Geotechnical Engineering Report

Design and Permitting for Sea Level Rise Pilot Project
Sands Subdivision in Big Pine Key, Monroe County, Florida

January 31, 2019
Terracon Project No. H8185048

Prepared for:

WSP USA
Miami, Florida

Prepared by:

Terracon Consultants, Inc.
Miami Lakes, Florida

January 31, 2019

WSP USA
7650 Corporate Center Drive, Suite 300
Miami, Florida 33126

Attn: Mr. Andres Cardona, P.E.
P: (305) 514 3144
E: Andres.cardona@wsp.com

Re: Geotechnical Engineering Report
Design and Permitting for Sea Level Rise Pilot Project
Father Tony Way between Avenue D and Avenue J
Sands Subdivision in Big Pine Key, Monroe County, Florida
Terracon Project No. H8185048

Dear Mr. Cardona:

We have completed the Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. PH8185048 dated October 5, 2018. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and pavement, pump station and gravity wall foundations for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.

HUGO E SOTO LICENSE No. 36440 STATE OF FLORIDA PROFESSIONAL ENGINEER

Rutugandha H. Nulkar, P.E.
Senior Engineer
FL Registration No. 70625

Hugo E. Soto, P.E.
Principal
FL Registration No. 36440

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Note: Refer to each individual Attachment for a listing of contents.

REPORT SUMMARY

Topic [1]	Overview Statement [2]
Project Description	It is proposed to raise the grade of the existing pavement along Father Tony Way from Avenue D to Avenue J. In addition, it is proposed to construct a pump station at the project location. A maximum of 5 foot tall gravity wall may be constructed within the project limits.
Geotechnical Characterization	The soil borings indicate asphaltic concrete pavement underlain by approximately 2 feet of sandy fill. This fill material is underlain by limestone formation that extends to the maximum depth of the borings of 6 and 40 feet.
Earthwork	**Proposed Raised Pavement:** Mill one-inch of the existing asphalt surface. Upon completion of milling, fill and base placement for the raised pavement can be completed. **Gravity Wall:** Compaction of existing soils or structural fill will be required upon completion of the site preparation as presented in this report. If the foundations are supported on limestone formation, the inspection of the exposed limestone is required. **Pump Station:** The excavation through the limestone formation may need special equipment.
Shallow Foundations	**Gravity Wall:** Shallow foundations will be sufficient Allowable bearing pressure = 3,000 psf for the gravity wall on sandy soils and 5,000 psf on limestone formation. **Pump Station:** Base slab of the pump station structure may be designed to allowable bearing pressure of 5000 psf. Expected settlements: less than one inch Detect and remove zones of fill as noted in **Earthwork**.
Pavements	Milling and removal of 4-8 inches of asphalt will be expensive. We recommend that one-inch of asphalt is milled to create a binding surface for the fill placement above it. For the minimum recommended pavement section we present two option: OPTION 1 **A.** Flexible Pavement – 2.0 inches of Asphaltic concrete - SP-9.5 Structural Course **B.** Base 6 inches – Group 1 **C.** Sub-base – from top of milled existing asphalt to bottom of base – LBR 40 material OPTION 2 To address the concern of erosion of subgrade and base material, we recommend that asphalt treated base be used from top of the milled existing asphalt to bottom of the new asphalt pavement surface.
General Comments	This section contains important information about the limitations of this geotechnical engineering report.

1. If the reader is reviewing this report as a pdf, the topics above can be used to access the appropriate section of the report by simply clicking on the topic itself.
2. This summary is for convenience only. It should be used in conjunction with the entire report for design purposes.

Geotechnical Engineering Report

Design and Permitting for Sea Level Rise Pilot Project
Father Tony Way between Avenue D and Avenue J
Sands Subdivision in Big Pine Key, Monroe County, Florida
Terracon Project No. H8185048
January 31, 2019

INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed raise grade of the existing roadway, to be located along Father Tony Way between Avenue D and Avenue J in Sands Subdivision in Big Pine Key, Monroe County, Florida. In addition, it is proposed to construct a pump station just south of Avenue G along Father Tony Way. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil and rock conditions
- Groundwater conditions
- Pavement recommendations
- Foundation recommendations for Gravity Wall and Pump Station

The geotechnical engineering Scope of Services for this project included the advancement of five (5) test borings to depths ranging from approximately 6 to 40 feet below existing site grades.

Maps showing the site and boring locations are shown in the **Site Location** and **Exploration Plan** sections, respectively. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs in the **Exploration Results** section.

SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Location	The project site is along the existing Father Tony roadway between Avenue D and Avenue J in Big Pine Key, Florida. See **Site Location**
Existing Improvements	The project site is currently covered by asphalt paved roadway with green areas on either side of the roadway.
Current Ground Cover	Asphaltic concrete pavement

Item	Description
Existing Topography	The project site is fairly level

PROJECT DESCRIPTION

Item	Description
Project Description	It is proposed to raise the grade of the existing Father Tony Way roadway between Avenue D and Avenue J to elevation 11 inches (NAVD 88) to address the sea level rises. In addition, it is proposed to construct one new pump station south of Avenue G and a possible gravity wall along the length of the project.

GEOTECHNICAL CHARACTERIZATION

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. Conditions encountered at each exploration point are indicated on the individual logs. The individual logs can be found in the **Exploration Results** section.

Layer No	Approx. Depth to Bottom of Stratum (ft)	Layer Name	General Description
1	**0.33 - 0.7**	**Asphalt**	4 to 8.5 inches thick
2	**1 – 1.3**	**FILL – Limerock Base**	Limerock, light brown with fine sand (GP)
3	**1.3 to 2.5**	**Fill**	Brown fine sand with trace limerock fragments (SM)
4	**40**	**LIMESTONE**	Light Brown Limestone with fine sand

Groundwater

The test borings were monitored while drilling for the presence and level of groundwater on January 14, 2019. Water levels observed at these times are indicated on the individual boring logs and are summarized in the following table.

Boring	Depth to Groundwater While Drilling (ft.) [1]	Approximate Depth to Bottom of Boring (ft.)
B-1	2.5	15
B-2	2.3	6
B-3	1.7	6
B-4	1.8	6
PS-1	1.8	40

1. Depth below ground surface.

These observations represent groundwater conditions at the time of the field exploration, and may not be indicative of other times, or at other locations. Groundwater levels can be expected to fluctuate with varying tidal, seasonal and weather conditions. Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. In addition, perched water can develop over low permeability soil strata following periods of heavy or prolonged precipitation. Therefore, groundwater levels during construction or at other times in the life of the structure may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

DCP Test Results

Dynamic Cone Penetration (DCP) Tests were performed within the top 2.5 feet (existing base and fill material) at the boring location PS-1. The DCP test data was used to determine the California Bearing Ratio (CBR) values by correlation for the existing material. The test results are presented in the Attachments. The results indicate a CBR value of 100 within the limerock base and a CBR value of 14-35 within the existing fill.

EARTHWORK

The following sections provide recommendations for use in the preparation of specifications for the work.

Site Preparation - Pavement

For the proposed roadway, we recommend that the existing asphaltic concrete pavement be milled by one-inch. Upon completion of the milling, the grade elevation of the roadway may be raised. We recommend that the designer accounts for higher runoff coefficient to address the drainage since the existing asphaltic pavement left in place will be considered impervious.

Site Preparation – Pump Station

Excavation

Excavation for the pump station and associated utility tie-ins should be made in accordance with all applicable State and Federal requirements. OSHA 29 CFR Part 1926 (Subpart P, Excavations) defines the subsurface profile within the planned depths of excavation as granular soils and natural limestone formation. If the prescribed sloping requirement cannot be met in the soils because of space limitations, a sheeting or shoring system will probably be necessary. The bottom elevation of the pump station is not available at this time. However, we anticipate that the pump station will be set using the caisson (a.k.a. tremie) method of construction. It should be noted that the limestone layer encountered between depths of 1.5 to 2.5 feet below existing grade and extends to a depth of 40 feet. The limestone formation is weakly to moderately cemented. There may be some difficulty while excavation through this material and special equipment may be required.

In-the-dry construction of the utility tie-ins will require groundwater lowering and control of groundwater seepage. If dewatering is required, the system needs to be designed by the specialty contractor.

Utility backfill should consist of clean granular fill as described under Fill Material Types.

Earth Retaining Structures

Retaining structures such as steel sheet piles that may be necessary for support of excavation walls should be designed to accommodate the lateral earth pressures that will be imposed. These structures should be designed using the lateral earth pressure criteria listed in the table on the following page.

LATERAL EARTH PRESSURE SOIL PARAMETERS							
Depth (feet)	Unit Weight (pcf)		Angle of Internal Friction (degrees)	Undrained Shear strength (psf)	Earth Pressure Coefficient		
	Moist	Buoyant			K_a	K_p	K_o
0 to 2	105	43	30	-	0.33	3.00	0.50
2 to 40	120	58	38	15600	0.24	4.20	0.38

Note: K_a indicates coefficient of active earth pressure

K_p indicates coefficient of passive earth pressure

K_o indicates coefficient of at-rest earth pressure

Site Preparation – Gravity Wall

We anticipate construction will be initiated by stripping vegetation, and loose, soft or otherwise unsuitable material. Stripped materials consisting of vegetation and organic materials should be wasted off site, or used to vegetate landscaped areas only.

Fill Material Types

Fill required to achieve design grade should be classified as structural fill. Structural fill is material used below, or within 10 feet of structures, pavements or constructed slopes. Earthen materials used for structural fill should meet the following material property requirements:

Fill Type	USCS Classification	Acceptable Location for Placement
General [1]	SP, SP-SM or GP, GP-GM (fines content < 12 percent, maximum particle size < 3 inches)	All locations and elevations

Fill Type	USCS Classification	Acceptable Location for Placement
Fill Placed Below Groundwater	Inorganic, non-plastic material, free of any man-made debris, limerock with a 3-inch maximum particle size with ASTM classification (USCS) of GP, GW or FDOT 57 Stone with less than 5 percent material finer than the No. 200 sieve and a maximum particle size of 3 inches. The FDOT 57 stone should not be placed more than one foot above the water table level.	Below groundwater
Asphalt treated Base	FDOT Standard Specifications for Road and Bridge Construction – Latest edition – Section 287	Above the existing milled asphalt pavement to bottom of the new asphalt pavement

1. Compacted structural fill should consist of approved materials that are free of organic matter and construction debris.

Fill Compaction Requirements

ITEM	DESCRIPTION
Fill Lift Thickness	Fill lift thicknesses vary with the compaction methods used and should be completed as follows: ▪ 12 inches or less in loose thickness when heavy vibratory compaction equipment is used. Maximum particle size should not exceed 3 inches in a 12-inch lift. ▪ 4 to 6 inches in loose thickness when hand-guided equipment (i.e. jumping jack or plate compactor) is used. Maximum particle size should not exceed 1½ inches in a 4- to 6-inch lift.
Compaction Requirements	The subgrade soils should be compacted to at least 95 percent of the maximum dry density as determined by the Modified Proctor Test (ASTM D 1557).
Moisture Content [1]	Within +/- 2 percent of optimum moisture content as determined by the Modified Proctor test, at the time of placement and compaction

1. We recommend that structural fill be tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.

Grading and Drainage

Positive drainage should be provided during construction and maintained throughout the life of the development. Infiltration of water into utility trenches or foundation excavations should be prevented during construction.

PUMP STATION FOUNDATION

The foundation for the proposed pump station is anticipated to lie within the limestone formation. The limestone formation should have adequate strength and bearing capacity to support the wet well structure, including the tremie plug. The base slab of the structure should be designed using an allowable bearing pressure of 5,000 pounds per square foot (psf). The slab should be well reinforced to resist the forces created by unbalanced hydrostatic pressures. Uplift forces can be resisted by the self-weight of the wet well and the tremie pour and frictional resistance at the wet well-backfill interface. Frictional resistance for the backfill may be calculated using at-rest lateral earth criteria described earlier in this report and a coefficient of friction of 0.20.

PAVEMENTS

General Pavement Comments

The SPT borings performed at the project site indicate asphaltic concrete pavement underlain by two (2) feet of existing fill material underlain by limestone formation. The fill primarily consists of gravel-sized limerock with fine to medium sands and fine to medium sand with limerock (A-1-a/A-1-b). We recommend that at least one inch of the existing asphalt pavement be milled. Upon completion of the milling, the grade of the roadway may be raised. We present two options for the pavement section thicknesses. We do not anticipate any significant heavy traffic loading on the roadway.

We recommend minimum thickness for the pavement design for regular traffic requirements as follows:

OPTION 1:

- Asphalt, Type SP: Traffic A - 2 inches – Type SP 9.5 Structural Course
- Limerock Base: 6 inches Group 1
- Subgrade: from top of the existing milled asphalt pavement to bottom of the limerock base layer use granular fill material of LBR 40

OPTION 2:

We understand that there is a concern of erosion of the limerock base and subgrade materials in the project area. Hence, we recommend that use of Asphalt treated base from the top of the existing milled asphalt pavement to the bottom of the new asphaltic pavement surface be considered.

For both the above-mentioned options, the designer should account for higher runoff coefficient to address the drainage since the existing asphaltic pavement left in place will be considered impervious.

<u>Flexible (Asphalt) Pavements</u>

In order for a conventional flexible asphalt pavement to perform satisfactorily, the subgrade soils must have sufficient strength and stability to support construction traffic loading and design traffic loading. Our flexible asphalt pavement thickness design is based on the following assumptions:

- The pavement subgrade soils have been compacted to at least 98 percent of the Modified Proctor maximum dry density (ASTM D-1557). The in-situ moisture content shall be within two percent (2%) of the optimum moisture content determined by the Modified Proctor test. This would require stabilizing the subgrade soils to minimum Limerock Bearing Ratio (LBR); Florida Method of Test Designation FM 5-515) value of 40 or replacing the in-place soils with new compacted fill that meets the minimum LBR value.

- The subgrade and the pavement surface have a minimum ¼ inch per foot slope to promote proper surface drainage.

- The base course should be limerock. Limerock base course should be mined from a Florida Department of Transportation (FDOT) approved source, have a LBR value of at least 100 and be compacted to a minimum of 98 percent of the maximum dry density as determined by the Modified Proctor test. The in-situ moisture content shall be within two percent (2%) of the optimum moisture content determined by the Modified Proctor test. Limerock should be placed in lifts not to exceed 6 inches in loose thickness. Recycled limerock will not be a suitable base material.

- All surface water should be directed away from the edges of the pavement.

FDOT asphalt surface courses are typically Superpave mixes. The asphalt contractor should have experience working with Superpave mixes in accordance with FDOT specifications. Flexible pavement design should also conform to any applicable local municipal requirements.

Pavement Drainage

Pavements should be sloped to provide rapid drainage of surface water. Water allowed to pond on or adjacent to the pavements could saturate the subgrade and contribute to premature pavement deterioration. In addition, the pavement subgrade should be graded to provide positive drainage within the granular base section. Appropriate sub-drainage or connection to a suitable daylight outlet should be provided to remove water from the granular subbase.

Based on the possibility of shallow and/or perched groundwater, we recommend installing a pavement subdrain system to control groundwater, improve stability, and improve long-term pavement performance.

Pavement Maintenance

The pavement sections represent minimum recommended thicknesses and, as such, periodic maintenance should be anticipated. Therefore, preventive maintenance should be planned and provided for through an on-going pavement management program. Maintenance activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment. Maintenance consists of both localized maintenance (e.g., crack and joint sealing and patching) and global maintenance (e.g., surface sealing). Preventive maintenance is usually the priority when implementing a pavement maintenance program. Additional engineering observation is recommended to determine the type and extent of a cost-effective program. Even with periodic maintenance, some movements and related cracking may still occur and repairs may be required.

Pavement performance is affected by its surroundings. In addition to providing preventive maintenance, the civil engineer should consider the following recommendations in the design and layout of pavements:

- Final grade adjacent to paved areas should slope down from the edges at a minimum 2%.
- Subgrade and pavement surfaces should have a minimum 2% slope to promote proper surface drainage.
- Install below pavement drainage systems surrounding areas anticipated for frequent wetting.
- Install joint sealant and seal cracks immediately.
- Seal all landscaped areas in or adjacent to pavements to reduce moisture migration to subgrade soils.
- Place compacted, low permeability backfill against the exterior side of curb and gutter.
- Place curb, gutter and/or sidewalk directly on clay subgrade soils rather than on unbound granular base course materials.

GRAVITY WALL

Terracon was requested to provide allowable bearing pressures for a concrete gravity walls to be constructed on the project site. The proposed wall is anticipated to be a maximum of 5 feet in height. In our opinion, the proposed gravity wall can be supported by a shallow footing foundation system on existing soil or compacted structural fill or existing limestone formation.

Design Recommendations

Design recommendations for the gravity wall foundation are presented in the following table

Item	Description
Maximum Net Allowable Bearing pressure [1, 2]	3,000 psf (foundations bearing within structural fill) 5,000 psf (foundation bearing on limestone formation)
Minimum Embedment below Finished Grade [4]	18 inches
Estimated Total Settlement from Structural Loads [2]	Less than a inch

1. The maximum net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. An appropriate factor of safety has been applied. Values assume that exterior grades are no steeper than 20% within 10 feet of structure.
2. Values provided are for maximum loads noted in **Project Description**. .
3. Use of passive earth pressures require the sides of the excavation for the spread footing foundation to be nearly vertical and the concrete placed neat against these vertical faces or that the footing forms be removed and compacted structural fill be placed against the vertical footing face.
4. Embedment necessary to minimize the effects of frost and/or seasonal water content variations. For sloping ground, maintain depth below the lowest adjacent exterior grade within 5 horizontal feet of the structure.

The Concrete Gravity Wall should be designed in accordance with Scheme 2 FDOT Index 6011.

GENERAL COMMENTS

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly impact excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety, and cost estimating including, excavation support, and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

ATTACHMENTS

SITE LOCATION AND EXPLORATION PLANS

SITE LOCATION

Monroe County-Sea Level Rise Pilot Project ■ Big Pine Key, FL
January 31, 2019 ■ Terracon Project No. H8185048

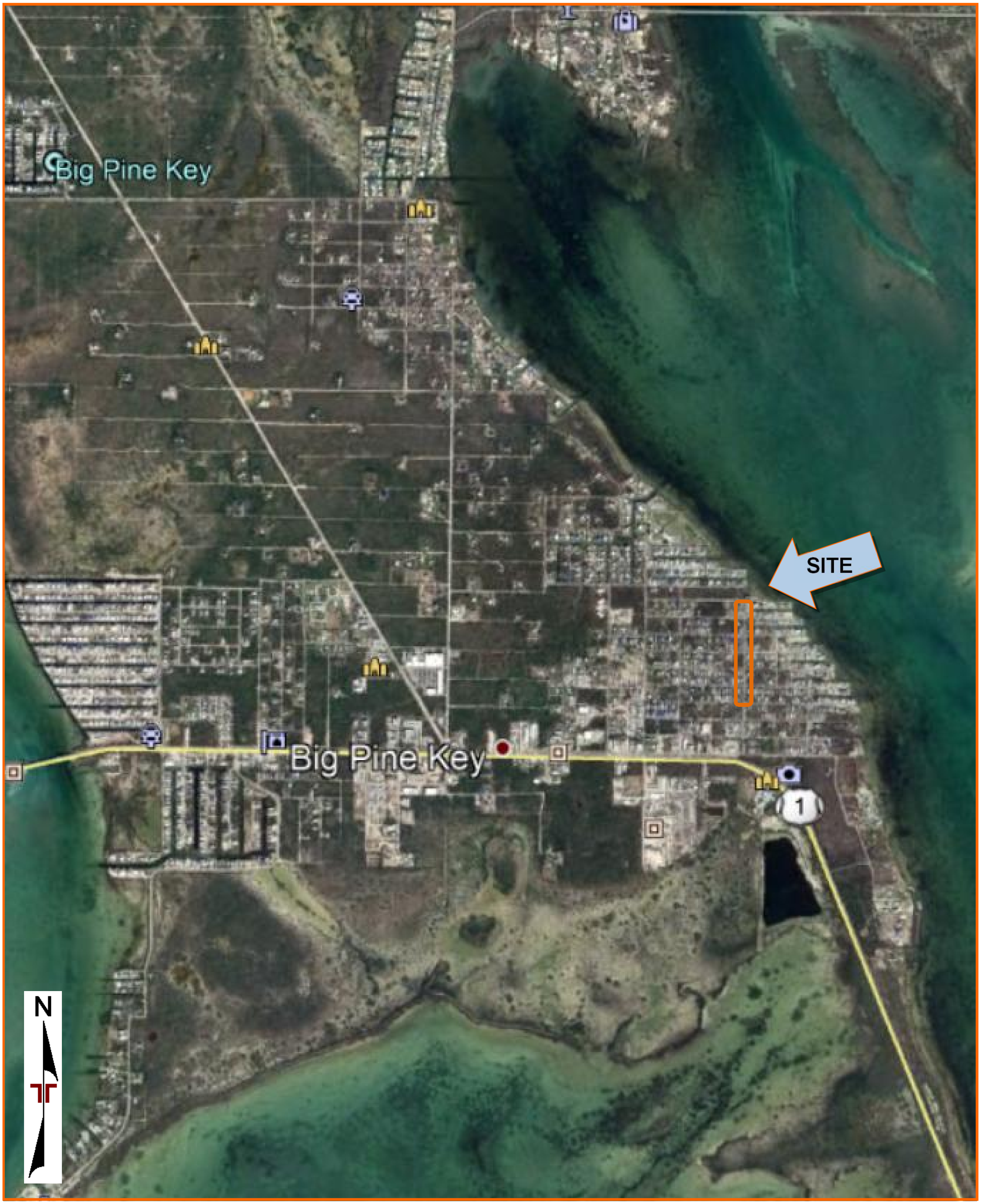


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS
NOT INTENDED FOR CONSTRUCTION PURPOSES

COURTESY OF GOOGLE EARTH PRO

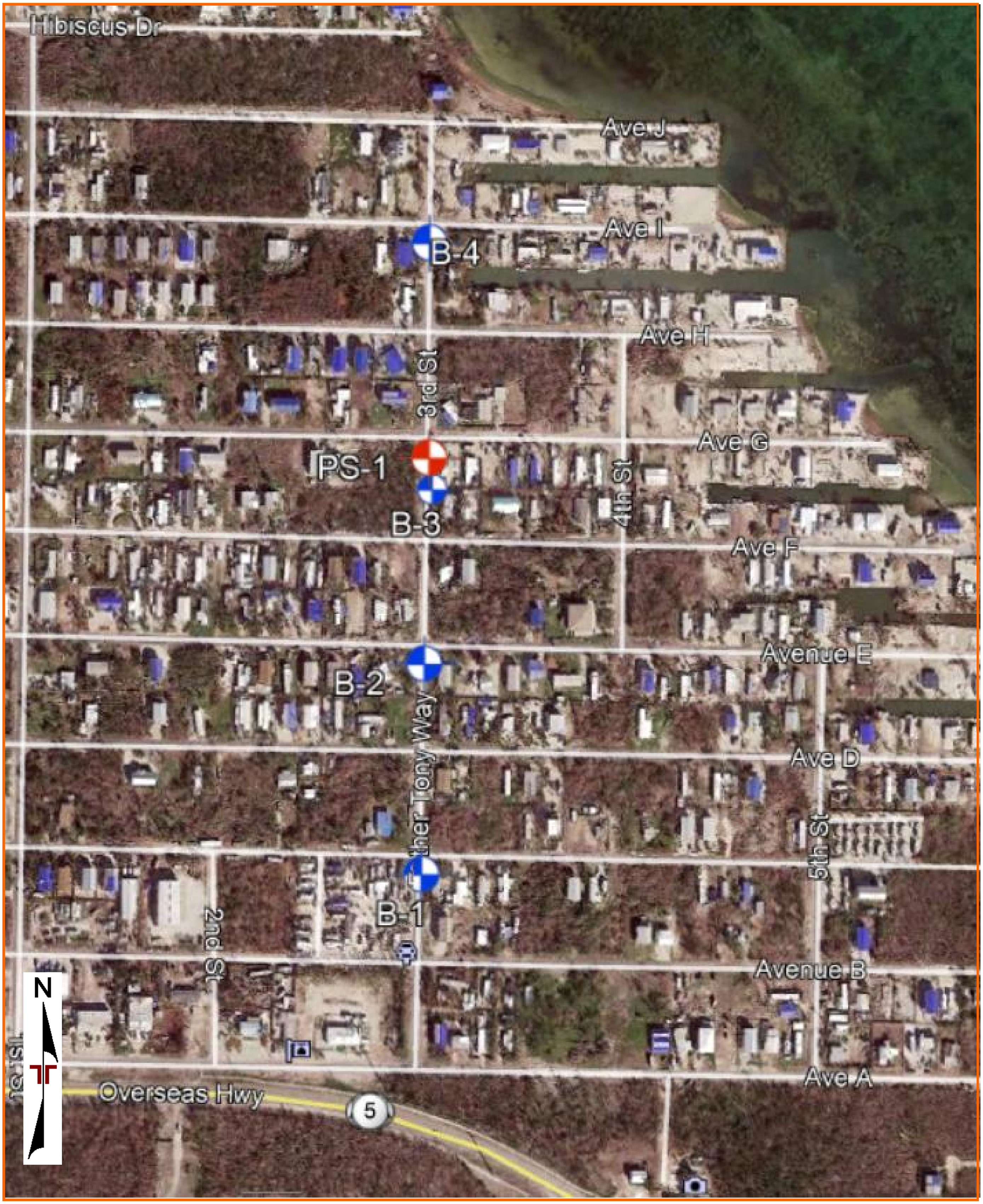


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

EXPLORATION RESULTS

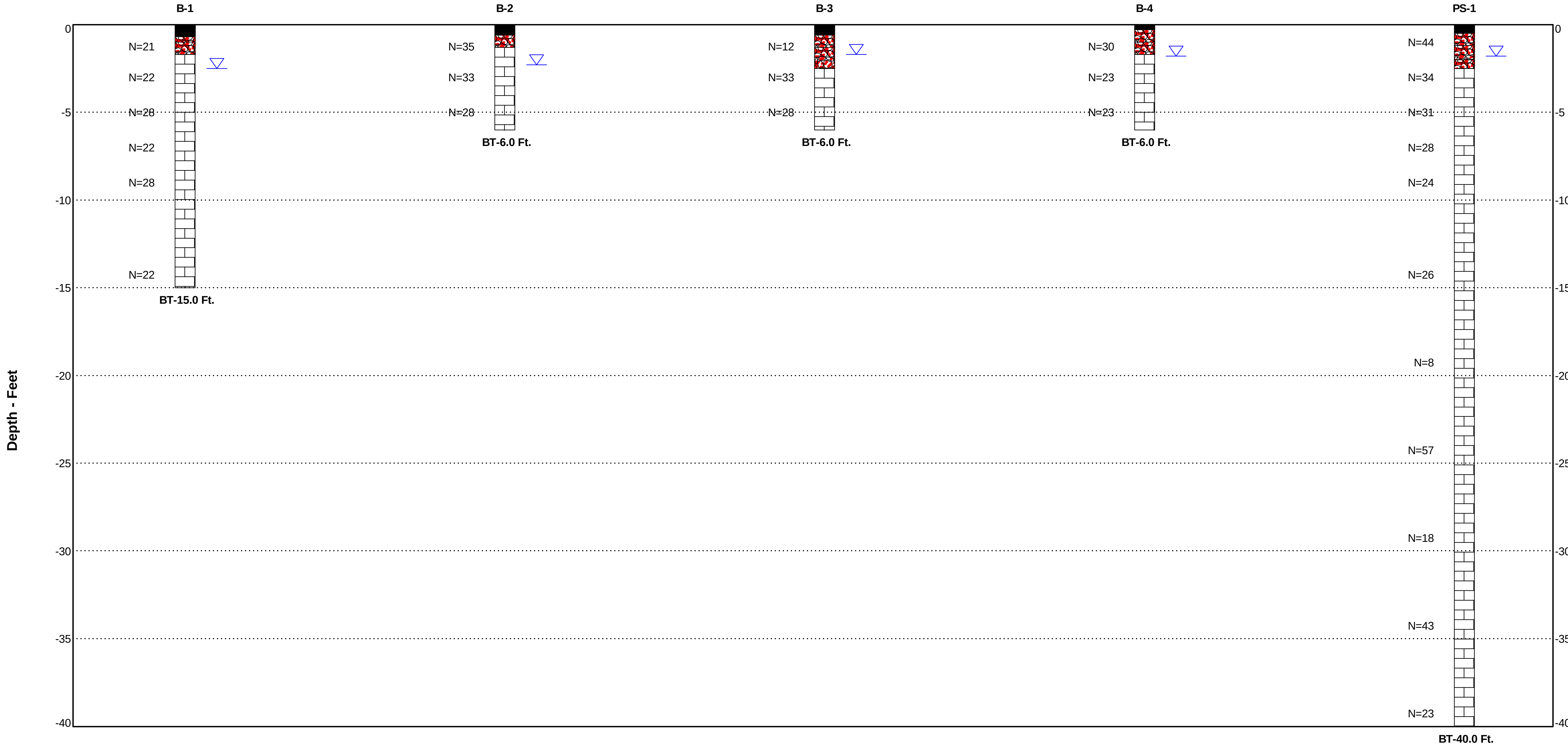
Contents:

Fence Diagram (A-1)

Boring Logs (A-2 through A-6)

Asphalt Core Photograph (A-7)

CBR Test Result (A-8)



Asphalt

Fill - Limerock / Silty Fine Sand

Limestone

Explanation

B-1 — Borehole Number

Moisture Content — %w

LL PL — Liquid and Plastic Limits

Sampling (See General Notes)

Borehole Lithology

AR BT — Borehole Termination Type

Water Level Reading at time of drilling.

Water Level Reading after drilling.

NOTES:

See Exploration Plan for orientation of soil profile.
See General Notes in Appendix C for symbols and soil classifications.
Soils profile provided for illustration purposes only.
Soils between borings may differ
AR - Auger Refusal
BT - Boring Termination

Project Manager:	Project No.: H8185048	Terracon	SUBSURFACE PROFILE	EXHIBIT
Drawn by: SDF	Scale: N.T.S.	16200 NW 59th Ave, Ste 106 Miami Lakes, FL	MONROE COUNTY-SEA LEVEL RISE PILOT PROJECT FATHER TONY WAY BIG PINE KEY, FL	A-1
Approved by: HES	File Name: H8185048			
Date: 1/25/2019		PH. 305-820-1997 FAX.		

BORING LOG NO. B-1

PROJECT: Monroe County-Sea Level Rise Pilot Project

CLIENT: WSP USA Inc.
Miami, FL

SITE: Father Tony Way
Big Pine Key, FL

LOCATION See Exploration Plan

DEPTH	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	ORGANIC CONTENT (%)	WATER CONTENT (%)	PERCENT FINES
0.7	**ASPHALT**, 8.5" thick				6-6-15 N=21			
1.0	**FILL - LIMEROCK (GP)**, with fine sand, light brown		▽		13-12-10-10 N=22			
1.7	**FILL - FINE SAND (SP)**, trace limerock and organics, brown	5			12-13-15-18 N=28			
	LIMESTONE, with fine sand, light brown				12-10-12-13 N=22			
		10			18-15-13-15 N=28			
15.0		15			10-10-12 N=22			

Boring Terminated at 15 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Rotary Mud Drilling and Casing

Abandonment Method:
Boring backfilled with grout upon completion.

Notes:
Total lost of drilling fluid from 0'

WATER LEVEL OBSERVATIONS

▽ *Water Initially Encountered at 2.5'*

Terracon
16200 NW 59th Ave, Ste 106
Miami Lakes, FL

Boring Started: 01-14-2019	Boring Completed: 01-14-2019
Drill Rig: CME 55	Driller: OC
Project No.: H8185048	Exhibit: A-2

BORING LOG NO. B-2

PROJECT: Monroe County-Sea Level Rise Pilot Project

**CLIENT: WSP USA Inc.
Miami, FL**

**SITE: Father Tony Way
Big Pine Key, FL**

LOCATION See Exploration Plan

DEPTH	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	ORGANIC CONTENT (%)	WATER CONTENT (%)	PERCENT FINES
0.6	**ASPHALT**, 7" thick							
1.3	**FILL - LIMEROCK (GP)**, with fine sand, light brown			X	10-16-19 N=35			
	LIMESTONE, with fine sand, light brown		▽	X	23-18-15-12 N=33			
6.0		5		X	18-15-13-15 N=28			

Boring Terminated at 6 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Rotary Mud Drilling and Casing

Abandonment Method:
Boring backfilled with grout upon completion.

Notes:

WATER LEVEL OBSERVATIONS

▽ *Water Initially Encountered at 2.3'*

Terracon
16200 NW 59th Ave, Ste 106
Miami Lakes, FL

Boring Started: 01-14-2019	Boring Completed: 01-14-2019
Drill Rig: CME 55	Driller: OC
Project No.: H8185048	Exhibit: A-3

BORING LOG NO. B-3

PROJECT: Monroe County-Sea Level Rise Pilot Project

CLIENT: WSP USA Inc.
Miami, FL

SITE: Father Tony Way
Big Pine Key, FL

GRAPHIC LOG	LOCATION See Exploration Plan DEPTH	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	ORGANIC CONTENT (%)	WATER CONTENT (%)	PERCENT FINES
	0.6 **ASPHALT**, 7" thick							
	1.3 **FILL - LIMEROCK (GP)**, with fine sand, light brown		▽	X	8-6-6 N=12		38	12
	2.5 **FILL - SILTY FINE SAND (SM)**, with limerock, light brown			X	7-15-18-12 N=33			
	LIMESTONE, with fine sand, light brown	5		X	10-13-15-18 N=28			
	6.0							
	Boring Terminated at 6 Feet							

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Rotary Mud Drilling and Casing

Abandonment Method:
Boring backfilled with grout upon completion.

Notes:

WATER LEVEL OBSERVATIONS

▽ *Water Initially Encountered at 1.7'*

Terracon
16200 NW 59th Ave, Ste 106
Miami Lakes, FL

Boring Started: 01-14-2019	Boring Completed: 01-14-2019
Drill Rig: CME 55	Driller: OC
Project No.: H8185048	Exhibit: A-4

BORING LOG NO. B-4

PROJECT: Monroe County-Sea Level Rise Pilot Project	**CLIENT: WSP USA Inc.** **Miami, FL**
SITE: Father Tony Way **Big Pine Key, FL**	

LOCATION See Exploration Plan

DEPTH	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	ORGANIC CONTENT (%)	WATER CONTENT (%)	PERCENT FINES
0.3	**ASPHALT**, 4" thick							
1.0	**FILL - LIMEROCK (GP)**, with fine sand, light brown		▽	X	18-6-24 N=30		42	16
1.7	**FILL - SILTY FINE SAND (SM)**, with limerock, light brown			X	15-13-10-12 N=23			
6.0	**LIMESTONE**, with fine sand, light brown	5		X	10-10-13-15 N=23			

Boring Terminated at 6 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Rotary Mud Drilling and Casing

Abandonment Method:
Boring backfilled with grout upon completion.

Notes:

WATER LEVEL OBSERVATIONS

▽ *Water Initially Encountered at 1.8'*

Terracon
16200 NW 59th Ave, Ste 106
Miami Lakes, FL

Boring Started: 01-14-2019	Boring Completed: 01-14-2019
Drill Rig: CME 55	Driller: OC
Project No.: H8185048	Exhibit: A-5

BORING LOG NO. PS-1

PROJECT: Monroe County-Sea Level Rise Pilot Project

CLIENT: WSP USA Inc.
Miami, FL

SITE: Father Tony Way
Big Pine Key, FL

LOCATION See Exploration Plan

DEPTH	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	ORGANIC CONTENT (%)	WATER CONTENT (%)	PERCENT FINES
0.5	**ASPHALT**, 7" thick							
1.2	**FILL - LIMEROCK (GP)**, with fine sand, light brown		▽	X	56-28-16-12 N=44			
2.0	**FILL - FINE SAND (SP)**, with limerock, brown			X	8-16-18-20 N=34			
2.5	**FILL - LIMEROCK (GP)**, with fine sand, light brown							
	LIMESTONE, with fine sand, light brown	5		X	13-16-15-13 N=31			
				X	10-13-15-15 N=28			
				X	12-12-12-16 N=24			
		10						
		15		X	12-13-13 N=26			
		20		X	5-3-5 N=8			
		25		X	18-32-25 N=57			
		30		X	10-10-8 N=18			
		35		X	15-23-20 N=43			
40.0		40		X	16-13-10 N=23			

Boring Terminated at 40 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Rotary Mud Drilling and Casing

Abandonment Method:
Boring backfilled with grout upon completion.

Notes:
Total lost of drilling fluid at 33 feet

WATER LEVEL OBSERVATIONS

▽ *Water Initially Encountered at 1.8'*

Terracon
16200 NW 59th Ave, Ste 106
Miami Lakes, FL

Boring Started: 01-14-2019	Boring Completed: 01-14-2019
Drill Rig: CME 55	Driller: OC
Project No.: H8185048	Exhibit: A-6

PS-1, 6-3/4” thick

Dynamic Cone Penetrometer Field Report (ASTM D6951)

DCP BORING NO. PS-1

Project No.: H8185048	**Location:** Sands Subdivision in Big Pine Key, Monroe County, Florida	
Project Name: Design and Permitting for the Sea Level Rise Pilot Project	1/15/2019	**1/14/2019**

Stratigraphy					DCP Data				
From (ft)	To (ft)	From (in)	To (in)	Material Description	No. of Blows	Accum. Pen. (mm)	Pen./ Blow (mm/blow)	DCP Index (mm/blow)	CBR (%)
0.0	0.6	0	6.75	**Asphalt**	---	---	---	---	---
0.6	1.1	6.75	12.75	**FILL - LIMEROCK (GP)**	57	152.4	2.7	2.7	100
1.1	1.6	12.75	18.75	**FILL - Fine SAND with limerock (SP)**	14	152.4	10.9	10.9	20
1.6	2.1	18.75	24.75		10	152.4	15.2	15.2	14
2.1	2.6	24.75	30.75	**FILL - LIMEROCK with fine Sand (GP)**	22	152.4	6.9	6.9	35

Groundwater Depth: Water Initially Encountered at 1.75'	**Advancement Method:** DCP	**Other Notes:** None
Test By: OC	**Reviewed By:** HES	

EXPLORATION AND TESTING PROCEDURES

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Borings	Boring Depth (feet)	Planned Location
3	6	pavement
1	15	pavement
1	40	Pump station

Boring Layout and Elevations: Unless otherwise noted, Terracon personnel provided the boring layout. Coordinates were obtained with a handheld GPS unit (estimated horizontal accuracy of about ±10 feet). If elevations and a more precise boring layout are desired, we recommend borings be surveyed following completion of fieldwork.

Subsurface Exploration Procedures: We advanced the borings with a truck-mounted, rotary drill rig. Four samples were obtained in the upper 10 feet of each boring and at intervals of 5 feet thereafter. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. We observed and recorded groundwater levels during drilling and sampling. For safety purposes, all borings were backfilled with auger cuttings after their completion. Pavements were patched with cold-mix asphalt and/or pre-mixed concrete, as appropriate.

The sampling depths, penetration distances, and other sampling information was recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and classification by a Geotechnical Engineer. Our exploration team prepared field boring logs as part of the drilling operations. These field logs included visual classifications of the materials encountered during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field logs. The final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests to understand the engineering properties of the various soil and rock strata, as necessary, for this project. Procedural standards noted below are for reference to methodology in general. In some cases, variations to methods were applied because of local practice or professional judgment. Standards noted below include reference to other, related standards. Such references are not necessarily applicable to describe the specific test performed.

- ASTM D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D422 Standard Test Method for Particle-Size Analysis of Soils

The laboratory testing program often included examination of soil samples by an engineer. Based on the material's texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System.

Rock classification was conducted using locally accepted practices for engineering purposes. Boring log rock classification was determined using the Description of Rock Properties.

SUPPORTING INFORMATION

Contents:

General Notes

Unified Soil Classification System

Description of Rock Properties

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING

- Auger Cuttings
- Rock Core
- Grab Sample
- No Recovery
- Shelby Tube
- Standard Penetration Test

WATER LEVEL

- Water Initially Encountered
- Water Level After a Specified Period of Time
- Water Level After a Specified Period of Time

Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.

FIELD TESTS

(HP)	Hand Penetrometer
(T)	Torvane
(DCP)	Dynamic Cone Penetrometer
(PID)	Photo-Ionization Detector
(OVA)	Organic Vapor Analyzer

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		CONSISTENCY OF FINE-GRAINED SOILS (50% of more passing the No. 200 sieve) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Descriptive Term (Density)	**Automatic Hammer SPT N-Value (Blows/Ft.)**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength Qu, (psf)**	**Automatic Hammer SPT N-Value (Blows/Ft.)**
Very Loose	< 3	Very Soft	Less than 500	< 1
Loose	3 – 8	Soft	500 to 1,000	1 – 3
Medium Dense	8 – 24	Medium Stiff	1,000 to 2,000	3 – 6
Dense	24 – 40	Stiff	2,000 to 4,000	6 – 12
Very Dense	> 40	Very Stiff	4,000 to 8,000	12 – 24
		Hard	> 8,000	> 24

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 – 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300 mm)
Cobble	12 in. to 3 in. (300 mm to 75 mm)
Gravel	3 in. to #4 sieve (75 mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other consituents	Percent of Dry Weight
Trace	< 5
With	5 – 12
Modifier	> 12

PLASTICITY DESCRIPTION

Term	Particle Size
Non-Plastic	0
Low	1 – 10
Medium	11 – 30
High	> 30

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification: Group Symbol	Soil Classification: Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu ³ 4 and 1 £ Cc £ 3 [E]		GW	Well-graded gravel [F]
			Cu < 4 and/or [Cc<1 or Cc>3.0] [E]		GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH		GM	Silty gravel [F, G, H]
			Fines classify as CL or CH		GC	Clayey gravel [F, G, H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	Cu ³ 6 and 1 £ Cc £ 3 [E]		SW	Well-graded sand [I]
			Cu < 6 and/or [Cc<1 or Cc>3.0] [E]		SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH		SM	Silty sand [G, H, I]
			Fines classify as CL or CH		SC	Clayey sand [G, H, I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots on or above “A” line [J]		CL	Lean clay [K, L, M]
			PI < 4 or plots below “A” line [J]		ML	Silt [K, L, M]
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay [K, L, M, N]
			Liquid limit - not dried			Organic silt [K, L, M, O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above “A” line		CH	Fat clay [K, L, M]
			PI plots below “A” line		MH	Elastic Silt [K, L, M]
		Organic:	Liquid limit - oven dried	< 0.75	OH	Organic clay [K, L, M, P]
			Liquid limit - not dried			Organic silt [K, L, M, Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve.

[B] If field sample contained cobbles or boulders, or both, add “with cobbles or boulders, or both” to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.

[E] $Cu = D_{60}/D_{10}$ $Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ³ 15% sand, add “with sand” to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add “with organic fines” to group name.

[I] If soil contains ³ 15% gravel, add “with gravel” to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add “with sand” or “with gravel,” whichever is predominant.

[L] If soil contains ³ 30% plus No. 200 predominantly sand, add “sandy” to group name.

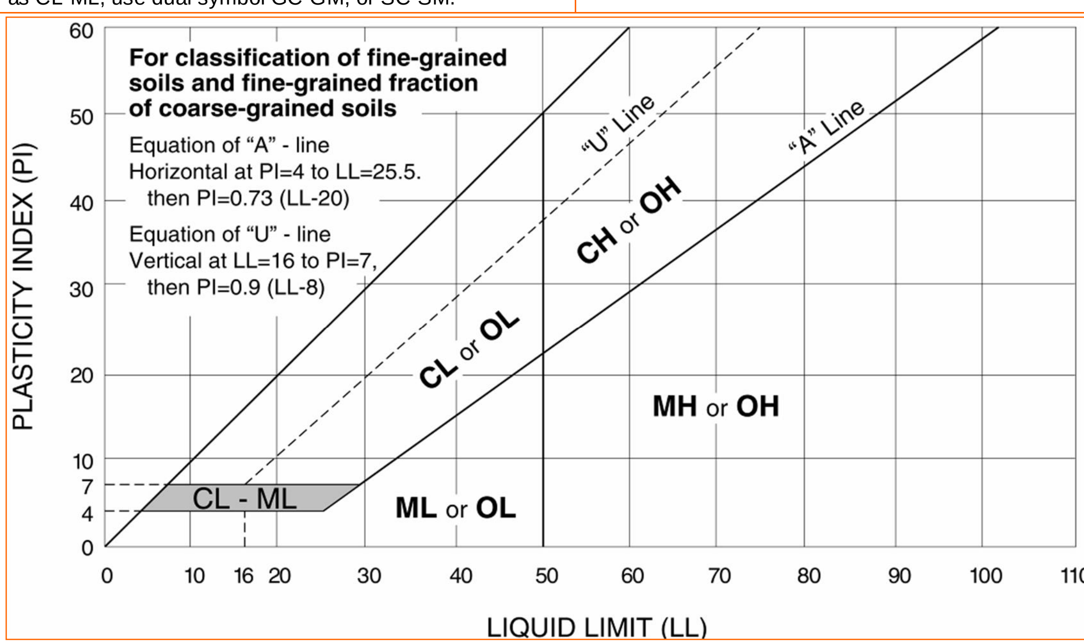
[M] If soil contains ³ 30% plus No. 200, predominantly gravel, add “gravelly” to group name.

[N] PI ³ 4 and plots on or above “A” line.

[O] PI < 4 or plots below “A” line.

[P] PI plots on or above “A” line.

[Q] PI plots below “A” line.



DESCRIPTION OF ROCK PROPERTIES

Terracon GeoReport

WEATHERING	
Term	**Description**
Unweathered	No visible sign of rock material weathering, perhaps slight discoloration on major discontinuity surfaces.
Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones.
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones.
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

STRENGTH OR HARDNESS		
Description	**Field Identification**	**Uniaxial Compressive Strength, psi (MPa)**
Extremely weak	Indented by thumbnail	40-150 (0.3-1)
Very weak	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	150-700 (1-5)
Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	700-4,000 (5-30)
Medium strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	4,000-7,000 (30-50)
Strong rock	Specimen requires more than one blow of geological hammer to fracture it	7,000-15,000 (50-100)
Very strong	Specimen requires many blows of geological hammer to fracture it	15,000-36,000 (100-250)
Extremely strong	Specimen can only be chipped with geological hammer	>36,000 (>250)

DISCONTINUITY DESCRIPTION			
Fracture Spacing (Joints, Faults, Other Fractures)		**Bedding Spacing (May Include Foliation or Banding)**	
Description	**Spacing**	**Description**	**Spacing**
Extremely close	< ¾ in (<19 mm)	**Laminated**	< ½ in (<12 mm)
Very close	¾ in – 2-1/2 in (19 - 60 mm)	**Very thin**	½ in – 2 in (12 – 50 mm)
Close	2-1/2 in – 8 in (60 – 200 mm)	**Thin**	2 in – 1 ft. (50 – 300 mm)
Moderate	8 in – 2 ft. (200 – 600 mm)	**Medium**	1 ft. – 3 ft. (300 – 900 mm)
Wide	2 ft. – 6 ft. (600 mm – 2.0 m)	**Thick**	3 ft. – 10 ft. (900 mm – 3 m)
Very Wide	6 ft. – 20 ft. (2.0 – 6 m)	**Massive**	> 10 ft. (3 m)

Discontinuity Orientation (Angle): Measure the angle of discontinuity relative to a plane perpendicular to the longitudinal axis of the core. (For most cases, the core axis is vertical; therefore, the plane perpendicular to the core axis is horizontal.) For example, a horizontal bedding plane would have a 0-degree angle.

ROCK QUALITY DESIGNATION (RQD) [1]	
Description	**RQD Value (%)**
Very Poor	0 - 25
Poor	25 – 50
Fair	50 – 75
Good	75 – 90
Excellent	90 - 100

1. The combined length of all sound and intact core segments equal to or greater than 4 inches in length, expressed as a percentage of the total core run length.

Reference: U.S. Department of Transportation, Federal Highway Administration, Publication No FHWA-NHI-10-034, December 2009 Technical Manual for Design and Construction of Road Tunnels – Civil Elements