4.0 Geology and Hydrogeology

The following is a discussion of the RI Study Area topography and drainage, geology, hydrogeology, and distribution of visual observations of anthropogenic impacts.

4.1 RI Study Area Geology

RI Study Area stratigraphy was developed based on observations of soil from the test pits and soil borings completed during the RI, as well as observations from previous investigations at the Historic MGP Site and along the Gowanus Canal (See Section 2. 7). Test pit and soil boring logs are included in Appendices B and C, respectively. Based on the information presented in these logs and previous investigations, four stratigraphic cross-sections were generated. The orientation of the cross-sections, shown on Figure 4-1, were positioned to present representative “slices” of the subsurface within the investigation area on-site, as well as off-site at 381 Hamilton Avenue and 537 Smith Street opposite the Site across the Gowanus Canal. Individual sections are provided on Figure 4-2 (A-A’), Figure 4-3 (B-B’), Figure 4-4 (C-C’), and Figure 4-5 (D-D’).

As shown on the cross sections, site specific observations are consistent with the regional description presented above. The upper 120 feet of the RI Study Area stratigraphy is dominated by three primary units:

1. anthropogenic fill
2. meadow mat
3. glacial outwash deposits consisting of predominately sand/ silt

These units are part of the upper Pleistocene and recent Holocene regional deposits. Within the sand /silt unit are discontinuous lenses of sand and gravel, organic silt, and silt and clay. One soil boring, SB-4D2, was advanced below 120 ft bgs to a final depth of 150 ft bgs, encountering the Gardiners Clay and the underlying Jameco Gravel. The Gardiners Clay was encountered at 121 ft bgs, and the Jameco Gravel was encountered at 135 ft bgs. The Jameco Gravel was the deepest unit encountered during the RI. The primary units encountered are described below in greater detail.

4.1.1 Fill

As shown on the cross-sectional views, fill was observed to be present in all areas of the Current Site in thicknesses typically ranging up to 15 feet, and within the range of the groundwater table (see Section 4. 4 below). The fill is comprised of mostly poorly graded sand, silt, and gravel with varying amounts of anthropogenic material: coal fragments, ash, concrete slabs, wood pieces, wood fragments, brick fragments, glass, and other urban fill debris.

4.1.2 Meadow Mat

The meadow mat consists of varying amounts of a densely compacted decomposed vegetative material (peat), organic clays, marine clays with shell fragments, and silt, and is brown/tan or grey in color with a distinctive organic-like odor. The unit acts to separate the underlying native soils from the overlying fill. The meadow mat likely represents the former ground surface prior to development (filling) in the Current Site area. This layer ranges from five to fifteen feet thick, was encountered 15 feet to 20 feet bgs, and was

observed in all Current Site borings with the exception of SB-5. The distribution of the unit is consistent with the historic marshy environment of this area (see Figure 2-4). As shown on cross-section A-A', the elevation of the bottom of the Gowanus Canal is equal to or lower than the elevation of the bottom of the adjacent meadow mat, which is typically absent beneath the canal (GEI, 2007). The bottom of the canal consists of Holocene aged silty and sandy native sediments that overly Upper Pleistocene aged glacial deposits consisting of a poorly sorted mixture of clay, silt, sand, and gravel mixed with more well sorted glacio-fluvial sands and gravels (GEI, 2007).

4.1.3 Sand/Silt

Between the bottom of the meadow mat and the top of the Gardiners Clay, are units of glacial outwash dominated by sands and silts. The unit varies in composition, occurring as tan and grey interbedded sand and silt beds and as well graded to poorly graded sands and silt zones. These zones vary in depth and distribution across the Current Site, and are not defined by clear boundaries. Therefore, on the cross-sections, they have been grouped into a single unit designated sand/silt.

Within the sand/silt unit are discontinuous lenses of sand and gravel, organic silt, and silty clay. The sand/gravel unit is the most abundant of these, and occurs in lenses from 3 to 25 ft thick, as single lenses or two stacked lenses. However, as shown in cross-section A-A', a relatively extensive deposit is located beneath the central area of the Current Site from roughly 60 to 85 ft bgs. The unit is predominately fine to coarse sand with less than 5 to 30% gravel, and has an appearance similar to the surrounding sand/silt unit.

The organic silt unit was observed at two locations (SB-17 and SB-5), and has a similar appearance to the organic silt in the meadow mat; however, the unit is encountered at greater depth (below 29 ft bgs) than the meadow mat and is not continuous. The silty clay unit consists of clay with interbedded silt and gravel, is brown to reddish brown, and has low plasticity. The unit was encountered from 85 to greater than 90 ft bgs at MW-21D.

4.1.4 Gardiners Clay

Soil boring MW-4D2, located adjacent to boring SB-4, was advanced to 150 ft bgs (Figures 4-1 and 4-2). A high plasticity, stiff, gray clay and silty clay were encountered from 121 to 135 ft bgs. This 14 foot thick unit is interpreted to be the Gardiners Clay, and is consistent in depth and composition as described by Buxton and Shernoff (1999) and Misut and Monti (1999). The unit is expected to be laterally continuous beneath the Current Site, have very low permeability, and represents a confining unit defining the lower extent of the shallow sand/silt aquifer.

4.1.5 Jameco Gravel

Below the Gardiners Clay is a brown, well graded, medium to coarse sand and gravel. This unit is interpreted to be the Jameco Gravel, and is consistent in depth and composition as described by Buxton and Shernoff (1999) and Misut and Monti (1999). The unit is expected to be laterally continuous beneath the Current Site. A silty sand was encountered below the gravel at this boring location, however, this unit does contain approximately 35% gravel, and is interpreted to be part of the Jameco Gravel unit.

4.2 Site Hydrogeology

Monitoring well construction details, groundwater gauging measurements, calculated groundwater elevations, and the Gowanus Canal surface water elevations are summarized on Table 3-2. The wells have been grouped into three general depth intervals:

1. shallow: wells screened across the water table surface in the fill and at depths generally ranging from 3 to 15 ft bgs.
2. intermediate: wells screened directly below the meadow mat and within the sand/silt unit at depths generally ranging from 25 to 50 ft bgs.
3. deep: wells screened within the sand/silt unit at depth from 60 to 70 ft.

One deep well was screened from 115 to 120 ft bgs directly above the Gardiners Clay, and one deep well was screened from 142 to 147 ft bgs, directly below the Gardiners Clay and within the Jameco Gravel. During the RI, groundwater gauging was performed on June 1st, July 26, August 23, September 29, October 4, October 22, November 22, 2010, April 29, 2011, and March 14, 2012. Figures 4-6, 4-7, and 4-8 present contours of groundwater elevations collected during low tide on March 14, 2012 for the shallow, intermediate, and deep intervals, respectively. Figures 4-9, 4-10, and 4-11 present contours of groundwater elevations collected during high tide on September 29, 2010 for the shallow, intermediate, and deep intervals, respectively.

The surface of the groundwater table is encountered between 1.9 (MW-3S) and 10.93 (MW-9S) ft bgs across the Current Site. The Gowanus Canal surface water elevation is roughly between 2 ft and 6 ft lower than the groundwater table elevation at adjacent wells (MW-4S, MW-9S, and MW-19S) depending on the tidal cycle. As shown on Figures 4-6 through 4-11, groundwater flow across the Current Site in the shallow, intermediate, and deep screened zones is from the east to the west, with a slightly more northwest flow direction towards the Gowanus Canal observed at low tide in the shallow zone above the meadow mat. Horizontal gradients calculated based on the groundwater elevation contours are summarized on Table 4-1. Horizontal hydraulic gradients calculated from the measurements collected during high tide (September 29, 2010) and low tide (March 14, 2012) were 5.98×10^{-3} ft/ft and 5.56×10^{-3} ft/ft, respectively, (average 5.77×10^{-3} ft/ft) in shallow zone wells, 2.72×10^{-3} ft/ft and 3.59×10^{-3} ft/ft, respectively, (average 3.16×10^{-3} ft/ft) in intermediate zone wells, and 1.90×10^{-3} ft/ft and 2.14×10^{-3} ft/ft, respectively, (average 2.02×10^{-3} ft/ft) in deep zone wells. Vertical gradients between the shallow zone to intermediate zone, intermediate zone to the deep zone, and shallow zone to the deep zone are summarized on Table 4-2. As would be expected, generally downward vertical hydraulic gradients are present along the central and eastern Current Site boundaries (MW-1, MW-3, MW-6, MW-7, and MW-8), and upward vertical hydraulic gradients are present adjacent to the Gowanus Canal (MW-4, MW-5, and MW-9), a condition that is generally consistent for each of the three screened zones and represents groundwater discharge from the shallow aquifer into the canal.

As summarized on Table 4-3, hydraulic conductivity testing was performed at nine monitoring wells on October 7 and 15, 2010. The AQTESOLVE® output files, including graphs of the fitted lines are provided in Appendix E. Based on the data (rising head tests), the calculated average hydraulic conductivity (K) of the shallow well locations (MW-1S, MW-3S, and MW-5S) ranged from 1.404 to 68.28 ft/day (521.7 ft/day was not considered to be representative), with a geometric mean of 17.9 ft/day. The hydraulic conductivity at well MW-3S (68.28 feet/day) is much higher due to the presence of a coarse sand fraction in the soil formation around this well compared to the silt and sand/silt formations around MW-1S and MW-5S, respectively. The calculated average hydraulic conductivity (K) of the intermediate well locations (MW-1I, MW-3I, and MW-5I) ranged from 1.905 to 74.72 feet/day, with a geometric mean of 10.0 feet/day. The calculated average hydraulic conductivity (K) of the deep well locations (MW-1D, MW-2D, and MW-5D) ranged from (1.041 to 38.04 ft/day), with a mean of 11.9 ft/day.

Using the calculated site hydraulic conductivity values and horizontal site gradients and estimated porosity in each aquifer zone, the groundwater seepage velocity beneath the Current Site was calculated using the following equation:

V=Ki/n, where

V=calculated groundwater seepage velocity
K-calculated hydraulic conductivity (obtained from aquifer slug testing)
i=calculated horizontal gradient (obtained from RI Study Area monitoring wells),
n=soil porosity (assumed to be 0. 3)

Using the geometric mean K estimate of the shallow zone wells of 17.9 feet/day and the average horizontal gradient of 5. 77 x 10^{-3} ft/ft, the estimated shallow groundwater horizontal seepage velocity is 0. 44 ft/day, or 126 ft/year. Using the geometric mean K estimate of the intermediate zone wells of 10.0 feet/day and the average horizontal gradient of 3. 16 x 10^{-3} ft/ft, the estimated intermediate groundwater horizontal seepage velocity is 0.105 ft/day, or 38.4 ft/year. Using the geometric mean K estimate of the deep zone wells of 11.9 feet/day and the average horizontal gradient of 2.02 x 10^{-3} ft/ft, the estimated deep groundwater horizontal seepage velocity is 0.080 ft/day, or 29.2 ft/year.

Continuous water level measurements collected over a 24 hour period on October 8 and 9, 2010 from select shallow, intermediate, and deep zone wells are plotted on Figures 4-12 (shallow zone), Figure 4-13 (intermediate zone), and Figure 4-14 (deep zone), respectively. Superimposed on each plot is the surface water elevation of the Gowanus Canal over the same time period. The distance from the canal is noted next to each well on the plots. Based on the tidal cycle monitoring, the strongest tidal effects are noted in the groundwater levels measured in the intermediate and deep zone wells. Groundwater elevations in the deep zone wells are influenced as far as 725 ft (MW-2D) from the canal, and fluctuate by more than a foot. The water levels in the intermediate zone wells also have fluctuations of about one foot, but the influence appears to dissipate between 410 ft (MW-6I) and 425 ft (MW-3I) from the canal. The tidal influence in the shallow zone, above the meadow mat, is less pronounced, with water level fluctuations of less than a foot and slightly irregular compared to the intermediate and deep zone responses. The tidal influence in the shallow zone dissipates by 200 ft (MW-8S) from the canal. The reduced influence may be the result of a dampening effect of the low permeability meadow mat, and the bulkhead supporting the bank of the canal preventing direct contact between groundwater in the fill and the surface water in the canal. As shown on the groundwater elevation contours and Table 4-1, which summarizes horizontal hydraulic gradients at low and high tide, the tidal influence does not appear to significantly alter groundwater flow direction or gradients, and in turn the seepage velocity, in the shallow, intermediate, and deep zones.