLAY to SILTY CLAY, with silty sand seams		5.94
9		End of Borehole		66.67 9.65

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	73 TP	PH
2	73 TP	PH
3	73 TP	PM
4	73 TP	PM
5	73 TP	PH
6	73 TP	PM
7	73 TP	PM
8	73 TP	PM
9	73 TP	PM
10	73 TP	PM

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

Note:
1. Soil stratigraphy inferred from various soil sampling methods and CPT.

DEPTH SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DWM
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-7-8

SHEET 1 OF 1

LOCATION: N 5020091.12 ;E 466560.97

INCLINATION: -90° AZIMUTH: ---

BORING DATE: June 7-10, 2013

DATUM: Geodetic

DEPTH SCALE METRES

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	76.41
TOPSOIL	0.00
Brown SILTY CLAY, with silty sand seams (Weathered Crust)	0.15
Firm to soft red grey CLAY to SILTY CLAY, with silty sand seams	75.19 1.22
Grey SILTY SAND	70.62 5.79
Soft grey CLAY to SILTY CLAY, with silty sand seams	5.94
End of Borehole Note: 1. Soil stratigraphy inferred from various soil sampling methods and CPT.	66.76 9.65

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	73 TP	PH
2	73 TP	PM
3	73 TP	PM
4	73 TP	PM
5	73 TP	PH
6	73 TP	PM
7	73 TP	PM
8	73 TP	PM
9	73 TP	PM
10	73 TP	WR

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ├─○W─┤ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

Depth scale: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DWM

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-8-2

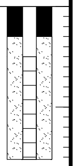
SHEET 1 OF 1

LOCATION: N 5021436.71 ;E 466032.27

INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 9, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m				
		GROUND SURFACE		76.41							
0	Geoprobe	TOPSOIL		0.00							 Protective Casing Bentonite Seal Silica Sand 32 mm Diam. PVC #10 Slot Screen
		Grey to grey brown SILTY SAND to SANDY SILT		0.20	1	53 mm TUBE	-				
1		Grey brown CLAYEY SILT, some sand		75.50 1.01							
		Grey brown SILTY SAND to SANDY SILT, trace gravel		75.11 1.30							
		Red brown SILTY CLAY, with silt seams (Weathered Crust)		1.52							
2		End of Borehole									
		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
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DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-8-3

SHEET 1 OF 1

LOCATION: N 5021438.32 ;E 466036.25
INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 9, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ├──○W──┤ Wl : 20 40 60 80

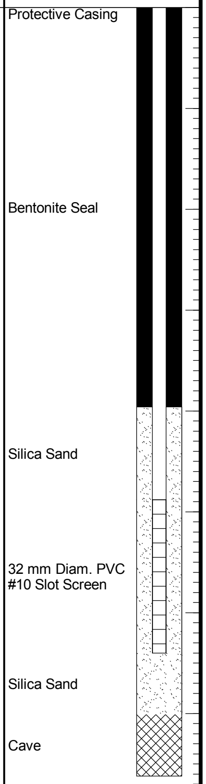
BORING METHOD: Geoprobe

SOIL PROFILE DESCRIPTION	ELEV.	DEPTH (m)	ADDITIONAL LAB. TESTING
GROUND SURFACE	76.43		
TOPSOIL		0.00	
Grey to grey brown SILTY SAND to SANDY SILT		0.20	
Grey brown CLAYEY SILT, some sand	75.52	1.01	
Grey brown SILTY SAND to SANDY SILT, trace gravel	75.13	1.30	
Red brown SILTY CLAY, with silt and silty sand seams (Weathered Crust)	74.54	1.89	
Red grey and grey CLAY to SILTY CLAY			
Grey SILT	72.24	4.23	
Red grey SILTY CLAY		4.37	MH
Grey SILTY SAND, trace clay	71.76	4.67	
Red grey to grey CLAY to SILTY CLAY, with black staining and silt seams			
End of Borehole	68.81	7.62	

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	53 mm TUBE	-
2	53 mm TUBE	-
3	53 mm TUBE	-
4	53 mm TUBE	-
5	53 mm TUBE	-

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE
1 : 75

LOGGED: DG
CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-9-2

SHEET 1 OF 1

LOCATION: N 5021532.90 ;E 466350.22

BORING DATE: March 20, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.05							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal Silica Sand
		Grey brown to brown SILTY SAND, trace clay		0.12	1	53 mm TUBE	-			MH	32 mm Diam. PVC #10 Slot Screen
1		Red brown SILTY CLAY, with black staining (Weathered Crust)		74.82 1.23							
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		74.53 1.52							
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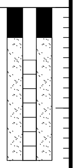

DEPTH SCALE

1 : 75

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-9-3

SHEET 1 OF 1

LOCATION: N 5021536.14 ;E 466347.26
INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 20, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl : 20 40 60 80
ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.08				
0	Geoprobe	TOPSOIL	0.00				Protective Casing
1		Grey brown to brown SILTY SAND, trace clay	0.12	1	53 mm TUBE	-	
		Red brown SILTY CLAY, with black staining and sand seams (Weathered Crust)	74.85 1.23				
2 3 4		Red grey CLAY to SILTY CLAY, with silt seams	74.15 1.93	2 3	53 mm TUBE 53 mm TUBE	- -	Bentonite Seal
		Grey SILTY SAND	71.79 4.40				
		Red grey SILTY CLAY	71.36				Silica Sand
		Grey SILTY SAND, with black staining	4.72				
5 6		Red grey to grey CLAY to SILTY CLAY - Grey silt layer from 4.95 m to 5.00 m - Grey silt layer from 5.41 m to 5.46 m		4	53 mm TUBE	-	32 mm Diam. PVC #10 Slot Screen
		Grey SILT	69.83				
7		Red grey to grey SILTY CLAY, with silt seams - Grey silt layer from 6.79 m to 6.82 m	6.35	5	53 mm TUBE	-	Silica Sand Cave
8		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	68.46 7.62				
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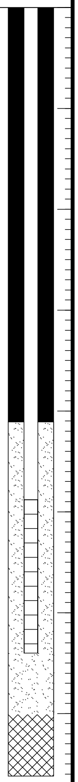

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: KE
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-10-2

SHEET 1 OF 1

LOCATION: N 5021245.94 ;E 466456.29

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 14, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.41							
0	Geoprobe	TOPSOIL	0.00							Protective Casing Bentonite Seal
		Grey brown to grey SAND, trace silt	0.12							Silica Sand
1				1	53 mm TUBE	-				32 mm Diam. PVC #10 Slot Screen
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	74.89 1.52							
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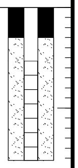


DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-10-3

SHEET 1 OF 1

LOCATION: N 5021244.40 ;E 466452.99

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 13, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

BORING METHOD: Geoprobe

DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	76.46
TOPSOIL	0.00
Grey brown to grey SAND, trace silt	0.12
Grey brown SAND, trace to some silt	74.08 2.38
Red grey to grey CLAY to SILTY CLAY, with black staining - Grey silt layer from 3.30 m to 3.33 m - Grey silt layer from 3.58 m to 3.63 m - Grey silt layer from 5.77 m to 5.80 m	73.75 2.71
Grey SILTY SAND, with black staining	70.59 5.87
Grey SILT, some sand to CLAYEY SILT	70.31 6.15
Red grey to grey CLAY to SILTY CLAY, with black staining - Clayey silt layer from 6.81 m to 6.83 m - Clayey silt layer from 7.11 m to 7.14 m - Clayey silt layer from 7.32 m to 7.34 m	70.01 6.45
End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	68.84 7.62

NUMBER	TYPE	BLOWS/0.3m
1	53 mm TUBE	-
2	53 mm TUBE	-
3	53 mm TUBE	-
4	53 mm TUBE	-
5	53 mm TUBE	-

ADDITIONAL LAB. TESTING: MH (approx. 1 m)

PIEZOMETER OR STANDPIPE INSTALLATION

- Protective Casing
- Bentonite Seal
- Silica Sand
- 32 mm Diam. PVC #10 Slot Screen
- Silica Sand
- Cave

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-11-2

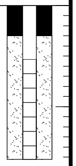
SHEET 1 OF 1

LOCATION: N 5021059.00 ;E 466865.18

BORING DATE: March 21, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	 TYPE	 BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.03							
0	Geoprobe	TOPSOIL *(0.00 m - 0.05 m)*		0.00 0.05							Protective Casing Bentonite Seal Silica Sand 32 mm Diam. PVC #10 Slot Screen 
		Grey brown to grey SAND, trace to some silt			1	53 mm TUBE	-				
1				74.51							
		End of Borehole		1.52							
2		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-12-2

SHEET 1 OF 1

LOCATION: N 5020785.00 ;E 466278.43

INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 10, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.19							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal
		Grey brown to red brown SILTY SAND, trace gravel		75.89 0.30	1	53 mm TUBE	-				Silica Sand 32 mm Diam. PVC #10 Slot Screen
1		Red brown SILTY CLAY (Weathered Crust)		75.00 1.19							
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		74.67 1.52							
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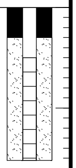


DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-12-3

SHEET 1 OF 1

LOCATION: N 5020781.01 ;E 466283.81

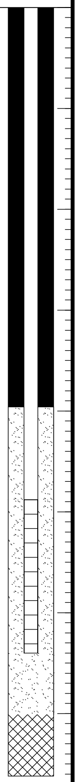
INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 10, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.27					
0	Geoprobe	TOPSOIL	0.00					Protective Casing
		Grey brown to red brown SILTY SAND, trace gravel	75.97 0.30	1	53 mm TUBE	-		
1		Red brown SILTY CLAY (Weathered Crust)	75.08 1.19					
		Red grey to grey CLAY to SILTY CLAY, with clayey silt and silt seams	74.75 1.52					
2				2	53 mm TUBE	-		Bentonite Seal
3								
4				3	53 mm TUBE	-		Silica Sand
5		Grey SILT, trace sand and clay	71.49 4.78				MH	
		Red grey to grey CLAY to SILTY CLAY, with silt seams	70.88 5.39	4	53 mm TUBE	-		32 mm Diam. PVC #10 Slot Screen
6								
7		Grey SILT	69.21	5	53 mm TUBE	-		Silica Sand
		Red grey to grey SILTY CLAY, with silt seams	7.16					Cave
		End of Borehole	68.65 7.62					

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.



DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80

SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80

DEPTH SCALE 8 9 10 11 12 13 14 15

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-13-2

SHEET 1 OF 1

LOCATION: N 5021366.28 ;E 466752.54

BORING DATE: March 13, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.21					
0	Geoprobe	TOPSOIL	0.00					Protective Casing Bentonite Seal
		Grey and brown SAND, some silt	0.12	1	53 mm TUBE	-	MH	Silica Sand 32 mm Diam. PVC #10 Slot Screen
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	74.69 1.52					

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-14-2

SHEET 1 OF 1

LOCATION: N 5020308.36 ;E 466088.22

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 26, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.48							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal Silica Sand
		Red brown SILTY CLAY, with sand seams (Weathered Crust)		0.08	1	53 mm TUBE	-				
1											32 mm Diam. PVC #10 Slot Screen
		Grey brown SILTY SAND		75.11							
		Red brown SILTY CLAY (Weathered Crust)		1.52							
2		End of Borehole									
		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
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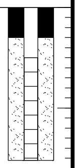

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-15-2

SHEET 1 OF 1

LOCATION: N 5020425.79 ;E 466407.29

BORING DATE: March 25, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.31							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal
		Grey brown SILTY SAND, trace gravel, with black staining		0.23	1	53 mm TUBE	-				Silica Sand
1				75.12							32 mm Diam. PVC #10 Slot Screen
		Grey brown to red brown SILTY CLAY (Weathered Crust) - Silty sand seam from 1.25 m to 1.28 m		1.19							
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		74.79 1.52							
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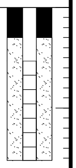


DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-15-3

SHEET 1 OF 1

LOCATION: N 5020428.87 ;E 466408.56

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 26, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
GROUND SURFACE	76.26			
TOPSOIL	0.00			
Grey brown SILTY SAND, trace gravel, with black staining	0.25	1	53 mm TUBE	-
Grey brown to red brown SILTY CLAY (Weathered Crust) - Silty sand layer from 1.25 m to 1.28 m	75.07 1.19			
Red grey and grey CLAY to SILTY CLAY, with silt seams	74.74 1.52	2	53 mm TUBE	-
Grey CLAYEY SILT	73.96 2.36			
Red grey to grey CLAY to SILTY CLAY, with silt seams		3	53 mm TUBE	-
Grey SANDY SILT, trace clay	71.84 4.52			
Grey SANDY SILT to CLAYEY SILT				
Red grey to grey CLAY to SILTY CLAY - Grey silt layer from 5.13 m to 5.23 m - Grey silt layer from 5.61 m to 5.65 m - Grey silt layer from 5.84 m to 5.88 m	71.38 4.88	4	53 mm TUBE	-
Grey SILT to CLAYEY SILT	69.94 6.32			
Red grey to grey CLAY to SILTY CLAY	6.45	5	53 mm TUBE	-
End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	68.72 7.54			

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

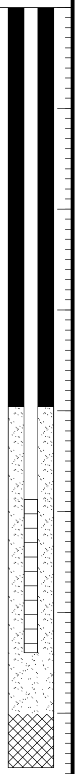
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING: 53 mm TUBE

PIEZOMETER OR STANDPIPE INSTALLATION



Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Silica Sand

Cave

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-16-2

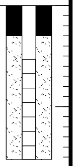
SHEET 1 OF 1

LOCATION: N 5020533.39 ;E 466705.54

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 25, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.04							
0	Geoprobe	TOPSOIL *(0.00 m - 0.05 m)*		0.00 0.05							Protective Casing Bentonite Seal 
		Grey brown to red brown SILTY SAND		75.05	1	53 mm TUBE	-				Silica Sand
1		Red brown SILTY CLAY, with silty sand seams (Weathered Crust)		0.99 74.52							32 mm Diam. PVC #10 Slot Screen
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		1.52							
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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-17-2

SHEET 1 OF 1

LOCATION: N 5020640.45 ;E 466998.14

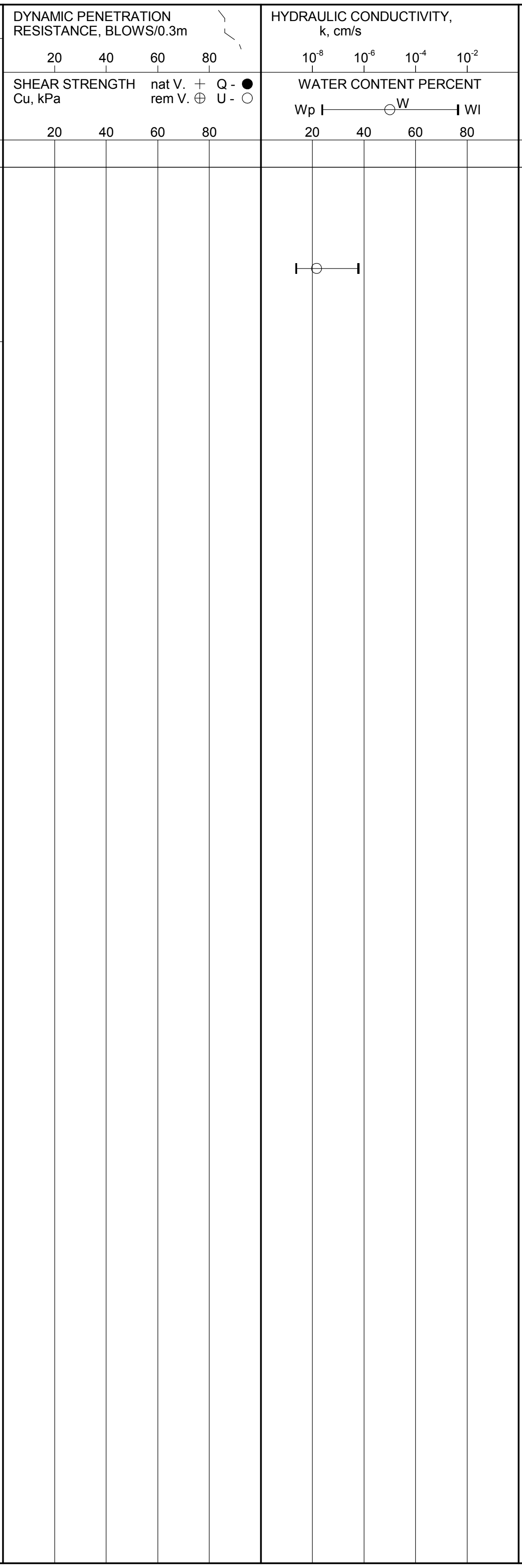
INCLINATION: -90° AZIMUTH: ---

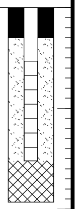
BORING DATE: March 13, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	75.99				
0	Geoprobe	PEAT *(0.00 m - 0.05 m)*	0.00 0.05				Protective Casing Bentonite Seal
		Brown SAND, trace to some silt		1	53 mm TUBE	-	Silica Sand
1		Red brown SILTY CLAY, with sand seams (Weathered Crust)	75.08 0.91				32 mm Diam. PVC #10 Slot Screen
		Grey brown SAND, trace silt	1.31				
		Red brown SILTY CLAY, with sand seams (Weathered Crust)	74.19 1.80	2	53 mm TUBE	-	Cave
2		Grey brown SAND, trace to some silt	2.02				
		Grey and red brown SILTY CLAY					
		End of Borehole					

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.





Depth scale: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: KE
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-17-3

SHEET 1 OF 1

LOCATION: N 5020640.47 ;E 467002.05

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 13, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○; 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl; 20 40 60 80

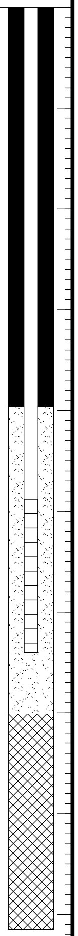
ADDITIONAL LAB. TESTING

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	76.04
PEAT *(0.00 m - 0.05 m)*	0.00 0.05
Brown SAND, trace to some silt	75.13 0.91
Red brown SILTY CLAY, with sand seams (Weathered Crust)	
Grey brown SAND, trace silt	1.31
Red brown SILTY CLAY, with sand seams (Weathered Crust)	74.24 1.80
Grey brown SAND, trace to some silt	2.02
Grey and red brown SILTY CLAY	
Grey and red brown CLAY to SILTY CLAY, with clayey silt seams	71.62 4.42
Grey SAND, trace to some silt	71.04 5.00
Grey CLAYEY SILT, some sand	5.15
Grey and red brown CLAY to SILTY CLAY, with clayey silt seams	69.94 6.10
Grey and red brown CLAY to SILTY CLAY, with silt and clayey silt seams and black staining	66.90 9.14
End of Borehole	

Note:
Soil stratigraphy inferred from various soil sampling methods and CPT.

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	53 mm TUBE	-
2	53 mm TUBE	-
3	53 mm TUBE	-
4	53 mm TUBE	-
5	53 mm TUBE	-
6	53 mm TUBE	-

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE
1 : 75

LOGGED: KE
CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-18-2

SHEET 1 OF 1

LOCATION: N 5019944.78 ;E 465851.70

INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 8, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.90							
0	Geoprobe	TOPSOIL *(0.00 m - 0.08 m)*	0.00 0.08							Protective Casing Bentonite Seal Silica Sand
		Grey brown SILTY SAND, trace organic matter	75.96	1	53 mm TUBE	-				
1		Red brown SILTY CLAY, with silty sand seams (Weathered Crust) - Silty sand layer from 1.11 m to 1.24 m - Silty sand layer from 1.37 m to 1.40 m	0.94 75.38							32 mm Diam. PVC #10 Slot Screen
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	1.52							
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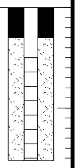


DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-18-3

SHEET 1 OF 1

LOCATION: N 5019935.70 ;E 465846.70

INCLINATION: -90° AZIMUTH: ---

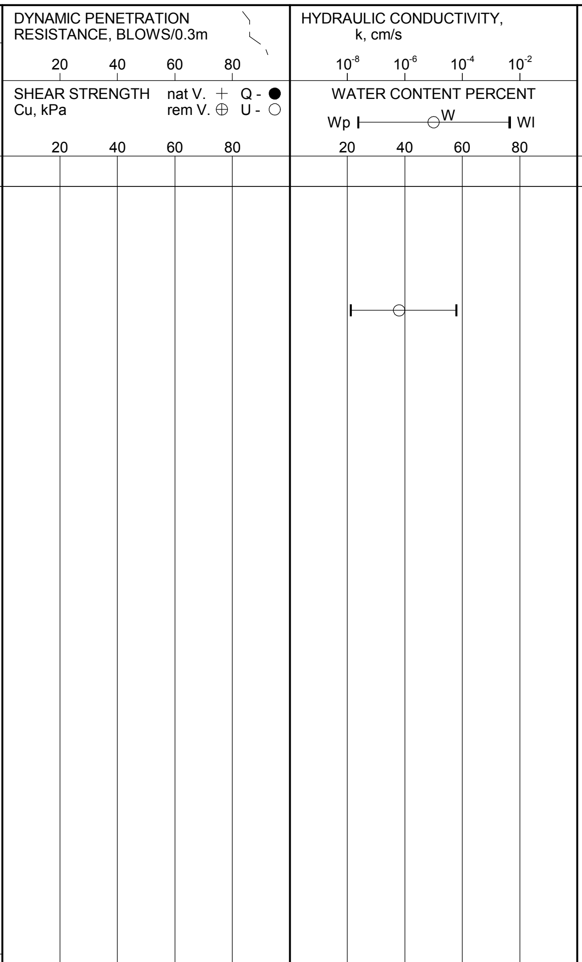
BORING DATE: April 8, 2013

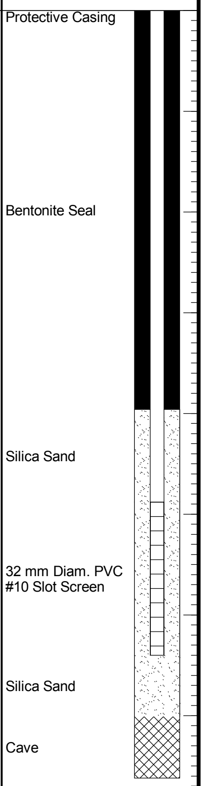
DATUM: Geodetic

BORING METHOD: Geoprobe

SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	ADDITIONAL LAB. TESTING
GROUND SURFACE	76.86	
TOPSOIL *(0.00 m - 0.08 m)*	0.00 0.08	
Grey brown SILTY SAND, trace organic matter	75.92 0.94	
Red brown SILTY CLAY, with silty sand seams (Weathered Crust) - Silty sand layer from 1.11 m to 1.24 m - Silty sand layer from 1.37 m to 1.40 m	75.34 1.52	
Red grey to grey CLAY to SILTY CLAY, with silty sand to silt seams - Grey silty sand layer from 1.98 m to 2.01 m - Grey silty sand layer from 2.34 m to 2.44 m - Grey silty sand layer from 2.54 m to 2.58 m - Grey silt layer from 3.61 m to 3.65 m - Grey silt, some sand layer from 4.32 m to 4.37 m	71.14 5.72	
Grey SILTY SAND, trace clay, with black staining	70.71 6.15	MH
Red grey to grey CLAY to SILTY CLAY, with silt seams and black staining - Grey silt layer from 6.20 m to 6.24 m - Grey silt layer from 6.61 m to 6.64 m - Grey silt layer from 6.76 m to 6.78 m - Grey silt layer from 6.91 m to 6.96 m	69.24 7.62	
End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	53 mm TUBE	-
2	53 mm TUBE	-
3	53 mm TUBE	-
4	53 mm TUBE	-
5	53 mm TUBE	-





DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-19-2

SHEET 1 OF 1

LOCATION: N 5019954.46 ;E 466203.76

BORING DATE: April 9, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.68				
0	Geoprobe	TOPSOIL	0.00				Protective Casing Bentonite Seal
		Grey brown to red brown SILTY SAND	0.15	1	53 mm TUBE	-	Silica Sand
1		Grey brown SANDY SILT	75.54 1.14				32 mm Diam. PVC #10 Slot Screen
		Red brown SILTY CLAY (Weathered Crust) - Silty sand layer from 1.34 m to 1.36 m	1.30				
2		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	1.52				

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ — 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl — 20 40 60 80

ADDITIONAL LAB. TESTING

3 4 5 6 7 8 9 10 11 12 13 14 15

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-20-2

SHEET 1 OF 1

LOCATION: N 5020206.88 ;E 466834.60

INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 5, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.21							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal
		Brown SILTY SAND		0.25	1	53 mm TUBE	-				Silica Sand
1											32 mm Diam. PVC #10 Slot Screen
		Red brown SILTY CLAY, with silty sand seams (Weathered Crust)		74.84 1.37							
		End of Borehole		1.52							
2		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-21-2

SHEET 1 OF 1

LOCATION: N 5019673.31 ;E 465949.60

BORING DATE: March 18, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		77.41							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal
		Grey brown to red brown SILTY SAND		0.26							Silica Sand
1					1	53 mm TUBE	-				32 mm Diam. PVC #10 Slot Screen
				75.89 1.52							
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
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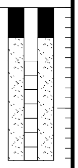

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-21-3

SHEET 1 OF 1

LOCATION: N 5019674.12 ;E 465947.84

INCLINATION: -90° AZIMUTH: ---

BORING DATE: April 9, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		77.27							
0	Geoprobe	TOPSOIL		0.00							
1		Grey brown to red brown SILTY SAND		0.26	1	53 mm TUBE	-				
2		Grey brown to red brown SILTY CLAY (Weathered Crust)		75.21 2.06	2	53 mm TUBE	-				
		Grey to red grey SILTY CLAY		74.86 2.41						MH	
		Grey SAND, trace silt		2.54							
3		Red grey CLAY to SILTY CLAY, with sandy silt seams - Sandy silt layer from 2.81 m to 2.83 m		2.74							
		End of Borehole		74.22 3.05							
4		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
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DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-22-2

SHEET 1 OF 1

LOCATION: N 5019635.82 ;E 466331.47

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 28, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ├──○W──┤ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.59							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal
		Grey SILTY SAND, trace black staining		76.32 0.27	1	53 mm TUBE	-				Silica Sand
1		Red brown SILTY CLAY, with silty sand and clayey silt seams (Weathered Crust) - Silty sand layer from 1.31 m to 1.36 m		75.40 1.19							32 mm Diam. PVC #10 Slot Screen
		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		75.07 1.52							
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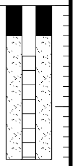

DEPTH SCALE

1 : 75

LOGGED: KE

CHECKED: SAT

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-23-2

SHEET 1 OF 1

LOCATION: N 5019741.47 ;E 466608.01

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 28, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	76.51							
0	Geoprobe	TOPSOIL	0.00							Protective Casing Bentonite Seal Silica Sand
		Grey brown to red brown SILTY CLAY (Weathered Crust)	0.26	1	53 mm TUBE	-				
1		Red brown to grey brown SAND, some silt, with black staining	75.42 1.09							32 mm Diam. PVC #10 Slot Screen
		Grey brown CLAYEY SILT								
		Red brown SILTY CLAY (Weathered Crust)	1.52							
2		End of Borehole								
		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.								
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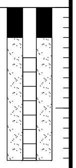

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-23-3

SHEET 1 OF 1

LOCATION: N 5019742.33 ;E 466606.09

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 28, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE / SHEAR STRENGTH	HYDRAULIC CONDUCTIVITY / WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.53							
0	Geoprobe	TOPSOIL		0.00							Protective Casing
		Grey brown to red brown SILTY CLAY (Weathered Crust)		0.26	1	53 mm TUBE	-				
1		Red brown to grey brown SAND, some silt, with black staining		75.44 1.09							
		Grey brown CLAYEY SILT									
2		Red brown SILTY CLAY (Weathered Crust)		1.52							Bentonite Seal
3 4		Red grey CLAY to SILTY CLAY, with clayey silt seams, silty sand seams and black staining - Clayey silt layer from 2.64 m to 2.69 m			2 3	53 mm TUBE 53 mm TUBE	- -				
		Grey SILT, some sand, trace clay		72.06 4.47						MH	Silica Sand
5 6		Red grey to grey CLAY to SILTY CLAY, with clayey silt seams and black staining		71.63 4.90	4	53 mm TUBE	-				32 mm Diam. PVC #10 Slot Screen
		Grey CLAYEY SILT		69.85 6.73	5	53 mm TUBE	-				Silica Sand
7		Red grey to grey SILTY CLAY, with black staining - Clayey silt layer from 6.81 m to 6.86 m									Cave
8 9 10 11 12 13 14 15		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.		68.91 7.62							

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

RECORD OF BOREHOLE: 13-24-2

SHEET 1 OF 1

LOCATION: N 5019877.31 ;E 466957.69

INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 21, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	SOIL PROFILE STRATA PLOT	SOIL PROFILE ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		76.11							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal Silica Sand
		Grey brown to red brown SILTY CLAY, trace sand (Weathered Crust)		0.18	1	53 mm TUBE	-				
1		- Silty sand layer from 0.88 m to 0.94 m		74.97							32 mm Diam. PVC #10 Slot Screen
		Grey SILTY SAND		1.18							
		Grey brown to red brown SILTY CLAY, with silty sand seams (Weathered Crust)		1.37							
		Grey SAND, some silt		1.52							
2		End of Borehole									
		Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
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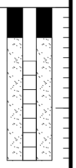


DEPTH SCALE

1 : 75

Golder Associates

LOGGED: KE

CHECKED: SAT

PROJECT: 12-1125-0045

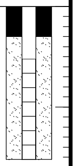
RECORD OF BOREHOLE: 13-25-2

SHEET 1 OF 1

LOCATION: N 5019999.00 ;E 467254.44
INCLINATION: -90° AZIMUTH: ---

BORING DATE: March 19, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m				
		GROUND SURFACE		75.99							
0	Geoprobe	TOPSOIL		0.00							Protective Casing Bentonite Seal Silica Sand 32 mm Diam. PVC #10 Slot Screen 
		Red brown SILTY CLAY (Weathered Crust)		0.23 75.41							
		Grey brown SILTY SAND, with black staining		0.64	1	53 mm TUBE	-				
1		Grey brown to red brown SILTY CLAY, with silty sand seams, clayey silt seams and black staining (Weathered Crust)		74.62 1.37							
		Red grey to grey CLAY to SILTY CLAY		1.52							
2		End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.									
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CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: KE
CHECKED: SAT

RECORD OF BOREHOLE: 13-25-3

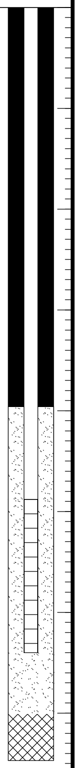
PROJECT: 12-1125-0045
LOCATION: N 5020010.92 ;E 467250.46
INCLINATION: -90° AZIMUTH: ---
BORING DATE: March 19, 2013
SHEET 1 OF 1
DATUM: Geodetic

BORING METHOD: Geoprobe

SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
GROUND SURFACE	75.98			
TOPSOIL	0.00			
Red brown SILTY CLAY (Weathered Crust)	0.23 75.40			
Grey brown SILTY SAND, with black staining	0.64	1		-
Grey brown to red brown SILTY CLAY, with silty sand seams, clayey silt seams and black staining (Weathered Crust)	74.61 1.37			
Red grey to grey CLAY to SILTY CLAY, with silt seams - Silt layer from 1.85 m to 1.88 m - Silt layer from 1.93 m to 1.95 m - Silt layer from 2.17 m to 2.19 m - Silt layer from 2.42 m to 2.46 m		2 3 4		- - -
Grey CLAYEY SILT	70.52 5.46			
Red grey CLAY to SILTY CLAY - Silt layer from 6.25 m to 6.31 m	70.04 5.94			
Grey CLAYEY SILT	69.58 6.40			
Red grey to grey CLAY to SILTY CLAY - Silt layer from 6.83 m to 6.86 m	6.55	5		-
End of Borehole Note: Soil stratigraphy inferred from various soil sampling methods and CPT.	68.51 7.47			

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80
ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE 1 : 75

LOGGED: KE
CHECKED: SAT

PROJECT: 12-1125-0045/8100

RECORD OF BOREHOLE: 13-1 (A13-1)

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: June 5, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	HEADSPACE ORGANIC VAPOUR CONCENTRATIONS [PPM] ⊕ ND = Not Detected (100, 200, 300, 400); HEADSPACE COMBUSTIBLE VAPOUR CONCENTRATIONS ☐ [%LEL] ND = Not Detected (20, 40, 60, 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20, 40, 60, 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		77.22							MON. WELL
0	Power Auger 200 mm Diam. (Hollow Stem)	Compact dark brown to black SILTY SAND, trace gravel and shale fragments		0.00	1	SS	15	⊕			Flush Mount Casing Bentonite Seal Silica Sand
		Compact brown SILTY fine SAND		76.46 0.76	2	SS	15	⊕			32 mm Diam. PVC #10 Slot Screen
1		Brown SILTY CLAY, trace thin silty sand seams (Weathered Crust)		75.70 1.52	3	SS	3	⊕			
2		Grey brown SILTY CLAY		74.93 2.29	4	SS	PH	⊕			Silica Sand
3		End of Borehole		74.17 3.05							W.L. in Screen at Elev. 76.564 on June 7, 2013
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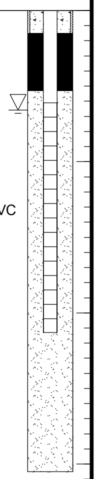


DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DWM

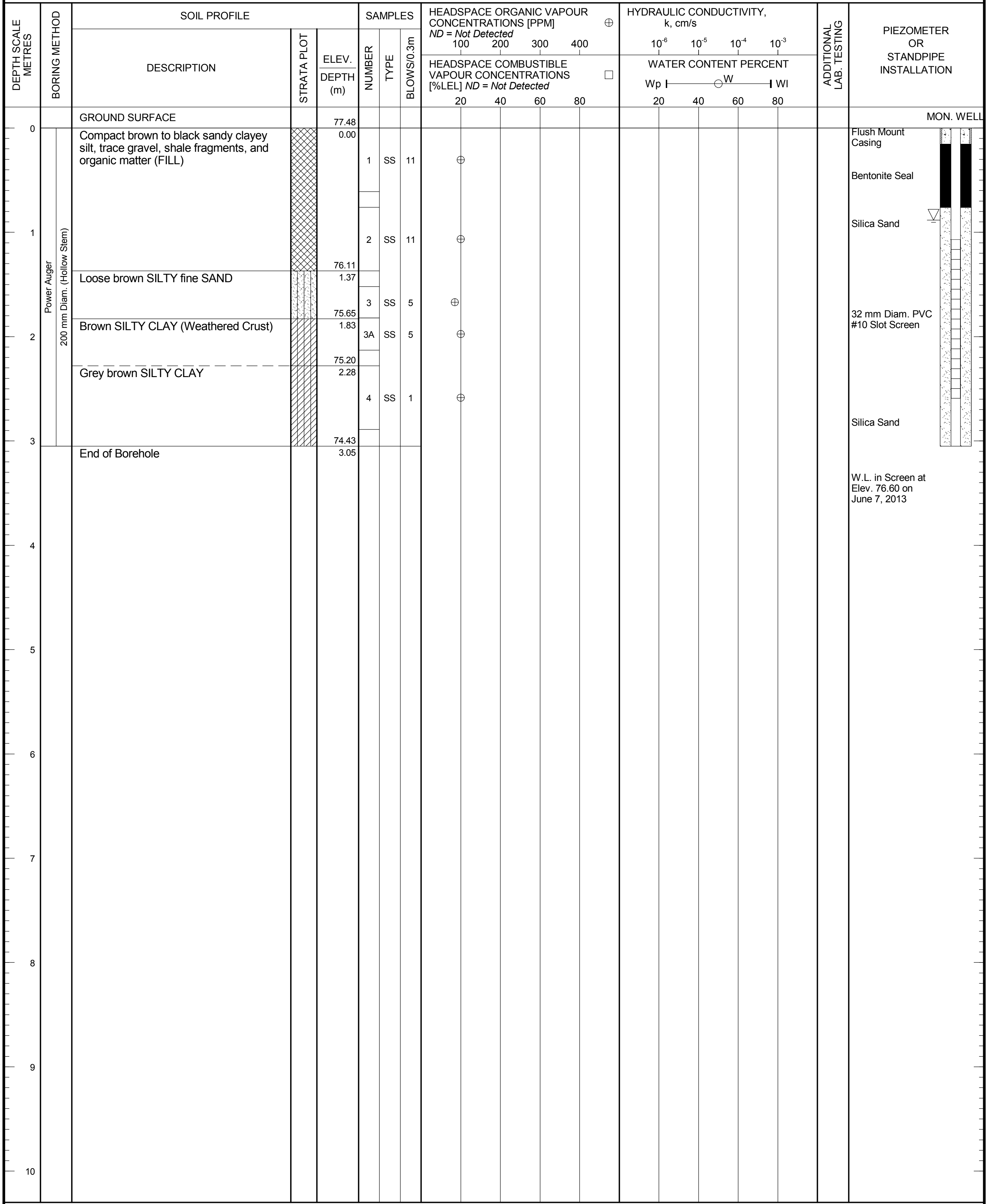
CHECKED: HLRF

PROJECT: 12-1125-0045/8100

RECORD OF BOREHOLE: 13-2 (A13-2)

SHEET 1 OF 1

LOCATION: See Site Plan
BORING DATE: June 5, 2013
DATUM: Geodetic
INCLINATION: -90° AZIMUTH: ---
SAMPLER HAMMER, 64kg; DROP, 760mm
PENETRATION TEST HAMMER, 64kg; DROP, 760mm



DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	77.48
Compact brown to black sandy clayey silt, trace gravel, shale fragments, and organic matter (FILL)	0.00
Loose brown SILTY fine SAND	76.11 1.37
Brown SILTY CLAY (Weathered Crust)	75.65 1.83
Grey brown SILTY CLAY	75.20 2.28
End of Borehole	74.43 3.05

NUMBER	TYPE	BLOWS/0.3m
1	SS	11
2	SS	11
3	SS	5
3A	SS	5
4	SS	1

Flush Mount Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Silica Sand

W.L. in Screen at Elev. 76.60 on June 7, 2013

DEPTH SCALE
1 : 50

LOGGED: DWM
CHECKED: HLRF

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-1

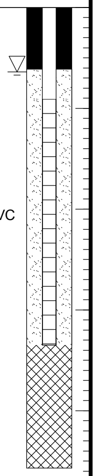
SHEET 1 OF 1

LOCATION: N 5020218.07 ;E 465752.57
INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 21, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								MON. WELL
0	Geoprobe	Brown silty sand, with organic matter (TOPSOIL)	0.00							Bentonite Seal
		Intermixed brown silty sand and red brown silty clay (Probable Fill)	0.46	1	53 mm TUBE	-				Silica Sand
2		Red brown SILTY CLAY	2.18							32 mm Diam. PVC #10 Slot Screen
		Intermixed brown SILTY SAND and red brown SILTY CLAY	2.44	2	53 mm TUBE	-				
		Grey SILTY SAND								
		Red grey SILTY CLAY	3.65	3	53 mm TUBE	-				Cave
		End of Borehole	4.57							WL in Screen at 0.64 m depth below ground surface on Nov. 5, 2013



DEPTH SCALE
1 : 75

Golder Associates

LOGGED: DG
CHECKED: DH

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-2

SHEET 1 OF 1

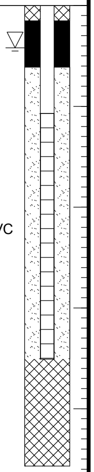
LOCATION: N 5020213.93 ;E 465749.43

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 21, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									MON. WELL
0	Geoprobe	Brown silty sand, with organic matter (TOPSOIL)		0.00							Native Backfill
1		Red brown silty sand (Probable Fill)		0.30	1	53 mm TUBE	-				Bentonite Seal Silica Sand
2 3		Grey fine sand, trace silt (Probable Fill)		1.22	2	53 mm TUBE	-				32 mm Diam. PVC #10 Slot Screen
4		Red grey SILTY CLAY		3.81	3	53 mm TUBE	-				Cave
5 6 7 8 9 10 11 12 13 14 15		End of Borehole		4.57							WL in Screen at 0.42 m depth below ground surface on Nov. 5, 2013



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-3

SHEET 1 OF 1

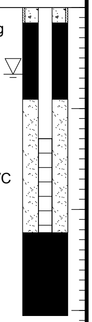
LOCATION: N 5020223.82 ;E 465747.43

BORING DATE: October 28, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									MON. WELL
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)	▨	0.00	1	53 mm TUBE	-				Flush Mount Protective Casing Bentonite Seal
1		Grey brown sandy silt, trace clay (FILL)	▨	0.91							Silica Sand
		Grey brown SILTY SAND		1.30							
		Brown SILTY SAND		1.52							32 mm Diam. PVC #10 Slot Screen
2		Red grey SILTY CLAY		2.23	2	53 mm TUBE	-				Bentonite Seal
3		End of Borehole		3.05							WL in Screen at 0.66 m depth below ground surface on Nov. 5, 2013



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-4

SHEET 1 OF 1

LOCATION: N 5020221.09 ;E 465748.67

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

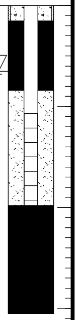
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE				
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-
1		Brown silty fine sand, trace medium sand (FILL)	0.91			
		Grey SILTY SAND	1.12			
		Brown SILTY SAND	1.52			
2		Red grey SILTY CLAY	1.98	2	53 mm TUBE	-
3		End of Borehole	3.05			
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



Flush Mount Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Bentonite Seal

WL in Screen at 0.65 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-5

SHEET 1 OF 1

LOCATION: N 5020219.28 ;E 465749.50

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m
		GROUND SURFACE					
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)		0.00	1	53 mm TUBE	-
		Brown fine sand, trace gravel (FILL)		0.81			
1		Dark grey to black silty fine sand to sandy silt, trace gravel and organic matter (TOPSOIL)		1.07			
		Grey SILTY SAND		1.52			
2		Mottled red brown to grey brown SILTY CLAY		1.78	2	53 mm TUBE	-
		Red grey SILTY CLAY		2.44			
3							
4					3	53 mm TUBE	-
5					4	53 mm TUBE	-
		Grey SILTY SAND		5.69			
6		Red grey SILTY CLAY		6.17			
7					5	53 mm TUBE	-
		End of Borehole		7.62			
8							
9							
10							
11							
12							
13							
14							
15							

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

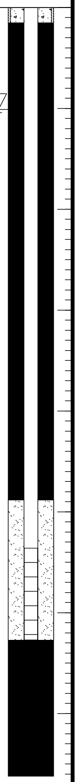
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



Flush Mount Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Bentonite Seal

WL in Screen at 1.01 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-6

SHEET 1 OF 1

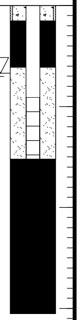
LOCATION: N 5020218.82 ;E 465748.50

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE								MON. WELL
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)	0.00							Flush Mount Protective Casing Bentonite Seal
				1	53 mm TUBE	-				Silica Sand
1		Brown silty fine sand, trace medium sand, trace organic clay tile (FILL)	0.91							32 mm Diam. PVC #10 Slot Screen
		Dark grey to black silty fine sand, trace gravel, wood and organic matter (TOPSOIL)	1.52							
2		Grey brown to red brown SILTY CLAY		2	53 mm TUBE	-				Bentonite Seal
3		End of Borehole	3.05							WL in Screen at 0.67 m depth below ground surface on Nov. 5, 2013



Depth scale: 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 09/04/14 JM

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: HEC
CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-7

SHEET 1 OF 1

LOCATION: N 5020213.64 ;E 465752.08

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

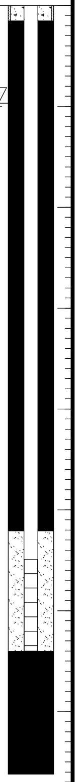
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE					MON. WELL
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-	Flush Mount Protective Casing
1		Brown to grey silty fine sand to sandy silt (FILL)	0.91				
		Grey silty fine sand, trace wood and organic matter (TOPSOIL)	1.30				
		Brown to grey brown SILTY SAND	1.52	2	53 mm TUBE	-	
2		Red brown to grey SILTY CLAY, with sand seams	2.29				Bentonite Seal
3				3	53 mm TUBE	-	
5				4	53 mm TUBE	-	Silica Sand
		Grey SILTY fine SAND	5.64				32 mm Diam. PVC #10 Slot Screen
6		Red grey SILTY CLAY	6.10	5	53 mm TUBE	-	Bentonite Seal
7		End of Borehole	7.62				WL in Screen at 0.97 m depth below ground surface on Nov. 5, 2013



DEPTH SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-8

SHEET 1 OF 1

LOCATION: N 5020212.73 ;E 465752.50

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

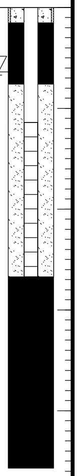
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE				
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-
1		Brown silty fine sand (FILL)	0.99			
		Grey brown silty fine sand, trace clay and black silt (TOPSOIL)	1.14			
		Red brown SILTY CLAY, some black silt (FILL)	1.52	2	53 mm TUBE	-
		Brown SILTY SAND	2.74			
3		Red grey SILTY CLAY, trace grey silty fine sand seams	3.12	3	53 mm TUBE	-
		End of Borehole	4.57			

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



Flush Mount Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Bentonite Seal

WL in Screen at 0.64 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE
1 : 75

LOGGED: HEC
CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-9

SHEET 1 OF 1

LOCATION: N 5020210.91 ;E 465753.33

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DEPTH SCALE METRES: 0 to 15

BORING METHOD: Geoprobe

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

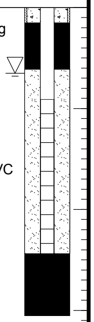
WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
GROUND SURFACE				
Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-
Brown fine sand, trace silt (FILL)	1.07			
Brown to grey silty fine sand, some gravel, trace wood, plastic and glass (FILL)	1.22			
Black to grey brown silty fine sand, some organic matter (TOPSOIL)	1.52	2	53 mm TUBE	-
Interbedded grey brown SILTY SAND and red brown SILTY CLAY	2.13			
Red brown SILTY CLAY	2.64			
End of Borehole	3.05			

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



Flush Mount Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Bentonite Seal

WL in Screen at 0.65 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-10

SHEET 1 OF 1

LOCATION: N 5020208.18 ;E 465754.57

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

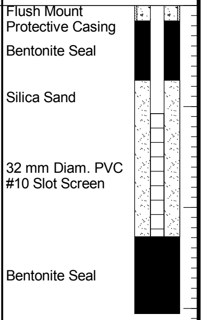
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
		GROUND SURFACE					
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-	
1		Brown silty fine sand, trace clay tile (FILL)	0.84				
		Black to grey silty fine sand, trace organic matter (TOPSOIL)	1.14				
2		Brown fine SILTY SAND	1.52	2	53 mm TUBE	-	
		Red brown SILTY CLAY	2.29				
3		End of Borehole	3.05				

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



WL in Screen at 0.64 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

Table A-1
Summary of Exploration Gas Well Reference Numbers

OGS Map Designation(1)	Well Name(2)	Well ID(3)
RU-1	Consumers No. 12022	T002264
RU-2	Consumers No. 12417	T002386
RU-3	Consumers No. 16050	T002438
RU-4	Consumers' 16051	T002443
RU-5	Consumers No. 16052	T002491
RU-6	Consumers Well# 16306	T002451
RU-7	Consumers No. 16307	T002468
RU-8	Consumers No. 16308	T002469
RU-9	Consumers No. 16309	T002476
RU-10	Consumers No. 16310	T002511
RU-11	Consumers No. 16311	T002535
RU-12	Consumers No. 16312	T002553
RU-13	Consumers No. 16313	T002552
RU-14	Consumers No. 16314	T002580
RU-15	Consumers No. 16315	T002592
RU-16	Consumers No. 16316	T002596
RU-17	Consumers No. 16317	T002629
RU-18	Consumers No. 16318	T002630
RU-19	Consumers 16319	T002628
RU-20	Consumers 16320	T002610
RU-21	Consumers No. 16321	T002661
RU-22	Consumers No. 16322	T002664
RU-23	Ottawa Dairy	N002586
RU-24	Geological Survey of Canada No. 2	T002252
RU-25	Standard Oil Company of Canada	N002585
RU-26	Standard Oil Company of Canada - Collins No. 1	N002584

Notes:

(1) - Williams, D.A., Rae, A.M., and Wolf. R.R. 1985: Paleozoic Geology of the Russell-Thurso Area. Southern Ontario: Ontario Geological Survey, Map P.2717, 1: 50,000.

(2) - Well name as provided on the Oil Gas and Salt Resource Library Well Card.

(3) - Well ID as provided by the Oil Gas and Salt Resource Library Well Card.

Table A-2
Summary of Exploration Gas Well Formation Depths

Borehole Number	Total depth	Drift	Bedrock Surface	10-Queenston Fm	9-Carlsbad Fm Bentonite	Bentonite layer	8B-Eastview M	8A-Lindsay Fm	7-Verulam Fm	6-Bobcaygeon Fm	5-Gull River Fm	4B-Upper Rockcliffe Fm	4A-Lower Rockcliffe Fm	3-Oxford/ March Fm	Nepean Fm WC	2-Nepean Fm G	1-Precambrian
RU-01	811.1	2.7	7.3	- -	7.3	89	228	238	260	302	392	430	446	496	610	646	802.8
RU-02	846.1	1.8	4.57	- -	4.57	96	235	245	265	308	400	437	455	506	618	658	826.6
RU-03	733.7	0.01	8.84	- -	8.84	25	166	175	197	236	328	364	379	426	541	579	722.4
RU-04	749.8	2.4	3.05	- -	3.05	86	217	226	248	264	354	390	408	457	569	608	742.5
RU-05	563	0.3	8.2	- -	8.2	37.5	180	190	208	252	343	380	397	442	559.6	- -	- -
RU-06	896.7	1.5	2.1	2.1	73	169	308.5	318	338	382	475	511	527	584	690	720	853.4
RU-07	732.1	2.7	3.7	- -	3.7	86.5	- -	- -	200	234	324	359	375	423	542.5	590	718
RU-08	811.1	1.8	4	- -	4	81	199.6	209	231	277.5	380	420	436	487	611	652	793.1
RU-09	729.1	1.9	10.3	- -	10.3	21	165	175	193	237	329	359	376	421	545.6	579	710.8
RU-10	722.4	1.8	3.1	- -	3.1	30	170	180	202	245	338	374	392	447	568	612	709.6
RU-11	572.7	0.3	6.4	- -	6.4	55	160	170	188	237	334	374	391	441	533	- -	- -
RU-12	569.4	0.3	1.5	- -	1.5	44	186	196	213	260	351	388	404	452	- -	- -	- -
RU-13	546.8	0.3	3.4	- -	3.4	25	167	177	195	239	331	368	384	429	- -	- -	- -
RU-14	541.6	0.3	4	- -	4	54	- -	168	182	226	318	355	372	417	- -	- -	- -
RU-15	540.1	0.3	1.5	- -	1.5	14	155	163	184	228	320	356	373	419	- -	- -	- -
RU-16	486.5	0.3	1.2	- -	1.2	30	172	182	200	244	335	372	389	435	- -	- -	- -
RU-17	556.3	0.3	5.5	- -	5.5	65	175	185	202	248	339	375	392	439	- -	- -	- -
RU-18	548.9	0.3	3.7	- -	3.7	71.5	214	224	241	288	382	417	433	462	- -	- -	- -
RU-19	537.7	0.3	1.8	- -	1.8	22	163	173	190	234	329	365	382	427	- -	- -	- -
RU-20	538.3	0.3	2.1	- -	2.1	26	165	175	192	237	329	366	382	428	- -	- -	- -
RU-21	734.6	3.05	6.4	- -	6.4	18	162	171	192	234	326	363	378	425	537.4	581	710.2
RU-22	340.5	0.3	2.4	- -	2.4	14	153.5	161	183	225.5	317	- -	- -	- -	- -	- -	- -
RU-23	387.1	0.3	15.2	- -	15.2	94	225.5	235	257	287.5	380	- -	- -	- -	- -	- -	- -
RU-24	823	0.01	14	14	39	139	274	283	308	339	440	479	494	554	663	700	- -
RU-25	304.8	2.1	14	- -	14	105	237	247	269	302	- -	- -	- -	- -	- -	- -	- -
RU-26	585.2	0.3	18.3	- -	18.3	78	204	214	236	276	369	405	423	480	- -	- -	- -

Notes:
All depths are in metres
- - formation or member not encountered
Fm - Formation
M - Member
Nepean Fm G - Golder pick for top of contact of Nepean Formation marking transition into silica sandstone sequence
Nepean Fm WC - Well card pick for top of Nepean Formation (possible dolomitic sandstone of March Formation)

Table A-3
Summary of Exploration Gas Well Formation Elevations

Borehole Number	Total depth	Drift	Bedrock Surface	10-Queenston Fm	9-Carlsbad Fm Bentonite	Bentonite layer	8B-Eastview M	8A-Lindsay Fm	7-Verulam Fm	6-Bobcaygeon Fm	5-Gull River Fm	4B-Upper Rockcliffe Fm	4A-Lower Rockcliffe Fm	3-Oxford/ March Fm	Nepean Fm WC	2-Nepean Fm G	1-Precambrian
RU-01	-732.2	76.2	71.6	- -	71.6	-10.1	-149.1	-159.1	-181.1	-223.1	-313.1	-351.1	-367.1	-417.1	-531.1	-567.1	-723.9
RU-02	-765.9	78.4	75.63	- -	75.63	-15.8	-154.8	-164.8	-184.8	-227.8	-319.8	-356.8	-374.8	-425.8	-537.8	-577.8	-746.4
RU-03	-659	74.69	65.86	- -	65.86	49.7	-91.3	-100.3	-122.3	-161.3	-253.3	-289.3	-304.3	-351.3	-466.3	-504.3	-647.7
RU-04	-673.33	74.07	73.42	- -	73.42	-9.53	-140.53	-149.53	-171.53	-187.53	-277.53	-313.53	-331.53	-380.53	-492.53	-531.53	-666.03
RU-05	-484.1	78.6	70.7	- -	70.7	41.4	-101.1	-111.1	-129.1	-173.1	-264.1	-301.1	-318.1	-363.1	-480.7	- -	- -
RU-06	-820.29	74.91	74.31	74.31	3.41	-92.59	-232.09	-241.59	-261.59	-305.59	-398.59	-434.59	-450.59	-507.59	-613.59	-643.59	-776.99
RU-07	-656.81	72.59	71.59	- -	71.59	-11.21	- -	- -	-124.71	-158.71	-248.71	-283.71	-299.71	-347.71	-467.21	-514.71	-642.71
RU-08	-736.4	72.9	70.7	- -	70.7	-6.3	-124.9	-134.3	-156.3	-202.8	-305.3	-345.3	-361.3	-412.3	-536.3	-577.3	-718.4
RU-09	-652.3	74.9	66.5	- -	66.5	55.8	-88.2	-98.2	-116.2	-160.2	-252.2	-282.2	-299.2	-344.2	-468.8	-502.2	-634
RU-10	-645.6	75	73.7	- -	73.7	46.8	-93.2	-103.2	-125.2	-168.2	-261.2	-297.2	-315.2	-370.2	-491.2	-535.2	-632.8
RU-11	-497.7	74.7	68.6	- -	68.6	20	-85	-95	-113	-162	-259	-299	-316	-366	-458	- -	- -
RU-12	-489.8	79.3	78.1	- -	78.1	35.6	-106.4	-116.4	-133.4	-180.4	-271.4	-308.4	-324.4	-372.4	- -	- -	- -
RU-13	-468.8	77.7	74.6	- -	74.6	53	-89	-99	-117	-161	-253	-290	-306	-351	- -	- -	- -
RU-14	-466.3	75	71.3	- -	71.3	21.3	- -	-92.7	-106.7	-150.7	-242.7	-279.7	-296.7	-341.7	- -	- -	- -
RU-15	-464.8	75	73.8	- -	73.8	61.3	-79.7	-87.7	-108.7	-152.7	-244.7	-280.7	-297.7	-343.7	- -	- -	- -
RU-16	-410	76.2	75.3	- -	75.3	46.5	-95.5	-105.5	-123.5	-167.5	-258.5	-295.5	-312.5	-358.5	- -	- -	- -
RU-17	-483.1	72.9	67.7	- -	67.7	8.2	-101.8	-111.8	-128.8	-174.8	-265.8	-301.8	-318.8	-365.8	- -	- -	- -
RU-18	-475.8	72.8	69.4	- -	69.4	1.6	-140.9	-150.9	-167.9	-214.9	-308.9	-343.9	-359.9	-388.9	- -	- -	- -
RU-19	-463.6	73.8	72.3	- -	72.3	52.1	-88.9	-98.9	-115.9	-159.9	-254.9	-290.9	-307.9	-352.9	- -	- -	- -
RU-20	-464.23	73.77	71.97	- -	71.97	48.07	-90.93	-100.93	-117.93	-162.93	-254.93	-291.93	-307.93	-353.93	- -	- -	- -
RU-21	-654.44	77.11	73.76	- -	73.76	62.16	-81.84	-90.84	-111.84	-153.84	-245.84	-282.84	-297.84	-344.84	-457.24	-500.84	-630.04
RU-22	-266.4	73.8	71.7	- -	71.7	60.1	-79.4	-86.9	-108.9	-151.4	-242.9	- -	- -	- -	- -	- -	- -
RU-23	-315.5	71.3	56.4	- -	56.4	-22.4	-153.9	-163.4	-185.4	-215.9	-308.4	- -	- -	- -	- -	- -	- -
RU-24	-749.2	73.79	59.8	59.8	34.8	-65.2	-200.2	-209.2	-234.2	-265.2	-366.2	-405.2	-420.2	-480.2	-589.2	-626.2	- -
RU-25	-227.7	75	63.1	- -	63.1	-27.9	-159.9	-169.9	-191.9	-224.9	- -	- -	- -	- -	- -	- -	- -
RU-26	-511.4	73.5	55.5	- -	55.5	-4.2	-130.2	-140.2	-162.2	-202.2	-295.2	-331.2	-349.2	-406.2	- -	- -	- -

Notes:

All elevations are in metres above sea level

- - formation or member not encountered

Fm - Formation

M - Member

Nepean Fm G - Golder pick for top of contact of Nepean Formation marking transition into silica sandstone sequence

Nepean Fm WC - Well card pick for top of Nepean Formation (possible dolomitic sandstone of March Formation)

PLOT DATE: June 27, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase 4000\1211250045-4000-A-1.dwg

BEDROCK GEOLOGY

10 QUEENSTON FORMATION

Dark reddish brown calcareous mudstone with interbeds of greenish grey siltstone and mudstone.

9 CARLSBAD/BILLINGS FORMATIONS

Dark grey shale interbedded with micritic limestone interbeds (Carlsbad Fm) grading down to dark grey to dark brownish black bituminous shale with minor laminations to very thin interbeds of calcareous siltstone and dolomitic limestone (Billings Fm).

8B UPPER LINDSAY FORMATION (EASTVIEW MEMBER)

Interbedded dark brownish black bituminous shale and dark brownish grey nodular micritic limestone.

8A LOWER LINDSAY FORMATION

Medium to dark brownish grey thickly bedded micritic to calcarenitic nodular limestone.

7 VERULAM FORMATION

Medium brownish grey thinly to medium bedded shaley calcarenitic limestone with interbeds of nodular limestone, minor thin lithoclastic calcarenite limestone beds and numerous dark grey to black very thin to thinly interbeds shale.

6 BOBCAYGEON FORMATION

Light to medium brownish grey, medium to thickly bedded calcarenitic limestone and interbedded units of argillaceous nodular limestone and shaley limestone.

5 GULL RIVER FORMATION

Medium grey, micritic to lithographic limestone, argillaceous to calcareous dolostone and medium to very thickly bedded dolostone, minor interbedded black shale, shaley dolostone, dolomitic siltstone and partly bioturbated quartz sandstone.

4B UPPER ROCKCLIFFE FORMATION

Interbedded sequence composed of medium to thick beds of dolostone and calcareous dolostone, dark grey to black shale, medium grey, argillaceous limestone, minor light grey, calcareous cemented quartz sandstone.

4A LOWER ROCKCLIFFE FORMATION

Light whitish grey, laminar textured to rippled and cross bedded, thin to thick bedded silica cemented quartz sandstone, minor interbeds of shale.

3 OXFORD/MARCH FORMATIONS

Fine grained, micritic dolostone, calcareous dolostone, argillaceous nodular dolostone, subordinate beds lithoclastic dolostone, dark grey to black shale laminations in upper half (Oxford Fm), grading down to sandy dolostone to dolomitic sandstone and carbonate cemented quartz sandstone.

2 NEPEAN FORMATION

Light grey, laminar to cross bedded, silica cemented quartz sandstone. Includes widely spaced interbeds of grey shale and shaley siltstone with individual beds of quartz pebbles and cobbles set in a coarse grained quartz sandstone matrix. 2A Golder pick for top contact of Nepean Fm marking transition into silica sandstone sequence, 2B MNR Well Card pick for top of Nepean Fm (possible dolomitic sandstone of March Fm). Includes un-subdivided Covey Hill Fm sandstone and conglomerate at base if present.

1 PRECAMBRIAN BASEMENT

Quartz feldspar biotite gneiss or dolomitic marble typically weathered near the unconformable surface with either the overlying Covey Hill Formation quartz pebble cobble conglomerate or the Nepean Formation sandstone.

BOREHOLE GEOPHYSICAL RECORDS

NATURAL GAMMA LOG

NEUTRON LOG

◢ DEPTH OF DRILL CASING

△						
REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
LEGEND

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045
DESIGN	JPAO	Sept. 2013
CAD	JFC	Feb. 2014
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

FILE No. 1211250045-4000-A-1.dwg
SCALE AS SHOWN REV.

FIGURE A-1

PLOT DATE: June 27, 2014
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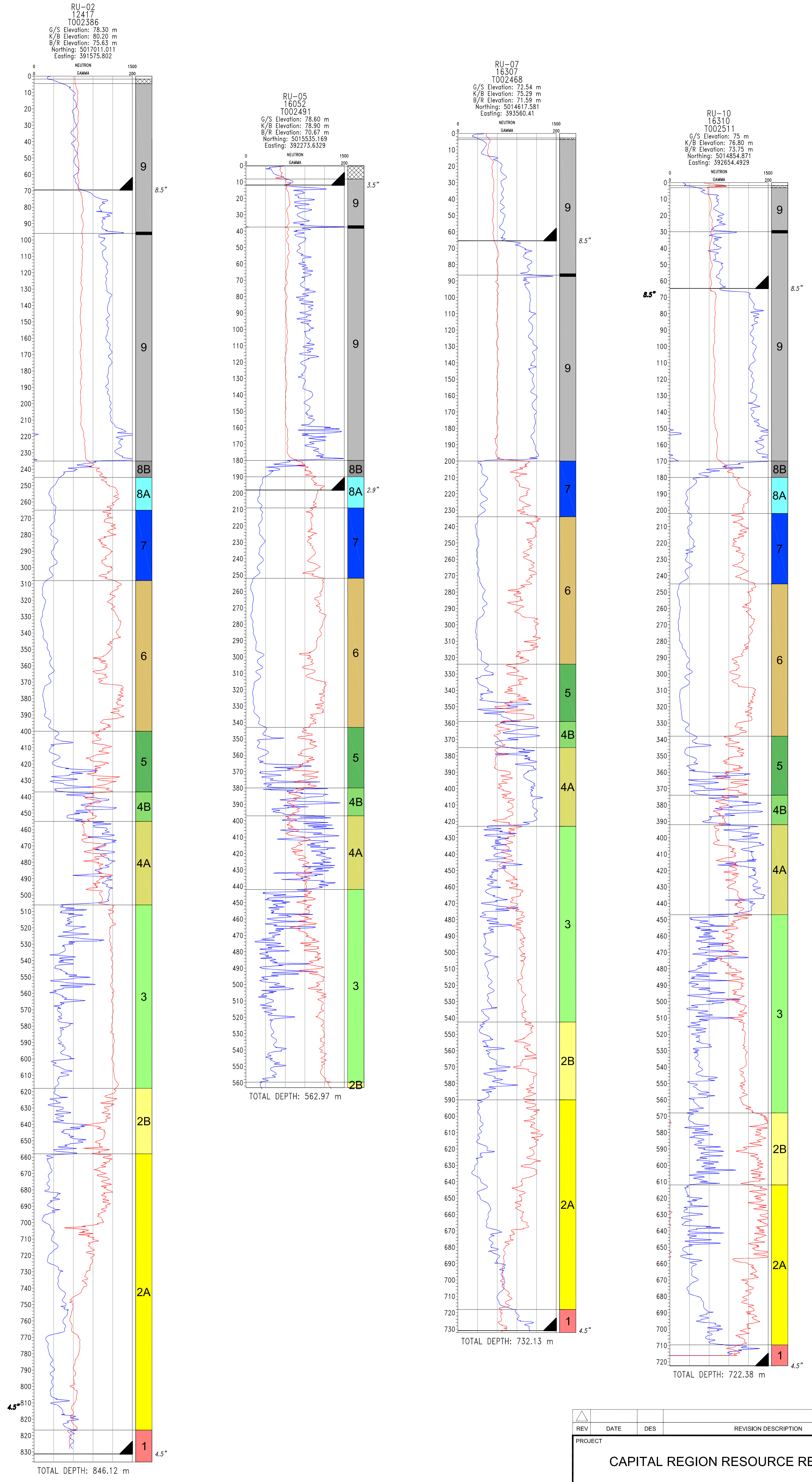

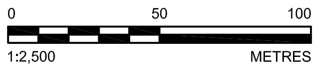

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

BOREHOLES DH RU-2, DH RU-5, DH RU-7 AND DH RU-10

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045
DESIGN	JPAO	Sept. 2013
CAD	JFC	Feb. 2014
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

FILE No. 1211250045-4000-A-2.dwg
SCALE AS SHOWN REV.

FIGURE A-2

PLOT DATE: June 27, 2014
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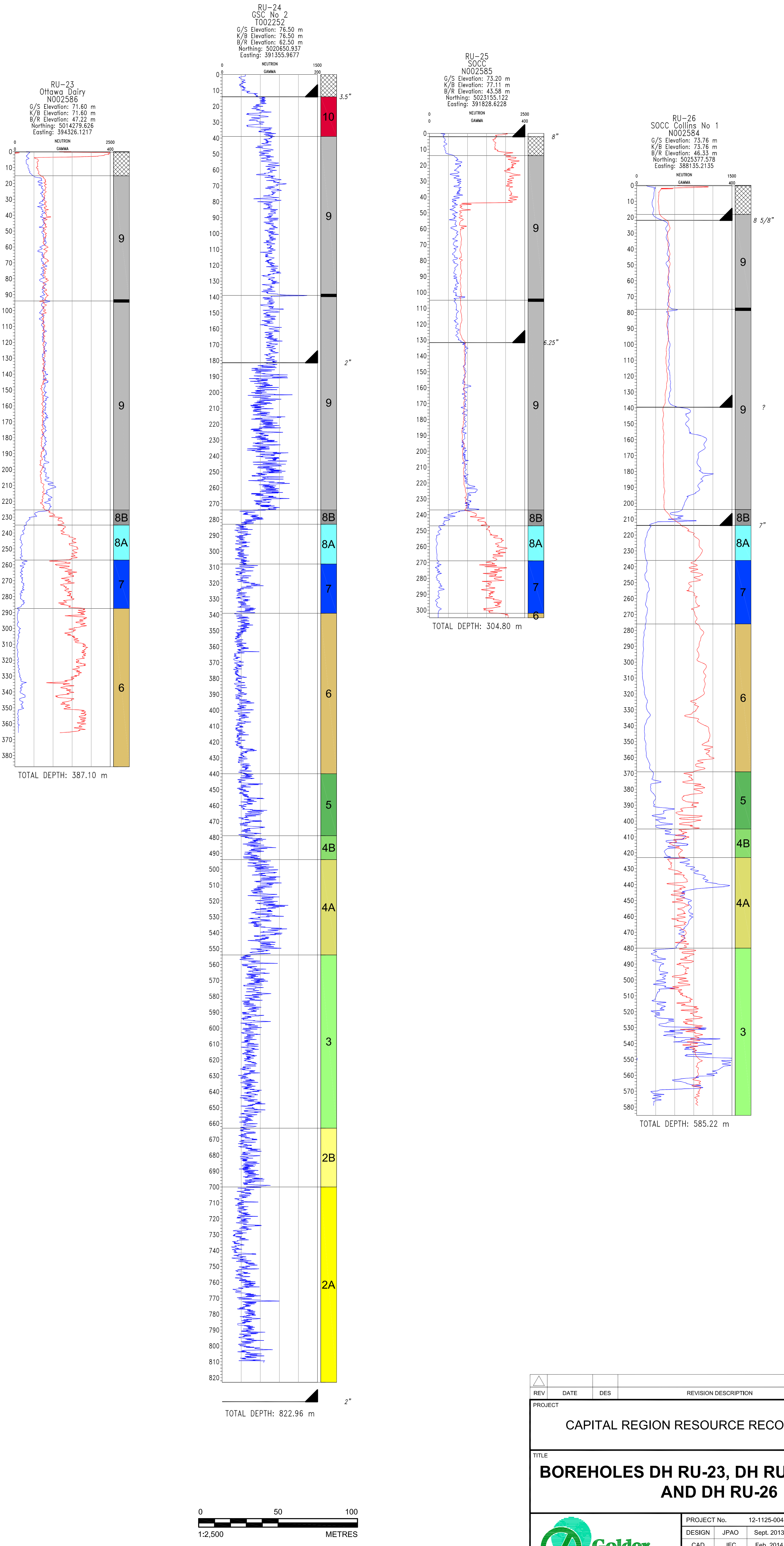


REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

BOREHOLES DH RU-23, DH RU-24, DH RU-25 AND DH RU-26

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		12-1125-0045
DESIGN	JPAO	Sept. 2013
CAD	JFC	Feb. 2014
CHECK	PLE	Aug. 2014
REVIEW	PAS	Aug. 2014

FILE No. 1211250045-4000-A-3.dwg
SCALE AS SHOWN REV.

FIGURE A-3

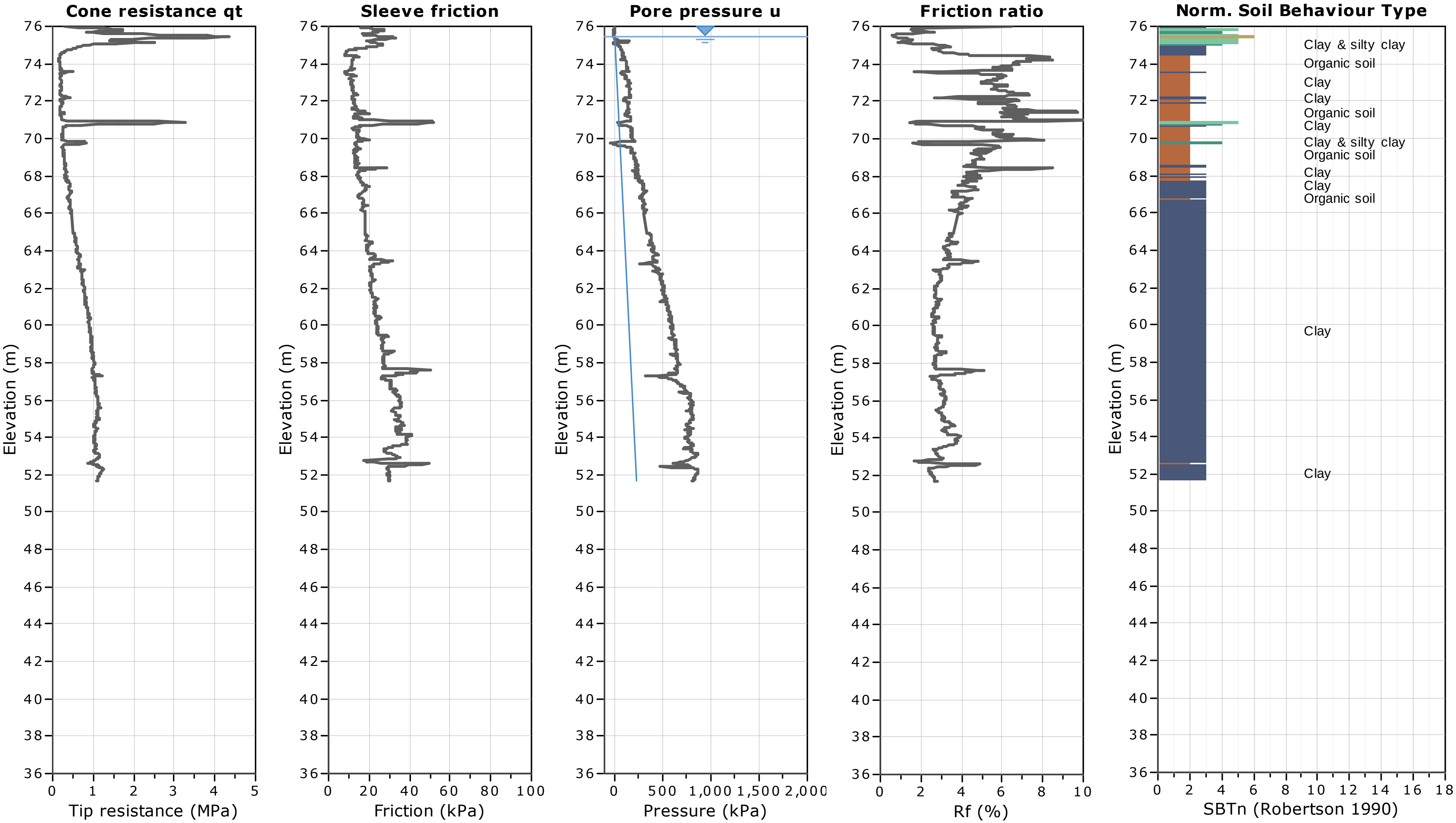
APPENDIX B

CPT Profiles

Golder Associates
Ottawa, ON
www.golder.com

CPT: 12-1-1 Rev 1
Total depth: 24.35 m, Date: 11/14/2012
Surface Elevation: 75.99 m
Coords: N 467130.4, E 5020302.9
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

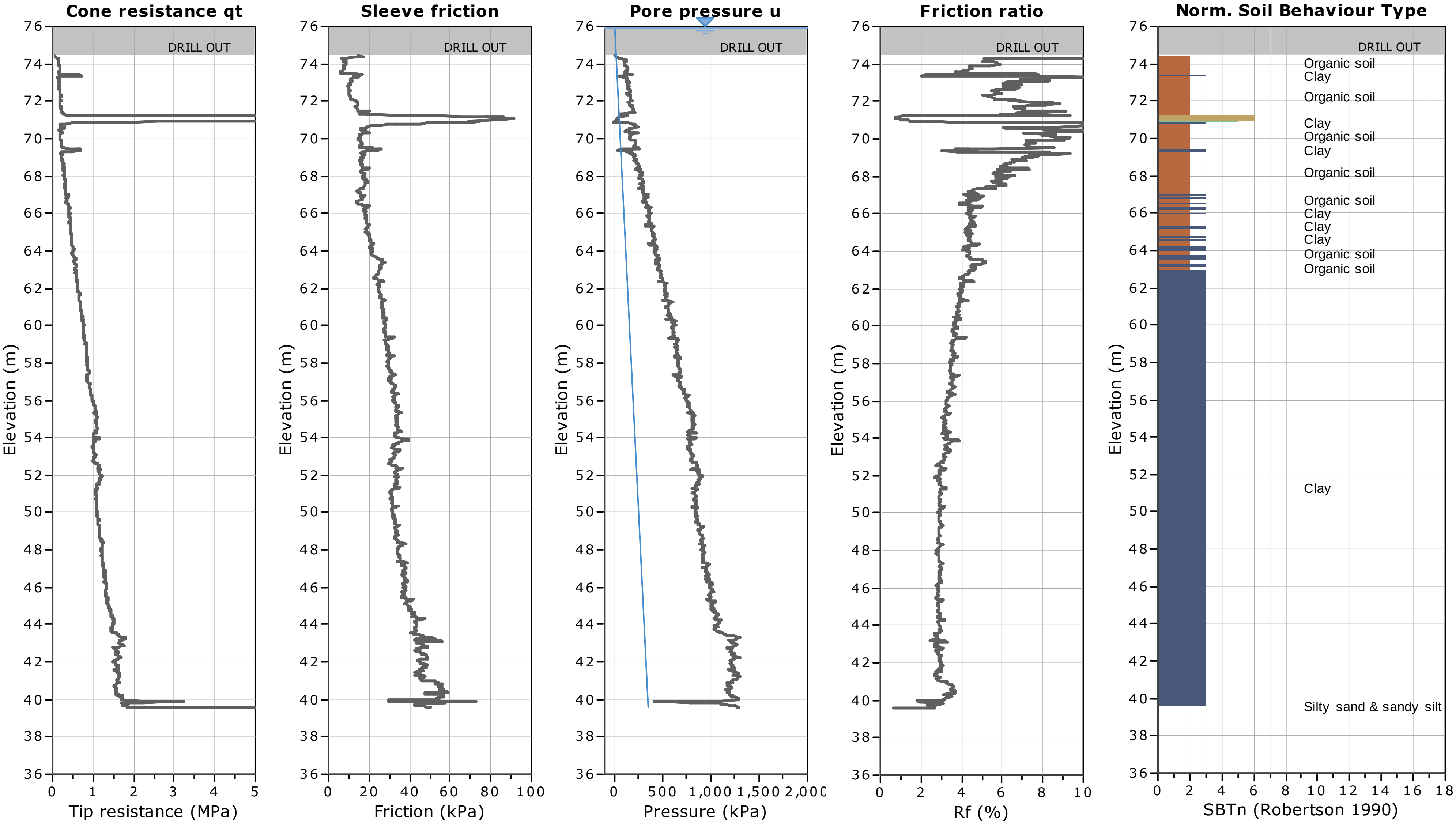
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 12-1-8 Rev 1
Total depth: 36.38 m, Date: 4/3/2013
Surface Elevation: 75.94 m
Coords: N 5020317.0, 467128.0
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

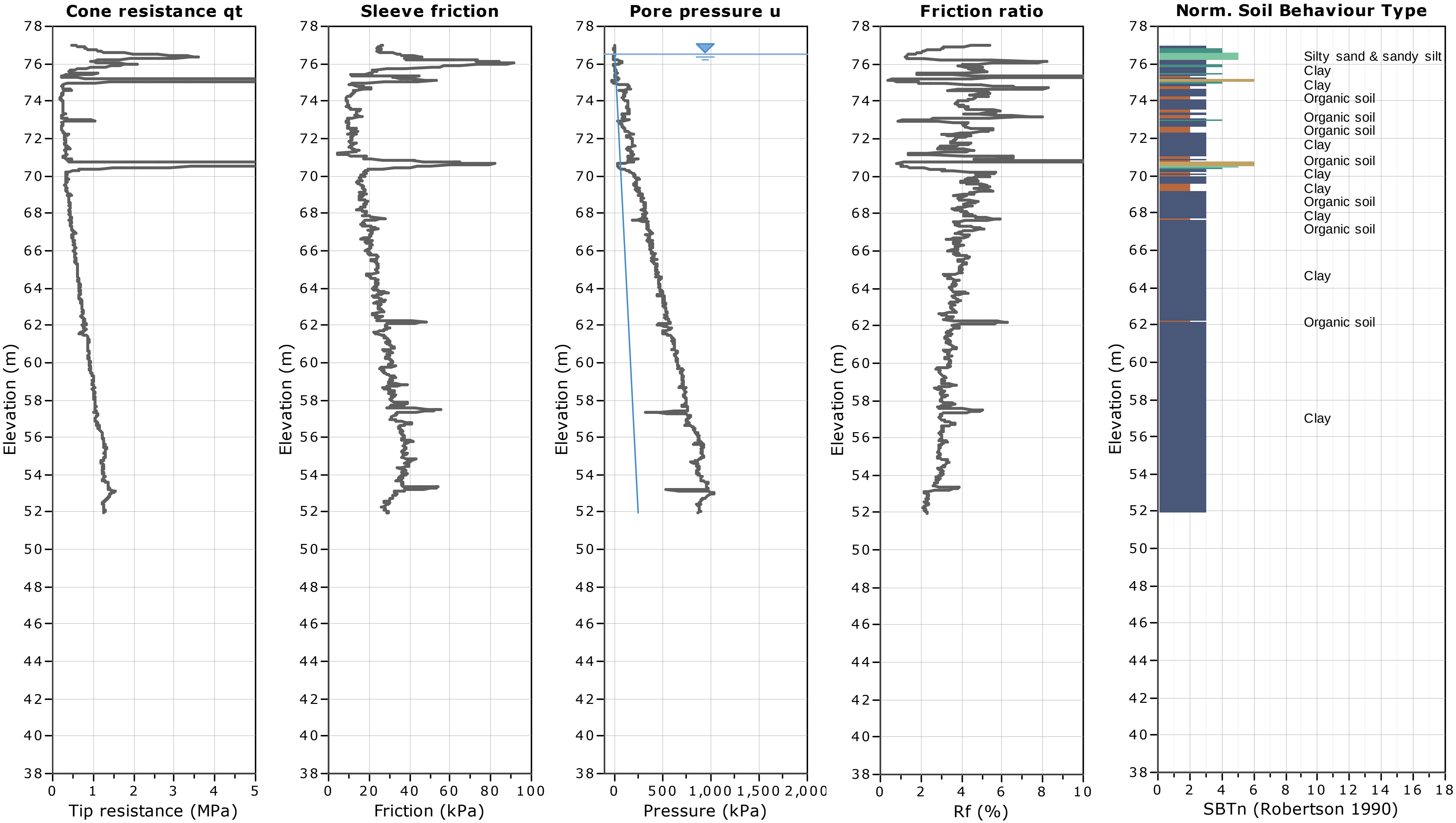
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

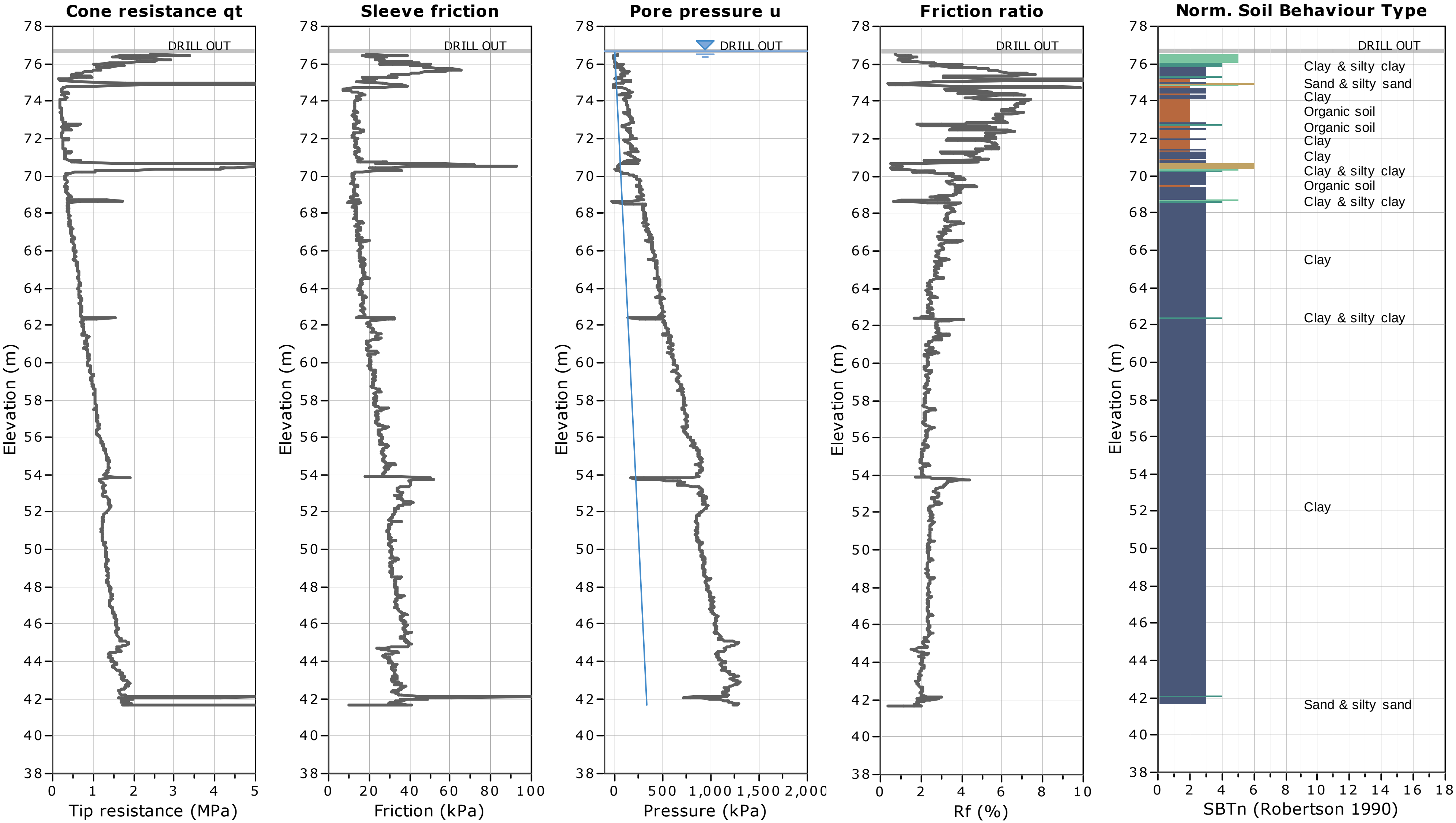
CPT: 12-2-1 Rev 1
Total depth: 25.06 m, Date: 12/20/2012
Surface Elevation: 77.02 m
Coords: N 466155.6, E 5019599.4
Cone Type: 10 cm2, u2, (4039)
Cone Operator: Golder (D. Grylls)



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

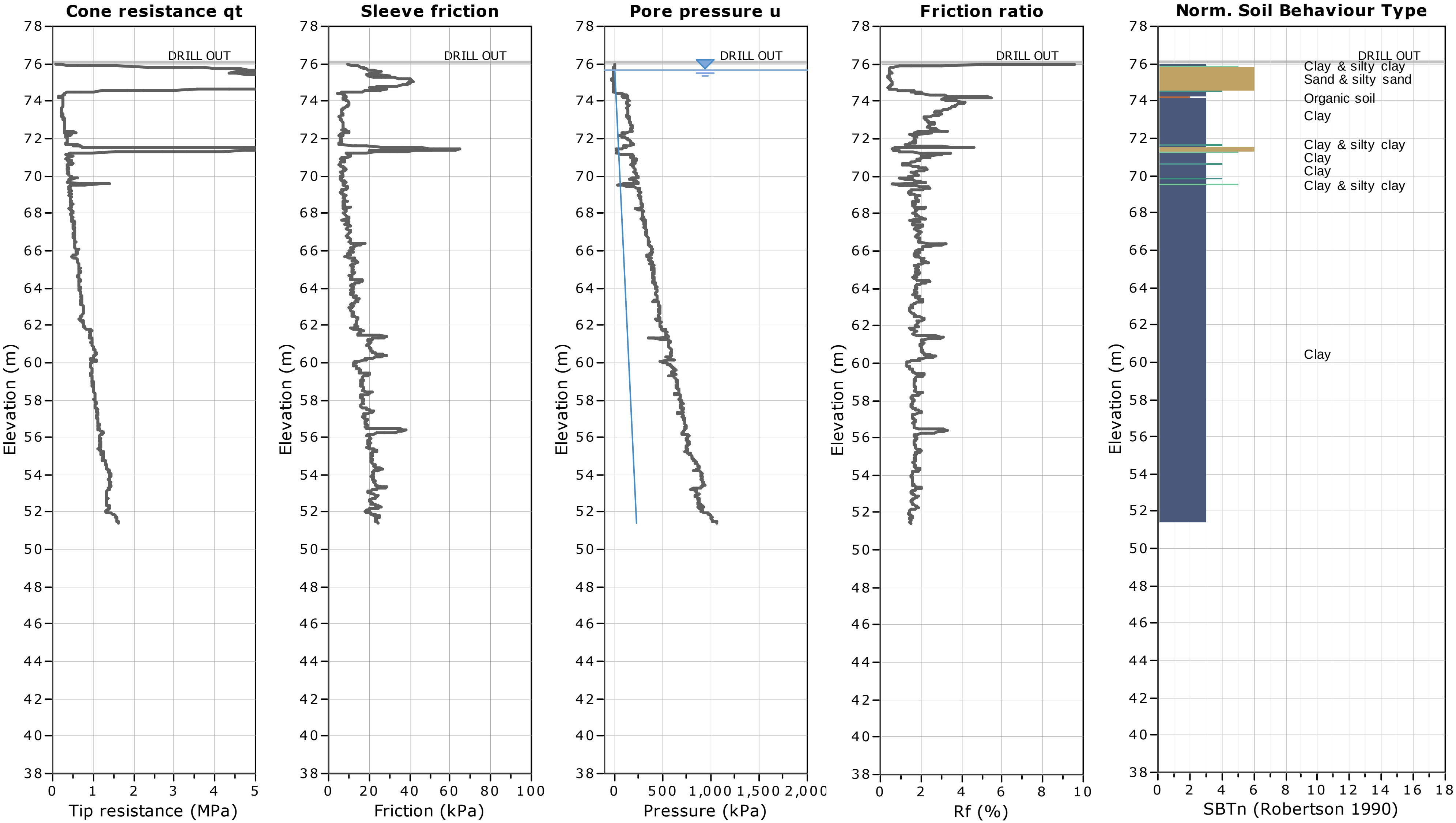
CPT: 12-2-8 Rev 1
Total depth: 35.17 m, Date: 3/18/2013
Surface Elevation: 76.81 m
Coords: N 5019594.0, E 466162.8
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)



Golder Associates
Ottawa, ON
www.golder.com

CPT: 12-3-1 Rev 1
Total depth: 24.71 m, Date: 11/29/2012
Surface Elevation: 76.16 m
Coords: N 5021575.2, E 466663.4
Cone Type: 10 cm2, u2, (4039)
Cone Operator: Golder (D. Grylls)

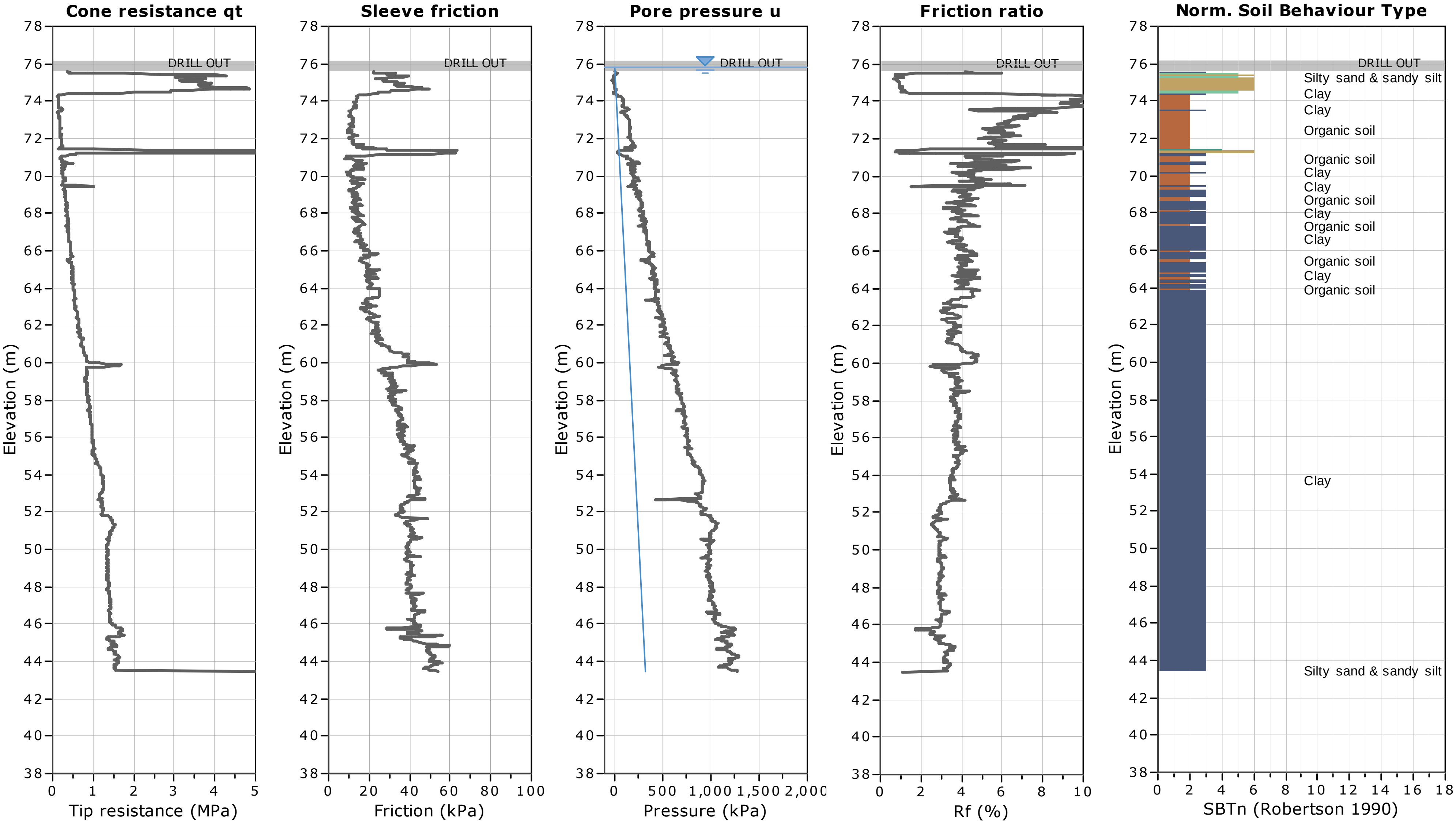
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 12-3-8 Rev 1
Total depth: 32.65 m, Date: 3/12/2013
Surface Elevation: 76.14 m
Coords: N 5021565.0, E 466655.9
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



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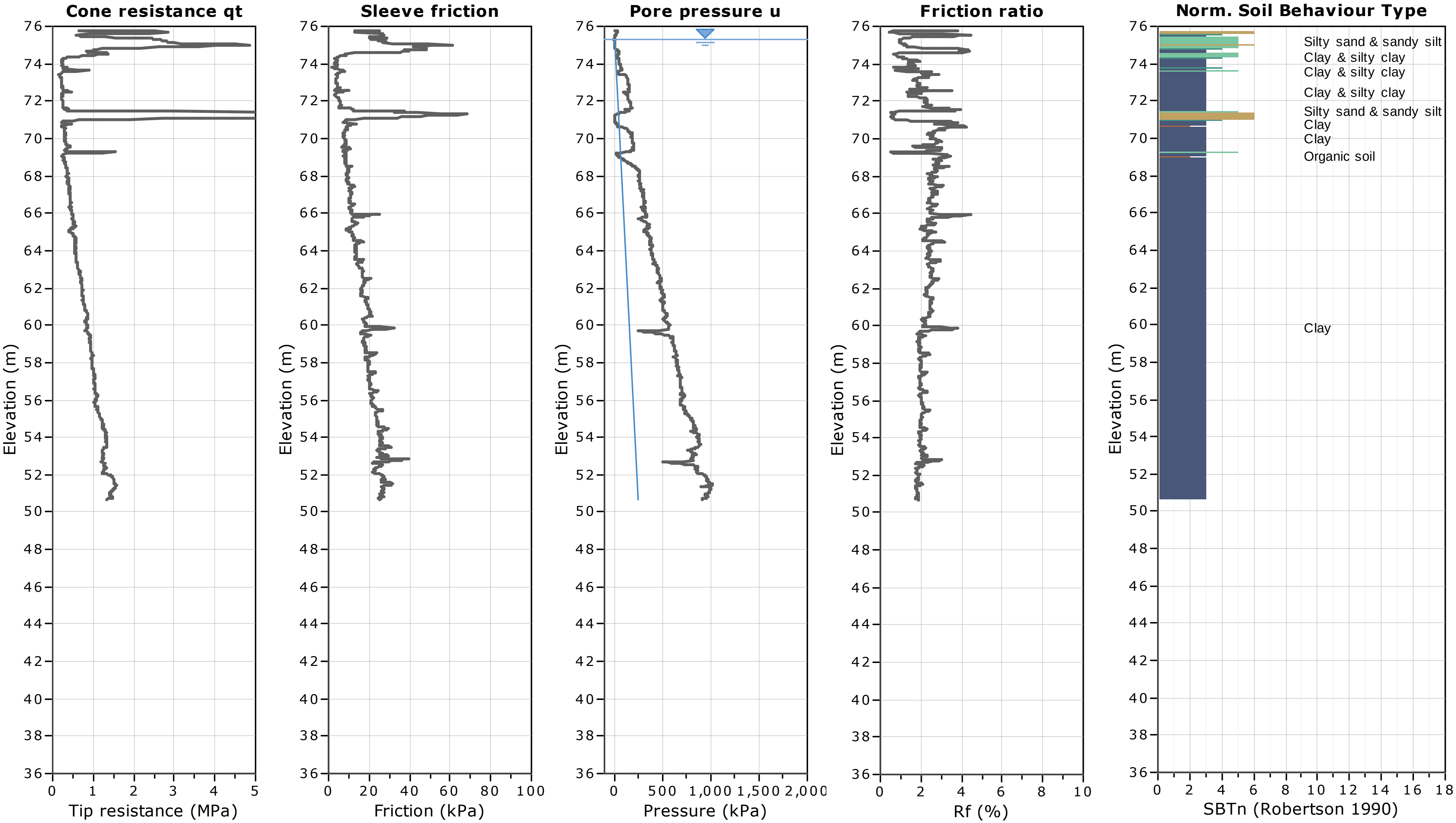
Project file: N:\Active\2012\1125 Ottawa\12-1125-0045 Boundary Road Ottawa\Boundary Road_Rev 1.cpt

Golder Associates
Ottawa, ON
www.golder.com

CPT: 12-4-1 Rev 1
Total depth: 25.20 m, Date: 1/22/2013
Surface Elevation: 75.82 m
Coords: N 5020868.0, E 466524.6
Cone Type: 10 cm2, u2, (4039)
Cone Operator: Golder (D. Grylls)

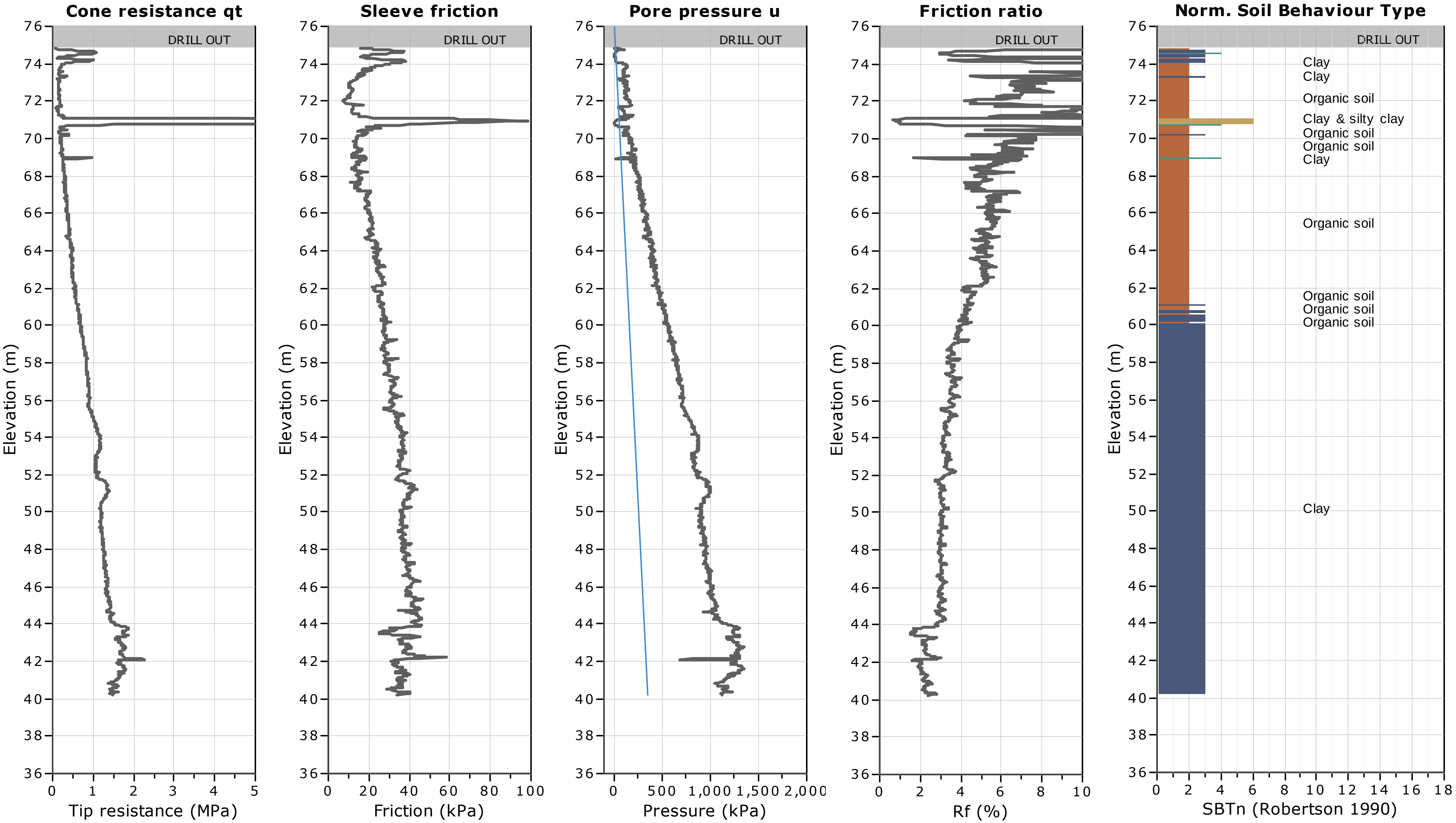
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

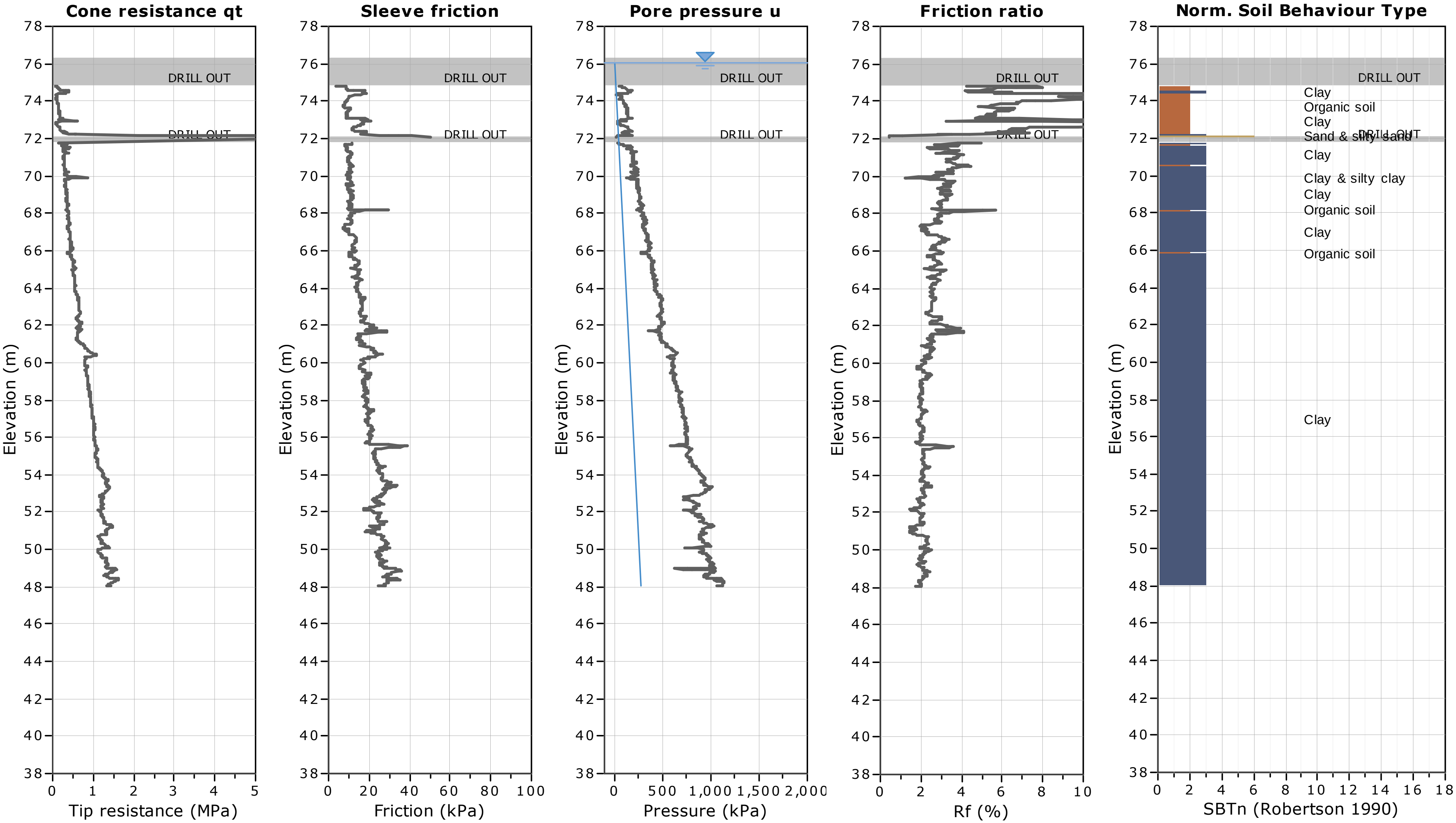
CPT: 12-4-8 Rev 1
Total depth: 35.89 m, Date: 4/2/2013
Surface Elevation: 76.14 m
Coords: N 5020848.0, E 466525.5
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-5-1 Rev 1
Total depth: 28.30 m, Date: 4/9/2013
Surface Elevation: 76.32 m
Coords: N 5021074.0, E 466161.4
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D.Grylls)

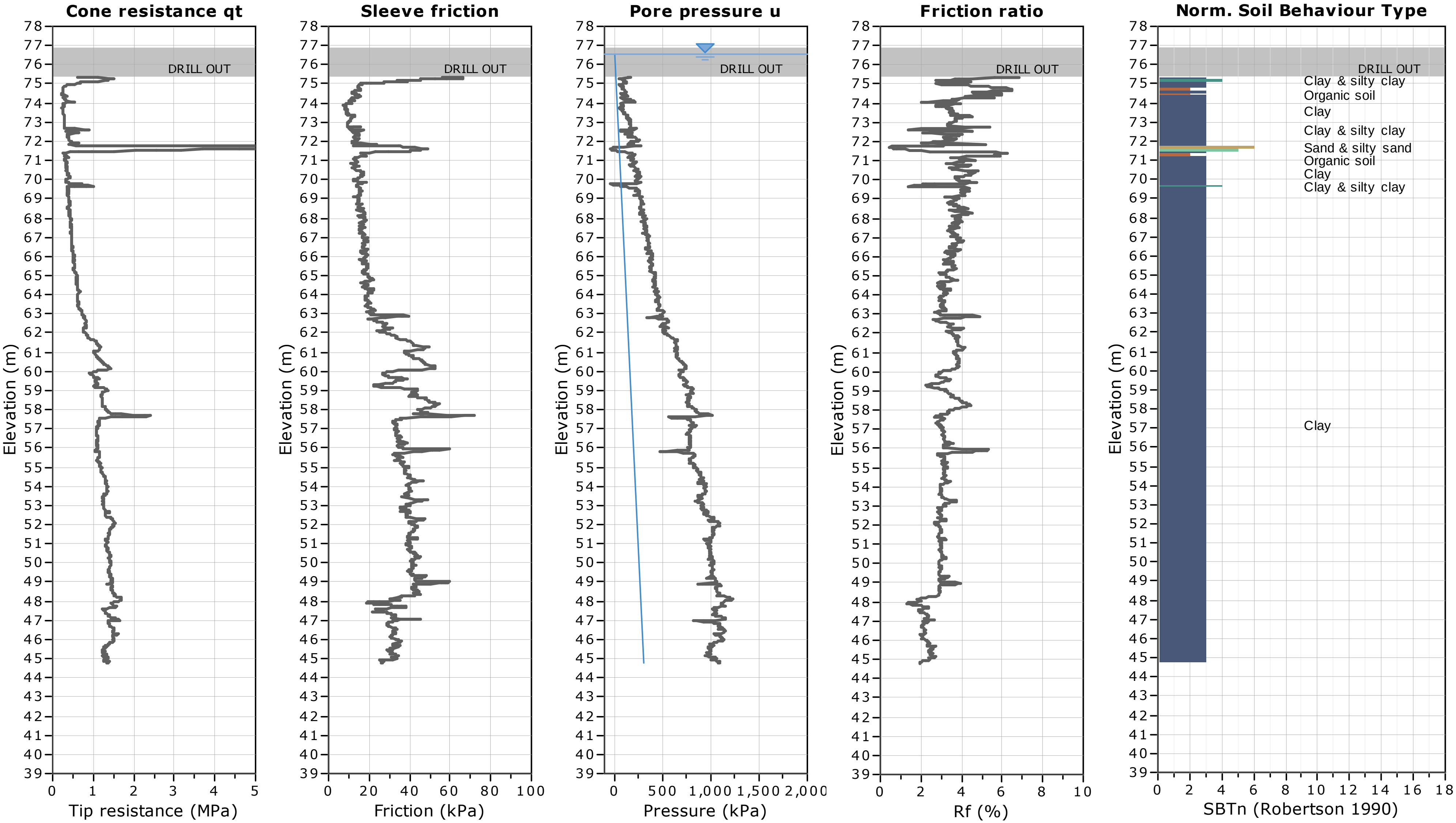
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

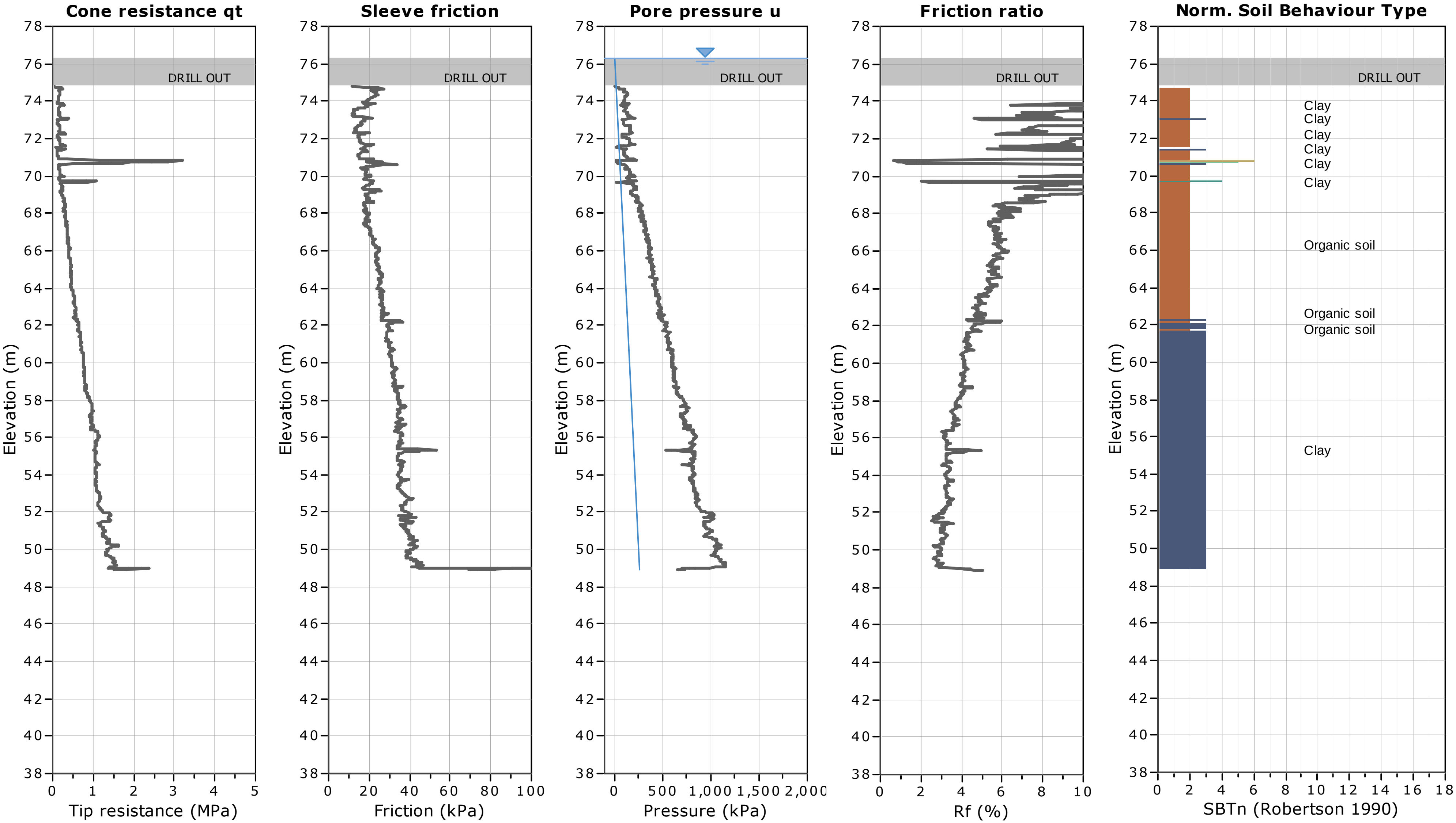
CPT: 13-6-1 Rev 1
Total depth: 32.10 m, Date: 3/27/2013
Surface Elevation: 76.87 m
Coords: N 5020388.0, E 465911.0
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-7-1 Rev 1
Total depth: 27.40 m, Date: 4/5/2013
Surface Elevation: 76.28 m
Coords: N 5020080.0, E 466532.4
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

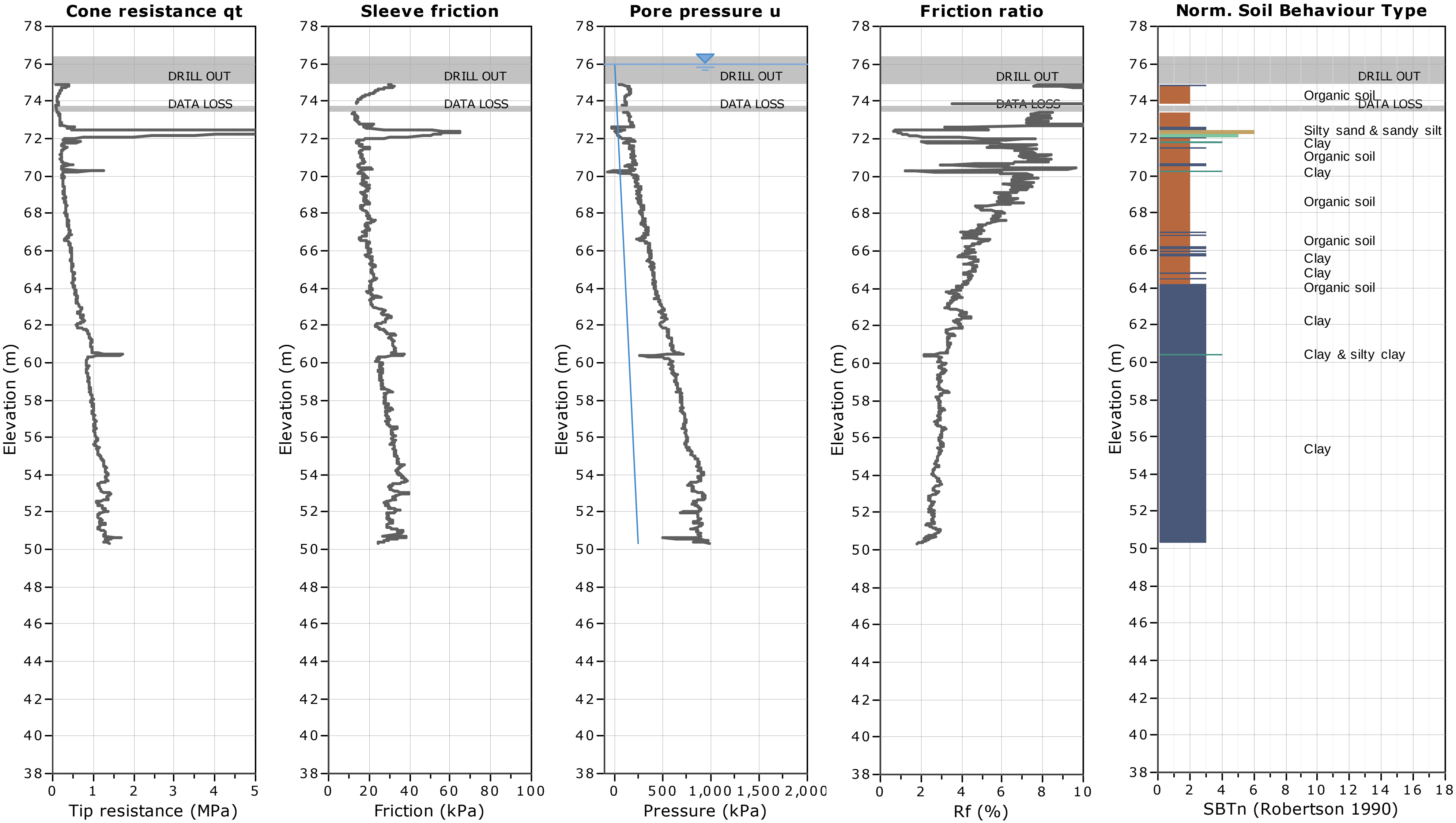
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-8-1 Rev 1
Total depth: 26.06 m, Date: 4/9/2013
Surface Elevation: 76.41 m
Coords: N 5021439.0, E 466041.4
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

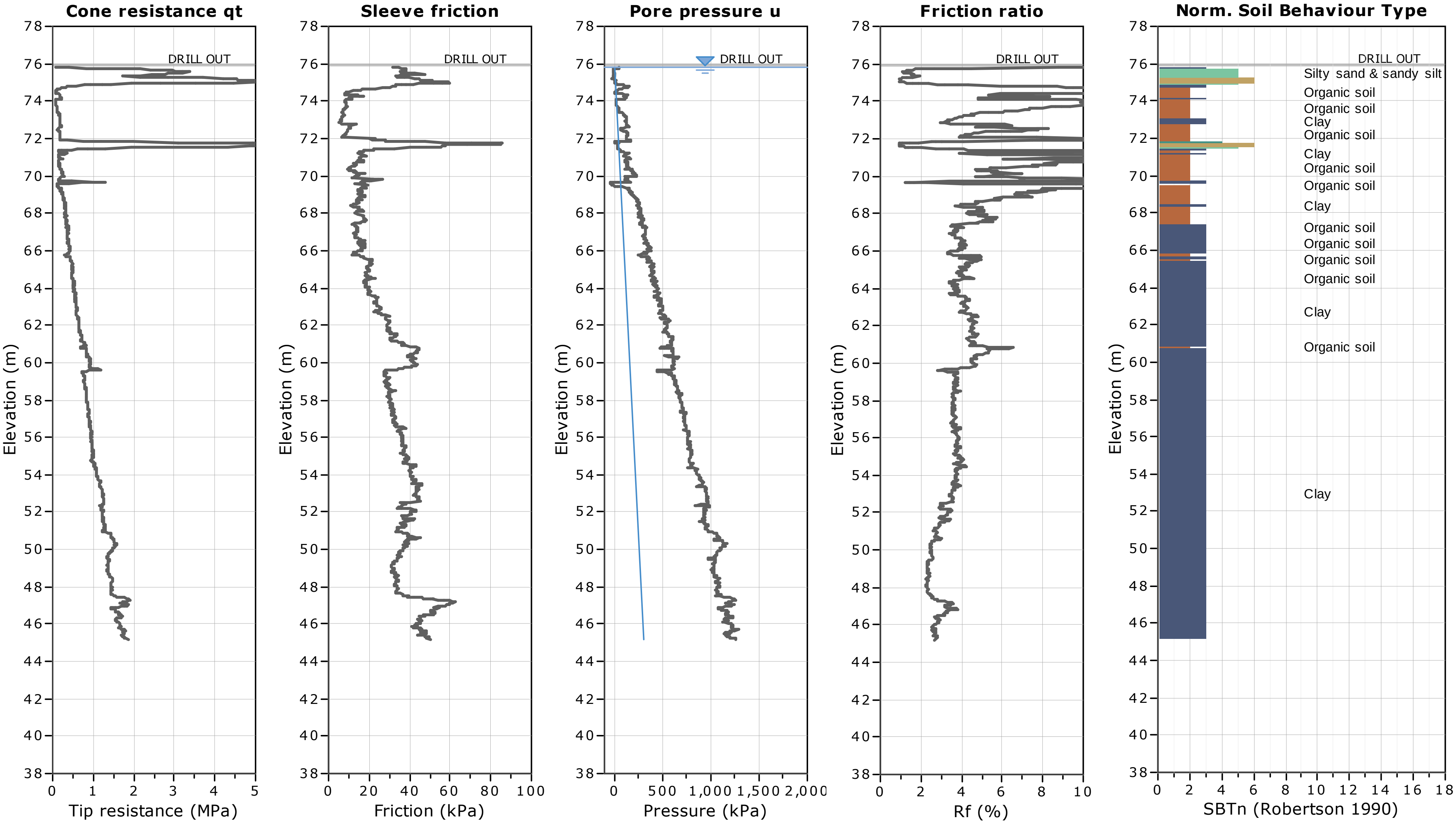
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-9-1 Rev 1
Total depth: 30.82 m, Date: 3/20/2013
Surface Elevation: 76.01 m
Coords: N 5021538.0, E 466351.9
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)

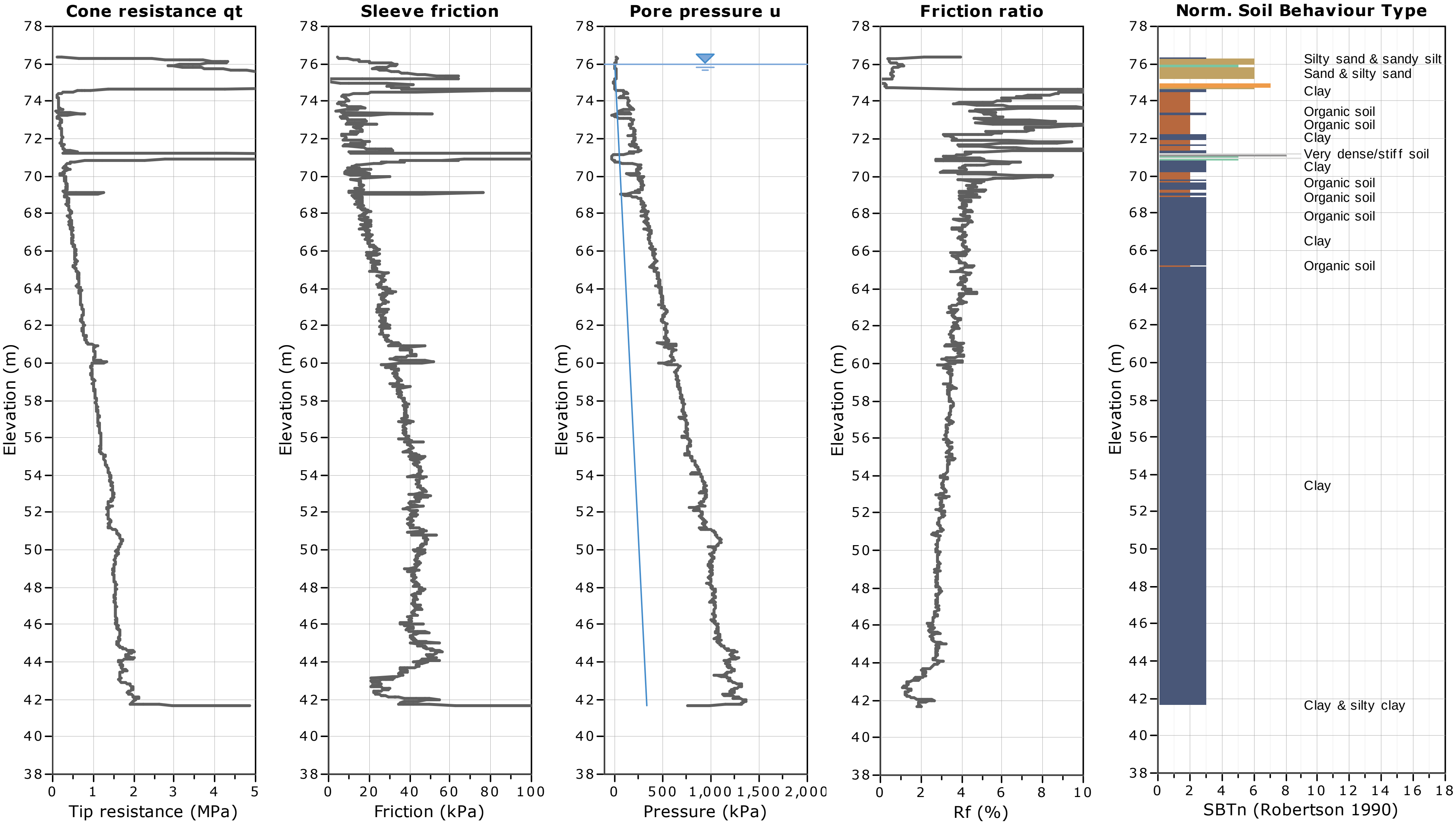
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-10-1 Rev 1
Total depth: 34.82 m, Date: 3/15/2013
Surface Elevation: 76.50 m
Coords: N 5021244.0, E 466448.3
Cone Type: 10 cm2, u2, (4039)
Cone Operator: Golder (K. Edney)

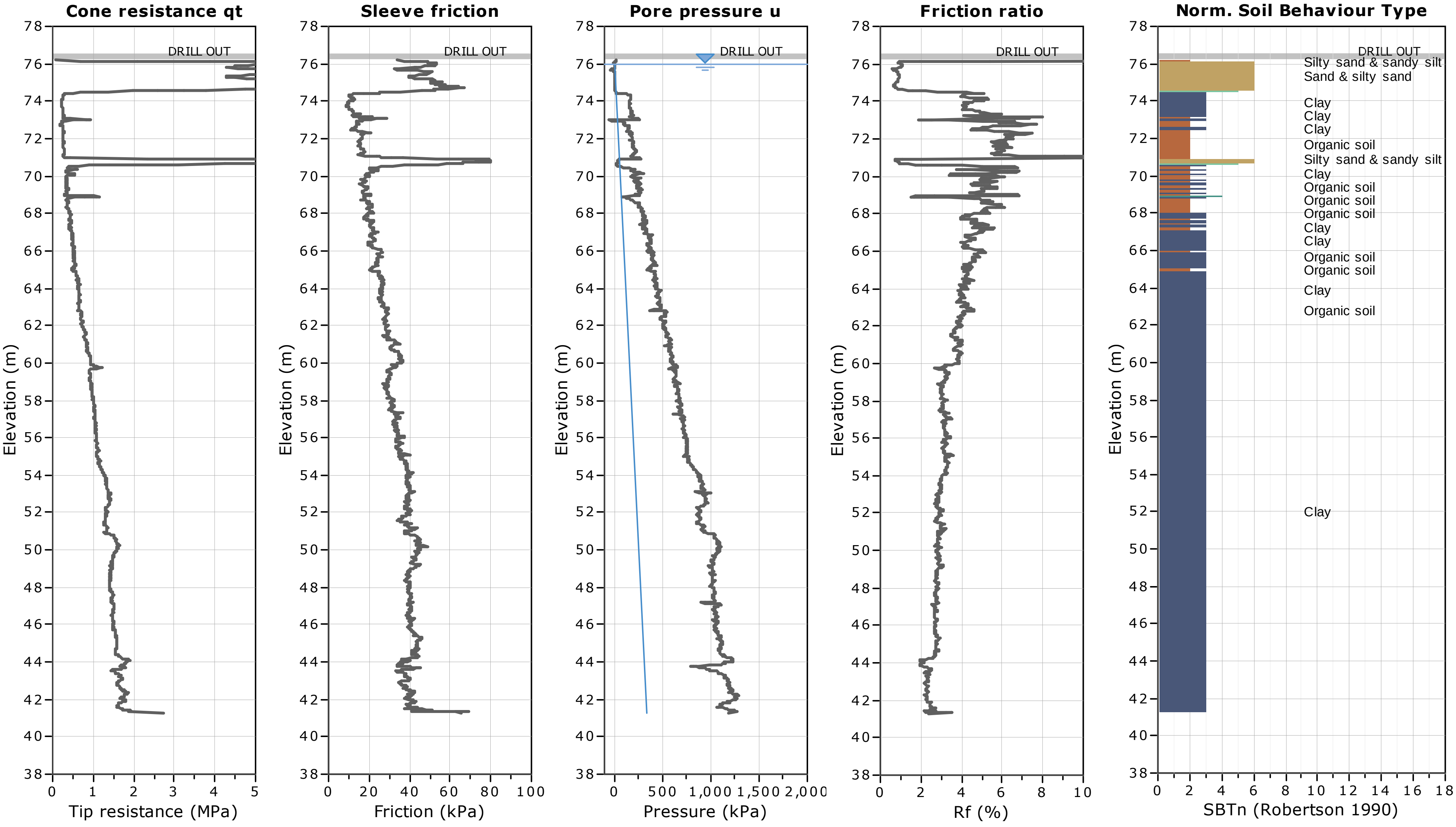
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-10-1A Rev 1
Total depth: 35.22 m, Date: 3/20/2013
Surface Elevation: 76.53 m
Coords: N 5021250.0, E 466452.8
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)

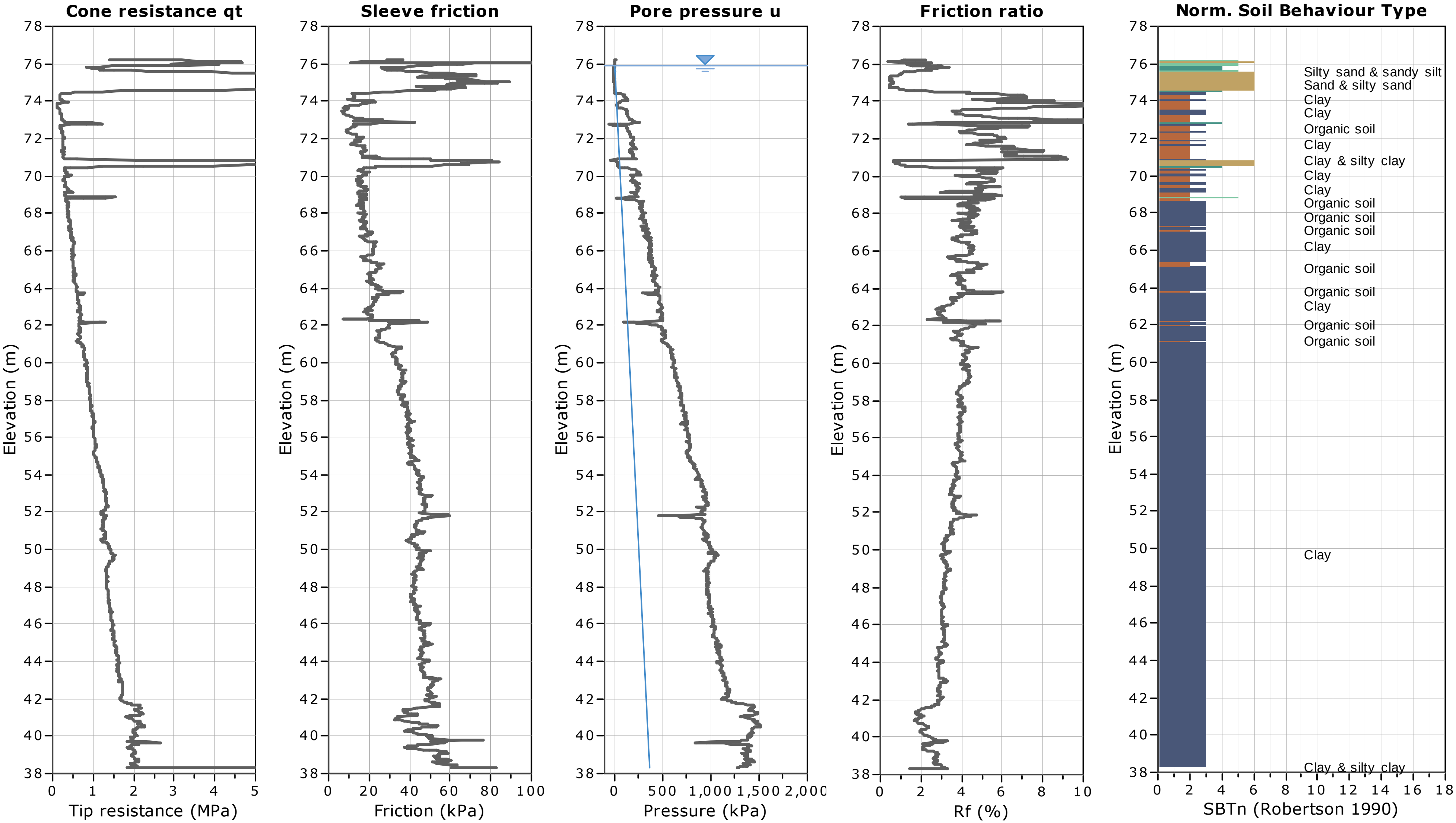
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-11-1 Rev 1
Total depth: 37.93 m, Date: 3/21/2013
Surface Elevation: 76.23 m
Coords: N 5021057.0, E 466859.7
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)

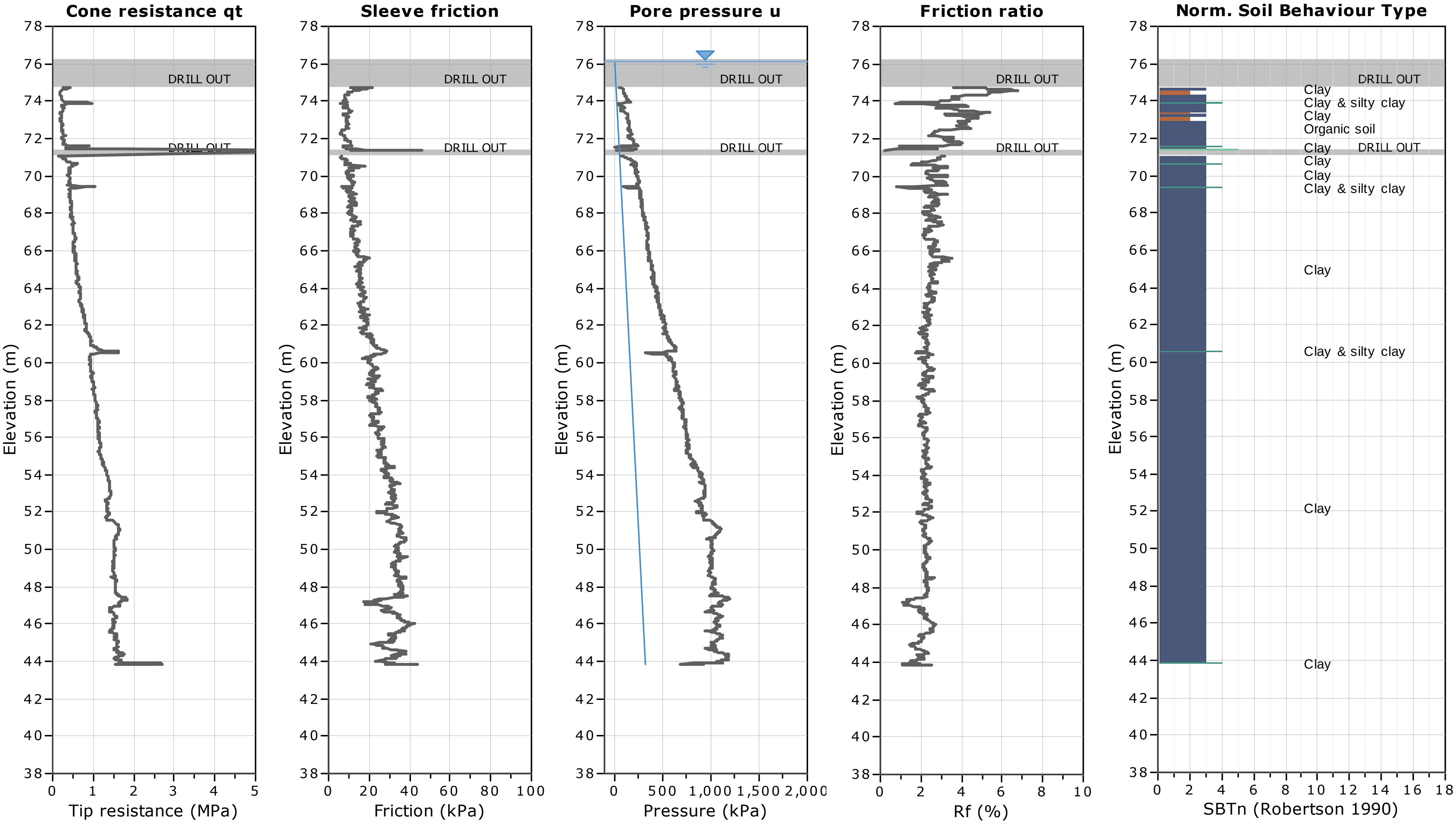
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-12-1 Rev 1
Total depth: 32.43 m, Date: 4/10/2013
Surface Elevation: 76.25 m
Coords: N 5020781.0, E 466280.2
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

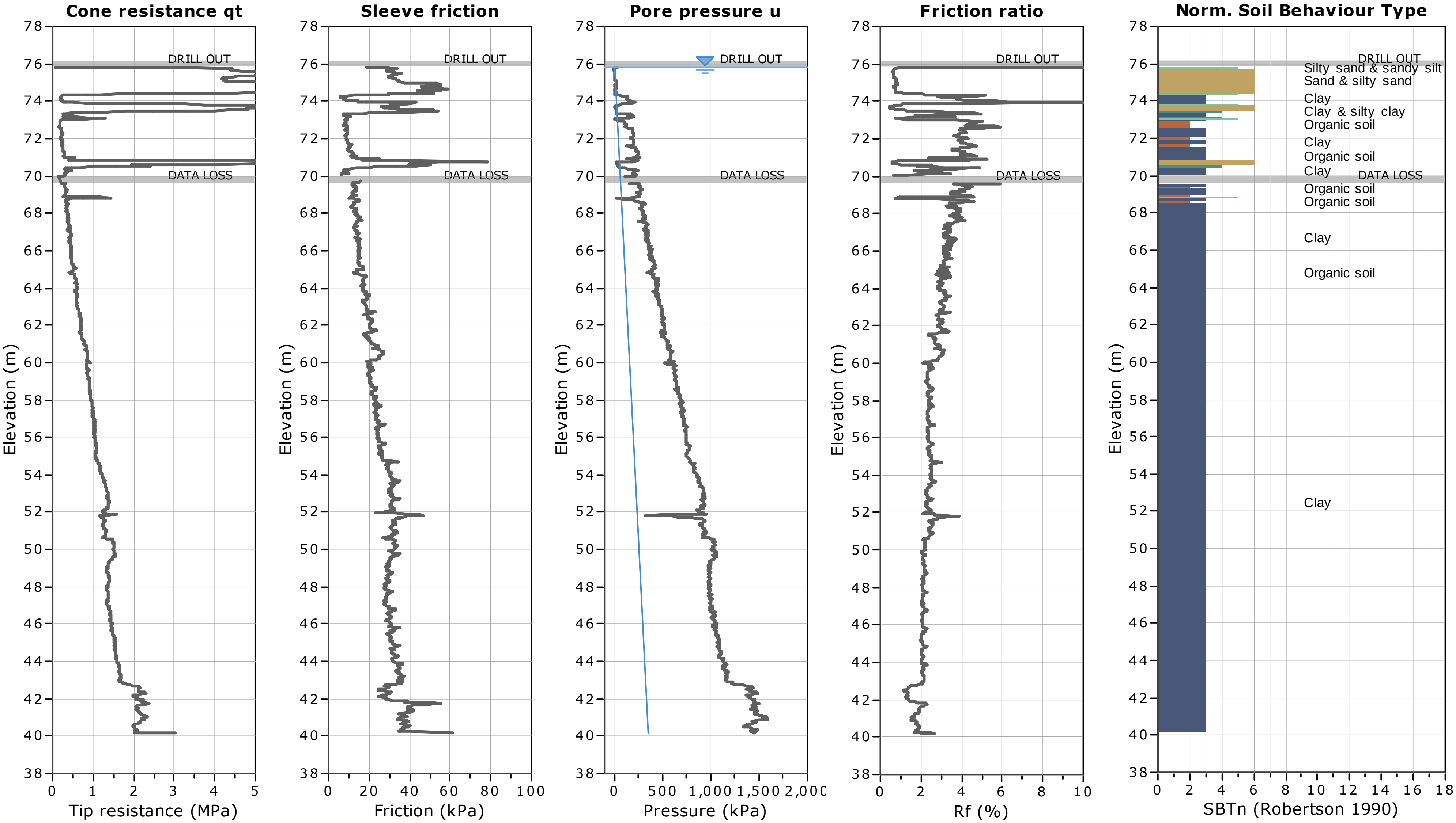
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-13-1 Rev 1
Total depth: 35.98 m, Date: 3/13/2013
Surface Elevation: 76.17 m
Coords: N 5021363.0, E 466755.4
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

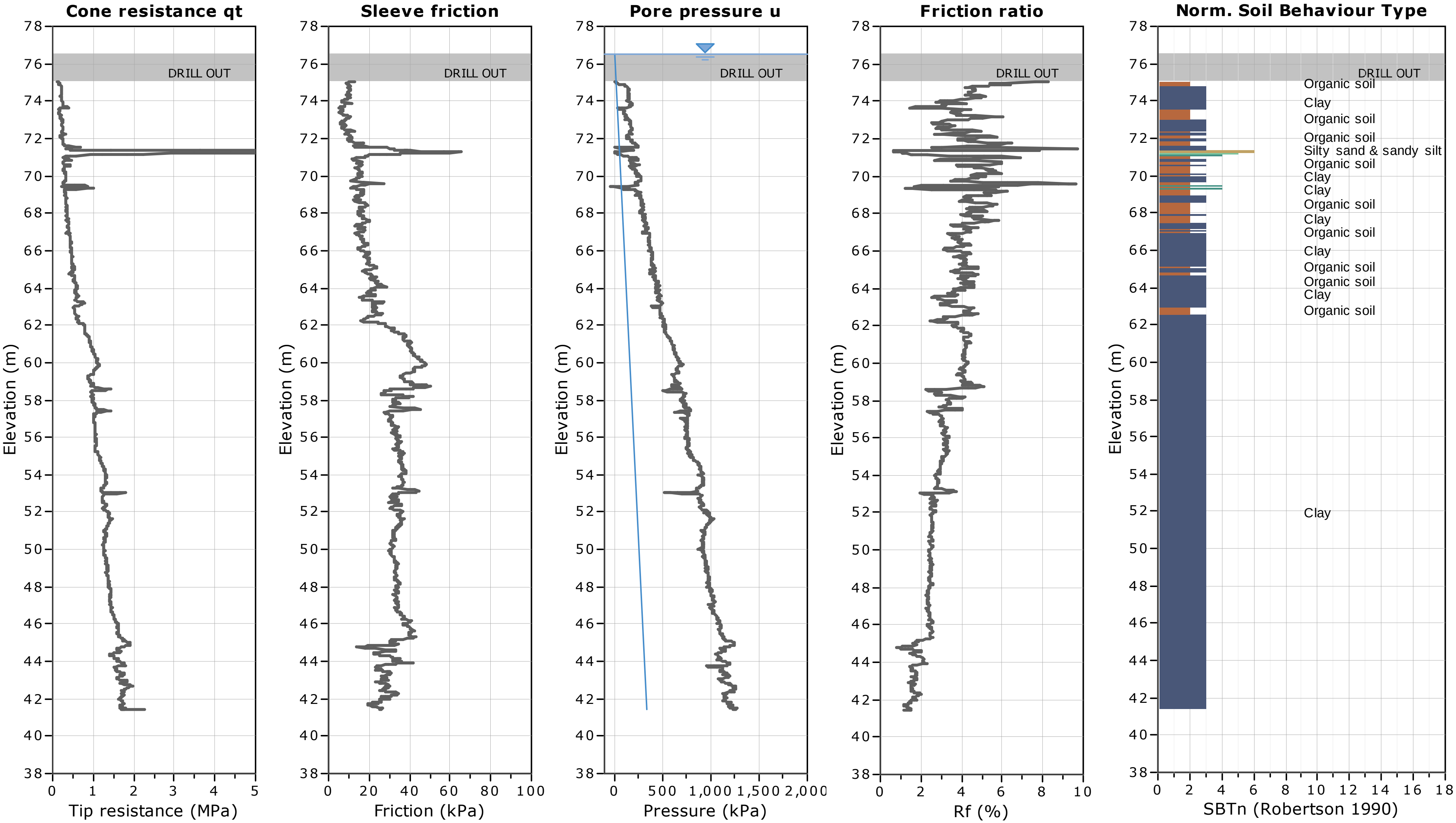
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-14-1 Rev 1
Total depth: 35.14 m, Date: 3/26/2013
Surface Elevation: 76.53 m
Coords: N 5020309.0, E 466094.2
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)

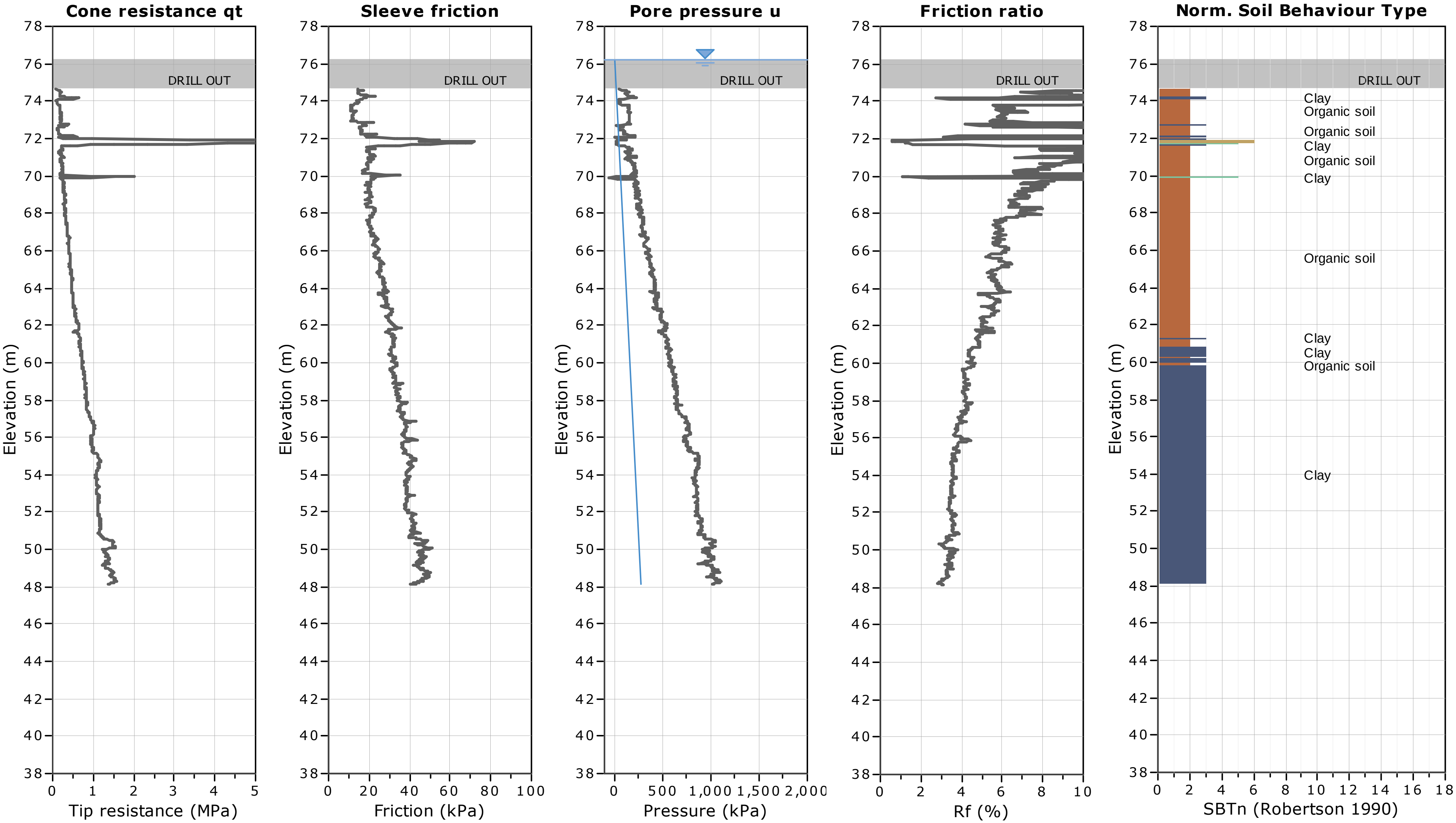
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-15-1 Rev 1
Total depth: 28.04 m, Date: 3/26/2013
Surface Elevation: 76.19 m
Coords: N 5020426.0, E 466400.2
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)

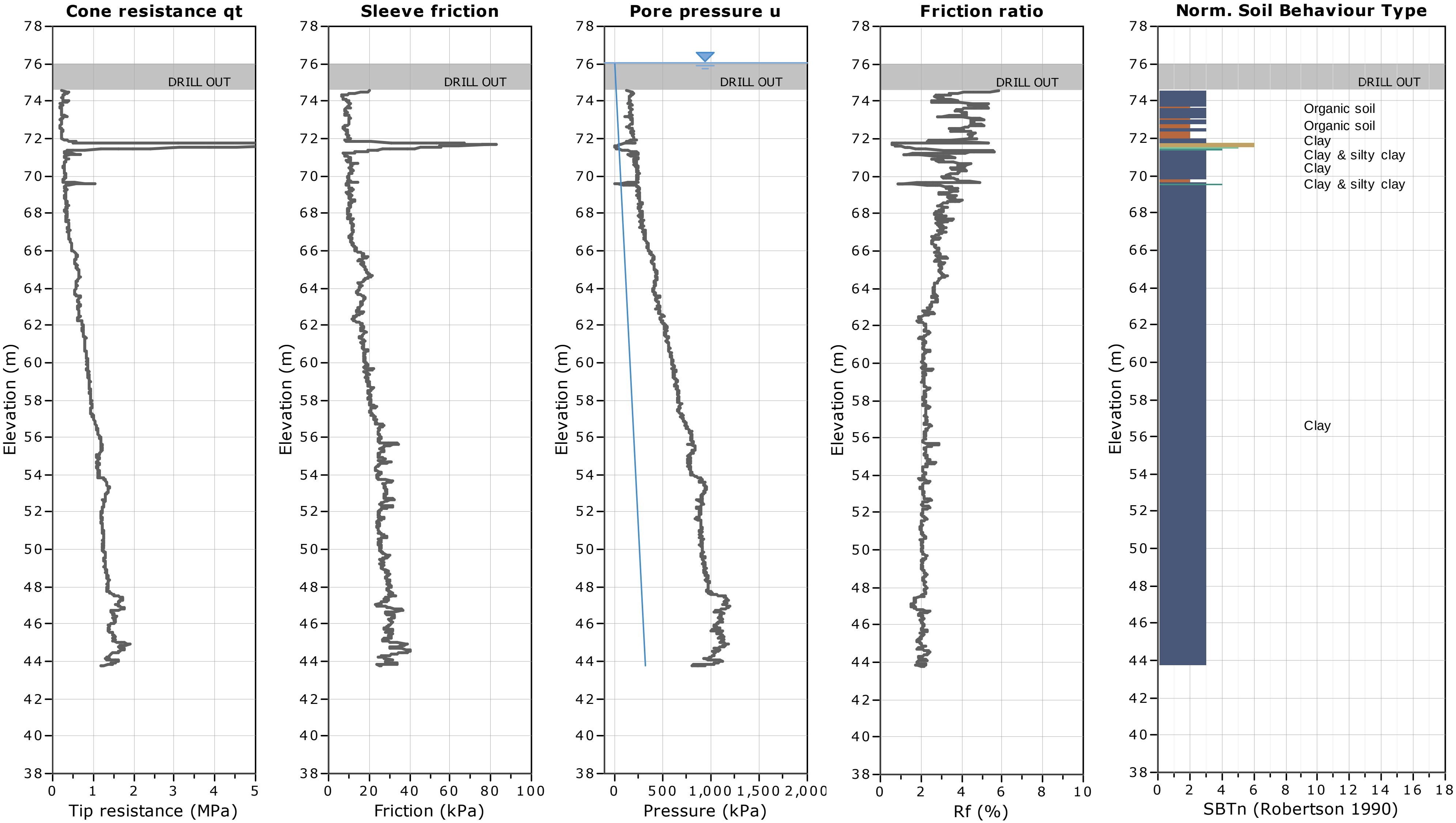
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

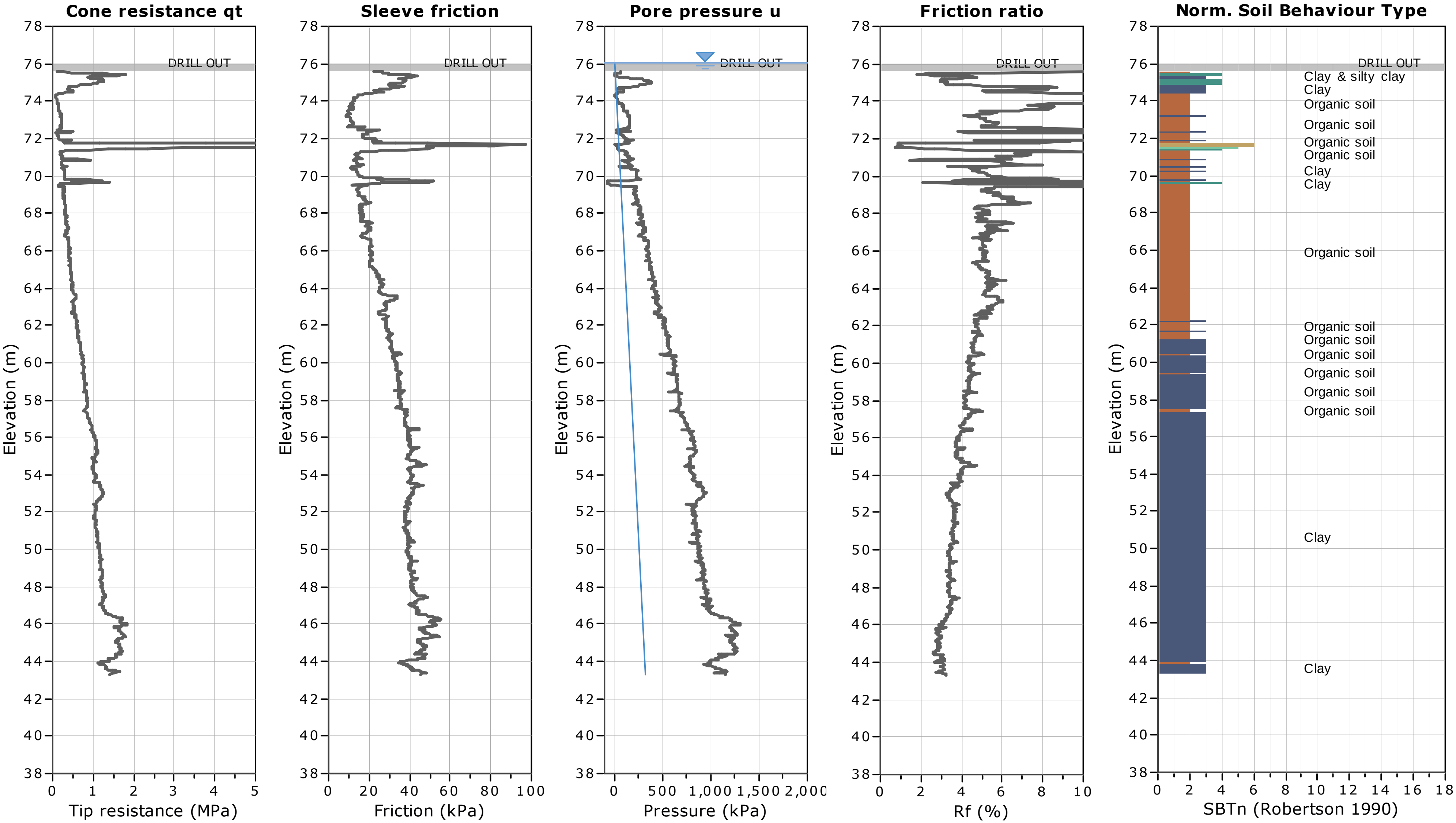
CPT: 13-16-1 Rev 1
Total depth: 32.28 m, Date: 3/25/2013
Surface Elevation: 76.03 m
Coords: N 5020535.0, E 466711.7
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)



Golder Associates
Ottawa, ON
www.golder.com

Project: 12-1125-0045 - CRRRC EA Eastern Ontario
Location: Boundary Road Site

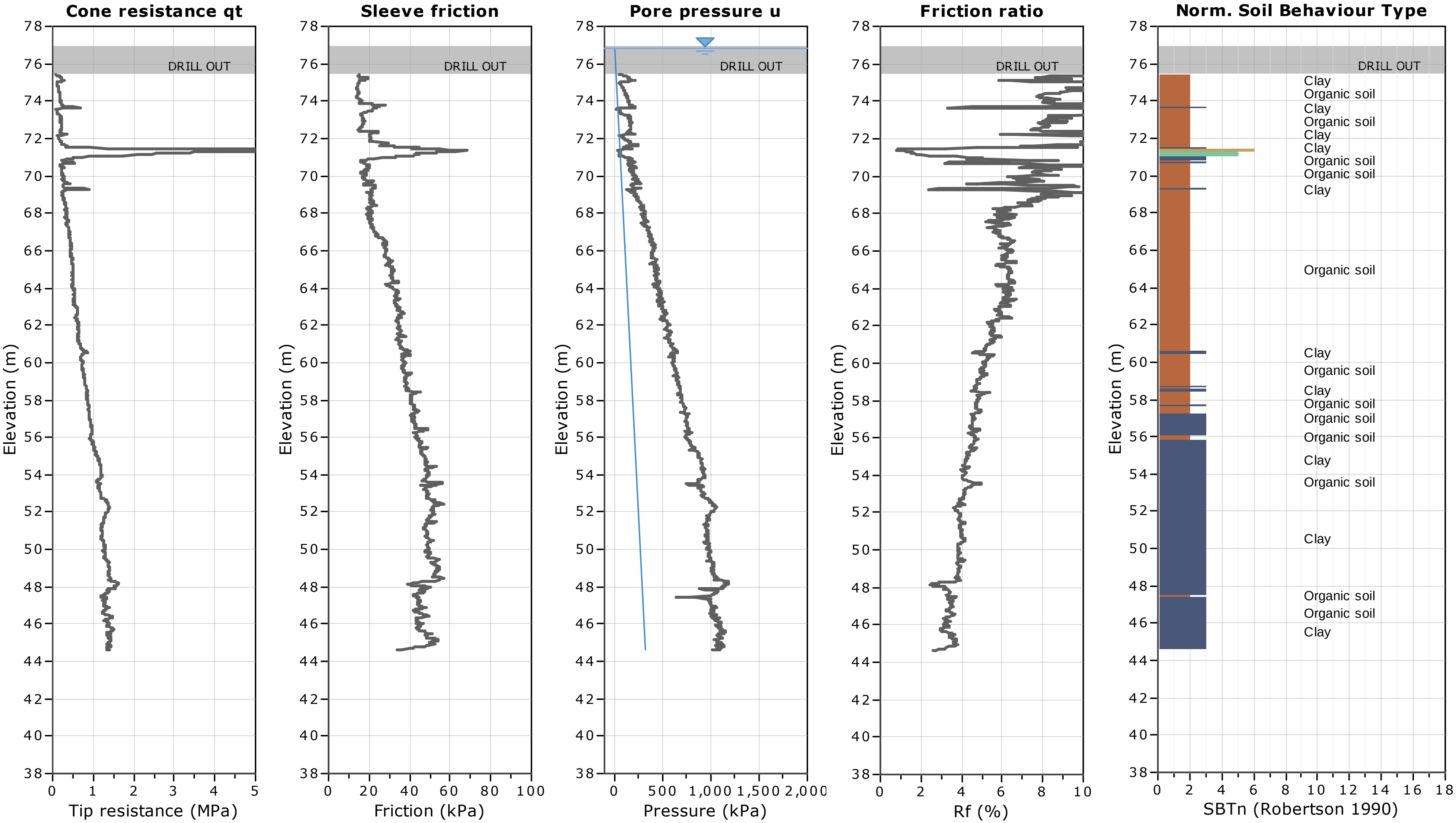
CPT: 13-17-1 Rev 1
Total depth: 32.70 m, Date: 3/12/2013
Surface Elevation: 76.03 m
Coords: N 5020639.0, E 467003.1
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-18-1 Rev 1
Total depth: 32.31 m, Date: 4/8/2013
Surface Elevation: 76.92 m
Coords: N 5019940.9, E 465846.5
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)

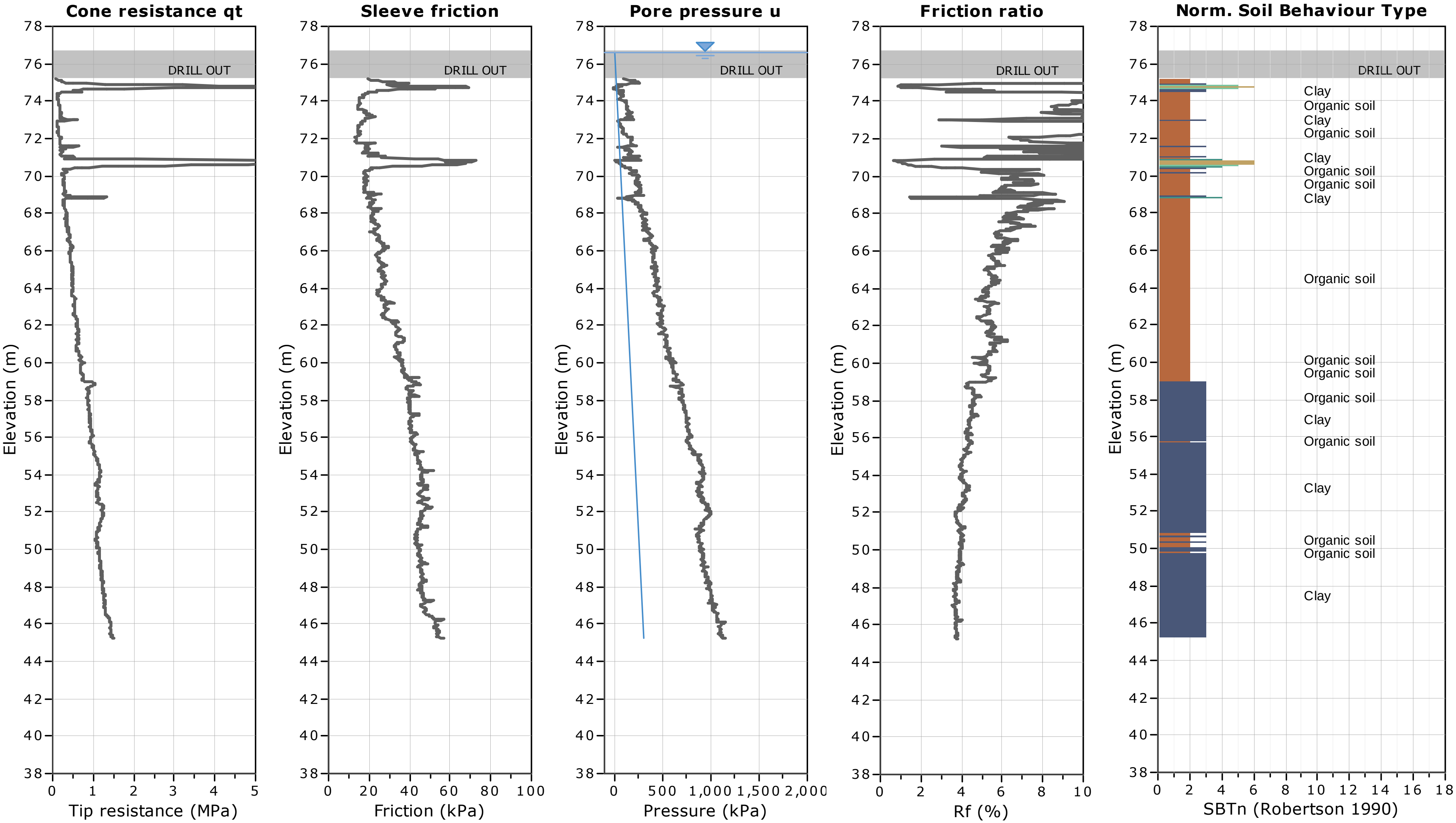
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

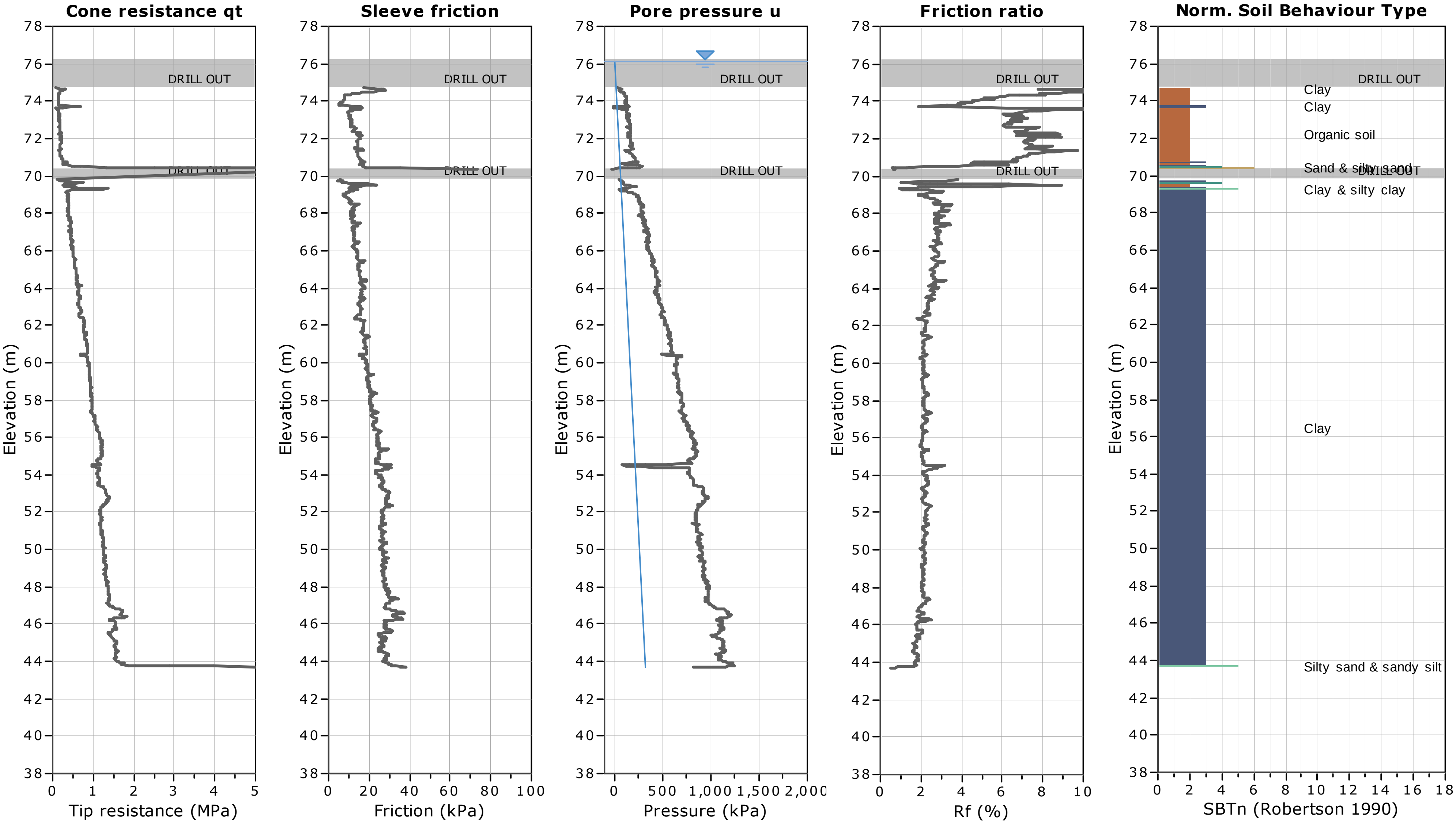
CPT: 13-19-1 Rev 1
Total depth: 31.41 m, Date: 4/8/2013
Surface Elevation: 76.66 m
Coords: N 5019951.0, 466202.8
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

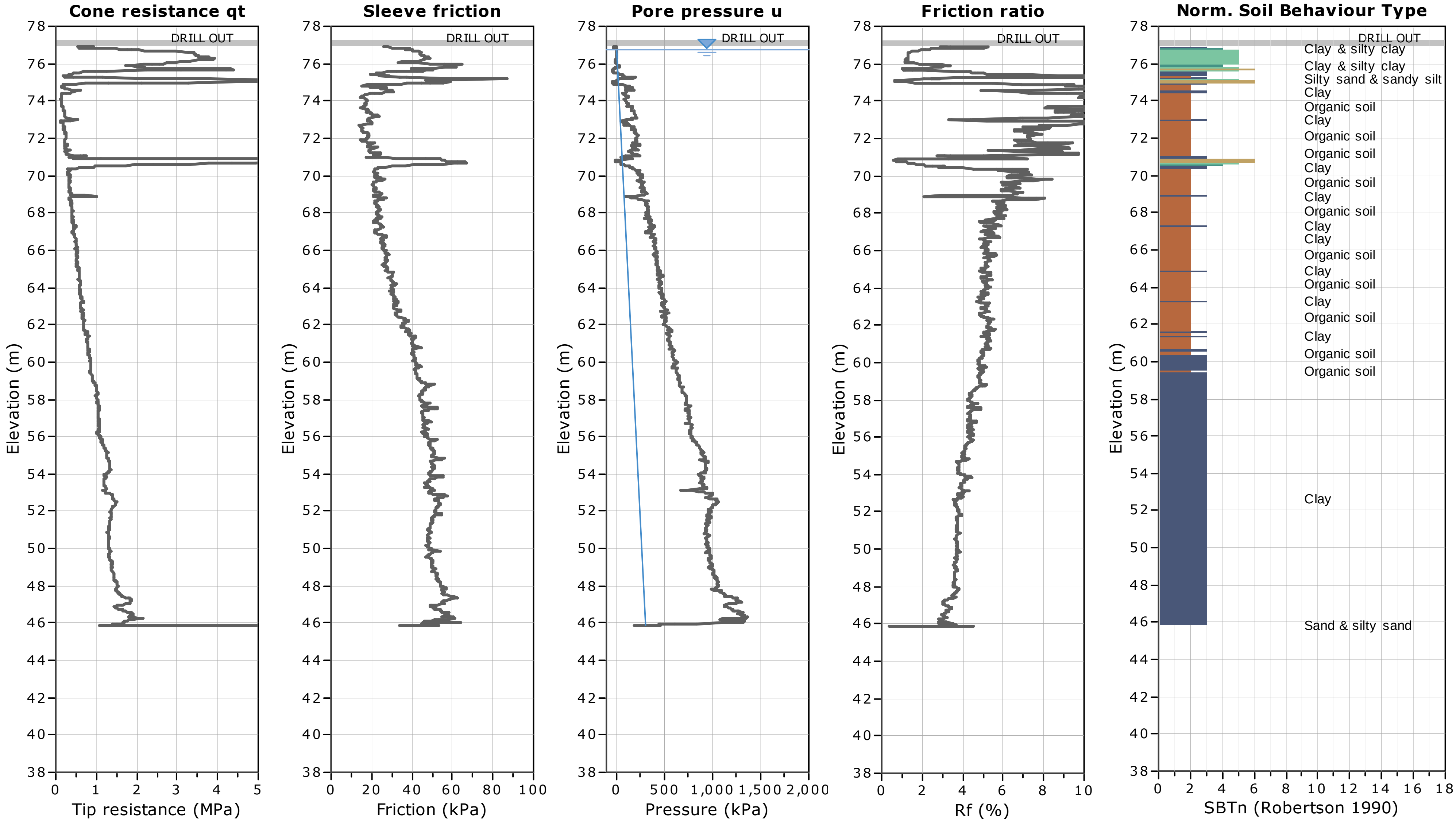
CPT: 13-20-1 Rev 1
Total depth: 32.50 m, Date: 4/5/2013
Surface Elevation: 76.19 m
Coords: N 5020202.0, E 466834.5
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (D. Grylls)



Golder Associates
Ottawa, ON
www.golder.com

CPT: 13-21-1 Rev 1
Total depth: 31.39 m, Date: 3/18/2013
Surface Elevation: 77.23 m
Coords: N 5019674.0, E 465945.8
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)

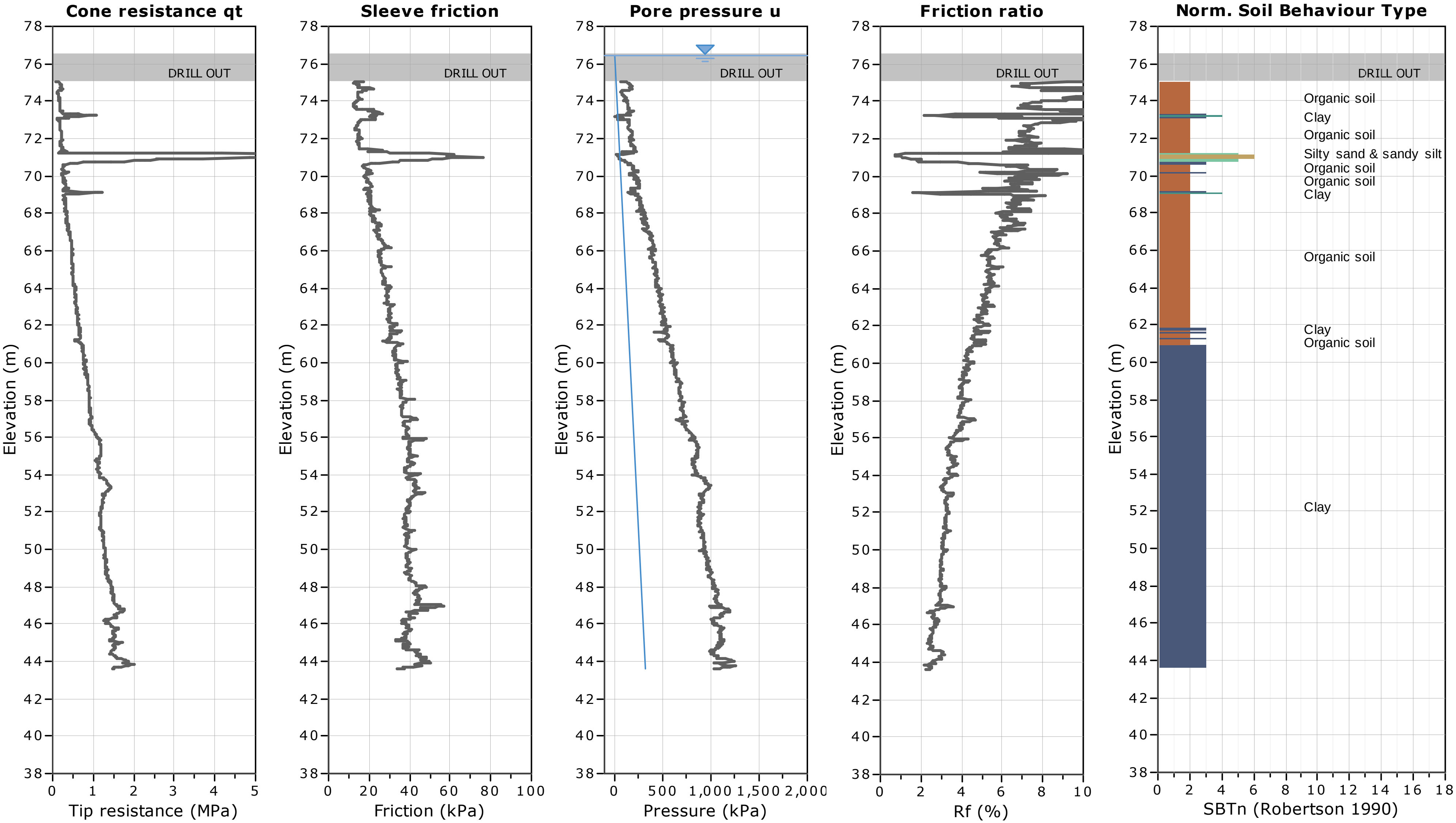
Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

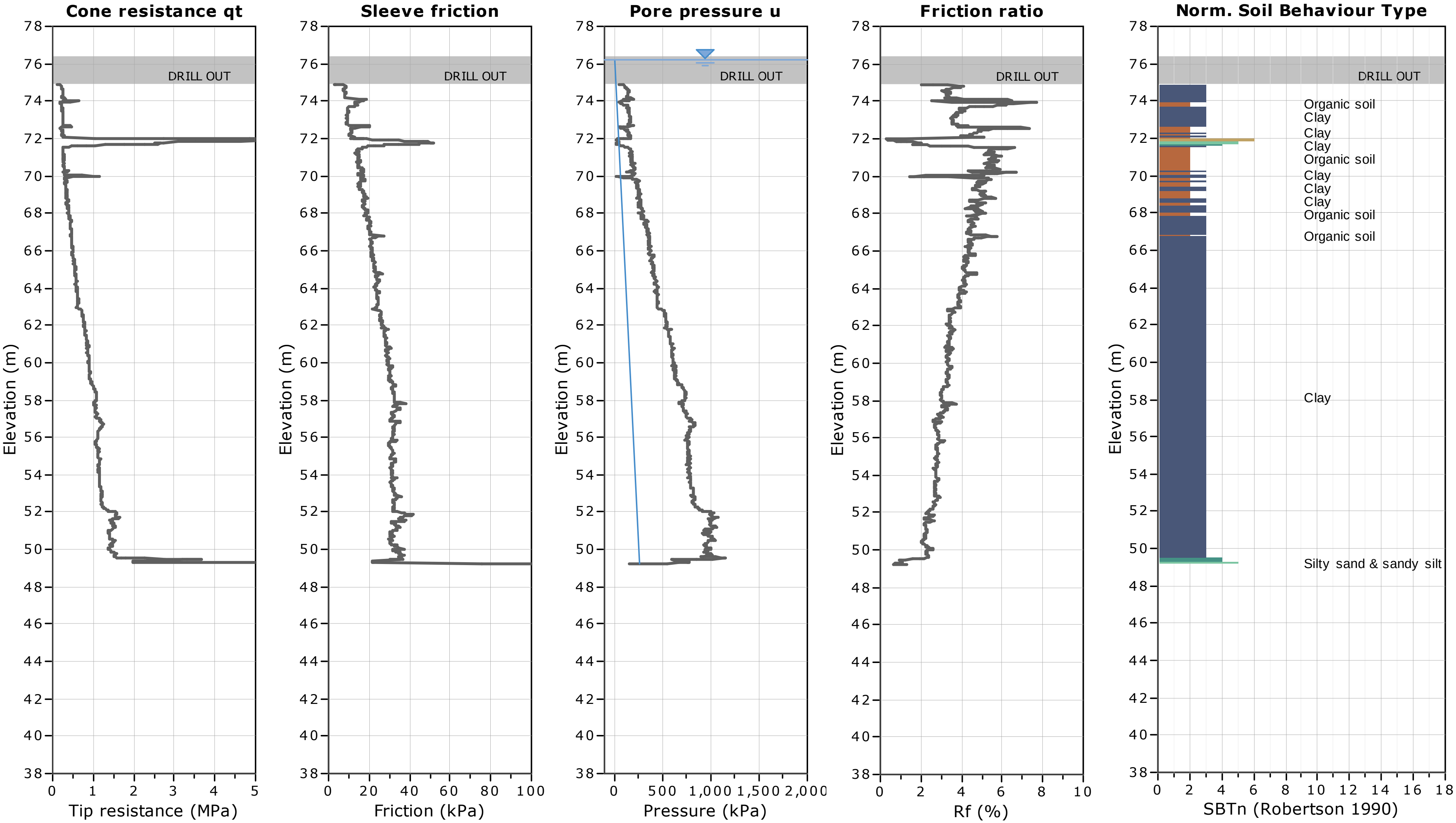
CPT: 13-22-1 Rev 1
Total depth: 32.96 m, Date: 3/25/2013
Surface Elevation: 76.54 m
Coords: N 5019640.0, E 466328.9
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

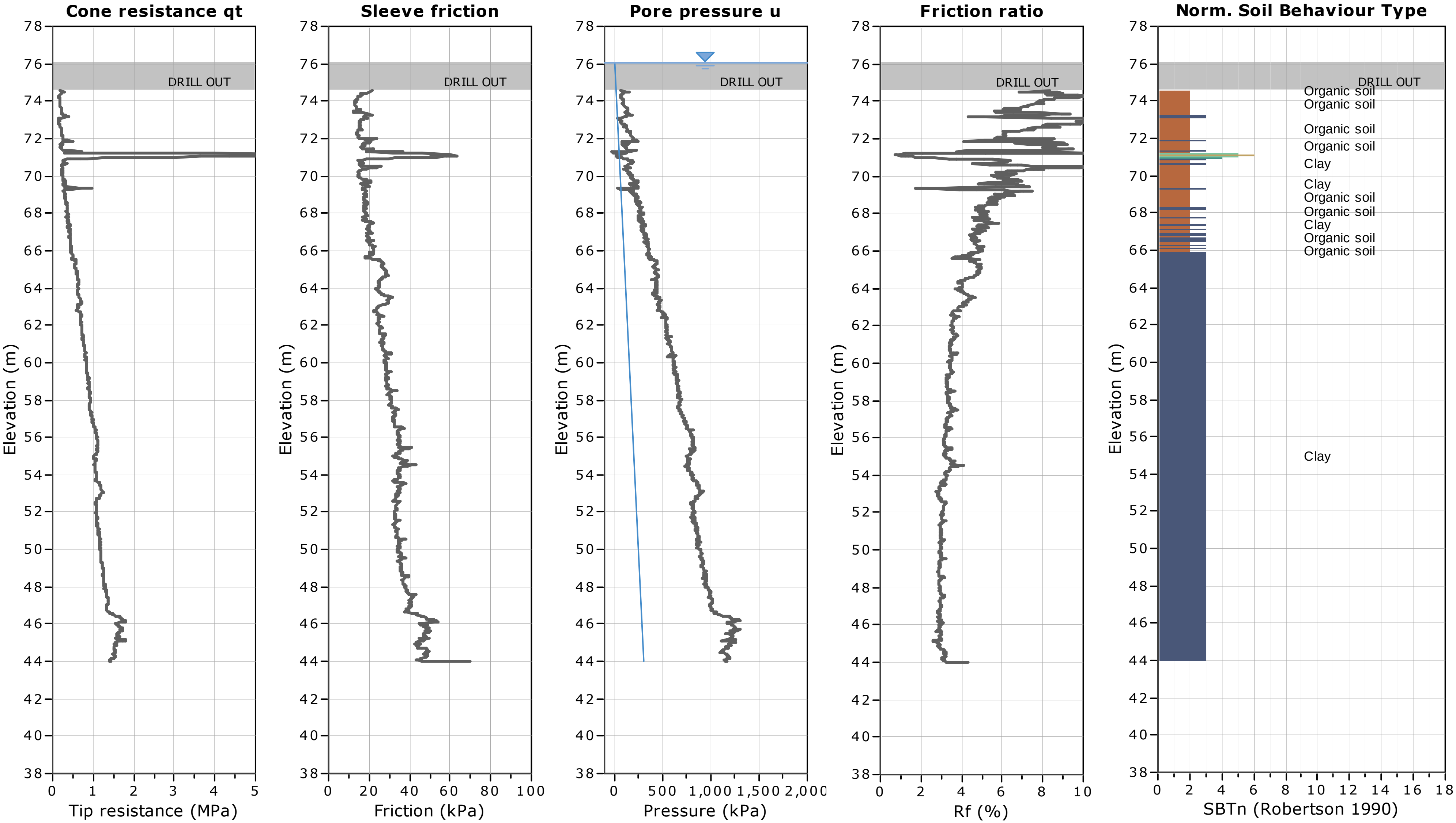
CPT: 13-23-1 Rev 1
Total depth: 27.16 m, Date: 3/21/2013
Surface Elevation: 76.39 m
Coords: N 5019746.0, E 466615.1
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)



Golder Associates
Ottawa, ON
www.golder.com

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

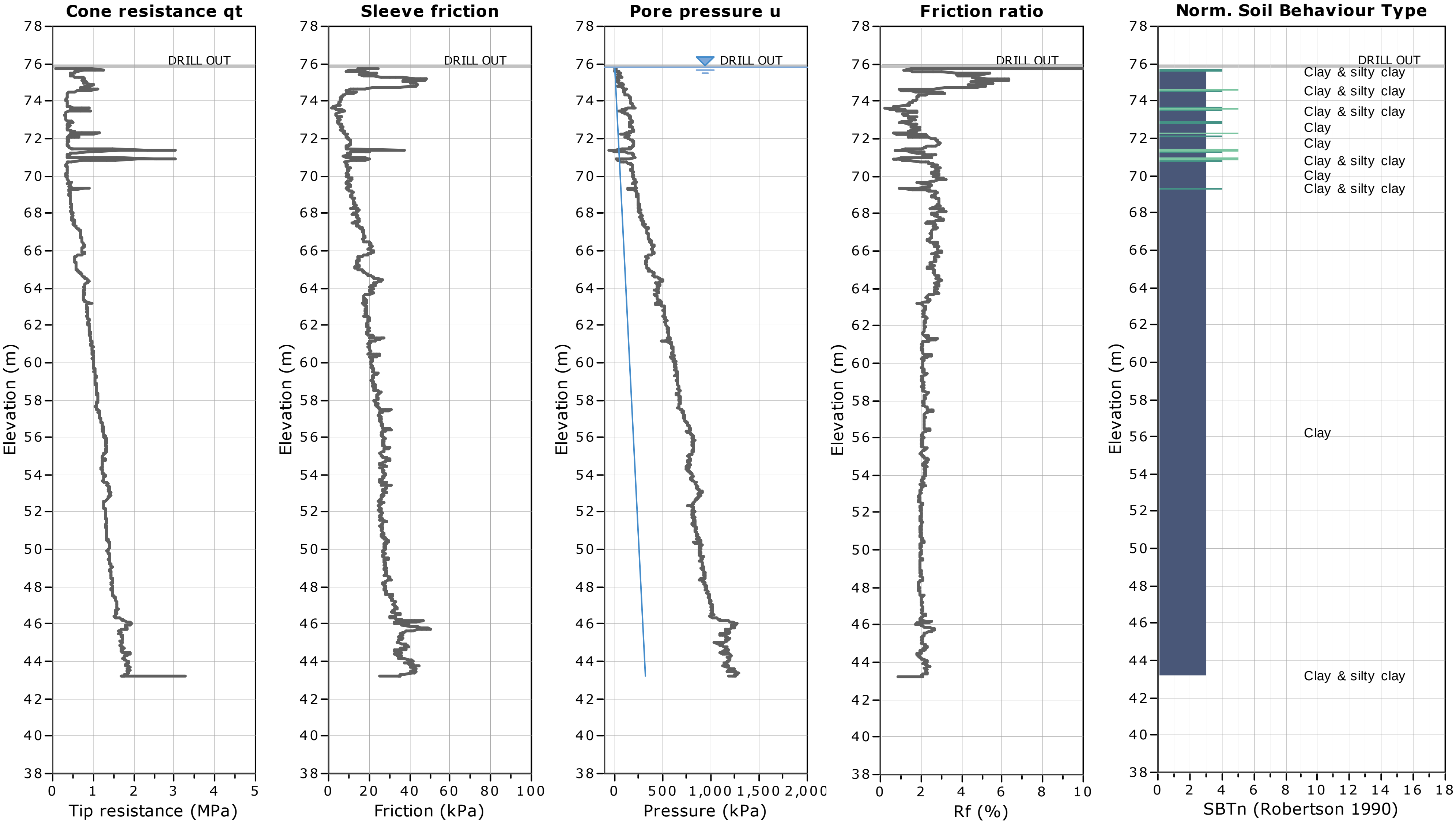
CPT: 13-24-1 Rev 1
Total depth: 32.06 m, Date: 3/21/2013
Surface Elevation: 76.07 m
Coords: N 5019877.0, E 466963.4
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)



Golder Associates
Ottawa, ON
www.golder.com

Project: 12-1125-0045 - CRRRC EA Eastern Ontario
Location: Boundary Road Site

CPT: 13-25-1 Rev 1
Total depth: 32.74 m, Date: 3/19/2013
Surface Elevation: 75.94 m
Coords: N 5020022.0, E 467247.0
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)

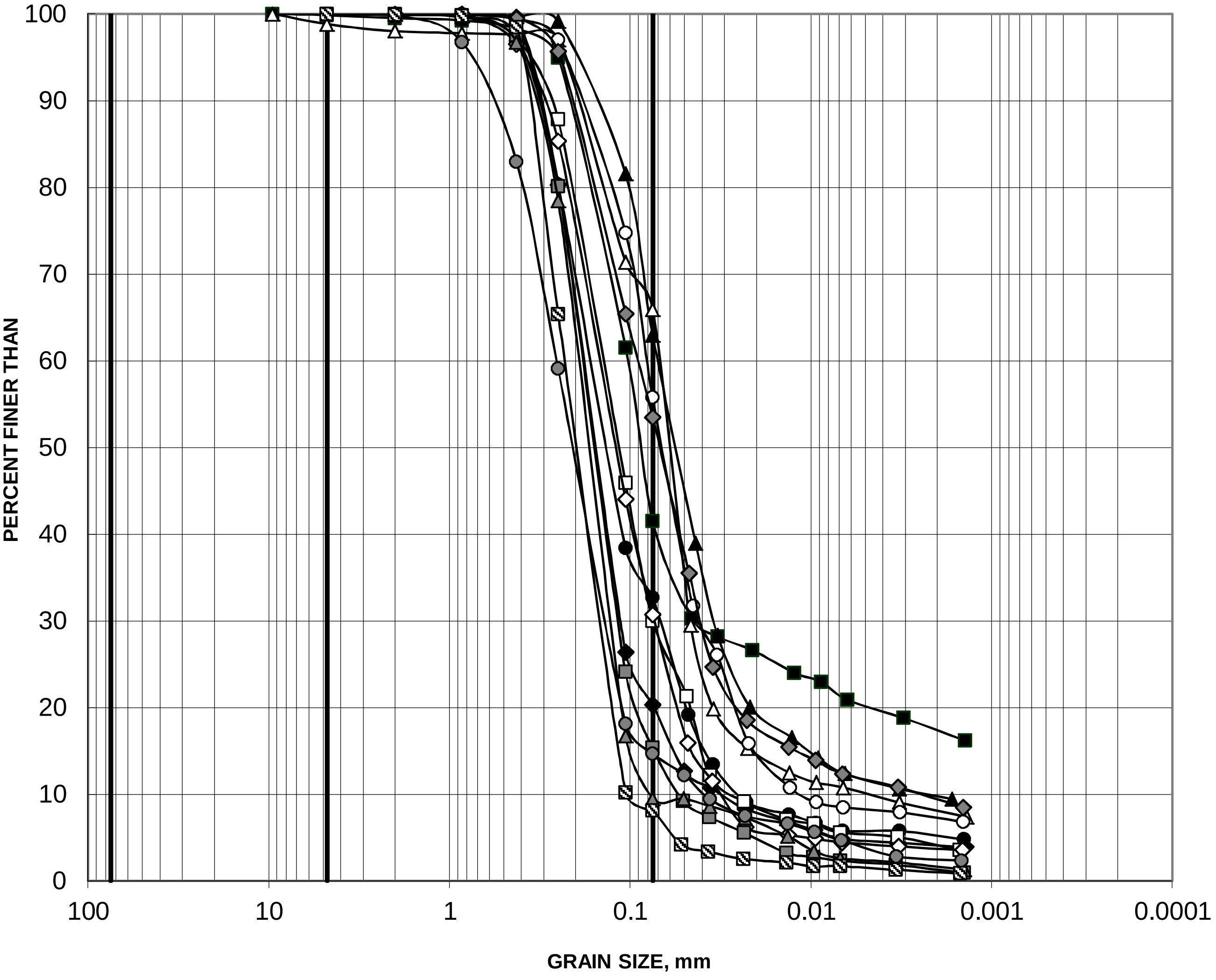


APPENDIX C

Grain Size Curves

GRAIN SIZE DISTRIBUTION	FIGURE C1

Surficial Silty SAND



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

Borehole	Sample	Depth (m)
■ 12-1-2	1B	0.25-0.55
◆ 12-1-7	1B	1.07-1.13
▲ 12-2-7	2A	2.10-2.29
● 12-2-7	2C	2.79-2.90
□ 12-3-2	2	0.61-1.22
◇ 12-3-7	1A	0.37-1.28
△ 12-3-7	2A	1.28-1.77
○ 12-4-7	1B	0.63-0.94
■ 13-6-7	2A	1.58-1.98
◆ 13-9-2	1B	0.88-1.22
▲ 13-10-3	1A	0.66-1.52
● 13-13-2	1A	0.79-1.52
▨ 13-21-3	2D	2.54-2.74

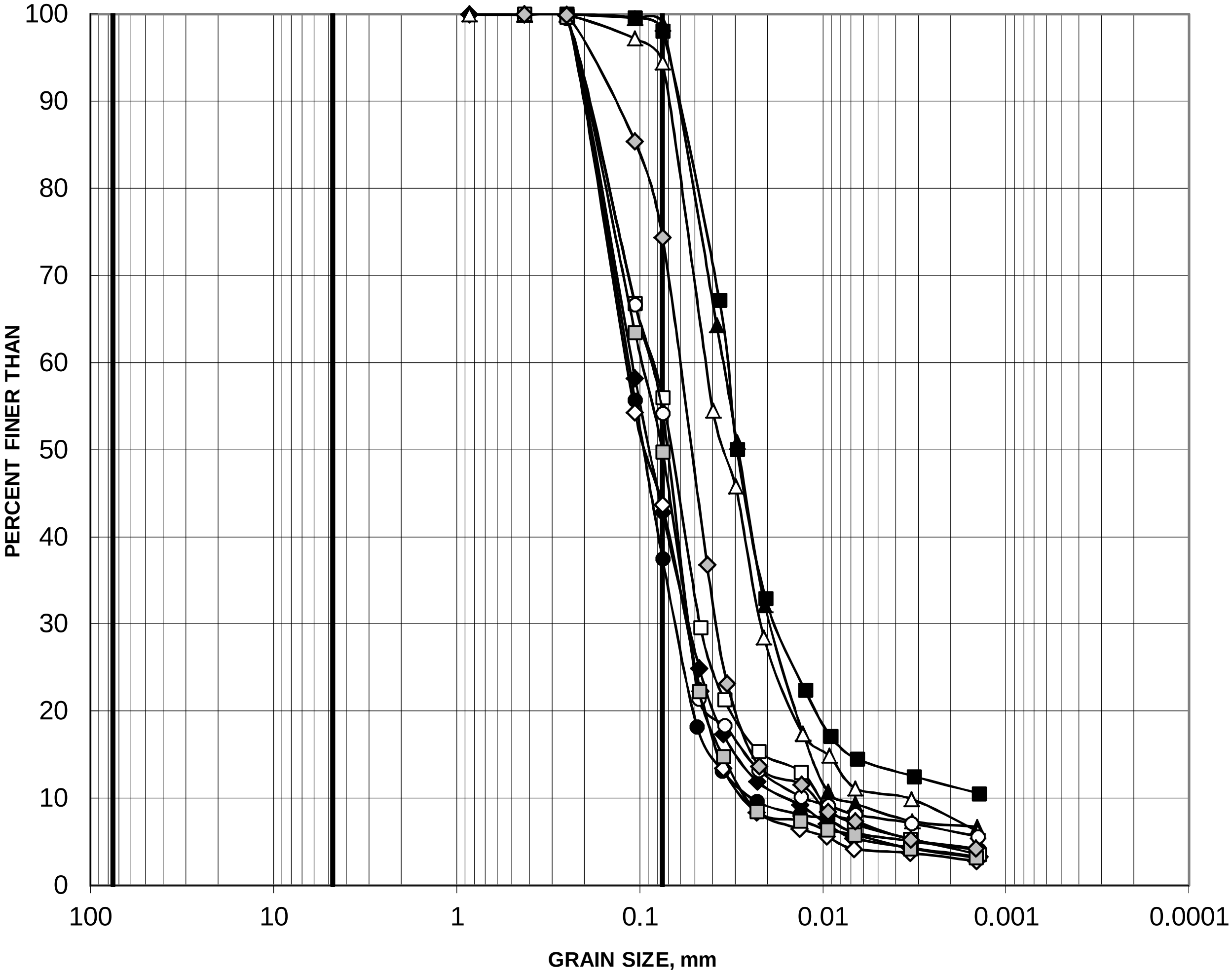
Created by: CW
Checked by: CNM

Project: 12-1125-0045/4000/0120 **Golder Associates**

GRAIN SIZE DISTRIBUTION

FIGURE C2

Silty Layer within the SILTY CLAY



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

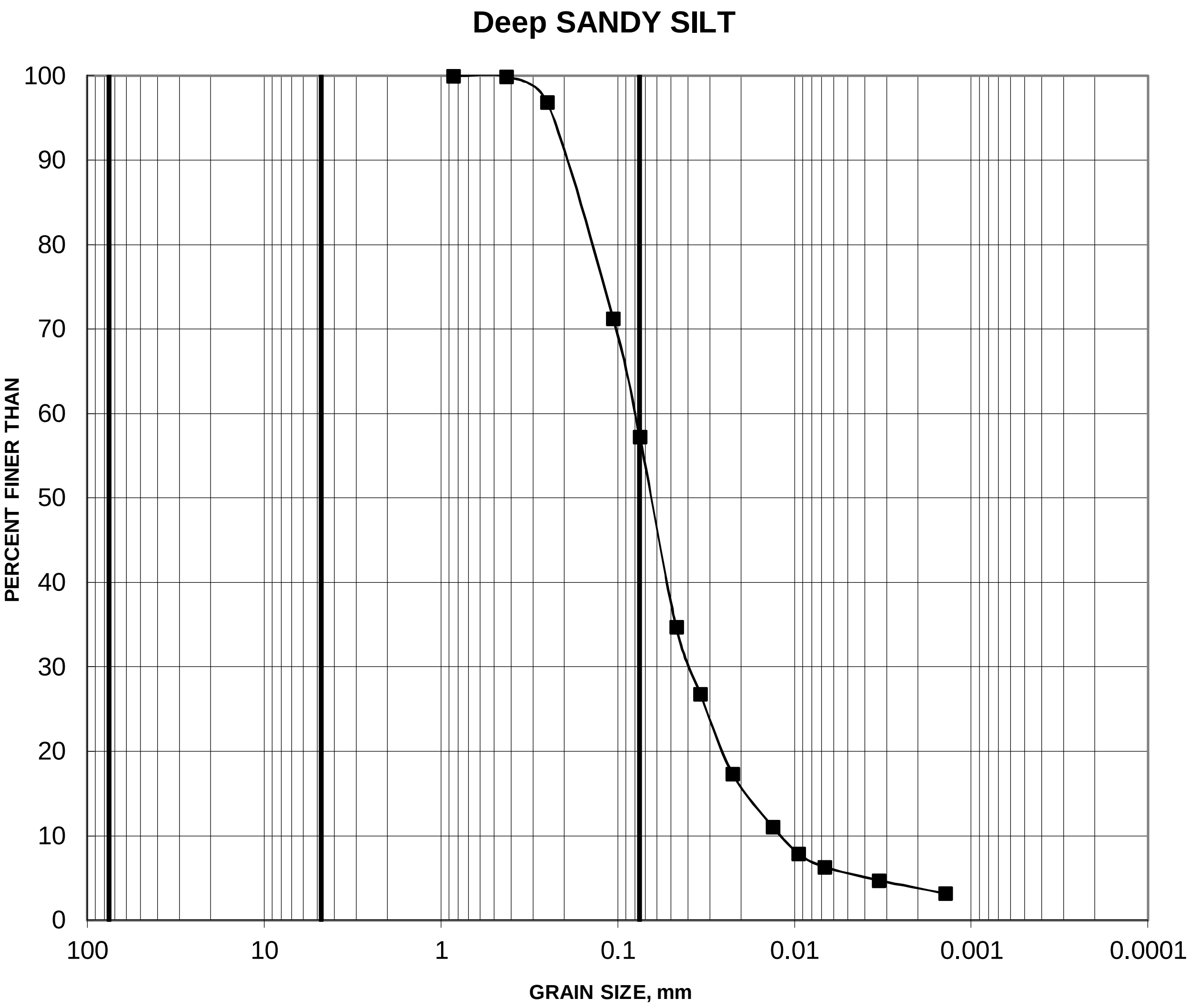
Borehole	Sample	Depth (m)
■ 12-1-7	4B	4.99-5.12
◆ 12-2-7	5B	6.81-7.03
▲ 12-3-7	4A	4.88-5.03
● 12-4-7	4A	4.73-4.95
□ 13-6-7	4C	5.39-5.59
◇ 13-8-3	3C	4.37-4.57
△ 13-12-3	4A	4.78-5.39
○ 13-15-3	3B	4.42-4.50
▨ 13-18-3	4B	5.72-6.10
◈ 13-23-3	3C	4.47-4.57

Created by: CW
Checked by: CNM

Project: 12-1125-0045/4000/0120 **Golder Associates**

GRAIN SIZE DISTRIBUTION

FIGURE C3



Cobble Size	coarse	fine	coarse	medium	fine	SILT AND CLAY
	GRAVEL SIZE		SAND SIZE			

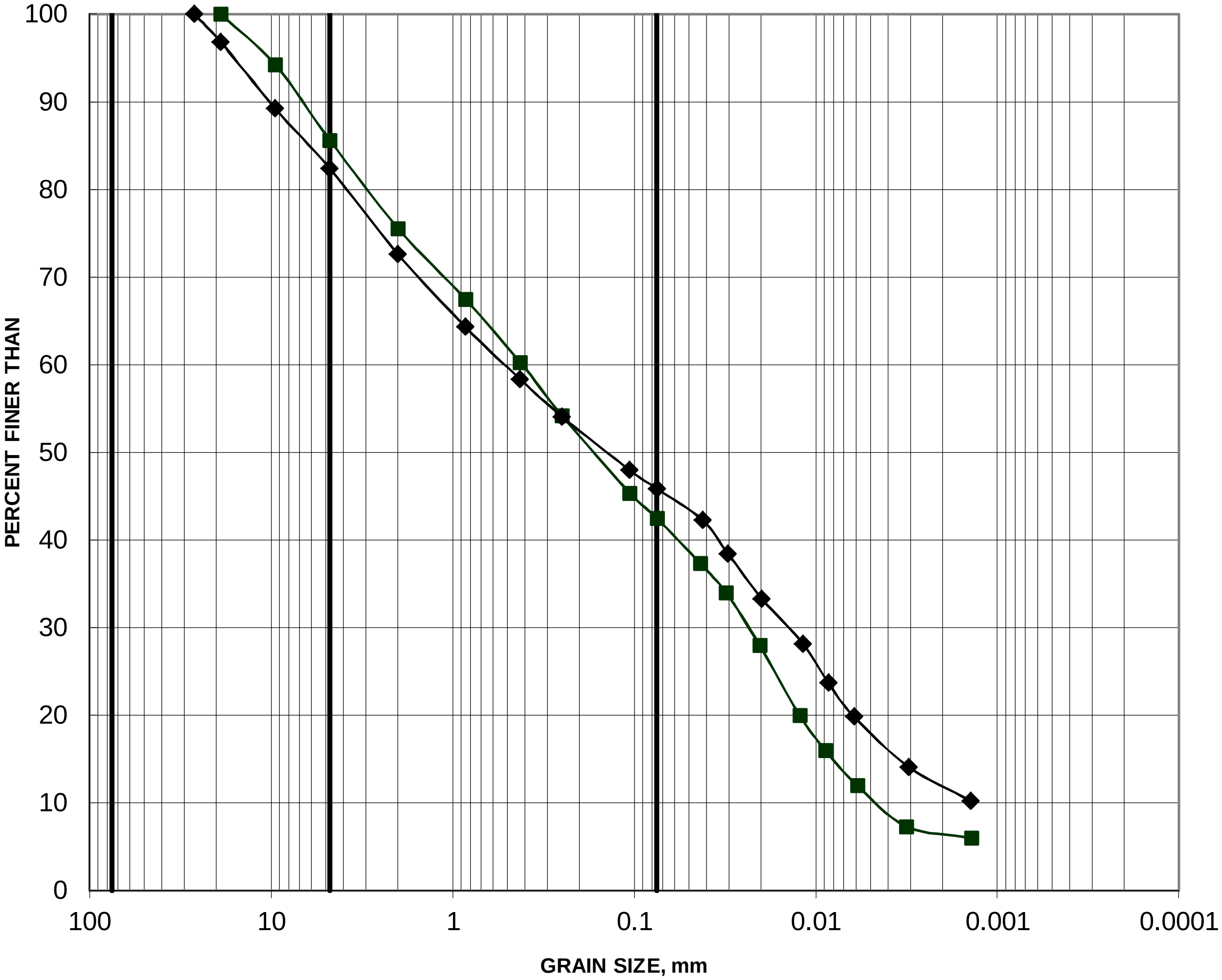
Borehole	Sample	Depth (m)
—■— 12-1-7	24A	34.50-35.76

Project: 12-1125-0045/4000/0120 **Golder Associates**

Created by: MI
Checked by: CNM

GRAIN SIZE DISTRIBUTION | **FIGURE C4**

GLACIAL TILL



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

Borehole	Sample	Depth (m)
■ 12-1-3	24	37.03-37.64
◆ 12-3-3	13	37.19-37.80

Project: 12-1125-0045/4000/0120 **Golder Associates**

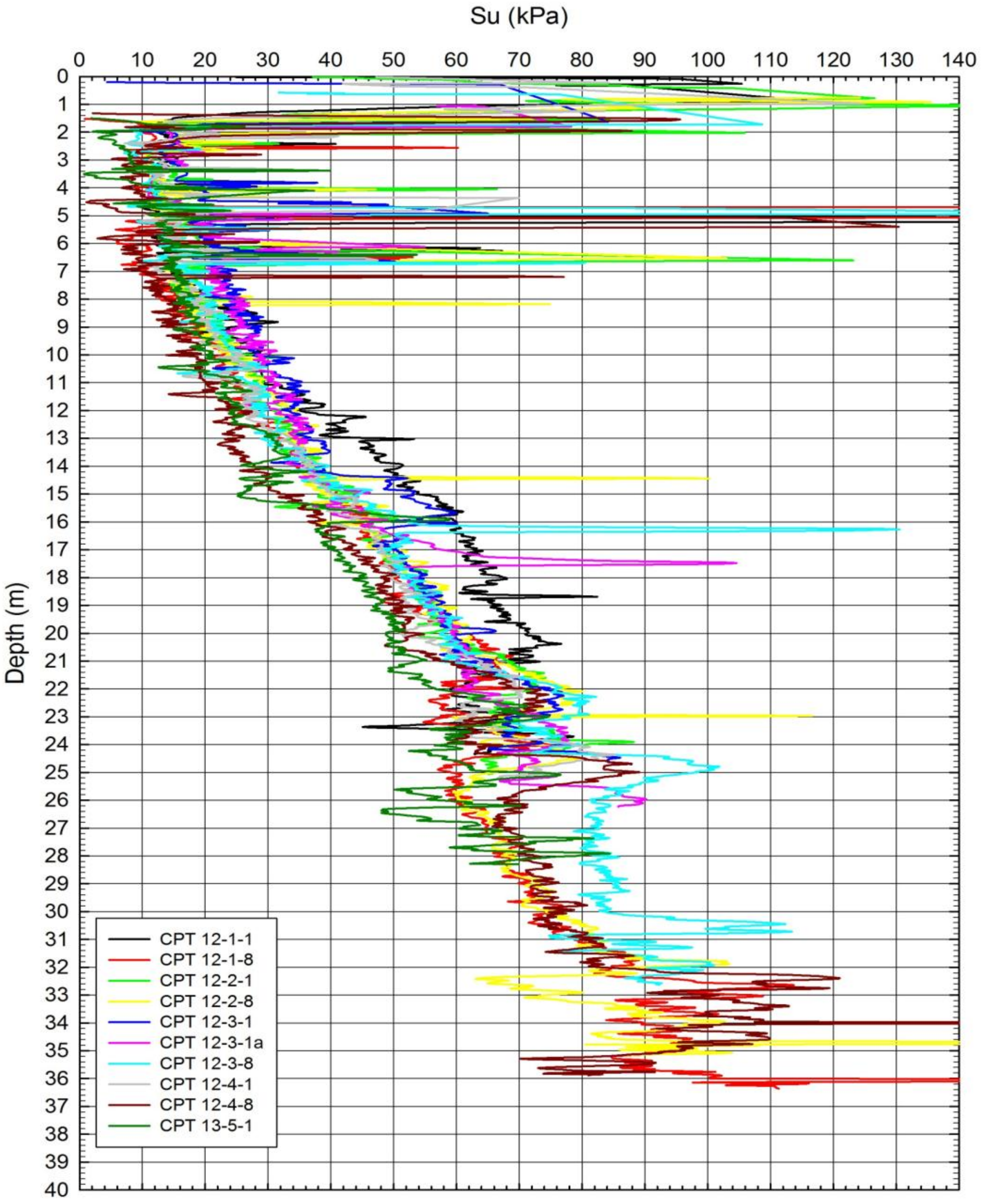
Created by: MI
Checked by: CNM

APPENDIX D

Undrained Shear Strength Profiles

UNDRAINED SHEAR STRENGTH VERSUS DEPTH

FIGURE D1



Date December 12, 2013

Project 12-1125-0045

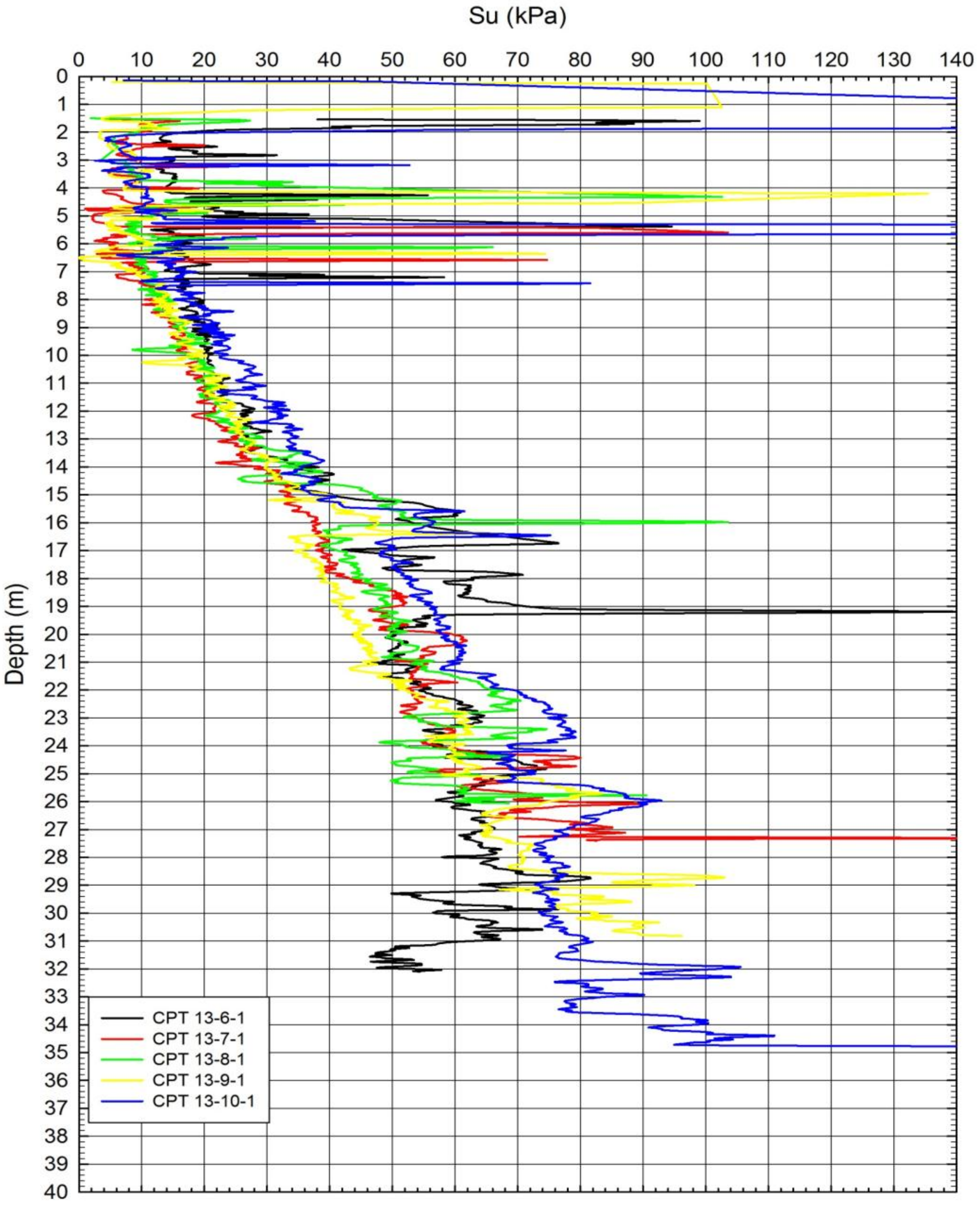
Golder Associates

Drawn CK

Chkd MIC

UNDRAINED SHEAR STRENGTH VERSUS DEPTH

FIGURE D2



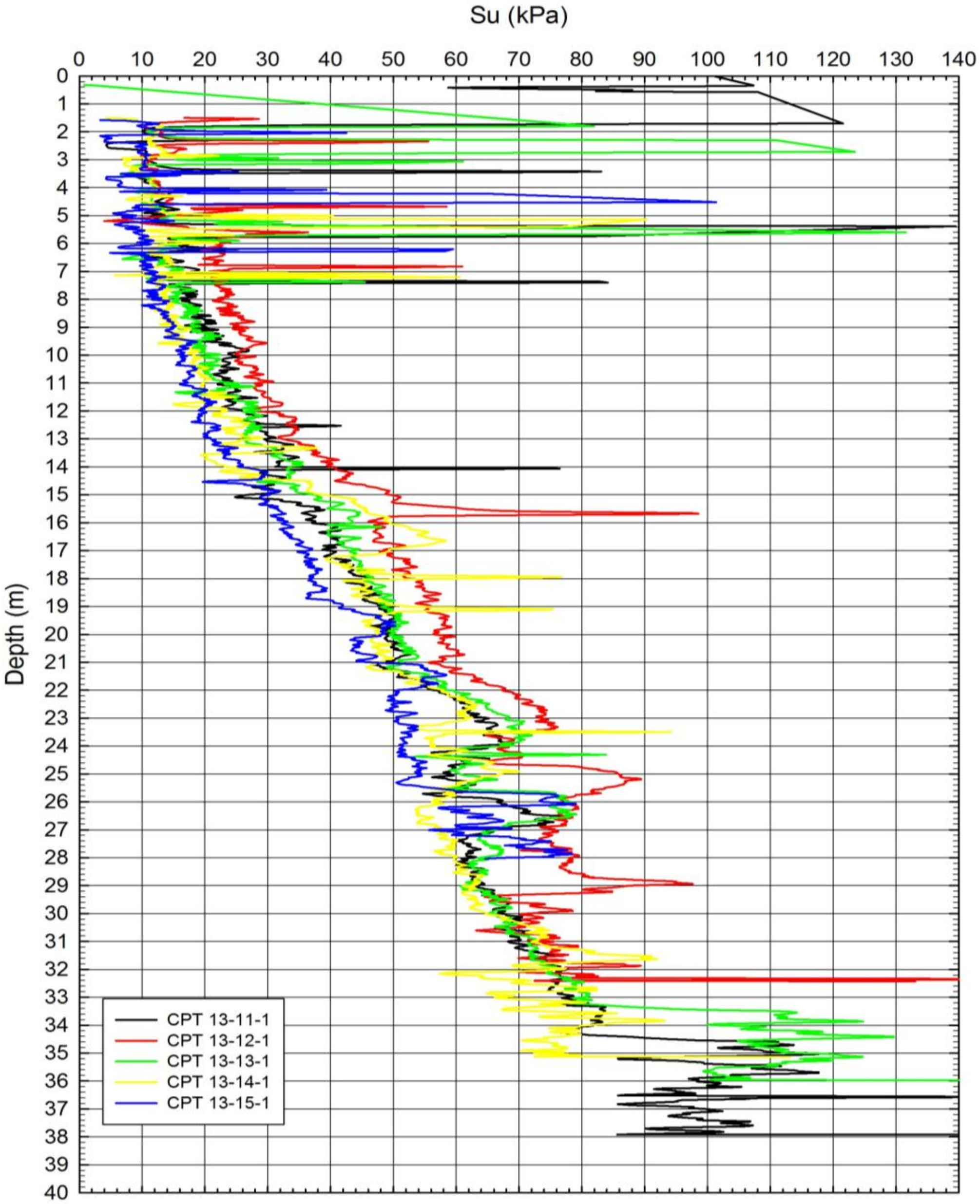
Date December 12, 2013
Project 12-1125-0045

Golder Associates

Drawn CK
Chkd MIC

UNDRAINED SHEAR STRENGTH VERSUS DEPTH

FIGURE D3



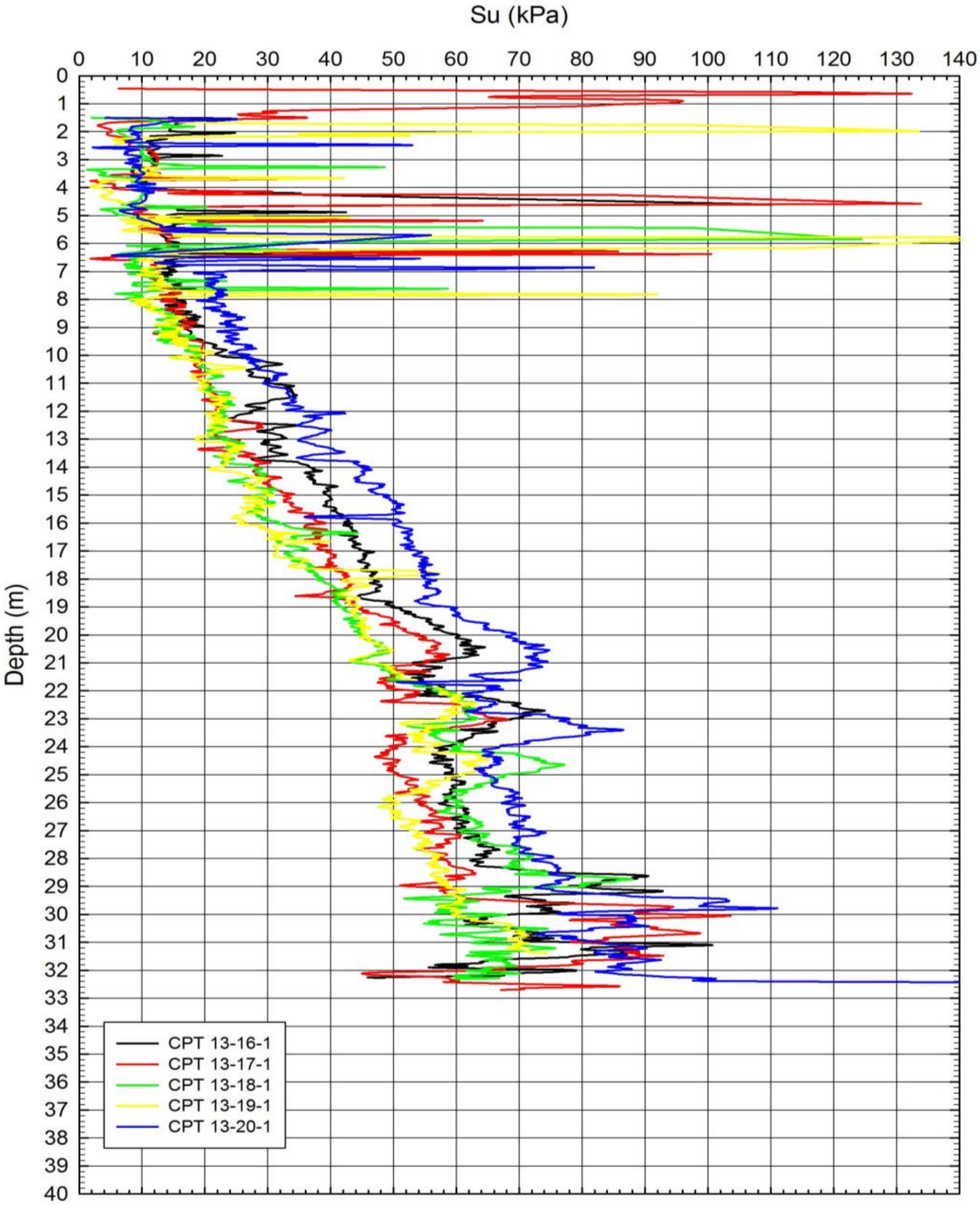
Date December 12, 2013
Project 12-1125-0045

Golder Associates

Drawn CK
Chkd MIC

UNDRAINED SHEAR STRENGTH VERSUS DEPTH

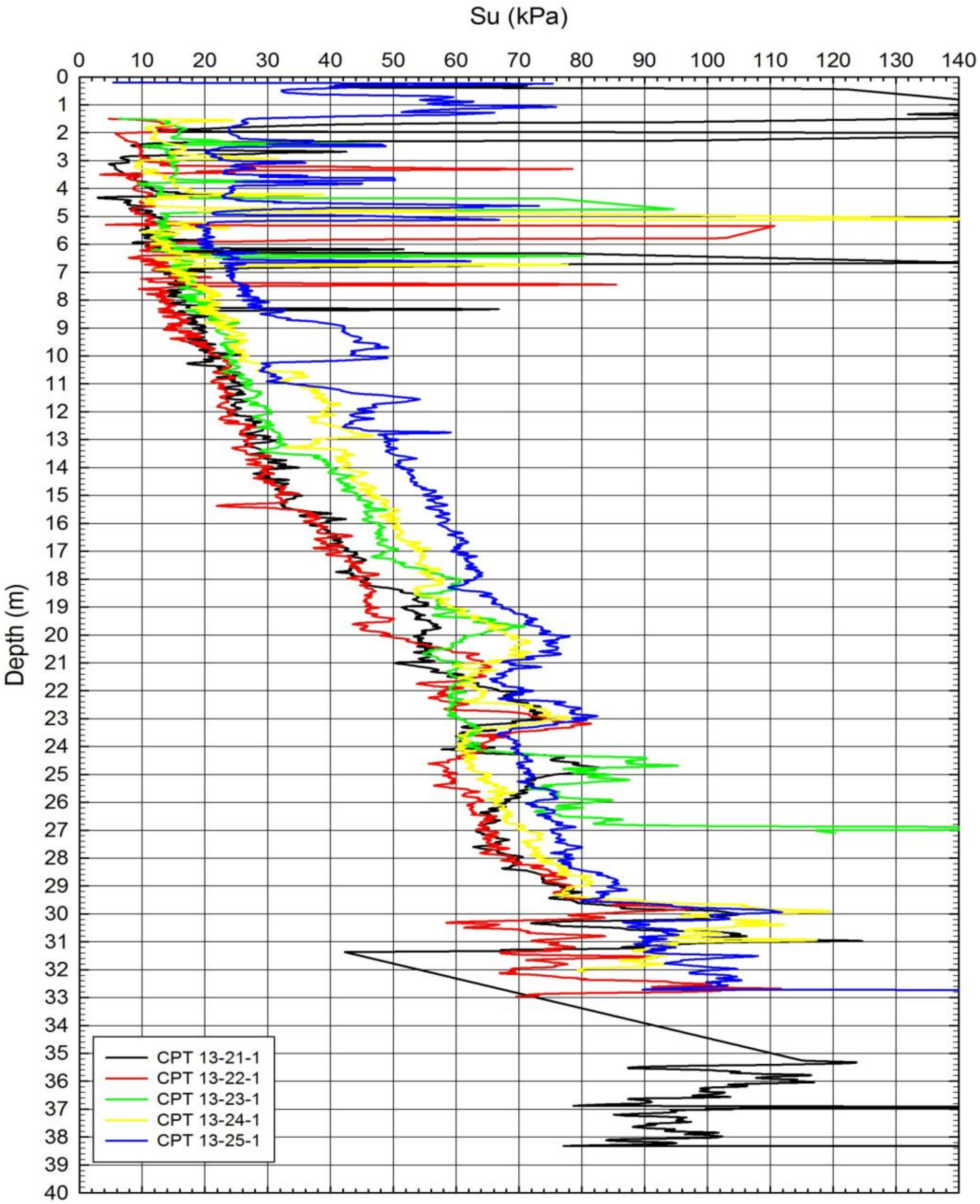
FIGURE D4



Date	December 12, 2013	**Golder Associates**	Drawn	CK
Project	12-1125-0045		Chkd	MIC

UNDRAINED SHEAR STRENGTH VERSUS DEPTH

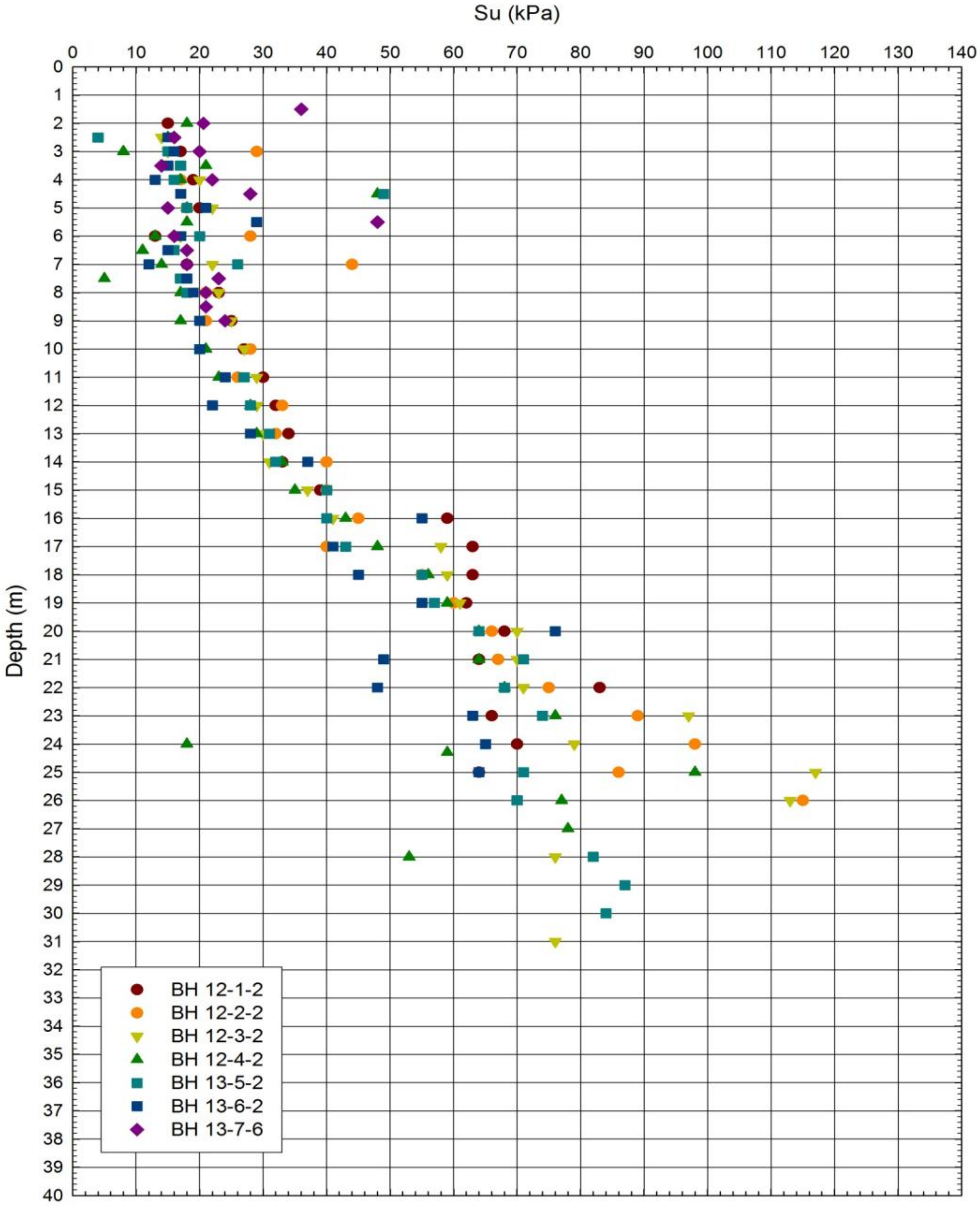
FIGURE D5



Date	December 12, 2013	**Golder Associates**	Drawn	CK
Project	12-1125-0045		Chkd	MIC

UNDRAINED SHEAR STRENGTH VERSUS DEPTH

FIGURE D6



Date December 12, 2013
Project 12-1125-0045

Golder Associates

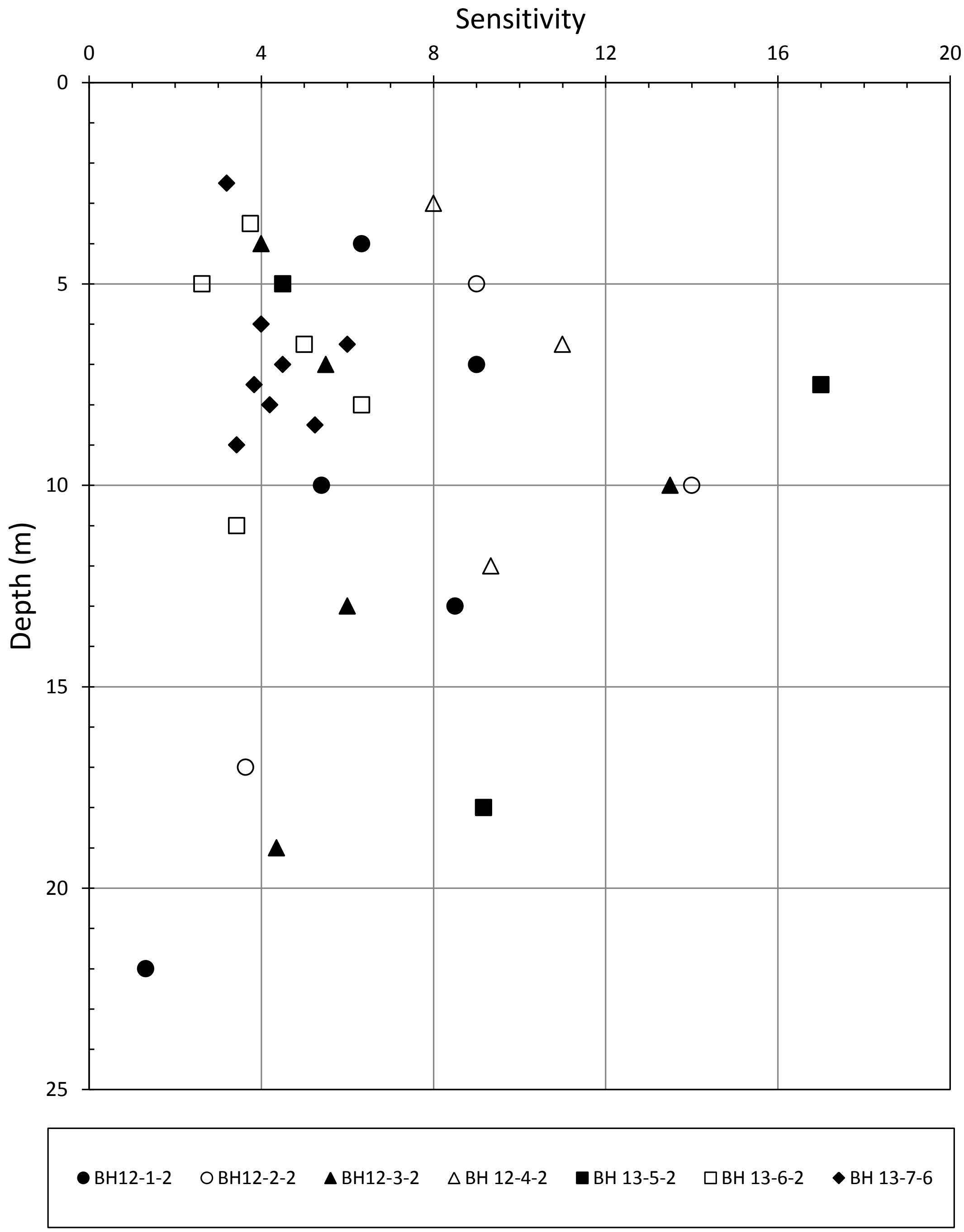
Drawn CK
Chkd MIC

APPENDIX E

Summary of Silty Clay Sensitivity

SUMMARY OF SENSITIVITIES VERSUS DEPTH

FIGURE E1

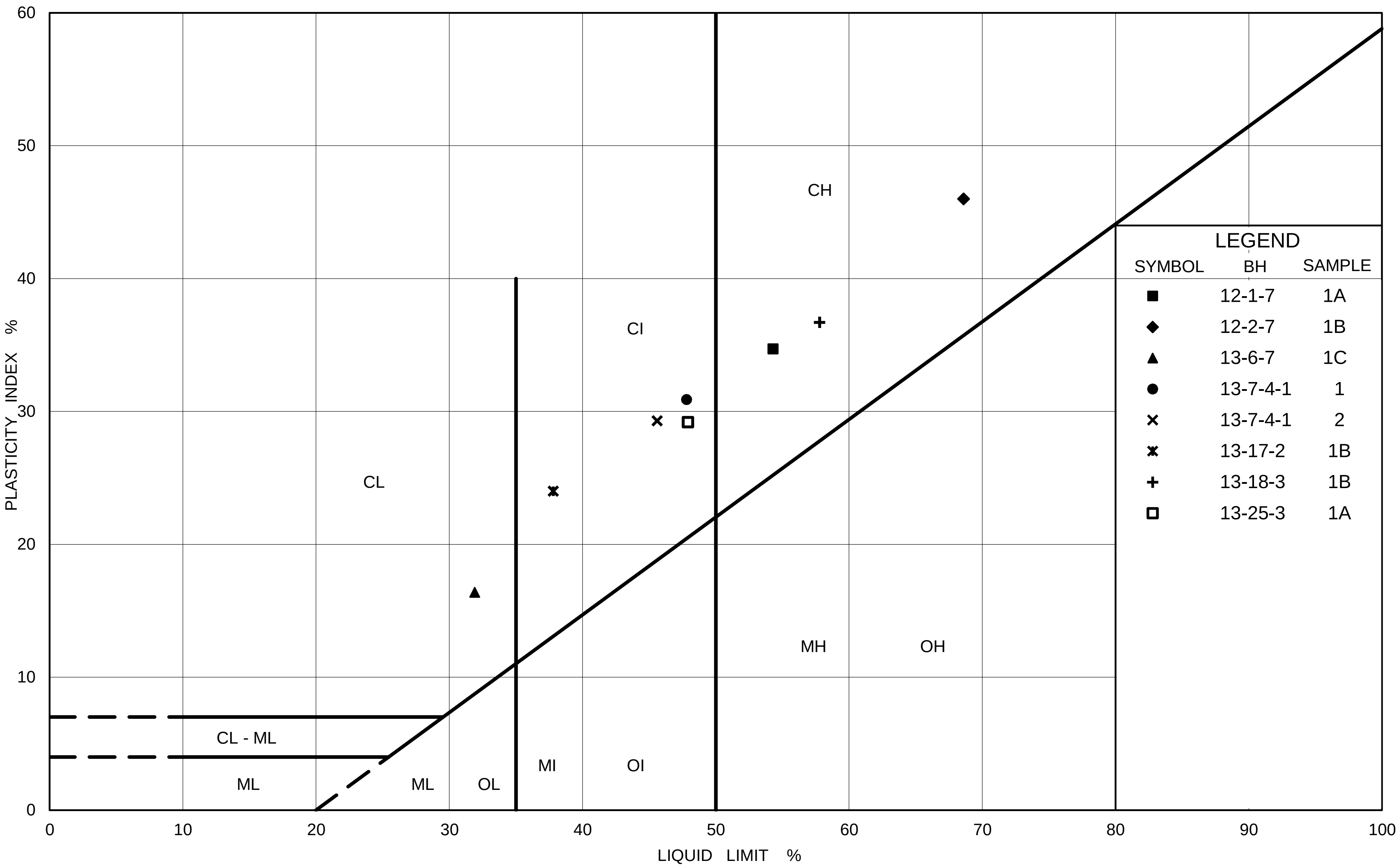


Date	November 28, 2013	**Golder Associates**	Drawn	SAT
Project	12-1125-0045		Chkd	MIC

APPENDIX F

Plasticity Charts, Consolidation Test Results and Secondary Compression Test Results

Oct 75, FF-S-21



Ministry of Transportation

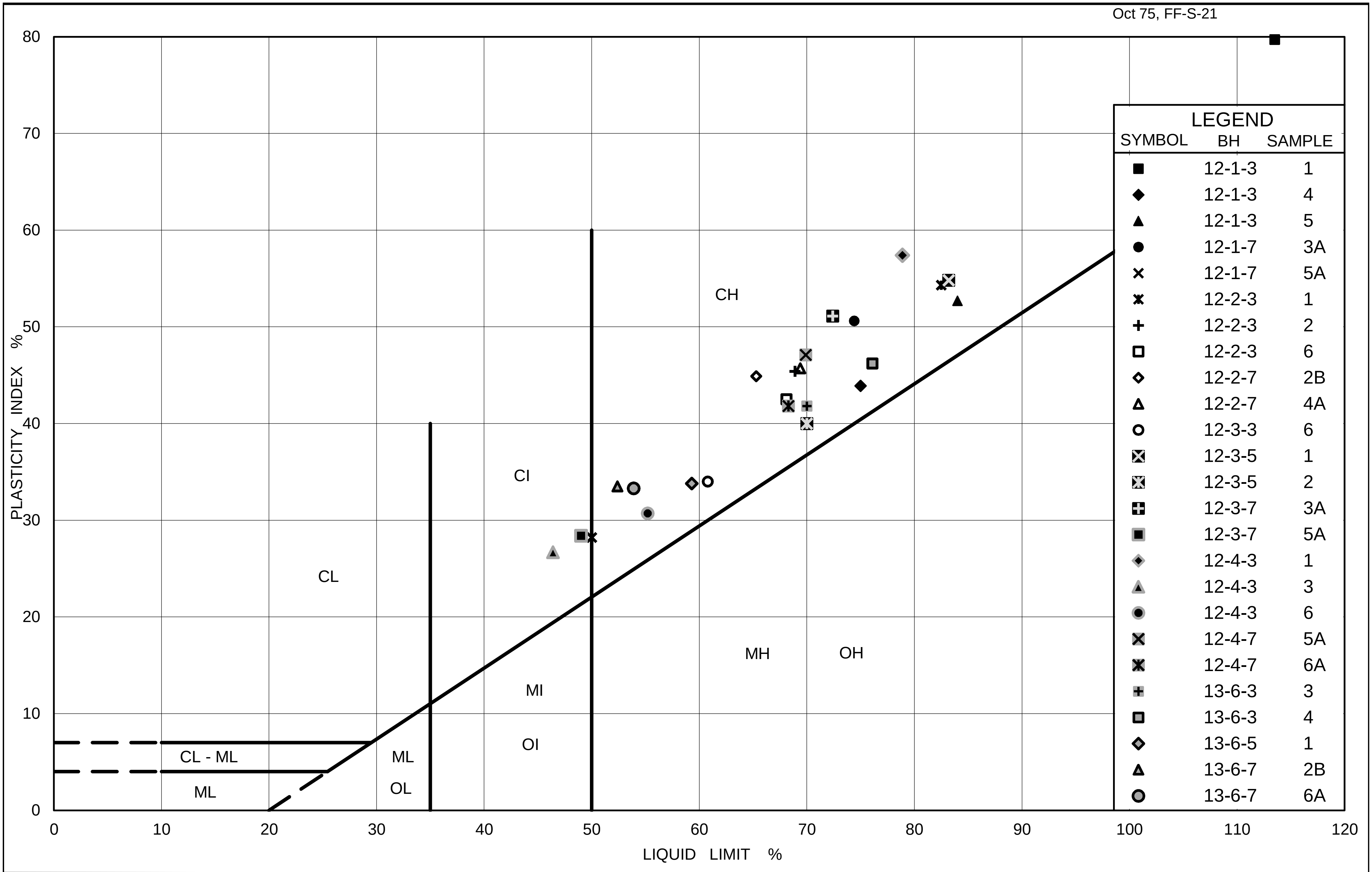
Ontario

PLASTICITY CHART
Weathered Clay to Silty Clay

FIG No. F1

Project No. 12-1125-0045/4000/0120

Compiled By : MI Checked By : CNM



Ministry of Transportation

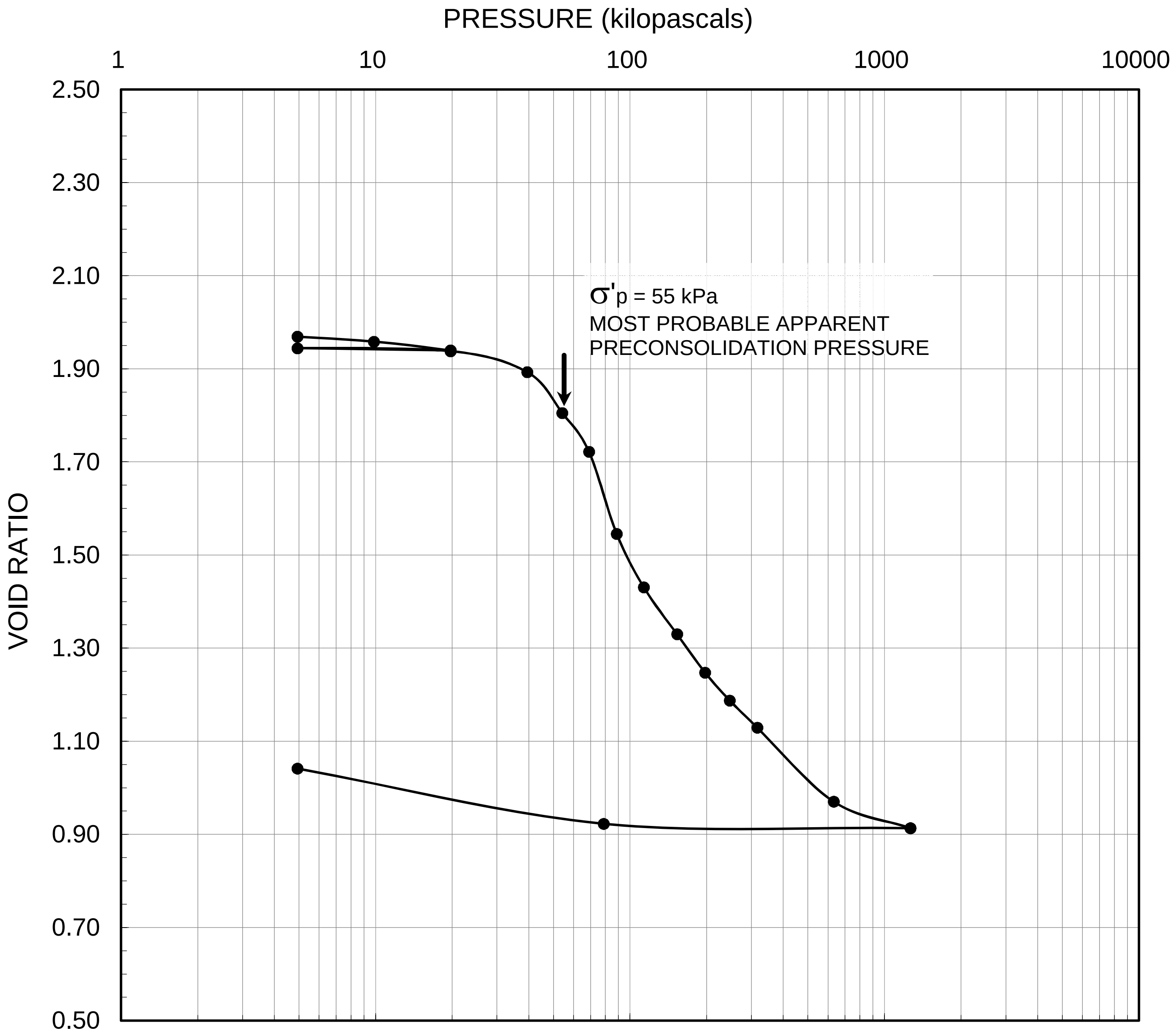
Ontario

PLASTICITY CHART
Unweathered Clay to Silty Clay

FIG No. F2

Project No. 12-1125-0045/4000/0120

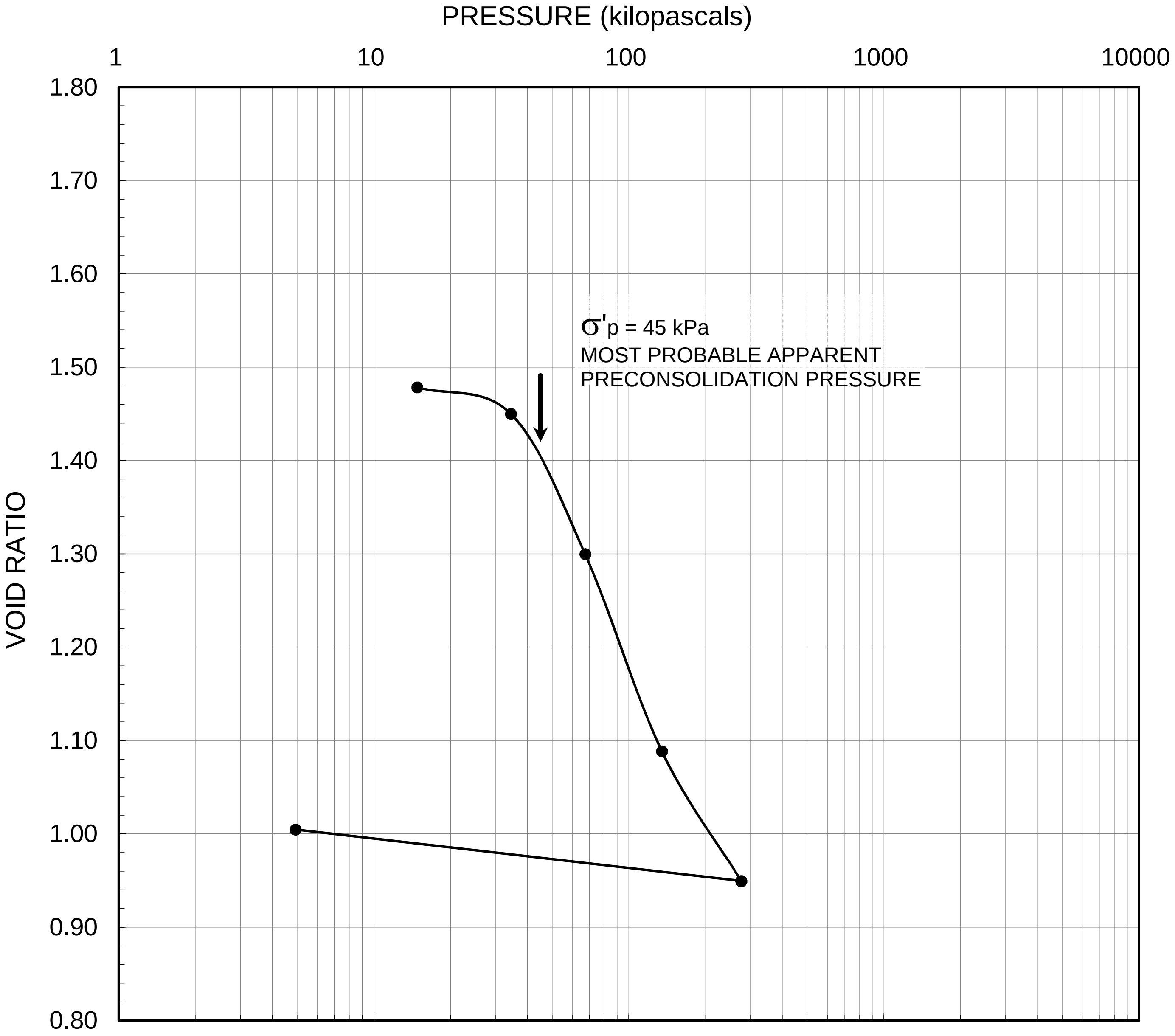
Compiled By : MI   Checked By : CNM



LEGEND

Borehole:	12-1-3	w_i =	71%	S_o =	100%	γ =	15.7 kN/m³
Sample:	1	w_f =	37%	e_o =	1.98	G_s =	2.78
Depth (m):	2.5	w_l =	114%	C_c =	1.59		
Elevation (m):	73.5	w_p =	34%	C_r =	0.010		

SCALE	AS SHOWN	TITLE	CONSOLIDATION TEST RESULTS
DATE	11/29/13		
CADD	N/A		
DESIGN	MI		
FILE No.	Consolidation summary	CHECK	CNM
PROJECT No.	12-1125-0045	REV.	3
REVIEW	MIC	FIGURE	F3



LEGEND

Borehole: 12-1-3
Sample: 2
Depth (m): 6.4
Elevation (m): 69.6

w_i = 54%
w_f = 37%
w_l = 23% *
w_p = NP *

S_o = 99%
e_o = 1.50
C_c = 0.69
C_r = N/A

γ = 16.6 kN/m³
G_s = 2.76

* : Limit specimen at 6.3m depth - Layered deposit

Golder Associates

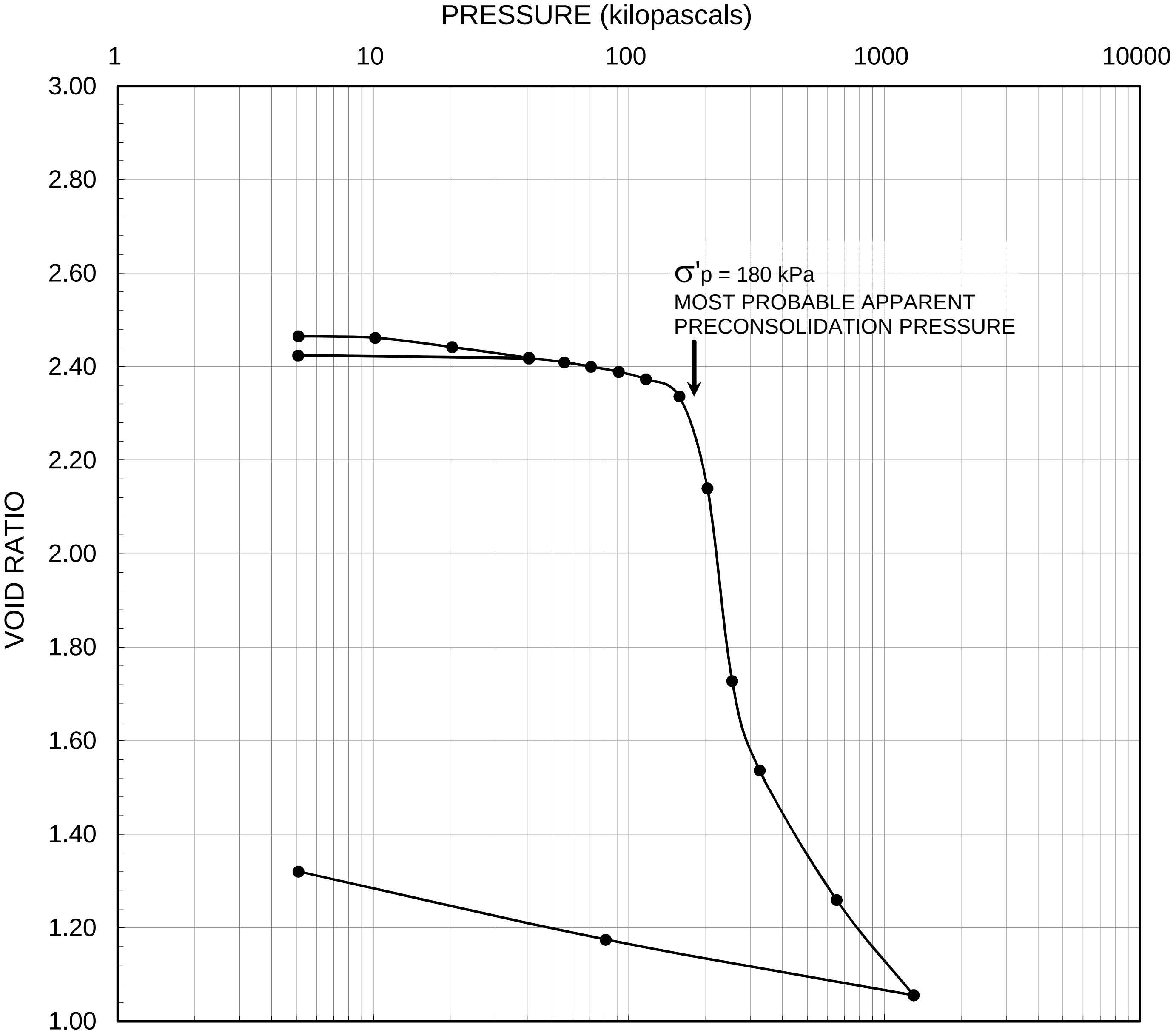
FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3

SCALE AS SHOWN
DATE 11/29/13
CADD N/A
DESIGN MI
CHECK CNM
REVIEW MIC

TITLE

CONSOLIDATION TEST RESULTS

FIGURE **F4**



LEGEND

Borehole:	12-1-3	w_i =	84%	S_o =	98%	γ =	15 kN/m³
Sample:	4	w_f =	48%	e_o =	2.47	G_s =	2.88
Depth (m):	13.3	w_l =	75%	C_c =	4.23		
Elevation (m):	62.7	w_p =	31%	C_r =	0.008		

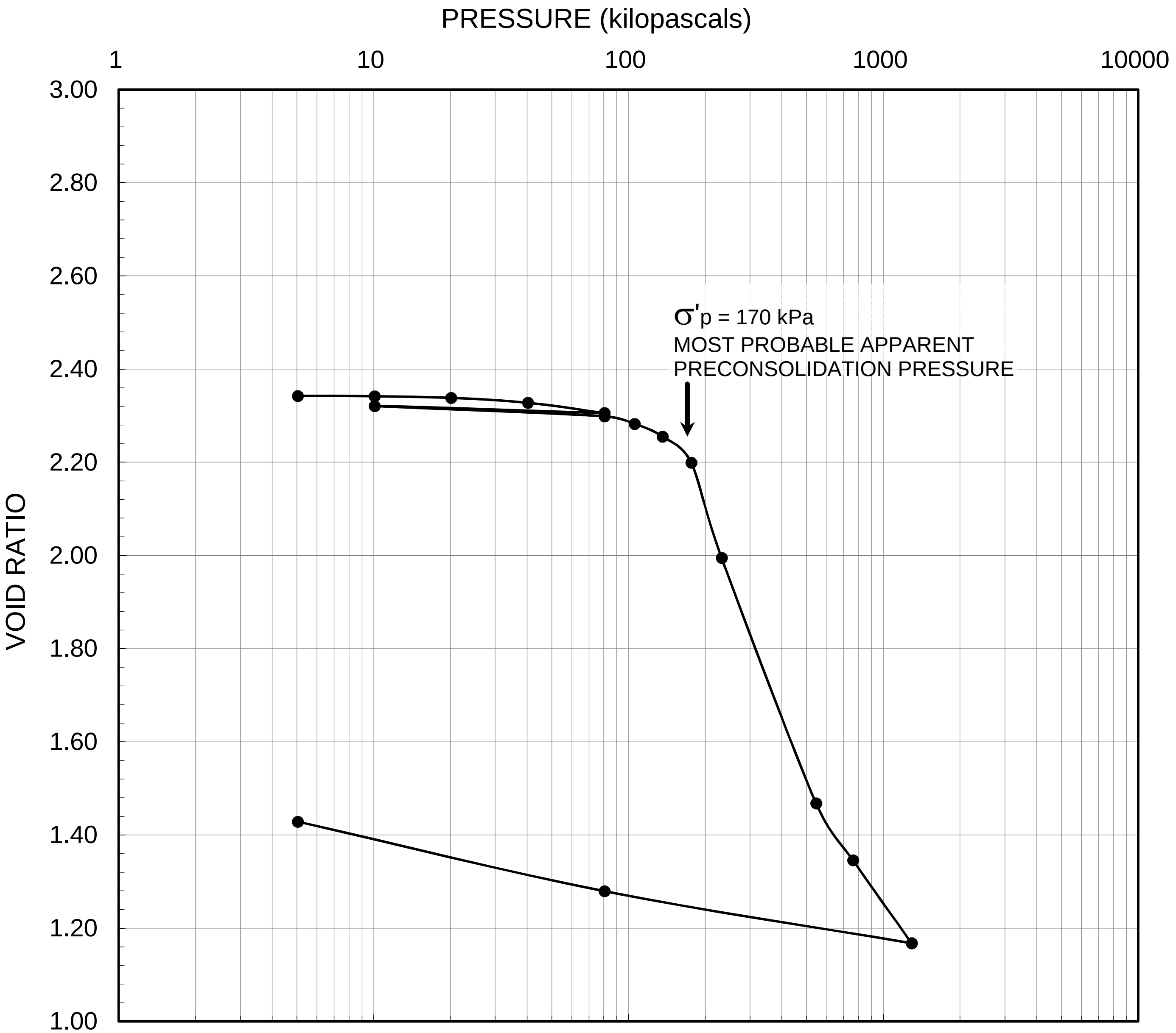
Golder Associates

SCALE AS SHOWN
DATE 11/29/13
CADD N/A
DESIGN MI
CHECK CNM
REVIEW MIC

TITLE

CONSOLIDATION TEST RESULTS

FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3
FIGURE **F5**



$\sigma'p$ = 170 kPa
MOST PROBABLE APPARENT
PRECONSOLIDATION PRESSURE

LEGEND

Borehole:	12-1-3	w_i = 82%	S_o = 100%	γ = 15.3 kN/m³
Sample:	5	w_f = 50%	e_o = 2.35	G_s = 2.87
Depth (m):	18.7	w_l = 84%	C_c = 1.70	
Elevation (m):	57.3	w_p = 31%	C_r = 0.024	

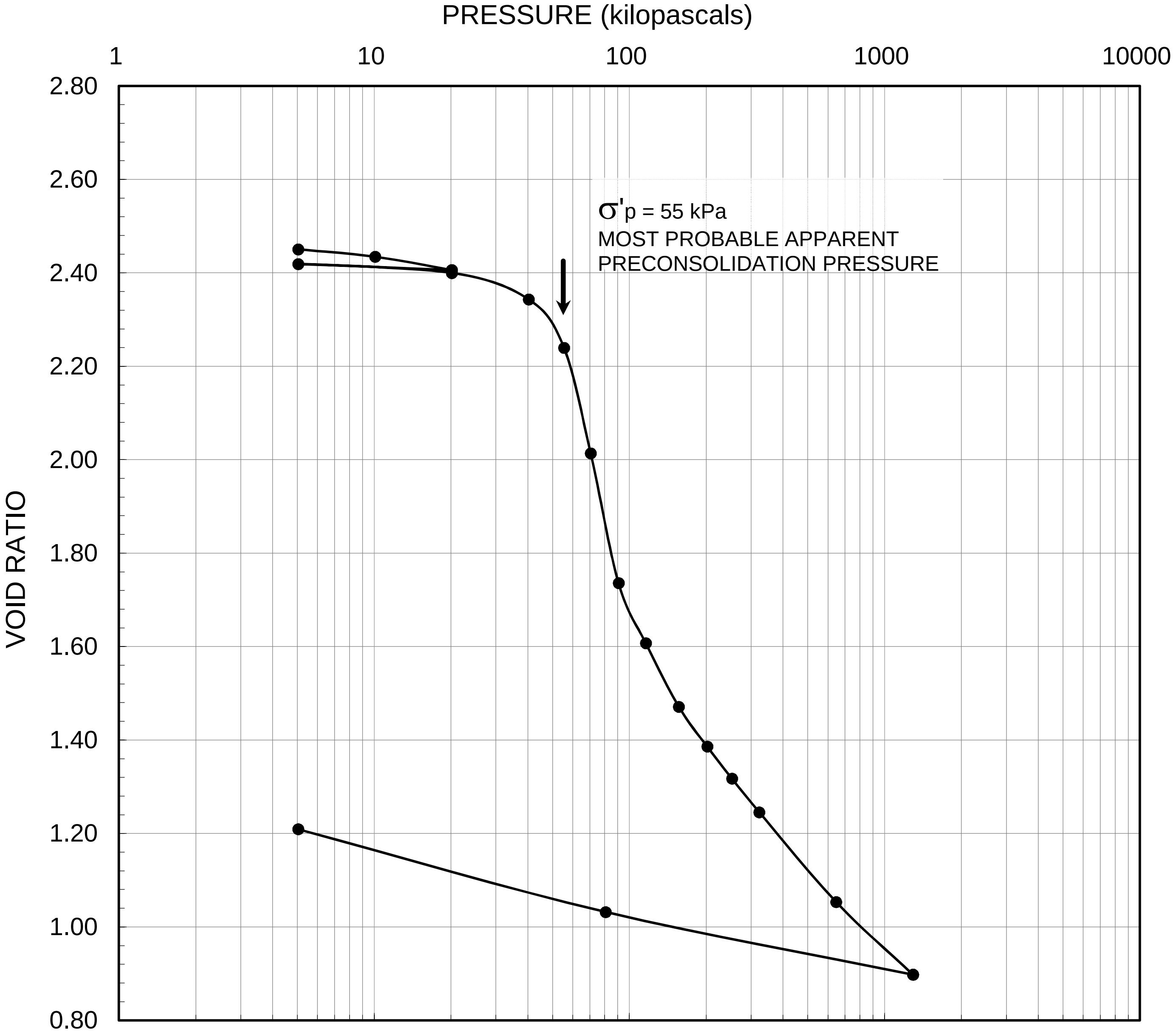
Golder Associates

FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3

SCALE AS SHOWN
DATE 11/29/13
CADD N/A
DESIGN MI
CHECK CNM
REVIEW MIC

TITLE
CONSOLIDATION TEST RESULTS

FIGURE **F6**



LEGEND

Borehole:	12-2-3	w_i =	89%	S_o =	100%	γ =	14.7 kN/m³
Sample:	1	w_f =	45%	e_o =	2.47	G_s =	2.75
Depth (m):	4.5	w_l =	83%	C_c =	2.57		
Elevation (m):	72.4	w_p =	28%	C_r =	0.032		

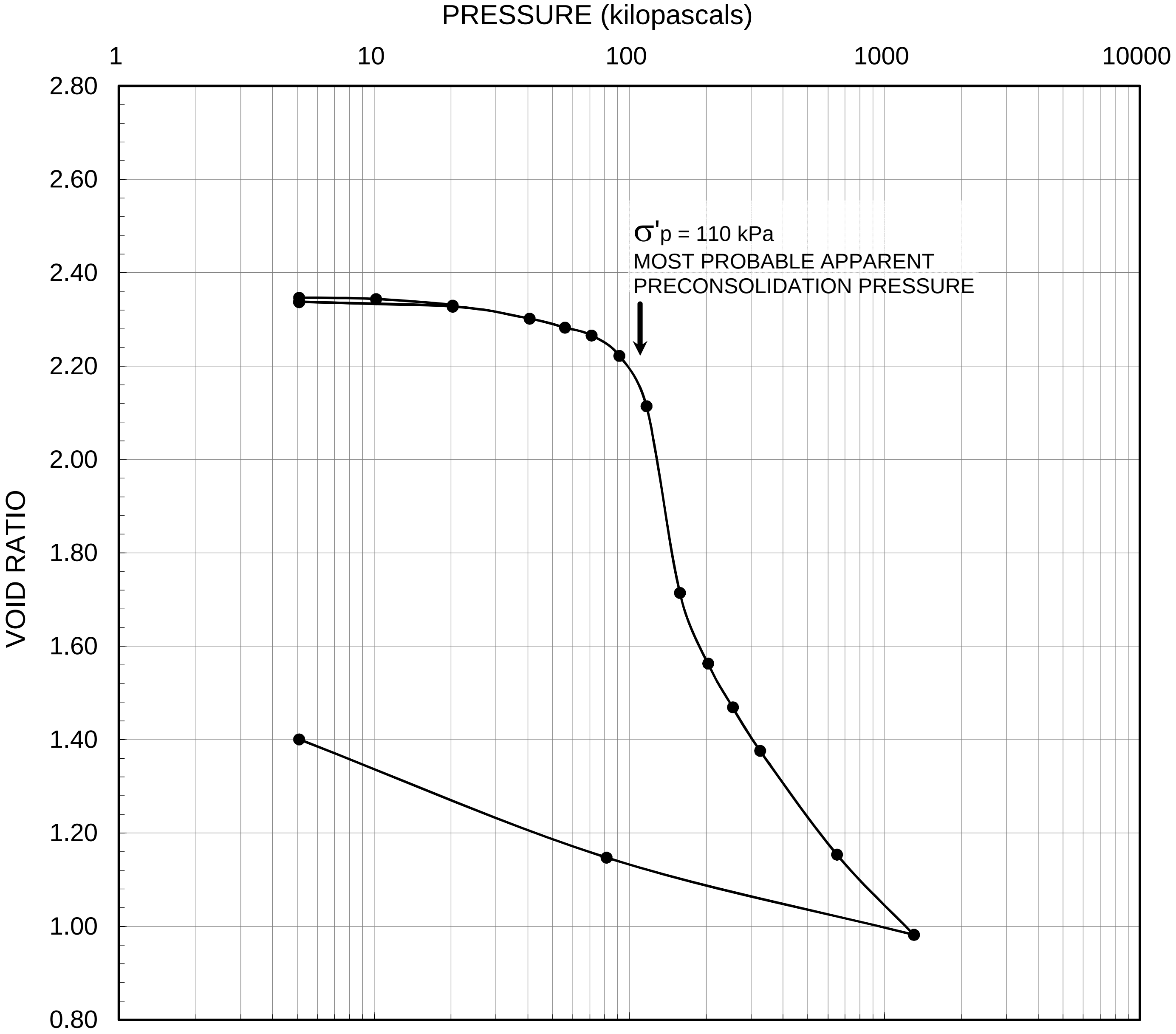
Golder Associates

SCALE	AS SHOWN	TITLE	
DATE	11/29/13		
CADD	N/A		
DESIGN	MI		
CHECK	CNM		
REVIEW	MIC	FIGURE	F7

FILE No. Consolidation summary

PROJECT No. 12-1125-0045 REV. 3

CONSOLIDATION TEST RESULTS



σ'_p = 110 kPa
MOST PROBABLE APPARENT
PRECONSOLIDATION PRESSURE

LEGEND

Borehole: 12-2-3
Sample: 2
Depth (m): 8.5
Elevation (m): 68.4

w_i = 85%
w_f = 51%
w_l = 69%
w_p = 23%

S_o = 100%
e_o = 2.35
C_c = 3.06
C_r = 0.017

γ = 15 kN/m³
G_s = 2.76

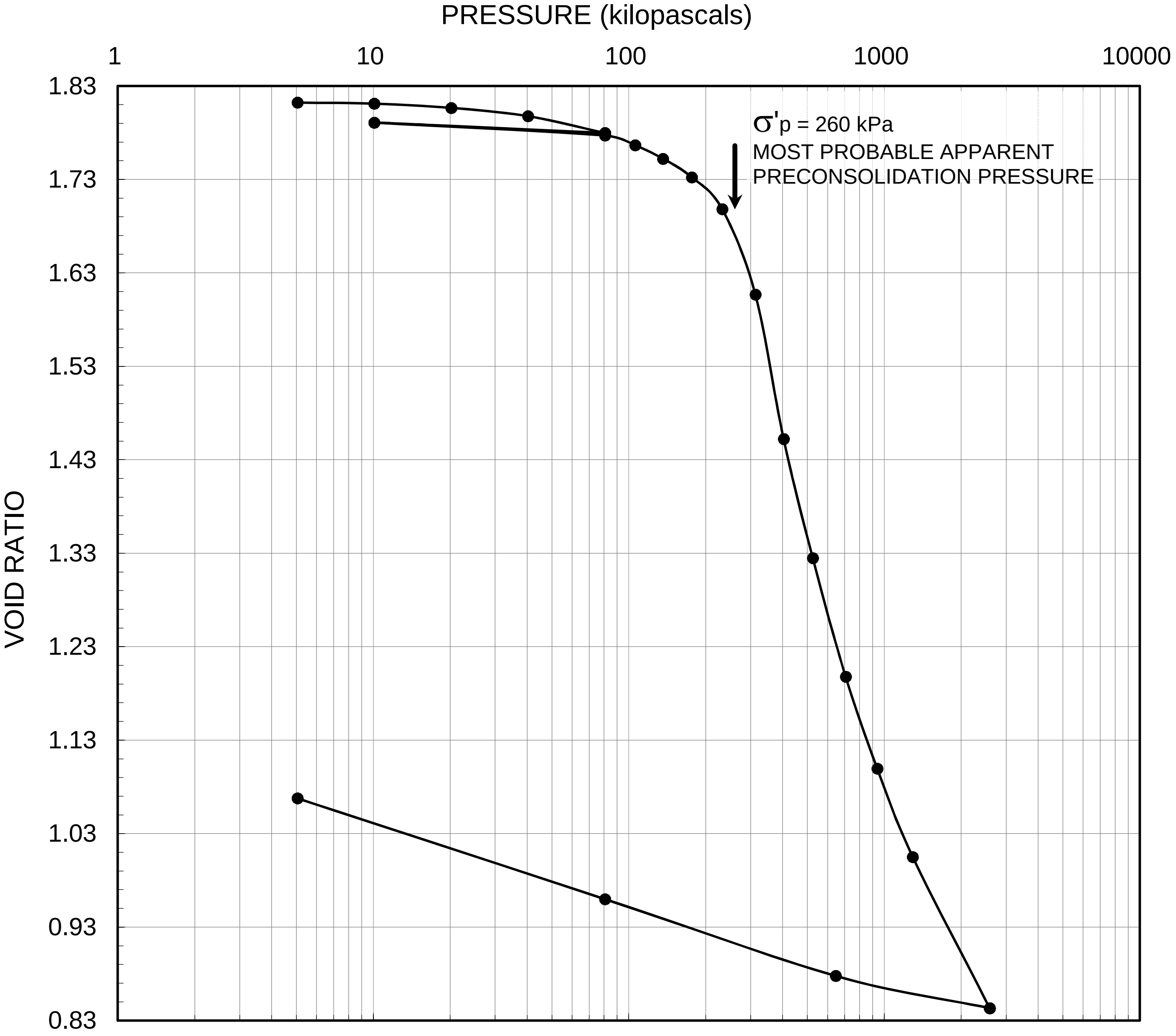
Golder Associates

SCALE AS SHOWN
DATE 11/29/13
CADD N/A
DESIGN MI
CHECK CNM
REVIEW MIC

FILE No. Consolidation summary
PROJECT No. 12-1125-0045
REV. 3

TITLE
CONSOLIDATION TEST RESULTS

FIGURE **F8**



LEGEND

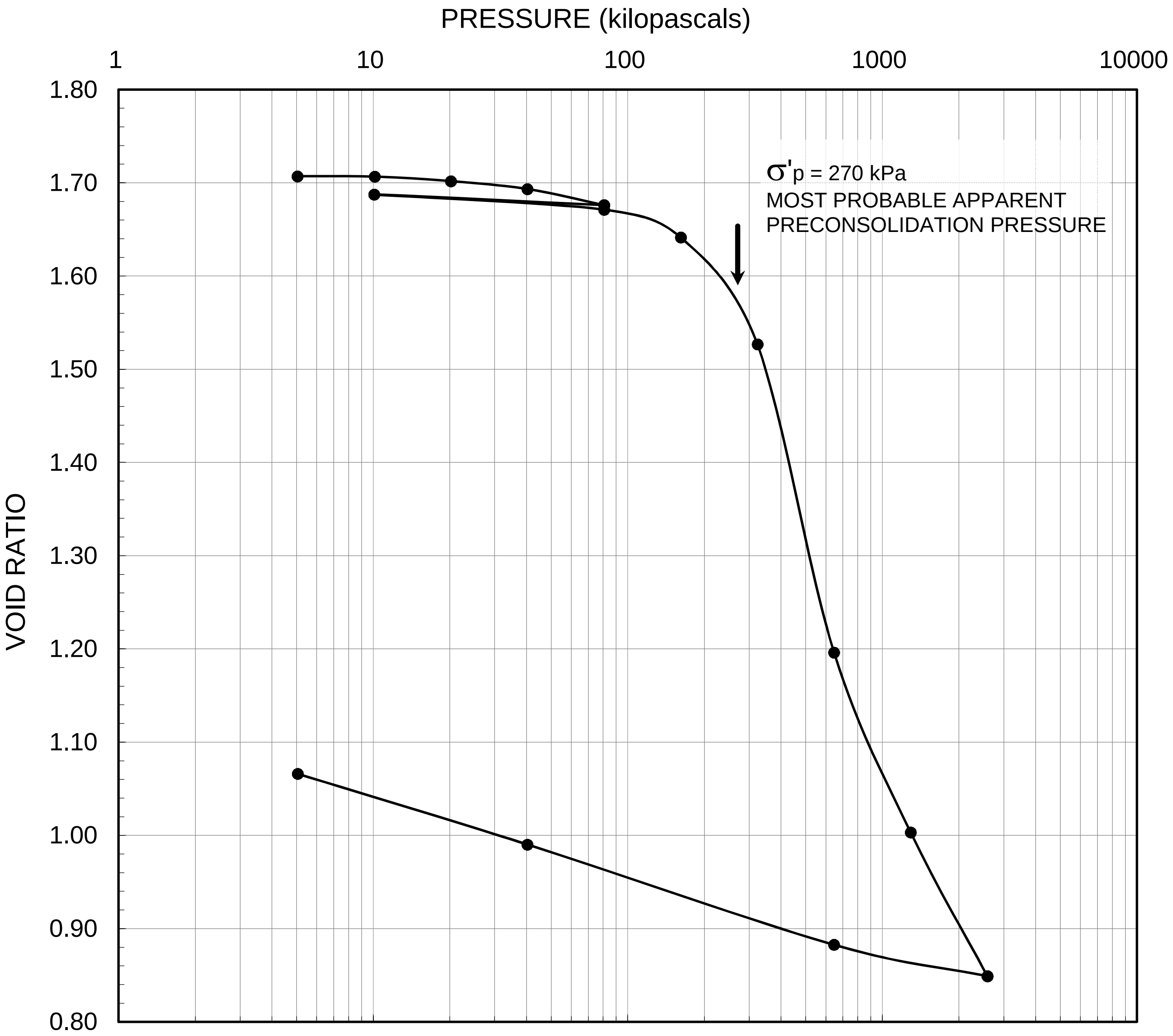
Borehole: 12-2-3
Sample: 6
Depth (m): 24.0
Elevation (m): 52.9

w_i = 65%
w_f = 39%
w_l = 68%
w_p = 26%

S_o = 101%
e_o = 1.81
C_c = 1.40
C_r = 0.015

γ = 16.1 kN/m³
G_s = 2.79

Golder Associates	
FILE No.	Consolidation summary
PROJECT No.	12-1125-0045
REV.	3
SCALE	AS SHOWN
DATE	11/29/13
CADD	N/A
DESIGN	MI
CHECK	CNM
REVIEW	MIC
TITLE	CONSOLIDATION TEST RESULTS
FIGURE	F9



LEGEND

Borehole:	12-3-3	w_i = 61%	S_o = 100%	γ = 16.3 kN/m³
Sample:	6	w_f = 39%	e_o = 1.71	G_s = 2.79
Depth (m):	29.4	w_l = 61%	C_c = 1.10	
Elevation (m):	46.8	w_p = 27%	C_r = 0.018	

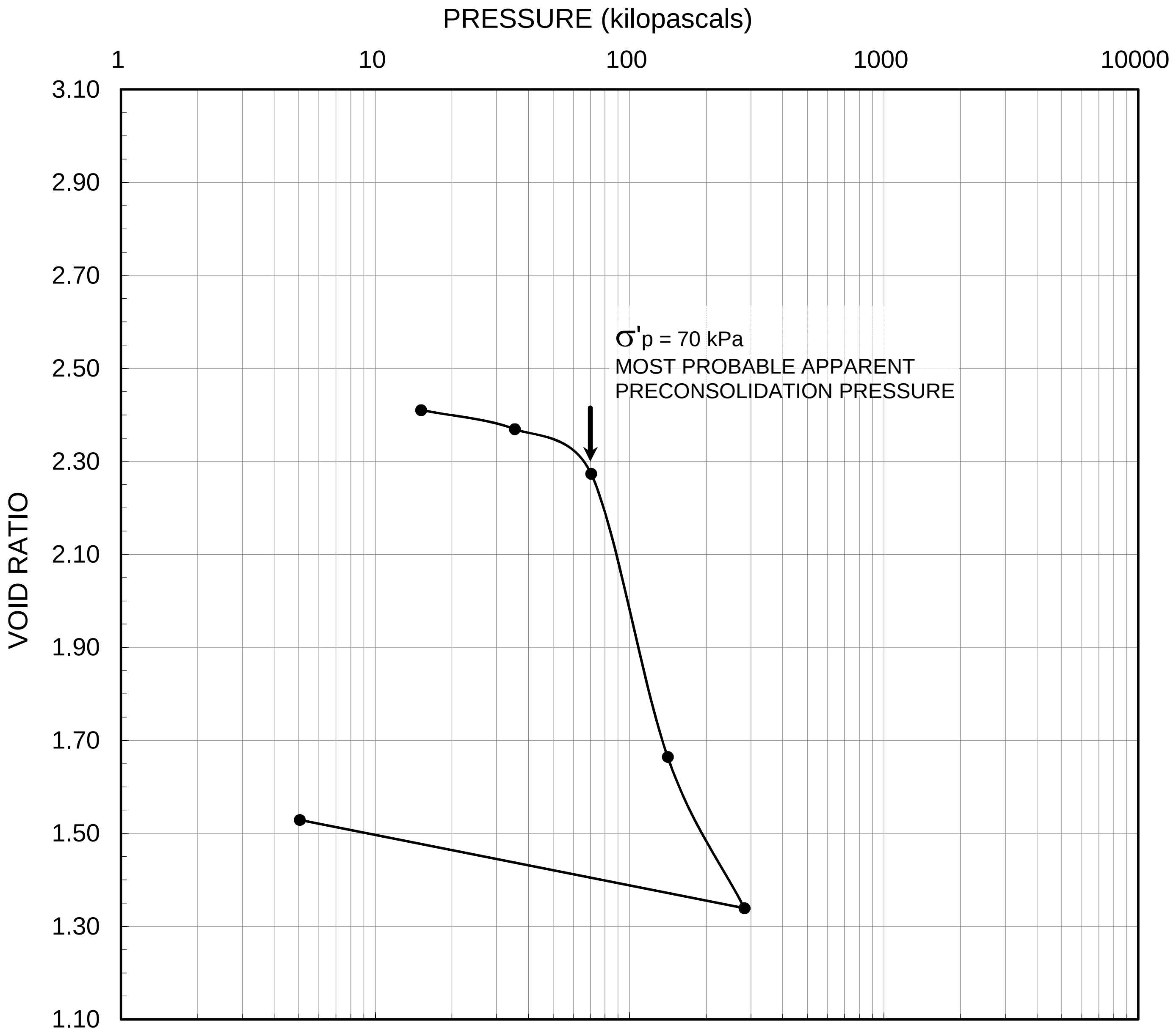
Golder Associates

SCALE AS SHOWN
DATE 11/29/13
CADD N/A
DESIGN MI
CHECK CNM
REVIEW MIC

TITLE

CONSOLIDATION TEST RESULTS

FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3
FIGURE F10



LEGEND

Borehole: 12-3-5
Sample: 1
Depth (m): 5.6
Elevation (m): 70.6

w_i = 88%
w_f = 57%
w_l = 83%
w_p = 28%

S_o = 100%
e_o = 2.44
C_c = 2.04
C_r = N/A

γ = 14.9 kN/m³
G_s = 2.79

Golder Associates

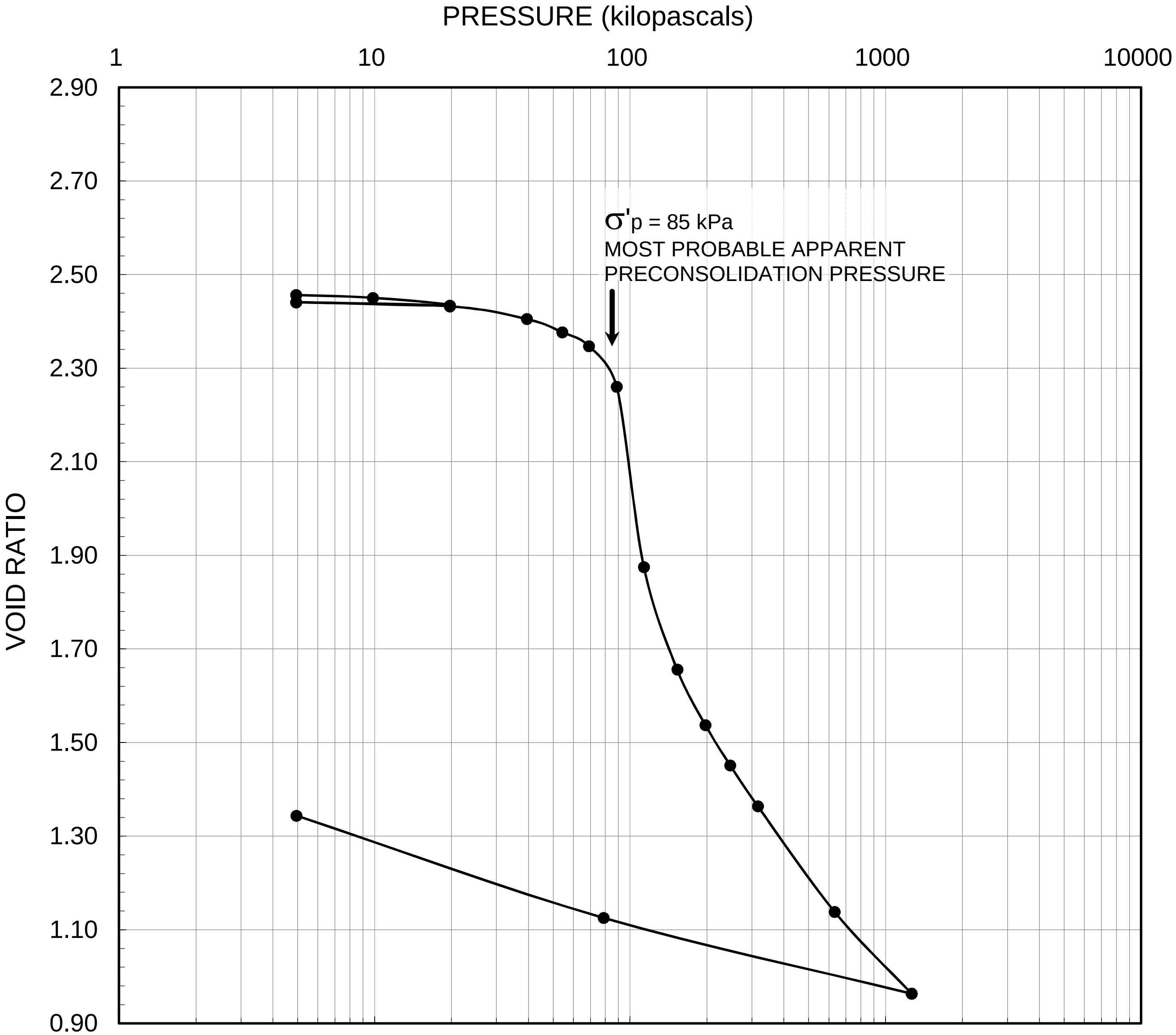
SCALE AS SHOWN
DATE 11/29/13
CADD N/A
ENTERED MI
CHECK CNM
REVIEW MIC

FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3

TITLE

CONSOLIDATION TEST RESULTS

FIGURE F11



σ'_p = 85 kPa
MOST PROBABLE APPARENT
PRECONSOLIDATION PRESSURE

LEGEND

Borehole:	12-3-5	w_i = 87%	S_o = 99%	γ = 14.8 kN/m³
Sample:	1	w_f = 48%	e_o = 2.46	G_s = 2.79
Depth (m):	5.7	w_l = 83%	C_c = 3.71	
Elevation (m):	70.5	w_p = 28%	C_r = 0.015	

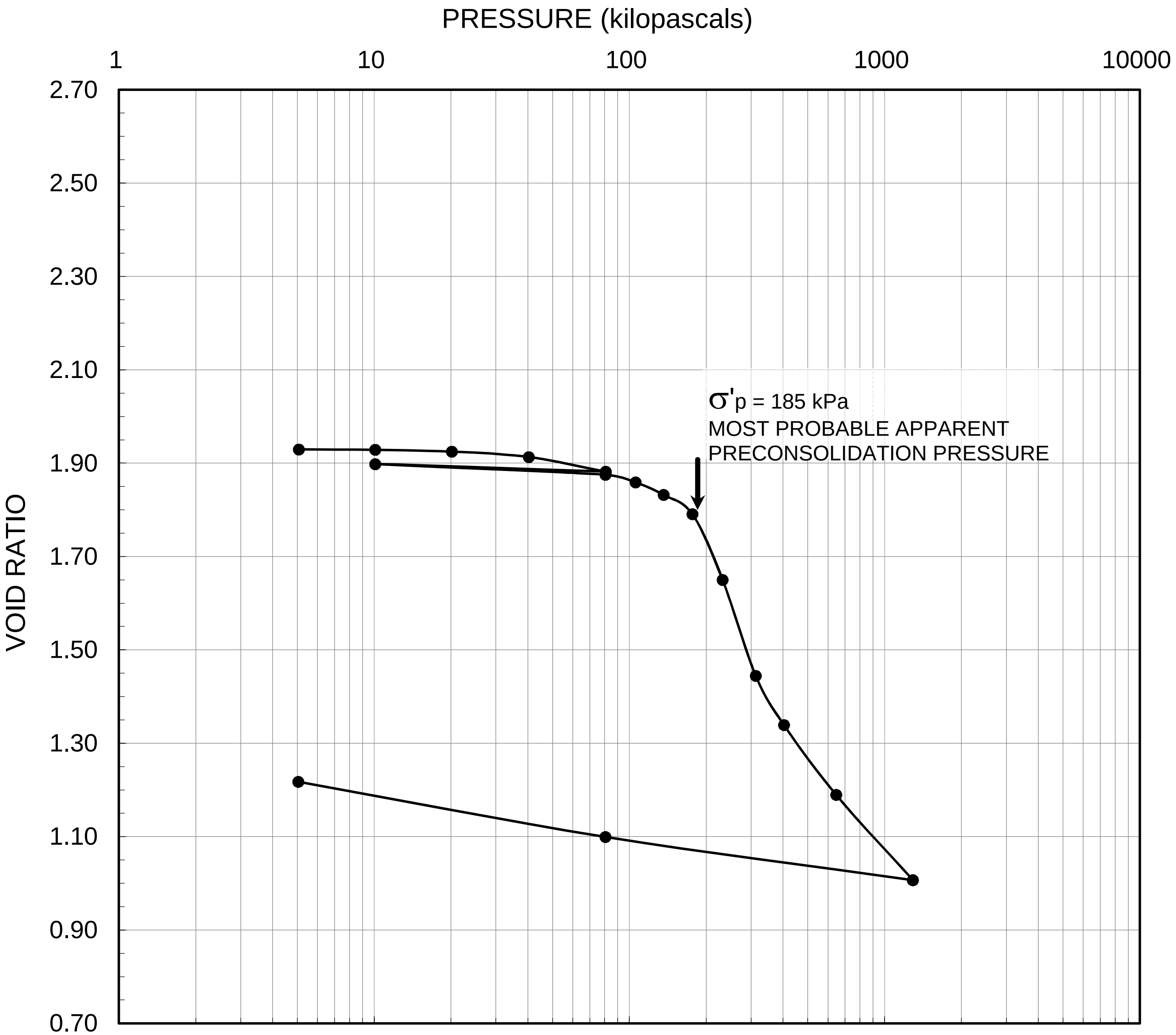
SCALE AS SHOWN
DATE 11/29/13
CADD N/A
DESIGN MI
CHECK CNM
REVIEW MIC

FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3

TITLE

CONSOLIDATION TEST RESULTS

FIGURE **F12**



LEGEND

Borehole: 12-3-5	w_i = 69%	S_o = 101%	γ = 15.9 kN/m³
Sample: 2	w_f = 45%	e_o = 1.93	G_s = 2.81
Depth (m): 15.7	w_l = 70%	C_c = 1.58	
Elevation (m): 60.5	w_p = 30%	C_r = 0.025	

Golder Associates

SCALE	AS SHOWN
DATE	11/29/13
CADD	N/A
DESIGN	MI
CHECK	CNM
REVIEW	MIC

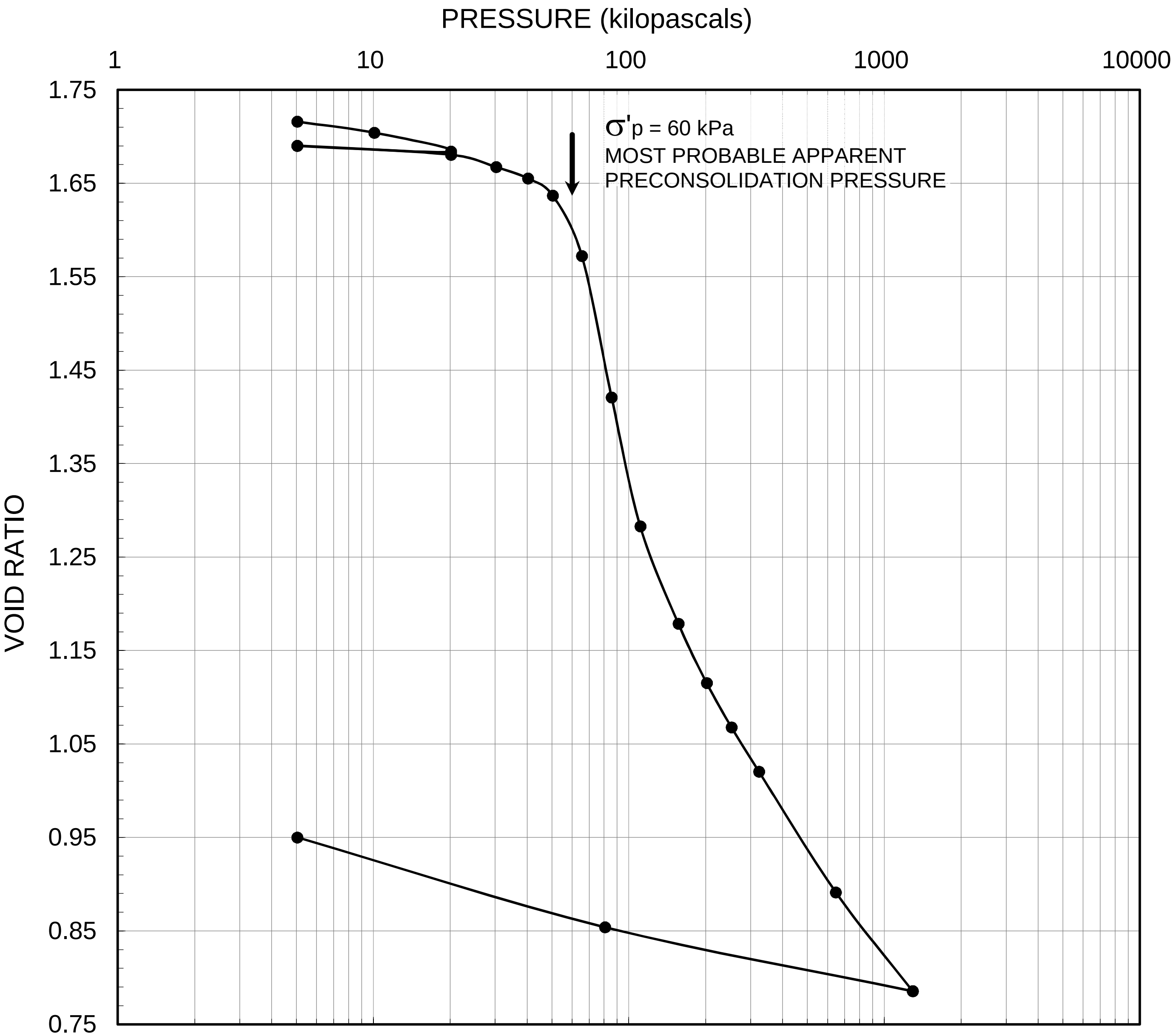
FILE No. Consolidation summary

PROJECT No. 12-1125-0045 REV. 3

TITLE

CONSOLIDATION TEST RESULTS

FIGURE **F13**



LEGEND

Borehole: 12-4-3
Sample: 1
Depth (m): 3.3
Elevation (m): 72.6

w_i = 64%
w_f = 35%
w_l = 79%
w_p = 22%

S_o = 101%
e_o = 1.73
C_c = 1.31
C_r = 0.015

γ = 16 kN/m³
G_s = 2.72

Golder Associates

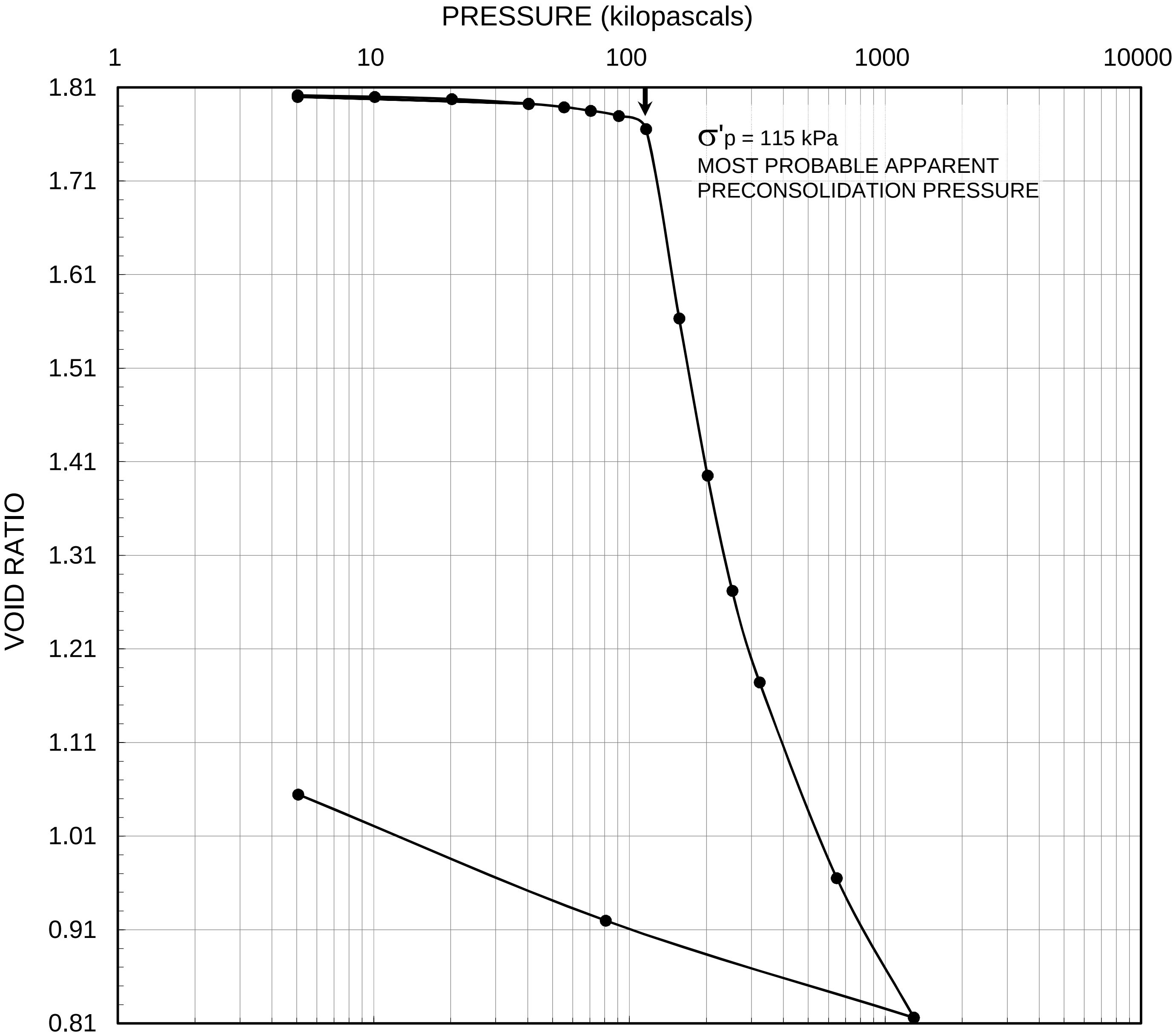
SCALE AS SHOWN
DATE 11/29/13
CADD N/A
ENTERED MI
CHECK CNM
REVIEW MIC

FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3

TITLE

CONSOLIDATION TEST RESULTS

FIGURE **F14**



σ'_p = 115 kPa
MOST PROBABLE APPARENT
PRECONSOLIDATION PRESSURE

LEGEND

Borehole: 12-4-3
Sample: 3
Depth (m): 11.1
Elevation (m): 64.8

w_i = 66%
w_f = 39%
w_l = 46%
w_p = 20%

S_o = 100%
e_o = 1.80
C_c = 1.58
C_r = 0.009

γ = 16 kN/m³
G_s = 2.76

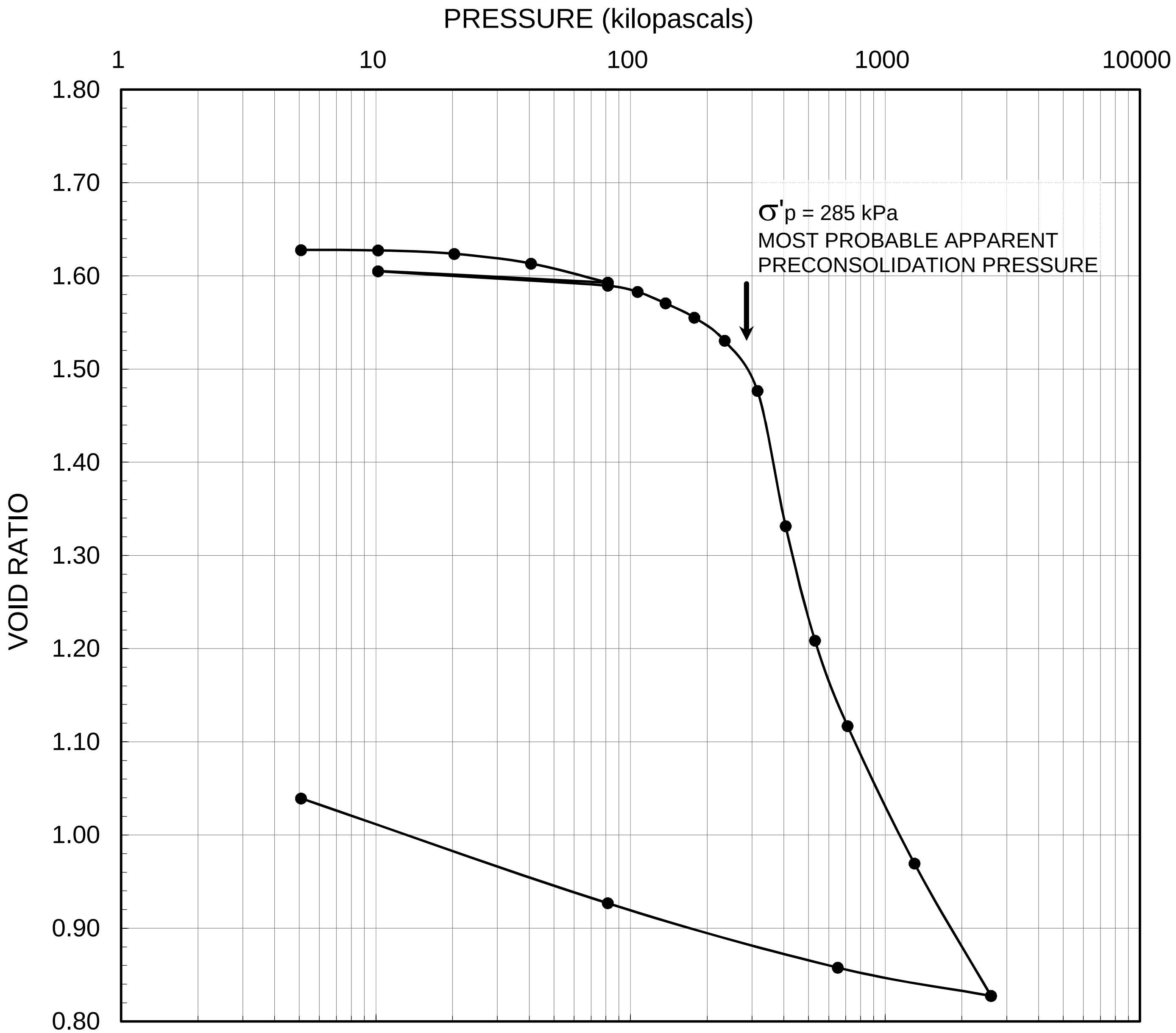
Golder Associates

SCALE AS SHOWN
DATE 11/29/13
CADD N/A
ENTERED MI
CHECK CNM
REVIEW MIC

FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3

TITLE
CONSOLIDATION TEST RESULTS

FIGURE **F15**



LEGEND

Borehole: 12-4-3 w_i = 60% S_o = 101% γ = 16.4 kN/m³
Sample: 6 w_f = 39% e_o = 1.63 G_s = 2.75
Depth (m): 26.2 w_l = 55% C_c = 1.32
Elevation (m): 49.7 w_p = 25% C_r = 0.017

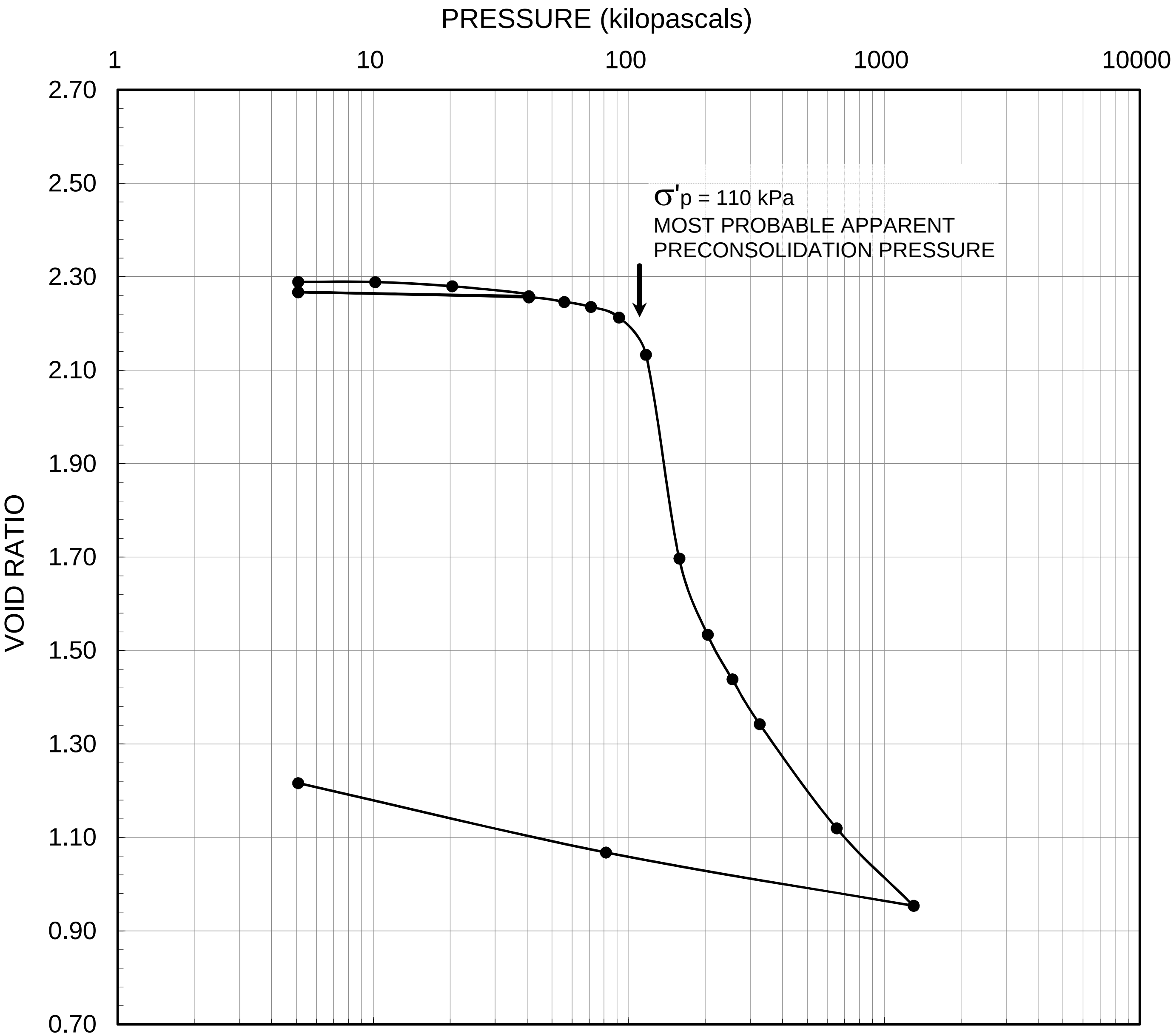
Golder Associates

SCALE AS SHOWN
DATE 11/29/13
CADD N/A
ENTERED MI
CHECK CNM
REVIEW MIC

TITLE

CONSOLIDATION TEST RESULTS

FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3
FIGURE **F16**



LEGEND

Borehole: 13-6-3

Sample: 3

Depth (m): 10.0

Elevation (m): 66.7

w_i = 83%

w_f = 45%

w_l = 70%

w_p = 28%

S_o = 100%

e_o = 2.29

C_c = 3.41

C_r = 0.010

γ = 15.1 kN/m³

G_s = 2.76

Golder Associates

SCALE	AS SHOWN
DATE	11/29/13
CADD	N/A
ENTERED	MI
CHECK	CNM
REVIEW	MIC

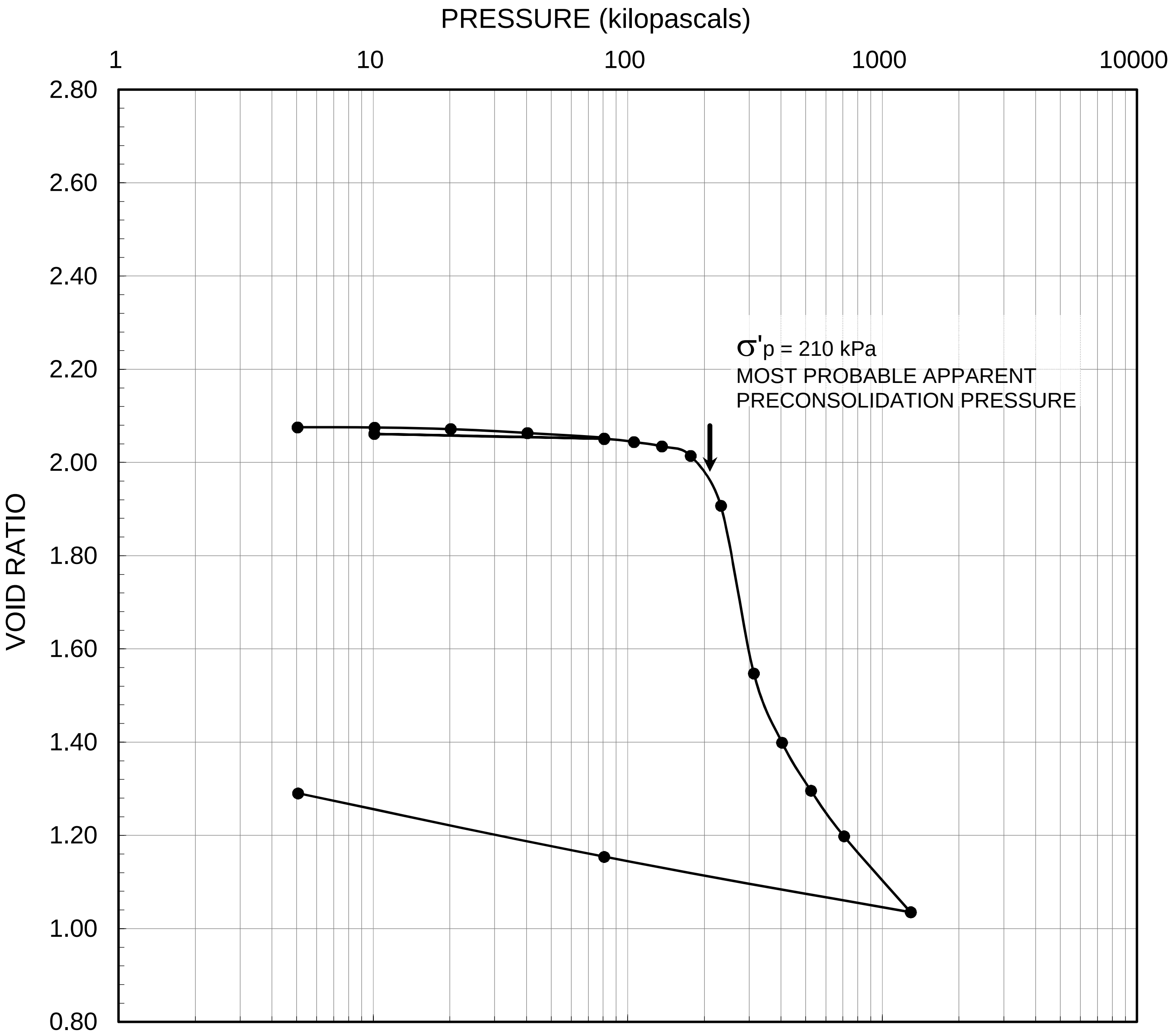
TITLE

CONSOLIDATION TEST RESULTS

FILE No. Consolidation summary

PROJECT No. 12-1125-0045 REV. 3

FIGURE **F17**



LEGEND

Borehole:	13-6-3	w_i =	76%	S_o =	101%	γ =	15.4 kN/m³
Sample:	4	w_f =	48%	e_o =	2.08	G_s =	2.75
Depth (m):	18.4	w_l =	76%	C_c =	2.80		
Elevation (m):	58.3	w_p =	30%	C_r =	0.011		

Golder Associates

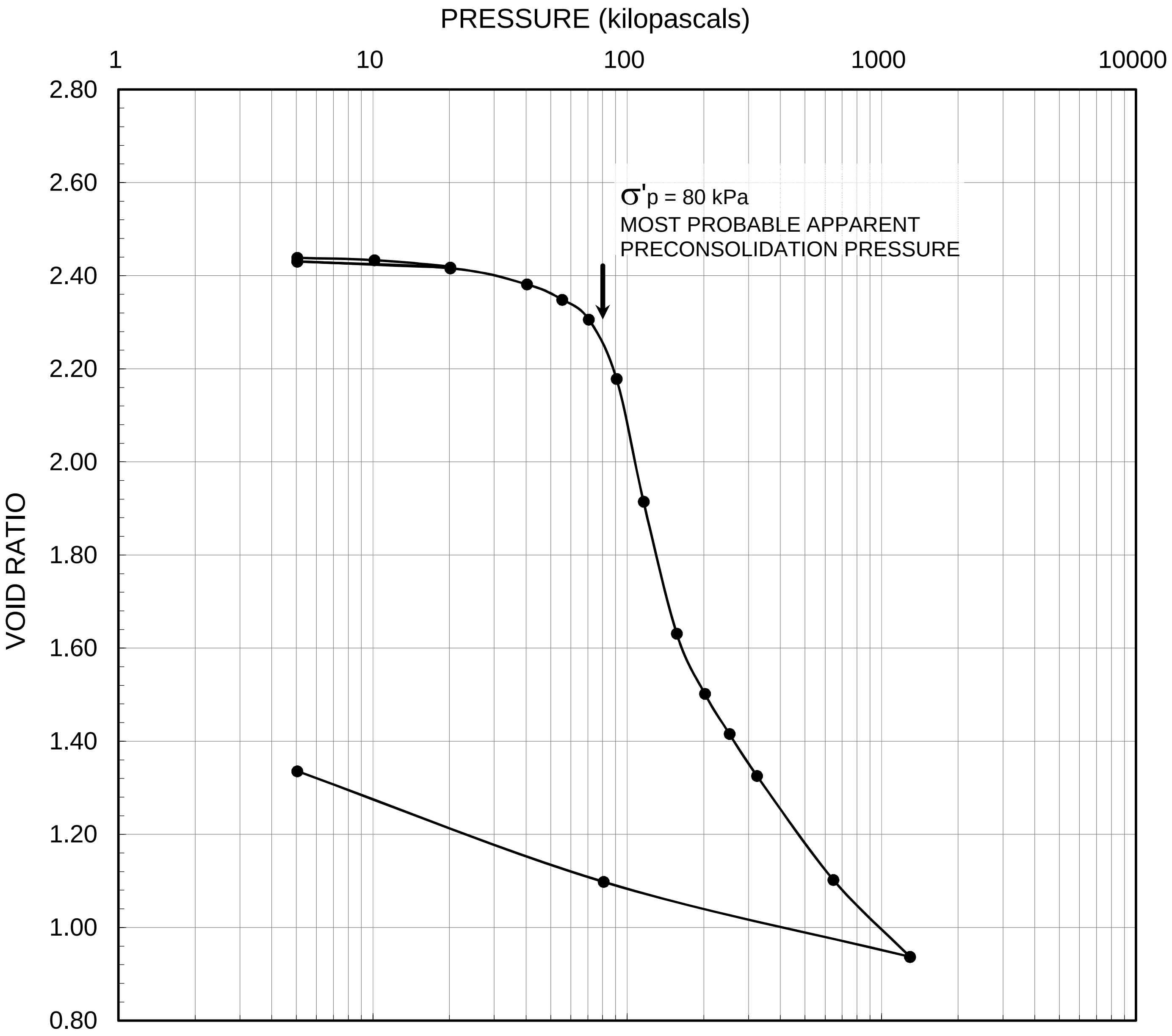
FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 3

SCALE AS SHOWN
DATE 11/29/13
CADD N/A
ENTERED MI
CHECK CNM
REVIEW MIC

TITLE

CONSOLIDATION TEST RESULTS

FIGURE **F18**



LEGEND

Borehole: 13-6-5
Sample: 1
Depth (m): 6.4
Elevation (m): 70.2

w_i = 89%
w_f = 51%
w_l = 59%
w_p = 26%

S_o = 100%
e_o = 2.44
C_c = 2.30
C_r = 0.025

γ = 14.8 kN/m³
G_s = 2.74

Golder Associates

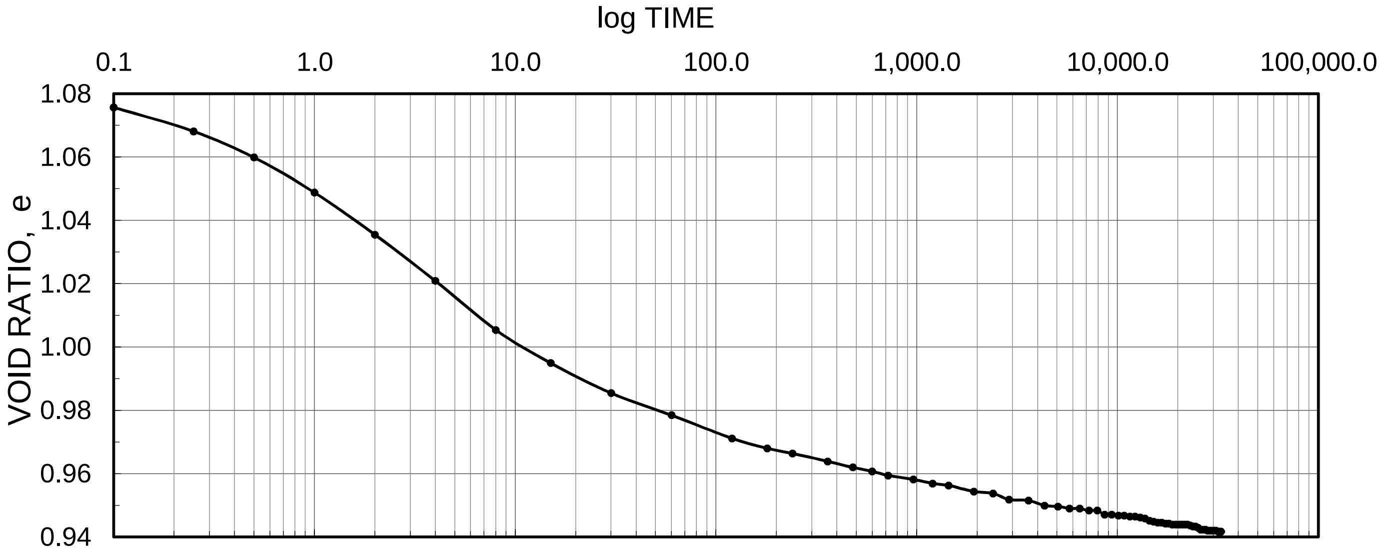
SCALE	AS SHOWN
DATE	11/29/13
CADD	N/A
ENTERED	MI
CHECK	CNM
REVIEW	MIC
FILE No.	Consolidation summary
PROJECT No.	12-1125-0045
REV.	3

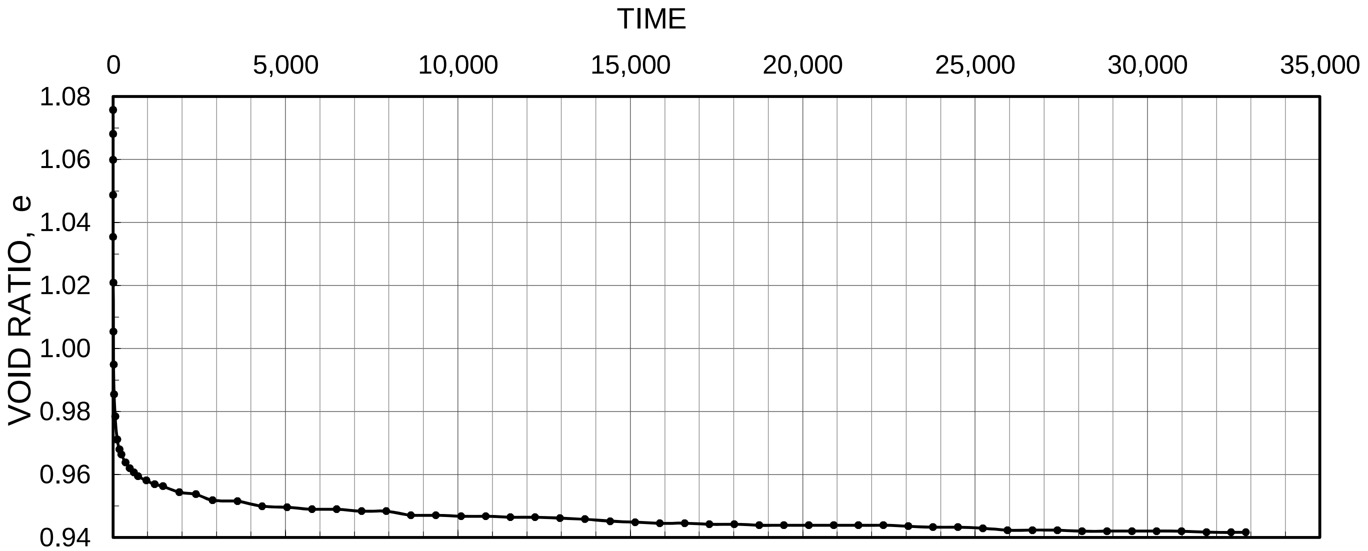
TITLE

CONSOLIDATION TEST RESULTS

FIGURE **F19**

PRESSURE = 276 kPa





LEGEND

Borehole: 12-1-3	w_i = 53.9%	S_o = 99%
Sample: 2	w_f = 36.9%	C_α = 0.011
Depth (m): 6.35	w_l = 23% *	
	w_p = NP *	

* : Limit specimen at 6.3m depth - Layered deposit

Golder Associates

SCALE AS SHOWN
DATE 11/29/13
DESIGN N/A
CADD MI
CHECK CNM
REVIEW MIC

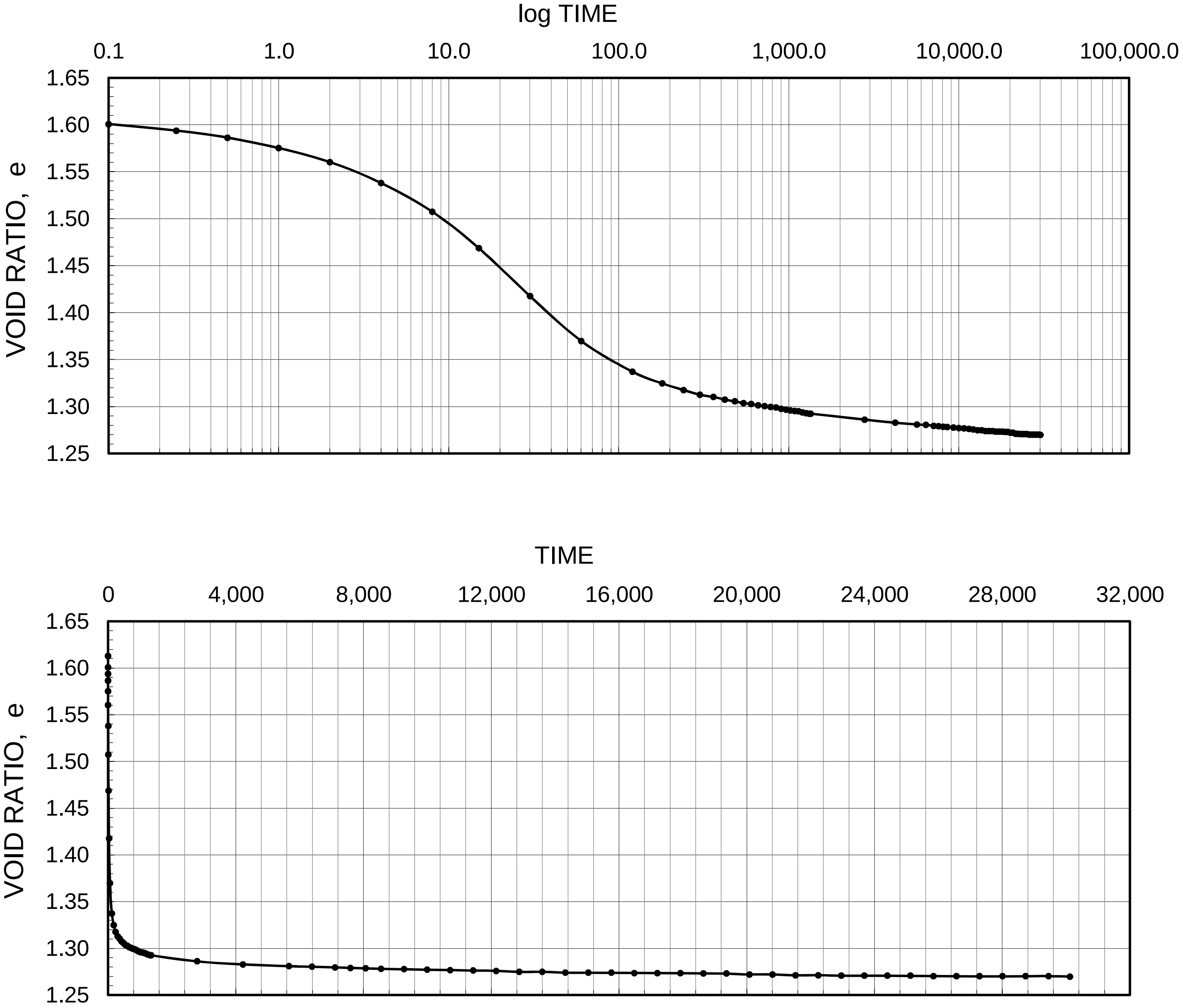
FILE No. Consolidation summary
PROJECT No. 12-1125-0045 REV. 2

TITLE

SUMMARY OF SECONDARY COMPRESSION TEST

FIGURE **F20**

PRESSURE = 280 kPa



LEGEND

Borehole: 12-3-5

Sample: 1

Depth (m): 5.60

w_i = 87.7%

w_f = 57.1%

w_l = 83.2%

w_p = 28.4%

S_o = 100%

C_α = 0.019

Golder Associates

SCALE	AS SHOWN	TITLE	
DATE	11/29/13		
DESIGN	N/A		
CADD	MI		
CHECK	CNM		
REVIEW	MIC	FIGURE	F21

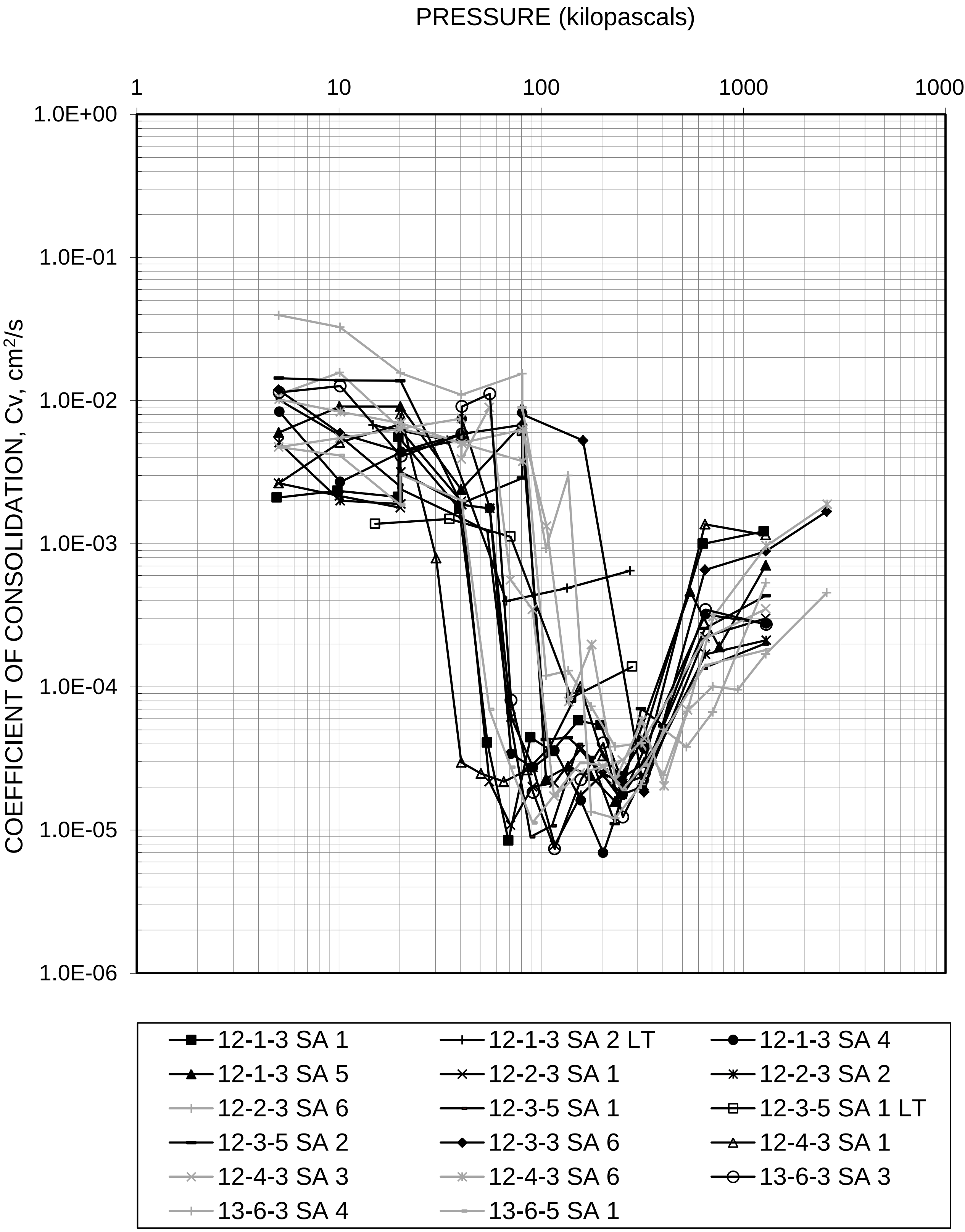
FILE No. Consolidation summary

PROJECT No. 12-1125-0045 REV. 2

SUMMARY OF SECONDARY COMPRESSION TEST

APPENDIX G

Summary of Measured/Interpreted Coefficients of Vertical and Horizontal Consolidation



Note : LIR not = 1, use Cv's with caution

Golder Associates

SCALE	AS SHOWN
DATE	11/28/13
CADD	N/A
DESIGN	CW
CHECK	SAT
REVIEW	MIC

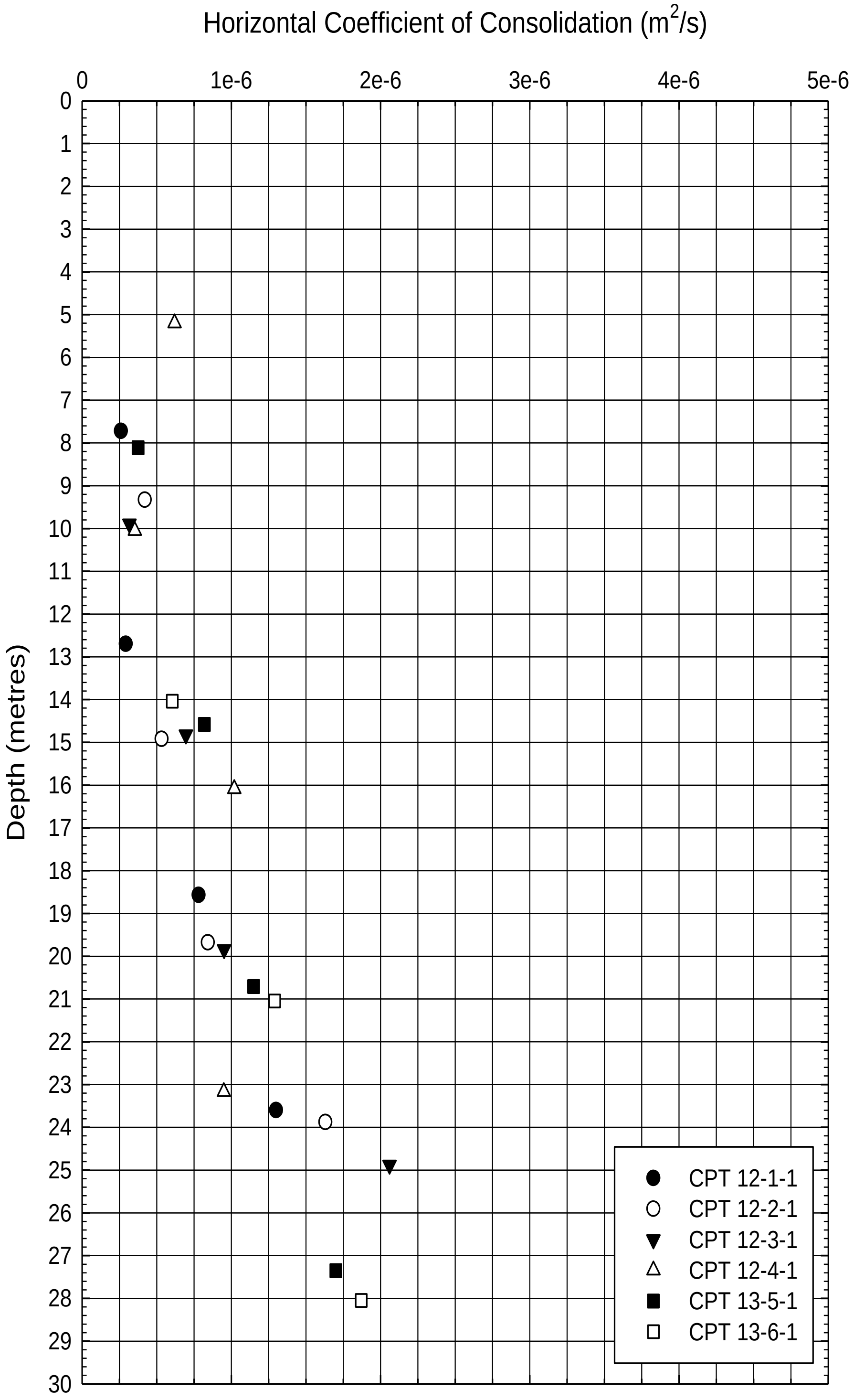
FILE No. Consolidation summary

PROJECT No. 12-1125-0045 REV. 0

TITLE

SUMMARY OF VERTICAL COEFFICIENTS OF CONSOLIDATION

FIGURE **G1**



SCALE	AS SHOWN
DATE	11/28/13
CADD	N/A
DESIGN	MIC
CHECK	SAT
REVIEW	
FILE No.	Consolidation summary
PROJECT No.	12-1125-0045
REV.	0

TITLE

SUMMARY OF HORIZONTAL COEFFICIENTS OF CONSOLIDATION

FIGURE **G2**

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

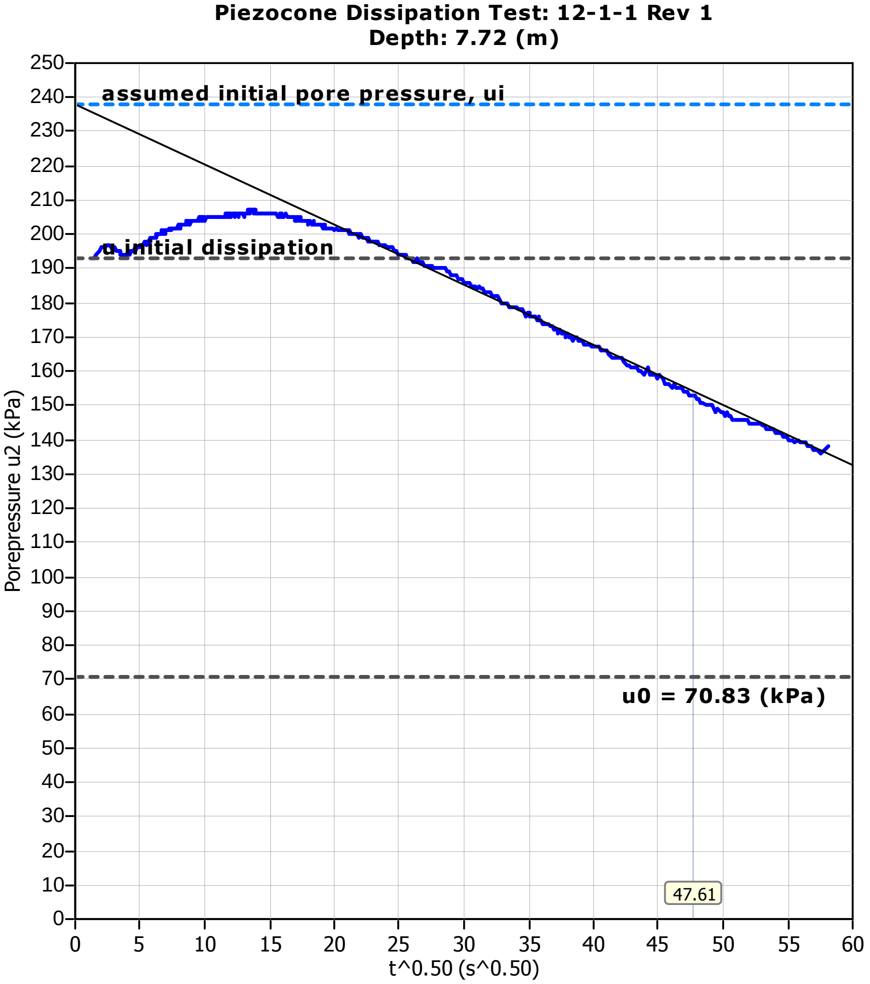
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

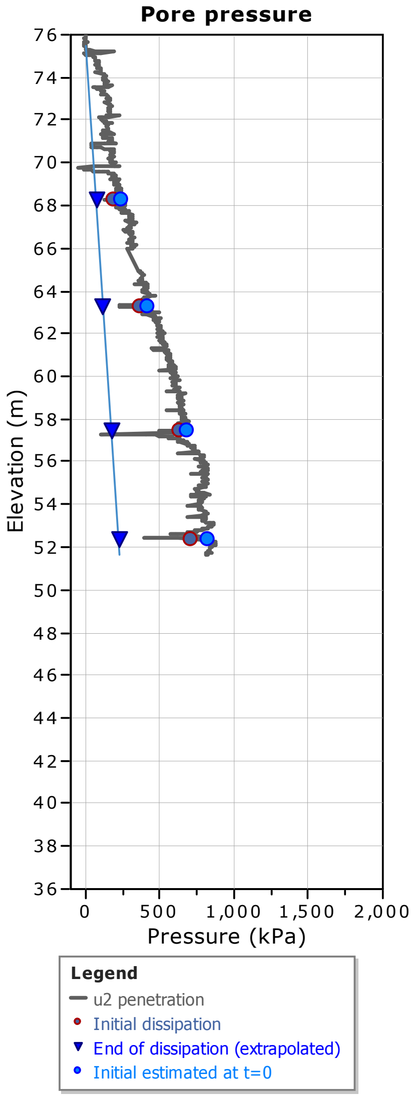
$$k_h = c_h \times \gamma_w / M$$

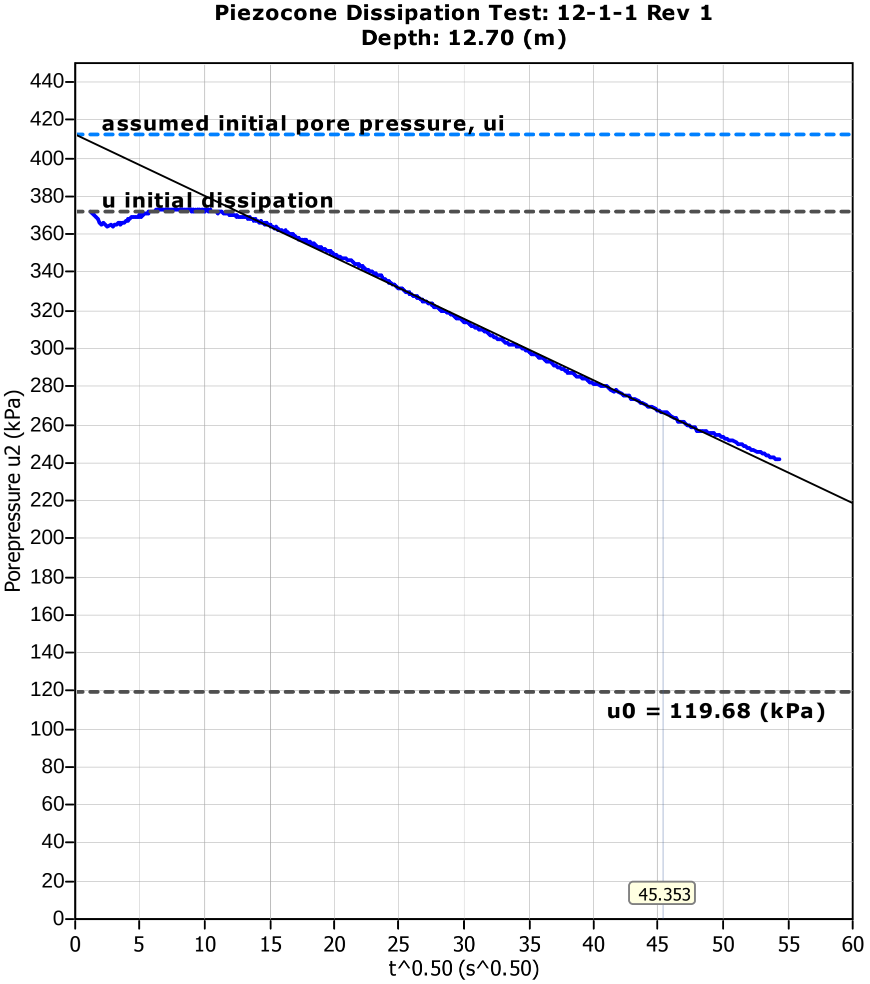
where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

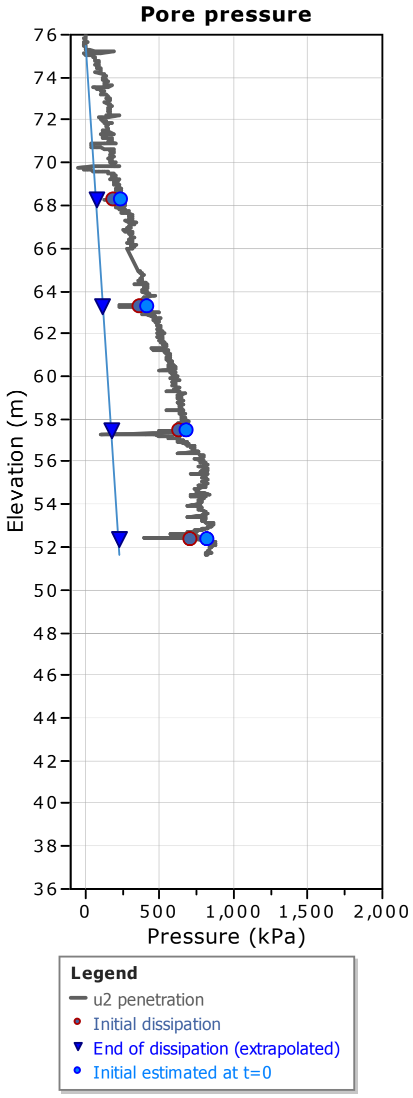
Tabular results

CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h (m^2/year)	M (MPa)	k_h (m/s)
12-1-1 Rev 1	7.72	47.6	2267	7.19E-005	57.00	2.61E-007	8	0.88	2.91E-009
12-1-1 Rev 1	12.70	45.4	2057	6.52E-005	59.00	2.93E-007	9	2.32	1.24E-009
12-1-1 Rev 1	18.57	25.7	659	2.09E-005	43.00	7.81E-007	25	3.71	2.06E-009
12-1-1 Rev 1	23.60	21.8	474	1.50E-005	62.00	1.30E-006	41	3.64	3.51E-009

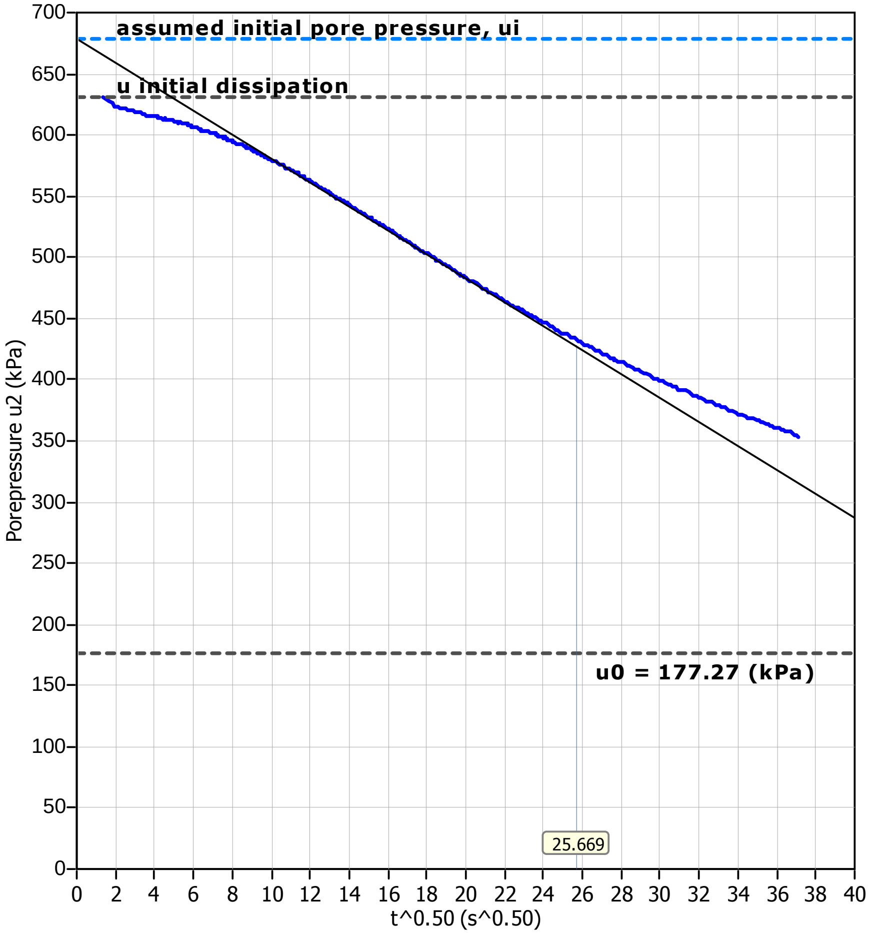

Piezocone Dissipation Test: 12-1-1 Rev 1
Depth: 7.72 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 70.83 (kPa)
47.61
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0
5
10
15
20
25
30
35
40
45
50
55
60
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


Pore pressure
Elevation (m)
Pressure (kPa)
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

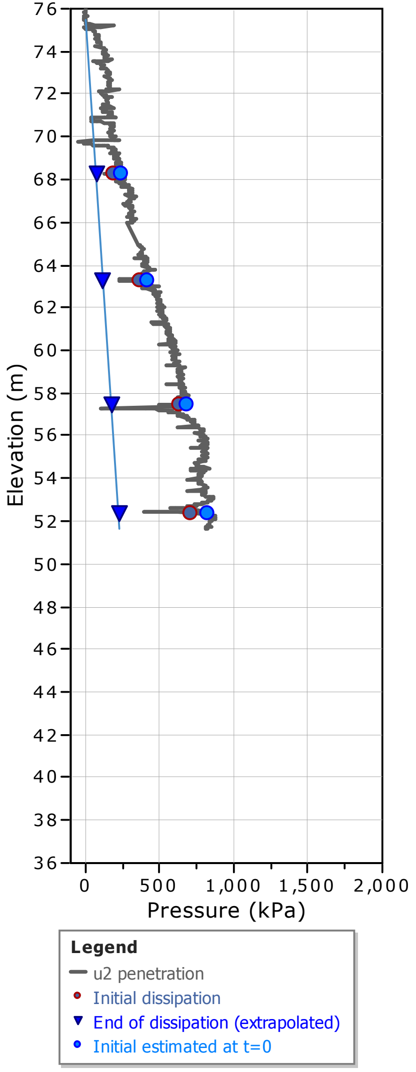

Piezocone Dissipation Test: 12-1-1 Rev 1
Depth: 12.70 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 119.68 (kPa)
45.353
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
0
5
10
15
20
25
30
35
40
45
50
55
60

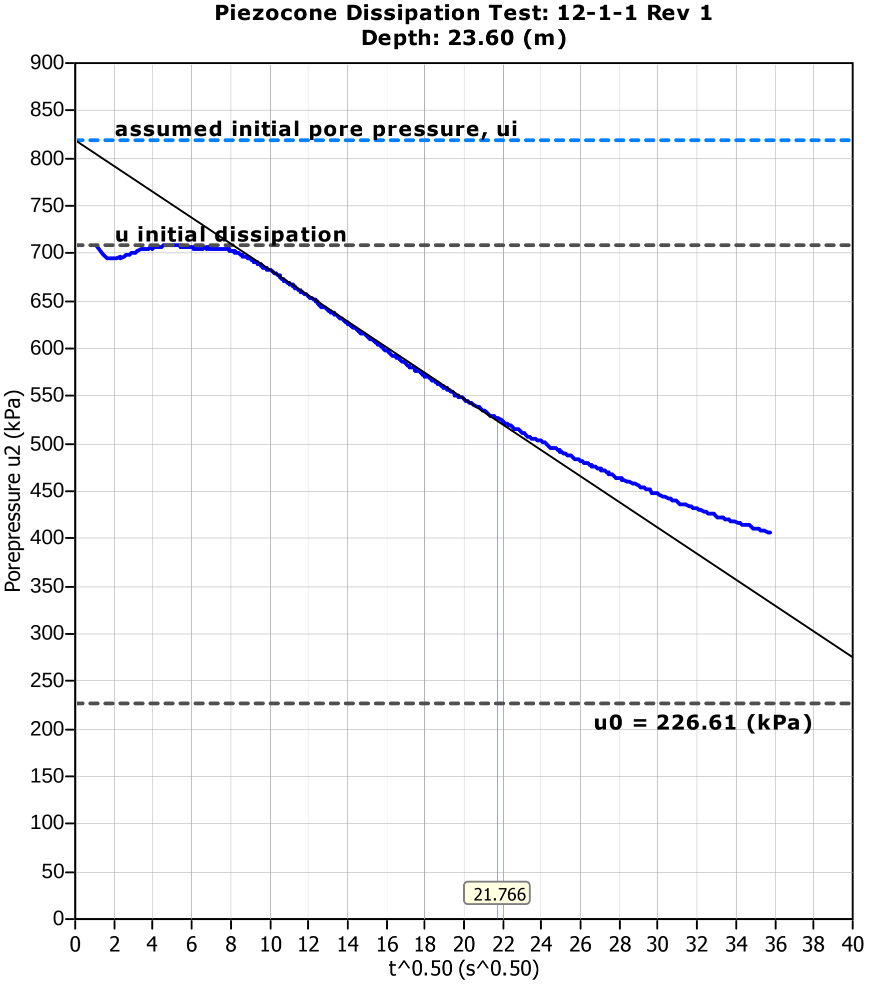

Pore pressure
Elevation (m)
Pressure (kPa)
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

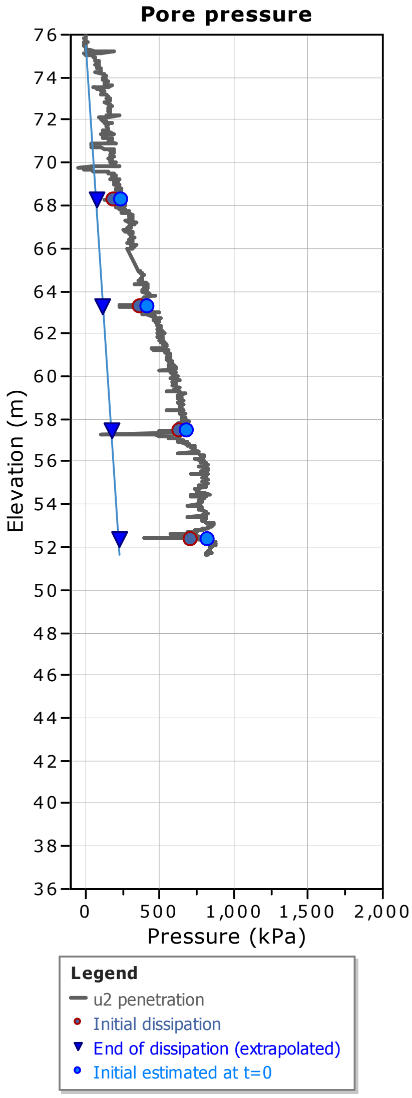
Piezocone Dissipation Test: 12-1-1 Rev 1
Depth: 18.57 (m)



Pore pressure




Piezocone Dissipation Test: 12-1-1 Rev 1
Depth: 23.60 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 226.61 (kPa)
21.766
Porepressure u2 (kPa)
t^0.50 (s^0.50)
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40


Pore pressure
Elevation (m)
Pressure (kPa)
76 74 72 70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36
0 500 1,000 1,500 2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

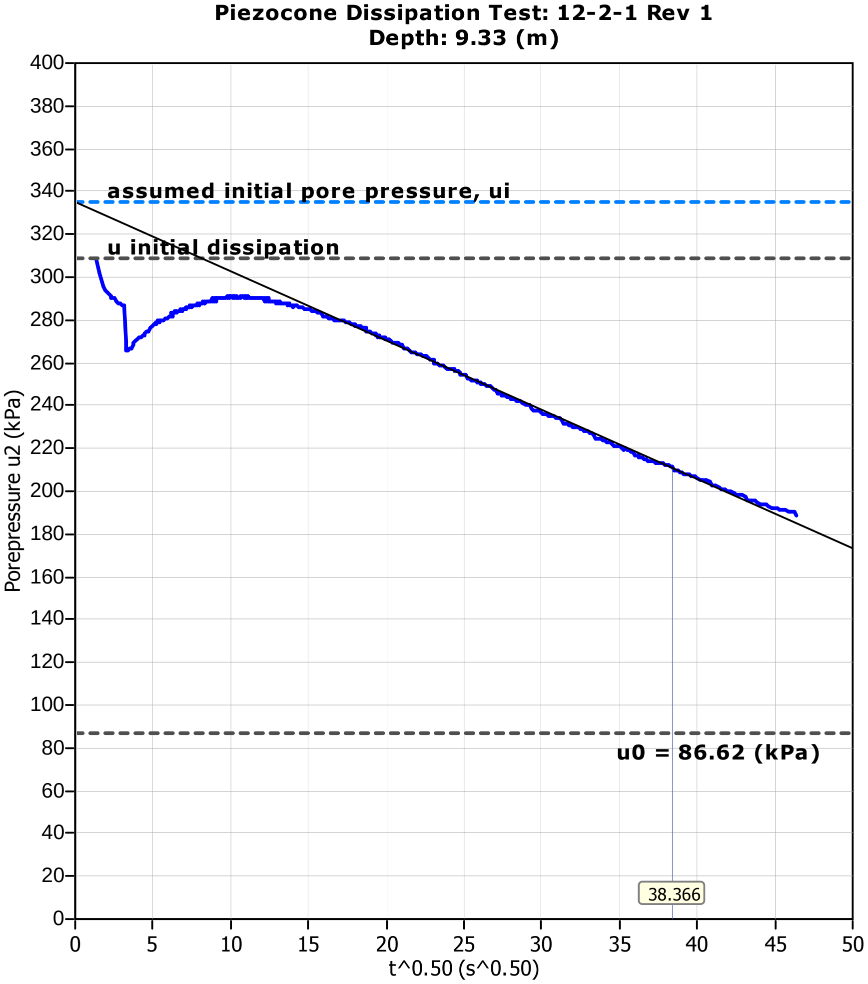
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

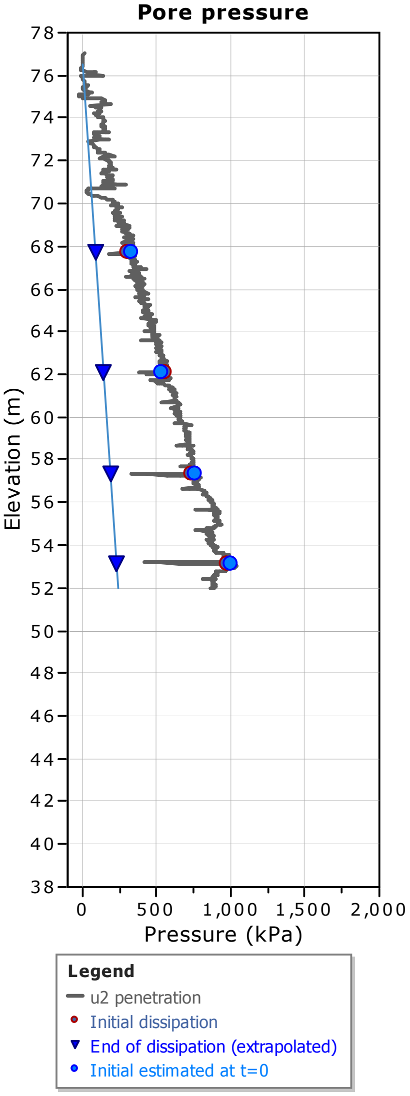
$$k_h = c_h \times \gamma_w / M$$

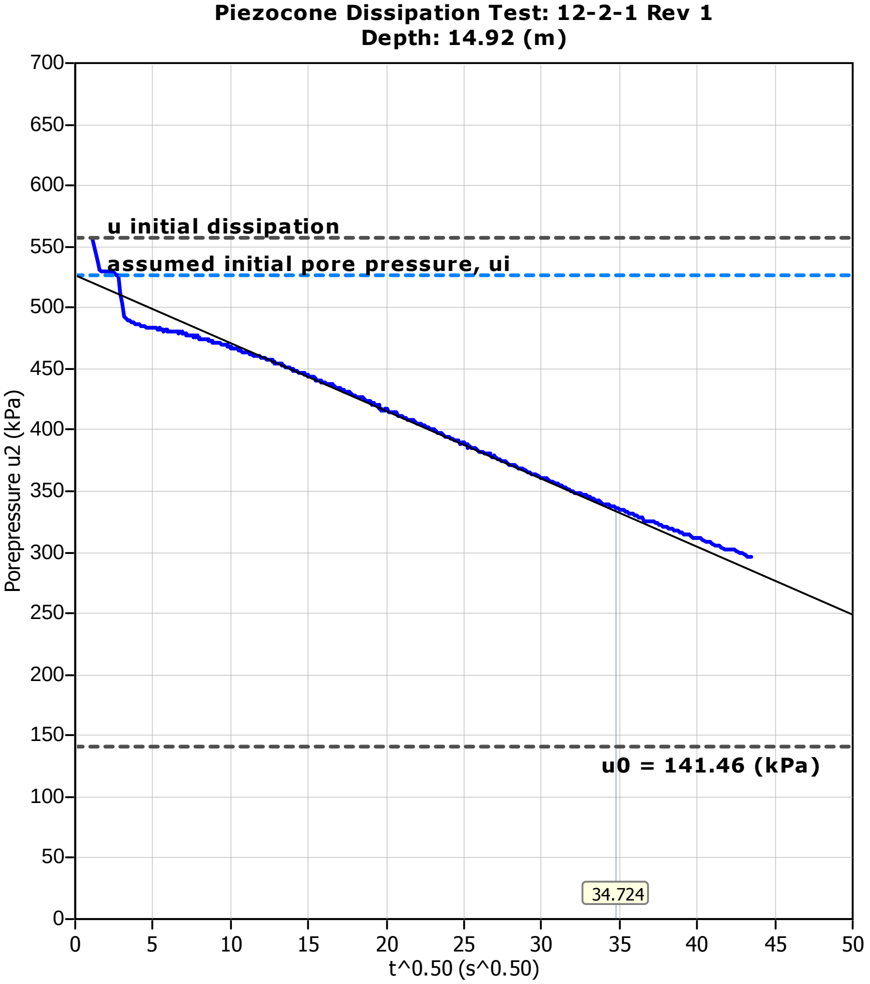
where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

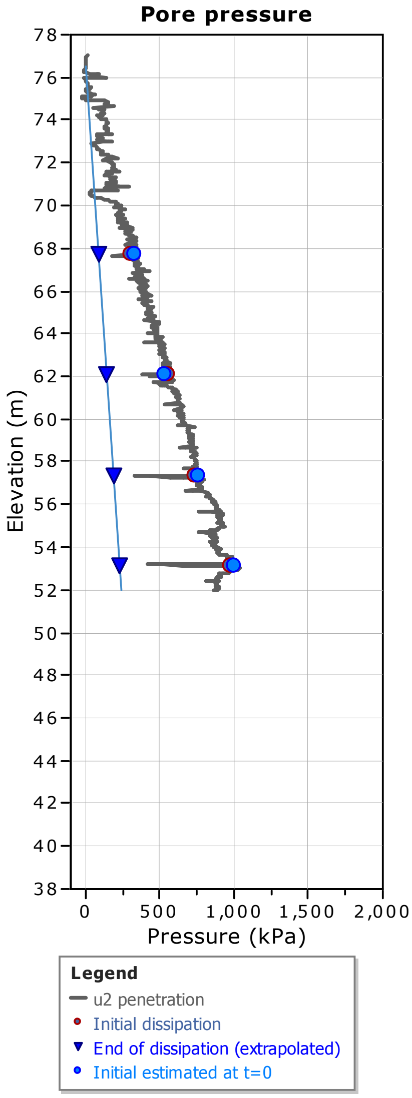
Tabular results

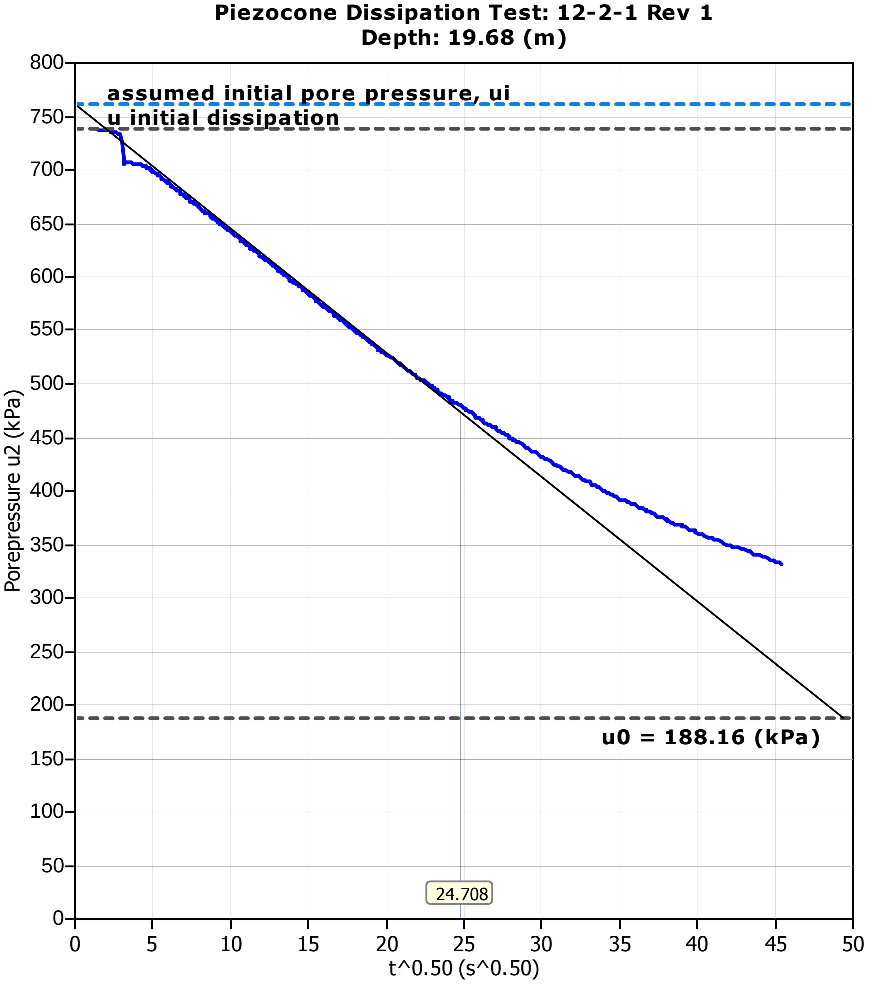
CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h (m^2/year)	M (MPa)	k_h (m/s)
12-2-1 Rev 1	9.33	38.4	1472	4.67E-005	62.00	4.20E-007	13	1.57	2.62E-009
12-2-1 Rev 1	14.92	34.7	1206	3.82E-005	67.00	5.33E-007	17	2.99	1.75E-009
12-2-1 Rev 1	19.68	24.7	610	1.94E-005	43.00	8.43E-007	27	3.68	2.24E-009
12-2-1 Rev 1	23.88	19.3	371	1.18E-005	59.00	1.63E-006	51	7.50	2.13E-009

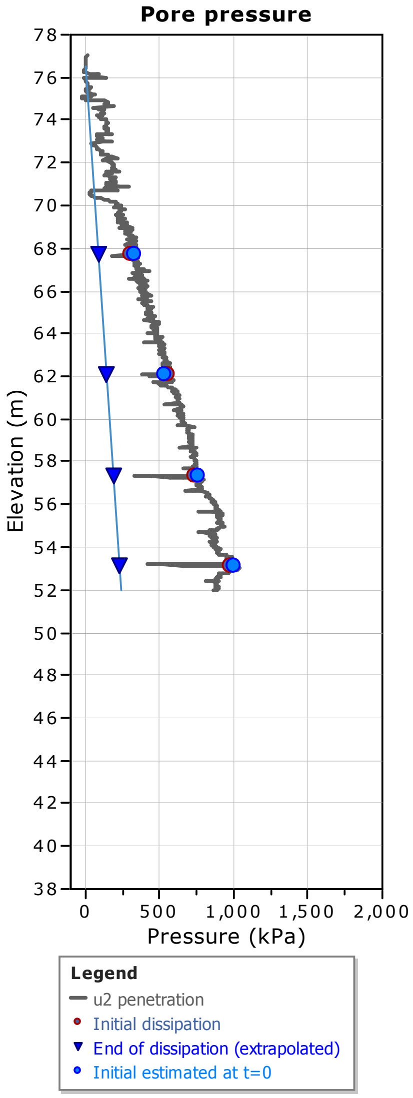

Piezocone Dissipation Test: 12-2-1 Rev 1
Depth: 9.33 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 86.62 (kPa)
38.366
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400

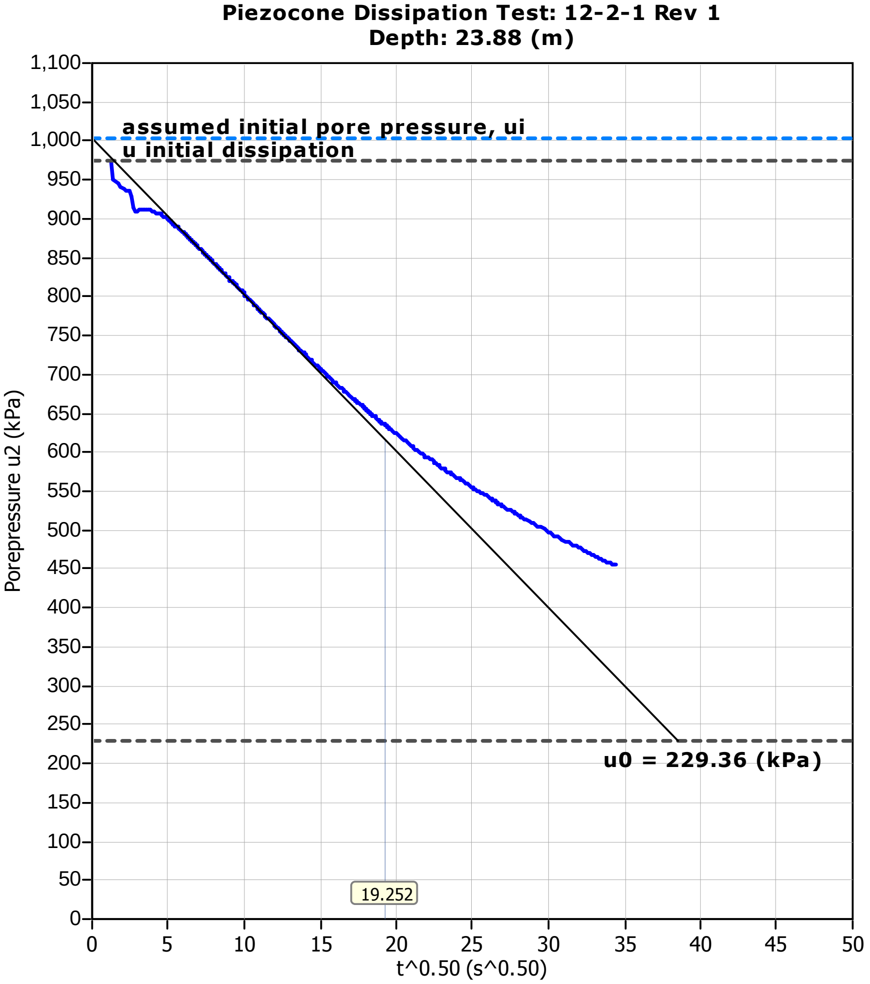

Pore pressure
Elevation (m)
Pressure (kPa)
0
500
1,000
1,500
2,000
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

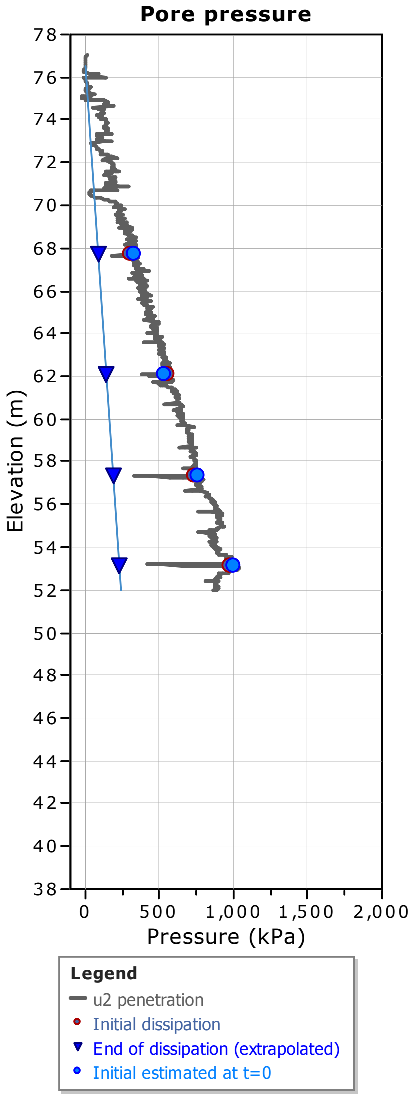

Piezocone Dissipation Test: 12-2-1 Rev 1
Depth: 14.92 (m)
u initial dissipation
assumed initial pore pressure, ui
u0 = 141.46 (kPa)
34.724
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
0
5
10
15
20
25
30
35
40
45
50


Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 12-2-1 Rev 1
Depth: 19.68 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 188.16 (kPa)
24.708
Porepressure u2 (kPa)
t^0.50 (s^0.50)
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
5
10
15
20
25
30
35
40
45
50


Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 12-2-1 Rev 1
Depth: 23.88 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 229.36 (kPa)
19.252
Porepressure u2 (kPa)
t^0.50 (s^0.50)
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50


Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Golder Associates
Ottawa, ON
www.golder.com

CPT: 12-3-1 Rev 1
Total depth: 24.71 m, Date: 11/29/2012
Surface Elevation: 76.16 m
Coords: N 5021575.2, E 466663.4
Cone Type: 10 cm2, u2, (4039)
Cone Operator: Golder (D. Grylls)

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

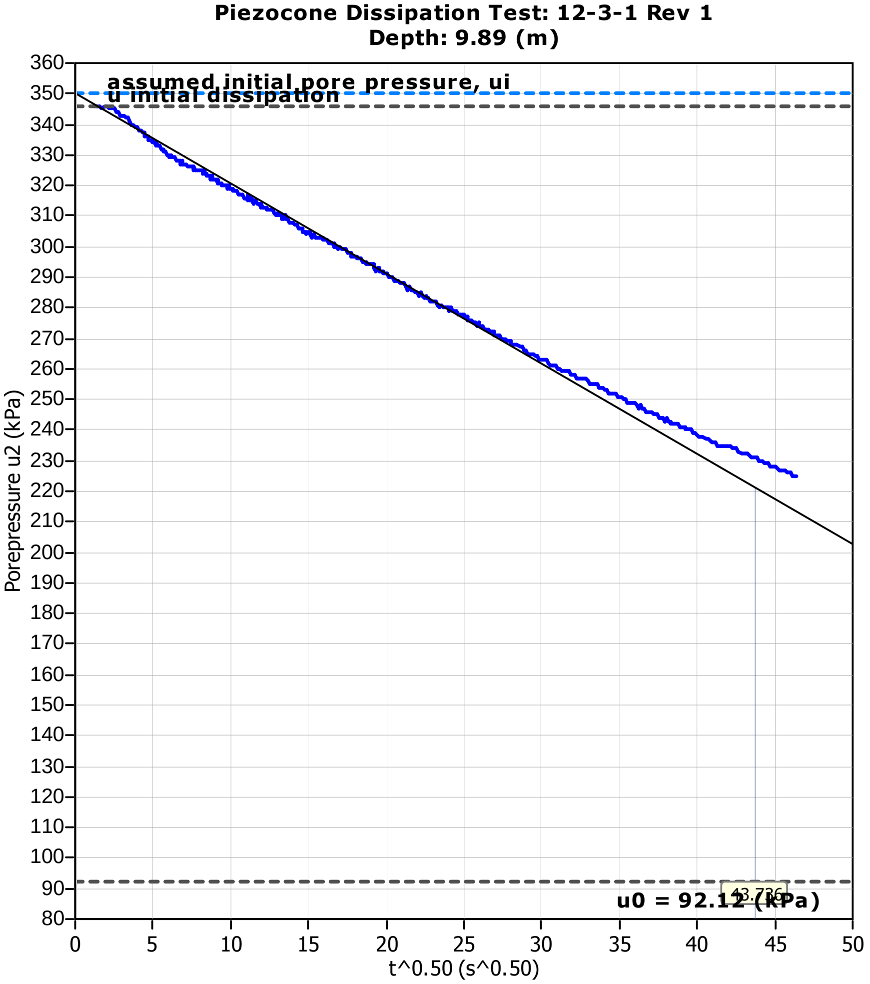
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

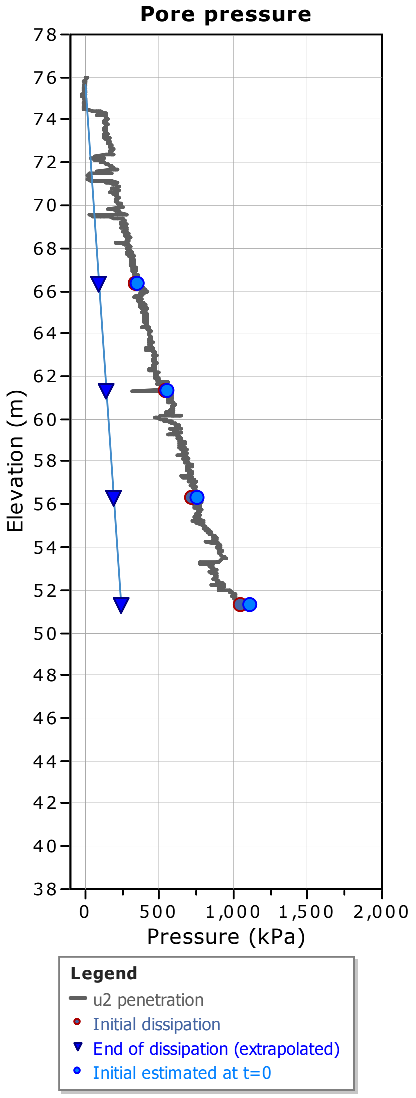
$$k_h = c_h \times \gamma_w / M$$

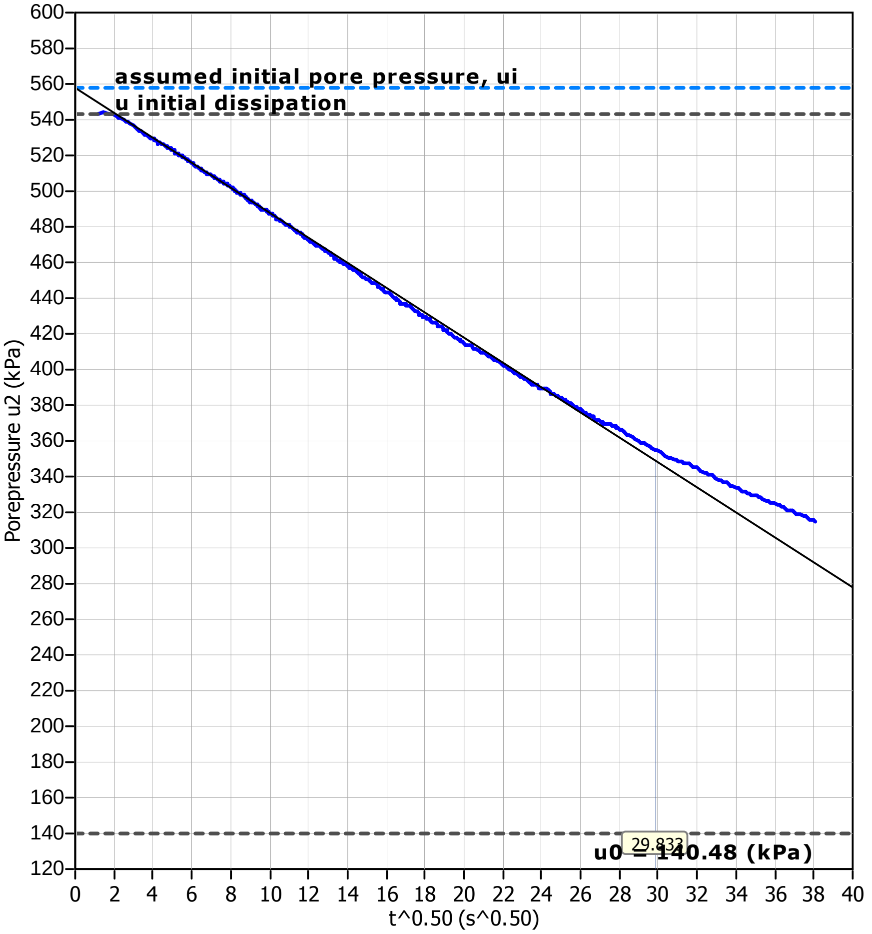
where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

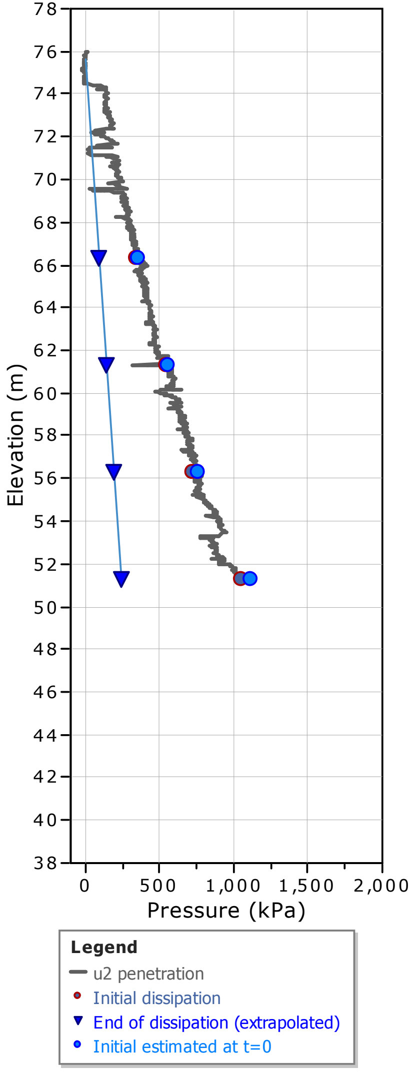
CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h (m^2/year)	M (MPa)	k_h (m/s)
12-3-1 Rev 1	9.89	43.7	1913	6.07E-005	60.00	3.18E-007	10	2.51	1.24E-009
12-3-1 Rev 1	14.82	29.8	890	2.82E-005	62.00	6.95E-007	22	5.09	1.34E-009
12-3-1 Rev 1	19.84	22.8	521	1.65E-005	40.00	9.52E-007	30	6.55	1.43E-009
12-3-1 Rev 1	24.88	16.8	283	8.98E-006	55.00	2.06E-006	65	9.57	2.11E-009


Piezocone Dissipation Test: 12-3-1 Rev 1
Depth: 9.89 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 92.12 (kPa)
43.736
Porepressure u2 (kPa)
t^0.50 (s^0.50)
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
0
5
10
15
20
25
30
35
40
45
50

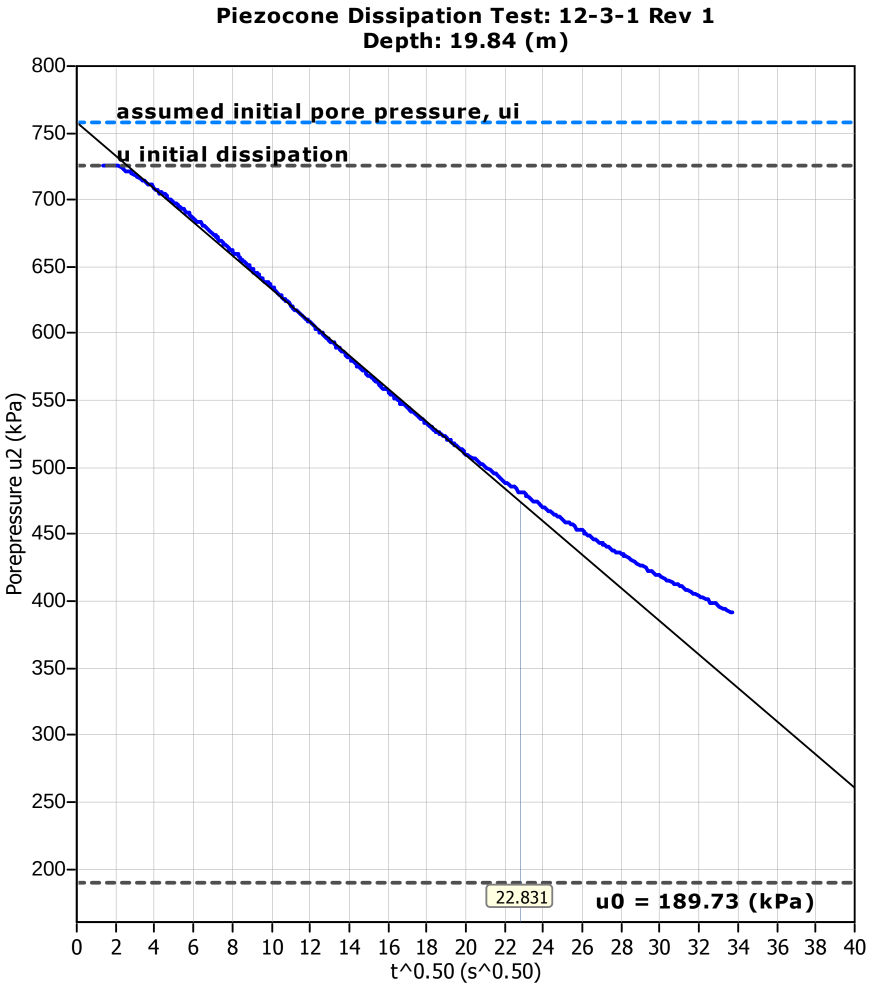

Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0



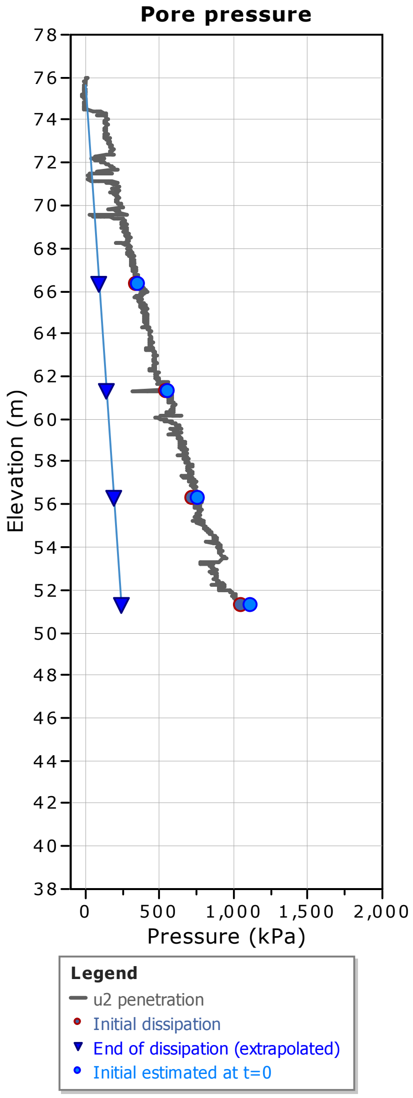
Piezocone Dissipation Test: 12-3-1 Rev 1
Depth: 14.82 (m)



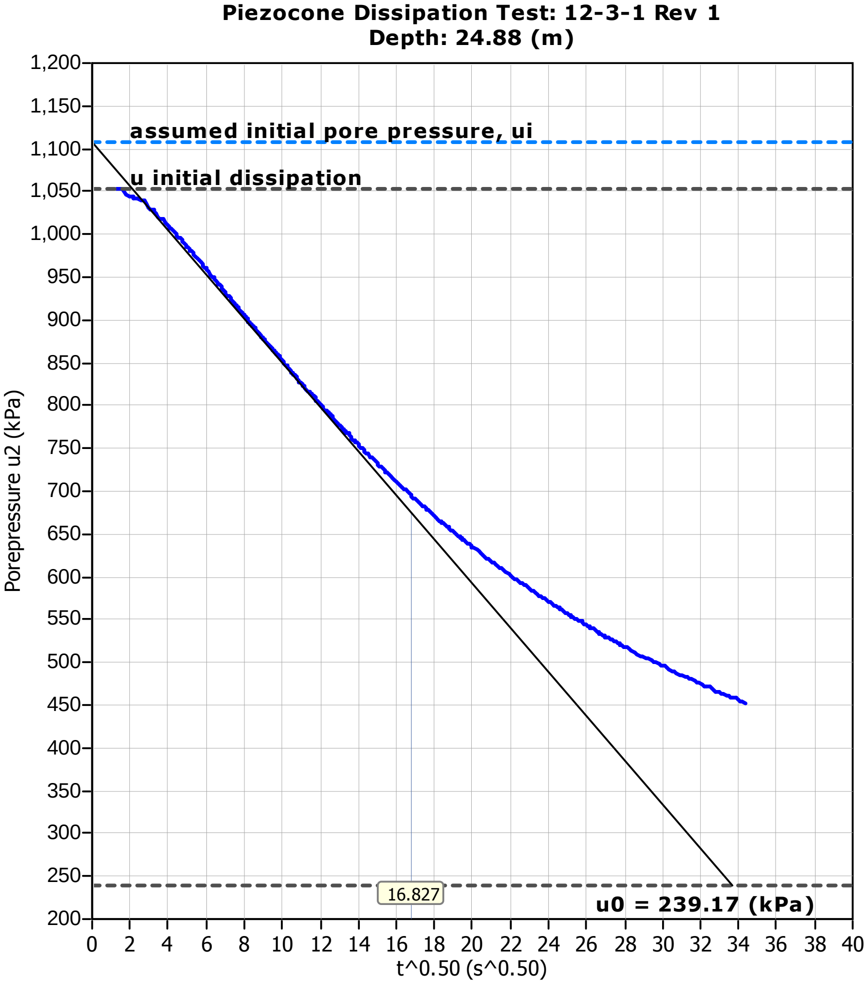
Pore pressure

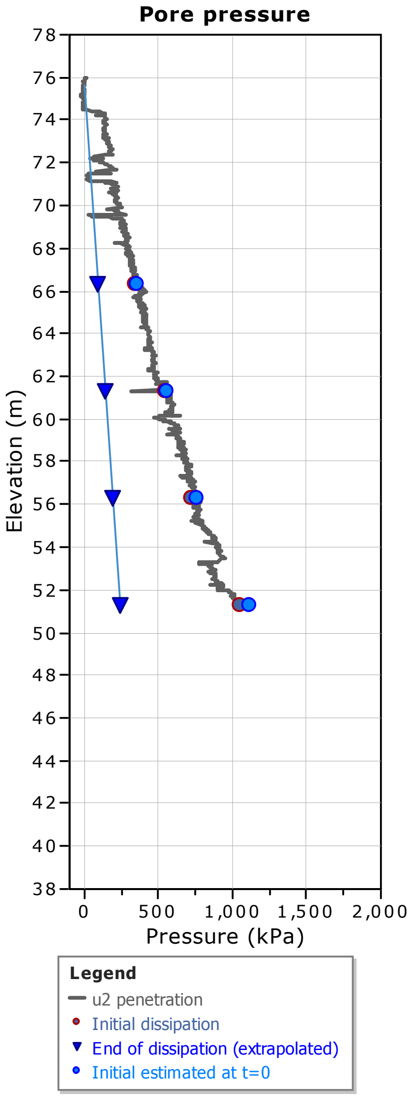


Piezocone Dissipation Test: 12-3-1 Rev 1
Depth: 19.84 (m)



Pore pressure


Piezocone Dissipation Test: 12-3-1 Rev 1
Depth: 24.88 (m)
assumed initial pore pressure, ui
u initial dissipation
16.827
u0 = 239.17 (kPa)
Porepressure u2 (kPa)
1,200
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
t^0.50 (s^0.50)


Pore pressure
Elevation (m)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
500
1,000
1,500
2,000
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

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$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

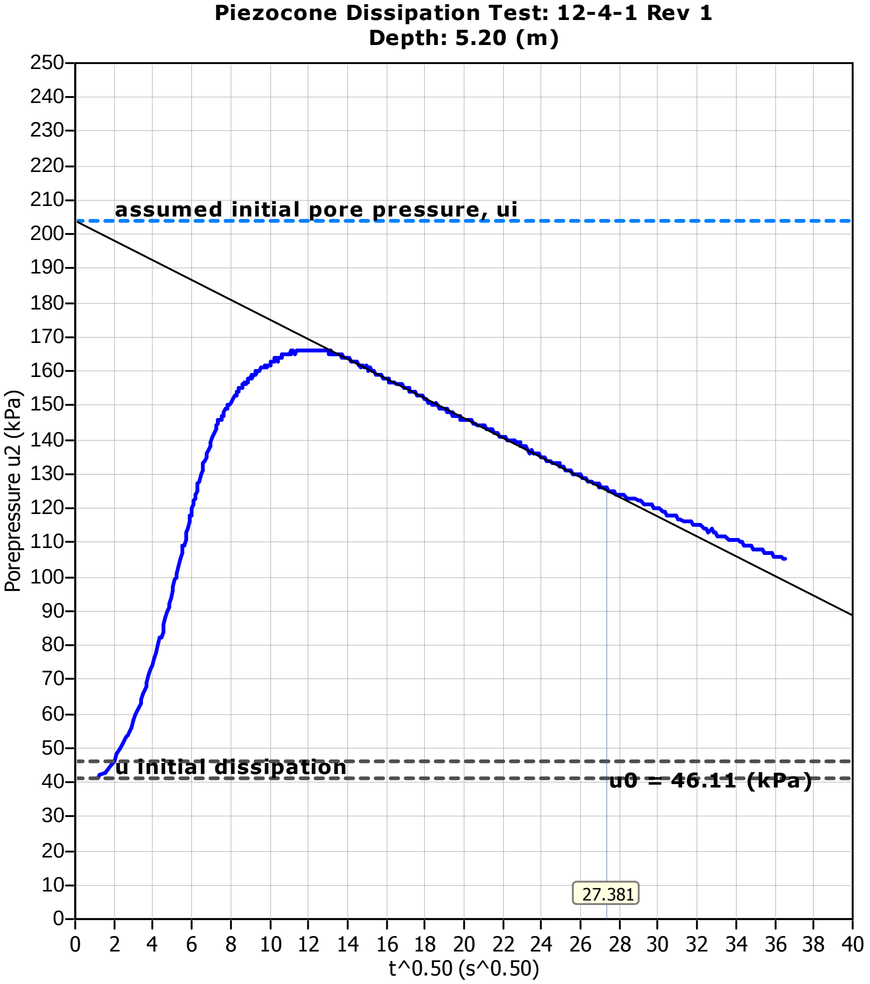
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

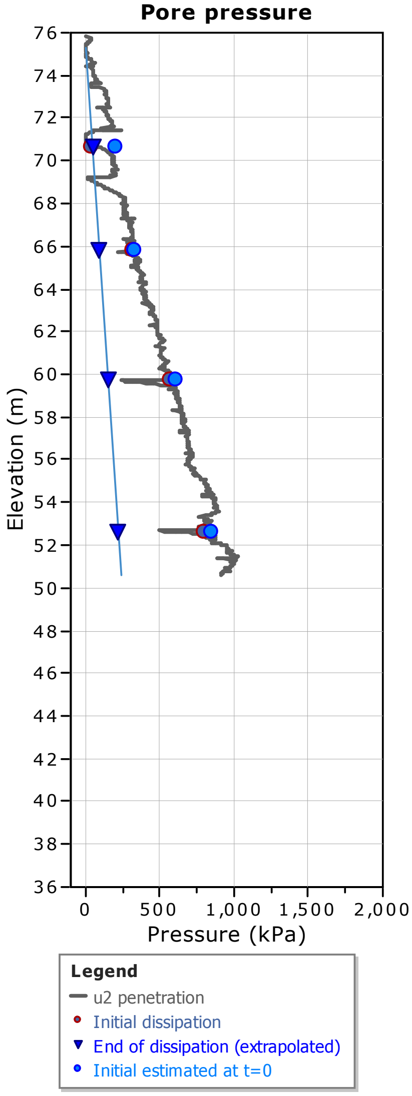
$$k_h = c_h \times \gamma_w / M$$

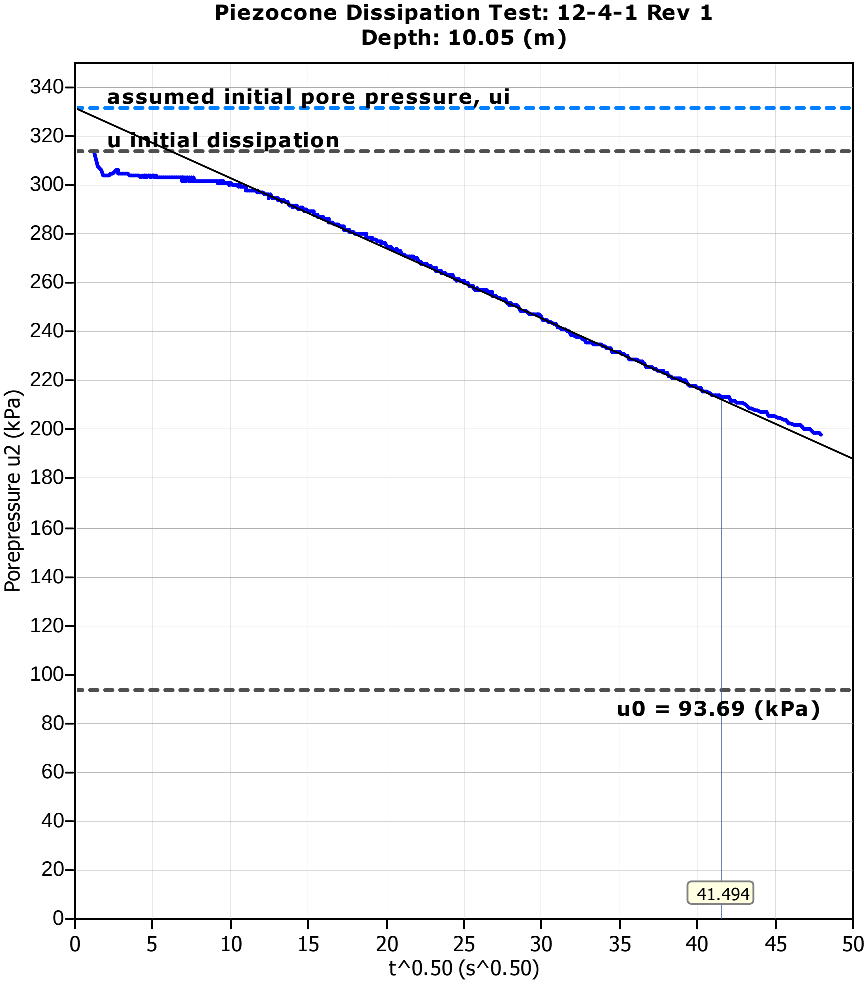
where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

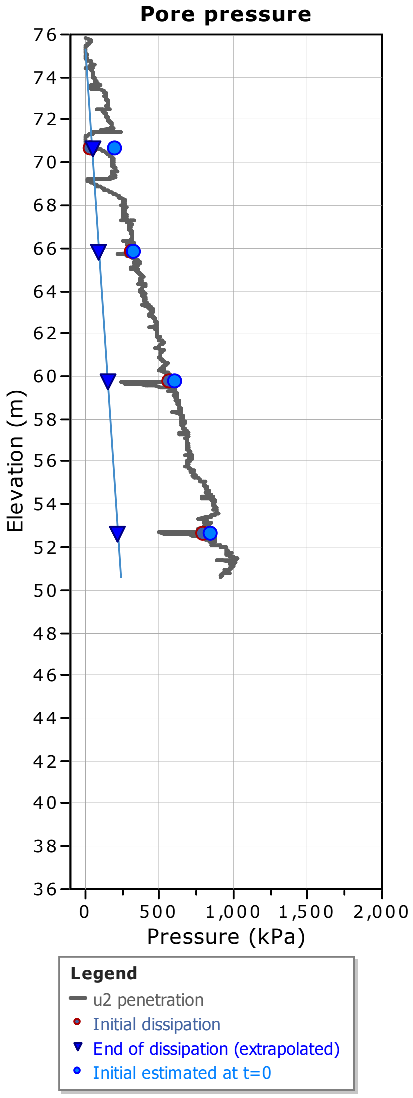
Tabular results

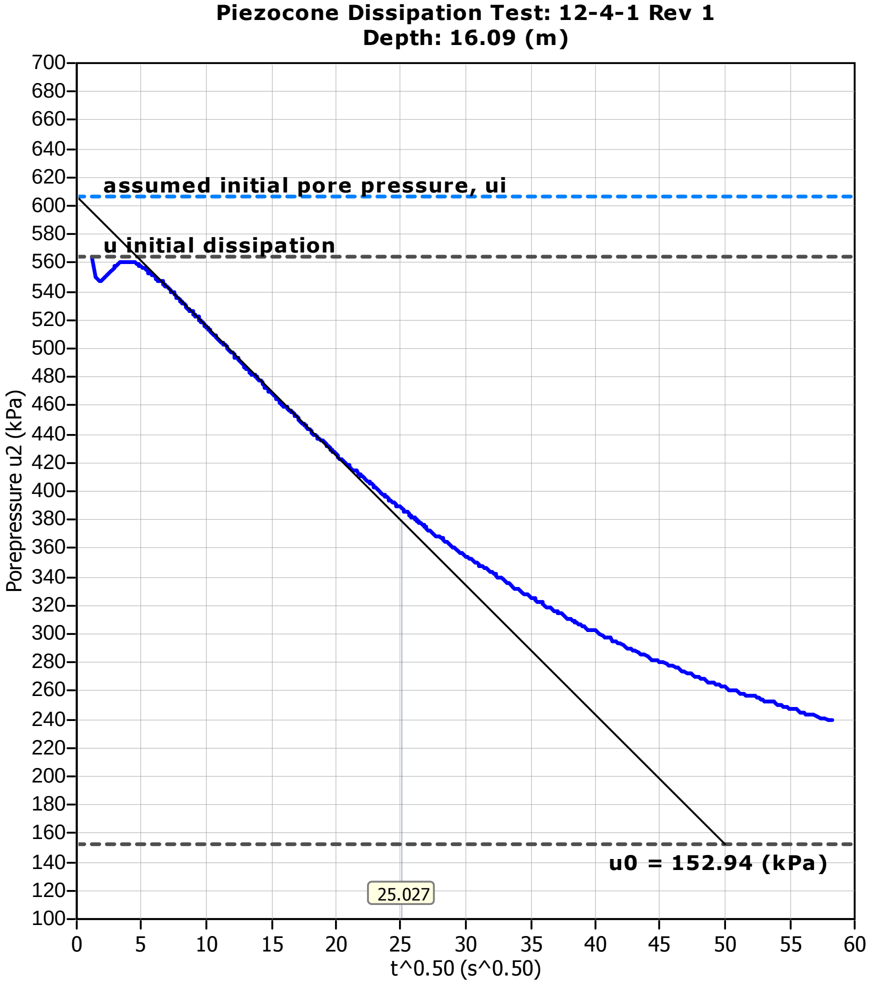
CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h ($m^2/year$)	M (MPa)	k_h (m/s)
12-4-1 Rev 1	5.20	27.4	750	2.38E-005	35.00	6.19E-007	20	0.43	1.43E-008
12-4-1 Rev 1	10.05	41.5	1722	5.46E-005	60.00	3.53E-007	11	2.26	1.53E-009
12-4-1 Rev 1	16.09	25.0	626	1.99E-005	66.00	1.02E-006	32	3.27	3.06E-009
12-4-1 Rev 1	23.17	25.3	640	2.03E-005	60.00	9.50E-007	30	4.84	1.93E-009

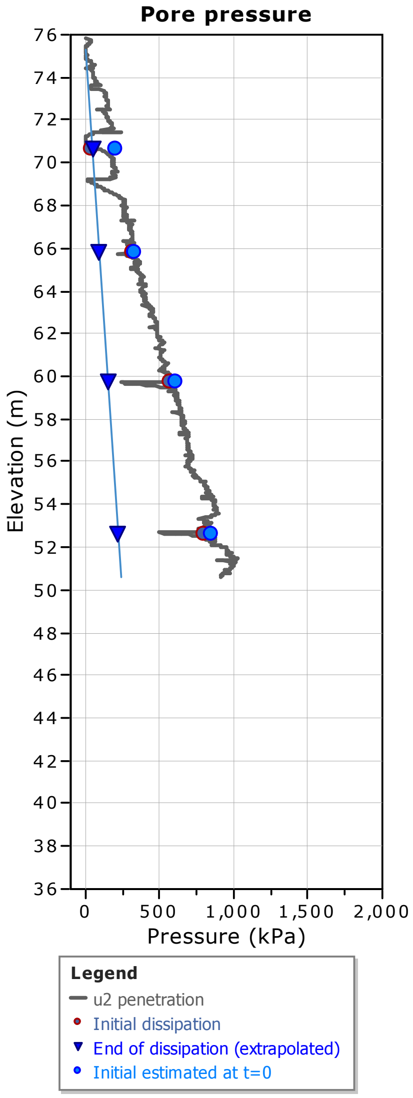

Piezocone Dissipation Test: 12-4-1 Rev 1
Depth: 5.20 (m)
Porepressure u2 (kPa)
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
assumed initial pore pressure, ui
u initial dissipation
u0 = 46.11 (kPa)
27.381
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
t^0.50 (s^0.50)

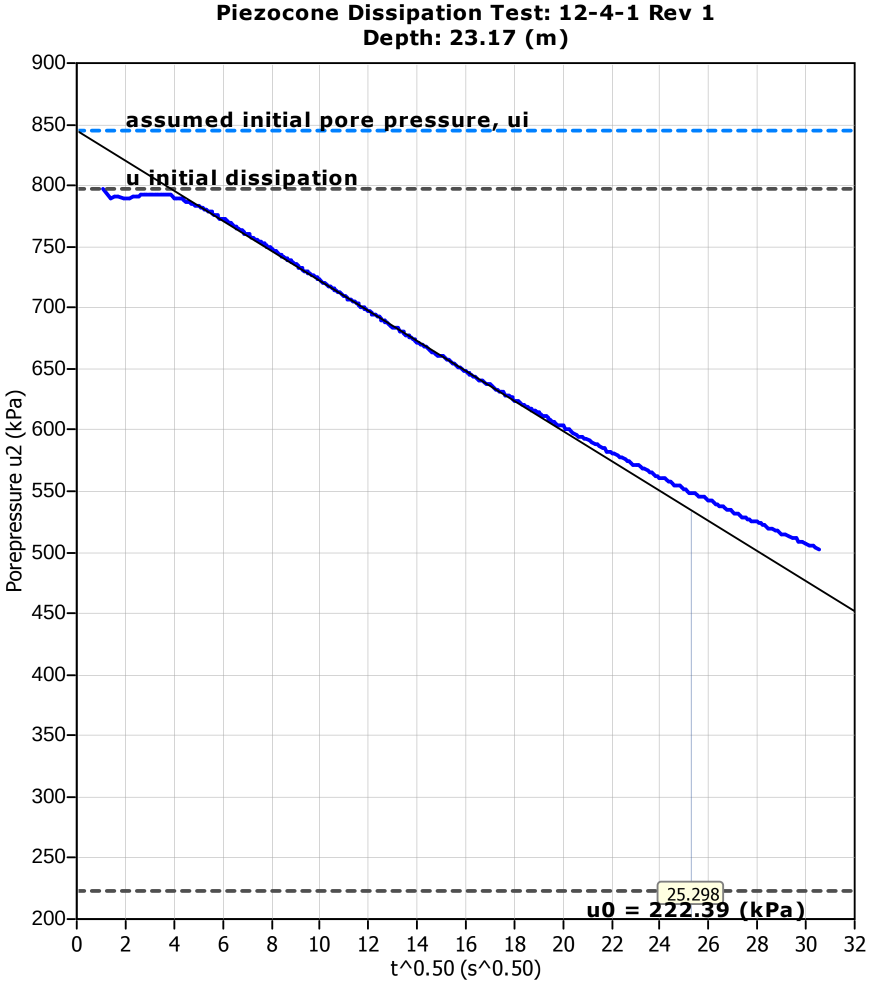

Pore pressure
Elevation (m)
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
0
500
1,000
1,500
2,000
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

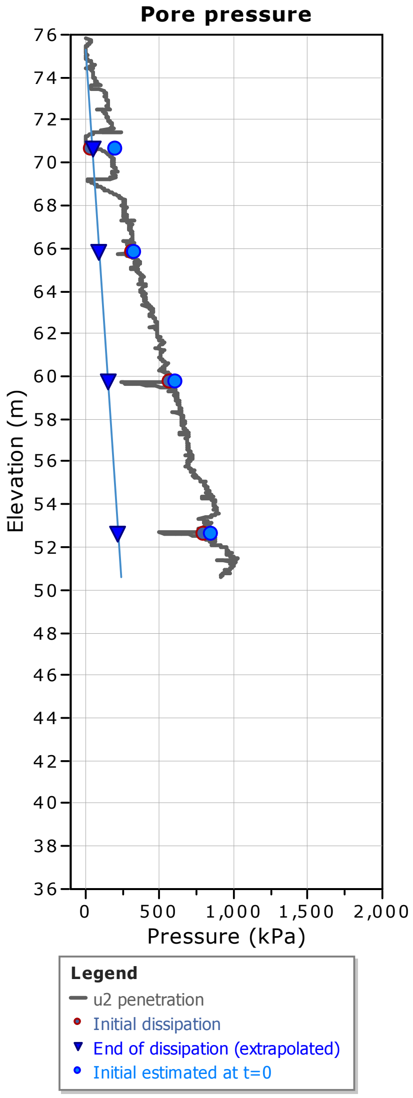

Piezocone Dissipation Test: 12-4-1 Rev 1
Depth: 10.05 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 93.69 (kPa)
41.494
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
0
5
10
15
20
25
30
35
40
45
50


Pore pressure
Elevation (m)
Pressure (kPa)
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 12-4-1 Rev 1
Depth: 16.09 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 152.94 (kPa)
25.027
Porepressure u2 (kPa)
700
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
0
5
10
15
20
25
30
35
40
45
50
55
60
t^0.50 (s^0.50)


Pore pressure
Elevation (m)
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
0
500
1,000
1,500
2,000
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 12-4-1 Rev 1
Depth: 23.17 (m)
assumed initial pore pressure, ui
u initial dissipation
25.298
u0 = 222.39 (kPa)
Porepressure u2 (kPa)
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
t^0.50 (s^0.50)


Pore pressure
Elevation (m)
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
0
500
1,000
1,500
2,000
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

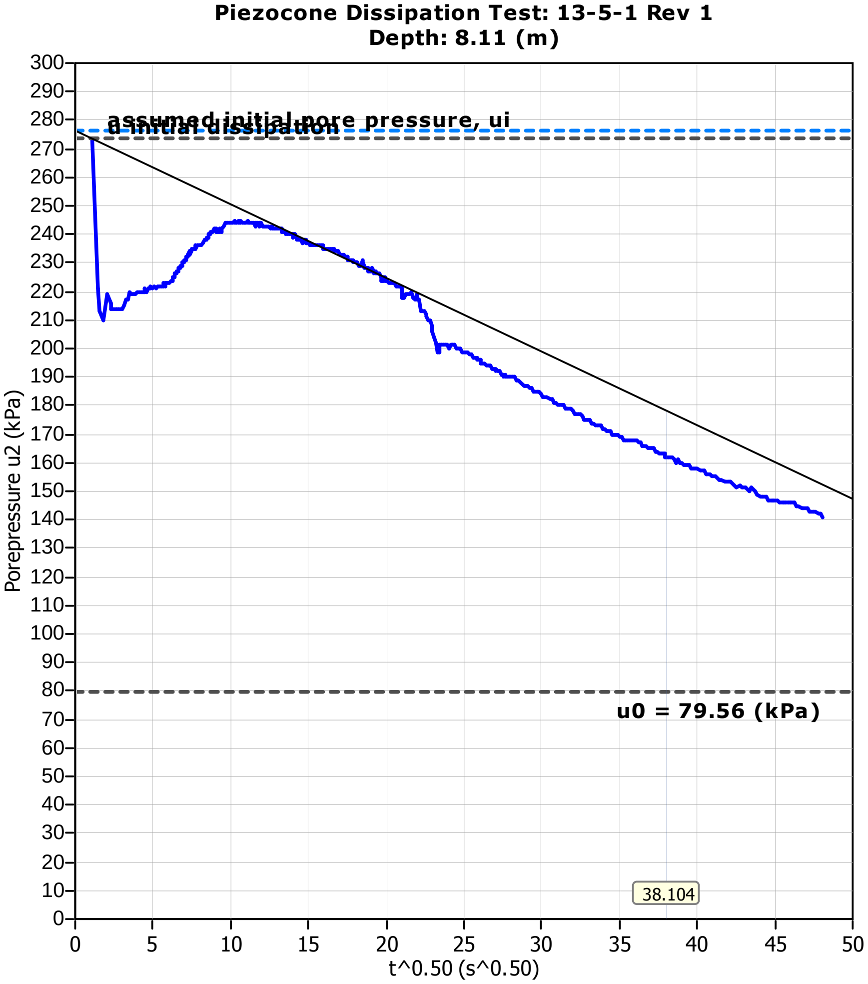
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

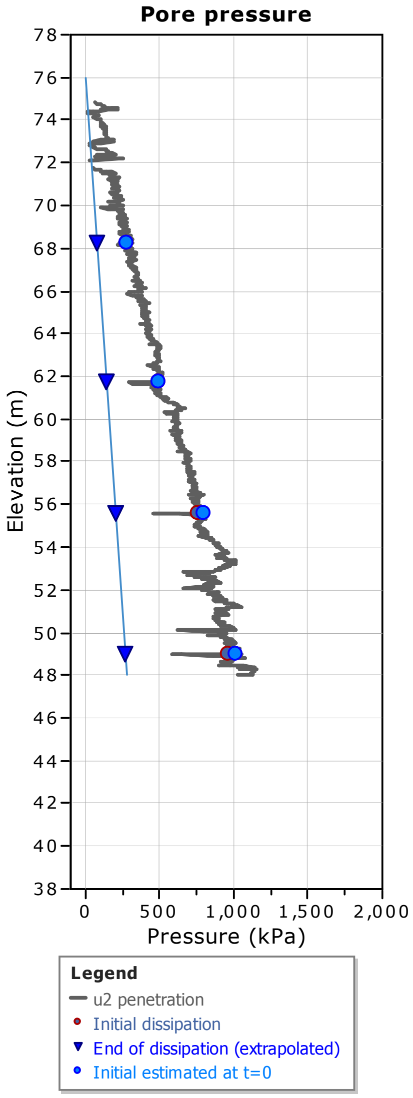
$$k_h = c_h \times \gamma_w / M$$

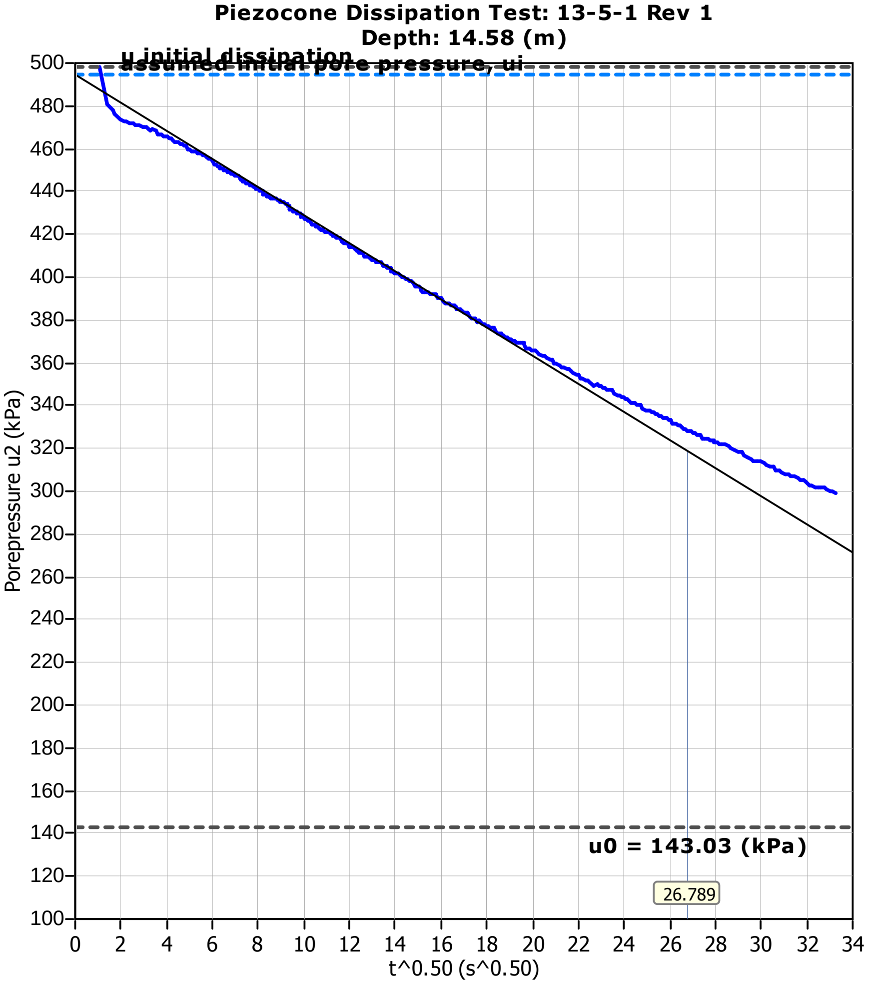
where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h ($m^2/year$)	M (MPa)	k_h (m/s)
13-5-1 Rev 1	8.11	38.1	1452	4.60E-005	48.00	3.75E-007	12	1.13	3.24E-009
13-5-1 Rev 1	14.58	26.8	718	2.28E-005	56.00	8.19E-007	26	2.46	3.26E-009
13-5-1 Rev 1	20.71	22.0	486	1.54E-005	51.00	1.15E-006	36	3.97	2.85E-009
13-5-1 Rev 1	27.35	21.7	472	1.50E-005	104.00	1.70E-006	53	6.90	2.41E-009


Piezocone Dissipation Test: 13-5-1 Rev 1
Depth: 8.11 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 79.56 (kPa)
38.104
Porepressure u2 (kPa)
t^0.50 (s^0.50)
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50


Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 13-5-1 Rev 1
Depth: 14.58 (m)
u initial dissipation
assumed initial pore pressure, ui
u0 = 143.03 (kPa)
26.789
Porepressure u2 (kPa)
t^0.50 (s^0.50)
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
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4
6
8
10
12
14
16
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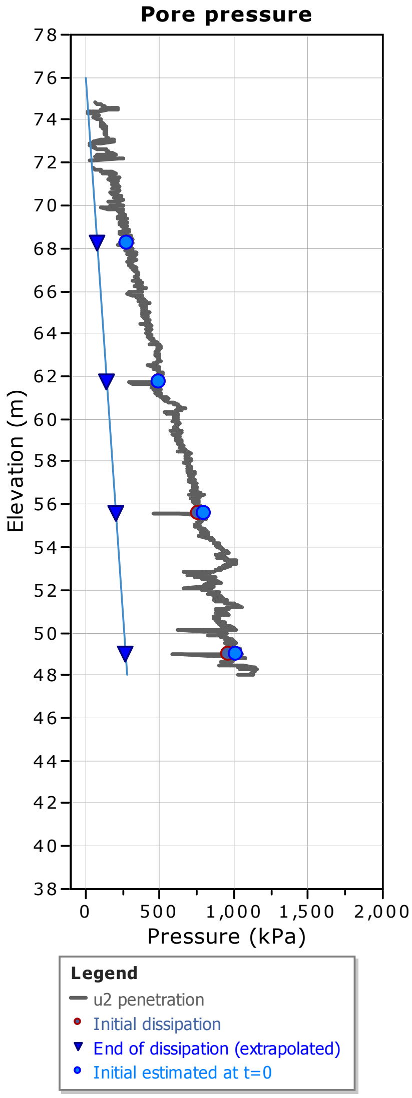
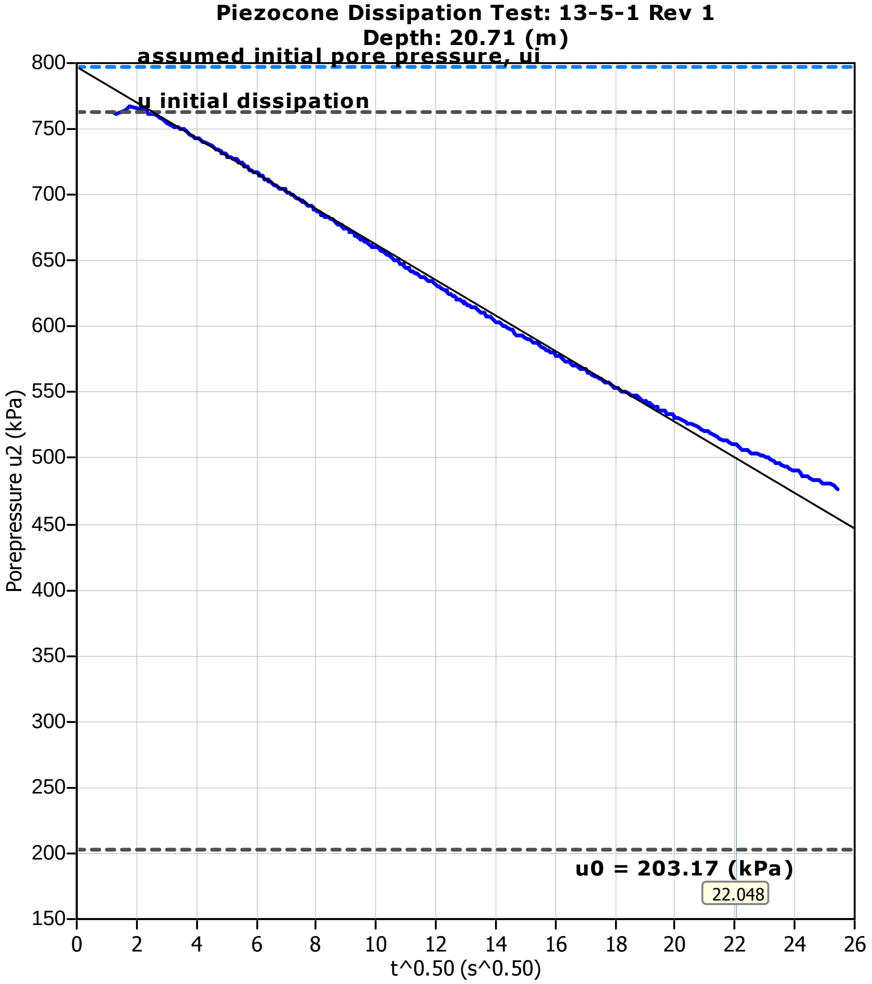
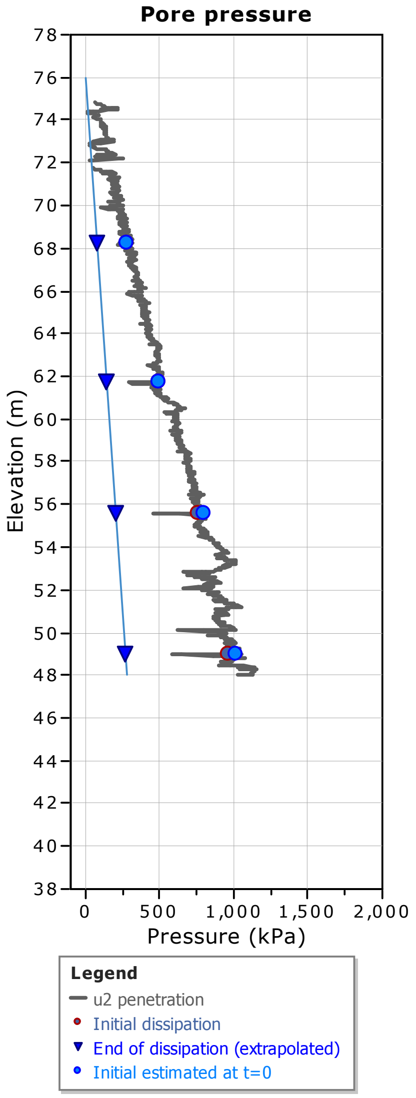
20
22
24
26
28
30
32
34


Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

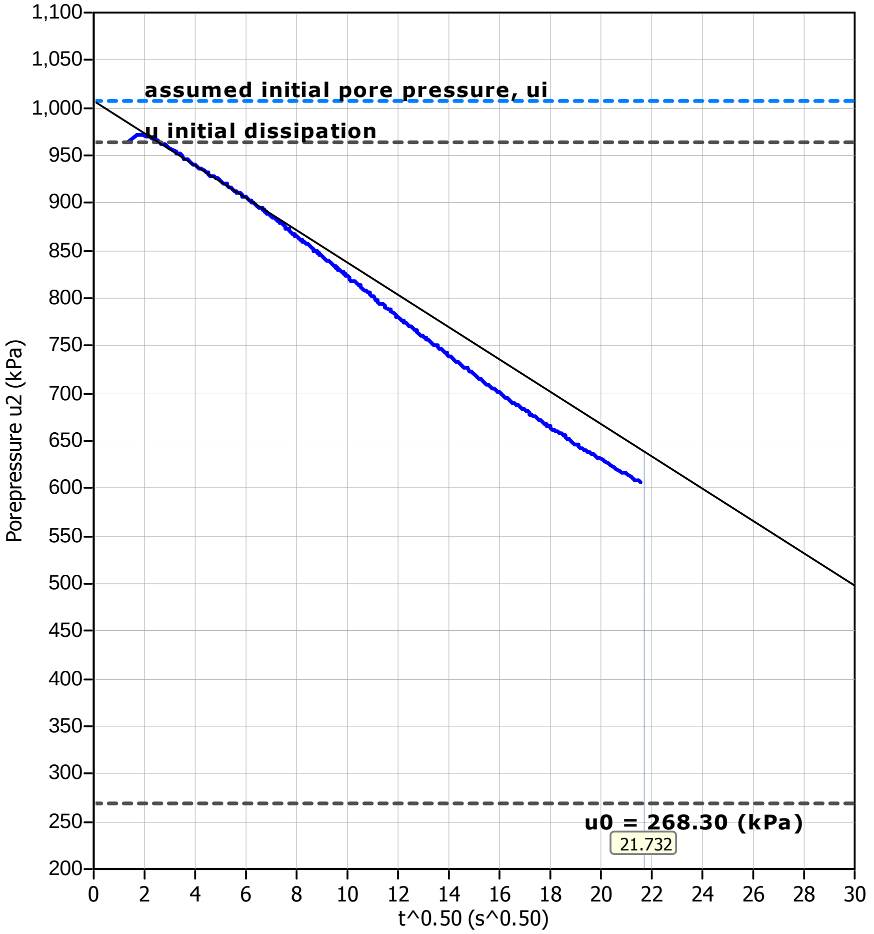


Piezocone Dissipation Test: 13-5-1 Rev 1
Depth: 20.71 (m)

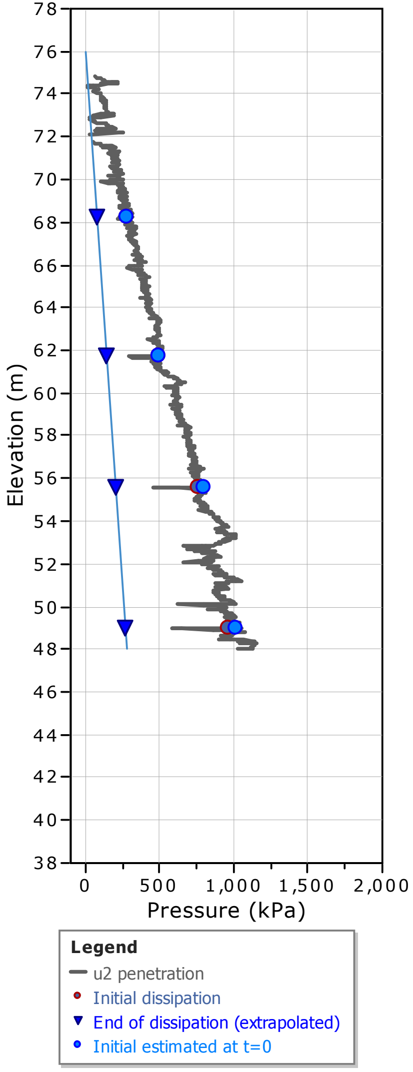


Pore pressure

Piezocone Dissipation Test: 13-5-1 Rev 1
Depth: 27.35 (m)



Pore pressure



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Ottawa, ON
www.golder.com

CPT: 13-6-1 Rev 1
Total depth: 32.10 m, Date: 3/27/2013
Surface Elevation: 76.87 m
Coords: N 5020388.0, E 465911.0
Cone Type: 10 cm2, (4039)
Cone Operator: Golder (K. Edney)

Project: **12-1125-0045 - CRRRC EA Eastern Ontario**
Location: **Boundary Road Site**

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

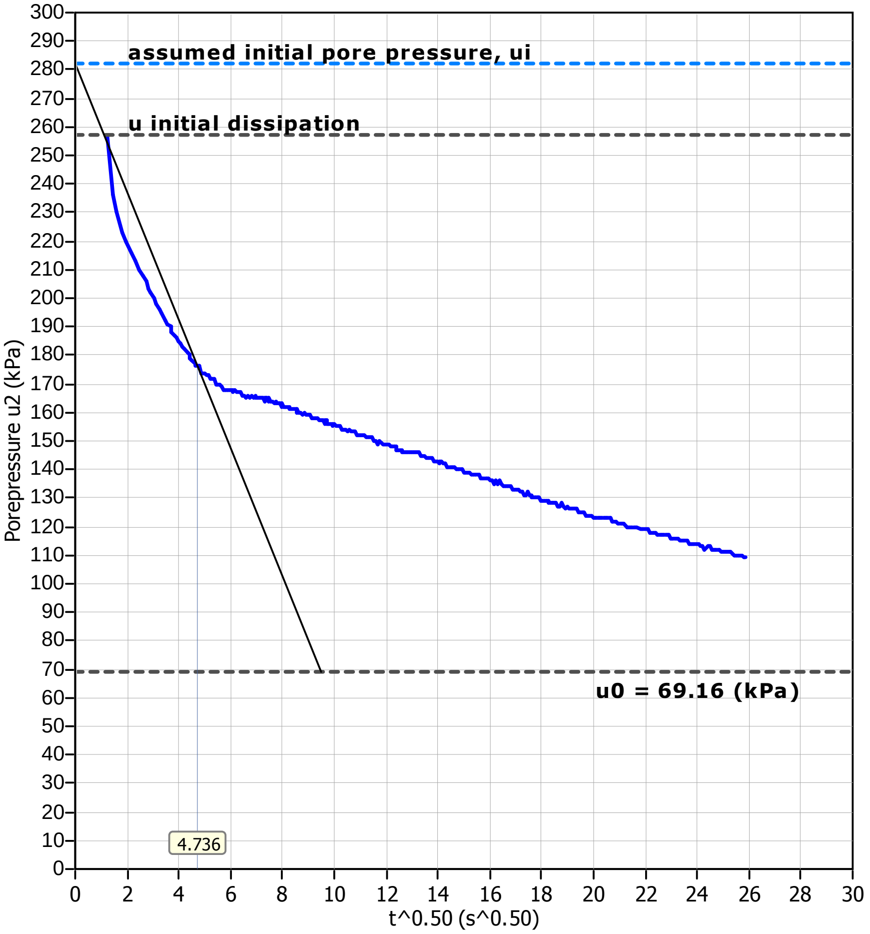
$$k_h = c_h \times \gamma_w / M$$

where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

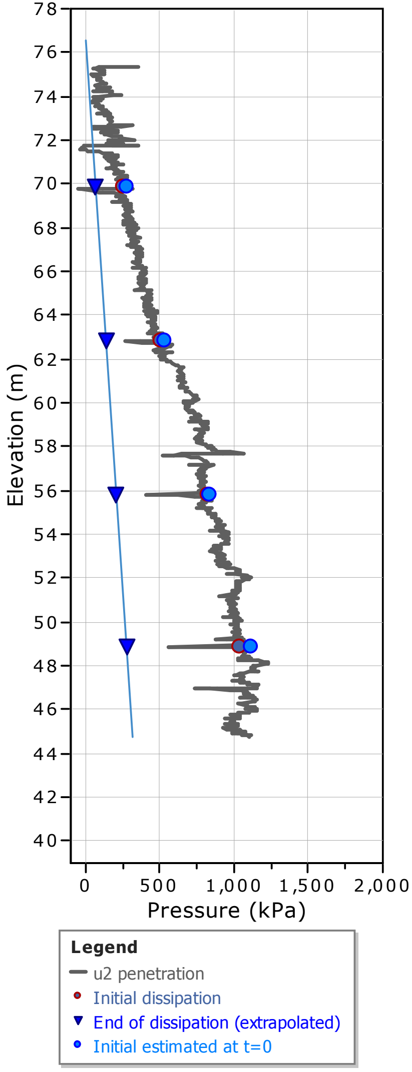
Tabular results

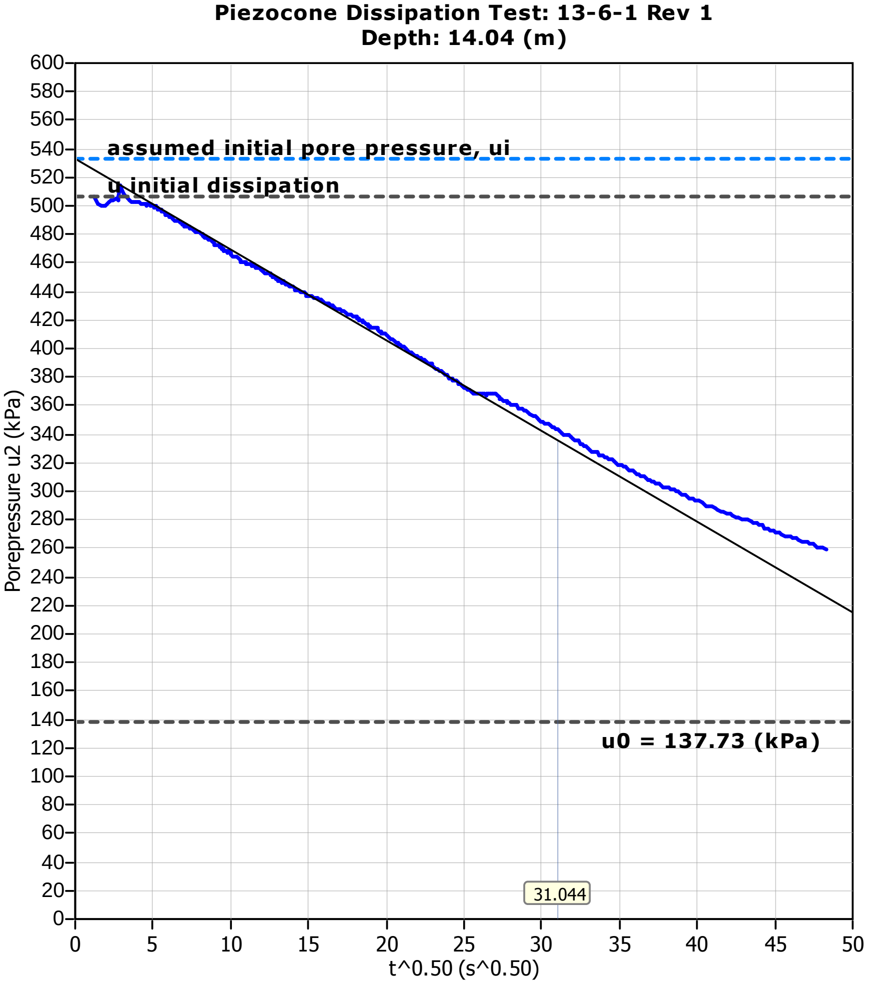
CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h (m^2/year)	M (MPa)	k_h (m/s)
13-6-1 Rev 1	7.05	4.7	22	7.11E-007	72.00	2.97E-005	936	1.61	1.81E-007
13-6-1 Rev 1	14.04	31.0	964	3.06E-005	55.00	6.04E-007	19	3.35	1.77E-009
13-6-1 Rev 1	21.05	21.0	439	1.39E-005	52.00	1.29E-006	41	3.31	3.82E-009
13-6-1 Rev 1	28.05	20.1	402	1.28E-005	92.00	1.87E-006	59	4.97	3.70E-009

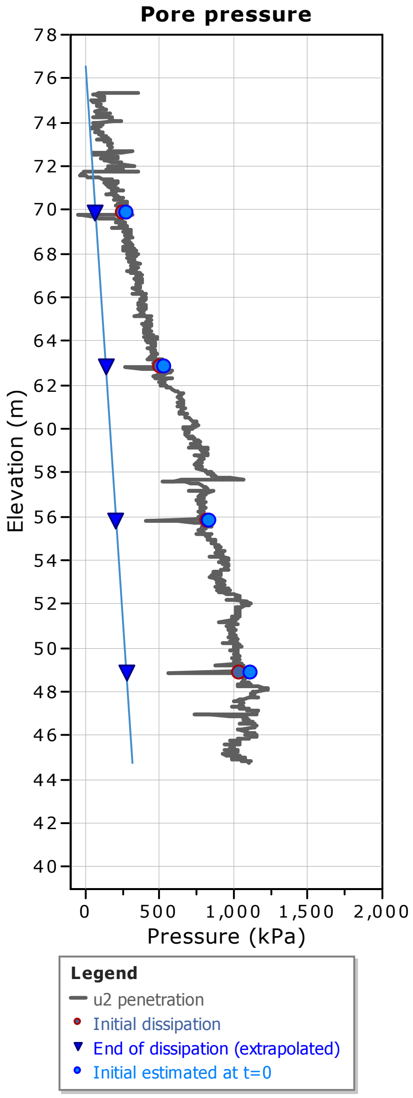
Piezocone Dissipation Test: 13-6-1 Rev 1
Depth: 7.05 (m)

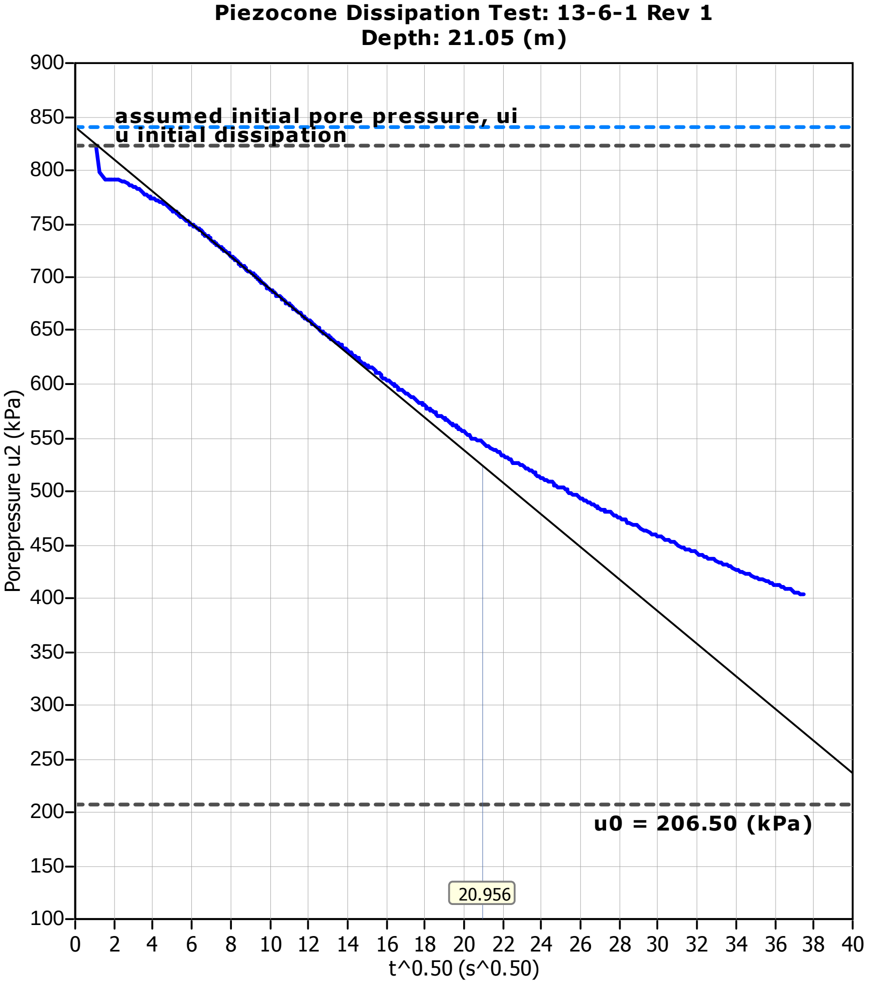


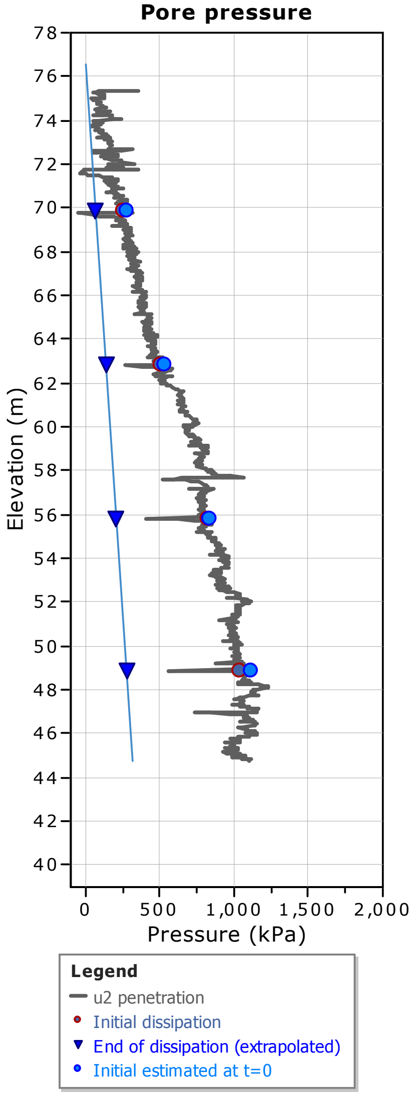
Pore pressure

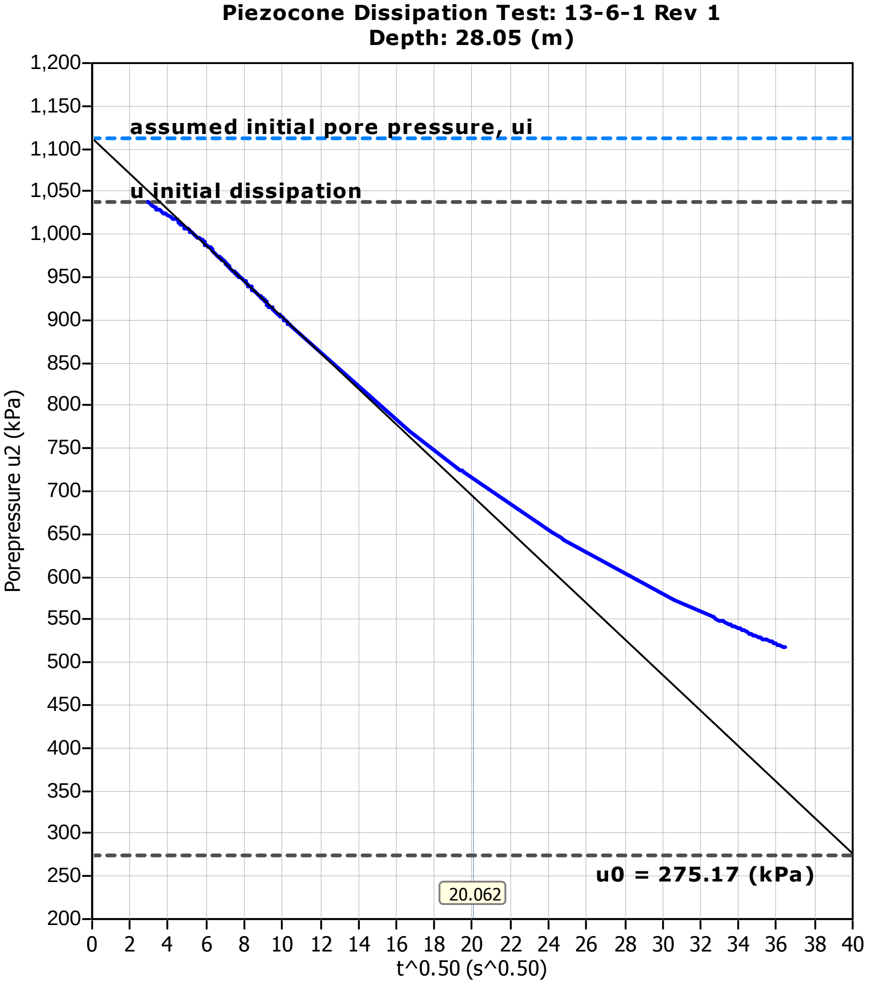


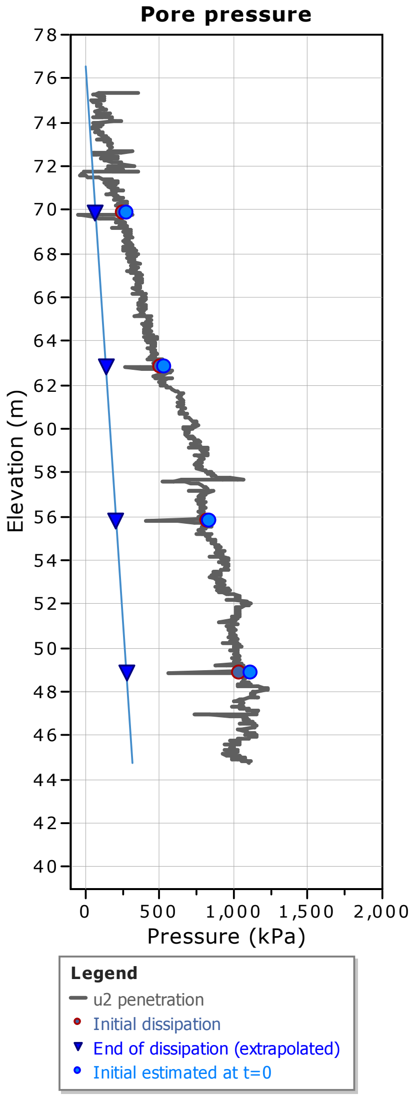

Piezocone Dissipation Test: 13-6-1 Rev 1
Depth: 14.04 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 137.73 (kPa)
31.044
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600
0 5 10 15 20 25 30 35 40 45 50


Pore pressure
Elevation (m)
Pressure (kPa)
40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78
0 500 1,000 1,500 2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 13-6-1 Rev 1
Depth: 21.05 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 206.50 (kPa)
20.956
Porepressure u2 (kPa)
t^0.50 (s^0.50)
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40


Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 13-6-1 Rev 1
Depth: 28.05 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 275.17 (kPa)
20.062
Porepressure u2 (kPa)
t^0.50 (s^0.50)
1,200
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40


Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

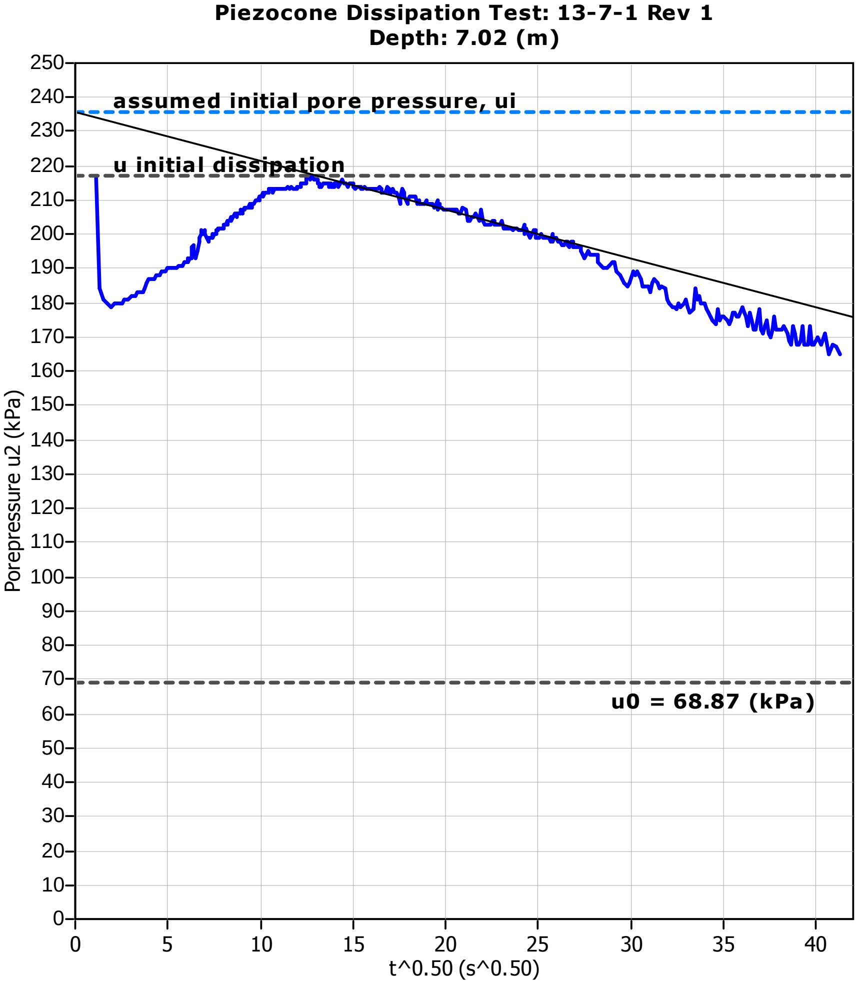
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

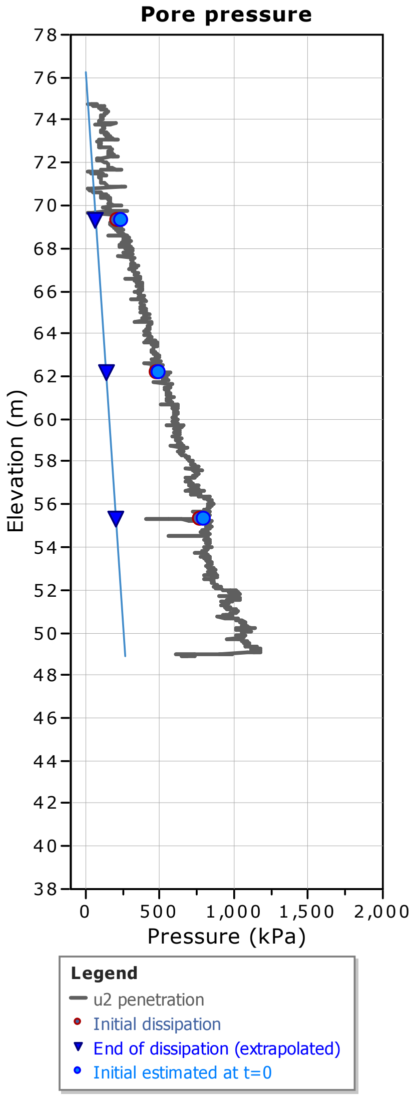
$$k_h = c_h \times \gamma_w / M$$

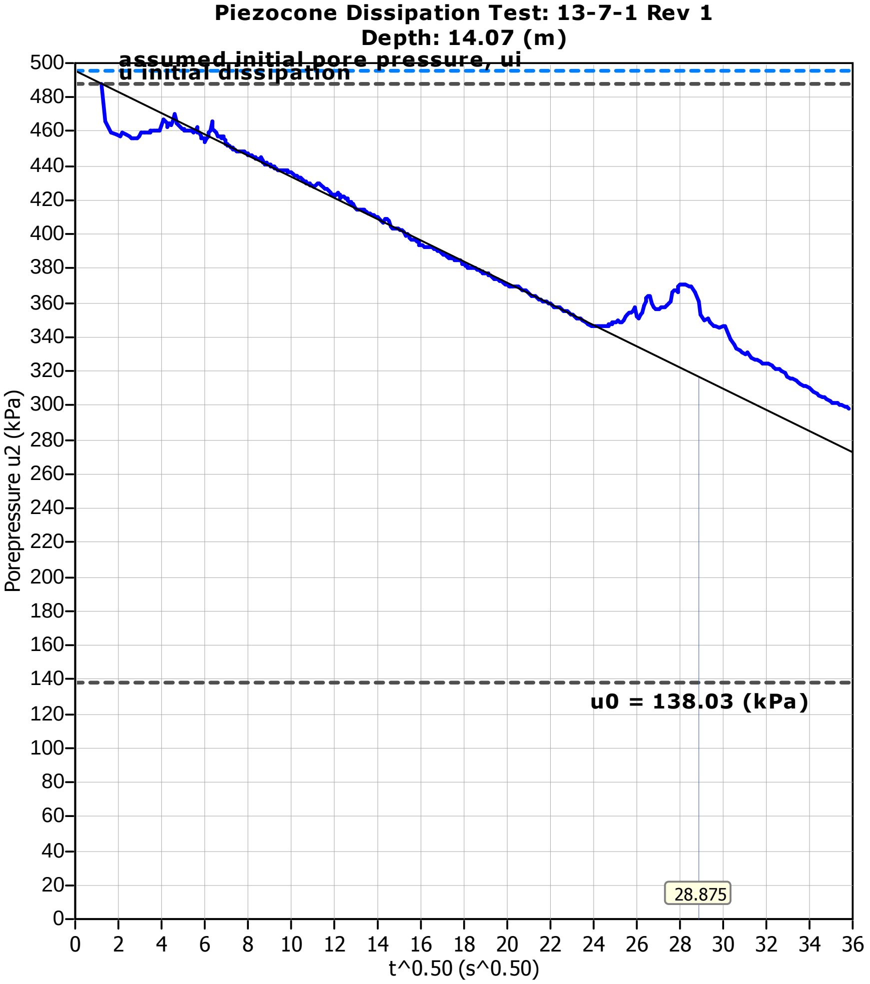
where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

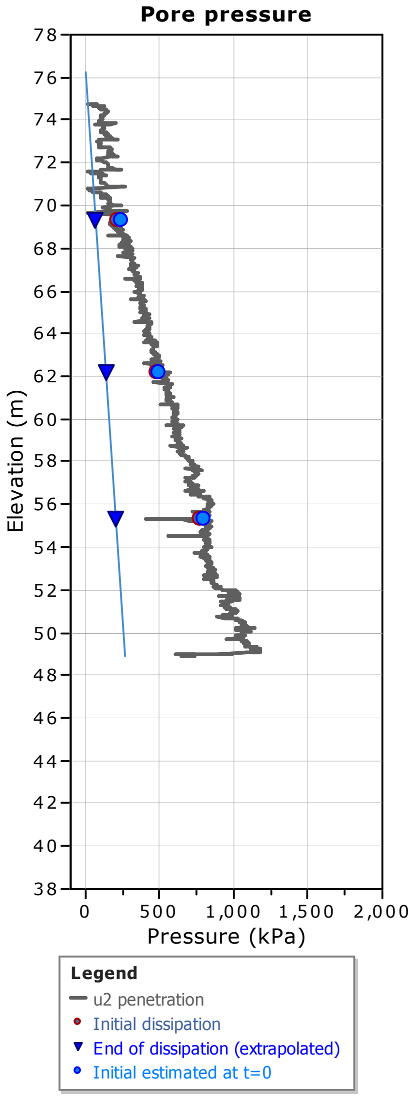
Tabular results

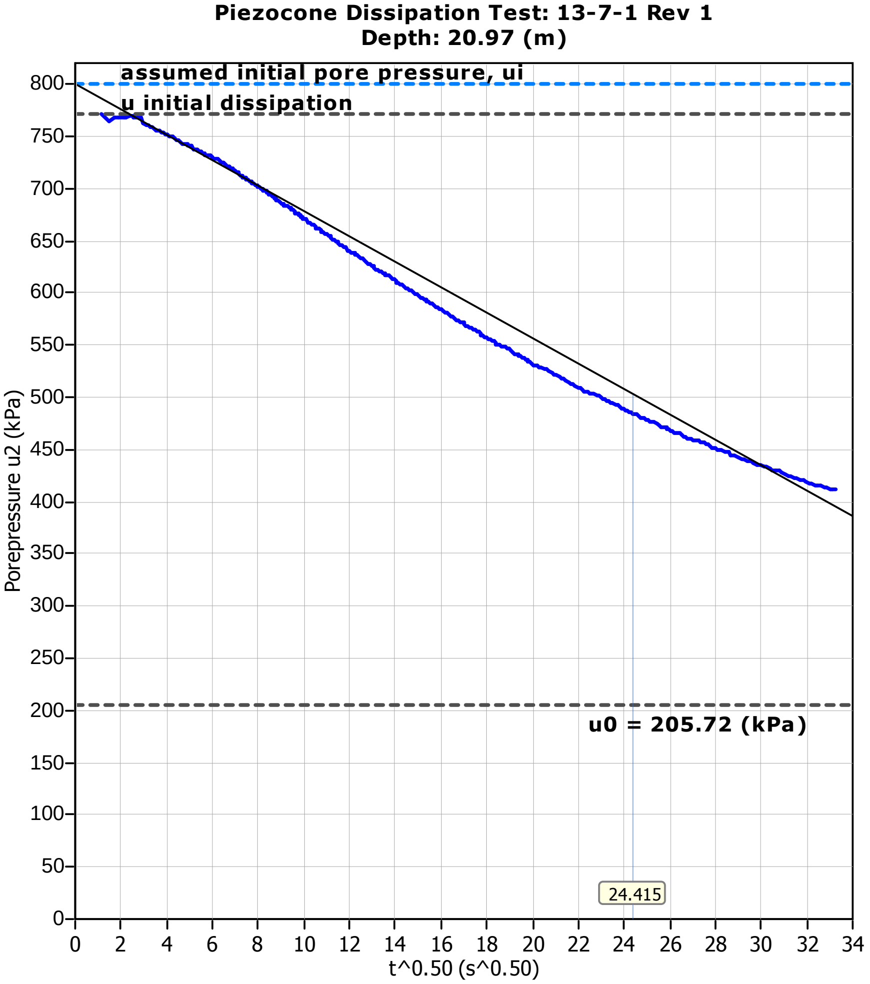
CPTU Borehole	**Depth (m)**	**$(t_{50})^{0.50}$**	**t_{50} (s)**	**t_{50} (years)**	**G/S_u**	**c_h (m^2/s)**	**c_h (m^2/year)**	**M (MPa)**	**k_h (m/s)**
13-7-1 Rev 1	7.02	58.5	3417	1.08E-004	74.00	1.98E-007	6	0.36	5.37E-009
13-7-1 Rev 1	14.07	28.9	834	2.64E-005	57.00	7.11E-007	22	1.45	4.80E-009
13-7-1 Rev 1	20.97	24.4	596	1.89E-005	52.00	9.50E-007	30	3.07	3.03E-009

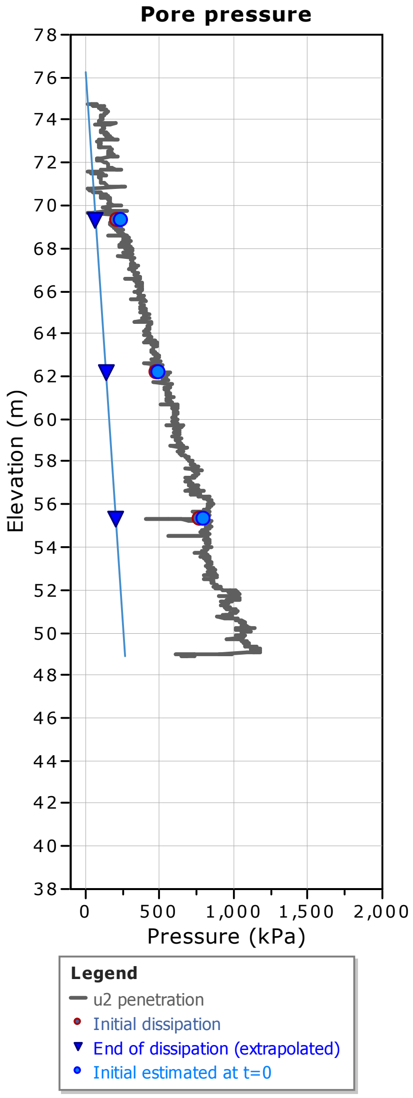

Piezocone Dissipation Test: 13-7-1 Rev 1
Depth: 7.02 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 68.87 (kPa)
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
5
15
25
35


Pore pressure
Elevation (m)
Pressure (kPa)
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 13-7-1 Rev 1
Depth: 14.07 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 138.03 (kPa)
28.875
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36

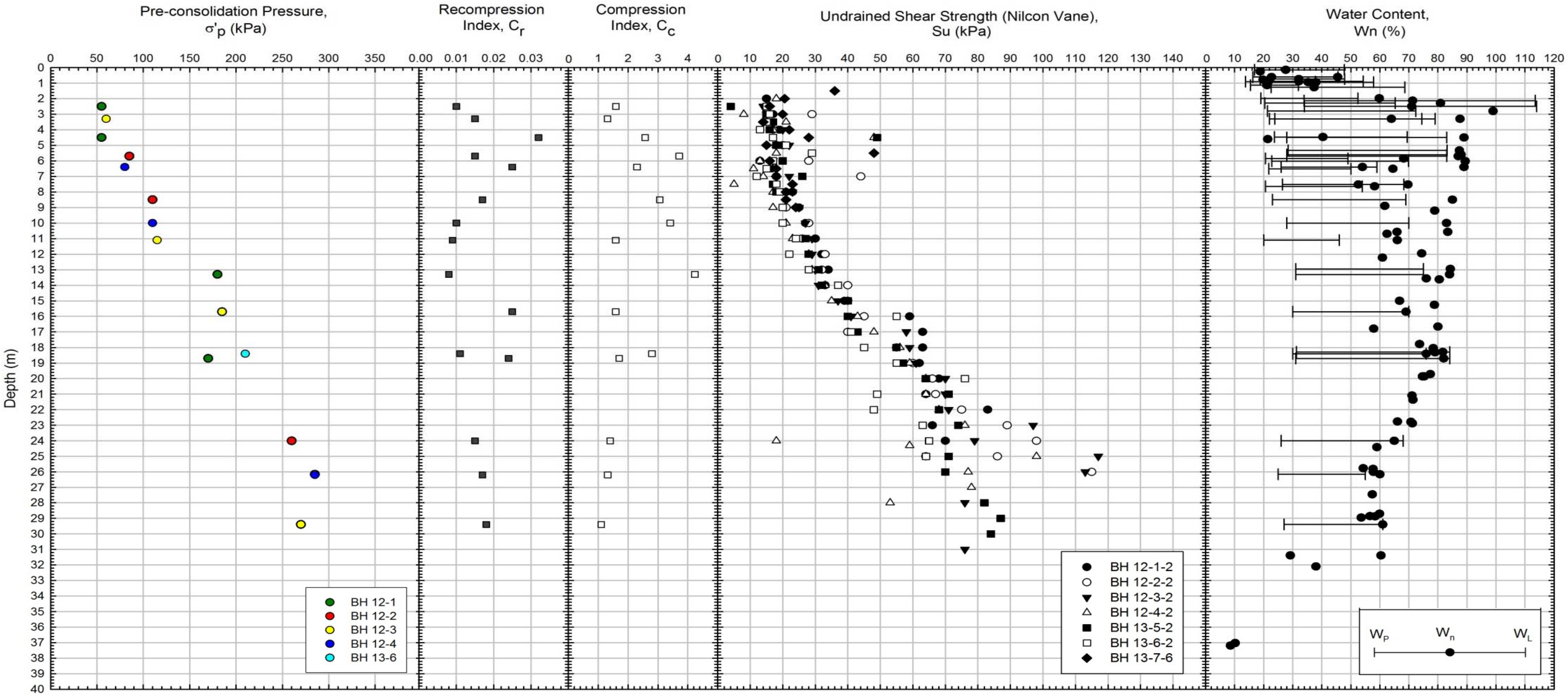

Pore pressure
Elevation (m)
Pressure (kPa)
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0


Piezocone Dissipation Test: 13-7-1 Rev 1
Depth: 20.97 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 205.72 (kPa)
24.415
Porepressure u2 (kPa)
t^0.50 (s^0.50)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34


Pore pressure
Elevation (m)
Pressure (kPa)
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
500
1,000
1,500
2,000
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

APPENDIX H

Summary of Engineering Properties



Golder Associates

SUMMARY OF ENGINEERING PROPOERTIES

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

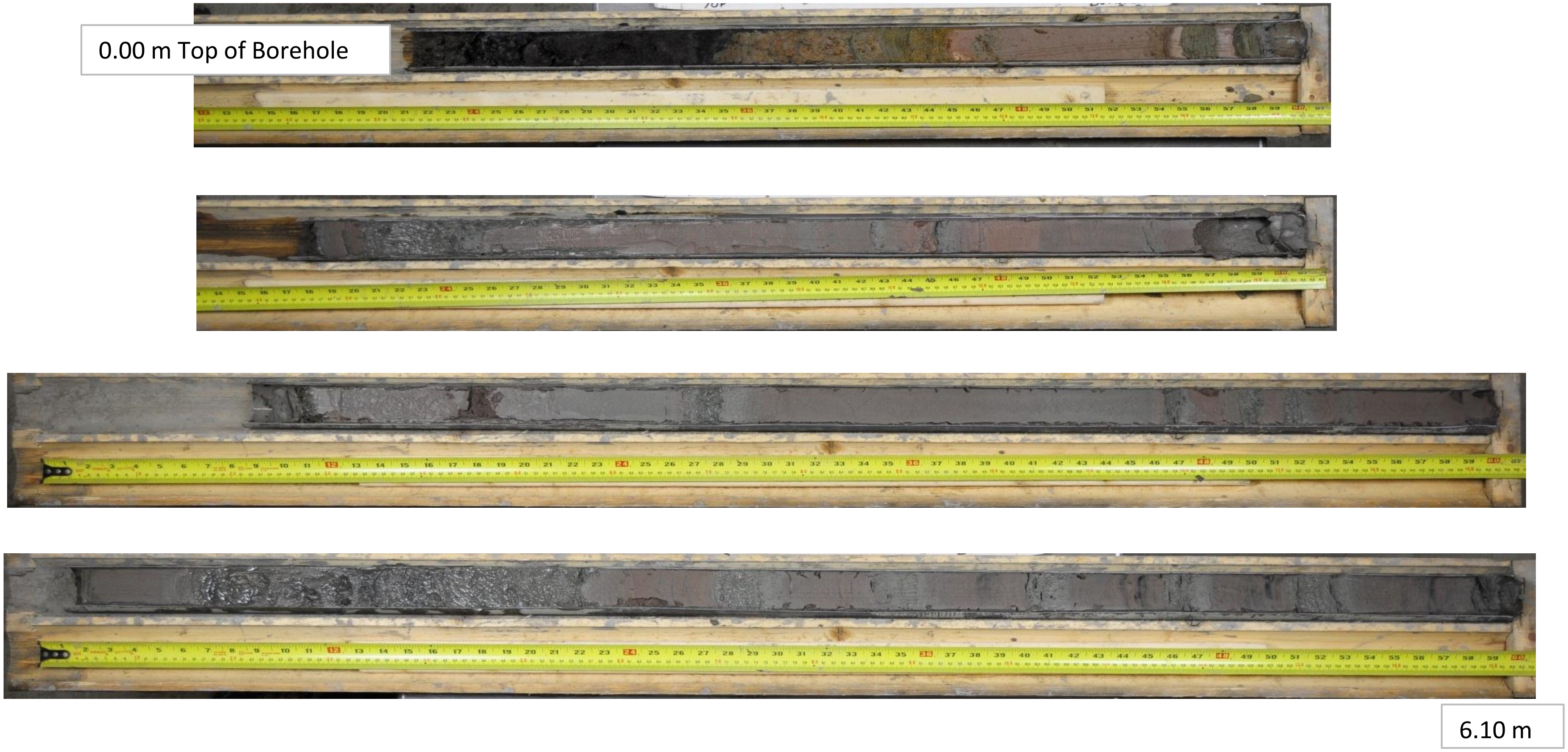
Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2013
Checked:	KE
Review:	MIC

Figure H1

APPENDIX I

Photographs of Direct Push Soil Samples

BH 12-1-7
Sampled Depth: 0.00 to 6.10 metres
Boxes 1 to 4 of 24



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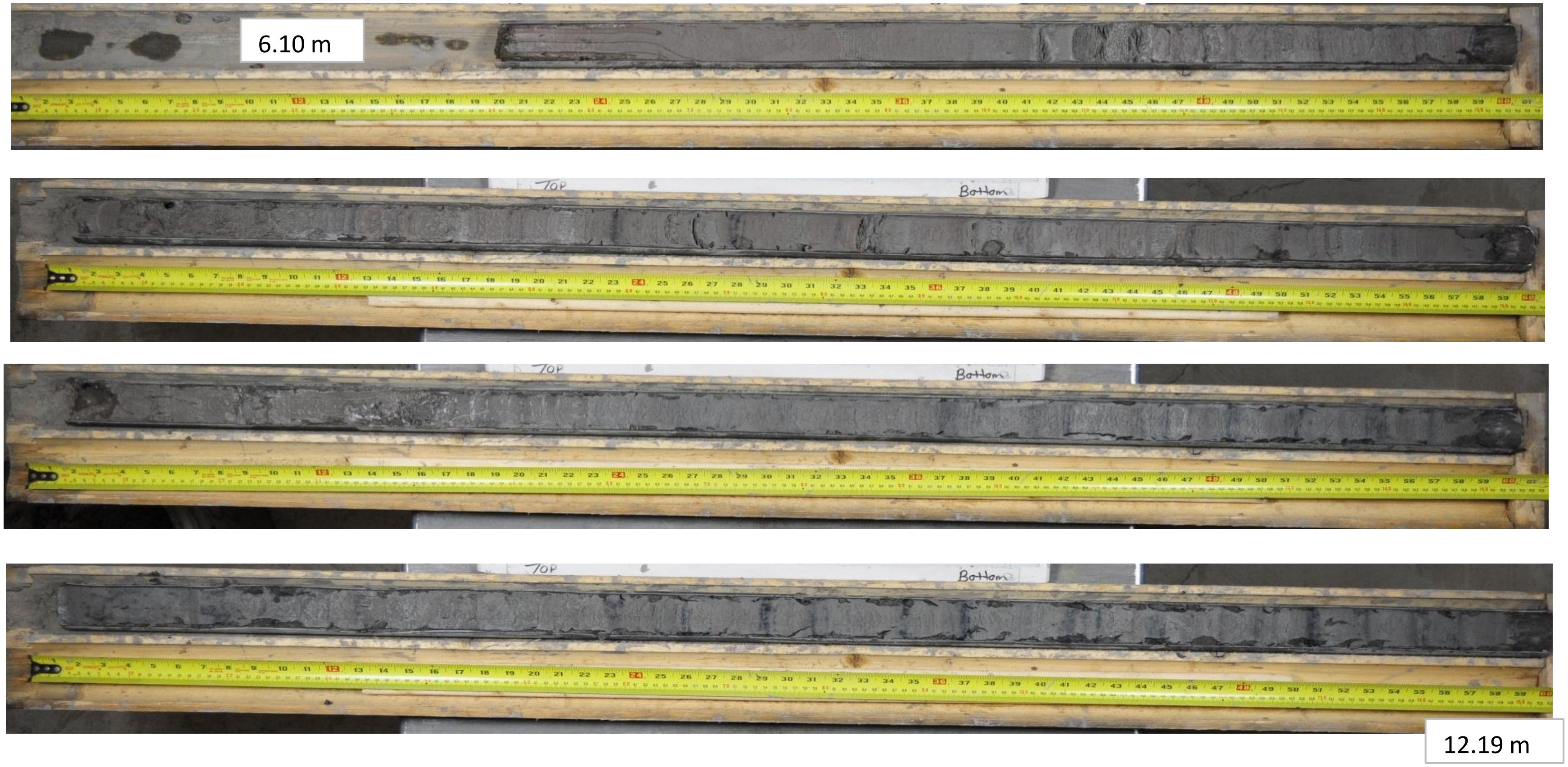
DIRECT PUSH SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I1

BH 12-1-7
Sampled Depth: 6.10 to 12.19 metres
Boxes 5 to 8 of 24



Golder Associates

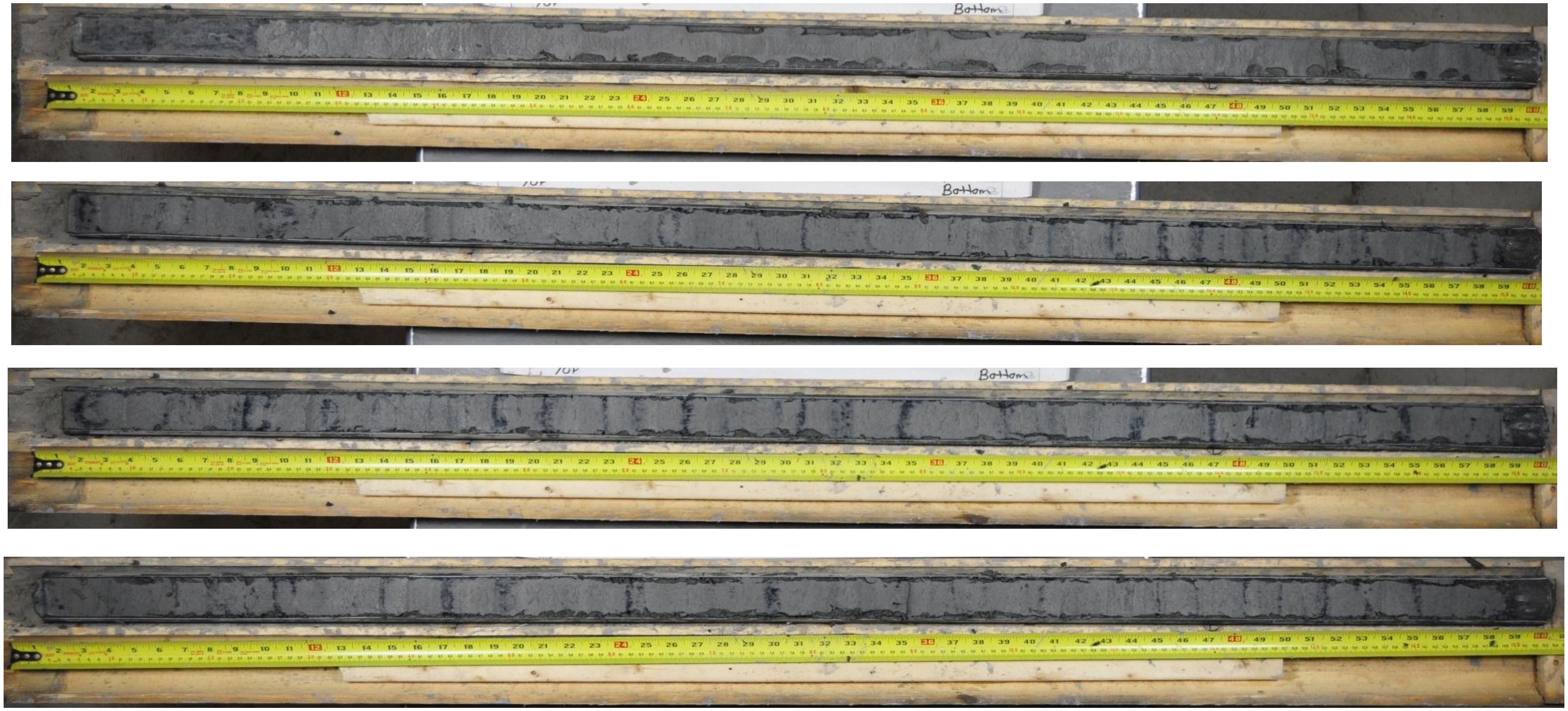
DIRECT PUSH SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I2

BH 12-1-7
Sampled Depth: 12.19 to 18.29 metres
Boxes 9 to 12 of 24



12.19 m

18.29 m

Golder Associates

DIRECT PUSH SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

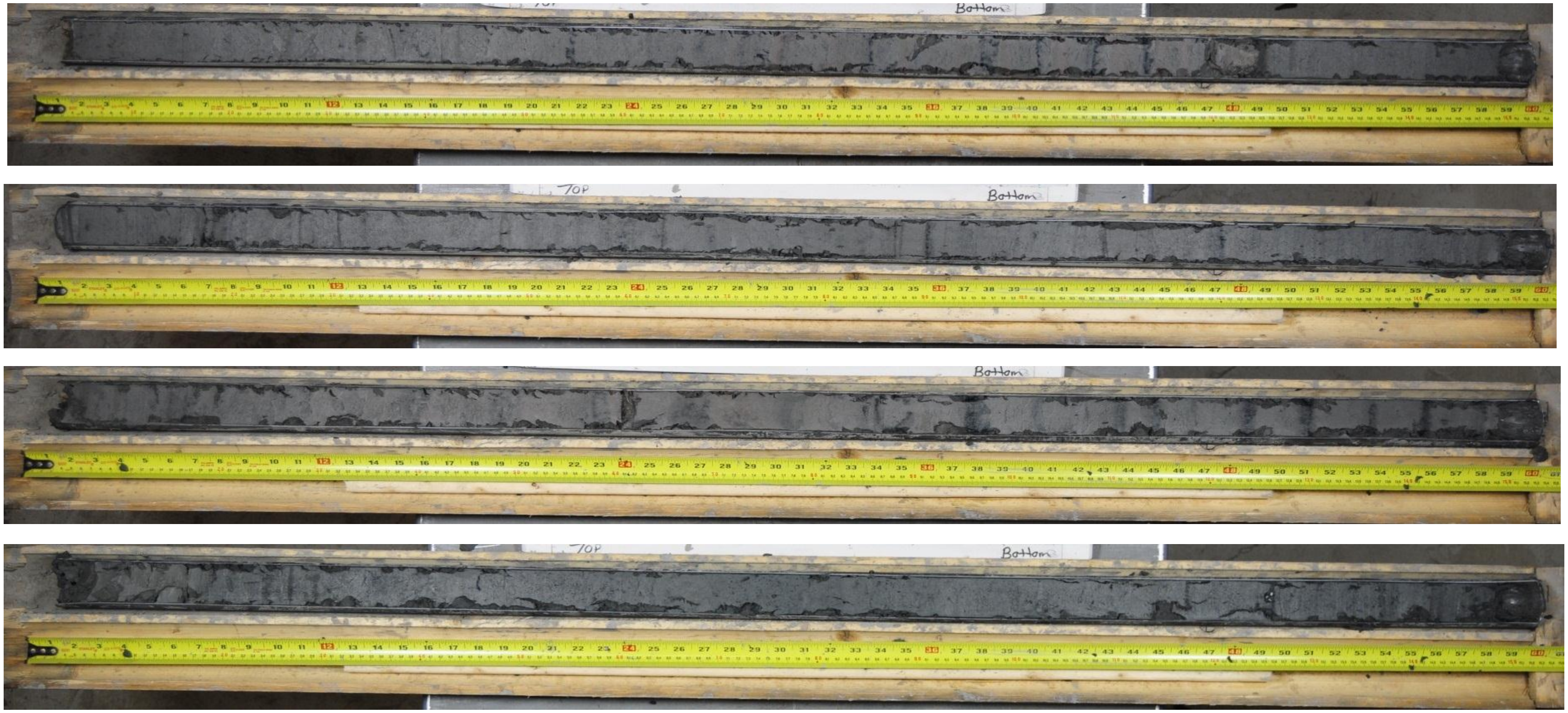
Figure I3

BH 12-1-7

Sampled Depth: 18.29 to 24.38 metres

Boxes 13 to 16 of 24

18.29 m



24.38 m

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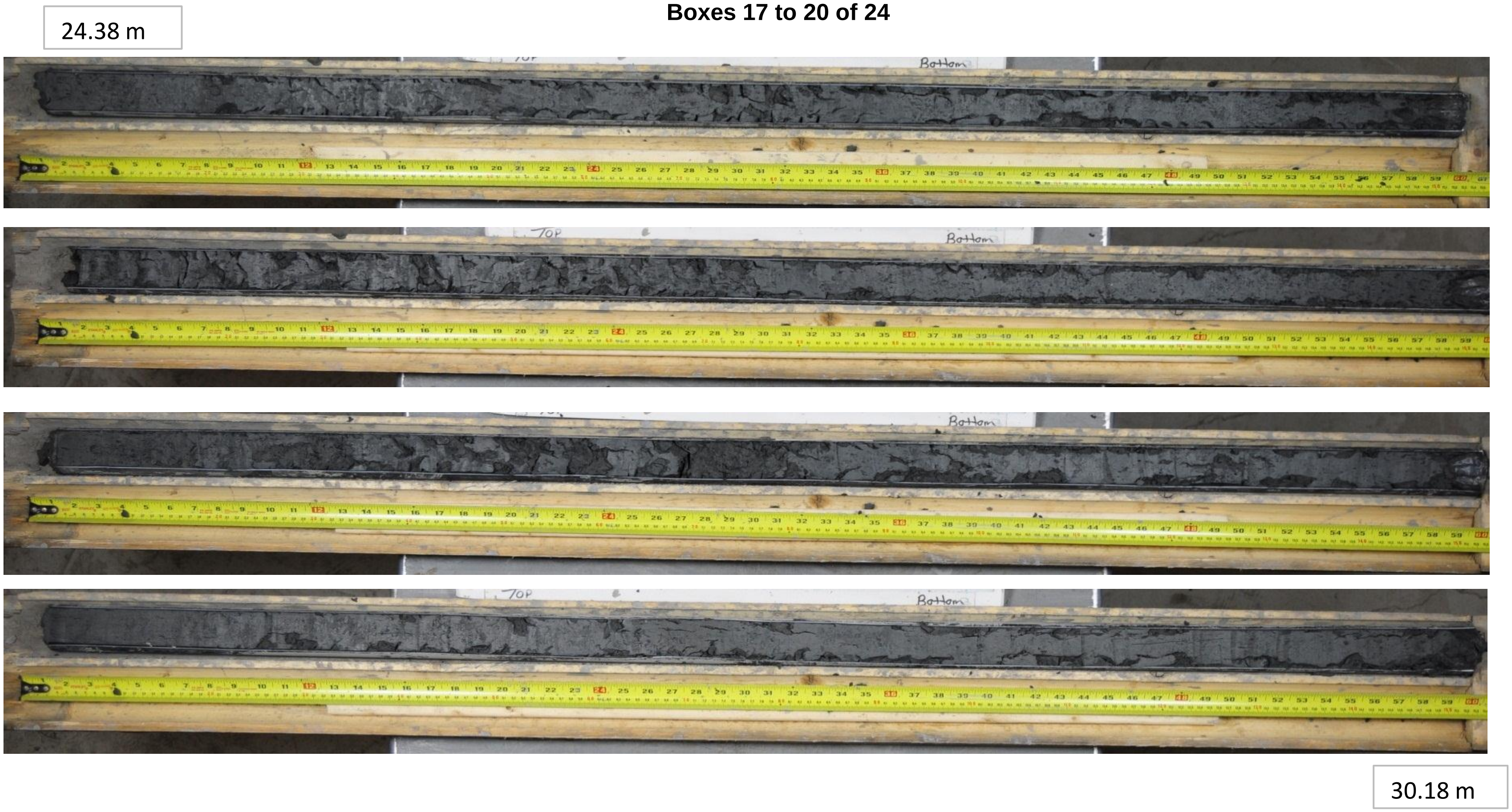
DIRECT PUSH SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I4

BH 12-1-7
Sampled Depth: 24.38 to 30.18 metres
Boxes 17 to 20 of 24



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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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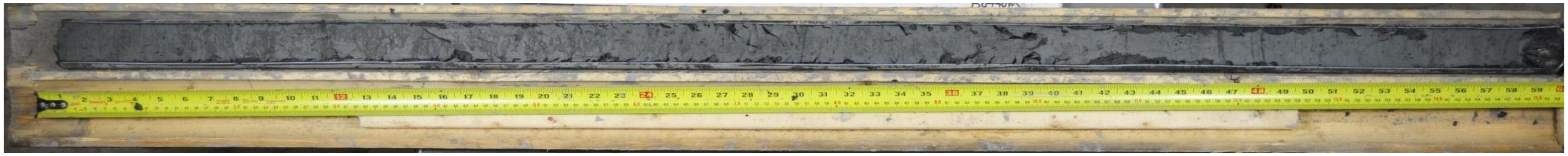
Review:	MIC

Figure I5

BH 12-1-7
Sampled Depth: 30.18 to 35.97 metres
Boxes 21 to 24 of 24

30.18 m



Sample 23 - No Recovery

35.97 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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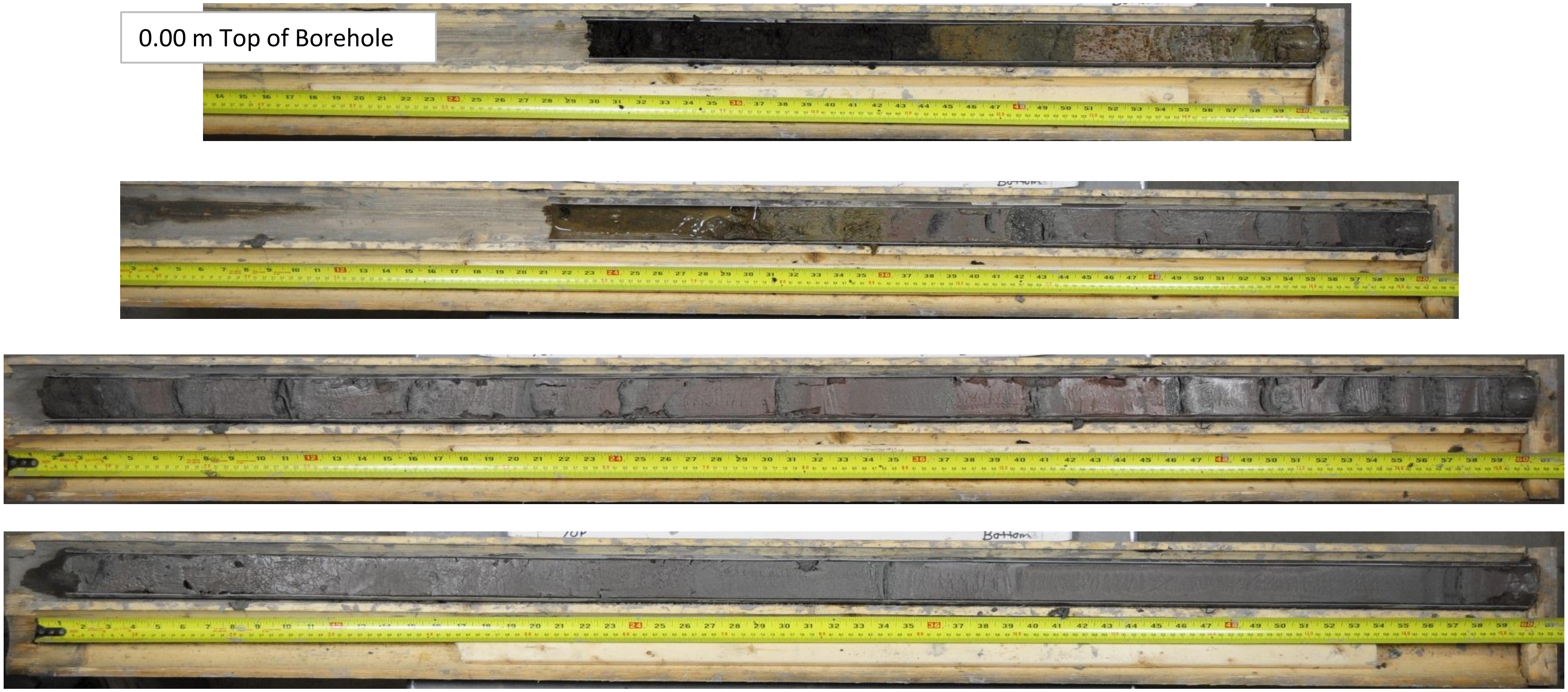
Review:	MIC

Figure I6

BH 12-2-7
Sampled Depth: 0.00 to 5.94 metres
Boxes 1 to 4 of 24



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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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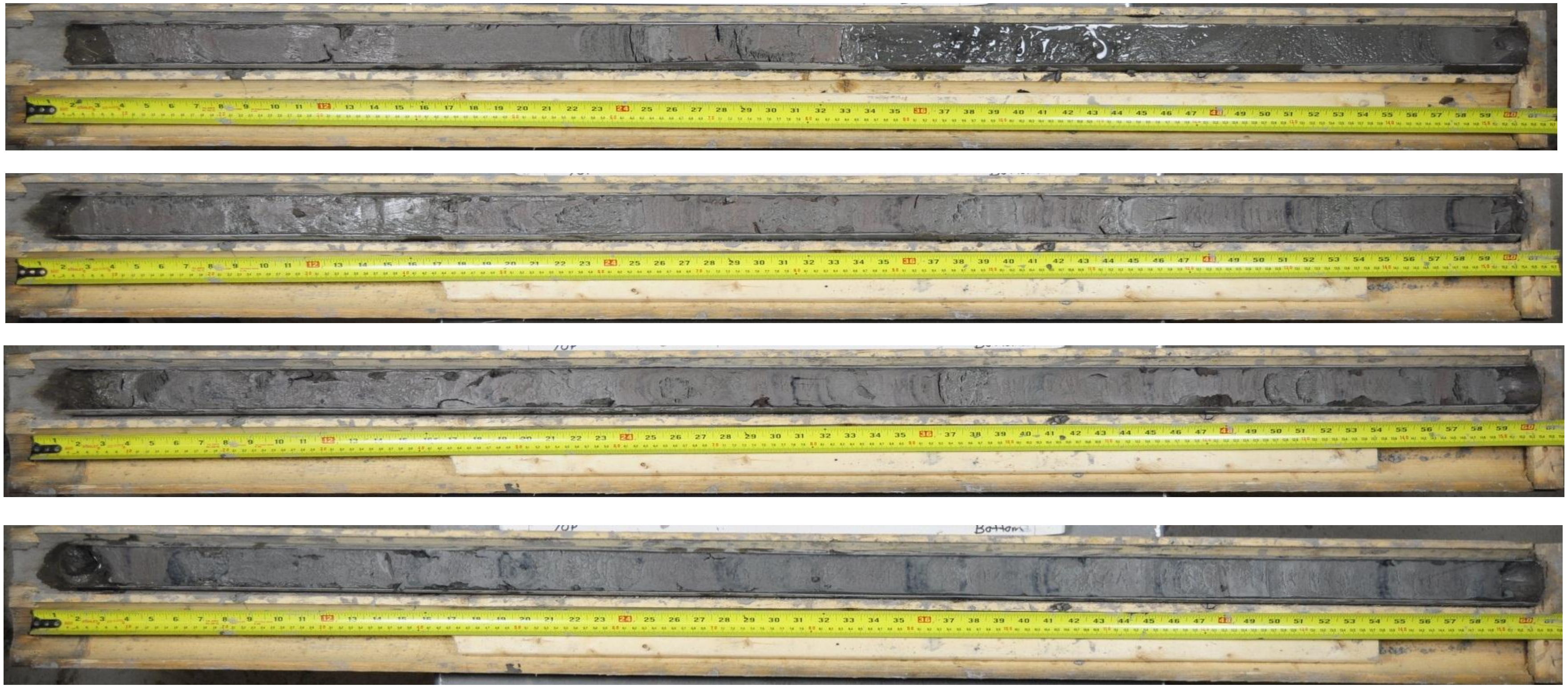
Review:	MIC

Figure I7

BH 12-2-7
Sampled Depth: 5.94 to 12.04 metres
Boxes 5 to 8 of 24

5.94 m



12.04 m

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Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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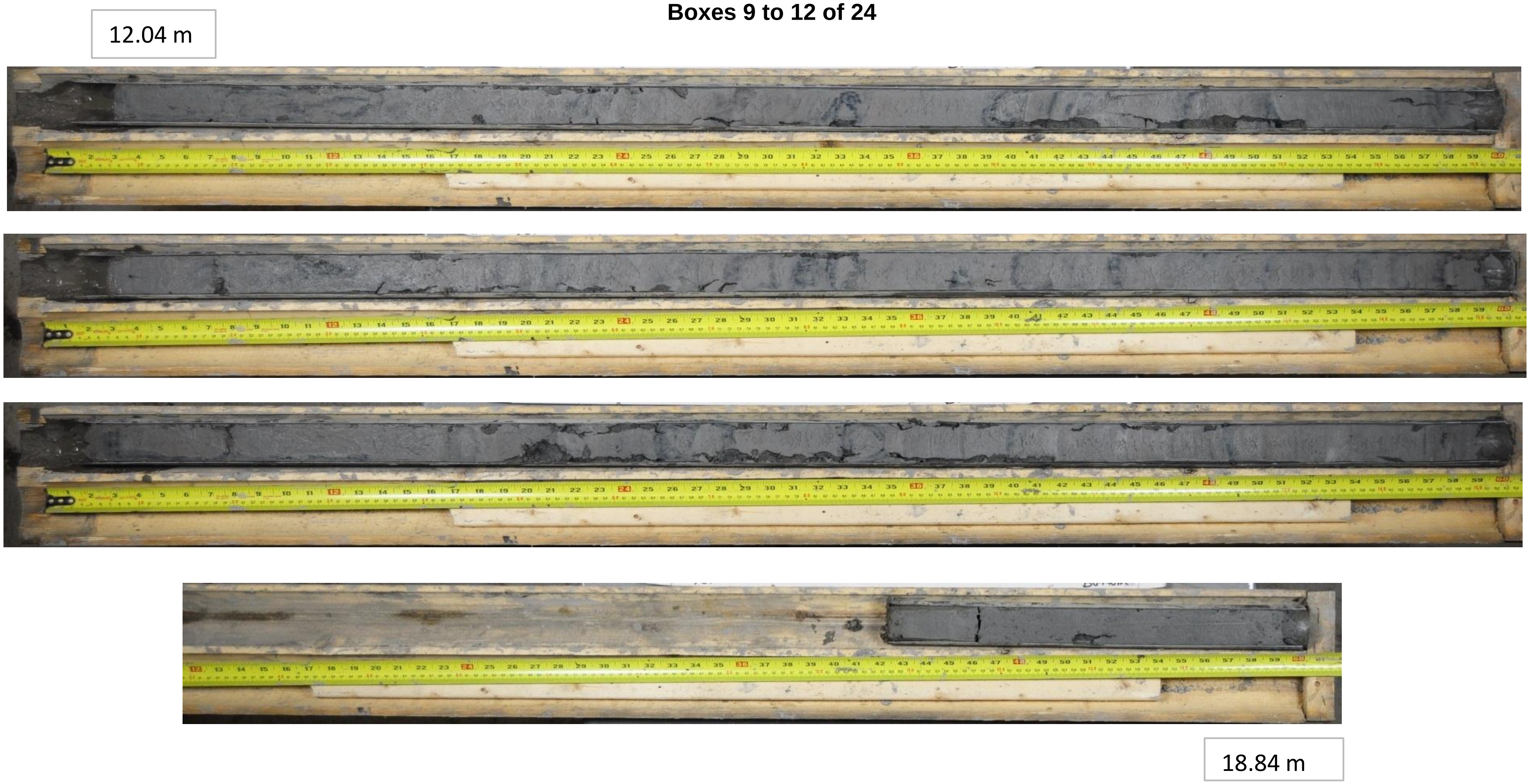
Review:	MIC

Figure I8

BH 12-2-7

Sampled Depth: 12.04 to 18.84 metres

Boxes 9 to 12 of 24



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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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Review:	MIC

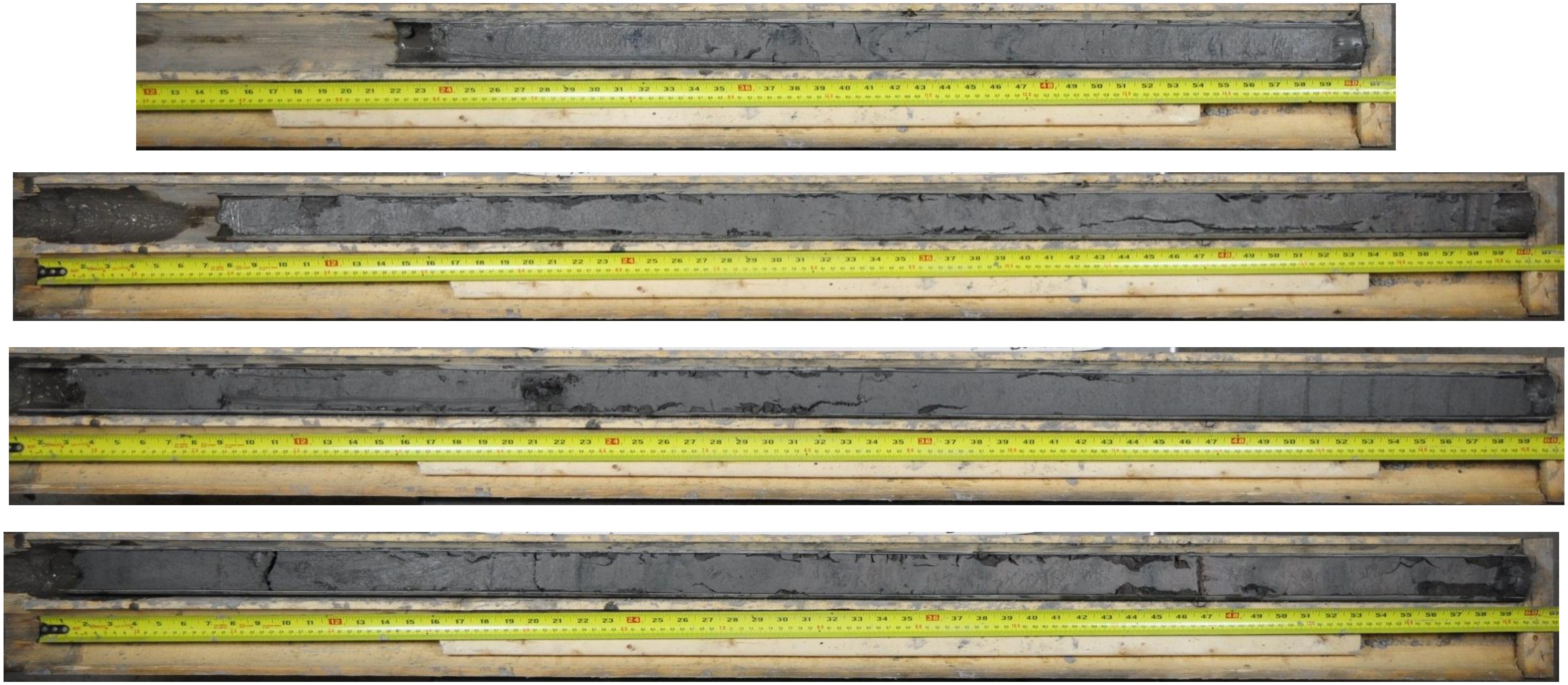
Figure I9

BH 12-2-7

Sampled Depth: 18.84 to 24.23 metres

Boxes 13 to 16 of 24

18.84 m



24.23 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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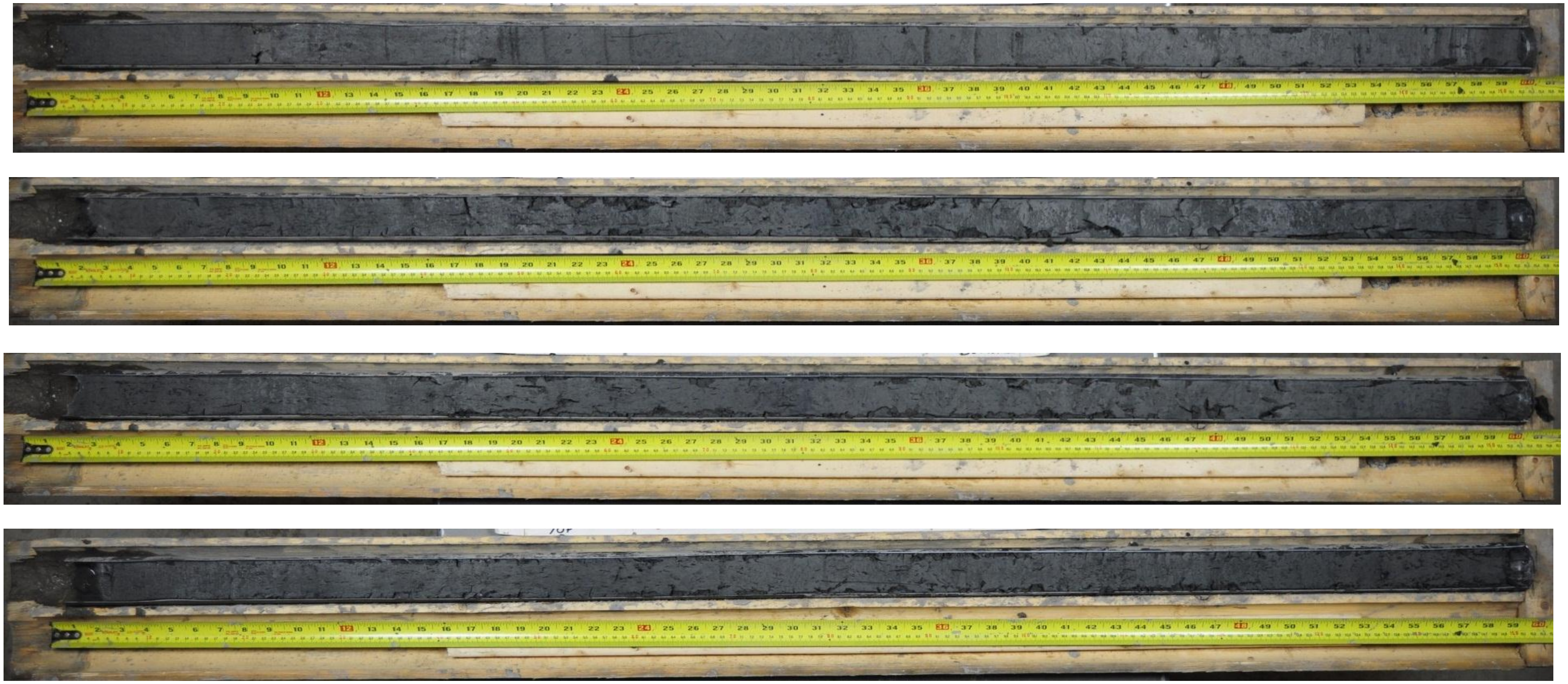
Review:	MIC

Figure I10

BH 12-2-7
Sampled Depth: 24.23 to 30.32 metres
Boxes 17 to 20 of 24

24.23 m



30.32 m

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Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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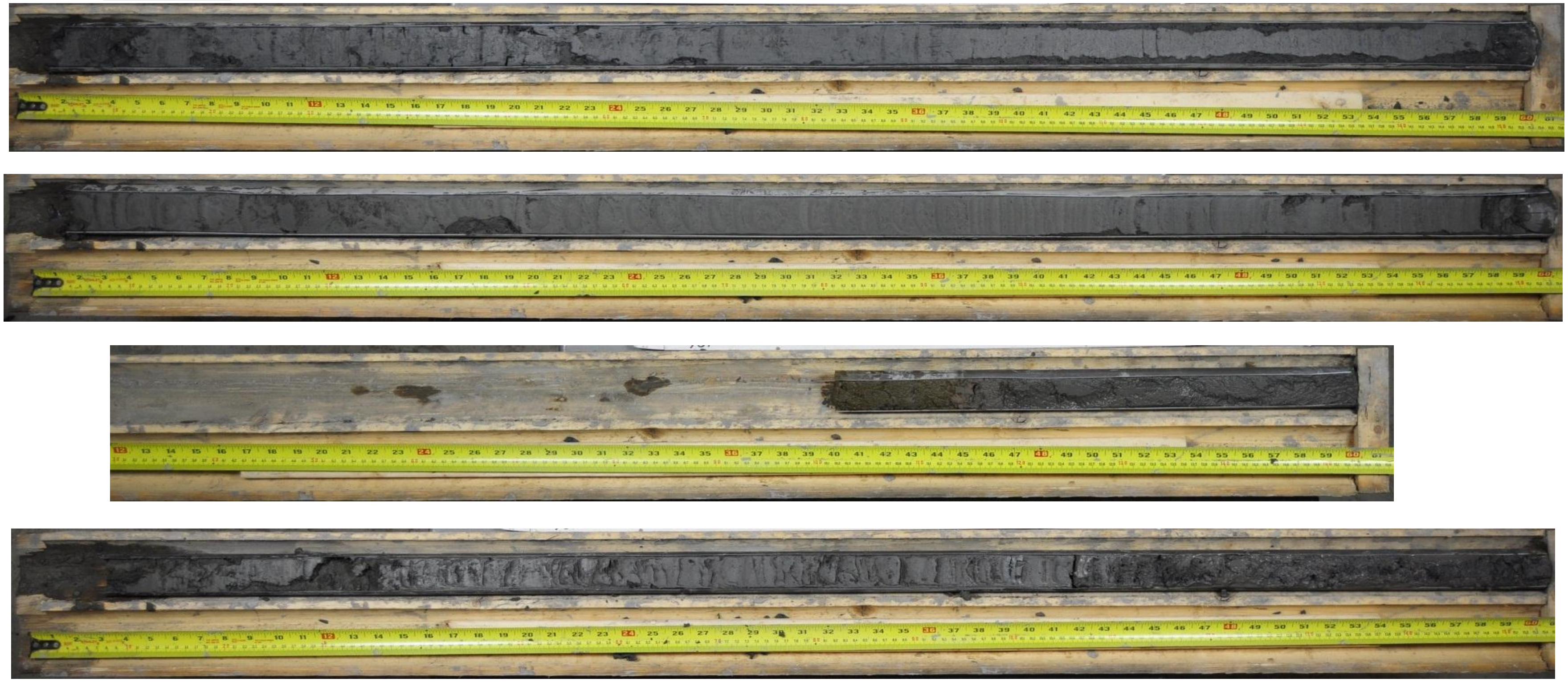
Review:	MIC

Figure I11

BH 12-2-7
Sampled Depth: 30.23 to 35.81 metres
Boxes 21 to 24 of 24

30.23 m



35.81 m End of Borehole

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Project No.	12-1125-0045
Drawn:	WAM
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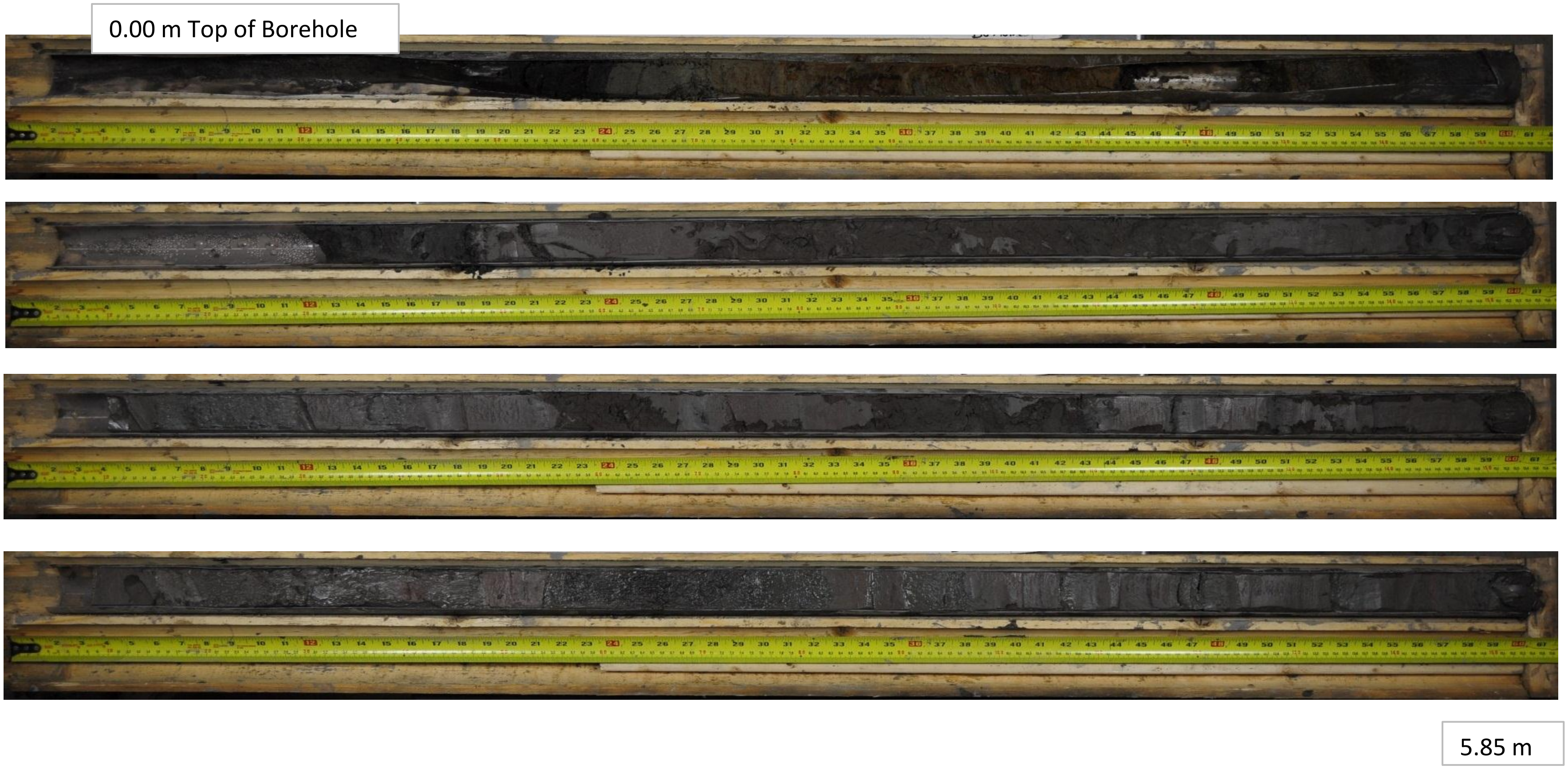
Review:	MIC

Figure I12

BH 12-3-7
Sampled Depth: 0.00 to 5.85 metres
Boxes 1 to 4 of 22



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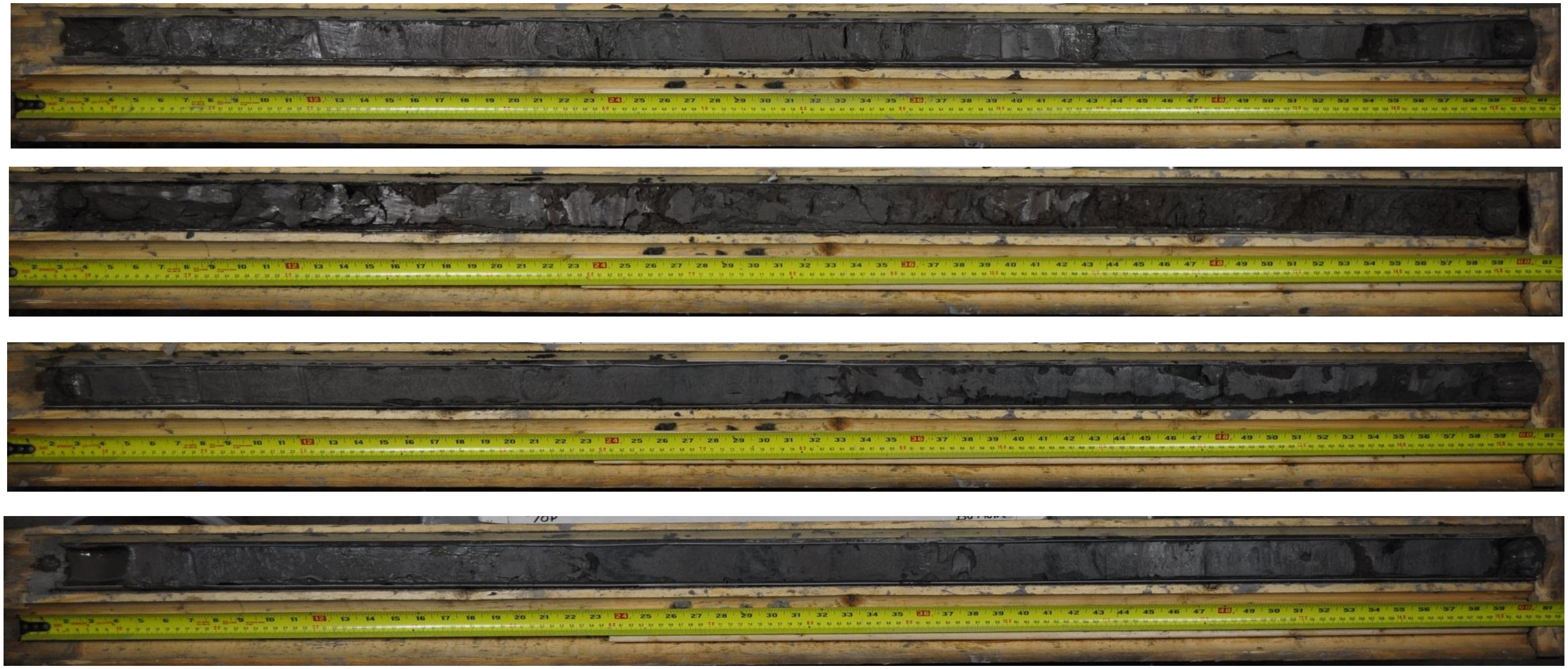
PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I13

BH 12-3-7
Sampled Depth: 5.85 to 11.95 metres
Boxes 5 to 8 of 22

5.85 m



11.95 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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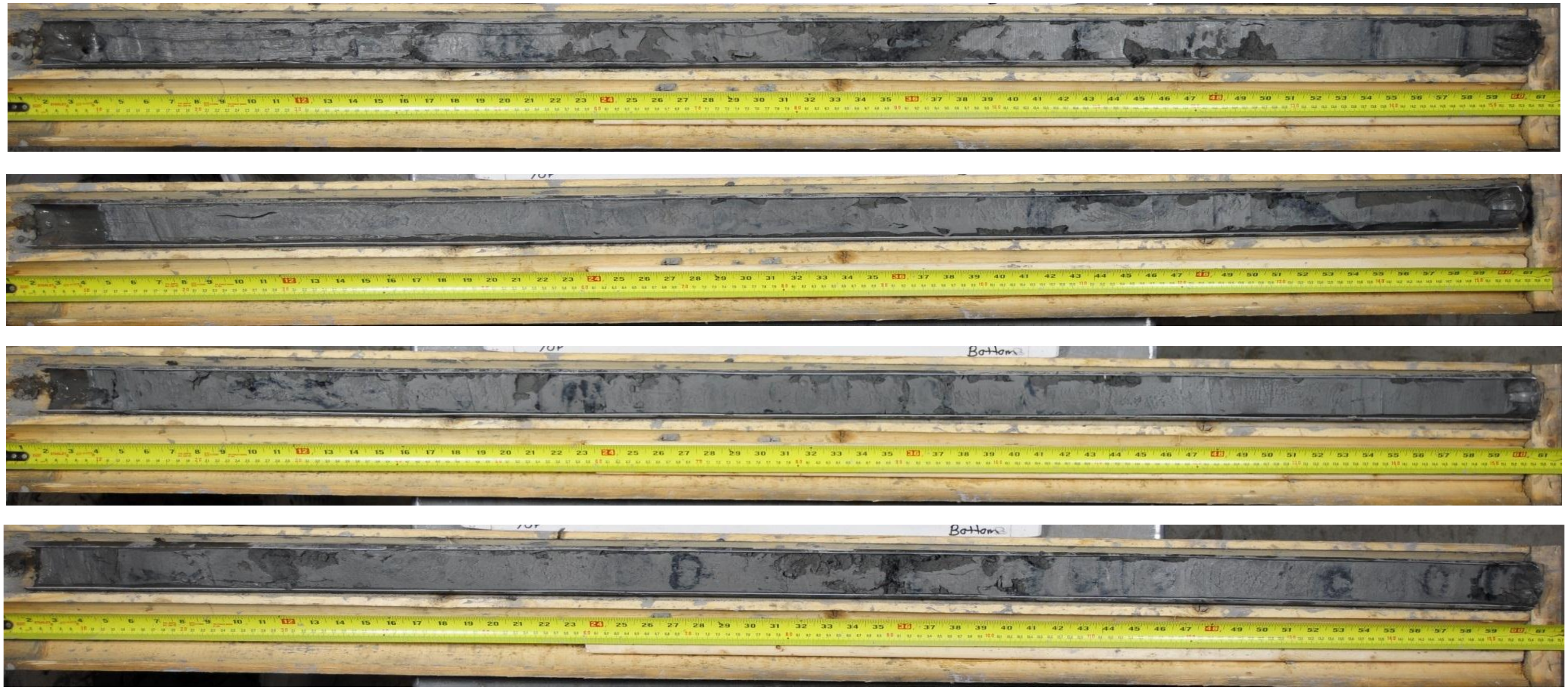
Review:	MIC

Figure I14

BH 12-3-7
Sampled Depth: 11.95 to 18.04 metres
Boxes 9 to 12 of 22

11.95 m



18.04 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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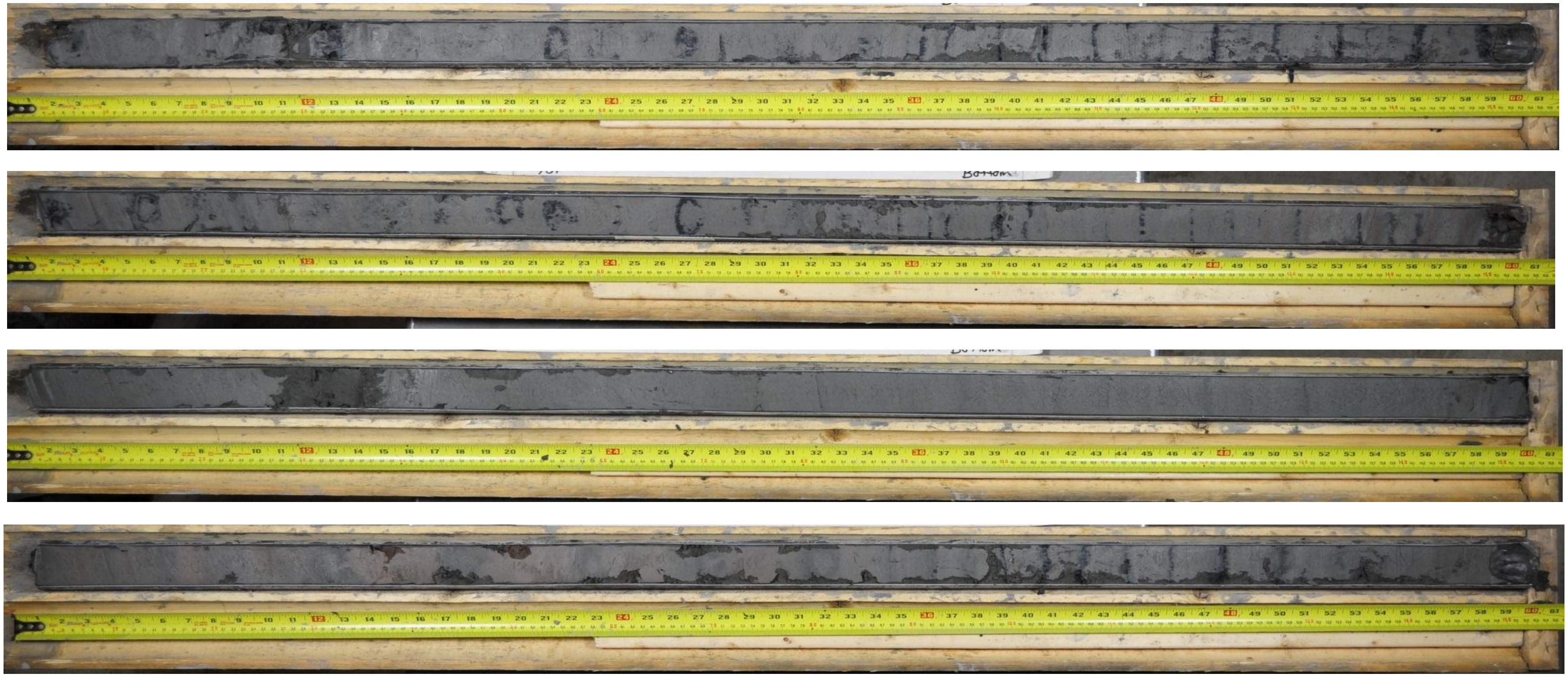
Review:	MIC

Figure I15

BH 12-3-7
Sampled Depth: 18.04 to 24.14 metres
Boxes 13 to 16 of 22

18.04 m



24.14 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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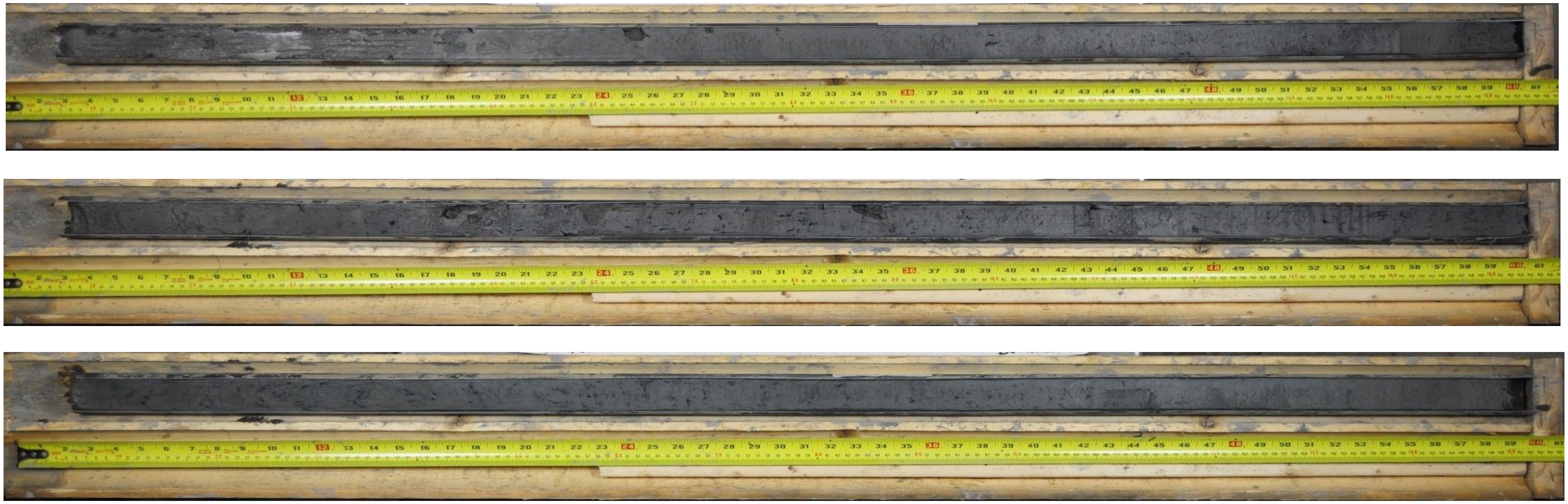
Review:	MIC

Figure I16

BH 12-3-7
Sampled Depth: 24.14 to 30.23 metres
Boxes 17 to 20 of 22

Sample 17 - No Recovery

25.67 m



30.23 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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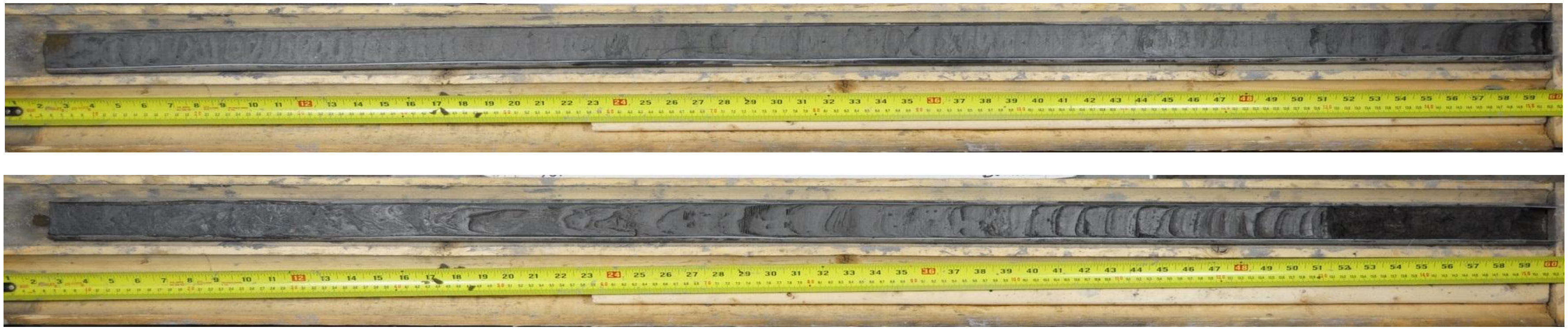
Review:	MIC

Figure I17

BH 12-3-7
Sampled Depth: 30.23 to 33.28 metres
Boxes 21 and 22 of 22

30.23 m



33.28 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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Review:	MIC

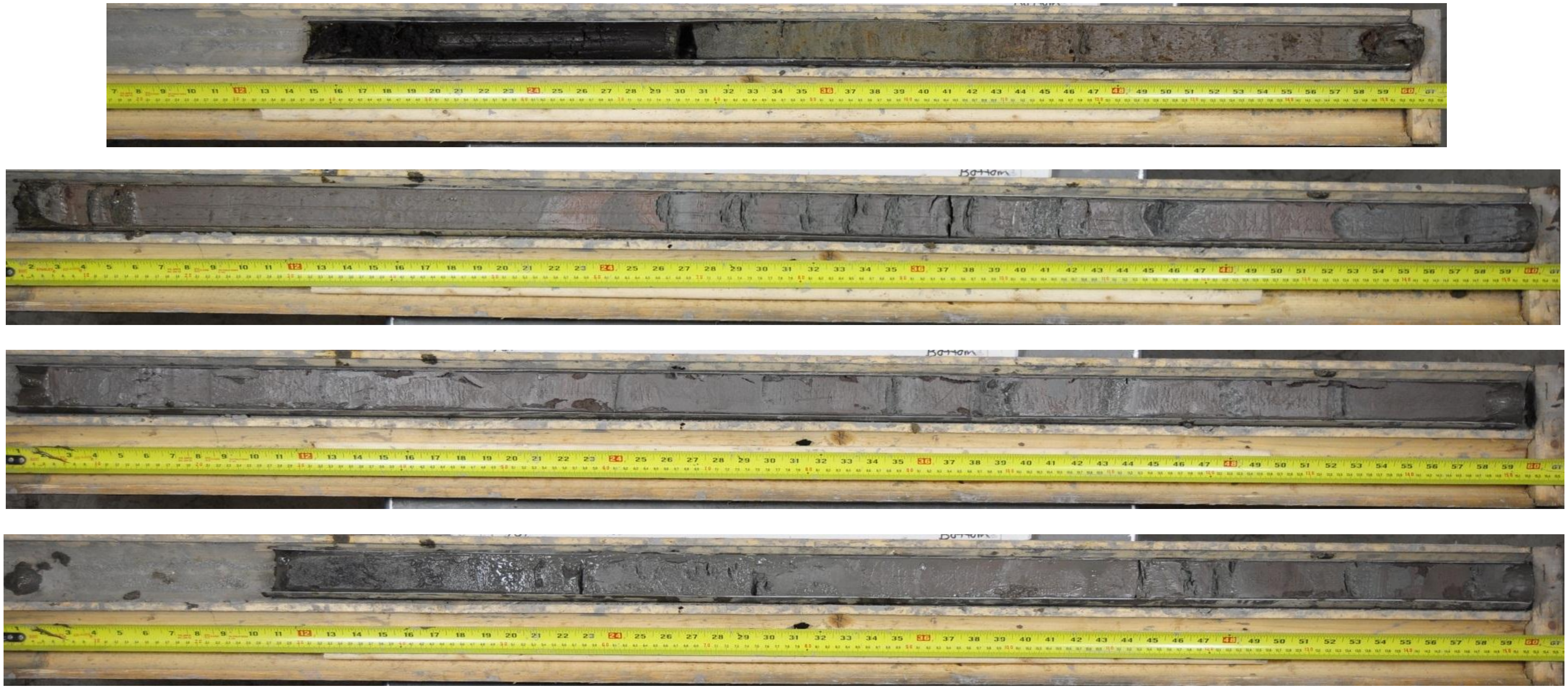
Figure I18

BH 12-4-7

Sampled Depth: 0.00 to 5.94 metres

Boxes 1 to 4 of 20

0.00 m Top of Borehole



5.94 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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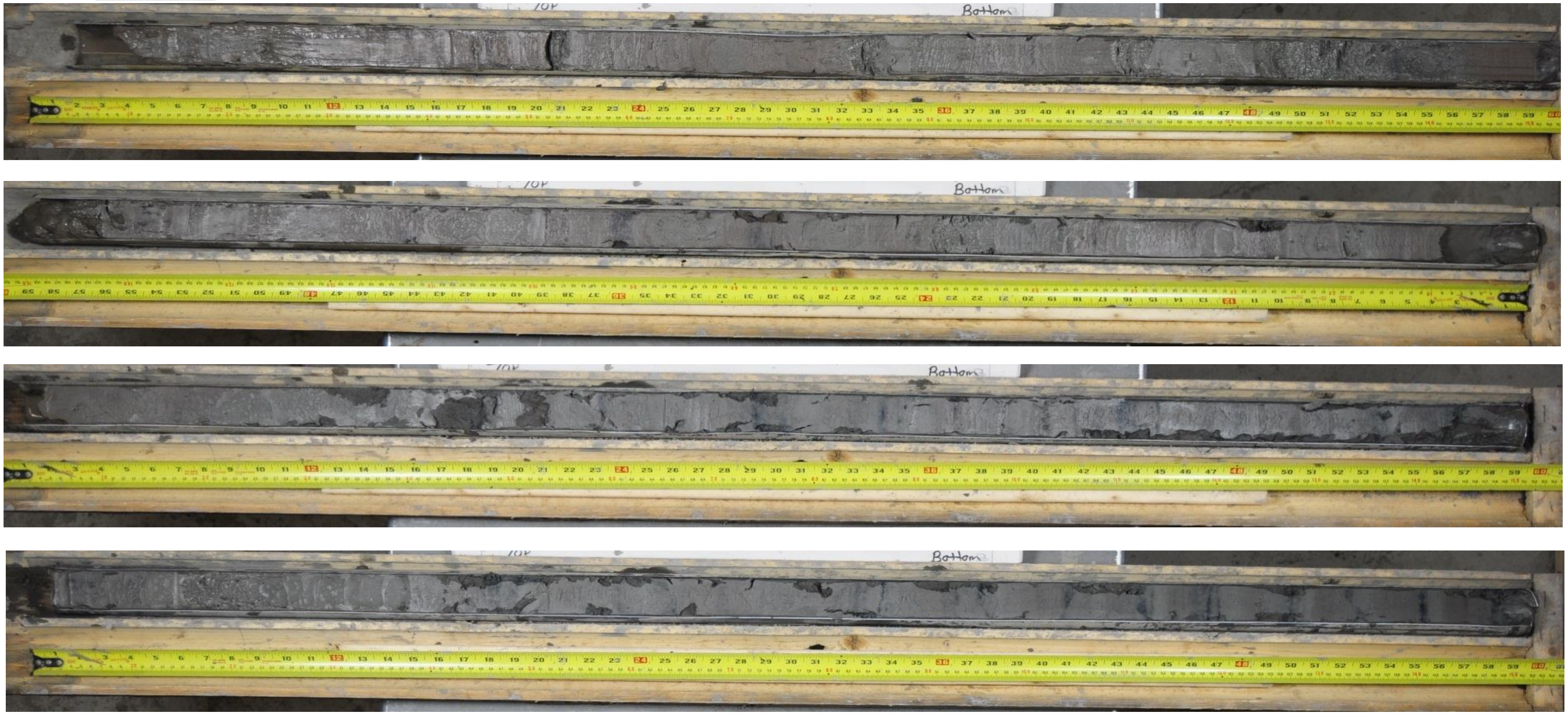
Review:	MIC

Figure I19

BH 12-4-7
Sampled Depth: 5.94 to 12.04 metres
Boxes 5 to 8 of 20

5.94 m



12.04 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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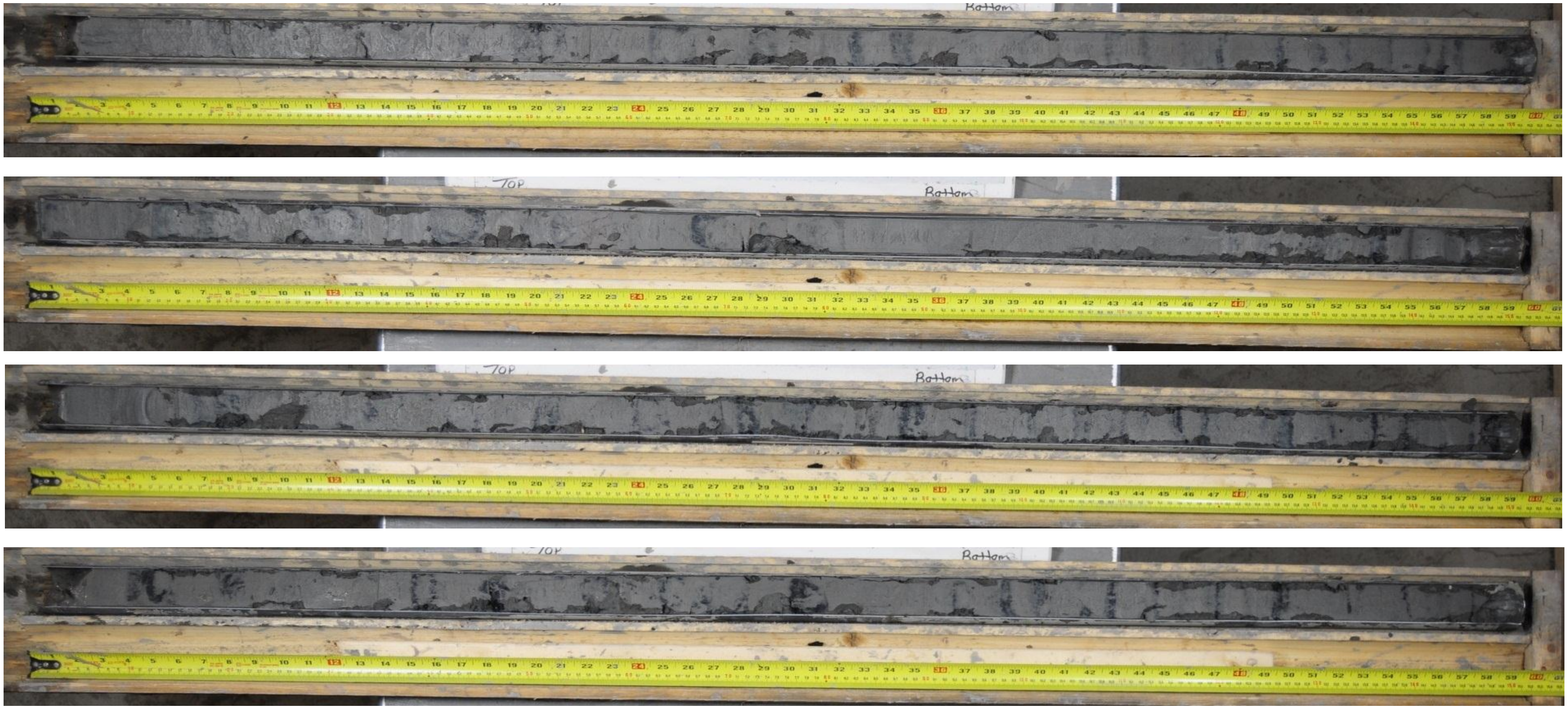
Review:	MIC

Figure I20

BH 12-4-7
Sampled Depth: 12.04 to 18.14 metres
Boxes 9 to 12 of 20

12.04 m



18.14 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
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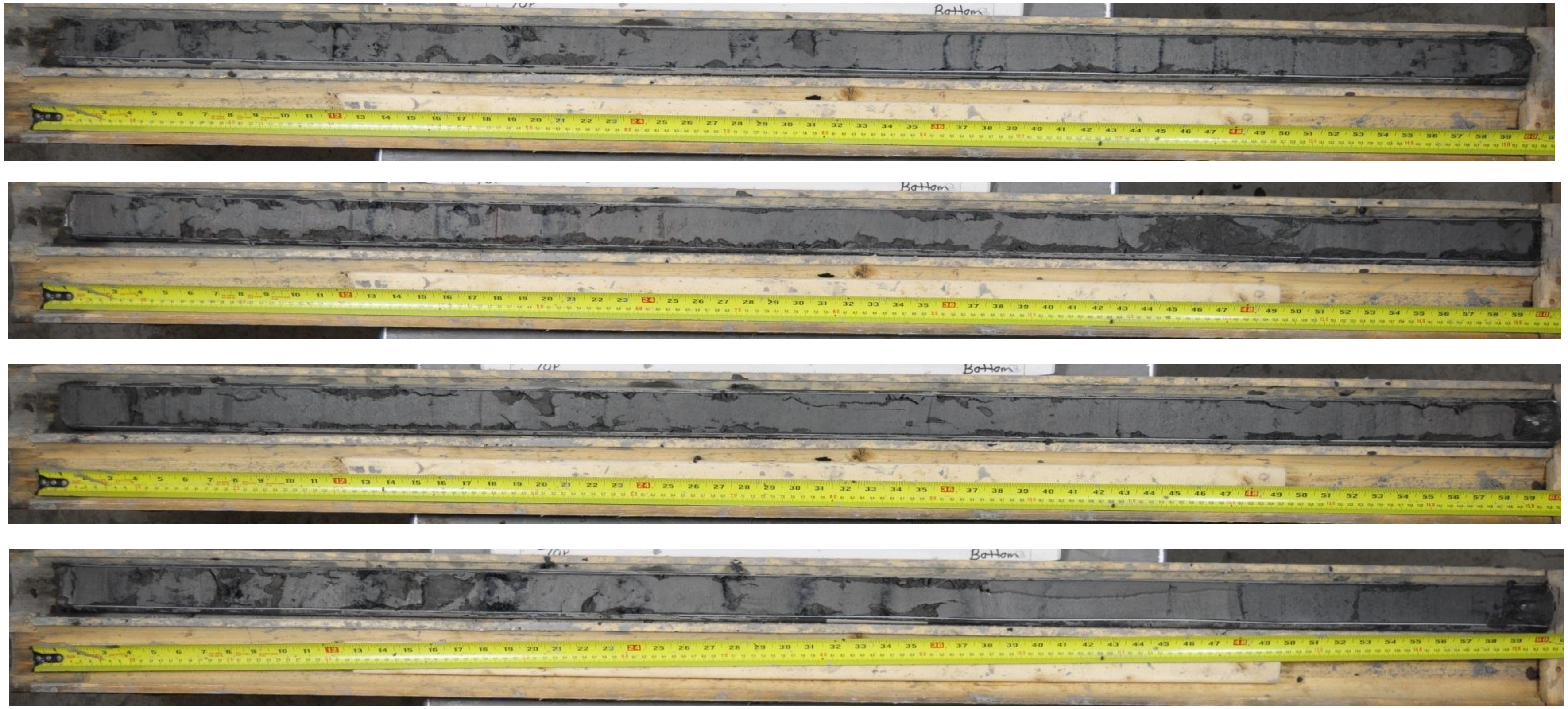
Figure I21

BH 12-4-7
Sampled Depth: 18.14 to 24.23 metres
Boxes 13 to 16 of 20



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Drawn:	WAM
Date:	7/31/2013
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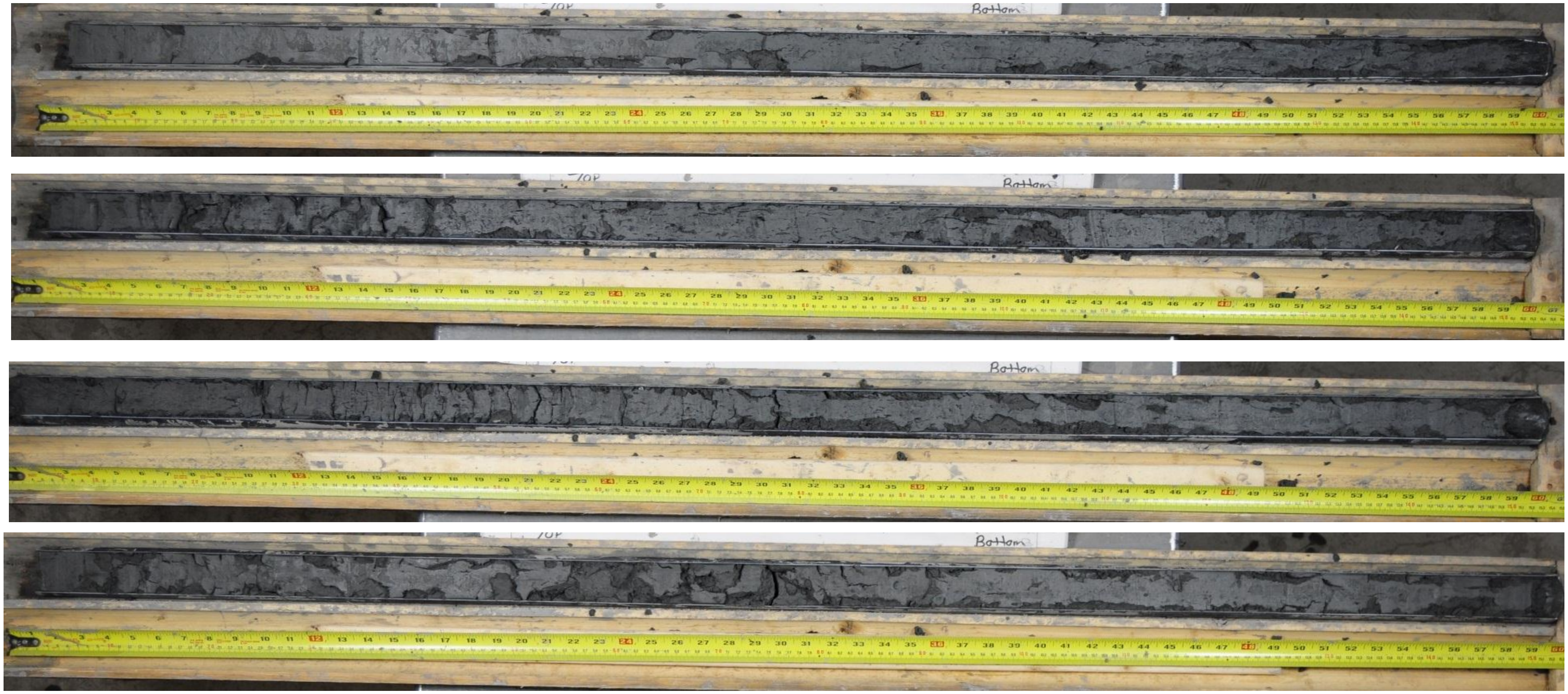
Figure I22

BH 12-4-7

Sampled Depth: 24.23 to 30.33 metres

Boxes 17 to 20 of 20

24.23 m



30.33 m End of Borehole

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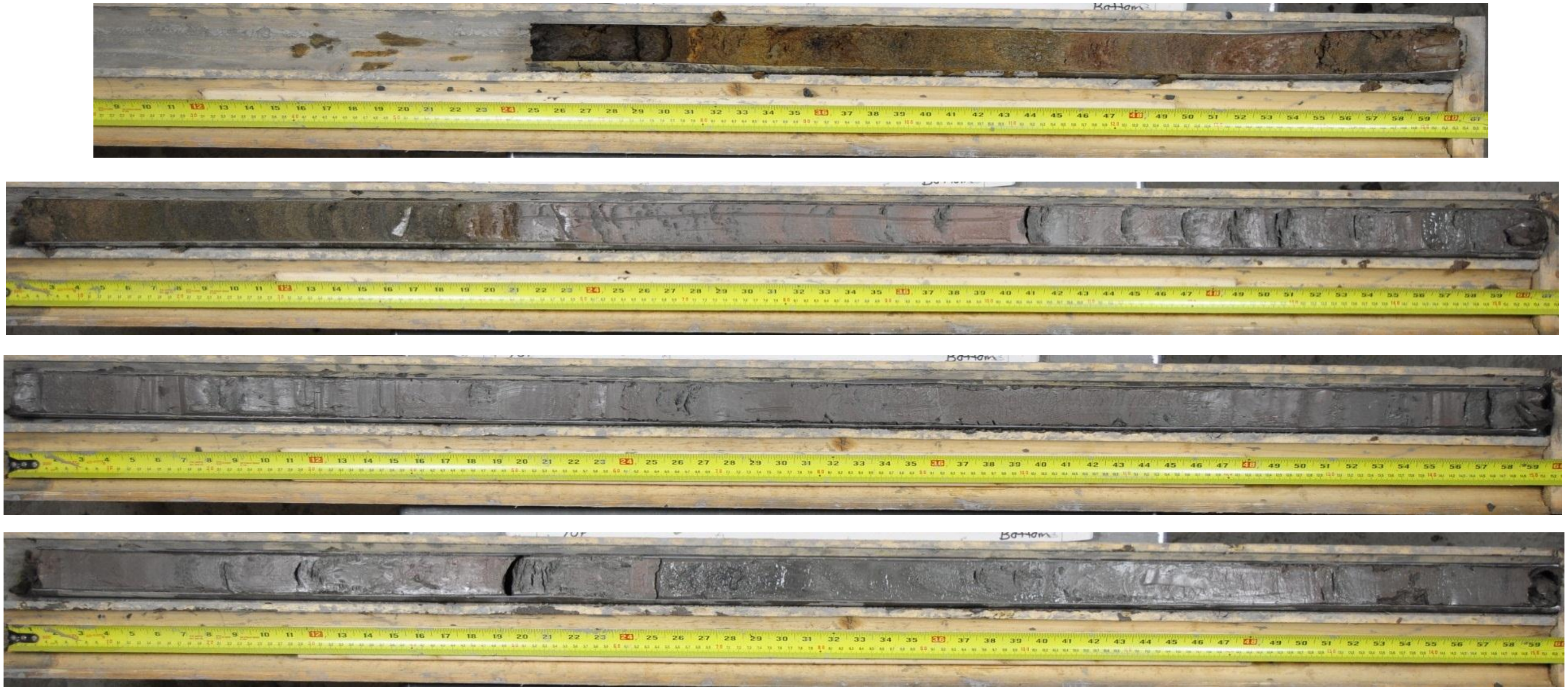
Review:	MIC

Figure I23

BH 13-6-7
Sampled Depth: 0.00 to 6.10 metres
Boxes 1 to 4 of 22

0.00 m Top of Borehole



6.10 m

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Project No.	12-1125-0045
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Review:	MIC

Figure I24

BH 13-6-7

Sampled Depth: 6.10 to 12.19 metres

Boxes 5 to 8 of 22

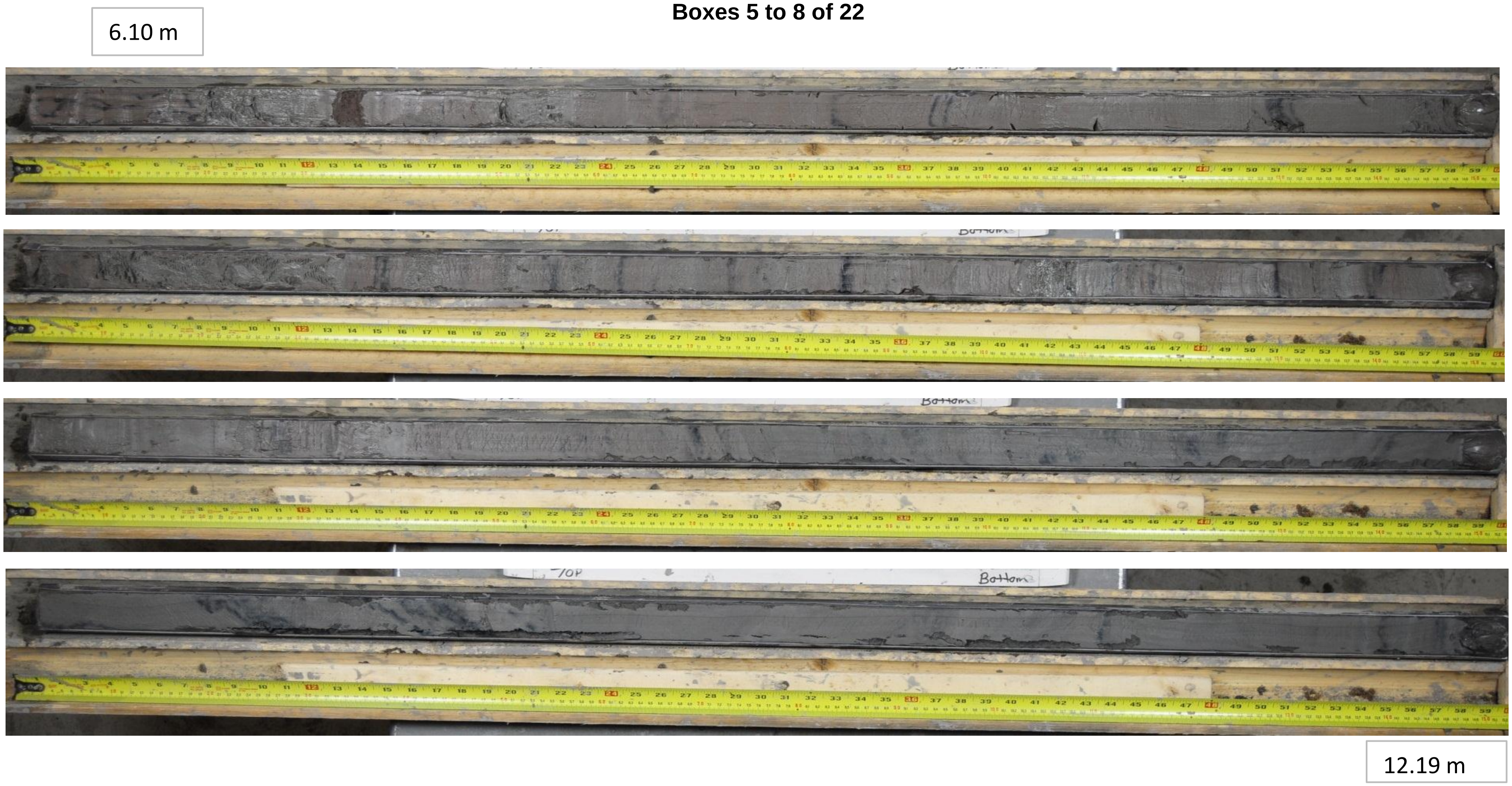

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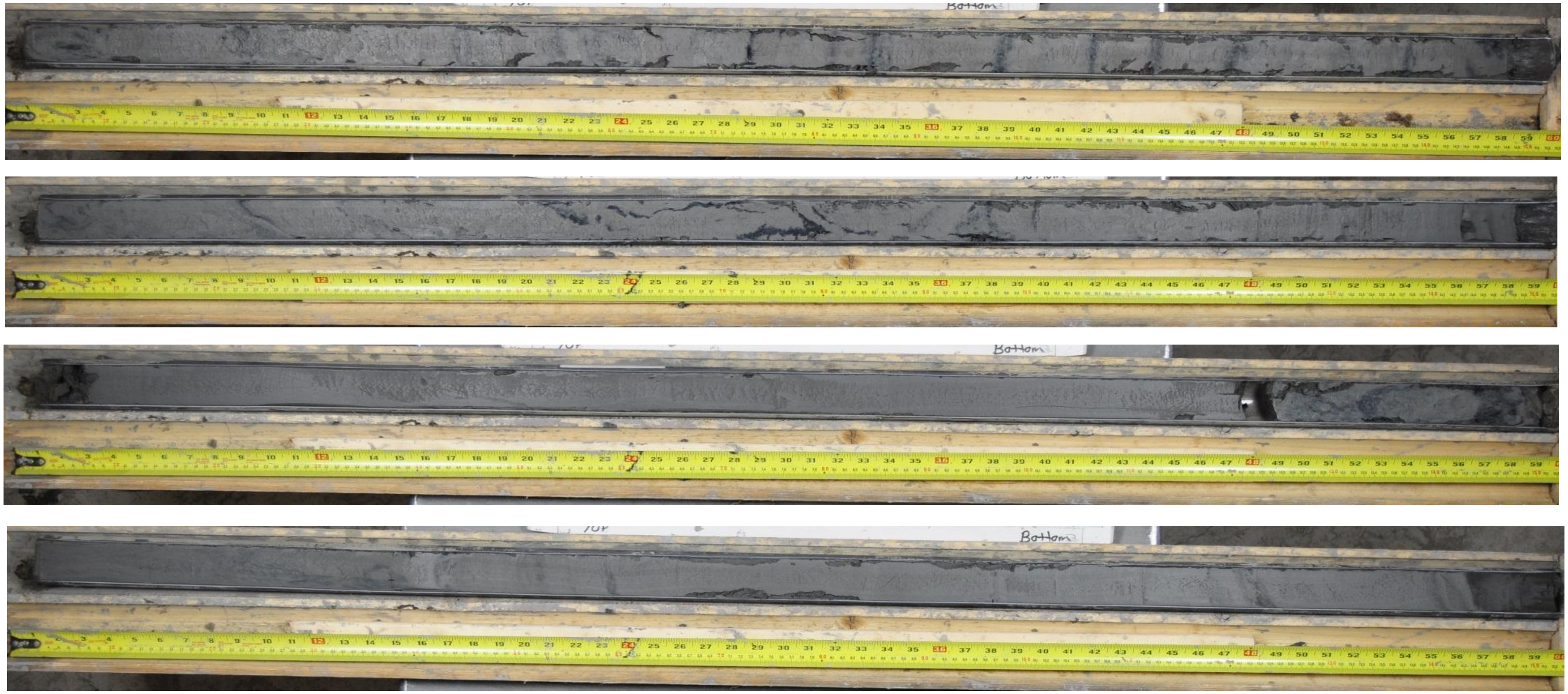
Figure I25

BH 13-6-7
Sampled Depth: 12.19 to 18.29 metres
Boxes 9 to 12 of 22

12.19 m



18.29 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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Date:	7/31/2013
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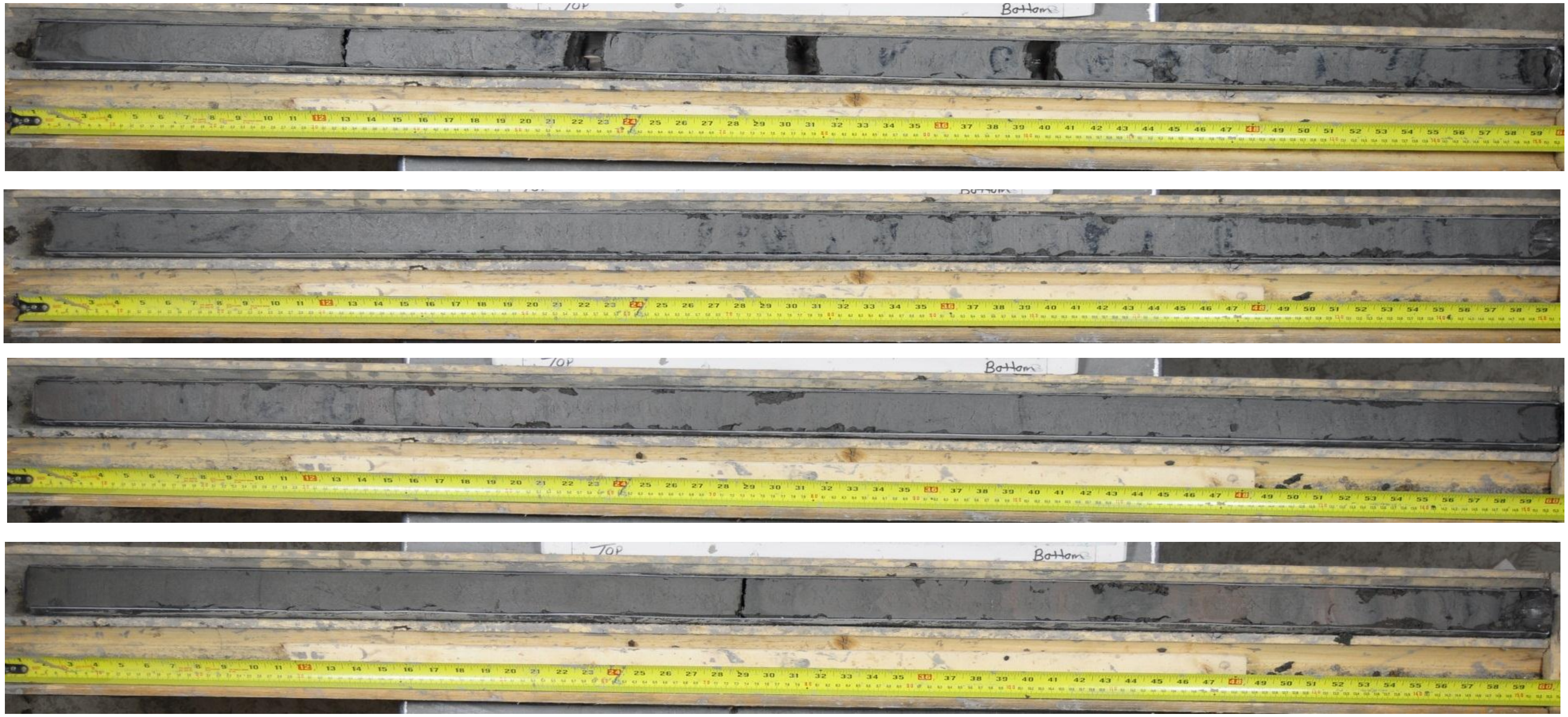
Figure I26

BH 13-6-7
Sampled Depth: 18.29 to 24.38 metres
Boxes 13 to 16 of 22

18.29 m



24.38 m

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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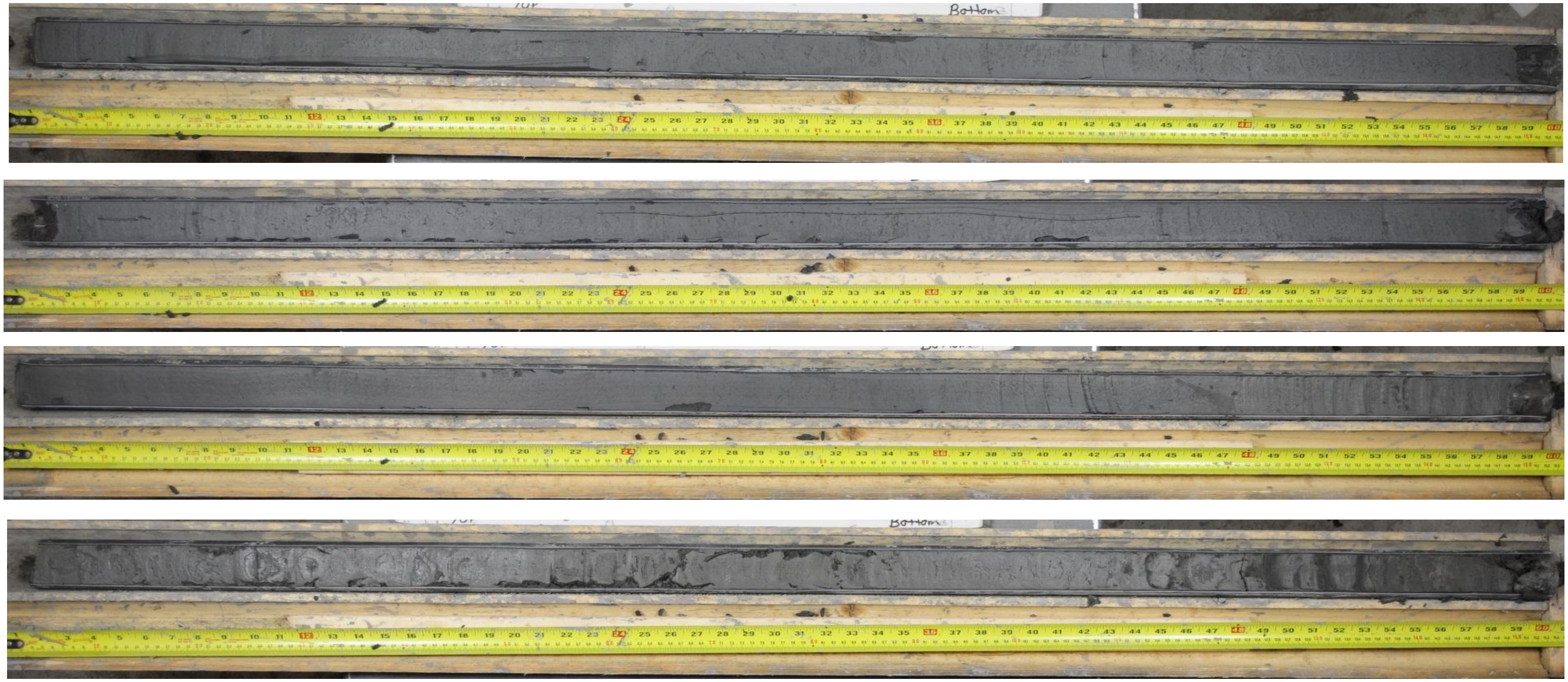
Figure I27

BH 13-6-7
Sampled Depth: 24.38 to 30.18 metres
Boxes 17 to 20 of 22

24.38 m



30.18 m

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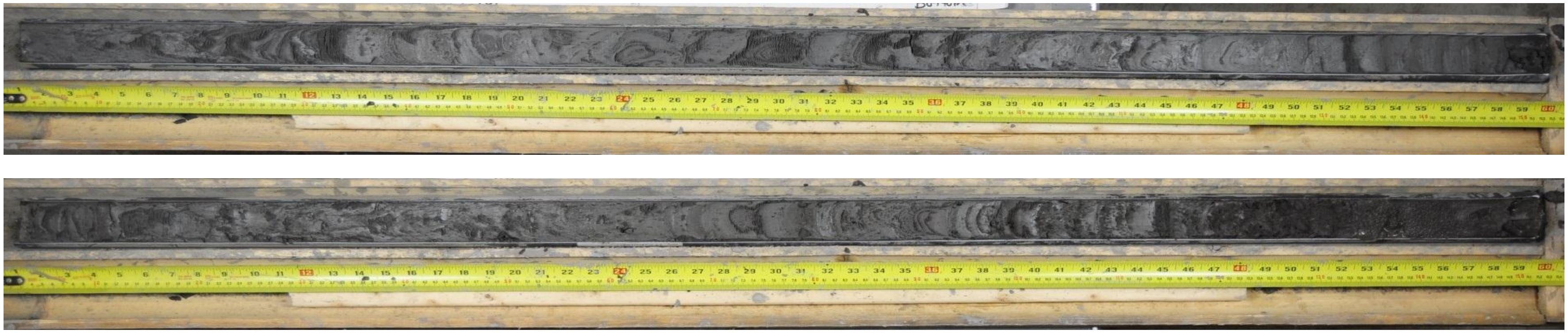
Figure I28

BH 13-6-7
Sampled Depth: 30.18 to 32.05 metres
Boxes 21 and 22 of 22

30.18 m



32.05 m End of Borehole

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Review:	MIC

Figure I29

BH 13-8-2
Sampled Depth: 0.00 to 1.52 metres
Box 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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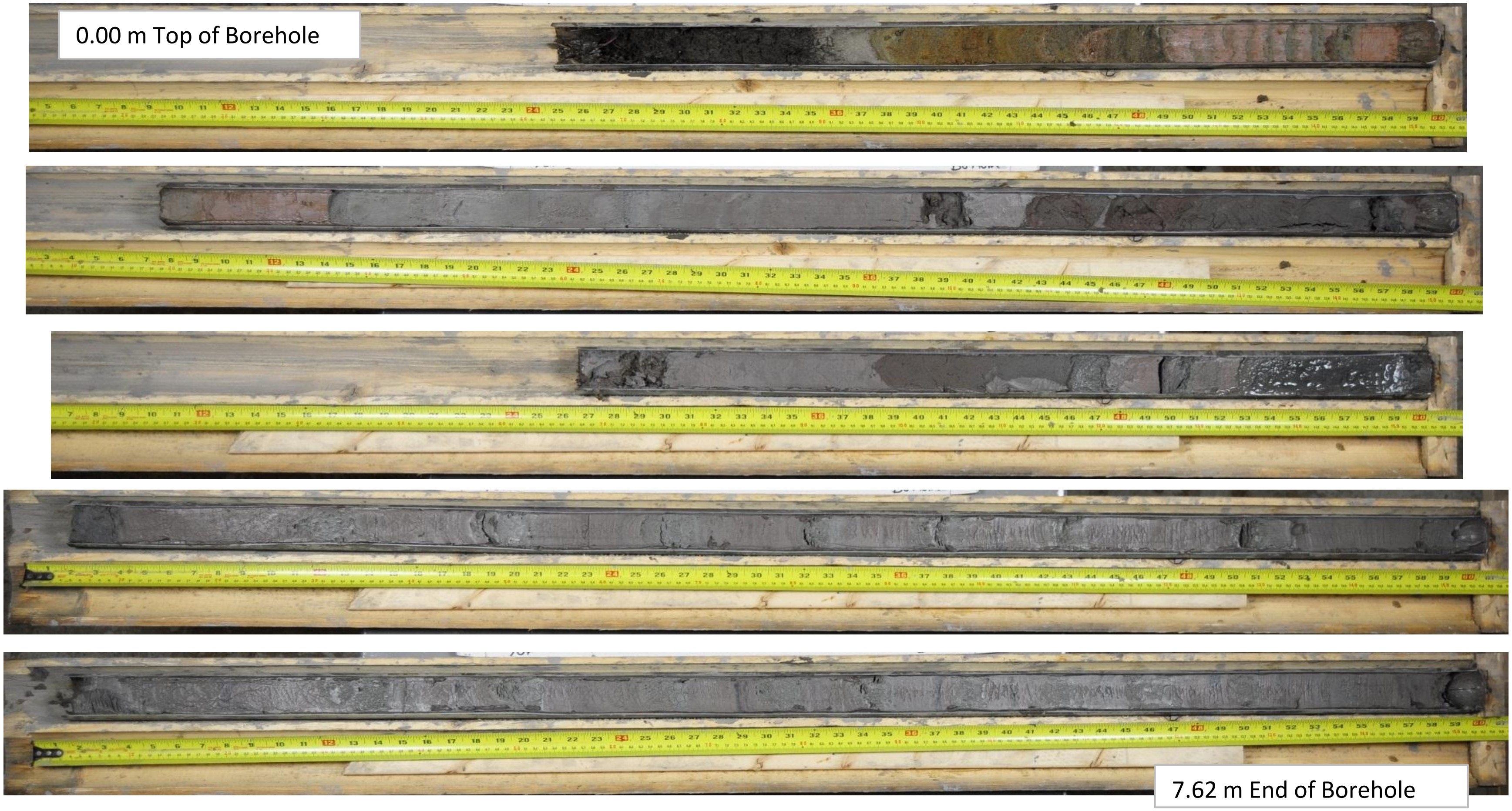
Review:	MIC

Figure I30

BH 13-8-3
Sampled Depth: 0.00 to 7.62 metres
Boxes 1 to 5 of 5



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Project No.	12-1125-0045
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Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I31

BH 13-9-2
Sampled Depth: 0.00 to 1.52 metres
Box 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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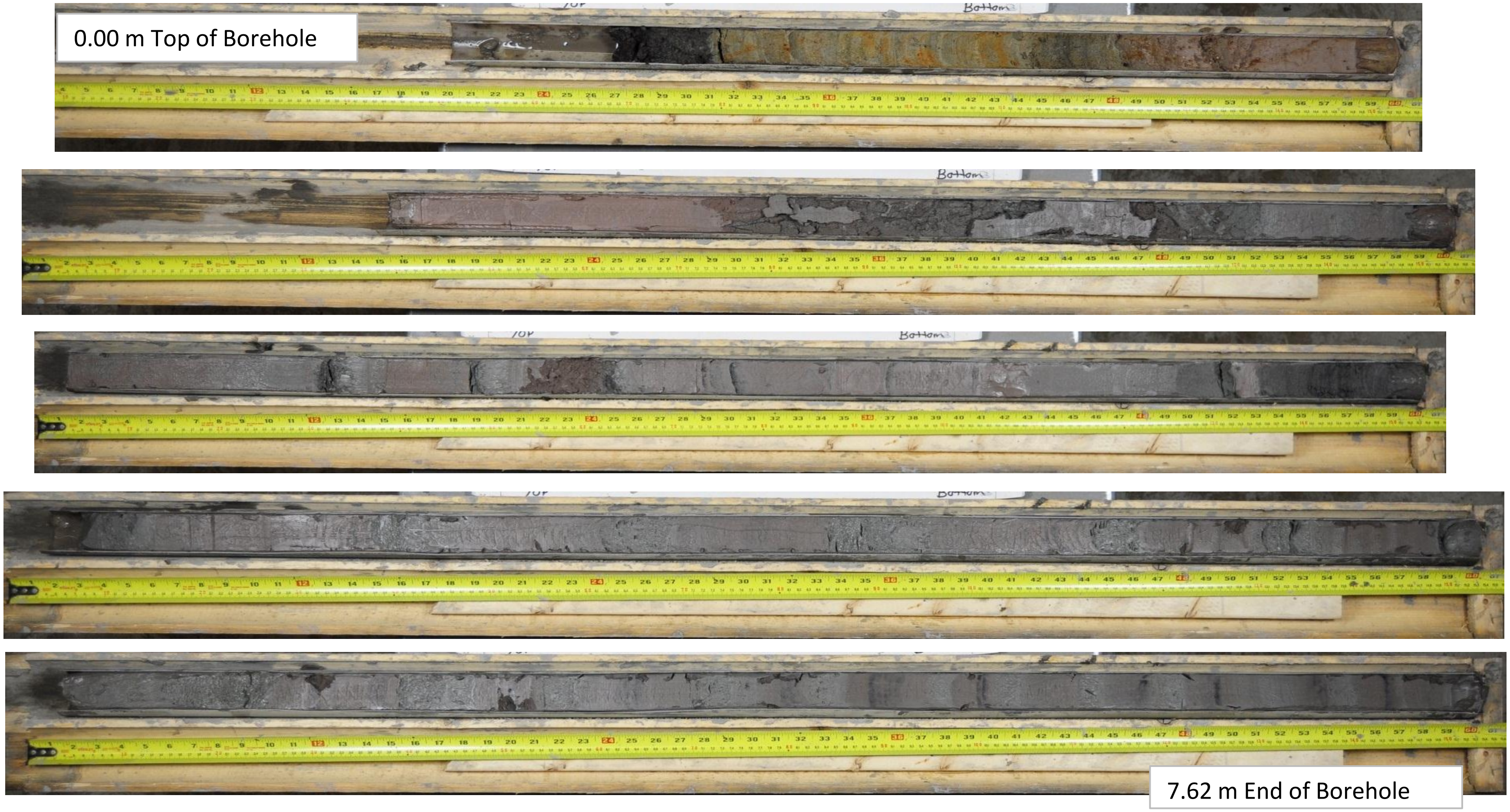
Figure I32

BH 13-9-3

Sampled Depth: 0.00 to 7.62 metres

Boxes 1 to 5 of 5



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Review:	MIC

Figure I33

BH 13-10-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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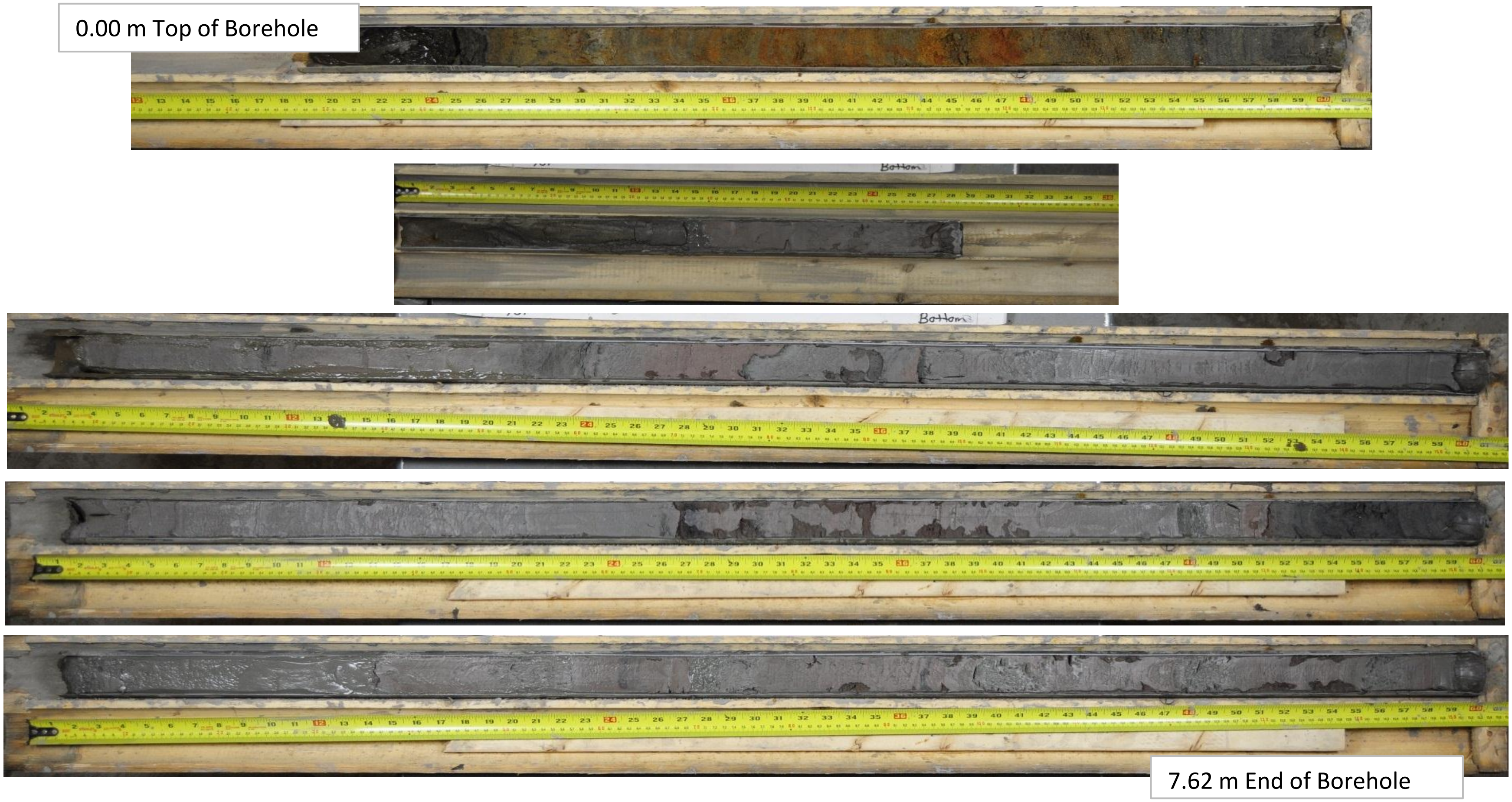
Figure I34

BH 13-10-3
Sampled Depth: 0.00 to 7.62 metres
Sample 1 to 5 of 5



0.00 m Top of Borehole

7.62 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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Review:	MIC

Figure I35

BH 13-11-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I36

BH 13-12-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

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Date:	7/31/2013
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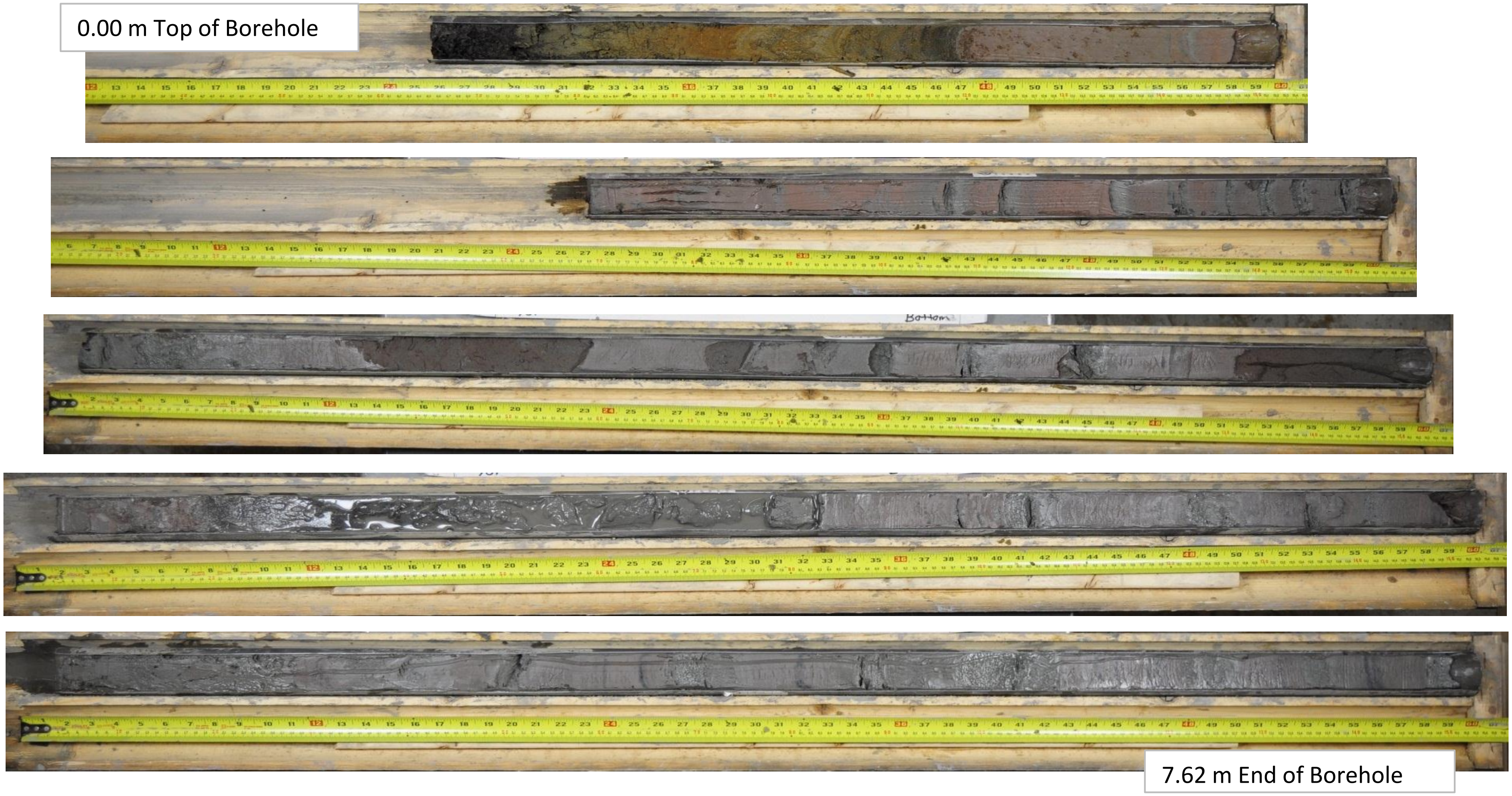
Figure I37

BH 13-12-3

Sampled Depth: 0.00 to 7.62 metres

Sample 1 to 5 of 5



0.00 m Top of Borehole

7.62 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I38

BH 13-13-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I39

BH 13-14-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I40

BH 13-15-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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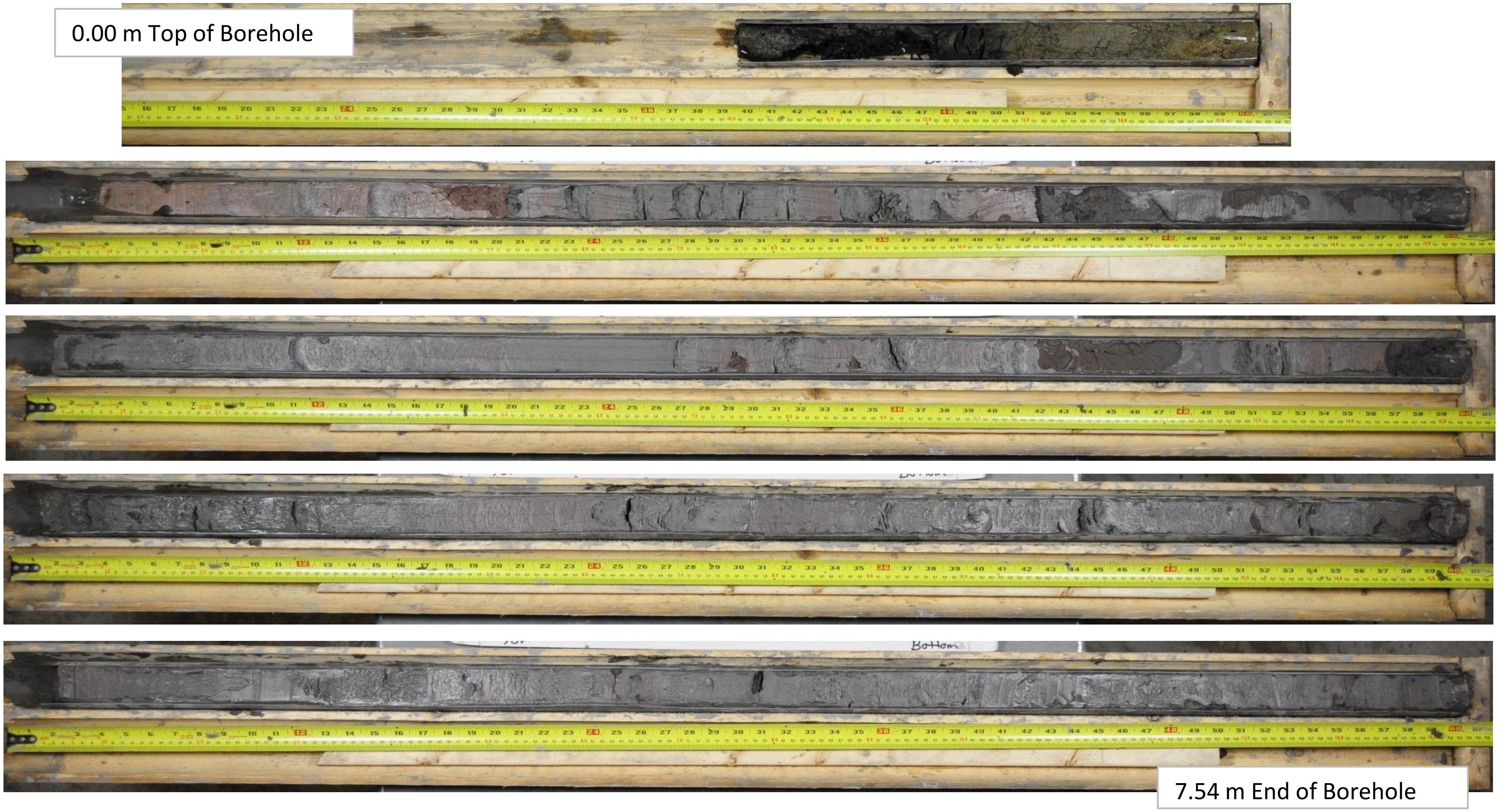
PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I41

BH 13-15-3
Sampled Depth: 0.00 to 7.54 metres
Sample 1 to 5 of 5



0.00 m Top of Borehole

7.54 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I42

BH 13-16-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I43

BH 13-17-2
Sampled Depth: 0.00 to 2.02 metres
Sample 1 and 2 of 2

0.00 m Top of Borehole

2.02 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

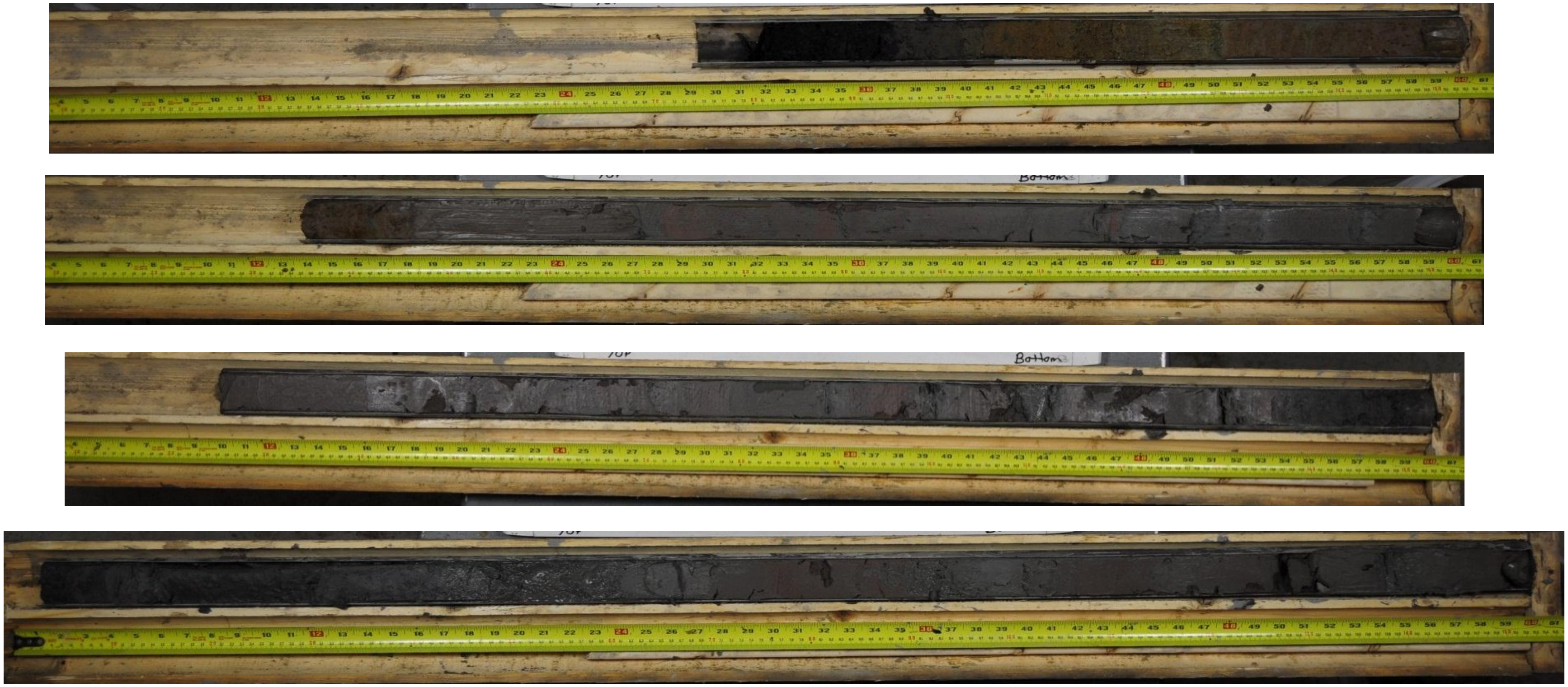
Figure I44

BH 13-17-3

Sampled Depth: 0.00 to 6.10 metres

Sample 1 to 4 of 6

0.00 m Top of Borehole



6.10 m

DIRECT PUSH SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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Date:	7/31/2013
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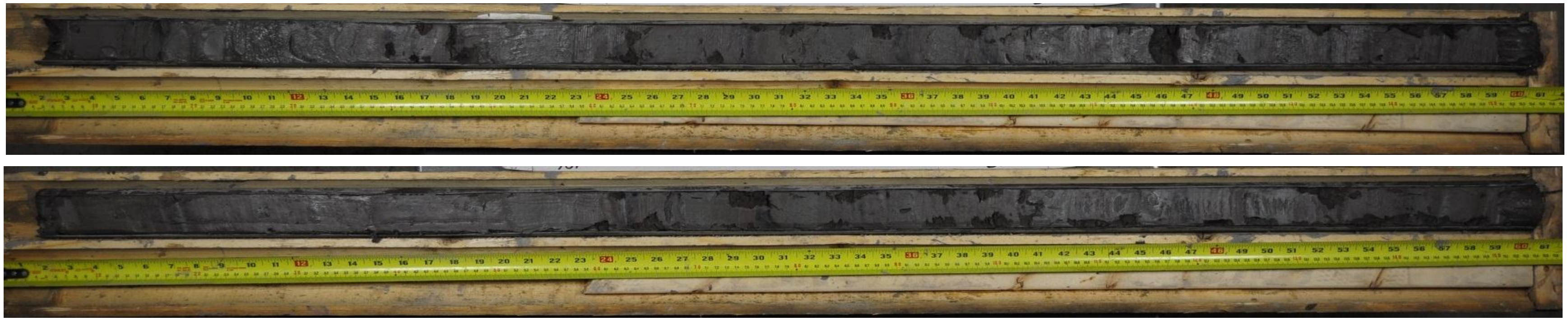
Review:	MIC

Figure I45

BH 13-17-3
Sampled Depth: 6.10 to 9.14 metres
Sample 5 and 6 of 6

6.10 m



9.14 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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Review:	MIC

Figure I46

BH 13-18-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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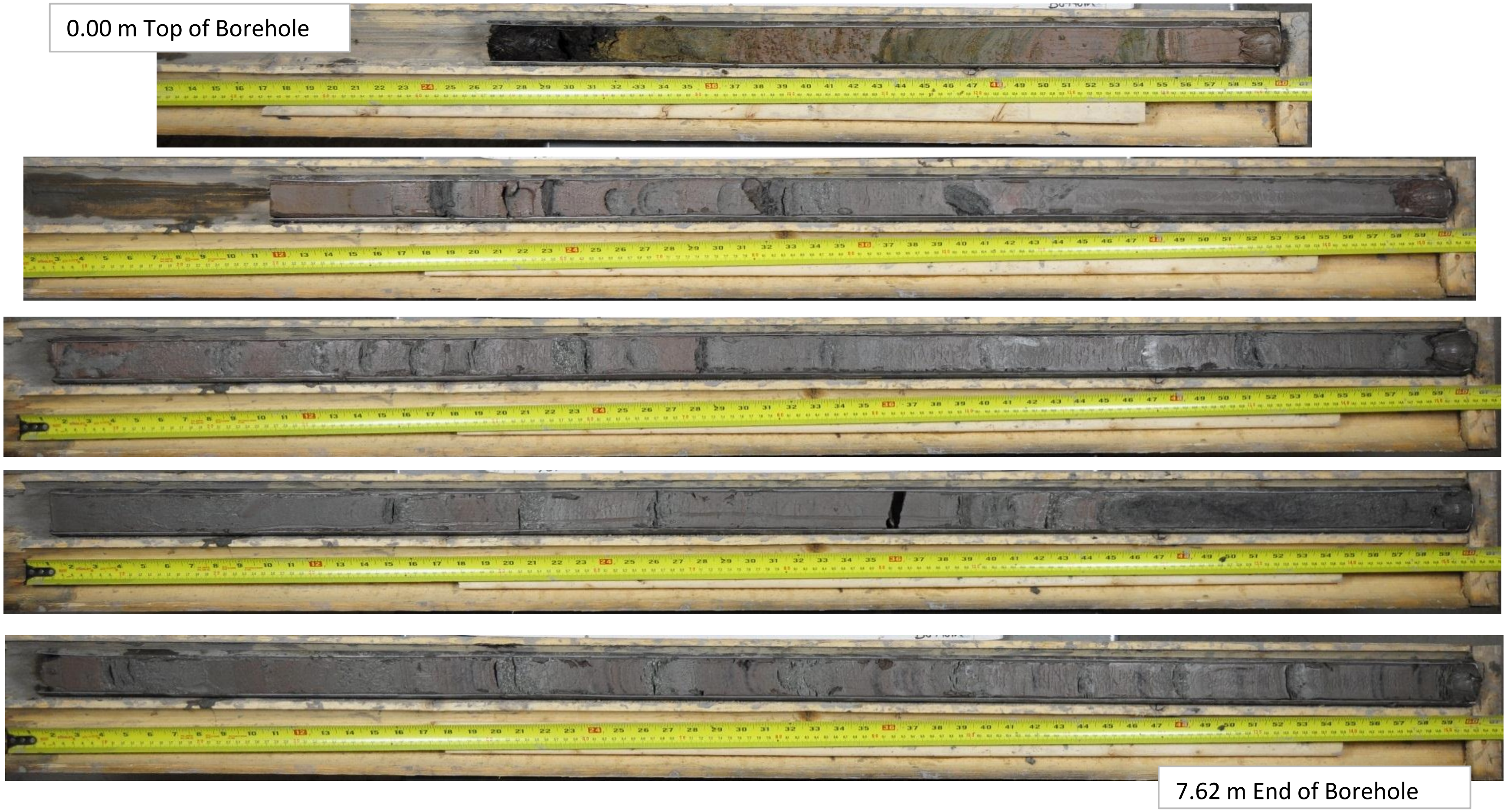
Review:	MIC

Figure I47

BH 13-18-3

Sampled Depth: 0.00 to 7.62 metres

Sample 1 to 5 of 5



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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I48

BH 13-19-2

Sampled Depth: 0.00 to 1.52 metres

Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I49

BH 13-20-2

Sampled Depth: 0.00 to 1.52 metres

Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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Review:	MIC

Figure I50

BH 13-21-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

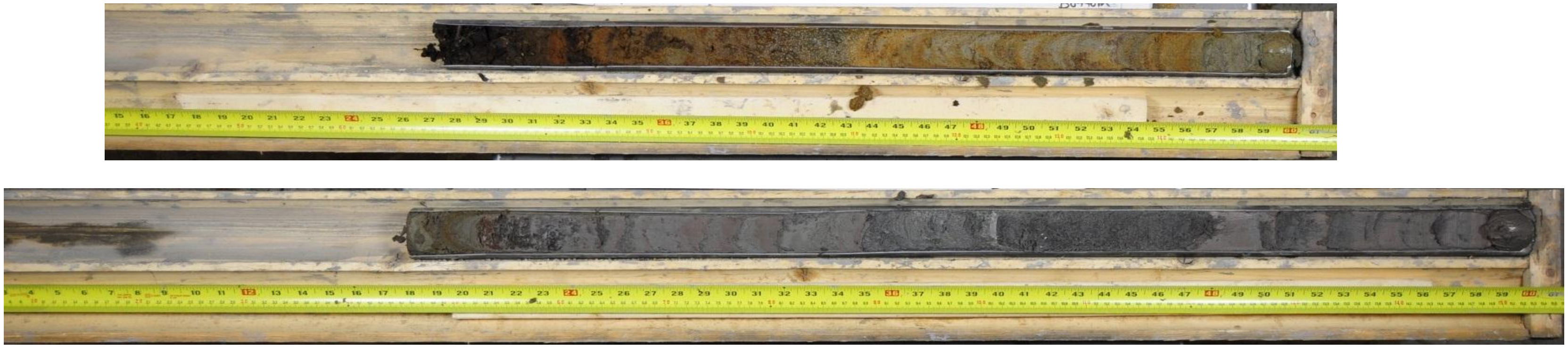
0.00 m Top of Borehole

1.52 m End of Borehole

Golder Associates	DIRECT PUSH SAMPLE PHOTOGRAPHS PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE	Project No.	12-1125-0045	Figure I51
		Drawn:	WAM	
		Date:	7/31/2013	
		Checked:	KE	
		Review:	MIC	

BH 13-21-3
Sampled Depth: 0.00 to 3.05 metres
Sample 1 and 2 of 2

0.00 m Top of Borehole



3.05 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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Review:	MIC

Figure I52

BH 13-22-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

DIRECT PUSH SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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Review:	MIC

Figure I53

BH 13-23-2

Sampled Depth: 0.00 to 1.52 metres

Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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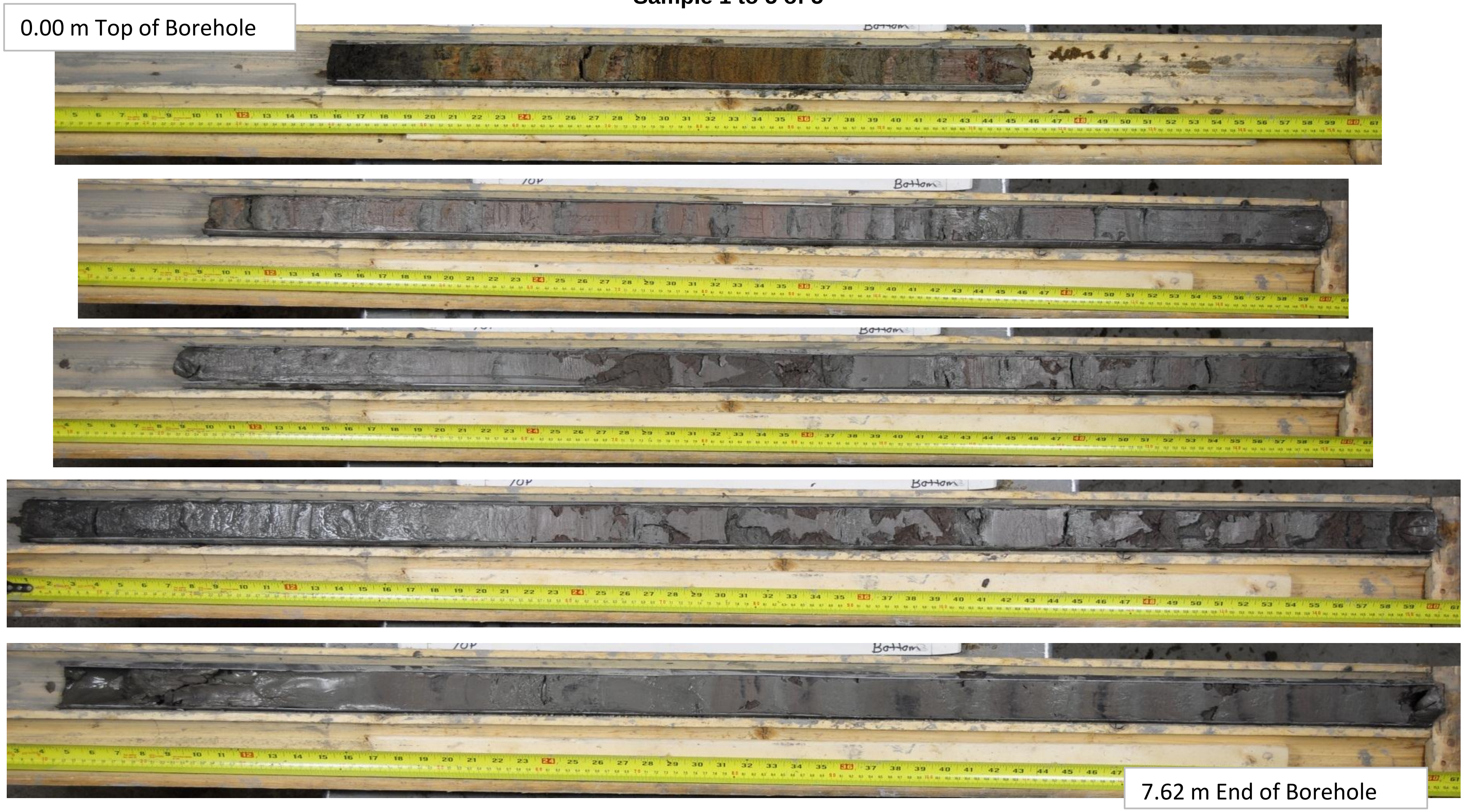
PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
Checked:	KE
Review:	MIC

Figure I54

BH 13-23-3
Sampled Depth: 0.00 to 7.62 metres
Sample 1 to 5 of 5



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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	7/31/2013
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Review:	MIC

Figure I55

BH 13-24-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
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Review:	MIC

Figure I56

BH 13-25-2
Sampled Depth: 0.00 to 1.52 metres
Sample 1 of 1

0.00 m Top of Borehole

1.52 m End of Borehole

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PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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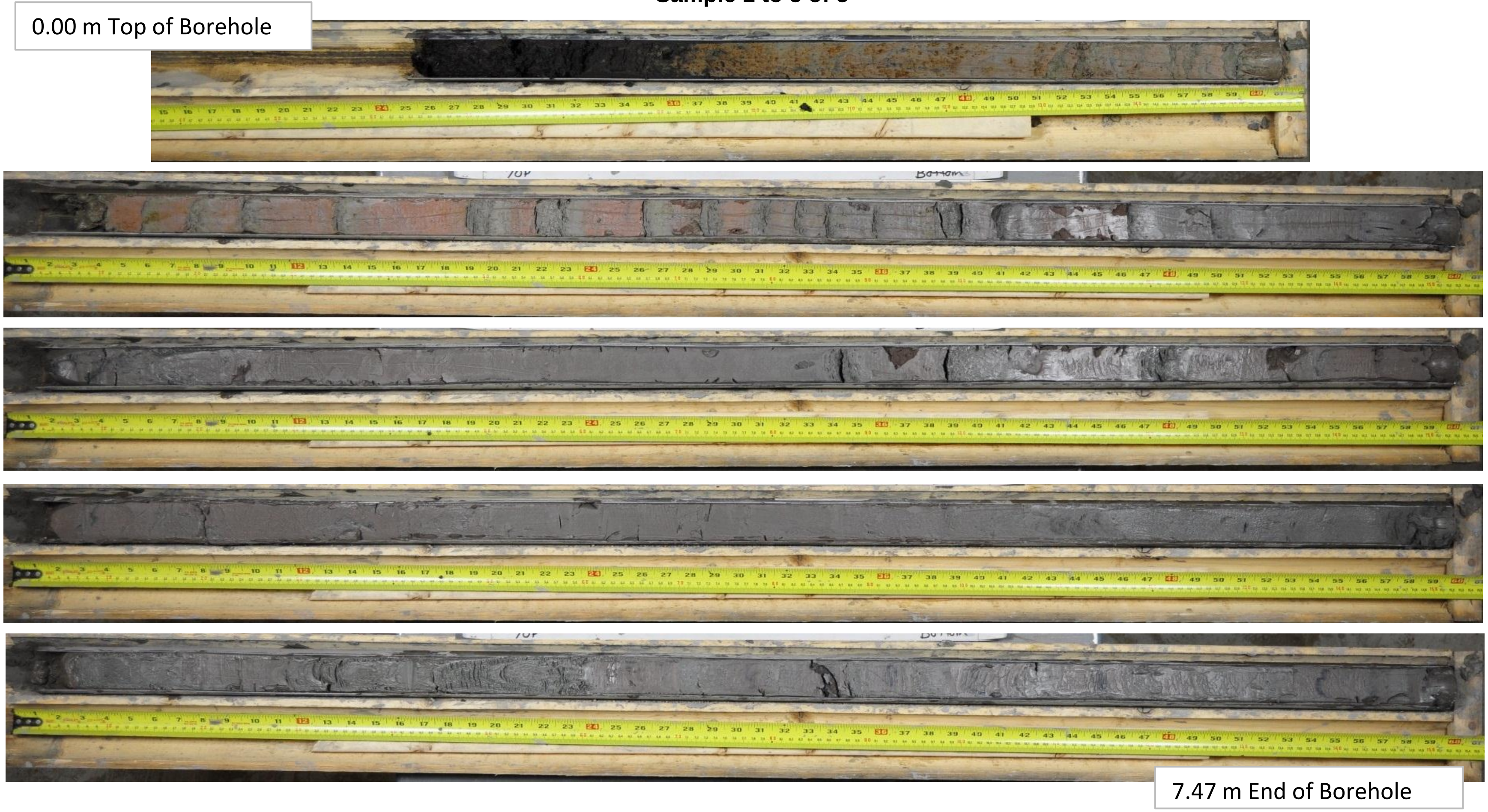
Checked:	KE
Review:	MIC

Figure I57

BH 13-25-3
Sampled Depth: 0.00 to 7.47 metres
Sample 1 to 5 of 5


0.00 m Top of Borehole

7.47 m End of Borehole

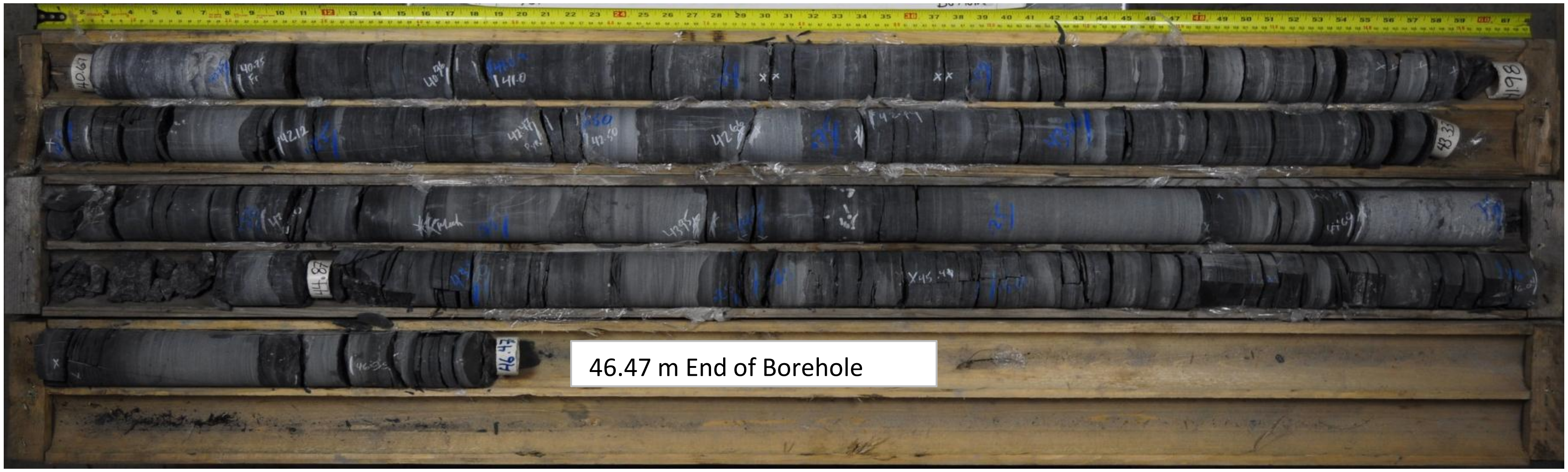
Golder Associates	DIRECT PUSH SAMPLE PHOTOGRAPHS PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE	Project No.	12-1125-0045	Figure I58
		Drawn:	WAM	
		Date:	7/31/2013	
		Checked:	KE	
		Review:	MIC	

APPENDIX J

Photographs of Bedrock Core Samples

BH 12-1-3
Cored Depth: 40.61 to 46.47 metres
Core Boxes 1 to 3 of 3

40.61 m Top of Bedrock



46.47 m End of Borehole

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BEDROCK CORE SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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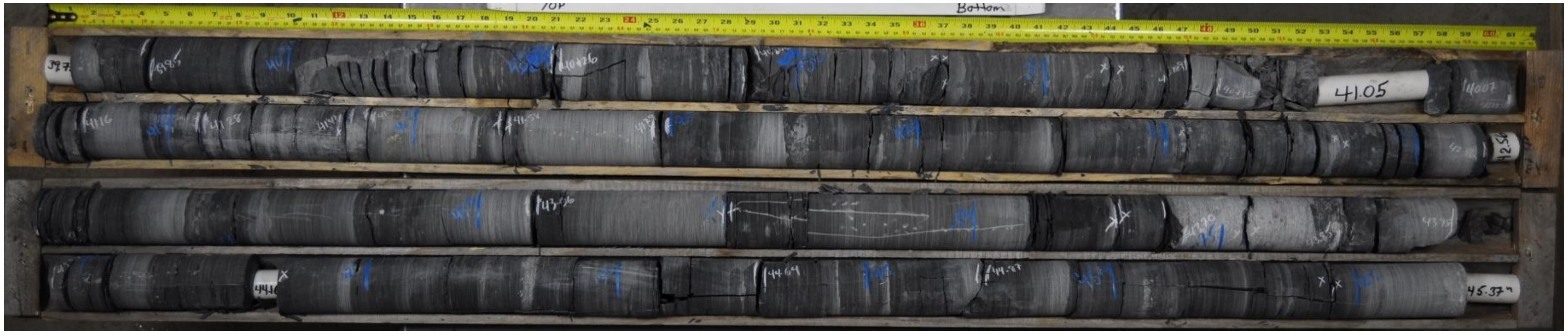
Review:	MIC

Figure J1

BH 12-1-3-1
Cored Depth: 39.78 to 45.37 metres
Core Boxes 1 and 2 of 2

39.78 m Top of Bedrock



45.37 m End of Borehole

BEDROCK CORE SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2013
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Review:	MIC

Figure J2

BH 12-2-3
Cored Depth: 36.74 to 41.95 metres
Core Boxes 1 and 2 of 2

36.74 m Top of Bedrock

41.95 m End of Borehole

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BEDROCK CORE SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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Date:	8/28/2013
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Review:	MIC

Figure J3

BH 12-3-3
Cored Depth: 39.84 to 45.42 metres
Core Boxes 1 and 2 of 2

39.84 m Top of Bedrock

45.42 m End of Borehole

BEDROCK CORE SAMPLE PHOTOGRAPHS

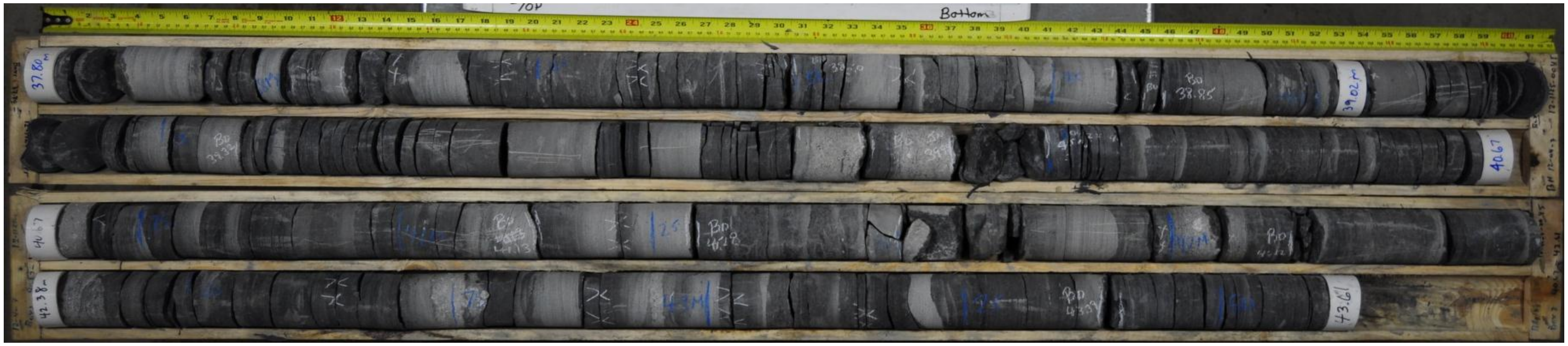
PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2013
Checked:	KE
Review:	MIC

Figure J4

BH 12-4-3
Cored Depth: 37.80 to 43.61 metres
Core Boxes 1 and 2 of 2

37.80 m Top of Bedrock



43.61 m End of Borehole

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BEDROCK CORE SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
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Date:	8/28/2013
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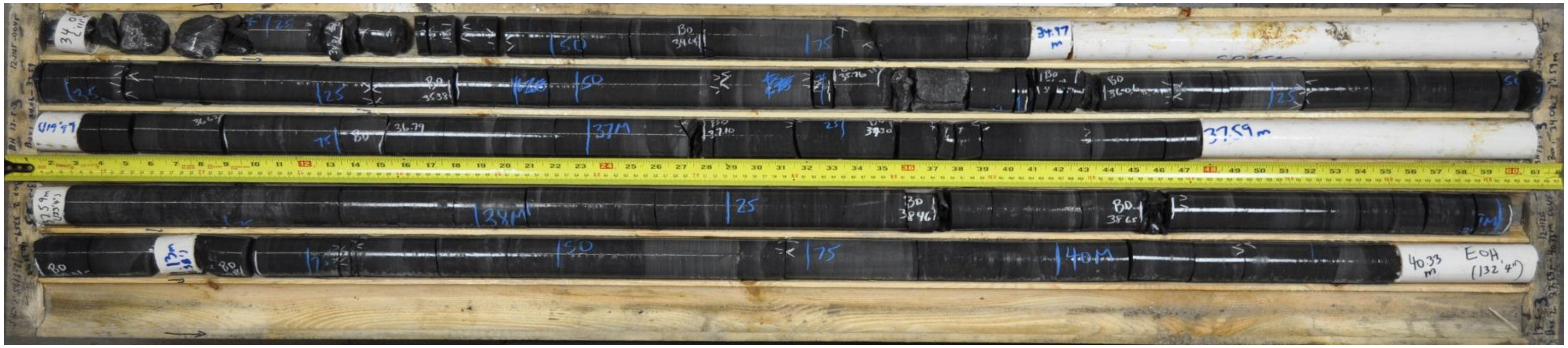
Review:	MIC

Figure J5

BH 13-5-3
Cored Depth: 34.06 to 40.33 metres
Core Boxes 1 and 2 of 2

34.06 m Cobbles

34.23 m Top of Bedrock



40.33 m End of Borehole

BEDROCK CORE SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

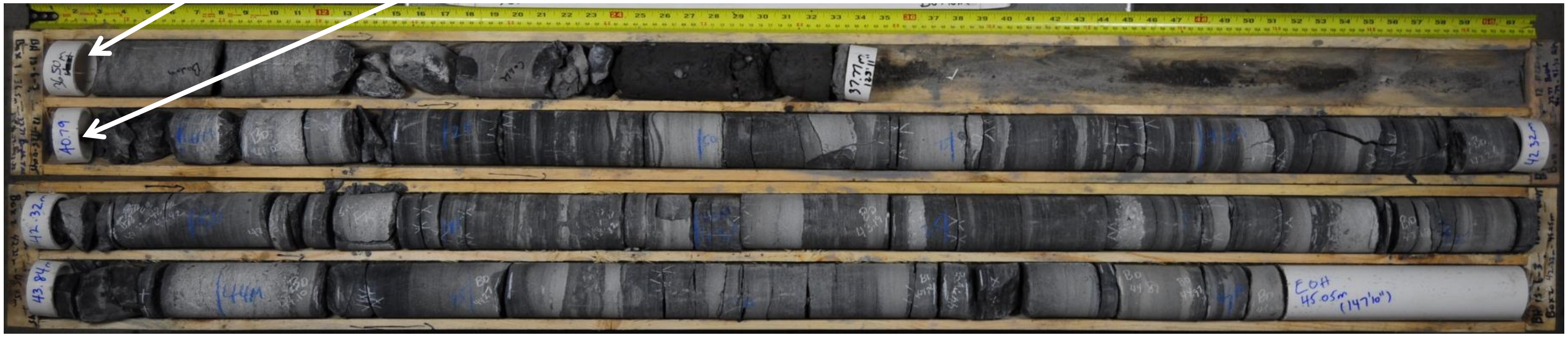
Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2013
Checked:	KE
Review:	MIC

Figure J6

BH 13-6-3
Cored Depth: 36.50 to 45.05 metres
Core Boxes 1 and 2 of 2

36.50 m Glacial Till

40.79 m Top of Bedrock



45.05 m End of Borehole

BEDROCK CORE SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2013
Checked:	KE
Review:	MIC

Figure J7

BH 13-7-2

Cored Depth: 33.37 to 39.47 metres

Core Boxes 1 and 2 of 2

33.37 m Top of Bedrock

39.47 m End of Borehole

BEDROCK CORE SAMPLE PHOTOGRAPHS

PROPOSED CAPITAL REGION RESOURCE RECOVERY CENTRE

Project No.	12-1125-0045
Drawn:	WAM
Date:	8/28/2013
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Review:	MIC

Figure J8

APPENDIX K

Technical Memorandum – Results of VSP Testing

Golder Associates

TECHNICAL MEMORANDUM

DATE March 2013 **PROJECT No.** 12-1125-0045

VSP TEST RESULTS – CRRRC SITE, OTTAWA, ONTARIO

This memorandum presents the results of the vertical seismic profile (VSP) testing performed at the Capital Region Resource Recovery Centre (CRRRC) Site (Site) located in the eastern portion of the City of Ottawa. VSP testing was completed in BH-12-2-3 and BH-12-3-3 on February 20 and 21, 2013. Both boreholes were cased with a PVC pipe grouted in place, which extended above ground surface. Borehole BH-12-2-3 consists of about 36.7 metres of overburden overlying limestone bedrock. The overburden consists of approximately 34.6 metres of clay to silty clay overlying about 2.2 metres of sand and silt. Borehole BH-12-3-3 consists of approximately 39.8 metres of overburden overlying shale bedrock. The overburden consists of about 34.1 metres of clay to silty clay overlying about 5.7 metres of sand to sandy silt.

Methodology

For the VSP method, seismic energy is generated at the ground surface by an active seismic source and recorded by a geophone located in a nearby borehole at a known depth (Figure 1). The methodology can be applied using an active seismic source that produces either compression or shear waves. The time required for the energy to travel from the source to the receiver (geophone) provides a measurement of the average compression or shear wave seismic velocity of the medium between the source and the receiver. Data obtained from different geophone depths are used to calculate a detailed vertical seismic velocity profile of the subsurface in the immediate vicinity of the test borehole.

The high resolution results of a VSP survey are often used for earthquake engineering site classification, as per the National Building Code of Canada, 2010.

Field Work

The field work was completed on February 20th and 21st, 2013, by personnel from the Golder Ottawa offices.

Both compression and shear wave seismic sources were measured using a source located in close vicinity to the borehole. The seismic source for the compression wave test consisted of a 9.9 kilogram sledge hammer vertically impacted on a metal plate, located 2 metres from the borehole. The seismic source for the shear wave test consisted of a 3.0 metres long, 150 millimetres by 150 millimetres wooden beam, weighted down by a vehicle and horizontally struck with a 9.9 kilogram sledge hammer on alternate ends of the beam to induce polarized shear waves. The shear sources were located 2 metres from the borehole. Test measurements started at ground surface and were recorded in the borehole with a 3-component receiver spaced at 1-metre intervals below the ground surface, to a maximum depth of the borehole (40.2 metres in borehole BH-12-2-3 and 44.3 metres in borehole BH-12-3-3).

The seismic records collected for each source location were stacked a minimum of ten times to minimize the effects of ambient background seismic noise on the collected data. The data was sampled at 0.020833 millisecond intervals and a total time window of 0.341 seconds was collected for each seismic shot.

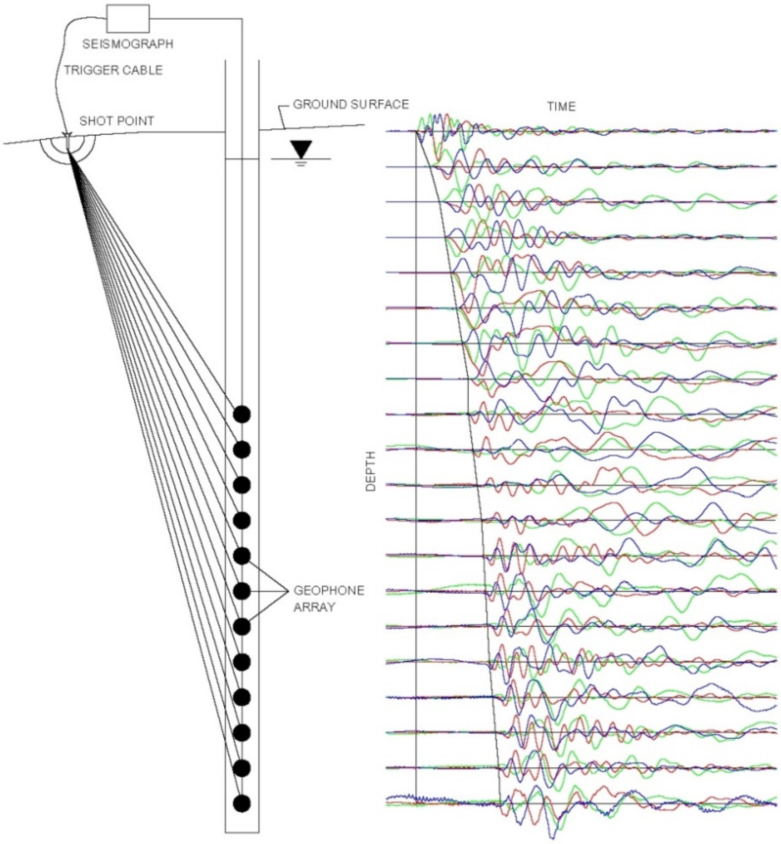

Figure 1: Example of Layout and resulting time traces from a VSP survey

Data Processing

Processing of the VSP test results consisted of the following main steps:

1) Combination of seismic records to present seismic traces for all depth intervals on a single plot for each seismic source and for each component;

2) Low Pass Filtering of data to remove spurious high frequency noise;

3) First break picking of the compression and shear wave arrivals; and,

4) Calculation of the average compression and shear wave velocity to each tested depth interval.

Processing of the VSP data was completed using the SeisImager/SW software package (Geometrics Inc.). The seismic records are presented on the following four plots and show the first break picks of the compression wave and shear wave arrivals for both boreholes overlaid on the seismic waveform traces recorded at the different geophone depths (Figures 2 to 5). The arrivals were picked on the vertical component for the compression source and on the two horizontal components for the shear source.

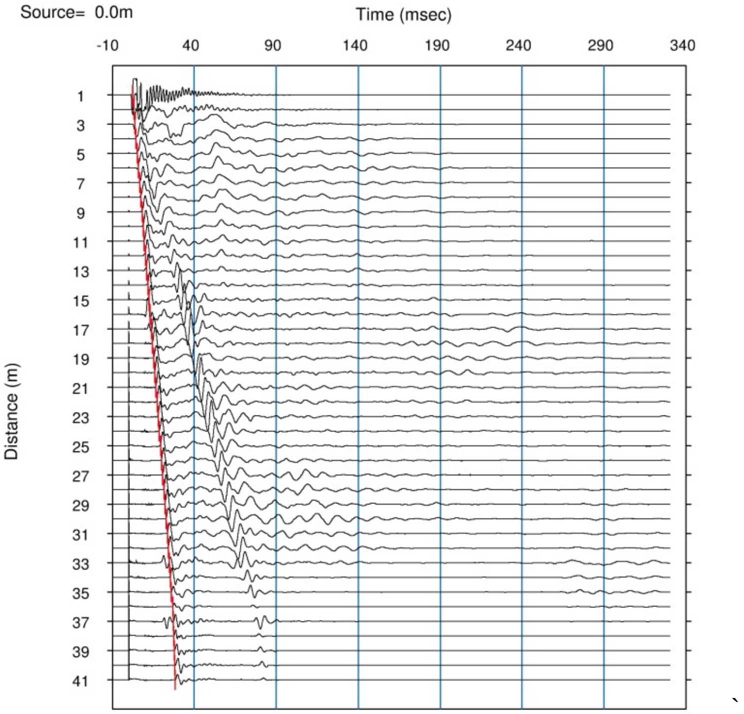

Figure 2: BH-12-2-3, first break picking of compression wave arrivals (red) along the seismic traces recorded at each receiver depth

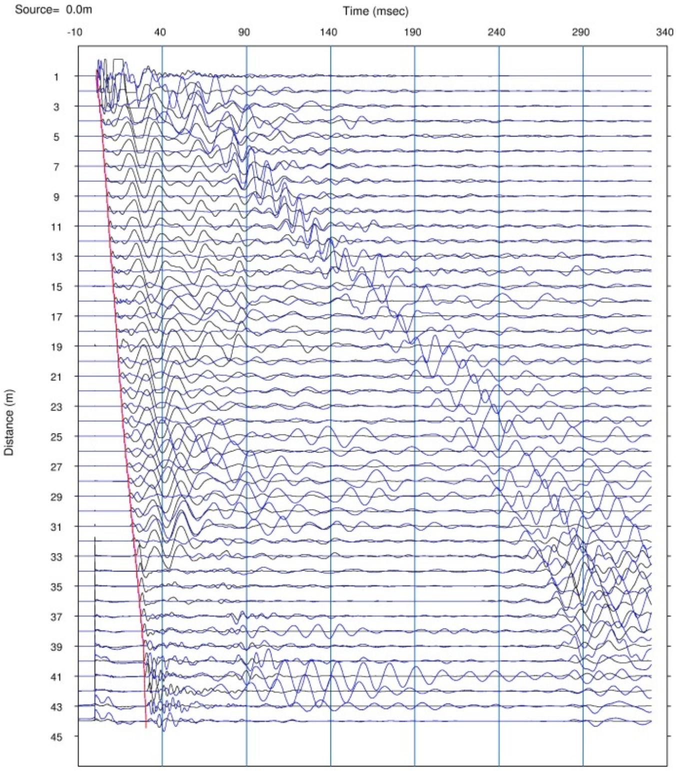

Figure 3: BH-12-3-3, first break picking of compression wave arrivals (red) along the seismic traces recorded at each receiver depth

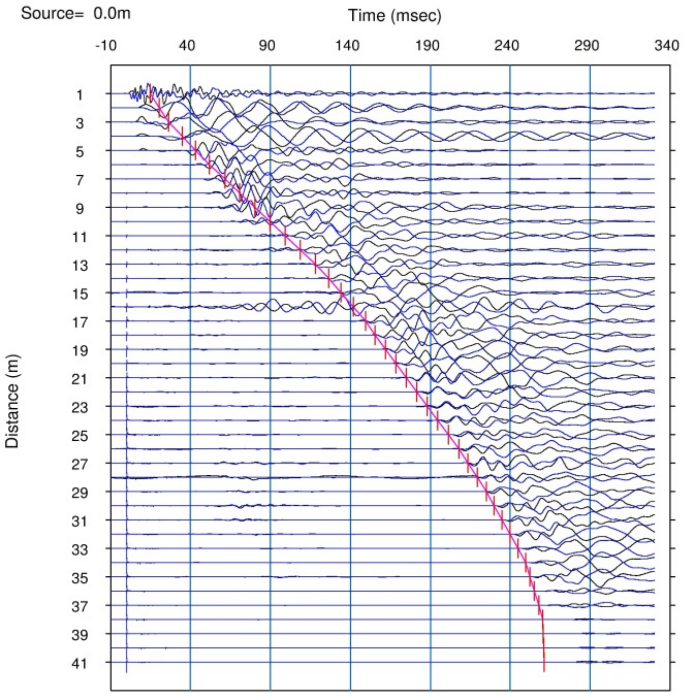

Figure 4: BH-12-2-3, first break picking of shear wave arrivals (red) along the seismic traces recorded at each receiver depth

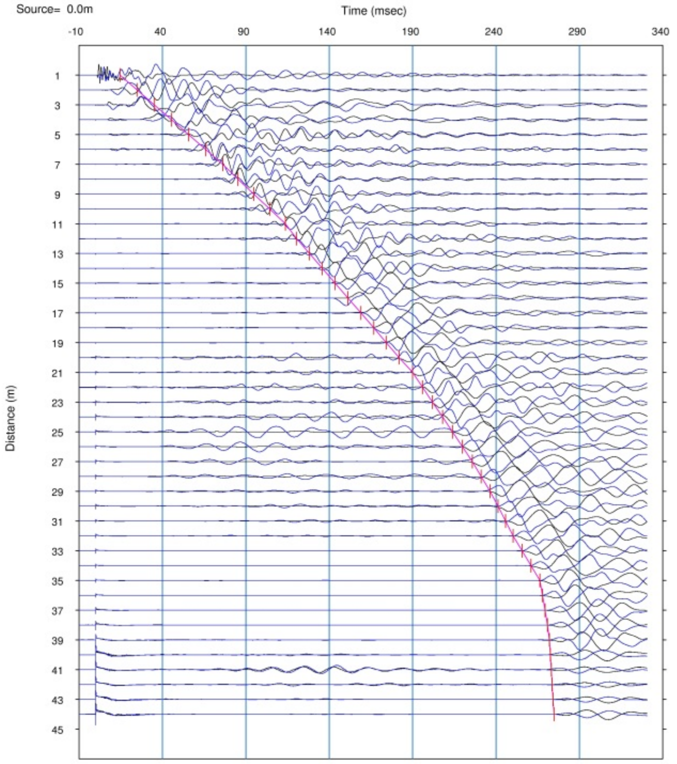

Figure 5: BH-12-3-3, first break picking of shear wave arrivals (red) along the seismic traces recorded at each receiver depth

Results

The VSP results are summarized in Table 1 for BH-12-2-3 and Table 2 for BH-12-3-3. The shear wave and compression wave layer velocities, at the field collected one-metre intervals, were calculated by best fitting a theoretical travel time model to the field data collected at either half or one metre intervals. The depths presented on the tables are relative to ground surface.

The estimated dynamic engineering moduli, based on the calculated wave velocities, are also presented on Table 1 and 2. The engineering moduli were calculated using an estimated bulk density, based on the borehole log, but a more detailed geotechnical investigation would be necessary to determine a more exact density for each layer. For the topsoil down to a depth of approximately 36 metres in BH-12-2-3 and 38 metres in BH-12-3-3, a bulk density of 1,750 kg/m^3 was estimated. Further down, to a depth of the bottom of the hole, the bulk density for the bedrock was estimated at 2,300 kg/m^3.

The first layer of both boreholes is likely frozen, which is why a relatively high velocity is measured for both the compressional and shear wave velocity.

The average shear wave velocity from ground surface to a depth of 30 metres was measured to be 117 m/s for BH-12-2-3 and 112 m/s for BH-12-3-3.

Closure

We trust that these results meet your current needs. If you have any questions or require clarification, please contact the undersigned at your convenience.

Yours truly,

GOLDER ASSOCIATES LTD.

Stephane Sol, Ph.D. Geophysics Group	Brian Byerley, M. Sc., P. Eng. Senior Hydrogeologist, Principal

SS/PF/BTB/sg
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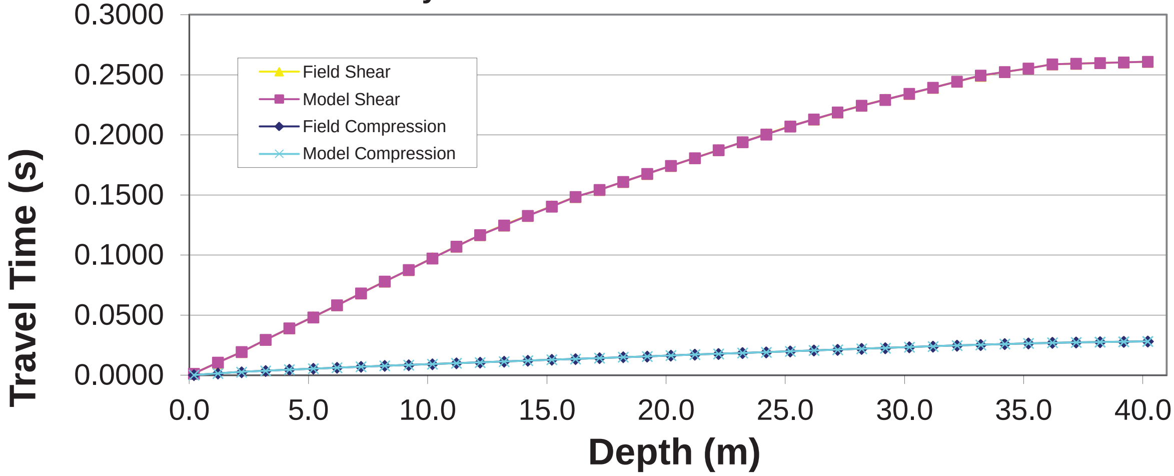
Attachments: Tables 1 and 2

TABLE 1
SHEAR WAVE VELOCITY PROFILE AT BH 12-2-3

Layer Depth (m)				Estimated Bulk Density (kg/m^3)	Dynamic Engineering Properties			
Top	Bottom	Compressional Wave (m/s)	Shear Wave (m/s)		Poissons Ratio	Shear Modulus (MPa)	Deformation Modulus (MPa)	Bulk Modulus (MPa)
0.0	0.2	872	138	1750	0.49	33	99	1286
0.0	1.2	747	110	1750	0.49	21	63	948
1.2	2.2	820	113	1750	0.49	22	67	1147
2.2	3.2	985	99	1750	0.49	17	51	1675
3.2	4.2	1115	104	1750	0.50	19	57	2150
4.2	5.2	1210	108	1750	0.50	20	61	2535
5.2	6.2	1260	99	1750	0.50	17	51	2755
6.2	7.2	1230	102	1750	0.50	18	54	2623
7.2	8.2	1345	102	1750	0.50	18	55	3142
8.2	9.2	1350	104	1750	0.50	19	57	3164
9.2	10.2	1370	103	1750	0.50	19	56	3260
10.2	11.2	1380	103	1750	0.50	19	56	3308
11.2	12.2	1390	105	1750	0.50	19	58	3355
12.2	13.2	1390	122	1750	0.50	26	78	3346
13.2	14.2	1390	125	1750	0.50	27	82	3345
14.2	15.2	1400	130	1750	0.50	30	88	3391
15.2	16.2	1400	128	1750	0.50	29	86	3392
16.2	17.2	1400	165	1750	0.49	48	142	3366
17.2	18.2	1400	150	1750	0.49	39	118	3378
18.2	19.2	1420	152	1750	0.49	40	121	3475
19.2	20.2	1410	152	1750	0.49	40	121	3425
20.2	21.2	1405	152	1750	0.49	40	121	3401
21.2	22.2	1400	152	1750	0.49	40	121	3376
22.2	23.2	1410	152	1750	0.49	40	121	3425
23.2	24.2	1490	152	1750	0.49	40	121	3831
24.2	25.2	1450	150	1750	0.49	39	118	3627
25.2	26.2	1450	170	1750	0.49	51	151	3612
26.2	27.2	1430	175	1750	0.49	54	160	3507
27.2	28.2	1350	180	1750	0.49	57	169	3114
28.2	29.2	1520	200	1750	0.49	70	209	3950
29.2	30.2	1520	200	1750	0.49	70	209	3950
30.2	31.2	1520	200	1750	0.49	70	209	3950
31.2	32.2	1520	200	1750	0.49	70	209	3950
32.2	33.2	1520	200	1750	0.49	70	209	3950
33.2	34.2	1520	340	1750	0.47	202	596	3773
34.2	35.2	1520	320	1750	0.48	179	529	3804
35.2	36.2	1900	300	1750	0.49	158	468	6108
36.2	37.2	3700	1900	2300	0.32	8303	21935	20416
37.2	38.2	3700	1900	2300	0.32	8303	21935	20416
38.2	39.2	3700	1900	2300	0.32	8303	21935	20416
39.2	40.2	3700	1900	2300	0.32	8303	21935	20416

Wave Velocity - Field Collected vs. Modelled Data

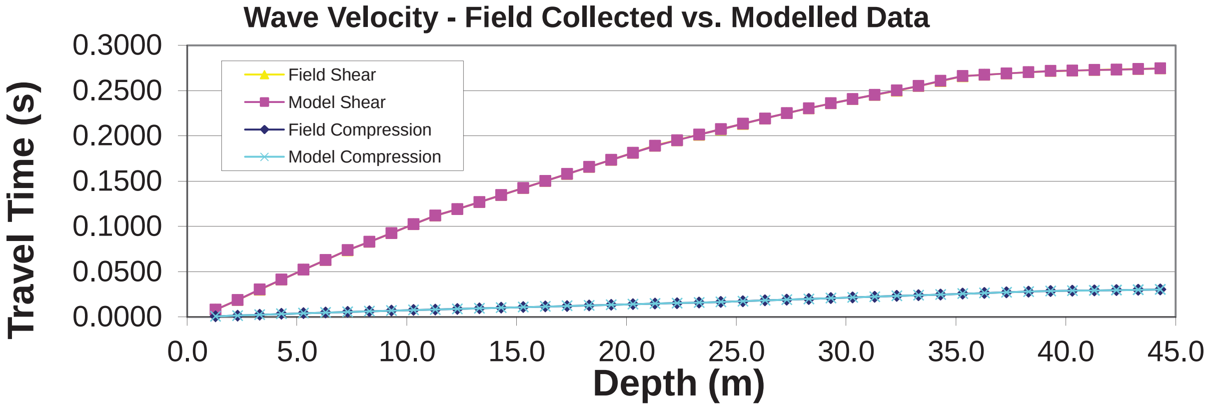


Notes

1. Depth Presented relative to ground surface.
2. This Table to be analyzed in conjunction with the accompanying report.

TABLE 2
SHEAR WAVE VELOCITY PROFILE AT BH 12-3-3

Layer Depth (m)				Estimated Bulk Density (kg/m^3)	Dynamic Engineering Properties			
Top	Bottom	Compressional Wave (m/s)	Shear Wave (m/s)		Poissons Ratio	Shear Modulus (MPa)	Deformation Modulus (MPa)	Bulk Modulus (MPa)
0.0	1.3	2385	165	1750	0.50	48	143	9891
0.0	2.3	1110	92	1750	0.50	15	44	2136
2.3	3.3	1020	88	1750	0.50	14	41	1803
3.3	4.3	1022	90	1750	0.50	14	42	1809
4.3	5.3	1260	92	1750	0.50	15	44	2759
5.3	6.3	1480	93	1750	0.50	15	45	3813
6.3	7.3	1500	93	1750	0.50	15	45	3917
7.3	8.3	1520	108	1750	0.50	20	61	4016
8.3	9.3	1530	103	1750	0.50	19	56	4072
9.3	10.3	1550	103	1750	0.50	19	56	4180
10.3	11.3	1550	103	1750	0.50	19	56	4180
11.3	12.3	1560	145	1750	0.50	37	110	4210
12.3	13.3	1560	125	1750	0.50	27	82	4222
13.3	14.3	1340	130	1750	0.50	30	88	3103
14.3	15.3	1550	130	1750	0.50	30	89	4165
15.3	16.3	1600	128	1750	0.50	29	86	4442
16.3	17.3	1550	128	1750	0.50	29	86	4166
17.3	18.3	1600	128	1750	0.50	29	86	4442
18.3	19.3	1600	130	1750	0.50	30	89	4441
19.3	20.3	1580	130	1750	0.50	30	89	4329
20.3	21.3	1580	125	1750	0.50	27	82	4332
21.3	22.3	1580	165	1750	0.49	48	142	4305
22.3	23.3	1580	165	1750	0.49	48	142	4305
23.3	24.3	1400	165	1750	0.49	48	142	3366
24.3	25.3	1250	165	1750	0.49	48	142	2671
25.3	26.3	1280	170	1750	0.49	51	151	2800
26.3	27.3	1250	170	1750	0.49	51	151	2667
27.3	28.3	1150	185	1750	0.49	60	178	2235
28.3	29.3	1250	185	1750	0.49	60	178	2655
29.3	30.3	1200	210	1750	0.48	77	229	2417
30.3	31.3	1200	215	1750	0.48	81	240	2412
31.3	32.3	1250	215	1750	0.48	81	240	2627
32.3	33.3	1200	190	1750	0.49	63	188	2436
33.3	34.3	1220	185	1750	0.49	60	178	2525
34.3	35.3	1220	190	1750	0.49	63	188	2520
35.3	36.3	1220	650	1750	0.30	739	1925	1619
36.3	37.3	1250	680	1750	0.29	809	2087	1655
37.3	38.3	1260	680	2300	0.29	1064	2754	2233
38.3	39.3	1500	800	1750	0.30	1120	2915	2444
39.3	40.3	3000	1800	2300	0.22	7452	18164	10764
40.3	41.3	3100	1900	2300	0.20	8303	19913	11032
41.3	42.3	3200	1800	2300	0.27	7452	18907	13616
42.3	43.3	3200	1800	2300	0.27	7452	18907	13616
43.3	44.3	3200	1800	2300	0.27	7452	18907	13616



Notes
1. Depth Presented relative to ground surface.
2. This Table to be analyzed in conjunction with the accompanying report.

APPENDIX L

Groundwater Level Monitoring Program

TABLE L-1
SUMMARY OF MONITORING WELL COMPLETION DETAILS
CRRRC SITE

Well ID	Easting	Northing	Hydraulic Conductivity (m/s)	Ground Surface Elevation	Top of Casing Elevation (masl)	Material	Top of Sand Pack Interval (mbgs)	Bottom of Sand Pack Interval (mbgs)
12-1-3.1	467124	5020301	2E-07	76.10	76.84	Upper Bedrock	40.1	44.8
12-1-4A	467126	5020300	3E-06	76.08	77.03	Glacial Till	36.0	39.5
12-1-4B	467126	5020300	-	76.08	77.01	Deep Clay	27.0	31.0
12-1-5A	467122	5020302	-	76.06	76.87	Middle Clay	12.8	15.3
12-1-5B	467122	5020302	1E-07	76.06	76.84	Shallow Clay with Silty Layer	4.0	6.0
12-1-6	467123	5020299	9E-08	76.06	76.82	Surficial Silty Sand	0.3	1.5
12-2-3	466157	5019604	2E-05	76.94	77.77	Upper Bedrock	37.0	42.0
12-2-4	466154	5019605	-	77.09	77.95	Deep Clay	30.0	32.2
12-2-5A	466158	5019607	-	76.99	77.82	Mid Clay	18.6	20.7
12-2-5B	466158	5019607	3E-07	76.99	77.77	Shallow Clay with Silty Layer	3.8	7.6
12-2-6	466155	5019608	2E-05	77.13	78.07	Surficial Silty Sand	0.4	2.3
12-3-3	466671	5021579	3E-06	76.22	77.00	Bedrock	40.1	45.4
12-3-4A	466673	5021576	2E-06	76.23	77.20	Glacial Till	35.0	38.7
12-3-4B	466673	5021576	-	76.23	77.20	Deep Clay	28.1	30.5
12-3-5A	466668	5021577	-	76.23	77.18	Middle Clay	13.8	15.8
12-3-5B	466668	5021577	2E-07	76.23	77.21	Shallow Clay with Silty Layer	4.0	6.1
12-3-6	466670	5021574	5E-06	76.27	77.09	Surficial Silty Sand	0.3	1.5
12-4-3	466523	5020873	2E-08	75.92	77.03	Upper Bedrock	38.5	43.6
12-4-4A	466522	5020876	2E-04	75.88	76.95	Glacial Till	34.8	36.7
12-4-4B	466522	5020876	-	75.88	76.98	Deep Clay	25.9	28.7
12-4-5A	466520	5020872	-	75.90	77.16	Middle Clay	14.0	16.2
12-4-5B	466520	5020872	7E-07	75.90	77.17	Shallow Clay with Silty Layer	3.5	6.0
12-4-6	466519	5020874	3E-06	75.89	77.20	Surficial Silty Sand	0.3	1.6
13-5-3	466176	5021083	5E-06	76.51	77.45	Bedrock	35.3	40.3
13-5-4A	466179	5021084	2E-06	76.43	77.40	Glacial Till	28.7	31.1
13-5-4B	466179	5021084	-	76.43	77.44	Mid Clay	14.0	16.5
13-5-5	466177	5021081	7E-07	76.38	77.39	Shallow Clay with Silty Layer	4.0	6.1
13-5-6	466179	5021081	9E-06	76.45	77.38	Surficial Silty Sand	0.3	1.5
13-6-3	465917	5020387	2E-07	76.69	77.65	Upper Bedrock	41.4	45.1
13-6-4A	465918	5020390	6E-07	76.69	77.67	Glacial Till	33.0	35.6
13-6-4B	465918	5020390	-	76.69	77.63	Deep Clay	25.7	31.7
13-6-5A	465920	5020386	-	76.60	77.61	Middle Clay	14.4	16.6
13-6-5B	465920	5020386	7E-07	76.60	77.63	Shallow Clay with Silty Layer	4.6	7.3
13-6-6	465917	5020387	8E-06	76.64	77.63	Surficial Silty Sand	0.6	1.6
13-7-2	466559	5020090	2E-07	76.35	77.23	Bedrock	34.6	39.5
13-7-3	466532	5020085	8E-09	76.35	77.46	Glacial Till	28.0	30.3
13-7-4-1	466536	5020088	-	76.38	77.38	Middle Clay	14.5	16.8
13-7-4-2	466536	5020089	8E-08	76.33	77.34	Shallow Clay with Silty Layer	4.4	6.4
13-7-5	466532	5020088	2E-06	76.35	77.52	Surficial Silty Sand	0.5	1.7
13-8-2	466032	5021437	1E-06	76.41	77.47	Surficial Silty Sand	0.3	1.5
13-8-3	466036	5021438	7E-09	76.43	77.37	Shallow Clay with Silty Layer	4.0	7.0
13-9-2	466350	5021533	-	76.05	77.20	Surficial Silty Sand	0.3	1.5
13-9-3	466347	5021536	-	76.08	77.14	Shallow Clay with Silty Layer	4.1	6.4
13-10-2	466456	5021246	2E-06	76.41	77.48	Surficial Silty Sand	0.3	1.5
13-10-3	466453	5021245	-	76.46	77.49	Shallow Clay with Silty Layer	4.0	7.0
13-11-2	466865	5021059	-	76.03	77.08	Surficial Silty Sand	0.3	1.5
13-12-2	466278	5020785	4E-06	76.19	77.28	Surficial Silty Sand	0.3	1.5
13-12-3	466284	5020781	5E-07	76.27	77.22	Shallow Clay with Silty Layer	4.0	7.0
13-13-2	466753	5021366	5E-07	76.21	77.15	Surficial Silty Sand	0.3	1.5
13-14-2	466088	5020308	-	76.48	77.50	Surficial Sand with Weathered Crust	0.3	1.5
13-15-2	466407	5020426	-	76.31	77.30	Surficial Silty Sand	0.3	1.5
13-15-3	466409	5020429	-	76.26	77.23	Shallow Clay with Silty Layer	4.0	7.0
13-16-2	466705	5020533	-	76.04	77.07	Surficial Silty Sand	0.3	1.5
13-17-2	466998	5020641	1E-06	75.99	76.99	Surficial Silty Sand	0.3	1.5
13-17-3	467002	5020640	4E-07	76.04	76.99	Shallow Clay with Silty Layer	4.0	7.0
13-18-2	465852	5019945	1E-05	76.90	77.89	Surficial Silty Sand	0.3	1.5
13-18-3	465847	5019936	2E-07	76.86	77.79	Shallow Clay with Silty Layer	4.0	7.0
13-19-2	466204	5019954	-	76.68	77.67	Surficial Sand and Weathered Clay	0.3	1.5
13-20-2	466835	5020207	-	76.21	77.13	Surficial Sand and Weathered Clay	0.3	1.5
13-21-2	465950	5019673	3E-06	77.41	78.43	Surficial Silty Sand	0.3	1.5
13-22-2	466332	5019636	-	76.59	77.55	Surficial Sand and Weathered Clay	0.3	1.5
13-23-2	466608	5019742	-	76.51	77.57	Surficial Sand and Weathered Clay	0.3	1.5
13-23-3	466606	5019742	-	76.53	77.50	Shallow Clay with Silty Layer	4.0	7.0
13-24-2	466958	5019877	2E-06	76.11	77.25	Surficial Silty Sand	0.3	1.5
13-25-2	467254	5019999	-	75.99	77.08	Surficial Silty Sand	0.3	1.5
13-25-3	467250	5020011	-	75.98	77.15	Shallow Clay with Silty Layer	4.0	7.0
A13-1	465500	5020864	-	77.22	77.18	Surficial Silty Sand	0.5	3.1
A13-2	465535	5020877	-	77.48	77.46	Surficial Silty Sand	0.8	3.1
B13-1	not surveyed	not surveyed	-	not surveyed	not surveyed	Surficial Silty Sand	0.6	3.4
B13-2	not surveyed	not surveyed	-	not surveyed	not surveyed	Surficial Silty Sand	0.6	3.5
B13-3	not surveyed	not surveyed	-	not surveyed	not surveyed	Surficial Silty Sand	0.9	2.2
B13-4	not surveyed	not surveyed	-	not surveyed	not surveyed	Surficial Silty Sand	0.8	2.0
B13-5	not surveyed	not surveyed	-	not surveyed	not surveyed	Shallow Clay with Silty Layer	4.9	6.3
B13-6	not surveyed	not surveyed	-	not surveyed	not surveyed	Surficial Silty Sand	0.6	1.5
B13-7	not surveyed	not surveyed	-	not surveyed	not surveyed	Shallow Clay with Silty Layer	5.2	6.4
B13-8	not surveyed	not surveyed	-	not surveyed	not surveyed	Surficial Silty Sand	0.8	2.7
B13-9	not surveyed	not surveyed	-	not surveyed	not surveyed	Surficial Silty Sand	0.6	2.4
B13-10	not surveyed	not surveyed	-	not surveyed	not surveyed	Surficial Silty Sand	0.7	2.3

Created by: DH
Checked by: JPAO

TABLE L-2
MONTHLY GROUNDWATER ELEVATIONS
CRRRC SITE

Well Location	Ground Surface Elevation (masl)	TOP Elevation (masl)	Groundwater Elevations (masl)										
			22-Jan-13	19-Feb-13	29-Apr-13	17-May-13	10-Jun-13	23-Jul-13	15-Aug-13	24-Sep-13	16-Oct-13	12-Nov-13	4-Dec-13
12-1-3.1	*76.10*	*76.84*	74.56	74.64	74.59	74.57	74.58	74.67	74.61	74.60	74.64	74.66	74.72
12-1-4A	*76.08*	*77.03*	74.42	74.55	74.53	74.52	74.47	74.53	74.50	74.44	74.49	74.61	74.67
12-1-4B	*76.08*	*77.01*	74.47	74.55	74.49	74.47	74.49	74.57	74.52	74.50	74.55	74.61	74.46
12-1-5A	*76.06*	*76.87*	frozen	frozen	75.29	75.36	75.29	75.19	75.17	75.21	75.25	75.30	75.31
12-1-5B	*76.06*	*76.84*	75.68	nm	75.47	75.44	75.51	75.34	75.38	75.49	75.54	75.56	75.56
12-1-6	*76.06*	*76.82*	frozen	frozen	75.94	75.53	76.02	75.76	75.52	75.91	75.91	75.92	frozen
12-2-3	*76.94*	*77.77*	75.11	75.14	75.14	75.11	75.15	75.17	75.17	75.21	75.27	75.24	75.31
12-2-4	*77.09*	*77.95*	65.06*	75.52	75.30	75.31	75.26	75.28	75.28	75.17	75.31	75.35	75.50
12-2-5A	*76.99*	*77.82*	frozen	frozen	75.17**	75.97	76.02	76.01	75.87	75.89	75.84	75.87	75.92
12-2-5B	*76.99*	*77.77*	76.07*	76.25	76.30	76.01	76.34	76.35	76.23	76.25	76.18	76.33	76.42
12-2-6	*77.13*	*78.07*	76.64	76.55	76.69	76.52	76.58	76.61	75.99	76.84	76.40	76.67	76.67
12-3-3	*76.22*	*77.00*	74.53	74.56	74.48	74.46	74.47	74.56	74.50	74.50	74.56	74.52	74.57
12-3-4A	*76.23*	*77.20*	74.59	74.62	74.54	74.52	74.52	74.68	74.62	74.62	74.70	74.64	74.82
12-3-4B	*76.23*	*77.20*	75.66	75.61	75.40	75.38	75.40	75.52	75.51	75.49	75.48	75.47	75.42
12-3-5A	*76.23*	*77.18*	frozen	frozen	75.48	75.47	75.48	75.49	75.48	75.49	75.51	75.56	75.62
12-3-5B	*76.23*	*77.21*	75.79	76.17	75.84	75.78	75.80	75.72	75.78	75.78	75.85	75.94	75.96
12-3-6	*76.27*	*77.09*	frozen	frozen	75.84	75.66	75.83	75.60	75.84	75.98	76.00	76.06	76.02
12-4-3	*75.92*	*77.03*	—	—	74.15	74.16	74.17	74.26	74.25	74.21	74.27	74.23	74.26
12-4-4A	*75.88*	*76.95*	—	—	74.50	74.47	74.48	74.56	74.53	74.50	74.57	74.54	74.55
12-4-4B	*75.88*	*76.98*	—	—	75.13	75.13	75.14	75.15	75.17	75.18	75.19	75.18	75.16
12-4-5A	*75.90*	*77.16*	—	—	75.44	75.42	75.44	75.38	75.37	75.37	75.37	75.39	75.37
12-04-5B	*75.90*	*77.17*	—	—	75.68	75.64	75.65	75.72	75.75	75.94	75.79	75.82	75.80
12-04-6	*75.89*	*77.20*	—	—	75.75	75.53	75.71	75.91	75.86	75.97	75.97	76.00	75.94
13-5-3	*76.51*	*77.45*	—	—	—	—	—	74.55	74.48	75.95**	74.57	74.54	74.57
13-5-4A	*76.43*	*77.40*	—	—	74.49	74.51	74.53	74.52	74.49	75.37**	74.58	74.55	74.60
13-5-4B	*76.43*	*77.44*	—	—	74.76	74.71	74.71	74.79	74.56	74.75	74.73	74.70	74.66
13-5-5	*76.38*	*77.39*	—	—	76.13	75.86	75.87	75.82	75.65	76.26**	75.93	75.98	75.96
13-5-6	*76.45*	*77.38*	—	—	76.00	75.45	75.54	75.60	75.54	76.24	76.32	76.35	76.33
13-6-3	*76.69*	*77.65*	—	—	74.89	74.90	74.90	74.77	74.75	74.80	74.83	74.78	74.94
13-6-4A	*76.69*	*77.67*	—	—	75.05	74.99	75.00	74.93	74.93	74.94	75.00	74.94	75.07
13-6-4B	*76.69*	*77.63*	—	—	76.84	76.85	76.78	76.68	76.63	76.56	76.50	76.46	76.43
13-6-5A	*76.60*	*77.61*	—	—	76.21	76.14	76.11	76.03	76.00	75.96	75.96	76.01	75.98
13-6-5B	*76.60*	*77.63*	—	—	76.37	76.34	76.36	76.25	76.18	76.17	76.26	76.38	76.37
13-6-6	*76.64*	*77.63*	—	—	76.56	76.47	76.53	76.21	75.99	76.48	76.51	76.56	76.55
13-7-2	*76.35*	*77.23*	—	—	—	—	—	74.86	74.77	74.79	74.91	74.88	75.21
13-7-3	*76.35*	*77.46*	—	—	74.76	74.68	74.80	74.82	74.75	74.81	74.79	74.76	74.94
13-7-4-1	*76.38*	*77.38*	—	—	75.54	75.52	75.69	75.71	75.58	75.61	75.66	75.68	75.74
13-7-4-2	*76.33*	*77.34*	—	—	76.17	76.09	76.21	76.20	76.10	76.09	76.16	76.19	76.31
13-7-5	*76.35*	*77.52*	—	—	76.36	76.29	76.37	76.38	76.15	76.33	76.33	76.37	76.36

TABLE L-2
MONTHLY GROUNDWATER ELEVATIONS
CRRRC SITE

Well Location	Ground Surface Elevation (masl)	TOP Elevation (masl)	Groundwater Elevations (masl)										
			22-Jan-13	19-Feb-13	29-Apr-13	17-May-13	10-Jun-13	23-Jul-13	15-Aug-13	24-Sep-13	16-Oct-13	12-Nov-13	4-Dec-13
13-8-2	*76.41*	*77.47*	—	—	76.41	76.20	76.22	75.72	75.55	75.74	75.82	75.84	75.82
13-8-3	*76.43*	*77.37*	—	—	76.02	75.95	75.96	75.81	75.70	75.85	75.97	76.01	76.00
13-9-2	*76.05*	*77.20*	—	—	75.86	75.18	75.20	75.43	75.28	75.96	76.01	76.04	76.02
13-9-3	*76.08*	*77.14*	—	—	75.85	75.60	75.62	75.61	75.49	75.58	75.72	75.76	75.75
13-10-2	*76.46*	*77.48*	—	—	75.94	75.35	75.39	75.52	75.39	75.96	76.05	76.08	76.06
13-10-3	*76.47*	*77.49*	—	—	75.77	75.66	75.69	75.67	75.59	75.52	75.66	75.70	75.68
13-11-2	*76.03*	*77.08*	—	—	75.86	75.63	76.01	75.36	75.41	75.54	75.66	75.69	75.67
13-12-2	*76.19*	*77.28*	—	—	76.09	75.80	75.81	75.68	75.52	75.59	76.03	76.06	76.03
13-12-3	*76.27*	*77.22*	—	—	75.93	75.87	75.89	75.82	75.74	75.76	75.87	75.89	75.90
13-13-2	*76.21*	*77.15*	—	—	75.79	75.69	75.71	75.73	75.71	75.86	75.92	75.95	75.91
13-14-2	*76.48*	*77.50*	—	—	76.49	76.36	76.38	76.40	76.07	76.46	76.49	76.50	frozen
13-15-2	*76.31*	*77.30*	—	—	76.28	76.20	76.23	76.20	75.45	76.23	76.25	76.27	76.25
13-15-3	*76.26*	*77.23*	—	—	76.14	76.09	76.12	76.11	75.74	76.07	76.13	76.15	76.14
13-16-2	*76.04*	*77.07*	—	—	76.03	75.98	76.03	76.04	75.71	76.01	76.01	76.03	76.00
13-17-2	*75.99*	*76.99*	—	—	76.02	75.91	75.98	75.97	75.16	75.33	75.33	75.36	75.34
13-17-3	*76.04*	*76.99*	—	—	75.69	75.61	75.64	75.62	75.31	75.29	75.37	75.40	75.38
13-18-2	*76.90*	*77.89*	—	—	76.72	76.70	76.81	76.83	76.26	76.45	76.67	76.70	76.68
13-18-3	*76.86*	*77.79*	—	—	76.43	76.40	76.68	76.69	76.33	76.20	76.35	76.38	76.37
13-19-2	*76.68*	*77.67*	—	—	76.59	76.53	76.59	75.98	76.31	76.46	76.55	76.58	76.58
13-20-2	*76.21*	*77.13*	—	—	76.10	75.98	76.07	76.08	75.89	76.05	76.06	76.08	76.09
13-21-2	*77.41*	*78.43*	—	—	76.78	76.53	76.63	76.65	DRY	DRY	74.95	74.99	75.01
13-22-2	*76.59*	*77.55*	—	—	76.43	76.30	76.41	76.42	75.82	76.36	76.43	76.46	76.45
13-23-2	*76.51*	*77.57*	—	—	76.22	75.91	76.10	76.12	75.57	76.07	76.02	76.06	76.02
13-23-3	*76.53*	*77.50*	—	—	76.12	75.98	76.06	76.06	75.81	75.89	75.99	76.02	76.01
13-24-2	*76.11*	*77.25*	—	—	76.15	75.85	76.02	76.01	75.68	76.09	76.09	76.12	76.08
13-25-2	*75.99*	*77.08*	—	—	75.79	75.66	75.75	75.77	75.63	75.89	75.87	75.90	75.86
13-25-3	*75.98*	*77.15*	—	—	75.57	75.54	75.60	75.61	75.53	75.58	75.61	75.64	75.62
A13-1	*77.22*	*77.18*	—	—	—	—	—	76.10	76.49	nm	76.46	76.48	frozen
A13-2	*77.48*	*77.46*	—	—	—	—	—	76.40	76.47	nm	76.51	76.53	frozen

Notes:

— Monitoring well location not yet established

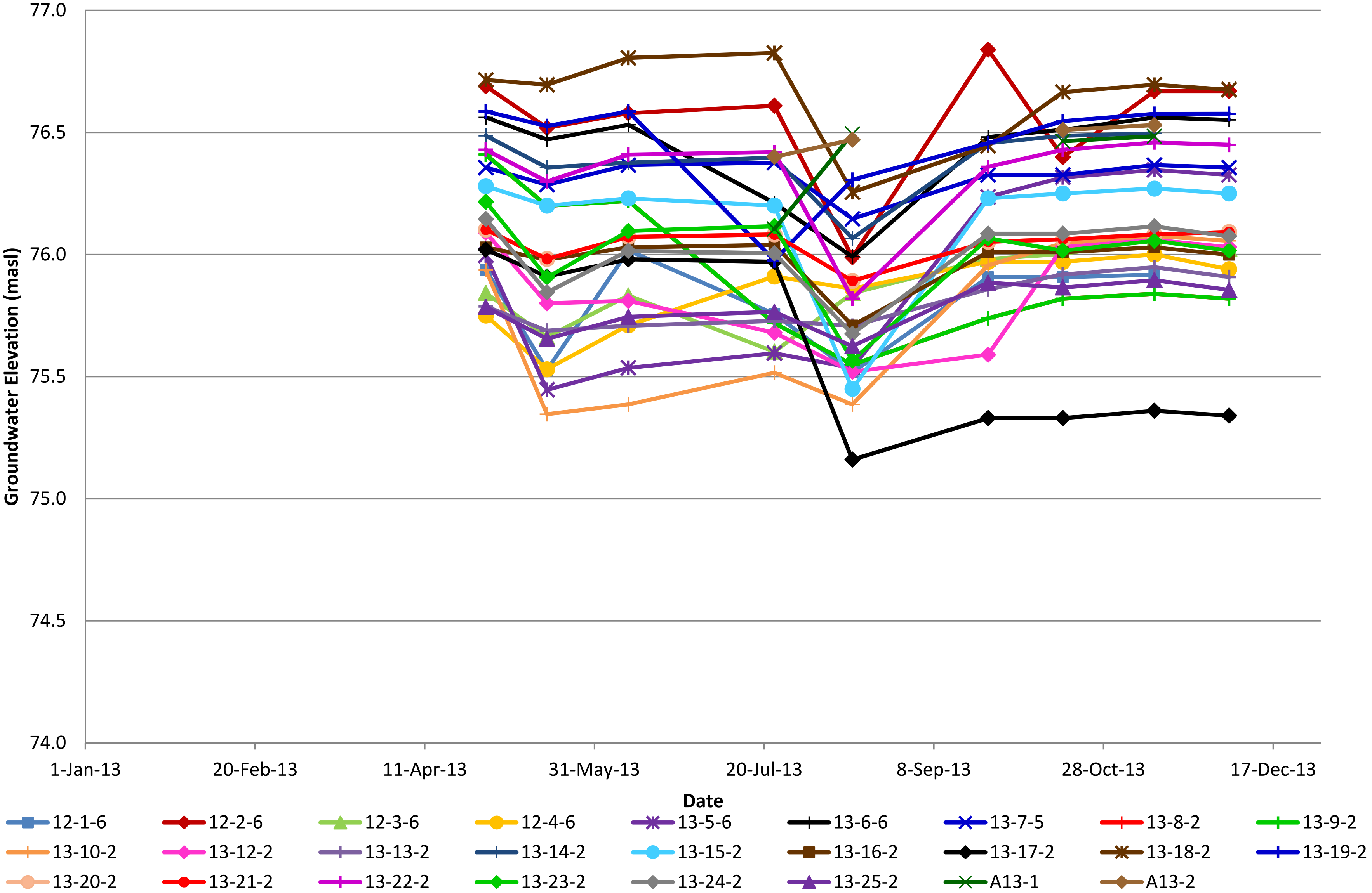
( ) Groundwater elevation prior to well development on January 21, 2013

* Non-stabilized groundwater elevation following well development

** Erroneous measurement

Dry - monitoring location was dry

nm - not monitored



Golder Associates

PROJECT No. 12-1125-0045

Created by	DH	DEC2013
Reviewed by	JPAO	AUG 2014

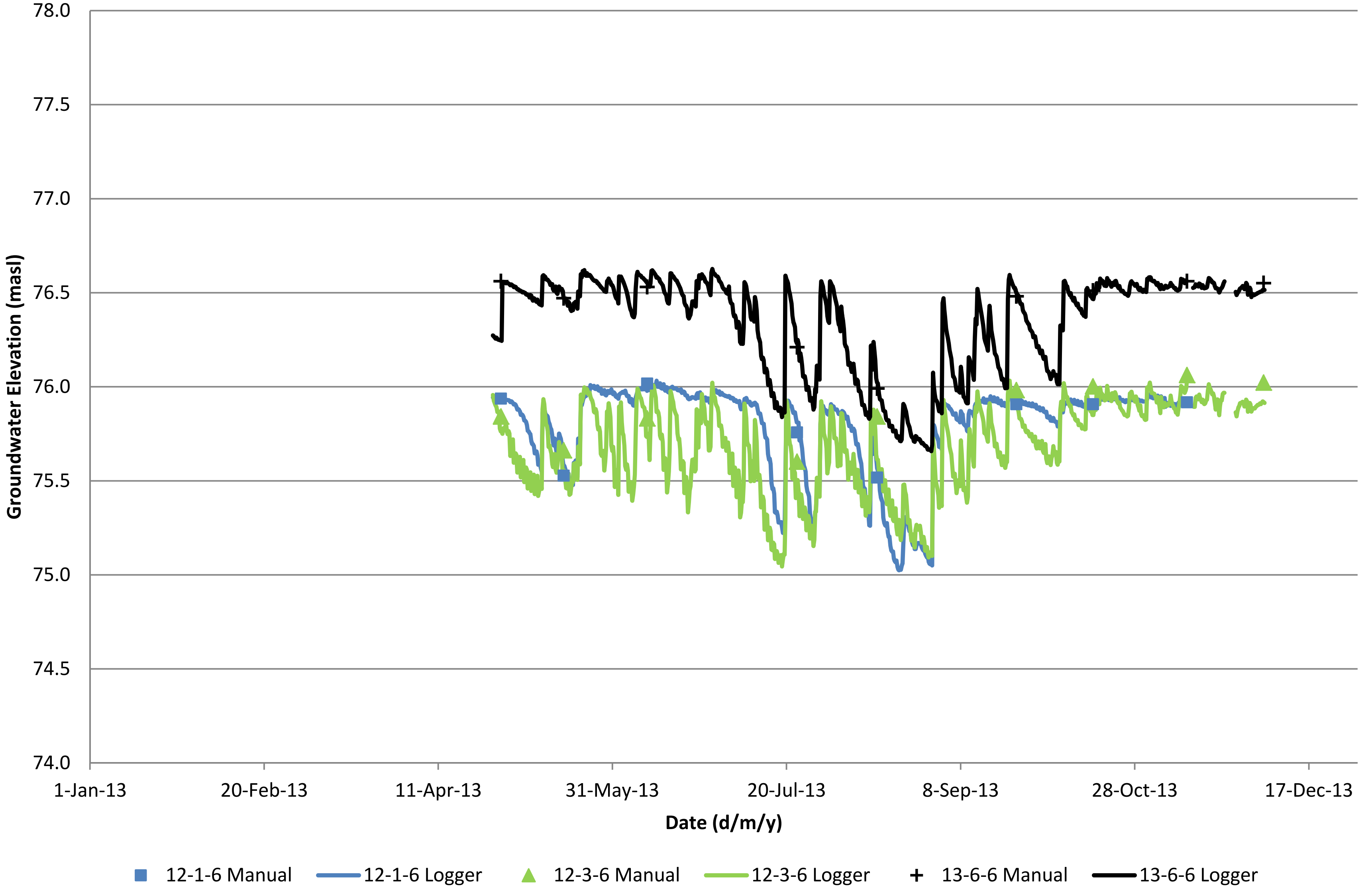
PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Monthly Groundwater Elevation Data for
All Surficial Silty Sand Monitoring Wells

FIGURE L1



PROJECT No. 12-1125-0045		
Created by	DH	DEC 2013
Reviewed by	JPAO	AUG 2014

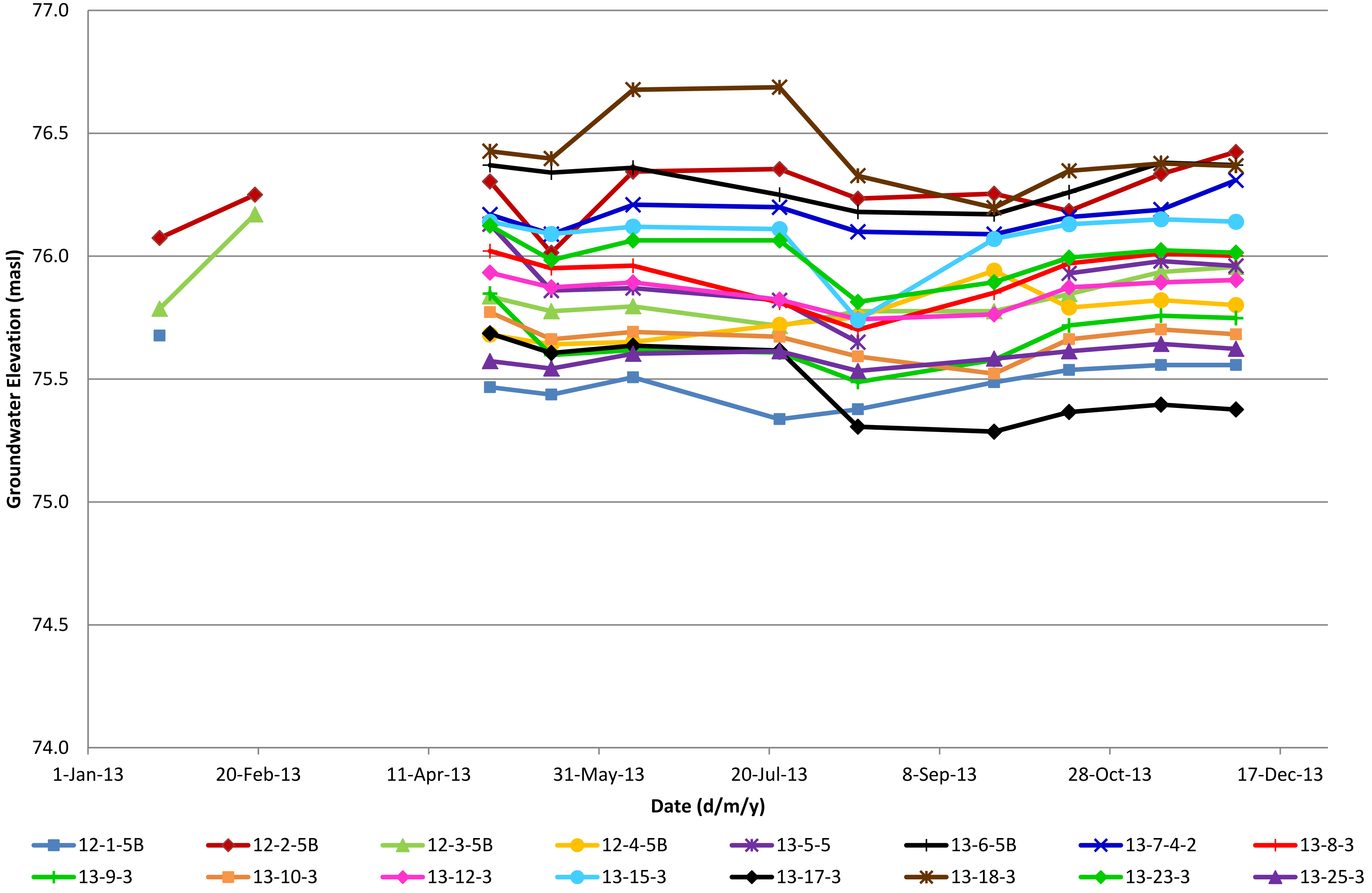
PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Daily Groundwater Elevation Data for
Surficial Silty Sand Monitoring Wells 12-1-6, 12-3-6 and 13-6-6

FIGURE L2



PROJECT No. 12-1125-0045		
Created by	DH	DEC 2013
Reviewed by	JPAO	AUG 2014

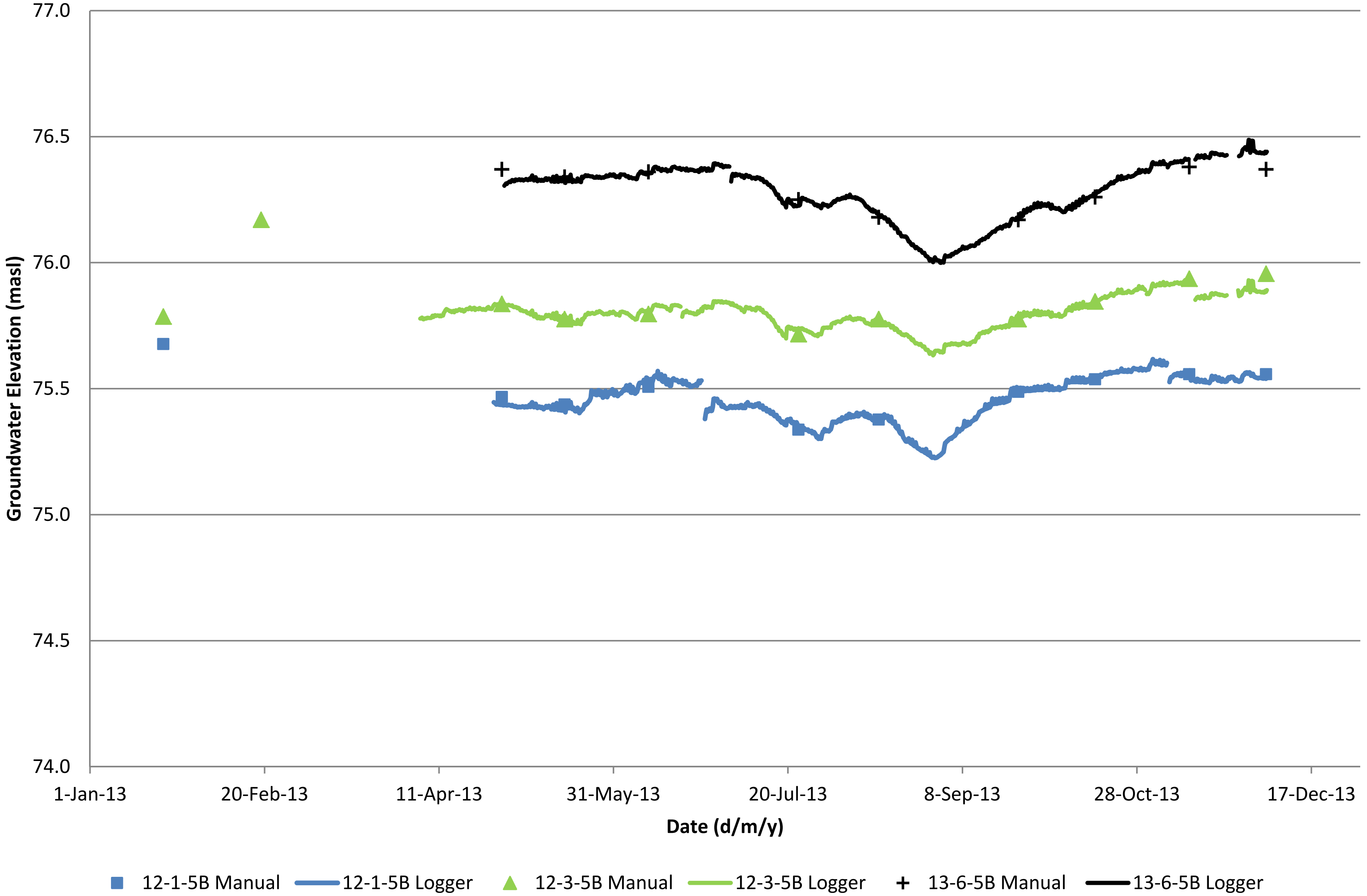
PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Monthly Groundwater Elevation Data for All
Silty Layer Monitoring Wells

FIGURE L3



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PROJECT No. 12-1125-0045

Created by	DH	DEC 2013
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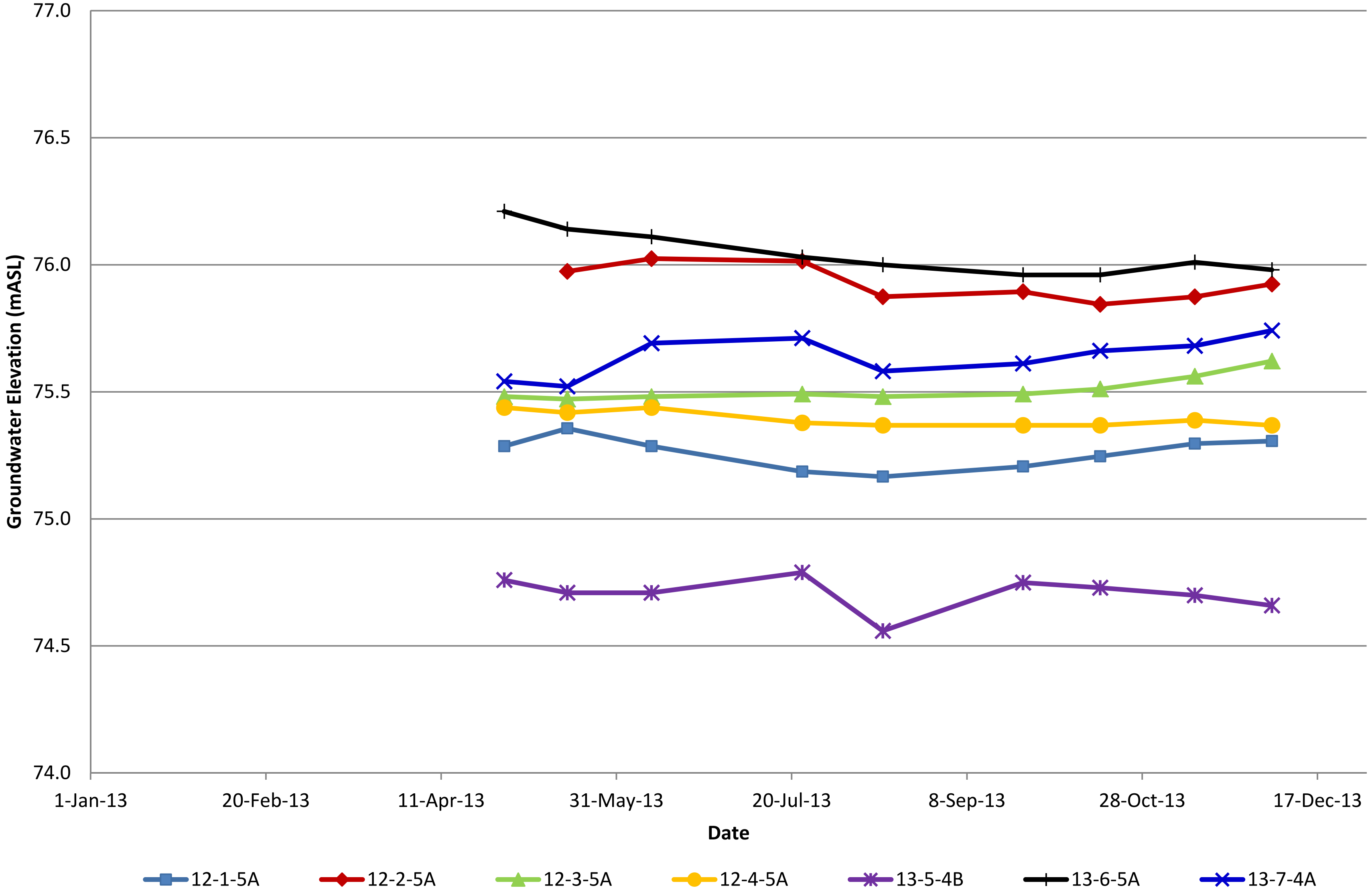
PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

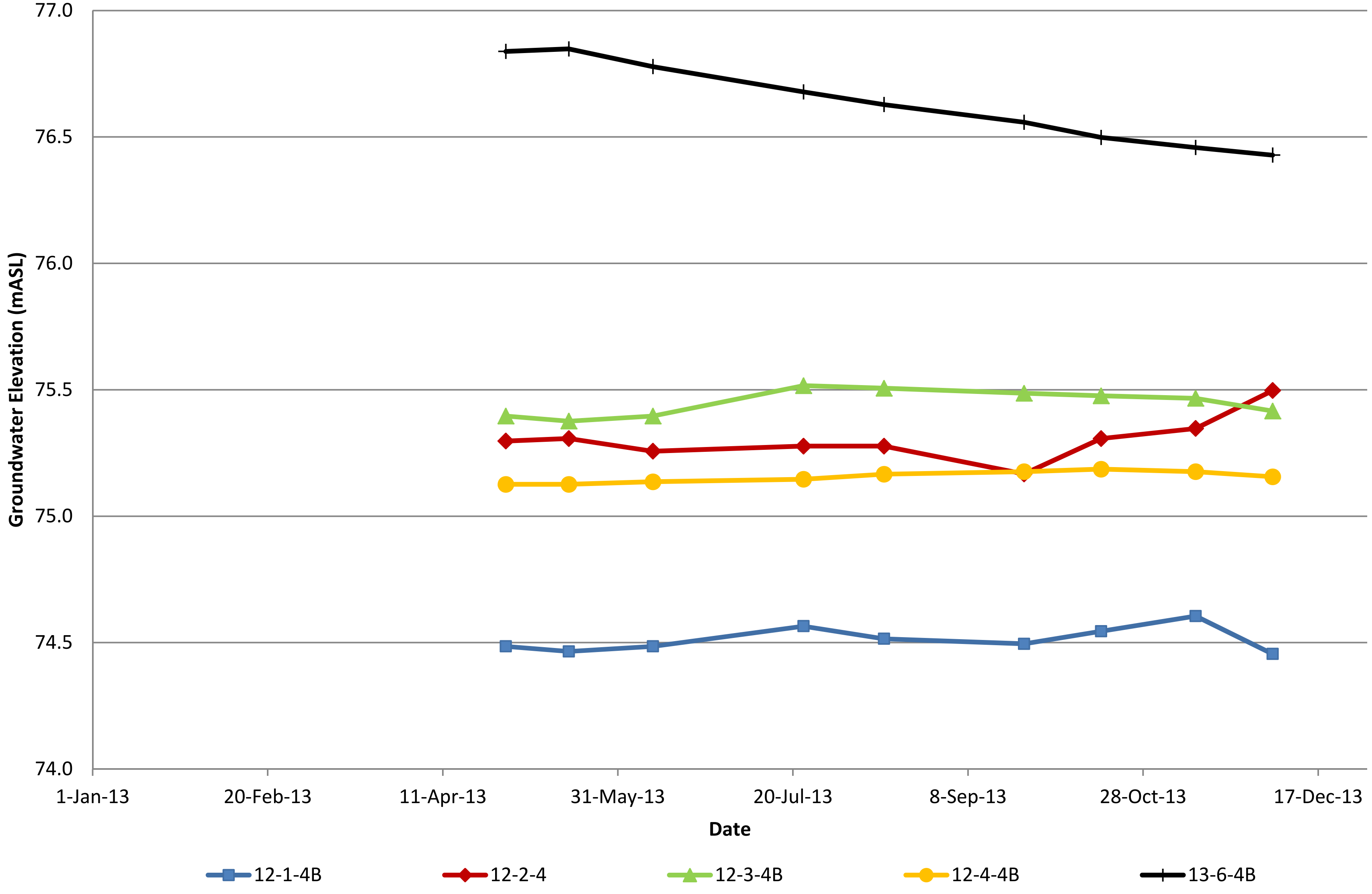
TITLE

Continuous Groundwater Elevation for Silty Layer
Monitoring Wells 12-1-5B, 12-3-5B and 13-6-5B

FIGURE L4



Golder Associates	PROJECT No. 12-1125-0045			PROJECT ENVIRONMENTAL ASSESSMENT OF THE CAPITAL REGION RESOURCE RECOVERY CENTRE	FIGURE L5
	Created by	DH	DEC 2013	TITLE Monthly Groundwater Elevation Data for All Middle Silty Clay Monitoring Wells	
	Reviewed by	JPAO	AUG 2014		



PROJECT No. 12-1125-0045		
Created by	DH	DEC 2013
Reviewed by	JPAO	AUG 2014

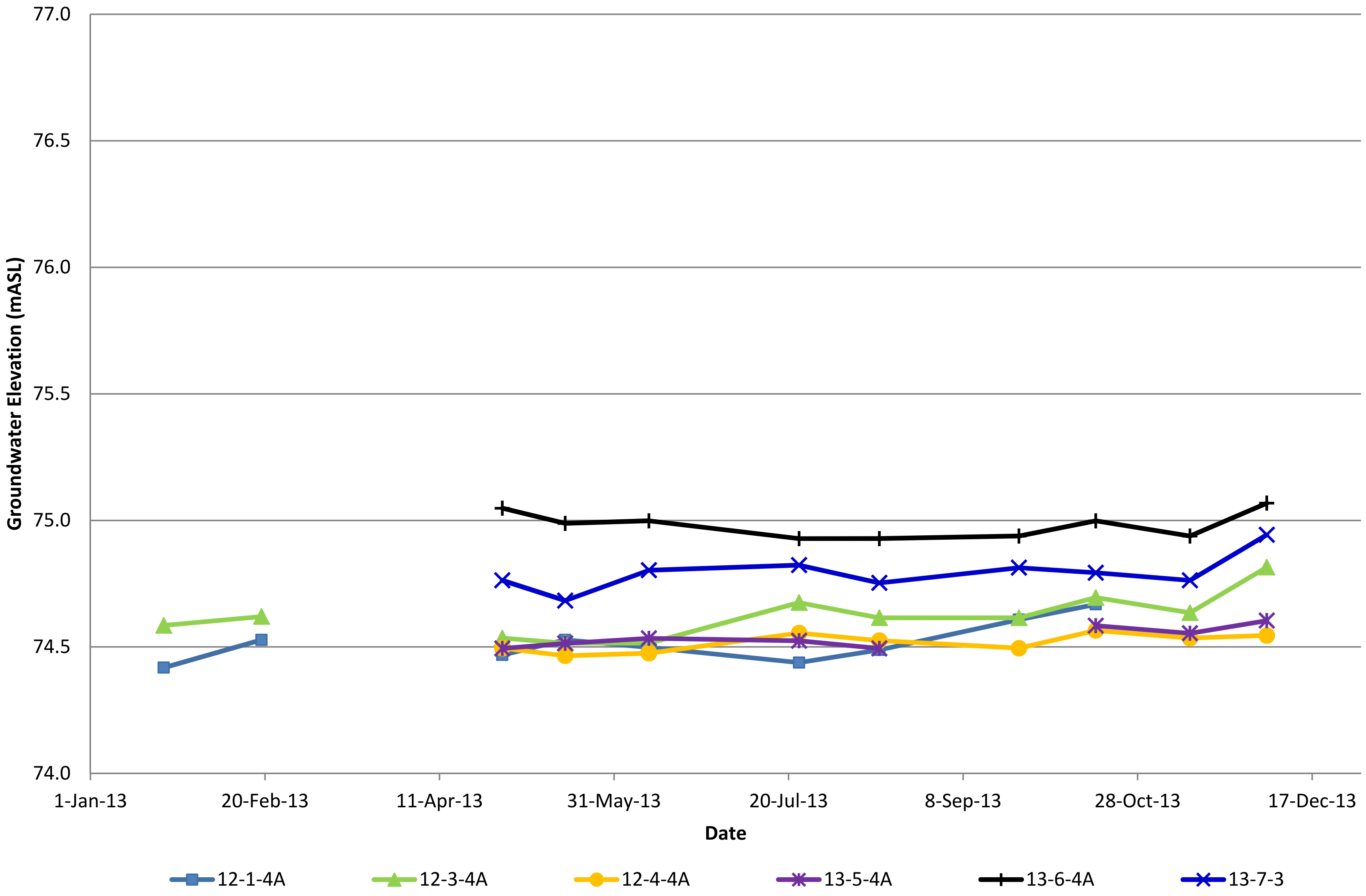
PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Monthly Groundwater Elevation Data for
All Deep Silty Clay Monitoring Wells

FIGURE L6



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Created by	DH	DEC 2013
Reviewed by	JPAO	AUG 2014

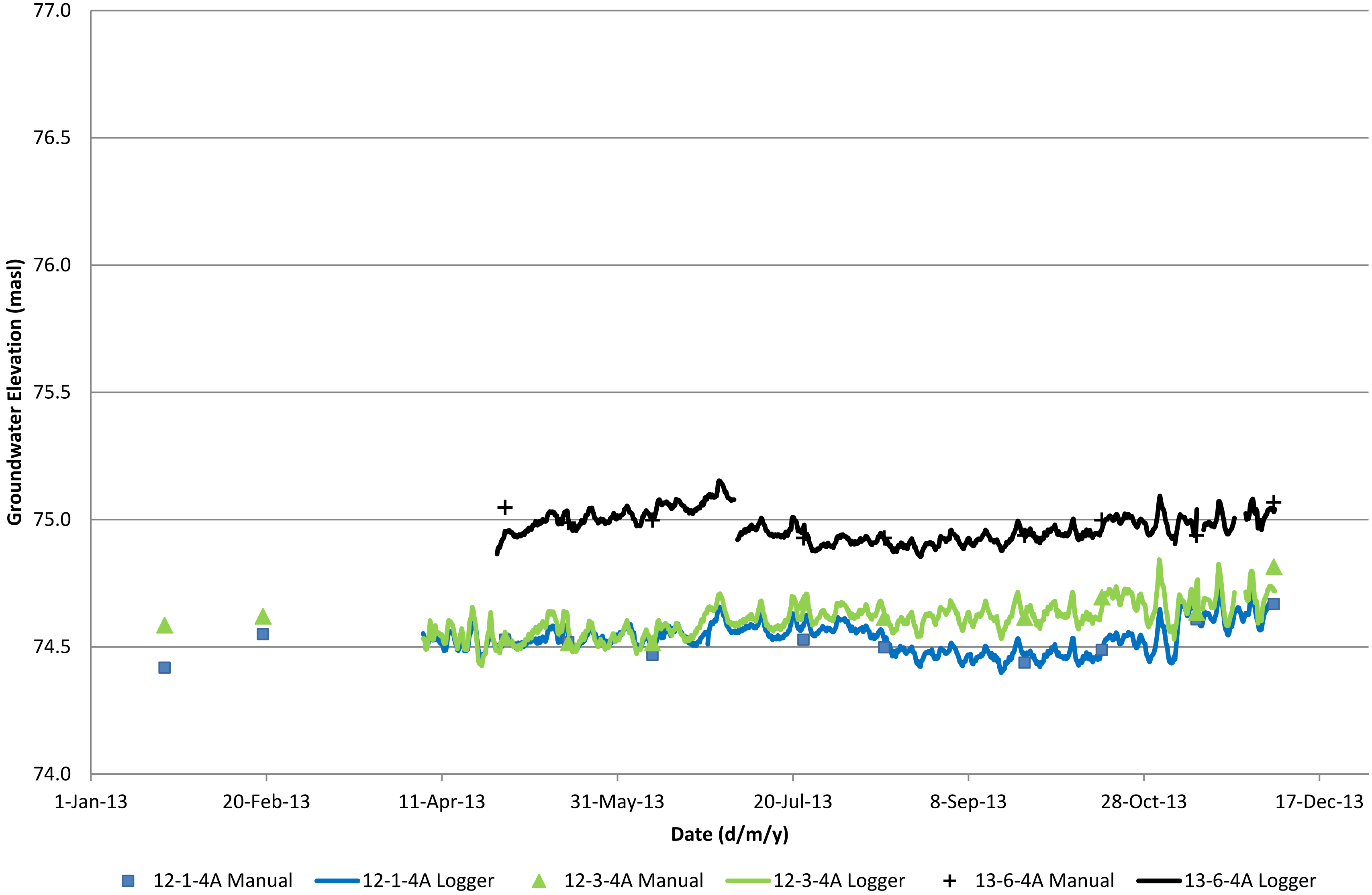
PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Monthly Groundwater Elevation Data for
All Glacial Till Monitoring Wells

FIGURE L7

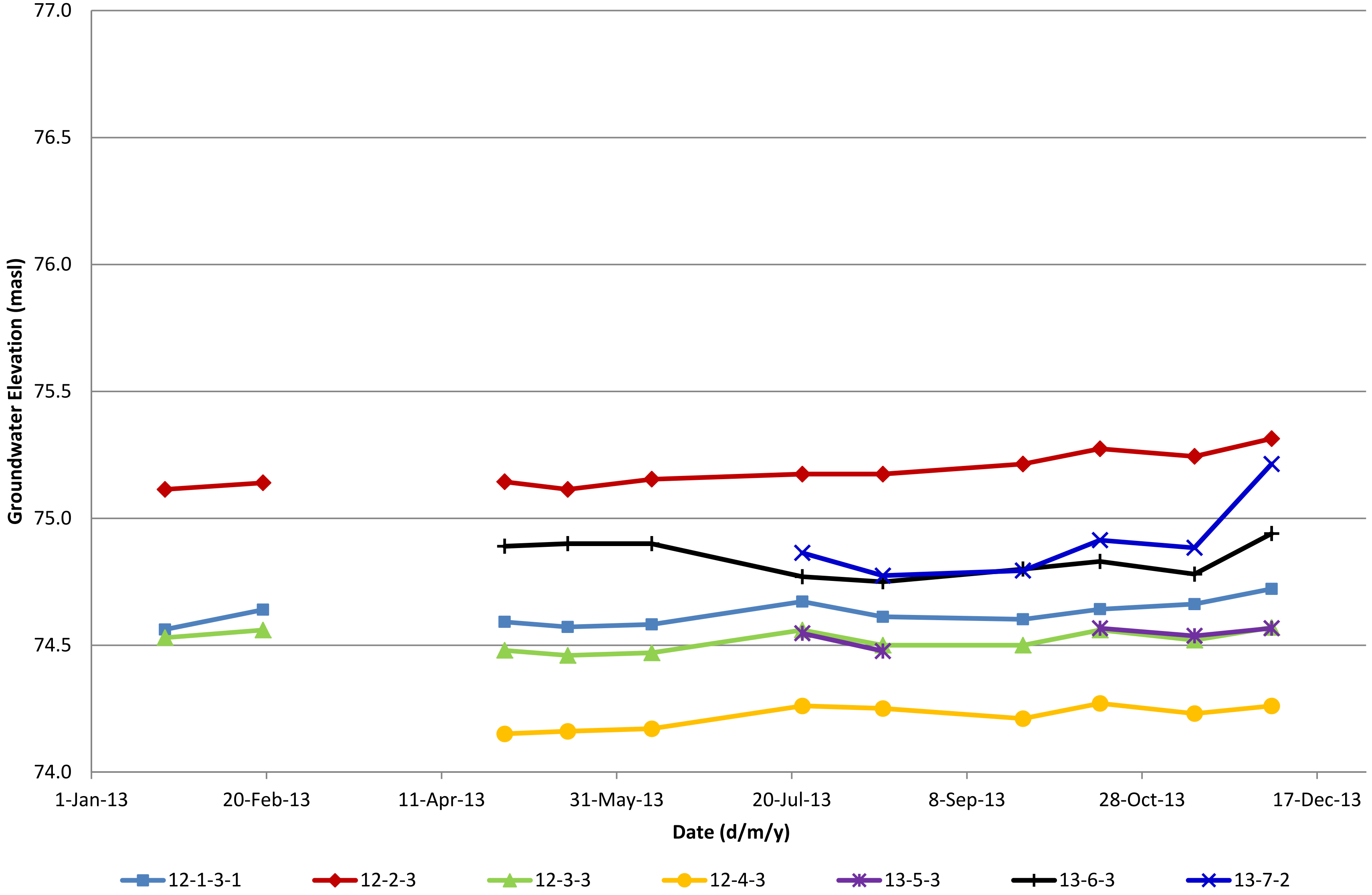


Golder Associates	PROJECT No. 12-1125-0045		
	Created by	DH	DEC 2013
	Reviewed by	JPAO	AUG 2014

PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
Daily Groundwater Elevation for Glacial Till
Monitoring Wells 12-1-4A, 12-3-4A and 13-6-4A

FIGURE L8



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PROJECT No. 12-1125-0045		
Created by	DH	DEC 2013
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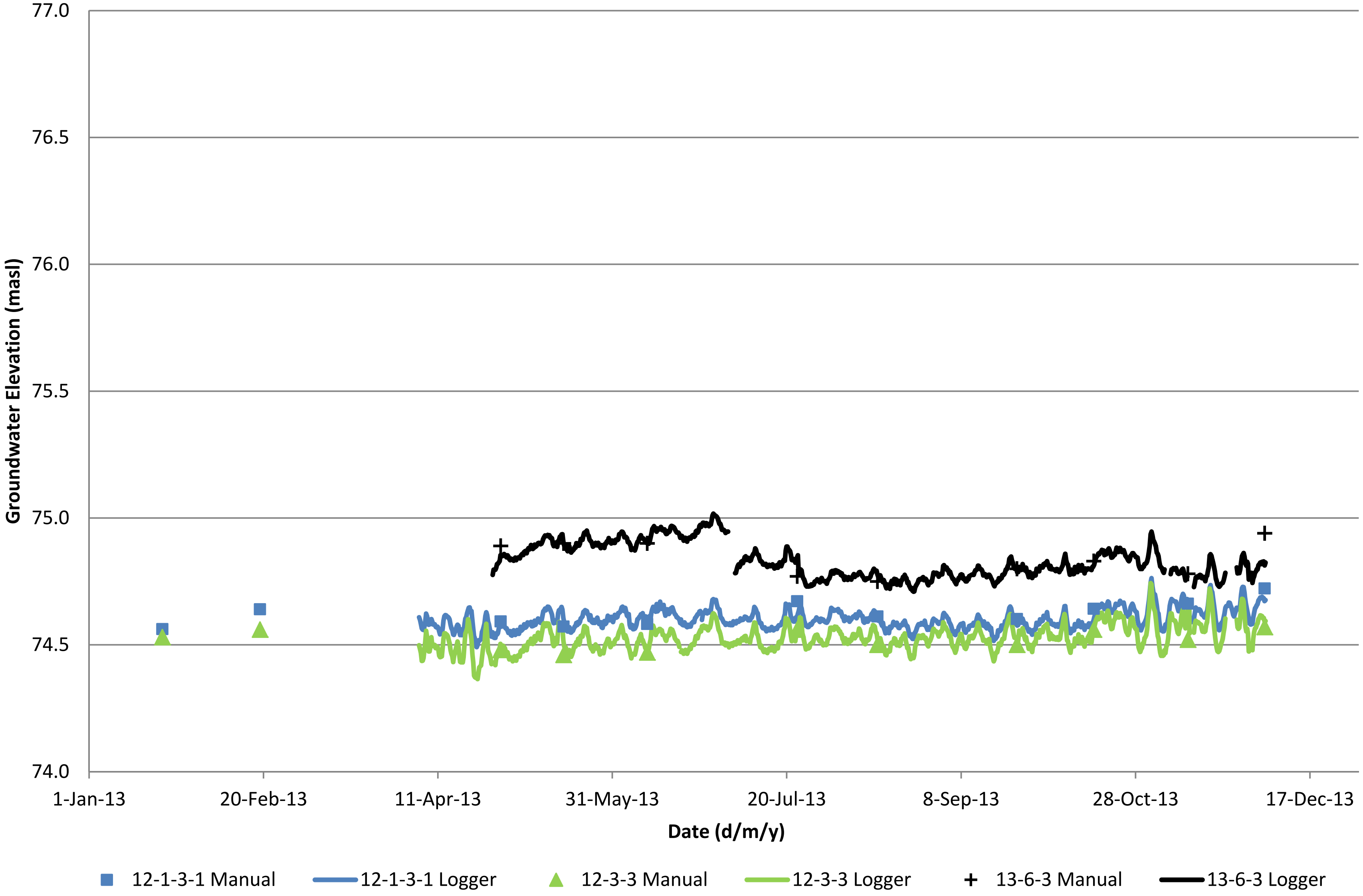
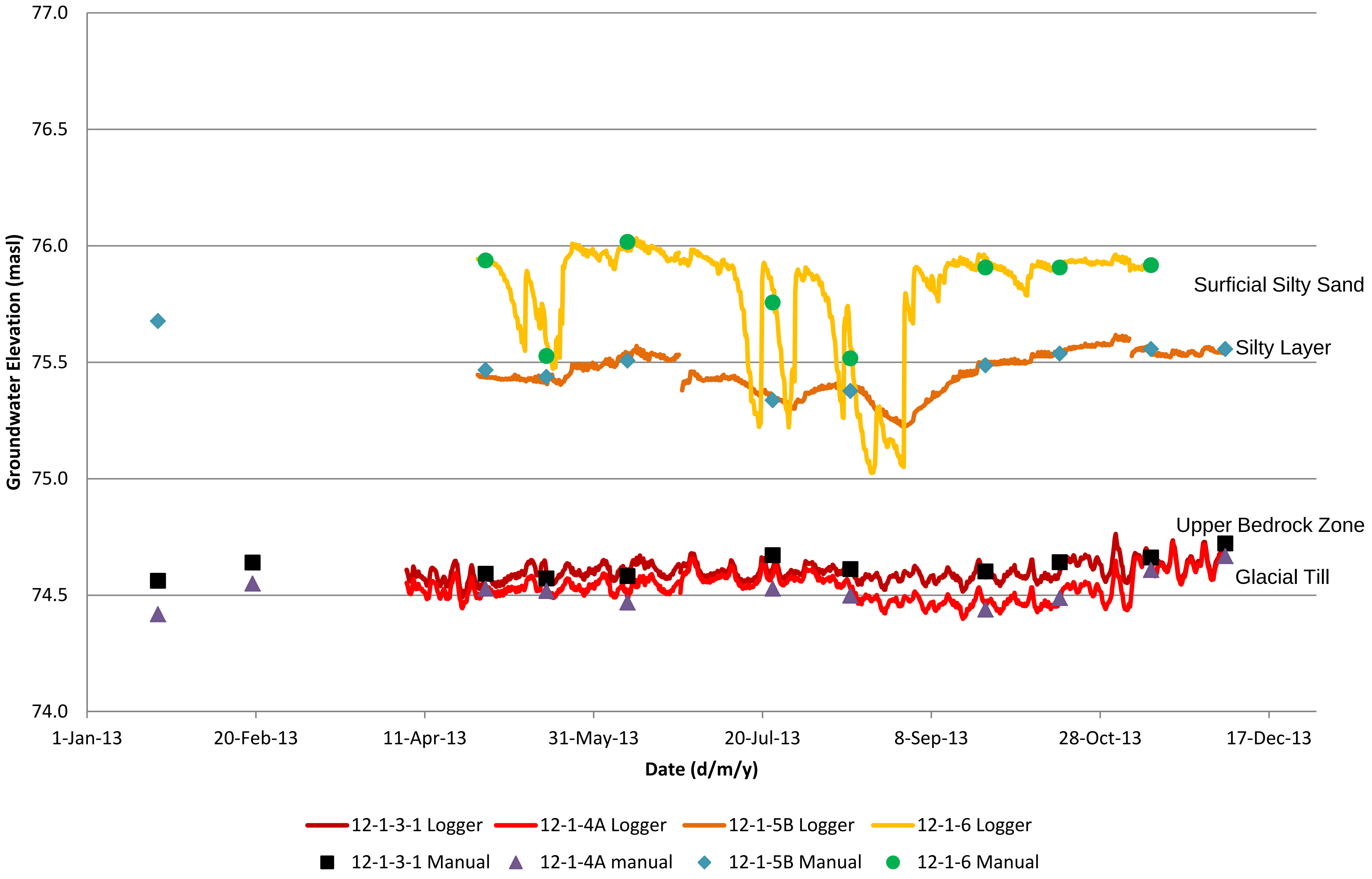
PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
Monthly Groundwater Elevation Data for All
Upper Bedrock Zone Monitoring Wells

FIGURE L9



PROJECT No. 12-1125-0045			PROJECT ENVIRONMENTAL ASSESSMENT OF THE CAPITAL REGION RESOURCE RECOVERY CENTRE	FIGURE L10
Created by	DH	DEC 2013	TITLE Daily Groundwater Elevation for Upper Bedrock Zone Monitoring Wells 12-1-3-1, 12-3-3 and 13-6-3	
Reviewed by	JPAO	AUG 2014		

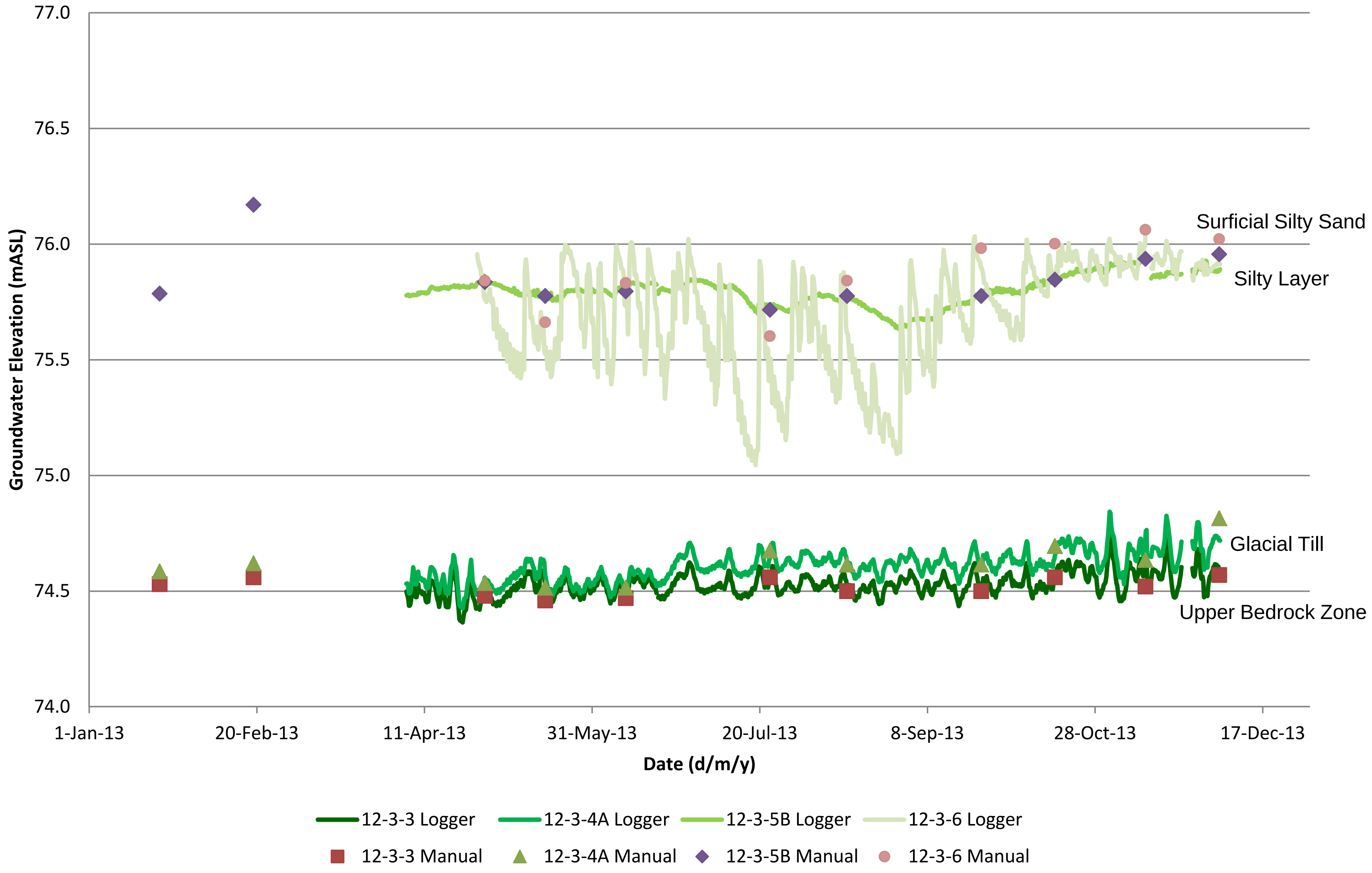


Golder Associates	PROJECT No. 12-1125-0045		
	Created by	DH	DEC 2013
	Reviewed by	JPAO	AUG 2014

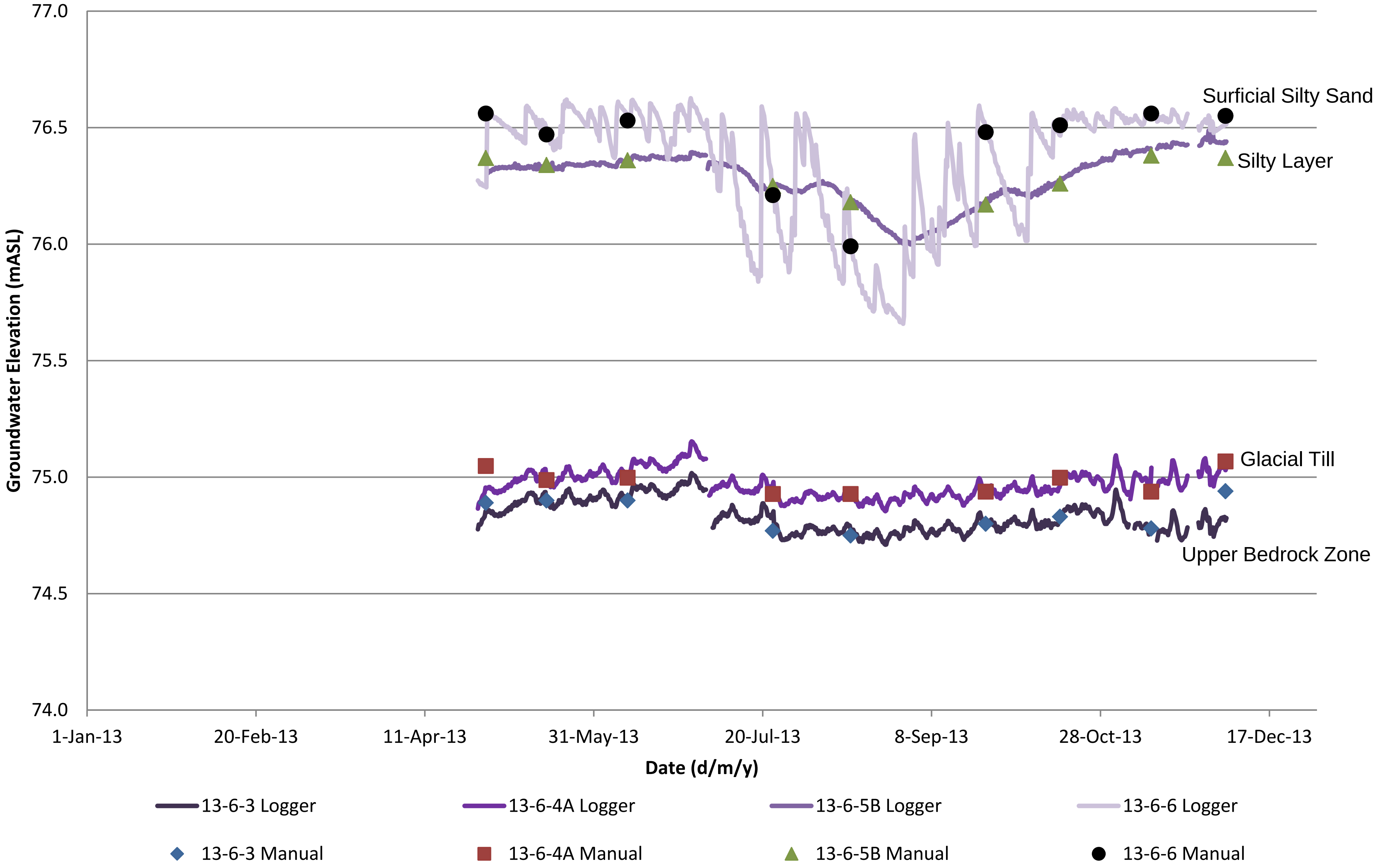
PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
Daily Groundwater Elevation Data for 12-1

FIGURE L11



Golder Associates	PROJECT No. 12-1125-0045		PROJECT ENVIRONMENTAL ASSESSMENT OF THE CAPITAL REGION RESOURCE RECOVERY CENTRE	FIGURE L12
	Created by	DH	DEC 2013	
	Reviewed by	JPAO	AUG 2014	TITLE Daily Groundwater Elevation Data for 12-3



PROJECT No. 12-1125-0045		
Created by	DH	DEC 2013
Reviewed by	JPAO	AUG 2014

PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Daily Groundwater Elevation Data for 13-6

FIGURE L13

APPENDIX M

Technical Memorandum – Dug Well Assessment

TECHNICAL MEMORANDUM

DATE November 2013 **PROJECT No.** 12-1125-0045/4500

DUG WELL ASSESSMENT – CRRRC SITE, OTTAWA, ONTARIO

Private water supply in the area of the Capital Region Resource Recovery Centre (CRRRC) Site (Site) is primarily from dug wells. Dug wells may also be used for (all or part of) the Site water supply. A hydrogeological investigation was completed on two existing dug wells situated on the Site for purposes of assessing water supply: (1) for the Environmental Assessment in terms of gathering information to assist in addressing concerns from residents about potential impacts of the project on their dug well water supply quantity and quality, and, (2) to provide information that could be used during the design of the water supply for the Site.

This technical memorandum provides a description of the methodology used to assess the hydrogeological properties of two existing dug wells, referred to as Frontier-1 and Boundary-2, situated on the Site (see locations on Figure 1). The assessment was designed to provide information on the yield of dug wells, how groundwater levels fluctuate within a dug well during typical operation, and to estimate the radius of influence (i.e., the zone around the well that experiences drawdown in groundwater levels) associated with the water taking from a dug well. The dug well assessment was divided into the following five tasks:

- Task 1 – Assess Construction Details and Selection of Dug Wells;
- Task 2 – Monitoring Well Installations;
- Task 3 – Groundwater Level Monitoring Program – Typical Use;
- Task 4 – Groundwater Level Monitoring Program – Pumping Test; and,
- Task 5 – Data Analysis.

The results of the above tasks are described below.

Assess Construction Details and Selection of Dug Wells

As an initial step, six dug well locations on or nearby the Site were identified as potential locations for use during the dug well assessment. Five of the dug wells are located on the Site, and one is located to the northwest of the Site. The dug wells are identified as Frontier-1 through Frontier-3 and Boundary-1 through Boundary-3. All dug wells are currently in use as water supply wells with the exception of Boundary-2. The dug wells at Frontier-1, Frontier-2 and Boundary-1 were sampled in January 2013 as part of the residential well sampling program completed in the vicinity of the Site. A water well and sewage disposal system survey was completed with the residents prior to sampling in January 2013. As part of the dug well assessment, the same survey was also completed at Frontier-3, Boundary-2 and Boundary-3.

The following information relating to well construction was obtained from the surveys:

- Frontier-1 – the dug well is approximately 3.6 metres deep, 0.91 metres in diameter and is accessible;
- Frontier-2 – the depth and diameter of the dug well is unknown and the well is currently inaccessible (i.e., buried). The approximate location of the dug well is known;
- Frontier-3 – the dug well is approximately 4.2 metres deep, 0.91 metres in diameter and is accessible;
- Boundary-1 – the dug well is 5.5 metres deep, 0.91 metres in diameter and is accessible;
- Boundary-2 – the dug well is approximately 3.7 metres deep, 0.91 metres in diameter and is accessible; and,
- Boundary-3 – the dug well is approximately 5.9 metres deep, 0.91 metres in diameter and is accessible.

All six dug wells are interpreted to obtain water primarily from the surficial silty sand layer. Dug wells Frontier-1 and Boundary-2 were selected for the hydrogeological assessment (see locations on Figure 1). The dug well assessment involved a groundwater level monitoring program under typical well use at Frontier-1, and an aquifer testing program at Boundary-2, which are described in further detail below.

Monitoring Well Installation

As part of the dug well assessment, a total of ten boreholes were completed within the vicinity of the selected dug wells. The boreholes were drilled to confirm the geological conditions in the vicinity of the dug wells, and to permit the installation of groundwater monitoring wells. The boreholes drilled as part of the dug well assessment are identified as B13-1 through B13-10, and are shown on Figure 1. Strata Drilling Group (Strata) of Carleton Place, Ontario completed the borehole drilling program using a track-mounted Geoprobe drill rig. The drilling and monitoring well installations in the vicinity of Frontier-1 (B13-1 and B13-2, two metres radial distance) and Boundary-2 (B13-3 through B13-10, one to eight metres radial distance) were completed on October 21, 2013 and October 28, 2013, respectively.

The monitoring wells installed within boreholes B13-1 and B13-2 allowed for the observation of groundwater levels in the shallow overburden (surficial silty sand) during typical operation of a dug well (i.e., the residence where this dug well is located is still occupied). The monitoring wells installed within boreholes B13-3 to B13-10 allowed for the observations of groundwater levels in the shallow overburden during a pumping test completed using dug well Boundary-2. The geological conditions encountered at locations B13-1 through B13-10, as well as the monitoring well completion details are provided on the borehole records in Attachment A.

Groundwater Level Monitoring Program – Typical Dug Well Use

Pressure transducers/data loggers were installed in dug well Frontier-1 and nearby monitoring wells B13-1 and B13-2 completed within the surficial silty sand. The data loggers recorded groundwater levels at specified intervals (one reading every 5 minutes October 15 to 23, 2013 and one reading every 20 to 30 seconds October 23 to November 29, 2013). The data loggers were installed on October 15, 2013 (Frontier-1) and October 23, 2013 (B13-1 and B13-2) and left in place for approximately one month to observe the changes in groundwater levels under typical water supply demands for domestic use. The one month monitoring period also allowed for observation of the change in water levels in the monitoring wells and the dug well in response to local precipitation events. The data logger within the dug well also provided information on the time required to recharge the dug well after each use, and the drawdown within the well under typical use. Occasional manual measurements of groundwater levels were taken to verify and supplement the measurements recorded by the data loggers.

Groundwater Level Monitoring Program – Pumping Test

A pumping test was completed at Boundary-2 on November 5, 2013 to assess the yield and associated radius of influence for a typical dug well completed within the vicinity of the Site. This well was selected for the pumping test because it is not currently in use, so there were no issues related to the interruption of water supply at this location. The pumping test was approximately 460 minutes in duration and involved a two-step process to (1) initially lower the water level in the dug well and adjacent storage area, and (2) maintain a target constant drawdown of approximately 2.5 metres. Dug well Boundary-2 was initially pumped at 20 litres per minute (L/min) for 100 minutes to a target drawdown (2.45 metres). The pumping rate was reduced to 4 L/min for a duration of 360 minutes in order to maintain a constant level of drawdown in the dug well. The drawdown and recovery was measured in the pumping well and in the monitoring wells completed within the shallow overburden consisting of fill and silty sand (B13-3, B13-4, B13-4, B13-6, B13-8, B13-9 and B13-10) and within a 0.5 metre thick silty layer encountered at a depth of approximately 5.6 metres below ground surface (B13-5 and B13-7). Groundwater levels were collected manually and using data loggers recording groundwater levels at 30 second intervals. The data loggers continued recording groundwater levels in the pumping well and monitoring wells at the end of the 460 minute pumping test for the duration of the recovery period, approximately 2.7 days.

Data Analysis

Groundwater Level Monitoring Program – Typical Use

Groundwater levels measured within the shallow overburden during the typical operation of a dug well (Frontier-1) between October 15, 2013 and November 29, 2013 are presented in Figure 2 (data logger data, occasional manual readings and precipitation data). Manual groundwater levels measured throughout the program are presented in Table 1.

Table 1: Manual Groundwater Level Measurements Observed During Typical Use

Date	Groundwater Levels (mbgs)		
	Frontier-1	B13-1	B13-2
October 23, 2013	0.32	0.66	0.43
October 29, 2013	0.37	0.67	0.43
November 5, 2013	0.31	0.64	0.42
November 12, 2013	0.23	0.65	0.36
November 20, 2013	0.30	0.65	0.42

Note: mbgs (metres below ground surface)

The depth below ground surface to the water table shows some variation between the three monitoring locations (Frontier-1, B13-1 and B13-2); however, the observed changes in water levels associated with pumping the dug well and recharge precipitation events are consistent at all three locations (see Figure 2). Household water use is shown on Figure 2 as periodic sharp declines in the depth to groundwater level at dug well Frontier-1. As shown on Figure 2, the water taking at dug well Frontier-1 results in an associated lowering of the water levels in the nearby monitoring wells. However, the decrease in the water level in the monitoring wells is less pronounced. Groundwater levels observed in dug well Frontier-1 ranged from 0.07 to 0.55 mbgs and fluctuated on average 0.13 metres daily with household use. The recovery periods of the groundwater level within the dug well in response to pumping varied according to the duration of water use, and ranged from approximately one to two hours. At a distance of two metres from dug well Frontier-1, the groundwater level in the monitoring wells varied by typically less than five centimetres as a result of water taking for household use. Based on these observations, it is interpreted that the radius of influence associated with the water taking at dug well Frontier-1 would be less than 10 metres around the well.

As shown on Figure 2, peak groundwater levels in all three monitoring locations coincide with precipitation recharge events which occurred on October 17, 19 and 26, 2013 and November 1, 9 and 18, 2013, based on daily precipitation data from the Environment Canada climatic station, Ottawa CDA (6105976). The spikes in groundwater levels associated with precipitation events occurred during or shortly after the precipitation events indicating that recharge for the well occurs locally (i.e., close to the well). The groundwater spikes associated with local precipitation events typically dissipate quickly.

Groundwater Level Monitoring Program – Pumping Test

A two-step pumping test was carried out at dug well Boundary-2 on November 5, 2013. Dug well Boundary-2 was initially pumped at 20 litres per minute (L/min) for 100 minutes to a target drawdown (2.45 metres) in order to dewater the wellbore storage in the dug well. The pumping rate was then reduced to 4 L/min for a duration of 360 minutes in order to maintain a constant level of drawdown in the dug well. After a cumulative 460 minutes of pumping, the final drawdown in dug well Boundary-2 measured 2.54 metres (See Figures 3 and 4). The drawdown and recovery was measured in the pumped well and in the monitoring wells completed within the shallow overburden consisting of fill and silty sand (B13-3, B13-4, B13-4, B13-6, B13-8, B13-9 and B13-10) and in the silty layer (B13-5 and B13-7). Figure 4 presents a cross-section showing the geological conditions encountered in the vicinity of dug well Boundary-2, the locations of the monitoring well installations, the initial groundwater levels prior to starting the pumping test and the final groundwater levels at the end of the pumping test. The water table prior to pumping is flat, which consistent with the groundwater level monitoring completed at the Site. There is a slight downward gradient between the fill/silty sand layer and the silty layer encountered at approximately 5.6 metres below ground surface. Figure 4 shows the symmetrical shape of the drawdown cone associated with the pumping test.

Table 2 below presents a compilation of the achieved drawdowns on November 5, 2013 after 100 minutes of pumping at 20 L/min, followed by 360 minutes of pumping at 4 L/min and percent recovery data collected on November 8, 2013.

Table 2: Drawdown and Water Levels Observed During Boundary-2 Pumping Test

Location	Radial Distance to Pumping Well (m)	Initial Groundwater Level (mbgs)	November 5, 2013 Pumping Duration = 100 min Pumping Rate = 20 L/min		November 5, 2013 Pumping Duration = 360 min (460 min cumulative) Pumping Rate = 4 L/min		November 8, 2013 Recovery Period	
			Water Level (mbgs)	Drawdown (mbgs)	Water Level (mbgs)	Drawdown (mbgs)	Water Level (mbgs)	Percent Recovered
B13-3	8	0.66	0.78	0.12	0.94	0.27	0.71	81
B13-4	5	0.65	0.89	0.24	1.10	0.38	0.70	87
B13-5	3	1.01	1.01	0	1.01	0	0.99	-
B13-6	3	0.67	1.08	0.41	1.34	0.57	0.71	93
Bou-2	0	0.53	2.98	2.45	3.07	2.54	0.66	95

Location	Radial Distance to Pumping Well (m)	Initial Groundwater Level (mbgs)	November 5, 2013 Pumping Duration = 100 min Pumping Rate = 20 L/min		November 5, 2013 Pumping Duration = 360 min (460 min cumulative) Pumping Rate = 4 L/min		November 8, 2013 Recovery Period	
			Water Level (mbgs)	Drawdown (mbgs)	Water Level (mbgs)	Drawdown (mbgs)	Water Level (mbgs)	Percent Recovered
B13-7	1	0.97	0.97	0	0.97	0	0.99	-
B13-8	2	0.64	0.96	0.32	1.21	0.67	0.69	93
B13-9	5	0.65	0.78	0.13	1.03	0.45	0.70	89
B13-10	8	0.64	0.73	0.09	0.91	0.28	0.67	89

Note: Bou-2 = Dug Well Boundary-2

Drawdown related to the pumping was observed at all monitoring wells completed within the shallow overburden wells (B13-3, B13-4, B13-6, B13-8, B13-9 and B13-10). No response to pumping was observed at monitoring wells B13-5 and B13-7 completed within the silty layer, situated at approximately 5.6 to 6.2 metres depth. The groundwater level in dug well Boundary-2 recovered by 95 percent approximately 2.7 days following the end of the pumping test, whereas groundwater levels within the shallow overburden wells recovered between 81 and 93 percent as shown in Table 2.

The transmissivity of the surficial silty sand layer was estimated by applying the Papadopulos-Cooper solution to the observed drawdown and recovery data. The following assumptions were made in support of the Papadopulos-Cooper analysis of the aquifer test data:

- The surficial silty sand layer is confined, isotropic, homogenous, of uniform thickness and has an infinite areal extent;
- Flow to dug well Boundary-2 is horizontal; and,
- Dug Well Boundary-2 fully penetrates the shallow overburden aquifer.

Using the Papadopulos-Cooper solution, the transmissivity of the surficial sand layer is estimated to be between 1.3 and 2.6 m^2/day. The Papadopulos-Cooper solution accounts for wellbore storage effects in a large-diameter (finite-diameter) pumping well; however, it is intended for a confined aquifer. The silty sand providing water to dug well Boundary-2 is considered unconfined; however, due to the relatively short duration of the pumping test (460 minutes), the unconfined behavior of the aquifer (release of water from storage reducing the rate of drawdown) was not observed. As such, the Papadopulos-Cooper solution provides the best estimate of transmissivity based on the available data. The Papadopulos-Cooper analysis of the pumping test is presented graphically on Figure 5. Assuming a saturated aquifer thickness of 3.7 metres, the hydraulic conductivity of the surficial silty sand within the vicinity of dug well Boundary-2 is approximately $4x10^{-6}$ to $8x10^{-6}$ metres per second.

The Thiem-Jacob distance-drawdown equation was used to estimate the radius of influence of the pumping test. The radius of influence associated with pumping dug well Boundary-2 at 20 L/min for 100 minutes is estimated to be 10 metres (see Figure 6). The radius of influence associated with the combined two-step pumping rate duration of 460 minutes is estimated to be up to 20 metres (see Figure 7).

Discussion

The surficial silty sand layer is characterized as moderately transmissive based on the estimated hydraulic conductivity and the radius of influence observed during the groundwater level monitoring program at dug well Frontier-1 and the pumping test at dug well Boundary-2. The range in hydraulic conductivity values of the fill/silty sand layer estimated from the pumping test at dug well Boundary-2 are consistent with the results of slug tests completed within the shallow overburden at the Site. Based on water level observations made during precipitation events, it is interpreted that the recharge for dug wells in the vicinity of the Site is local (i.e., close to the well).

The results of the pumping test at dug well Boundary-2 suggest that dug wells completed within the shallow overburden have the ability to sustain a pumping rate of approximately 4 L/min (following the removal of approximately 2,000 Litres of wellbore storage which contributes significantly to the ability of the dug well to provide a water supply). Under typical use, the radius of influence (area of drawdown associated with the water taking) is interpreted to be less than 10 metres. Based on the pumping test at dug well Boundary-2, when the wellbore storage is rapidly removed and the well is pumped for an additional six hours at close to the maximum sustainable rate (i.e., a significantly greater water demand than observed under typical use), the associated radius of influence was approximately 20 metres.

GOLDER ASSOCIATES LTD.

Dale Holtze

Dale Holtze, M.Sc., P.Geo.
Hydrogeologist

Jaime Oxtobee, M.Sc., P.Geo.
Senior Hydrogeologist, Associate

DH/JPAO/sg
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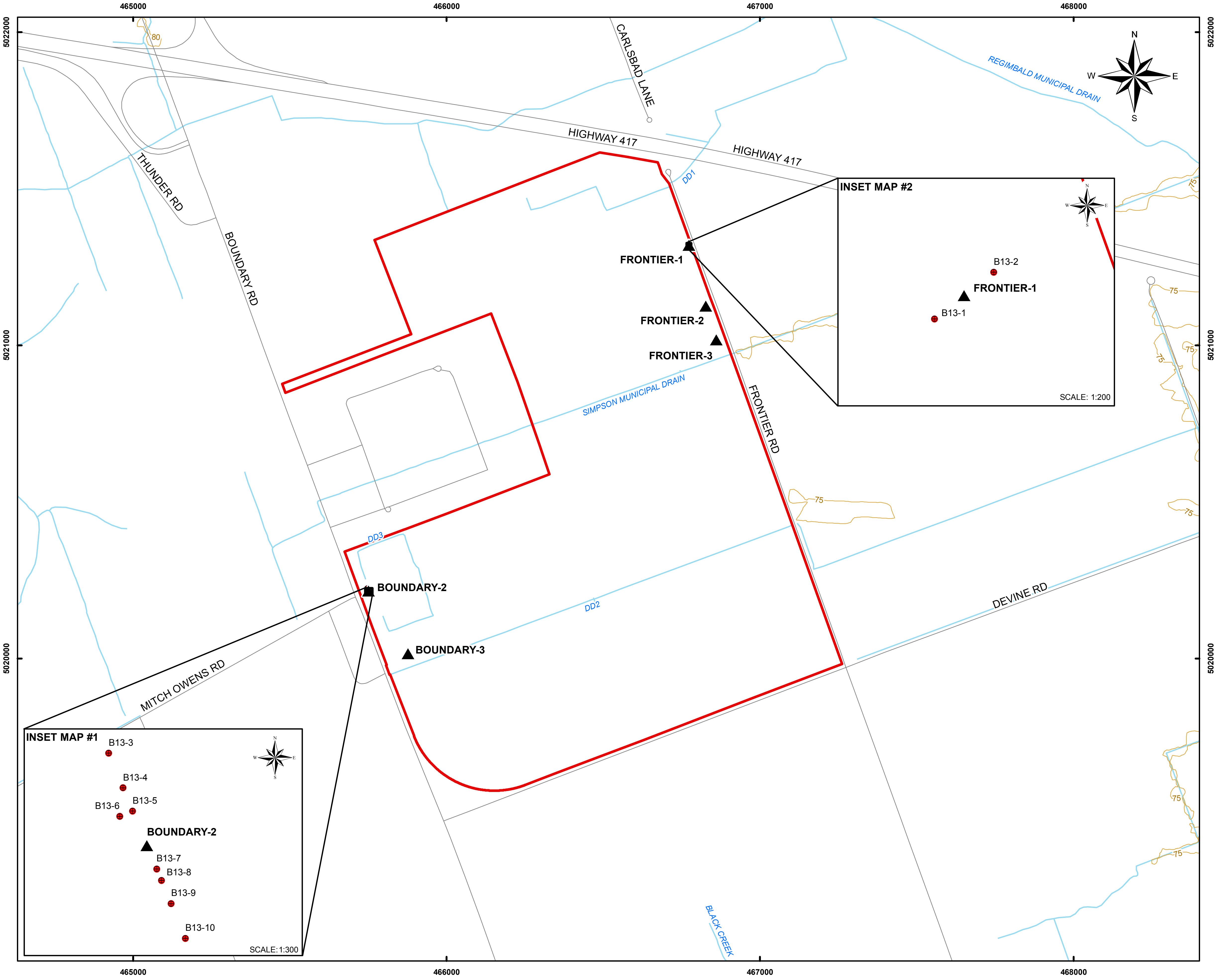
Attachments: Figure 1 – Site Plan
Figure 2 – Groundwater Level Monitoring Program at Dug Well Frontier-1, B13-1 and B13-2
Figure 3 – Dug Well Boundary-2 Pumping Test Groundwater Levels
Figure 4 – Cross-Section: Dug Well Boundary-2 Pumping Test
Figure 5 – Papadopulos-Cooper Pumping Test Analysis
Figure 6 – Theim-Jacob Distance Drawdown Plot at T=100 min
Figure 7 – Theim-Jacob Distance Drawdown Plot at T=460 min
Attachment A – Borehole Records



LEGEND

▲	DUG WELL LOCATION CONSIDERED AS PART OF DUG WELL ASSESSMENT
●	GOLDER DUG WELL ASSESSMENT MONITORING LOCATION
—	ROAD
—	CONTOUR LINE, (5m)
—	SURFACE WATER FEATURE
▨	WATER AREA
☐	PROPERTY BOUNDARY

200 100 0 200

SCALE 1:12,000 METRES

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT.

REFERENCE

LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2012.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18

PROJECT

CAPITAL REGION RESOURCE
RECOVERY CENTRE

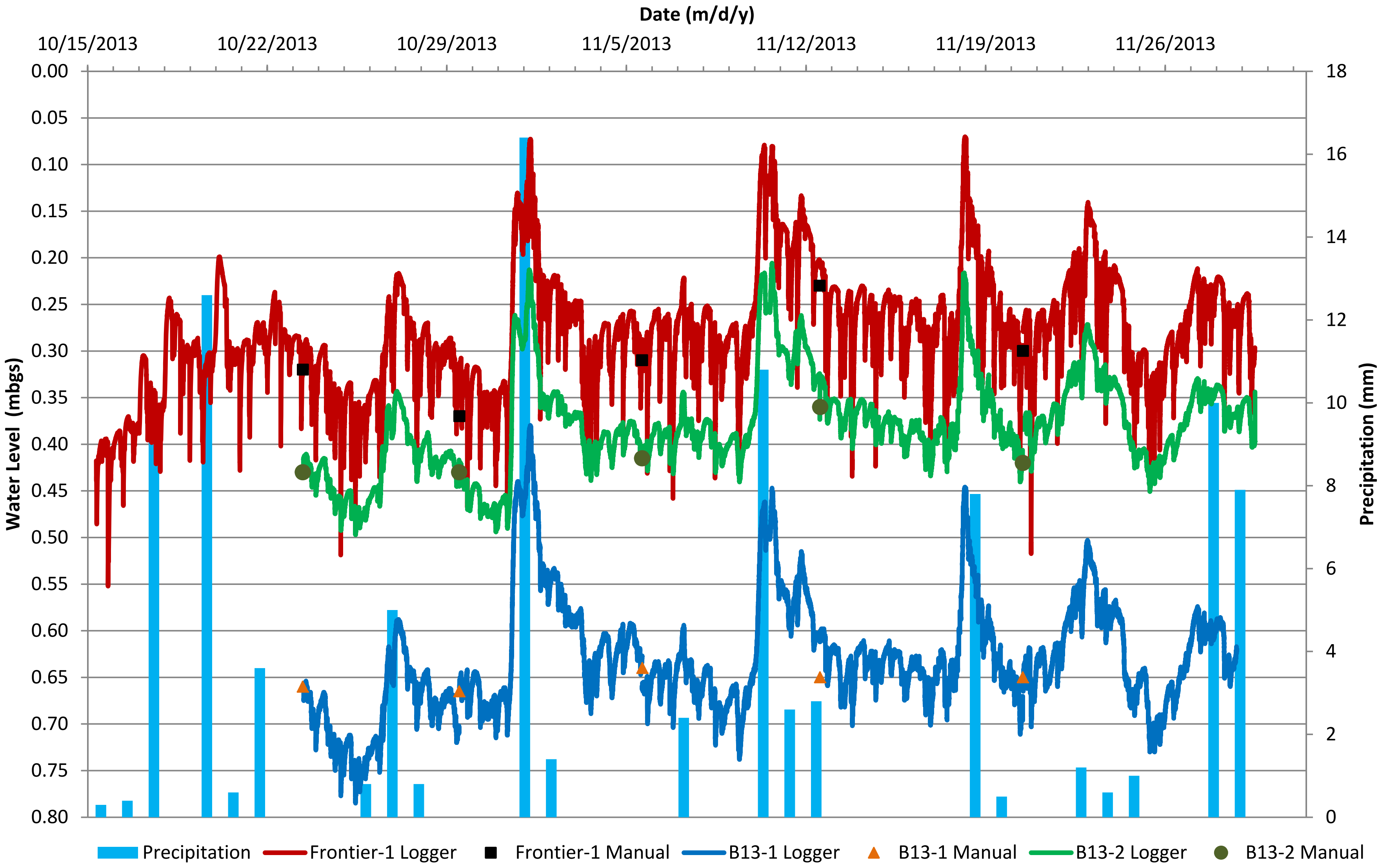
TITLE

SITE PLAN

Golder Associates

PROJECT No. 12-1125-0045			SCALE AS SHOWN	REV. 0
DESIGN	JPAO	NOV. 2013	FIGURE 1	
GIS	BR	NOV. 2013		
CHECK	DH	NOV. 2013		
REVIEW	JPAO	NOV. 2013		

Path: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\GIS\MXDs\12-1125-0045\Working\Phase1100\1211250045-1100-1-SitePlan.mxd



Golder Associates

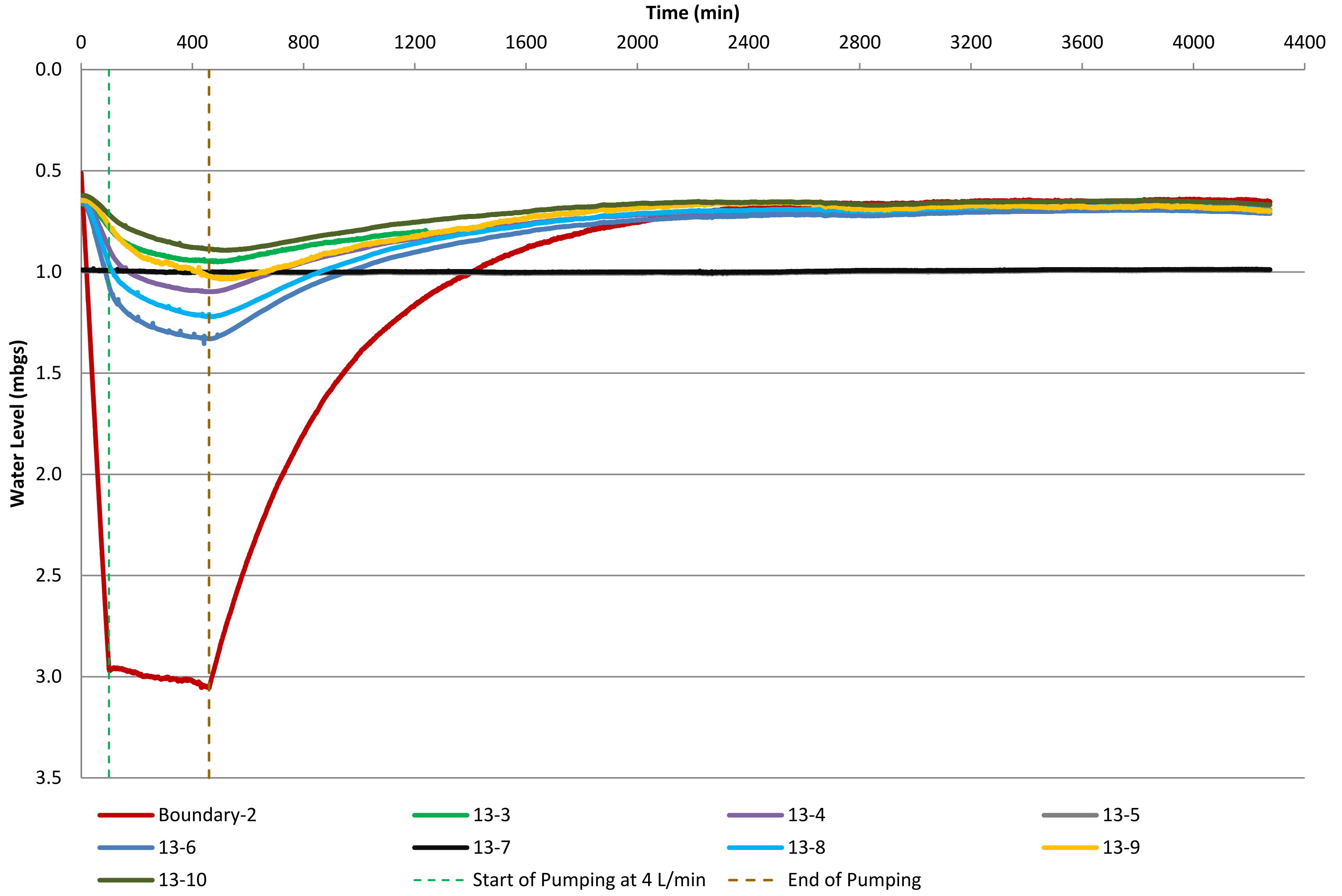
PROJECT No. 12-1125-0045

Created by	DH	NOV 2013
Reviewed by	JPAO	NOV 2014

PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
Groundwater Level Monitoring Program at
Dug Well Frontier-1, B13-1 and B13-2

FIGURE 2



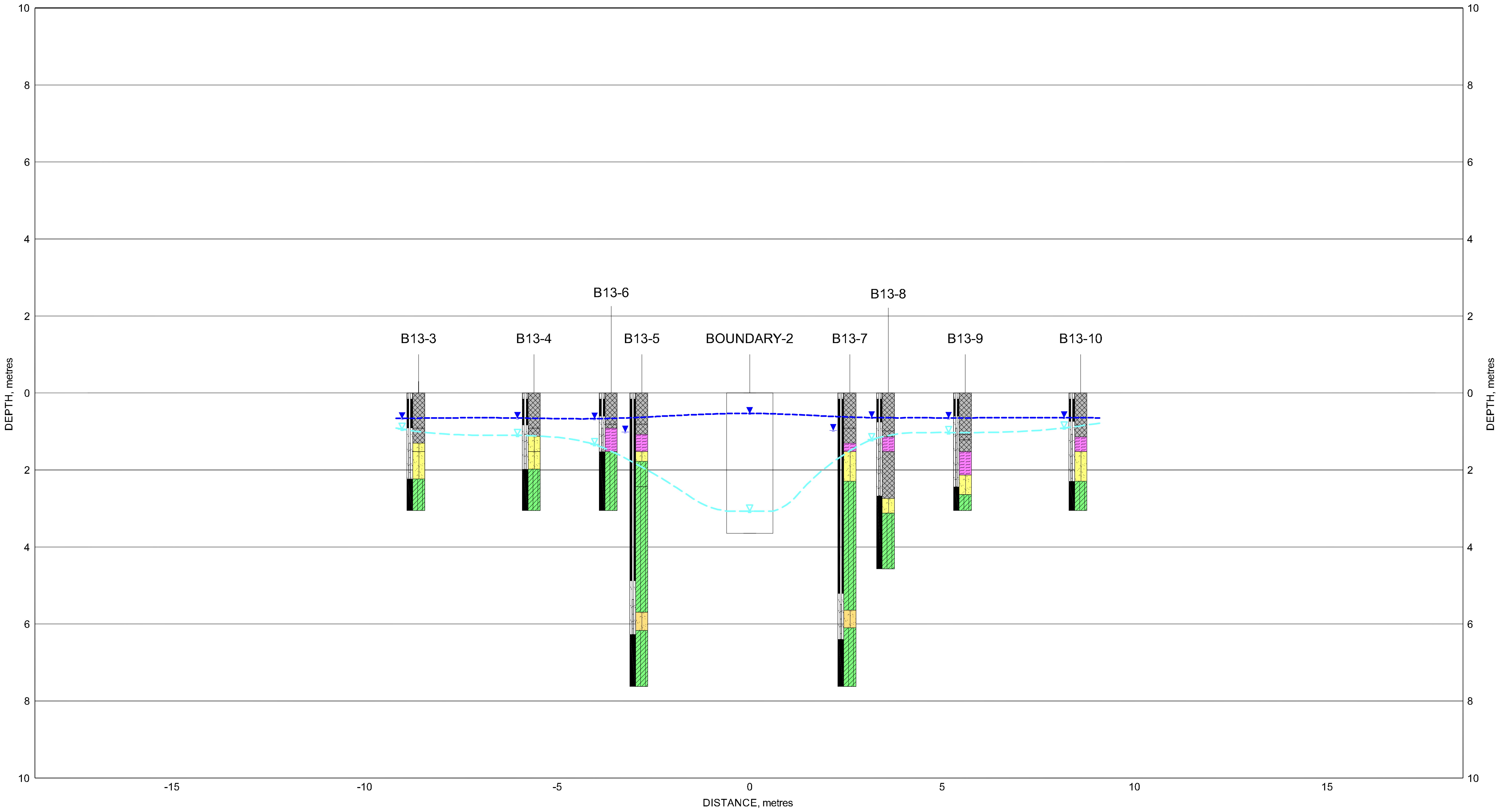
Golder Associates

PROJECT No. 12-1125-0045		
Created by	DH	NOV 2013
Reviewed by	JPAO	NOV 2014

PROJECT
ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
Dug Well Boundary-2 Pumping Test Groundwater Levels

FIGURE 3



SUBSURFACE STRATIGRAPHY

🟪 TOPSOIL
▩ FILL
🟩 SILTY CLAY
🟨 SILTY SAND
🟧 SILTY LAYER

LEGEND

▼ INITIAL GROUNDWATER LEVEL
▽ FINAL GROUNDWATER LEVELS AT THE END OF THE PUMPING TEST
- - - INITIAL GROUNDWATER LEVEL
— — FINAL GROUNDWATER LEVEL AT END OF PUMPING TEST

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 12-1125-0045-1100

2 0 2
SCALE 1:100 METRES

Golder Associates
Ottawa, Ontario, Canada

SCALE	1:100
DATE	Nov. 2013
DESIGN	DH
CAD	JM
CHECK	DH
REVIEW	JPAO

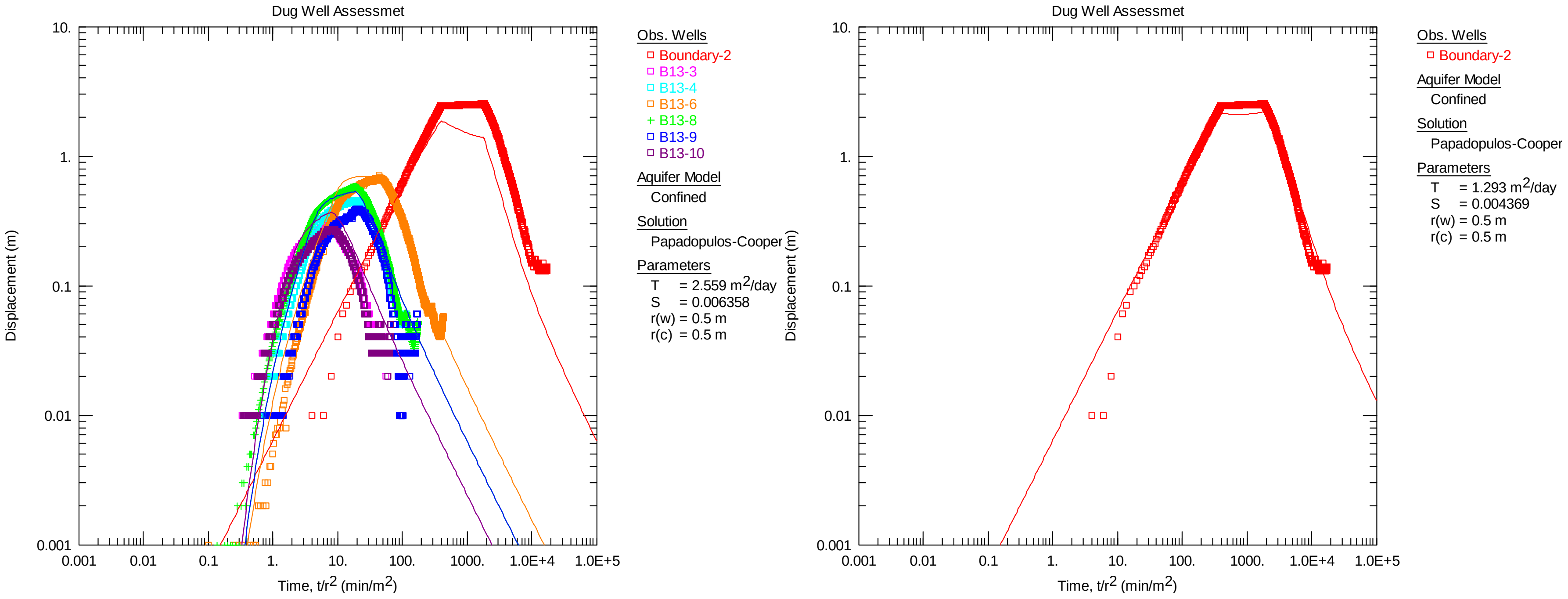
FILE No. 1211250045-1100-04.dwg
PROJECT No. 12-1125-0045 REV.

TITLE
CROSS-SECTION: DUG WELL BOUNDARY-2 PUMPING TEST

CAPITAL REGION RESOURCE RECOVERY CENTRE

FIGURE
4

PLOT DATE: November 18, 2014
FILENAME: N:\Active\Spatial_IM\Miller_Paving_Ltd\CRRRC\ACAD\Phase 1100\1211250045-1100-04.dwg



Golder Associates

PROJECT No. 12-1125-0045		
Created by	DH	NOV 2013
Reviewed by	JPAO	NOV 2014

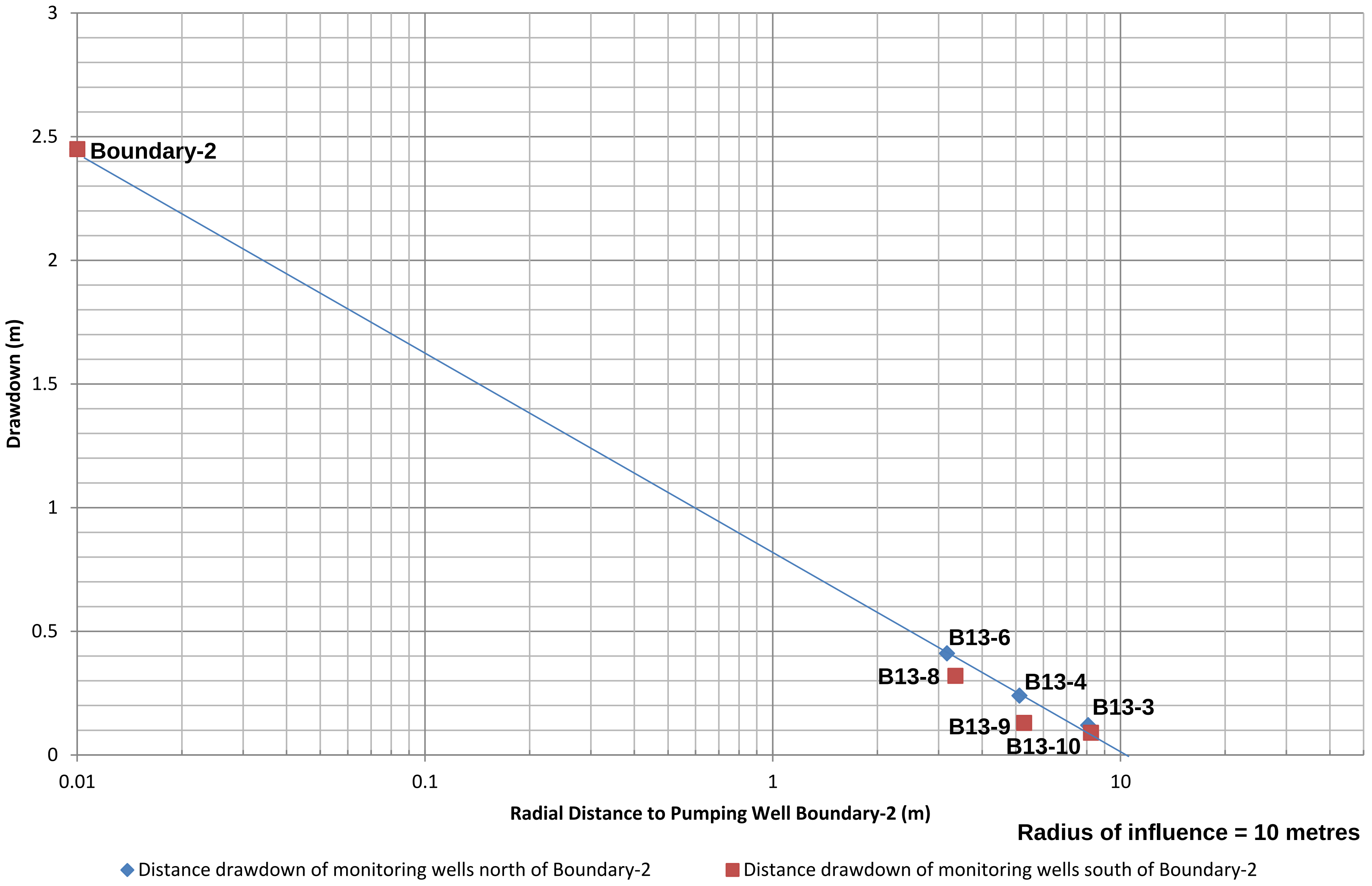
PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Papadopulos-Cooper Pumping Test Analysis

FIGURE 5



PROJECT No. 12-1125-0045			
Created by	DH	NOV 2013	
Reviewed by	JPAO	NOV 2014	

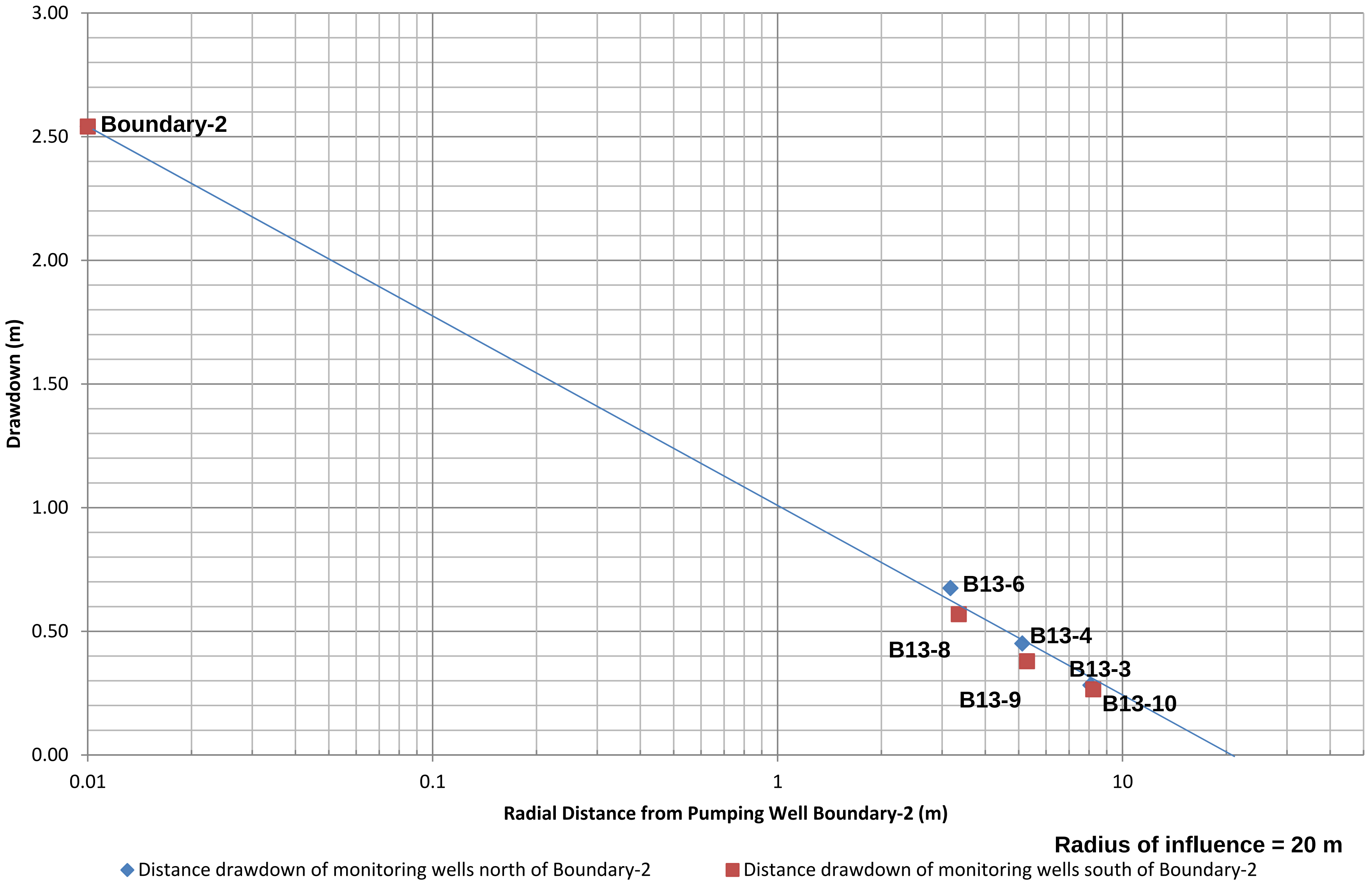
PROJECT

ENVIRONMENTAL ASSESSMENT OF THE
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

Theim-Jacob Distance Drawdown Plot at T=100 min

FIGURE 6



Golder Associates	PROJECT No. 12-1125-0045			PROJECT ENVIRONMENTAL ASSESSMENT OF THE CAPITAL REGION RESOURCE RECOVERY CENTRE	FIGURE 7
	Created by	DH	NOV 2013	TITLE Theim-Jacob Distance Drawdown Plot at T = 460 min	
	Reviewed by	JPAO	NOV 2014		

ATTACHMENT A

Borehole Records

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures, and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open-ended, driven or pushed tube samplers
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample
DT	Dual tube sample
DD	Diamond drilling

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split spoon sampler for a distance of 300 mm (12 in.).

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive an uncased 50 mm (2 in.) diameter, 60^0 cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60^0 conical tip and a projected end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	**N** Blows/300 mm Or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

	C_u or S_u	
Consistency	kPa	Psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	Over 200	Over 4,000

IV. SOIL TESTS

w	Water content
w_p or PL	Plastic limited
w_1 or LL	Liquid limit
C	Consolidaiton (oedometer) test
CHEM	Chemical analysis (refer to text)
CID	Consolidated isotropically drained triaxial test[1]
CIU	Consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	Relative density
DS	Direct shear test
Gs	Specific gravity
M	Sieve analysis for particle size
MH	Combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	Organic content test
SO_4	Concentration of water-soluble sulphates
UC	Unconfined compression test
UU	Unconsolidated undrained triaxial test
V	Field vane test (LV-laboratory vane test)
γ	Unit weight

Note: [1] Tests which are anisotropically consolidated prior shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$ x or log x	logarithm of x to base 10
g	acceleration due to gravity
t	time
FOS	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma'$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial vertical effective overburden stress
$\sigma_1\sigma_2\sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3) / 3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_1 or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity Index $= (w_1 - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_c	consistency index $= (w_1 - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (overconsolidated range)
C_s	swelling index
C_α	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	overconsolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p or τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u or s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3) / 2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3) / 2$
q	$(\sigma_1 - \sigma_3) / 2$ or $(\sigma'_1 - \sigma'_3) / 2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:

[1] $\tau = c' + \sigma' \tan \phi'$

[2] shear strength = (compressive strength) / 2

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-1

SHEET 1 OF 1

LOCATION: N 5020218.07 ;E 465752.57

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 21, 2013

DATUM: Geodetic

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○: 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

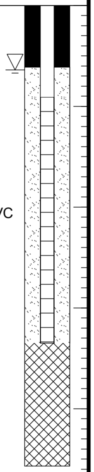
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl: 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m
	GROUND SURFACE					
Geoprobe	Brown silty sand, with organic matter (TOPSOIL)		0.00			
	Intermixed brown silty sand and red brown silty clay (Probable Fill)		0.46	1	53 mm TUBE	-
	Red brown SILTY CLAY		2.18			
	Intermixed brown SILTY SAND and red brown SILTY CLAY		2.44	2	53 mm TUBE	-
	Grey SILTY SAND					
	Red grey SILTY CLAY		3.65	3	53 mm TUBE	-
	End of Borehole		4.57			

MON. WELL



Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Cave

WL in Screen at 0.64 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: DH

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 11/18/14 JM

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-2

SHEET 1 OF 1

LOCATION: N 5020213.93 ;E 465749.43

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 21, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

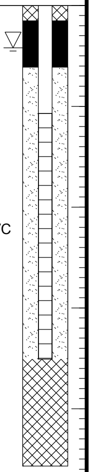
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE				
0	Geoprobe	Brown silty sand, with organic matter (TOPSOIL)	0.00			
		Red brown silty sand (Probable Fill)	0.30	1	53 mm TUBE	-
1		Grey fine sand, trace silt (Probable Fill)	1.22	2	53 mm TUBE	-
4		Red grey SILTY CLAY	3.81	3	53 mm TUBE	-
		End of Borehole	4.57			

MON. WELL



Native Backfill

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Cave

WL in Screen at 0.42 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: DG

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-3

SHEET 1 OF 1

LOCATION: N 5020223.82 ;E 465747.43

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

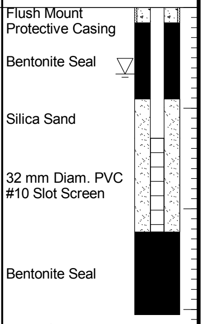
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m
GROUND SURFACE				
Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-
Grey brown sandy silt, trace clay (FILL)	0.91			
Grey brown SILTY SAND	1.30			
Brown SILTY SAND	1.52			
Red grey SILTY CLAY	2.23	2	53 mm TUBE	-
End of Borehole	3.05			

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



WL in Screen at 0.66 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE 1 : 75

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-4

SHEET 1 OF 1

LOCATION: N 5020221.09 ;E 465748.67

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2}; WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									MON. WELL
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)		0.00	1	53 mm TUBE	-				Flush Mount Protective Casing Bentonite Seal ▽
1		Brown silty fine sand, trace medium sand (FILL)		0.91							Silica Sand
		Grey SILTY SAND		1.12							32 mm Diam. PVC #10 Slot Screen
		Brown SILTY SAND		1.52							
2		Red grey SILTY CLAY		1.98	2	53 mm TUBE	-				Bentonite Seal
3		End of Borehole		3.05							WL in Screen at 0.65 m depth below ground surface on Nov. 5, 2013
4											
5											
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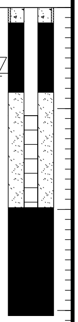
12											
13											
14											
15											



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-5

SHEET 1 OF 1

LOCATION: N 5020219.28 ;E 465749.50
INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

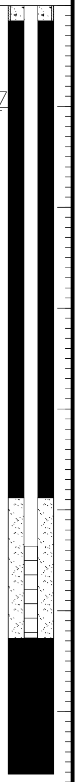
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80
SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○; 20 40 60 80
HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; 20 40 60 80

BORING METHOD: Geoprobe

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	
Grey crushed stone (ENGINEERED FILL)	0.00
Brown fine sand, trace gravel (FILL)	0.81
Dark grey to black silty fine sand to sandy silt, trace gravel and organic matter (TOPSOIL)	1.07
Grey SILTY SAND	1.52
Mottled red brown to grey brown SILTY CLAY	1.78
Red grey SILTY CLAY	2.44
Grey SILTY SAND	5.69
Red grey SILTY CLAY	6.17
End of Borehole	7.62

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	53 mm TUBE	-
2	53 mm TUBE	-
3	53 mm TUBE	-
4	53 mm TUBE	-
5	53 mm TUBE	-

PIEZOMETER OR STANDPIPE INSTALLATION: MON. WELL



Flush Mount Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Bentonite Seal

WL in Screen at 1.01 m depth below ground surface on Nov. 5, 2013

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 11/18/14 JM

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: HEC
CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-6

SHEET 1 OF 1

LOCATION: N 5020218.82 ;E 465748.50

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-8} 10^{-6} 10^{-4} 10^{-2}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									MON. WELL
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)		0.00							Flush Mount Protective Casing Bentonite Seal
					1	53 mm TUBE	-				Silica Sand
1		Brown silty fine sand, trace medium sand, trace organic clay tile (FILL)		0.91							32 mm Diam. PVC #10 Slot Screen
		Dark grey to black silty fine sand, trace gravel, wood and organic matter (TOPSOIL)									
		Grey brown to red brown SILTY CLAY		1.52							
2					2	53 mm TUBE	-				Bentonite Seal
3		End of Borehole		3.05							WL in Screen at 0.67 m depth below ground surface on Nov. 5, 2013
4											
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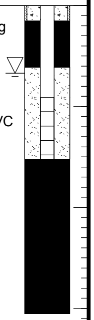
15											



DEPTH SCALE
1 : 75

LOGGED: HEC
CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-7

SHEET 1 OF 1

LOCATION: N 5020213.64 ;E 465752.08

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

BORING METHOD: Geoprobe

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

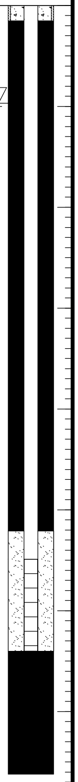
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
GROUND SURFACE				
Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-
Brown to grey silty fine sand to sandy silt (FILL)	0.91			
Grey silty fine sand, trace wood and organic matter (TOPSOIL)	1.30			
Brown to grey brown SILTY SAND	1.52	2	53 mm TUBE	-
Red brown to grey SILTY CLAY, with sand seams	2.29			
		3	53 mm TUBE	-
		4	53 mm TUBE	-
Grey SILTY fine SAND	5.64			
Red grey SILTY CLAY	6.10	5	53 mm TUBE	-
End of Borehole	7.62			

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



Flush Mount Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Bentonite Seal

WL in Screen at 0.97 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-8

SHEET 1 OF 1

LOCATION: N 5020212.73 ;E 465752.50

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

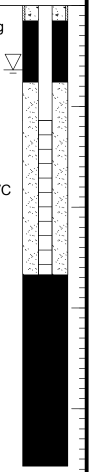
WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE				
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-
1		Brown silty fine sand (FILL)	0.99			
		Grey brown silty fine sand, trace clay and black silt (TOPSOIL)	1.14			
		Red brown SILTY CLAY, some black silt (FILL)	1.52	2	53 mm TUBE	-
2						
3		Brown SILTY SAND	2.74			
		Red grey SILTY CLAY, trace grey silty fine sand seams	3.12	3	53 mm TUBE	-
4						
		End of Borehole	4.57			

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL



Flush Mount Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Bentonite Seal

WL in Screen at 0.64 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-9

SHEET 1 OF 1

LOCATION: N 5020210.91 ;E 465753.33

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-8} 10^{-6} 10^{-4} 10^{-2} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE									MON. WELL
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)		0.00	1	53 mm TUBE	-				Flush Mount Protective Casing Bentonite Seal Silica Sand
1		Brown fine sand, trace silt (FILL)		1.07							
		Brown to grey silty fine sand, some gravel, trace wood, plastic and glass (FILL)		1.22							32 mm Diam. PVC #10 Slot Screen
2		Black to grey brown silty fine sand, some organic matter (TOPSOIL)		1.52							
		Interbedded grey brown SILTY SAND and red brown SILTY CLAY		2.13	2	53 mm TUBE	-				
		Red brown SILTY CLAY		2.64							Bentonite Seal
3		End of Borehole		3.05							WL in Screen at 0.65 m depth below ground surface on Nov. 5, 2013
4											
5											
6											
7											
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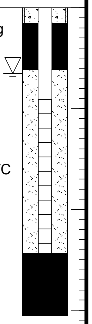
9											
10											
11											
12											
13											
14											
15											



DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

PROJECT: 12-1125-0045-1100

RECORD OF BOREHOLE: B13-10

SHEET 1 OF 1

LOCATION: N 5020208.18 ;E 465754.57

INCLINATION: -90° AZIMUTH: ---

BORING DATE: October 28, 2013

DATUM: Geodetic

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○: 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-8} 10^{-6} 10^{-4} 10^{-2}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl: 20 40 60 80

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m
		GROUND SURFACE				
0	Geoprobe	Grey crushed stone (ENGINEERED FILL)	0.00	1	53 mm TUBE	-
1		Brown silty fine sand, trace clay tile (FILL)	0.84			
		Black to grey silty fine sand, trace organic matter (TOPSOIL)	1.14			
2		Brown fine SILTY SAND	1.52	2	53 mm TUBE	-
		Red brown SILTY CLAY	2.29			
3		End of Borehole	3.05			

PIEZOMETER OR STANDPIPE INSTALLATION

MON. WELL

Flush Mount Protective Casing

Bentonite Seal

Silica Sand

32 mm Diam. PVC #10 Slot Screen

Bentonite Seal

WL in Screen at 0.64 m depth below ground surface on Nov. 5, 2013

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: HEC

CHECKED: DH

CRRRC-SOIL 1211250045.GPJ GAL-MIS.GDT 11/18/14 JM

APPENDIX N

Laboratory and In-Situ Hydraulic Conductivity Testing Results

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD)

SAMPLE IDENTIFICATION

PROJECT NUMBER	12-1125-0045	SAMPLE	1
PROJECT TITLE		SAMPLE DEPTH, m	2.13-2.68
BOREHOLE NUMBER	12-03-03	DATE	03/12/2013

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	7.66	UNIT WEIGHT, kN/m^3	15.44
SAMPLE DIAMETER, cm	6.90	DRY UNIT WEIGHT, kN/m^3	8.71
SAMPLE AREA, cm^2	37.40	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	286.59	VOLUME OF SOLIDS, cm^3	94.24
TOTAL MASS, g	451.30	VOLUME OF VOIDS, cm^3	192.34
DRY MASS, g	254.46	VOID RATIO	2.04
WATER CONTENT, %	77.4		

SATURATION STAGE

CELL PRESSURE, kPa	210	EFFECTIVE CONFINING STRESS, kPa	5
HEAD PRESSURE, kPa	205	DURATION, min	2,790
BACK PRESSURE, kPa	205	B COEFFICIENT	0.99

CONSOLIDATION STAGE

CELL PRESSURE, kPa	226	EFFECTIVE CONFINING STRESS, kPa	21
HEAD PRESSURE, kPa	205	DURATION, min	1,425
BACK PRESSURE, kPa	205	VOLUME CHANGE, cm^3	2.7
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	7.64	SAMPLE AREA, cm^2	37.17
SAMPLE DIAMETER, cm	6.88	SAMPLE VOLUME, cm^3	283.89

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	241	EFFECTIVE CONFINING STRESS, kPa	21
HEAD PRESSURE, kPa	220	DURATION, min	4409.0
BACK PRESSURE, kPa	205	HYDRAULIC GRADIENT, i	20

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	7.64	UNIT WEIGHT, kN/m^3	15.40
SAMPLE DIAMETER, cm	6.88	DRY UNIT WEIGHT, kN/m^3	8.79
SAMPLE AREA, cm^2	37.17	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	283.89	VOLUME OF SOLIDS, cm^3	94.24
TOTAL MASS, g	445.80	VOLUME OF VOIDS, cm^3	189.65
DRY MASS, g	254.46	VOID RATIO	2.01
WATER CONTENT, %	75.2		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	4409.0
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	33.6
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	37.6
HYDRAULIC CONDUCTIVITY (INFLOW) (cm/s)	1.71E-07
HYDRAULIC CONDUCTIVITY (OUTFLOW) (cm/s)	1.91E-07
HYDRAULIC CONDUCTIVITY, K, cm/s	**1.81E-07**

NOTES:

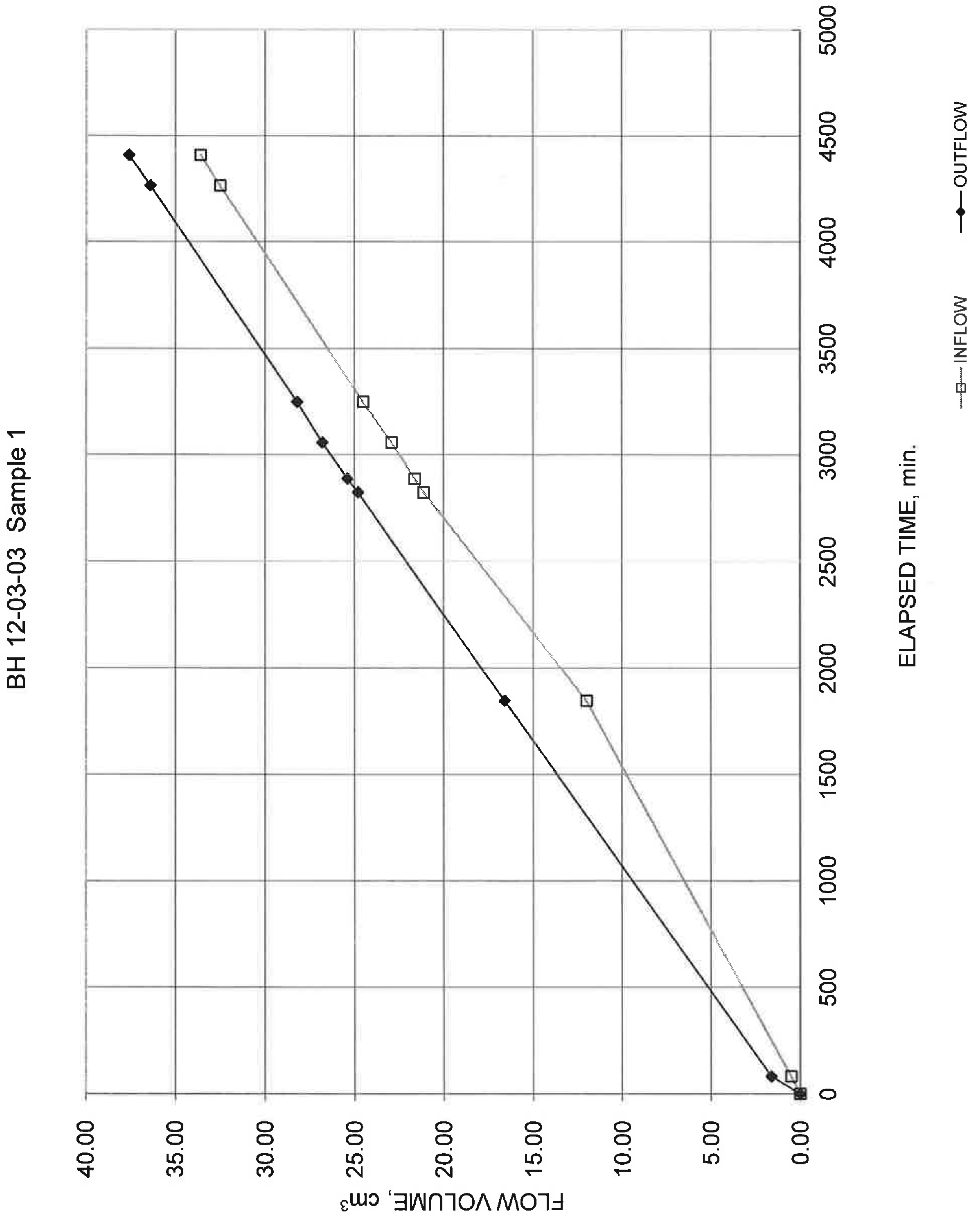
PERMEANT FLUID	Deaired tap water

Prepared By:RD

Golder Associates

Checked By:

HYDRAULIC CONDUCTIVITY TEST



Project No: 12-1125-0045
Prepared By: RD

Golder Associates

Checked By:

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD)

SAMPLE IDENTIFICATION

PROJECT NUMBER	12-1125-0045	SAMPLE	3
PROJECT TITLE		SAMPLE DEPTH, m	11.43-12.00
BOREHOLE NUMBER	12-02-03	DATE	03/01/2013

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	7.48	UNIT WEIGHT, kN/m^3	16.07
SAMPLE DIAMETER, cm	6.92	DRY UNIT WEIGHT, kN/m^3	9.94
SAMPLE AREA, cm^2	37.61	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	281.32	VOLUME OF SOLIDS, cm^3	105.57
TOTAL MASS, g	460.90	VOLUME OF VOIDS, cm^3	175.75
DRY MASS, g	285.03	VOID RATIO	1.66
WATER CONTENT, %	61.7		

SATURATION STAGE

CELL PRESSURE, kPa	350	EFFECTIVE CONFINING STRESS, kPa	5
HEAD PRESSURE, kPa	345	DURATION, min	4,140
BACK PRESSURE, kPa	345	B COEFFICIENT	0.96

CONSOLIDATION STAGE

CELL PRESSURE, kPa	416	EFFECTIVE CONFINING STRESS, kPa	71
HEAD PRESSURE, kPa	345	DURATION, min	1,485
BACK PRESSURE, kPa	345	VOLUME CHANGE, cm^3	5.5
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	7.43	SAMPLE AREA, cm^2	37.12
SAMPLE DIAMETER, cm	6.87	SAMPLE VOLUME, cm^3	275.85

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	431	EFFECTIVE CONFINING STRESS, kPa	71
HEAD PRESSURE, kPa	360	DURATION, min	4223.0
BACK PRESSURE, kPa	345	HYDRAULIC GRADIENT, i	21

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	7.43	UNIT WEIGHT, kN/m^3	16.27
SAMPLE DIAMETER, cm	6.87	DRY UNIT WEIGHT, kN/m^3	10.13
SAMPLE AREA, cm^2	37.12	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	275.85	VOLUME OF SOLIDS, cm^3	105.57
TOTAL MASS, g	457.60	VOLUME OF VOIDS, cm^3	170.28
DRY MASS, g	285.03	VOID RATIO	1.61
WATER CONTENT, %	60.5		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	4223.0
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	17.3
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	18.0
HYDRAULIC CONDUCTIVITY (INFLOW) (cm/s)	8.91E-08
HYDRAULIC CONDUCTIVITY (OUTFLOW) (cm/s)	9.30E-08
HYDRAULIC CONDUCTIVITY, K, cm/s	**9.10E-08**

NOTES:

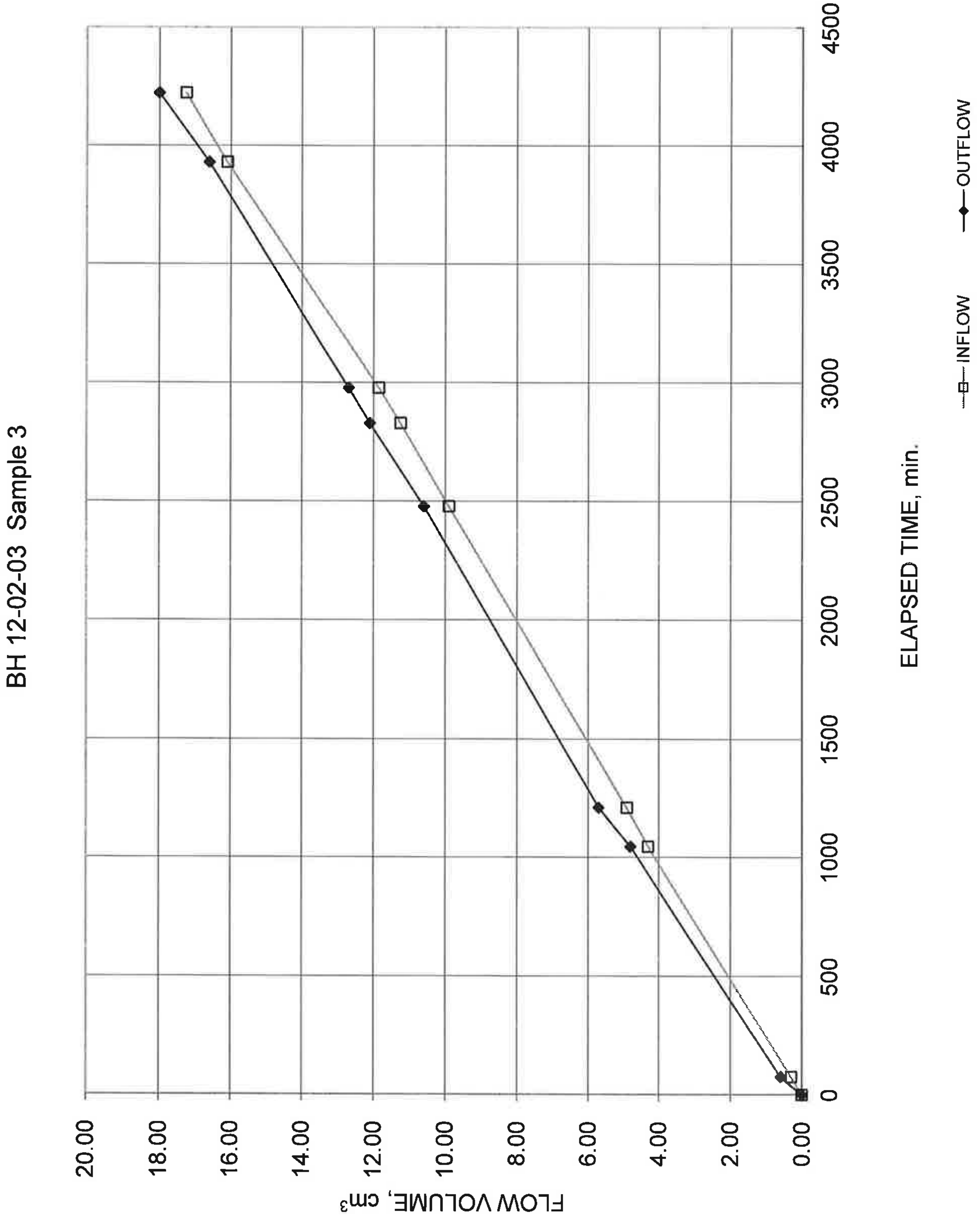
PERMEANT FLUID: Deaired tap water

Prepared By:RD

Golder Associates

Checked By:

HYDRAULIC CONDUCTIVITY TEST



Project No: 12-1125-0045
Prepared By: RD

Golder Associates

Checked By:

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD)

SAMPLE IDENTIFICATION

PROJECT NUMBER	12-1125-0045	SAMPLE	6
PROJECT TITLE		SAMPLE DEPTH, m	21.26-21.82
BOREHOLE NUMBER	12-01-03	DATE	03/01/2013

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	6.98	UNIT WEIGHT, kN/m^3	15.53
SAMPLE DIAMETER, cm	6.94	DRY UNIT WEIGHT, kN/m^3	9.13
SAMPLE AREA, cm^2	37.84	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	264.26	VOLUME OF SOLIDS, cm^3	91.17
TOTAL MASS, g	418.60	VOLUME OF VOIDS, cm^3	173.09
DRY MASS, g	246.16	VOID RATIO	1.90
WATER CONTENT, %	70.1		

SATURATION STAGE

CELL PRESSURE, kPa	210	EFFECTIVE CONFINING STRESS, kPa	5
HEAD PRESSURE, kPa	205	DURATION, min	2,520
BACK PRESSURE, kPa	205	B COEFFICIENT	0.99

CONSOLIDATION STAGE

CELL PRESSURE, kPa	322	EFFECTIVE CONFINING STRESS, kPa	117
HEAD PRESSURE, kPa	205	DURATION, min	2,250
BACK PRESSURE, kPa	205	VOLUME CHANGE, cm^3	11.5
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	6.88	SAMPLE AREA, cm^2	36.74
SAMPLE DIAMETER, cm	6.84	SAMPLE VOLUME, cm^3	252.87

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	336	EFFECTIVE CONFINING STRESS, kPa	117
HEAD PRESSURE, kPa	219	DURATION, min	3333.0
BACK PRESSURE, kPa	205	HYDRAULIC GRADIENT, i	21

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	6.88	UNIT WEIGHT, kN/m^3	16.08
SAMPLE DIAMETER, cm	6.84	DRY UNIT WEIGHT, kN/m^3	9.55
SAMPLE AREA, cm^2	36.74	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	252.87	VOLUME OF SOLIDS, cm^3	91.17
TOTAL MASS, g	414.66	VOLUME OF VOIDS, cm^3	161.70
DRY MASS, g	246.16	VOID RATIO	1.77
WATER CONTENT, %	68.5		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	0.0
DURATION OF STEADY STATE FLOW (min)	3333.0
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	10.9
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	11.3
HYDRAULIC CONDUCTIVITY (INFLOW) (cm/s)	7.15E-08
HYDRAULIC CONDUCTIVITY (OUTFLOW) (cm/s)	7.42E-08
HYDRAULIC CONDUCTIVITY, K, cm/s	**7.28E-08**

NOTES:

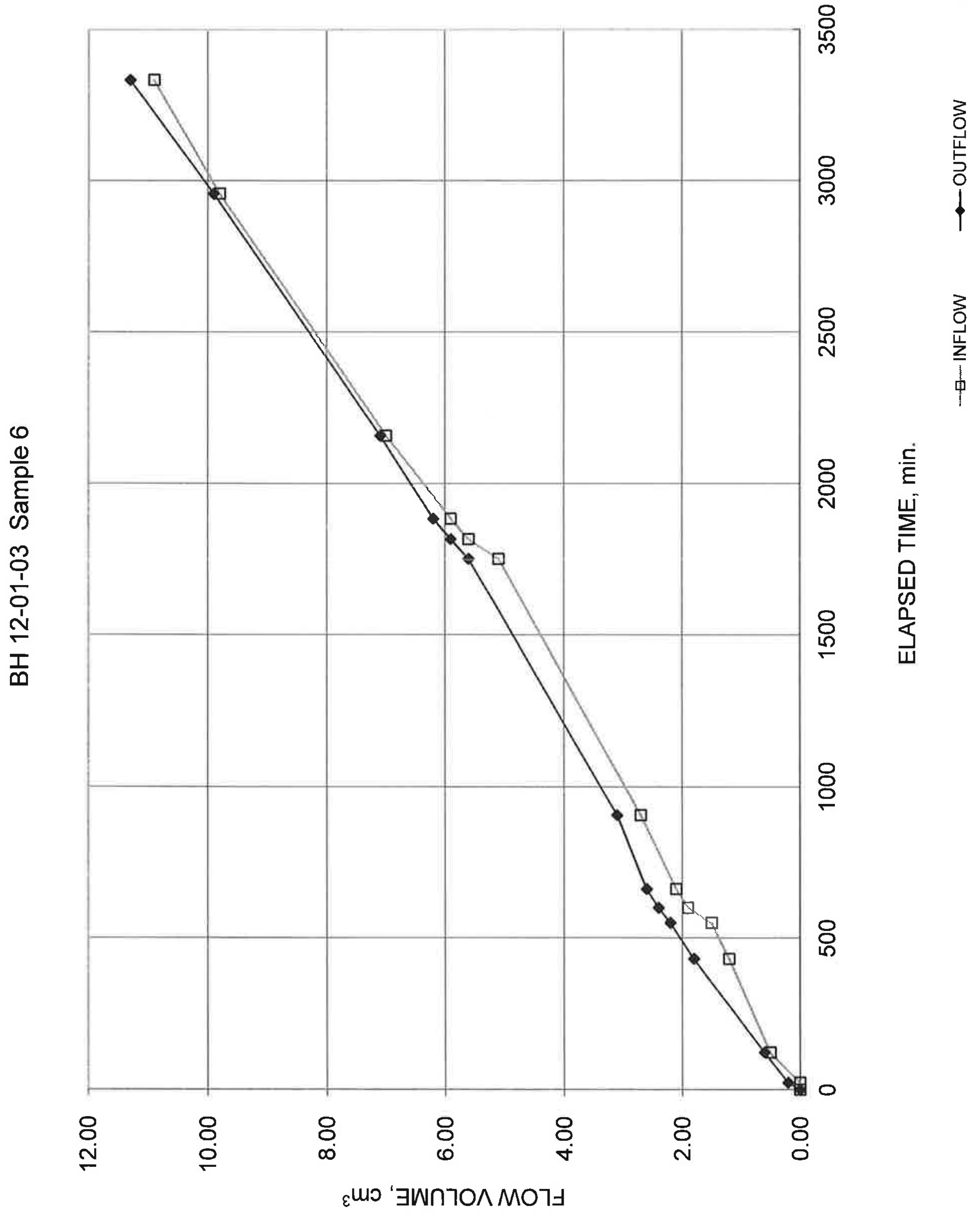
PERMEANT FLUID	Deaired tap water

Prepared By:RD

Golder Associates

Checked By:

HYDRAULIC CONDUCTIVITY TEST



Project No: 12-1125-0045
Prepared By: RD

Golder Associates

Checked By:

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-1-3-1

INTERVAL (metres below ground surface)

Top of Interval = 40.1
Bottom of Interval = 45.4

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

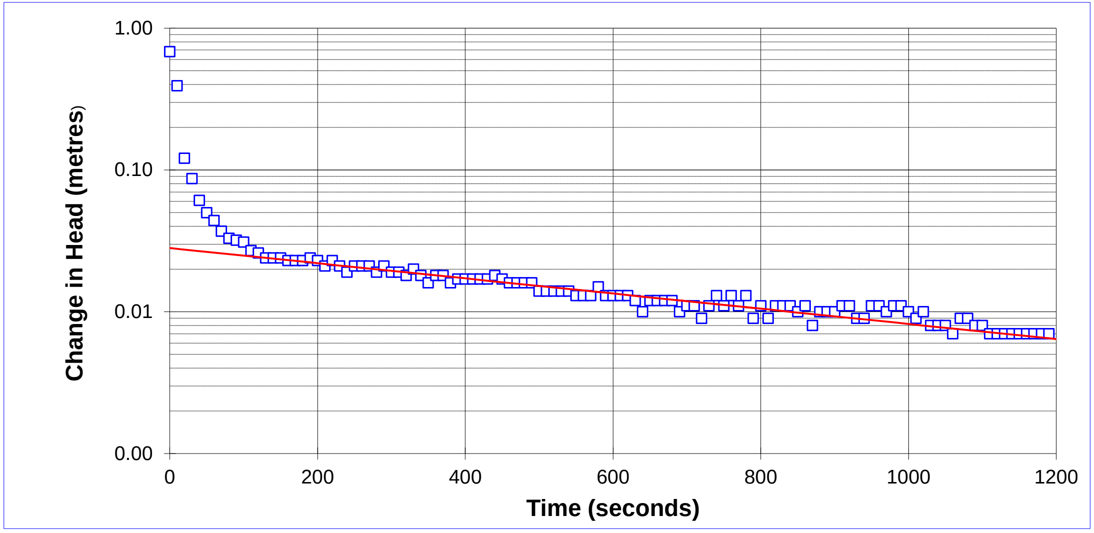
where:

r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	0.03
r_w =	0.05
L_e =	5.27
$ln(R_e/r_w)$	3.10
y_0 =	0.02
y_t =	0.01
t =	600.0

RESULTS

K=	2E-07	m/sec
K=	2E-05	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/14/13

Analysis By: DH
Checked By: BH
Analysis Date: 1/15/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-1-4A

INTERVAL (metres below ground surface)

Top of Interval = 36.0
Bottom of Interval = 39.5

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

r_c = casing radius (metres);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

y_0 = initial drawdown (metres)

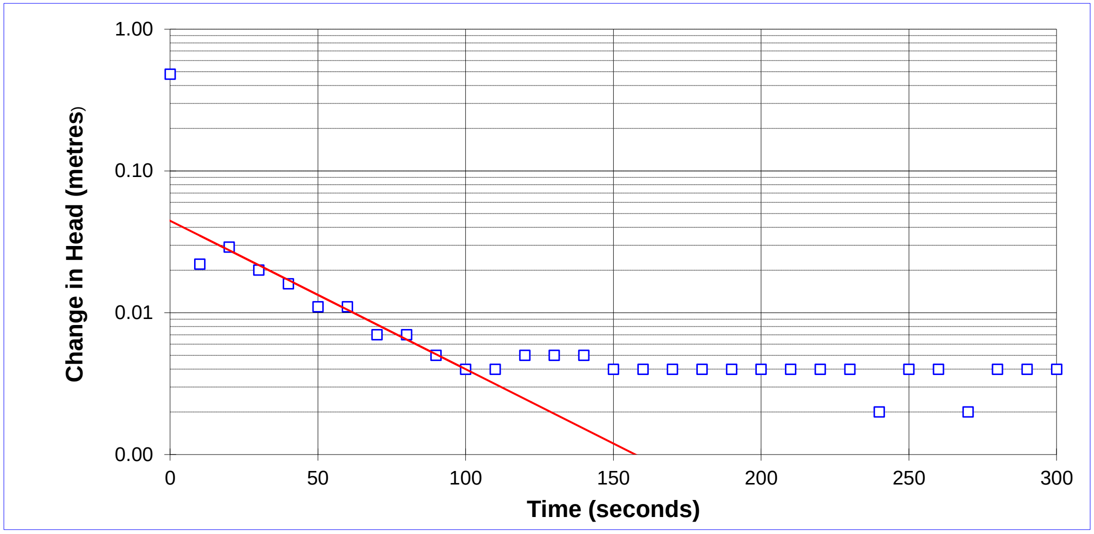
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = **0.02**
r_w = **0.06**
L_e = **3.50**
$ln(R_e/r_w)$ **2.92**
y_0 = **0.04**
y_t = **0.00**
t = **90.0**

RESULTS

K=	3E-06	**m/sec**
K=	3E-04	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/14/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/15/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-1-5B

INTERVAL (metres below ground surface)

Top of Interval = 4.8
Bottom of Interval = 5.0

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

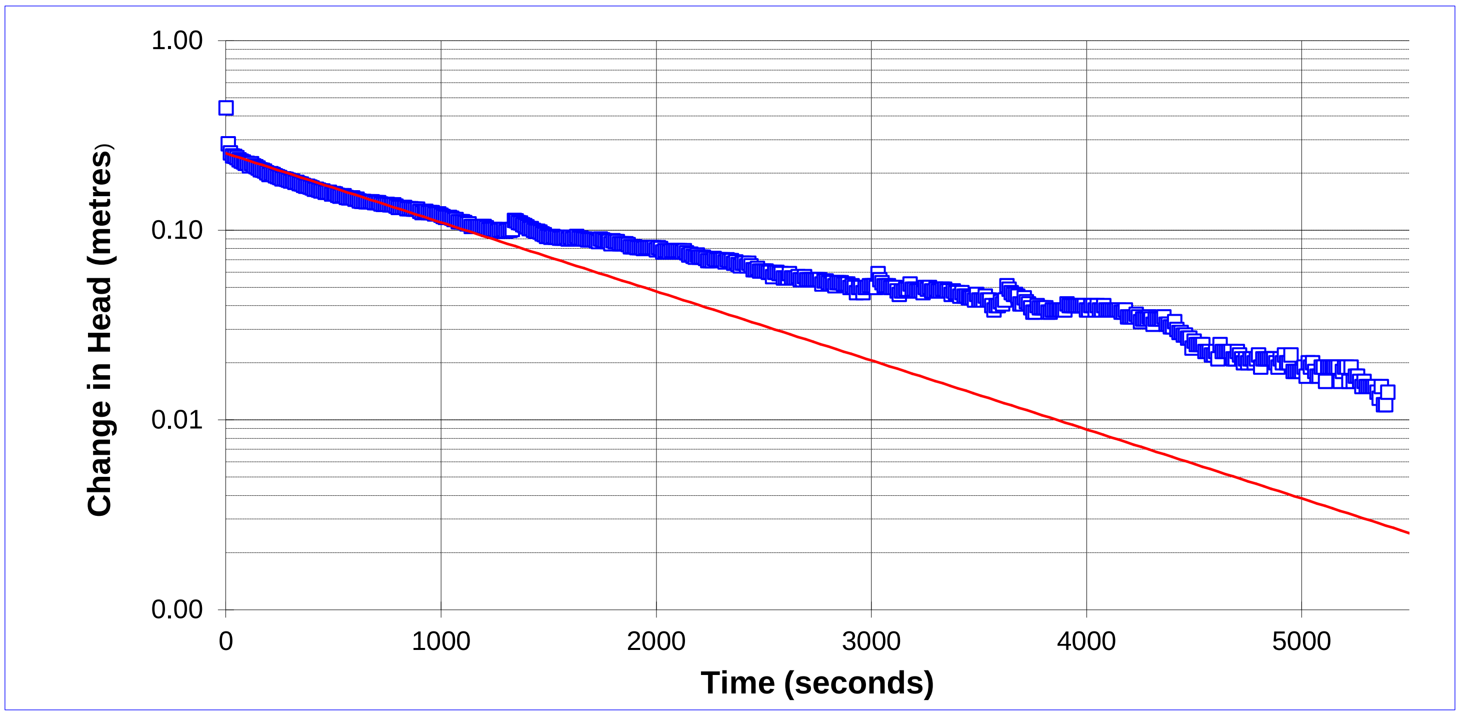
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.02
r_w =	0.10
L_e =	0.24
$\ln(R_e/r_w)$	1.03
y_0 =	0.25
y_t =	0.11
t =	980.0

RESULTS

K=	5E-07	m/sec
K=	5E-05	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/14/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/15/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-1-6

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

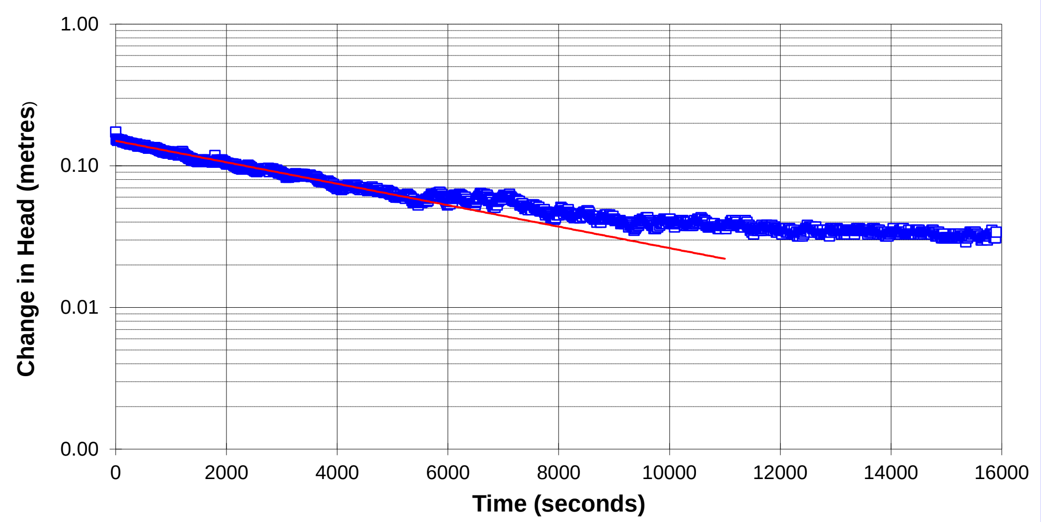
where:

r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	0.03
r_w =	0.10
L_e =	1.20
$ln(R_e/r_w)$	1.84
y_0 =	0.15
y_t =	0.13
t =	1000.0

RESULTS

K=	9E-08	m/sec
K=	9E-06	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/14/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/15/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-2-3

INTERVAL (metres below ground surface)

Top of Interval = 37.0
Bottom of Interval = 42.0

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

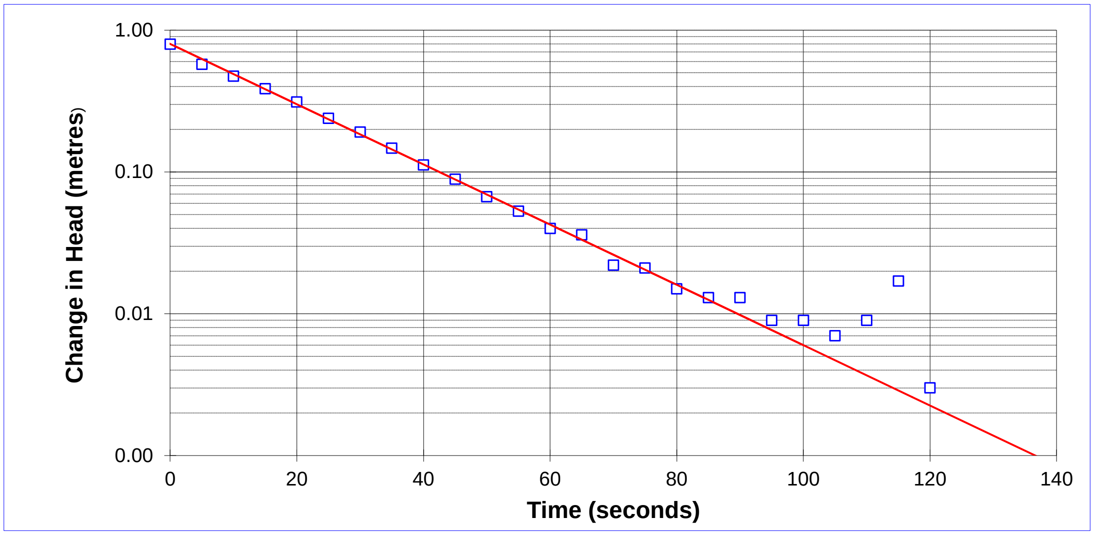
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.05
L_e =	4.95
$\ln(R_e/r_w)$	3.05
y_0 =	0.80
y_t =	0.01
t =	100.0

RESULTS

K=	2E-05	m/sec
K=	2E-03	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/22/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/22/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST BH12-2-5B

INTERVAL (metres below ground surface)

Top of Interval = 6.3
Bottom of Interval = 6.6

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

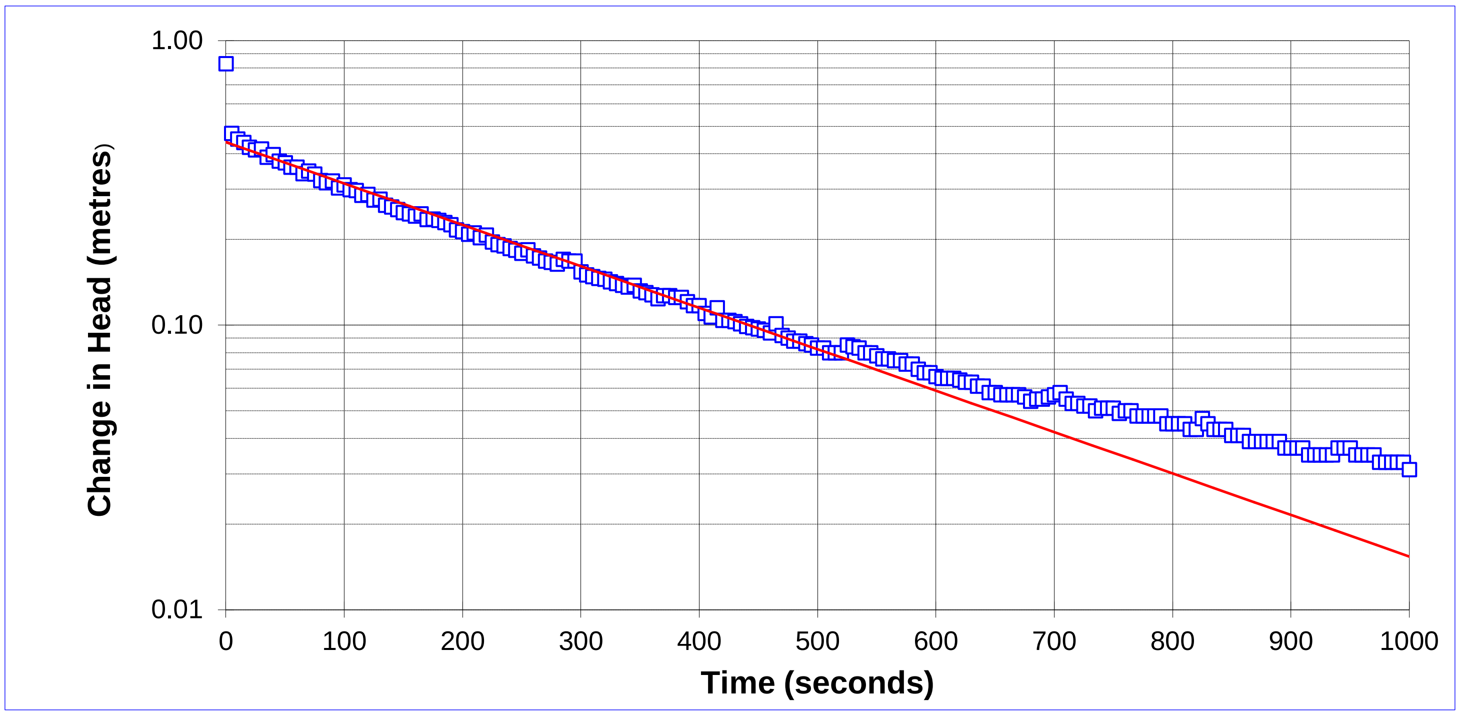
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = 0.02
r_w = 0.06
L_e = 0.30
$\ln(R_e/r_w)$ 1.13
y_0 = 0.44
y_t = 0.23
t = 200.0

RESULTS

K=	2E-06	**m/sec**
K=	2E-04	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/22/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/22/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-2-6

INTERVAL (metres below ground surface)

Top of Interval = 0.4
Bottom of Interval = 2.3

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln\frac{y_0}{y_t}$$

where K=m/sec

where:

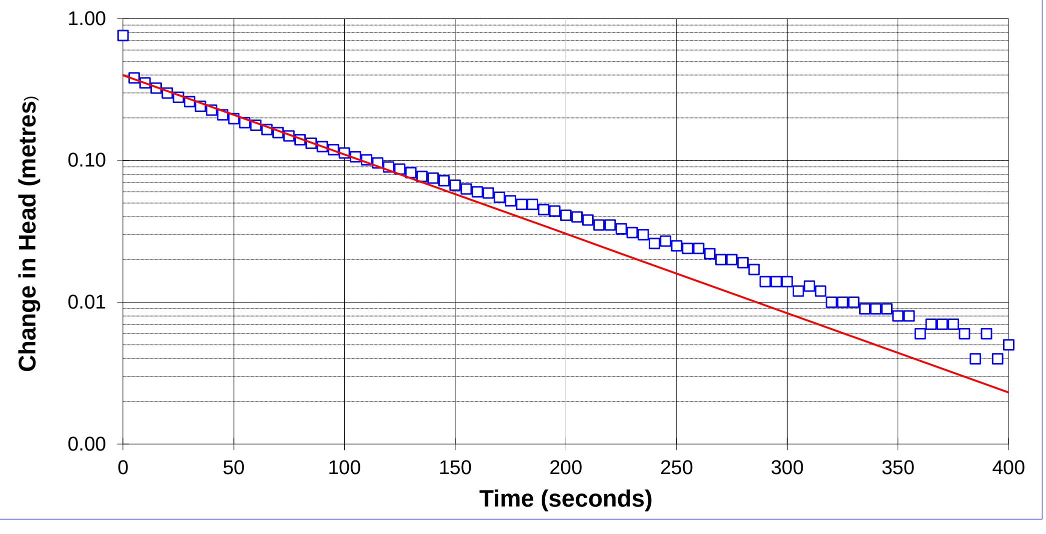
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.06
r_w =	0.10
L_e =	1.81
$ln(R_e/r_w)$	1.78
y_0 =	0.40
y_t =	0.21
t =	50.0

RESULTS

K=	2E-05	m/sec
K=	2E-03	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/22/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/22/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-3-3

INTERVAL (metres below ground surface)

Top of Interval = 40.1
Bottom of Interval = 45.4

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

r_c = casing radius (metres);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

y_0 = initial drawdown (metres)

y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = **0.03**

r_w = **0.05**

L_e = **5.30**

$\ln(R_e/r_w)$ **3.08**

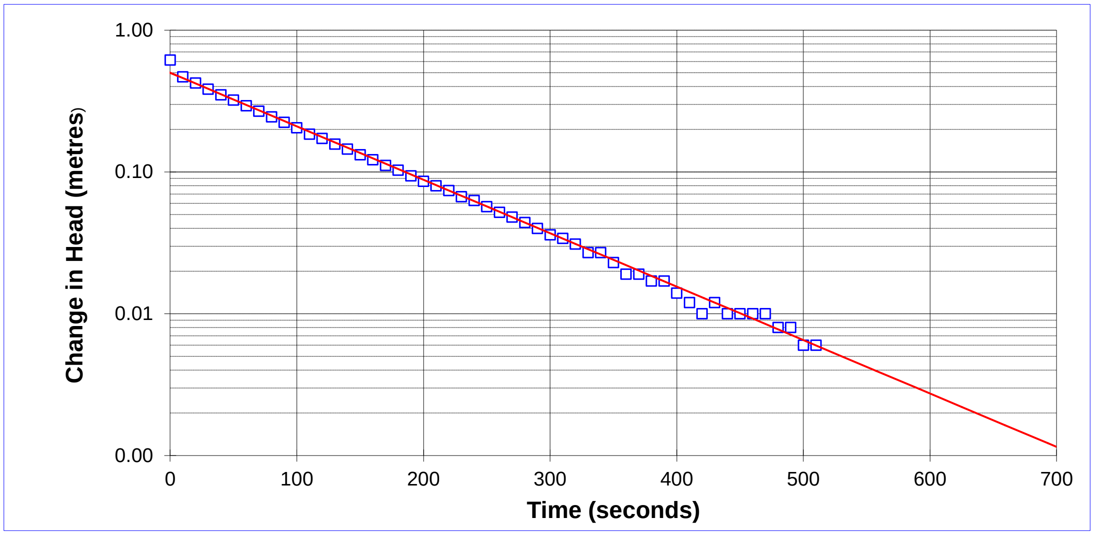
y_0 = **0.50**

y_t = **0.04**

t = **300.0**

RESULTS

K=	3E-06	**m/sec**
K=	3E-04	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/14/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/15/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-3-4A

INTERVAL (metres below ground surface)

Top of Interval = 35.1
Bottom of Interval = 38.7

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

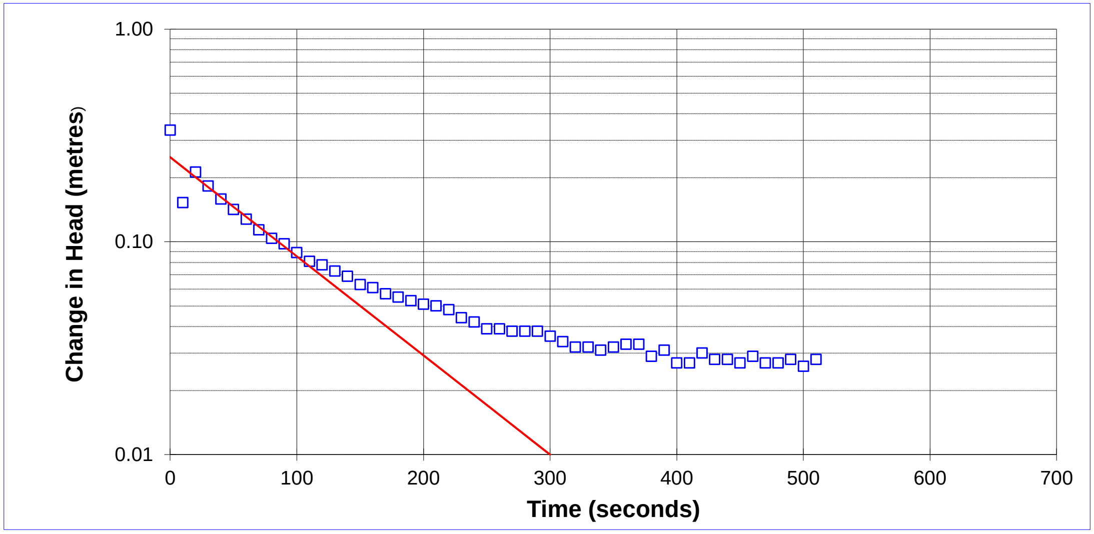
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.02
r_w =	0.06
L_e =	3.60
$\ln(R_e/r_w)$	3.39
y_0 =	0.25
y_t =	0.01
t =	300.0

RESULTS

K=	2E-06	m/sec
K=	2E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/14/13
Analysis By: DH
Checked By: CHM
Analysis Date: 1/16/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-3-5B

INTERVAL (metres below ground surface)

Top of Interval = **4.6**
Bottom of Interval = **4.9**

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

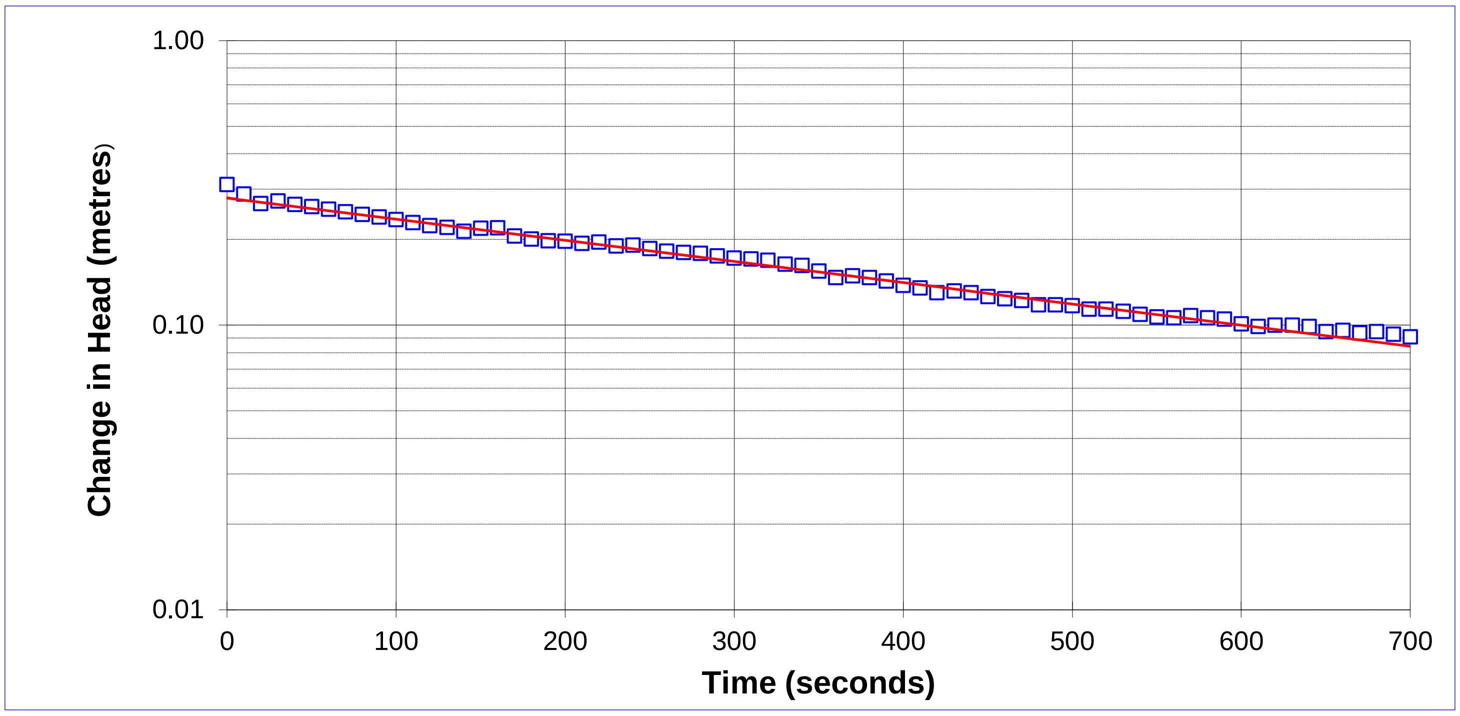
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = **0.02**
r_w = **0.10**
L_e = **0.30**
$\ln(R_e/r_w)$ **1.00**
y_0 = **0.28**
y_t = **0.10**
t = **600.0**

RESULTS

K=	7E-07	**m/sec**
K=	7E-05	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/14/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/15/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-3-6

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

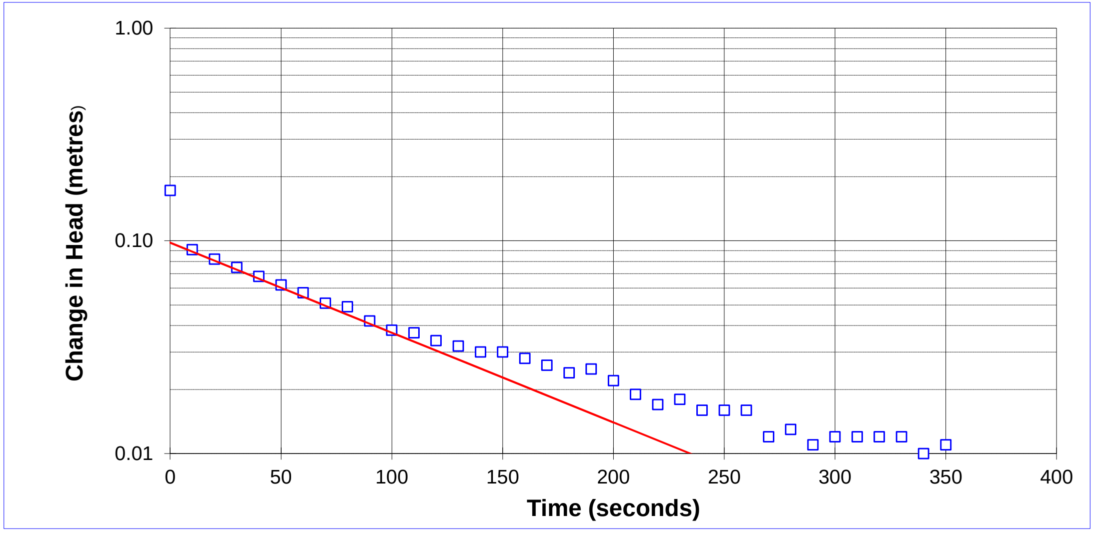
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.10
L_e =	1.20
$\ln(R_e/r_w)$	1.87
y_0 =	0.10
y_t =	0.01
t =	200.0

RESULTS

K=	5E-06	m/sec
K=	5E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1125-0045
Test Date: 01/14/13

Analysis By: DH
Checked By: CHM
Analysis Date: 1/15/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-4-3

INTERVAL (metres below ground surface)

Top of Interval = 38.5
Bottom of Interval = 43.6

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

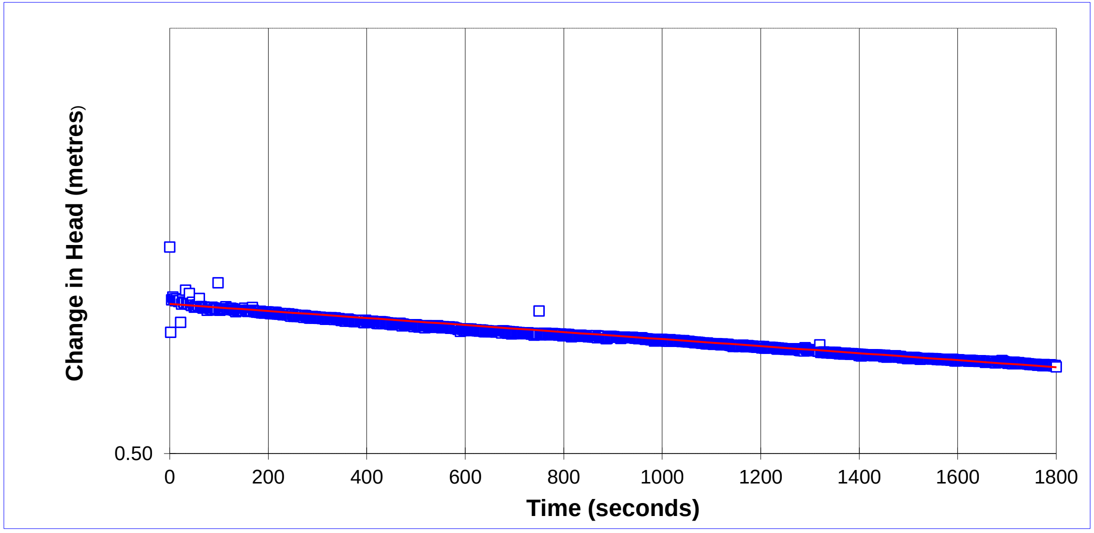
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.05
L_e =	5.10
$\ln(R_e/r_w)$	4.13
y_0 =	0.64
y_t =	0.62
t =	500.0

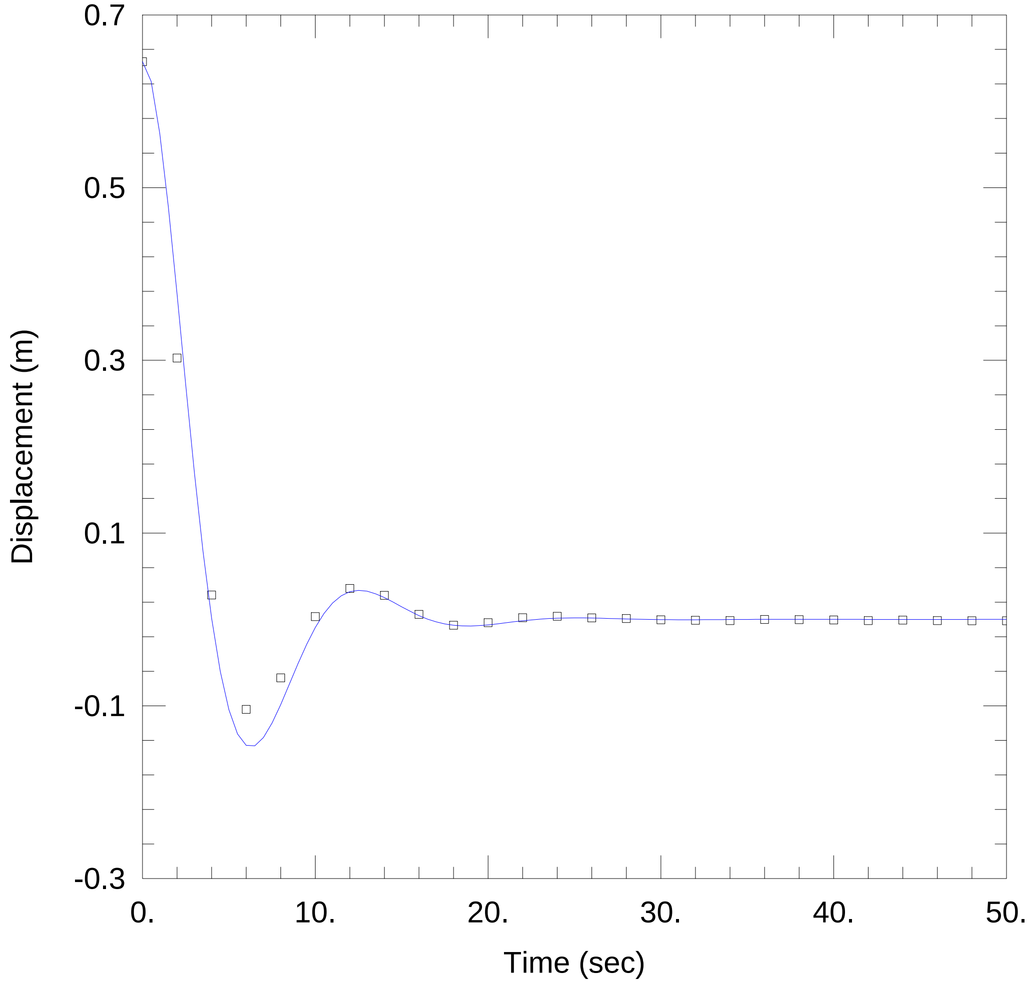
RESULTS

K=	2E-08	m/sec
K=	2E-06	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/18/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/2/2013



WELL TEST ANALYSIS

Data Set: \...\BH12-4-4A RHT-1_BH.aqt
Date: 12/05/13 Time: 16:41:56

PROJECT INFORMATION

Company: Golder Associate Ltd.
Client: CRRRC/Eastern EA ON/Boundary R
Project: 12-1125-0045/1000/0120
Test Well: 12-4-4A
Test Date: 4/18/2013

AQUIFER DATA

Saturated Thickness: 4.36 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (12-4-4A)

Initial Displacement: 0.6458 m
Total Well Penetration Depth: 2.89 m
Casing Radius: 0.016 m
Static Water Column Height: 35.28 m
Screen Length: 1.85 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Butler

K = 0.0001774 m/sec
Le = 31.97 m

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 12-4-5B

INTERVAL (metres below ground surface)

Top of Interval = 4.7
Bottom of Interval = 5.0

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

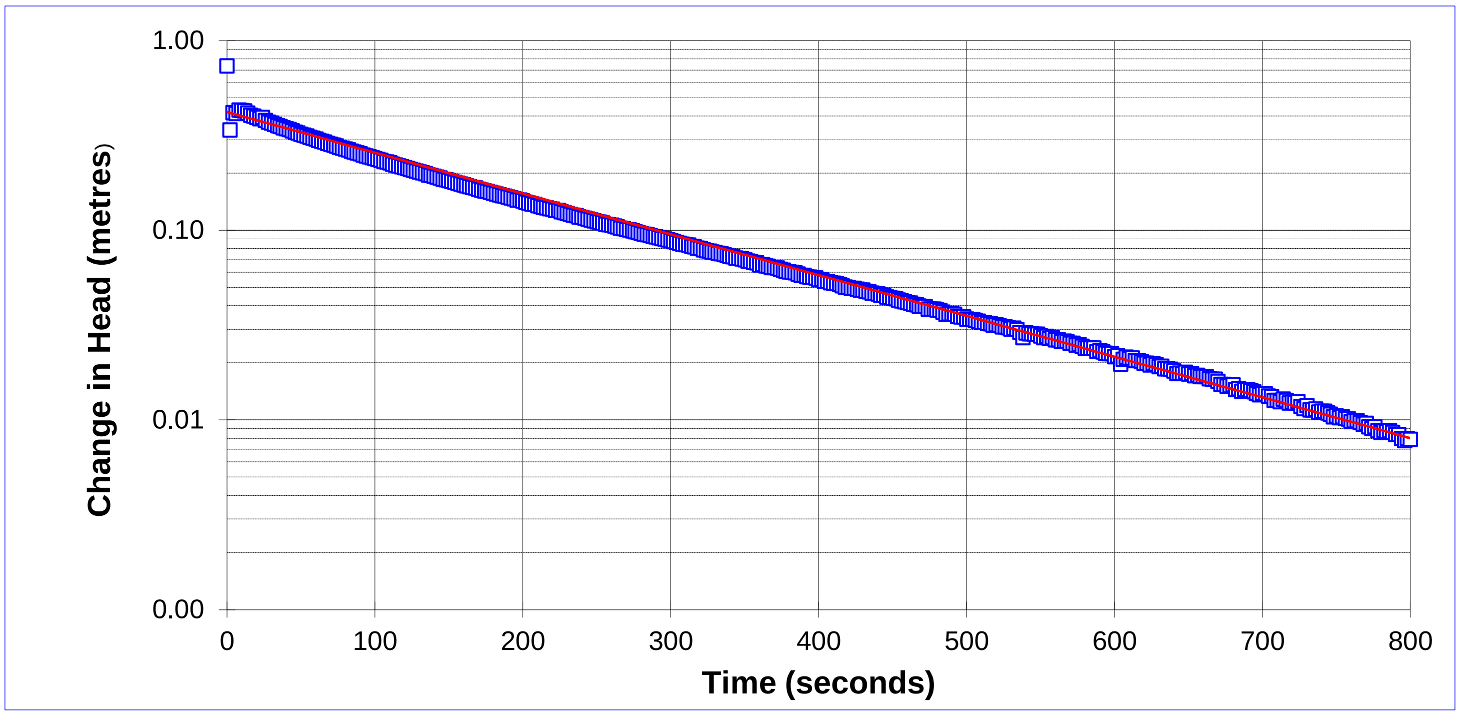
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = **0.02**
r_w = **0.06**
L_e = **0.23**
$\ln(R_e/r_w)$ **1.06**
y_0 = **0.42**
y_t = **0.06**
t = **400.0**

RESULTS

K=	3E-06	**m/sec**
K=	3E-04	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/18/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/2/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 12-4-6

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.6

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

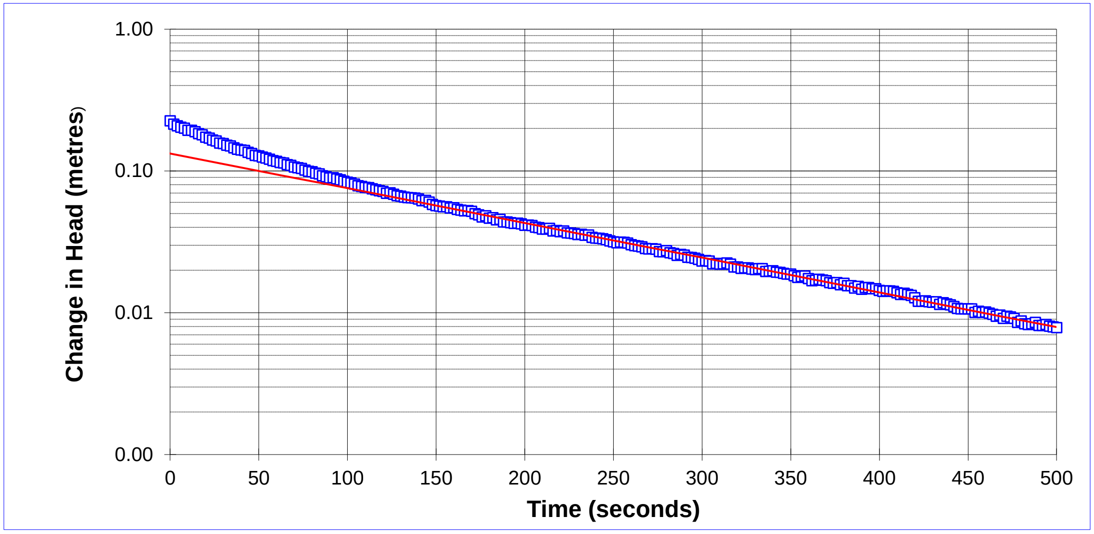
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.06
L_e =	1.30
$ln(R_e/r_w)$	2.05
y_0 =	0.06
y_t =	0.01
t =	300.0

RESULTS

K=	3E-06	m/sec
K=	3E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/24/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-10-2

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^{2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

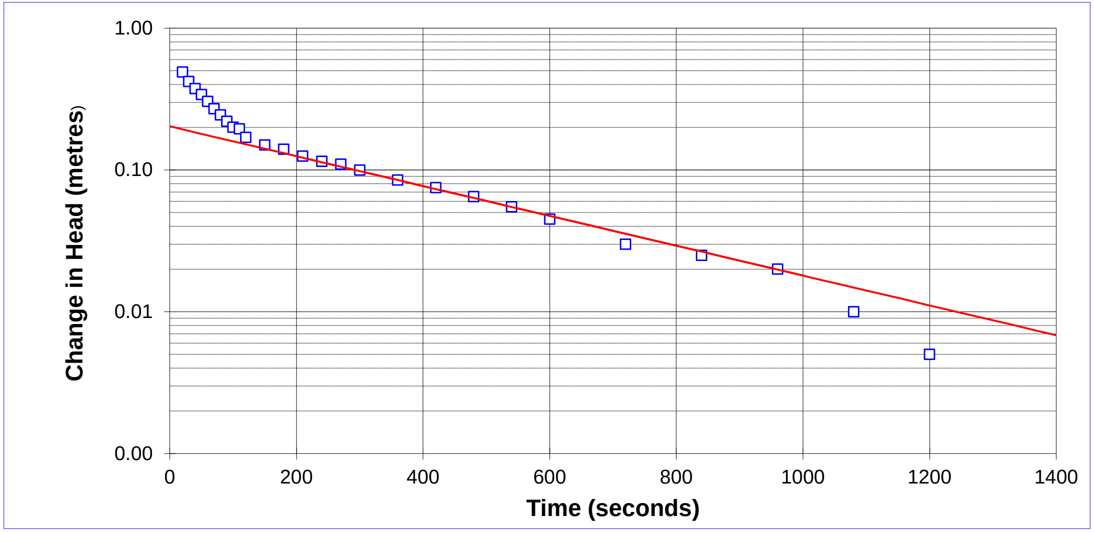
where:

r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	**0.03**
r_w =	**0.06**
L_e =	**1.13**
$\ln(R_e/r_w)$	**1.92**
y_0 =	**0.13**
y_t =	**0.02**
t =	**800.0**

RESULTS

K=	2E-06	**m/sec**
K=	2E-04	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/22/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/6/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-10-3

INTERVAL (metres below ground surface)

Top of Interval = 5.87
Bottom of Interval = 6.15

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

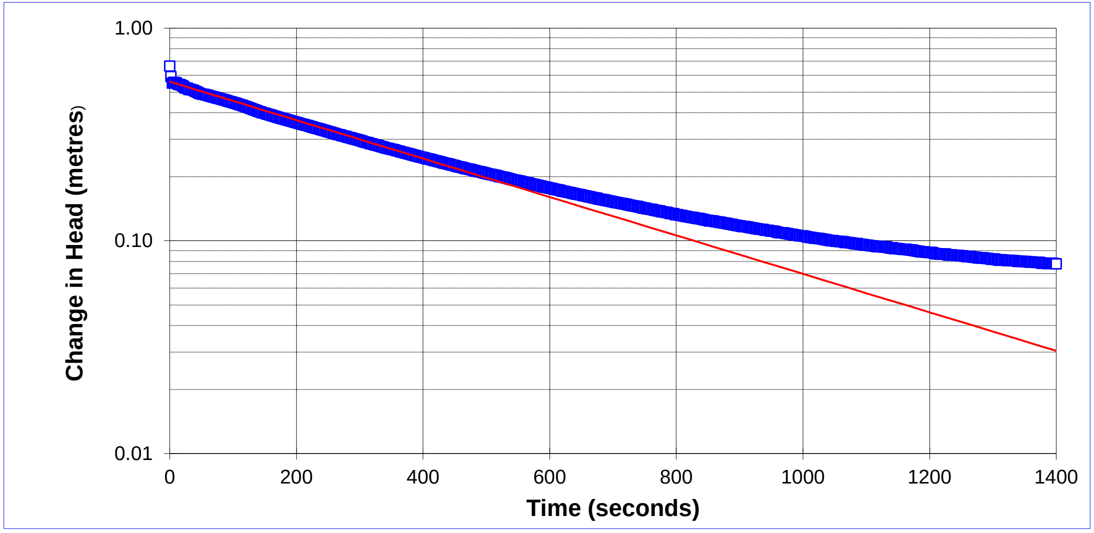
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = **0.02**
r_w = **0.06**
L_e = **0.28**
$ln(R_e/r_w)$ **1.15**
y_0 = **0.56**
y_t = **0.30**
t = **300.0**

RESULTS

K=	1E-06	**m/sec**
K=	1E-04	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/18/13

Analysis By: DH
Checked By: BH
Analysis Date: 7/23/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-12-2

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln\frac{y_0}{y_t}$$

where K=m/sec

where:

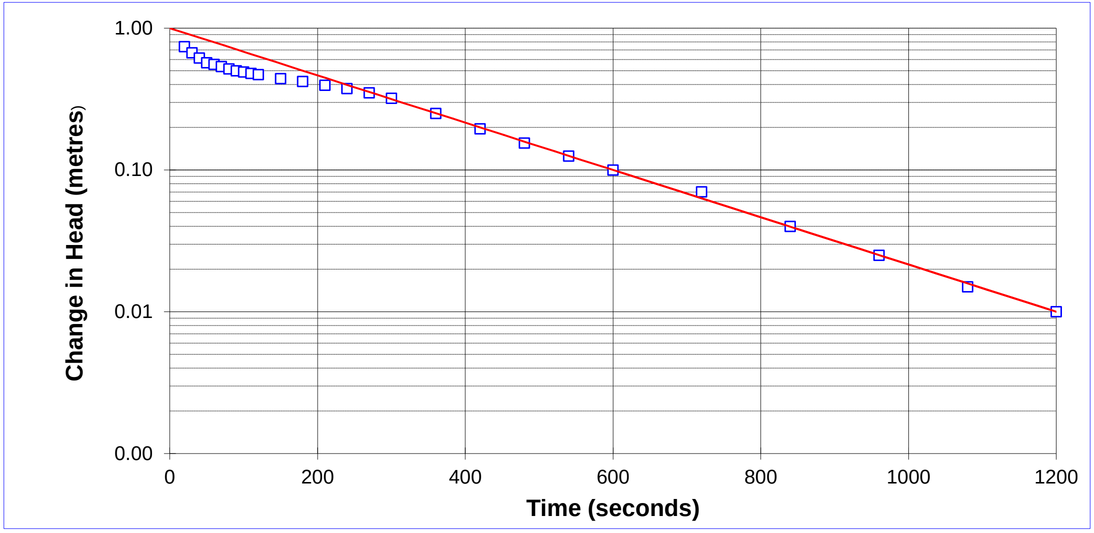
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.06
L_e =	1.22
$ln(R_e/r_w)$	2.43
y_0 =	0.10
y_t =	0.01
t =	600.0

RESULTS

K=	4E-06	m/sec
K=	4E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/24/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/6/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-12-3

INTERVAL (metres below ground surface)

Top of Interval = 4.8
Bottom of Interval = 5.4

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

r_c = casing radius (metres);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

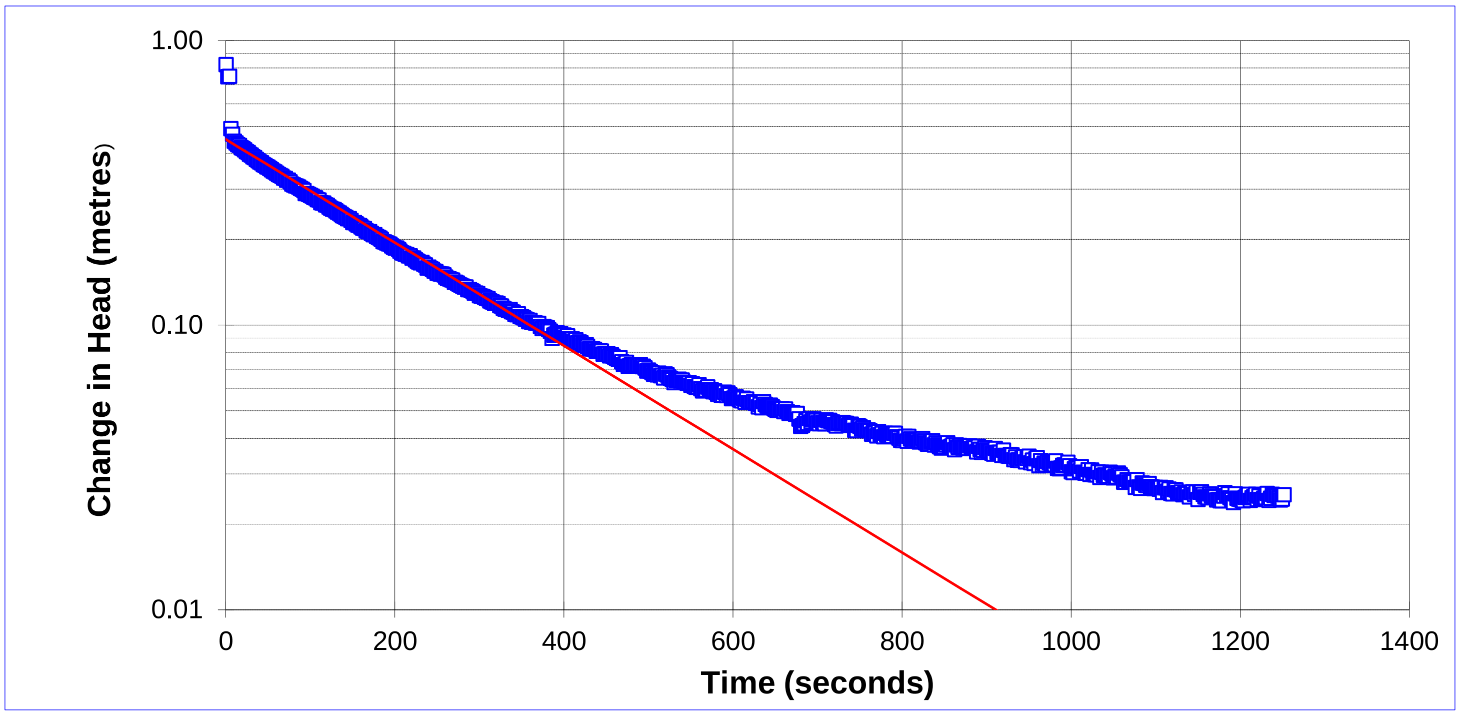
y_0 = initial drawdown (metres)

y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	0.02
r_w =	0.06
L_e =	0.61
$\ln(R_e/r_w)$	1.71
y_0 =	0.45
y_t =	0.20
t =	200.0

RESULTS

K=	1E-06	m/sec
K=	1E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/18/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/9/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-17-2

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln\frac{y_0}{y_t}$$

where K=m/sec

where:

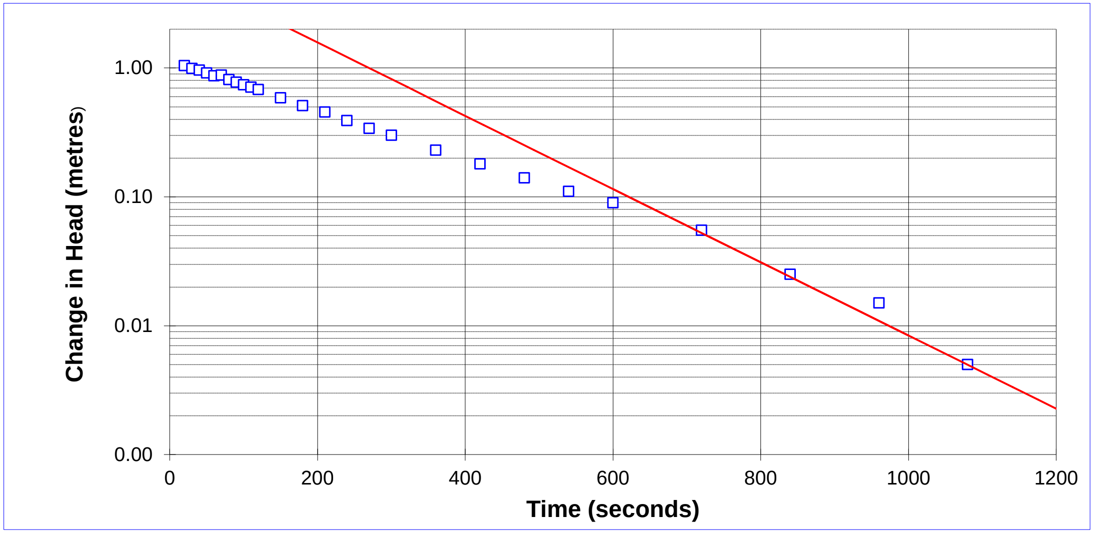
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.02
r_w =	0.06
L_e =	1.22
$ln(R_e/r_w)$	2.16
y_0 =	0.12
y_t =	0.01
t =	400.0

RESULTS

K=	1E-06	m/sec
K=	1E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/24/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-17-3

INTERVAL (metres below ground surface)

Top of Interval = 4.4
Bottom of Interval = 5.0

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

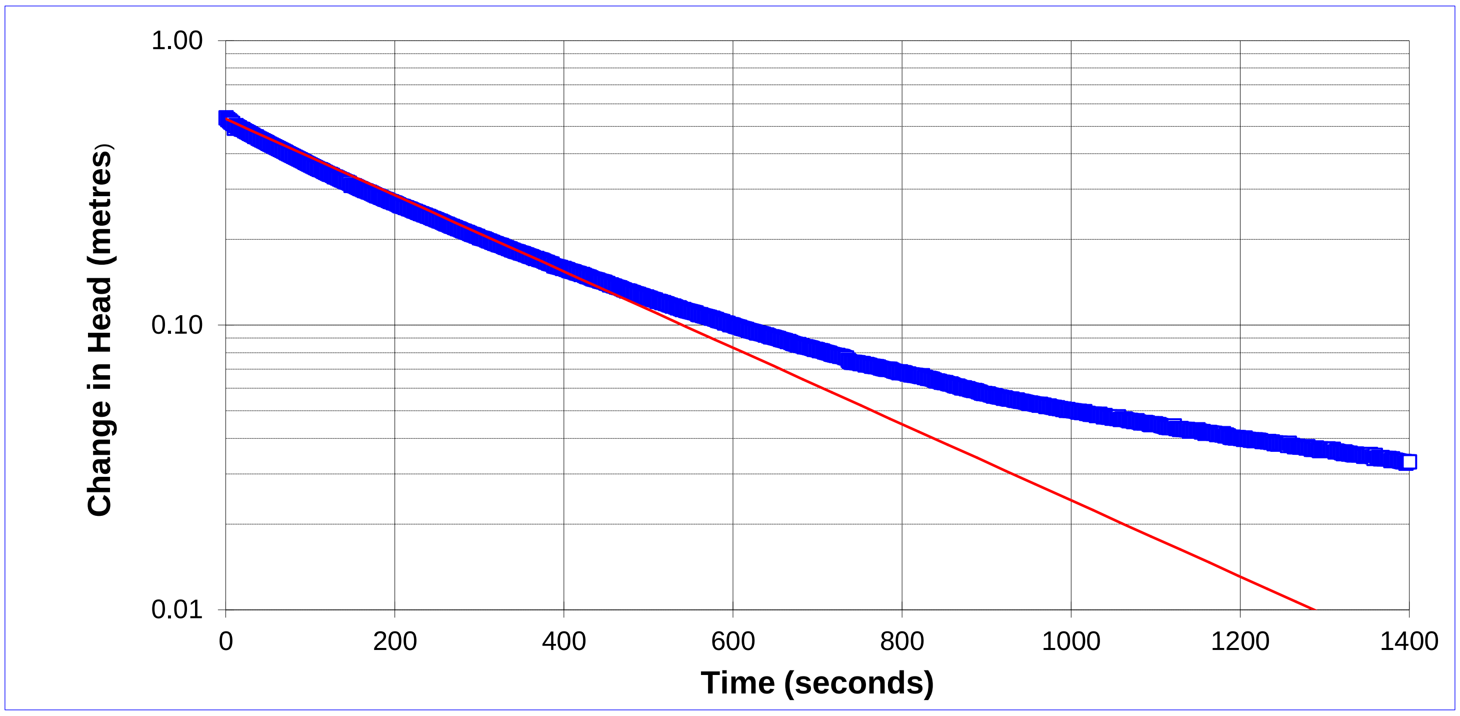
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.02
r_w =	0.06
L_e =	0.58
$\ln(R_e/r_w)$	1.67
y_0 =	0.53
y_t =	0.21
t =	300.0

RESULTS

K=	1E-06	m/sec
K=	1E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/17/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/2/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-18-2

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

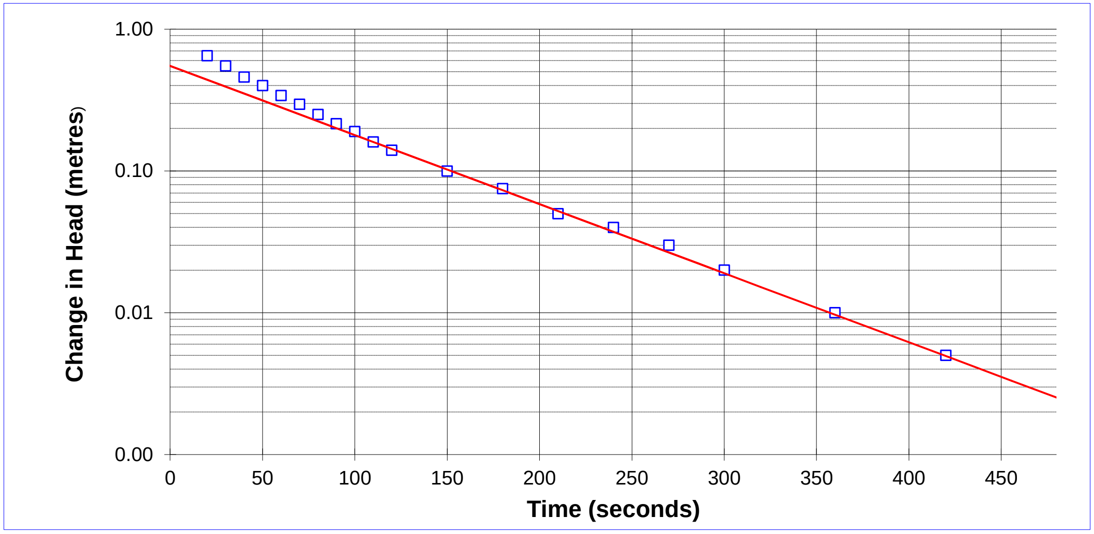
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.06
L_e =	1.22
$\ln(R_e/r_w)$	2.16
y_0 =	0.55
y_t =	0.02
t =	300.0

RESULTS

K=	1E-05	m/sec
K=	1E-03	cm/sec



Project Name:	CRRRC/EA Eastern ON/Boundary Rd	Analysis By:	DH
Project No.:	12-1127-00125/1000/0120	Checked By:	BH
Test Date:	04/22/13	Analysis Date:	5/6/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-18-3

INTERVAL (metres below ground surface)

Top of Interval = 5.7
Bottom of Interval = 6.2

$$K = \frac{r_c^{2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

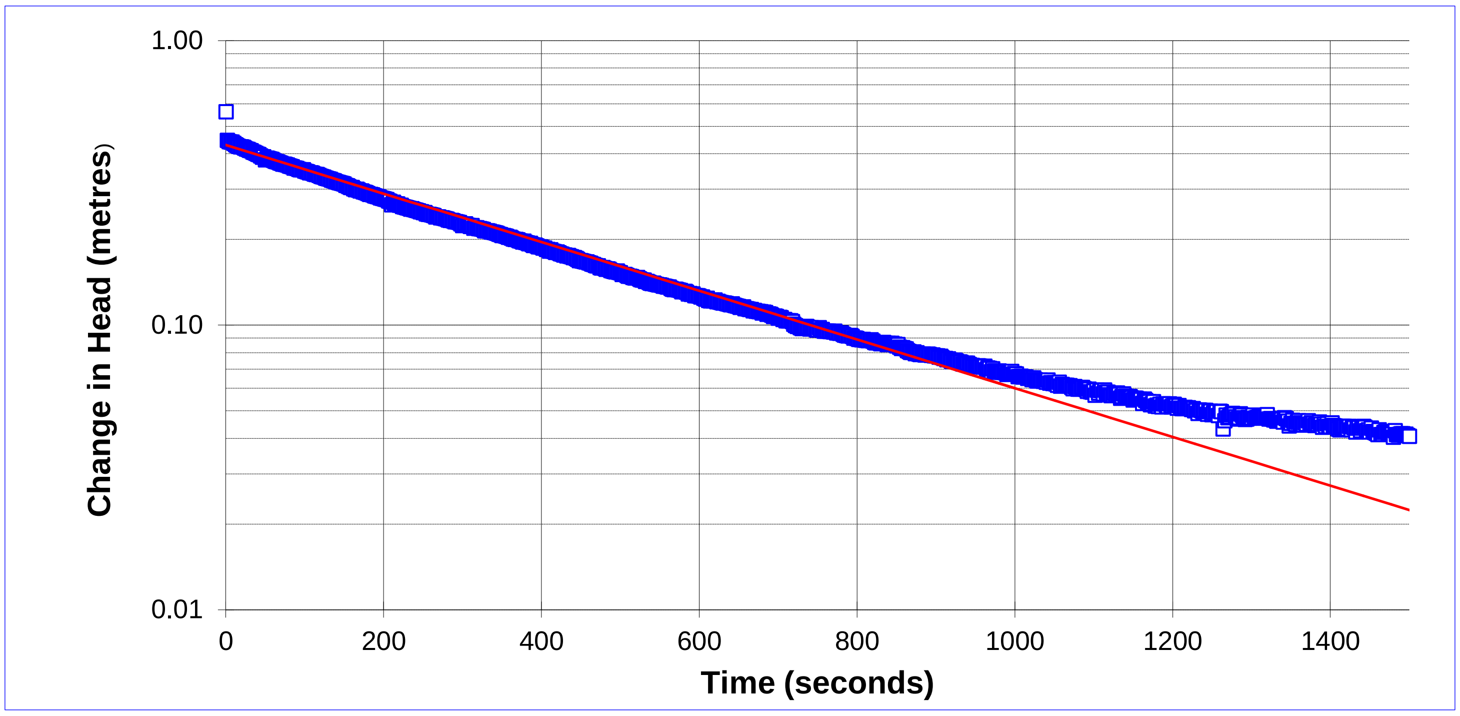
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = 0.02
r_w = 0.06
L_e = 0.43
$\ln(R_e/r_w)$ 1.43
y_0 = 0.43
y_t = 0.06
t = 1000.0

RESULTS

K=	8E-07	**m/sec**
K=	8E-05	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/22/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/6/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-21-2

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

r_c = casing radius (metres);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

y_0 = initial drawdown (metres)

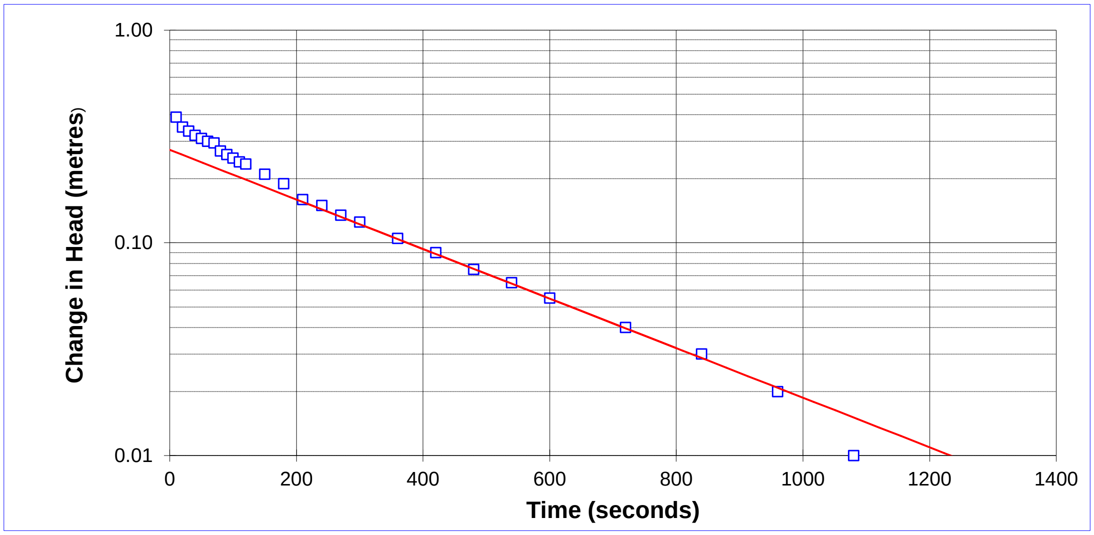
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.06
L_e =	0.94
$ln(R_e/r_w)$	1.77
y_0 =	0.16
y_t =	0.03
t =	600.0

RESULTS

K=	3E-06	m/sec
K=	3E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/22/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/3/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-24-2

INTERVAL (metres below ground surface)

Top of Interval =	**0.3**
Bottom of Interval =	**1.5**

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

r_c = casing radius (metres);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

y_0 = initial drawdown (metres)

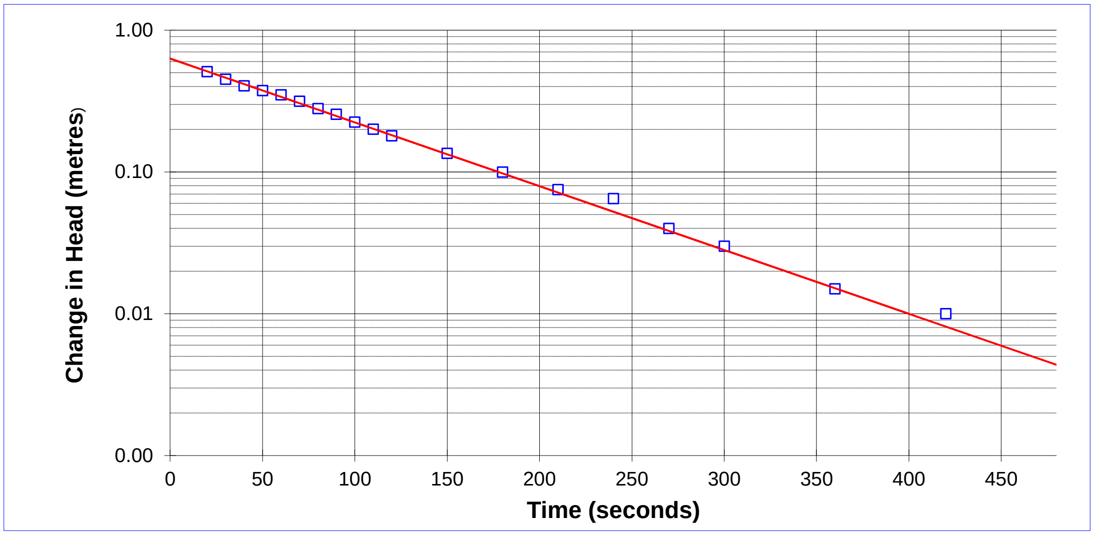
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	**0.02**
r_w =	**0.06**
L_e =	**1.22**
$ln(R_e/r_w)$	**2.14**
y_0 =	**0.63**
y_t =	**0.01**
t =	**400.0**

RESULTS

K=	2E-06	**m/sec**
K=	2E-04	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/22/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/6/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-5-3

INTERVAL (metres below ground surface)

Top of Interval = 35.3
Bottom of Interval = 40.3

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

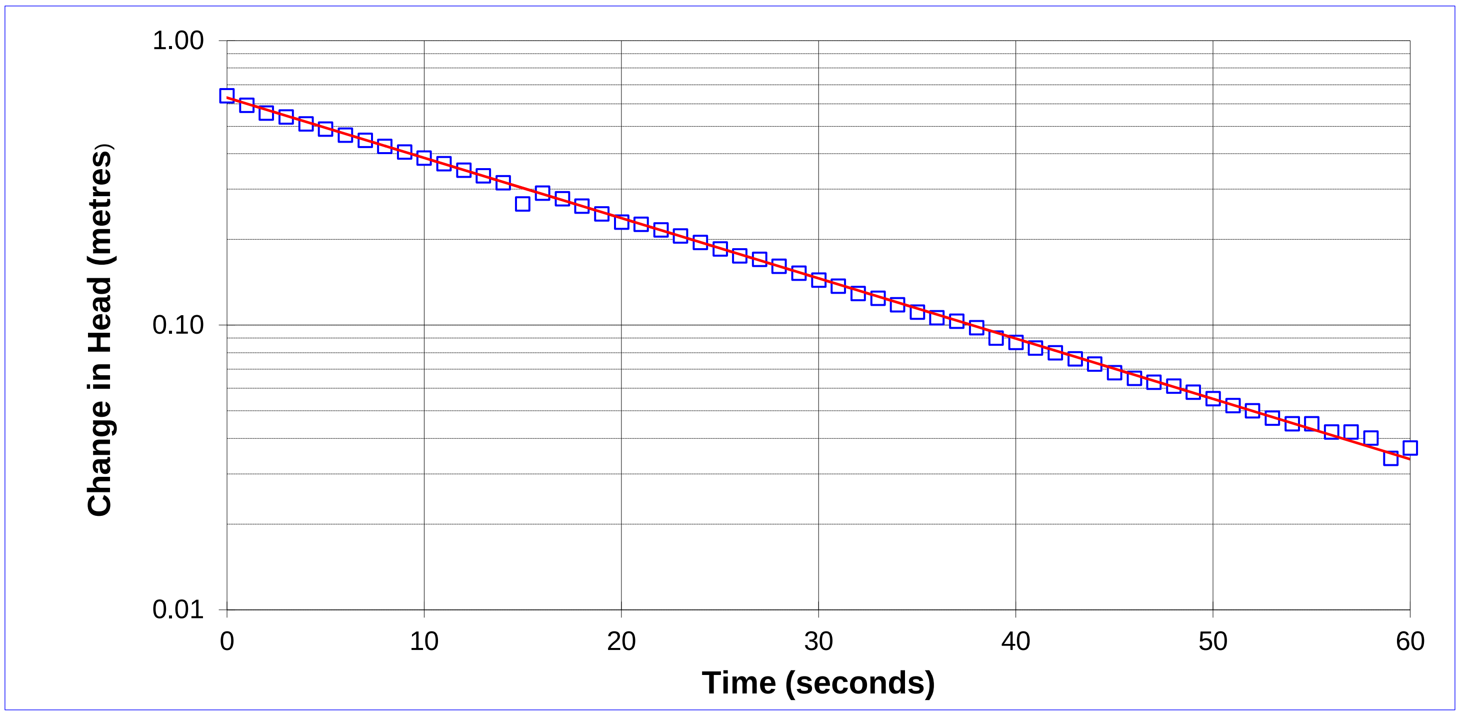
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = 0.02
r_w = 0.04
L_e = 5.08
$\ln(R_e/r_w)$ 4.24
y_0 = 0.63
y_t = 0.06
t = 50.0

RESULTS

K=	5E-06	m/sec
K=	5E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 07/09/13

Analysis By: DH
Checked By: BH
Analysis Date: 7/12/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-5-4A

INTERVAL (metres below ground surface)

Top of Interval =	**28.7**
Bottom of Interval =	**31.1**

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln\frac{y_0}{y_t}$$

where K=m/sec

where:

r_c = casing radius (metres);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

y_0 = initial drawdown (metres)

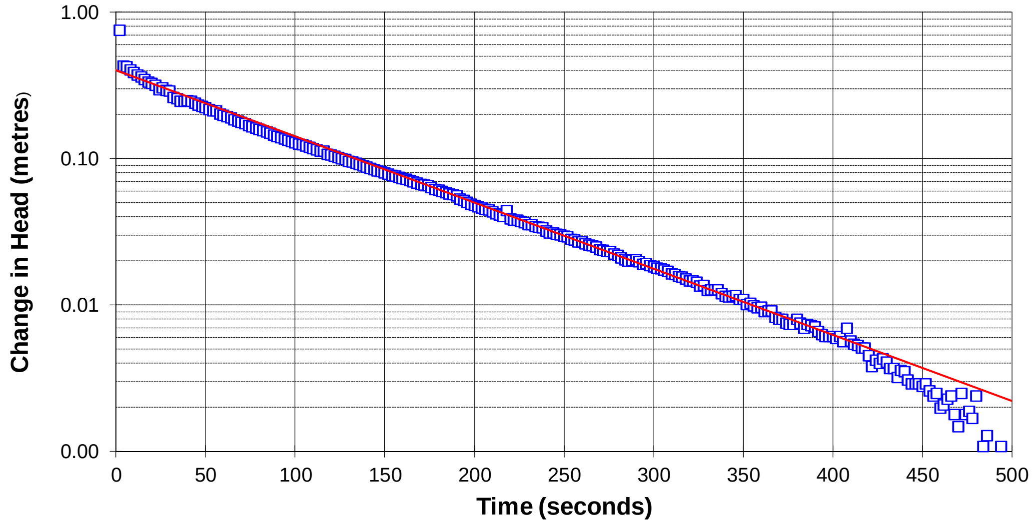
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	**0.02**
r_w =	**0.06**
L_e =	**2.44**
$\ln(R_e/r_w)$	**2.65**
y_0 =	**0.40**
y_t =	**0.05**
t =	**200.0**

RESULTS

K=	**2E-06**	**m/sec**
K=	**2E-04**	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/25/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-5-5

INTERVAL (metres below ground surface)

Top of Interval = 4.3
Bottom of Interval = 4.9

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

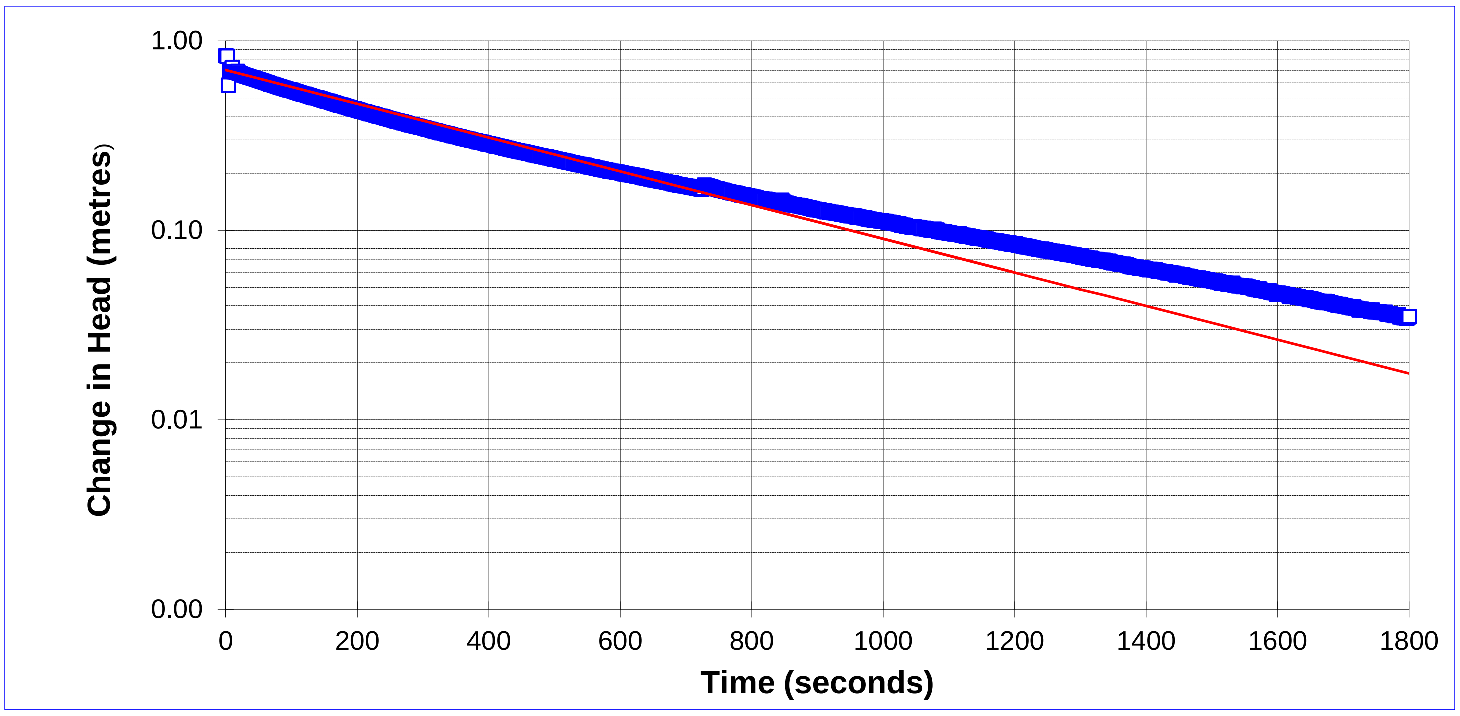
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.10
L_e =	0.60
$\ln(R_e/r_w)$	1.23
y_0 =	0.70
y_t =	0.06
t =	1200.0

RESULTS

K=	1E-06	m/sec
K=	1E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/24/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-5-6

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

r_c = casing radius (metres);

R_e = effective radius (metres);

L_e = length of screened interval (metres);

r_w = radial distance to undisturbed aquifer (metres)

y_0 = initial drawdown (metres)

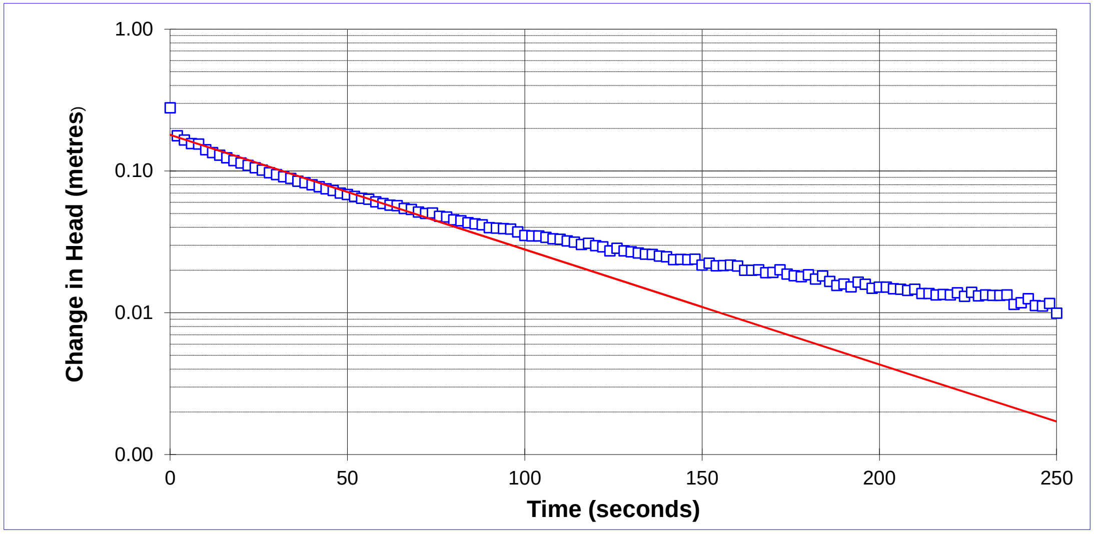
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.10
L_e =	1.22
$\ln(R_e/r_w)$	1.81
y_0 =	0.18
y_t =	0.01
t =	150.0

RESULTS

K=	9E-06	m/sec
K=	9E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/25/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-6-3

INTERVAL (metres below ground surface)

Top of Interval = 41.4
Bottom of Interval = 44.7

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

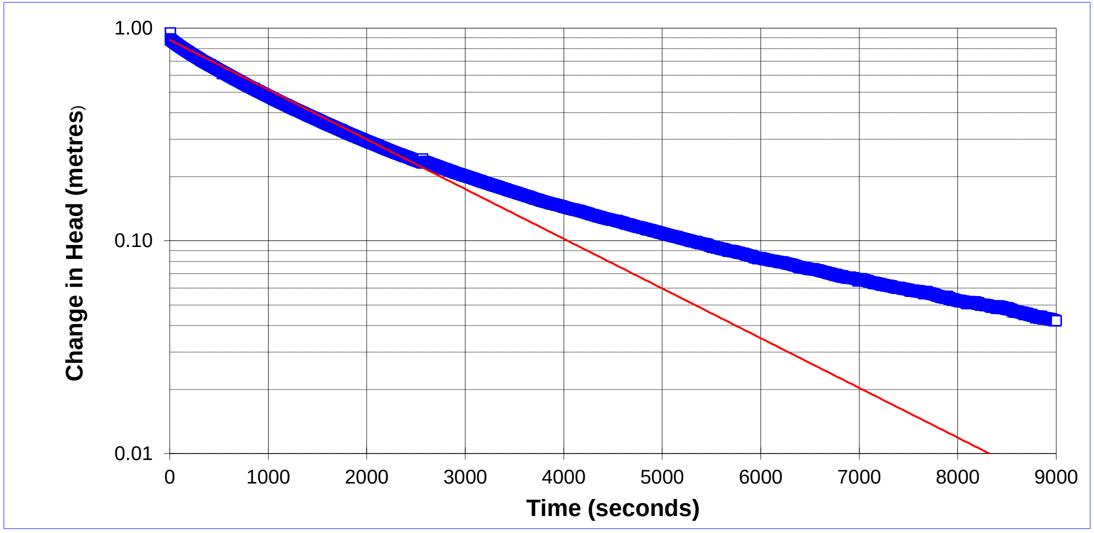
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = **0.03**
r_w = **0.05**
L_e = **3.34**
$\ln(R_e/r_w)$ **3.15**
y_0 = **0.88**
y_t = **0.30**
t = **2000.0**

RESULTS

K=	2E-07	**m/sec**
K=	2E-05	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/22/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/3/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-6-4A

INTERVAL (metres below ground surface)

Top of Interval = 33.0
Bottom of Interval = 35.6

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

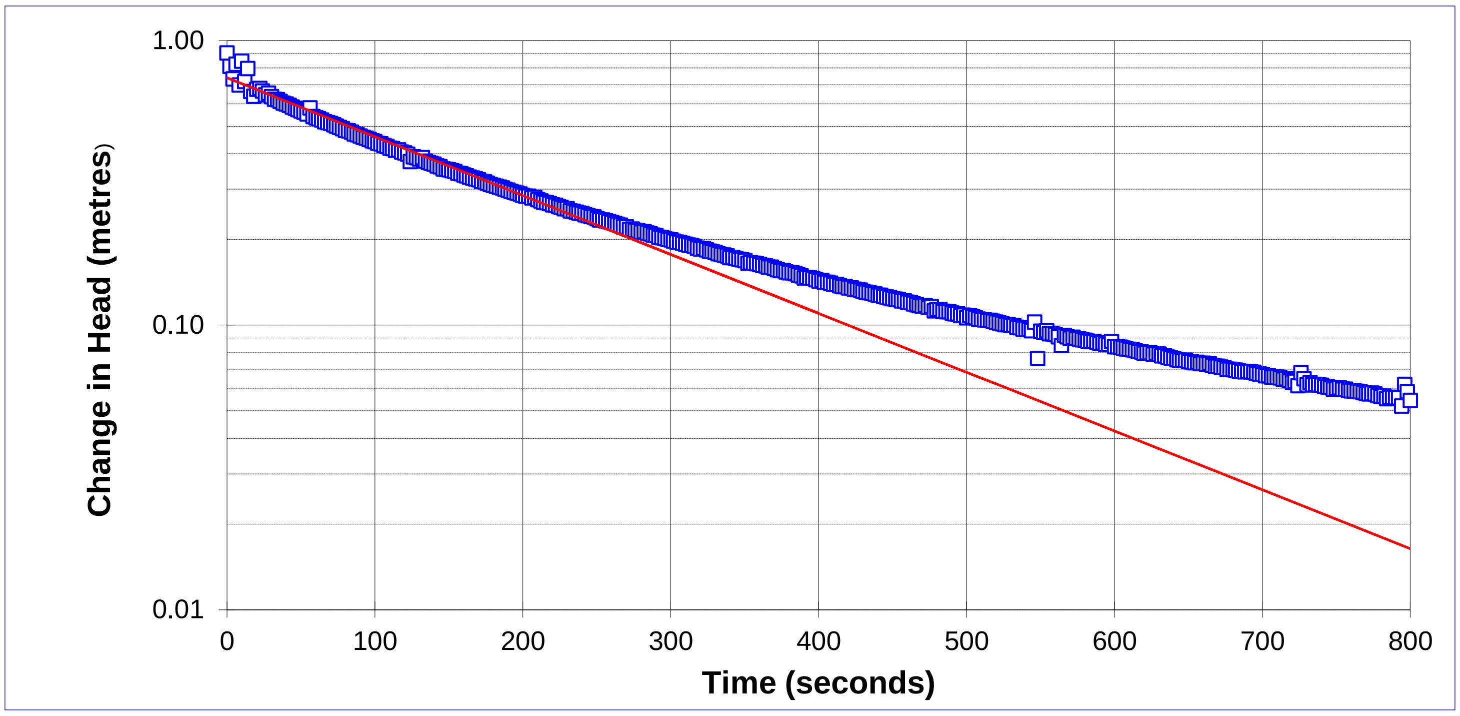
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = 0.02
r_w = 0.06
L_e = 2.58
$\ln(R_e/r_w)$ 2.69
y_0 = 0.74
y_t = 0.11
t = 400.0

RESULTS

K=	6E-07	m/sec
K=	6E-05	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/17/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/3/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-6-5B

INTERVAL (metres below ground surface)

Top of Interval = 5.2
Bottom of Interval = 5.6

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

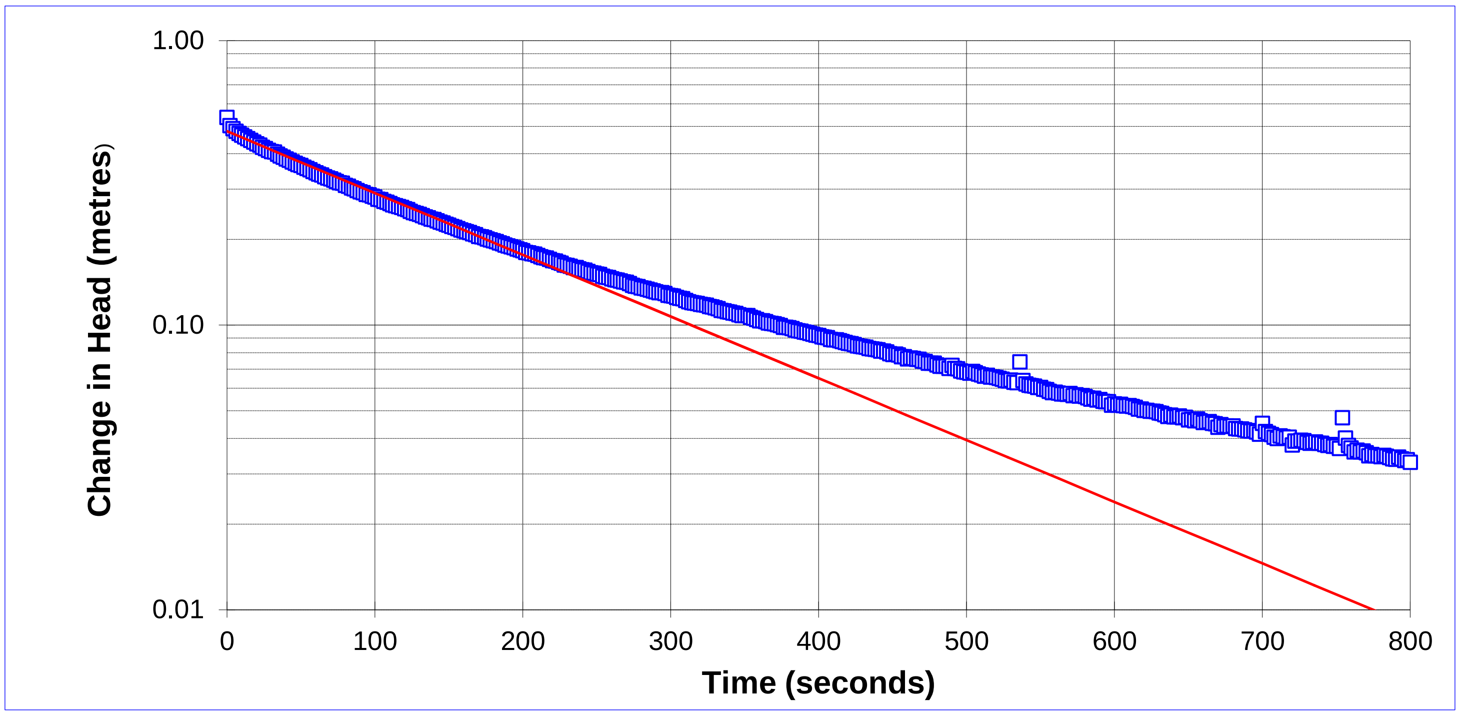
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.02
r_w =	0.06
L_e =	0.38
$\ln(R_e/r_w)$	1.34
y_0 =	0.48
y_t =	0.07
t =	400.0

RESULTS

K=	2E-06	m/sec
K=	2E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/17/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/3/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-6-6

INTERVAL (metres below ground surface)

Top of Interval = 0.6
Bottom of Interval = 1.6

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

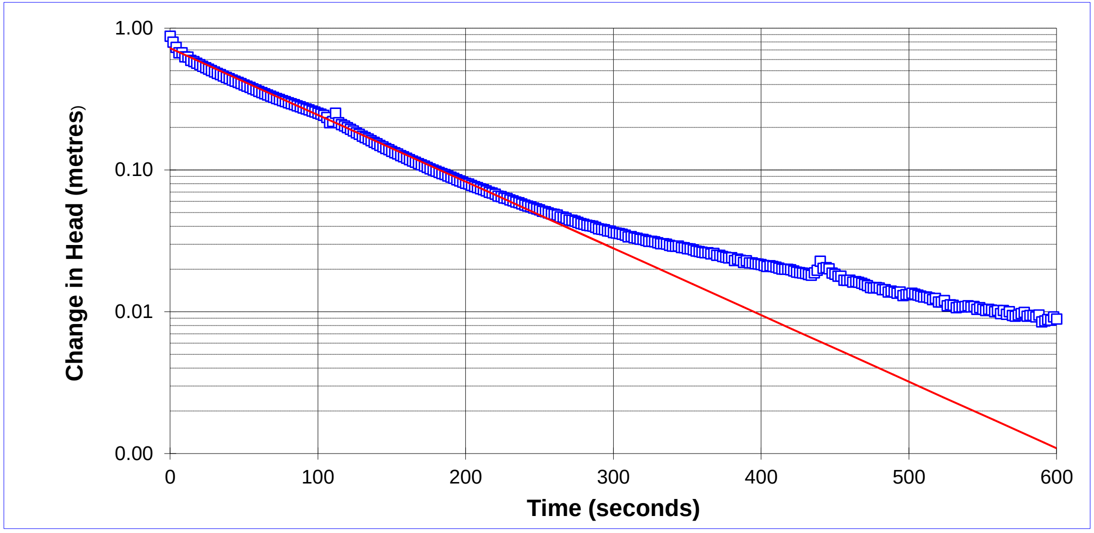
where:

r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	0.03
r_w =	0.06
L_e =	1.00
$ln(R_e/r_w)$	2.16
y_0 =	0.72
y_t =	0.03
t =	300.0

RESULTS

K=	8E-06	m/sec
K=	8E-04	cm/sec



Project Name:	CRRRC/EA Eastern ON/Boundary Rd	Analysis By:	DH
Project No.:	12-1127-00125/1000/0120	Checked By:	BH
Test Date:	04/17/13	Analysis Date:	4/22/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-7-2

INTERVAL (metres below ground surface)

Top of Interval = 34.6
Bottom of Interval = 39.5

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

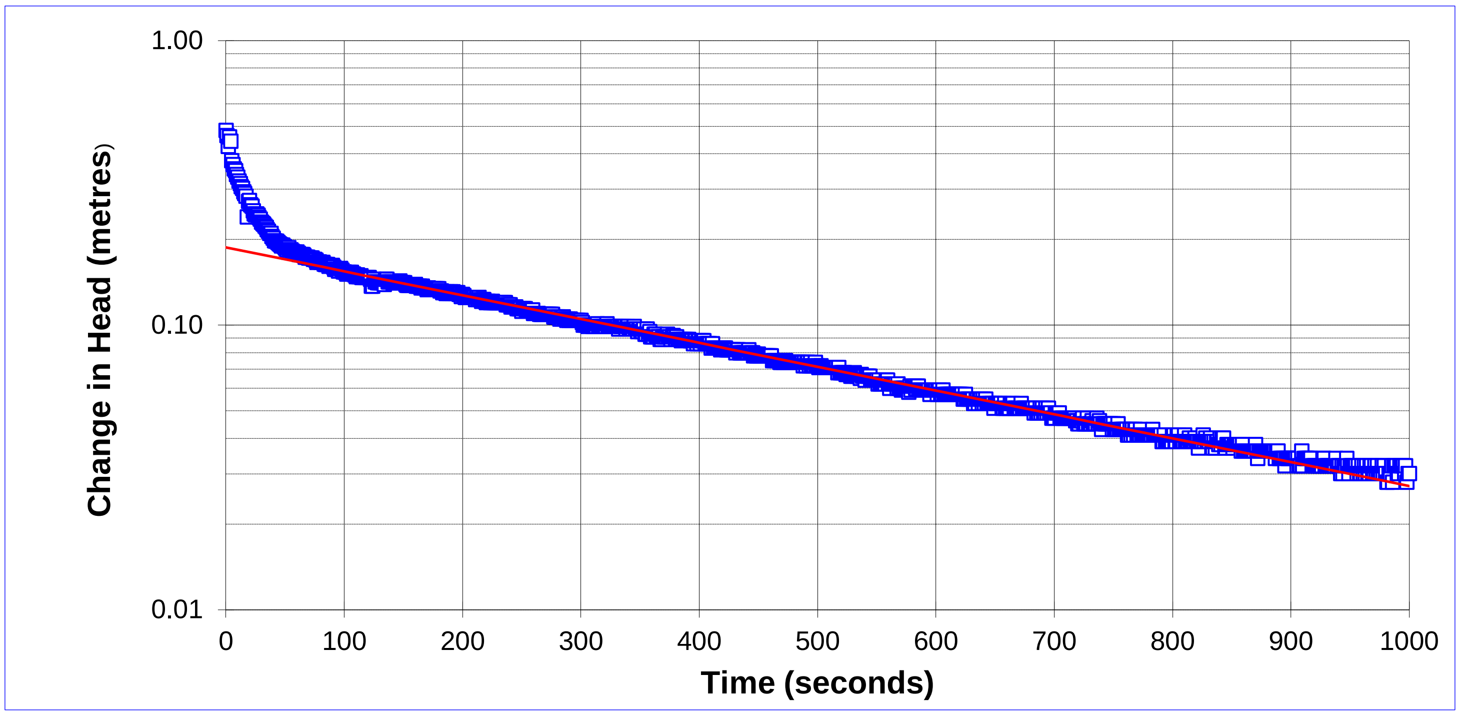
where:

r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	0.02
r_w =	0.04
L_e =	4.87
$\ln(R_e/r_w)$	4.21
y_0 =	0.11
y_t =	0.04
t =	500.0

RESULTS

K=	2E-07	m/sec
K=	2E-05	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 07/09/13

Analysis By: DH
Checked By: BH
Analysis Date: 7/9/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-7-3

INTERVAL (metres below ground surface)

Top of Interval = 28.0
Bottom of Interval = 30.3

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

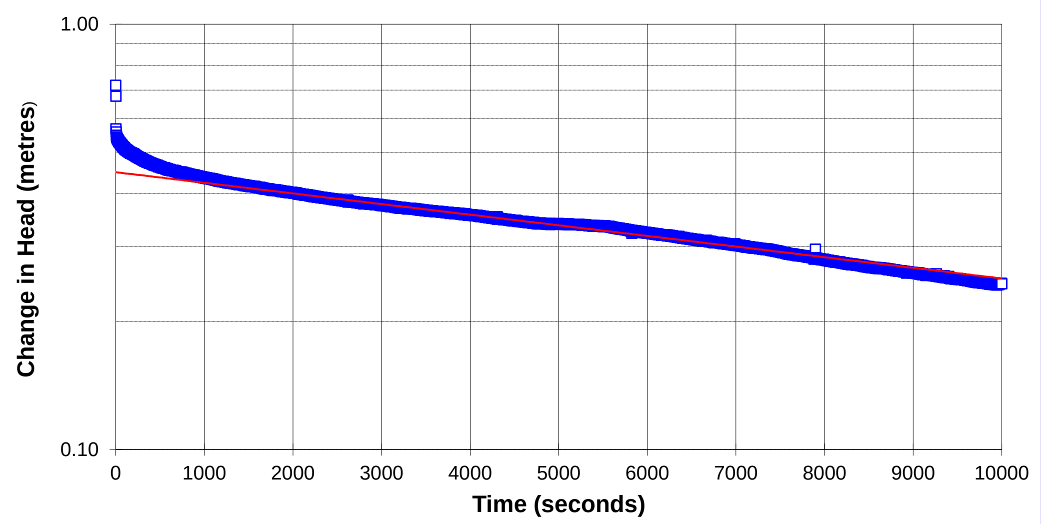
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = **0.02**
r_w = **0.06**
L_e = **2.27**
$\ln(R_e/r_w)$ **2.62**
y_0 = **0.40**
y_t = **0.30**
t = **5000.0**

RESULTS

K=	8E-09	**m/sec**
K=	8E-07	**cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/25/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-7-4-2

INTERVAL (metres below ground surface)

Top of Interval = 5.8
Bottom of Interval = 5.9

$$K = \frac{r_c^{2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln\frac{y_0}{y_t}$$

where K=m/sec

where:

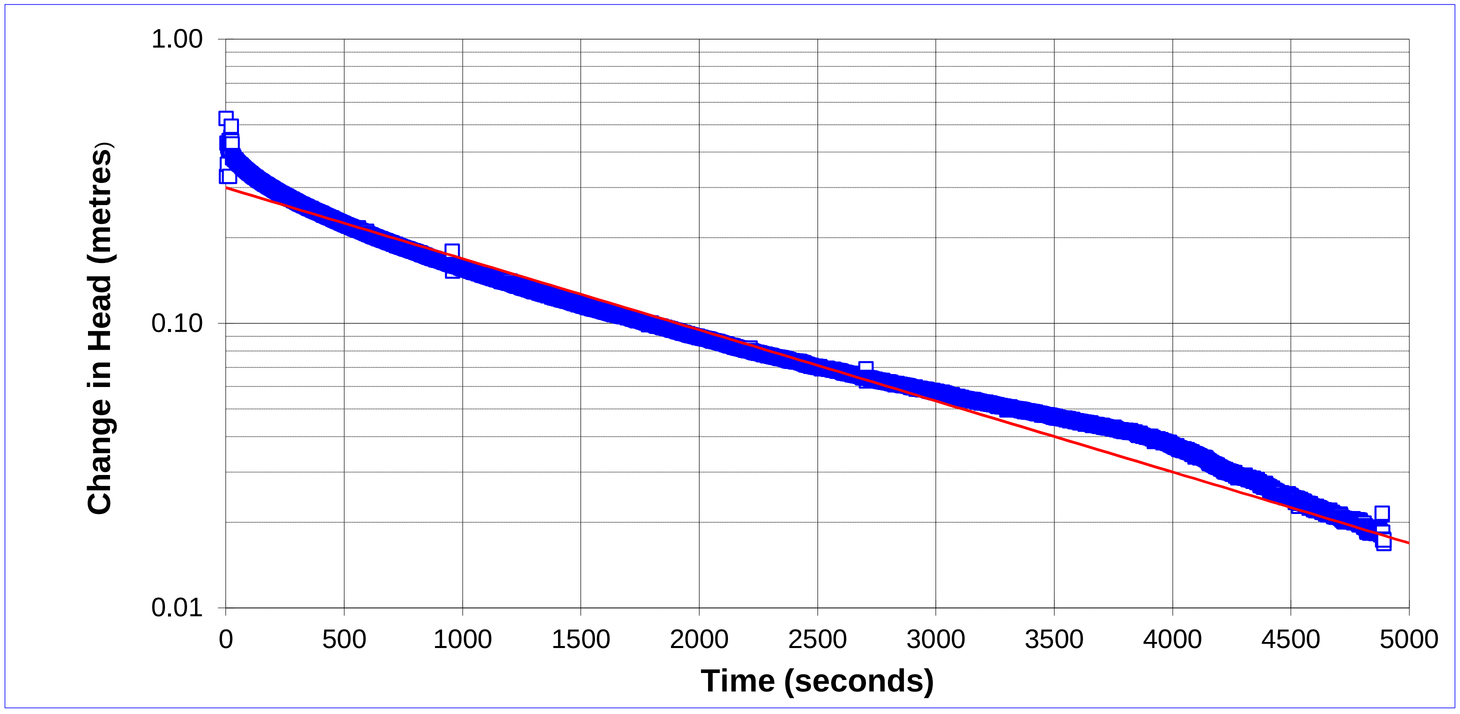
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = **0.02**
r_w = **0.10**
L_e = **0.15**
$\ln(R_e/r_w)$ **1.36**
y_0 = **0.30**
y_t = **0.03**
t = **4000.0**

RESULTS

K= 7E-07 **m/sec**
K= 7E-05 **cm/sec**



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/25/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/8/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-7-5

INTERVAL (metres below ground surface)

Top of Interval = 0.5
Bottom of Interval = 1.7

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

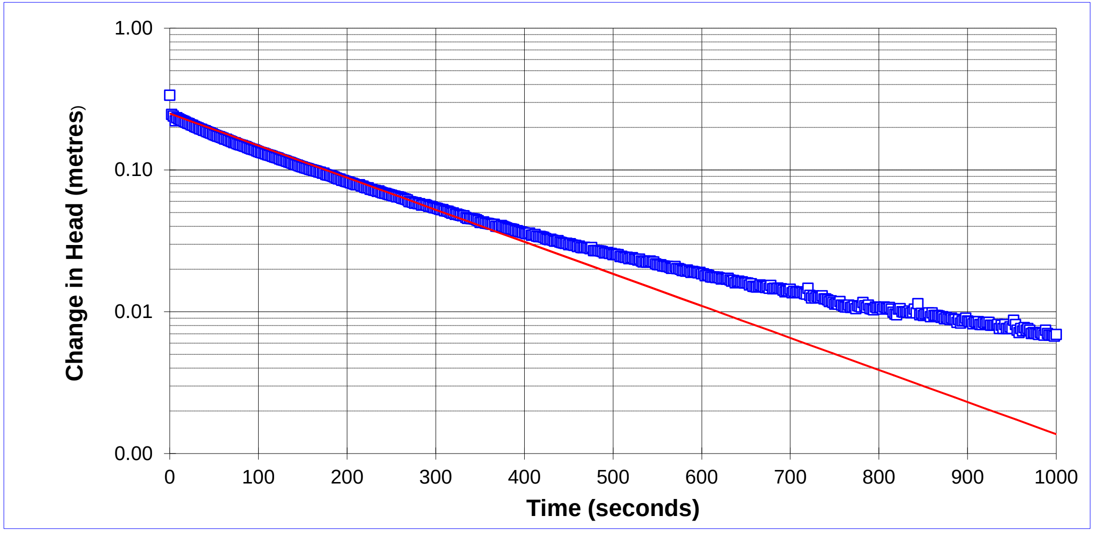
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c = 0.03
r_w = 0.10
L_e = 1.18
$\ln(R_e/r_w)$ 1.46
y_0 = 0.25
y_t = 0.01
t = 600.0

RESULTS

K=	2E-06	m/sec
K=	2E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/25/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST 13-8-2

INTERVAL (metres below ground surface)

Top of Interval = 0.3
Bottom of Interval = 1.5

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

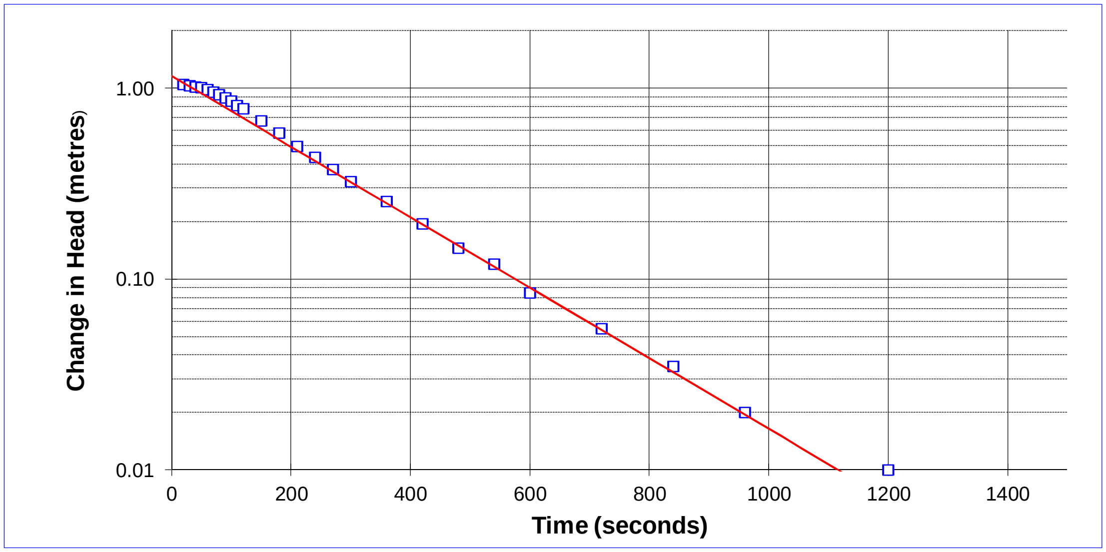
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.02
r_w =	0.06
L_e =	1.22
$\ln(R_e/r_w)$	2.31
y_0 =	0.09
y_t =	0.01
t =	600.0

RESULTS

K=	1E-06	m/sec
K=	1E-04	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/24/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST 13-8-3

INTERVAL (metres below ground surface)

Top of Interval = 4.4
Bottom of Interval = 4.7

$$K = \frac{r_c^{\,2} \ln\left(\frac{R_e}{r_w}\right)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

where K=m/sec

where:

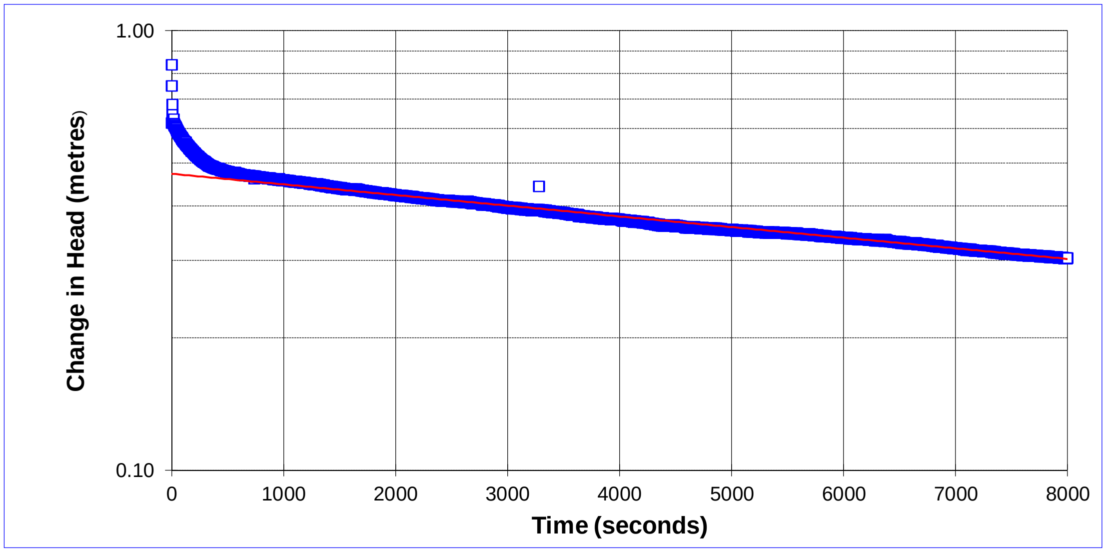
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.02
r_w =	0.06
L_e =	0.30
$\ln(R_e/r_w)$	1.19
y_0 =	0.40
y_t =	0.32
t =	4000.0

RESULTS

K=	3E-08	m/sec
K=	3E-06	cm/sec



Project Name: CRRRC/EA Eastern ON/Boundary Rd
Project No.: 12-1127-00125/1000/0120
Test Date: 04/24/13

Analysis By: DH
Checked By: BH
Analysis Date: 5/7/2013

APPENDIX O

Background Groundwater Quality Data

O-I: Background Groundwater Quality (Monitoring Wells)

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-1-3.1	12-1-3.1	12-1-3.1
				11-Jan-2013 (9)	25-Jun-2013 (10)	05-Nov-2013 (9)
				A-1	12-1-3	12-1-3
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	510	540	530
Ammonia Nitrogen	mg/l	--	--	12 (11)	13 (11)	12
Biologic Oxygen Demand, Five Day	mg/l	--	--	17	6.0	<2.0
Chemical Oxygen Demand	mg/l	--	--	140	110	140
Chloride, dissolved	mg/l	--	250	*7300*	*8000*	*7600*
Conductivity	uS/cm	--	--	23000	23000	24000
Conductivity (Field)	uS/cm	--	--	>3999	>3999	>3999
Dissolved Organic Carbon	mg/l	--	5	*8.5*	*6.5*	*7.1*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.050	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	12 (11)	12 (11)	12
pH	-	--	--	7.98	8.05	7.86
pH (Field)	-	--	--	7.69	7.71	7.75
Phosphorus	mg/l	--	--	0.23	0.060	0.45
Sulfate, dissolved	mg/l	--	500 (6)	6	1	2
Temperature (Field)	deg c	--	15	6.5	8.4	9.7
Total Dissolved Solids	mg/l	--	500	*12700*	*13400*	*12900*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.01	<0.01	0.011
Barium, dissolved	mg/l	1	--	16	17	17
Boron, dissolved	mg/l	5	--	1.7	1.8	1.9
Cadmium, dissolved	mg/l	0.005	--	<0.0010	<0.0010	<0.0010
Calcium, dissolved	mg/l	--	--	67	67	77
Chromium, dissolved	mg/l	0.05	--	<0.05	<0.05	<0.05
Copper, dissolved	mg/l	--	1	<0.01	<0.01	<0.01
Iron, dissolved	mg/l	--	0.3	<1	<1	*1.2*
Lead, dissolved	mg/l	0.01	--	<0.0050	<0.0050	<0.0050
Magnesium, dissolved	mg/l	--	--	330	340	320
Manganese, dissolved	mg/l	--	0.05	*0.082*	*0.066*	*0.075*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	90	93	89
Sodium, dissolved	mg/l	--	200 (7)	*4800*	*5000*	*4800*
Zinc, dissolved	mg/l	--	5	<0.05	<0.05	<0.05
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00025	<0.00025	<0.00010
Toluene	mg/l	--	0.024	<0.00050	<0.00050	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	0.0072
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00050	<0.00050	<0.00020
Methane	l/m3	--	3	*16*	*64*	*50*
Methane	mg/l	--	3 (8)	10	42	33
Methylene Chloride	mg/l	0.05	--	<0.0013	<0.0013	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00050	<0.00050	<0.00020

Created by: DH
Reviewed by: JPAO

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-1-4A 11-Jan-2013 A-2	12-1-4A 25-Jun-2013 (10) 12-1-4A	12-1-4A 05-Nov-2013 (9) 12-1-4A
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	490	560	600
Ammonia Nitrogen	mg/l	--	--	12	12	12
Biologic Oxygen Demand, Five Day	mg/l	--	--	15	6.0	16
Chemical Oxygen Demand	mg/l	--	--	110	110	160
Chloride, dissolved	mg/l	--	250	*7100*	*7300*	*7500*
Conductivity	uS/cm	--	--	22000	22000	23000
Conductivity (Field)	uS/cm	--	--	>3999	>3999	>3999
Dissolved Organic Carbon	mg/l	--	5	*8.6*	*8.0*	*8.3*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.050	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	14	12	12
pH	-	--	--	7.99	8.05	7.92
pH (Field)	-	--	--	7.86	7.84	7.88
Phosphorus	mg/l	--	--	6.9	0.14	3.3
Sulfate, dissolved	mg/l	--	500 (6)	10	3	3
Temperature (Field)	deg c	--	15	6.1	8.2	10.2
Total Dissolved Solids	mg/l	--	500	*12500*	*12400*	*12900*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.01	0.012	0.011
Barium, dissolved	mg/l	1	--	15	17	16
Boron, dissolved	mg/l	5	--	1.7	1.8	1.7
Cadmium, dissolved	mg/l	0.005	--	<0.0010	<0.0010	<0.0010
Calcium, dissolved	mg/l	--	--	71	68	68
Chromium, dissolved	mg/l	0.05	--	<0.05	<0.05	<0.05
Copper, dissolved	mg/l	--	1	<0.01	<0.01	<0.01
Iron, dissolved	mg/l	--	0.3	<1	<1	*1.5*
Lead, dissolved	mg/l	0.01	--	<0.0050	<0.0050	<0.0050
Magnesium, dissolved	mg/l	--	--	330	340	330
Manganese, dissolved	mg/l	--	0.05	*0.12*	*0.086*	*0.14*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	91	93	92
Sodium, dissolved	mg/l	--	200 (7)	*4900*	*4900*	*4600*
Zinc, dissolved	mg/l	--	5	<0.05	<0.05	<0.05
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00025	<0.00025	<0.00010
Toluene	mg/l	--	0.024	<0.00050	<0.00050	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	0.0075
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00050	<0.00050	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.0013	<0.0013	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00050	<0.00050	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-1-5B	12-1-5B	12-1-5B
				11-Jan-2013 (9)	25-Jun-2013 (13)	05-Nov-2013 (9)
				A-3	12-1-5B	12-1-5B
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	710	750	750
Ammonia Nitrogen	mg/l	--	--	3.4	2.5	2.4
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	2.0	10
Chemical Oxygen Demand	mg/l	--	--	220	87	96
Chloride, dissolved	mg/l	--	250	*1600*	*1600*	*1500*
Conductivity	uS/cm	--	--	6400	6200	6000
Conductivity (Field)	uS/cm	--	--	>3999	>3999	>3999
Dissolved Organic Carbon	mg/l	--	5	*6.2*	*5.1*	*5.1*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	0.31
Nitrogen, Total Kjeldahl	mg/l	--	--	11	5.7	7.7
pH	-	--	--	8.07	8.15	7.91
pH (Field)	-	--	--	7.82	7.91	7.89
Phosphorus	mg/l	--	--	130	23	22
Sulfate, dissolved	mg/l	--	500 (6)	38	13	12
Temperature (Field)	deg c	--	15	6.4	10.9	10.4
Total Dissolved Solids	mg/l	--	500	*3460*	*3310*	*3140*
Metals						
Arsenic, dissolved	mg/l	0.025	--	0.0022	0.0057	0.0045
Barium, dissolved	mg/l	1	--	0.2	0.19	0.16
Boron, dissolved	mg/l	5	--	0.34	0.31	0.3
Cadmium, dissolved	mg/l	0.005	--	<0.00020	<0.00020	<0.00020
Calcium, dissolved	mg/l	--	--	67	71	68
Chromium, dissolved	mg/l	0.05	--	<0.02	<0.01	<0.01
Copper, dissolved	mg/l	--	1	<0.0020	0.0022	0.0029
Iron, dissolved	mg/l	--	0.3	<0.2	<0.2	*0.37*
Lead, dissolved	mg/l	0.01	--	<0.0010	<0.0010	<0.0010
Magnesium, dissolved	mg/l	--	--	130	140	130
Manganese, dissolved	mg/l	--	0.05	*0.064*	*0.069*	*0.067*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	26	25	22
Sodium, dissolved	mg/l	--	200 (7)	*1200*	*1200*	*1000*
Zinc, dissolved	mg/l	--	5	<0.01	<0.01	0.013
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00020	<0.00050	<0.00010
Toluene	mg/l	--	0.024	<0.00040	<0.0010	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00040	<0.0010	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.0010	<0.0025	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00040	<0.0010	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-1-6	12-1-6	12-1-6
				11-Jan-2013	25-Jun-2013	05-Nov-2013
				A-5	12-1-6	12-1-6
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	660	540	460
Ammonia Nitrogen	mg/l	--	--	0.26	0.14	<0.050
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	<2.0	<2.0
Chemical Oxygen Demand	mg/l	--	--	51	29	27
Chloride, dissolved	mg/l	--	250	*360*	250	220
Conductivity	uS/cm	--	--	2700	2000	1700
Conductivity (Field)	uS/cm	--	--	2564	2408	1818
Dissolved Organic Carbon	mg/l	--	5	4.8	*6.6*	*8.3*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	0.022	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	3.0	1.2	0.74
pH	-	--	--	7.70	7.79	7.46
pH (Field)	-	--	--	7.75	7.74	7.20
Phosphorus	mg/l	--	--	1.5	0.64	0.46
Sulfate, dissolved	mg/l	--	500 (6)	160	140	88
Temperature (Field)	deg c	--	15	2.5	12.2	9.8
Total Dissolved Solids	mg/l	--	500	*1540*	*1140*	*832*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.0010	0.0013	<0.0010
Barium, dissolved	mg/l	1	--	0.079	0.061	0.079
Boron, dissolved	mg/l	5	--	0.067	0.058	0.027
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Calcium, dissolved	mg/l	--	--	130	110	100
Chromium, dissolved	mg/l	0.05	--	0.0072	<0.0050	<0.0050
Copper, dissolved	mg/l	--	1	0.0011	0.0010	0.0021
Iron, dissolved	mg/l	--	0.3	<0.1	0.13	<0.1
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.00050
Magnesium, dissolved	mg/l	--	--	88	60	48
Manganese, dissolved	mg/l	--	0.05	*0.33*	*0.18*	*0.093*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	6.2	5.6	3.8
Sodium, dissolved	mg/l	--	200 (7)	*380*	*280*	*210*
Zinc, dissolved	mg/l	--	5	<0.0050	<0.0050	0.011
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Toluene	mg/l	--	0.024	<0.00020	<0.00020	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00020	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

		(2) (1)	(4) (3)	12-2-3	12-2-3	12-2-3	12-2-3
Parameter	**Unit**	**ODWQS(169/03)-Health**	**ODWQS-AO**	**21-Jan-2013**	**26-Jun-2013** (9)	**30-Oct-2013**	**12-Nov-2013**
				12-02-3	12-2-3	12-2-3	12-2-3
General Chemistry							
Alkalinity (Total as CaCO3)	mg/l	--	--	590	620	610	--
Ammonia Nitrogen	mg/l	--	--	6.9	7.2	7.1	--
Biologic Oxygen Demand, Five Day	mg/l	--	--	4.0	5.0	8.0	--
Chemical Oxygen Demand	mg/l	--	--	56	67	45	--
Chloride, dissolved	mg/l	--	250	*2800*	*3200*	*3300*	--
Conductivity	uS/cm	--	--	10000	11000	11000	--
Conductivity (Field)	uS/cm	--	--	>3999	>3999	>3999	--
Dissolved Organic Carbon	mg/l	--	5	*5.6*	*6.8*	*8.0*	--
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10	--
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010	--
Nitrogen, Total Kjeldahl	mg/l	--	--	7.4	7.7	7.7	--
pH	-	--	--	8.07	8.25	8.20	--
pH (Field)	-	--	--	7.73	8.19	7.31	--
Phosphorus	mg/l	--	--	0.087	0.059	0.095	--
Sulfate, dissolved	mg/l	--	500 (6)	250	260	230	--
Temperature (Field)	deg c	--	15	3.6	8.9	7.3	--
Total Dissolved Solids	mg/l	--	500	*5560*	*5970*	*6100*	--
Metals							
Arsenic, dissolved	mg/l	0.025	--	<0.0050 (14)	0.0065	<0.005	--
Barium, dissolved	mg/l	1	--	0.09	0.18	0.11	--
Boron, dissolved	mg/l	5	--	1.5	1.7	1.6	--
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00050	<0.0001	--
Calcium, dissolved	mg/l	--	--	27	34	33	--
Chromium, dissolved	mg/l	0.05	--	<0.025 (14)	<0.025	<0.005	--
Copper, dissolved	mg/l	--	1	<0.0010	<0.0050	<0.001	--
Iron, dissolved	mg/l	--	0.3	<0.1	<0.5	<0.1	--
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.0025	<0.0005	--
Magnesium, dissolved	mg/l	--	--	93	120	110	--
Manganese, dissolved	mg/l	--	0.05	0.018	0.019	0.016	--
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010	--
Potassium, dissolved	mg/l	--	--	50	56	54	--
Sodium, dissolved	mg/l	--	200 (7)	*2000*	*2400*	*2500*	--
Zinc, dissolved	mg/l	--	5	<0.0050	<0.025	<0.005	--
Petroleum Hydrocarbons							
Benzene	mg/l	0.005	--	<0.00010	<0.00010	--	<0.00010
Toluene	mg/l	--	0.024	<0.00020	<0.00020	--	0.00032
Phenols							
Phenolics, Total Recoverable	mg/l	--	--	0.0058 (15)	0.0052	0.010	--
VOCs							
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00020	--	<0.00020
Methane	l/m3	--	3	0.46	1.2	0.81	--
Methane	mg/l	--	3 (8)	0.30	0.79	0.53	--
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	--	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	--	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-	(4) (3) ODWQS-AO	12-2-5B	12-2-5B	12-2-5B	12-2-5B
				21-Jan-2013	**26-Jun-2013** (16)	**30-Oct-2013**	**12-Nov-2013**
				12-02-5B	12-2-5B	12-2-5B	12-2-5B
General Chemistry							
Alkalinity (Total as CaCO3)	mg/l	--	--	200	470	490	--
Ammonia Nitrogen	mg/l	--	--	2.3	2.0	2.3	--
Biologic Oxygen Demand, Five Day	mg/l	--	--	68	<2.0	2.0	--
Chemical Oxygen Demand	mg/l	--	--	740	260	380	--
Chloride, dissolved	mg/l	--	250	*350*	*880*	*960*	--
Conductivity	uS/cm	--	--	1700	3600	3900	--
Conductivity (Field)	uS/cm	--	--	1507	3548	3332	--
Dissolved Organic Carbon	mg/l	--	5	*45*	4.9	*5.2*	--
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10	--
Nitrite as N	mg/l	1	--	0.056	<0.010	<0.010	--
Nitrogen, Total Kjeldahl	mg/l	--	--	19	11	9.7	--
pH	-	--	--	8.36	8.30	8.26	--
pH (Field)	-	--	--	7.37	8.26	7.18	--
Phosphorus	mg/l	--	--	78	29	110	--
Sulfate, dissolved	mg/l	--	500 (6)	32	7	8	--
Temperature (Field)	deg c	--	15	5.0	10.2	7.7	--
Total Dissolved Solids	mg/l	--	500	*958*	*1840*	*2000*	--
Metals							
Arsenic, dissolved	mg/l	0.025	--	0.0021	0.0068	0.007	--
Barium, dissolved	mg/l	1	--	0.044	0.1	0.11	--
Boron, dissolved	mg/l	5	--	0.13	0.21	0.2	--
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.0001	--
Calcium, dissolved	mg/l	--	--	19	40	36	--
Chromium, dissolved	mg/l	0.05	--	<0.0050	<0.0050	<0.005	--
Copper, dissolved	mg/l	--	1	<0.0010	<0.0010	<0.001	--
Iron, dissolved	mg/l	--	0.3	<0.1	0.18	0.19	--
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.0005	--
Magnesium, dissolved	mg/l	--	--	12	55	54	--
Manganese, dissolved	mg/l	--	0.05	0.044	*0.13*	*0.13*	--
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010	--
Potassium, dissolved	mg/l	--	--	5.2	12	11	--
Sodium, dissolved	mg/l	--	200 (7)	*350*	*660*	*750*	--
Zinc, dissolved	mg/l	--	5	<0.0050	<0.0050	<0.005	--
Petroleum Hydrocarbons							
Benzene	mg/l	0.005	--	0.00061	<0.00020	--	<0.00010
Toluene	mg/l	--	0.024	0.00035	<0.00040	--	<0.00020
Phenols							
Phenolics, Total Recoverable	mg/l	--	--	0.0020 (15)	<0.0010	<0.0010	--
VOCs							
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00040	--	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.0010	--	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00040	--	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-2-6 21-Jan-2013	12-2-6 26-Jun-2013	12-2-6 30-Oct-2013	12-2-6 12-Nov-2013
				12-02-6	12-2-6	12-2-6	12-2-6
General Chemistry							
Alkalinity (Total as CaCO3)	mg/l	--	--	390	330	340	--
Ammonia Nitrogen	mg/l	--	--	0.37	0.33	0.077	--
Biologic Oxygen Demand, Five Day	mg/l	--	--	5.0	<2.0	<2.0	--
Chemical Oxygen Demand	mg/l	--	--	140	120	18	--
Chloride, dissolved	mg/l	--	250	71	43	40	--
Conductivity	uS/cm	--	--	1000	820	820	--
Conductivity (Field)	uS/cm	--	--	920	825	800	--
Dissolved Organic Carbon	mg/l	--	5	*5.7*	4.0	3.5	--
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10	--
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010	--
Nitrogen, Total Kjeldahl	mg/l	--	--	4.0	4.5	1.7	--
pH	-	--	--	7.57	7.84	7.78	--
pH (Field)	-	--	--	7.72	7.85	7.03	--
Phosphorus	mg/l	--	--	25	26	1.8	--
Sulfate, dissolved	mg/l	--	500 (6)	55	34	42	--
Temperature (Field)	deg c	--	15	3.4	13.4	7.1	--
Total Dissolved Solids	mg/l	--	500	*570*	490	468	--
Metals							
Arsenic, dissolved	mg/l	0.025	--	<0.0010	<0.0010	<0.001	--
Barium, dissolved	mg/l	1	--	0.058	0.07	0.068	--
Boron, dissolved	mg/l	5	--	0.042	0.03	0.013	--
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.0001	--
Calcium, dissolved	mg/l	--	--	76	66	63	--
Chromium, dissolved	mg/l	0.05	--	<0.0050	<0.0050	<0.005	--
Copper, dissolved	mg/l	--	1	<0.0010	0.0027	0.003	--
Iron, dissolved	mg/l	--	0.3	<0.1	<0.1	<0.1	--
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.0005	--
Magnesium, dissolved	mg/l	--	--	35	27	28	--
Manganese, dissolved	mg/l	--	0.05	*0.25*	*0.19*	0.008	--
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010	--
Potassium, dissolved	mg/l	--	--	4.7	5	5.1	--
Sodium, dissolved	mg/l	--	200 (7)	87	66	81	--
Zinc, dissolved	mg/l	--	5	<0.0050	<0.0050	0.007	--
Petroleum Hydrocarbons							
Benzene	mg/l	0.005	--	<0.00010	<0.00010	--	<0.00010
Toluene	mg/l	--	0.024	<0.00020	<0.00020	--	<0.00020
Phenols							
Phenolics, Total Recoverable	mg/l	--	--	0.0018 (15)	<0.0010	<0.0010	--
VOCs							
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00020	--	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	--	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	--	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-3-3 11-Jan-2013 (17) B-1	12-3-3 19-Jun-2013 (18) 12-3-3	12-3-3 05-Nov-2013 (9) 12-3-3
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	680	660	690
Ammonia Nitrogen	mg/l	--	--	9.7	8.6	9.1
Biologic Oxygen Demand, Five Day	mg/l	--	--	<40	12	12
Chemical Oxygen Demand	mg/l	--	--	100	75	92
Chloride, dissolved	mg/l	--	250	*6000*	*6700*	*6400*
Conductivity	uS/cm	--	--	21000	19000	20000
Conductivity (Field)	uS/cm	--	--	>3999	>3999	>3999
Dissolved Organic Carbon	mg/l	--	5	*8.1*	*11*	*9.0*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	9.8	9.3	9.3
pH	-	--	--	8.03	8.12	7.93
pH (Field)	-	--	--	7.88	7.84	7.76
Phosphorus	mg/l	--	--	0.23	0.096	0.064
Sulfate, dissolved	mg/l	--	500 (6)	4	1	<1
Temperature (Field)	deg c	--	15	6.9	8.6	9.3
Total Dissolved Solids	mg/l	--	500	*11600*	*11200*	*10900*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.01	<0.01	0.012
Barium, dissolved	mg/l	1	--	17	15	17
Boron, dissolved	mg/l	5	--	1.7	1.6	1.7
Cadmium, dissolved	mg/l	0.005	--	<0.0010	<0.0010	<0.0010
Calcium, dissolved	mg/l	--	--	62	60	56
Chromium, dissolved	mg/l	0.05	--	<0.05	<0.05	<0.05
Copper, dissolved	mg/l	--	1	<0.01	<0.01	<0.01
Iron, dissolved	mg/l	--	0.3	<1	<1	<1
Lead, dissolved	mg/l	0.01	--	<0.0050	<0.0050	<0.0050
Magnesium, dissolved	mg/l	--	--	240	220	230
Manganese, dissolved	mg/l	--	0.05	0.031	*0.097*	0.036
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	81	75	81
Sodium, dissolved	mg/l	--	200 (7)	*4300*	*4000*	*4300*
Zinc, dissolved	mg/l	--	5	<0.05	<0.05	<0.05
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	0.00072	<0.00025	<0.00010
Toluene	mg/l	--	0.024	0.00027	<0.00050	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0050 (19)
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00050	<0.00020
Methane	l/m3	--	3	*39*	*61*	*51*
Methane	mg/l	--	3 (8)	--	40	33
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.0013	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00050	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

		(2) (1)	(4) (3)	12-3-4A	12-3-4A	12-3-4A
Parameter	Unit	ODWQS(169/03)-Health	ODWQS-AO	11-Jan-2013 (9)	19-Jun-2013 (18)	05-Nov-2013 (9)
				B-2	12-3-4A	12-3-4A
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	620	670	640
Ammonia Nitrogen	mg/l	--	--	8.7 (11)	8.4	7.9 (11)
Biologic Oxygen Demand, Five Day	mg/l	--	--	8.0	6.0	31
Chemical Oxygen Demand	mg/l	--	--	85	75	100
Chloride, dissolved	mg/l	--	250	*6100*	*6700*	*6300*
Conductivity	uS/cm	--	--	19000	19000	19000
Conductivity (Field)	uS/cm	--	--	>3999	>3999	>3999
Dissolved Organic Carbon	mg/l	--	5	*9.4*	*11*	*14*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	8.3 (11)	9.2	7.6 (11)
pH	-	--	--	8.07	8.16	7.97
pH (Field)	-	--	--	8.12	8.12	8.04
Phosphorus	mg/l	--	--	0.37	0.14	0.96
Sulfate, dissolved	mg/l	--	500 (6)	18	2	3
Temperature (Field)	deg c	--	15	6.8	8.9	8.6
Total Dissolved Solids	mg/l	--	500	*10400*	*12100*	*9990*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.01	<0.01	0.012
Barium, dissolved	mg/l	1	--	14	14	14
Boron, dissolved	mg/l	5	--	1.5	1.7	1.6
Cadmium, dissolved	mg/l	0.005	--	<0.0010	<0.0010	<0.0010
Calcium, dissolved	mg/l	--	--	57	56	46
Chromium, dissolved	mg/l	0.05	--	<0.05	<0.05	<0.05
Copper, dissolved	mg/l	--	1	<0.01	<0.01	<0.01
Iron, dissolved	mg/l	--	0.3	<1	<1	<1
Lead, dissolved	mg/l	0.01	--	<0.0050	<0.0050	0.016
Magnesium, dissolved	mg/l	--	--	210	220	200
Manganese, dissolved	mg/l	--	0.05	0.05	*0.13*	*0.12*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	74	74	72
Sodium, dissolved	mg/l	--	200 (7)	*4000*	*4100*	*3900*
Zinc, dissolved	mg/l	--	5	<0.05	<0.05	<0.05
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00025	<0.00025	<0.00010
Toluene	mg/l	--	0.024	<0.00050	<0.00050	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	0.0013	0.0061
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00050	<0.00050	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.0013	<0.0013	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00050	<0.00050	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/ 03)-Health	(4) (3) ODWQS-AO	12-3-5B	12-3-5B	12-3-5B	12-3-5B
				11-Jan-2013	19-Jun-2013	30-Oct-2013	12-Nov-2013
				B-3	12-3-5B	12-3-5B	12-3-5B
General Chemistry							
Alkalinity (Total as CaCO3)	mg/l	--	--	340	340	410	--
Ammonia Nitrogen	mg/l	--	--	1.7	1.4	1.5	--
Biologic Oxygen Demand, Five Day	mg/l	--	--	20	3.0	<2.0	--
Chemical Oxygen Demand	mg/l	--	--	380	180	350	--
Chloride, dissolved	mg/l	--	250	*900*	*630*	*540*	--
Conductivity	uS/cm	--	--	3900	2900	2600	--
Conductivity (Field)	uS/cm	--	--	3364	3108	2395	--
Dissolved Organic Carbon	mg/l	--	5	*21*	*12*	*11*	--
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10	--
Nitrite as N	mg/l	1	--	<0.010	<0.010	0.012	--
Nitrogen, Total Kjeldahl	mg/l	--	--	14	9.7	10	--
pH	-	--	--	8.16	8.29	8.21	--
pH (Field)	-	--	--	7.71	7.67	7.17	--
Phosphorus	mg/l	--	--	48	22	25	--
Sulfate, dissolved	mg/l	--	500 (6)	130	87	75	--
Temperature (Field)	deg c	--	15	6.8	12.4	9.8	--
Total Dissolved Solids	mg/l	--	500	*2170*	*1660*	*1460*	--
Metals							
Arsenic, dissolved	mg/l	0.025	--	0.0021 (14)	0.0038	0.002	--
Barium, dissolved	mg/l	1	--	0.2	0.15	0.15	--
Boron, dissolved	mg/l	5	--	0.18	0.17	0.15	--
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.0001	--
Calcium, dissolved	mg/l	--	--	120	82	68	--
Chromium, dissolved	mg/l	0.05	--	<0.01 (14)	<0.0050	<0.005	--
Copper, dissolved	mg/l	--	1	<0.0010	<0.0010	<0.001	--
Iron, dissolved	mg/l	--	0.3	<0.1	<0.1	<0.1	--
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.0005	--
Magnesium, dissolved	mg/l	--	--	34	33	32	--
Manganese, dissolved	mg/l	--	0.05	*1.4*	*1.3*	*0.99*	--
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010	--
Potassium, dissolved	mg/l	--	--	12	11	10	--
Sodium, dissolved	mg/l	--	200 (7)	*690*	*520*	*470*	--
Zinc, dissolved	mg/l	--	5	<0.0050	<0.0050	<0.005	--
Petroleum Hydrocarbons							
Benzene	mg/l	0.005	--	0.0043	0.0016	--	0.00035
Toluene	mg/l	--	0.024	0.0011	0.00043	--	<0.00020
Xylenes, Total	mg/l	--	0.3	--	--	--	0.00011
Phenols							
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010	--
VOCs							
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00050	<0.00020	--	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.0013	<0.00050	--	<0.00050
Vinyl Chloride	mg/l	0.002	--	0.0013	0.00028	--	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-3-6 11-Jan-2013 B-4	12-3-6 19-Jun-2013 12-3-6	12-3-6 30-Oct-2013 12-3-6	12-3-6 12-Nov-2013 12-3-6
General Chemistry							
Alkalinity (Total as CaCO3)	mg/l	--	--	320	270	320	--
Ammonia Nitrogen	mg/l	--	--	0.22	0.16	0.068	--
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	<2.0	<2.0	--
Chemical Oxygen Demand	mg/l	--	--	26	13	24	--
Chloride, dissolved	mg/l	--	250	*950*	*880*	*950*	--
Conductivity	uS/cm	--	--	3900	3600	3600	--
Conductivity (Field)	uS/cm	--	--	3108	2996	3280	--
Dissolved Organic Carbon	mg/l	--	5	4.5	4.0	3.8	--
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10	--
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010	--
Nitrogen, Total Kjeldahl	mg/l	--	--	1.9	1.3	0.73	--
pH	-	--	--	7.54	7.85	7.72	--
pH (Field)	-	--	--	7.81	7.84	7.10	--
Phosphorus	mg/l	--	--	6.3	1.9	1.9	--
Sulfate, dissolved	mg/l	--	500 (6)	83	83	77	--
Temperature (Field)	deg c	--	15	3.5	12.6	10.6	--
Total Dissolved Solids	mg/l	--	500	*2270*	*2320*	*2200*	--
Metals							
Arsenic, dissolved	mg/l	0.025	--	<0.0020 (14)	<0.0010	<0.005	--
Barium, dissolved	mg/l	1	--	0.36	0.21	0.2	--
Boron, dissolved	mg/l	5	--	0.017	0.023	<0.01	--
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.0001	--
Calcium, dissolved	mg/l	--	--	240	180	200	--
Chromium, dissolved	mg/l	0.05	--	0.011 (14)	<0.0050	<0.005	--
Copper, dissolved	mg/l	--	1	0.0016	0.0015	0.002	--
Iron, dissolved	mg/l	--	0.3	<0.1	<0.1	<0.1	--
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.0005	--
Magnesium, dissolved	mg/l	--	--	56	38	44	--
Manganese, dissolved	mg/l	--	0.05	*0.51*	*0.39*	*0.48*	--
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010	--
Potassium, dissolved	mg/l	--	--	6	6.6	7	--
Sodium, dissolved	mg/l	--	200 (7)	*530*	*530*	*540*	--
Zinc, dissolved	mg/l	--	5	<0.0050	<0.0050	0.006	--
Petroleum Hydrocarbons							
Benzene	mg/l	0.005	--	<0.00010	<0.00010	--	<0.00010
Ethylbenzene	mg/l	--	0.0024	--	--	--	<0.00010
m,p-Xylenes	mg/l	--	--	--	--	--	<0.00010
o-Xylene	mg/l	--	--	--	--	--	<0.00010
Toluene	mg/l	--	0.024	<0.00020	<0.00020	--	<0.00020
Xylenes, Total	mg/l	--	0.3	--	--	--	<0.00010
Phenols							
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010	--
Semi-VOCs							
4-Methyl-2-pentanone	mg/l	--	--	--	--	--	<0.0050
Styrene	mg/l	--	--	--	--	--	<0.00020
VOCs							
1,1,1,2-Tetrachloroethane	mg/l	--	--	--	--	--	<0.00020
1,1,1-Trichloroethane	mg/l	--	--	--	--	--	<0.00010
1,1,2,2-Tetrachloroethane	mg/l	--	--	--	--	--	<0.00020
1,1,2-Trichloroethane	mg/l	--	--	--	--	--	<0.00020
1,1-Dichloroethane	mg/l	--	--	--	--	--	<0.00010
1,1-Dichloroethylene	mg/l	0.014	--	--	--	--	<0.00010
1,2-Dibromoethane	mg/l	--	--	--	--	--	<0.00020
1,2-Dichlorobenzene	mg/l	0.2	0.003	--	--	--	<0.00020
1,2-Dichloroethane	mg/l	0.005	--	--	--	--	<0.00020
1,2-Dichloropropane	mg/l	--	--	--	--	--	<0.00010
1,3-Dichlorobenzene	mg/l	--	--	--	--	--	<0.00020
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00020	--	<0.00020
Methyl Ethyl Ketone	mg/l	--	--	--	--	--	<0.0050
Acetone	mg/l	--	--	--	--	--	<0.01
Bromodichloromethane	mg/l	--	--	--	--	--	<0.00010
Bromoform	mg/l	--	--	--	--	--	<0.00020
Bromomethane	mg/l	--	--	--	--	--	<0.00050
Carbon Tetrachloride	mg/l	0.005	--	--	--	--	<0.00010
Chlorobenzene	mg/l	0.08	0.03	--	--	--	<0.00010
Chloroform	mg/l	--	--	--	--	--	<0.00010
cis-1,2-Dichloroethene	mg/l	--	--	--	--	--	<0.00010
cis-1,3-Dichloropropene	mg/l	--	--	--	--	--	<0.00020
Dibromochloromethane	mg/l	--	--	--	--	--	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-3-6	12-3-6	12-3-6	12-3-6
				11-Jan-2013	19-Jun-2013	30-Oct-2013	12-Nov-2013
				B-4	12-3-6	12-3-6	12-3-6
Dichlorodifluoromethane	mg/l	--	--	--	--	--	<0.00050
Methyl tert-Butyl Ether	mg/l	--	--	--	--	--	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	--	<0.00050
n-Hexane	mg/l	--	--	--	--	--	<0.00050
Tetrachloroethylene	mg/l	0.03	--	--	--	--	<0.00010
trans-1,2-Dichloroethene	mg/l	--	--	--	--	--	<0.00010
trans-1,3-Dichloropropene	mg/l	--	--	--	--	--	<0.00020
Trichloroethene	mg/l	0.005	--	--	--	--	<0.00010
Trichlorofluoromethane	mg/l	--	--	--	--	--	<0.00020
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	--	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

		(2) (1)	(4) (3)	12-4-3	12-4-3	12-4-3
		ODWQS(169	ODWQS-	03-Apr-2013 (20)	04-Jul-2013 (21)	13-Nov-2013 (22)
Parameter	Unit	/03)-Health	AO	BH12-04-3	12-4-3	12-4-3
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	220	65	55
Ammonia Nitrogen	mg/l	--	--	28	23 (11)	21
Biologic Oxygen Demand, Five Day	mg/l	--	--	34	14	19
Chemical Oxygen Demand	mg/l	--	--	210	150	210
Chloride, dissolved	mg/l	--	250	*7200*	*9600*	*10000*
Conductivity	uS/cm	--	--	23000	27000	30000
Conductivity (Field)	uS/cm	--	--	>3999	>3999	>3999
Dissolved Organic Carbon	mg/l	--	5	*47*	*15*	*19*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.050	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	28	23 (11)	24
pH	-	--	--	11.1	9.51	9.17
pH (Field)	-	--	--	7.69	8.01	10.85
Phosphorus	mg/l	--	--	0.59	1.7	0.27
Sulfate, dissolved	mg/l	--	500 (6)	32	23	9
Temperature (Field)	deg c	--	15	6.2	8.2	8.1
Total Dissolved Solids	mg/l	--	500	*13600*	*17700*	*18400*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.01	<0.02	<0.02
Barium, dissolved	mg/l	1	--	16	12	20
Boron, dissolved	mg/l	5	--	0.29	0.32	0.46
Cadmium, dissolved	mg/l	0.005	--	<0.0010	<0.0010	<0.0020
Calcium, dissolved	mg/l	--	--	910	1100	1100
Chromium, dissolved	mg/l	0.05	--	<0.05	<0.05	<0.1
Copper, dissolved	mg/l	--	1	<0.01	<0.01	<0.02
Iron, dissolved	mg/l	--	0.3	<1	<1	<2
Lead, dissolved	mg/l	0.01	--	<0.0050	<0.0050	<0.01
Magnesium, dissolved	mg/l	--	--	2.2	86	200
Manganese, dissolved	mg/l	--	0.05	<0.02	<0.02	<0.04
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	110	100	89
Sodium, dissolved	mg/l	--	200 (7)	*4000*	*5300*	*5400*
Zinc, dissolved	mg/l	--	5	<0.05	<0.05	<0.1
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.0050	<0.00020	<0.0020
Toluene	mg/l	--	0.024	<0.01	0.00047	<0.0040
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	0.0086 (15)	<0.0010	0.0052
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.01	<0.00040	<0.0040
Methane	l/m3	--	3	*16*	*39*	*24*
Methane	mg/l	--	3 (8)	10	25	16
Methylene Chloride	mg/l	0.05	--	<0.025	<0.0010	<0.01
Vinyl Chloride	mg/l	0.002	--	<0.01	<0.00040	<0.0040

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

		(2) (1)	(4) (3)	12-4-4A	12-4-4A	12-4-4A
		ODWQS(169/03)-Health	ODWQS-AO	03-Apr-2013 (9)	04-Jul-2013 (23)	13-Nov-2013 (23)
Parameter	**Unit**			BH12-04-4A	12-4-4B	12-4-4A
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	630	670	710
Ammonia Nitrogen	mg/l	--	--	6.5	6.7	6.6
Biologic Oxygen Demand, Five Day	mg/l	--	--	3.0	2.0	<2.0
Chemical Oxygen Demand	mg/l	--	--	72	62	71
Chloride, dissolved	mg/l	--	250	*3800*	*4100*	*4100*
Conductivity	uS/cm	--	--	12000	13000	14000
Conductivity (Field)	uS/cm	--	--	136	3168	2289
Dissolved Organic Carbon	mg/l	--	5	*7.7*	*8.5*	*8.5*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	6.8	7.3	7.4
pH	-	--	--	8.18	8.13	8.21
pH (Field)	-	--	--	8.03	7.81	8.11
Phosphorus	mg/l	--	--	0.11	1.3	0.058
Sulfate, dissolved	mg/l	--	500 (6)	11	10	9
Temperature (Field)	deg c	--	15	4.5	9.3	7.1
Total Dissolved Solids	mg/l	--	500	*6350*	*6860*	*7560*
Metals						
Arsenic, dissolved	mg/l	0.025	--	0.0054	<0.0050	<0.01
Barium, dissolved	mg/l	1	--	4	4.5	4.8
Boron, dissolved	mg/l	5	--	1.4	1.5	1.5
Cadmium, dissolved	mg/l	0.005	--	<0.00050	<0.00050	<0.0010
Calcium, dissolved	mg/l	--	--	24	21	23
Chromium, dissolved	mg/l	0.05	--	<0.025	<0.025	<0.05
Copper, dissolved	mg/l	--	1	<0.0050	<0.0050	<0.01
Iron, dissolved	mg/l	--	0.3	<0.5	<0.5	<1
Lead, dissolved	mg/l	0.01	--	<0.0025	<0.0025	<0.0050
Magnesium, dissolved	mg/l	--	--	97	110	120
Manganese, dissolved	mg/l	--	0.05	*0.068*	0.032	0.035
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	50	53	53
Sodium, dissolved	mg/l	--	200 (7)	*2600*	*2900*	*2800*
Zinc, dissolved	mg/l	--	5	<0.025	<0.025	<0.05
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	0.00014	<0.00020	<0.00010
Toluene	mg/l	--	0.024	0.0029	<0.00040	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0020 (19)
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00040	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.0010	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00040	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	12-4-5B	12-4-5B	12-4-5B
				03-Apr-2013	04-Jul-2013	13-Nov-2013 (24)
				BH12-04-5B	12-4-5B	12-4-5B
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	580	620	630
Ammonia Nitrogen	mg/l	--	--	1.4	1.3	1.2
Biologic Oxygen Demand, Five Day	mg/l	--	--	3.0	<2.0	2.0
Chemical Oxygen Demand	mg/l	--	--	66	30	73
Chloride, dissolved	mg/l	--	250	*620*	*640*	*660*
Conductivity	uS/cm	--	--	3100	3100	3200
Conductivity (Field)	uS/cm	--	--	2562	3314	3159
Dissolved Organic Carbon	mg/l	--	5	*6.6*	*6.0*	*7.2*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.50
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.050
Nitrogen, Total Kjeldahl	mg/l	--	--	3.5	2.8	4.5
pH	-	--	--	8.01	8.00	7.91
pH (Field)	-	--	--	7.71	7.66	8.01
Phosphorus	mg/l	--	--	13	22	19
Sulfate, dissolved	mg/l	--	500 (6)	36	13	14
Temperature (Field)	deg c	--	15	6.2	12.1	8.2
Total Dissolved Solids	mg/l	--	500	*1630*	*1650*	*1730*
Metals						
Arsenic, dissolved	mg/l	0.025	--	0.0037	0.0012	0.0014
Barium, dissolved	mg/l	1	--	0.16	0.12	0.13
Boron, dissolved	mg/l	5	--	0.21	0.22	0.21
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Calcium, dissolved	mg/l	--	--	80	69	66
Chromium, dissolved	mg/l	0.05	--	0.02	<0.0050	<0.0050
Copper, dissolved	mg/l	--	1	<0.0010	<0.0010	0.0014
Iron, dissolved	mg/l	--	0.3	0.19	0.28	<0.1
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.00050
Magnesium, dissolved	mg/l	--	--	74	81	80
Manganese, dissolved	mg/l	--	0.05	*0.79*	*0.31*	*0.24*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	13	13	13
Sodium, dissolved	mg/l	--	200 (7)	*510*	*530*	*510*
Zinc, dissolved	mg/l	--	5	<0.0050	<0.0050	<0.0050
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	<0.00020	<0.00010
Toluene	mg/l	--	0.024	0.0022	<0.00040	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00040	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.0010	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00040	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	ODWQS(169/03)-Health [2] [1]	ODWQS-AO [4] [3]	12-4-6	12-4-6	12-4-6
				24-Apr-2013 [25]	04-Jul-2013	13-Nov-2013
				12-04-6	12-4-6	12-4-6
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	220	340	390
Ammonia Nitrogen	mg/l	--	--	0.21	0.27	0.050
Biologic Oxygen Demand, Five Day	mg/l	--	--	43	<2.0	<2.0
Chemical Oxygen Demand	mg/l	--	--	270	100	140
Chloride, dissolved	mg/l	--	250	36	81	120
Conductivity	uS/cm	--	--	770	1100	1300
Conductivity (Field)	uS/cm	--	--	694	3212	1594
Dissolved Organic Carbon	mg/l	--	5	*32*	*12*	*15*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	6.8	3.9	7.5
pH	-	--	--	7.60	7.55	7.74
pH (Field)	-	--	--	7.00	7.84	7.25
Phosphorus	mg/l	--	--	3.5	3.2	3.3
Sulfate, dissolved	mg/l	--	500 [6]	120	150	130
Temperature (Field)	deg c	--	15	8.7	14.1	6.2
Total Dissolved Solids	mg/l	--	500	466	*684*	*808*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.0010	0.0011	<0.0010
Barium, dissolved	mg/l	1	--	0.078	0.11	0.14
Boron, dissolved	mg/l	5	--	0.044	0.054	0.03
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Calcium, dissolved	mg/l	--	--	73	100	97
Chromium, dissolved	mg/l	0.05	--	<0.0050	<0.0050	<0.0050
Copper, dissolved	mg/l	--	1	0.0031	0.0016	0.0036
Iron, dissolved	mg/l	--	0.3	0.16	<0.1	<0.1
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.00050
Magnesium, dissolved	mg/l	--	--	24	37	37
Manganese, dissolved	mg/l	--	0.05	*0.86*	*0.88*	*0.49*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	3	4.3	5.1
Sodium, dissolved	mg/l	--	200 [7]	59	100	140
Zinc, dissolved	mg/l	--	5	0.0059	<0.0050	<0.0050
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00050	<0.00020	<0.00010
Toluene	mg/l	--	0.024	0.0011	<0.00040	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	0.0042	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.0010	<0.00040	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.0025	<0.0010	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.0010	<0.00040	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	13-5-3	13-5-3	13-5-3
				05-Jul-2013	15-Jul-2013	13-Nov-2013 (22)
				BH13-5-3	13-5-3	13-5-3
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	710	--	770
Ammonia Nitrogen	mg/l	--	--	5.8	--	5.7
Biologic Oxygen Demand, Five Day	mg/l	--	--	--	<2.0	12
Chemical Oxygen Demand	mg/l	--	--	67	--	65
Chloride, dissolved	mg/l	--	250	*3700*	--	*3700*
Conductivity	uS/cm	--	--	11000	--	12000
Conductivity (Field)	uS/cm	--	--	>3999	--	1376
Dissolved Organic Carbon	mg/l	--	5	*7.0*	--	*7.9*
Nitrate as N	mg/l	10	--	<0.10	--	<0.10
Nitrite as N	mg/l	1	--	<0.010	--	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	8.1	--	8.1
pH	-	--	--	--	8.11	8.28
pH (Field)	-	--	--	7.84	--	8.18
Phosphorus	mg/l	--	--	0.068	--	0.14
Sulfate, dissolved	mg/l	--	500 (6)	22	--	10
Temperature (Field)	deg c	--	15	8.4	--	7.5
Total Dissolved Solids	mg/l	--	500	*6270*	--	*6790*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.005	--	<0.0050
Barium, dissolved	mg/l	1	--	14	--	14
Boron, dissolved	mg/l	5	--	1.6	--	1.5
Cadmium, dissolved	mg/l	0.005	--	<0.0001	--	<0.00050
Calcium, dissolved	mg/l	--	--	16	--	24
Chromium, dissolved	mg/l	0.05	--	<0.005	--	<0.025
Copper, dissolved	mg/l	--	1	<0.001	--	<0.0050
Iron, dissolved	mg/l	--	0.3	<0.1	--	<0.5
Lead, dissolved	mg/l	0.01	--	<0.0005	--	<0.0025
Magnesium, dissolved	mg/l	--	--	84	--	95
Manganese, dissolved	mg/l	--	0.05	0.006	--	0.014
Mercury, dissolved	mg/l	0.001	--	<0.00010	--	<0.00010
Potassium, dissolved	mg/l	--	--	52	--	56
Sodium, dissolved	mg/l	--	200 (7)	*2500*	--	*2600*
Zinc, dissolved	mg/l	--	5	<0.005	--	<0.025
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	--	<0.00025
Toluene	mg/l	--	0.024	<0.00020	--	<0.00050
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	0.042	--	0.016
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	--	<0.00050
Methane	l/m3	--	3	*15*	--	*36*
Methane	mg/l	--	3 (8)	9.8	--	24
Methylene Chloride	mg/l	0.05	--	<0.00050	--	<0.0013
Vinyl Chloride	mg/l	0.002	--	<0.00020	--	<0.00050

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	13-5-4A	13-5-4A	13-5-4A
				09-Apr-2013	09-Jul-2013	13-Nov-2013 (22)
				13-05-4A	13-5-4A	13-5-4A
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	850	860	950
Ammonia Nitrogen	mg/l	--	--	3.0	2.7	2.7
Biologic Oxygen Demand, Five Day	mg/l	--	--	6.0	7.0	18
Chemical Oxygen Demand	mg/l	--	--	210	180	180
Chloride, dissolved	mg/l	--	250	*2300*	*2300*	*1900*
Conductivity	uS/cm	--	--	8200	8100	7600
Conductivity (Field)	uS/cm	--	--	>3999	2894	>3999
Dissolved Organic Carbon	mg/l	--	5	*14*	*15*	*25*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	8.1	5.2	8.0
pH	-	--	--	8.36	8.32	8.37
pH (Field)	-	--	--	8.05	7.84	8.59
Phosphorus	mg/l	--	--	9.8	11	18
Sulfate, dissolved	mg/l	--	500 (6)	36	5	1
Temperature (Field)	deg c	--	15	9.0	8.6	7.4
Total Dissolved Solids	mg/l	--	500	*4620*	*4540*	*4290*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.0050	<0.0050	<0.0050
Barium, dissolved	mg/l	1	--	3	3.1	2.2
Boron, dissolved	mg/l	5	--	0.91	0.95	0.87
Cadmium, dissolved	mg/l	0.005	--	<0.00050	<0.00010	<0.00050
Calcium, dissolved	mg/l	--	--	21	17	21
Chromium, dissolved	mg/l	0.05	--	<0.025	<0.0050	<0.025
Copper, dissolved	mg/l	--	1	<0.0050	<0.0010	<0.0050
Iron, dissolved	mg/l	--	0.3	<0.5	<0.1	*0.67*
Lead, dissolved	mg/l	0.01	--	<0.0025	<0.00050	<0.0025
Magnesium, dissolved	mg/l	--	--	57	62	55
Manganese, dissolved	mg/l	--	0.05	*0.053*	0.043	*0.1*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	39	39	33
Sodium, dissolved	mg/l	--	200 (7)	*1800*	*1900*	*1600*
Zinc, dissolved	mg/l	--	5	<0.025	<0.0050	<0.025
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.0010	<0.00010	<0.00020
Toluene	mg/l	--	0.024	<0.0020	<0.00020	<0.00040
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.0020	<0.00020	<0.00040
Methane	l/m3	--	3	--	*79*	--
Methane	mg/l	--	3 (8)	--	52	--
Methylene Chloride	mg/l	0.05	--	<0.0050	<0.00050	<0.0010
Vinyl Chloride	mg/l	0.002	--	<0.0020	<0.00020	<0.00040

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

		(2) (1)	(4) (3)	13-5-5	13-5-5	13-5-5	13-5-5
		ODWQS(169 /03)-Health	ODWQS- AO	09-Apr-2013	05-Jul-2013	15-Jul-2013	13-Nov-2013
Parameter	**Unit**			13-05-5	BH13-5-5	13-5-5	13-5-5
General Chemistry							
Alkalinity (Total as CaCO3)	mg/l	--	--	470	480	--	450
Ammonia Nitrogen	mg/l	--	--	1.1	0.98	--	0.69
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	--	<2.0	4.0
Chemical Oxygen Demand	mg/l	--	--	95	94	--	82
Chloride, dissolved	mg/l	--	250	200	220	--	120
Conductivity	uS/cm	--	--	1500	1600	--	1300
Conductivity (Field)	uS/cm	--	--	1290	3000	--	1325
Dissolved Organic Carbon	mg/l	--	5	4.3	3.7	--	3.4
Nitrate as N	mg/l	10	--	<0.10	<0.10	--	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	--	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	4.6	3.9	--	5.5
pH	-	--	--	8.16	--	8.01	8.11
pH (Field)	-	--	--	7.73	7.91	--	8.08
Phosphorus	mg/l	--	--	62	18	--	29
Sulfate, dissolved	mg/l	--	500 (6)	11	5	--	35
Temperature (Field)	deg c	--	15	8.9	11.6	--	7.9
Total Dissolved Solids	mg/l	--	500	*834*	*892*	--	*744*
Metals							
Arsenic, dissolved	mg/l	0.025	--	0.0054	0.002	--	0.0015
Barium, dissolved	mg/l	1	--	0.1	0.072	--	0.065
Boron, dissolved	mg/l	5	--	0.18	0.23	--	0.13
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.0001	--	<0.00010
Calcium, dissolved	mg/l	--	--	52	42	--	46
Chromium, dissolved	mg/l	0.05	--	<0.0050	<0.005	--	<0.0050
Copper, dissolved	mg/l	--	1	<0.0010	<0.001	--	<0.0010
Iron, dissolved	mg/l	--	0.3	<0.1	0.1	--	<0.1
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.0005	--	<0.00050
Magnesium, dissolved	mg/l	--	--	42	37	--	29
Manganese, dissolved	mg/l	--	0.05	*0.076*	*0.088*	--	*0.13*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	--	<0.00010
Potassium, dissolved	mg/l	--	--	8.9	7.7	--	5.7
Sodium, dissolved	mg/l	--	200 (7)	*260*	*240*	--	200
Zinc, dissolved	mg/l	--	5	<0.0050	<0.005	--	<0.0050
Petroleum Hydrocarbons							
Benzene	mg/l	0.005	--	<0.00010	<0.00010	--	<0.00010
Toluene	mg/l	--	0.024	0.00023	<0.00020	--	<0.00020
Phenols							
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	--	<0.0010
VOCs							
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00020	--	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	--	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	--	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	13-5-6	13-5-6	13-5-6	13-5-6
				09-Apr-2013	05-Jul-2013	15-Jul-2013	13-Nov-2013
				13-05-6	BH13-5-6	13-5-6	13-5-6
General Chemistry							
Alkalinity (Total as CaCO3)	mg/l	--	--	140	210	--	290
Ammonia Nitrogen	mg/l	--	--	0.13	0.081	--	0.063
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	--	<2.0	<2.0
Chemical Oxygen Demand	mg/l	--	--	26	21	--	26
Chloride, dissolved	mg/l	--	250	30	38	--	36
Conductivity	uS/cm	--	--	460	600	--	710
Conductivity (Field)	uS/cm	--	--	441	2814	--	699
Dissolved Organic Carbon	mg/l	--	5	4.5	2.3	--	1.9
Nitrate as N	mg/l	10	--	5.9	4.6	--	2.8
Nitrite as N	mg/l	1	--	<0.010	<0.010	--	0.042
Nitrogen, Total Kjeldahl	mg/l	--	--	3.3	0.80	--	2.1
pH	-	--	--	7.86	--	7.66	7.76
pH (Field)	-	--	--	7.84	7.91	--	7.43
Phosphorus	mg/l	--	--	25	27	--	11
Sulfate, dissolved	mg/l	--	500 (6)	25	30	--	18
Temperature (Field)	deg c	--	15	5.4	13.2	--	5.7
Total Dissolved Solids	mg/l	--	500	150	402	--	382
Metals							
Arsenic, dissolved	mg/l	0.025	--	<0.0010	<0.001	--	<0.0010
Barium, dissolved	mg/l	1	--	0.026	0.065	--	0.083
Boron, dissolved	mg/l	5	--	0.014	0.03	--	0.024
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.0001	--	<0.00010
Calcium, dissolved	mg/l	--	--	52	62	--	77
Chromium, dissolved	mg/l	0.05	--	<0.0050	<0.005	--	<0.0050
Copper, dissolved	mg/l	--	1	0.0013	0.001	--	0.0011
Iron, dissolved	mg/l	--	0.3	<0.1	<0.1	--	<0.1
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.0005	--	<0.00050
Magnesium, dissolved	mg/l	--	--	18	23	--	29
Manganese, dissolved	mg/l	--	0.05	0.0060	0.005	--	*0.091*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	--	<0.00010
Potassium, dissolved	mg/l	--	--	2.1	3.6	--	2.7
Sodium, dissolved	mg/l	--	200 (7)	23	29	--	27
Zinc, dissolved	mg/l	--	5	<0.0050	<0.005	--	<0.0050
Petroleum Hydrocarbons							
Benzene	mg/l	0.005	--	<0.00010	<0.00010	--	<0.00010
Toluene	mg/l	--	0.024	<0.00020	<0.00020	--	<0.00020
Phenols							
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	--	<0.0010
VOCs							
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00020	--	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	--	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	--	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	13-6-3	13-6-3	13-6-3
				18-Apr-2013 (26	03-Jul-2013	05-Nov-2013 (9)
				13-06-3	13-6-3	13-6-3
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	47	69	65
Ammonia Nitrogen	mg/l	--	--	7.8	8.0	7.8
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	2.0	5.0
Chemical Oxygen Demand	mg/l	--	--	130	140	130
Chloride, dissolved	mg/l	--	250	*8700*	*9200*	*8200*
Conductivity	uS/cm	--	--	25000	26000	25000
Conductivity (Field)	uS/cm	--	--	>3999	3964	>3999
Dissolved Organic Carbon	mg/l	--	5	4.2	4.2	*5.5*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.10	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	9.9	9.2	7.9
pH	-	--	--	7.92	7.77	7.68
pH (Field)	-	--	--	8.80	7.96	7.63
Phosphorus	mg/l	--	--	0.67	3.0	3.0
Sulfate, dissolved	mg/l	--	500 (6)	98	82	98
Temperature (Field)	deg c	--	15	10.1	9.1	9.9
Total Dissolved Solids	mg/l	--	500	*15000*	*19700*	*14900*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.01	<0.02	<0.01
Barium, dissolved	mg/l	1	--	4.1	15	2.9
Boron, dissolved	mg/l	5	--	0.58	0.67	0.64
Cadmium, dissolved	mg/l	0.005	--	<0.001	<0.00050	<0.0010
Calcium, dissolved	mg/l	--	--	540	750	540
Chromium, dissolved	mg/l	0.05	--	<0.05	<0.025	<0.05
Copper, dissolved	mg/l	--	1	<0.01	<0.0050	<0.01
Iron, dissolved	mg/l	--	0.3	<1	<0.5	<1
Lead, dissolved	mg/l	0.01	--	<0.005	<0.0025	<0.0050
Magnesium, dissolved	mg/l	--	--	270	350	260
Manganese, dissolved	mg/l	--	0.05	*0.21*	*0.44*	*0.4*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	56	72	57
Sodium, dissolved	mg/l	--	200 (7)	*4900*	*5400*	*4700*
Zinc, dissolved	mg/l	--	5	<0.05	<0.025	<0.05
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	<0.0020	<0.00010
Toluene	mg/l	--	0.024	0.00033	<0.0040	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	0.0054
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.0040	<0.00020
Methane	l/m3	--	3	2.5	2.3	*3.8*
Methane	mg/l	--	3 (8)	1.7	1.5	2.5
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.01	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.0040	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	13-6-4A 16-Apr-2013 (13)	13-6-4A 03-Jul-2013	13-6-4A 05-Nov-2013 (9)
				13-06-4A	13-6-4A	13-6-4A
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	420	540	540
Ammonia Nitrogen	mg/l	--	--	6.1	7.0	6.3
Biologic Oxygen Demand, Five Day	mg/l	--	--	8.0	4.0	5.0
Chemical Oxygen Demand	mg/l	--	--	100	160	120
Chloride, dissolved	mg/l	--	250	*4400*	*5600*	*5600*
Conductivity	uS/cm	--	--	14000	17000	18000
Conductivity (Field)	uS/cm	--	--	>3999	>3999	>3999
Dissolved Organic Carbon	mg/l	--	5	*11*	*9.7*	*16*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	9.4	9.8	6.9
pH	-	--	--	9.05	8.14	8.00
pH (Field)	-	--	--	7.75	7.79	8.25
Phosphorus	mg/l	--	--	7.5	6.5	3.6
Sulfate, dissolved	mg/l	--	500 (6)	84	50	23
Temperature (Field)	deg c	--	15	9.2	9.4	10.2
Total Dissolved Solids	mg/l	--	500	*7700*	*9900*	*9920*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.01	<0.01	<0.01
Barium, dissolved	mg/l	1	--	0.46	0.47	1
Boron, dissolved	mg/l	5	--	1.2	1.3	1.4
Cadmium, dissolved	mg/l	0.005	--	<0.00050	<0.00050	<0.00050
Calcium, dissolved	mg/l	--	--	65	52	61
Chromium, dissolved	mg/l	0.05	--	<0.025	<0.025	<0.025
Copper, dissolved	mg/l	--	1	<0.0050	<0.0050	<0.0050
Iron, dissolved	mg/l	--	0.3	<0.5	<0.5	*1.4*
Lead, dissolved	mg/l	0.01	--	<0.0025	<0.0025	<0.0025
Magnesium, dissolved	mg/l	--	--	160	190	190
Manganese, dissolved	mg/l	--	0.05	*0.097*	*0.099*	*0.17*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	56	65	60
Sodium, dissolved	mg/l	--	200 (7)	*3000*	*3500*	*3800*
Zinc, dissolved	mg/l	--	5	<0.025	<0.025	0.057
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.0025	<0.00050	<0.00010
Toluene	mg/l	--	0.024	<0.0050	<0.0010	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	0.010	<0.0010	<0.0050 (19)
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.0050	<0.0010	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.013	<0.0025	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.0050	<0.0010	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	[2] [1] ODWQS(169/03)-Health	[4] [3] ODWQS-AO	13-6-5B	13-6-5B	13-6-5B
				11-Apr-2013	03-Jul-2013	05-Nov-2013
				13-06-5B	13-6-5B	13-6-5B
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	570	610	620
Ammonia Nitrogen	mg/l	--	--	1.7	1.7	1.7
Biologic Oxygen Demand, Five Day	mg/l	--	--	3.0	<2.0	3.0
Chemical Oxygen Demand	mg/l	--	--	22	80	75
Chloride, dissolved	mg/l	--	250	*1100*	*1200*	*1100*
Conductivity	uS/cm	--	--	4200	4500	4600
Conductivity (Field)	uS/cm	--	--	3945	3861	>3999
Dissolved Organic Carbon	mg/l	--	5	*7.3*	*5.4*	*6.2*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	3.7	4.8	3.0
pH	-	--	--	8.19	8.08	8.02
pH (Field)	-	--	--	8.04	7.82	8.04
Phosphorus	mg/l	--	--	24	25	41
Sulfate, dissolved	mg/l	--	500[6]	9	7	<1
Temperature (Field)	deg c	--	15	5.1	12.2	9.7
Total Dissolved Solids	mg/l	--	500	*2280*	*2510*	*2420*
Metals						
Arsenic, dissolved	mg/l	0.025	--	0.003	0.0033	0.0059
Barium, dissolved	mg/l	1	--	0.19	0.18	0.18
Boron, dissolved	mg/l	5	--	0.26	0.27	0.29
Cadmium, dissolved	mg/l	0.005	--	<0.0001	<0.00010	<0.00010
Calcium, dissolved	mg/l	--	--	55	53	53
Chromium, dissolved	mg/l	0.05	--	<0.005	<0.0050	<0.0050
Copper, dissolved	mg/l	--	1	<0.001	<0.0010	<0.0010
Iron, dissolved	mg/l	--	0.3	<0.1	<0.1	<0.1
Lead, dissolved	mg/l	0.01	--	<0.0005	<0.00050	<0.00050
Magnesium, dissolved	mg/l	--	--	75	87	83
Manganese, dissolved	mg/l	--	0.05	*0.18*	*0.14*	*0.16*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	15	17	17
Sodium, dissolved	mg/l	--	200[7]	*780*	*890*	*900*
Zinc, dissolved	mg/l	--	5	0.015	<0.0050	<0.0050
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	<0.00025	<0.00010
Toluene	mg/l	--	0.024	0.00051	<0.00050	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00050	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.0013	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00050	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

		(2) (1)	(4) (3)	13-6-6	13-6-6	13-6-6
		ODWQS(169/03)-Health	ODWQS-AO	10-Apr-2013	03-Jul-2013	05-Nov-2013
Parameter	Unit			13-06-6	13-6-6	13-6-6
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	280	370	470
Ammonia Nitrogen	mg/l	--	--	0.23	0.18	0.076
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	<2.0	<2.0
Chemical Oxygen Demand	mg/l	--	--	56	51	45
Chloride, dissolved	mg/l	--	250	210	200	190
Conductivity	uS/cm	--	--	1300	1400	1500
Conductivity (Field)	uS/cm	--	--	1249	3049	1572
Dissolved Organic Carbon	mg/l	--	5	2.3	2.0	2.2
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	0.024	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	4.1	4.9	2.6
pH	-	--	--	8.14	7.79	7.71
pH (Field)	-	--	--	7.40	7.94	7.50
Phosphorus	mg/l	--	--	9.5	12	7.4
Sulfate, dissolved	mg/l	--	500 (6)	45	42	40
Temperature (Field)	deg c	--	15	5.3	12.6	10.5
Total Dissolved Solids	mg/l	--	500	*724*	*802*	*760*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.0010	<0.0010	0.0012
Barium, dissolved	mg/l	1	--	0.033	0.047	0.067
Boron, dissolved	mg/l	5	--	0.023	0.05	0.05
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Calcium, dissolved	mg/l	--	--	75	80	99
Chromium, dissolved	mg/l	0.05	--	<0.0050	<0.0050	<0.0050
Copper, dissolved	mg/l	--	1	0.0014	<0.0010	<0.0010
Iron, dissolved	mg/l	--	0.3	<0.1	<0.1	<0.1
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.00050
Magnesium, dissolved	mg/l	--	--	34	36	44
Manganese, dissolved	mg/l	--	0.05	0.013	*0.11*	*0.076*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	2.9	3.8	4.7
Sodium, dissolved	mg/l	--	200 (7)	140	190	200
Zinc, dissolved	mg/l	--	5	0.011	<0.0050	<0.0050
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Toluene	mg/l	--	0.024	<0.00020	<0.00020	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00020	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	13-7-2 02-Jul-2013 13-7-2	13-7-2 13-Nov-2013 (5) 13-7-2
General Chemistry					
Alkalinity (Total as CaCO3)	mg/l	--	--	370	390
Ammonia Nitrogen	mg/l	--	--	6.3	6.3
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	5.0
Chemical Oxygen Demand	mg/l	--	--	80	71
Chloride, dissolved	mg/l	--	250	*5600*	*6000*
Conductivity	uS/cm	--	--	17000	18000
Conductivity (Field)	uS/cm	--	--	>3999	>3999
Dissolved Organic Carbon	mg/l	--	5	3.7	4.0
Nitrate as N	mg/l	10	--	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	6.7	7.8
pH	-	--	--	7.96	7.90
pH (Field)	-	--	--	7.84	7.99
Phosphorus	mg/l	--	--	0.94	1.2
Sulfate, dissolved	mg/l	--	500 (6)	7	7
Temperature (Field)	deg c	--	15	8.2	8.1
Total Dissolved Solids	mg/l	--	500	*10800*	*10100*
Metals					
Arsenic, dissolved	mg/l	0.025	--	<0.01	<0.01
Barium, dissolved	mg/l	1	--	15	13
Boron, dissolved	mg/l	5	--	1.1	1.2
Cadmium, dissolved	mg/l	0.005	--	<0.00050	<0.0010
Calcium, dissolved	mg/l	--	--	200	190
Chromium, dissolved	mg/l	0.05	--	<0.025	<0.05
Copper, dissolved	mg/l	--	1	<0.0050	<0.01
Iron, dissolved	mg/l	--	0.3	<0.5	<1
Lead, dissolved	mg/l	0.01	--	<0.0025	<0.0050
Magnesium, dissolved	mg/l	--	--	160	160
Manganese, dissolved	mg/l	--	0.05	*0.16*	*0.15*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	50	50
Sodium, dissolved	mg/l	--	200 (7)	*3500*	*3600*
Zinc, dissolved	mg/l	--	5	<0.025	<0.05
Petroleum Hydrocarbons					
Benzene	mg/l	0.005	--	<0.00050	<0.00025
Toluene	mg/l	--	0.024	<0.0010	<0.00050
Phenols					
Phenolics, Total Recoverable	mg/l	--	--	0.0034	0.012
VOCs					
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.0010	<0.00050
Methane	l/m3	--	3	*32*	*36*
Methane	mg/l	--	3 (8)	21	24
Methylene Chloride	mg/l	0.05	--	<0.0025	<0.0013
Vinyl Chloride	mg/l	0.002	--	<0.0010	<0.00050

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	13-7-3	13-7-3	13-7-3
				24-Apr-2013 (27)	04-Jul-2013 (23)	13-Nov-2013 (23)
				13-07-3	13-7-3	13-7-3
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	340	430	440
Ammonia Nitrogen	mg/l	--	--	4.4	5.7	4.9
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	12	14
Chemical Oxygen Demand	mg/l	--	--	48	180	250
Chloride, dissolved	mg/l	--	250	*4300*	*5400*	*5700*
Conductivity	uS/cm	--	--	12000	17000	17000
Conductivity (Field)	uS/cm	--	--	>3999	3891	>3999
Dissolved Organic Carbon	mg/l	--	5	*7.6*	*11*	*13*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	0.011
Nitrogen, Total Kjeldahl	mg/l	--	--	4.7	9.1	13
pH	-	--	--	8.18	8.11	8.00
pH (Field)	-	--	--	8.19	7.93	8.49
Phosphorus	mg/l	--	--	0.51	8.6	10
Sulfate, dissolved	mg/l	--	500 (6)	27	56	81
Temperature (Field)	deg c	--	15	9.8	8.6	6.7
Total Dissolved Solids	mg/l	--	500	*7430*	*9490*	*9800*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.01 (19)	<0.01	<0.01
Barium, dissolved	mg/l	1	--	3.3	4.3	3.8
Boron, dissolved	mg/l	5	--	0.8	1.1	1.1
Cadmium, dissolved	mg/l	0.005	--	<0.00050	<0.00050	<0.0010
Calcium, dissolved	mg/l	--	--	60	46	45
Chromium, dissolved	mg/l	0.05	--	<0.025	<0.025	<0.05
Copper, dissolved	mg/l	--	1	<0.0050	0.0087	<0.01
Iron, dissolved	mg/l	--	0.3	<0.5	<0.5	<1
Lead, dissolved	mg/l	0.01	--	<0.0025	0.0037	<0.0050
Magnesium, dissolved	mg/l	--	--	160	190	190
Manganese, dissolved	mg/l	--	0.05	*0.057*	*0.06*	*0.097*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	47	51	52
Sodium, dissolved	mg/l	--	200 (7)	*2800*	*3000*	*3500*
Zinc, dissolved	mg/l	--	5	<0.025	<0.025	<0.05
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	<0.00020	<0.00010
Toluene	mg/l	--	0.024	<0.00020	<0.00040	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	0.0036	<0.0010	0.0032
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00040	<0.00020
Methane	l/m3	--	3	*38*	--	--
Methane	mg/l	--	3 (8)	25	--	--
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.0010	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00040	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

		(2) (1)	(4) (3)	13-7-4-2	13-7-4-2	13-7-4-2
		ODWQS(169/03)-Health	ODWQS-AO	10-Apr-2013	02-Jul-2013	13-Nov-2013 (16)
Parameter	**Unit**			13-07-4B	13-7-4B	13-7-4B
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	650	640	680
Ammonia Nitrogen	mg/l	--	--	2.2	2.1	1.9
Biologic Oxygen Demand, Five Day	mg/l	--	--	3.0	2.0	8.0
Chemical Oxygen Demand	mg/l	--	--	290	150	260
Chloride, dissolved	mg/l	--	250	*1300*	*1300*	*1200*
Conductivity	uS/cm	--	--	4900	4800	4900
Conductivity (Field)	uS/cm	--	--	>3999	3879	>3999
Dissolved Organic Carbon	mg/l	--	5	*7.6*	*6.0*	*12*
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	6.9	8.4	11
pH	-	--	--	8.21	7.96	8.08
pH (Field)	-	--	--	7.57	7.92	8.07
Phosphorus	mg/l	--	--	130	54	50
Sulfate, dissolved	mg/l	--	500 (6)	18	9	53
Temperature (Field)	deg c	--	15	8.8	11.1	7.3
Total Dissolved Solids	mg/l	--	500	*2690*	*2680*	*2680*
Metals						
Arsenic, dissolved	mg/l	0.025	--	0.0026	<0.0020	<0.0020 (28)
Barium, dissolved	mg/l	1	--	0.24	0.23	0.19
Boron, dissolved	mg/l	5	--	0.26	0.29	0.27
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Calcium, dissolved	mg/l	--	--	66	65	64
Chromium, dissolved	mg/l	0.05	--	0.012	<0.01 (19)	<0.01 (28)
Copper, dissolved	mg/l	--	1	<0.0010	<0.0010	<0.0010
Iron, dissolved	mg/l	--	0.3	<0.1	<0.1	*0.62*
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.00050
Magnesium, dissolved	mg/l	--	--	91	100	95
Manganese, dissolved	mg/l	--	0.05	*0.25*	*0.28*	*0.58*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	19	19	17
Sodium, dissolved	mg/l	--	200 (7)	*810*	*860*	*790*
Zinc, dissolved	mg/l	--	5	<0.0050	<0.0050	<0.0050
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	<0.00050	<0.00025
Toluene	mg/l	--	0.024	0.00053	<0.0010	<0.00050
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	0.0016	<0.0010	0.0021
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.0010	<0.00050
Methane	l/m3	--	3	0.61	--	--
Methane	mg/l	--	3 (8)	0.40	--	--
Methylene Chloride	mg/l	0.05	--	0.0014	<0.0025	<0.0013
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.0010	<0.00050

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	13-7-5	13-7-5	13-7-5
				10-Apr-2013	02-Jul-2013	13-Nov-2013
				13-07-5	13-7-5	13-7-5
General Chemistry						
Alkalinity (Total as CaCO3)	mg/l	--	--	530	570	570
Ammonia Nitrogen	mg/l	--	--	0.52	0.15	0.074
Biologic Oxygen Demand, Five Day	mg/l	--	--	35	2.0	6.0
Chemical Oxygen Demand	mg/l	--	--	190	62	58
Chloride, dissolved	mg/l	--	250	170	180	170
Conductivity	uS/cm	--	--	1600	1700	1800
Conductivity (Field)	uS/cm	--	--	1565	3291	1708
Dissolved Organic Carbon	mg/l	--	5	*18*	2.6	2.3
Nitrate as N	mg/l	10	--	<0.10	<0.10	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	6.2	2.6	3.3
pH	-	--	--	8.02	7.68	7.88
pH (Field)	-	--	--	7.17	7.63	8.31
Phosphorus	mg/l	--	--	5.7	5.2	11
Sulfate, dissolved	mg/l	--	500 (6)	72	75	98
Temperature (Field)	deg c	--	15	6.9	10.9	5.9
Total Dissolved Solids	mg/l	--	500	*892*	*1020*	*1000*
Metals						
Arsenic, dissolved	mg/l	0.025	--	<0.0010	0.0011	0.0010
Barium, dissolved	mg/l	1	--	0.093	0.11	0.11
Boron, dissolved	mg/l	5	--	0.039	0.048	0.035
Cadmium, dissolved	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Calcium, dissolved	mg/l	--	--	92	92	78
Chromium, dissolved	mg/l	0.05	--	0.0065	<0.0050	0.0052
Copper, dissolved	mg/l	--	1	0.0013	<0.0010	<0.0010
Iron, dissolved	mg/l	--	0.3	<0.1	0.11	*0.39*
Lead, dissolved	mg/l	0.01	--	<0.00050	<0.00050	<0.00050
Magnesium, dissolved	mg/l	--	--	52	49	44
Manganese, dissolved	mg/l	--	0.05	*0.2*	*1.3*	*0.83*
Mercury, dissolved	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium, dissolved	mg/l	--	--	3.6	4.2	3.5
Sodium, dissolved	mg/l	--	200 (7)	*210*	*250*	*270*
Zinc, dissolved	mg/l	--	5	0.012	0.0061	<0.0050
Petroleum Hydrocarbons						
Benzene	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Toluene	mg/l	--	0.024	0.00021	<0.00020	<0.00020
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	0.00028	<0.00020	<0.00020
Methane	l/m3	--	3	0.005	--	--
Methane	mg/l	--	3 (8)	0.003	--	--
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	<0.00020

TABLE O-1
BACKGROUND GROUNDWATER QUALITY
MONITORING WELLS
CRRRC SITE

Footnotes:

Tables should be read in conjunction with the accompanying document.

< value = Indicates parameter not detected above laboratory method detection limit.

> value = Indicates parameter detected above equipment analytical range.

-- Chemical not analyzed or criteria not defined.

Grey background indicates exceedances.

(1) Ontario Drinking Water Quality Standards - Health Based Standards

(2) Underlined Font = Parameter concentration greater than ODWQS(169/03)-Health

(3) Ontario Drinking Water Quality Standards - Aesthetic Objectives. Aesthetic Objectives are established for parameters that may impair the taste, odour or colour of water or which may interfere with good water quality control practices. For certain parameters, both aesthetic objectives and health-related MACs have been derived.

(4) Italic Font = Parameter concentration greater than ODWQS-AO

(5) Metals Analysis: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.VOC Analysis: Due to foaming and insufficient sample volume, sample required dilution. Detection limits were adjusted accordingly.

(6) There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.

(7) The aesthetic objective for sodium in drinking water is 200 mg/L. The local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.

(8) Reporting units and Guideline units are not convertible into each other.

(9) Metal analysis:Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

(10) VOC Water Analysis: Due to foaming, sample required dilution. The detection limits were adjusted accordingly.Metal analysis:Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.Nitrite/Nitrate: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.

(11) TKN < NH4: Both values fall within acceptable RPD limits for duplicates and are likely equivalent.

(12) Monitoring location was frozen during this sampling event. No sample was collected.

(13) VOC Water Analysis: Due to foaming, sample required dilution. The detection limits were adjusted accordingly.Metal analysis:Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

(14) Metal analysis:Detection Limit was raised due to matrix interferences.

(15) Result revised May 24, 2013

(16) VOC Water Analysis: Due to foaming, sample required dilution. The detection limits were adjusted accordingly.

(17) Metal analysis:Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.BOD Analysis:BOD was reported as ND due to unknown matrix interference

(18) VOC Analysis: Due to the foaming, sample required dilution. Detection limits were adjusted accordingly.Metals Analysis: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.

(19) Detection Limit was raised due to matrix interferences.

(20) Metal analysis:Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.VOC Analysis: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.

(21) Nitrite/Nitrate: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.Metals Analysis: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.

(22) Metals Analysis: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.VOC Water Analysis: Due to foaming, sample required dilution. The detection limits were adjusted accordingly.

(23) Metals Analysis: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.

(24) Nitrite/Nitrate: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.

(25) VOC Analysis: Due to the foaming, sample required dilution. Detection limits were adjusted accordingly.

(26) Metal Analysis:Sample was diluted due to high concentrations of elemnts and are effecting Internal Standard. RDLs were adjusted accordingly.Nitrite/Nitrate: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.

(27) Metal Analysis:Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

(28) Metal Analysis:Detection Limit was raised due to matrix interferences.

O-II: Background Groundwater Quality (Residential and Commercial Water Supply Wells)

TABLE O-2
BACKGROUND GROUNDWATER QUALITY
RESIDENTIAL AND COMMERICIAL WATER SUPPLY WELLS
CRRRC SITE

Parameter	Unit	(2) (1) ODWQS(169/03)-Health	(4) (3) ODWQS-AO	BOUNDARY-1 (7)	FRONTIER-1	FRONTIER-2
				17-Jan-2013	18-Jan-2013	17-Jan-2013
General Chemistry						
Alkalinity, Carbonate as CaCO3	mg/l	--	--	370	220	220
Ammonia Nitrogen	mg/l	--	--	0.40	<0.050	<0.050
Biologic Oxygen Demand, Five Day	mg/l	--	--	<2.0	<2.0	<2.0
Chemical Oxygen Demand	mg/l	--	--	18	15	11
Chloride	mg/l	--	250	130	71	60
Conductivity	uS/cm	--	--	1200	830	690
Dissolved Organic Carbon	mg/l	--	5	*7.4*	*5.4*	*5.6*
Nitrate as N	mg/l	10	--	<0.10	2.5	<0.10
Nitrite as N	mg/l	1	--	<0.010	<0.010	<0.010
Nitrogen, Total Kjeldahl	mg/l	--	--	0.93	0.68	0.69
pH	-	--	--	7.83	7.65	7.73
Phosphorus	mg/l	--	--	0.058	<0.020	<0.020
Sulfate	mg/l	--	500 (5)	74	81	37
Total Dissolved Solids	mg/l	--	500	*720*	374	422
Metals						
Arsenic	mg/l	0.025	--	<0.0010	<0.0010	<0.0010
Barium	mg/l	1	--	0.048	0.069	0.04
Boron	mg/l	5	--	0.11	0.18	0.016
Cadmium	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Calcium	mg/l	--	--	99	89	85
Chromium	mg/l	0.05	--	<0.0050	<0.0050	<0.0050
Copper	mg/l	--	1	0.0015	0.018	0.073
Iron	mg/l	--	0.3	0.65	<0.1	0.23
Lead	mg/l	0.01	--	<0.00050	<0.00050	<0.00050
Magnesium	mg/l	--	--	40	25	15
Manganese	mg/l	--	0.05	*1.2*	*0.13*	*0.094*
Mercury	mg/l	0.001	--	<0.00010	<0.00010	<0.00010
Potassium	mg/l	--	--	7.7	6.3	2.3
Sodium	mg/l	--	200 (6)	100	55	30
Zinc	mg/l	--	5	<0.0050	0.019	0.0092
Phenols						
Phenolics, Total Recoverable	mg/l	--	--	<0.0010	<0.0010	<0.0010
VOCs						
1,4-Dichlorobenzene	mg/l	0.005	0.001	<0.00020	<0.00020	<0.00020
Methylene Chloride	mg/l	0.05	--	<0.00050	<0.00050	<0.00050
Vinyl Chloride	mg/l	0.002	--	<0.00020	<0.00020	<0.00020
Benzene	mg/l	0.005	--	<0.00010	<0.00010	<0.00010
Toluene	mg/l	--	0.024	<0.00020	<0.00020	<0.00020

Footnotes:

Tables should be read in conjunction with the accompanying document.

< value = Indicates parameter not detected above laboratory method detection limit

> value = Indicates parameter detected above equipment analytical range

-- Chemical not analyzed or criteria not defined

Grey background indicates exceedance of ODWQS

(1) Ontario Drinking Water Quality Standards - Health Based Standards

(2) Underlined Font = Parameter concentration greater than ODWQS(169/03)-Health

(3) Ontario Drinking Water Quality Standards - Aesthetic Objectives. Aesthetic Objectives are established for parameters that may impair the taste, odour or colour of water or which may interfere with good water quality control practices. For certain parameters, both aesthetic objectives and health-related MACs have been derived.

(4) Italic Font = Parameter concentration greater than ODWQS-AO

(5) There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.

(6) The aesthetic objective for sodium in drinking water is 200 mg/L. The local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.

(7) Commercial water supply well.

[redacted]

CRRRC PROJECT
WATER WELL AND SEWAGE DISPOSAL SYSTEM
SURVEY QUESTIONNAIRE

PROPERTY IDENTIFICATION NUMBER (PIN): Boundary - 1

TYPE OF DWELLING: ☐ Residential ☒ Commercial ☐ Institutional ☐ Other

I. OWNER / OCCUPANT INFORMATION AND GENERAL QUESTIONS:

OWNER:

Name: [redacted]

Address: [redacted] Boundry Rd.

Number of Bedrooms —

Telephone No. (business) [redacted]

Telephone No. (home)

Number of Occupants —

OCCUPANT (if other than Owner):

Name:

Address:

Number of Bedrooms

Telephone No. (business)

Telephone No. (home)

Number of Occupants

GENERAL QUESTIONS

How long have you owned/occupied this dwelling? 77 years

Is well water used for drinking water supply? Yes ☐ No ☒

If no, why not? just to be safe

If no, how long has it been since well water was used for drinking? never

If no, what is origin of drinking water?

II. WATER WELL

A. WELL CONSTRUCTION DETAILS:

Date or Year Constructed 50+ yrs

Contractor Themselves

Type of Well: Drilled ☐ Dug ☒

Well Diameter (inches) 36" +/-

Present Well Depth:

Original Well Depth 18-20'

☐ Same as Present

Is Well Vented and How?:

PIN: [redacted] Boundary

Boundary -1

Top of Well Casing is:

1) Above ground surface ☒ 2) Buried inside a well pit ☐ 3) Buried, but not in a well pit ☐

The accurate location of well is known ☒ Unknown ☐

Type of pump: Submersible ☒ Jet pump ☐ Depth of Pump Intake (if known) ....

Well completed into: Bedrock .... Overburden (Soil) ..X....... Both ....

Do you have a copy of the MOE Water Well Record? ☐ Yes ☒ No

ATTACH A COPY OF WATER WELL RECORD, IF POSSIBLE (WELL RECORD NO. ....)

B. WELL WATER LEVELS:

Indicate whether measured from ☐ ground level or ☐ from top of casing

Original water level depth .... metres on (date) ....

Subsequent water level measurements (give depths in metres and dates)................................

....

C. WATER QUANTITY

Does your well supply enough water for your use? Yes ☒ No ☐

If no, is this the case: All the time ☒ Some of the time ☐ Seasonally ☐ Other ....

Use: Domestic: No ☐ Yes ☒ No. of persons using water from well —

Livestock: No ☐ Yes ☐ Lawn Watering: No ☒ Yes ☐

Other Uses washing equipment Daily Usage (if known) ....

Have you ever experienced any problems with your well? None

If so, when? ....

What was the cause of the problem? ☐ Drought ☐ Pump Failure ☐ Plugging

☐ Increased Usage ☐ Interference ☐ Other (Please Specify) ....

Did you ever have your well deepened or cleaned, or a new well constructed? not that

If so, why? they could remember

PIN: [redacted] Boundary.
Boundary -1

D. WATER QUALITY

Water Treatment (if any)............none

Has your well recently been chlorinated and, if so, when?.......No

How would you describe quality of your water? ☐Poor ☒Good ☐Excellent

Has your water quality previously been tested? No ☐ Yes ☒

If yes, for what and how often? (bacteriological, chemical analyses, etc.) ....Bacti, awhile ago

ATTACH COPY OF ANY PREVIOUS CHEMICAL AND/OR BACTERIOLOGICAL ANALYSIS RESULTS ON THE WELL WATER, IF AVAILABLE

E. WATER SAMPLING INFORMATION

Water Quality Field Observations:

Appearance (clear, cloudy)..Clear.......... Odour ...None

Field Measured Parameters:

Temperature ....6°C.......... pH ....

Conductivity .... H_2S ....

Other Comments ....no sediments, no colour

Water Sample Collected No ☐ Yes ☒ If no, why?..........

Note: Collect Sample of "Untreated" Water only

Duplicate Water Sample Collected (10% of Locations for Project QA/QC) No ☒ Yes ☐

III. SEWAGE DISPOSAL SYSTEM

SYSTEM DETAILS

What type of sewage disposal system do you have:

☐ Holding Tank

☒ Septic Tank and Inground Leaching Bed

☐ Septic Tank and Raised or Partially Raised Leaching Bed

☐ Other Treatment System (e.g. peat bed, peat filter, etc.) If so, specify ....

☐ Don't know

Date or year Constructed ..30 yrs +/-.......... Contractor ....Themselves

PIN: [redacted] Boundry

How often do you have the holding tank or septic tank pumped out? N/A Boundary -1

When was the last time? N/A

Is the septic tank comprised of ☒ one chamber ☐ 2 chambers ☐ don't know

Have you ever had any problems with your sewage disposal systems? (e.g. leaks from holding tank, failure of septic system including surficial release of sewage, visibly stained areas, unusual odours, soft ground, etc.) None

Technician Signature

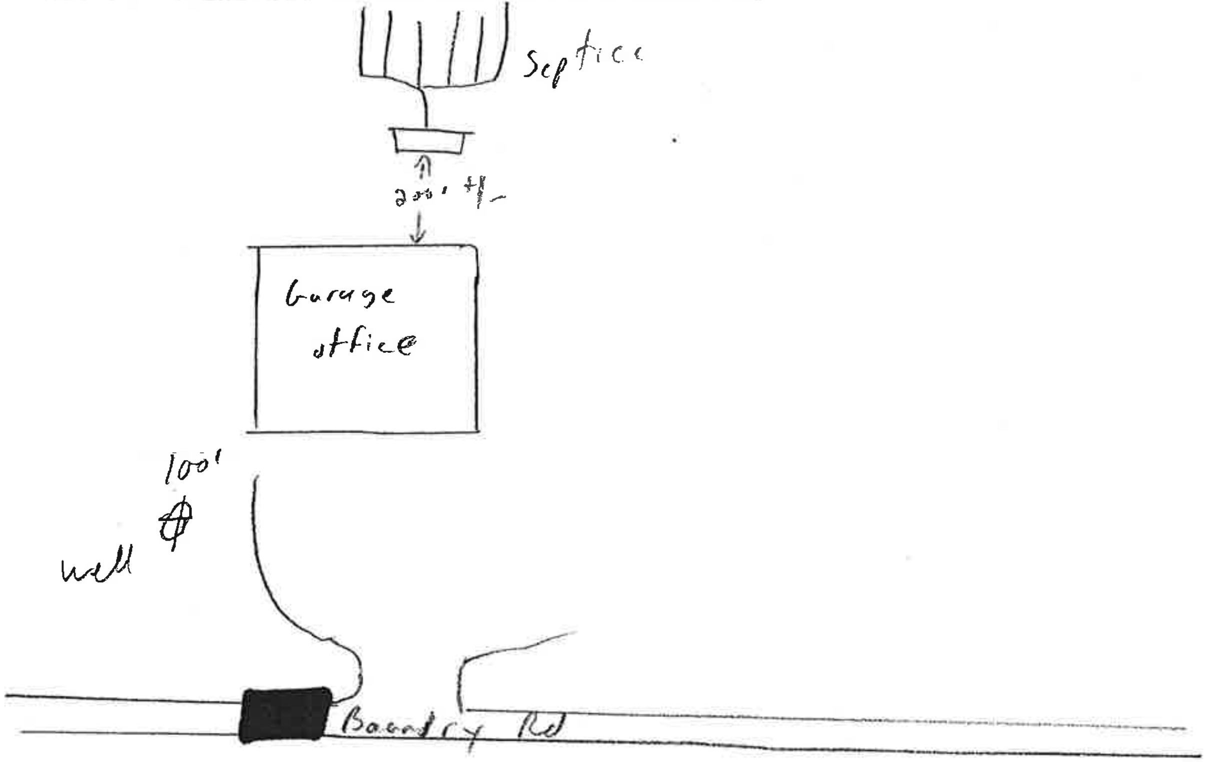
Date Jan /13

PIN: [redacted] Boundry

Boundary - 1

IV. PROPERTY SKETCH

Sketch the location of the septic system (including approximate leaching bed area), the well and the house, giving the best approximated distance between each of them. Include any indication of soil types (e.g. gravel, sand, silt, clay); overburden thickness, and slope (in degrees or percentage). Note any indications of septic system failure such as stained areas, **surficial release of sewage**, unusual odours, soft ground, etc.



Indicate all dimensions in metres

Note distance between well and septic system(s), if possible

Was there any existing evidence of a surficial release of sewage? ☐ No ☐ Yes

---

Other Symbols - Please Specify

Drilled Well
Dug Well
Septic Field
Septic Tank
Holding Tank
Bedrock Outcrop

Break of Slope
Minor
Steep
House
Road
Shed

Tree
Underground Line
Drainage
Ditch
Lot Line
Sidewalk
Fence

[redacted]

CRRRC PROJECT
WATER WELL AND SEWAGE DISPOSAL SYSTEM
SURVEY QUESTIONNAIRE

Frontier -1

PROPERTY IDENTIFICATION NUMBER (PIN): [redacted] Frontier Rd

TYPE OF DWELLING: ☒ Residential ☐ Commercial ☐ Institutional ☐ Other

---

I. OWNER / OCCUPANT INFORMATION AND GENERAL QUESTIONS:

~~**OWNER:**~~ Renters

Name: [redacted]

Address: [redacted] Frontier Rd

Number of Bedrooms 3

Telephone No. (business)

Telephone No. (home) [redacted]

Number of Occupants 3

OCCUPANT (if other than Owner):

Name:

Address:

Number of Bedrooms

Telephone No. (business)

Telephone No. (home)

Number of Occupants

GENERAL QUESTIONS

How long have you owned/occupied this dwelling? 18 years

Is well water used for drinking water supply? Yes ☐ No ☒

If no, why not? To be safe

If no, how long has it been since well water was used for drinking?

If no, what is origin of drinking water?

II. WATER WELL

A. WELL CONSTRUCTION DETAILS: house is 110 yrs old

Date or Year Constructed 20 yrs+

Contractor

Type of Well: Drilled ☐ Dug ☒

Well Diameter (inches) 36"

Present Well Depth: 12'

Original Well Depth

☐ Same as Present

Is Well Vented and How?

PIN: [redacted]rontier Rd

Frontier - 1

Top of Well Casing is:

1) Above ground surface ☒ 2) Buried inside a well pit ☐ 3) Buried, but not in a well pit ☐

The accurate location of well is known ☒ Unknown ☐

Type of pump: Submersible ☐ Jet pump ☐ Depth of Pump Intake (if known) ....

Well completed into: Bedrock .... Overburden (Soil) ✓ Both ....

Do you have a copy of the MOE Water Well Record? ☐ Yes ☒ No

ATTACH A COPY OF WATER WELL RECORD, IF POSSIBLE (WELL RECORD NO. ....)

B. WELL WATER LEVELS:

Indicate whether measured from ☐ ground level or ☐ from top of casing

Original water level depth .... metres on (date) ....

Subsequent water level measurements (give depths in metres and dates)...............................

....

C. WATER QUANTITY

Does your well supply enough water for your use? Yes ☒ No ☐ This summer went dry once but usually lots of water

If no, is this the case: All the time ☐ Some of the time ☐ Seasonally ☐ Other ....

Use: Domestic: No ☐ Yes ☒ No. of persons using water from well 3

Livestock: No ☒ Yes ☐ Lawn Watering: No ☒ Yes ☐

Other Uses .... Daily Usage (if known) ....

Have you ever experienced any problems with your well? No

If so, when? ....

What was the cause of the problem? ☐ Drought ☐ Pump Failure ☐ Plugging

☐ Increased Usage ☐ Interference ☐ Other (Please Specify) ....

Did you ever have your well deepened or cleaned, or a new well constructed? No

If so, why? ....

PIN: [redacted] Frontier Rd

Frontier - 1

D. WATER QUALITY

Water Treatment (if any) None

Has your well recently been chlorinated and, if so, when? No

How would you describe quality of your water? ☐Poor ☒Good ☐Excellent

Has your water quality previously been tested? No ☒ Yes ☐

If yes, for what and how often? (bacteriological, chemical analyses, etc.)

ATTACH COPY OF ANY PREVIOUS CHEMICAL AND/OR BACTERIOLOGICAL ANALYSIS RESULTS ON THE WELL WATER, IF AVAILABLE

E. WATER SAMPLING INFORMATION

Water Quality Field Observations:

Appearance (clear, cloudy) clear Odour none

Field Measured Parameters:

Temperature pH

Conductivity H_2S

Other Comments no sediments, no colour

Water Sample Collected No ☐ Yes ☒ If no, why?

Note: Collect Sample of "Untreated" Water only

Duplicate Water Sample Collected (10% of Locations for Project QA/QC) No ☒ Yes ☐

III. SEWAGE DISPOSAL SYSTEM

SYSTEM DETAILS

What type of sewage disposal system do you have:

☐ Holding Tank

☒ Septic Tank and Inground Leaching Bed

☐ Septic Tank and Raised or Partially Raised Leaching Bed

☐ Other Treatment System (e.g. peat bed, peat filter, etc.) If so, specify

☐ Don't know

Date or year Constructed N/A Contractor N/A

PIN: [redacted] Frontier Rd
Frontier -1

How often do you have the holding tank or septic tank pumped out? 4yrs

When was the last time? 4yrs

Is the septic tank comprised of ☐ one chamber ☐ 2 chambers ☐ don't know

Have you ever had any problems with your sewage disposal systems? (e.g. leaks from holding tank, failure of septic system including surficial release of sewage, visibly stained areas, unusual odours, soft ground, etc.) None

Technician Signature

Date Jan 18/13

* Note

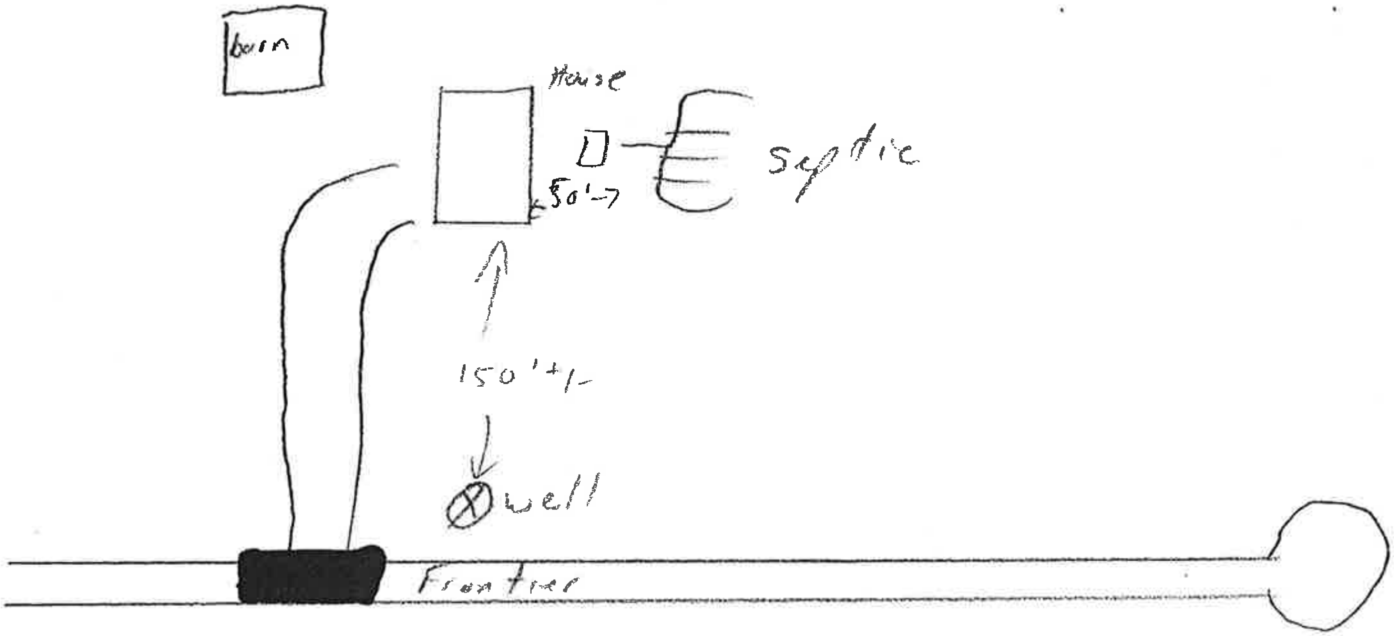
- Home owner mentions sulphur odor sometimes iron staining & some sediment periodically

PIN: [redacted] Frontier

Frontier - 1

IV. PROPERTY SKETCH

Sketch the location of the septic system (including approximate leaching bed area), the well and the house, giving the best approximated distance between each of them. Include any indication of soil types (e.g. gravel, sand, silt, clay); overburden thickness, and slope (in degrees or percentage). Note any indications of septic system failure such as stained areas, **surficial release of sewage**, unusual odours, soft ground, etc.



Indicate all dimensions in metres

Note distance between well and septic system(s), if possible

Was there any existing evidence of a surficial release of sewage? ☒ No ☐ Yes

Other Symbols - Please Specify

Drilled Well
Dug Well
Septic Field
Septic Tank
Holding Tank
Bedrock Outcrop

Break of Slope
Minor
Steep
House
Road
Shed

Tree
Underground Line
Drainage
Ditch
Lot Line
Sidewalk
Fence

[redacted]

CRRRC PROJECT
WATER WELL AND SEWAGE DISPOSAL SYSTEM
SURVEY QUESTIONNAIRE

Frontier -2

PROPERTY IDENTIFICATION NUMBER (PIN): [redacted] Frontier Rd

TYPE OF DWELLING: ☒ Residential ☐ Commercial ☐ Institutional ☐ Other

---

I. OWNER / OCCUPANT INFORMATION AND GENERAL QUESTIONS:

OWNER:

Name: [redacted]

Address: [redacted] Frontier Rd.

Number of Bedrooms 3

Telephone No. (business)

Telephone No. (home) [redacted]

Number of Occupants 4

OCCUPANT (if other than Owner):

Name:

Address:

Number of Bedrooms

Telephone No. (business)

Telephone No. (home)

Number of Occupants

GENERAL QUESTIONS

How long have you owned/occupied this dwelling? 4 yrs

Is well water used for drinking water supply? Yes ☑ No ☐

If no, why not?

If no, how long has it been since well water was used for drinking?

If no, what is origin of drinking water?

II. WATER WELL

A. WELL CONSTRUCTION DETAILS: house built in late 70's well too.

Date or Year Constructed late 70's

Contractor —

Type of Well: Drilled ☐ Dug ☑

Well Diameter (inches) —

Present Well Depth: —

Original Well Depth —

☐ Same as Present

Is Well Vented and How?:

PIN: [redacted] Frontier

Frontier - 2

Top of Well Casing is:

1) Above ground surface ☐ 2) Buried inside a well pit ☑ 3) Buried, but not in a well pit ☐

The accurate location of well is known ☒ Unknown ☐

Type of pump: Submersible ☒ Jet pump ☐ Depth of Pump Intake (if known) ....

Well completed into: Bedrock .... Overburden (Soil) ...✓... Both ....

Do you have a copy of the MOE Water Well Record? ☐ Yes ☒ No

ATTACH A COPY OF WATER WELL RECORD, IF POSSIBLE (WELL RECORD NO. ....)

B. WELL WATER LEVELS:

Indicate whether measured from ☐ ground level or ☐ from top of casing

Original water level depth .... metres on (date) ....

Subsequent water level measurements (give depths in metres and dates).............................

....

C. WATER QUANTITY

Does your well supply enough water for your use? Yes ☑ No ☐

If no, is this the case: All the time ☐ Some of the time ☐ Seasonally ☐ Other ....

Use: Domestic: No ☐ Yes ☑ No. of persons using water from well ....4..........

Livestock: No ☒ Yes ☐ Lawn Watering: No ☑ Yes ☐

Other Uses .... Daily Usage (if known) ....—....................

Have you ever experienced any problems with your well? ....No...........................

If so, when? ....

What was the cause of the problem? ☐ Drought ☐ Pump Failure ☐ Plugging

☐ Increased Usage ☐ Interference ☐ Other (Please Specify) ....

Did you ever have your well deepened or cleaned, or a new well constructed? ...No..........

If so, why? ....

PIN: [redacted] Frontier

Frontier-2

D. WATER QUALITY

Water Treatment (if any) None

Has your well recently been chlorinated and, if so, when? possible iron & hardness in sinks toilets stained

How would you describe quality of your water? ☐Poor ☐Good ☐Excellent

Has your water quality previously been tested? No ☒ Yes ☐

If yes, for what and how often? (bacteriological, chemical analyses, etc.) —

ATTACH COPY OF ANY PREVIOUS CHEMICAL AND/OR BACTERIOLOGICAL ANALYSIS RESULTS ON THE WELL WATER, IF AVAILABLE

E. WATER SAMPLING INFORMATION

Water Quality Field Observations:

Appearance (clear, cloudy) clear Odour none

Field Measured Parameters:

Temperature 7°c pH

Conductivity H_2S

Other Comments no sediments, no colour

Water Sample Collected No ☐ Yes ☒ If no, why?

Note: Collect Sample of "Untreated" Water only

Duplicate Water Sample Collected (10% of Locations for Project QA/QC) No ☒ Yes ☐

III. SEWAGE DISPOSAL SYSTEM

SYSTEM DETAILS

What type of sewage disposal system do you have:

☐ Holding Tank

☑ Septic Tank and Inground Leaching Bed

☐ Septic Tank and Raised or Partially Raised Leaching Bed

☐ Other Treatment System (e.g. peat bed, peat filter, etc.) If so, specify

☐ Don't know

Date or year Constructed N/A Contractor —

PIN: [redacted] Frontier
Frontier-2

How often do you have the holding tank or septic tank pumped out? 4 yrs

When was the last time? no yet

Is the septic tank comprised of ☐ one chamber ☐ 2 chambers ☐ don't know

Have you ever had any problems with your sewage disposal systems? (e.g. leaks from holding tank, failure of septic system including surficial release of sewage, visibly stained areas, unusual odours, soft ground, etc.) None

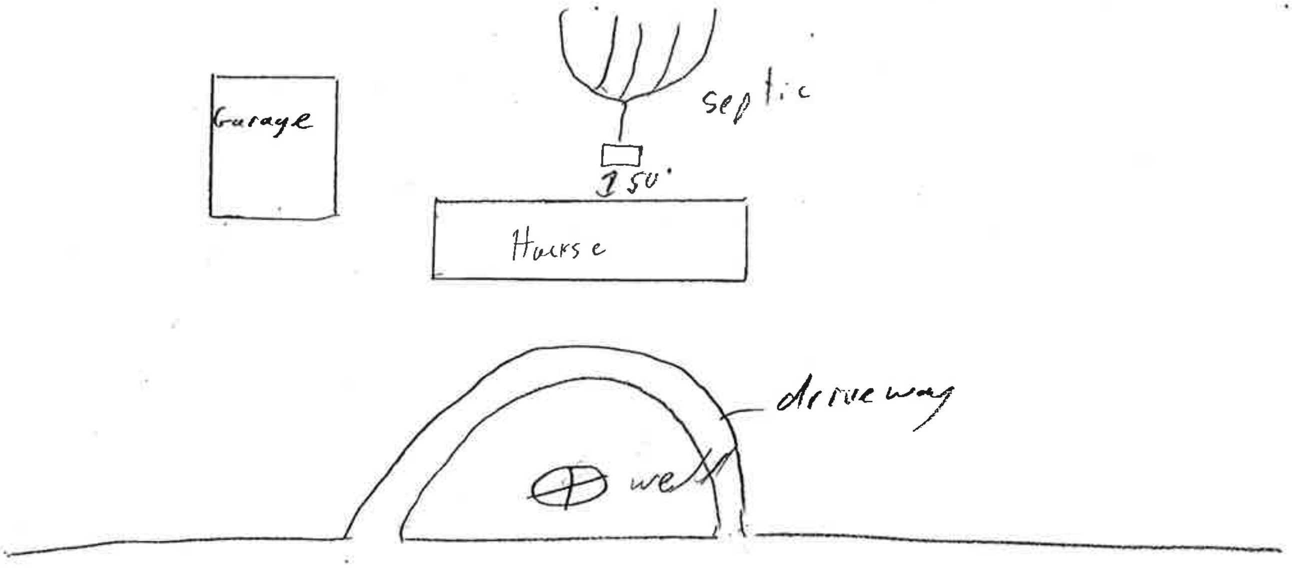
Technician Signature

Date Jun 17th/13

PIN: [redacted] Frontier
Frontier-2

IV. PROPERTY SKETCH

Sketch the location of the septic system (including approximate leaching bed area), the well and the house, giving the best approximated distance between each of them. Include any indication of soil types (e.g. gravel, sand, silt, clay); overburden thickness, and slope (in degrees or percentage). Note any indications of septic system failure such as stained areas, **surficial release of sewage**, unusual odours, soft ground, etc.



Indicate all dimensions in metres

Note distance between well and septic system(s), if possible

Was there any existing evidence of a surficial release of sewage? ☒ No ☐ Yes

Other Symbols - Please Specify

Drilled Well
Dug Well
Septic Field
Septic Tank
Holding Tank
Bedrock Outcrop

Break of Slope
Minor
Steep
House
Road
Shed

Tree
Underground Line
Drainage
Ditch
Lot Line
Sidewalk
Fence

APPENDIX P

Background Surface Water Quality Data

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

			BSW1	**BSW1**	**BSW1**	**BSW1**	**BSW1**
		(2) (1)	**05-Dec-2012**	**09-May-2013**	**24-Jul-2013**	**15-Oct-2013** (4)	**29-Nov-2013**
Parameter	**Unit**	**PWQO**	BSW1	W-5	W-5	W-4	S-3
General Chemistry							
Alkalinity (Total as CaCO3)	ug/l	-- (3)	120000	70000	54000	65000	83000
Ammonia Nitrogen	ug/l	--	240	310	110	54	54
Biologic Oxygen Demand, Five Day	ug/l	--	4000	4000	<2000	6000	<2000
Chemical Oxygen Demand	ug/l	--	45000	170000	90000	150000	150000
Chloride, dissolved	ug/l	--	47000	48000 (5)	34000 (5)	39000	34000
Conductivity	uS/cm	--	430	310	250	270	300
Conductivity (Field)	uS/cm	--	485	666	445	520	395
Dissolved Oxygen (Field)	ug/l	-- (6)	**2300**	**4770**	**3680**	**4110**	**3010**
Nitrate as N	ug/l	--	1200	<100	<500	<1000	<100
Nitrite as N	ug/l	--	58	<10	<50	<100	<10
Nitrogen, Total Kjeldahl	ug/l	--	1100	3100	1500	3400	2500
pH	-	8.5	7.06	7.36	7.33	7.26	7.08
pH (Field)	-	8.5	7.32	7.8	7.6	7.7	7.5
Phosphorus	ug/l	30 (7)	61	130	89	90	48
Sulfate, dissolved	ug/l	--	17000	<5000 (5)	<5000 (5)	<5000 (5)	<5000 (8)
Temperature (Field)	deg c	-- (9)	1.2	19	22	5	0
Total Dissolved Solids	ug/l	--	246000	170000	236000	260000	256000
Total Suspended Solids	ug/l	--	1000	6000	4000	5000	2000
Metals							
Arsenic	ug/l	5	<1.0	1.2	<1.0	<1	<1
Barium	ug/l	--	18	20	18	20	18
Boron	ug/l	200 (10)	17	11	17	13	<10
Cadmium	ug/l	0.5 (10)	<0.10	<0.10	<0.10	<0.1	0.1
Chromium	ug/l	1 (11)	<5.0	<5.0	<5.0	<5	<5
Copper	ug/l	5	2.5	2.0	1.7	1	2
Iron	ug/l	300	790	2400	2200	2600	1100
Lead	ug/l	5 (12)	<0.50	0.79	<0.50	0.8	1.2
Mercury, dissolved	ug/l	0.2	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	ug/l	30	16	11	<5.0	7	17
Phenols							
Phenolics, Total Recoverable	ug/l	1 (13)	<1.0	<1.0	<1.0	27	3.8

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

			BSW2	BSW2	BSW2	BSW2	BSW2
		(2) (1)	05-Dec-2012	09-May-2013	24-Jul-2013	15-Oct-2013	29-Nov-2013
Parameter	**Unit**	**PWQO**	BSW2	W-3	W-4	W-1	S-2
General Chemistry							
Alkalinity (Total as CaCO3)	ug/l	-- (3)	250000	230000	180000	180000	70000
Ammonia Nitrogen	ug/l	--	54	69	73	<50	55
Biologic Oxygen Demand, Five Day	ug/l	--	5000	3000	<2000	<2000	<2000
Chemical Oxygen Demand	ug/l	--	31000	60000	43000	51000	160000
Chloride, dissolved	ug/l	--	250000	130000	96000	110000	26000
Conductivity	uS/cm	--	1800	1100	770	910	240
Conductivity (Field)	uS/cm	--	1696	1010	1005	980	1005
Dissolved Oxygen (Field)	ug/l	-- (6)	8810	**5210**	5080	**5400**	**3220**
Nitrate as N	ug/l	--	<100	<100	<100	<100	<100
Nitrite as N	ug/l	--	<10	<10	<10	<10	<10
Nitrogen, Total Kjeldahl	ug/l	--	1200	970	980	1000	2600
pH	-	8.5	7.76	8.07	8.21	7.95	6.98
pH (Field)	-	8.5	6.86	7.7	7.5	7.4	7.7
Phosphorus	ug/l	30 (7)	37	69	38	29	54
Sulfate, dissolved	ug/l	--	200000	85000	68000	99000	<5000 (8)
Temperature (Field)	deg c	-- (9)	0	16	24	6	1
Total Dissolved Solids	ug/l	--	966000	616000	448000	538000	224000
Total Suspended Solids	ug/l	--	7000	7000	2000	2000	1000
Metals							
Arsenic	ug/l	5	<1.0	<1.0	<1.0	<1	<1
Barium	ug/l	--	68	47	24	46	18
Boron	ug/l	200 (10)	63	32	34	33	<10
Cadmium	ug/l	0.5 (10)	<0.10	<0.10	<0.10	0.1	0.2
Chromium	ug/l	1 (11)	<5.0	<5.0	<5.0	<5	<5
Copper	ug/l	5	3.1	2.5	1.7	<1	3
Iron	ug/l	300	680	830	110	210	1000
Lead	ug/l	5 (12)	0.63	<0.50	<0.50	<0.5	1.4
Mercury, dissolved	ug/l	0.2	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	ug/l	30	11	5.0	<5.0	6	19
Phenols							
Phenolics, Total Recoverable	ug/l	1 (13)	<1.0	<1.0	<1.0	5.9	3.1

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

			BSW3	BSW3	BSW3	BSW3	BSW3
		(2) (1)	05-Dec-2012	09-May-2013	24-Jul-2013	15-Oct-2013	29-Nov-2013
Parameter	**Unit**	**PWQO**	BSW3	W-2	W-2	W-3	S-1
General Chemistry							
Alkalinity (Total as CaCO3)	ug/l	-- (3)	83000	130000	230000	92000	150000
Ammonia Nitrogen	ug/l	--	<50	69	83	<50	56
Biologic Oxygen Demand, Five Day	ug/l	--	4000	3000	2000	4000	<2000
Chemical Oxygen Demand	ug/l	--	70000	99000	44000	81000	90000
Chloride, dissolved	ug/l	--	270000	210000	440000	140000	84000
Conductivity	uS/cm	--	1300	1100	2000	830	620
Conductivity (Field)	uS/cm	--	1175	1015	1075	985	1495
Dissolved Oxygen (Field)	ug/l	-- (6)	9290	5840	**3880**	**4010**	**2040**
Nitrate as N	ug/l	--	<100	<100	<100	<100	100
Nitrite as N	ug/l	--	<10	<10	<10	<10	<10
Nitrogen, Total Kjeldahl	ug/l	--	2200	1500	1000	940	2400
pH	-	8.5	6.94	7.76	7.98	7.44	7.23
pH (Field)	-	8.5	7.04	7.6	7.7	7.5	7.7
Phosphorus	ug/l	30 (7)	130	93	61	110	200
Sulfate, dissolved	ug/l	--	63000	18000	63000	52000	32000
Temperature (Field)	deg c	-- (9)	1.5	17	23	6	1
Total Dissolved Solids	ug/l	--	750000	596000	1070000	524000	376000
Total Suspended Solids	ug/l	--	8000	4000	2000	8000	19000
Metals							
Arsenic	ug/l	5	<1.0	1.1	<1.0	<1	<1
Barium	ug/l	--	61	68	83	47	53
Boron	ug/l	200 (10)	<10	15	19	13	15
Cadmium	ug/l	0.5 (10)	<0.10	<0.10	<0.10	<0.1	<0.1
Chromium	ug/l	1 (11)	<5.0	<5.0	<5.0	<5	<5
Copper	ug/l	5	6.9	2.4	2.2	2	2
Iron	ug/l	300	310	610	450	540	1300
Lead	ug/l	5 (12)	<0.50	<0.50	<0.50	<0.5	<0.5
Mercury, dissolved	ug/l	0.2	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	ug/l	30	13	26	<5.0	27	23
Phenols							
Phenolics, Total Recoverable	ug/l	1 (13)	<1.0	<1.0	<1.0	28	3.6

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

Parameter	Unit	(2) (1) PWQO	BSW4	BSW4	BSW4	BSW4	BSW4
			05-Dec-2012	09-May-2013	24-Jul-2013	15-Oct-2013	29-Nov-2013
			BSW4	W-4	W-9	W-5	S-7
General Chemistry							
Alkalinity (Total as CaCO3)	ug/l	-- (3)	200000	240000	170000	180000	240000
Ammonia Nitrogen	ug/l	--	50	52	85	<50	150
Biologic Oxygen Demand, Five Day	ug/l	--	3000	3000	<2000	2000	<2000
Chemical Oxygen Demand	ug/l	--	18000	58000	43000	45000	44000
Chloride, dissolved	ug/l	--	210000	140000	95000	110000	110000
Conductivity	uS/cm	--	1500	1100	770	910	900
Conductivity (Field)	uS/cm	--	1420	1070	995	1020	1015
Dissolved Oxygen (Field)	ug/l	-- (6)	**5520**	**5110**	**4440**	**4600**	**2990**
Nitrate as N	ug/l	--	220	<100	<100	<100	3200
Nitrite as N	ug/l	--	<10	<10	<10	<10	<10
Nitrogen, Total Kjeldahl	ug/l	--	770	790	810	930	1400
pH	-	8.5	7.66	8.10	8.31	7.99	7.74
pH (Field)	-	8.5	6.85	7.6	7.6	7.4	7.6
Phosphorus	ug/l	30 (7)	26	65	39	28	110
Sulfate, dissolved	ug/l	--	170000	93000	68000	99000	42000
Temperature (Field)	deg c	-- (9)	0.5	17	20	5	0
Total Dissolved Solids	ug/l	--	796000	646000	462000	532000	492000
Total Suspended Solids	ug/l	--	6000	7000	<1000	3000	61000
Metals							
Arsenic	ug/l	5	<1.0	<1.0	<1.0	<1	<1
Barium	ug/l	--	51	48	22	45	110
Boron	ug/l	200 (10)	65	35	32	31	35
Cadmium	ug/l	0.5 (10)	<0.10	<0.10	<0.10	<0.1	<0.1
Chromium	ug/l	1 (11)	<5.0	<5.0	<5.0	<5	6
Copper	ug/l	5	3.4	2.7	1.4	1	4
Iron	ug/l	300	640	840	<100	210	2900
Lead	ug/l	5 (12)	0.61	<0.50	<0.50	<0.5	1.3
Mercury, dissolved	ug/l	0.2	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	ug/l	30	17	9.5	<5.0	8	20
Phenols							
Phenolics, Total Recoverable	ug/l	1 (13)	<1.0	<1.0	<1.0	8.0	<1.0

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

Parameter	Unit	(2) (1) PWQO	BSW5 05-Dec-2012 (14) 5	BSW5 09-May-2013 W-1	BSW5 24-Jul-2013 W-1	BSW5 15-Oct-2013 (4) W-9	BSW5 29-Nov-2013 S-8
General Chemistry							
Alkalinity (Total as CaCO3)	ug/l	-- (3)	--	180000	140000	150000	350000
Ammonia Nitrogen	ug/l	--	--	<50	100	<50	<50
Biologic Oxygen Demand, Five Day	ug/l	--	--	2000	<2000	38000	<2000
Chemical Oxygen Demand	ug/l	--	--	75000	47000	150000	42000
Chloride, dissolved	ug/l	--	--	440000	170000	87000	430000
Conductivity	uS/cm	--	--	1900	1000	630	2200
Conductivity (Field)	uS/cm	--	--	1800	720	810	870
Dissolved Oxygen (Field)	ug/l	-- (6)	--	6290	**3110**	**3490**	**2740**
Nitrate as N	ug/l	--	--	<100	<100	<1000	<100
Nitrite as N	ug/l	--	--	<10	<10	<100	<10
Nitrogen, Total Kjeldahl	ug/l	--	--	1400	1000	2200	1100
pH	-	8.5	--	7.90	7.74	7.65	7.56
pH (Field)	-	8.5	--	7.5	7.8	7.7	7.6
Phosphorus	ug/l	30 (7)	--	71	45	140	38
Sulfate, dissolved	ug/l	--	--	42000	55000	11000	110000
Temperature (Field)	deg c	-- (9)	--	18	22	7	0
Total Dissolved Solids	ug/l	--	--	1070000	558000	420000	1210000
Total Suspended Solids	ug/l	--	--	3000	8000	5000	9000
Metals							
Arsenic	ug/l	5	--	<1.0	<1.0	<1	<1
Barium	ug/l	--	--	62	39	37	65
Boron	ug/l	200 (10)	--	13	19	22	<10
Cadmium	ug/l	0.5 (10)	--	<0.10	<0.10	<0.1	<0.1
Chromium	ug/l	1 (11)	--	<5.0	<5.0	<5	<5
Copper	ug/l	5	--	1.3	2.1	1	1
Iron	ug/l	300	--	1100	910	3100	1600
Lead	ug/l	5 (12)	--	<0.50	<0.50	<0.5	<0.5
Mercury, dissolved	ug/l	0.2	--	<0.10	<0.10	<0.10	<0.10
Zinc	ug/l	30	--	5.4	<5.0	6	9
Phenols							
Phenolics, Total Recoverable	ug/l	1 (13)	--	<1.0	<1.0	55	2.1

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

Parameter	Unit	(2) (1) PWQO	BSW6 05-Dec-2012 BSW6	BSW6 09-May-2013 W-7	BSW6 24-Jul-2013 W-7	BSW6 15-Oct-2013 W-7	BSW6 29-Nov-2013 S-5
General Chemistry							
Alkalinity (Total as CaCO3)	ug/l	-- (3)	230000	180000	250000	220000	280000
Ammonia Nitrogen	ug/l	--	<50	72	110	<50	<50
Biologic Oxygen Demand, Five Day	ug/l	--	3000	<2000	<2000	<2000	<2000
Chemical Oxygen Demand	ug/l	--	14000	38000	17000	41000	8100
Chloride, dissolved	ug/l	--	160000	68000	90000	90000	57000
Conductivity	uS/cm	--	1200	650	850	800	830
Conductivity (Field)	uS/cm	--	1190	596	970	995	825
Dissolved Oxygen (Field)	ug/l	-- (6)	8540	11020	5910	**6200**	**5600**
Nitrate as N	ug/l	--	3500	3500	3500	2700	8400
Nitrite as N	ug/l	--	<10	39	58	<10	<10
Nitrogen, Total Kjeldahl	ug/l	--	790	900	1100	160	610
pH	-	8.5	7.97	8.24	8.09	8.15	7.89
pH (Field)	-	8.5	7.17	8.1	7.8	7.6	7.8
Phosphorus	ug/l	30 (7)	42	38	52	24	29
Sulfate, dissolved	ug/l	--	75000	26000	36000	35000	34000
Temperature (Field)	deg c	-- (9)	0.3	19	20	6	1
Total Dissolved Solids	ug/l	--	670000	316000	502000	462000	460000
Total Suspended Solids	ug/l	--	4000	3000	7000	5000	24000
Metals							
Arsenic	ug/l	5	<1.0	<1.0	<1.0	<1	<1
Barium	ug/l	--	100	120	120	79	210
Boron	ug/l	200 (10)	54	36	59	46	68
Cadmium	ug/l	0.5 (10)	<0.10	<0.10	<0.10	<0.1	<0.1
Chromium	ug/l	1 (11)	<5.0	<5.0	<5.0	<5	<5
Copper	ug/l	5	4.5	1.8	2.0	2	3
Iron	ug/l	300	740	840	240	1700	610
Lead	ug/l	5 (12)	<0.50	<0.50	<0.50	<0.5	<0.5
Mercury, dissolved	ug/l	0.2	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	ug/l	30	<5.0	<5.0	<5.0	6	7
Phenols							
Phenolics, Total Recoverable	ug/l	1 (13)	<1.0	<1.0	<1.0	4.9	<1.0

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

Parameter	Unit	(2) (1) PWQO	BSW7	BSW7	BSW7	BSW7	BSW7
			05-Dec-2012	**09-May-2013**	**24-Jul-2013**	**15-Oct-2013**	**29-Nov-2013**
			BSW7	W-8	W-8	W-8	S-6
General Chemistry							
Alkalinity (Total as CaCO3)	ug/l	-- (3)	220000	190000	250000	220000	220000
Ammonia Nitrogen	ug/l	--	66	<50	110	<50	210
Biologic Oxygen Demand, Five Day	ug/l	--	3000	<2000	<2000	<2000	<2000
Chemical Oxygen Demand	ug/l	--	17000	26000	16000	42000	56000
Chloride, dissolved	ug/l	--	220000	86000	92000	98000	87000
Conductivity	uS/cm	--	1400	750	870	810	790
Conductivity (Field)	uS/cm	--	1325	700	895	915	860
Dissolved Oxygen (Field)	ug/l	-- (6)	12350	11490	6880	6940	**5840**
Nitrate as N	ug/l	--	3000	3500	2800	1900	2800
Nitrite as N	ug/l	--	<10	74	27	<10	26
Nitrogen, Total Kjeldahl	ug/l	--	810	800	970	550	2000
pH	-	8.5	7.93	8.14	8.11	8.12	7.69
pH (Field)	-	8.5	7.13	7.8	7.9	7.7	7.9
Phosphorus	ug/l	30 (7)	42	21	37	47	110
Sulfate, dissolved	ug/l	--	83000	32000	39000	39000	37000
Temperature (Field)	deg c	-- (9)	0.6	18	22	6	1
Total Dissolved Solids	ug/l	--	736000	416000	510000	474000	456000
Total Suspended Solids	ug/l	--	12000	3000	3000	3000	51000
Metals							
Arsenic	ug/l	5	<1.0	<1.0	<1.0	<1	<1
Barium	ug/l	--	120	110	110	80	93
Boron	ug/l	200 (10)	41	42	62	47	32
Cadmium	ug/l	0.5 (10)	<0.10	<0.10	<0.10	<0.1	<0.1
Chromium	ug/l	1 (11)	<5.0	<5.0	<5.0	<5	<5
Copper	ug/l	5	3.4	1.8	2.1	1	3
Iron	ug/l	300	860	310	130	770	2300
Lead	ug/l	5 (12)	<0.50	<0.50	<0.50	<0.5	1.0
Mercury, dissolved	ug/l	0.2	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	ug/l	30	<5.0	<5.0	<5.0	6	16
Phenols							
Phenolics, Total Recoverable	ug/l	1 (13)	<1.0	<1.0	<1.0	3.2	1.0

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

		(2) (1)	**BSW8**	**BSW8**	**BSW8**	**BSW8**
			09-May-2013	**24-Jul-2013**	**15-Oct-2013**	**29-Nov-2013**
Parameter	**Unit**	**PWQO**	W-6	W-6	W-6	S-4
General Chemistry						
Alkalinity (Total as CaCO3)	ug/l	-- (3)	190000	230000	290000	98000
Ammonia Nitrogen	ug/l	--	75	160	<50	190
Biologic Oxygen Demand, Five Day	ug/l	--	<2000	2000	<2000	2000
Chemical Oxygen Demand	ug/l	--	13000	<4000	6600	120000
Chloride, dissolved	ug/l	--	48000	61000	67000	45000
Conductivity	uS/cm	--	650	740	840	360
Conductivity (Field)	uS/cm	--	700	895	1010	920
Dissolved Oxygen (Field)	ug/l	-- (6)	9890	5250	**5420**	**4290**
Nitrate as N	ug/l	--	6300	6100	4600	<100
Nitrite as N	ug/l	--	38	100	<10	<10
Nitrogen, Total Kjeldahl	ug/l	--	610	860	1100	2200
pH	-	8.5	8.28	8.02	8.12	6.97
pH (Field)	-	8.5	8.2	7.9	7.7	7.9
Phosphorus	ug/l	30 (7)	38	69	17	55
Sulfate, dissolved	ug/l	--	26000	28000	32000	<5000 (8)
Temperature (Field)	deg c	-- (9)	16	23	7	0
Total Dissolved Solids	ug/l	--	360000	468000	476000	264000
Total Suspended Solids	ug/l	--	4000	6000	2000	3000
Metals						
Arsenic	ug/l	5	<1.0	<1.0	<1	<1
Barium	ug/l	--	190	200	180	20
Boron	ug/l	200 (10)	47	60	86	<10
Cadmium	ug/l	0.5 (10)	<0.10	<0.10	<0.1	<0.1
Chromium	ug/l	1 (11)	<5.0	<5.0	<5	<5
Copper	ug/l	5	1.4	1.9	1	2
Iron	ug/l	300	160	120	<100	1800
Lead	ug/l	5 (12)	<0.50	<0.50	<0.5	1.0
Mercury, dissolved	ug/l	0.2	<0.10	<0.10	<0.10	<0.10
Zinc	ug/l	30	<5.0	<5.0	<5	18
Phenols						
Phenolics, Total Recoverable	ug/l	1 (13)	<1.0	<1.0	<1.0	3.2

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

			BSW9	BSW9	BSW9
		(2) (1)	08-Nov-2013	29-Nov-2013 (16)	11-Dec-2013
Parameter	Unit	PWQO	M-1	s9	BSW-9
General Chemistry					
Alkalinity (Total as CaCO3)	ug/l	-- (3)	170000	--	220000
Ammonia Nitrogen	ug/l	--	<50	--	<50
Biologic Oxygen Demand, Five Day	ug/l	--	3000	--	2000
Chemical Oxygen Demand	ug/l	--	45000	--	40000
Chloride, dissolved	ug/l	--	30000	--	37000
Conductivity	uS/cm	--	490	--	630
Conductivity (Field)	uS/cm	--	474	--	479
Dissolved Oxygen (Field)	ug/l	-- (6)	9620	--	-- (15)
Nitrate as N	ug/l	--	<100	--	<100
Nitrite as N	ug/l	--	<10	--	<10
Nitrogen, Total Kjeldahl	ug/l	--	660	--	1300
pH	-	8.5	7.64	--	7.85
pH (Field)	-	8.5	7.83	--	7.63
Phosphorus	ug/l	30 (7)	17	--	56
Sulfate, dissolved	ug/l	--	41000	--	44000
Temperature (Field)	deg c	-- (9)	5.6	--	0.1
Total Dissolved Solids	ug/l	--	284000	--	328000
Total Suspended Solids	ug/l	--	3000	--	4000
Metals					
Arsenic	ug/l	5	<1	--	<1
Barium	ug/l	--	24	--	29
Boron	ug/l	200 (10)	50	--	52
Cadmium	ug/l	0.5 (10)	<0.1	--	<0.1
Chromium	ug/l	1 (11)	<5	--	<5
Copper	ug/l	5	2	--	3
Iron	ug/l	300	210	--	370
Lead	ug/l	5 (12)	<0.5	--	<0.5
Mercury, dissolved	ug/l	0.2	<0.10	--	<0.10
Zinc	ug/l	30	<5	--	11
Phenols					
Phenolics, Total Recoverable	ug/l	1 (13)	3.6	--	3.9

TABLE P-1
BACKGROUND SURFACE WATER QUALITY

Footnotes:

Tables should be read in conjunction with the accompanying document.
< value = Indicates parameter not detected above laboratory method detection limit.
> value = Indicates parameter detected above equipment analytical range.
-- Chemical not analyzed or criteria not defined.
Grey background indicates exceedances.
Bold indicates parameter concentration less than PWQO range for dissolved oxygen
(1) Provincial Water Quality Objectives
(2) Underlined Font = Parameter concentration greater than PWQO
(3) Alkalinity should not be decreased by more than 25% of the natural concentration.
(4) Nitrite/Nitrate: Due to the colour interferences, sample required dilution. Detection limits were adjusted accordingly.
(5) Due to colour interferences, sample required dilution. Detection limit was adjusted accordingly.
(6) Objective depends on water temperature and biota. Dissolved oxygen concentrations should not be less than the values specified in the PWQO document for cold water biota (e.g. salmonid fish communities) and warm water biota (e.g. centrarchid fish communities).
(7) Current scientific evidence is insufficient to develop a firm Objective at this time. Accordingly, the following phosphorus concentrations should be considered as general guidelines which should be supplemented by site-specific studies: To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 ug/L; A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 ug/L or less. This should apply to all lakes naturally below this value; Excessive plant growth in rivers and streams
(8) Detection Limit was raised due to matrix interferences.
(9) (1) General: The natural thermal regime of any body of water shall not be altered so as to impair the quality of the natural environment. In particular, the diversity, distribution and abundance of plant and animal life shall not be significantly changed. (2) Waste Heat Discharge: (a) Ambient Temperature Changes: The temperature at the edge of a mixing zone shall not exceed the natural ambient water temperature at a representative control location by more than 10°C (18°F). However, in special circumstances, local conditions may require a significantly lower temperature difference than 10°C (18°F). Potential dischargers are to apply to the MOEE for guidance as to the allowable temperature rise for each thermal discharge. This ministry will also specify the nature of the mixing zone and the procedure for the establishment of a representative control location for temperature recording on a case-by-case basis. (b) Discharge Temperature Permitted: The maximum temperature of the receiving body of water, at any point in the thermal plume outside a mixing zone, shall not exceed 30°C (86°F) or the temperature of a representative control location plus 10°C (18°F) or the allowed temperature difference, which ever is the lesser temperature. These maximum temperatures are to be measured on a mean daily basis from continuous records. (c) Taking and Discharging of Cooling Water: Users of cooling water shall meet both the Objectives for temperature outlined above and the "Procedures for the Taking and Discharge of Cooling Water" as outlined in the MOEE publication Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters(1994).
(10) See Section 1.2.3. of PWQO. This Interim PWQO was set for emergency purposes based on the best information readily available. Employ due caution when applying this value.
(11) PWQO values exist for Cr(III) and Cr(VI).
(12) If Alkalinity as $CaCO_3$ < 20 mg/L, PWQO = 5 µg/L; if alkalinity as $CaCO_3$ from 20 to 40 mg/L, PWQO = 10 µg/L; if alkalinity as $CaCO_3$ from 40 to 80 mg/L, PWQO = 20 µg/L; if alkalinity as $CaCO_3$ > 80 mg/L, PWQO = 25 ug/L.
(13) Determined by the total reactive phenols test - the 4-AAP (4-amino-antipyrine) test. This objective should be used primarily as a screening tool. The isomer specific PWQOs for various phenolics should be employed where possible.
(14) Monitoring location was dry during this sampling event. No sample was collected.
(15) Parameter was not measured.
(16) Monitoring location was not accessible.

APPENDIX Q

Technical Memorandum – Seismic Stability Dynamic Analyses

TECHNICAL MEMORANDUM

DATE April 7, 2014 **REFERENCE No.** 12-1125-0045

DYNAMIC ANALYSIS – CRRRC SITE, OTTAWA, ONTARIO

This Technical Memorandum presents the results of dynamic analyses carried out for the Capital Region Resource Recovery Centre (CRRRC) landfill that is proposed to be in the eastern part of the City of Ottawa, in the former Township of Cumberland and just southeast of the Highway 417/Boundary Road interchange.

The purpose of the dynamic analysis was to investigate the seismic stability of the conceptual landfill configuration in its closure configuration, at the end of filling to its maximum height, when subjected to strong earthquake shaking. The analyses were carried out for the landfill configuration depicted in the Site Development Plan with approximately 25 m of waste placed to an elevation of about 100 masl and the results from the worst case analysis are presented herein.

This memorandum presents a summary of the methodology used to assess the seismic stability and earthquake-induced deformations in the waste materials and the underlying foundations, and the results of the analyses. Information on the existing subsurface conditions was obtained from the investigations carried out by Golder Associates Ltd. (Golder), as well as from the findings of previous investigations in the area.

1.0 SITE SUBSURFACE CONDITIONS

The overburden soils underlying the CRRRC Site (Site) comprise topsoil overlying surficial sandy soil of about 0.3 to 1.3 m thickness underlain discontinuously by weathered silty clay. The surficial materials and weathered silty clay typically have a combined total thickness of about 1.5 m. Underlying the weathered clay is a deposit of highly plastic silty clay (PI = 30 to 80) that is about 30 m in thickness. The silty clay deposit is, in turn, underlain by approximately 2 to 8 m of basal gravelly glacial till, followed by bedrock. The bedrock consists of inter-bedded shale and limestone of the Carlsbad Formation.

The upper portion of the unweathered silty clay deposit, under current overburden stress conditions, has a soft consistency to a depth of about 9 to 10 m. Below this depth, its shear strength increases with depth gradually and becomes stiff. The silty clay deposit has a high natural water content, typical of the Leda marine clay deposits underlying the Ottawa area.

2.0 SEISMICITY AND GROUND MOTION PARAMETERS

The seismicity at the site results from upper to mid-crustal earthquakes with predominantly thrust (reverse) faulting mechanisms. The Western Quebec Zone comprising the urban areas of Montreal, Ottawa-Hull and Cornwall was the site of at least three significant earthquakes in the past. An earthquake estimated at magnitude M5.8 shook Montreal in 1732. In 1935, the area of Temiscaming was shaken by an M6.2 earthquake. In 1944, an M5.6 earthquake occurred between Cornwall, Ontario and Massena, New York. Figure 2-1 shows some significant earthquakes that have occurred in eastern Canada. The hypocentres of these earthquakes are reported to be located at depths varying from 10 to 20 km below ground surface.

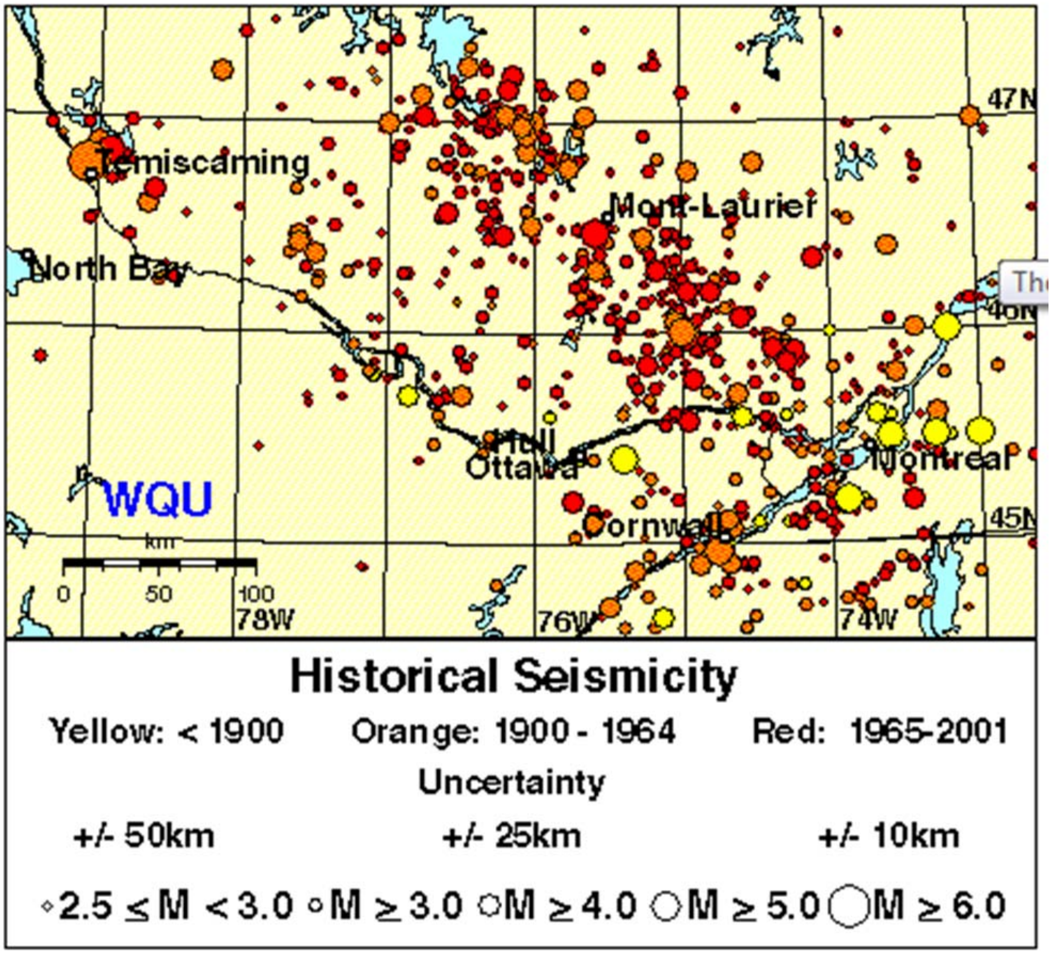


Figure 2-1: Historical Earthquakes in Eastern Canada

2.1 Seismic Design Criteria

Seismic design guidelines established for solid waste landfills in the USA require that such facilities be designed to resist ground motions with a return period of 1:2,475-yrs (ref. RCRA Subtitle D (258) – Seismic Design Guidance for Solid Waste Landfill Facilities published by the Environmental Protection Agency). This level of ground shaking is also consistent with the seismic design provisions in the 2010 NBCC for buildings. Consistent with the guidelines established in practice for similar facilities, earthquake ground motions with a return period of 1:2475-yrs have been considered for the design and analysis of the subject landfill.

2.2 Site Ground Motions

Seismic ground motion parameters for the site have been evaluated using the seismic hazard models and seismogenic zones developed on a regional basis by the Natural Resources Canada for use in the National Building Code of Canada for a return period of 2,475-years (equivalent to having a 2% chance of being exceeded in 50 years). In the analyses completed for this study, the seismic ground motions that correspond to a return period of 2,475-years were used as input and were propagated from bedrock upwards towards the ground surface using ground response analysis models. The models consider the influence of 25 m of waste, about 35 m of silty clay, glacial till, and 10 m of bedrock underlying the site on site response. The input ground motions were applied at bedrock, which has been characterized based on in-situ measurements as having a shear wave velocity in excess of 1,500 m/s (*i.e.*, Site Class A). The applicable input ground motions were developed following a four-step procedure:

Step-1: Obtain the ground motion parameters for the Reference Ground Condition (RGC) at the site from the interactive website maintained by Natural Resources Canada for the site coordinates. These ground motion parameters correspond to Site Class C, which is the RGC where the average shear wave velocity in the top 30 m varies between 360 m/s and 760 m/s.

Step-2: De-aggregate the seismic hazard at periods varying between 0.2s and 2.0s to establish the mean earthquake magnitude and distance that dominates the seismic hazard at the subject site.

Step-3: Develop the response spectrum that corresponds to Site Class A ground motion parameters using the short and long-period amplification factors F_a and F_v as per Tables 4.1.8.4B and 4.1.8.4C of NBCC (2010).

Step-4: Select applicable outcropping acceleration time-histories for Site Class A and for the mean earthquake magnitude that dominates the seismic risk at the subject site following guidelines for ground motion selection by Atkinson (2009).

The Site Class A spectrum derived using the code-based F_a and F_v values following the above-described procedure provides a conservative estimate of spectral accelerations when compared with the spectral accelerations derived from the RGC Factors recommended for hard rock in GSCs Open File No. 4459.

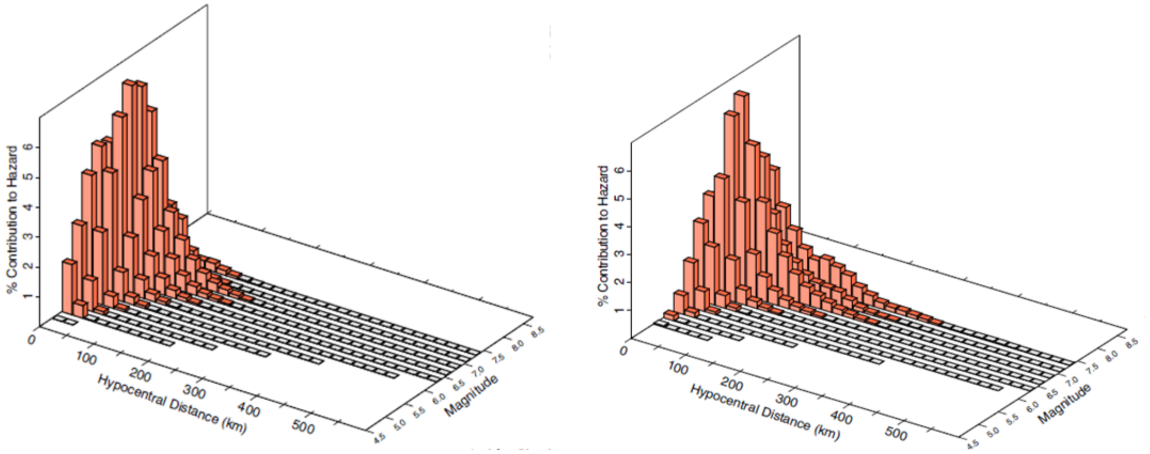
The 5-percent damped target response spectrum established for Site Class C (RGC) is shown in Table 2-1. The response spectrum for Site Class A developed using F_a and F_v factors of 0.75 and 0.5, respectively, is also provided in Table 2-1.

Table 2-1: Ground Motion Parameters

Return Period	PHGA	Sa (0.2s)	Sa (0.5s)	Sa (1.0s)	Sa (2.0s)
2,475-Years [RGC or Site Class C] (2% probability of exceedance in 50 years)	0.32 g	0.64 g	0.31 g	0.14 g	0.05 g
2,475-Years [Site Class A – F_a = 0.75 and F_v = 0.50] (2% probability of exceedance in 50 years)	0.24 g	0.48 g	0.16 g	0.07 g	0.02 g

Note: In Table 2-1, PHGA refers to peak horizontal ground acceleration; Sa refers to the 5-percent damped spectral acceleration for a given period.

The de-aggregated hazard for the subject site has been obtained from Geological Survey of Canada and Figure 2-2 shows the de-aggregation results for the 2,475-year ground motions for spectral accelerations with periods of 0.2 and 1.0 seconds. The de-aggregated hazard indicates that the earthquake characteristics at the subject site correspond to “mean” earthquake magnitudes ranging between M6 and M7 and the associated distances will be between 25 km and 72 km.



(a) Sa(0.2s)

Mean Magnitude = 6.38, Mean Distance = 38 km

(b) Sa(1.0s)

Mean Magnitude = 6.85, Mean Distance = 63 km

Figure 2-2: Magnitude-Distance Distributions for Spectral Accelerations at Periods of 0.2 and 1 sec.

Figure 2-3 illustrates the response spectra for the site corresponding to Site Class A and Site Class C ground conditions.

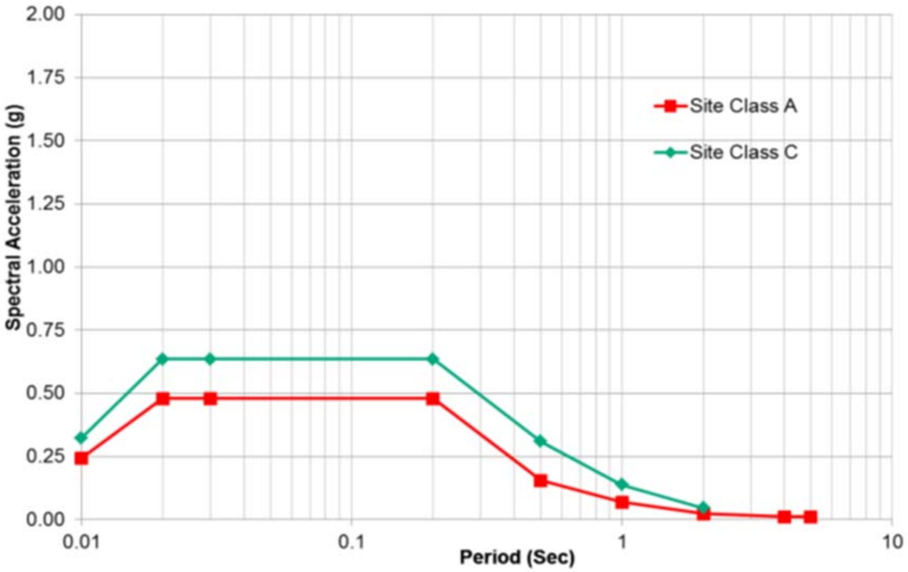


Figure 2-3: Response Spectra for Class A and C Ground Conditions

2.3 Site Classification for Above Ground Facilities

The ground motions described in Section 2.2 above correspond to Site Class A ground condition, or for hard rock, that is present at a depth of about 35 m below the existing ground surface. The near surface ground motions for the design of structures as per the seismic design provisions in the NBCC (2010) are derived based on the following:

- Site Class established based on the time-average shear wave velocity of the overburden soils in the upper 30 m as per Table 4.1.8.4A of the NBCC.
- Shaking level-dependent amplification factors F_a and F_v that correspond to the Sa(0.2s) and Sa(1.0s) established for the RGC and the Site Class as per Tables 41.8.4B and 4.1.8.4C of the NBCC.

Based on site-specific shear wave velocity profiling completed at the subject site, the average shear wave velocity of the upper 30 m of overburden soils has been established as less than 180 m/s (see Figure 4-4 for the profile of shear wave velocity). The overburden soils are, in turn, underlain by bedrock with an average shear wave velocity in excess of 1,500 m/s providing a significant contrast in impedance that can result in amplification of ground motions as they propagate from bedrock towards the ground surface.

The ground surface response spectra for the design of structures supported on shallow foundations may be computed using $F_a = 1.2$ and $F_v = 2.1$ as per Tables 4.1.8.4B and 4.1.8.4C and appropriate for Site Class E and Sa(0.2) and Sa(1.0) values summarized in Table 2-1 above for the subject site.

2.4 Bedrock Acceleration Time-Histories

Bedrock acceleration time-histories that correspond to the earthquake magnitudes and distances based upon the determination of the seismic hazard at the subject site were selected for use in the site response analyses. The acceleration time-histories that correspond to a Site Class A conditions were selected from the database maintained by the University of Western Ontario (UWO) (Ref. Engineering Seismology Toolbox at www.seismotoolbox.ca).

The UWO database contains synthetic earthquake records for Eastern Canada for various site classes including Site Class A. The records are available for earthquake magnitudes of M6 and M7. For purposes of this analyses, a total of six M7 earthquake records were selected and they were linearly scaled to match the target uniform hazard response spectrum (UHRS) for the site over the period range of interest of 0.3 to 0.8 sec considering the fundamental period of the soils underlying the site based on the guidelines provided by Atkinson (2009).

The bracketed duration of strong shaking of the selected time-histories varies between 10 and 15 seconds. Details of the selected earthquake records are summarized in Table 2-2.

Table 2-2: Selected Rock Earthquake Records

Ground Motion Identifier	Magnitude	Distance (km)
Earthquake No. 4	7	50
Earthquake No. 5	7	50
Earthquake No.11	7	50
Earthquake No.17	7	63
Earthquake No.37	7	96
Earthquake No.44	7	99

The bedrock acceleration time-histories of the modified records are shown on Figure 2-4; the corresponding response spectra, and the target response spectrum for the site are shown on Figure 2-5.

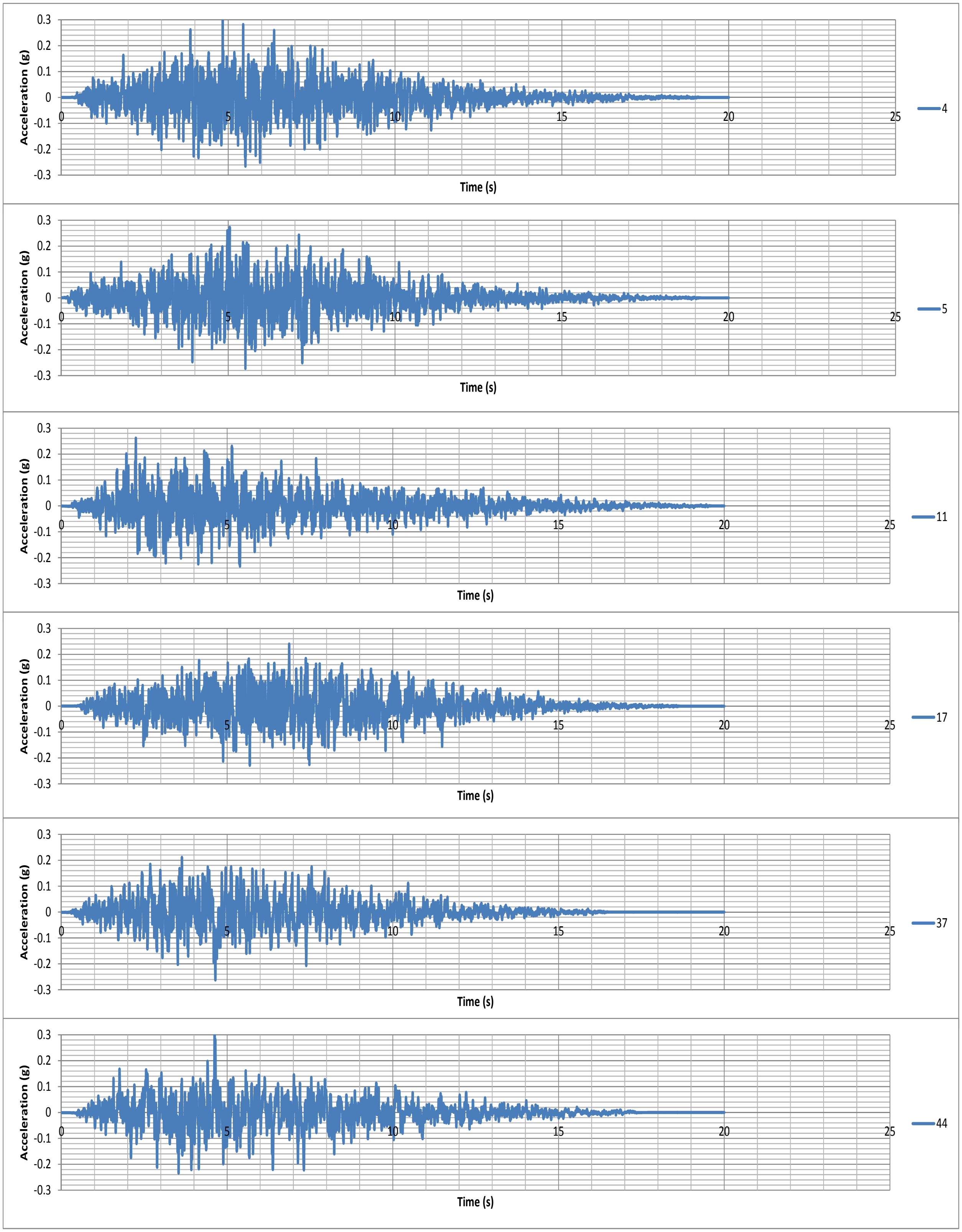


Figure 2-4: Modified Bedrock Acceleration Time-Histories

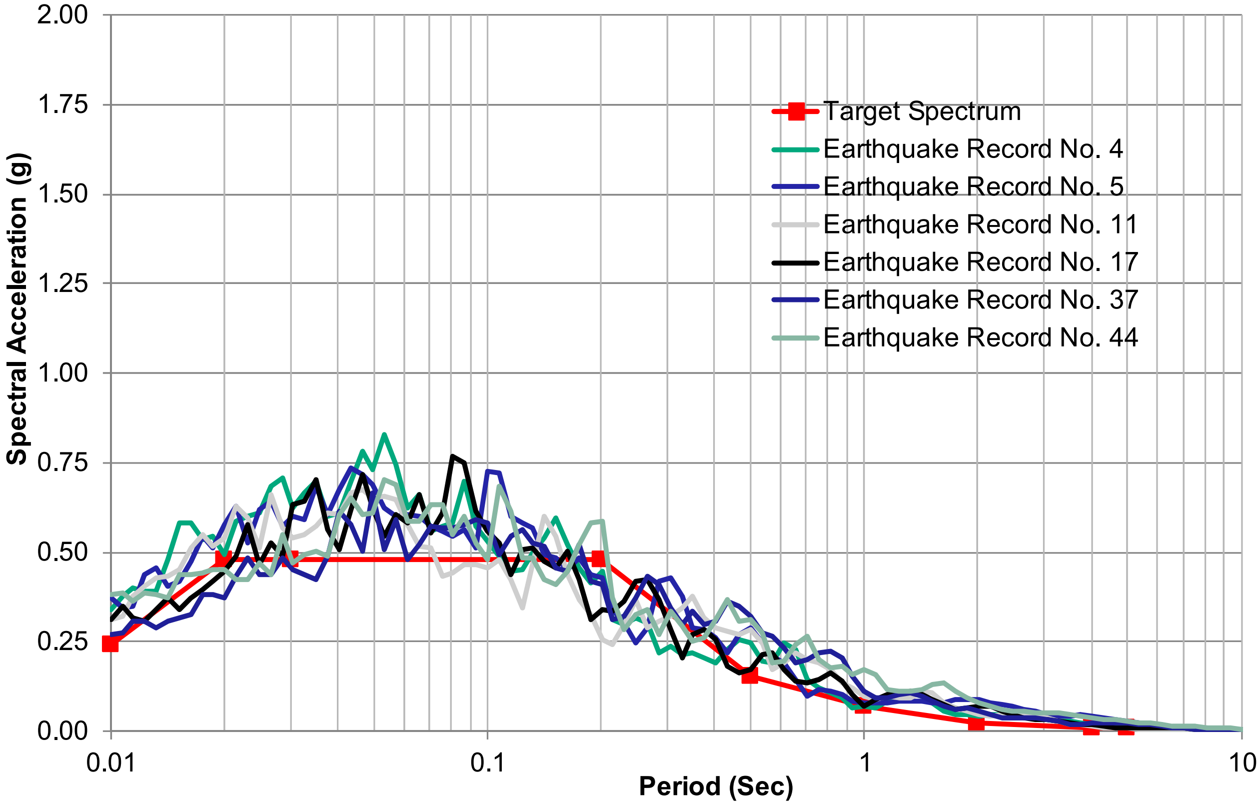


Figure 2-5: Target Response Spectrum and Spectra of the Modified Rock Records

3.0 ANALYSIS METHODOLOGY

Non-linear dynamic time-history analyses were carried out to assess the seismic stability and deformations of the CRRRC landfill at the closure condition when subjected to an excitation level with a 2,475-year return period. Considering the time required to reach the closure condition (planned period of 30 years) in comparison to the return period of the design ground motions (*i.e.,* 2,475-years), analyzing the landfill response for this case is, in our opinion, considered appropriate. The key features of the analyses completed are presented herein.

The dynamic analyses were carried out considering two-dimensional plane strain conditions. In a strict sense, such analyses are representative of stress-deformation conditions along the centerline of the landfill. The model boundaries were extended all the way to the bedrock in the vertical direction and some 160 m to either side of the toe of the landfill or the perimeter berms. The deformations estimated at the landfill corners were established as the resultant of deformations in the two directions. A schematic of the two-dimensional model developed for the analysis of landfill response is shown in Figure 3-1.

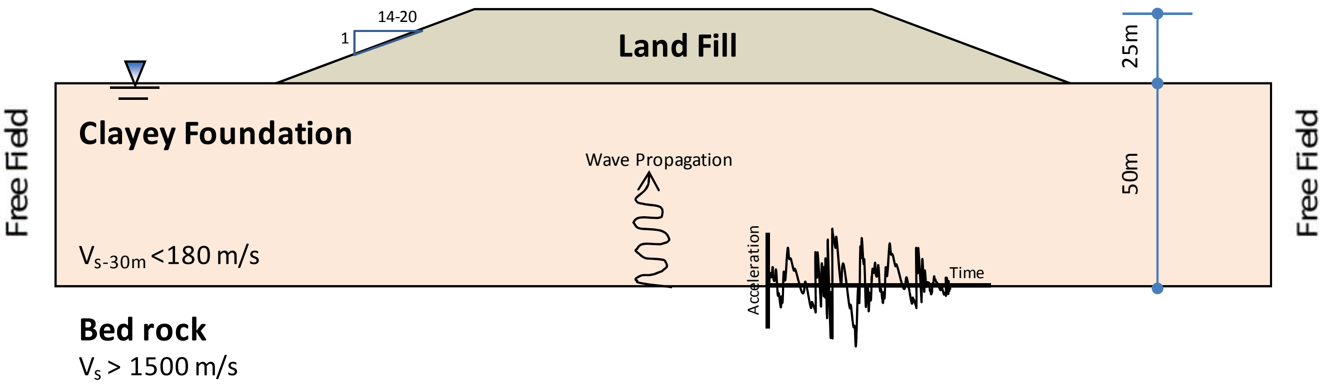
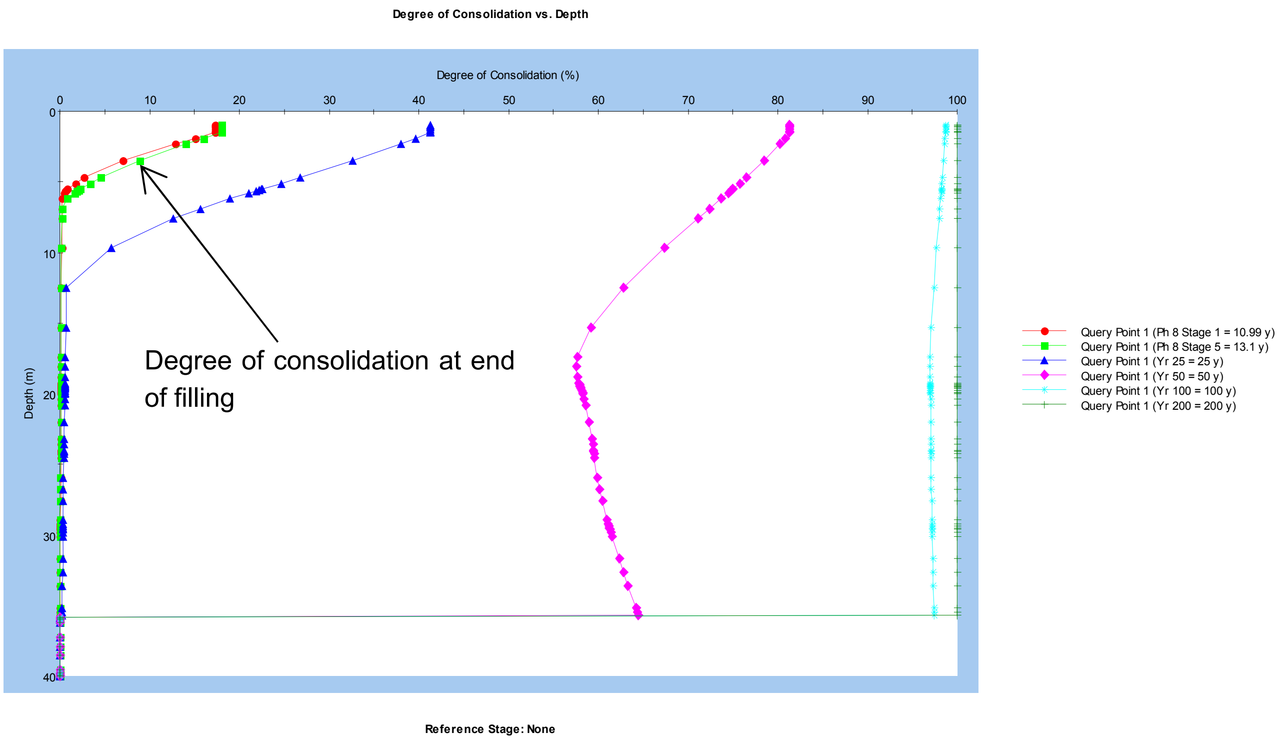


Figure 3-1: A Schematic of the 2D Plane Strain Model Considered for Deformation Analysis

The analyses were carried out using the computer code FLAC^{2D} *V6* (*Itasca,* 2008), which is a commercially available finite difference code with the capability to analyse coupled stress-flow-deformation response of earth structures that can undergo large deformations under static and dynamic loading conditions. It has several built-in and widely-used constitutive models (*e.g.,* elastic and Mohr-Coulomb) and also has the capability to incorporate user-defined constitutive models. Although the code has the capability to carry out consolidation and seepage analyses, such analyses were not conducted as part of this specific assignment.

FLAC utilizes a time-marching procedure to solve the equations for static and dynamic loading. This procedure first invokes the equations of motion to derive new velocities and displacements from stresses and forces. Then, strain rates are derived from velocities, and new stresses from strain rates. It takes one time-step for every cycle around the loop. The internal dynamic time-step is chosen to be sufficiently small (in the order of 10^{-5} to 10^{-6} seconds) so that no information will physically be transmitted from one element to another over the selected time interval. The dynamic time-step is computed considering the highest stiffness assigned in the model.

It has been considered that the landfill at the Site will be constructed after a shallow excavation is made into the surficial silty sand and weathered clay, with a base level close to the underlying soft clayey soils without the provision of a synthetic liner. The waste materials of the landfill extend from about elevation 76 masl to its maximum elevation at 100 masl over an estimated period of filling of some 30 years. The self-weight loads imposed by the landfill materials will induce consolidation settlements in the underlying clayey soils. The consolidation of those soils will increase the strength and stiffness of the clay foundation soils with time; *i.e.*, larger increases with longer time. The consolidation-induced strength and stiffness gain in the clayey soils were estimated based on SETTLE^{3D} analyses carried out as part of the geotechnical analysis of the landfill to simulate the static loading-induced settlements as a function of time. The estimated degree of consolidation at the end of filling, and beneath the ‘youngest’ phases of the landfill (*i.e.*, Phases 6, 7, and 8), ranged between 0 and 18% within the upper 7 m of foundation soils and 0% in the soils below 7 m as shown in Figure 3-2. These effective degrees of consolidation were used in the analyses to estimate the undrained shear strength and stiffness at the end of filling.



Degree of consolidation at end of filling

Figure 3-2: Consolidation of Foundations Soils Under Landfill Loading
[Note: Analysis Assumes Landfill Built to Full Height In Stages. The analysis reference time ("time zero") was from the start of filling of Phase 6, with Phase 8 being completed/filled 13.1 years thereafter]

The response of the landfill-foundation system to earthquake shaking was carried out in two stages. In the first stage, the landfill and its foundation was analyzed with the strength and stiffness parameters that reflect the effects of consolidation of clayey soils under gravity loads (static mode) to establish the pre-earthquake stress state. Thereafter, the analysis was switched to the dynamic mode with updated undrained strength and stiffness properties assigned to the foundation soils.

The foundation soils and waste were modeled as Mohr-Coulomb materials under gravity (or static) loading conditions. Under seismic loading conditions, the waste was modeled as a Mohr-Coulomb material with an equivalent linear approach (ELA) to simulate the non-linear cyclic behavior, including shear modulus degradation with increasing shear strain and shear strain-dependent damping, using the three parameter hysteretic model built into FLAC. The foundation soils were modeled as non-linear Mohr-Coulomb materials using the hyperbolic stress-strain model and modified Masing's rule incorporated in the user-defined routine UBCHYST developed at the University of British Columbia, Vancouver, Canada. The bedrock was modeled as a linear-elastic material.

4.0 FLAC^{2D} MODEL AND MATERIAL PARAMETERS

The proposed ~25 m maximum height landfill section with a near-flat crest was discretized into 2,600 smaller zones of 1 m in height, supported on a 50 m thick foundation layer. Considering the soft and compressible silty clay underlying the site, the waste slopes were considerably flatter than typical for landfills constructed in locations with stronger foundation soil conditions, and varied from 14H:1V in the lower portion and becoming flatter to 20H:1V from just above the mid height to the crest (as indicated for the Site Development Plan).

The foundation layer comprised some 7,300 smaller zones with the nominal height of each zone varying from 1 to 5 m. The foundation zone extended laterally about 160 m from the toe of the landfill on either side. The water table was assigned at a depth of 1 m below the existing ground surface.

Figures 4-1 and 4-2 show the FLAC model with the different material zones used in the analyses. As shown in the figures, the landfill model comprises the waste material and two perimeter toe soil berms. The foundation model includes clayey soil layers (*e.g.*, soft upper clay), glacial till and part of the bedrock foundation. It was assumed that the upper surficial sand materials will be excavated and removed from within the footprint of the landfill to create the base of the landfill at shallow depth below original ground surface.

The analyses were conducted using the total-stress approach where undrained shear strength parameters are assigned to the clayey foundation soils.

The shear strength profile for the clayey soils comprising the foundation under as-is conditions was established based on the SHANSEP concept (Ladd & DeGroot, 2004) and suggestions by Mesri & Huvaj, (2007) using data from the Boundary Road site investigations (*i.e.*, vane tests, CPT tests). Figure 4-3 shows the as-is undrained shear strength (S_u) profile established from the in-situ strength measurements and laboratory consolidation testing of undisturbed samples. The shear strength profile selected for design is also shown on Figure 4-3.

The shear stiffness (*i.e.*, G) of the foundation soils was evaluated based on site-specific in-situ shear wave velocity (V_s) measurements, obtained using the VSP (Vertical Seismic Profiling) method. Figure 4-4 shows the details of the V_s data for the site along with the design shear wave velocity profile used in the analyses. On average, the measured shear wave velocity of site soils is less than 180 m/s.

A time-averaged shear wave velocity close to 140 m/s is representative of the site, which translates to a site fundamental period of about 1 sec. Based on micro-tremor studies completed for the Ottawa Area (ref. Motazedian et al, 2010), the fundamental period of the site is estimated to be between 0.8 and 1.2 seconds. The estimated site period compares well with the micro-tremor measurements.

The silty clay foundation soils underlying the site are of marine origin, with as-is peak undrained shear strengths varying from 10 to 15 kPa in the upper 7 m and varying to in excess of 70 kPa at a depth of 35 m below ground surface. The strength sensitivity (S_t), expressed as the ratio of the peak undrained shear strength to remolded strength, generally varies between 4 and 14 with an average of 9, indicating medium to extra high sensitivity (CFEM, 2006). Laboratory cyclic simple shear tests carried out on undisturbed soil samples obtained from similar deposits in the Ottawa region indicate only nominal strain softening as a result of the application of up to 10 uniform cycles of shear loading that correspond to the anticipated intensity of site-specific cyclic loading. At higher intensities of cyclic loading and with the application of a large number of cycles of shear loading (*i.e.*, N = 100 to 500), the foundation soils would be expected to soften considerably, resulting in significant reductions in the shear stiffness and undrained shear strength. However, these stress levels and numbers of cycles are in excess of those anticipated for the seismic loading for the Site.

The strength parameters of the waste materials were estimated based on the data found in the literature (*e.g.*, Kavazanjian et al. 1996, EPA1995, Kavazanjian et al. 2013). Figure 4-5 shows shear wave velocity data from various landfill sites reported by Kavazanjian et al. (1996) along with a recommended design profile.

Table 4-1 lists the material parameters for various soil types and waste used in the analysis.

Table 4-1: Material Properties Used in FLAC Analyses

Material Type	Total Unit Weight (kN/m^3)	Su (As Is) (kPa)	Su (At End-of-Filling)^2 (kPa)	Φ (^{0})
1. Solid Waste Landfill	12	-	-	30
2. Soft Clayey Layer^1	15	10 to 11	No increase	-
3. Upper Clayey Layer^1	15	Variable^1	No increase	-
4. Lower Clayey Layer^1	16	Variable^1	No increase	-
5. Glacial Till	21	-		38
6. Bedrock Foundation	22	-	-	-
7. Perimeter Sandy Berm	18	-	-	28

Notes:

1 See Figure 4-3 for S_u profile.

2 The estimated degree of consolidation at the end of filling ranges between 0 and 18% within the upper 7 m (see Figure 3-2). This results in an effective stress lower than pre-consolidation pressure (Pc) of the layer, so no strength gain is predicted by this time.

5.0 RESULTS

The FLAC analysis considered the self-weight loads of the foundation followed by the application of the landfill loading. The resulting landfill-foundation system with waste placed to its full height of some 25 m was brought to equilibrium under self-weight loads. Figure 5-1 shows the computed vertical effective stress contours for the foundation (along with the boundary conditions) for static loading for the as-is case (compression is negative). As shown, the stress pattern uniformly follows the geometry of the foundation model. Figure 5-2 shows the vertical stress contours for the landfill-foundation system.

After the landfill-foundation system was brought to equilibrium under gravity loads, the dynamic mode of the FLAC program was invoked and the model was subjected to horizontal shaking at the model base. A compliant boundary was considered in the analysis. The acceleration time-histories were converted to equivalent shear stress time-histories. The user-defined stress-strain model (UBCHYST) was calibrated to represent the published modulus reduction and damping curves that correspond to clay soils with a PI = 45 (Vucetic & Dobry, 1991) and the curves recommended by Kavazanjian et al (1998) for waste materials. Figure 5-3 shows a comparison of the modulus reduction and damping curves derived from UBCHYST with the base curves obtained from literature for the foundation soils. Figure 5-4 shows the comparison of the modulus reduction and damping curves derived from the FLAC ELA approach with the base curves obtained from literature for the waste materials. While the modulus reduction curves compare well, the FLAC simulations use a conservative estimate of damping for the waste materials.

Figure 5-5 shows the acceleration time-history at the landfill crest from earthquake record No. 37. Figure 5-6 shows a typical stress-strain response for a zone in the upper clay layer (see Figure 4-1 for the location of the zone), which indicates no significant strain softening under the design ground motions.

The computed lateral displacement pattern is shown on Figure 5-7 and the results shown correspond to the end of shaking. Due to the symmetry of the landfill configuration analyzed, the results indicate that the landfill experiences similar permanent lateral movements on both sides. The computed seismic loading-induced lateral movements of the section analyzed are less than 400 mm. Figure 5-8 shows the (50 times magnified) distorted mesh compared to the original mesh (undeformed). As shown on the figure, the earthquake-induced deformations of the landfill are the result of deformations occurring in the upper clay layers directly below the landfill; *i.e.*, the waste material rides on top of the soft upper clay layer.

Analyses were carried out for a total of six earthquake records developed following the methods outlined in Section 2.0. All of the analyses showed similar patterns of deformations and the landfill configuration is predicted to be stable under the design ground motions. Table 5-1 lists the lateral and vertical seismic loading-induced displacements computed at the toe of the landfill at the end of shaking from the six earthquake records. At the corners of the landfill, the displacements may be larger by about 40% due to three-dimensional seismic loading effects.

It is noted that the maximum lateral displacements *during* shaking (*i.e.*, under transient loading conditions) were computed to vary from 210 mm to 360 mm, which is up to 20**%** higher than those computed at the end of shaking.

Figure 5-9 shows a typical displacement time-history computed for a location at the toe of the landfill illustrating the variations in the transient displacements computed during shaking and permanent displacements computed after cessation of ground shaking. These results are indicative of a relatively stable landfill under the design seismic loading conditions.

The results of the 2D FLAC analyses were compared with simplified Newmark sliding block analyses using the yield acceleration values established for typical failure surfaces and the peak ground surface acceleration estimated using 1-D wave propagation analyses, and found to be in good agreement.

Table 5-1: Computed Permanent Seismic Displacements[1] at the Toe of the Landfill

Earthquake Record	Vertical Displacement (mm) (End of Shaking)	Lateral Displacement (mm) (End of Shaking)
1. Earthquake No. 4	60	190
2. Earthquake No. 5	80	240
3. Earthquake No. 11	70	250
4. Earthquake No. 17	60	230
5. Earthquake No. 37	40	200
6. Earthquake No. 44	80	340

Note: [1] The seismic displacements summarized here are in addition to the static loading-induced settlements and correspond to conditions at the end of filling.

6.0 SUMMARY

A dynamic analysis of the proposed landfill at the Site has been carried out. The analysis was carried out for the 25 m high maximum landfill configuration with waste slopes varying from 14H:1V to 20H:1V. A geotechnical model was developed that included the waste material, the soft to stiff overburden clayey soils, till, and a portion of the bedrock foundation zone to a total thickness of about 50 m. The primary focus of the analysis was to confirm the landfill seismic stability and to quantify the anticipated deformations for the landfill-foundation system when subjected to ground motions with a return period of 1:2,475-yrs, consistent with the design shaking considered in the National Building Code of Canada. The analyses were carried out using bedrock ground motions developed for "Site Class A" ground conditions applied at a depth of some 50 m below ground surface.

The strength and stiffness properties of the waste materials were obtained from published literature. The strength and stiffness properties of the silty clay deposit comprising the foundation of the landfill were derived from site-specific in-situ measurements (*i.e.*, Nilcon vane shear and downhole shear wave velocity testing) and state-of-the-practice followed in the analysis of these soils in the Ottawa region. The stiffness properties of the till and bedrock were established based on in-situ shear-wave velocity measurements.

The dynamic analyses were carried out using the computer program FLAC (V6, Itasca, 2008) considering a Mohr-Coulomb constitutive model for the waste materials and clayey foundation, and elastic material properties for the bedrock foundation, allowing for stiffness/modulus reduction due to seismic shaking. The seismic response of the foundation soils and waste material was established based on the published data available for similar materials. Two dimensional plane strain conditions were considered.

The results indicate the following:

1) The landfill configuration is stable under the design seismic loading conditions;

2) The zones closest to the landfill toe undergo maximum permanent lateral displacements of about 340 mm during shaking that corresponds to the 2,475-year return period ground motions. The resultant permanent ground movements at the corners of the landfill may be larger and by about 40% due to three-dimensional loading effects, reaching values close to 500 mm;

3) The landfill lateral displacements are mainly controlled by the response of the soft clayey foundation soils directly below the waste materials and in the upper 20 m;

4) The permanent lateral displacements are approximately symmetrical, resulting from the near horizontal soil stratigraphy and the landfill configuration;

5) The results of the 2D FLAC analyses predict displacements that are consistent with those established from simplified methods of analyses such as the Newmark sliding block analysis; and,

6) Because the ongoing consolidation of the clay deposit beneath the waste will result in increased shear strength and corresponding increased resistance to the effects of earthquake shaking, the stability of the landfill will improve and the potential displacements will decrease with time after filling is complete.

7.0 CLOSURE

We trust that the contents of this Technical Memorandum meet with the requirements of the study. Please do not hesitate to contact the undersigned, if you have questions or need clarification of contents.

GOLDER ASSOCIATES LTD.

Mahmood Seid-Karbasi, Ph.D., P.Eng.
Geotechnical Engineer

Upul D. Atukorala, Ph.D., P.Eng.
Principal and Senior Geotechnical Engineer

MSK/UDA/VF/sg
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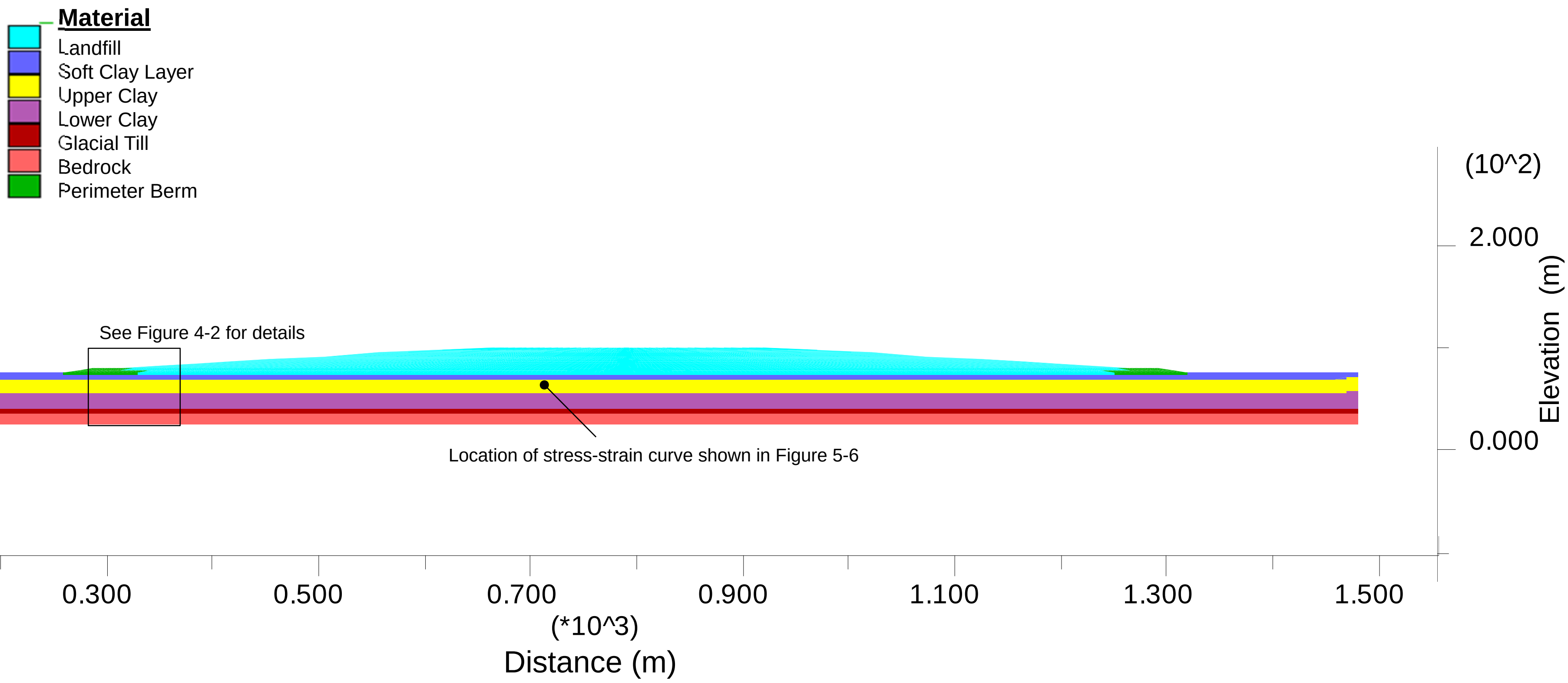
Attachments:
Figure 4-1: FLAC Model and Material Types
Figure 4-2: FLAC Finite Difference Grid and Material Types
Figure 4-3: Strength Profile of Foundation Soils (As-is)
Figure 4-4: Shear Wave Velocity Profile of Foundation
Figure 4-5: Shear Wave Velocity Data for Solid Waste Landfills
Figure 5-1: Contours of σ'_v for Foundation, As-is
Figure 5-2: Contours of σ_v Foundation-Landfill System
Figure 5-3: Modulus Reduction and Damping Curves for Foundation Soils, FLAC Simulation vs. Published Data
Figure 5-4: Modulus Reduction and Damping Curves for Solid Waste Materials, FLAC Simulation vs Published Data
Figure 5-5: Acceleration Time History at Landfill Crest (Earthquake No. 37)
Figure 5-6: Typical Stress-Strain Response of Clayey Soils (Earthquake No. 37)
Figure 5-7: Contours of Lateral Displacements End of Shaking (Earthquake No. 37)
Figure 5-8: Distorted Mesh Compared with Original Shape (Earthquake No. 37)
Figure 5-9: Time-History of Lateral Displacement at Landfill Toe (Earthquake No. 37)



PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

FLAC MODEL AND MATERIAL TYPES

PROJECT No.		12-1125-0045	PHASE / TASK No.	4500
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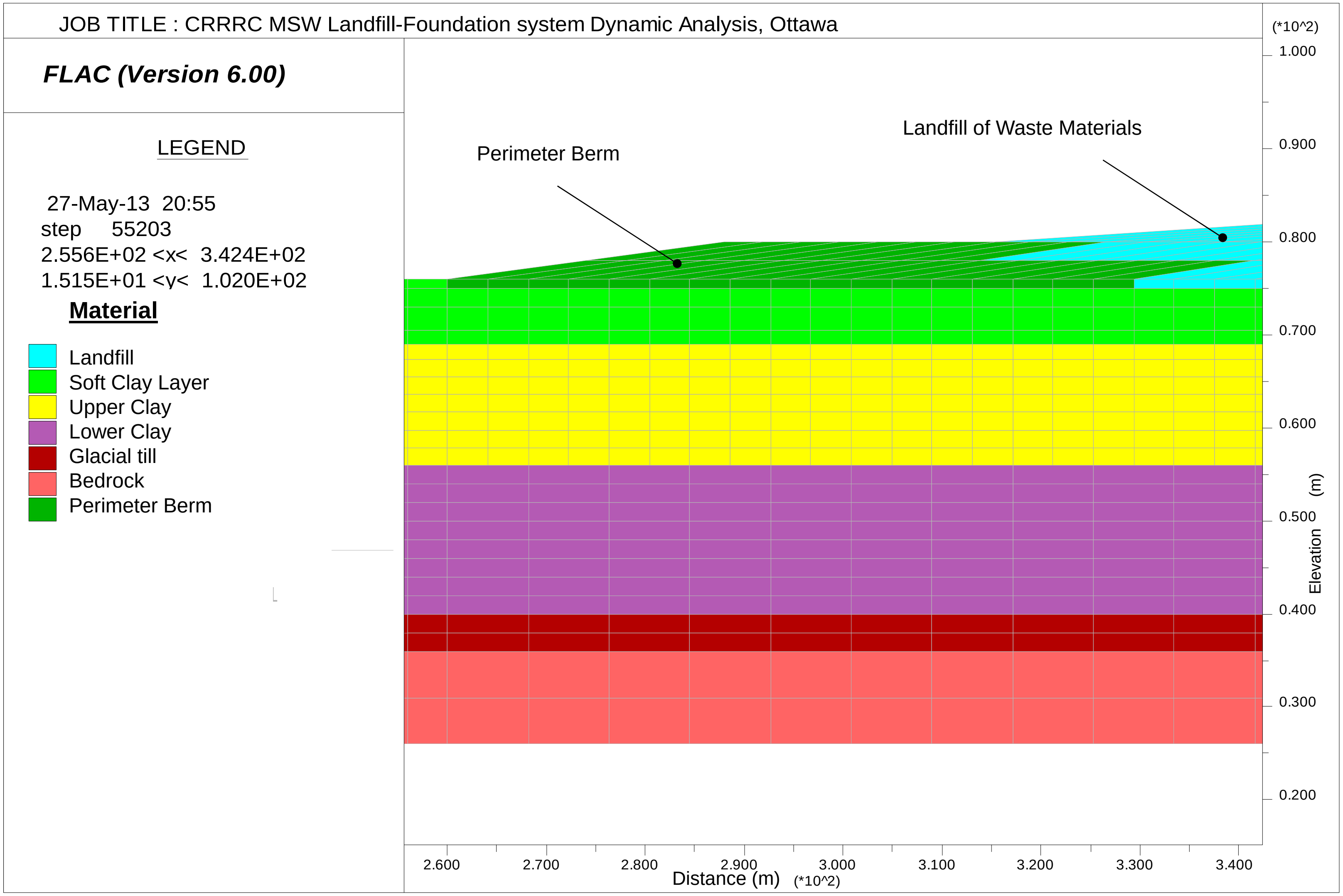

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

**FLAC FINITE DIFFERENCE GRID
AND
MATERIAL TYPES**

Golder Associates

PROJECT No.		12-1125-0045
DESIGN	MSK	30MAR14
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REVIEW	PAS	AUG 14

PHASE / TASK No. 4500

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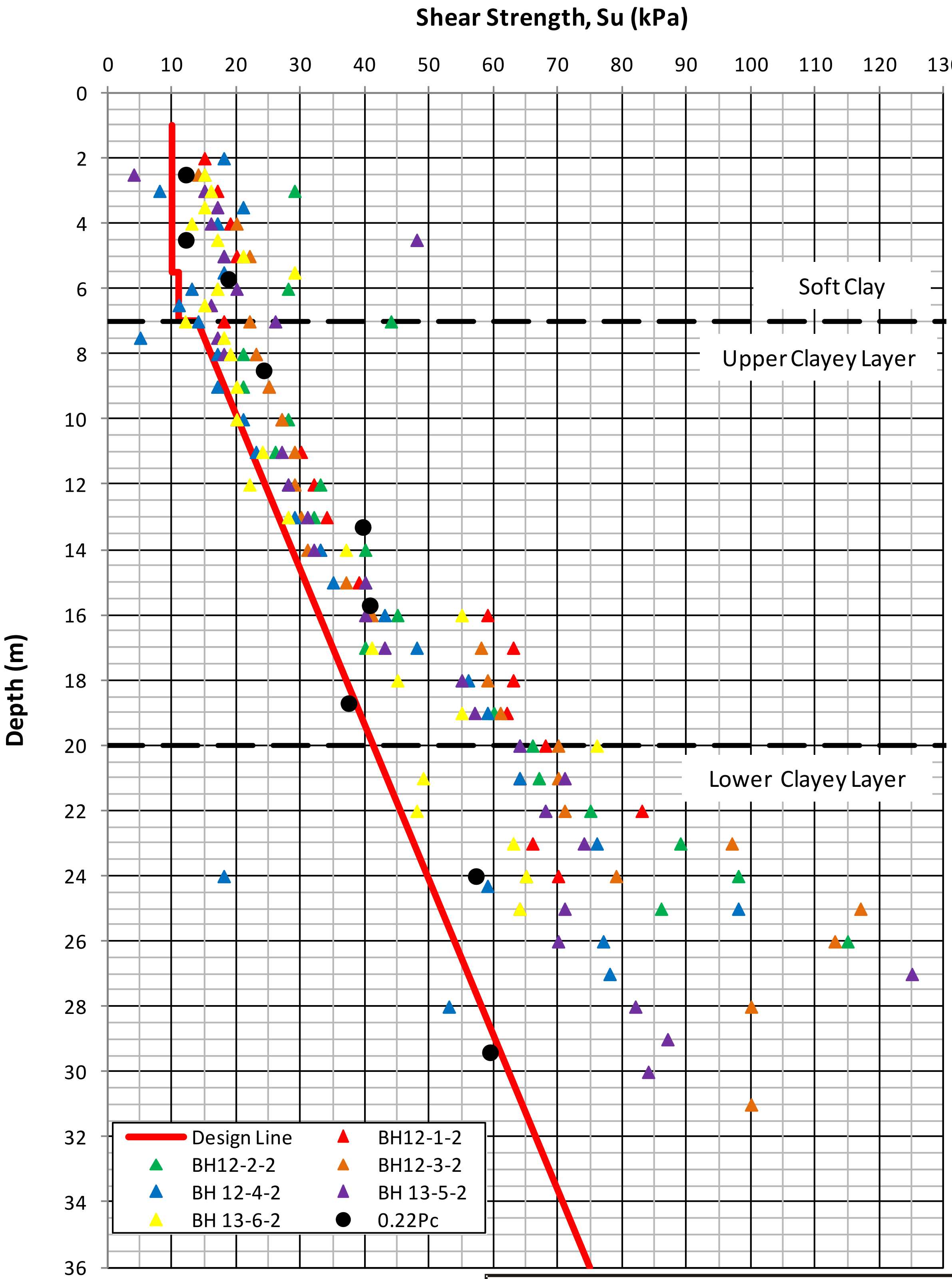
FIGURE 4-2



PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
STRENGTH PROFILE OF FOUNDATION SOILS (AS-IS)

Golder Associates

PROJECT No.	12-1125-0045		PHASE / TASK No.	4500
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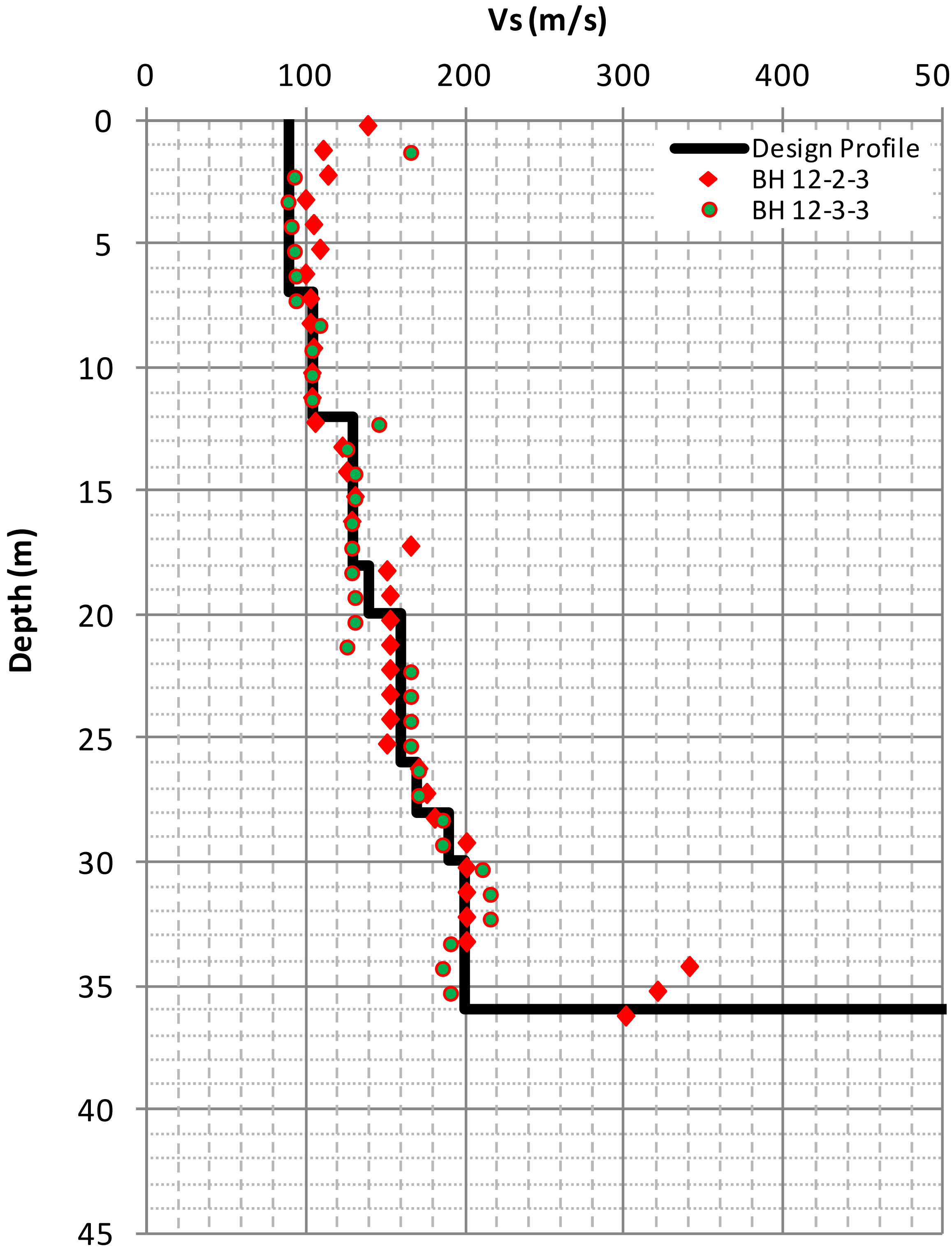

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

SHEAR WAVE VELOCITY PROFILE OF FOUNDATION

Golder Associates

PROJECT No.	12-1125-0045		PHASE / TASK No. 4500	
DESIGN	M.S.K	31 MAR14	SCALE NTS	REV.
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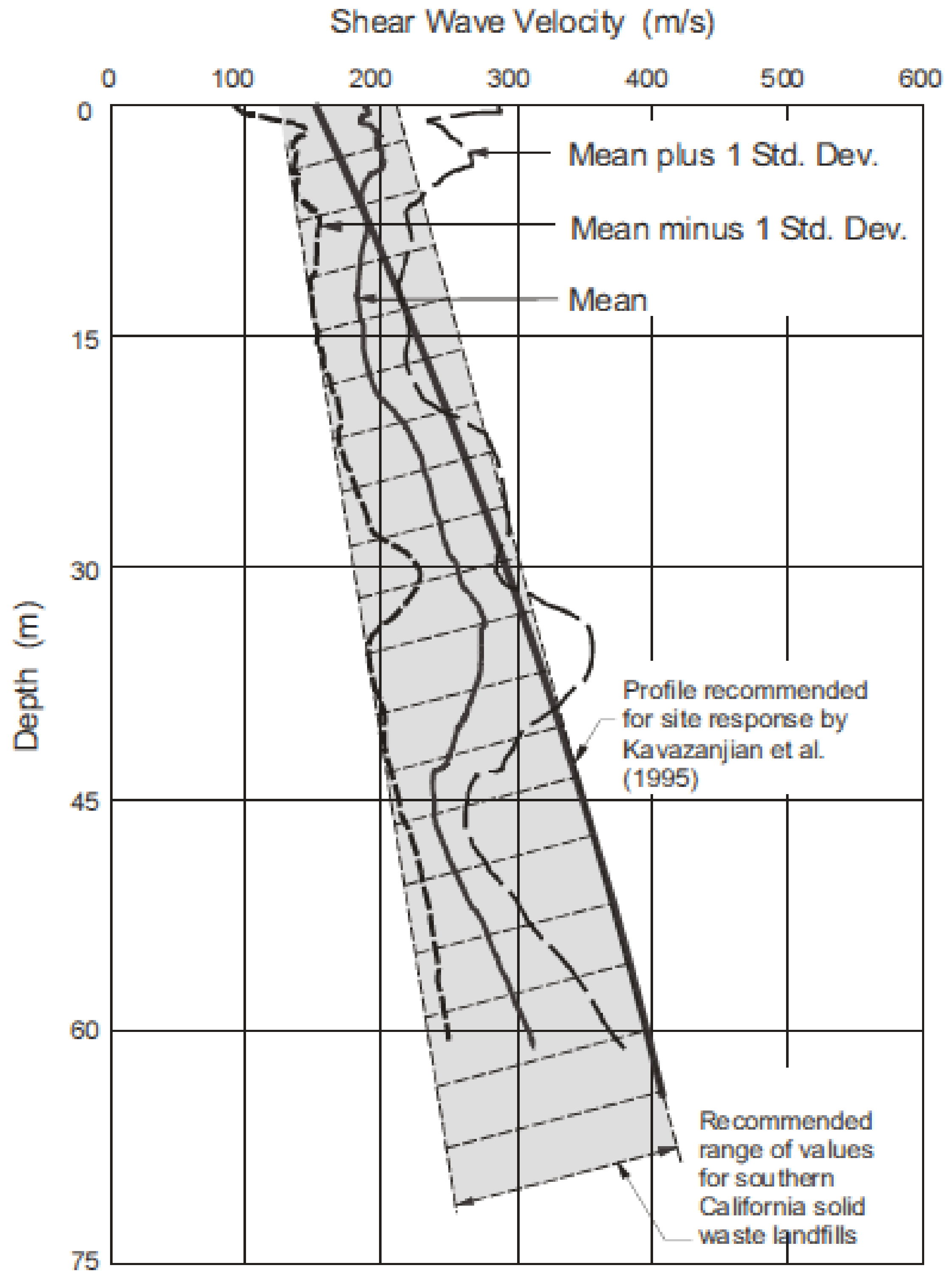

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
SHEAR WAVE VELOCITY DATA FOR SOLID WASTE LANDFILLS

Golder Associates

PROJECT No.	12-1125-0045		PHASE / TASK No. 4500	
DESIGN	M.S.K	31 MAR14	SCALE NTS	REV.
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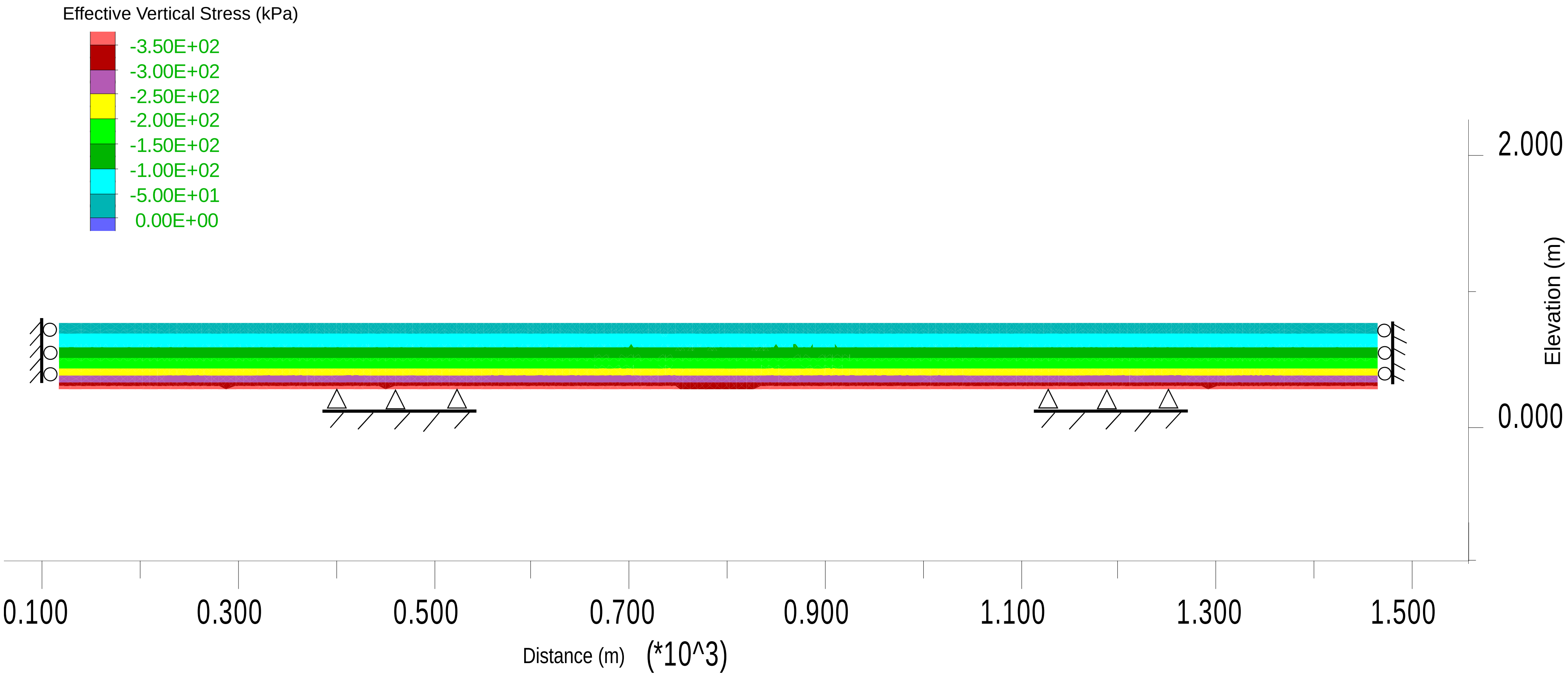

Note: Negative is compression stress

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

CONTOURS OF EFFECTIVE VERTICAL STRESS
FOR FOUNDATION, AS-IS

Golder Associates

PROJECT No.		12-1125-0045	PHASE / TASK No. 4500	
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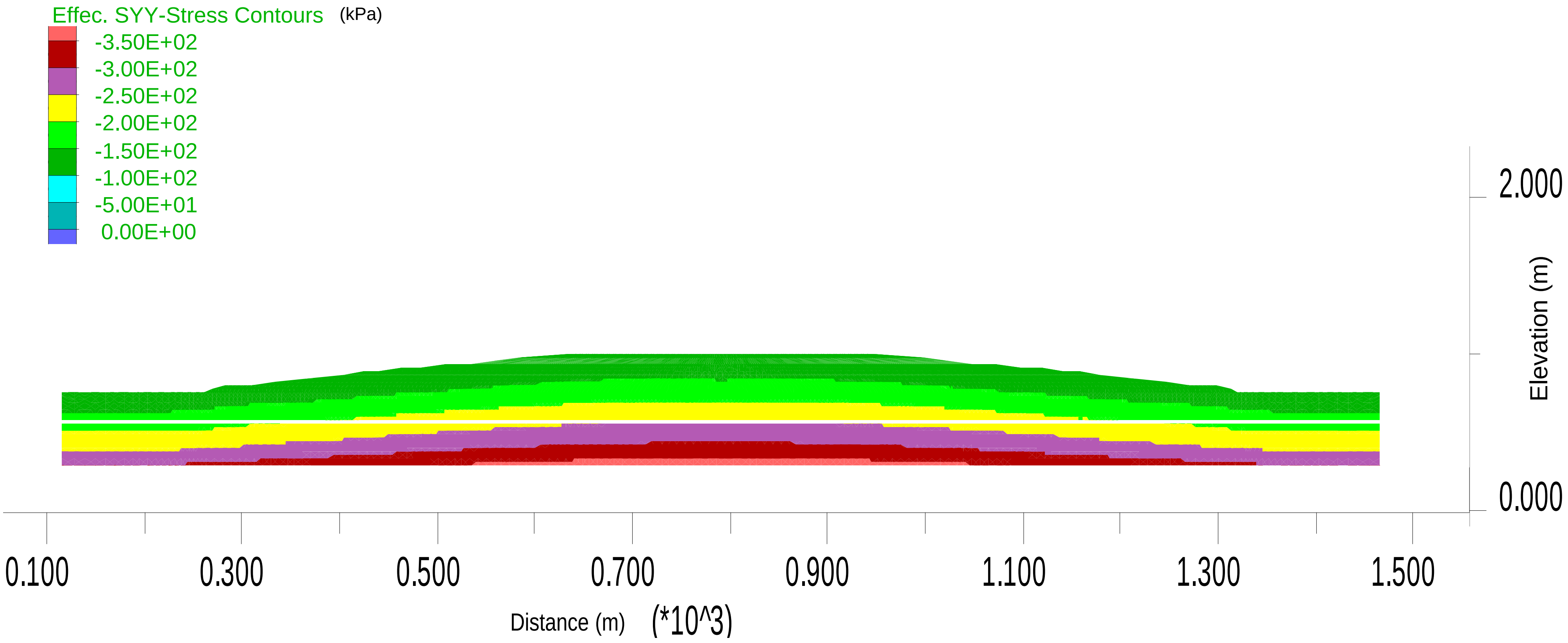

Note: Negative is compression stress

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

CONTOURS OF TOTAL VERTICAL STRESS FOUNDATION-LANDFILL SYSTEM

Golder Associates

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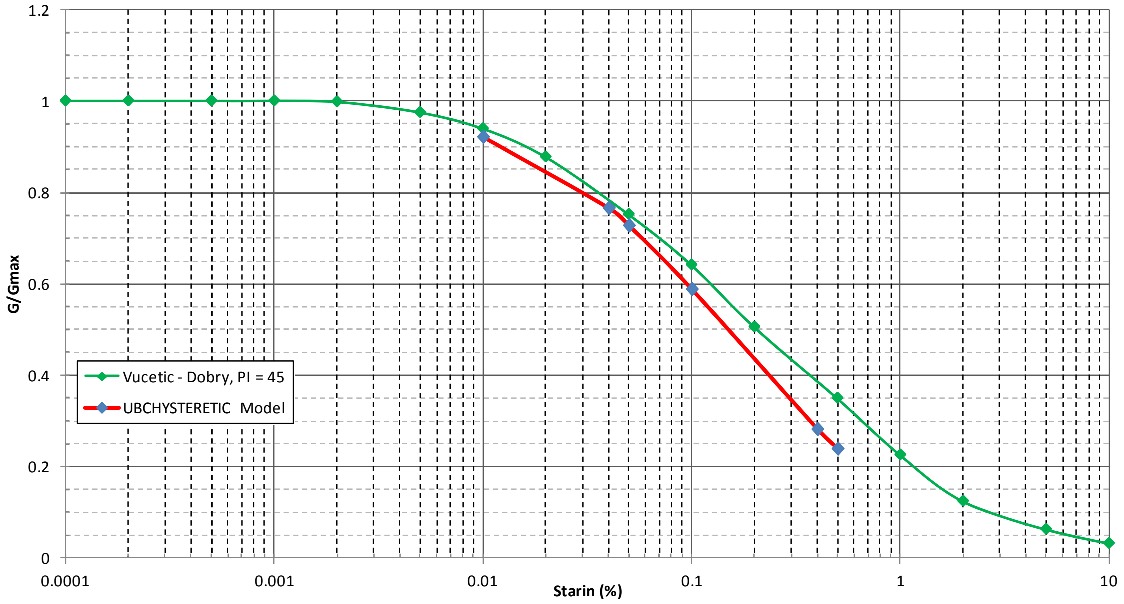
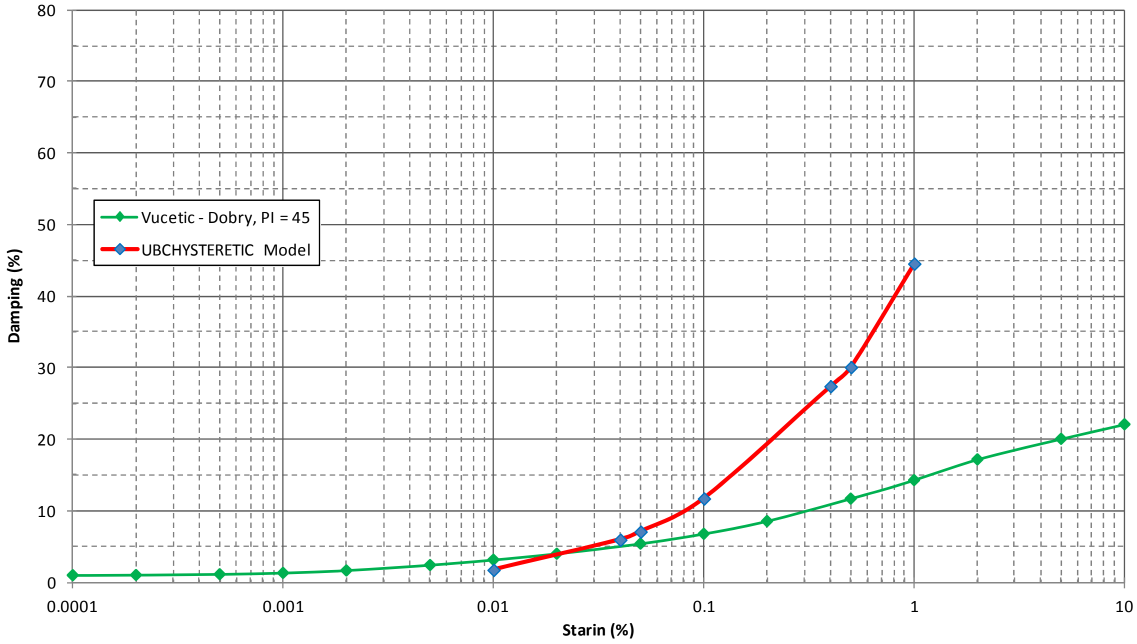


Modulus Reduction Curves



Damping Curves

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

MODULUS REDUCTION AND DAMPING CURVES
FOR FOUNDATION SOILS
FLAC SIMULATION VS. PUBLISHED DATA

PROJECT No.	12-1125-0045	
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PHASE / TASK No. 4500

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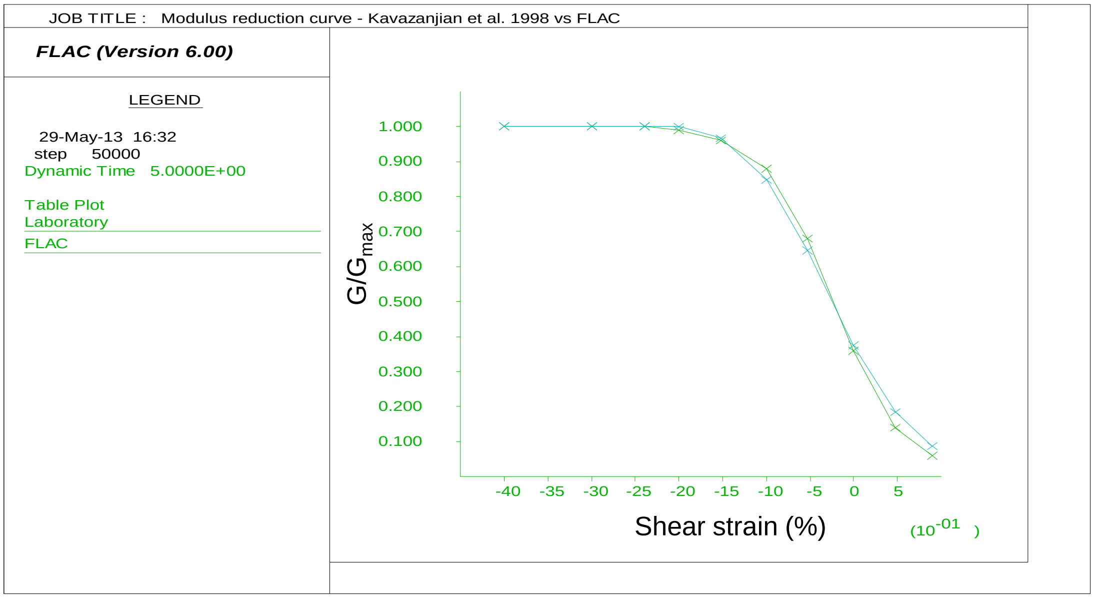
FIGURE 5-3



JOB TITLE : Modulus reduction curve - Kavazanjian et al. 1998 vs FLAC

FLAC (Version 6.00)

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Table Plot
Laboratory
FLAC

Modulus Reduction Curves

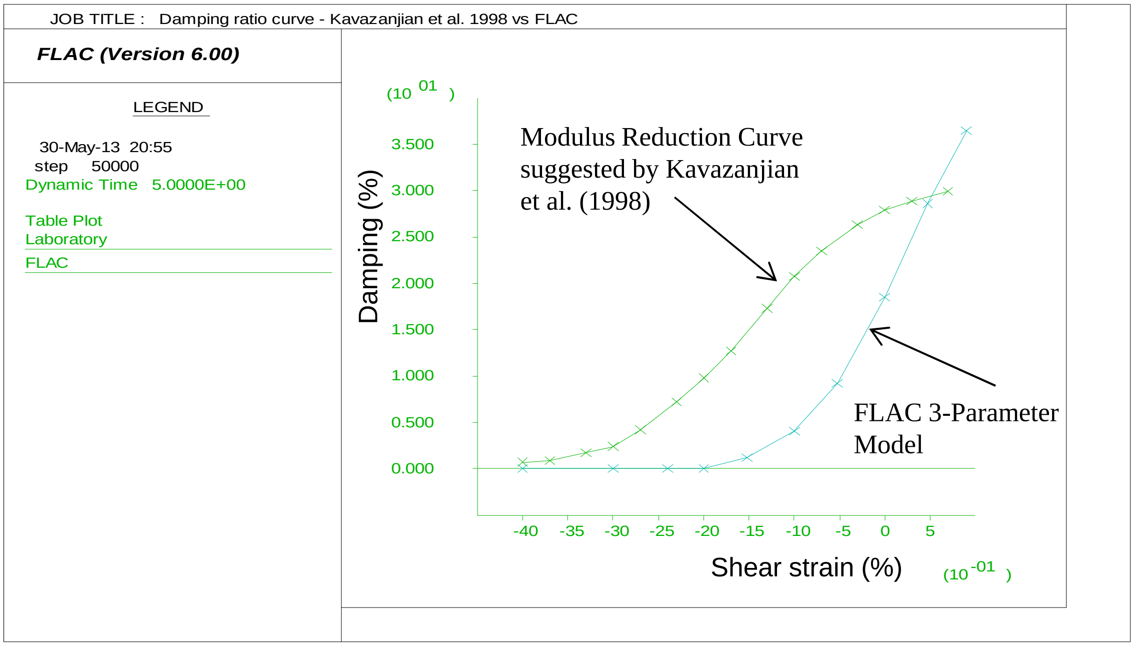

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Table Plot
Laboratory
FLAC

Damping Curves

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
MODULUS REDUCTION AND DAMPING CURVES
FOR SOLID WASTE MATERIALS
FLAC SIMULATION VS. PUBLISHED DATA

PROJECT No.	12-1125-0045	
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FIGURE 5-4

JOB TITLE : CRRRC MSW Landfill-Foundation system Dynamic Analysis, Ottawa

FLAC (Version 6.00)

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HISTORY PLOT
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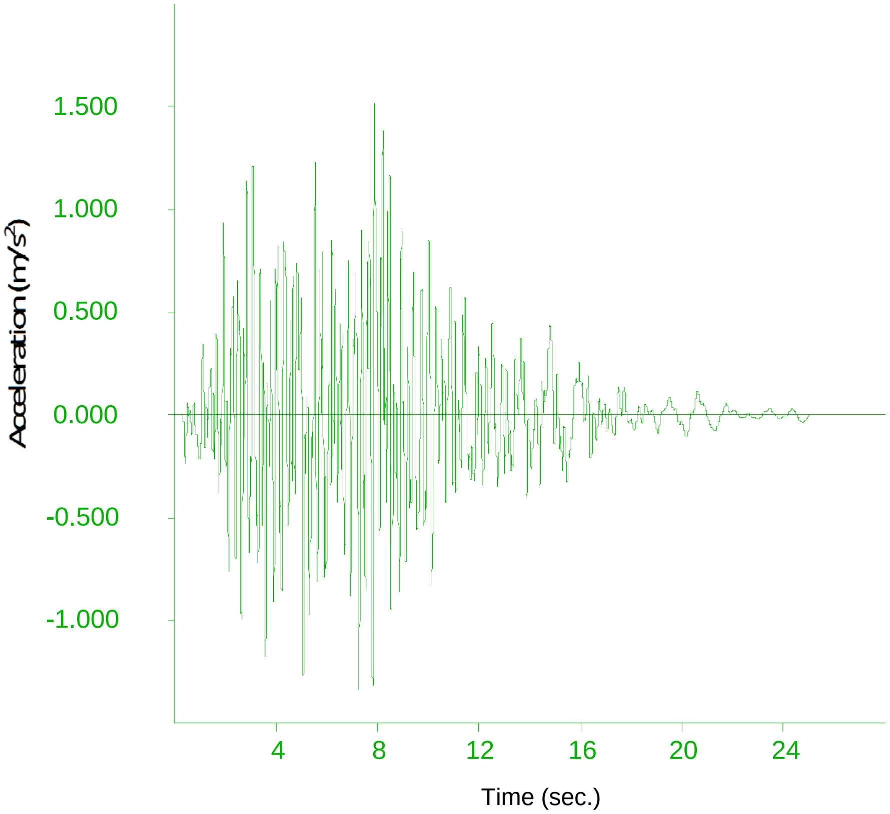

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
ACCELERATION TIME HISTORY AT LANDFILL CREST (EARTHQUAKE NO. 37)

Golder Associates

PROJECT No. 12-1125-0045			PHASE / TASK No. 4500	
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JOB TITLE : CRRRC MSW Landfill-Foundation system Dynamic Analysis, Ottawa

FLAC (Version 6.00)

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HISTORY PLOT
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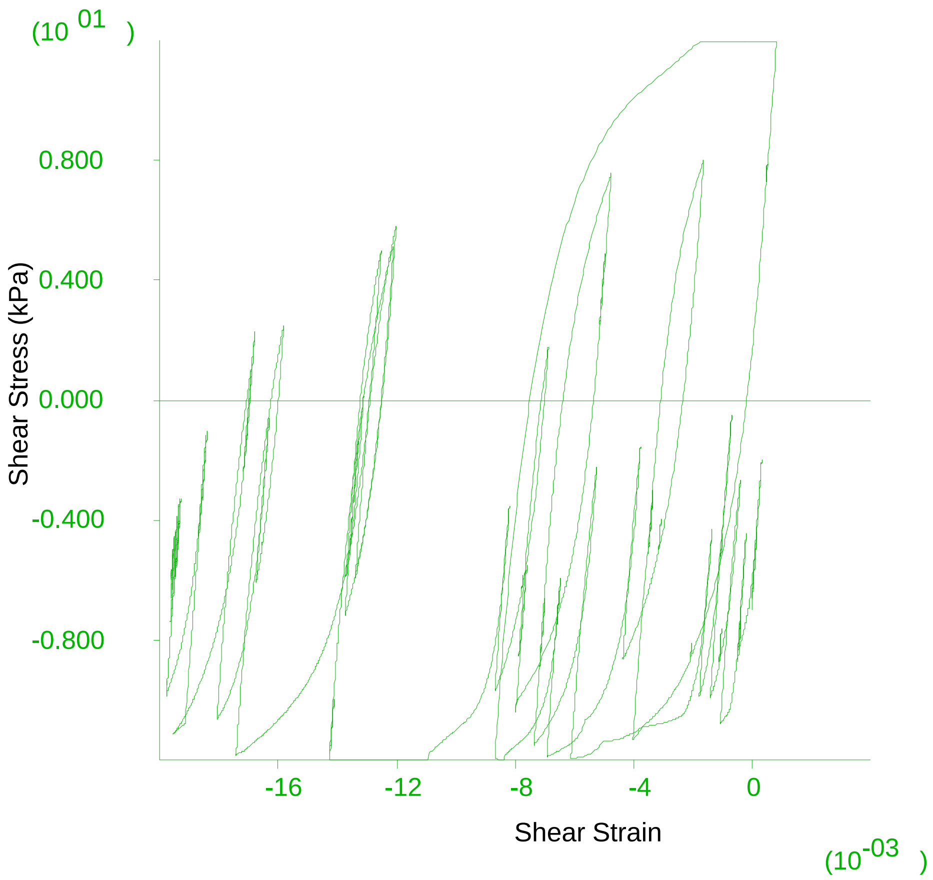

PROJECT
CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE
TYPICAL STRESS-STRAIN RESPONSE OF CLAYEY SOILS (EARTHQUAKE NO. 37)

Golder Associates

PROJECT No. 12-1125-0045			PHASE / TASK No. 4500	
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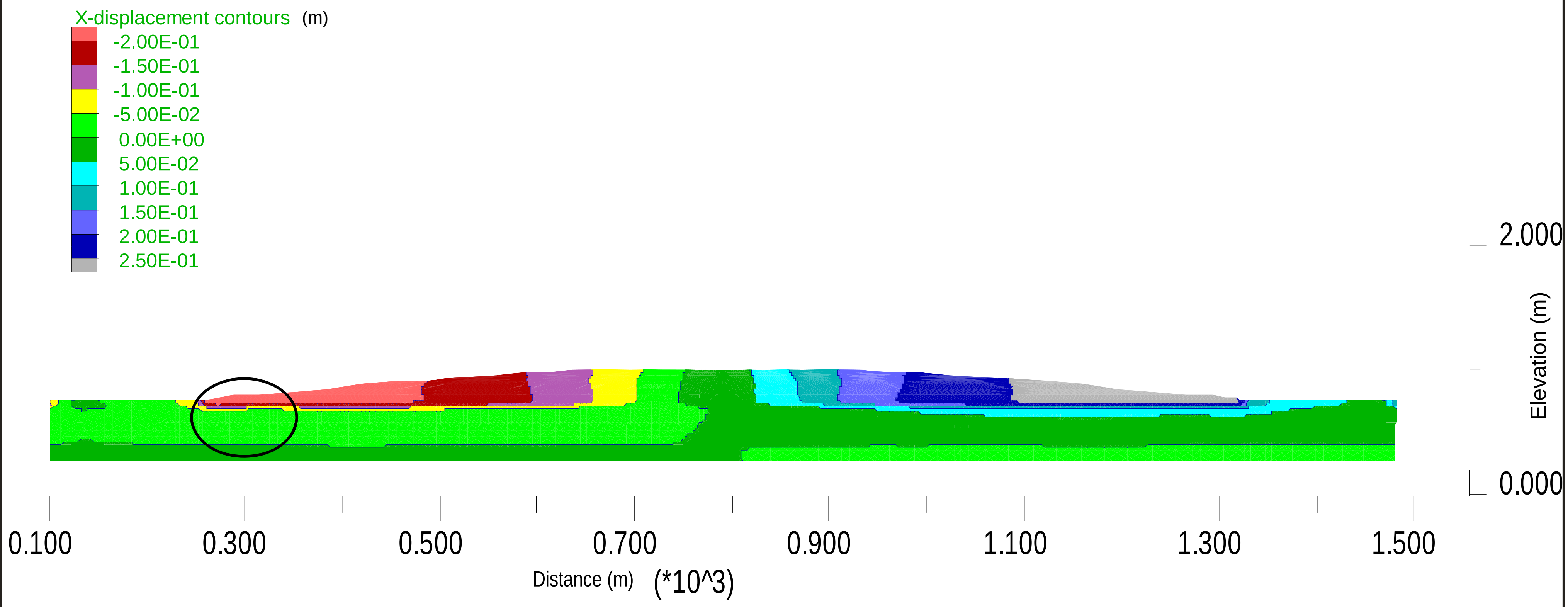
CHECK	PLE.	AUG 2014		
REVIEW	PAS.	AUG 2014		



Note: Displacement contours are in meters.

PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

CONTOURS OF LATERAL DISPLACEMENTS
END OF SHAKING (EARTHQUAKE NO. 37)

PROJECT No.		12-1125-0045
DESIGN	MSK	31MAR14
CADD	----	----
CHECK	PLE	AUG 2014
REVIEW	PAS	AUG 2014

PHASE / TASK No. 4500

SCALE.

REV. -

FIGURE 5-7

REVISION DATE: BY: FILE:

JOB TITLE : CRRRC MSW Landfill-Foundation system Dynamic Analysis, Ottawa

FLAC (Version 6.00)

LEGEND

31-Mar-14 12:27
step 2545773
Dynamic Time 2.5000E+01
3.047E+02 <x< 3.856E+02
1.549E+01 <y< 9.643E+01

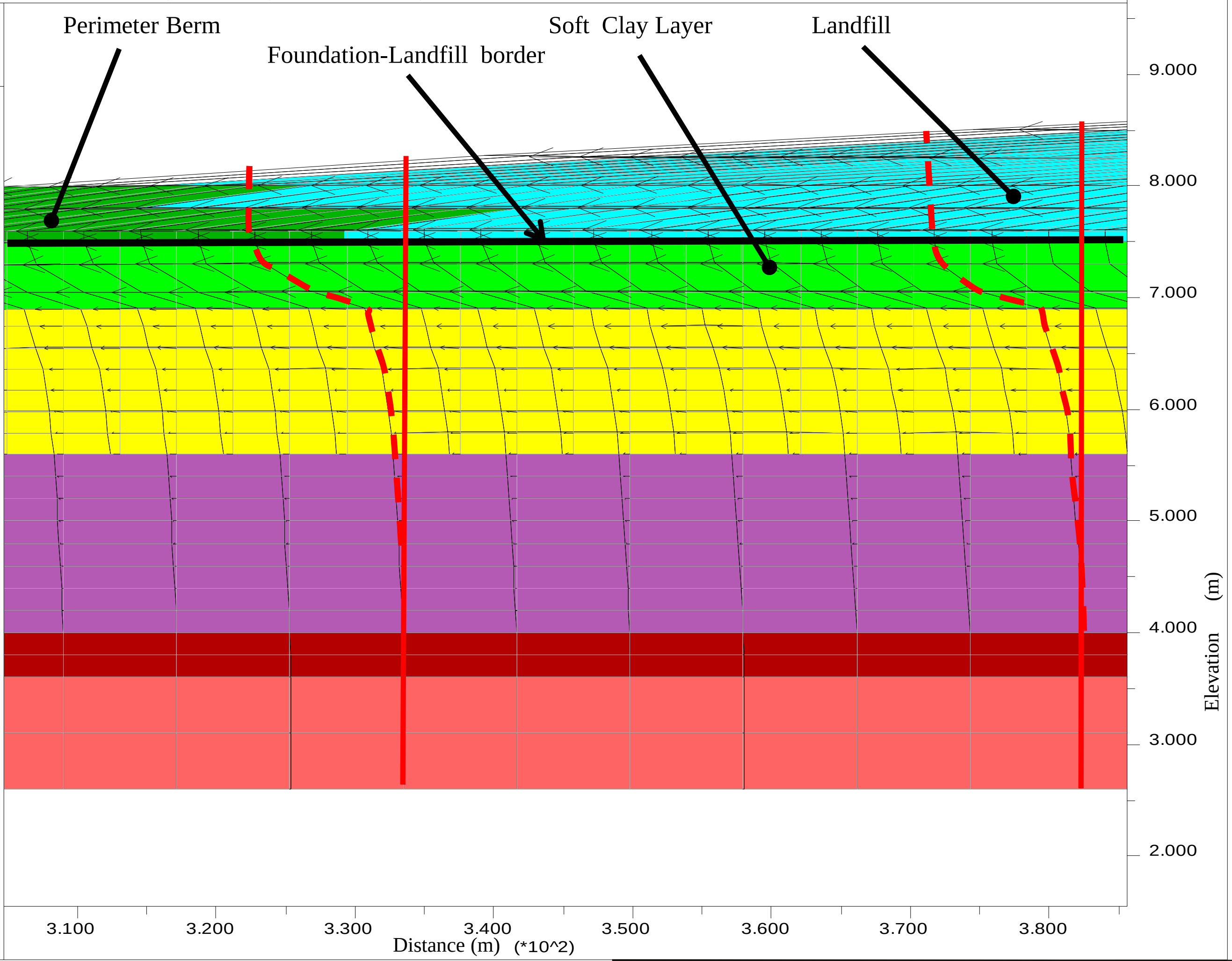
Material

🟦 Landfill
🟩 Soft Clay Layer
🟨 Upper Clay
🟪 Lower Clay
🟥 Glacial Till
🟥 Bedrock
🟩 Perimeter Berm

Exaggerated Grid Distortion
Magnification = 5.000E+01
Max Disp = 2.174E-01

Exaggerated Grid Distortion
Magnification = 0.000E+00
Max Disp = 2.174E-01

Displacement vectors
max vector = 2.174E-01
0 5E -1



PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

DISTORTED MESH COMPARED WITH ORIGINAL SHAPE
(EARTHQUAKE No. 37)

Golder Associates

PROJECT No. 12-1125-0045			PHASE / TASK No. 4500
DESIGN	M.S.K	31 MAR.14	SCALE NTS REV.
CADD	--	--	**FIGURE 5-8**
CHECK	PLE	AUG 2014	
REVIEW	PAS	AUG 2014	

REVISION DATE: BY: FILE:

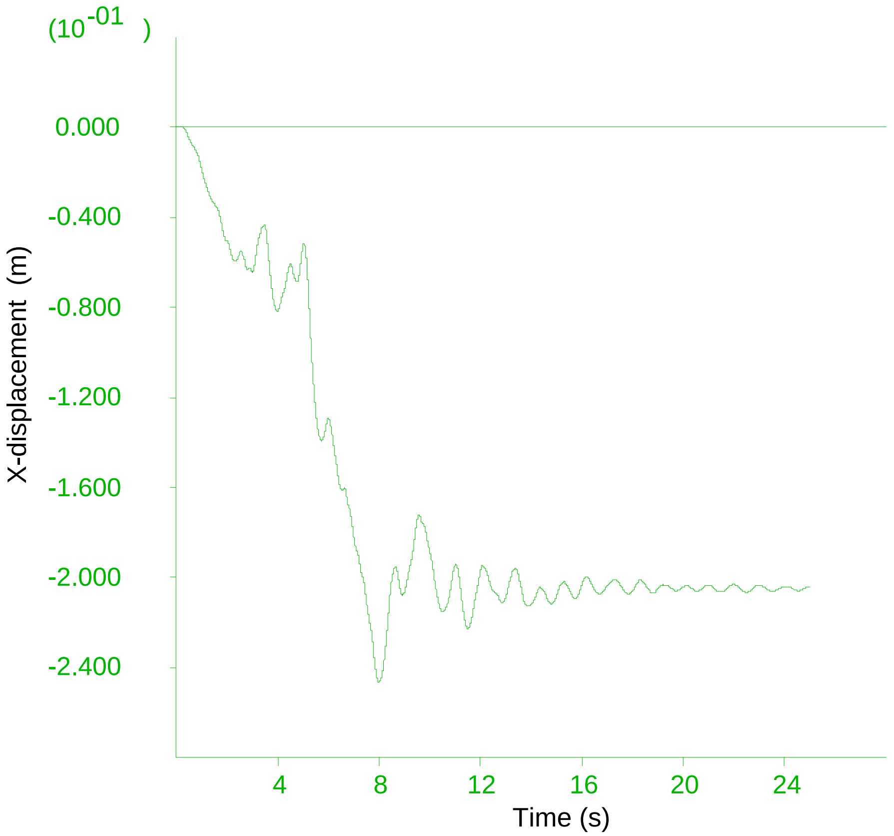
JOB TITLE : CRRRC MSW Landfill-Foundation system Dynamic Analysis, Ottawa

FLAC (Version 6.00)

LEGEND

31-Mar-14 11:32
step 2545773
Dynamic Time 2.5000E+01

HISTORY PLOT
Y-axis :
53 X displacement(23, 25)
X-axis :
2 Dynamic time



PROJECT

CAPITAL REGION RESOURCE RECOVERY CENTRE

TITLE

TIME HISTORY OF LATERAL DISPLACEMENT AT LANDFILL TOE (EARTHQUAKE NO. 37)

Golder Associates

PROJECT No. 12-1125-0045			PHASE / TASK No. 4500	
DESIGN	M.S.K	31 MAR.14	SCALE NTS	REV.
CADD	--	--	**FIGURE 5-9**	
CHECK	PLE	AUG 2014		
REVIEW	PAS	AUG 2014		

APPENDIX R

Contaminant Transport Model

POLLUTEv7

Version 7.13

CRRRC Till B Settle

**THE VARIABLE VELOCITY AND/OR CONCENTRATION OPTION HAS BEEN USED
NOTE THAT THE ACCURACY OF THE CALCULATIONS WITH THIS OPTION WILL DEPEND ON THE NUMBER OF SUBLAYERS USED**

**THE PASSIVE SINK OPTION HAS BEEN USED
NOTE : THE USER IS RESPONSIBLE FOR ENSURING THAT VELOCITY CHANGES ARE CONSISTENT WITH THE PASSIVE SINK**

Layer Properties

Layer	Thickness	Number of Sublayers	Coefficient of Hydrodynamic Dispersion	Matrix Porosity	Distributon Coefficient	Dry Density
Upper Silty Clay	2.1 m	200	0.019 m2/a	0.54	1 mL/g	1.9 g/cm3
Lower Silty Clay	23.3 m	200	0.019 m2/a	0.54	1 mL/g	1.9 g/cm3

Boundary Conditions

Finite Mass Top Boundary

Fixed Outflow Bottom Boundary
Landfill Length = 1160 m
Landfill Width = 1 m
Base Thickness = 3 m
Base Porosity = 0.35

VARIATION IN PROPERTIES WITH TIME:

TIME PERIODS WITH THE SAME SOURCE AND VELOCITY

Period	Start Time	No. of Steps	Time Step	Source Conc	Rate of Change	Height of Leachate	Volume Collected
1	0 year	20	1 year	0 mg/L	0.85	10000000 m	0.2895 m/a
2	20 year	10	1 year	-1 mg/L	0	7.3 m	0.2695 m/a
3	30 year	40	1 year	-1 mg/L	0	7.3 m	0.2695 m/a
4	70 year	30	1 year	-1 mg/L	0	7.3 m	0.2695 m/a
5	100 year	4	1 year	-1 mg/L	0	7.3 m	0 m/a
6	104 year	4	1 year	-1 mg/L	0	7.3 m	0 m/a
7	108 year	4	1 year	-1 mg/L	0	7.3 m	0 m/a
8	112 year	100	10 year	-1 mg/L	0	7.3 m	0.268 m/a

Period	Start Time	End Time	Darcy Velocity	Dispersivity	Base Velocity
1	0 year	20 year	1 m/a	0.33 m	0.11 m/a
2	20 year	30 year	1 m/a	0.33 m	0.11 m/a
3	30 year	70 year	1 m/a	0.33 m	0.11 m/a
4	70 year	100 year	1 m/a	0.33 m	0.115 m/a
5	100 year	104 year	1 m/a	0.33 m	0.281 m/a
6	104 year	108 year	1 m/a	0.33 m	0.448 m/a
7	108 year	112 year	1 m/a	0.33 m	0.614 m/a
8	112 year	1112 year	1 m/a	0.33 m	0.78 m/a

VELOCITY AND SINK PROFILE:

Time Period	Minimum Depth	Maximum Depth	Vertical Velocity	Horizontal Outflow
1 / 1	0 m	2.1 m	-0.00295 m/a	0 m/a
	2.1 m	2.4 m	0.000133 m/a	0 m/a
	2.4 m	25.4 m	0.000133 m/a	0 m/a
1 / 2	0 m	2.1 m	-0.00295 m/a	0 m/a
	2.1 m	2.4 m	0.000133 m/a	0 m/a
	2.4 m	25.4 m	0.000133 m/a	0 m/a
1 / 3	0 m	2.1 m	-0.00295 m/a	0 m/a
	2.1 m	2.4 m	0.000133 m/a	0 m/a
	2.4 m	25.4 m	0.000133 m/a	0 m/a
1 / 4	0 m	2.1 m	-0.00295 m/a	0 m/a
	2.1 m	2.4 m	0.000133 m/a	0 m/a
	2.4 m	25.4 m	0.000133 m/a	0 m/a
1 / 5	0 m	2.1 m	-0.00295 m/a	0 m/a
	2.1 m	2.4 m	0.000133 m/a	0 m/a
	2.4 m	25.4 m	0.000133 m/a	0 m/a
1 / 6	0 m	2.1 m	-0.00295 m/a	0 m/a
	2.1 m	2.4 m	0.000133 m/a	0 m/a
	2.4 m	25.4 m	0.000133 m/a	0 m/a
1 / 7	0 m	2.1 m	-0.00295 m/a	0 m/a
	2.1 m	2.4 m	0.000133 m/a	0 m/a
	2.4 m	25.4 m	0.000133 m/a	0 m/a

1 / 8	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 9	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 10	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 11	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 12	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 13	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 14	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 15	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 16	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 17	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 18	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 19	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
1 / 20	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 1	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a

2 / 2	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 3	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 4	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 5	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 6	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 7	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 8	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 9	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
2 / 10	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.00295 m/a 0.000133 m/a 0.000133 m/a	0 m/a 0 m/a 0 m/a
3 / 1	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 2	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 3	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 4	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 5	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 6	0 m	2.1 m	-0.015 m/a	0 m/a

	2.1 m 2.4 m	2.4 m 25.4 m	0.000143 m/a 0.000143 m/a	0 m/a 0 m/a
3 / 7	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 8	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 9	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 10	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 11	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 12	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 13	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 14	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 15	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 16	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 17	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 18	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 19	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 20	0 m 2.1 m	2.1 m 2.4 m	-0.015 m/a 0.000143 m/a	0 m/a 0 m/a

	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 21	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 22	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 23	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 24	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 25	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 26	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 27	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 28	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 29	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 30	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 31	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 32	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 33	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a
3 / 34	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.000143 m/a	0 m/a
	2.4 m	25.4 m	0.000143 m/a	0 m/a

3 / 35	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 36	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 37	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 38	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 39	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
3 / 40	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.015 m/a 0.000143 m/a 0.000143 m/a	0 m/a 0 m/a 0 m/a
4 / 1	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 2	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 3	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 4	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 5	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 6	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 7	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 8	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a

4 / 9	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 10	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 11	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 12	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 13	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 14	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 15	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 16	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 17	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 18	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 19	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 20	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 21	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 22	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	-0.019 m/a 0.00015 m/a 0.00015 m/a	0 m/a 0 m/a 0 m/a
4 / 23	0 m	2.1 m	-0.019 m/a	0 m/a

	2.1 m	2.4 m	0.00015 m/a	0 m/a
	2.4 m	25.4 m	0.00015 m/a	0 m/a
4 / 24	0 m	2.1 m	-0.019 m/a	0 m/a
	2.1 m	2.4 m	0.00015 m/a	0 m/a
	2.4 m	25.4 m	0.00015 m/a	0 m/a
4 / 25	0 m	2.1 m	-0.019 m/a	0 m/a
	2.1 m	2.4 m	0.00015 m/a	0 m/a
	2.4 m	25.4 m	0.00015 m/a	0 m/a
4 / 26	0 m	2.1 m	-0.019 m/a	0 m/a
	2.1 m	2.4 m	0.00015 m/a	0 m/a
	2.4 m	25.4 m	0.00015 m/a	0 m/a
4 / 27	0 m	2.1 m	-0.019 m/a	0 m/a
	2.1 m	2.4 m	0.00015 m/a	0 m/a
	2.4 m	25.4 m	0.00015 m/a	0 m/a
4 / 28	0 m	2.1 m	-0.019 m/a	0 m/a
	2.1 m	2.4 m	0.00015 m/a	0 m/a
	2.4 m	25.4 m	0.00015 m/a	0 m/a
4 / 29	0 m	2.1 m	-0.019 m/a	0 m/a
	2.1 m	2.4 m	0.00015 m/a	0 m/a
	2.4 m	25.4 m	0.00015 m/a	0 m/a
4 / 30	0 m	2.1 m	-0.019 m/a	0 m/a
	2.1 m	2.4 m	0.00015 m/a	0 m/a
	2.4 m	25.4 m	0.00015 m/a	0 m/a
5 / 1	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.00058 m/a	0 m/a
	2.4 m	25.4 m	0.00058 m/a	0 m/a
5 / 2	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.00058 m/a	0 m/a
	2.4 m	25.4 m	0.00058 m/a	0 m/a
5 / 3	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.00058 m/a	0 m/a
	2.4 m	25.4 m	0.00058 m/a	0 m/a
5 / 4	0 m	2.1 m	-0.015 m/a	0 m/a
	2.1 m	2.4 m	0.00058 m/a	0 m/a
	2.4 m	25.4 m	0.00058 m/a	0 m/a
6 / 1	0 m	2.1 m	-0.009 m/a	0 m/a
	2.1 m	2.4 m	0.00102 m/a	0 m/a
	2.4 m	25.4 m	0.00102 m/a	0 m/a
6 / 2	0 m	2.1 m	-0.009 m/a	0 m/a
	2.1 m	2.4 m	0.00102 m/a	0 m/a
	2.4 m	25.4 m	0.00102 m/a	0 m/a
6 / 3	0 m	2.1 m	-0.009 m/a	0 m/a
	2.1 m	2.4 m	0.00102 m/a	0 m/a

	2.4 m	25.4 m	0.00102 m/a	0 m/a
6 / 4	0 m	2.1 m	-0.009 m/a	0 m/a
	2.1 m	2.4 m	0.00102 m/a	0 m/a
	2.4 m	25.4 m	0.00102 m/a	0 m/a
7 / 1	0 m	2.1 m	-0.004 m/a	0 m/a
	2.1 m	2.4 m	0.00145 m/a	0 m/a
	2.4 m	25.4 m	0.00145 m/a	0 m/a
7 / 2	0 m	2.1 m	-0.004 m/a	0 m/a
	2.1 m	2.4 m	0.00145 m/a	0 m/a
	2.4 m	25.4 m	0.00145 m/a	0 m/a
7 / 3	0 m	2.1 m	-0.004 m/a	0 m/a
	2.1 m	2.4 m	0.00145 m/a	0 m/a
	2.4 m	25.4 m	0.00145 m/a	0 m/a
7 / 4	0 m	2.1 m	-0.004 m/a	0 m/a
	2.1 m	2.4 m	0.00145 m/a	0 m/a
	2.4 m	25.4 m	0.00145 m/a	0 m/a
8 / 1	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 2	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 3	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 4	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 5	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 6	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 7	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 8	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 9	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a

8 / 10	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 11	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 12	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 13	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 14	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 15	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 16	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 17	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 18	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 19	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 20	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 21	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 22	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 23	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a

8 / 24	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 25	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 26	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 27	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 28	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 29	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 30	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 31	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 32	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 33	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 34	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 35	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 36	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 37	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 38	0 m	2.1 m	0.00193 m/a	0 m/a

	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 39	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 40	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 41	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 42	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 43	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 44	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 45	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 46	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 47	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 48	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 49	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 50	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 51	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 52	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a

	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 53	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 54	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 55	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 56	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 57	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 58	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 59	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 60	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 61	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 62	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 63	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 64	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 65	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 66	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a

8 / 67	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 68	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 69	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 70	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 71	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 72	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 73	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 74	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 75	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 76	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 77	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 78	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 79	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 80	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a

8 / 81	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 82	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 83	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 84	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 85	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 86	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 87	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 88	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 89	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 90	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 91	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 92	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 93	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 94	0 m 2.1 m 2.4 m	2.1 m 2.4 m 25.4 m	0.00193 m/a 0.00188 m/a 0.00188 m/a	0 m/a 0.181 m/a 0 m/a
8 / 95	0 m	2.1 m	0.00193 m/a	0 m/a

	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 96	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 97	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 98	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 99	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a
8 / 100	0 m	2.1 m	0.00193 m/a	0 m/a
	2.1 m	2.4 m	0.00188 m/a	0.181 m/a
	2.4 m	25.4 m	0.00188 m/a	0 m/a

Laplace Transform Parameters

TAU = 7 **N** = 20 **SIG** = 0 **RNU** = 2

Calculated Concentrations at Selected Times and Depths

Time year	**Depth m**	**Concentration mg/L**
1	0.000E+00	8.500E-01
	2.100E+00	6.717E-39
	2.540E+01	0.000E+00
2	0.000E+00	1.700E+00
	2.100E+00	7.835E-28
	2.540E+01	0.000E+00
3	0.000E+00	2.550E+00
	2.100E+00	8.756E-22
	2.540E+01	0.000E+00
4	0.000E+00	3.400E+00
	2.100E+00	7.936E-19
	2.540E+01	0.000E+00
5	0.000E+00	4.250E+00
	2.100E+00	4.746E-17
	2.540E+01	0.000E+00
6	0.000E+00	5.100E+00

	2.100E+00 2.540E+01	7.488E-16 0.000E+00
7	0.000E+00 2.100E+00 2.540E+01	5.950E+00 5.543E-15 0.000E+00
8	0.000E+00 2.100E+00 2.540E+01	6.800E+00 2.556E-14 0.000E+00
9	0.000E+00 2.100E+00 2.540E+01	7.650E+00 8.599E-14 0.000E+00
10	0.000E+00 2.100E+00 2.540E+01	8.500E+00 2.356E-13 0.000E+00
11	0.000E+00 2.100E+00 2.540E+01	9.350E+00 6.149E-13 0.000E+00
12	0.000E+00 2.100E+00 2.540E+01	1.020E+01 2.045E-12 0.000E+00
13	0.000E+00 2.100E+00 2.540E+01	1.105E+01 9.587E-12 0.000E+00
14	0.000E+00 2.100E+00 2.540E+01	1.190E+01 4.810E-11 0.000E+00
15	0.000E+00 2.100E+00 2.540E+01	1.275E+01 2.149E-10 0.000E+00
16	0.000E+00 2.100E+00 2.540E+01	1.360E+01 8.246E-10 0.000E+00
17	0.000E+00 2.100E+00 2.540E+01	1.445E+01 2.745E-09 0.000E+00
18	0.000E+00 2.100E+00 2.540E+01	1.530E+01 8.072E-09 0.000E+00
19	0.000E+00 2.100E+00 2.540E+01	1.615E+01 2.135E-08 0.000E+00
20	0.000E+00 2.100E+00	1.700E+01 5.156E-08

	2.540E+01	0.000E+00
21	0.000E+00 2.100E+00 2.540E+01	1.632E+01 1.150E-07 9.999E-07
22	0.000E+00 2.100E+00 2.540E+01	1.569E+01 2.400E-07 9.998E-07
23	0.000E+00 2.100E+00 2.540E+01	1.508E+01 4.715E-07 9.996E-07
24	0.000E+00 2.100E+00 2.540E+01	1.451E+01 8.793E-07 9.995E-07
25	0.000E+00 2.100E+00 2.540E+01	1.396E+01 1.566E-06 9.994E-07
26	0.000E+00 2.100E+00 2.540E+01	1.343E+01 2.675E-06 9.993E-07
27	0.000E+00 2.100E+00 2.540E+01	1.293E+01 4.407E-06 9.992E-07
28	0.000E+00 2.100E+00 2.540E+01	1.245E+01 7.025E-06 9.991E-07
29	0.000E+00 2.100E+00 2.540E+01	1.199E+01 1.087E-05 9.990E-07
30	0.000E+00 2.100E+00 2.540E+01	1.155E+01 1.638E-05 9.989E-07
31	0.000E+00 2.100E+00 2.540E+01	1.115E+01 1.668E-05 9.989E-07
32	0.000E+00 2.100E+00 2.540E+01	1.076E+01 1.911E-05 9.988E-07
33	0.000E+00 2.100E+00 2.540E+01	1.039E+01 2.206E-05 9.987E-07
34	0.000E+00 2.100E+00 2.540E+01	1.003E+01 2.546E-05 9.986E-07

35	0.000E+00 2.100E+00 2.540E+01	9.688E+00 2.932E-05 9.986E-07
36	0.000E+00 2.100E+00 2.540E+01	9.357E+00 3.365E-05 9.985E-07
37	0.000E+00 2.100E+00 2.540E+01	9.037E+00 3.848E-05 9.984E-07
38	0.000E+00 2.100E+00 2.540E+01	8.728E+00 4.384E-05 9.983E-07
39	0.000E+00 2.100E+00 2.540E+01	8.431E+00 4.975E-05 9.983E-07
40	0.000E+00 2.100E+00 2.540E+01	8.144E+00 5.626E-05 9.982E-07
41	0.000E+00 2.100E+00 2.540E+01	7.867E+00 6.340E-05 9.981E-07
42	0.000E+00 2.100E+00 2.540E+01	7.601E+00 7.120E-05 9.980E-07
43	0.000E+00 2.100E+00 2.540E+01	7.344E+00 7.970E-05 9.980E-07
44	0.000E+00 2.100E+00 2.540E+01	7.095E+00 8.893E-05 9.979E-07
45	0.000E+00 2.100E+00 2.540E+01	6.856E+00 9.892E-05 9.978E-07
46	0.000E+00 2.100E+00 2.540E+01	6.625E+00 1.097E-04 9.978E-07
47	0.000E+00 2.100E+00 2.540E+01	6.402E+00 1.213E-04 9.977E-07
48	0.000E+00 2.100E+00 2.540E+01	6.188E+00 1.338E-04 9.976E-07

49	0.000E+00 2.100E+00 2.540E+01	5.980E+00 1.472E-04 9.976E-07
50	0.000E+00 2.100E+00 2.540E+01	5.780E+00 1.616E-04 9.975E-07
51	0.000E+00 2.100E+00 2.540E+01	5.587E+00 1.769E-04 9.974E-07
52	0.000E+00 2.100E+00 2.540E+01	5.401E+00 1.932E-04 9.974E-07
53	0.000E+00 2.100E+00 2.540E+01	5.221E+00 2.105E-04 9.973E-07
54	0.000E+00 2.100E+00 2.540E+01	5.047E+00 2.289E-04 9.973E-07
55	0.000E+00 2.100E+00 2.540E+01	4.880E+00 2.484E-04 9.972E-07
56	0.000E+00 2.100E+00 2.540E+01	4.718E+00 2.689E-04 9.971E-07
57	0.000E+00 2.100E+00 2.540E+01	4.562E+00 2.906E-04 9.971E-07
58	0.000E+00 2.100E+00 2.540E+01	4.412E+00 3.135E-04 9.970E-07
59	0.000E+00 2.100E+00 2.540E+01	4.266E+00 3.376E-04 9.970E-07
60	0.000E+00 2.100E+00 2.540E+01	4.126E+00 3.628E-04 9.969E-07
61	0.000E+00 2.100E+00 2.540E+01	3.990E+00 3.893E-04 9.968E-07
62	0.000E+00 2.100E+00 2.540E+01	3.859E+00 4.170E-04 9.968E-07
63	0.000E+00	3.733E+00

	2.100E+00 2.540E+01	4.459E-04 9.967E-07
64	0.000E+00 2.100E+00 2.540E+01	3.611E+00 4.762E-04 9.967E-07
65	0.000E+00 2.100E+00 2.540E+01	3.493E+00 5.076E-04 9.966E-07
66	0.000E+00 2.100E+00 2.540E+01	3.380E+00 5.404E-04 9.966E-07
67	0.000E+00 2.100E+00 2.540E+01	3.270E+00 5.745E-04 9.965E-07
68	0.000E+00 2.100E+00 2.540E+01	3.164E+00 6.098E-04 9.964E-07
69	0.000E+00 2.100E+00 2.540E+01	3.061E+00 6.465E-04 9.964E-07
70	0.000E+00 2.100E+00 2.540E+01	2.962E+00 6.844E-04 9.963E-07
71	0.000E+00 2.100E+00 2.540E+01	2.867E+00 6.567E-04 9.963E-07
72	0.000E+00 2.100E+00 2.540E+01	2.775E+00 6.587E-04 9.962E-07
73	0.000E+00 2.100E+00 2.540E+01	2.687E+00 6.647E-04 9.962E-07
74	0.000E+00 2.100E+00 2.540E+01	2.602E+00 6.726E-04 9.961E-07
75	0.000E+00 2.100E+00 2.540E+01	2.520E+00 6.815E-04 9.960E-07
76	0.000E+00 2.100E+00 2.540E+01	2.440E+00 6.911E-04 9.960E-07
77	0.000E+00 2.100E+00	2.364E+00 7.011E-04

	2.540E+01	9.959E-07
78	0.000E+00	2.290E+00
	2.100E+00	7.115E-04
	2.540E+01	9.959E-07
79	0.000E+00	2.218E+00
	2.100E+00	7.220E-04
	2.540E+01	9.958E-07
80	0.000E+00	2.149E+00
	2.100E+00	7.327E-04
	2.540E+01	9.958E-07
81	0.000E+00	2.082E+00
	2.100E+00	7.435E-04
	2.540E+01	9.957E-07
82	0.000E+00	2.017E+00
	2.100E+00	7.543E-04
	2.540E+01	9.957E-07
83	0.000E+00	1.955E+00
	2.100E+00	7.651E-04
	2.540E+01	9.956E-07
84	0.000E+00	1.894E+00
	2.100E+00	7.759E-04
	2.540E+01	9.955E-07
85	0.000E+00	1.836E+00
	2.100E+00	7.867E-04
	2.540E+01	9.955E-07
86	0.000E+00	1.779E+00
	2.100E+00	7.975E-04
	2.540E+01	9.954E-07
87	0.000E+00	1.725E+00
	2.100E+00	8.082E-04
	2.540E+01	9.954E-07
88	0.000E+00	1.672E+00
	2.100E+00	8.188E-04
	2.540E+01	9.953E-07
89	0.000E+00	1.621E+00
	2.100E+00	8.294E-04
	2.540E+01	9.953E-07
90	0.000E+00	1.571E+00
	2.100E+00	8.398E-04
	2.540E+01	9.952E-07
91	0.000E+00	1.524E+00
	2.100E+00	8.502E-04
	2.540E+01	9.952E-07

92	0.000E+00 2.100E+00 2.540E+01	1.477E+00 8.604E-04 9.951E-07
93	0.000E+00 2.100E+00 2.540E+01	1.433E+00 8.705E-04 9.951E-07
94	0.000E+00 2.100E+00 2.540E+01	1.389E+00 8.805E-04 9.950E-07
95	0.000E+00 2.100E+00 2.540E+01	1.348E+00 8.904E-04 9.950E-07
96	0.000E+00 2.100E+00 2.540E+01	1.307E+00 9.002E-04 9.949E-07
97	0.000E+00 2.100E+00 2.540E+01	1.268E+00 9.098E-04 9.949E-07
98	0.000E+00 2.100E+00 2.540E+01	1.230E+00 9.192E-04 9.948E-07
99	0.000E+00 2.100E+00 2.540E+01	1.193E+00 9.286E-04 9.948E-07
100	0.000E+00 2.100E+00 2.540E+01	1.158E+00 9.377E-04 9.947E-07
101	0.000E+00 2.100E+00 2.540E+01	1.165E+00 1.026E-03 9.947E-07
102	0.000E+00 2.100E+00 2.540E+01	1.172E+00 1.082E-03 9.946E-07
103	0.000E+00 2.100E+00 2.540E+01	1.178E+00 1.133E-03 9.946E-07
104	0.000E+00 2.100E+00 2.540E+01	1.184E+00 1.181E-03 9.945E-07
105	0.000E+00 2.100E+00 2.540E+01	1.190E+00 1.369E-03 9.945E-07

106	0.000E+00 2.100E+00 2.540E+01	1.195E+00 1.506E-03 9.945E-07
107	0.000E+00 2.100E+00 2.540E+01	1.199E+00 1.641E-03 9.944E-07
108	0.000E+00 2.100E+00 2.540E+01	1.203E+00 1.778E-03 9.944E-07
109	0.000E+00 2.100E+00 2.540E+01	1.206E+00 2.070E-03 9.943E-07
110	0.000E+00 2.100E+00 2.540E+01	1.209E+00 2.320E-03 9.943E-07
111	0.000E+00 2.100E+00 2.540E+01	1.212E+00 2.579E-03 9.943E-07
112	0.000E+00 2.100E+00 2.540E+01	1.214E+00 2.849E-03 9.942E-07
122	0.000E+00 2.100E+00 2.540E+01	8.610E-01 9.154E-03 9.939E-07
132	0.000E+00 2.100E+00 2.540E+01	6.166E-01 1.990E-02 9.935E-07
142	0.000E+00 2.100E+00 2.540E+01	4.456E-01 3.477E-02 9.932E-07
152	0.000E+00 2.100E+00 2.540E+01	3.251E-01 5.220E-02 9.929E-07
162	0.000E+00 2.100E+00 2.540E+01	2.398E-01 7.047E-02 9.925E-07
172	0.000E+00 2.100E+00 2.540E+01	1.789E-01 8.820E-02 9.922E-07
182	0.000E+00 2.100E+00 2.540E+01	1.351E-01 1.045E-01 9.919E-07
192	0.000E+00	1.033E-01

	2.100E+00	1.189E-01
	2.540E+01	9.916E-07
202	0.000E+00	8.016E-02
	2.100E+00	1.311E-01
	2.540E+01	9.914E-07
212	0.000E+00	6.310E-02
	2.100E+00	1.411E-01
	2.540E+01	9.911E-07
222	0.000E+00	5.042E-02
	2.100E+00	1.491E-01
	2.540E+01	9.908E-07
232	0.000E+00	4.091E-02
	2.100E+00	1.552E-01
	2.540E+01	9.905E-07
242	0.000E+00	3.369E-02
	2.100E+00	1.597E-01
	2.540E+01	9.903E-07
252	0.000E+00	2.816E-02
	2.100E+00	1.628E-01
	2.540E+01	9.900E-07
262	0.000E+00	2.388E-02
	2.100E+00	1.647E-01
	2.540E+01	9.898E-07
272	0.000E+00	2.051E-02
	2.100E+00	1.655E-01
	2.540E+01	9.895E-07
282	0.000E+00	1.784E-02
	2.100E+00	1.655E-01
	2.540E+01	9.893E-07
292	0.000E+00	1.570E-02
	2.100E+00	1.648E-01
	2.540E+01	9.891E-07
302	0.000E+00	1.395E-02
	2.100E+00	1.635E-01
	2.540E+01	9.888E-07
312	0.000E+00	1.251E-02
	2.100E+00	1.618E-01
	2.540E+01	9.886E-07
322	0.000E+00	1.131E-02
	2.100E+00	1.598E-01
	2.540E+01	9.884E-07
332	0.000E+00	1.030E-02
	2.100E+00	1.575E-01

	2.540E+01	9.882E-07
342	0.000E+00	9.441E-03
	2.100E+00	1.549E-01
	2.540E+01	9.880E-07
352	0.000E+00	8.702E-03
	2.100E+00	1.523E-01
	2.540E+01	9.877E-07
362	0.000E+00	8.060E-03
	2.100E+00	1.495E-01
	2.540E+01	9.875E-07
372	0.000E+00	7.499E-03
	2.100E+00	1.466E-01
	2.540E+01	9.873E-07
382	0.000E+00	7.004E-03
	2.100E+00	1.437E-01
	2.540E+01	9.871E-07
392	0.000E+00	6.565E-03
	2.100E+00	1.408E-01
	2.540E+01	9.869E-07
402	0.000E+00	6.172E-03
	2.100E+00	1.378E-01
	2.540E+01	9.867E-07
412	0.000E+00	5.820E-03
	2.100E+00	1.349E-01
	2.540E+01	9.866E-07
422	0.000E+00	5.501E-03
	2.100E+00	1.321E-01
	2.540E+01	9.864E-07
432	0.000E+00	5.211E-03
	2.100E+00	1.292E-01
	2.540E+01	9.862E-07
442	0.000E+00	4.947E-03
	2.100E+00	1.264E-01
	2.540E+01	9.860E-07
452	0.000E+00	4.706E-03
	2.100E+00	1.237E-01
	2.540E+01	9.858E-07
462	0.000E+00	4.484E-03
	2.100E+00	1.210E-01
	2.540E+01	9.856E-07
472	0.000E+00	4.280E-03
	2.100E+00	1.184E-01
	2.540E+01	9.855E-07

482	0.000E+00	4.091E-03
	2.100E+00	1.159E-01
	2.540E+01	9.853E-07
492	0.000E+00	3.916E-03
	2.100E+00	1.134E-01
	2.540E+01	9.851E-07
502	0.000E+00	3.753E-03
	2.100E+00	1.109E-01
	2.540E+01	9.849E-07
512	0.000E+00	3.601E-03
	2.100E+00	1.086E-01
	2.540E+01	9.848E-07
522	0.000E+00	3.460E-03
	2.100E+00	1.063E-01
	2.540E+01	9.846E-07
532	0.000E+00	3.327E-03
	2.100E+00	1.040E-01
	2.540E+01	9.844E-07
542	0.000E+00	3.203E-03
	2.100E+00	1.019E-01
	2.540E+01	9.843E-07
552	0.000E+00	3.087E-03
	2.100E+00	9.975E-02
	2.540E+01	9.841E-07
562	0.000E+00	2.977E-03
	2.100E+00	9.770E-02
	2.540E+01	9.840E-07
572	0.000E+00	2.874E-03
	2.100E+00	9.570E-02
	2.540E+01	9.838E-07
582	0.000E+00	2.777E-03
	2.100E+00	9.376E-02
	2.540E+01	9.836E-07
592	0.000E+00	2.685E-03
	2.100E+00	9.188E-02
	2.540E+01	9.835E-07
602	0.000E+00	2.598E-03
	2.100E+00	9.005E-02
	2.540E+01	9.833E-07
612	0.000E+00	2.516E-03
	2.100E+00	8.828E-02
	2.540E+01	9.832E-07

622	0.000E+00 2.100E+00 2.540E+01	2.438E-03 8.655E-02 9.830E-07
632	0.000E+00 2.100E+00 2.540E+01	2.364E-03 8.488E-02 9.829E-07
642	0.000E+00 2.100E+00 2.540E+01	2.293E-03 8.325E-02 9.827E-07
652	0.000E+00 2.100E+00 2.540E+01	2.226E-03 8.167E-02 9.826E-07
662	0.000E+00 2.100E+00 2.540E+01	2.162E-03 8.013E-02 9.825E-07
672	0.000E+00 2.100E+00 2.540E+01	2.102E-03 7.863E-02 9.823E-07
682	0.000E+00 2.100E+00 2.540E+01	2.044E-03 7.718E-02 9.822E-07
692	0.000E+00 2.100E+00 2.540E+01	1.988E-03 7.577E-02 9.820E-07
702	0.000E+00 2.100E+00 2.540E+01	1.935E-03 7.440E-02 9.819E-07
712	0.000E+00 2.100E+00 2.540E+01	1.885E-03 7.306E-02 9.818E-07
722	0.000E+00 2.100E+00 2.540E+01	1.836E-03 7.176E-02 9.816E-07
732	0.000E+00 2.100E+00 2.540E+01	1.790E-03 7.050E-02 9.815E-07
742	0.000E+00 2.100E+00 2.540E+01	1.745E-03 6.927E-02 9.814E-07
752	0.000E+00 2.100E+00 2.540E+01	1.702E-03 6.808E-02 9.812E-07
762	0.000E+00	1.661E-03

	2.100E+00 2.540E+01	6.691E-02 9.811E-07
772	0.000E+00 2.100E+00 2.540E+01	1.622E-03 6.578E-02 9.810E-07
782	0.000E+00 2.100E+00 2.540E+01	1.584E-03 6.467E-02 9.808E-07
792	0.000E+00 2.100E+00 2.540E+01	1.547E-03 6.360E-02 9.807E-07
802	0.000E+00 2.100E+00 2.540E+01	1.512E-03 6.255E-02 9.806E-07
812	0.000E+00 2.100E+00 2.540E+01	1.478E-03 6.153E-02 9.804E-07
822	0.000E+00 2.100E+00 2.540E+01	1.446E-03 6.053E-02 9.803E-07
832	0.000E+00 2.100E+00 2.540E+01	1.414E-03 5.956E-02 9.802E-07
842	0.000E+00 2.100E+00 2.540E+01	1.384E-03 5.862E-02 9.801E-07
852	0.000E+00 2.100E+00 2.540E+01	1.355E-03 5.770E-02 9.800E-07
862	0.000E+00 2.100E+00 2.540E+01	1.327E-03 5.680E-02 9.798E-07
872	0.000E+00 2.100E+00 2.540E+01	1.299E-03 5.592E-02 9.797E-07
882	0.000E+00 2.100E+00 2.540E+01	1.273E-03 5.506E-02 9.796E-07
892	0.000E+00 2.100E+00 2.540E+01	1.247E-03 5.423E-02 9.795E-07
902	0.000E+00 2.100E+00	1.223E-03 5.341E-02

	2.540E+01	9.794E-07
912	0.000E+00	1.199E-03
	2.100E+00	5.262E-02
	2.540E+01	9.792E-07
922	0.000E+00	1.176E-03
	2.100E+00	5.184E-02
	2.540E+01	9.791E-07
932	0.000E+00	1.153E-03
	2.100E+00	5.108E-02
	2.540E+01	9.790E-07
942	0.000E+00	1.132E-03
	2.100E+00	5.034E-02
	2.540E+01	9.789E-07
952	0.000E+00	1.111E-03
	2.100E+00	4.961E-02
	2.540E+01	9.788E-07
962	0.000E+00	1.090E-03
	2.100E+00	4.890E-02
	2.540E+01	9.787E-07
972	0.000E+00	1.070E-03
	2.100E+00	4.821E-02
	2.540E+01	9.785E-07
982	0.000E+00	1.051E-03
	2.100E+00	4.753E-02
	2.540E+01	9.784E-07
992	0.000E+00	1.033E-03
	2.100E+00	4.687E-02
	2.540E+01	9.783E-07
1002	0.000E+00	1.014E-03
	2.100E+00	4.622E-02
	2.540E+01	9.782E-07
1012	0.000E+00	9.968E-04
	2.100E+00	4.559E-02
	2.540E+01	9.781E-07
1022	0.000E+00	9.797E-04
	2.100E+00	4.497E-02
	2.540E+01	9.780E-07
1032	0.000E+00	9.631E-04
	2.100E+00	4.436E-02
	2.540E+01	9.779E-07
1042	0.000E+00	9.469E-04
	2.100E+00	4.377E-02
	2.540E+01	9.777E-07

1052	0.000E+00 2.100E+00 2.540E+01	9.312E-04 4.319E-02 9.776E-07
1062	0.000E+00 2.100E+00 2.540E+01	9.159E-04 4.262E-02 9.775E-07
1072	0.000E+00 2.100E+00 2.540E+01	9.010E-04 4.206E-02 9.774E-07
1082	0.000E+00 2.100E+00 2.540E+01	8.865E-04 4.152E-02 9.773E-07
1092	0.000E+00 2.100E+00 2.540E+01	8.724E-04 4.099E-02 9.772E-07
1102	0.000E+00 2.100E+00 2.540E+01	8.586E-04 4.046E-02 9.771E-07
1112	0.000E+00 2.100E+00 2.540E+01	8.452E-04 3.995E-02 9.770E-07

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Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
32 Steacie Drive
Kanata, Ontario, K2K 2A9
Canada
T: +1 (613) 592 9600