Subsurface Soil Exploration and
Geotechnical Engineering Evaluation
Proposed Naples Beach Restoration and
Water Quality Improvement Project
Naples, Collier County, Florida

Ardaman & Associates, Inc.

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Ardaman & Associates, Inc.

Geotechnical, Environmental and
Materials Consultants

Ardaman Project No. 19-33-4545
September 5, 2019

Erickson Consulting Engineers, Inc.
7201 Delainey Court
Sarasota, Florida 34240

Attention: Ms. Christin L. Perkinson, Ph.D., P.E., D.CE.

SUBJECT: Subsurface Soil Exploration and
Geotechnical Engineering Evaluation
Proposed Naples Beach Restoration and
Water Quality Improvement Project
Naples, Collier County, Florida

Dear Ms. Perkinson:

As requested and authorized by **Erickson Consulting Engineers, Inc.**, we have completed a shallow subsurface soil exploration for the subject project. The purposes of performing this exploration were to evaluate the general subsurface conditions within the vicinity of the proposed stormwater trunk line alignment and associated stormwater structures and to provide recommendations for site preparation, pipeline/foundation support and pavement design.

This report documents our findings and conclusions. It has been prepared for the exclusive use of **Erickson Consulting Engineers, Inc.** for specific application to the subject project in accordance with generally accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

SCOPE

The scope of our services was limited to the following items:

1. Conducting 11 Standard Penetration Test (SPT) borings to determine the nature and condition of the subsurface soils.

2. Reviewing each soil sample obtained in our field exploration program by a geotechnical engineer in our laboratory for further identification and assignment of laboratory tests.

3. Performing the appropriate laboratory tests on selected samples.

4. Analyzing the existing soil conditions with respect to the proposed construction as it relates to foundation and pavement design.

5. Preparing this report to document the results of our field exploration, engineering analysis and recommendations.

SITE LOCATION AND SITE DESCRIPTION

The proposed stormwater trunk line improvements are located along the east side of Gulf Shore Boulevard between South Golf Drive and 2nd Avenue South in Naples, Collier County, Florida. The approximate project alignment is shown on an aerial photograph obtained from Google Earth Pro presented on Figure 1.

We understand that the proposed stormwater trunk line and associated stormwater structures will be constructed adjacent to existing utility alignments and existing subsurface structures. The proposed stormwater trunk line and associated stormwater structures will underlie existing roads and green space areas.

PROPOSED CONSTRUCTION AND GRADING

It is our understanding that the approximate 4,600 linear feet of stormwater trunk line will consist of a combination of 36-inch FPVC, 42-inch pipe culvert of optional material and manhole structures. A pump station with a stormwater vault will be installed at the intersection of Gulf Shore Boulevard and 3rd Avenue North.

We understand that the stormwater trunk line and manhole structures will be embedded to depths ranging from approximately 5 to 10½ feet below the existing ground surface. At the intersection of Gulf Shore Boulevard and 3rd Avenue North, the proposed pump station will be embedded approximately 20 feet below the existing ground surface and the stormwater vault will be embedded approximately 11½ feet below the existing ground surface. We have assumed that the stormwater trunk line, manhole structures and the pump station with connecting stormwater vault will be installed using open cut methodology.

Existing Gulf Shore Boulevard is proposed to be raised six inches and widened for bike lanes. Two section options are proposed: Option A includes a 4-foot bike lane with a 10-foot travel lane and option B includes a 4-foot buffered bike lane with a 10-foot travel lane. Essentially, option A will result in widening the existing 24-foot wide roadway two feet on each side, and option B four feet on each side. New Type F curbs are planned for both sides.

FIELD EXPLORATION PROGRAM

SPT Borings

Our field exploration consisted of performing 11 Standard Penetration Test (SPT) borings at locations and depths requested by **Erickson Consulting Engineers, Inc**. The SPT borings were drilled to depths of 10 and 20 feet below the existing ground surface. The SPT borings were conducted using methods consistent with ASTM D-1586. The equipment and procedures used in the SPT borings are described in detail in the **Appendix**.

The groundwater level at each of the boring locations was measured during drilling. The borings were grouted with cement bentonite slurry upon completion.

Pavement Coring

The field exploration program also included obtaining cores of the existing pavement along Gulf Shore Boulevard (asphalt and base) at the locations where the SPT borings were being performed in the roadway. At each boring location, the asphalt and underlying base course were measured in the field for thickness and the type of base was recorded. Upon completion, the core holes were filled with asphaltic “cold patch” material. A summary of the measurements made of the core samples are included in the “Results of Pavement Cores” section of this report.

Test Locations

The approximate locations of the borings are schematically illustrated on a site aerial photograph shown on Figure 2. After completion of the test borings, the project surveyor (Dagostino and Wood) located the borings by Northing and Easting and determined the pavement elevation at each location. This information is summarized on the attached soil boring logs.

LABORATORY TESTING PROGRAM

Representative soil samples obtained during our field sampling operation were packaged and transferred to our office and, thereafter, examined by a geotechnical engineer to obtain more accurate descriptions of the existing soil strata. Laboratory testing was performed on selected samples as deemed necessary to aid in soil classification and to further define the engineering properties of the soils. The laboratory tests included Natural Moisture Content, Organic Content, and Percent Finer than the U.S. No. 200 Sieve (percent silt and clay).

The test results are presented on the attached soil boring logs at the depths from which the samples were recovered. The soil descriptions shown on the logs are based upon visual-manual procedures in accordance with local practice. Soil classification is in general accordance with the Unified Soil Classification System (ASTM D-2487) and is also based on visual-manual procedures.

GENERAL SUBSURFACE CONDITIONS

General Soil Profile

The general subsurface conditions encountered during the field exploration are shown on the attached soil boring logs. Soil stratification is based on examination of recovered soil samples and interpretation of the field boring logs. The stratification lines represent the approximate boundaries between the soil types, the actual transitions may be gradual.

The results of the borings indicate a general soil profile consisting of a pavement section underlain by fine sand (SP) and slightly silty fine sand (SP-SM) to the boring termination depths. As exceptions, Boring B-5 and B-6 encountered silty fine sand (SM) from a depth of 1 to 3 feet and 17½ to 20 feet below the existing ground surface, respectively, and Boring B-9 encountered soft weathered limestone from a depth of 17½ to 20 feet below the existing ground surface. In addition, Boring B-7 encountered slightly organic slightly silty fine sand (SP-SM) from a depth of 1 to 3 feet, underlain by organic slightly silty fine sand (SM) to a depth of 4½ feet, in turn underlain by wood with slightly silty fine sand to a depth of 6 feet below the existing ground surface.

Results of Pavement Cores

Cores of the existing pavement within the roadway were obtained using a 4-inch diameter core barrel. After coring the asphalt pavement, an auger and/or split-spoon sampler were used to advance the borehole through the pavement base. The thickness of the asphalt pavement and base were measured. The core samples of the asphalt pavement were returned to our laboratory for further examination and measurements.

The following table summarizes the data obtained from the cores.

Boring Location	Thickness of Asphalt (in)	Thickness of Base (in)	Base Type
B-1	2¼	9	Limerock
B-2	3	8	Limerock
B-3	2½	10	Limerock
B-4	2	9	Limerock
B-5	2	10	Limerock
B-6	1½	8	Limerock
B-7	2¼	8	Limerock
B-8	2	8	Limerock
B-9	1½	10	Limerock
B-10	2½	8	Limerock
B-11	2¼	8	Limerock

The subgrade below the limerock base at each core location was observed to be fine sand (SP/SP-SM) with an estimated LBR value of 30.

Groundwater Level

The depths at which groundwater was encountered in the boreholes ranged from 1 to 4½ feet below the existing ground surface at the time of our field exploration (July 15 through 17, 2019). The groundwater depths shown on the boring logs represent the groundwater surface encountered on the dates shown. Fluctuations in groundwater level should be anticipated throughout the year due to seasonal variations in rainfall, and other factors.

ENGINEERING EVALUATION AND RECOMMENDATIONS

General

The results of our exploration indicate that, with proper site preparation as recommended in this report, the existing soils are suitable for supporting the proposed stormwater trunk line, manhole structures and pump station with connecting stormwater vault, except for the silty sand with organic fines and wood as encountered in Boring B-7 at a depth of approximately 3 to 6 feet below the existing ground surface. The silty sand with organic fines and wood is not suitable for providing trunk line/structure foundation support and must be removed in accordance with the "demucking" section of this report. Silty sand with organic fines and wood depths and thicknesses may be greater at unexplored locations.

We note that silty fine sand (SM) was encountered near the proposed installation depth for the pump station in Boring B-6. Because these soils are difficult to moisture condition and compact, it may be more feasible to over-excavate these soils approximately one or two feet below the proposed pump station foundation bottom and backfill with compacted "clean" sand (Unified Classification SP or SP-SM) or gravel such as FDOT No. 57 Stone.

Also, because the silty fine sand (SM) is difficult to moisture condition and compact, these soils are generally considered poor quality to unsuitable for use as compacted backfill in excavations. Import fill soils should be anticipated.

The following are our recommendations for overall site preparation, foundation support and pavement design which we feel are best suited for the proposed construction and existing soil conditions. The recommendations are made as a guide for the design engineer, parts of which should be incorporated into the project's specifications.

Excavation

Based on the conditions encountered during the field exploration, we anticipate that most of the sandy soils as encountered in the borings can be excavated with standard earth moving equipment (i.e., front-end loaders and backhoes).

The soils below the bottom of the excavations should not be disturbed by the excavation process. If soils become disturbed and difficult to compact, they should be over-excavated to a depth necessary to remove all disturbed soils. Over-excavated areas should be replaced with compacted backfill meeting the “Backfill Requirements” presented in a following report section. The actual methods of excavation should be determined by the contractor; however, the excavation should be safely braced to prevent injury to personnel or damage to equipment.

Demucking

The silty sand with organic fines (referred to as muck hereafter) and wood as encountered in Boring B-7 are deleterious and not suitable for providing trunk line/structure foundation support. The muck and wood should be removed (“demucked”) to its entire vertical limits and to a minimum horizontal margin equivalent to the depth of muck outside the development area. A minimum horizontal margin of 5 feet should be used if the depth to the bottom of the muck is less than 5 feet.

The excavated organic muck and wood must not be used as fill material and should be disposed of as directed by the Owner. The excavations should be sloped or braced to prevent slope failure as required. Means and methods of preventing slope failure and providing a safe work zone relative to excavations should be the responsibility of the Contractor.

“Demucking” may extend to depths below the groundwater table. Demucking should be performed “in the dry”. The use of well points and/or sheet piles may be required to help control groundwater during excavation and backfilling. Regardless of the dewatering method used, we recommend that the groundwater level be maintained at least 24 inches below all earthwork and compaction surfaces. Dewatering is further discussed in the “Dewatering” section of this report.

Actual limits and quantities of demucking will be determined during construction. Prior to backfilling of the excavation, the bottom of the excavation must be inspected to verify the complete removal of all deleterious material deemed unsuitable.

Dewatering

The control of groundwater will be required to achieve the necessary depths of excavation and subsequent construction and backfilling and compaction requirements presented in the following sections. The actual method(s) of dewatering should be determined by the Contractor, however, regardless of the method(s) used, we suggest drawing down the water table sufficiently, say 2 to 3 feet, below the bottom of the excavation(s) to preclude “pumping” and/or compaction-related problems with foundation soils. The dewatering should be accomplished in advance of the excavation.

Foundation Support by Mat Foundation and Foundation Compaction Criteria for the Manhole Structures and Pump Station

After the excavation (and over-excavation and backfilling, as required) is complete, verify the in-place compaction for a depth of one foot below the manhole and pump station foundation bottoms. If necessary, compact the soils at the bottom of the excavations to at least 95 percent of the modified Proctor maximum dry density (ASTM D-1557) for a depth of one foot below the foundation bottoms. Alternatively, the foundation soils may be overexcavated 1-foot and replaced with gravel such as FDOT No. 57 Stone. Based on the existing soil conditions, and assuming the above outlined excavation and compaction criteria are implemented, a net increase in allowable soil bearing pressure of 500 pounds per square foot (psf) may be used in the foundation design. The maximum net increase in bearing pressure should result in foundation settlement within tolerable limits (i.e., 1-inch or less).

Pipeline Bedding

Pipe bedding material should be compacted as necessary to achieve a density equivalent to 95 percent of the maximum dry density, as determined by the modified Proctor (ASTM D-1557), to a minimum depth of 6 inches below the bottom of the pipe (compact deeper if recommended by the pipe manufacturer).

It is our recommendation that the bedding for the pipe be pre-shaped by means of a template, prior to placement of the structure, to ensure that the upward reaction on the bottom of the pipe will be well distributed over the width of the bedding contact.

If level bedding is utilized, it will be necessary to place and compact the haunching backfill (backfill between the bedding and the centerline of the pipe) to the centerline of the pipe. This material should be placed in simultaneous layers on each side of the pipe and must be compacted in such a manner as to ensure an intimate contact with the sides of the pipe. Do not use blocking to raise the pipe to grade. Provide bell holes at each joint to permit the joint to be assembled while maintaining uniform pipe support.

Backfill Requirements

As a general guide to aid the Contractor, we recommend using fill with less than 12 percent by dry weight of material passing the U.S. Standard No. 200 sieve size. Soils with more than 12 percent passing the No. 200 sieve will be more difficult to compact due to their inherent nature to retain soil moisture. Based on the soil samples obtained during our subsurface investigation, the fine sand and slightly silty fine sand (SP and SP-SM) appear to be suitable for use as structural backfill for the pipe and manhole and pump station structures. We note that material removed from below the groundwater table will be wet and require time to dry sufficiently.

The silty fine sand (SM) may be used as structural backfill, however, these soils will be more difficult to moisture condition and compact than soils discussed in the above paragraph. These soils will be difficult to compact because of their relatively high fines content. They may be used as backfill if it is possible to achieve the required degree of compaction. However, extensive moisture conditioning would likely be required. The Contractor may elect at their discretion to import fill with less than 12 percent passing the No. 200 sieve rather than going to additional efforts to moisture condition and compact the silty soils. Weather conditions during construction may also affect this decision.

The muck and wood should not be used as backfill and should be disposed of as directed by the Owner or his representative.

The final backfill above the haunching or centerline of the pipe, and around manholes, must extend all the way to the trench walls and should be placed in level lifts not exceeding 8 inches. Each lift should be compacted to at least 95 percent of the maximum dry density, as determined by the modified Proctor (ASTM D-1557). Care should be taken not to damage the pipe by compacting directly above the pipe where there is insufficient cover material present. Minimum cover criteria should be in accordance with the pipe manufacturer's recommendations.

A soils engineer or a designated representative from Ardaman & Associates, Inc. should observe and test all prepared and compacted areas to verify that all bedding, haunching, and final backfill are prepared and compacted in accordance with the aforementioned specifications.

Pipeline Foundation Support and Estimated Settlements

The permanent structures such as anchor blocks, thrust blocks, air release valves, blow offs, etc., bearing at least 18 inches below adjacent grade can be designed for the maximum vertical bearing capacities presented below.

- 1,500 psf on undisturbed natural granular soils.

- 2,000 psf on compacted natural or backfilled subgrade; this value assumes compaction of 95 percent of the modified Proctor maximum density (ASTM D-1557, AASHTO T-100) for a depth of 1-foot below the structure.

Pipe settlement during and after construction should be negligible (less than ½-inch), provided the bedding and backfilling criteria in the above sections are satisfied. The volume of soil displaced by the pipe, compared to the weight of the pipe when full, will result in little if any net increase in bearing stress to the subsurface soils.

Resistance to Horizontal Forces on Pipeline Structures

Horizontal forces which act on structures such as thrust blocks or anchor blocks can be resisted to some extent by the earth pressures that develop in contact with the buried vertical face (buried vertical face is perpendicular and in front of the applied horizontal load) of the block structures and by shearing resistance mobilized along the base of the block structures and subgrade interface.

Allowable earth pressure resistance may be determined using an equivalent fluid density of 105 pounds per cubic foot (pcf) for moist soil and 60 pcf for submerged soils below the water table.

Equivalent fluid density (moist soil) = $K_p\gamma_m$/S.F. = 105 pcf
Equivalent fluid density (submerged soil) = K_p (γ_s-γ_w)/S.F. = 60 pcf

Where:

K_p = effective coefficient of passive earth pressure = 3.0
S.F. = safety factor = (values given below)
γ_m= unit weight of moist soil = 105 pcf
γ_s = unit weight of saturated soils = 113 pcf
γ_w = unit weight of water = 62.4 pcf

The passive earth pressures are developed from ground surface (assuming there is no excavation in the vicinity of the block structure that would reduce the available passive pressure) to the bottom of the block structure.

The values presented above presume that the block structures are surrounded by well compacted sand backfill extending at least 5 feet horizontally beyond the vertical buried face. In addition, it is presumed that the block structures can withstand horizontal movements on the order of one-quarter (1/4) to three-eighths (3/8) inch before mobilizing full passive resistance. The factors of safety assumed in the above recommendations are 2.5 for passive pressure with submerged conditions, and 3.0 for passive pressure without submerged conditions.

The sliding shearing resistance mobilized along the base of the block structure may be determined by the following formula:

Allowable Shearing Resisting Force, P=V tan (2/3φ)/F.S.

Where:

P = Shearing Resistance Force (pounds)
V = Net Vertical Force (total weight of block and soil overlying the structure minus uplift forces including buoyancy forces) (pounds)
φ = Angle of Internal Friction of Soil = 30 degrees
S.F. = Safety Factor = 1.5

The vertical earth pressures developed by the overburden weight of soil can be calculated using the following unit weights:

- Compacted moist soil = 105 pcf
- Saturated soil = 113 pcf

Vertical pressure distributions in accordance with the above do not take into account vertical forces from construction equipment, wheel loads or other surcharge loads.

Uplift Resistance

Permanent structures submerged below the groundwater table will be subjected to uplift forces caused by buoyancy. The components resisting this buoyancy include: 1) the total weight of the pipe or structure divided by an appropriate factor of safety; 2) the buoyant weight of soil overlying the pipe or structure; and 3) the shearing forces that act on shear planes that radiate vertically upward from the perimeter of the pipe or the edges of the structure to the ground surface. The allowable unit shearing resistance may be determined by the following formula:

Allowable Unit Shearing Resistance, $F=K_o\gamma_m h(2/3 \tan\varphi)/S.F.$ (above groundwater table)

Allowable Unit Shearing Resistance, $F=K_o[\gamma_m h_w+\gamma_b(h-h_w)](2/3\tan\varphi)/S.F.$ (below groundwater table)

Where:

F = unit shearing resistance (psf)
K_o = coefficient of earth pressure at rest = 0.5
γ_m = unit weight of moist soil = 105 pcf
γ_b = buoyant unit weight of soil = 50.6 pcf
h = vertical depth (feet) below grade at which shearing resistance is determined
h_w = vertical depth (feet) below grade to groundwater table
φ = angle of internal friction of the soil = 30 degrees
S.F. = safety factor = 2

The values given for the above parameters assume that the permanent structures are covered by clean, well compacted granular backfill that extends horizontally at least 2 feet beyond the structures.

Earth Pressure on Shoring and Bracing

If temporary shoring and bracing is required for any excavations, the system should be designed to resist lateral earth pressure. The design earth pressure will be a function of the flexibility of the shoring and bracing system. For a flexible system restrained laterally by braces placed as the excavation proceeds, the design earth pressure for shoring and bracing can be computed using a uniform earth pressure distribution with depth. It is recommended that soils be de-watered around the excavations. For such de-watered excavations, we recommended using the following uniform pressure distribution over the full braced height as follows:

Uniform Soil Pressure Distribution, $p = 0.65K_a\gamma_sH$

Where:

p = uniform pressure distribution for design of braced excavation
K_a = coefficient of active earth pressure = 0.33
γ_s = unit weight of saturated soils = 113 pcf
H = depth of excavation

An appropriate factor of safety should be applied for the design of the braced excavations.

Lateral pressure distributions determined in accordance with the above do not take hydrostatic pressures or surcharge loads into account. To the extent that such pressures and forces may act on the walls, they should be included in the design.

Construction equipment and excavated fill should be kept a minimum distance of 5 feet from the edge of the braced or shored excavation. Backfill material placed adjacent to (maintaining a minimum 5-foot horizontal clearance) the braced or shored excavation should have a minimum slope of 2.0H:1.0V, or flatter if required by site specific conditions and/or to meet OSHA requirements.

Means and methods of excavation and bracing should be the responsibility of the Contractor; however, excavation and/or bracing should at a minimum adhere to the requirements of the Occupational Safety Health Administration (OSHA).

Lateral Earth Pressures

Lateral loads acting on the embedded structures will include at-rest earth pressures as well as hydrostatic pressures and surcharge loads. The lateral earth pressure will be a function of both the depth below ground surface and the soil unit weight (submerged or moist) plus hydrostatic pressure (if applicable). The following equations can be used to determine the lateral at-rest earth pressure:

$\sigma_h = K_o \gamma_m h$ (above groundwater table)
$\sigma_h = K_o [\gamma_m h_w + \gamma_b (h - h_w)]$ (below groundwater table)

Where:

σ_h = lateral earth pressure (psf)

K_o = coefficient of at rest earth pressure (0.5) (this value assumes that the backfill is lightly compacted yet not overcompacted)
γ_m = effective moist unit weight of soil = 105 pcf for compacted moist soil above the water table.
γ_b = buoyant unit weight of soil = 50.6 pcf for compacted saturated soil below the water table.
h = vertical depth (feet) below grade at which lateral earth pressure is determined
h_w = vertical depth (feet) below grade to groundwater table

For design, an appropriate factor of safety should be applied to the lateral earth pressure calculated using the above equation. Lateral pressure distributions determined in accordance with the above do not include hydrostatic pressures or surcharge loads. Where applicable, they should be incorporated in the design.

Excavation Backfill

Backfill placed adjacent to the structure walls (if necessary) should consist of granular soils that are free draining and relatively free of fines. The backfill within 5 feet of the structure walls should be placed in thin lifts and compacted with hand-held compactors to between 95 and 100 percent of the modified Proctor (ASTM D-1557) maximum dry density value. Over-compaction of the backfill should be avoided since it could cause excessively large earth pressures to develop against the walls. Heavy equipment should be kept at least 5 feet away from the wall.

Pavement Design

The existing pavement section of Gulf Shore Boulevard on average consists of 2 inches of Type S asphalt in good condition (layer coefficient = 0.34) and 8 inches of Limerock base in good condition (layer coefficient = 0.18). The subgrade was observed to be a fine sand with an estimated LBR value = 30 (layer coefficient 0.06). Therefore, existing structural number, SN_E = 2.50 (after 1-inch of asphalt milling). We believe that the 18-kip ESAL's 20 year period is 300,000 to 3,500,000 (Traffic Level B) requiring a minimum structural course of 2 inches and a minimum base group of 6 (8-inch Limerock) bearing on 12-inches of stabilized subgrade (LBR 40). Required structural number SN_R = 3.28. The structural number of the structural layers needed in the overlay SN_O = 0.78.

Existing Gulf Shore Boulevard was observed to be in good condition; however, we recommend that the existing road be milled approximately 1-inch before any overlay, which will then require approximately seven inches of asphalt to achieve final grade. We recommend that all overlay layers be Type SP Asphaltic Concrete except that the final lift should be 1 ½ to 2 inches of friction course FC-12.5. The paving contractor will determine the individual layer thickness for the asphalt structural courses observing the minimum and maximum allowable thickness ranges as stated below:

Type SP-9.5	1 to 1½ inches
Type SP-12.5	1½ to 2½ inches
Type SP-19.0	2 to 4 inches

For example, the first layer could be 2½" SP-12.5, the second layer 2½" SP-12.5 and the final layer 2" FC-12.5. Resulting additional structural number = 3.08.

For the pavement widening of both sides of Gulf Shore Boulevard, either two feet or four feet, we recommend removing the existing curb and gutter as well as any pipes and structures scheduled to be removed. The resulting excavation and backfilling procedures should be in accordance with FDOT Standard Plans Index 120-001 and 120-002 and FDOT Standard Specifications for Road and Bridge Construction (SSRBC). To provide a firm bearing surface for placement of the asphalt overlay, we recommend the use of 6 inches of granular subbase meeting the requirements of Section 290-2 and 290-3 (Limerock, Shell-Rock, etc.) of the FDOT SSRBC. The subbase in the widening sections should be flush with the milled surface of Gulf Shore Boulevard and compacted to 98 percent of modified Proctor maximum dry density (AASHTO-T180). The widening sections will be paved as overlay. The resulting structural number is at least 4.0 which exceeds the SN_R of 3.28.

QUALITY CONTROL

We recommend establishing a comprehensive quality control program to verify that all excavation, "demucking", bedding, and backfilling are conducted in accordance with the appropriate plans and specifications. Materials testing and inspection services should be provided by Ardaman & Associates, Inc.

In-situ density tests should be conducted during bedding and backfilling activities to verify that the required densities are achieved. Backfill for the proposed pipeline should be tested at a minimum frequency of one in-place density test for each lift for each 200 linear feet of pipe. Additional tests should be performed beneath foundations and in backfill for the proposed manhole structures and pump station. In-situ density values should be compared to laboratory Proctor moisture-density results for each different natural and fill soils encountered.

CLOSURE

The analyses and recommendations submitted herein are based on the data obtained from the soil borings performed at the approximate locations indicated on Figure 2. This report does not reflect any variations which may occur adjacent to or between borings. The nature and extent of the variations between the boring may not become evident until during construction. If variations then appear evident, it will be necessary to re-evaluate the recommendations presented in this report after performing on-site observations during the construction period and nothing the characteristics of the variations.

When the final design and specifications are completed, we would like the opportunity to review them to determine whether changes in the original concept may have affected the validity of our recommendations and whether these recommendations have been implemented in the design and specifications.

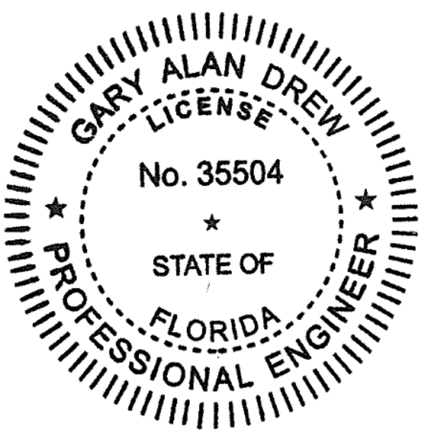
While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the subsurface materials of the region are anticipated and may be encountered. The boring logs and related information are based on the driller's logs and visual examination of selected sample in the laboratory. The delineation between soil types shown on the logs is approximate and the description represents our interpretation of subsurface conditions at the designated boring locations and on the particular date drilled.

If you have any questions about this report, please contact this office.

Very truly yours,

Ardaman & Associates, Inc.
Florida Certificate of Authorization No. 00005950

Ethan H. Drew, E.I.
Project Engineer



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Gary A Drew
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on the date adjacent to the seal.

Printed copies of this document are not considered signed and sealed and the signature must be verified on any electronic copies.

Gary A. Drew, P.E. No. 35504
Vice President/Branch Manager

EHD/GAD

ATTACHMENTS

- **SITE LOCATION MAP (FIGURE 1)**
- **BORING LOCATION PLAN (FIGURE 2)**
- **BORING LOGS – B-1 THROUGH B-11**

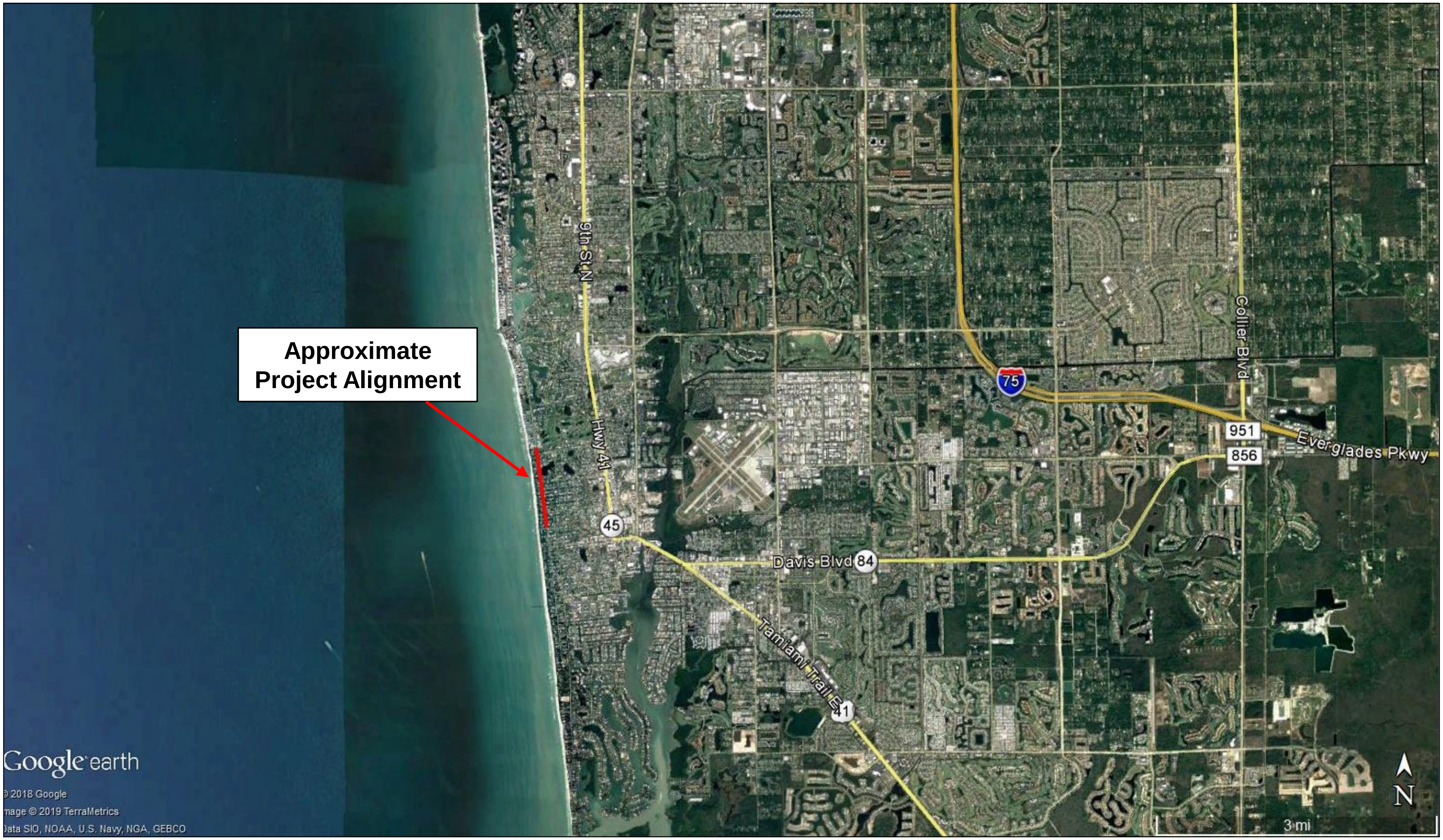


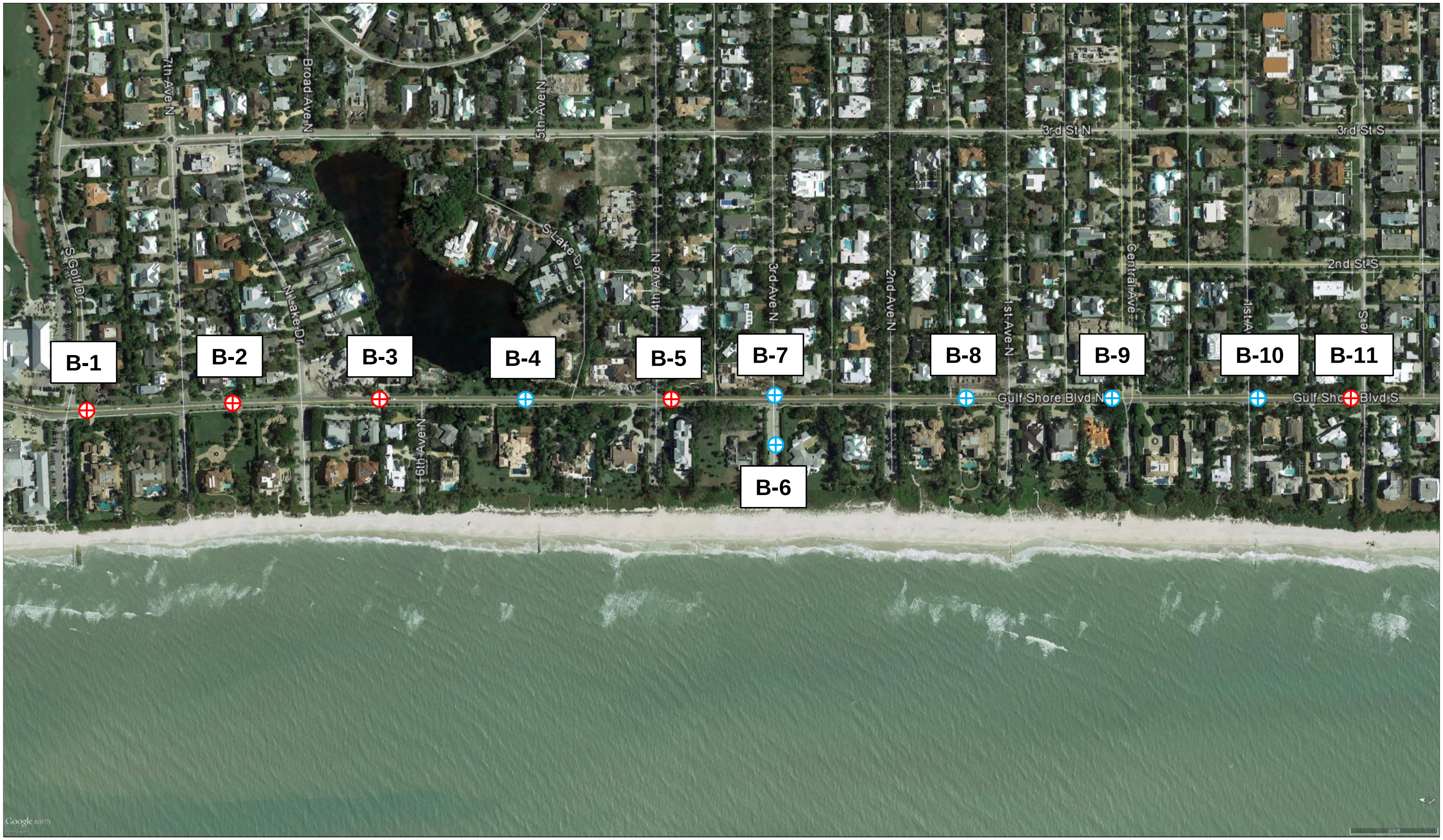
FIGURE 1
SITE LOCATION MAP

SOURCE: GOOGLE EARTH PRO©

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

Proposed Naples Beach Restoration & Water Quality Improvement Project
Naples, Collier County, Florida

Drawn By: ED	Checked By: GD	Date: 8/1/19
File No.: 19-33-4545	Approved By: Gary Drew, P.E.	Figure No: 1



⊕ = 10' SPT Boring

⊕ = 20' SPT Boring

N E S W

FIGURE 2
BORING LOCATION PLAN

SOURCE: GOOGLE EARTH PRO©

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

Proposed Naples Beach Restoration & Water Quality Improvement Project
Naples, Collier County, Florida

Drawn By: ED	Checked By: GD	Date: 8/2/19
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BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 663127.5 **EASTING:** 391071.3
DATE DRILLED: 7/17/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 4.12 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 1.5 **DATE:** 7/17/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0	CUT- 26- 10	36	1			Asphaltic Concrete and Limerock Base						
					SP	Poorly Graded Sand - Gray to grayish brown fine sand.						
	6- 7- 9	16	2									
	6- 6- 6	12	3									
5	6- 6- 7	13	4					22	3.4			
	7- 9- 10	19	5		SP-SM	Poorly Graded Sand with Silt - Dark brown slightly silty fine sand.						
	7- 10- 10	20	6									
10	7- 5- 5	10	7		SP	Poorly Graded Sand - Grayish brown fine sand.						
						TERMINATED AT 10.5'						
15												
20												
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-1

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 662632.1 **EASTING:** 391156.8
DATE DRILLED: 7/17/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 3.98 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 1.0 **DATE:** 7/17/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0						Asphaltic Concrete and Limerock Base						
	CUT- 14- 7	21	1		SP-SM	Poorly Graded Sand with Silt - Gray slightly silty fine sand, trace gravel (shell and limerock fragments).						
	5- 5- 4	9	2									
	4- 6- 7	13	3		SP-SM	Poorly Graded Sand with Silt - Gray slightly silty fine sand.						
5	6- 7- 8	15	4		SP	Poorly Graded Sand - Light brown to dark brown fine sand.						
	7- 8- 8	16	5					23		2.4		
	8- 10- 8	18	6		SP-SM	Poorly Graded Sand with Silt - Grayish brown slightly silty fine sand.						
10	7- 8- 10	18	7									
						TERMINATED AT 10.5'						
15												
20												
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-2

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 662137.0 **EASTING:** 391229.6
DATE DRILLED: 7/16/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 3.86 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 2.5 **DATE:** 7/16/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0	CUT- 20- 5	25	1			Asphaltic Conrete and Limerock Base						
					SP-SM	Poorly Graded Sand with Silt - Gray slightly silty fine sand.						
	2- 4- 5	9	2									
	7- 8- 9	17	3		SP	Poorly Graded Sand - Grayish brown fine sand.						
5	8- 9- 9	18	4									
	9- 10- 10	20	5		SP-SM	Poorly Graded Sand with Silt - Grayish brown slightly silty fine sand.						
	10- 9- 7	16	6									
10	7- 9- 8	17	7									
						TERMINATED AT 10.5'						
15												
20												
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-3

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 661640.6 **EASTING:** 391289.8
DATE DRILLED: 7/16/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 4.04 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 3.0 **DATE:** 7/16/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0	CUT- 17- 9	26	1			Asphaltic Concrete and Limerock Base						
					SP-SM	Poorly Graded Sand with Silt - Dark brown slightly silty fine sand.						
	5- 6- 7	13	2					21	11	1.2		
	6- 6- 9	15	3		SP	Poorly Graded Sand - Light gray fine sand.						
5	9- 9- 10	19	4									
	10- 10- 10	20	5		SP-SM	Poorly Graded Sand with Silt - Grayish brown to dark brown to brown slightly silty fine sand.						
	10- 8- 9	17	6									
10	8- 11- 12	23	7									
15	6- 6- 5	11	8									
20	1- 0- 0	0	9									
						TERMINATED AT 20.5'						
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-4

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 661143.8 **EASTING:** 391351.0
DATE DRILLED: 7/16/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 3.62 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 3.0 **DATE:** 7/16/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0	CUT- 18- 8	26	1			Asphaltic Concrete and Limerock Base						
					SM	Silty Sand - Dark brown silty fine sand.						
	2- 2- 4	6	2					33	20	2.4		
	3- 4- 4	8	3		SP-SM	Poorly Graded Sand with Silt - Grayish brown to dark brown to brown slightly silty fine sand.						
5	2- 3- 4	7	4									
	4- 4- 5	9	5									
	4- 4- 5	9	6									
10	3- 4- 4	8	7									
						TERMINATED AT 10.5'						
15												
20												
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-5

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 660771.4 **EASTING:** 391239.5
DATE DRILLED: 7/17/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 4.29 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 3.5 **DATE:** 7/17/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0						Asphaltic Concrete and Limerock Base						
	CUT- 11- 9	20	1		SP	Poorly Graded Sand - Light brown fine sand.						
	6- 6- 5	11	2									
	2- 1- 1	2	3									
5	1- 0- 1	1	4		SP-SM	Poorly Graded Sand with Silt - Brown slightly silty fine sand.		29		1.6		
	7- 5- 5	10	5		SP	Poorly Graded Sand - Light brown to light gray fine sand.						
	8- 8- 10	18	6									
10	6- 6- 5	11	7									
					SP-SM	Poorly Graded Sand with Silt - Brown slightly silty fine sand.						
15	4- 4- 4	8	8									
					SM	Silty Sand - Brown silty fine sand.						
20	4- 5- 6	11	9					24	16	0.2		
						TERMINATED AT 20.5'						
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-6

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 660802.7 **EASTING:** 391414.3
DATE DRILLED: 7/15/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 3.47 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 4.0 **DATE:** 7/15/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0	CUT- 13- 11	24	1			Aspaltic Concrete and Limerock Base						
					SP-SM	Poorly Graded Sand with Silt - Dark brown slightly organic slightly silty fine sand.						
	6- 4- 4	8	2									
	4- 5- 7	12	3		SM	Silty Sand with Organic Fines - Dark brown organic slightly silty fine sand.		42	14	11		
5	6- 8- 8	16	4			Wood with dark brown slightly silty fine sand.						
	9- 11- 13	24	5		SP-SM	Poorly Graded Sand with Silt - Dark brown to gray to light gray slightly silty fine sand.						
	10- 10- 12	22	6									
10	10- 9- 9	18	7									
15	2- 2- 3	5	8									
20	1- 0- 0	0	9					24	9.4			
						TERMINATED AT 20.5'						
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-7

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 660148.4 **EASTING:** 391472.1
DATE DRILLED: 7/15/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 3.90 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 4.0 **DATE:** 7/15/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0						Asphaltic Concrete and Limerock Base						
	CUT- 12- 9	21	1		SP-SM	Poorly Graded Sand with Silt - Grayish brown slightly silty fine sand.						
	11- 8- 7	15	2									
	6- 6- 5	11	3									
5	6- 7- 7	14	4									
	5- 6- 7	13	5									
	6- 6- 7	13	6									
10	6- 7- 8	15	7		SP-SM	Poorly Graded Sand with Silt - Grayish brown to dark brown slightly silty fine sand, trace gravel (cemented sands).						
15	1- 0- 1	1	8									
					SP-SM	Poorly Graded Sand with Silt - Brown slightly silty fine sand.						
20	1- 0- 0	0	9									
						TERMINATED AT 20.5'						
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-8

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 659662.5 **EASTING:** 391531.9
DATE DRILLED: 7/16/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 3.63 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 4.5 **DATE:** 7/16/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0	CUT- 23- 14	37	1			Asphaltic Concrete and Limerock Base						
	7- 7- 10	17	2		SP	Poorly Graded Sand - Grayish brown to light brown fine sand.						
	7- 5- 5	10	3									
5	5- 5- 6	11	4									
	5- 7- 8	15	5									
	8- 12- 12	24	6		SP-SM	Poorly Graded Sand with Silt - Dark brown slightly silty fine sand.						
10	10- 13- 11	24	7		SP	Poorly Graded Sand - Dark brown fine sand.		24	3.1			
					SP-SM	Poorly Graded Sand with Silt - Brown slightly silty fine sand.						
15	1- 1- 0	1	8									
						Soft Weathered Limestone.						
20	1- 2- 3	5	9									
						TERMINATED AT 20.5'						
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-9

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 659154.6 **EASTING:** 391594.6
DATE DRILLED: 7/15/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 4.15 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 4.0 **DATE:** 7/15/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0	CUT- 24- 16	40	1			Asphaltic Concrete and Limerock Base						
			2		SP-SM	Poorly Graded Sand with Silt - Gray slightly silty fine sand.						
	11- 10- 10	20	3		SP	Poorly Graded Sand - Light gray or light brown fine sand.						
	6- 8- 8	16	4									
5	7- 10- 10	20	5									
	9- 10- 10	20	6									
	10- 7- 7	14	7									
10	6- 5- 5	10	8		SP-SM	Poorly Graded Sand with Silt - Brown slightly silty fine sand.						
15	4- 5- 5	10	9									
20	3- 2- 2	4	10									
						TERMINATED AT 20.5'						
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-10

BORING LOCATION: SEE BORING LOCATION PLAN
NORTHING: 658838.8 **EASTING:** 391633.5
DATE DRILLED: 7/15/2019 **START:** **FINISH:**
GROUND SURFACE ELEVATION: 3.65 ft (NAVD88) **TIME:**
WATER TABLE DEPTH (ft): 4.0 **DATE:** 7/15/2019

CLIENT: ERICKSON CONSULTING ENGINEERS, INC.
PROJECT: PROPOSED NAPLES BEACH RESTORATION & WATER QUALITY IMPROVEMENT PROJECT
LOCATION: NAPLES, COLLIER COUNTY, FLORIDA
DRILL CREW: LOCKLEY / CENTENO **LOGGED BY:** E. DREW

DRILL MAKE & MODEL: CME-55 W/ AUTO **BIT:** 3-7/8" DIA. TRICONE ROLLER **DRILLING RODS:** NW
DRILLING METHOD: ROTARY WASH WITH DRILLING FLUID **WEATHER CONDITIONS:** SUNNY

DEPTH, FT.	BLOWS	SPT N-VALUE	SAMPLE NO.	GRAPHIC LOG	USCS	SOIL DESCRIPTION	REMARKS	% WATER CONTENT	PERCENT FINES	% ORGANIC CONTENT	LIQUID LIMIT	PLAST. INDEX
0	CUT- 15- 10	25	1			Asphaltic Concrete and Limerock Base						
					SP-SM	Poorly Graded Sand with Silt - Grayish brown slightly silty fine sand.						
	8- 7- 8	15	2									
	6- 8- 8	16	3		SP	Poorly Graded Sand - Grayish brown to light brown fine sand.		23	3.3			
5	8- 8- 8	16	4									
	8- 9- 9	18	5									
	8- 7- 7	14	6		SP-SM	Poorly Graded Sand with Silt - Brown slightly silty fine sand.						
10	6- 7- 8	15	7									
						TERMINATED AT 10.5'						
15												
20												
25												
30												
35												

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REVIEWED BY: GARY A. DREW, P.E. **FILE NO:** 19-33-4545 **BORING NO.:** B-11

APPENDIX

- **SOIL BORING, SAMPLING AND TESTING METHODS**
  PROJECT SOIL DESCRIPTION PROCEDURE – UNIFIED

SOIL BORING, SAMPLING AND TESTING METHODS

STANDARD PENETRATION TEST

The Standard Penetration Test (SPT) is a widely accepted method of in-situ testing of foundation soils (ASTM D-1586). A 2-foot (0.6 m) long, 2-inch (50 mm) O.D. split-barrel sampler attached to the end of a string of drilling rods is driven 18 inches (0.45 m) into the ground by successive blows of a 140-pound (63.5 Kg) hammer freely dropping 30 inches (0.76 m). The number of blows needed for each 6 inches (0.15 m) of penetration is recorded. The sum of the blows required for penetration of the second and third 6-inch (0.15 m) increments penetration constitutes the test result or N-value. After the test, the sampler is extracted from the ground and opened to allow visual description of the retained soil sample. The N-value has been empirically correlated with various soil properties allowing a conservative estimate of the behavior of soils under load. The following tables relate N-values to a qualitative description of soil density and, for cohesive soils, an approximate unconfined compressive strength (Qu):

Cohesionless Soils:

N-Value Safety Hammer	N-Value Auto Hammer	Description	Relative Density
< 4	< 3	Very loose	0 - 15%
4 - 10	3 - 8	Loose	15 - 35%
10 - 30	8 - 24	Medium dense	35 - 65%
30 - 50	24 - 40	Dense	65 - 85%
> 50	> 40	Very dense	85 - 100%

Cohesive Soils:

N-Value Safety Hammer	N-Value Auto Hammer	Description	Unconfined Compressive Strength, Qu
< 2	< 1	Very soft	< 0.25 tsf (25 kPa)
2 - 4	1 - 3	Soft	0.25 - 0.50 tsf (25 - 50 kPa)
4 - 8	3 - 6	Firm	0.50 - 1.0 tsf (50 - 100 kPa)
8 - 15	6 - 12	Stiff	1.0 - 2.0 tsf (100 - 200 kPa)
15 - 30	12 - 24	Very stiff	2.0 - 4.0 tsf (200 - 400 kPa)
> 30	> 24	Hard	> 4.0 tsf (400 kPa)

The tests are usually performed at 5-foot (1.5 m) intervals. However, more frequent or continuous testing is done by our firm through depths where a more accurate definition of the soils is required. The test holes are advanced to the test elevations by rotary drilling with a cutting bit, using circulating fluid to remove the cuttings and hold the fine grains in suspension. The circulating fluid, which is bentonitic drilling mud, is also used to keep the hole open below the water table by maintaining an excess hydrostatic pressure inside the hole. In some soil deposits, particularly highly pervious ones, flush-coupled casing must be driven to just above the testing depth to keep the hole open and/or prevent the loss of circulating fluid. After completion of a test boring, the hole is kept open until a steady state groundwater level is recorded. The hole is then sealed by backfilling with neat cement.

Representative split-spoon samples from each sampling interval and from different strata are brought to our laboratory in air-tight jars for classification and testing, if necessary. Afterwards, the samples are discarded unless prior arrangements have been made.

POWER AUGER BORINGS

Auger borings are used when a relatively large, continuous sampling of soil strata close to the ground surface is desired. A 4-inch (100 mm) diameter, continuous flight, helical auger with a cutting head at its end is screwed into the ground in 5-foot (1.5 m) sections. It is powered by the rotary drill rig. The sample is recovered by withdrawing the auger out of the ground without rotating it. The soil sample so obtained, is described and representative samples put in bags or jars and returned to the laboratory for classification and testing, if necessary.

HAND AUGER BORINGS

Hand auger borings are used, if soil conditions are favorable, when the soil strata are to be determined within a shallow (approximately 5-foot [1.5 m]) depth or when access is not available to power drilling equipment. A 3-inch (75 mm) diameter hand bucket auger with a cutting head is simultaneously turned and pressed into the ground. The bucket auger is retrieved at approximately 6-inch (0.15 m) intervals and its contents emptied for inspection. Sometimes post-hole diggers are used, especially in the upper 3 feet (1 m) or so. The soil sample obtained is described and representative samples put in bags or jars and transported to the laboratory for classification and testing, if necessary.

UNDISTURBED SAMPLING

Undisturbed sampling implies the recovery of soil samples in a state as close to their natural condition as possible. Complete preservation of in-situ conditions cannot be realized; however, with careful handling and proper sampling techniques, disturbance during sampling can be minimized for most geotechnical engineering purposes. Testing of undisturbed samples gives a more accurate estimate of in-situ behavior than is possible with disturbed samples.

Normally, we obtain undisturbed samples by pushing a 2.875-inch (73 mm) I.D., thin wall seamless steel tube 24 inches (0.6 m) into the soil with a single stroke of a hydraulic ram. The sampler, which is a Shelby tube, is 30 (0.8 m) inches long. After the sampler is retrieved, the ends are sealed in the field and it is transported to our laboratory for visual description and testing, as needed. Undisturbed sampling is noted on the boring logs as thus "U-".

LABORATORY TEST METHODS

Soil samples returned to our laboratory are looked at again by a geotechnical engineer or geotechnician to obtain more accurate descriptions of the soil strata. Laboratory testing is performed on selected samples as deemed necessary to aid in soil classification and to help define engineering properties of the soils. The test results are presented on the soil boring logs at the depths at which the respective sample was recovered, except that grain-size distributions or selected other test results may be presented on separate tables, figures or plates as discussed in this report, the results of which will be located in an Appendix. The soil descriptions shown on the logs are based upon visual-manual procedures in accordance with local practice. Soil classification is in general accordance with the Unified Soil Classification System (ASTM D-2487) and is also based on visual-manual procedures. Following is a list of abbreviations that may appear in the Remarks column on the boring logs indicating additional laboratory testing was performed, the results of which will usually be located in an Appendix.

DD: Unit Weight/Classification of Undisturbed "Shelby Tube" samples

PP: Pocket Penetrometer reading on cohesive samples in tons per sq. ft. (tsf)

k: Hydraulic Conductivity

Qu: Unconfined Compression Strength; ASTM D-2166

UU: Unconsolidated-Undrained Triaxial Test; ASTM D 2850

Consol: One-Dimensional Consolidation test performed on subsample from undisturbed sample; ASTM D-2435

THE PROJECT SOIL DESCRIPTION PROCEDURE FOR SOUTHWEST FLORIDA[(1)]
For use with the ASTM D 2487 Unified Soil Classification System
CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

BOULDERS (>12" [300 mm]) and COBBLES (3" [75 mm] TO 12" [300 mm]):

GRAVEL: Coarse Gravel: 3/4" (19 mm) to 3" (75 mm)
Fine Gravel: No. 4 (4.75 mm) Sieve to 3/4" (19 mm)

Descriptive adjectives:

0 – 5%	---	no mention of gravel in description
5 – 15%	---	trace
15 – 29%	---	some
30 – 49%	---	gravelly (shell, limerock, cemented sands)

SANDS

COARSE SAND: No. 10 (2 mm) Sieve to No. 4 (4.75 mm) Sieve
MEDIUM SAND: No. 40 (425 μm) Sieve to No. 10 (2 mm) Sieve
FINE SAND: No. 200 (75 μm) Sieve to No. 40 (425 μm) Sieve

Descriptive adjectives:

0 – 5%	---	no mention of sand in description
5 – 15%	---	trace
15 – 29%	---	some
30 – 49%	---	sandy

SILT/CLAY: < #200 (75 μm) sieve

SILTY OR SILT: PI < 4
SILTY CLAYEY OR SILTY CLAY: 4 ≤ PI ≤ 7
CLAYEY OR CLAY: PI > 7

Descriptive adjectives:

0 – 5%	--- clean (no mention of silt or clay in description)
5 – 12% to 15%	--- slightly
16 – 35%	--- clayey, silty, or silty clayey
36 – 49%	--- very

ORGANIC SOILS

Organic Content	Descriptive adjectives	Classification
0 – 2.5%	no mention of organics in description	See above
2.6 – 5%	slightly organic	See above
5 – 20%	organic	Add "with organic fines" to group name

THE PROJECT SOIL DESCRIPTION PROCEDURE FOR SOUTHWEST FLORIDA[1]
For use with the ASTM D 2487 Unified Soil Classification System
CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

HIGHLY ORGANIC SOILS AND MATTER

Organic Content	Description	Classification
20-75%	highly organic sand or muck	Peat (PT)
	sandy peat	Peat (PT)
>75%	amorphous or fibrous peat	Peat (PT)

STRATIFICATION AND STRUCTURE

Descriptive Term with interbedded	Thickness
seam:	less than 1/2-inch (13 mm) thick
layer:	1/2 to 12-inches (13 to 300 mm) thick
stratum:	more than 12-inches (300 mm) thick
pocket:	small, erratic deposit, usually less than 1-foot
occasional:	one or less per foot of thickness
frequent:	more than one per foot of thickness
calcareous:	containing calcium carbonate (reaction to diluted HCL)
hardpan:	spodic horizon usually medium dense
marl:	mixture of carbonate clays, silts, shells and sands.

ROCK CLASSIFICATION

Description

Hard Limestone or Caprock – N-values >50 bpf

Soft Weathered Limestone – N values <50 bpf

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(1) This soil description procedure was developed specifically for projects in southwest Florida because it is believed that the terminology will be better understood as a result of local practice. It is not intended to supplant other visual-manual classification procedures for description and identification of soils such as ASTM D 2488. BY: G.A. DREW, P.E. (1995) (Revised 2016).

UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D2487)

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]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [E]	GW	Well-graded gravel [F]
			$Cu < 4$ and/or $1 > Cc > 3$ [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]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [E]	SW	Well-graded sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$ [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 / Liquid limit - not dried < 0.75	OL	Organic clay [K,L,M,N]
					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 / Liquid limit - not dried < 0.75	OH	Organic clay [K,L,M,P]
					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-in. (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] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 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 ≥ 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 ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

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

[N] PI ≥ 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.