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.