CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING
ENGINEERING AND CONSTRUCTION DIVISION

GEOTECHNICAL STUDY
HOLLISTER ROAD PAVING AND DRAINAGE
WHITE OAK BAYOU TO WEST GULF BANK

WBS NO. N-000704-0001-3
CITY OF HOUSTON, TEXAS

PROJECT NO. 12-762E

TO

PARSONS BRINCKERHOFF, INC.
HOUSTON, TEXAS

BY

GEOTECH ENGINEERING AND TESTING

SERVICING

TEXAS, LOUISIANA, NEW MEXICO, OKLAHOMA

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TEXAS BOARD OF PROFESSIONAL ENGINEERS
REGISTRATION NUMBER F-001183

Parsons Brinckerhoff, Inc.
16295 Park Ten Place, Suite 400
Houston, Texas 77084

Project No.: 12-762E
Report No: 1
Project Type: 24/33/35
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Attention: Mr. Gabriel Y. Johnson, P.E.
Vice President

GEOTECHNICAL STUDY
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Gentlemen:

Submitted here is Geotech Engineering and Testing (GET) geotechnical report on the study of subsurface conditions for the above referenced project. This study was conducted in general accordance with our Proposal No. P12-373, Revision III, dated August 22, 2013. Authorization to proceed for this study was received through a Professional Services Contract between Parsons Brinckerhoff, Inc. and GET and signed by Mr. Gabriel Y. Johnson, Vice President of Parsons Brinckerhoff on September 27, 2013.

This report presents the results of our field exploration and laboratory testing together with design recommendations for the construction of the proposed paving and drainage improvements for the proposed alignment.

We appreciate the opportunity to be of service. Should you have any questions or need additional assistance, please call.

Very truly yours,

GEOTECH ENGINEERING AND TESTING
TEXAS BOARD OF PROFESSIONAL ENGINEERS
REGISTRATION NUMBER F-001183

Sam Samoo, M.S.C.E.
Project Manager

Moe Tavassoli, Ph.D., P.E.
Engineering Manager

STATE OF TEXAS
Moe Tavassoli
112015
LICENSED
PROFESSIONAL ENGINEER

Moe Tavassoli
03-11-14

SS/MT/ss

Copies Submitted: (1) Hard Copy – Parsons Brinckerhoff, Inc. – Mr. Gabriel Y. Johnsons, P.E.
(1) PDF Copy Email – Mr. Gabriel Y. Johnsons, P.E.
(1) PDF Copy Email – Mr. Murad A. Mohammad, P.E.
(1) Digital Copy

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1.0 EXECUTIVE SUMMARY

It is planned to reconstruct approximately 1,900± linear feet of Hollister Road from White Oak Bayou to West Gulf Bank in City of Houston, Texas. We understand that the new roadway will consist of a four lane concrete roadway with curb and gutters. In addition, underground utilities will be installed along the proposed project alignment. The invert depths for the water/storm and sanitary sewers will be less than 15-ft below the existing grade.

Furnished information indicates that open-trench or augering method of construction will be used for underground utility installations. This study was conducted is general accordance with the City of Houston (COH) Department of Public Works & Engineering, Infrastructure and Design Manual, dated July 2012. This report contains a description of our field and laboratory testing results together with engineering analysis and recommendations for the construction of the proposed facilities along the project alignment.

The soil conditions were explored by conducting two (2) soil borings (B-1 and B-2) for paving and underground utilities. The soil borings were drilled along the project alignment to depth of 25-ft below the existing grade. The soil stratigraphy for the project alignment is summarized as follows:

1. In general, based on our field exploration and laboratory test data, the soils along the project alignment appear to be uniform. The soils stratigraphy along the project alignment is summarized as follows:

Stratum No.	Depth, ft.	Soil Type
		CONCRETE PAVEMENT (6.6” to 6.7” in Thickness)
I	0.5 – 2	FILL: SANDY SILT (ML); In Boring B-1 only
II	0.5 – 2	FILL: LEAN CLAY (CL); In Boring B-2 only
III	2 – 25	LEAN CLAY WITH SAND (CL)

2. Depth to groundwater water will be important for design and construction of the proposed facilities. No groundwater was encountered during and 24-hours after drilling of the borings.

3. We understand that either open excavation or augering methods of construction will be used for the underground utilities installations. The bedding and backfill recommendations for the construction of the proposed underground utilities are also presented in this report.

4. We understand that the proposed paving for the Hollister Road will consist of concrete pavement. The concrete pavement was designed on the basis of "1993 AASHTO Guide for Design of Pavement Structures." Furthermore, the proposed pavement will be designed based on major thoroughfare traffic. Based on the assumed traffic conditions, the recommended concrete pavement thickness is as follows:

Design, ESAL × 10^6	Concrete Pavement Thickness, inch(es)	Subgrade Stabilization Thickness, inch(es)
10.0	10.0	8.0

5. The type of subgrade stabilization for the concrete pavement areas will depend on the final grade elevation. Furthermore, the type and amount of stabilization should be evaluated once the final grade is reached. Subgrade preparation in pavement areas should specify compaction of the upper six-inch to at least 95% of maximum Standard Proctor density (ASTM D 698) at a moisture content between ±2% of optimum. Depending on the major type of soils encountered along the project alignment, lime-fly ash stabilization of the subgrade soils should most likely be performed. The upper eight-inch of the soils should be lime-fly ash stabilized, using 2% lime and 8% fly-ash by dry weight. The application rates corresponding to these additives amounts would be 12 pounds of lime and 48 pounds of fly-ash per square yard for eight-inch of compacted thickness. The actual type and amount of stabilization should be determined at the time of construction after the pavement surface has been exposed. City of Houston Standard Specification 02337 should be used as a procedural guide for placing, mixing and compacting the lime-fly ash stabilizer and soils.

6. We understand that storm/sanitary sewers are planned for this project. The maximum depth of the storm/sanitary sewers will be less than 15-ft. The design recommendations for the storm/sanitary sewers are presented in this report.

2.0 INTRODUCTION

It is planned to reconstruct approximately 1,900± linear feet of Hollister Road from White Oak Bayou to West Gulf Bank in City of Houston, Texas. A site vicinity map of the project alignment is presented on Plate 1. We understand that the existing concrete paving will be removed and replaced with concrete paving. In addition, underground utilities will be constructed along the project alignment. The specific project information is as follows:

Facility	Remarks
Underground Utilities	We understand that the maximum invert depth for the water/ storm/sanitary sewers lines will be less than 15-ft
Pavement	It is planned to reconstruct 1,900± linear feet of Hollister Road from White Oak Bayou to West Gulf Bank in City of Houston, Texas. We understand that existing concrete paving will be removed and replaced with new concrete paving.

Furnished information indicates that open-trench or augering method of construction will be used for underground utility installations. This report contains a description of our field and laboratory testing programs together with engineering analysis and recommendations for the proposed project alignment. The pavement design in this study is in general accordance with ASSHTO 1993 Guide of Design of Pavement Structure (Ref. 1). Furthermore, this report provides recommendation for construction of the underground utilities along the project alignment. Our recommendations on underground utilities, site preparation and soil stabilization are in general accordance with the City of Houston (COH) Department of Public Works & Engineering, Infrastructure and Design Manual, dated July 2012 (Ref. 2). The scope of work (Number of Borings) for this project was specified by City of Houston.

3.0 FIELD EXPLORATION

3.1 Pavement Coring

The existing pavement was cored prior to drilling and sampling the soil borings. The results of pavement coring show that the existing pavement consists of concrete pavement. The existing pavement thicknesses are presented on Plate 2 and on the respective boring logs. The pavement core locations were patched with ready mix grout.

3.2 Drilling and Sampling

At the request of the City of Houston, the soil conditions were explored by conducting two (2) soil borings (B-1 and B-2) along the project alignment. The soil boring locations were discussed with Mr. Murad Mohammad, P.E. of Parsons Brinckerhoff, Inc. prior to drilling. A summary of the borings coordinates, elevations and station number information are presented on Plate 3.

The borings were drilled along the project alignments to a depth 25-ft below the existing grade and the soil sampling was done continuously. Approximate boring locations are presented in Appendix A.

Soil samples were examined and classified in the field, and cohesive soil strengths were estimated using a calibrated hand penetrometer. This data, together with a classification of the soils encountered and strata limits, is presented on the soil stratigraphy profile presented in Appendix A. The logs of borings and key to the log terms and symbols are also presented in Appendix A.

Depth to groundwater is important for design and construction of the proposed facilities. For this reason, borings were drilled dry. Water level observations made during drilling and shortly after drilling are indicated at the bottom portion of each individual boring log. The boreholes were grouted using tremie method after the completion of the field work.

4.0 LABORATORY TESTS

4.1 General

Soil classifications and shear strengths were further evaluated by laboratory tests on representative samples of the major strata. The laboratory tests were performed in general accordance with ASTM Standards. Specifically, ASTM D 2487 is used for classification of soils for engineering purposes. Furthermore, summary of test results are presented in Appendix A.

4.2 Classification Tests

As an aid to visual soil classifications, physical properties of the soils were evaluated by classification tests. The tests were conducted in general accordance with ASTM standards. These tests consisted of natural moisture content tests (ASTM D 4643), percent finer than the No. 200 sieve tests (ASTM D 1140) and Atterberg limit determinations (ASTM D 4318, Method A). Similarity of these properties is indicative of uniform strength and compressibility characteristics for soils of essentially the same geological origin. Results of these tests are tabulated on the boring logs at respective sample depths.

4.3 Strength Tests

Undrained shear strengths of the cohesive soils, measured in the field, were verified by calibrated hand penetrometer tests, unconfined compressive strength tests (ASTM D 2166) and torvane tests. Natural water content and dry unit weight were determined routinely for each unconfined compressive strength test. These test results are also presented on the boring logs.

4.4 Particle Size Analysis Test

This test was conducted in general accordance with ASTM D 422, the Standard Method for Particle-Size Analysis of Soils. This test was performed on selected sample obtained from Borings B-1 and B-2 at depths of 6- to 8-ft and 4- to 6-ft, respectively. The analysis results are presented on Plates 4 and 5.

4.5 Soil Sample Storage

Soil samples tested or not tested in the laboratory will be stored for a period of fourteen days subsequent to submittal of this report. The samples will be discarded after this period, unless we are instructed otherwise in writing

5.0 SITE GEOLOGY

According to the soil survey of Harris County, Texas (prepared by the U.S. Department of Agriculture Soil and Conservation Service (1976), geologically the project areas at the proposed alignment lies on the Clodine loam (Cd) and Nahatche loam (Na). The geologic character of each soil type is described below:

Clodine Loam loam (Cd) – This is a nearly level soil on broad, irregular areas, about400 acres in size that are generally low on the landscape. Slopes are 0 to 1percent but average 0.5 percent. The surface layer is friable, dark gray loam about 12 inches thick. The layer below that is friable, moderately alkaline, gray loam about 17 inches thick. The next layer extends to a depth of 72 inches. It is friable, moderately alkaline, light brownish gray loam that has irregular, pitted calcium carbonate concretions. Included with this soil in mapping are small areas of Addicks, Aris, Gessner, Midland, Edna, and Katy soils and small areas of saline soils.

Nahatche loam (Na) – This is a nearly level soil on the flood plains of major streams and tributaries. Mapped areas are oblong and have smooth boundaries. They average about 60 acres, but some areas are 400 acres in size. Slopes range from 0 to 2 percent along some old stream channels but range mainly from 0 to 1 percent, and the average slope is 0.6 percent. A few areas are dissected by old channel scars.

The surface layer is friable, medium acid, dark grayish brown loam about 5 inches thick. The layer below that is friable, medium acid, grayish brown loam over firm, moderately alkaline, gray clay loam that has mottles of light gray and brownish yellow. This soil is somewhat poorly drained. Surface runoff is slow. Permeability is moderate. The available water capacity is medium.

6.0 GENERAL SOILS AND DESIGN CONDITIONS

6.1 Site Conditions

The project alignment generally consists of concrete paved roadway. In general residences, commercial and residential structures exist in the vicinity of the project alignment. Project site pictures were taken during our site visit and drilling operation. These pictures are presented in Appendix B.

6.2 General Soil Stratigraphy

Field and laboratory test data indicate that soil stratigraphy along the project alignments are relatively uniform. **Details of subsoil conditions at each boring location are presented on the respective boring logs, provided in Appendix A**. In general, the soils can be grouped into three (3) major strata with depth limits and characteristics as follows:

Stratum No.	Range of Depth, ft.	Soil Description*
		EXISTING CONCRETE PAVEMENT (6.6” to 6.7” in Thickness)
I	0.5 – 2	FILL: SANDY SILT, gray, brown, with root fibers to 2’, clay pockets (ML); In Boring B-1 only
II	0.5 – 2	FILL: LEAN CLAY, stiff, dark gray, with root fibers to 2’, with ferrous nodules, sands (CL)
III	2 – 25	LEAN CLAY WITH SAND, soft to hard, light gray, gray, dark gray, reddish brown, ferrous nodules (CL)

6.3 Soil Properties

Soil strength and index properties and how they relate to the pavement design and underground utility installations along the project alignment are summarized below:

Stratum No.	Soil Type	PI(s)	Soil Expansivity	Soil Strength, tsf	Remarks
I	Fill: Sandy Silt (ML)	–	–	–	Moisture Sensitive
II	Fill: Lean Clay (CL)	–	–	0.78	–
III	Lean Clay with Sand (CL)	12 – 22	Non- to Low Expansive	0.23 – 2.22	–

Legend: PI = Plasticity Index

6.4 Water-Level Measurements

The soil borings were first drilled dry to evaluate the presence of perched or free-water conditions. The levels where free water was first encountered in the open boreholes during drilling and 24 hours after drilling are shown on the boring logs. Our groundwater water measurements are as follows:

Boring No.	Groundwater Depth, ft. at the Time of Drilling	Groundwater Depth, ft. at 24-Hour Later
B-1 and B-2	Dry	Dry

Fluctuations in groundwater generally occur as a function of seasonal moisture variation, temperature, groundwater withdrawal and future construction activities that may alter the surface drainage and subdrainage characteristics of this site.

An accurate evaluation of the hydrostatic water table in the relatively impermeable clays and low permeable silts/sands requires long term observation of monitoring wells and/or piezometers. It is not possible to accurately predict the pressure and/or level of groundwater that might occur based upon short-term site exploration. The installation of piezometers/monitoring wells was beyond the scope of our study. We recommend that the groundwater level be verified just before construction if any excavations such as construction of underground utilities, etc. are planned.

We recommend that GET be immediately notified if a noticeable change in groundwater water occurs from that mentioned in our report. We would be pleased to evaluate the effect of any groundwater changes on our design and construction sections of this report.

7.0 UNDERGROUND UTILITIES

7.1 General

We understand that underground utility installations will include storm sewers, sanitary sewers and water lines. Furnished information indicated that the maximum depth of these utilities with less than 15-ft. Furthermore, Open-trench or Augering method will be used for the underground utility installations. Soil Borings B-1 and B-2 were drilled along the project alignment for the underground utilities and paving to depths of 25-ft below the existing grade. We understand that the proposed underground utilities will be constructed according to the "City of Houston Specifications, Section 02317 – Excavation and Backfill for Utilities, and Section 02447 – Augering Pipe and Conduit".

7.2 Open-Trench Method

7.2.1 Sewerlines

In general, where dry stable trench conditions exist, bedding and backfill for the sanitary sewerlines should be in accordance with the City of Houston Specifications Drawing No. 02317-03. Bedding for the sanitary sewerlines, where wet stable trench conditions exist (where excavations below groundwater table are required), should be in accordance with the City of Houston Specifications Drawing No. 02317-02.

The results of our field exploration and laboratory testing indicate that unsatisfactory soils for excavation, such as sandy silt (ML) and soft clay (CL) soils, exist at various depths in the borings along the project alignment. A summary of the unsatisfactory soils, locations and depths are as follows:

Boring(s)	Depth Range, ft.
B-1	0 to 2 and 6 to 8

If these conditions are encountered during the time of construction, suitable groundwater control measures should be implemented in accordance with the "City of Houston Standard Specifications, Section 01578 – Control of Groundwater and Surface Water". Furthermore, the contractor may have to over excavate an additional 6-inch and remove unstable or unsuitable materials with approval by geotechnical engineer, and then place an equal depth of cement stabilization sand.

Due to potential variability of the on-site soils, unstable trench conditions may still exist in the areas where we did not conduct our borings. If these conditions are encountered during the time of construction, a stable trench should be provided to allow proper bedding and installation.

Sand backfill used in the cement-stabilized sand and sand backfill sections should be free of clay lumps, organic materials, or other deleterious substances, and should have a PI less than 4 for the cement-stabilized sand and less than 7 for the sand backfill section, and not more than 15% passing the No. 200 sieve. Cement stabilized sand should conform to the "City of Houston Standard Specifications, Section 02321 – Cement Stabilized Sand".

7.2.2 Water Lines

The bedding and backfill for the proposed water lines should be constructed in accordance with the City of Houston Specifications drawing No. 02317-04 for open-trench construction. Trenches for the proposed water lines must have a width below the top of the pipe of not less than the outside diameter of the pipe plus 24-inches and shall be wide enough to permit making up the joints but shall not be wider than the outside diameter of the pipe plus 36-inches.

In general, 12-inch of bank sand should be placed above the waterlines. Twelve-inch lifts of bank sand should be placed below the waterlines for dry excavation bottom. In case of wet excavation bottom, geotextile fabrics should be placed at the excavation bottom and along the excavation sides to a height of at least 24 inches.

7.3 Augering and Augering Pits

7.3.1 Sanitary Sewerlines

We understand that Augering may be used for the underground utility installations along the proposed alignment in City of Houston, Texas. The augering should be conducted in accordance with the City of Houston Standard Specifications 02447 – Augering Pipe and Conduit or 02448 – Pipe and Casing Augering for Sewers. Augering should be started from approved pit locations. Excavation for pits and shoring installation should conform to the aforementioned City of Houston Standard Specifications and 02317 – Excavation and Backfill for Utilities. If the augering zone is within the cohesionless soils or collapsible soils, install casings as required by City of Houston Standard Specifications 02447 – Augering Pipe and Conduit. The augering near existing structures or utility lines should be conducted in accordance with the City of Houston Standard Specification 02233 – Clearing and Grubbing.

Diameter of auger hole should not exceed pipe bell diameter plus 2-inches. The receiving pit distance should conform to the aforementioned City of Houston Standard Specifications. A minimum spacing of 6-inch should be provided between the pipe and walls of bore pit. The maximum allowable width of pit shall be 5-ft unless approved by City Engineers. Width of pit at surface shall not be less than the pit width at the bottom.

7.4 Groundwater Control

7.4.1 General

We understand that the depths of underground utilities will be less than 15-ft below existing grade. Our short-term field exploration along the project alignment indicated that groundwater was not encountered during and 24-hours after drilling. Hence, groundwater dewatering may not be required. Fluctuations in groundwater can occur as a function of seasonal moisture variation. Groundwater control recommendations are presented in the following report sections.

7.4.2 Dewatering Technique

In the event that groundwater is encountered during construction, it is our opinion that groundwater should be lowered to a depth of at least three-ft below the deepest excavation grade in order to provide dry working conditions and firm bedding. Any minor water inflow in cohesive soil layers can probably be removed using a sump-pump or trench sump-pump. Wellpoint system can be used in the event that sand/silt soils are encountered. Since the wellpoint suction lift is about 15-ft, multi-stage wellpoint system or ejector systems may be used for dewatering.

Design of a dewatering system should consider the amount of groundwater to be lowered and the permeability of the affected soils. The selection and proper implementation of an effective groundwater control system is the responsibility of the contractor. The design of groundwater and surface water should be in accordance with the City of Houston Specifications, Section 01578 − Control of Ground Water and Surface Water.

7.5 OSHA Soil Classifications

The subsoils can be classified in accordance with Occupational Safety and Health Administration (OSHA) Standards, dated October 31, 1989 of the Federal Register. OSHA classification system categorizes the soil and rock in four types based on shear strength and stability. The description of four (4) types in classification system is summarized in the Appendix C.

Based on our geotechnical exploration and laboratory test results, details of soil classifications at each boring are summarized in the OSHA Soil Classification, presented in Appendix C. Furthermore, a letter for trench safety recommendation is provided separately.

7.6 Excavations

Each side of an excavation or trench which is five-ft or deeper must be protected by sheeting/bracing shoring or sloped. Based on soil strength data and OSHA soil classifications, temporary (less than 24 hours) open-trenched, non-surcharged, and unsupported excavations should be made on slopes of about 1.5(h):1(v). Vertical cuts can be constructed, provided shoring and bracing are used for the excavation wall stability. Benched excavation can also be used with average slopes of about 1(h):1(v) and steps should not be higher than five-ft. In all cases, excavations should conform to OSHA guidelines. Flatter slopes may have to be used if large amounts of sand need to be excavated for deep installations. Specifications should require that no water be allowed to pond in the excavations. The surface slopes should be protected from deterioration and weathering if they are to be left open for more than 24 hours.

Excavations should be performed with equipment capable of providing a relatively clean bearing area. Excavation equipment should not disturb the soil beneath the design excavation bottom and should not leave large amounts of loose soil in the excavation.

7.7 Lateral Earth Pressures

In the event that open excavations are not used, the proposed underground utilities can be installed using trench sheeting. The sheeting can be constructed in the form of cantilever sheeting or with bracing. Lateral earth pressures for each method used are summarized on Plate 6. The trenching and shoring operations should follow OSHA Standards. We recommend a geotechnical engineer monitor all phases of trench excavation and bracing to assure trench safety.

7.8 Backfilling for Auger Pits and Auger Holes

Sand backfill used in the cement-stabilized sand and sand backfill sections should be free of clay lumps, organic materials, or other deleterious substances, and should have a PI less than 4 for the cement-stabilized sand and less than 7 for the sand backfill section, and not more than 15% passing the No. 200 sieve.

Cement stabilized sand should conform to the “City of Houston Specifications, Section 02321 – Cement Stabilized Sand”. Backfill should be placed in accordance with “City of Houston Standard Specifications, Section 02317 – Excavation and Backfill for Utilities”. City of Houston Standard Specification Drawing No. 02447-01 should be followed when backfilling the auger pits. The annular space between the pipe and the auger hole should be backfilled to a minimum of 12-inches on both sides beyond the auger pit as indicated in the City of Houston Standard Specification Drawing No. 02447-01.

8.0 PAVEMENT RECOMMENDATIONS

8.1 General

It is planned to reconstruct approximately 1,900± linear feet of Hollister Road from White Oak Bayou to West Gulf Bank in City of Houston, Texas. We understand that the existing concrete pavement will be removed and replaced with new concrete paving. The new pavement design is in accordance with the "1993 ASSHTO Guide for Design of Pavement Structures" (Ref. 1). Furthermore, our recommendations on site preparation and soil stabilization are in general accordance with the City of Houston (COH) Department of Public Works & Engineering, Infrastructure and Design Manual, dated July 2012 (Ref. 2).

8.2 Traffic Information

Based on the information provided by the client, GET estimated the traffic volume and 18-kip equivalent axle loads (EALs). Furthermore, the pavement will be designed based on major thoroughfare traffic. A design ESAL of 10×10^6 was used for the proposed project alignment. The results of the pavement design analyses are provided in the following sections.

8.3 Subgrade Stabilization

The type of subgrade stabilization for the concrete pavement areas will depend on the final grade elevation. Furthermore, the type and amount of stabilization should be evaluated once the final grade is reached. Subgrade preparation in pavement areas should specify compaction of the upper six-inch to at least 95% of maximum standard Proctor density (ASTM D 698) at a moisture content between ±2% of optimum. Depending on the major type of soils encountered along the project alignment, lime-fly ash stabilization of the subgrade soils should most likely be performed. The upper eight-inch of the soils should be lime-fly ash stabilized, using 2% lime and 8% fly-ash by dry weight. The application rates corresponding to these additive amounts would be 12 pounds of lime and 48 pounds of fly-ash per square yard for eight-inch of compacted thickness. City of Houston Standard Specification 02337 should be used as a procedural guide for placing, mixing and compacting the lime-fly ash stabilizer and soils.

Our recommendations on subgrade stabilization are preliminary. The actual depth and type of stabilization should be determined in the field at the time of construction just after site stripping and proofrolling. Furthermore, the type and amount of the stabilizer may vary depending on the final grade elevation and the soil type encountered.

8.4 Recommended Subgrade Design Values

Results of the soils test indicated that subgrade soils consist of silt (ML) and clay (CL) soils based on Unified Soils Classification System (ASTM D 2487). The recommended design parameters based on sand (ML) and clay (CL) for CBR and M_R values are 5 and 7,500 psi, respectively.

8.5 Concrete Pavement

The following design parameters (based on 1993 AASHTO Guide for Design of Pavement Structures, Ref. 1) were used in the concrete pavement design for the proposed project alignment.

AASHTO Design Parameter	Pavement Design Value
ESAL × 10^6 for 20-year design life	10.0
Reliability, R	95%
Overall Standard Deviation, S_0	0.35
Load Transfer Coefficient, J	3.2
Loss of Support, LS	1.0
Drainage Coefficient, C_d	1.2
Design Serviceability Loss, Δ psi	2.0
Concrete Modules of Rupture (28 days) in psi, S_c'	620
Concrete Compressive Strength at 28 days in psi, f_c'	3,500
Effective Modulus of Subgrade Reaction k, in pci	130

Based on the above design parameters, the minimum concrete pavement section thickness are as follows:

Design, ESAL × 10^6	Concrete Pavement Thickness, inch(es)	Subgrade Stabilization Thickness, inch(es)
10.0	10.0	8.0

Detailed design computations are presented in Appendix E. Our design recommendations also consider excellent drainage is provided near the pavement structures, assuming the pavement are exposed to moisture levels approaching saturation from 1 to 5 percent of the time. Concrete should meet the requirements of the City of Houston design paving specifications as well as AASHTO "Guide Specifications for Highway Construction and the Structural Specifications for Transportation Materials." The construction of rigid pavement should be in accordance with the City of Houston Standard Specification Drawing No. 02751-01.

The steel reinforcement was designed using No. 4 and No. 5 bars as described below:

- The reinforcing steel was designed on the basis of Grade 60 steel. The longitudinal steel reinforcement should be No. 4 bars at 12.5-inch spacing. The transverse steel reinforcement should be No. 4 bars at the spacing of 36-inch for a pavement width of 25-ft. We recommend a lap length of 22-inches for the No. 4 bars. The end bar spacing should be 3.5 inches.

- The reinforcing steel was designed on the basis of Grade 60 steel. The longitudinal steel reinforcement should be No. 5 bars at 18.25-inch spacing. The transverse steel reinforcement should be No. 5 bars at the spacing of 36-inch for a pavement width of 25-ft. We recommend a lap length of 27-inches for the No. 5 bars. The end bar spacing should be 4-inches.

9.0 CONSTRUCTION CONSIDERATIONS

9.1 Site Preparation

The project alignment has the potential for construction problems related to the surficial layer of sandy silt fill soils. These permeable surficial soils are underlain by relatively impermeable lean clay soils. Thus, due to poor site drainage, wet season or site geohydrology, water ponds on the clays and creates a "perched water table condition." The surficial sandy silt fill soils become extremely soft when wet, and must be stabilized, aerated, or replaced. Site preparation should be conducted in accordance with the "City of Houston Standard Specifications, Section 02221 – Removing Existing Pavements and Structures and Section 02233 – Clearing and Grubbing". In general, subgrade preparation should be as follows:

1. The requirement for removal of any existing paving, and subsoil materials will depend on final grades and other alignment information. In general, remove all vegetation, tree roots, organic topsoil, existing foundations, paved areas and any undesirable materials from the construction area. Tree trucks under the pavement should be removed to a root size of less than 0.5-inches. We recommend that the stripping depth be evaluated at the time of construction by a soil technician.

2. The subgrade areas should then be proofrolled with a loaded dump truck or similar pneumatic-tired equipment with loads ranging from 25- to 50-tons. The proofrolling serves to compact surficial soils and to detect any soft or loose zones. The proofrolling should be conducted in accordance with TxDOT Standard Specification Item 216. Any soils deflecting excessively under moving loads should be undercut to firm soils and recompacted. Any subgrade stabilization should be conducted after site proofrolling is completed and approved by the geotechnical engineer. The proofrolling operations should be observed by an experienced geotechnician.

3. Off-site borrow for fill should consist of lean clays with a liquid limit not exceeding 40 and a PI between 12 and 20. These soils should be placed in loose lifts not exceeding eight-inches and compacted to at least 95% of maximum standard Proctor density (ASTM D 698) at moisture contents between optimum and +3% of optimum. Bank sands should not be used as select structural fill. On-site soils, free of organics, (with the exception of sands and silts) are also suitable for use as structural fill.

4. In cut areas, the soil should be excavated to grade and the surficial soil proofrolled and scarified to a minimum depth of six-inches and recompacted to the previously mentioned density and moisture content.

5. Positive site drainage should be developed at the beginning of the project to limit construction difficulties with wet surface soils.

9.2 Suitability of On-Site Soils for Use as Fill

9.2.1 General

Fill requirements should be in accordance with the 'City of Houston Standard Specifications, Section 02316 –Excavation and Backfill for Structures, Section 02317 – Excavation and Backfill for Utilities and Section 02320 – Utility Backfill Materials". The on-site soils can be used as fill materials as described in the following report sections.

9.2.2 Select Backfill

This is the type of fill that can be used for the structures or utilities. These soils should consist of lean clays with plasticity indices between 8 and 20 and amount of passing No. 200 sieve greater than 50 percent.

9.2.3 Random Backfill

This type of fill does not meet the Atterberg limit requirements for select structural fill. This fill should consist of lean clays or fat clays. They can be used for the structures or utilities after treatment.

9.2.4 General Fill

This type of fill consists of silts, sands and clays. However, the silts and sands are moisture sensitive and are difficult to compact in a wet condition (they may pump). Furthermore, these soils can erode easily. Their use is not recommended as backfill materials. They can be used for site grading and in unimproved areas.

9.2.5 On-Site Fill Soil Classification

Based on Borings B-1 and B-2, the on-site soils can be used as fill materials as described below:

Stratum No.[1]	Soil Type	Use as Fill: Select Backfill	Use as Fill: Random Backfill	Use as Fill: General Fill	Notes
I	Fill: Sandy Silt (ML)	–	–	✓	2, 3
II	Fill: Lean Clay (CL)	–	✓	✓	2, 4
III	Lean Clay with Sand (CL)	–	✓	✓	2, 4

Notes:
1. See soil stratigraphy and design conditions sections of this report for strata description.
2. All fill soils should be free of organics, roots, etc.
3. The on-site cohesionless soils are moisture sensitive and erode easily. These soils will pump when they get wet. Compaction difficulties will occur in these soils in a wet condition.
4. Soils with PI greater than 20 should be lime modified with 5% by dry weight and can be used as select structural fill.

9.3 Site Drainage

It is recommended that site drainage be well developed. Surface water should be directed away from the structure (use a slope of about 5% in the grass within 10-ft of the structure). No ponding of surface water should be allowed near the structure.

9.4 Earthwork

9.4.1 General

Difficult access and workability problems can occur in the surficial soils due to poor site drainage, wet season, or site geohydrology. Based on the laboratory test results, the subsurface soils at the project site consists of sandy silt (ML) and lean clay (CL) fill soils. Considering the soils stratigraphy, the construction of this project should be conducted during the dry season to avoid major earthwork problems. Our recommendations for earthwork activity for areas with cohesive and cohessionless soils are provided separately.

9.4.2 Earthwork for Cohesive Soils

Difficult access and workability problems can occur in the surficial clay (CL) soils due to poor site drainage, wet season, or site geohydrology. Should this condition develop, drying of the soils for support of pavement may be improved by the addition of 5% lime by dry weight. The application rate corresponding to this additive amount would be 23 pounds of lime per square yard for eight-inch of compacted thickness.

City of Houston Standard Specifications 02336 shall be used as procedural guides for placing, mixing, and compacting lime stabilizer and the soils.

Our recommendations on subgrade stabilization are preliminary. The actual depth and type of stabilization should be determined in the field at the time of construction just after site stripping and proofrolling. Furthermore, the type and amount of the stabilizer may vary depending on the final grade elevation and the soil type encountered.

Provided the site work is performed during dry weather and/or project schedules permit aeration of wet soils, the subgrade will be suitable for pavement support.

9.4.3 Earthwork for Cohesionless Soils

In the event the subgrade soils become wet and experience pumping problems, they can be (a) opened up to dry up, (b) removed and replaced with dry cohesive soils or (c) chemically modified or stabilized. These alternatives are discussed in the following report sections.

9.4.3.1 Subgrade Drying

The on-site wet soils can be opened up so that it would dry up. However, opening up the surficial cohesionless soils for drying purposes may not be practical, due to cyclic rainfall in the Gulf-Coast area.

9.4.3.2 Removal and Replacement

The surficial cohesionless soils can be removed and replaced with select structural fill. The actual depth of removal and replacement should be evaluated in the field, but it can be whole thickness of surficial cohesionless soils. This procedure will include removal of the surficial cohesionless soils, proofrolling and compacting the subgrade cohesive soils to a minimum of 95 percent standard proctor density (ASTM D 698). The site can then be backfilled with select structural fill, compacted to a minimum of 95 percent of standard proctor density. The proofrolling should be in accordance with the site preparation section of this report. All of the fill soils should be placed and tested in accordance with the site preparation section of this report.

9.4.3.3 Modification/Stabilization

We recommend that the on-site cohesionless soils be modified (to dry up), using 5 to 10 percent fly ash by dry weight. City of Houston Standard Specifications 02337, shall be used as a procedural guide for placing, mixing and compacting the fly-ash stabilizer. The estimated amount of fly ash per depth of modification are as follows:

Modification Depth, in.	Fly Ash Weight Range, lbs. per Square Yard
6	23 − 45
12	46 − 90
18	69 − 135
24	92 − 180

We recommend that five percent fly ash be used if the surficial soils are relatively moist at the time of application. Higher levels (10 percent) of fly ash should be used if wet and soggy subgrade soils are encountered.

The subgrade soils should be removed to a depth of 24-inch (or more) below existing grade. These soils should be stockpiled. The soils below a depth of 24-inch should be modified to a depth of 12-inch. These soils should be compacted to a minimum of 95 percent of standard proctor density (ASTM D 698). The stockpiled soils should then be modified and replaced in six-inch lifts and compacted to 95 percent of maximum dry density as determined by ASTM D 698 at moisture contents within ±2 percent of optimum.

Due to poor drainage and the depth of the cohesionless soils, the depth of stabilization may be as deep as depth of cohesionless soils. A test section can be implemented for this purpose. The subgrade soils should be modified in six-inch lifts and compacted within four hours of mixing and placement. All of the subgrade soils should be compacted to a minimum of 95 percent of the standard proctor density at the moisture content with optimum. The degree of compaction for the lifts, below a depth of 24-inch can be relaxed to 90 percent of maximum dry density to ease the construction procedures.

The subcontractor who will be doing the subgrade modification or stabilization should be experienced with stabilization procedures and methods. Furthermore, all of the earthwork at this project should be monitored by our geotechnician to assured compliance with the project specifications.

Once the subgrade is constructed, the soils at the top of subgrade should be slicked and the subgrade needs to be crowned such that the all surface water would drain away. No low areas should be left within the subgrade areas, since these areas would hold water and destroy the subgrade structure.

9.5 Construction Surveillance

Construction surveillance and quality control tests should be planned to verify materials and placement in accordance with the specifications. The recommendations presented in this report were based on a discrete number of soil test borings. Soil type and properties may vary across the site. As a part of quality control, if this condition is noted during the construction, we can then evaluate and revise the design and construction to minimize construction delays. We recommend the following quality control procedures be followed by a qualified engineer or technician during the construction of the facility:

- Observe the site stripping and proofrolling.
- Verify the compaction of subgrade soils.
- Verify the type, depth and amount stabilizer.
- Evaluate the quality of fill and monitor the fill compaction for all lifts.
- Observe all phases of trench safety.
- Observe all excavation operations.
- Monitor concrete placement, conduct slump tests and make concrete cylinders.

It is the responsibility of the client to notify GET of when each phase of the construction is taking place so that proper quality control and procedures are implemented.

10.0 RECOMMENDED ADDITIONAL STUDIES

This report has been based on assumed conditions/characteristics of the proposed project area where specific information was not available. It is recommended that the architect, civil engineer and structural engineer along with any other design professionals involved in this project carefully review these assumptions to ensure they are consistent with the actual planned development. When discrepancies exist, they should be brought to our attention to ensure they do not affect the conclusions and recommendations provided herein. We recommend that GET be retained to review the plans and specifications to ensure that the geotechnical related conclusions and recommendations provided herein have been correctly interpreted as intended.

11.0 STANDARD OF CARE

The recommendations described herein were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical engineering profession practicing contemporaneously under similar conditions in the locality of the project. No other warranty or guarantee, expressed or implied, is made other than the work was performed in a proper and workmanlike manner.

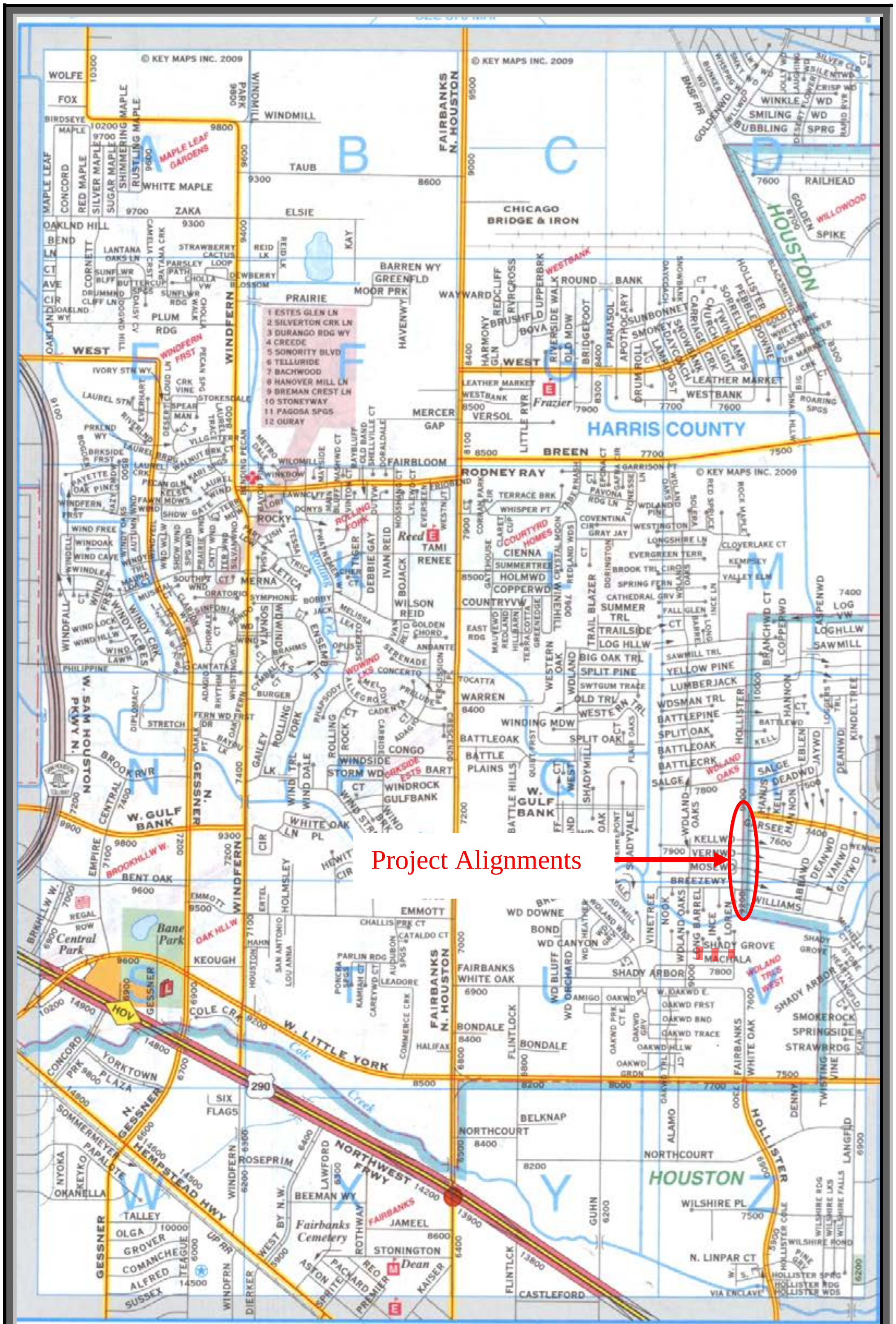
12.0 REPORT DISTRIBUTION

This report was prepared for the sole and exclusive use by our client (Parsons Brinckerhoff, Inc.) and owner (City of Houston), based on specific and limited objectives. All reports, boring logs, field data, laboratory test results, maps and other documents prepared by GET as instruments of service shall remain the property of GET. GET assumes no responsibility or obligation for the unauthorized use of this report by other parties and for purposes beyond the stated project objectives and work limitations.

13.0 REFERENCES

1. AASHTO Specifications, "Guide for Design of Pavement Structures", American Association of State Highway and Transportation Officials, 1993.

2. "City of Houston Standard Construction Specifications", Department of Pubic Works and Engineering, City of Houston, July 2012.



SITE VICINITY MAP

PROJECT: Prop. Hollister Road Paving and Drainage –White Oak Bayou to West Gulf Bank
WBS No. N-000704-0001-3, City of Houston, Texas

SCALE: NOT TO SCALE	DATE: MARCH 2014	PROJECT NO.: 12-762E

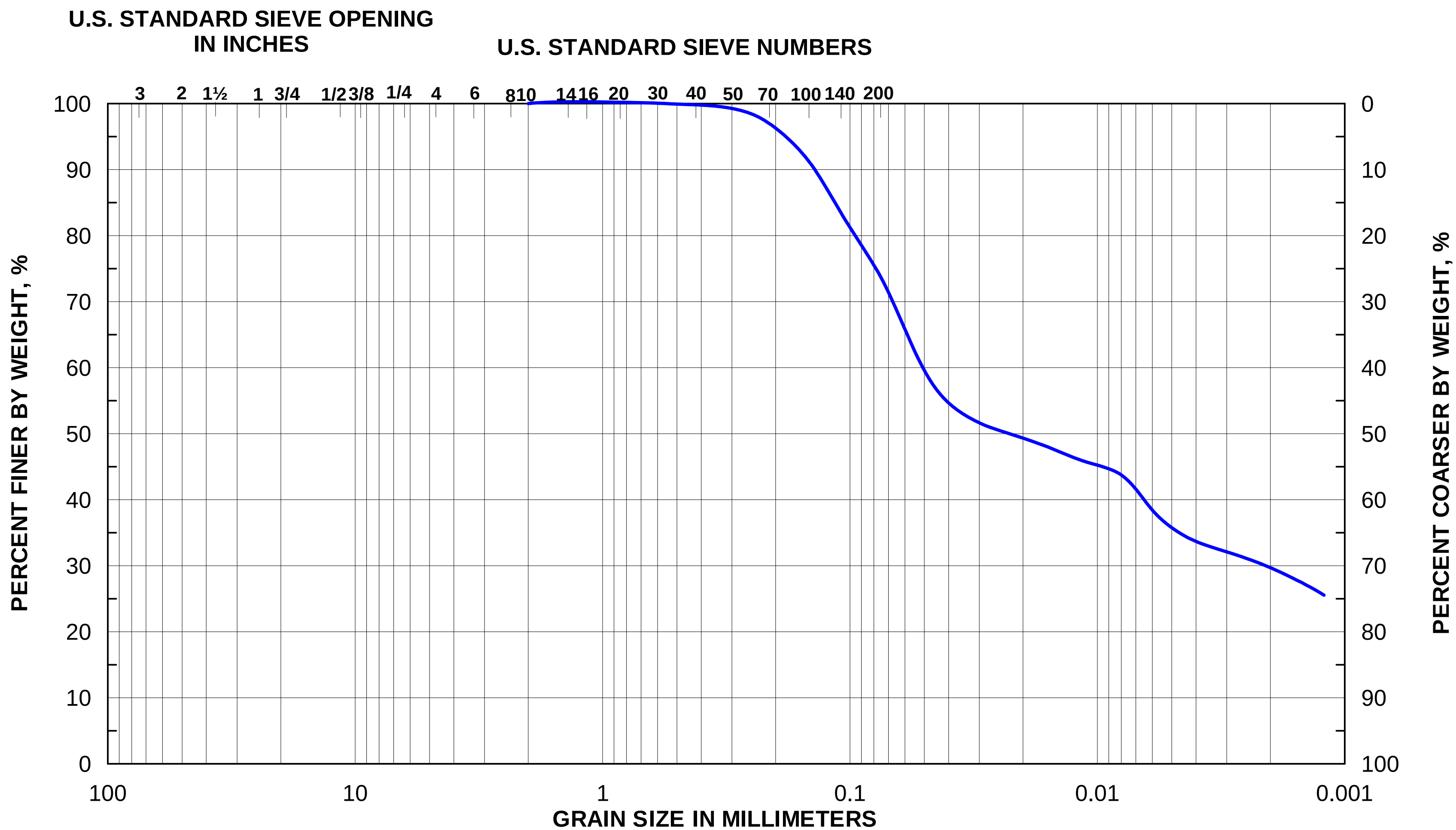
NORTH

EXISTING PAVEMENT THICKNESS

	Thickness, inches
Core Locations	Concrete Pavement
C-1	6.7
C-2	6.6

SUMMARY OF BORING LOCATIONS

Boring No.	Alignment	Northing	Easting	Elevation	Station No.	Offset
B-1	Hollister Road	13,883,769.19	3,075,313	83.7’	29+74.97	32.32’
B-2	Hollister Road	13,883,769.19	3075337.74	83.7’	21+25.24	32.56’



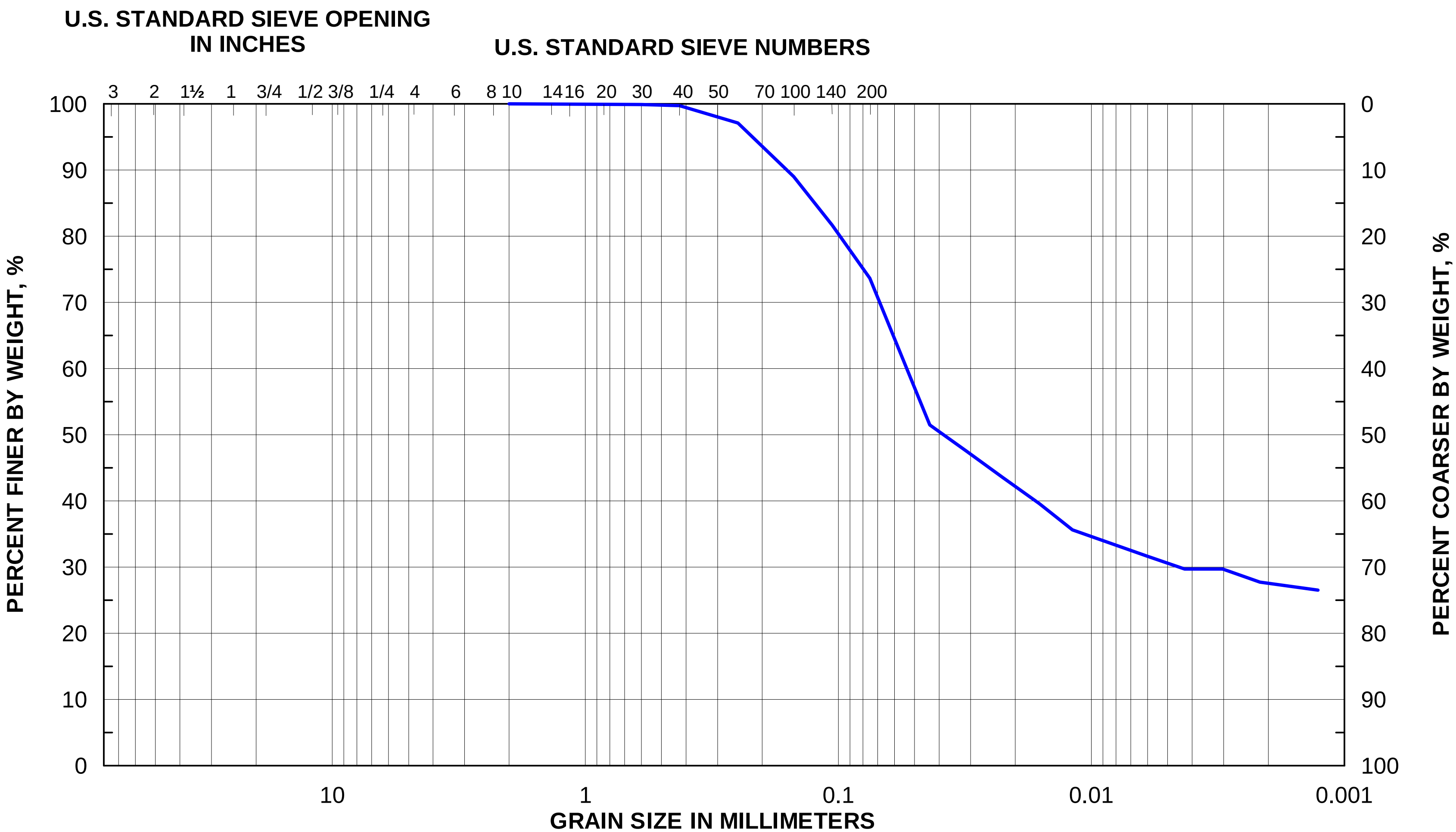
GRAVEL		SAND			SILT	CLAY
Coarse	Fine	Coarse	Medium	Fine		

USCS Soil Classification: Lean Clay with Sand (CL)

Percent Passing - 200: 76%

PARTICLE SIZE DISTRIBUTION CURVE FOR B- 1 (6' TO 8')

Project No. 12-762E



GRAVEL		SAND			SILT	CLAY
Coarse	Fine	Coarse	Medium	Fine		

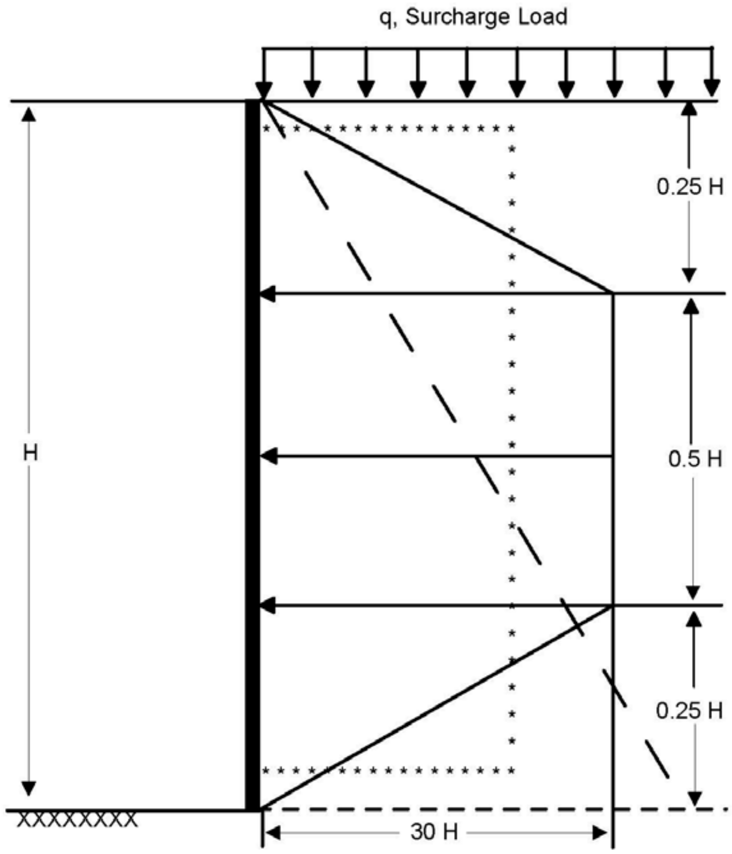
USCS Soil Classification: Lean Clay with Sand (CL)

-200: 74% Passing

GRAIN SIZE DISTRIBUTION CURVES FOR BORING B-2 (4' TO 6')

Project No. 12-762E

LATERAL EARTH PRESSURE DIAGRAM



Legend:

———————— Braced Excavation (stiff clays)
* * * * * * * * * * * * * Braced Excavation (sands)
- - - - - - - - - - - - - - - Cantilevered sheeting

Active Pressure:

(a) Braced Excavation (stiff clays) = 0.5q + 30H + 62.4H
(b) Braced Excavation (sands) = 0.4q + 18H + 62.4H
(c) Cantilevered sheeting = 0.7q + 42H + 62.4H

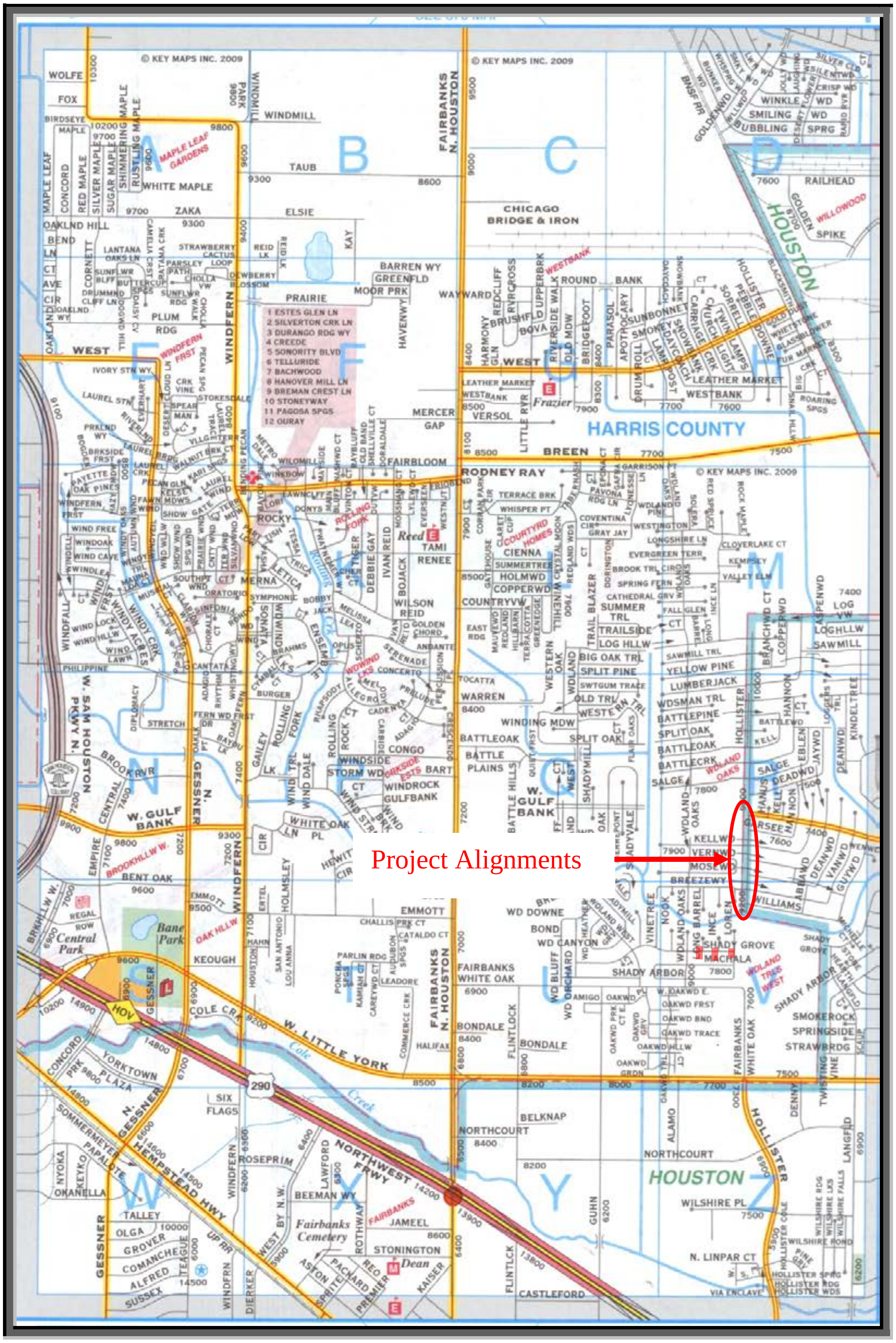
where: q = surcharge load, psf: A value of 250 psf can be assumed.
H = wall height, ft.

Notes:

1. The above Active Pressure Equations account for the groundwater at the surface.
2. The final lateral pressures should be reviewed prior to construction.
3. Trench excavation and construction should be observed by a geotechnical engineer.
4. The means and methods for a safe excavation is the responsibility of the contractor.
5. In case of layered soils, active pressure should be calculated based on the dominant or more critical soil conditions.

APPENDIX A

Site Vicinity Map
Plan of Borings
Soil Stratigraphy
Logs of Borings
Key to Log Terms and Symbols
Summary of Laboratory Test Results



SITE VICINITY MAP

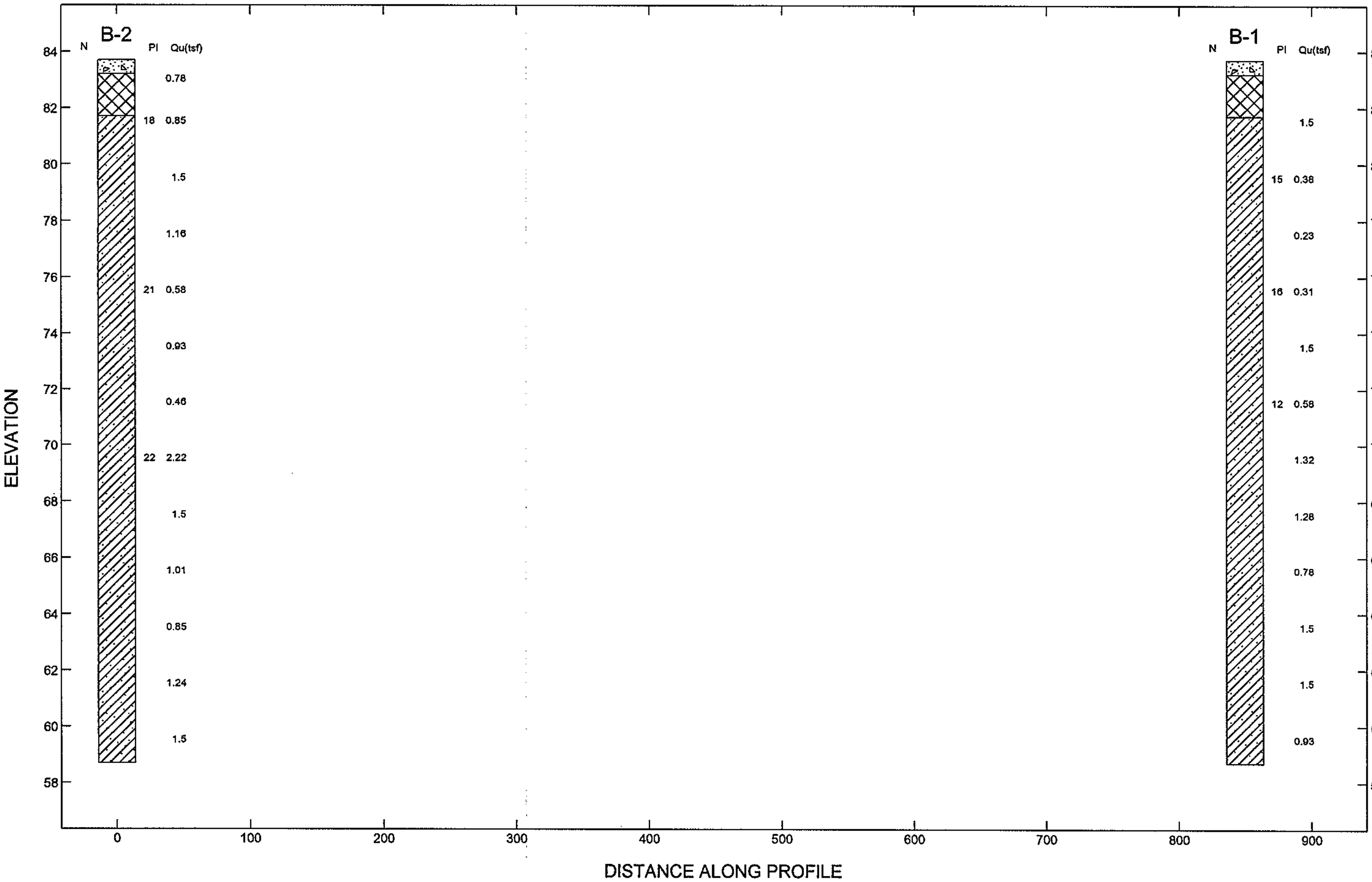
PROJECT: Prop. Hollister Road Paving and Drainage – White Oak Bayou to West Gulf Bank
WBS No. N-000704-0001-3, City of Houston, Texas

SCALE: NOT TO SCALE	DATE: MARCH 2014	PROJECT NO.: 12-762E

NORTH

Legend: B-1: Soil Boring Location
C-1: Concrete Coring Location

PLAN OF BORINGS/CORINGS (borings and coring locations are approximate)			NORTH
PROJECT: Proposed Hollister Road Paving and Drainage from White Oak Bayou to West Gulf Bank WBS No. N-000704-0001-3, City of Houston, Texas			
SCALE: NOT TO SCALE	DATE: MARCH 2014	PROJECT NO.: 12-762E	

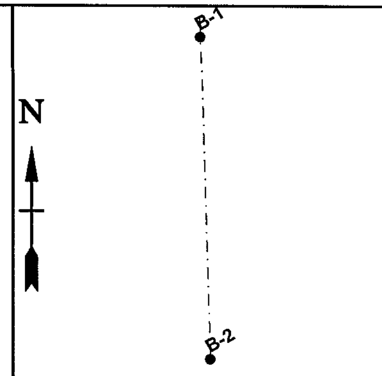


Lithology Graphics

Concrete

Fill

USCS Low Plasticity Sandy Clay



Site Map Scale 1 inch equals 510 feet

Explanation

B-1 — Borehole Number

Borehole Lithology

Water Level Reading at time of drilling.

Water Level Reading after drilling.

0 138

Horizontal Scale

Vertical Exaggeration: 21.5x

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022

Prop. Hollister Road Paving and Drainage from White Oak Bayou to West Gulf Bank

City of Houston
Texas

JOB NUMBER	PLATE NUMBER
N-000704-0001-3	PLATE A-3

BERNARD 12-762E.1.GPJ FANWNL01.GDT 10/21/13

LOG OF BORING NO. B-1

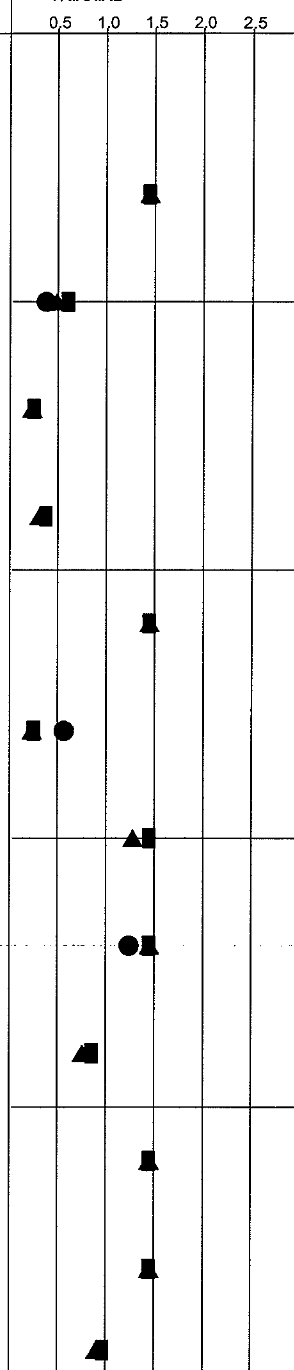
Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Prop. Hollister Road Paving and Drainage from White Oak Bayou to West Gulf Bank
LOCATION: City of Houston, Texas
PROJECT NO.: N-000704-0001-3 STATION NO.: 29+74.97
DATE: 9-27-12 COMPLETION DEPTH: 25.0 ft.

Latitude: N 29 52 45.23868
Longitude: W 95 30 25.03
Northing: 13,883,769.19
Easting: 3,075,313
Elevation: 83.7'

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			CONCRETE PAVEMENT (6.7")									
			FILL: SANDY SILT (ML), gray, brown, with root fibers to 2', clay pockets	11				72				
			LEAN CLAY WITH SAND (CL), very stiff, light gray, with ferrous nodules	13								
5			- stiff 4' to 6'	14	30	15	15			107		
			- soft 6' to 8'	19								
			- firm 8' to 10'	19	32	16	16					
10				14								
			- stiff 12' to 14'	18	29	17	12			110		
15				16								
			- reddish brown 16' to 25'	18						109		
			- stiff 18' to 20'	18								
20				18								
				21								
25			- stiff 24' to 25'	16								

UNDRAINED SHEAR STRENGTH, tsf
▲ HAND PENETROMETER
■ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL



WATER OBSERVATIONS:
NO FREE WATER ENCOUNTERED DURING DRILLING

DRY AUGER: 0 TO 25 ft.
WET ROTARY: ____ TO ____ ft.

DRILLED BY: GET
LOGGED BY: Erik

OVM2 12-762E.1.GPJ OVM.GDT 10/21/13

LOG OF BORING NO. B-2

Geotech Engineering and Testing
800 Victoria Drive
Houston, Texas 77022
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Prop. Hollister Road Paving and Drainage from White Oak Bayou to West Gulf Bank

LOCATION: City of Houston, Texas

PROJECT NO.: N-000704-0001-3 STATION NO.: 21+25.24

DATE: 9-27-12 COMPLETION DEPTH: 25.0 ft.

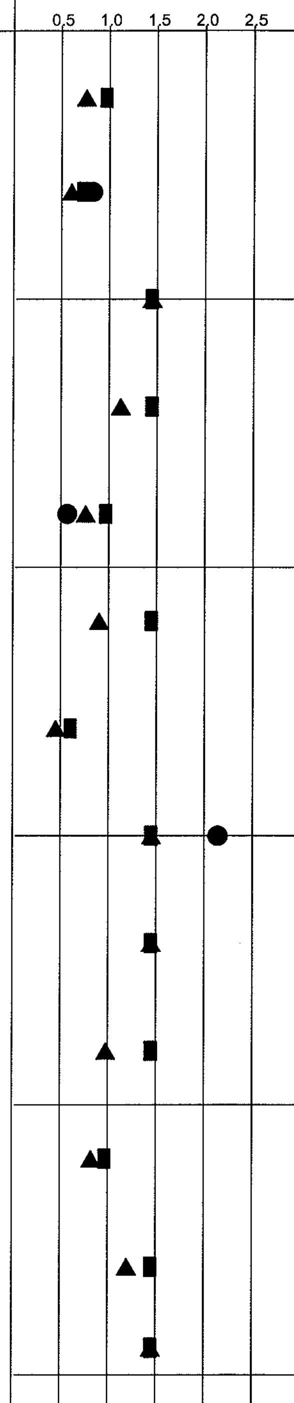
Latitude: N 29 52 36.83
Longitude: W 95 30 25
Northing: 13,882,919.9
Easting: 3,075,337.7
Elevation: 83.7'

DEPTH, ft	DESCRIPTION
0	CONCRETE PAVEMENT (6.6")
	FILL: LEAN CLAY (CL), stiff, dark gray, with root fibers to 2', ferrous nodules, sands
	LEAN CLAY WITH SAND (CL), stiff, gray, dark gray, with ferrous nodules
	- very stiff 4' to 8'
10	- reddish brown 10' to 25'
	- firm 12' to 14'
	- hard 14' to 16'
20	- stiff 20' to 22'
25	

NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
18								
18	34	16	18			113		
15								
16								
18	38	17	21	79		108		
16								
18								
17	39	17	22			114		
16								
24								
18								
31								
22								

UNDRAINED SHEAR STRENGTH, tsf

▲ HAND PENETROMETER
■ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL



WATER OBSERVATIONS:
NO FREE WATER ENCOUNTERED DURING DRILLING

DRY AUGER: 0 TO 25 ft.
WET ROTARY: ____ TO ____ ft.

DRILLED BY: GET
LOGGED BY: Erik

OVM2 12-762E.1.GPJ OVM.GDT 10/21/13

KEY TO LOG TERMS AND SYMBOLS

UNIFIED SOIL CLASSIFICATIONS

Symbol	Material Descriptions
GW	WELL GRADED-GRAVELS, GRAVEL-SAND MIXTURES LITTLE OR NO FINES
GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GM	SILTY GRAVELS, GRAVEL-SAND SILT MIXTURES
GC	CLAY GRAVELS, GRAVEL-SAND CLAY MIXTURES
SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SP	POORLY GRADED SANDS, OR GRAVELLY SANDS, LITTLE OR NO FINES
SM	SILTY SANDS, SAND-SILT MIXTURES a
SC	CLAYEY SANDS, SAND-SILT MIXTURES b
ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS
OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENT
	FILL SOILS

TERMS CHARACTERIZING SOIL STRUCTURE

Slickensided	-	Having incline planes of weakness that are slick and glossy in appearance.
Fissured	-	Containing shrinkage cracks frequently filled with fine sand or silt: usually vertical.
Laminated	-	Composed of thin layers of varying colors and soil sample texture.
Interbedded	-	Composed of alternate layers of different soil types.
Calcareous	-	Containing appreciable quantities of calcium carbonate.
Well Graded	-	Having wide range in grain sizes and substantial amounts of all intermediate particle sizes.
Poorly Graded	-	Predominantly of one grain size, or having a range of sizes with some intermediate sizes missing.
Pocket	-	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	-	Inclusion less than 1/8-inch thick extending through the sample.
Seam	-	Inclusion 1/8- to 3-inch thick extending through the sample.
Layer	-	Inclusion greater than 3-inch thick extending through the sample.
Interlayered	-	Soils sample composed of alternating layers of different soil types.
Intermixed	-	Soil samples composed of pockets of different soil type and layered or laminated structure is not evident.

COARSE GRAINED SOILS (major portion retained on No. 200 Sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Conditions rated according to standard penetration test (SPT)* as performed in the field.

Descriptive Terms	Blows Per Foot*
Very Loose	0 – 4
Loose	5 – 10
Medium Dense	11 – 30
Dense	31 – 50
Very Dense	over 50

* 140 pound weight having a free fall of 30-inch

SOIL SAMPLERS

- SHELBY TUBE SAMPLER
- STANDARD PENETRATION TEST
- AUGER SAMPLING

FINE GRAINED SOILS (major portion passing No. 200 Sieve): Include (1) inorganic or organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by hand penetrometer readings or by unconfined compression tests.

Descriptive Term	Undrained Shear Strength Ton/Sq. Ft.
Very Soft	Less than 0.13
Soft	0.13 to 0.25
Firm	0.25 to 0.50
Stiff	0.50 to 1.00
Very Stiff	1.00 to 2.00
Hard	2.00 or higher

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above because of weakness or cracks in the soil. The consistency ratings of such soils are based on hand penetrometer readings.

TERMS CHARACTERIZING ROCK PROPERTIES

VERY SOFT OR PLASTIC	Can be remolded in hand: corresponds in consistency up to very stiff in soils.
SOFT	Can be scratched with fingernail.
MODERATELY HARD	Can be scratched easily with knife; cannot be scratched with fingernail. Difficult to scratch with knife.
VERY HARD	Cannot be scratched with knife.
POORLY CEMENTED OR FRIABLE	Easily crumbled.
CEMENTED	Bounded Together by chemically precipitated materials.
UNWEATHERED	Rock in its natural state before being exposed to atmospheric agents.
SLIGHTLY WEATHERED	Noted predominantly by color change with no disintegrated zones.
WEATHERED	Complete color change with zones of slightly decomposed rock.
EXTREMELY WEATHERED	Complete color change with consistency, texture, and general appearance or soil.

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: Proposed Hollister Road Paving and Drianage – White Oak Bayou to West Gulf Bank

COH WBS NUMBER: R-000704-001-3

CONSULTANT PROJECT NUMBER: 12-762E

BORING NO.	SAMPLE NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-1	1	0	0.5													Concrete Pavement
	2	0.5	2	UD		11					72					Fill: Sandy Silt (ML)
	3	2	4	UD		13								1.5	1.5	Lean Clay with Sand (CL)
	4	4	6	UD		14	107	30	15	15	76	0.38		0.62	0.5	Lean Clay with Sand (CL)
	5	6	8	UD		19								0.25	0.23	Lean Clay with Sand (CL)
	6	8	14	UD		19								0.38	0.31	Lean Clay with Sand (CL)
	7	10	12	UD		14								1.5	1.5	Lean Clay with Sand (CL)
	8	12	14	UD		18	110	29	17	12	74	0.58		0.25	0.23	Lean Clay with Sand (CL)
	9	14	16	UD		16								1.5	1.32	Lean Clay with Sand (CL)
	10	16	18	UD		18	109					1.28		1.5	1.5	Lean Clay with Sand (CL)
	11	18	20	UD		18								0.88	0.78	Lean Clay with Sand (CL)
	12	20	22	UD		18								1.5	1.5	Lean Clay with Sand (CL)
	13	23	25	UD		21								1.5	0.93	Lean Clay with Sand (CL)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

AG = AUGER CUTTINGS

SPT = STANDARD PENETRATION TEST

LL = LIQUID LIMIT

PL = PLASTIC LIMIT

PI = PLASTIC INDEX

UU = TRIAXIAL COMPRESSION

NOTES:

PLATE A-7

SUMMARY OF LABORATORY TEST RESULTS

Geotechnical Consultant's Name: Geotech Engineering and Testing

PROJECT NAME: Proposed Hollister Road Paving and Drianage – White Oak Bayou to West Gulf Bank

COH WBS NUMBER: R-000704-001-3

CONSULTANT PROJECT NUMBER: 12-762E

BORING NO.	SAMPLE NO.	DEPTH (FT) Top	DEPTH (FT) Bottom	TYPE	SPT	WATER CONTENT(%)	DRY DENSITY (pcf)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	PERCENT PASSING SIEVE 200 (%)	SHEAR STRENGTH (TSF) UNCONFINED COMPRESSION TEST	UU TEST (CONFINING PRESSURE. TSF)	TORVANE	POCKET PENETRO METER	TYPE OF MATERIAL
B-2	1	0	0.5													Concrete Pavement
	2	0.5	2	UD		18								1	0.78	Fill: Lean Clay (CL)
	3	2	4	UD		18	113	34	16	18	78	0.85		0.75	0.62	Lean Clay With Sand (CL)
	4	4	6	UD		15								1.5	1.5	Lean Clay With Sand (CL)
	5	6	8	UD		16								1.5	1.16	Lean Clay With Sand (CL)
	6	8	10	UD		18	108	38	17	21	79	0.58		1	0.78	Lean Clay With Sand (CL)
	7	10	12	UD		16								1.5	0.93	Lean Clay With Sand (CL)
	8	12	14	UD		18								0.62	0.46	Lean Clay With Sand (CL)
	9	14	16	UD		17	114	39	17	22		2.22		1.5	1.5	Lean Clay With Sand (CL)
	10	16	18	UD		16								1.5	1.5	Lean Clay With Sand (CL)
	11	18	20	UD		24								1.5	1.01	Lean Clay With Sand (CL)
	12	20	22	UD		18								1	1.5	Lean Clay With Sand (CL)
	13	23	25	UD		31								1.5	1.24	Lean Clay With Sand (CL)

LEGEND:

UD = UNDISTURBED SAMPLE, EXTRUDED IN FIELD

SS = SPLIT SPOON SAMPLE

AG = AUGER CUTTINGS

SPT = STANDARD PENETRATION TEST

LL = LIQUID LIMIT

PL = PLASTIC LIMIT

PI = PLASTIC INDEX

UU = TRIAXIAL COMPRESSION

NOTES:

PLATE A-8

APPENDIX B

Project Site Pictures

PROJECT PICTURES
Project No. 12-762E

P-1 (A Picture of Project Alignment along Hollister Road)

P-2 (A Picture of Coring and Traffic Control)

PROJECT PICTURES
Project No. 12-344E

P-3 (A Picture of Drilling Operations and Traffic Control)

P-4 (A Picture of Grouting using Tremie Method)

APPENDIX C

OSHA Soil Classification

OSHA SOIL CLASSIFICATION

General

Occupational Safety and Health Administration (OSHA) has required a trench protective system for trenches deeper than five-ft. Trenches that are deeper than five-ft, should be shored, sheeted, braced or laid back to a stable slope, or some other appropriate means of protection should be provided where workers might be exposed to moving ground or caving. OSHA developed a soil classification system to be used as a guideline in determining protective requirements for trench excavations.

OSHA classification system categorizes the soil and rock in four types based on shear strength and stability. These classifications are summarized in the following report sections.

Stable Rock

means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A Soil

means cohesive soils with an unconfined compressive strength of 1.5-ton per square foot (tsf) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam, silty clay loam, sandy clay loam, caliche and hardpan. No soil is Type A if:

- The soil is fissured; or
- The soil is subject to vibration from heavy traffic, pile driving or similar effects; or

The soil has been previously disturbed; or

- The soil is part of a slope, layered system where the layers dip into the excavation on a slope of 4(h): 1(v) or greater; or
- The material is subject to other factors that would require it to be classified as a less stable material.

Type B Soil

- Cohesive soil with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf; or
- Granular cohesionless soils including: angular gravel, silt, silt loam, sandy loam, and in some case, silty clay loam and sandy clay loam; or
- Previously disturbed soils except those which would otherwise be classified as Type C soil; or
- Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

- o Dry rock that is not stable; or
- o Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than 4(h): 1(v), but only if the material would otherwise be classified as Type B.

Type C Soil

- o Cohesive soil with an unconfined compressive strength of 0.5 tsf or less; or
- o Granular soils including gravel, sand, and loamy sand; or
- o Submerged soil or soil from which water is freely seeping; or
- o Submerged rock that is not stable; or
- o Materials in a sloped, layered system where the layers dip into the excavation on a slope 4 (h) : 1(v) or steeper.

Under the assumption that appropriate groundwater control measures are carried out, and the groundwater table, if present, is lowered and maintained at least 3 feet below the excavation depths, the stable cohesive soils (CL) & (CH), with unconfined compressive strength greater than 0.5 tsf, are classified as OSHA soil Type "B". The granular soils, which are less stable, are classified as OSHA soil Type "C".

Based on our geotechnical exploration and laboratory test results details of soil classifications at each boring are summarized below:

OSHA SOIL TYPE

Boring No.	Depth Range (1), ft	Soil Type	OSHA Soil Classification
B-1	0 – 2	Fill: Sandy Silt (ML)	C
	2 – 6	Lean Clay with Sand (CL)	B
	6 – 8	Lean Clay with Sand (CL)	C
	8 – 10	Lean Clay with Sand (CL)	B
	10 – 25	Lean Clay with Sand (CL)	B
B-2	0 – 2	Fill: Lean Clay (CL)	B
	2 – 12	Lean Clay with Sand (CL)	B
	12 – 14	Lean Clay with Sand (CL)	B
	14 – 25	Lean Clay with Sand (CL)	B

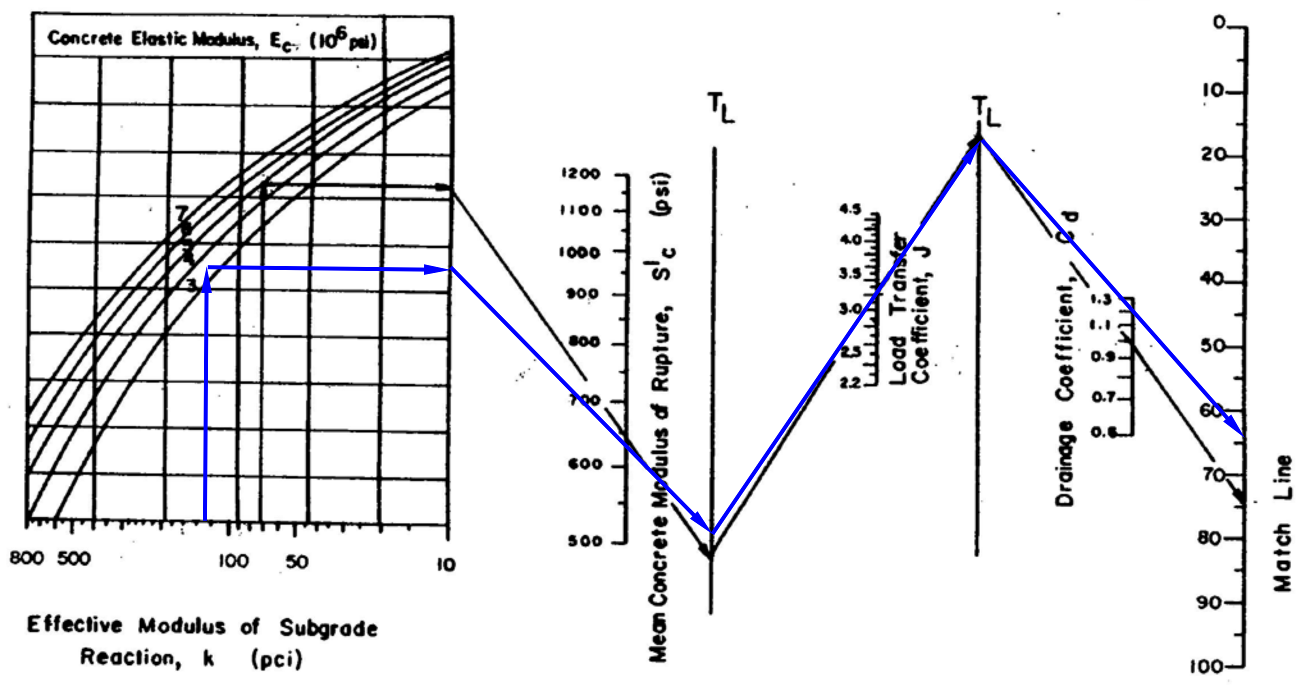
Note: 1. Refer to each boring log for soils stratigraphy

APPENDIX D

Pavement Design Computations

NOMOGRAPH SOLVES:

$$\log_{10} W_{18} = Z_R * S_o + 7.35 * \log_{10}(D+1) - 0.06 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.5 - 1.5}\right]}{1 + \frac{1.624*10^7}{(D+1)^{8.46}}} + (4.22 - 0.32p_t) * \log_{10}\left[\frac{S'_c * C_d \left[D^{0.75} - 1.132\right]}{215.63*J\left[D^{0.75} - \frac{18.42}{(E_c/k)^{0.25}}\right]}\right]$$



Legend :

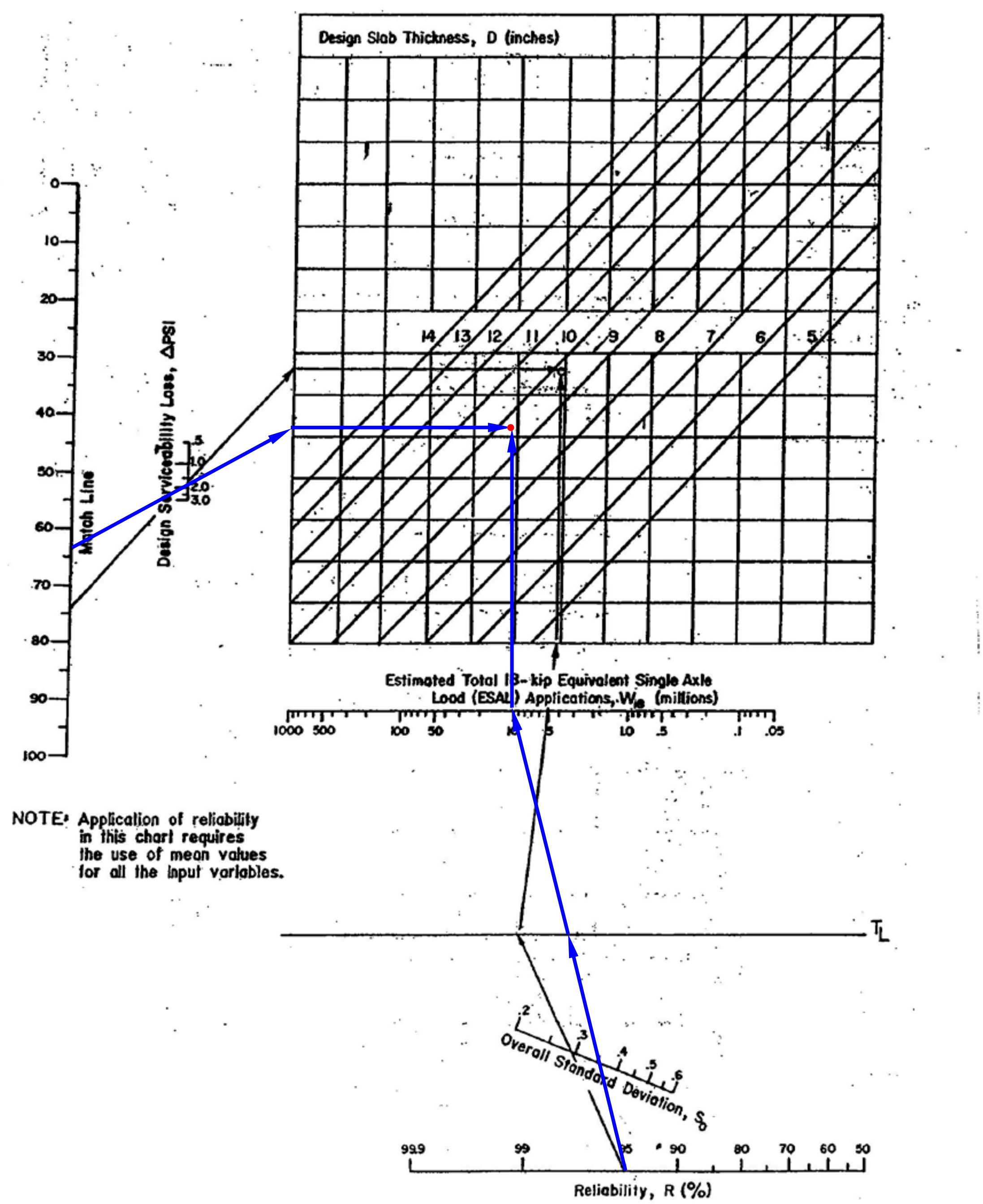
Pavement Design for This Study

Calculation:

k = 130 pci	$S_0 = 0.35$
$E_c = 3.60\times 10^6$	R = 95%
$S_c = 570$ psi	ΔPSI = 4.5-2.5 = 2.0
J = 3.2	
$C_d = 1.2$	

Solution:

W_{18} (18kip ESAL x 10^6)	Concrete Pavement Thickness, inch(es)
10.0	10.0



DESIGN CHART FOR RIGID PAVEMENTS BASED ON USING MEAN VALUES FOR EACH INPUT VARIABLES (SEGMENT 2)