FINAL
GEOTECHNICAL INVESTIGATION
SKYSCRAPER SHADOWS LOCAL DRAINAGE PROJECT
STORM SEWER AND PAVING
HOUSTON, TEXAS
WBS NO. M-000126-0070-3

SUBMITTED TO
AECOM
5444 WESTHEIMER RD, SUITE 200
HOUSTON, TEXAS 77056

BY
HVJ ASSOCIATES, INC.
HOUSTON, TEXAS
FEBRUARY 20, 2015

REPORT NO. 98-240G-06
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HVJ ASSOCIATES

Houston
Austin
Dallas
San Antonio

6120 S. Dairy Ashford Rd.
Houston, TX 77072-1010
281.933.7388 Ph
281.933.7293 Fax
www.hvj.com

February 20, 2015

Ms. Erin E. Williford, PE
AECOM
5444 Westheimer Rd, Suite 200
Houston, Texas 77056

Re: Geotechnical Investigation
Skyscraper Shadows Local Drainage Project - Storm Sewer and Paving
WBS No. M-000126-0070-3
Houston, Texas
Owner: City of Houston
HVJ Report No. 98-240G-06

Dear Ms. Williford:

Submitted herein is the final report of our geotechnical investigation for the above referenced project. The study was conducted in general accordance with our proposal number 98-240G-06 dated July 1, 2014 and is subject to the limitations presented in this report. We appreciate the opportunity of working with you on this project. Please read the entire report and notify us if there are any questions concerning this report or if we may be of further assistance.

Sincerely,

HVJ ASSOCIATES, INC.
Texas Firm Registration No. F-000646

SVedantam

Sharmi P. Vedantam, PE
Project Manager

STATE OF TEXAS
SHARMI P. VEDANTAM
2/20/15
100218
LICENSED
PROFESSIONAL ENGINEER

S. Sanjeevan

Sanjeevan Selvaratnam, EIT
Staff Engineer

SV/SS

Copies submitted: 2

The seal appearing on this document was authorized by Sharmi P. Vedantam, PE 100218 on February 20, 2015. Alteration of a sealed document without proper notification to the responsible engineer is an offense under the Texas Engineering Practice Act.

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1 EXECUTIVE SUMMARY

The project includes replacement of storm sewers and associated pavement along Gulick Lane from Randolph Street to Monroe Street, along Holiday Lane from Wingtip Drive to Monroe Road, at the intersection of Wetherby Lane and Monroe Road, and at the intersection of Swiftwater Lane and Monroe Road in Houston, Texas. Based on the subsurface conditions obtained by the soil borings, the findings and recommendations of this report are summarized below:

1. Cohesive soils were generally encountered in the borings. Notably, Boring B-1 consists of sand layer from 10 to 15 feet below the existing grade, Boring B-5 consists of silt layer from 13 to 15 feet below the existing grade, and Boring B-6 consists of silt layer from 10 to 12 feet below the existing grade.

2. Based on our desktop fault study, faulting is anticipated to impact the project site and a fault study is recommended.

3. Groundwater was encountered in borings B-1, B-4 and B-5 at depths ranging between 11 and 13.7 feet below the existing grade during drilling operations. One piezometer was installed at boring location B-6 (PZ-1) to obtain the 24-hour, and 30-day water level readings. Based on the 24-hour water level reading, we expect the groundwater to be at a depth of approximately 12 feet below existing grade.

4. Both cohesive and cohesionless soils were encountered at the proposed storm sewer invert depths. Recommendations for replacement of storm sewers using open cut techniques are presented in Section 6 of this report.

5. Unsatisfactory and soft foundation soils are encountered at the proposed pipe invert depths in some of the borings along the project alignment. The table below provides the locations and depths where unsatisfactory and soft soils are encountered in the project area.

Boring No	Approximate Depth, Feet		Material
	From	To	
B-3	8	10	Soft fat Clay
B-5	13	15	Loose Silt with Sand
B-6	10	12	Loose Sandy Silt

6. The pavement was cored at boring locations B-1 through B-6 and the pavement thickness information was obtained. The existing pavement thickness at boring locations B-1 through B-6 comprise of 3 to 4 inches of asphaltic concrete over 8 inches of cement treated crushed limestone base over 4 inches of shell base.

7. HVJ recommends 1.5" of HMAC surface over 2" HMAC base. We also recommend 8" of crushed limestone base over 6" of lime stabilized subgrade below the HMAC base for the pavement.

Please note that this executive summary does not fully relate our findings and opinions. Those findings and opinions are only presented through our full report.

2 INTRODUCTION

2.1 Project Description

HVJ Associates, Inc. was retained by AECOM to provide geotechnical and pavement recommendations for the Skyscraper Shadows Local Drainage Project in Houston, Texas. The project includes replacement of storm sewers and associated pavement along Gulick Lane from Randolph Street to Monroe Street, along Holiday Lane from Wingtip Drive to Monroe Road, at the intersection of Wetherby Lane and Monroe Road, and at the intersection of Swiftwater Lane and Monroe Road in Houston, Texas. Based on the 90% design drawings provided to us by AECOM, the invert depth of the storm sewers will range from 7 to 12 feet below the existing grade. Based on the subsurface conditions obtained by the soil borings, the findings and recommendations of this report are summarized below:

2.2 Geotechnical Investigation Program

The major objectives of this study were to gather information on subsurface conditions at the site and to provide design and construction recommendations for the proposed storm sewer, and pavement improvements. This investigation was performed in general accordance with the City of Houston Department of Public Works and Engineering Infrastructure Design Manual dated July 2012. The objectives were accomplished by:

- Coring six (6) pavement locations to obtain pavement thicknesses.
- Drilling six (6) soil borings to a depth of 15 feet below the existing grade to determine soil stratigraphy and to obtain samples for laboratory testing.
- Installing one (1) piezometer to gain an understanding of the groundwater conditions at the site and to evaluate the potential need for dewatering during construction.
- Performing laboratory tests to determine physical and engineering characteristics of the soils.
- Performing engineering analyses to develop design guidelines and construction recommendations for the proposed storm sewers, and pavement reconstruction.

Subsequent sections of this report contain descriptions of the field exploration, laboratory-testing program, general subsurface conditions, design recommendations, and construction considerations.

3 FIELD INVESTIGATION

3.1 Geotechnical Borings

The field exploration program undertaken at the project site was performed between December 11, 2014 and December 17, 2014. Subsurface conditions were investigated by drilling six (6) soil borings to a depth of 15 feet below the existing grade.

All boreholes except the one converted into piezometer, were backfilled with cement grout by tremie method in accordance with the City guidelines and patched at the surface. The piezometer will be plugged after obtaining the 30 day water level readings. Approximate boring locations are presented on Plate 2 of the report.

3.2 Survey Data

The survey data for borings is provided by AECOM and is presented on the boring logs in Appendix A.

3.3 Sampling Methods

Soil samples were obtained continuously to the termination depth of the borings. Cohesive soil samples were obtained with a three-inch thin-walled (Shelby) tube sampler in general accordance with ASTM D-1587 standard. Each sample was removed from the sampler in the field, carefully examined, and then classified. The shear strength of the cohesive soils was estimated by a hand penetrometer in the field. Cohesionless soils were sampled with the split spoon sampler in accordance with ASTM D 1586 standard. Suitable portions of each sample were sealed and packaged for transportation to our laboratory.

Detailed descriptions of the soils encountered in the borings are given on the boring logs presented in Appendix A. A key to the soils classification and symbols used in the boring logs is also presented in Appendix A.

3.4 Water Level Measurements

Groundwater was measured at all boring locations during the drilling operations. One piezometer was installed at boring location B-6 to obtain the 24-hour, and 30-day water level readings. The piezometer set-up consists of 2-inch PVC screen surrounded by 20/40 sieve filter pack sand below a 2-inch diameter PVC riser which is surrounded by hydrated bentonite pellets. The installed piezometer was flush mounted with steel covers and surrounded in 4-foot by 4-foot by 2-inch concrete pads. During plugging or abandonment, all the components of the installed piezometer are pulled out and the hole is filled with bentonite pellets/cement slurry to restore the site. Piezometer installation records and groundwater level data are provided in Appendix C. Piezometer "Well Report" and "Plugging Report" are also provided in Appendix C.

4 LABORATORY TESTING

Selected soil samples were tested in the laboratory to determine applicable physical and engineering properties. All tests were performed according to the relevant ASTM Standards. These tests consisted of moisture content measurement, percent passing No. 200 sieve, Atterberg limits, unconsolidated undrained compression and unit dry weight tests.

The Atterberg Limits and percent passing number 200 sieve tests were utilized to verify field classification by the Unified Soils Classification System, and the unconsolidated undrained compression tests were performed to obtain the undrained shear strength of the soil. The type and number of tests performed for this investigation are summarized below:

Table 4-1 Type and Number of test Performed

Type of Test	Number of Tests
Moisture Content (ASTM D2216)	30
Atterberg Limits (ASTM D4318)	16
Percent Passing No. 200 Sieve (ASTM D1140)	11
Unconsolidated Undrained Triaxial (ASTM D2850)	13
Standard Proctor (ASTM D698)	1
Laboratory CBR (ASTM D1883)	1

The laboratory test results are presented on the boring logs in Appendix A. The conversion between pocket penetrometer readings obtained in the field to the shear strength parameters presented in the borings logs were obtained using a conversion factor of 1/3. A summary of laboratory test results is provided in Appendix B.

4.1 Standard Proctor & California Bearing Ratio (CBR) Test

HVJ performed one standard proctor & California Bearing Ratio (CBR) test in accordance with ASTM D1883 on a composite sample obtained from all the borings in the upper 4 feet. The method of compaction was in accordance to ASTM D698. According to the ASTM requirements, 95% of Maximum Dry Density (MDD) obtained from Standard Proctor is considered for CBR testing. The MDD for the composite sample was found to be 110.8 pcf and the CBR corresponding to 95% of MDD is 2.4. The CBR and Standard Proctor test results are presented in Appendix E.

5 SITE CHARACTERIZATION

5.1 General Geology

There are two major surface geological formations that exist in the Houston area: the Beaumont formation and the Lissie formation. The Beaumont formation is a relatively younger formation generally found to the southeast of the Lissie formation. The Beaumont formation dips southeastward and extends beneath beach sand and waters of the Gulf of Mexico as far as the continental shelf. The project alignment is located in the Beaumont formation. A geologic map is presented on Plate 3.

The Beaumont formation was deposited on land near sea level in flat river deltas and in inter-delta regions. Soil deposition occurred in fresh water streams and in flood plains (as backwater marsh and natural levees). The courses of major streams and deltaic tributaries changed frequently during the period of deposition, generating within the Beaumont clay a complex stratification of sand, silt and clay deposits. Frequently, stream courses were diverted significant distances from a given point in a backwater marsh, and the water overlying the soil would evaporate since it was cut off from a drainage path. Such water, which would be highly alkaline, would precipitate large nodules of calcium carbonate (calcareous nodules) throughout the surface of evaporation. With the coming of the Second Wisconsin Ice Age, the nearby sea withdrew, leaving the formation several hundred feet above sea level and permitting the soil to desiccate. The process of desiccation compressed the clays in the formation such that they became significantly overconsolidated to a large depth. In addition to preconsolidating the soil, the process of desiccation, together with the later rewetting, produced a network of fissures and slickensides that are now closed but which represent potential planes of weakness in the soil.

5.2 Geologic Faulting

The tectonic history of the Texas Gulf Coast includes a relatively stable depositional cycle since the Cretaceous Period (about 65 million years). During this period the area was subjected to deposition of clays, silts, and sands resulting in over 30 thousand feet of sedimentary rocks. Underlying this clastic sequence are salt formations, which have migrated upwards to produce the typical salt dome features associated with the Texas Gulf Coast. In conjunction with salt movement, dewatering and compaction of some of the deeper sediments in the basin have resulted in the development of growth faults.

A literature review of surface faults near the project area was conducted based on the Bureau of Economic Geology, University of Texas at Austin, Geologic Atlas of Texas Houston Sheet, Paul

Weaver Memorial Edition (revised in 1982). The primary objective of this review was to evaluate available information from published and open file reports. Based on our review, an unnamed fault is crossing the project alignment. Faulting is anticipated to impact the project site and a fault study is recommended. A detailed fault study is performed in the project area and a fault study report was submitted to AECOM under separate cover.

5.3 Soil Stratigraphy

HVJ's interpretation of soil and groundwater conditions at the project site is based on information obtained at the boring locations only. This information has been used as the basis for our conclusions and recommendations. Significant variations at areas not explored by the project borings may require reevaluation of our findings and conclusions.

Cohesive soils were generally encountered in the borings. Notably, Boring B-1 consists of sand with silt (SP-SM) layer from 10 to 15 feet below the existing grade. Also, Boring B-5 consists of silt with sand (ML) layer from 13 to 15 feet below the existing grade and Boring B-6 consists of sandy silt (ML) layer from 10 to 12 feet below the existing grade. A generalized summary of the subsurface soil conditions encountered in our borings is shown below in Table 5-1 and Table 5-2. Details of the subsurface stratigraphy encountered in the borings are shown on the boring logs presented in Appendix A.

Substantial deviations from the summarized conditions exist at several of the boring locations and should be accounted for in the design and construction recommendations.

Table 5-1 Generalized Soil Profile (Borings B-2, B-3, B-4 and B-6)

Stratum	Approximate Depth, Feet		Material
	From	To	
I	Bottom of the Pavement	Termination Depth of Borings	Cohesive Soil (CL, CH)

Table 5-2 Generalized Soil Profile (Borings B-1 and B-5)

Stratum	Approximate Depth, Feet		Material
	From	To	
I	Bottom of the Pavement	10.0-13.0	Cohesive Soil (CL, CH)
I	10.0-13.0	Termination Depth of Borings	Cohesionless Soil (SP-SM, ML)

Details of the subsurface stratigraphy at specific depths encountered in the borings are shown on the boring logs presented in Appendix A. Subsurface soil profile along the project alignment is presented in Appendix D. The soil profile plates will be updated with elevations and invert depths in the final report after obtaining survey information from AECOM.

The Casagrande's Plasticity Chart presented in Figure 5-1 illustrates the range of plasticity of the cohesive soils found during our investigation.

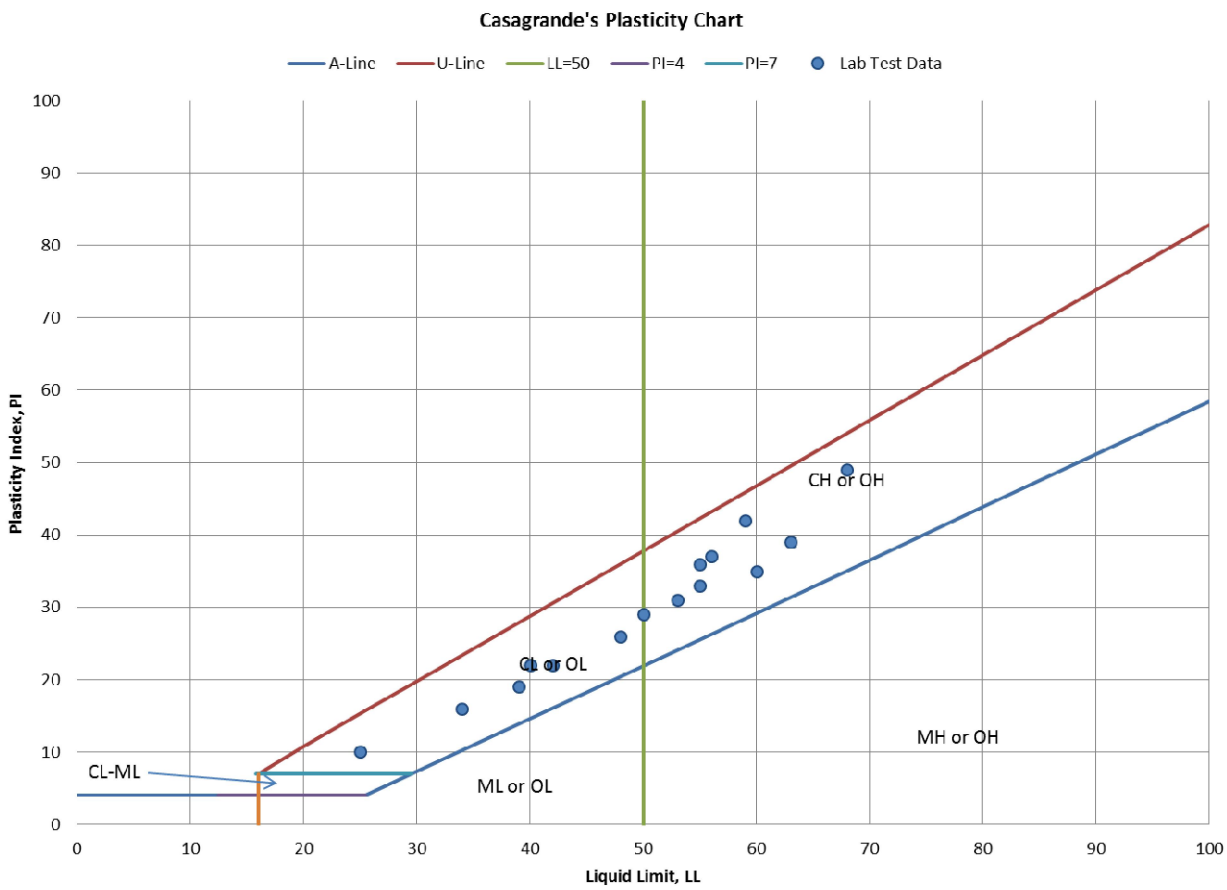


Figure 5-1 Casagrande's Plasticity Chart

5.4 Groundwater Conditions

Groundwater was encountered in borings B-1, B-4 and B-5 during drilling operations. One piezometer was installed at boring location B-6 (PZ-1) to obtain the 24-hour, and 30-day water level readings. Piezometer installation records are provided in Appendix C. Table 5-3 shows a record of the groundwater readings taken during drilling as well as the piezometer readings after 24 hours. The 30-day water level reading will be updated in the final report.

Table 5-3 Groundwater Observations

Boring No.	Groundwater Depth First Encountered (feet)	Groundwater Reading	
		Groundwater Depth after 24 Hours (feet)	Groundwater Depth after 30 Days (feet)
B-1	11.0	-	-
B-2	dry	-	-
B-3	dry	-	-
B-4	13.7	-	-
B-5	11.0	-	-
B-6 (PZ-1)	dry	12.1	4.4

Based on the 24-hour and 30-day water level reading, we expect the groundwater to be at a depth of approximately 4 to 5 feet below existing ground. It should be noted that groundwater levels determined during drilling may not accurately reflect the true groundwater conditions, and therefore should only be considered as approximate. Groundwater levels measured in open standpipe piezometers are, on the other hand are more accurate; however, these readings will fluctuate seasonally and in response to rainfall. Other factors that might impact piezometric groundwater levels include leakage from existing water lines, storm sewers and/or sanitary sewers.

6 UTILITY DESIGN CRITERIA AND RECOMMENDATIONS FOR OPEN CUT TECHNIQUES

6.1 General

The project includes replacement of storm sewer and associated pavement along Gulick Lane from Randolph Street to Monroe Street, along Holiday Lane from Wingtip Drive to Monroe Road, at the intersection of Wetherby Lane and Monroe Road, and at the intersection of Swiftwater Lane and Monroe Road. We did not perform any soil borings at the intersection of Wetherby Lane and Monroe Road and at the intersection of Swiftwater Lane and Monroe Road. However, we utilized the subsurface soils information from boring B-6 to provide design recommendations at these intersections. Based on the 90% design drawings provided by AECOM, the invert depth of the storm sewer will range from 7 to 12 feet below the existing grade. HVJ's recommendations for the installation of storm sewers using open cut techniques are presented below.

6.2 Geotechnical Parameters

Geotechnical design parameters are presented in Table 6-1. Design parameters given in the table are based on field and laboratory test data obtained at boring locations drilled for utilities at the approximate invert depth.

Table 6-1 Utility Design Parameters

Boring No.	Street	Invert Depth (feet)	Soil Description at Invert Depth	Total Unit Weight (pcf)	Undrained Shear Strength (psf)/Friction Angle (deg)	Allowable Bearing Capacity (psf)	E'_n, Long Term (psi)
B-1	Gulick	7.0	Stiff Clay	133	1500/-	2500	600
B-2	Gulick	8.0	Stiff Clay	131	1500/-	2500	600
B-3	Gulick	8.5	Soft Clay	122	400/-	600	200
B-4	Gulick	9.0	Stiff Clay	127	1400/-	2300	600
B-5	Holiday	10.0	Firm to stiff Clay	126	1000/-	1700	300
B-6	Holiday	11.0	Loose Silt	120	-/28	2000	300
B-6	Wetherby/Monroe	9.0	Firm to stiff Clay	125	1200/-	2000	600
B-6	Swiftwater/Monroe	12.0	Loose Silt	120	-/28	2000	300

The values shown in the above table represent HVJ's interpretation of the soil properties based on the available laboratory and field test data. Use of the soil properties shown above may or may not be appropriate for a particular analysis, since choice of design parameters often depends on whether total or effective stress analysis is used, rate of loading, duration of loading, geometry of loaded area, and other factors. The total unit weight values shown above represent our interpretation of soil unit weight at natural moisture content. The undrained shear strength and allowable bearing capacity values represent our interpretation of the shear strength in clay soils based primarily on the results of

unconsolidated undrained compression tests and hand penetrometer tests. The allowable bearing capacity includes a factor of safety of three.

6.3 Pipe Design

The loads imposed on underground pipes depend principally upon the method of installation, the weight of overburden soils, roadway traffic load, and loads due to existing surface structures. For design of rigid pipes installed using open-cut method, loads due to overburden and traffic can be determined from Plate 5.

The traffic load applied to the rigid pipe can be calculated using 85% of wheel load with an impact factor of 1.5 for one foot of soil cover, 50% of wheel load with an impact factor of 1.35 for 2 feet of cover, and 30% of wheel load with an impact factor of 1.15 for 3 feet of cover. This results in a total design traffic load on the pipe or box culvert of about 1.28, 0.68 and 0.35 times the wheel load for 1, 2 and 3 feet of cover, respectively. For pipes with four or more feet of cover, the traffic loads may be taken as a surcharge equivalent to 250 psf.

6.4 Open Cut Bedding and Backfill

Pipe Bedding. The storm sewer may be installed using City of Houston standard bedding details as outlined on Standard Drawing Nos. 02317-02 and 02317-03. If needed, we recommend groundwater control in accordance with Section 01578 of City of Houston Standard Specifications be implemented to achieve stable trench conditions and satisfactory foundation base.

The excavations should be performed with equipment capable of providing a relatively clean bearing area. Stable soils are essential to provide a strong base during construction. In addition, stable soils enhance trench bottom stability, support for bedding compaction, and minimize possible pipe settlement. Whenever soft foundation soils are encountered such as those encountered in Boring B-3 during trench excavation, we recommend over excavating 3 feet below the base of the foundation and replacing with on-site soils compacted to at least 95% of maximum dry density in loose lifts not exceeding 8 inches.

Trench Backfill. Trench backfill for storm sewer should be in accordance with Section 02317, Excavation and Backfill for Utilities, of the City of Houston Standard Specifications, July 2012. Backfill around the storm sewers, including manholes and other underground structures, should be in accordance with the provisions that are explained in the City of Houston Standard Details on Drawing Nos. 02317-02 and 02317-03.

It should be noted that unsatisfactory soil conditions are encountered in some of the boring locations along the project alignment. Table 6-2 below presents the locations where unsatisfactory soils and soft foundation soils are encountered within the project area.

Table 6-2 Unsatisfactory and Soft Foundation Soils

Boring No	Approximate Depth, Feet		Material
	From	To	
B-3	8	10	Soft fat Clay
B-5	13	15	Loose Silt with Sand
B-6	10	12	Loose Sandy Silt

City of Houston Standard Specification 02317, Item 3.09 provides information related to backfill materials. According to this specification, for pipes of nominal sizes 36 inches in diameter and smaller, cement stabilized sand should be used as backfill material up to pavement. For pipes with diameter greater than 42-inches below pavement or natural in satisfactory soil conditions, backfill from 12-inches above top of pipe to 12 inches below pavement with suitable on-site material or select backfill with PI between 8 and 20. For sewer pipes 42 inches in diameter and larger, under pavement or natural ground, in unsatisfactory soil conditions, backfill from 12 inches above top of pipe to 12 inches below pavement with suitable on-site material or select backfill.

Fill material should be placed in loose lifts not exceeding eight inches, and should be compacted to 95 percent of the standard Proctor maximum dry density as determined by ASTM D 698 as specified City of Houston Standard Specifications, Section 02317. However, the backfill up to 12 inches above the top of the pipe should be compacted carefully so as to prevent structural damage to the pipe.

7 UTILITY CONSTRUCTION RECOMMENDATIONS

7.1 General

This section is intended to address issues that might arise during construction. HVJ's recommendations are intended for use as guidelines in dealing with particular soil conditions. The topics addressed in this section include trench excavation stability, groundwater control, and open-cut construction considerations.

The recommendations contained herein are not intended to dictate construction methods or sequences. Instead they are provided solely to assist designers in identifying potential construction problems related to excavation, based upon findings derived from sampling. Depending upon the final design chosen for the project, the recommendations may also be useful to personnel who observe construction activity.

Prospective contractors for the project must evaluate potential construction problems on the basis of their review of the contract documents, their own knowledge of and experience in the local area, and on the basis of similar projects in other localities, taking into account their own proposed methods and procedures.

7.2 Open Cut Excavation Considerations

Excavations should satisfy two requirements. First, the soils above final grade must be removed without disturbing the soil below, which will support constructed facilities. Second, the sides of the excavation must be stable to prevent damage to adjacent streets and facilities as a result of either vertical or lateral movements of the soil. In addition, a satisfactory excavation procedure must include an adequate construction dewatering system to lower and maintain the water level at least a few feet below the lowest excavation grade.

<u>Excavation Stability</u>. Excavations shall be shored, laid back to a stable slope or some other equivalent means may be used to provide safety for workers and adjacent structures. Earth pressures for braced excavations are presented on Plates 6A through 6C. Assessment of the need for excavation sloping, use of trench boxes, or other measures required to provide a stable excavation, and the use of appropriate construction practices and/or equipment is the contractor's responsibility. The following comments are intended to represent common solutions to stability problems encountered in similar soil conditions in the Houston area, and may not be construed as

excavation system design recommendations. The excavation operations shall be performed in accordance with 29 CFR Part 1926 subpart P, as amended, including rules published in the Federal Register, Vol. 54, No. 209, dated October 31, 1989, as a minimum. In addition, the provisions of legislation enacted by the Texas Legislature and City of Houston should be satisfied. Table 7-2 shows the classification of soils for excavations according to OSHA standards.

Table 7-1 OSHA Soil Type

Boring No.	OSHA Soil Type		
	Depth of Trench (ft.)		
	0 – 5	5 – 10	10-15
B-1	B	B	C
B-2	B	B	B
B-3	B	C	C
B-4	B	B	C
B-5	B	B	C
B-6	B	B	C

We recommend that a professional engineer should design temporary support for trenches deeper than 20 feet, and that the OSHA tables are not used below this depth.

In general, it is HVJ's opinion that the pressure distribution (for braced walls) should be used for design of sheeting or trench boxes. To reduce the potential for ground movement adjacent to the top of the excavation, the bracing should be preloaded in stages as the excavation is deepened. The detailed earth pressure diagrams are presented on Plates 6A through 6C.

The planned construction will be performed along alignments near existing utility installations (either crossing or paralleling the new alignments). The contractors should be aware of potential excavation stability problems while working in the vicinity of old trenches and the excavation system should be designed to accommodate this weak material (trench backfill).

The vertical walls of excavations should be located a safe distance from existing utilities in order to prevent movement in the soil mass behind the excavation that may adversely affect the utilities. We recommend that the horizontal distance of existing utilities should be greater than their vertical distance from the bottom of excavation.

7.3 Select Fill and General Earthwork Recommendations

The select fill required to rise the grade or backfill should consist of sandy clay with a liquid limit less than 40 and a plasticity index between 8 and 20. Fill material that is used should be placed in loose lifts not exceeding eight inches and should be compacted to 95 percent of standard Proctor maximum dry density as determined by ASTM D698.

7.4 Spoil Disposal

Spoil from construction will be generated from trench excavations. Soils that will be excavated from this project area will consist primarily of cohesive soils (CH). Economically, possible uses of the cohesive spoil material may be limited to land reclamation, site grading, and final cover in sanitary landfill operations. These soils may not be suitable for use in engineered fill.

7.5 Groundwater Control

Based on our field investigation, limited groundwater seepage is expected during excavation at the invert depths of the utilities. Assessment of the need for groundwater control and installation of appropriate dewatering equipment is the contractor's responsibility at the time of construction. The following comments are intended to represent common solutions to groundwater control problems encountered in similar soil conditions in the Houston area, and may not be construed as dewatering system design recommendations. A conventional pump and sump arrangement may be adequate if water bearing cohesive soils are encountered during trench excavations. Well points or eductors may be utilized to lower the groundwater level to at least three feet below the excavation level where water bearing cohesionless soils are encountered. Well points are generally not effective below about 15 feet beneath the top of the well point, and deeper dewatering requires deep wells with submersible pumps and eductors.

Based on the 24-hour and 30-day water level readings, we expect the groundwater to be at a depth of approximately 4 to 5 feet below the existing ground throughout the project area. Water bearing cohesionless soils were encountered in the borings B-1, B-5 and B-6. HVJ expect well point or educator dewatering may be required in the vicinity of borings B-1, B-5 and B-6. Control of groundwater should be accomplished in a manner that will preserve the strength of the foundation soils, will not cause instability of the excavation, and will not result in damage to existing structures. Where necessary, the water will be lowered in advance of excavation by pump and sump arrangement, wells, well points, or similar methods. Open pumping should not be permitted if it results in boils, loss of fines, softening of the subgrade, or excavation instability. Discharge should be arranged to facilitate sampling by the owner's representative or engineer.

8 PAVEMENT DESIGN RECOMMENDATIONS

8.1 General

HVJ understands that due to the installation of storm sewers along Gulick Lane, Holiday Lane, Wetherby Lane and Swiftwater Lane, pavement reconstruction may be required for these streets. Pavement thickness designs were completed using DARWin, software based on the AASHTO Design Procedure.

8.2 Existing Pavement Thickness

The existing pavement within the project area was cored prior to drilling at all the boring locations. The existing pavement structure and thickness are presented in Table 8-1. Based on the available pavement core information, we understand that the existing pavement is a flexible pavement.

Table 8-1 Existing Pavement Thicknesses

Street	Boring No.	Asphalt (inch)	Cement Treated Crushed Limestone Base (inch)	Stabilized Shell Base (inch)
Gullick	B-1	3	8	4
Gullick	B-2	4	8	4
Gullick	B-3	3	8	4
Gullick	B-4	3.5	8	4
Holiday	B-5	3	8	4
Holiday	B-6	4	8	4

8.3 Traffic Data

All the streets that are to be reconstructed in the project are classified as Residential Streets based on GIMS maps of City of Houston. The parameters required for design of pavement include initial average daily traffic (ADT), growth rate, truck factor, and percent trucks in ADT.

Traffic count data was not available for the residential streets from the Houston Regional Traffic Count Map as prepared by TxDOT. Since no traffic information was available for these residential streets, an ADT of 1,000 was assumed for calculating the design traffic. The design 18 kip Equivalent Single Axle Loads (ESALs) in one direction was then calculated based on an assumed 4% trucks and an estimated average truck factor of 0.46 for flexible pavement resulting in a 20-year design ESALs of 92,744 for the residential classified streets within the project limits.

8.4 Design Criteria and Performance Constraints

The design and performance constraints selected for design are summarized in the following paragraphs.

Reliability Level and Overall Standard Deviation. A reliability (R) of 85 percent was selected for pavement design performance. A mean value of the overall standard deviation (S_o) was selected to be 0.49 for flexible pavement based on AASHTO Guide for Design of Pavement Structures, 1993 and the case where the variance of projected future traffic is considered (Chapter 4, Section 4.3).

Serviceability: The serviceability of a pavement is defined as its ability to serve the type of traffic that uses the facility. The condition of the pavement after the performance period is characterized by a Terminal Serviceability Index (P_t), which is a function of the pavement structure. A Terminal Serviceability Index of 2.0 was selected for design. The time at which a given pavement structure reaches its terminal serviceability depends on traffic volume and the original or initial serviceability (P_o), which was selected as 4.2. The design serviceability loss, the difference between the initial and terminal serviceability indices is 2.2.

Drainage: The treatment for the expected level of drainage for a rigid pavement is through the use of a drainage coefficient, C_d. Based on an average 104 days of rain per year in Houston, Texas, the pavement is exposed to moisture approaching saturation 28% of the time. As per AASHTO with good quality of drainage, a C_d value of 1.0 was selected for design. According to the AASHTO design guide, good quality drainage is defined as water being removed from the roadway within 24 hours.

8.5 Subgrade Strength

Based on the subgrade soil investigations, the soil beneath the pavement at the locations of the borings generally consisted of Fat clays (CH). The Plasticity Index (PI) of the soils ranged from 16 to 49. One California Bearing Ratio (CBR) test was performed on the composite material obtained from the borings in accordance to ASTM D1883. The method of compaction was in accordance to ASTM D698. According to the City of Houston compaction requirements, 95% of Maximum Dry Density (MDD) is specified and this is considered for the CBR. The MDD for the composite sample was found to be 110.8 pcf based on the Standard Proctor Test and the CBR corresponding to 95% of MDD is 2.4. The Standard Proctor and CBR test results are presented in Appendix E.

CBR was used to calculate the correlated subgrade resilient modulus using equation (1) below resulting in 3,600 psi.

Subgrade Resilient Modulus = 1500 * CBR (1)

8.6 Summary of Flexible Pavement Design Inputs

The estimated and assumed values for the design of flexible pavement are summarized in the following table. DARWin outputs are presented in Appendix F.

Table 8-2 Summary of Design Inputs

Parameter	Value
Subgrade Resilient Modulus, M_R	3,600 psi
Drainage Coefficient, C_d	1.0
Design Serviceability Loss	2.2
Reliability, R	85%
Overall Standard Deviation, S_o	0.49
Design Traffic ESALs	92,744
Required Structural Number	2.93

8.7 Flexible Pavement Sections

We have estimated the following asphalt pavement section for the residential streets to be reconstructed along the project alignment. DARWin outputs are presented in Appendix F.

1.5" HMAC Surface
2" HMAC Base
8" Crushed Limestone Base
6" Lime Stabilized Subgrade

8.8 Preparation of Subgrade

The lime stabilization of the subgrade provides the following benefits: 1) a depth of non-swelling material, 2) a moisture barrier to minimize moisture fluctuations in the subgrade that can cause shrinkage/swelling; and 3) helps bind the fines and delay potential pumping, however is still considered an erodable material.

Based on the Plasticity Index of the subgrade soil, 6% of hydrated lime per dry unit weight appears to be an appropriate estimate for stabilization of the onsite clays to perform satisfactory as pavement subgrade. The lime percentages are only estimations based on test results of the subgrade material at the boring locations. The actual amount of lime percentage should be determined for subgrade soils by conducting laboratory lime series tests on the exposed subgrade material during construction.

HVJ recommends the following procedures for subgrade preparation.

1. Clear the proposed project limits of existing pavement and subgrade to the grade required for the proposed pavement section.

2. In areas where soft, compressible or loose soils are encountered, additional excavation may be required. Excavation should extend a minimum of two feet beyond the edge of the proposed pavement, if appropriate.

3. Surfaces exposed after excavation should be proof-rolled in accordance with TxDOT Standard Specification Item 216 or equivalent City of Houston specification. If rutting develops, tire pressures should be reduced. The purpose of the proof-rolling operation

is to identify any underlying zones or pockets of soft soils and to remove such weak materials.

Before stabilizing the subgrade, scarify the upper 6 inches of exposed material throughout the width of pavement as required to provide loose material to facilitate distribution of lime. Due to the thickness of stabilization the lime stabilization may need to be placed in two lifts, unless contractor proposed equipment can demonstrate adequate mixing depth. Mix 6% lime by dry weight and compact to 95 percent of standard proctor maximum dry density (ASTM D698).

9 MONITORING

9.1 Excavation Safety

As required under OSHA regulations, the contractor should provide a "competent person" to inspect trench excavations daily before the start of work, as needed during the shift, and after every rainstorm or other hazard increasing occurrence. When the competent person finds evidence of a hazardous condition, exposed workers should be removed from the hazardous area until the necessary precautions have been taken to ensure their safety. A competent person means one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous or dangerous to workers, and who has authorization to take prompt corrective measures to eliminate them.

9.2 Construction Materials Testing

HVJ recommends that backfill be monitored by an accredited testing laboratory to verify that construction is performed in conformance with project specifications. HVJ routinely provides materials testing verification and observation services and would be pleased to do so for this project.

10 DESIGN REVIEW

HVJ should be retained to review the final design plans and specifications for this project to determine whether the geotechnical recommendations have been properly interpreted, and to confirm that the assumptions made at the time this report was prepared are consistent with the project as final design.

11 LIMITATIONS

This investigation was performed for the exclusive use of AECOM to provide geotechnical and pavement recommendations for the Skyscraper Shadows Local Drainage Project in Houston, Texas. HVJ has endeavored to comply with generally accepted geotechnical engineering practice common in the local area. HVJ makes no warranty, express or implied. The analyses and recommendations contained in this report are based on data obtained from subsurface exploration, laboratory testing, the project information provided to us and our experience with similar soils and area conditions. The methods used indicate subsurface conditions only at the specific locations where samples were obtained, only at the time they were obtained, and only to the depths penetrated. Samples cannot be relied on to accurately reflect the strata variations that usually exist between sampling locations. Should any subsurface conditions other than those described in our boring logs be encountered, HVJ should be immediately notified so that further investigation and supplemental recommendations can be provided.

12 REFERENCES

1. City of Houston Department of Public Works And Engineering (July 2012) "Infrastructure Design Manual"
2. American Association of State Highway And Transportation Officials (1993) "AASHTO Guide for Design of Pavement Structures"

PLATES

1 inch = 8904 feet

CITY OF HOUSTON

Department of Public Works and Engineering

Geographic Information & Management System (GIMS)

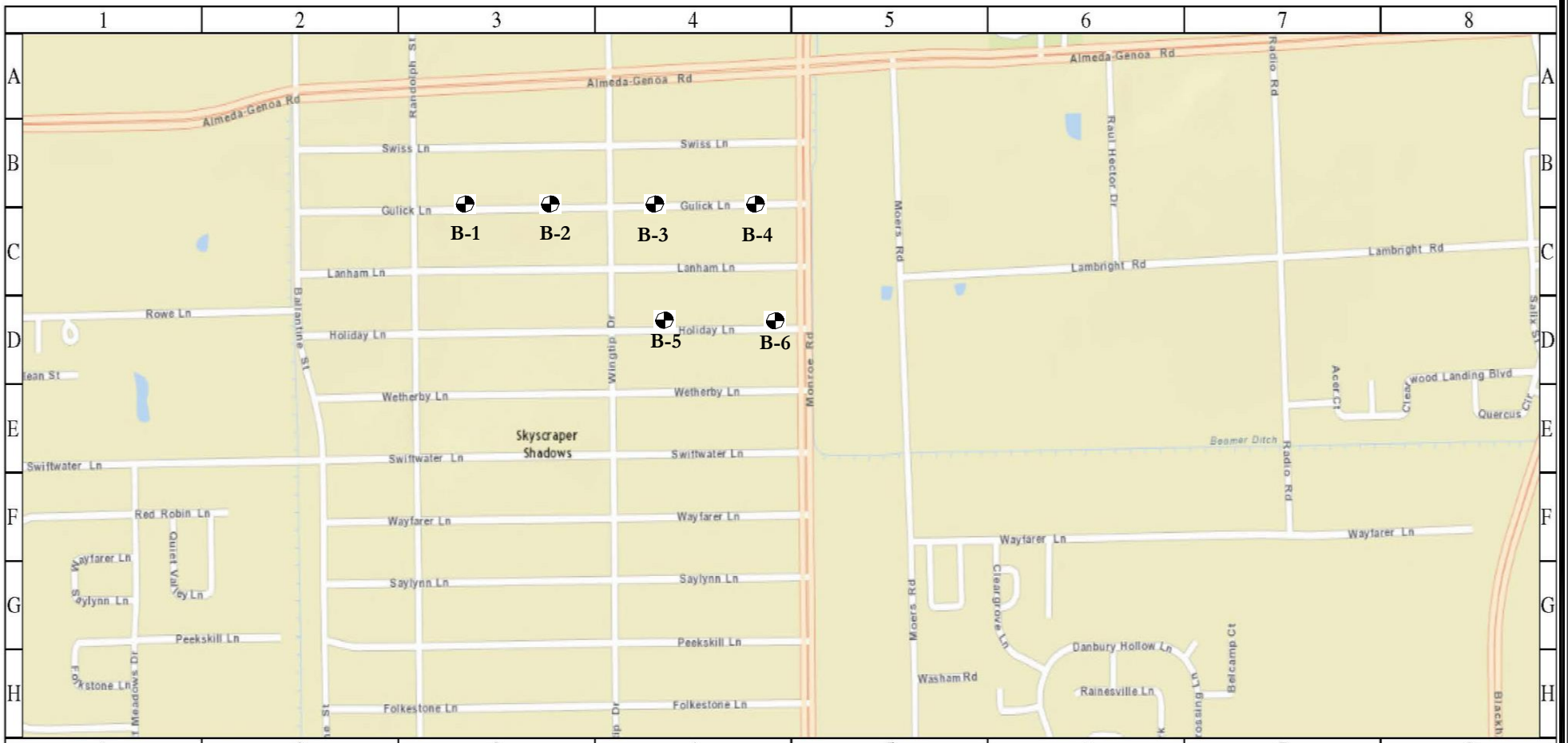
DISCLAIMER: THIS MAP REPRESENTS THE BEST INFORMATION AVAILABLE TO THE CITY. THE CITY DOES NOT WARRANT ITS ACCURACY OR COMPLETENESS. FIELD VERIFICATIONS SHOULD BE DONE AS NECESSARY.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 1/5/2015	APPROVED BY: SV	PREPARED BY: SS

SITE VICINITY
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No. M-000126-0070-3

PROJECT NO.:	DRAWING NO.:
98-240G-06	PLATE 1



N
W E
S

1 inch = 283 feet

CITY OF HOUSTON
Department of Public Works and Engineering
Geographic Information & Management System (GIMS)

DISCLAIMER: THIS MAP REPRESENTS THE BEST INFORMATION AVAILABLE TO THE CITY.
THE CITY DOES NOT WARRANT ITS ACCURACY OR COMPLETENESS.
FIELD VERIFICATIONS SHOULD BE DONE AS NECESSARY.

LEGEND:

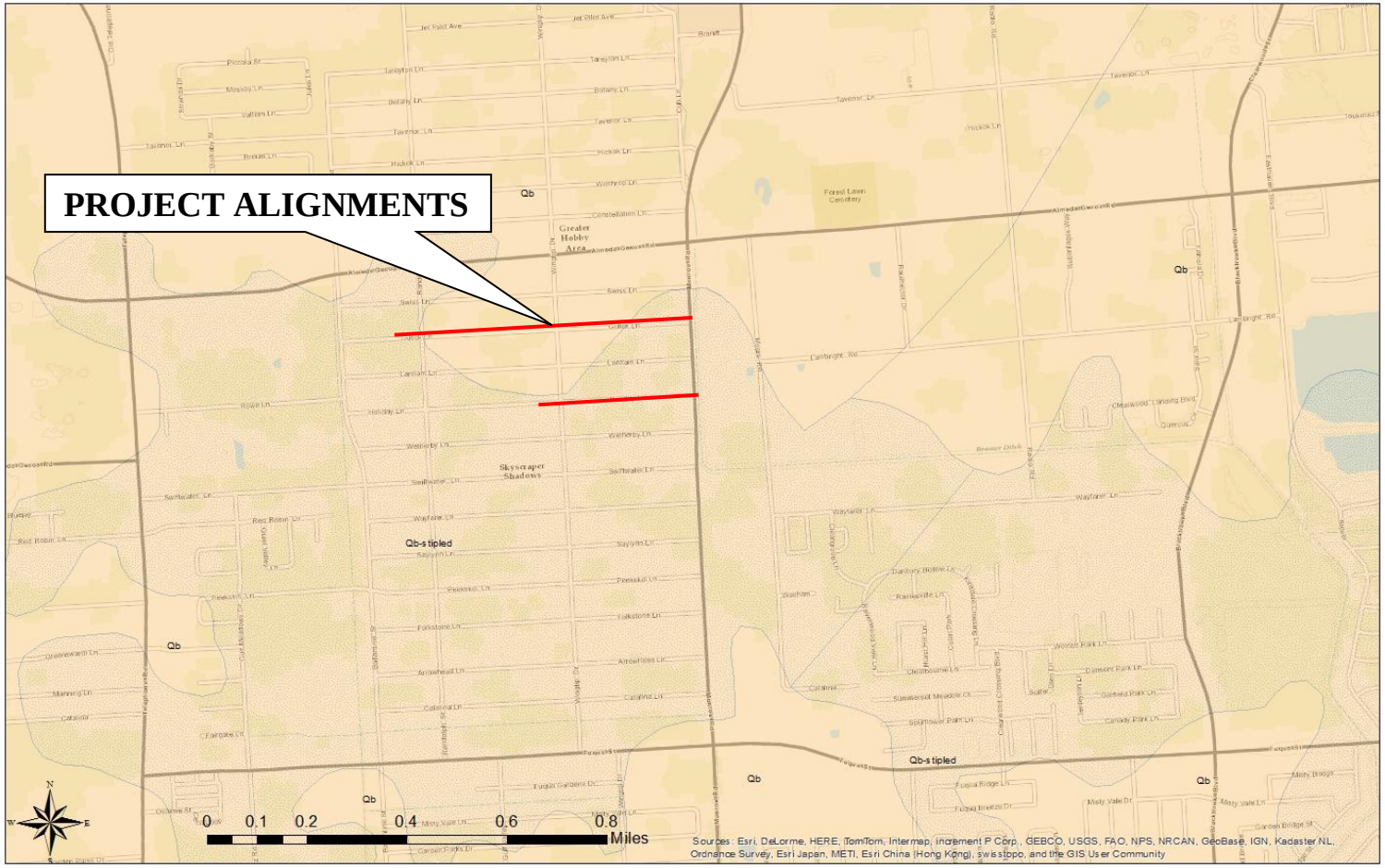
APPROXIMATE BORING LOCATIONS

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/30/2014	APPROVED BY: SV	PREPARED BY: SS

PLAN OF BORINGS
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No. M-000126-0070-3

PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE 2



Qb-stipled

<u>Beaumont Formation</u> -- Dominantly clay and mud of low permeability, high water-holding capacity, high compressibility, high to very high shrink-swell potential, poor drainage, level to depressed relief, low shear strength, and high plasticity; geologic units include interdistributary muds, abandoned channel-fill muds, and overbank fluvial muds.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/29/2014	APPROVED BY: SV	PREPARED BY: RS

GEOLOGIC MAP
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No. M-000126-0070-3

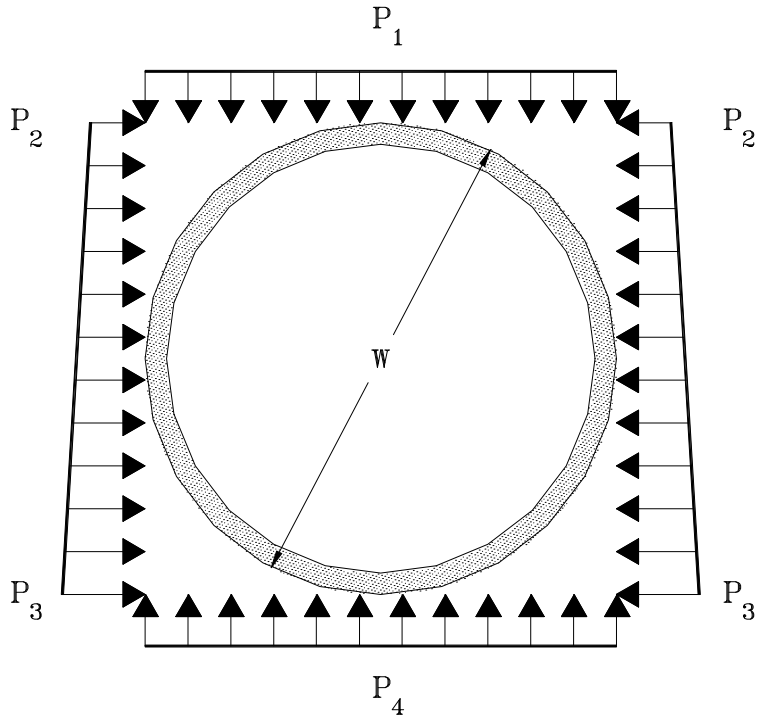
PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE 3

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/29/2014	APPROVED BY: SV	PREPARED BY: RS

FAULT MAP
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No. M-000126-0070-3

PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE 4



For

$D_w \leq H$

$P_1 = \gamma D_w + (H - D_w)(\gamma - \gamma_w) + P_s + (H - D_w)\gamma_w$

$P_2 \equiv [\gamma D_w + (H - D_w)(\gamma - \gamma_w) + P_s]K_o + (H - D_w)\gamma_w$

$P_3 = [\gamma D_w + (H + W - D_w)(\gamma - \gamma_w) + P_s]K_o + (H + W - D_w)\gamma_w$

$P_4 = \gamma D_w + (H + W - D_w)(\gamma - \gamma_w) + P_s + (H + W - D_w)\gamma_w$

For

$H < D_w < H + W$

$P_1 \equiv H\gamma + P_s$

$P_2 = (\gamma H + P_s)K_o$

$P_3 = [\gamma D_w + (H + W - D_w)(\gamma - \gamma_w) + P_s]K_o + (H + W - D_w)\gamma_w$

$P_4 = \gamma D_w + (H + W - D_w)(\gamma - \gamma_w) + P_s + (H + W - D_w)\gamma_w$

For

$D_w \geq (H + W)$

$P_1 \equiv H\gamma + P_s$

$P_2 = (\gamma H + P_s)K_o$

$P_3 = [(H + W)\gamma + P_s]K_o$

$P_4 = (H + W)\gamma + P_s$

Where

P_1, P_2, P_3 = Pressure imposed on pipe, psf

D_w = Depth of groundwater, feet

H = Depth of top of pipe from ground surface, feet

W = Diameter of pipe, feet

γ = Total Unit weight of soil, pcf

γ_w = Unit weight of water, pcf

P_s = Surcharge load, psf

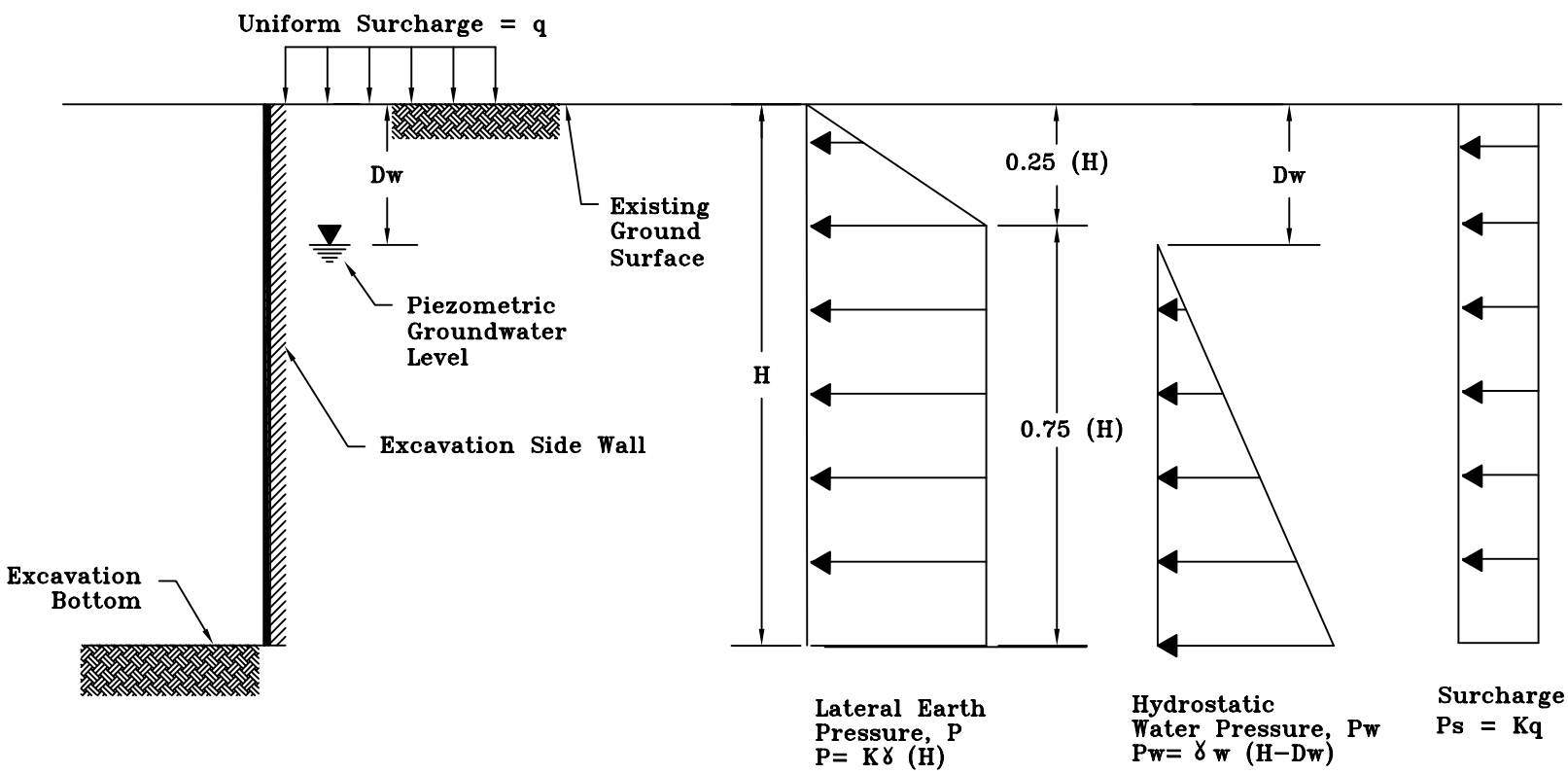
K_o = Coefficient of earth pressure, (1.0 for clays and 0.5 for sands)

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 1/5/2015	APPROVED BY: SV	PREPARED BY: FD

RIGID PIPE LOADS
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No.: M-00126-0070-3

PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE 5



H, (ft) = Depth to Excavation Bottom

Ps, (psf) = Surcharge loading adjacent to Excavation wall

Dw, (ft) = Depth to groundwater below Existing grade

= Zero for temporary excavation

K = Lateral Earth Pressure coefficient

= Ka "active" for short-term conditions (use 0.50)

= Ko "at rest" for long-term conditions (use 1.0)

γ, (pcf) = Total unit weight above water table or submerged unit weight below groundwater level

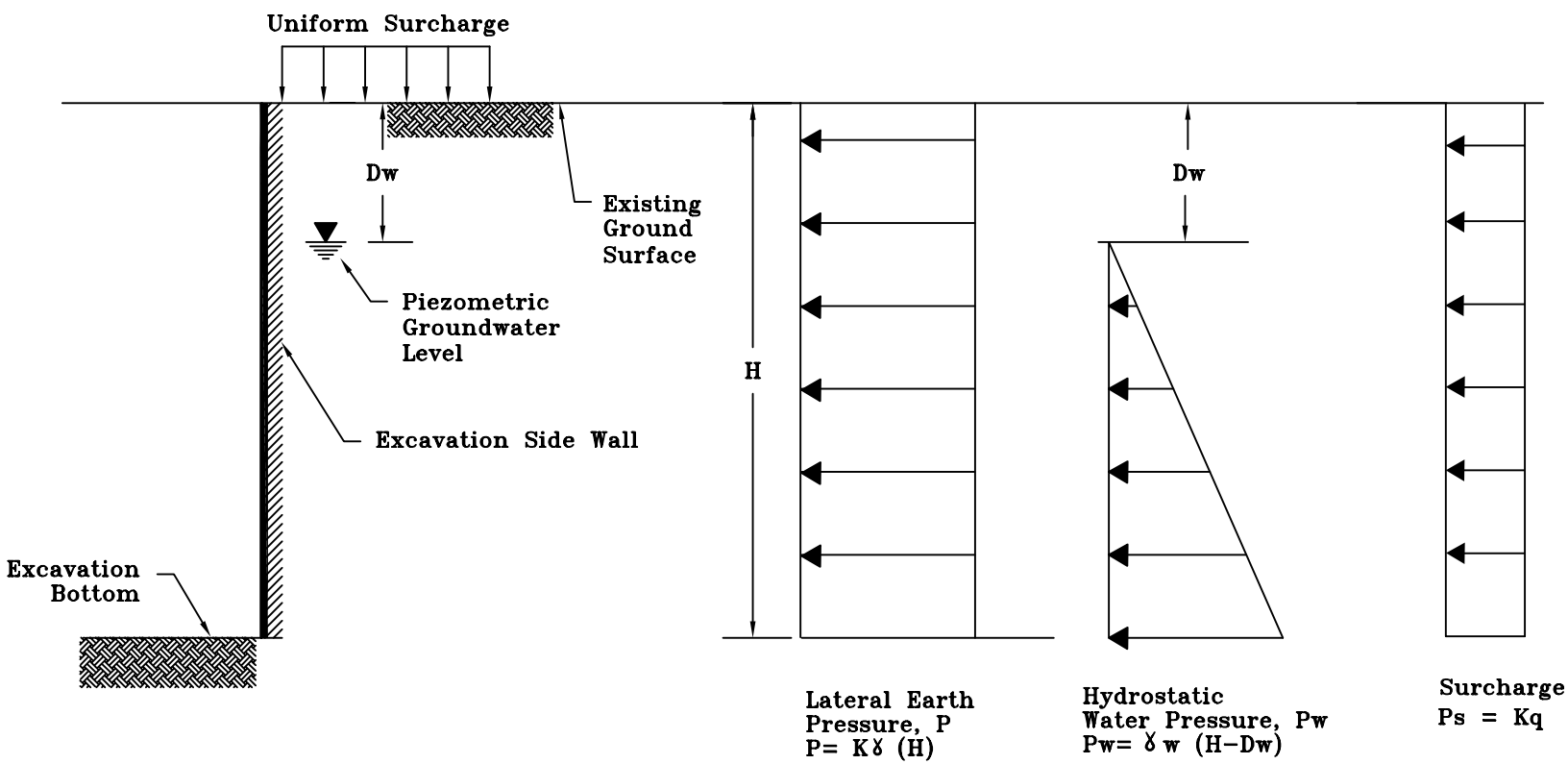
γw, (pcf) = Unit weight of water = 62.4 pcf

Note: The pressure diagram shown is not appropriate for design of cantilever walls.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

BRACED EXCAVATION
LATERAL EARTH PRESSURE DIAGRAM (CLAY)
WBS No.: M-00126-0070-3

PROJECT NO.:	DRAWING NO.:
98-240G-06	PLATE 6A



H, (ft) = Depth to Excavation Bottom

Ps, (psf) = Surcharge loading adjacent to Excavation wall

Dw, (ft) = Depth to groundwater below Existing grade

= Zero for temporary excavation

K = Lateral Earth Pressure coefficient

= Ka "active" for short-term conditions (use 0.35)

= Ko "at rest" for long-term conditions (use 0.50)

γ, (pcf) = Total unit weight above water table or submerged unit weight below groundwater level

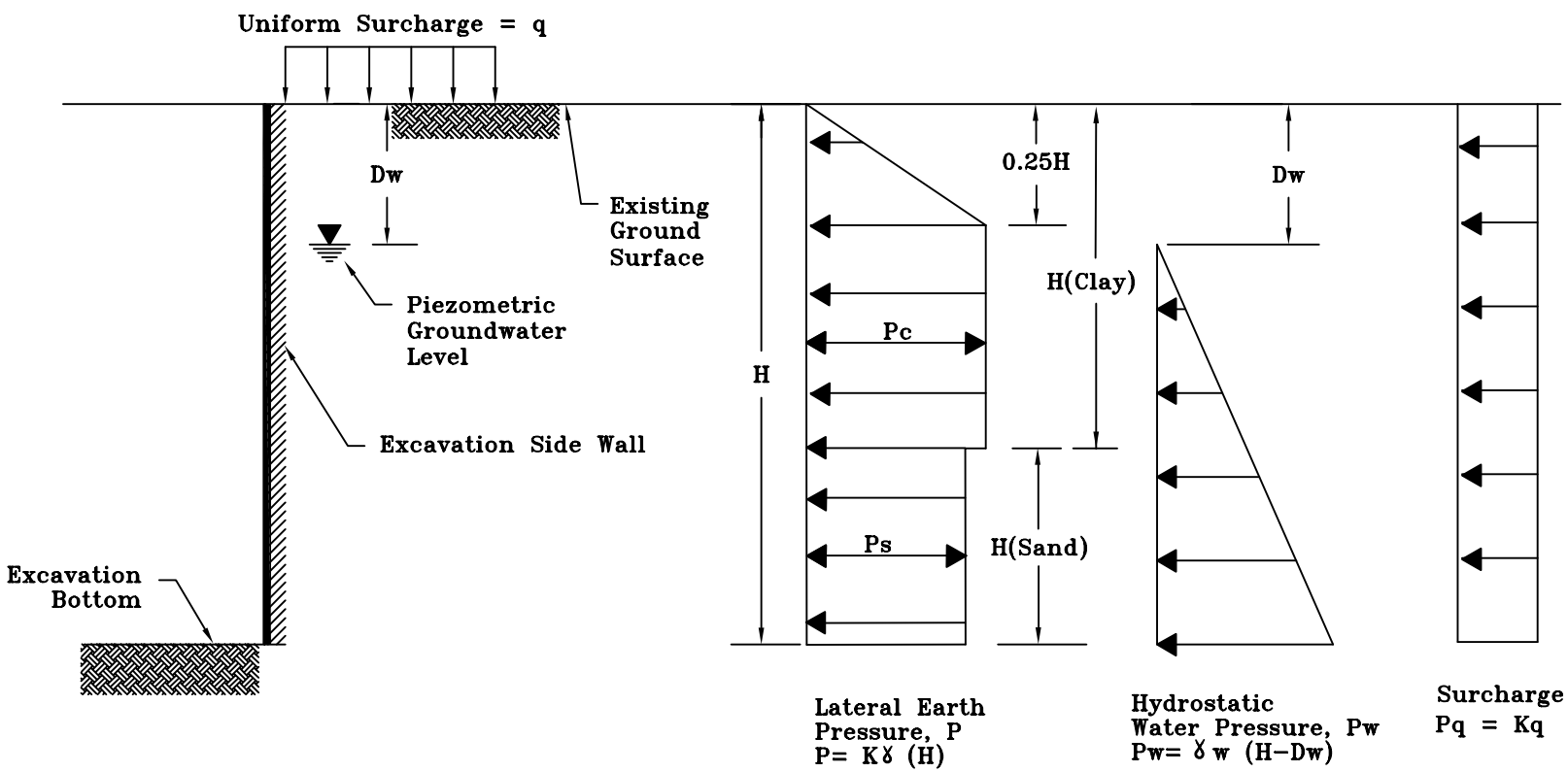
γw, (pcf) = Unit weight of water = 62.4 pcf

Note: The pressure diagram shown is not appropriate for design of cantilever walls.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

BRACED EXCAVATION
LATERAL EARTH PRESSURE DIAGRAM (SAND/SILT)
WBS No.: M-00126-0070-3

PROJECT NO.:	DRAWING NO.:
98-240G-06	PLATE 6B



H, (ft) = Depth to Excavation Bottom

Ps, (psf) = Surcharge loading adjacent to Excavation wall

Dw, (ft) = Depth to groundwater below Existing grade

= Zero for temporary excavation

γ, (pcf) = Total unit weight above water table or submerged unit weight below groundwater level

γw, (pcf) = Unit weight of water = 62.4 pcf

Kc = Lateral Earth Pressure coefficient of clay
= Ka "active" for short-term conditions (use 0.50)
= Ko "at rest" for long-term conditions (use 1.0)

Ks = Lateral Earth Pressure coefficient of sand
= Ka "active" for short-term conditions (use 0.35)
= Ko "at rest" for long-term conditions (use 0.50)

Note: The pressure diagram shown is not appropriate for design of cantilever walls.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

BRACED EXCAVATION
LATERAL EARTH PRESSURE DIAGRAM (CLAY OVER SAND)
WBS No.: M-000126-0070-3

PROJECT NO.:	DRAWING NO.:
98-240G-06	PLATE 6C

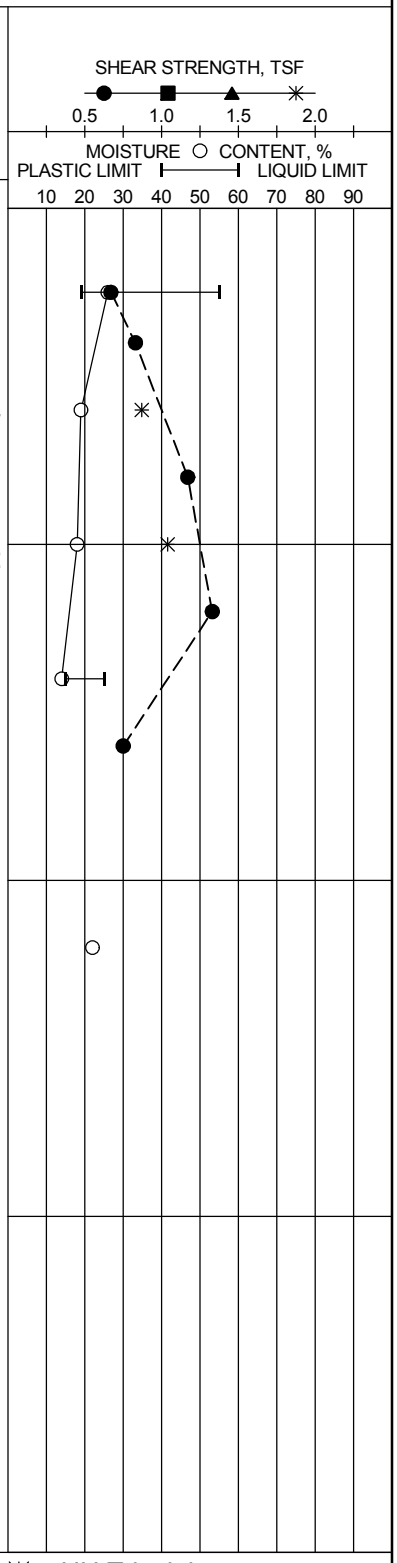
APPENDIX A

BORING LOGS AND KEY TO TERMS & SYMBOLS

LOG OF BORING

Project: Skyscaper Shadows Storm Sewer | WBS No: M-00126-0070-3 | Project No.: 98-240G-06
Boring No.: B-1 | Date: 12/11/2014 | Elevation: 43.51 feet
Groundwater during drilling: 11 feet | Northing: 13,795,000.0 | Station: --
Groundwater 24 hours after drilling: --- | Easting: 3,152,916.5 | Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		Pavement: 3" Asphalt, 8" Cement Treated Crushed Limestone Base, 4" Stabilized Shell Base		
		Stiff to very stiff, grayish brown, FAT CLAY WITH SAND (CH)	77.9	117
40 / 5				112
		Stiff to very stiff, brownish gray, SANDY LEAN CLAY (CL)	55.6	
35 / 10	2-3-4	Loose to medium dense, brown, SAND WITH SILT (SP-SM)	12.0	
	4-12-14			
30 / 15	7-9-11			
25 / 20				



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

PLATE A-1

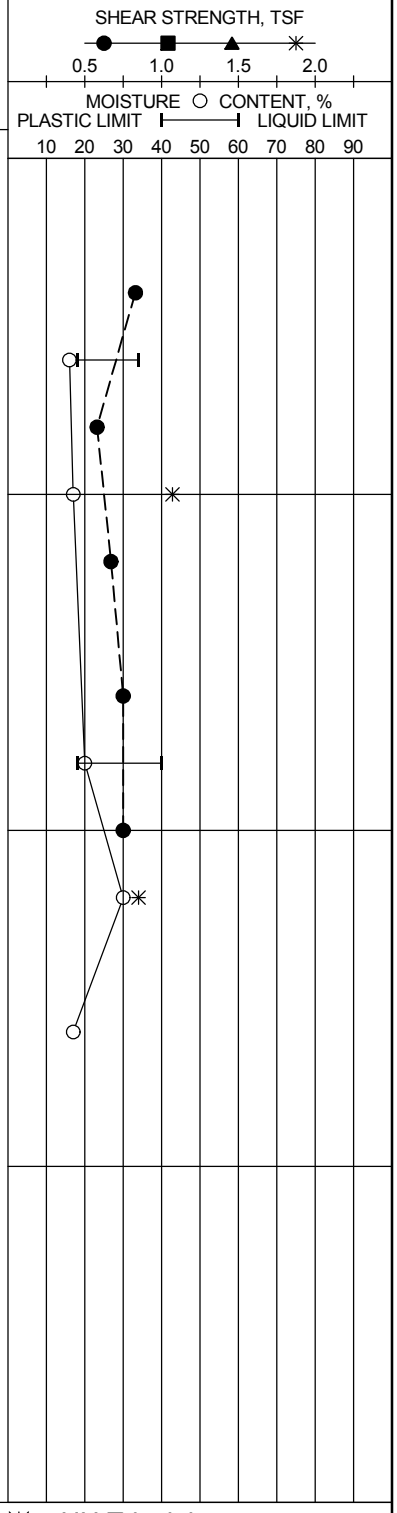
HVJ ASSOCIATES

LOG OF SOIL BORING 98-240G-06.GPJ HVJ.GDT 2/20/15

LOG OF BORING

Project: Skyscaper Shadows Storm Sewer | WBS No: M-00126-0070-3 | Project No.: 98-240G-06
Boring No.: B-2 | Date: 12/17/2014 | Elevation: 44.42 feet
Groundwater during drilling: --- | Northing: 13,795,009.7 | Station: --
Groundwater 24 hours after drilling: --- | Easting: 3,153,397.9 | Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		Pavement: 4" Asphalt, 8" Cement Treated Crushed Limestone Base, 4" Stabilized Shell Base		
		Stiff to very stiff, dark gray to light brownish gray, LEAN CLAY WITH SAND (CL), w/ calcareous nodules	73.7	111
		Stiff to very stiff, grayish brown to brown, SANDY LEAN CLAY (CL), w/ silt	51.9	99
	6-7-10			
	7-9-13			



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

PLATE A-2

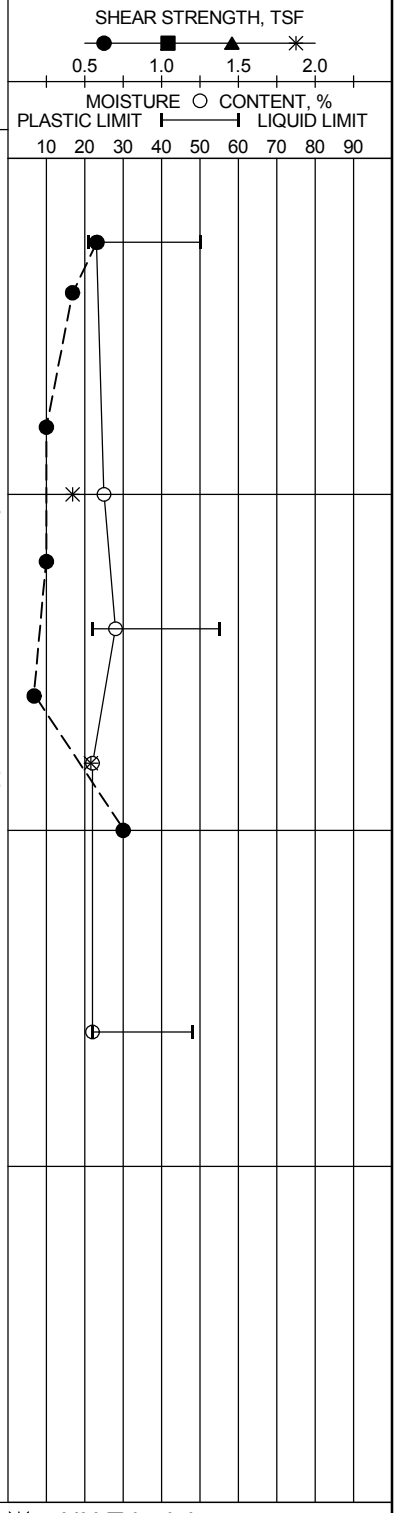
HVJ ASSOCIATES

LOG OF SOIL BORING 98-240G-06.GPJ HVJ.GDT 2/20/15

LOG OF BORING

Project: Skyscaper Shadows Storm Sewer | WBS No: M-00126-0070-3 | Project No.: 98-240G-06
Boring No.: B-3 | Date: 12/17/2014 | Elevation: 45.03 feet
Groundwater during drilling: --- | Northing: 13,795,042.0 | Station: --
Groundwater 24 hours after drilling: --- | Easting: 3,153,887.0 | Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
45 — 0		Pavement: 3" Asphalt, 8" Cement Treated Crushed Limestone Base, 4" Stabilized Shell Base		
		Soft to stiff, dark grayish brown to brownish gray, FAT CLAY (CH), w/ calcareous nodules		
40 — 5				104
			93.2	
				102
35 — 10		Stiff, brown, LEAN CLAY (CL), w/ calcareous nodules		
	5-5-7			
	5-7-7		90.2	
30 — 15				
20				



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

PLATE A-3

HVJ ASSOCIATES

LOG OF SOIL BORING 98-240G-06.GPJ HVJ.GDT 2/20/15

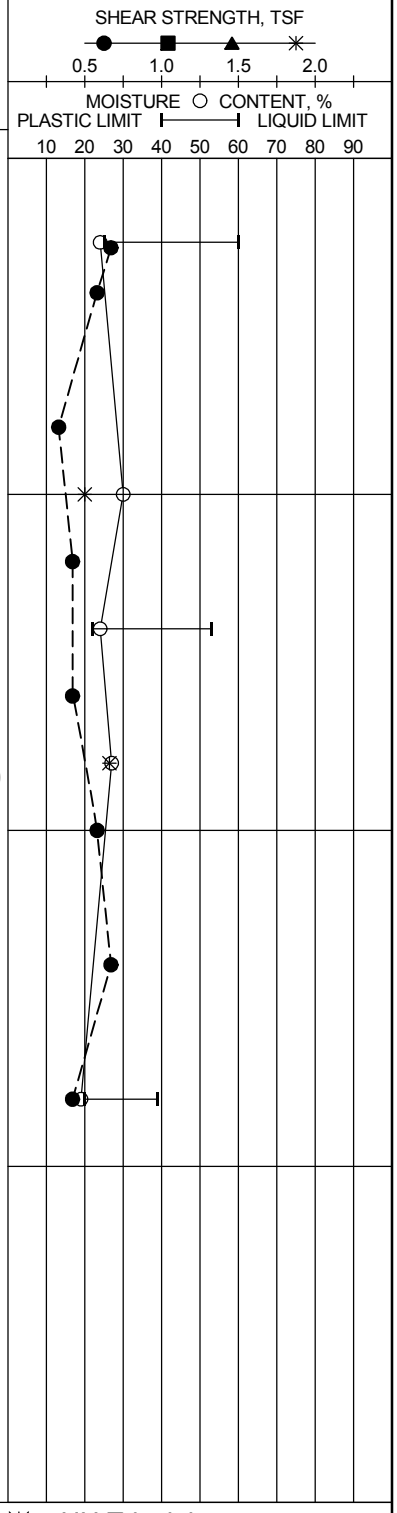
LOG OF BORING

Project: Skyscaper Shadows Storm Sewer
Boring No.: B-4
Groundwater during drilling: 13.7 feet
Groundwater 24 hours after drilling: ---

WBS No: M-00126-0070-3
Date: 12/17/2014
Northing: 13,795,067.6
Easting: 3,154,411.4

Project No.: 98-240G-06
Elevation: 44.82 feet
Station: --
Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		Pavement: 3.5" Asphalt, 8" Cement Treated Crushed Limestone Base, 4" Stabilized Shell Base		
		Firm to stiff, dark grayish brown to grayish brown, FAT CLAY (CH), w/ ferrous stains and calcareous nodules	90.0	
40 / 5				91
				100
35 / 10		Firm to stiff, brown, LEAN CLAY (CL), w/ calcareous nodules and silt seams		
			91.1	
30 / 15				
25 / 20				



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

PLATE A-4

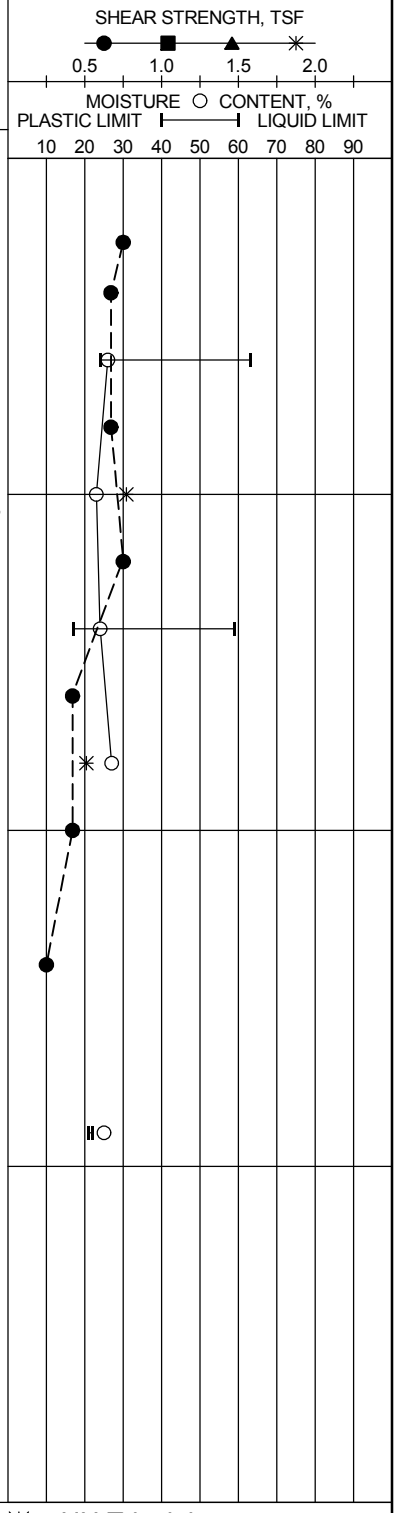
HVJ ASSOCIATES

LOG OF SOIL BORING 98-240G-06.GPJ HVJ.GDT 2/20/15

LOG OF BORING

Project: Skyscaper Shadows Storm Sewer | WBS No: M-00126-0070-3 | Project No.: 98-240G-06
Boring No.: B-5 | Date: 12/11/2014 | Elevation: 44.82 feet
Groundwater during drilling: 11 feet | Northing: 13,794,291.9 | Station: --
Groundwater 24 hours after drilling: --- | Easting: 3,154,125.9 | Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
0		Pavement: 3" Asphalt, 8" Cement Treated Crushed Limestone Base, 4" Stabilized Shell Base		
		Firm to stiff, dark grayish brown to reddish brown and gray, FAT CLAY (CH), w/ ferrous stains		
40 — 5				104
				99
35 — 10				
	3-4-5	Loose, brown, SILT WITH SAND (ML)	80.6	
30 — 15				
25 — 20				



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

PLATE A-5

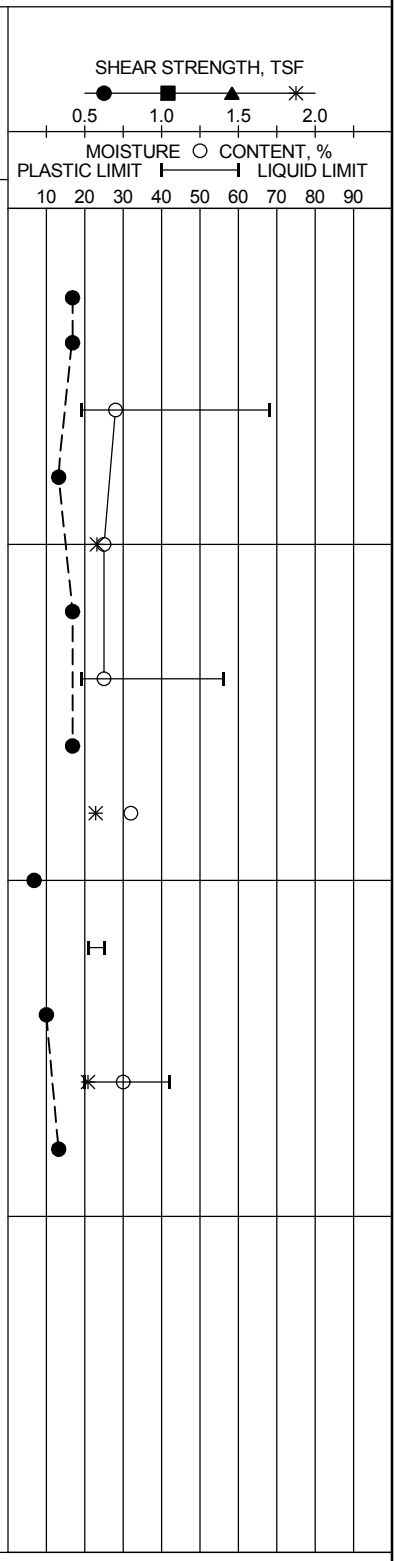
HVJ ASSOCIATES

LOG OF SOIL BORING 98-240G-06.GPJ HVJ.GDT 2/20/15

LOG OF BORING

Project: Skyscaper Shadows Storm Sewer | WBS No: M-00126-0070-3 | Project No.: 98-240G-06
Boring No.: B-6 (PZ) | Date: 12/11/2014 | Elevation: 45.28 feet
Groundwater during drilling: --- | Northing: 13,794,310.6 | Station: --
Groundwater 24 hours after drilling: 12.1 feet | Easting: 3,154,539.6 | Offset: --

ELEV. DEPTH, FEET	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	SOIL/ROCK CLASSIFICATION	% PASSING NO. 200 SIEVE	DRY DENSITY PCF
45 / 0		Pavement: 4" Asphalt, 8" Cement Treated Crushed Limestone Base, 4" Stabilized Shell Base		
		Firm to stiff, dark gray to gray, FAT CLAY (CH), w/ ferrous stains and calcareous nodules		
40 / 5				98
				95
35 / 10		Loose, brown, SANDY SILT (ML)	49.8	
		Firm to stiff, grayish brown, LEAN CLAY (CL), w/ trace silt	94.6	98
30 / 15				
20				



Shear Types: ● = Hand Penet. ■ = Torvane ▲ = Unconf. Comp. ✳ = UU Triaxial

PLATE A-6

HVJ ASSOCIATES

LOG OF SOIL BORING 98-240G-06.GPJ HVJ.GDT 2/20/15

SOIL SYMBOLS

Soil Types

Clay | Silt | Sand | Gravel

Modifiers

Clayey | Silty | Sandy | Cemented

Construction Materials

Asphaltic Concrete | Stabilized Base | Fill or Debris | Portland Cement Concrete

SAMPLER TYPES

- Thin Walled Shelby Tube
- No Recovery
- Split Barrel
- Core
- Liner Tube
- Jar Sample

WATER LEVEL SYMBOLS

- Groundwater level after drilling in open borehole or piezometer
- Groundwater level determined during drilling operations

SOIL GRAIN SIZE

Classification	Particle Size	Particle Size or Sieve No. (U.S. Standard)
Clay	< 0.002 mm	< 0.002 mm
Silt	0.002 - 0.075 mm	0.002 mm - #200 sieve
Sand	0.075 - 4.75 mm	#200 sieve - #4 sieve
Gravel	4.75 - 75 mm	#4 sieve - 3 in.
Cobble	75 - 200 mm	3 in. - 8 in.
Boulder	> 200 mm	> 8 in.

DENSITY OF COHESIONLESS SOILS

Descriptive Term	Penetration Resistance "N" * Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	> 50

CONSISTENCY OF COHESIVE SOILS

Consistency	Undrained Shear Strength (tsf)	Penetration Resistance "N" * Blows/Foot
Very Soft	0 - 0.125	0 - 2
Soft	0.125 - 0.25	2 - 4
Firm	0.25 - 0.5	4 - 8
Stiff	0.5 - 1.0	8 - 16
Very Stiff	1.0 - 2.0	16 - 32
Hard	> 2.0	> 32

PENETRATION RESISTANCE

3/6	Blows required to penetrate each of three consecutive 6-inch increments per ASTM D-1586 *
50/4"	If more than 50 blows are required, driving is discontinued and penetration at 50 blows is noted
0/18"	Sampler penetrated full depth under weight of drill rods and hammer

* The N value is taken as the blows required to penetrate the final 12 inches

TERMS DESCRIBING SOIL STRUCTURE

Slickensided	Fracture planes appear polished or glossy, sometimes striated
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Inclusion	Small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Parting	Inclusion less than 1/4 inch thick extending through the sample
Seam	Inclusion 1/4 inch to 3 inches thick extending through the sample
Layer	Inclusion greater than 3 inches thick extending through the sample
Laminated	Soil sample composed of alternating partings of different soil type
Stratified	Soil sample composed of alternating seams or layers of different soil type
Intermixed	Soil sample composed of pockets of different soil type and laminated or stratified structure is not evident
Calcareous	Having appreciable quantities of calcium carbonate
Ferrous	Having appreciable quantities of iron
Nodule	A small mass of irregular shape

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

KEY TO TERMS AND SYMBOLS USED ON BORING LOGS

PROJECT NO.: 98-240G-06

DRAWING NO.: PLATE A-7

APPENDIX B

SUMMARY OF LABORATORY TEST RESULTS

Project: Skyscraper Shadows Local Drainage Project
Location: Houston, Texas
Number: 98-240G-06 (WBS No. M-000126-0070-3)

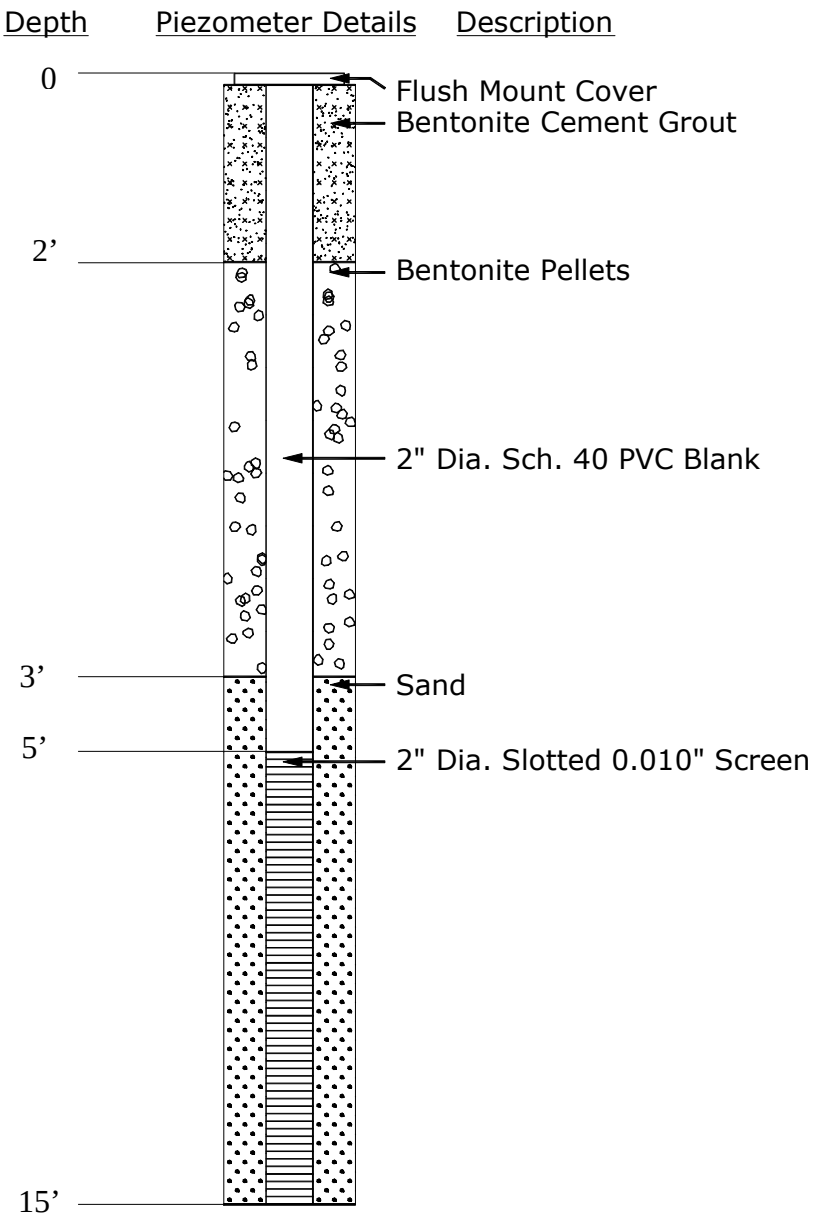
Borehole	Depth	Liquid Limit	Plasticity Index	% Pass #200 Sieve	Moisture Content (%)	Wet Density (pcf)	Shear Strength (UU) (tsf)	Shear Strength (Pocket Pen) (tsf)
B-1	0							0.67
	1	55	36	78	26			
	2							0.83
	3				19	139	0.9	
	4							1.17
	5				18	133	1.0	
	6							1.33
	7	25	10		14			
	8							0.75
	11			12	22			
B-2	2							0.83
	3	34	16	74	16			
	4							0.58
	5				17	131	1.1	
	6							0.67
	8							0.75
	9	40	22		20			
	10							0.75
	11				30	128	0.9	
	13			52	17			
B-3	0							0.58
	1	50	29		23			
	2							0.42
	4							0.25
	5				25	129	0.4	
	6							0.25
	7	55	33	93	28			
	8							0.17
	9				22	125	0.5	
	10							0.75
	13	48	26		22			
	14			90				
B-4	0							0.67
	1	60	35		24			
	2							0.58
	3			90				
	4							0.33
	5				30	119	0.5	
	6							0.42
	7	53	31		24			
	8							0.42
	9				27	127	0.7	
	10							0.58

Project: Skyscraper Shadows Local Drainage Project
Location: Houston, Texas
Number: 98-240G-06 (WBS No. M-000126-0070-3)

Borehole	Depth	Liquid Limit	Plasticity Index	% Pass #200 Sieve	Moisture Content (%)	Wet Density (pcf)	Shear Strength (UU) (tsf)	Shear Strength (Pocket Pen) (tsf)
B-4	12							0.67
	14	39	19	91	19			0.42
B-5	0							0.75
	2							0.67
	3	63	39		26			
	4							0.67
	5				23	128	0.8	
	6							0.75
	7	59	42		24			
	8							0.42
	9				27	126	0.5	
	10							0.42
	12							0.25
	14.5	22	1	81	25			
B-6	0							0.42
	2							0.42
	3	68	49		28			
	4							0.33
	5				25	123	0.6	
	6							0.42
	7	56	37		26			
	8							0.42
	9				32	125	0.6	
	10							0.17
	11	25	4	50				
	12							0.25
	13	42	22	95	30	123	0.5	
	14							0.33
Total		**17**	**17**	**11**	**30**	**13**	**13**	**39**

APPENDIX C

PIEZOMETER INSTALLATION RECORDS



Water Level Readings

Date	Depth (ft.)	Elev. (ft.)
12/12/2014	12.1’	33.2’
1/11/2015	4.5’	40.8’

NOTES:

- Piezometer was installed on 12/11/2014.
- See Plate 2 for boring location.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

PIEZOMETER INSTALLATION REPORT
PIEZOMETER NO. PZ-1 (B-6)

PROJECT NO.:	DRAWING NO.:
98-240G-06	PLATE C-1

STATE OF TEXAS WELL REPORT for Tracking #387508

Owner:	**City of Houston**	Owner Well #:	**B6**
Address:	**611 Walker Houston , TX 77002**	Grid #:	**65-30-3**
Well Location:	**N/A Holiday Lane Houston , TX 77075**	Latitude:	**29° 37' 12" N**
Well County:	**Harris**	Longitude:	**095° 16' 17" W**
Elevation:	**No Data**	GPS Brand Used:	**Magellan**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date:	Started: **12/11/2014** Completed: **12/11/2014**
Diameter of Hole:	Diameter: **4 in From Surface To 15 ft**
Drilling Method:	**Mud Rotary**
Borehole Completion:	Other: **(No Data)**
Annular Seal Data:	1st Interval: **From 0 ft to 3 ft with .5 bentonite (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**20/40 3-15**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No Data** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No Data**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Envirotech Drilling Services 2718 South Brompton Drive Pearland , TX 77584**
Driller License Number:	**58171**

Licensed Well Driller Signature:	**Jaime Vasquez**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#387508**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft)	Description
0-10	**dark grey clay**
10-12	**brown sandy silt**
12-15	**greyish brown lean clay**

CASING, BLANK PIPE & WELL SCREEN DATA

Dia.	New/Used	Type	Setting From/To
2	**New**	**PVC Riser 0-5 Sch. 40**	
2	**New**	**PVC Sreen 5-15 .010**	

STATE OF TEXAS PLUGGING REPORT for Tracking #99624

Owner:	**City Of Houston**	Owner Well #:	**B6**
Address:	**611 Walker Houston , TX 77002**	Grid #:	**65-30-3**
Well Location:	**N/A Holiday Lane Houston , TX 77075**	Latitude:	**29° 37' 12" N**
Well County:	**Harris**	Longitude:	**095° 16' 17" W**
		GPS Brand Used:	**Magellan**

Well Type: **Monitor**

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	**Jaime Vasquez**
Driller's License Number of Original Well Driller:	**58171**
Date Well Drilled:	**12/11/2014**
Well Report Tracking Number:	**387508**
Diameter of Borehole:	**4 inches**
Total Depth of Borehole:	**15 feet**

Date Well Plugged:	**1/14/2015**
Person Actually Performing Plugging Operation:	**Jaime Vasquez**
License Number of Plugging Operator:	**58171**
Plugging Method:	**Pour in 3/8 bentonite chips when standing water in well is less than 100 feet in depth, cement top 2 feet.**
Plugging Variance #:	**No Data**
Casing Left Data:	1st Interval: **2 inches diameter, From 0 ft to 5 ft** 2nd Interval: **2 inches diameter, From 5 ft to 15 ft** 3rd Interval: **No Data**
Cement/Bentonite Plugs Placed in Well:	1st Interval: **From 0 ft to 3 ft; Sack(s)/type of cement used: .5 bentonite** 2nd Interval: **No Data** 3rd Interval: **No Data** 4th Interval: **No Data** 5th Interval: **No Data**

Certification Data:	The plug installer certified that the plug installer plugged this well (or the well was plugged under the plug installer's direct supervision) and that each and all of the statements herein are true and correct. The plug installer understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Envirotech Drilling Services 2718 South Brompton Drive Pearland , TX 77584** **58171**

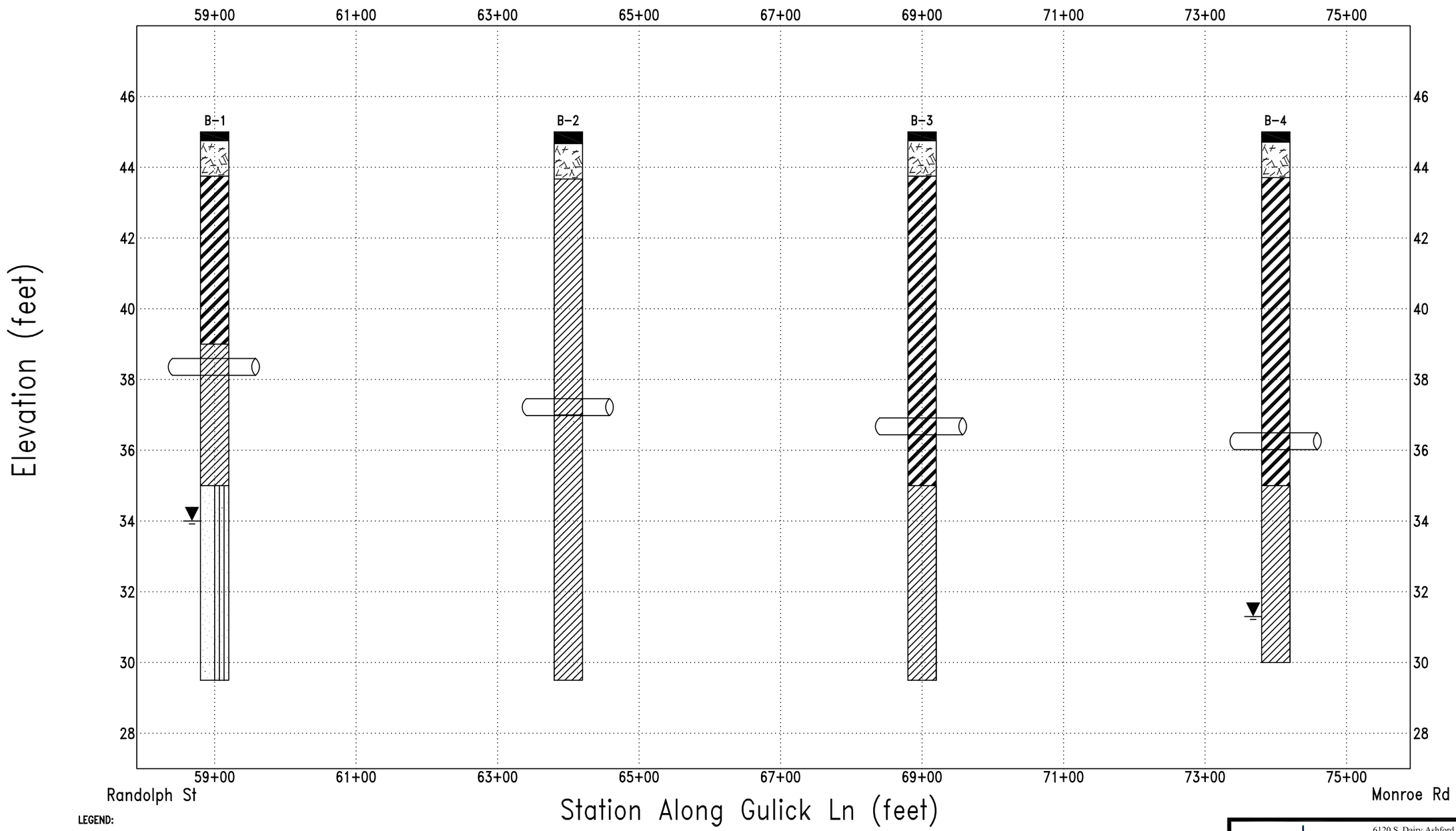
Plug Installer License Number:	
Licensed Plug Installer Signature:	**Jaime Vasquez**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**No Data**

Please include the plugging report's tracking number (Tracking **#99624**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

APPENDIX D

BORING LOG SOIL PROFILES



LEGEND:

- Asphalt
- Cement Treated Base / Stabilized Shell Base
- Fat Clay (CH)
- Lean Clay (CL)
- Sandy Lean Clay (CL)
- Sand with Silt (SP-SM)

APPROXIMATE INVERT ELEVATION OF PROPOSED UTILITY

GROUNDWATER ELEVATION ENCOUNTERED DURING DRILLING

24-HOUR PIEZOMETER READING

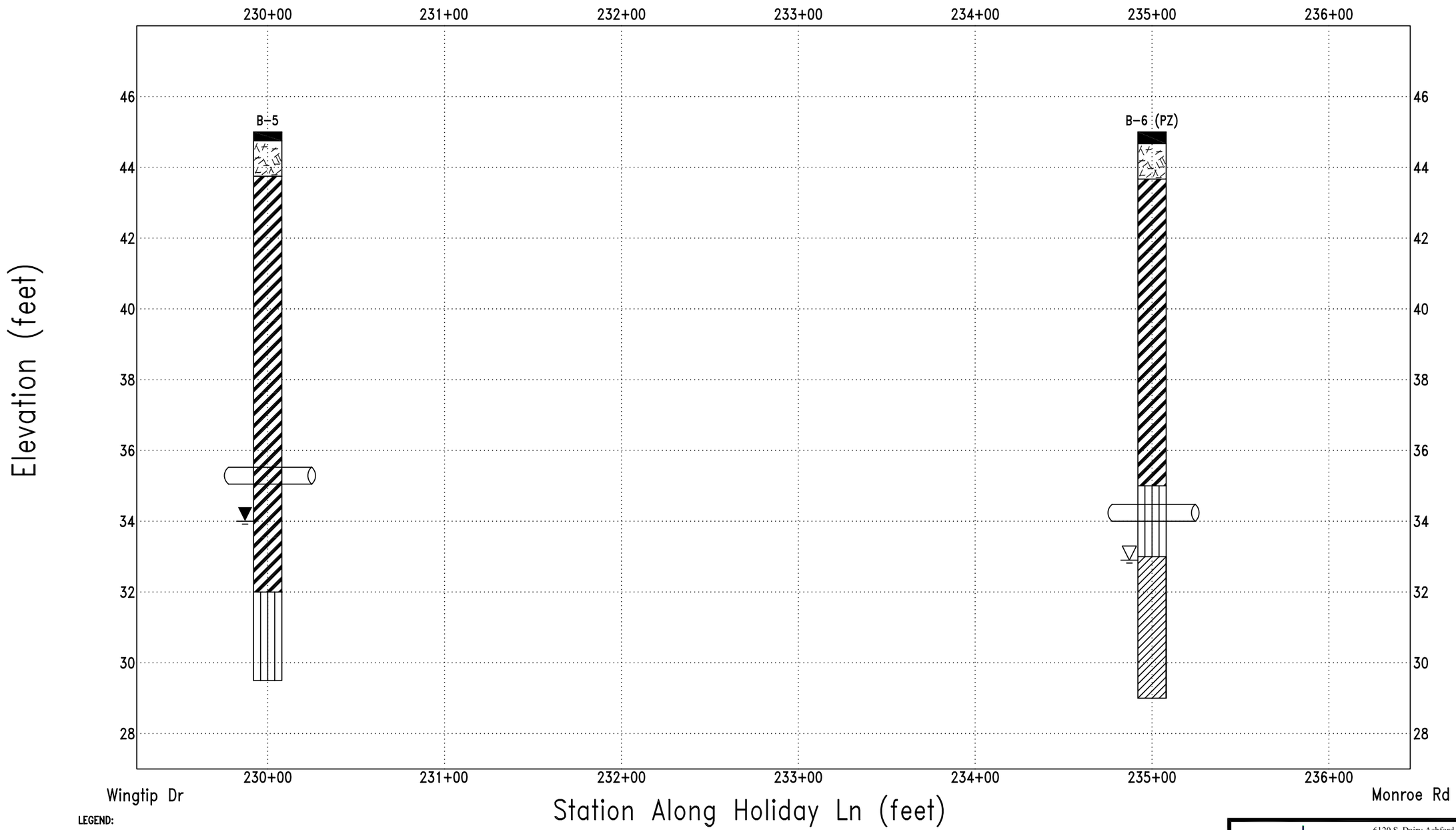
PROPOSED UTILITIES PROVIDED BY AECOM ON 12/17/2014. A 45-FT ELEVATION WAS ASSUMED FOR THE BORINGS.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/30/2014	APPROVED BY: SV	PREPARED BY: RS

BORING LOG PROFILE
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No.: M-000126-0070-3

PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE D-1



LEGEND:

- Asphalt
- Cement Treated Base / Stabilized Shell Base
- Fat Clay (CH)
- Lean Clay (CL)
- Sandy Lean Clay (CL)
- Silt with Sand (ML)

APPROXIMATE INVERT ELEVATION OF PROPOSED UTILITY

GROUNDWATER ELEVATION ENCOUNTERED DURING DRILLING

24-HOUR PIEZOMETER READING

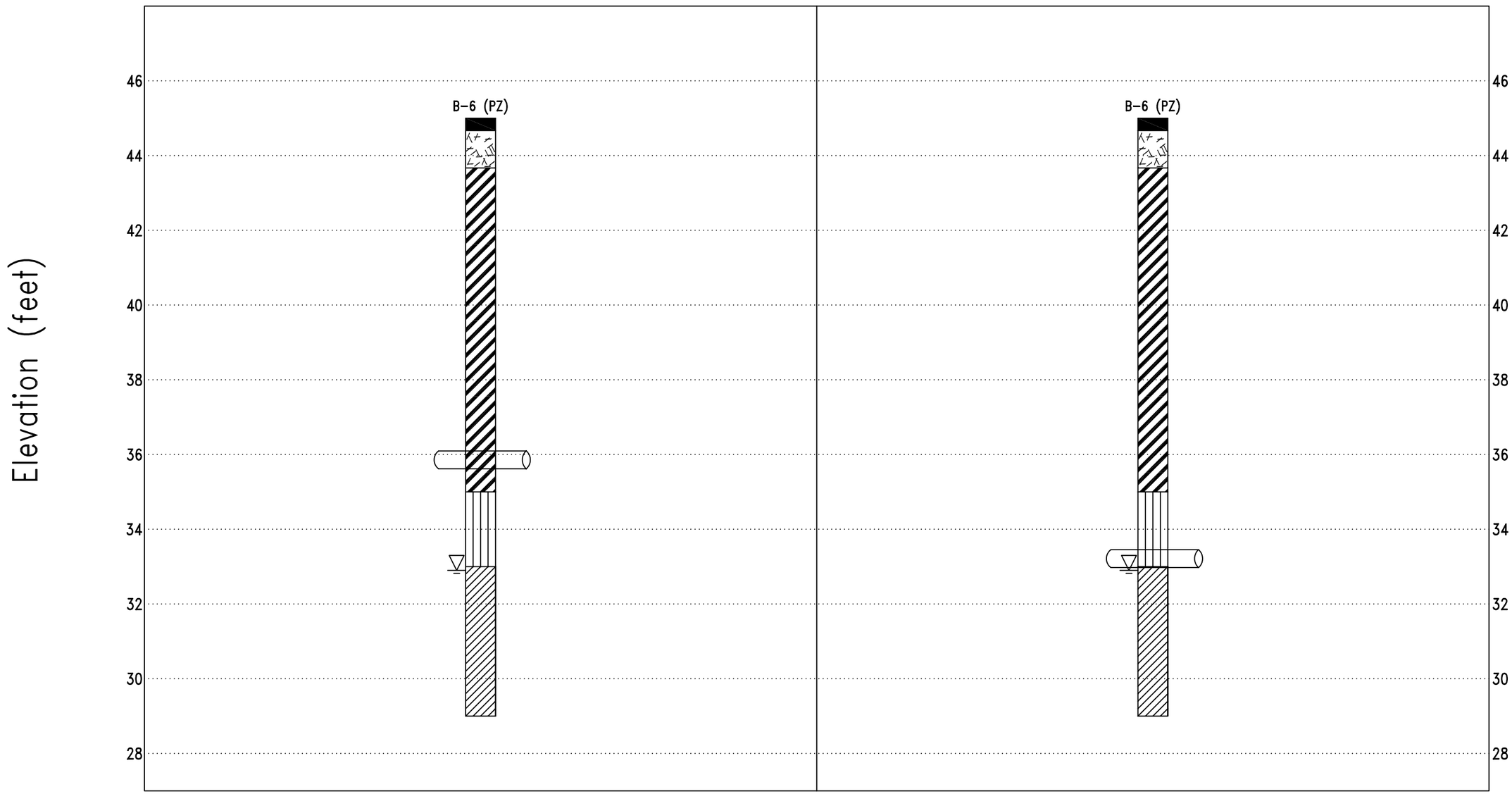
PROPOSED UTILITIES PROVIDED BY AECOM ON 12/17/2014. A 45-FT ELEVATION WAS ASSUMED FOR THE BORINGS.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/30/2014	APPROVED BY: SV	PREPARED BY: RS

BORING LOG PROFILE
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No.: M-000126-0070-3

PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE D-2



Wetherby Ln (STA 334+40 to 337+60)

Swift Water Ln (STA 434+00 to 436+20)

LEGEND:

- Asphalt
- Cement Treated Base / Stabilized Shell Base
- Fat Clay (CH)
- Lean Clay (CL)
- Sandy Lean Clay (CL)
- Silt with Sand (ML)

APPROXIMATE INVERT ELEVATION OF PROPOSED UTILITY

GROUNDWATER ELEVATION ENCOUNTERED DURING DRILLING

24-HOUR PIEZOMETER READING

PROPOSED UTILITIES PROVIDED BY AECOM ON 12/17/2014. A 45-FT ELEVATION WAS ASSUMED FOR THE BORINGS.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/30/2014	APPROVED BY: SV	PREPARED BY: RS

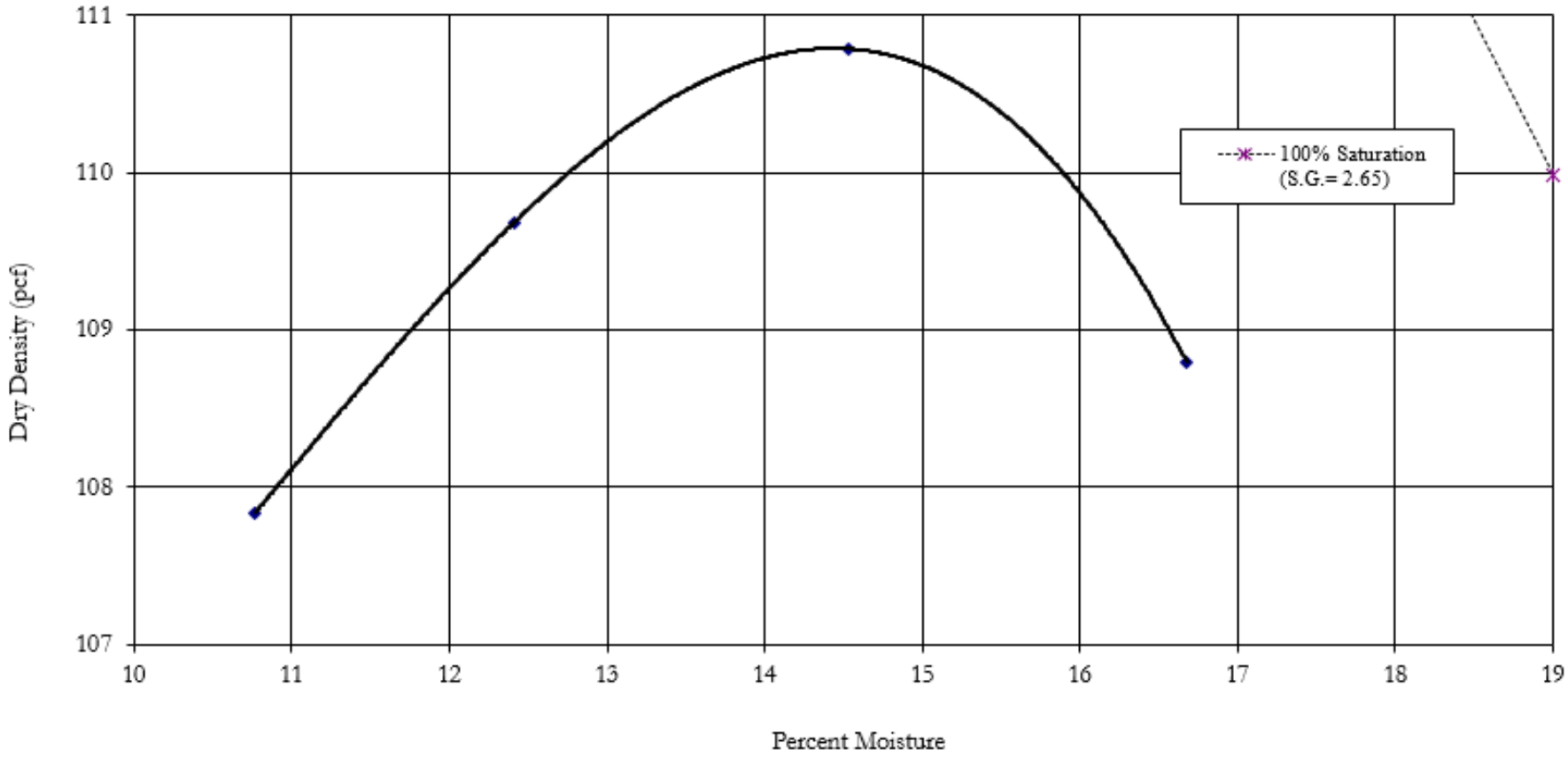
BORING LOG PROFILE
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No.: M-000126-0070-3

PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE D-3

APPENDIX E

STANDARD PROCTOR & CBR TEST RESULTS

METHOD OF TEST ☑ STANDARD ASTM D-698 ☐ MODIFIED ASTM D-1557



DATE TESTED:	12/23/14	
TYPE OF MATERIAL :	Brownish Gray Lean Clay with Sand (CL)	
MAXIMUM DRY DENSITY :	110.8	pcf
OPT. MOISTURE CONTENT :	14.4	%

LIQUID LIMIT :	40
PLASTICITY INDEX :	24
-200 SEIVE % :	76.7

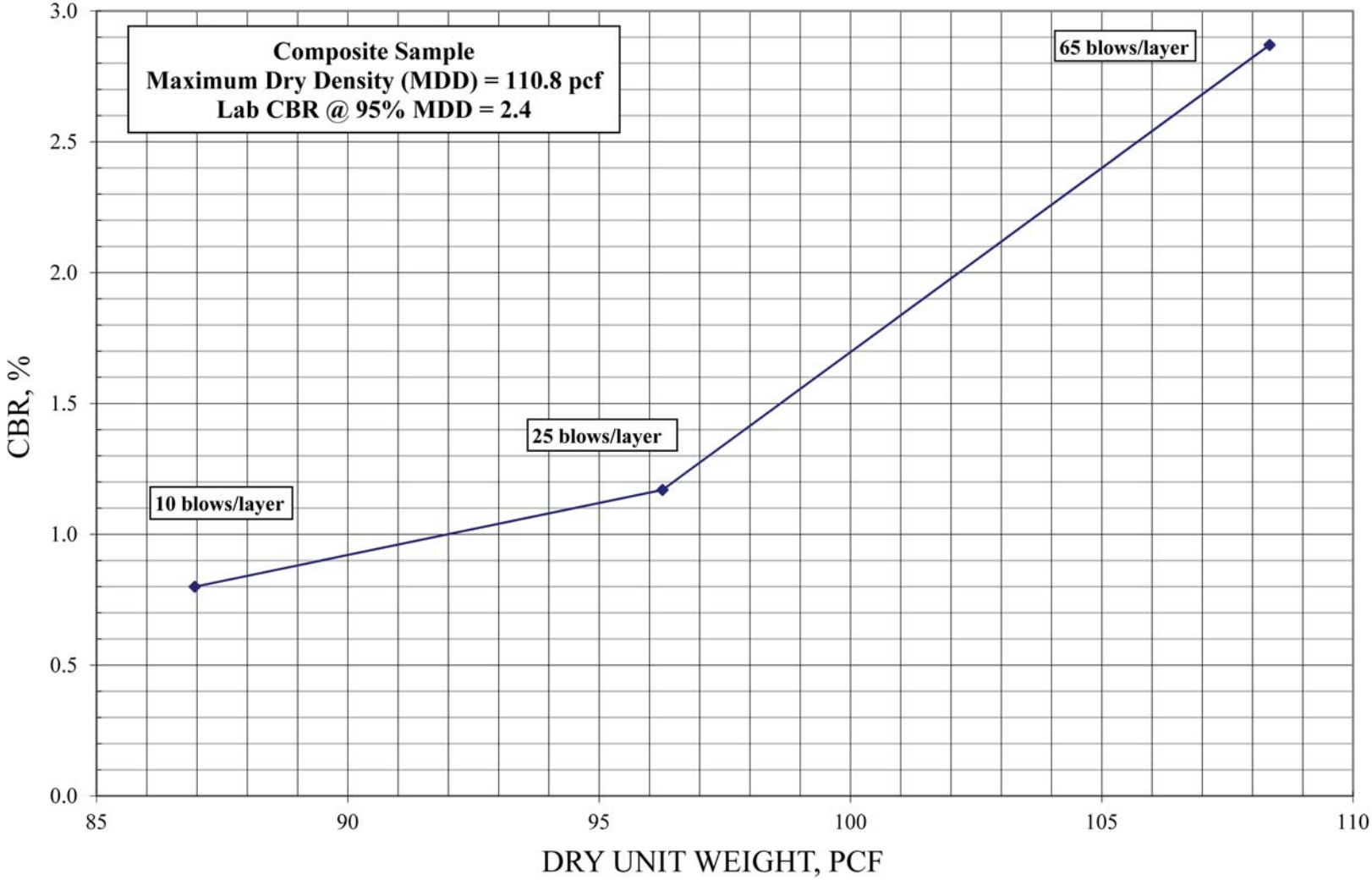
HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/31/2014	APPROVED BY: SV	PREPARED BY: RS

PROCTOR TEST RESULTS
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No. M-000126-0070-3

PROJECT NO.:	DRAWING NO.:
98-240G-06	PLATE E-1

CALIFORNIA BEARING RATIO TEST RESULT



HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/31/2014	APPROVED BY: SV	PREPARED BY: RS

CBR TEST RESULTS
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No. M-000126-0070-3

PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE E-2

CBR (CALIFORNIA BEARING RATIO) OF LABORATORY COMPACTED SOILS ASTM D-1883

Project: Skyscraper Shadows Storm Sewer and Paving

Sample Location: Composite

Liquid Limit: 40 **Plastic Limit:** 16 **Plasticity Index:** 24

Method of Compaction: ☒ ASTM D698
☐ ASTM D1557

Sample Condition: ☒ soaked ☐ unsoaked

No. of Blows:	**10**	**25**	**65**
Dry Density Before Soaking (pcf):	87.0	96.3	108.3
Dry Density After Soaking (pcf):	86.9	94.6	105.0
Moisture Content:			
Before Compaction (%):	13.4	14.4	15.2
Top 1-inch Layer After Soaking (%):	32.9	31.0	23.8
Swell (%):	3.52	5.74	3.78
Bearing Ratio (%): (☒ soaked ☐ unsoaked)	0.80	1.17	2.87

Surcharge: 10 lbs.

HVJ ASSOCIATES
6120 S. Dairy Ashford Road
Houston, Texas 77072-1010
281.933.7388 Ph
281.933.7293 Fax

DATE: 12/31/2014	APPROVED BY: SV	PREPARED BY: RS

CBR TEST RESULTS
SKYSCRAPER SHADOWS STORM SEWER AND PAVING
WBS No. M-000126-0070-3

PROJECT NO.: 98-240G-06	DRAWING NO.: PLATE E-3

APPENDIX F

DARWIN OUTPUT

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

98-240G-06-Flexible Pavement Design

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	92,744
Initial Serviceability	4.2
Terminal Serviceability	2
Reliability Level	85 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,600 psi
Stage Construction	1
Calculated Design Structural Number	2.93 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	1,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	4 %
Average Initial Truck Factor (ESALs/truck)	0.46
Annual Truck Factor Growth Rate	0 %
Annual Truck Volume Growth Rate	4 %
Growth	Simple
Total Calculated Cumulative ESALs	92,744

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	HMA	0.44	1	1.5	12	0.66
2	Black Base	0.34	1	2	12	0.68
3	Crushed Limestone Base	0.14	1	8	12	1.12
4	Lime Stabilized Subgrade	0.11	1	6	12	0.66
Total	-	-	-	17.50	-	3.12