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:

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

Where:

- t = groundwater residence time;
- $T_{1/2}$ = half life of ^3H (12.43 years);
- $^3He_{tri}$ = tritiogenic ^3He (helium from the decay of ^3H); and
- ^3H = measured ^3H 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.