NEW BOSTON LANDFILL
BOWIE COUNTY, TEXAS
TCEQ PERMIT APPLICATION NO. MSW 576C

PERMIT AMENDMENT APPLICATION

PART III:
Attachment E – Geology Report and
Attachment F – Groundwater Sampling and Analysis Plan

Volume 4

Prepared for

Waste Management of Texas, Inc.

July 2013

Prepared by

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PART III – SITE DEVELOPMENT PLAN
ATTACHMENT E
GEOLOGY REPORT

Prepared for

Waste Management of Texas, Inc.

July 2013

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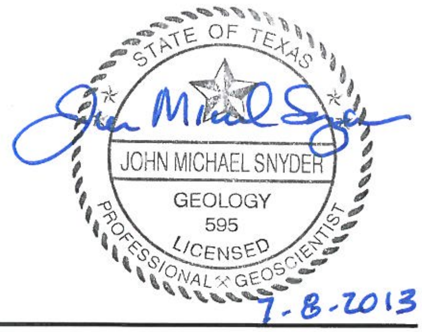

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TABLES

1 REGIONAL GEOLOGIC/HYDROGEOLOGIC INFORMATION

30 TAC §§330.57(f)(2), 330.63(e)(1)

This geology and geotechnical report has been prepared for the New Boston Landfill consistent with 30 Texas Administrative Code (TAC) §§330.57(f)(2) and 330.63(e)(1).

1.1 Regional Physiography and Topography

The site is located in the West Gulf Coastal Plain. This physiographic province is characterized by low relief and gentle gulfward slope. Topographic features include rolling hilly uplands and level floodplains and terraces. Streams have wide floodplains bounded by several terraces, which can have up to 100 feet of relief from the stream below (Baker et al., 1963).

The proposed expansion is generally trapezoidal, encompassing approximately 234.8 acres. Natural surface elevations vary from approximately 390 feet above mean sea level (msl) on the northern boundary to approximately 355 feet msl near the center of the southern boundary. Natural slopes range from about 0.4 to 3.6 degrees. As shown on Figure E2-2, an intermittent stream (Rice Creek) traverses the site flowing from the northeast to the center of the southern boundary. A constructed sedimentation pond also exists near the center of the southern boundary. T and P Lake, just across U.S. 82 from the southern boundary of the site, drains to Lake Texarkana, approximately three miles southeast of the site. Less than a mile north of the site, Red Bayou, an intermittent stream, drains into the Red River, approximately 1.5 miles north of the site.

1.2 Regional Geology

1.2.1 Geologic History

Rocks exposed in the West Gulf Coastal Plain range in age from Cretaceous to recent. The West Gulf Coastal Plain experienced many shoreline transgressions and regressions, resulting in periods of deposition alternating with periods of erosion. For much of the Paleozoic, the area was a large depositional basin. Orientation of the sediments was altered by subsequent structural deformation. As the land was tilted down to the west during an orogenic event in the Middle Pennsylvanian, the seas moved westward. Lagoonal sediments were deposited in the early Permian as a result of oscillating sea levels. In the Late Permian, the sediments changed to redbeds, evaporites, and precipitates. The Paleozoic Era came to a close as the Permian sea retreated for the last time (Baker et al., 1963).

The area was above sea level during the Triassic, and terrestrial sediments, probably from mountains in southern Colorado, were deposited. Northeast Texas was inundated by Jurassic seas and thousands of feet of evaporites, carbonates, and clastics were deposited before the seas finally retreated toward the southeast. Before the end of the

Mesozoic, Cretaceous seas inundated the area, depositing thousands of feet of sediment beneath the site (Baker et al., 1963).

In the Cenozoic, marine transgressions and regressions continued, depositing the sediments at the surface of the site. Extensive fluvial and deltaic deposition occurred. Present physiographic boundaries were established in the Quaternary when stream downcutting created the present topography (Baker et al., 1963).

1.2.2 Regional Stratigraphy

The site lies in the Midway Group of Paleocene age. The Midway is characterized by undifferentiated clay and marl with occasional thin beds of sand and silt. The lower contact is unconformable and usually marked by a layer of glauconite or polished black phosphatic nodules (Sellards et al., 1932). The limestone and glauconitic layers thin eastward and southward beneath the surface. This group is approximately 200 to 300 feet thick in Bowie County. The Midway Group has a marine facies throughout its extent. The strata are littoral in origin and record the transgression of the lower Eocene sea over the Cretaceous base-leveled plain (Sellards et al., 1932). The compositions of its upper portion indicate shallow waters at least locally.

The Midway is considered an aquiclude and does not yield useable quantities of water, although large-diameter dug wells may yield sufficient water for a single-family dwelling.

Underlying the Midway is the Navarro Group of Upper Cretaceous age. The Navarro is divided into four formations; from top to bottom they are the Kemp Clay, the Corsicana Marl, the Nacatoch Sand, and the Neylandville Marl. The Kemp Clay, Corsicana Marl, and Neylandville Marl are each clay-rich geologic units that serve as aquicludes and were deposited during the landward transgressions of the Cretaceous seas. East of Hunt County, the units are mapped collectively as the undivided Navarro Group. At the site the Navarro Group is greater than 300 feet beneath the site.

The Nacatoch Sand consists of light gray unconsolidated massive glauconitic calcareous sand and marl. Sandstone layers consist predominately of rounded, moderately sorted to well sorted, fine grained sand and silt, which is moderately consolidated to unconsolidated with occasional thin, calcite-cemented layers. The Nacatoch formation, which was deposited during a minor influx of terrigenous clastics, is sandwiched between the marine clays of the Upper and Lower Navarro Formations. The thickness of the Nacatoch Sand ranges from about 500 feet in parts of Bowie County, decreasing westward along the strike, to about 350 feet in parts of Delta and Hunt counties. The Nacatoch Sand dips outward at about 80 feet per mile. The Nacatoch Sand is considered a secondary aquifer and yields moderate volumes of fresh to slightly saline water (Baker et al., 1963).

Movement of groundwater in the Nacatoch is southward in the direction of dip. Hydraulic conductivity in Bowie County has been calculated as 1.0×10^{-3} cm/sec (Ashworth, 1988). The Nacatoch Sand of the Navarro Group underlies the Midway Group at the site, but was not encountered in any of the exploratory borings. McGowen and Lopez (1983) interpret the top of the Nacatoch at 460 feet below ground surface from an electric log of the Bass McGee #1 boring located approximately two miles southwest of the site.

Regional stratigraphy is summarized in Table E-1. A geologic vicinity map is shown on Figure E1-1.

1.2.3 Regional Structure

The major structural features in the West Gulf Coastal Plain are the East Texas Basin, the Sabine Uplift, the Preston anticline, the Sherman syncline, the Luling-Mexia-Talco fault system, and the Rodessa fault. The site is surrounded by the East Texas Basin on the southwest, the Sabine Uplift and the Preston anticline/Sherman syncline on the south, and the eastern extent of the Mexia fault zone on the west.

These tectonic features interrupt the overall gulfward dip of the Cretaceous and Tertiary sediments. The Preston anticline and the Sherman syncline plunged southeastward. The Luling-Mexia-Talco fault system trends along the Cretaceous-Tertiary boundary. The faults commonly have displacements of 300 to 500 feet and act as a barrier to the down-dip movement of groundwater in the Cretaceous aquifers in the area (Baker et al., 1963).

Table E-1
New Boston Landfill
Regional Stratigraphic Column

<table>
<tr><th>System</th><th>Series</th><th>Group</th><th>Formation</th><th>Maximum Thickness (ft)</th><th></th></tr>
<tr><td rowspan="5">Tertiary</td><td>Pliocene</td><td rowspan="3">Claiborne</td><td>Sparta Sand</td><td>50</td><td></td></tr>
<tr><td rowspan="3">Eocene</td><td>Mt. Selman</td><td>400</td><td></td></tr>
<tr><td>Carrizo</td><td>100</td><td></td></tr>
<tr><td colspan="2">Wilcox</td><td>800</td><td></td></tr>
<tr><td>Paleocene</td><td colspan="2">Midway</td><td>900</td><td>← SITE</td></tr>
<tr><td rowspan="7">Upper Cretaceous</td><td rowspan="7">Gulf</td><td rowspan="4">Navarro</td><td>Kemp Clay</td><td>400</td><td></td></tr>
<tr><td>Corsicana Marl</td><td>20</td><td></td></tr>
<tr><td>Nacatoch Sand</td><td>450</td><td></td></tr>
<tr><td>Neylandville Marl</td><td>125</td><td></td></tr>
<tr><td colspan="2">Taylor</td><td>750</td><td></td></tr>
<tr><td colspan="2">Austin</td><td>400</td><td></td></tr>
<tr><td colspan="2">Eagle Ford</td><td>675</td><td></td></tr>
</table>

2 GEOLOGIC PROCESSES

30 TAC §§330.63(e)(2), 330.61(j)(2)

A discussion of the geologic processes in the vicinity of the landfill follows.

2.1 Fault Areas

2.1.1 Previous Investigation

In 1995, the New Boston Landfill was examined for the presence of faulting according to 30 TAC §330.555 criteria. The study was conducted by performing a site reconnaissance, reviewing available literature, maps, and aerial photographs of the area that allowed delineation within 3,000 feet from the site. No faults have been mapped within 3,000 feet of the property boundary. No lineaments were interpreted from aerial photographs or from a review of literature to occur within approximately 0.5 mile of the property boundary.

A review of black and white stereo photography, taken by INTERA in 1994, did not indicate any disruption in the alluvial patterns (i.e., sag ponds or truncated alluvial spurs). The upland ridge and resultant drainage patterns do not represent topography that would suggest offsetting by tectonic means but rather are the result of differential erosion of anisotropic sediments of the Midway Group.

A series of subparallel, normal faults spanning five to nine miles in length and trending generally east-west are mapped approximately 7.5 miles south of the site separating sediments in Wilcox Group (36 to 40 million years before present) (Barnes, 1966). These faults, part of the Luling-Mexia-Talco fault zone, generally dip toward the Gulf of Mexico and are downthrown to the north. Farther west, these faults couple with normal faults downthrown to the south, resulting in structural grabens. Ewing (1991) indicates that these faults parallel and are continuous with faulting in the basement (Cretaceous-age Austin Chalk Formation) structure approximately 3,000 feet below the ground surface. If extended, none of the fault trends would project through the site. No other faulting is mapped within 7.5 miles of the site.

Faulting in the Luling-Mexia-Talco Fault Zone commenced during early development of the Gulf of Mexico, and tectonic activity probably continued through early Cenozoic (Eocene) geologic time. This zone represents a structural hinge between carbonate sequences to the north and west and noncarbonate sequences to the south and east. There is no evidence of active faulting within the last 11,000 years (Holocene time).

A review of black and white stereo pair photograph (1 inch = 300 feet) of the site vicinity did not indicate any lineaments on the site or within 200 feet of the site perimeter. Woodruff (1990) indicates the nearest lineament to the site occurs approximately 0.5 mile to the southwest. If projected, this feature would not extend within 200 feet of the site boundary.

2.1.2 Recent Investigation

The property on which the New Boston Landfill is located was re-examined for the presence of faulting according to §330.555 criteria. A fault study was conducted by reviewing aerial photographs of the site, reviewing available geologic literature and maps of the area, conducting site reconnaissance, and examining the subsurface boring data from the site.

A site walkover was conducted by an experienced geologist familiar with the faulting and solid waste disposal facilities. No unusual scarps or topographic breaks were interpreted within 200 feet of the site. No evidence of faulting was found associated with formation outcrops; no evidence of faulting was found by examination of area roadways; no structural influence of stream courses was found; and no unusual relief or topographic features, such as sag ponds or truncated alluvial spurs, were observed on the site. No unusual vegetation change was noted. No changes of site benchmark elevations have occurred. In addition, no significant crude oil production has occurred in the immediate area. No unexplained lineations were seen on aerial photographs or topographic maps that would indicate faulting.

Cores retrieved from exploration borings revealed no evidence of faulting. Fractures seen in the cores showed no evidence of displacement.

In summary, no fault scarps were observed at the surface within 200 feet of the site and there was no evidence of vertical subsidence on any outcrops of geologic materials. No vertical displacement or stratigraphic offsets indicative of faults was observed in outcrops or in any of the cores from the site borings. There is no active faulting within 200 feet of the site; therefore the site complies with §330.555. A location restriction certification for faulting is included in Part II of the Application.

2.2 Seismic Impact Zones

The location criterion in §330.557 requires that new municipal solid waste landfill (MSWLF) units and lateral expansions shall not be located in seismic impact zones, unless the owner or operator demonstrates to the executive director that all containment structures (including liners, leachate collection systems, and surface water control systems) are designed to resist the maximum horizontal acceleration in lithified earth material for the site. A seismic impact zone is defined as an area with a probability of 10 percent or greater that the maximum horizontal acceleration in rock, expressed as a percentage of the earth's gravitational pull, will exceed 0.10g in 250 years. If the maximum horizontal acceleration is less than 0.10g, then the design of the unit will not be required to incorporate an evaluation of seismic effects.

Areas within the United States where seismic effects need to be evaluated, as determined by the USGS, are shown in Appendix E4 on Figure E4-1. As indicated on this figure, the New Boston Landfill is not located within a seismic impact zone.

2.3 Unstable Areas

Consistent with §§330.61(j)(4), 330.63(e)(2), and 330.559, unstable areas documentation was prepared as part of this application to demonstrate that the New Boston Landfill site meets the location restriction for unstable areas.

An unstable area is defined by the TCEQ as a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of the landfill's structural components responsible for preventing releases from the landfill. An unstable area can include poor foundation conditions, areas susceptible to mass movement, and karst terrains.

The evaluation of potential unstable areas at the site is based on the following observations, analyses and reviews of site specific information.

- The boring logs and laboratory data did not indicate the presence of poor foundation conditions such as soft clay or loose sand beneath the landfill. The standard penetration values indicate that the sands are dense to very dense and the hand penetrometer values and unit dry weight results indicate that the clays are stiff to hard.
- The settlement and heave analyses presented in Part III, Attachment D, Appendix D5-A show that the landfill components will not undergo detrimental differential settlement.
- The slope stability analyses presented in Part III, Attachment D, Appendix D5-B show that landfill components will be stable.
- Evidence to suspect mass movement of natural formations of earthen material on or in the vicinity of this site was not observed at the site, in the borings or on the geologic maps.
- Evidence of karst terrain was not observed at the site, in the borings or on the geologic maps.

Based on this evaluation, the site is not located in an unstable area and thus meets the location restriction.

3 REGIONAL AQUIFERS

30 TAC §330.63(e)(3)

3.1 Regional Hydrogeology

The Midway Group, on which the site is located, is considered an aquiclude and produces only small quantities of water to large-diameter dug wells. The Nacatoch Sand is the uppermost regional aquifer beneath the site. It is defined as a minor aquifer (Ashworth and Hopkins, 1995) and yields only moderate volumes of water for domestic and industrial use in the site vicinity. In its outcrop, groundwater is under water table conditions, but to the south, it is covered by younger deposits and the groundwater becomes confined (Baker et al., 1963).

The Nacatoch Sand generally consists of unconsolidated, light gray calcareous sand and marl. Some beds near the top of the formation are continuous over several counties; lower sand units demonstrate great lateral variability within a few miles. The formation is generally about 50 percent sand, but in the subsurface of Bowie County it is predominantly marl (Baker et al., 1963). A regional cross section of the Nacatoch Sand in the vicinity of the site is presented in Figure E1-3.

The Nacatoch dips about 80 feet per mile to the south. The depth to the top of the Nacatoch in the vicinity of the site is approximately 400 feet (Ashworth, 1988). In Bowie County, the potentiometric surface of Nacatoch groundwater is approximately 90 feet below ground surface and has a hydraulic gradient of approximately 0.001 foot/foot to the southeast (Ashworth, 1988). A regional potentiometric surface map of the Nacatoch is presented in Figure E1-4.

Estimates from regional pumping tests of the Nacatoch Sand indicate a hydraulic conductivity of 2.34×10^{-5} cm/sec. This is a conservative estimate, for the area of testing was in a deltaic sequence where the aquifer is most productive (Ashworth, 1988). With this hydraulic conductivity value, the approximated hydraulic gradient of 0.001 foot/foot, and an estimated effective porosity of 20 percent for the described sands, the approximate horizontal groundwater flow rate in the Nacatoch in the vicinity of the site would be less than one foot per year.

Recharge to the Nacatoch is primarily from infiltration of precipitation into the outcrop area of the formation. The volume of recharge is limited by the areal extent of the outcrop, the volume of precipitation onto the outcrop, and the permeability of the outcrop soils. Typical soils associated with the Nacatoch are described by the Soil Conservation Service as sandy to silty loam at the surface underlain by dense clay subsoil, which is poorly permeable (Ashworth, 1988). The nearest recharge area of the Nacatoch Sand is located approximately two miles north, northwest of the facility (McGowan and Lopez, 1983).

Quality of groundwater pumped from the Nacatoch outcrop area is generally good for domestic and industrial supply. Down-dip, concentrations of chloride and other dissolved constituents progressively increase. High sodium concentrations generally make the Nacatoch groundwater unacceptable for irrigation (Ashworth, 1988). The chemical analysis results from Nacatoch groundwater is presented in Table E-2. Water wells within 1 mile of the perimeter of the site were identified by a water well search and are shown in Figure E1-5.

Table E-2
New Boston Landfill
Hydraulic Properties of Regional Aquifer
Compiled from Ashworth, 1988

Parameters	Nacatoch Aquifer
Composition	Clay, sand, marl
Transmissivity	200–2200 ft^2/day
Hydraulic Conductivity	2.34×10^{-5} cm/sec*
Water Table/Confined	Confined
Groundwater Flow Rate	3.5 feet/year**
Water Quality: Total Dissolved Solids Other	 350–730 mg/L Calcium, Magnesium, Sodium, Chloride
Recharge Zones	2 miles north
Regional Water Table	See Figure E1-4
Present Use of Water	Domestic, industrial
Identification of Water Wells Within 1 Mile	See Table E-3 and Figure E1-5

* From pumping tests, Ashworth, 1988.
** Calculated from K (hydraulic conductivity) and i (gradient) from Ashworth, 1988.
All values shown in the above table are representative of the regional aquifer.

The top of the Nacatoch Sand of the Navarro Group is at least 400 feet below the site (McGowan and Lopez, 1983; Ashworth, 1988). The sands of Layer II are separated from the uppermost regional aquifer by several hundred feet of clay and therefore are not hydraulically connected to any other deeper aquifers.

There are no other known aquifiers beneath the site (TWDB, 1990). The Carrizo/Wilcox Aquifer outcrops several miles south of the site and dips to the south and southeast, away from the site (Baker, 1963; Barnes, 1966; Ashworth and Hopkins, 1995). Additional deeper sands within the Nacatoch Aquifer exist but are not hydraulically connected beneath the site. The Layer II sands beneath the site are underlain by at least 90 feet of Layer III clay. Laboratory permeability tests of this clay are in the range of 1×10^{-8} cm/sec. Therefore, any deeper sands would not be hydraulically connected.

3.2 Water Well Locations

A water well search was conducted to identify known water wells within a one-mile radius of the proposed site boundary. The search identified 15 water well records within the one-mile radius. None of the known wells located within one-mile of the site are within 500 feet of the site boundary. Texas Railroad Commission (RRC) records for a dry hole that was drilled in 1963 included an application to convert it to a water well; however, there is no indication that the well was used as a water well and the remaining well casing was plugged in 2004. The plugging reports for this dry hole are provided in Appendix E4, pages E4-3 through E4-9. The location of the dry hole, which is within the permit boundary but outside the waste footprint, is depicted on drawing E4-2.

Most of the wells are screened in the Nacatoch Sand, with total depths from approximately 42 to 650 feet. Well 16-37-103 and the two wells numbered 16-37-1E are downgradient from the landfill.

The water well search included a review of the interactive map and well records available on the Texas Water Development Board (TWDB) website *www.twdb.state.tx.us* in the Water Information Integration and Dissemination (WIID) ArcIMS mapping application. The Texas Commission on Environmental Quality (TCEQ) website *www.tceq.state.tx.us* was also reviewed for water well records. The U.S. Geological Society database (URL:*http://wdr.water.usgs.gov/nwisgmap/*) was checked for groundwater sites on which it collects data that might be in the vicinity but none are located within five miles of the site. The TCEQ Water Utility Database (*www.tceq.state.tx.us/permitting/water_supply/ud/iwud.html*) was also consulted to determine if there were any public water utility wells in the area. Both area utilities, the City of New Boston Municipal Water Utility (No. 13164) and the Central Bowie County Water Supply Corporation (No. 10525), purchase water from surface water sources.

An attempt was also made to locate wells visible from nearby roads and streets and confirm water well locations within one mile of the facility. No obvious water well production equipment, such as well houses, pump handles, windmills, or pressure tanks were identified from the street. However, any residence in this area may have a water well associated with it, especially where no public water supply is available.

The available information about each of the wells is summarized in Table E-3 – Water Wells within a One-Mile Radius, and locations of the known water wells are depicted in Drawing E1-5 – Water Well Location Map.

Table E-3
New Boston Landfill
Water Wells Within a One-Mile Radius

Well Locator	Well ID No.	Depth (ft)	Completion Formation	Well Use
Water Wells Inside a One-Mile Radius				
1	16-37-1	70	Unknown	Domestic
103	16-37-103	650	Nacatoch	Domestic
1E	16-37-1E	366	Nacatoch[1]	Domestic
1E	16-37-1E	360	Nacatoch[1]	Domestic
1J	16-37-1J	220	Unknown	Domestic
2	16-37-2	78	Unknown	Domestic
202	16-37-202	440	Nacatoch	Domestic
2A	16-37-2A	69	Unknown	Domestic
2B	16-37-2B	460	Nacatoch[1]	Unknown
2C	16-37-2C	460	Nacatoch[1]	Domestic
303	133303	300	Nacatoch[1]	Domestic
6	NA	42	Unknown	Domestic
6	NA	45	Unknown	Domestic
Wells Just Outside a One-Mile Radius				
102	16-37-102	580	Nacatoch	Unused
1F	16-37-1F	1078	Nacatoch[1]	Domestic
2D	16-37-2D	50	Unknown	Domestic

[1] The completion formation is apparently Nacatoch. No zone was identified on the state forms.

3.3 Oil and Gas Well Locations

An oil and gas well search of state records was conducted in October 2012 to identify locations of any existing or abandoned on-site crude oil or natural gas wells, or other wells associated with mineral recovery that are under the jurisdiction of the RRC. One dry hole (i.e., a plugged well that never produced oil or gas) location was identified that is inside the permit boundary but outside the waste footprint and is depicted in Appendix E4, Figure E4-2 – Locations of Oil and Gas Producing Wells. The plugging records for this well are provided in Appendix E4 as Figures E4-3 through E4-9.

4 SUBSURFACE INVESTIGATION REPORT

30 TAC §330.63(e)(4)(A)-(H)

The current and previous site characterization investigations of the geology, geotechnical properties, and hydrogeology of the site have resulted in more than 100 borings, piezometers, and wells. Based on site characterization, a sufficient number of borings were drilled to establish subsurface site stratigraphy and to determine the geotechnical properties of the soils beneath the site. Geologic strata have been characterized to depths of up to 150 feet. Based on correlation of strata identified in the borings the uppermost aquifer and lower confining unit (aquiclude) were identified.

Borings were drilled in accordance with TCEQ approved boring plans and established field exploration methods. Installation, abandonment, and plugging of borings were performed in accordance with the TCEQ rules in effect at the time.

4.1 Soil Boring Plan

A boring plan for this site was approved as complying with 30 TAC §330.63(e)(4), by a letter dated October 29, 2010, from the TCEQ (Figure E2-1). A summary of the boring data is provided in Table E-4 and a plan of the borings is shown in Appendix E2, Figure E2-2. The expansion area will have a waste footprint in the North and South Disposal Areas with a maximum design capacity of no more than 78.6 acres. The total number of borings to drill for a site 50-100 acres in size is 15-20 borings. Of those, the regulations and guidance suggest that about 12 should be drilled a minimum of 30 feet below the EDE. The boring plan proposed to drill a total of 25 new borings, all to depths greater than 30 feet below the EDE. Subsurface conditions were evaluated for the boring plan by examination of logs from 36 borings drilled between 1990 and 2001 as described in Section 4.2 of this attachment.

Table E-4
New Boston Landfill
Summary of Borings

BORING NO.	SURFACE ELEVATION	DEPTH (ft)	ELEVATION at TOTAL DEPTH	DEPTH BELOW EDE[1] (ft)	PIEZOMETER OR MONITORING WELL	NORTHING	EASTING
2010 - 2011 BME BORINGS AND PIEZOMETERS							
BME-01	379.60	90.00	289.60	40.40	Yes	12198.615	11006.903
BME-02	369.50	85.00	284.50	45.50	No	12200.000	11426.000
BME-03	376.85	80.00	296.85	33.15	No	12200.000	11844.000
BME-04	388.80	95.00	293.80	36.20	Yes	12201.326	12251.516
BME-05	386.41	100.00	286.41	43.59	No	12200.000	12679.000
BME-06	386.10	95.00	291.10	38.90	No	12200.000	13097.000
BME-07	382.98	95.00	287.98	42.02	Yes	12063.981	13523.019
BME-08	377.00	85.00	292.00	38.00	No	11782.000	11009.000
BME-09	370.80	85.00	285.80	44.20	Yes	11797.633	11267.617
BME-10	371.40	80.00	291.40	38.60	No	11782.000	11844.000
BME-11	384.40	100.00	284.40	45.60	No	11782.000	12262.000
BME-12	386.20	95.00	291.20	38.80	Yes	11785.155	12685.993
BME-13	385.87	100.00	285.87	44.13	No	11782.000	13097.000
BME-14	377.70	85.00	292.70	37.30	Yes	11355.710	11842.239
BME-15	386.30	95.00	291.30	38.70	No	11365.000	12262.000
BME-16	384.87	95.00	289.87	40.13	Yes	11359.970	12678.221
BME-17	381.64	95.00	286.64	43.36	No	10947.000	11844.000
BME-18	381.00	90.00	291.00	39.00	No	10947.150	12261.000
BME-19	372.60	80.00	292.60	37.40	No	10529.520	11844.040
BME-20	372.14	85.00	287.14	42.86	Yes	10532.096	12259.448
BME-21	373.80	85.00	288.80	41.20	No	12535.520	10663.490
BME-22	389.80	100.00	289.80	40.20	Yes	12489.659	11946.876
BME-23	386.80	95.00	291.80	38.20	Yes	12455.078	12944.632
BME-24	385.10	95.00	290.10	39.90	No	12393.880	13670.590
BME-25	380.90	90.00	290.90	39.10	No	12108.980	13962.260
BME-01(P)	379.60	80.00	299.60	30.40	Yes	12197.913	11007.955
BME-04(P)	388.80	79.00	309.80	20.20	Yes	12200.171	12252.169
BME-07(P)	382.98	74.00	308.98	21.02	Yes	12062.614	13522.785
BME-09(P)	370.80	64.00	306.80	23.20	Yes	11796.604	11268.827
BME-12(P)	386.20	72.00	314.20	15.80	Yes	11783.864	12685.805
BME-14(P)	377.70	66.00	311.70	18.30	Yes	11354.748	11843.276
BME-16(P)	384.87	68.00	316.87	13.13	Yes	11358.696	12679.018
BME-20(P)	372.14	63.00	309.14	20.86	Yes	10532.096	12259.448
BME-22(P)	389.80	78.00	311.80	18.20	Yes	12488.989	11947.935
BME-23(P)	386.80	74.00	312.80	17.20	Yes	12453.857	12944.987
2008 – 2009 BME BORINGS AND PIEZOMETERS							
B-1	373.53	65.00	308.53	21.47	Yes	12139.430	8055.950
B-2	384.00	85.00	299.00	31.00	No	12873.400	9033.890
B-3	371.00	72.00	299.00	31.00	No	12826.250	9769.090
B-4	376.02	75.00	301.02	28.98	No	12176.080	8304.980
B-5	379.74	78.00	301.74	28.26	No	12526.940	9047.030
B-6	377.66	75.00	302.66	27.34	No	12673.920	9410.870
B-7	370.51	65.00	305.51	24.49	Yes	11657.230	7761.900
P-1	373.53	20.00	353.53	-23.53	Yes	12139.430	8055.950

Table E-4
New Boston Landfill
Summary of Borings

BORING NO.	SURFACE ELEVATION	DEPTH (ft)	ELEVATION at TOTAL DEPTH	DEPTH BELOW EDE[1] (ft)	PIEZOMETER OR MONITORING WELL	NORTHING	EASTING
P-7	370.51	17.00	353.51	-23.51	Yes	11657.230	7761.900
2000 – 2001 BME BORINGS AND PIEZOMETERS							
B-13a	373.02	70.00	303.02	26.98	Yes	11700.000	8150.000
B-16a	381.59	80.00	301.59	28.41	Yes	12700.000	10650.000
B-29	380.00	100.00	280.00	50.00	No	10760.000	9960.000
B-30	371.23	90.00	281.23	48.77	No	11466.690	10033.470
B-31	369.26	100.00	269.26	60.74	No	12168.380	10193.090
B-32	380.73	100.00	280.73	49.27	No	12295.860	9291.250
B-33	379.77	110.00	269.77	60.23	Yes	11888.060	8408.330
B-34	368.89	52.50	316.39	13.61	Yes	11850.000	9784.000
FP-1	371.46	42.70	328.76	1.24	Yes	10425.348	10034.900
FP-2	364.57	40.00	324.57	5.43	Yes	11399.867	9847.719
FP-3	366.52	30.00	336.52	-6.52	Yes	12251.051	9957.320
B-6/P-6	377.87	70.00	307.87	22.13	Yes	10550.000	10240.000
P-12	365.63	57.00	308.63	21.37	Yes	11950.000	10300.000
P-13a	373.02	20.00	353.02	-23.02	Yes	11702.300	8141.440
P-14	387.00	87.00	300.00	30.00	Yes	12050.000	8800.000
P-16a	381.59	80.00	301.59	28.41	Yes	12648.880	10301.870
P-33	379.77	27.00	352.77	-22.77	Yes	11887.030	8390.630
P-34	368.89	52.5	316.39	13.61	Yes	11850.110	9784.397
1998 GEC BORING							
GEC-B-1	387.48	84.00	303.48	26.52	No	12138.000	8927.000
1990 ESE BORINGS AND PIEZOMETERS							
B-01	370.15	150.00	220.15	109.85	No	10977.959	8068.615
B-02	359.51	56.00	303.51	26.49	No	10729.387	8768.763
B-03/P-1	364.90	62.00	302.90	27.10	Yes	10341.037	9599.757
B-04	362.26	100.00	262.26	67.74	No	9991.215	10276.262
B-05	367.97	60.00	307.97	22.03	No	10812.904	9578.773
B-06	376.71	68.00	308.71	21.29	No	10574.269	10248.655
B-07	370.57	62.00	308.57	21.43	No	11333.542	8080.530
B-08	369.48	60.00	309.48	20.52	No	11303.922	8787.337
B-09	357.11	60.00	297.11	32.89	No	11280.320	9597.593
B-10	382.55	80.00	302.55	27.45	No	11250.272	10271.770
B-11	368.89	60.00	308.89	21.11	No	11844.409	9620.966
B-12	365.42	60.00	305.42	24.58	No	11955.072	10293.227
B-13/P-2	370.90	62.00	308.90	21.10	Yes	11713.300	8123.582
B-14	385.85	60.00	325.85	4.15	No	12035.065	8811.917
B-15	373.39	100.00	273.39	56.61	No	12406.163	9638.773
B-16/P-3	378.35	72.00	306.35	23.65	Yes	12655.648	10334.590
B-17	367.57	64.00	303.57	26.43	No	10900.255	8504.935
B-18	358.45	60.00	298.45	31.55	No	10527.410	9308.037
B-19	366.11	6.00	360.11	-30.11	No	10220.909	9970.912
B-20	370.43	6.00	364.43	-34.43	No	10379.164	10042.972
B-21	376.95	6.00	370.95	-40.95	No	10654.866	10120.333
B-22	382.40	16.00	366.40	-36.40	No	11061.112	10175.905

Table E-4
New Boston Landfill
Summary of Borings

BORING NO.	SURFACE ELEVATION	DEPTH (ft)	ELEVATION at TOTAL DEPTH	DEPTH BELOW EDE[1] (ft)	PIEZOMETER OR MONITORING WELL	NORTHING	EASTING
B-23	375.13	6.00	369.13	-39.13	No	11306.224	10131.567
B-24	370.09	6.00	364.09	-34.09	No	11520.840	10097.646
B-25	371.13	20.00	351.13	-21.13	No	12367.460	10160.161
B-26	372.37	20.00	352.37	-22.37	No	12286.514	10178.653
B-27	362.74	6.00	356.74	-26.74	No	11344.392	9868.044
EXISTING AND HISTORIC MONITORING WELLS							
MW-1	378.60	76.00	302.60	27.40	Yes	12675.000	10338.000
MW-2	385.70	85.00	300.70	29.30	Yes	12122.168	8963.786
MW-2A[2]	385±	86±	299±	31±	Yes	12122.168	8963.786
MW-2B[2]	385±	85±	300±	30±	Yes	12122.168	8963.786
MW-2C[2]	385±	84±	301±	29±	Yes	12122.168	8963.786
MW-2D[2]	385±	85±	300±	30±	Yes	12122.168	8963.786
MW-2R(GEC-PZ-1)	387.48	39.75	347.73	-17.73	Yes	12138.000	8927.000
MW-3	370.80	63.00	307.80	22.20	Yes	11693.106	8128.109
MW-3R	372.46	64.00	308.46	21.54	Yes	11738.500	8103.430
MW-4	370.60	69.00	301.60	28.40	Yes	11014.000	8123.000
MW-5[3]	373.27	70.57	302.70	27.30	Yes	10914.000	8512.000
MW-6	357.80	50.00	307.80	22.20	Yes	10546.247	9314.030
MW-6R	359.12	50.00	309.12	20.88	Yes	10476.000	9314.000
MW-7	365.31	48.00	317.31	12.70	Yes	10141.000	10154.000
MW-8	360.19	55.00	305.19	24.80	Yes	10759.000	8761.000
MW-9	364.54	48.50	316.04	14.00	Yes	10273.000	9665.000
MW-10	383.64	78.00	305.64	24.40	Yes	11941.500	8528.600
MW-11	373.37	62.00	311.37	18.60	Yes	11365.100	8082.600
MW-12	361.12	53.00	308.12	21.90	Yes	10587.600	9078.200
MW-13	372.28	60.00	312.28	17.72	Yes	10402.700	10272.900

[1] Elevation of Deepest Excavation: 330 feet msl.
[2] Coordinates were not included on the original log and have been estimated from site topography map.
[3] MW-5 was reconditioned on 10/12/2005.

4.1.1 Biggs and Matthews Environmental – 2009 to 2011

Field exploration activities were conducted in October 2010 and March through April 2011. The new borings are designated BME-01 through BME-25. These borings were drilled using hollow stem augers and sampled continuously using Shelby tubes and split spoons where appropriate. Ten piezometers were installed: BME-01, BME-04, BME-07, BME-09, BME-12, BME-14, BME-16, BME-20, BME-22, and BME-23. Piezometers were installed immediately adjacent to the corresponding boring number. The original borehole was sampled and logged, and then the boring was plugged. Once piezometer screened intervals were selected, the piezometer borings were drilled and cuttings were logged to confirm consistency with the original boring lithologies. When found to be consistent, the original sample descriptions were then used for the piezometer logs.

In addition, in 2009, in order to characterize low levels of barium in Layer IA sands on the northern perimeter of the West Disposal Area, BME conducted the elements of a workplan approved by TCEQ in a letter dated January 29, 2008. The workplan included drilling seven borings, installing piezometers, recording water level readings, interpreting stratigraphy and flow direction, and analyzing groundwater for barium and chloride. The conclusions drawn from the data and the interpretations from the study, when combined with previous demonstrations, indicate that the barium detected in Layer IA is either naturally occurring or is from an upgradient source.

4.2 Previous Drilling Activities

Two previous subsurface investigations conducted at the site are described below. In addition, groundwater monitoring wells have been drilled and installed at the site and are described below. Borings were drilled in accordance with established field exploration methods. Installation, abandonment, and plugging of borings were performed in accordance with TCEQ rules in effect at the time. Figure E2-2 illustrates the locations of all soil borings, piezometers, and monitoring wells previously advanced on site. All available boring logs are included in Appendix E2.

4.2.1 Biggs and Mathews Environmental – Site Exploration 2000 and 2001

Field drilling and sampling of the exploratory borings completed in 2000 and 2001 were performed using thin-walled tube and mud-rotary drilling techniques. Borings were continuously sampled from the surface to total depth. Shallow, highly weathered soils were sampled by hydraulically pushing 3-inch-diameter, thin-walled tubes from the surface to refusal (where the drill rig can no longer push the sample tubes) or to a depth conducive to core sampling. At several locations, after nearby shallow formation layers were characterized as consistent, shallow soils were sampled using rotary wash and a sample catcher until more cohesive formation materials were encountered. Coring then proceeded to total depth. Coring was accomplished using 5 and 10-foot length, double-tube core barrels with mud rotary techniques. All samples were extracted in the field and logged, with representative samples selected approximately every 5 feet, wrapped to protect against moisture loss, identification-marked, and packaged for transportation. Samples were then transported to a soils laboratory for testing of selected physical parameters.

The field exploration programs were under the direct supervision of a certified professional geologist or registered professional engineer.

Borings were field-logged by a qualified geologist at the time of drilling in general accordance with ASTM D 2488. The field logs, in conjunction with field and laboratory testing, were used to prepare the final boring logs. The data generated during the field exploration program are presented on the final logs of borings provided in Appendix E2 of this attachment. General notes supplementing the logs are on Figure E2-2.

4.2.2 Field Drilling and Sampling – 1990 to 1999

Geotechnical borings and monitoring wells were drilled using hollow-stem augers and mud rotary techniques. Samples were collected continuously, generally alternating between disturbed and relatively undisturbed sampling methodologies in cohesive strata and using disturbed sampling only in cohesionless units. Sample methodologies included pushing Shelby tubes, split spoons, and coring. Representative samples were transported to the laboratory for testing. Laboratory tests included sieve analysis, Atterberg limits, moisture content, density, permeability and compaction testing (a summary of the laboratory testing performed is included in Appendix E5). Upon completion of borehole drilling, most boreholes were pressure-grouted from the bottom up with bentonite grout using the tremie method. Piezometers were installed in several borings upon completion.

Environmental Science and Engineering (ESE) drilled and sampled 36 borings in July and September 1990. ESE installed six monitoring wells in September 1990 and October 1992. HMA Environmental Services installed two monitoring wells in September 1995 and four piezometers in 1997.

Genesis Environmental Consultants drilled boring GEC-B-1 in November 1998 and installed piezometer GEC-PZ-1 at the same location (which was later converted to MW-2R) in November 1999.

A geologist or qualified engineer was present in the field during all drilling operations to log boreholes using procedures in general accordance with ASTM Standard D 2488 (HMA, 1990, 1992, 1997; and BME, 2000 and 2001). The boring logs from the previous investigations by ESE, HMA, and BME are provided in Figures E2-3 through E2-226.

4.3 Site Stratigraphy

Three distinct geologic units (Layer I, II, and III) exist in the shallow subsurface at the site. In addition, two subsets (Layer IA and Layer IIA) occur in Layer I and II, respectively, as lenses that are laterally discontinuous and uncorrelatable across the site. Each of these is interpreted to be members of the Midway Group of Paleocene age and is described in the following section. The Upper Cretaceous Navarro Group, including the Nacatoch Sand, was not encountered by the exploratory borings. The top of the Nacatoch Sand of the Navarro Group is at least 400 feet below the site (McGowen and Lopez, 1983; Ashworth, 1988).

These three geologic units were encountered to the depth of the site soil borings (maximum of 150 feet). These units are illustrated on the site stratigraphic column in Table E-5. The basal unit (Layer III) consisted of a dark gray, hard clay, which was encountered at depths from 47 to 80 feet. The Layer II sands, which directly overlie the Layer III clay unit, are approximately 30 to 75 feet below ground surface. The thickness of this unit in the site borings ranges from 8 to 28 feet. Layer I is a surface clay unit that ranges from about 20 to more than 70 feet thick. Within the Layer II sand there are clay lenses that have been identified as Layer IIA. The minimum thickness of this surface clay unit below the lowest landfill base grade elevation is approximately nine feet, except in one area (BME-05) on the North Disposal Area where the excavation bottom will be approximately three feet from the top of the Layer II sand. Within Layer I are silts and sand lenses that are clayey that have been identified as Layer IA. The Layer IA sands and silts occur only on the far northwest part of the West Disposal Area. These units are all part of the lower Midway Group.

Table E-5
New Boston Landfill
Generalized Site Stratigraphy

Geologic Unit	Lithology	Average Depth to Top of Unit (ft)	Average Thickness of Unit (ft)	Hydrogeologic Unit
Layer I	CLAY, with silt and sand	0	44	Vadose Zone
Layer IA[1]	SAND, clayey, silt, fine to very fine, reddish brown	NA[2]	0	Discontinuous Shallow Perched Water
Layer II	SAND, silty, clayey, very fine to fine, gray to olive	46	12	Uppermost Aquifer Confined
Layer IIA	CLAY, sandy, silty, gray to olive	NA[2]	7	Discontinuous and Uncorrelatable
Layer III	CLAY, dark gray to black, hard	60	16[3]	Aquiclude to Layer II

[1] Layer IA is only present on the West Disposal Area of the site, only on the far northwestern perimeter. It is not present within the North and South Disposal Areas of the site.

[2] No calculation of average depth for IA and IIA because they are not present across the site.

[3] Layer III was not fully penetrated throughout the site. Depths penetrated across the site ranged from 1 to 86 feet and averaged 16 feet.

4.3.1 Layer I

Layer I is a surface clay unit that ranges from about 20 to more than 70 feet thick and consists predominantly of brown and/or red clay with some sandy and silty clay lenses. The average thickness of this surface clay unit below the lowest landfill base grade elevation is approximately 15 feet across the site. Within Layer I are silts and sand lenses that are clayey that have been identified as Layer IA.

4.3.2 Layer IA

The Layer IA sands/silts are present as a significant, correlatable unit only on the far northwestern perimeter of the West Disposal Area. A contour map of the thickness of Layer IA is shown on Figure E3-12. The map indicates that the sands and silty clays of Layer IA are of limited areal extent that is localized on the northern perimeter of the West Disposal Area only. Layer IA is not present on the North and South Disposal Areas. Most of the Layer IA sand is limited to a small area along the north boundary of the West Disposal Area starting at the northwest corner of the site (see Figure E3-12).

4.3.3 Layer II

Layer II sand, which directly overlies the Layer III clay unit, is approximately 30 to 75 feet below ground surface and consists of light gray to pale olive, wet, dense, clayey and silty sands. The thickness of this unit in the site borings ranges from 8 to 28 feet. The areal distribution and geometry of Layer II can be seen on a contour map of the thickness of Layer II (Figure E3-13) and a structural contour map of the base of the sand (Figure E3-14). This transmissive unit exhibits great lateral variation in grain size within distances of a few hundred feet. Consistent with the regional geology of the Midway Group, the Layer II sand isopach and structure maps indicate two generally north-south trending sand deposits that are separated near the middle of the site by clay. These clay deposits are likely overbank/levee deposits that were deposited following channel flooding during storm events. The Layer II sand is continuous and correlatable across the North and South Disposal Area.

The Layer II sand occurs at the base of Layer I. Where no Layer II sand is present, the contact between Layer I and Layer III is transitional. Layer I clay is generally lighter colored (brown, reddish or yellow-brown) whereas Layer III is a darker gray color. In areas where no sand is present, cross sections E3-2, E3-3, and E3-4 show contact between Layer I and Layer III.

4.3.4 Layer IIA

Layer IIA clay are clay lenses that are laterally discontinuous and uncorrelatable across the site. These clay lenses are found within the Layer II sand. Layer IIA was only observed in a limited number of borings. Where present this unit ranges from five to eight feet in thickness.

4.3.5 Layer III

Layer III represents the basal aquiclude (lower confining unit) and consists of a dark gray, hard clay, which was encountered at depths from 47 to 80 feet. The uppermost one to three feet of this unit is locally mottled, somewhat sandy, and generally moist because it is in contact with the saturated portion of the overlying sand unit. The unit has occasional slickensides. This clay unit is continuous across the site to the maximum depth of the borings (150 feet). Borings that did not penetrate below about 310 feet msl did not reach this unit on the West Disposal Area. However, all borings drilled on the North and South Expansion Area as part of the current investigation reached Layer III and penetrated this unit a minimum of 10 feet. Layer II sand channels eroded the surface of the Layer III clays.

5 GEOTECHNICAL DATA

30 TAC §330.63(e)(5)(A)-(F)

The geotechnical properties of the subsurface materials at this site are based on the subsurface investigations that are described in Section 4 of this attachment. The geotechnical design of the facility is provided in Attachment D5 – Geotechnical Design.

5.1 Laboratory Reports

Geotechnical tests were performed on samples recovered from each soil layer or stratum that will form the bottom and sides of the proposed excavation and from those that are less than 34 feet below the elevation of the deepest excavation. The laboratory tests were performed by independent third party laboratories using the industry standards that were applicable at the time that the tests were performed. The results of the laboratory tests are compiled in Appendix E5 of this attachment. Descriptions of the tests, the number performed, and the test standards are summarized in Table E-6.

Table E-6
New Boston Landfill
Laboratory Test Summary

Test Description	Test Method	Number Of Tests
Sieve Analysis	ASTM D 1140	60
Atterberg Limits	ASTM D 4318	52
Moisture Content	ASTM D 2216	80
Unit Dry Weight	ASTM D 2937	30
Permeability	ASTM D 5084	12

Atterberg limits and sieve analysis tests were used to classify the soils according to the Unified Soil Classification System. In addition, the Atterberg limits and sieve analyses were used to estimate the parameters for the settlement/heave and slope stability calculations and to evaluate the suitability of the materials for use as compacted soil liner and final cover infiltration layer. The moisture content and unit dry weight were used to estimate the parameters used for the settlement/heave and the slope stability calculations.

The permeability tests were used to estimate the parameters used for the temporary dewatering system design and to evaluate the suitability of the materials for use as compacted soil liner and final cover infiltration layer.

A total of twelve hydraulic conductivity tests have been performed on selected undisturbed samples from the current and previous explorations that will form the bottom and sides of the proposed excavations. In addition, field tests were performed to confirm the horizontal permeability of the excavation sidewall soils. The laboratory and field test results were used to evaluate the hydrogeologic parameters of the site and the hydraulic conductivity of engineered fill constructed from on-site materials.

5.2 Material Characteristics

The boring logs and the results of the laboratory tests from all site explorations were reviewed to identify the properties of the soils that may be encountered in the excavations for the North and South Disposal Areas. The cross sections in Appendix E3 show that the excavation may encounter sand, clayey sand, clay, silty clay, and sandy clay In Layer 1. The average properties for all soil types are summarized in Table E-7, and the laboratory test results are presented in Appendix E5.

Table E-7
New Boston Landfill
Average Properties of On-Site Materials

Layer	USCS Classification	Liquid Limit %	Plastic Limit %	Plasticity Index %	Passing 200 Sieve %	Moisture Content %	Unit Dry Weight (pcf)	In Situ Permeability (cm/sec)	Remolded Permeability (cm/sec)
I	CH	64	24	40	94	25.2	99.1	2.17×10^{-7}	5.6×10^{-8}
I	CL	40	19	21	79	18.0	104.8	1.73×10^{-7}	NA[2]
I	CL-ML	25	21	4	83	15.9	100.1	NA[1]	NA[2]
II	SC	32	17	15	30	17.3	109.7	4.30×10^{-6}	NA[2]
II	SM/SP	NP[3]	NP[3]	NP[3]	48	9.3	NA[1]	NA[1]	NA[2]
IIA	CH	53	24	29	87	19.4	NA[1]	NA[1]	NA[2]
III	CH	79	29	50	98	22.0	105.5	2.20×10^{-8}	NA[2]

[1] Sufficiently undisturbed samples could not be obtained for unit weight and permeability testing.
[2] Remolded permeability tests were only performed on soil likely to be used for compacted soil liner.
[3] NP = Non plastic

The geotechnical design calculations that are presented in Attachment D5 – Geotechnical Design, show that the in situ soils will provide adequate support for the proposed landfill. Total settlement beneath the liner system should be less than 15 inches and differential settlement should not exceed 5 inches, which is well within the strain tolerance of the proposed liner system. The factors of safety against slope failure exceeded the recommended factors of safety for all conditions that were analyzed.

5.3 Material Requirements

On-site soils will be required for construction of the soil liner and protective cover components of the liner system, and the infiltration layer and erosion layer components of the final cover system. On-site soils will also be required for operational cover (daily, weekly, and intermediate) and general earthfill. Typical material requirements for the various landfill components are summarized in Table E-8.

The soil liner and final cover infiltration layer must be constructed from soils that can be compacted to form a low hydraulic conductivity barrier. The classification and hydraulic conductivity test results indicate that the clayey soils excavated from the site should be satisfactory for use as compacted soil liner and infiltration layer material.

Protective cover and the erosion layer soils should not contain large rocks or boulders. Operational cover soils shall not have been previously mixed with waste materials and erosion layer material shall be capable of sustaining vegetation. The test results and boring logs indicate that any of the soil material excavated from the site should be suitable for use as operational and protective cover, and that the surface soils should be suitable for use as the upper layer of the final cover system erosion layer.

General earthfill used to construct the site roads and embankments should consist of medium to low plasticity soils. The classification test results indicate that the on-site soils are suitable for use as structural fill material.

Table E-8
New Boston Landfill
Typical Soil Requirements for Landfill Construction

Landfill Component	Classification	LL	PI	% - 200	Hydraulic Conductivity cm/sec	Material Source
Soil Liner	SC, CL, CH, MH	30 min	15 min	30 min	1×10^{-7} max	On-site
Infiltration Layer	SC, CL, CH, MH	30 min	15 min	30 min	1×10^{-5} max	
Protective Cover	SP, SW, SM, SC, CL, CH, ML, MH	No large rocks				
Erosion Layer	SC, CH, CL, SM, ML, CL-ML	Suitable to support plant growth				
Operational Cover (Daily, Weekly, and Intermediate Cover)	SP, SC, CL, CH, CL-ML, MH, ML	Not mixed with waste				
General Fill	SC, CL, CH, ML, CL-ML, MH	NA	5 min	15 min	NA	

5.4 Groundwater Occurrence

5.4.1 Groundwater Observation Points – Piezometers and Monitoring Wells

Groundwater observation points are summarized in Table E-9. Data from 22 piezometers and 16 groundwater monitoring wells, as well as the information from borings, were used to characterize site hydrogeology.

Logs of monitoring wells and piezometers are provided in Appendix E2. Existing monitoring well and piezometer locations are shown on Appendix E2, Figure E2-2 of this attachment. Proposed monitoring well details and locations are provided in Attachment F.

Table E-9
New Boston Landfill
Piezometer and Groundwater Monitoring Well Details

Well Name	Install Date	Surface Elevation (ft msl)	Total Depth (ft bgs)	Top of Casing Elevation (ft msl)	Filter Pack Elevation (ft msl)	Screen Elevation (ft msl)	Layer / Lithology Screened
MONITORING WELLS							
MW-1	9/6/1990	378.60	73.00	379.61	328.60 - 302.60	320.60 - 305.60	II / Sand
MW-2[1]	9/12/1990	385.70	82.00	388.31	331.20 - 300.70	328.70 - 303.70	I & II / Clay & Sand
MW-2R (GEC-PZ-1)	11/24/1999	387.48	39.75	390.00	359.58 - 347.73	358.73 - 348.23	I / Clay
MW-3[2]	9/15/1990	370.80	62.00	373.43	330.80 - 307.80	328.80 - 308.80	II / Sand
MW-3R	3/2/2009	372.46	64.00	374.07	321.46 - 308.46	318.46 - 308.46	II / Sand
MW-4	9/17/1990	370.60	66.00	373.19	332.60 - 301.60	329.60 - 304.60	I & II / Clay & Sand
MW-5[3]	9/12/1990	373.27	68.10	377.36	323.71 - 302.70	321.21 - 306.21	II / Sand
MW-6[4]	9/14/1990	357.80	50.00	360.93	321.80 - 307.80	317.80 - 307.80	II / Sand
MW-6R	8/18/2004	359.12	50.00	362.16	328.12 - 309.12	320.12 - 310.12	II / Sand
MW-7	10/7/1992	365.31	45.00	368.29	334.31 - 317.31	330.31 - 320.31	II / Sand
MW-8	9/29/1995	360.19	42.50	363.04	332.69 - 305.69	330.69 - 317.69	II & III / Sand & Clay
MW-9	9/28/1995	364.54	48.50	367.15	331.54 - 316.04	328.54 - 316.04	II / Sand
MW-10	4/7/2011	383.64	78.00	386.51	319.14 - 305.64	316.14 - 306.14	II / Sand
MW-11	4/8/2011	373.37	62.00	377.01	324.87 - 311.37	321.87 - 311.87	II & III / Sand & Clay
MW-12	4/6/2011	361.12	53.00	363.33	321.62 - 308.12	318.62 - 308.62	II / Sand
MW-13	4/5/2011	372.28	60.00	375.20	325.78 - 312.28	322.78 - 312.78	II / Sand
PIEZOMETERS							
P-1	6/23/2009	373.53	20.00	373.22[5]	366.03 - 355.50	364.03 - 353.00	I & IA / Clay & Sand
P-6 (B-6)	11/8/2001	377.87	70.00	379.87	315.87 - 307.87	312.37 - 307.87	Layer I Clay
P-7	6/22/2009	370.51	17.00	370.65	361.01 - 353.51	359.01 - 353.00	I & IA / Clay & Sand
P-12	11/8/2001	365.63	57.00	367.63	325.63 - 308.63	318.63 - 308.63	Layer II Sand
P-13a	12/9/2000	373.02	20.00	375.81	363.00 - 353.50	360.00 - 354.50	I & IA / Clay & Sand
P-14	11/9/2001	387.00	87.00	389.00	314.00 - 300.00	312.00 - 302.00	Layer I & III Clay
P-16a	12/8/2000	381.59	80.00	384.17	316.60 - 301.60	314.60 - 304.10	II / Sand
P-33	12/8/2000	379.77	27.00	382.60	366.40 - 352.30	363.80 - 353.30	I & IA / Clay & Sand
P-34	11/9/2001	368.89	52.50	370.89	330.89 - 316.39	327.89 - 317.89	Layer II Sand
BME-01(P)	10/4/2010	379.60	80.00	381.64	307.10 - 305.10	305.10 - 300.10	II / Sand
BME-04(P)	3/30/2011	388.80	79.00	392.36	322.30 - 320.30	320.30 - 310.30	II / Sand
BME-07(P)	10/12/2010	382.98	74.00	385.83	321.48 - 319.48	319.48 - 309.48	II / Sand
BME-09(P)	10/7/2010	370.80	64.00	374.14	319.30 -317.30	317.30 - 307.30	II / Sand
BME-12(P)	3/31/2011	386.20	72.00	389.12	322.20 - 319.70	319.70 -314.70	II / Sand
BME-14(P)	3/29/2011	377.70	66.00	381.40	324.20 - 322.20	322.20 -312.20	II / Sand
BME-16(P)	10/7/2010	384.87	68.00	387.62	329.37 - 327.37	327.37 - 317.37	II / Sand
BME-20(P)	10/8/2010	372.14	63.00	375.49	322.14 - 319.64	319.64 - 309.64	II / Sand
BME-22(P)	9/13/2011	389.80	78.00	391.75	324.30 - 322.30	322.30 - 312.30	II / Sand
BME-23(P)	9/12/2011	386.80	74.00	388.93	325.30 - 323.30	323.30 - 313.30	II / Sand
FP-1[6]	1/31/2001	371.46	42.70	373.90	339.10 - 328.80	337.00 - 332.00	I / Clay
FP-2[6]	1/31/2001	364.57	40.00	367.20	331.70 - 324.60	330.10 - 324.70	I / Clay
FP-3[6]	1/31/2001	366.52	30.00	369.26	342.52 - 337.52	331.52 - 336.52	I / Clay

[1] MW-2 was replaced by MW-2R in 1999 and is still in place for groundwater observation.
[2] MW-3 was replaced by MW-3R in 2009 and was plugged and abandoned.
[3] MW-5 was reconditioned on 10/12/2005.
[4] MW-6 was replaced by MW-6R in 2004 and was plugged and abandoned.
[5] Flush-mount surface completion.
[6] Field permeability test only.

5.4.2 Water Level Measurements

Water levels at the site have been measured from February 1992 through January 2013 in site monitoring wells and piezometers. These data are compiled in Tables E-10 and E-11. Measurements of water levels were made to 0.01 foot using an electronic water level indicator. Water level elevations were calculated using measured water levels and surveyed well elevations (top of casing). Borehole water level data are noted on logs. Because the borings were drilled with water, it was not generally possible to distinguish between drilling water and formation water. Borehole fluid level data were not used in engineering calculations because the piezometers were properly constructed and screened to provide water level data on individual strata; these data are much more reliable than borehole data.

Table E-10
New Boston Landfill
Historic Water Levels – Monitoring Wells

Date	MW-1	MW-2	MW-2R	MW-3	MW-3R	MW-4	MW-5	MW-6	MW-6R	MW-7	MW-8	MW-9	MW-10	MW-11	MW-12	MW-13
2/1991	354.59	335.11		319.73		318.97	318.49	347.43								
5/1991	357.37	337.84		320.14		319.18	318.61	348.01								
8/1991	356.91	338.70		319.94		319.19	318.68	346.28								
10/1991	356.29	338.63		319.24		319.00	318.63	346.63								
4/1992	358.19	339.93		320.71		319.69	319.18	348.43								
10/1992	357.74	339.93		321.22		320.11	319.52	345.54								
4/1993	358.64	341.41		321.31		320.43	319.86	348.99								
10/1993	357.81	341.93		321.98		320.99	320.43	346.43		340.29						
4/1994	358.71	342.15		322.66		321.61	320.97	349.20		341.67						
10/1994	358.30	342.81		323.36		322.21	321.60	347.15		341.63						
3/1995	359.29	343.43		324.69		323.34	322.73	349.77		343.14						
11/1995	357.57	344.69		325.83		324.49	323.88	346.27		342.29	336.22	343.89				
3/1996	356.93	344.59		326.17		325.18	324.57	346.61		342.15	335.88	344.35				
5/1996	355.82	344.07		326.35		325.19	325.13	345.69		341.49	335.51	344.21				
9/1996	356.32	345.02		327.46		326.38	326.06	347.22		342.30	335.86	344.54				
11/1996	356.62	345.94		327.68		326.87	326.38	347.90		342.34	336.07	344.96				
2/1997	359.44	345.92		329.28		327.65	327.25	349.18		343.03	336.98	346.21				
5/1997	358.67	347.90		329.81		329.06	328.73	349.31		343.69	337.83	346.34				
9/1997	358.11	351.11		331.15		330.55	330.28	347.35		343.31	337.24	344.97				
4/1998	359.12	354.48		336.10		335.67	335.40	350.36		344.60	340.17	347.33				
12/1999	357.69	361.13	362.10	344.43		344.26	343.43	346.82		343.41	343.85	344.60				
5/2000	358.03		363.37	345.58		345.41	345.49	349.35		344.15	344.86	346.49				
4/17/2001	359.55		366.49	346.71		346.61	346.73			344.30						
4/18/2001								350.06			346.30	347.09				
9/27/2001			366.88													
11/26/2001	359.65			348.30												
11/27/2001						348.15	348.31	349.89			347.44	346.87				
11/28/2001			366.70							344.91						
1/1/2002	359.57		366.41	348.51		348.39	348.47	350.81			347.72	347.89				
3/1/2002			367.26													
6/3/2002	360.61		366.90	348.62		349.10										
6/4/2002							349.21	350.94		345.69	348.25	347.99				
11/14/2002	359.21		365.10	348.33		348.17	348.32	347.81		343.93	347.06	345.95				
6/3/2003	358.91		366.18	349.22		349.09	349.21	349.48		344.71	347.84	346.55				
11/6/2003	358.15		364.78	348.88		348.77	348.93	346.87		343.59	347.36	344.41				
12/17/2003											347.26					
5/25/2004	358.19		365.64	349.10		348.99	349.13			344.25	347.90	346.29				
7/1/2004								350.50								

Table E-10
New Boston Landfill
Historic Water Levels – Monitoring Wells

Date	MW-1	MW-2	MW-2R	MW-3	MW-3R	MW-4	MW-5	MW-6	MW-6R	MW-7	MW-8	MW-9	MW-10	MW-11	MW-12	MW-13
11/22/2004	357.73		365.54	349.81							348.12					
11/23/2004						349.89	349.98		347.96	344.49		345.66				
2/14/2005									347.96							
5/24/2005	357.35			349.19			349.15		348.10							
5/25/2005			365.84			349.09				344.33	347.60	345.83				
8/29/2005									347.31							
11/11/2005	356.11		363.20	348.33		348.23	348.76		345.70	342.73	346.75	343.41				
3/1/2006									346.60							
5/23/2006	354.59		362.90	348.15		348.07	348.52		347.54	343.23	346.96	344.61				
8/29/2006									345.10							
11/28/2006	355.05			347.80			348.15		345.84							
11/29/2006			362.33			347.68				342.94	346.34	343.61				
2/15/2007	355.36		360.43	347.43		347.31	347.78		347.94	343.34	346.44	345.00				
5/17/2007	355.93		361.06	347.53		347.44	347.91			343.74		345.57				
5/18/2007									348.39		346.52					
8/22/2007	356.81		362.71	348.12			348.53		347.94	343.91	346.79	345.25				
8/23/2007						348.07										
11/7/2007	356.49			348.01												
11/8/2007			362.00			348.03	348.88					344.55				
11/9/2007									347.11	343.67	346.80					
11/14/2007				348.41												
5/13/2008	357.96		365.92	349.06		348.97	349.59									
5/14/2008									349.84	344.74	348.29	346.75				
11/19/2008	357.48			349.23			349.66									
11/20/2008			364.67			349.07			348.31			345.53				
11/21/2008										343.99	347.94					
1/1/2009											348.40	346.15				
5/29/2009	358.58		367.08			349.79	350.31		349.71	345.22		347.05				
6/1/2009											348.81					
6/12/2009					350.73											
8/28/2009					350.30											
11/3/2009			367.45			349.83				345.29						
11/4/2009	358.71				350.07		350.29		349.76		348.77	347.06				
2/25/2010					350.92											
5/12/2010	359.59		367.78			350.99			350.53	345.86	349.50	347.17				
5/13/2010					351.27		351.43									
8/19/2010					351.32											
8/31/2010					351.12											

Table E-10
New Boston Landfill
Historic Water Levels – Monitoring Wells

Date	MW-1	MW-2	MW-2R	MW-3	MW-3R	MW-4	MW-5	MW-6	MW-6R	MW-7	MW-8	MW-9	MW-10	MW-11	MW-12	MW-13
12/14/2010	357.41		365.62		351.12		350.88		347.08							
12/15/2010						350.84				344.51		345.18				
12/16/2010											348.37					
2/23/2011					350.67	350.37										
6/29/2011			365.08		350.67	350.23										
6/30/2011	357.39						350.71						350.81	350.79	347.12	344.57
7/1/2011									347.61	343.99	348.29	344.91				
8/4/2011													350.83	350.79	346.08	344.26
9/30/2011	356.61				350.04		350.46		345.52	343.03	347.41	343.06	350.18	350.16	345.02	343.47
10/14/2011	356.51				350.16		350.55		345.46	343.04	347.40	342.94	350.29	350.29	344.94	343.50
10/28/2011	356.46				349.87	349.52	350.28		345.31	342.79	347.27	342.80	350.01	349.98	344.81	343.25
11/9/2011	356.36				349.79		350.21									
11/10/2011						349.27			345.25	342.59	347.11	342.71				
11/11/2011													350.03	349.96	344.85	343.17
11/28/2011	356.24				349.87	349.70	350.26		345.69	343.02	347.30	343.50	350.12	350.01	345.45	343.54
12/9/2011	356.28				349.59	349.48	350.04		345.83	342.92	346.93	343.67	349.79	349.77	345.37	343.42
1/23/2012	356.33				349.66	349.56	350.15		347.16	343.26	347.61	344.54	349.85	349.85	346.67	343.77
2/27/2012	356.89				350.14	349.97	350.54			343.82	347.80	345.50	349.64	349.67	347.65	343.90
3/15/2012	356.49				349.60	349.52	350.06		347.10	343.57	347.67	345.49	349.48	349.79	347.93	344.09
4/26/2012	356.79				349.99	349.84	350.39		347.24	343.97	347.95	345.87	350.13	350.13	348.40	344.55
5/25/2012	356.73				349.86	349.82	350.38		347.18	343.80	347.86	345.76	350.08	350.07	347.65	344.38
5/30/2012					350.00		350.46									
5/31/2012	356.81					349.94			348.06	343.89	348.23	345.13	350.21	350.21	347.58	344.48
6/8/2012	356.56				349.84	349.74	350.29		347.88	343.63	348.01	344.83	350.01	350.01	347.20	344.20
7/2/2012					349.70											
8/29/2012	356.16				349.80	349.65	350.18		346.31	343.21	347.37	343.73	349.94	349.93	345.85	343.75
9/19/2012	355.91				349.40	349.29	349.84		345.69	342.79	347.19	343.22	349.58	349.56	345.19	343.30
11/8/2012	355.81				349.22	349.09	349.61		345.48	342.45	347.07	342.72	349.51	349.31	344.99	343.02
1/18/2013							349.20									
2/1/2013						348.69										
3/28/2013							349.43						349.23	349.26	347.33	343.53
4/19/2013							349.50									
5/14/2013	355.88				348.96	348.99	349.55		347.96	343.21	347.64	344.99	349.16	349.15	347.48	343.80

Table E-11
New Boston Landfill
Historic Water Levels – Piezometers

Date	P-1	P-6 (B-6)	P-7	P-12	P-13A	P-14	P-16A	P-33	P-34	BME-01(P)	BME-04(P)	BME-07(P)	BME-09(P)	BME-12(P)	BME-14(P)	BME-16(P)	BME-20(P)	BME-22(P)	BME-23(P)
4/17/2001					366.50		359.81	366.96											
6/4/2001					360.35		360.25	372.70											
12/3/2001		351.62		357..29	365.14	352.27	377.92	366.23	355.79										
12/6/2001		351.58		357.30	365.21	352.23	377.87	366.37	355.82										
12/10/2001		351.49		357.31	365.31	352.20	360.55	366.40	355.85										
12/13/2001		351.46		357.40	365.76	352.27	360.69	366.68	355.99										
1/24/2002		351.05		357.89	366.43	352.19	360.37	367.27	356.35										
7/10/09	367.20		363.77		368.86		358.56	365.70											
7/17/09	365.98		363.47		363.16		358.44	365.28											
7/24/09	365.36		362.88		362.68		358.38	364.87											
7/31/09	365.94		364.32		363.56		358.68	365.00											
8/28/09	366.62		364.15		363.97		358.37	365.77											
10/1/09	367.17		365.04		364.60		358.41	366.22											
11/3/09	368.92		367.35		366.97		358.74	367.78											
2/25/10	370.12		367.85		368.36		359.75	369.31											
5/12/10					365.72		359.68	363.96											
8/19/10	365.32		362.90		363.44		358.66	365.13											
8/31/10							358.50												
12/14/10	364.76		362.72		362.51		357.48	364.10											
2/21/11	366.07		365.05		364.09		357.39	364.99											
6/30/11	364.72		362.60		362.36			364.23											
9/30/2011										354.89	342.23	320.11	343.66	339.82	342.73	333.17	341.83	342.47	320.43
10/14/2011										354.85	342.16	320.37	343.68	339.97	342.60	333.35	342.29	342.60	320.60
10/28/2011										354.69	341.87	320.18	343.40	339.70	342.24	333.11	341.63	342.32	320.49
11/11/2011										354.62	341.92	320.32	343.25	339.73	342.33	333.20	341.67	342.40	320.65
11/28/2011										354.62	341.91	320.43	343.36	339.72	342.31	333.25	341.66	342.36	320.66
12/9/2011										354.48	341.64	320.22	343.20	339.45	342.07	333.02	341.37	342.08	320.60
1/23/2012										354.62	341.76	320.54	343.46	339.59	342.24	333.22	341.49	342.20	320.75
2/27/2012										354.92	341.62	320.48		339.44	342.12	333.04	341.37	342.05	320.66
3/15/2012										354.67	341.69	320.55	343.54	339.50	342.22	333.08	341.45	342.12	320.78
4/26/2012										355.02	341.96	317.28	343.88	339.78	342.60	333.38	341.79	342.40	321.05
5/25/2012										354.90	341.91	320.85	344.04	339.73	342.60	333.31	341.76	342.35	321.08
6/8/2012										354.82	341.84	320.75	343.78	339.66	342.50	333.17	341.69	342.27	320.90
8/29/2012										354.42	341.92	321.02	343.72	339.84	342.47	333.37	341.74	342.42	321.19
9/19/2012										354.09	341.56	320.63	343.44	339.48	342.06	332.97	341.32	342.00	320.93

5.4.3 Water Level Measurements During Drilling

The depth at which groundwater was encountered and records of after-equilibrium measurements noted on boring logs are summarized in Table E-12. The cross sections in Appendix E3 are annotated to document the level at which stabilized groundwater levels were obtained from site monitoring wells and piezometers. Borehole water level data are noted on the logs. However, because the borings were drilled with water, it was not generally possible to distinguish between drilling water and formation water. Borehole fluid level data were not used in engineering calculations because the piezometers were properly constructed and screened to provide water level data on individual strata; these data are much more reliable than borehole data.

Table E-12
New Boston Landfill
Groundwater Observations During Drilling

Boring No.	Install Date	Surface Elevation (msl)	Well Depth (ft)	Water Level During Drilling Depth to Water (ft)	Stabilized Depth to Water (ft)	Groundwater Elevation (msl)
2010 - 2011 BME BORINGS						
BME-01	10/4/2010	379.60	90.00	60.00	21.50	358.10
BME-02	10/6/2010	369.50	85.00	35.00	14.60	354.90
BME-03	10/5/2010	376.85	80.00	60.00	32.20	344.70
BME-04	3/30/2011	388.80	95.00	63.50	NA	325.30
BME-05	10/11/2010	386.41	100.00	54.00	49.50	336.90
BME-06	4/1/2011	386.10	95.00	72.50	NA	313.60
BME-07	10/12/2010	382.98	95.00	54.50	38.50	344.50
BME-08	3/28/2011	377.00	85.00	70.50	NA	306.50
BME-09	10/7/2010	370.80	85.00	41.00	29.00	341.80
BME-10	3/29/2011	371.40	80.00	61.50	26.70	344.70
BME-11	10/5/2010	384.40	100.00	64.00	41.50	342.90
BME-12	3/31/2011	386.20	95.00	68.00	NA	318.20
BME-13	10/12/2010	385.87	100.00	55.50	64.00	321.90
BME-14	3/29/2011	377.70	85.00	52.00	NA	325.70
BME-15	3/30/2011	386.30	95.00	57.50	NA	328.80
BME-16	10/7/2010	384.87	95.00	52.00	52.80	332.10
BME-17	10/6/2010	381.64	95.00	60.00	36.50	345.10
BME-18	9/7/2011	381.00	90.00	62.00	38.30	342.70
BME-19	9/8/2011	372.60	80.00	57.00	40.00	332.60
BME-20	10/8/2010	372.14	85.00	50.00	24.50	347.60
BME-21	9/6/2011	373.80	85.00	46.00	17.10	356.70
BME-22	9/13/2011	389.80	100.00	69.00	36.80	353.00
BME-23	9/12/2011	386.80	95.00	57.00	65.80	321.00
BME-24	9/13/2011	385.10	95.00	57.00	51.50	333.60
BME-25	9/9/2011	380.90	90.00	56.00	30.50	350.40
GEC-B-1	11/23/1998	387.48	84.00	32.00	23.83	363.65
B-1/P-1	6/23/2009	373.53	65.00	11.00	NA	362.53
B-2	10/06/2008	384.00	85.00	25.00	NA	359.00
B-4	10/06/2008	386.02	75.00	14.50	NA	371.52

Table E-12
New Boston Landfill
Groundwater Observations During Drilling

Boring No.	Install Date	Surface Elevation (msl)	Well Depth (ft)	Water Level During Drilling Depth to Water (ft)	Stabilized Depth to Water (ft)	Groundwater Elevation (msl)
B-6	6/26/2009	377.66	75.00	55.00	NA	322.66
B-7/P-7	6/22/2009	370.51	65.00	12.00	NA	358.51
B-30	12/06/2000	371.23	90.00	57.00	NA	314.23
B-01	7/27/1990	370.15	150.00	50.00	NA	320.15
B-02	7/20/1990	359.51	56.00	30.00	NA	329.51
B-03/P-1	7/24/1990	364.90	62.00	42.00	NA	322.90
B-04	7/24/1990	362.26	100.00	36.00	NA	326.26
B-05	9/13/1990	367.97	60.00	38.00	NA	329.97
B-07	9/6/1990	370.57	62.00	52.00	NA	318.57
B-08	7/27/1990	369.48	60.00	48.00	NA	321.48
B-09	7/19/1990	357.11	60.00	40.00	NA	317.11
B-10	9/4/1990	382.55	80.00	70.00	NA	312.55
B-11	9/13/1990	368.89	60.00	46.00	NA	322.89
B-13/P-2	7/24/1990	370.90	62.00	51.00	NA	319.90
B-15	7/21/1990	373.39	100.00	26.00	NA	347.39
B-16/P-3	7/21/1990	378.35	72.00	58.00	NA	320.35
B-17	9/7/1990	367.57	64.00	54.00	NA	313.57
B-18	9/8/1990	385.45	60.00	44.00	NA	341.45
B-22	9/24/1990	382.40	16.00	14.00	NA	368.40
FP-1	1/31/2001	371.46	42.70	28.73	NA	342.73
FP-2	1/31/2001	364.57	40.00	12.80	NA	351.77
FP-3	1/31/2001	366.52	30.00	28.30	NA	338.22
MW-1	9/6/1990	378.60	76.00	23.00	NA	355.60
MW-2	9/11/1990	385.70	85.00	65.00	NA	320.70
MW-2R (GEC-PZ-1)	11/23/1999	387.48	39.75	28.00	27.81	359.67
MW-3	9/15/1990	370.80	63.00	44.00	NA	326.80
MW-3R	3/2/2009	372.46	64.00	13.00	NA	359.46
MW-4	9/17/1990	370.60	69.00	52.00	NA	318.60
MW-5*	9/12/1990	367.70	65.00	49.00	NA	318.70
MW-6	9/14/1990	357.80	50.00	42.00	NA	315.80
MW-6P	8/18/2004	359.12	50.00	43.00	NA	314.12
MW-7	10/7/1992	365.3	48.00	30.00	26.00	339.30
MW-8	9/29/1995	360.2	42.50	35.00	26.90	333.30
MW-9	9/28/1995	364.5	48.50	21.00	20.70	343.80
MW-10	4/7/2011	383.6	78.00	28.00	28.83	354.81
MW-11	4/7/2011	373.4	62.00	55.00	19.96	353.41
MW-12	4/6/2011	361.1	53.00	40.00	11.39	349.73
MW-13	4/5/2011	372.28	60.00	43.00	25.08	347.20

NA – Not observed
*MW-5 reconditioned 10/12/2005; surface elevation raised to 373.27.

5.5 Groundwater Monitoring Analytical Data

A tabulation of historic groundwater chemistry results is provided in Appendix E7. The history of the groundwater monitoring program at the site is discussed in Attachment F.

5.6 Hydrogeologic Units

Three distinct geologic units of the Midway Group were encountered in site borings. Each of these is interpreted to be members of the Midway Group of Paleocene age and is described in the following section. The Upper Cretaceous Navarro Group, including the Nacatoch Sand, was not encountered by the exploratory borings. Each of the units and its significance is discussed below.

5.6.1 Layer I

Layer I is a surface clay unit that ranges from about 20 to more than 70 feet thick and consists predominantly of brown and/or red clay with some sandy and silty clay lenses. Within Layer I are silts and sand lenses that are clayey, and have been identified as Layer IA.

Because the isolated Layer IA sand and silty clay is contained within the Layer I unit, the Layer IA sands/silty clays are directly underlain by the Layer I clay. The Layer I clays thus serve as the lower confining unit to the Layer IA sand and silty clays.

5.6.2 Layer IA

The Layer IA sands/silts are present as a correlatable unit only on the northwestern perimeter of the West Disposal Area. Layer IA is not present within the North or South Disposal Areas. Based on the results from borings drilled north and west of the site, a sand channel exists north and northwest of the West Disposal Area that is oriented north/south to northeast/southwest. The northwestern perimeter of the West Disposal Area appears to be on the southern or southeastern edge of the channel. Based on previous borings, very little Layer IA sand existed within the footprint of the West Disposal Area waste excavation of the West Disposal Area at the site. What little sand may have existed has been removed by the excavation, leaving only a narrow area in the buffer zone of the West Disposal Area. Groundwater flow directions determined from potentiometric surface maps consistently show groundwater flow from north to south from areas north of the site toward the north and northwest part of the site and areas west of the site.

Groundwater is contained in the Layer IA sands and silty clay. Because of the lack of areal extent, recharge to this sandy unit is limited to infiltration of precipitation from the surface primarily through the Layer I clays. Groundwater movement in Layer IA is limited to the areas where the sand is present. Because the isolated Layer IA sand and silty clay is contained within the Layer I clays, the Layer IA sands/silty clays are directly underlain by the Layer I clay. The Layer I clays thus serve as the lower confining unit to the Layer IA sand and silty clays.

5.6.3 Layer II – Uppermost Aquifer

Layer II sand, which directly overlies the Layer III clay unit, is approximately 30 to 75 feet below ground surface and consists of light gray to pale olive, wet, dense, clayey and silty sands. The thickness of this unit in the site borings ranges from 8 to 28 feet. The areal distribution and geometry of Layer II can be seen on a contour map of the thickness of Layer II (Figure E3-13) and a structural contour map of the base of the sand (Figure E3-14). Consistent with the regional geology of the Midway group, the Layer II sand Isopach and structure maps indicate two generally north-south trending sand deposits that are separated near the middle of the West Disposal Area by clay. In addition, there is a clay interval on the east side of the West Disposal Area where Layer II soil is absent. These clay deposits are likely overbank/levee deposits that were deposited following channel flooding during storm events. The Layer II sand is continuous and correlatable across the North and South Disposal Areas.

The Layer II sand occurs at the base of Layer I. Where no Layer II sand is present, the contact between Layer I and Layer III is transitional. Layer I clay is generally lighter colored (brown, reddish or yellow-brown) whereas Layer III is a darker gray color. In areas where no sand is present, such as those shown in cross sections E3-2, E3-3, and E3-4, Layer I and Layer III are in contact.

Groundwater enters Layer II sands northwest and north of the site (upgradient). Figures E6-1 through E6-14 are potentiometric surface maps of water levels in Layer II. Layer II groundwater flows within the channels of Layer II sands on the West Disposal Area; to the southwest in the channel on the western portion of the West Disposal Area and to the south and southeast in the channel on the eastern portion of the West Disposal Area. Groundwater flows generally to the southwest on the western portion of the North and South Disposal Areas and to the east, southeast, and northeast on the eastern portion of the North and South Disposal Areas.

Groundwater flow velocities were estimated using hydraulic conductivity values calculated from the slug tests, gradients derived from the potentiometric surface maps shown on Figures E6-1 through E6-14 and effective porosity values estimated from McWhorter and Sunada (1977). The estimated flow velocity for the site is about 65.6 ft/year. The groundwater flow velocity parameters and calculations are provided in Appendix F. Velocity differences can be attributed to varying hydraulic conductivities and gradients across the site.

5.6.4 Layer IIA

Layer IIA are clay lenses that are laterally discontinuous and uncorrelatable across the site. These clay lenses are found within the Layer II sand. The Layer IIA clays were only observed in a few borings. Where present this unit ranges from five to eight feet in thickness.

5.6.5 Layer III – Lower Confining Unit

Layer III represents the basal aquiclude (lower confining unit) and consists of a dark gray, hard clay that was encountered at depths from 47 to 80 feet. The uppermost one to three feet of this unit is locally mottled, somewhat sandy, and generally moist because it is in contact with the saturated portion of the overlying Layer II sand unit. Slickensides occur in the upper part of the unit. This clay unit is continuous across the site to the maximum depth of the borings (150 feet). Borings that did not penetrate below about 310 feet msl did not reach this unit on the West Disposal Area. However, all borings drilled as part of the current investigation (BME-01 through BME-25) were drilled into Layer III. Layer II sand channels cut down into the Layer III clays. The Layer III clay is the lower confining unit to the Layer II sands.

5.6.6 Field Permeability (Slug) Tests

Slug tests were performed in selected groundwater monitoring wells (Layer II). Rising and falling head tests were conducted in the monitoring wells. Data were collected by pressure transducer and electronic data logger. The raw data were analyzed by EMCON using Bouwer and Rice (1976) and the Cooper, Bredehoeft, and Papadopulos (1967) models. The test results are summarized in Table E-13. Hydraulic conductivity values ranged from 6.8×10^{-3} to 6.1×10^{-5} centimeters per second. Only monitoring wells screened primarily in Layer II were used to calculate arithmetic mean. Field permeability tests were also conducted in FP-1 and FP-3 within the Layer I clay.

Slug tests were generally conducted by measuring the rising head or falling head of water levels with time following removal of a water column using a bailer or addition of a slug displacing a water volume. At each piezometer, a depth to static water level was measured to the nearest 0.01-foot prior to testing. A pressure transducer probe was placed near the base of the well to record initial water column heights and changes in water column heights as water levels fell or rose to static water levels.

Table E-13
New Boston Landfill
Hydraulic Conductivity Values

Well No.	Screen Interval, ft msl	Lithology at Screen Interval	Layer	Hydraulic Conductivity (cm/sec)	
				Falling Head	Rising Head
MW-1[1]	320-305	Clay & Sand	I & II	3.0×10^{-4}	7.0×10^{-4}
MW-2[1,4]	329-304	Clay & Sand	I & II	4.6×10^{-3}	6.8×10^{-3}
MW-3[2]	329-309	Clay & Sand	II	6.1×10^{-5}	1.0×10^{-4}
MW-4[2,3,4]	330-305	Clay & Sand	I & II	1.0×10^{-4}	1.0×10^{-4}
MW-5[2]	321-306	Sand	II	1.8×10^{-4}	1.9×10^{-4}
MW-6[1,3]	318-308	Sand	II	4.4×10^{-3}	4.7×10^{-3}
FP-1[4]	328-339	Clay	I		8.38×10^{-6}
FP-3[4]	336-344	Clay	I		8.58×10^{-7}
Arithmetic Mean				1.33×10^{-3}	

[1] Cooper et al. (1967) model used.
[2] Bouwer and Rice (1976) model used.
[3] Results are an average of two tests.
[4] Only monitoring wells screened primarily in Layer II were used to calculate arithmetic mean.

5.6.7 Groundwater Flow Rate

Travel times across the site were estimated using the formula:

$$v = (k * i) / n_e$$

Where: v = travel velocity
k = hydraulic conductivity of the aquifer
i = hydraulic gradient
n_e = effective porosity

The estimated flow velocity for the site is 65.6 ft/year. Layer II hydraulic conductivity values were used for calculation and are shown in Table E-13. The groundwater flow velocity calculation is included in Appendix E6 as Figure E6-15.

Groundwater flow in Layer II (which is the uppermost aquifer for groundwater monitoring purposes), is generally to the southwest in the sand channel on the western portion of the West Disposal Area, and to the south and southeast in the sand channel on the eastern portion of the West Disposal Area (Attachment F, Appendix F1, Figure F1-1). Groundwater flows generally to the southwest on the western portion of the North and South Disposal Area and to the east, southeast, and northeast on the eastern portion of the North and South Disposal Area. Multiple potentiometric surface maps were previously constructed for a period from 1996 through 2007 for the West Disposal Area, while potentiometric surface maps that include the piezometers for the North and South Disposal Areas were constructed from September 2011 through August 2012 (Figures E6-1 through E6-14), to account for possible seasonal and temporal affects to groundwater flow direction and gradient position.

6 ARID EXEMPTION

30 TAC §330.63(e)(6)

The applicant is not seeking an arid exemption for the landfill unit; therefore, 30 TAC §330.63(e)(6) is not applicable to this application.

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