US Army Corps
of Engineers®
New England District

FAIRFIELD AND NEW HAVEN COUNTIES, CT

**COASTAL STORM RISK MANAGEMENT
FEASIBILITY STUDY AND ENVIRONMENTAL
ASSESSMENT**

APPENDIX D3: GEOTECHNICAL DESIGN

October 2020

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NEW HAVEN CONNECTICUT
GENERAL INVESTIGATION
GEOTECHNICAL DESIGN APPENDIX

TABLE OF CONTENTS

1. Project Information

1.1. Location and Existing Problem

The New Haven County, CT study area is highly vulnerable to damages resulting from coastal storm events such as Hurricanes and Nor'easters. Hurricane Sandy (2012) is the most recent major event to cause wide spread damage to the region. The USACE North Atlantic Coast Comprehensive Study (completed in 2015) identified areas of high exposure and risk along the Connecticut coast study including New Haven county. Low lying coastal communities contain thousands of high-value residential structures, commercial properties and government facilities. Critical infrastructure throughout the region including the I-95 corridor and multiple railroad transportation systems, government facilities, and medical facilities become more at risk of damage from coastal storm events as climate changes.

This purpose of this general investigation was to determine the feasibility of a number of flood protection structures and alignments along the coast near Long Wharf adjacent to I-95 (Figure 1.1).

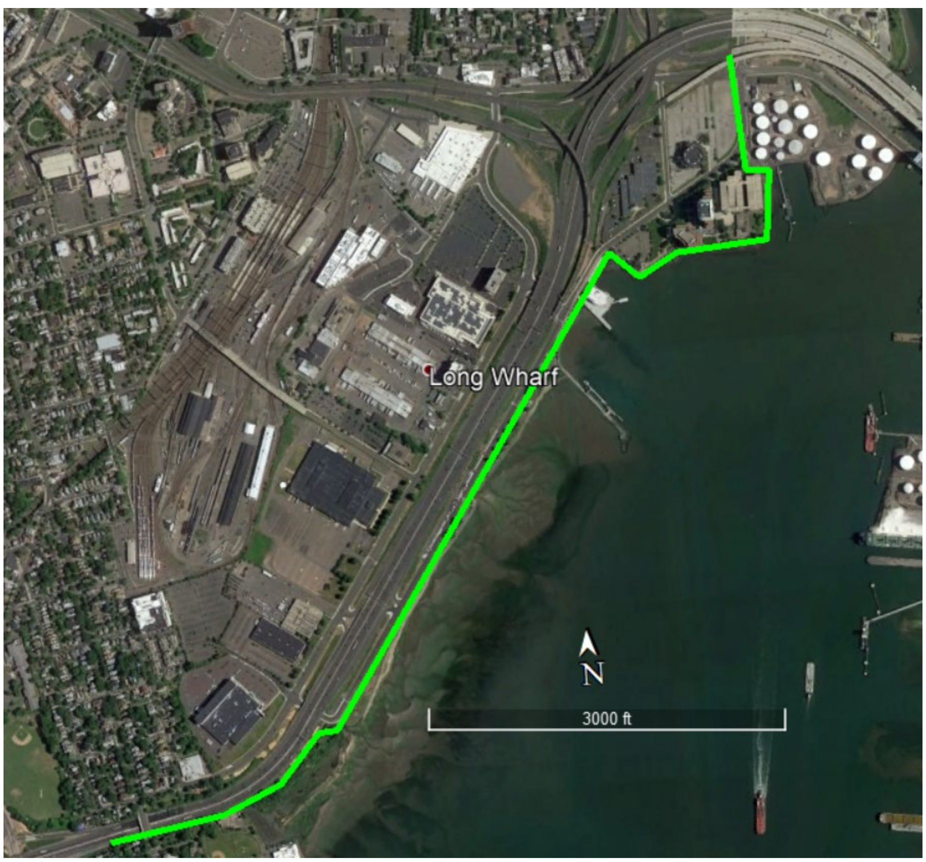

Figure 1.1: Approximate extent of potential flood protection structure alignments in New Haven

2. Explorations

2.1. Available Boring Information

New Haven subsurface information was provided by previous Long Wharf and I-95 pre-construction investigations performed by Langan Engineering & Environmental Services, the Connecticut Department of Transportation (CTDOT), and GZA GeoEnvironmental Inc. Boring information was available along the length of the coast of Long Wharf from the Long Wharf Drive underpass to just north of the jetty (Figure 2.1).

The three borings (PB-5, PB-6, PB-7) developed by the Connecticut Department of Transportation were all to depths 122 feet below surface. Boring information utilized from the Langan Engineering effort (LB-1, LB-4, LB-5, LB-6) varied from 47 to 52 feet below ground surface. The GZA boring (GZ-11) was drilled to 47 feet below the ground surface.

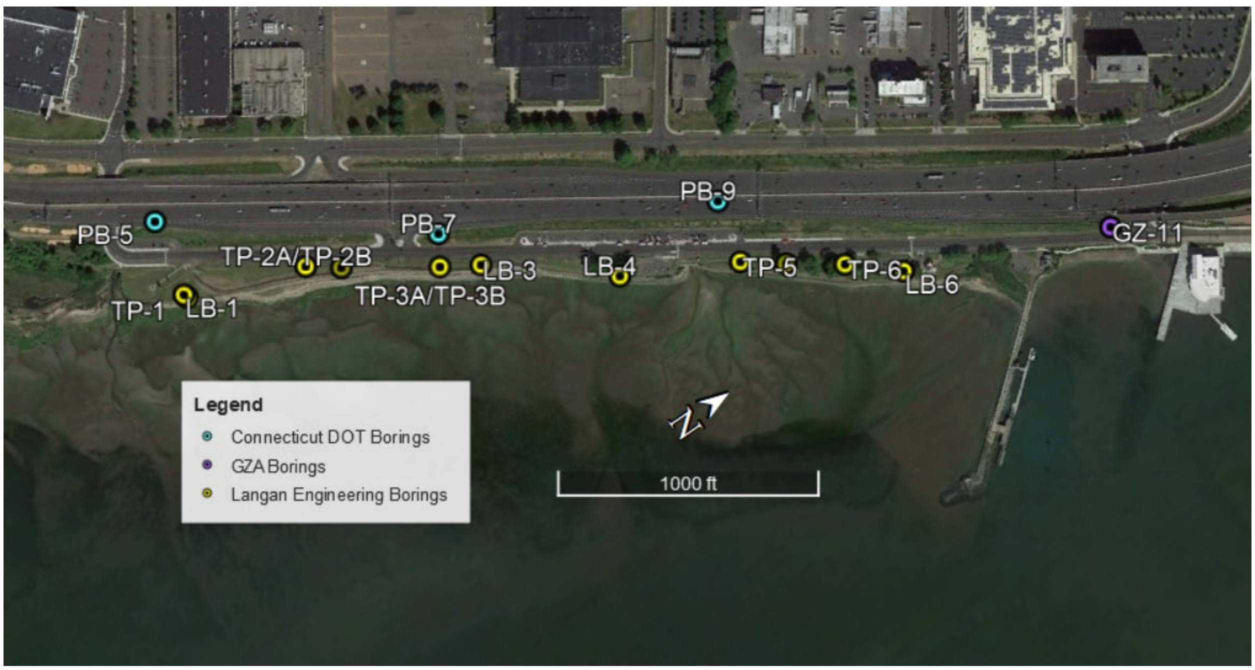

Figure 2.1: Location of borings utilized in design for New Haven

2.2. Foundation Materials

A detailed description of the subsurface conditions at Long Wharf is available in a November 2010 report by Langan Engineering & Environmental Services based on the same information currently available for this study. It was assumed these soil stratifications would be similar to areas north and south of the Long Wharf where borings are not available. Below is a summary of these findings with additional notes regarding information from the CT DOT borings closer to the I-95 embankment.

Miscellaneous Fill (SP) - Up to 12 feet below grade is comprised of a miscellaneous sand fill. This includes medium to fine sands with varying levels of silt and gravel throughout. SPT N-values had a wide range of values from 1 to 55 blows per foot (bpf) indicating varying levels of compaction throughout the coastline. Samples in this area have average percent fines of approximately 13% with average water content of approximately 4%.

Upper Sand (SP-SW) - Beneath the miscellaneous fill is a dark layer of sand ranging in thickness from 10 to 29 feet. This sand layer is a medium dense coarse sand with varying proportions of silty gravel and silt. SPT N-values range from 6 to 23 bpf. This layer had an average 5% fines average water content of 17%.

While it is not referenced in the Langan report, this upper sand layer is not present in borings near the I-95 embankment. It appears that the miscellaneous sand fill discussed above was placed directly on top of a shallower organic silt layer as a part of the I-95 embankment construction.

Organic Clayey Silt (OL/OH) – Beneath the miscellaneous fill and upper sand is a thick layer of organic clayey silt with traces of shells, organics, and fines sand. The thickness varied from 14 to 40 feet. While SPT N-values ranged from weight of hammer (WOH) to 21 bpf, the average blow counts ranged from WOH to 2 bpf. This layer had an average water content of 68%. The average Liquid Limit, Plastic Limit, and Plasticity Index are approximately 84%, 38%, and 46%, respectively.

The Langan report notes that the average undrained shear strength was approximately 620 psf; results of the four UU tests showed significant variation in undrained strengths, ranging from a high of 918 psf, to a low of 432 psf. For this design, the lower bound of the undrained shear strengths were assumed.

Lower Sand (SP) – All of the Langan borings terminate within this lower sand layer beneath the organic silts. This is a layer of medium dense medium to fine sand with SPT N-values varying from 12 to 26 bpf. The deeper Connecticut DOT borings indicate this layer thickness varies from 8 to 10 feet. This layer has average percent fines of 8% and average percent water content of 24%.

Upper and Lower Silts – As the Langan borings terminate above this layer, the presence of the silts below the lower sands are indicated only in the CTDOT borings. The thickness of this layer varies from 58 to 63 feet. For the purpose of feasibility design this layer was separated into upper and lower silts due to varying SPT N-values directly below the organics and those deeper within the strata. Fines content varies from 77 to 98%.

3. Development of Design Soil Stratification

Due to the size of the project impact area and limited boring information along the proposed alignments it was necessary to create generalized soil stratifications that would be applicable for large portions of the proposed flood protection alignment.

Prior to developing the design soil strata, the blow counts for all applicable borings were normalized to N_{60} values. Free-draining granular material properties were estimated using the blow count correlations provided by Bowles (1984) and Koshida (1967) found in Table 1. Additional shear strength testing, in conjunction with future boring explorations, should be performed on soils using these correlations to confirm strength and unit weight assumptions.

Table 1: N-value Correlation Tables

ESTIMATED TOTAL UNIT WEIGHT AS A FUNCTION OF BLOW COUNTS[1]

Fine Grained Soils				Granular Soils			
N	γ_{total}	N	γ_{total}	N	γ_{total}	N	γ_{total}
	(pcf)		(pcf)		(pcf)		(pcf)
0	95	31	135	0	80	31	125.5
1	106	32	135	1	85	32	126
2	110	33	135	2	90	33	126.5
3	114	34	135	3	93	34	127
4	117	35	135	4	96	35	127.5
5	118.5	36	135	5	98.5	36	128
6	120	37	135	6	101	37	128.5
7	122	38	135	7	103.5	38	129
8	123	39	135	8	106	39	129.5
9	124.5	40	135	9	108	40	130
10	125.5	41	135	10	110	41	130.5
11	126.5	42	135	11	111	42	131
12	127.5	43	135	12	112	43	131.5
13	128	44	135	13	113.25	44	132
14	129	45	135	14	114.5	45	132.5
15	129.5	46	135	15	115.25	46	133
16	130	47	135	16	116	47	133.5
17	130.5	48	135	17	116.75	48	134
18	131	49	135	18	117.5	49	134.5
19	131.5	50	135	19	118.25	50	135
20	132	51	135	20	119	51	135
21	132.25	52	135	21	119.75	52	135
22	132.5	53	135	22	120.5	53	135
23	133	54	135	23	120.75	54	135
24	133.5	55	135	24	121	55	135
25	134	56	135	25	122	56	135
26	135	57	135	26	123	57	135
27	135	58	135	27	123.5	58	135
28	135	59	135	28	124	59	135
29	135	60	135	29	124.5	60	135
30	135			30	125		

[1] Bowles, J.E., "Physical and Geotechnical Properties of Soils", 2nd edition, McGraw-Hill Book Company, 1984. p. 18

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INTERNAL FRICTION ANGLE OF GRANULAR SOILS[2]

N-values	Internal Friction Angle
N	f(N)
0	15.00
1	19.47
2	21.32
3	22.75
4	23.94
5	25.00
6	25.95
7	26.83
8	27.65
9	28.42
10	29.14
11	29.83
12	30.49
13	31.12
14	31.73
15	32.32
16	32.89
17	33.44
18	33.97
19	34.49
20	35.00
21	35.49
22	35.98
23	36.45
24	36.91
25	37.36
26	37.80
27	38.24
28	38.66
29	39.08
30	39.49
31	39.90
32	40.00
33	40.00
34	40.00
35	40.00
36	40.00
37	40.00
38	40.00
39	40.00
40	40.00

[2] Kishida, H. 1967. "Ultimate Bearing Capacity of Pile Driven into Loose Sand." Soil and Foundations, vol.7, no.3: 20-29.

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The simplified sections were developed based on the similarities between nearby soil borings and whether or not the structure alignment was closer or further from shore. The depth to the organics layer, which appeared in all New Haven borings, is what largely dictated the separation between sections. It was shown in the available boring information that the organics layer was significantly shallower near the I-95 embankment when compared to the depth nearer the shoreline. There was also a noted presence of looser soils near the south end of the I-95 embankment. New Haven was eventually broken down into four separate reaches as noted on Figure 3.1. Design soil strata is provided in Table 2.

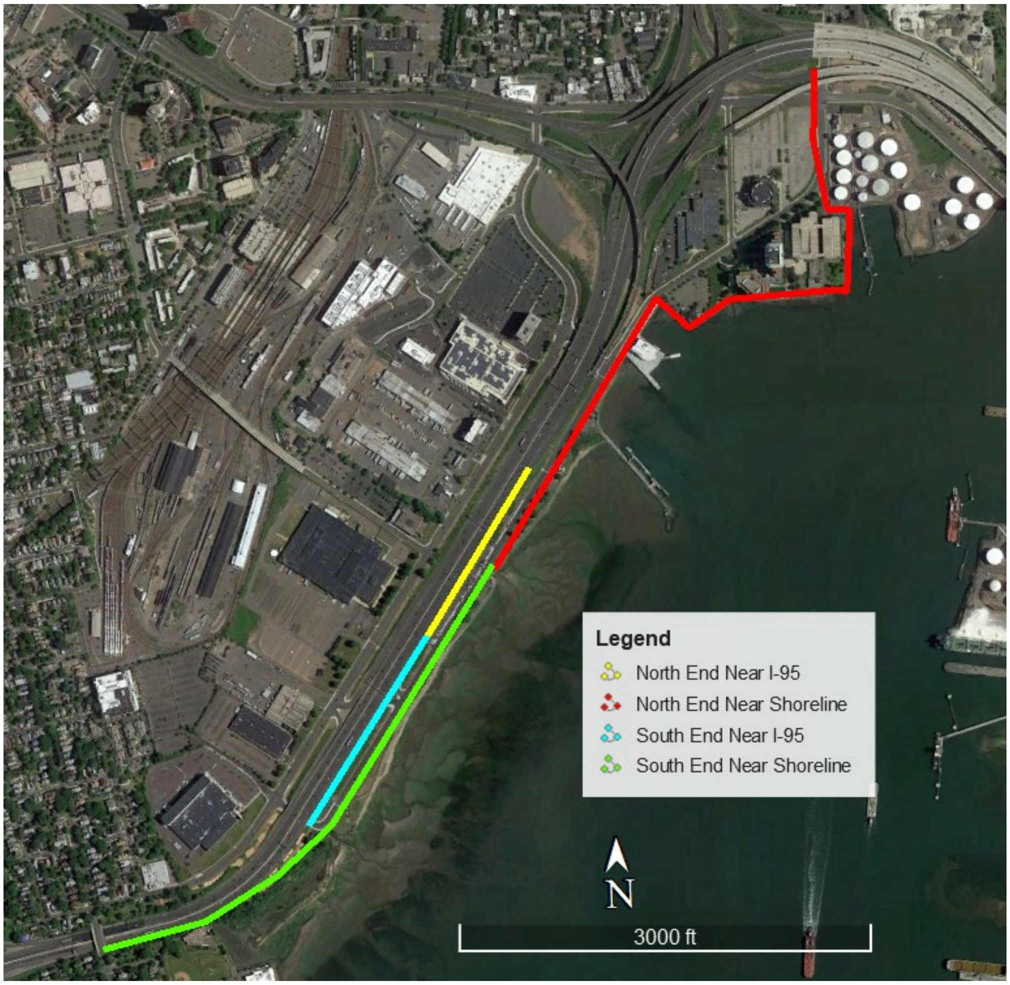

Figure 3.1: Design Soil Stratification Applicable Areas at New Haven

Table 2: Design Soil Stratification and Soil Properties at New Haven

South End Near I-95 (PB-5 and PB-7)

[1]Layer Top Elv. (ft,NGVD29)	[1]Layer Bottom Elv. (ft,NGVD29)	Depth (ft)	Soil Type	[2]N60	[3]γt (pcf)	[4]c (psf)	[5]ϕ (deg)	c' (psf)	[6]ϕ' (deg)
6	4	0	Sand trace silt (Fill)	15	115	0	32	0	32
4	0	4	Sand trace silt (Fill)	15	115	0	32	0	32
0	-34	38	Organic Silt (OH)	1	100	450	0	0	22
-34	-41	45	Medium to Fine Sand (SP)	10	125	0	30	0	30
-41	-58	62	[7]Upper Silt trace Clay	12	128	0	25	0	25
-58	-102	106	Lower Silt trace Clay	20	132	0	25	0	25

South End Near Shoreline (LB-1 and LB-4)

[1]Layer Top Elv. (ft,NGVD29)	[1]Layer Bottom Elv. (ft,NGVD29)	Depth (ft)	Soil Type	[2]N60	[3]γt (pcf)	[4]c (psf)	[5]ϕ (deg)	c' (psf)	[6]ϕ' (deg)
6	4	0	Sand trace silt (Fill)	15	115	0	32	0	32
4	0	4	Sand trace silt (Fill)	15	115	0	32	0	32
0	-9	13	Coarse to Fine Sand (SW)	20	120	0	35	0	35
-9	-37	41	Organic Silt (OH)	1	100	450	0	0	22
-37	-47	51	Medium to Fine Sand (SP)	20	120	0	35	0	35
-47	-75	79	[7]Upper Silt trace Clay	12	128	0	25	0	25
-75	-120	124	Lower Silt trace Clay	20	132	0	25	0	25

Northend Near Shoreline (LB-5, LB-6, and GZ-11)

[1]Layer Top Elv. (ft,NGVD29)	[1]Layer Bottom Elv. (ft,NGVD29)	Depth (ft)	Soil Type	[2]N60	[3]γt (pcf)	[4]c (psf)	[5]ϕ (deg)	c' (psf)	[6]ϕ' (deg)
6	4	0	Sand trace silt (Fill)	20	120	0	35	0	35
4	-3	7	Sand trace silt (Fill)	20	120	0	35	0	35
-3	-14	18	Sand trace Silt (SP/SW)	15	115	0	32	0	32
-14	-40	44	Organic Silt (OH)	1	100	450	0	0	22
-40	-50	54	Medium to Fine Sand (SP)	20	120	0	35	0	35
-50	-100	104	[7] Silt trace Clay	25	134	0	27	0	27

Northend Near I-95 (PB-9)

[1]Layer Top Elv. (ft,NGVD29)	[1]Layer Bottom Elv. (ft,NGVD29)	Depth (ft)	Soil Type	[2]N60	[3]γt (pcf)	[4]c (psf)	[5]ϕ (deg)	c' (psf)	[6]ϕ' (deg)
6	4	0	Sand trace silt (Fill)	15	115	0	32	0	32
4	1	3	Sand trace silt (Fill)	15	115	0	32	0	32
1	-39	43	Organic Silt (OH)	1	100	450	0	0	22
-39	-50	54	Medium to Fine Sand (SP)	30	125	0	35	0	35
-50	-110	114	[7]Silt trace clay	20	132	0	25	0	25

Notes:

1. Design strata is based on the boring information provided by the indicated borings. Top of pile assumed at 4 feet NGVD29.
2. N blow counts are based on N60 corrected blow counts from soil borings
3. Unit weights are developed from Bowels 1984 correlations, assumed saturated unit weight and moist unit weight are equal
4. Organic silt undrained properties and unit weights based on UU testing on soil from LB-1, LB-4, LB-6, and PB-9
5. ϕ for granular soil based on N60 values and Kishida 1967 correlations. No shear strength lab testing information available for lower silts, assumed ϕ for loose to medium dense silts using Bowels 1988 representative values.
6. Drained friction angle for organic silt estimated based on low undrained shear strengths and assumption of no cohesion. Typical values are not readily available, however it is assumed that the organics will have some drained shear strength similar to a very loose cohesionless silt.
7. Depths to silts below El. -50 ft, NGVD29 are based on deep borings PB-5, PB-7, and PB-9

4. Structure Selection

Concrete filled friction pipe pile supported T-walls with sheet pile seepage cutoff walls are recommended for the flood wall retaining structures. The general selection of a pile supported structure retaining wall was determined based on the following site conditions and limitations of other flood protection structures.

4.1. I-walls

I-walls were extensively considered in feasibility, but a number of factors excluded their use. The Corps engineering circular for I-wall design, EC 1110-2-6066 (April 2011), was referenced frequently to determine the general feasibility of I-walls. A number of criteria outlined in the EC regarding the availability of information to properly describe the site conditions as well as a number of caveats regarding the presence of soft soil are presented below.

As noted previously there was a general low availability of subsurface information along the proposed structure alignments. Table 3 shows the minimum drilling and sampling requirements for I-wall design during different project phases. As available boring information indicates soft fine grain soils are present (organic silt) the nominal boring spacing for feasibility level design is recommended at 500 feet. For pre-construction design the nominal boring spacing is 300 ft. At New Haven, this requirement is met in limited areas, largely along the southern beach shore, however it is not met along the entire alignment along the I-95 embankment and north of the Long Wharf shoreline jetty. Due to the limited number of borings available along the alignment the site could be considered as having "limited site information" available. Page 2-23 of the EC notes "*All I-walls serving as flood control barriers are critical and cannot be designed based on limited site information*".

Table 3: Minimum Drilling and Sampling Requirements for I-walls
(Table 5-1 in EC 1110-2-6066)

Project Phase	Soil Type	Sample Type and Frequency	Nominal Boring Spacing (ft)*	Minimum Boring Depth	Remarks
Reconnaissance/Feasibility	Soft Fine-Grained Soils	One Undisturbed 5" Shelby tube sample every 10 feet in depth with disturbed sampling between tube samples.	500	- 3 x total height of protection above original ground, or - 5 x exposed I-wall height, or - total thickness of soft clay layers, or - 50 feet	- clay foundations also require borings at both sides of levee
	Medium/Stiff Fine-grained Soils		1000		- Some borings should extend to 100 feet or top of rock.
	Loose Granular Soils	SPT method supplemented as appropriate with CPT data	500		- sand foundations also require borings perpendicular to protection
	Medium/Dense Granular Soils		1000		- Some borings should extend to 100 feet or top of rock, whichever is less
Preconstruction Design	Soft Fine-Grained Soils	One Undisturbed 5" Shelby tube sample every 5 feet in depth.	300		- All clay strata must be continuously sampled for laboratory testing
	Medium/Stiff Fine-Grained Soils		500		
	Loose Granular Soils	SPT method supplemented as appropriate with CPT data	250		- Undisturbed sampling in clays can be supplemented with SPT, CPT, and/or geoprobes
	Medium/Dense Granular Soils		500		
Post Construction Modifications to Existing Structures**	Soft Fine-Grained Soils	One Undisturbed 5" Shelby tube sample every 5 feet in depth.	100 – 250		- geophysical methods shall be used, as appropriate
	Medium/Stiff Fine-Grained Soils		250 – 500		- ambient groundwater levels during drilling shall be recorded.
	Loose Granular Soils	SPT method supplemented as appropriate with CPT data	100 – 250		
	Medium/Dense Granular Soils		250 - 500		- Piezometric response data is required by installing appropriate instrumentation.

* Boring Layout must be consistent with uncertainties of strata and properties.
** For post construction activities, boring spacings shall be closer to the lower end of the range. Closer spacing may be required to adequately assess specific problem areas.

Next is the inclusion of soft organic soils. Page 6-34 of the EC notes, "*For new designs, the maximum unsupported stem height for I-walls constructed on existing levees or in soft soils shall be limited to 6 feet.*" This 6 foot limiter would preclude the use of I-walls in many areas where required wall heights could extend upwards of 10 feet.

While this would seem to indicate that I-walls could be used in areas where the required protection requires a less than 6 foot wall, an additional condition is presented in the EC on page 5-5. The EC explicitly states that if "*…Normally consolidated to slightly overconsolidated soft clays, silts, or peat having SPT resistance less than 4 blows/foot or shear strength less than 500 psf located within 10 feet of the original ground surface…*" are found during feasibility, I-walls should not be considered, and the design of the flood protection system should be completed using T-based floodwalls, L-walls, or levees. This condition is applicable to much of the New Haven study area.

The blow counts (<1-2 in most areas) and available UU test data indicates that the organic soils present have less than 500 psf shear strength. Based on the available borings, soft organics are present within the first 10 feet for most of the proposed alignment. The areas where soft organics are not within the first 10 feet are in areas where an I-wall would not be appropriate (directly along the shore of Long Wharf New Haven). It cannot be said with confidence that soft organic soils would not be present within 10 feet of the ground surface for the proposed structure alignments. Therefore a pile supported T-wall was chosen as the appropriate design to use for this project phase.

I-walls may be considered during final design in some areas only after extensive subsurface information is obtained along the proposed alignments.

4.2. T-wall Configuration

T-walls were first considered without the use of pile foundations, but for various reasons it was determined that pipe supported walls would be necessary. At New Haven, for alignments closer to the shoreline where wave pressures would be highest, shallow foundations would not meet the overturning or sliding criteria without unrealistically wide bases or extensive backfilling behind the wall. For walls aligned closer to the I-95 embankment, shallow foundations would not meet the bearing capacity requirements due to the top of organics layer being shallower further inland at approximately El. 0 ft NAVD88. The depth of the T-wall bearing slip surfaces, which are generally estimated as the width of the base of the wall, would result in a large amount of the required shear strength being dependent on the soft organic layer. There was also a general concern with the space available near the I-95 embankment which would preclude the use of wide shallow foundations.

For the above reasons a pile supported T-wall, which would act more as a pile cap, was chosen as the general feasibility level structure type.

A sheetpile seepage cut off wall was also included with the intention of having a global seepage gradient less than 0.15. During the feasibility level of design the width of the base was largely dependent on the pile configuration which may change following feasibility. Therefore the shortest seepage path did not consider the width of the T-wall base. The shortest seepage path was considered to be twice the length of the sheet pile, plus the embedment of the wall (~4 feet). This assumes the seepage moves along the entire length of the sheet pile.

Driven piles were chosen for the foundation support structure for the retaining wall. Due to the presence of soft soils and limited boring information for sections of the study area, it was assumed that sufficient end bearing capacity of the piles could not be assured. Therefore, it was assumed that the piles would be acting as friction piles and that the forces transferred from the retaining wall would be carried entirely by the frictional skin resistance of the piles. This is a generally conservative assumption; if additional explorations borings are made available and the pile tip would pass entirely through the organics and into the underlying sand, then the final pile lengths may be reduced in design. Friction type piles are generally recommended to be driven, and the soft soils would make pre-drilled non-displacement pile construction difficult.

Due to the presence of soft soils across the site, drilled shaft and other non-displacement methods should only be considered for limited use in areas where space limitations for a pile cap or vibrations would be an issue. These non-displacement type piles may be considered in design phase.

As the piles are located in a marine environment, there is a risk of water intrusion that could damage the interior of piles. Concrete fill will prevent internal corrosion of the pipe that would otherwise occur if left open. There are additional structural benefits to concrete filled pilings which can account for potential flaws in the pipes during manufacturing, such as joints at splices.

5. Design Methods and Assumptions

5.1 Allowable Axial Loading

Pile supports were designed using empirical methods described in EM 1110-2-2906 to determine allowable axial loadings at depth. NAE Structural Engineering Section had determined that the general required loading would be approximately 50kips compression and 20 kips tension per pile. To determine the appropriate pile length and size the allowable axial loading was determined at the base of each soil layer type.

Due to the lack of subsurface information for large portions of the alignment and the presence of organics, it could not be guaranteed that the piles would terminate outside of these soft layers. Therefore, it was determined that the bearing capacity of the piles would not be considered for the allowable axial strengths at either site. Only the allowable capacity afforded by the skin friction would be considered.

An excel sheet was developed to assist with calculations using methods described in EM 1110-2-2906 to test different pile sizes. For each design soil strata, calculations were made to determine the appropriate pile length to reach the loading requirement.

Calculations were made near the lowest final ground surface elevation, or what could be considered the highest wall height. This was a wall height assumed to be near 10 feet in height, so ground surface was assumed to be near 6 feet NAVD88, and the top of the piles would be near 4 feet NAVD88. This would result in the maximum pile depths which could then be modified in final design after additional borings are performed.

As required skin friction is fairly high, larger diameter piles will be needed. It was determined that 20 inch close ended pipe piles for New Haven would be the most feasible without requiring additional splicing of smaller pile sizes. 24 inch close ended pipe piles are recommended along alignments at New Haven along the I-95 embankment. It is likely these pile sizes and depth could be reduced with further subsurface information and assuming additional bearing capacity could be guaranteed.

The presence of organics largely dictated the design of the piles. N values derived from blow count values for these materials were frequently low (1 to 4) with a number of weight of hammer and weight of rod SPT readings recorded across multiple borings. Unconfined undrained (UU) testing was available for the organic silts, however no Consolidated Undrained (CU) or Consolidated Drained (CD) tests were performed on these soils to determine drained properties. For this level of design, undrained shear strengths were assumed to be on the lower end of the available UU test data between 400 and 500 psf. The drained friction angle was assumed to be in the low 20s at 22° with no cohesion/adhesion which resulted in drained analyses dictating the overall depths and design of the piles.

EM 1110-2-2906 allows for piles to be battered using vertical axial loading calculations as long as the total axial loading of the battered pile does not exceed the allowable axial loading calculated assuming vertical piles.

5.2 Allowable Lateral Loading

Allowable lateral loading of vertical piles for concrete drilled shafts to be used at the closure structures was requested by structural engineering. The software program L-PILE was used to analyze multiple drilled shaft diameters varying from 2 feet to 5 feet diameters. L-PILE was set to test the piles with gradually increasing loads until the piles failed as noted by large excessive lateral deflections. It was determined that lateral loading against vertical piles would not be sufficient to support the resist the expected lateral loading and that pile battering would be required.

6 Conclusions

6.1 General

The New Haven study area has limited boring information along the structure alignment which in general led to a more conservative design of a pile supported T-wall. Other structure types were examined during feasibility, largely I-walls, however the lack of extensive boring information and presence of soft soils made these much higher risk structure types that would not be appropriate in most areas at a feasibility level.

Thick layers of soft soils (blow counts <1) were found along Long Wharf and the depth and extent of these soils is not clear along the entire length of the proposed alignments. This led to generally conservative assumptions for the T-wall design, such as assuming bearing capacity could not be guaranteed in the piles or that the soft soils would not be able to support shallow foundations. Even with these assumptions, due to the lack of information, it is not known whether these assumptions are actually conservative without obtaining additional subsurface information.

It is possible that the T-walls may be replaced with I-walls in some areas during design phase when more subsurface information and final structure alignments are determined.

A pile supported T-wall with a sheet pile seepage cutoff wall was selected for the proposed New Haven flood protection structures. This structure type was largely decided upon based on the large wave forces along Long Wharf beach, the thick layers of organics beneath the ground surface, and the limited boring information for portions of the alignment, especially north and south of the Long Wharf beach.

7 Recommendations

7.1 Additional Subsurface Explorations

It is possible that the T-walls may be replaced with I-walls in some areas during design phase when more subsurface information and final structure alignments are determined. Page 5-4 in the I-wall design engineering circular (EC 1110-2-6066) describes the required nominal boring spacing during different project phases (Table 3). As the site is primarily comprised of loose granular soils and soft fine-grained soils (organic layers) the required nominal boring spacing for

I-walls during design is 250 to 300 feet. Boring plans could target specific areas where I-walls would be preferred over T-walls by increasing the density of borings.

Boring information at New Haven was limited to the stretch of coast along Long Wharf. As alignments of alternatives are located both north and south of Long Wharf additional borings or the retrieval of additional boring information in these areas is recommended. Specifically this would include borings in the industrial park and restaurant area along the coast north of Long Wharf. To the south, boring information is needed for areas near 6th street and Howard Avenue where the southern section of the wall is planned for placement. It is possible this information is already available due to the number of large structures on the north end of New Haven and the recent I-95 construction.

7.2 Pile Driving Program

7.2.1 Vibration Reduction

Prior to driving piles near structures such as home residences, bridges, etc., a structural survey of these structures should be made to ensure vibration from the driving does not cause additional damage to these structures. During driving, vibrations should be monitored and additional measures be taken to reduce vibrations as needed. This may include pre-drilling holes to an elevation beneath the adjacent building foundations or trenching near pile driving. This could prevent pile vibrations from being transferred to adjacent foundations. This or other methods may be applied to reduce vibrations from pile driving.

7.2.2 Pile Testing

It is expected that load testing in accordance with ASTM D 4945 (IBC Chapter 18) would be performed on approximately 5% of the piles used at New Haven to determine axial capacity. Additional lateral load testing would also need to be performed on both driven and drilled piles. The cost of testing will include data interpretation and evaluation, which would be a requirement for all pile testing performed at the site.

8 References

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U.S. Army Corps of Engineers, “EC 1110-2-2502 Retaining and Flood Walls”, 29 September 1989

ATTACHMENT A: ALLOWABLE AXIAL PILE LOADING

OBJECTIVE: Geotechnical Engineering Section (GES) has calculated the allowable axial capacity of piles proposed to be used along the New Haven, CT shoreline using empirical methods described in EM 1110-2-2906. Available borings and lab data used to develop design soil strata along four separate reaches of the New Haven project. The reaches were determined by the availability of boring information and their location relative to project alternative alignments. Figure 1 presents the reaches at which the differing allowable capacities are applicable.

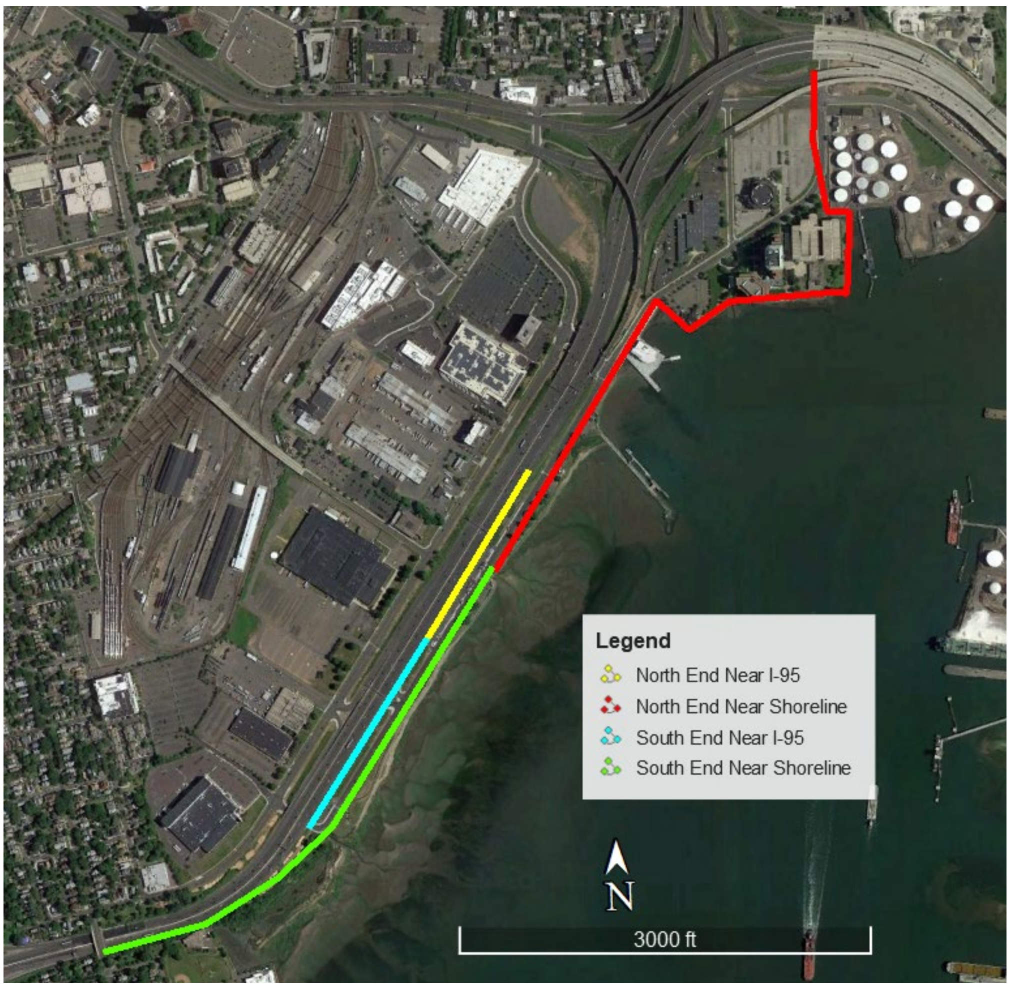


Figure 1: Design Soil Stratification Applicable Areas at New Haven

PROCEDURE:

1. Determine soil parameters based on existing boring information.
   a) New Haven subsurface information was provided by a previous subsurface investigation performed by Langan Engineering & Environmental Services and GZA Engineering. Borings information was available along the length of the coast of Long Wharf from the Long Wharf Drive underpass to the jetty, as well as a number of borings north of the wharf along the alignments of the I-95/I-91/CT-34 connector (Figure 2).

   Final design strata soil properties are presented in Table 1 and 2.

Figure 2: Location of borings utilized in design for New Haven

Table 1: New Haven Design Soil Stratigraphy and Properties

South End Near I-95 (PB-5 and PB-7)

[1]Layer Top Elv. (ft,NGVD29)	[1]Layer Bottom Elv. (ft,NGVD29)	Depth (ft)	Soil Type	[2]N60	[3]γt (pcf)	[4]c (psf)	[5]ϕ (deg)	c' (psf)	[6]ϕ' (deg)
6	4	0	Sand trace silt (Fill)	15	115	0	32	0	32
4	0	4	Sand trace silt (Fill)	15	115	0	32	0	32
0	-34	38	Organic Silt (OH)	1	100	450	0	0	22
-34	-41	45	Medium to Fine Sand (SP)	10	125	0	30	0	30
-41	-58	62	[7]Upper Silt trace Clay	12	128	0	25	0	25
-58	-102	106	Lower Silt trace Clay	20	132	0	25	0	25

South End Near Shoreline (LB-1 and LB-4)

[1]Layer Top Elv. (ft,NGVD29)	[1]Layer Bottom Elv. (ft,NGVD29)	Depth (ft)	Soil Type	[2]N60	[3]γt (pcf)	[4]c (psf)	[5]ϕ (deg)	c' (psf)	[6]ϕ' (deg)
6	4	0	Sand trace silt (Fill)	15	115	0	32	0	32
4	0	4	Sand trace silt (Fill)	15	115	0	32	0	32
0	-9	13	Coarse to Fine Sand (SW)	20	120	0	35	0	35
-9	-37	41	Organic Silt (OH)	1	100	450	0	0	22
-37	-47	51	Medium to Fine Sand (SP)	20	120	0	35	0	35
-47	-75	79	[7]Upper Silt trace Clay	12	128	0	25	0	25
-75	-120	124	Lower Silt trace Clay	20	132	0	25	0	25

Northend Near Shoreline (LB-5, LB-6, and GZ-11)

[1]Layer Top Elv. (ft,NGVD29)	[1]Layer Bottom Elv. (ft,NGVD29)	Depth (ft)	Soil Type	[2]N60	[3]γt (pcf)	[4]c (psf)	[5]ϕ (deg)	c' (psf)	[6]ϕ' (deg)
6	4	0	Sand trace silt (Fill)	20	120	0	35	0	35
4	-3	7	Sand trace silt (Fill)	20	120	0	35	0	35
-3	-14	18	Sand trace Silt (SP/SW)	15	115	0	32	0	32
-14	-40	44	Organic Silt (OH)	1	100	450	0	0	22
-40	-50	54	Medium to Fine Sand (SP)	20	120	0	35	0	35
-50	-100	104	[7] Silt trace Clay	25	134	0	27	0	27

Northend Near I-95 (PB-9)

[1]Layer Top Elv. (ft,NGVD29)	[1]Layer Bottom Elv. (ft,NGVD29)	Depth (ft)	Soil Type	[2]N60	[3]γt (pcf)	[4]c (psf)	[5]ϕ (deg)	c' (psf)	[6]ϕ' (deg)
6	4	0	Sand trace silt (Fill)	15	115	0	32	0	32
4	1	3	Sand trace silt (Fill)	15	115	0	32	0	32
1	-39	43	Organic Silt (OH)	1	100	450	0	0	22
-39	-50	54	Medium to Fine Sand (SP)	30	125	0	35	0	35
-50	-110	114	[7]Silt trace clay	20	132	0	25	0	25

Notes:
1. Design strata is based on the boring information provided by the indicated borings. Top of pile assumed at El. 4 feet NGVD29. Groundwater table elevation is generally tidal due to the distance from the shoreline. For calculations assume 3 feet NGVD29.
2. Blow counts are based on N60 corrected field blow counts from soil borings
3. Unit weights are developed from Bowles 1984 correlations, assumed saturated unit weight and moist unit weight are equal
4. Organic silt undrained properties and unit weights based on UU testing on soil from LB-1, LB-4, LB-6, and PB-9
5. ϕ and ϕ' for granular soil based on N60 values and Kishida 1967 correlations. No shear strength lab testing information available for lower silts, assumed ϕ for loose to medium dense silts using Bowles 1988 representative values.
6. Drained friction angle for organic silt estimated based on low undrained shear strengths and normally consolidated. Typical values are not readily available, however it is assumed that the organics will have some drained shear strength similar to a very loose cohesionless silt.
7. Depths to silts below El. -50 ft, NGVD29 are based on deep borings PB-5, PB-7, and PB-9. LL and PI testing was not available to properly categorize these silts as MH or ML.

b) Due to the large thickness of the organic soils and low number of borings for large sections of the alignment, it was assumed that pile tip could not be guaranteed to terminate below the organic layer. Therefore, it was assumed that tip capacity would not be guaranteed and the capacity of the pile was assumed to be held entirely by the skin friction of the piles. As no drained testing was available for the organic silts, it was assumed that the drained conditions for the organics would be a low friction angle and normally consolidated. Both drained and undrained analyses were performed during analysis, calculation results showed the drained properties of the organic layers would dictate design.

d) An excel sheet was developed to assist in calculating the various allowable axial loads for given depths. Below is a sample calculation for a 20 inch pipe pile along the north end of the New Haven shoreline.

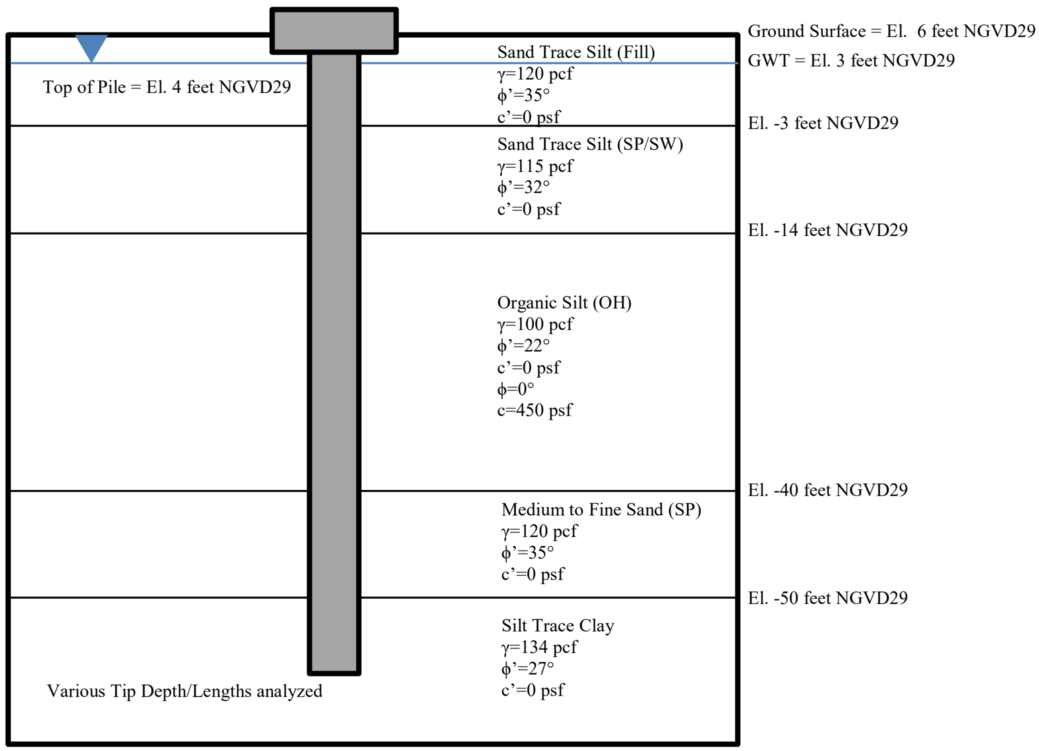


Figure 3: Pile configuration

<u>Calculated Effective Stress</u>:

$$\sigma'_{vo} = \sigma_{vo} - u$$
$$\sigma'_{vo} = \Sigma(\gamma_{soil,i} * z_{soil\ depth,i} - \gamma_{water} * z_{water\ depth,i})$$

a) *"Skin Friction. For design purposes the skin friction of piles in sand increase linearly to an assumed critical depth (Dc) and then remain constant below that depth. The critical depth varies between 10 to 20 pile diameters or widths (B), depending on the relative density of the sand. The critical depth is assumed as:*

Dc = 10B for loose sands and silts
Dc = 15B for medium dense sands and silts
Dc = 20B for dense sands and silts"

-EM 1110-2-2906

Due to the presence of loose sands and silts. 10B was used as the critical depth. In this case, a 20 inch pipe pile is being used, **the critical depth is 17 feet deep**. Diagram of total and effective vertical stress is include in Figure 4.

At El. 4 feet (Top of Pile)

$$\sigma'_{vo} = \sigma_{vo} = 120\ pcf * 2\ ft = 240\ psf$$

At El. 3 feet (Top of GWT)

$$\sigma'_{vo} = \sigma_{vo} = 120\ pcf * 3\ ft = 360\ psf$$

At El. -3 feet

$$\sigma'_{vo} = 360\ psf + (120pcf - 62.4pcf) * 6ft = 705.6\ psf$$

At El. -11 feet (Critical Depth)

For the purpose of skin friction calculations the effective stress is constant below the critical depth

$$\sigma'_{vo} = 705.6\ psf + (115pcf - 62.4pcf) * 8ft = 1126\ psf$$

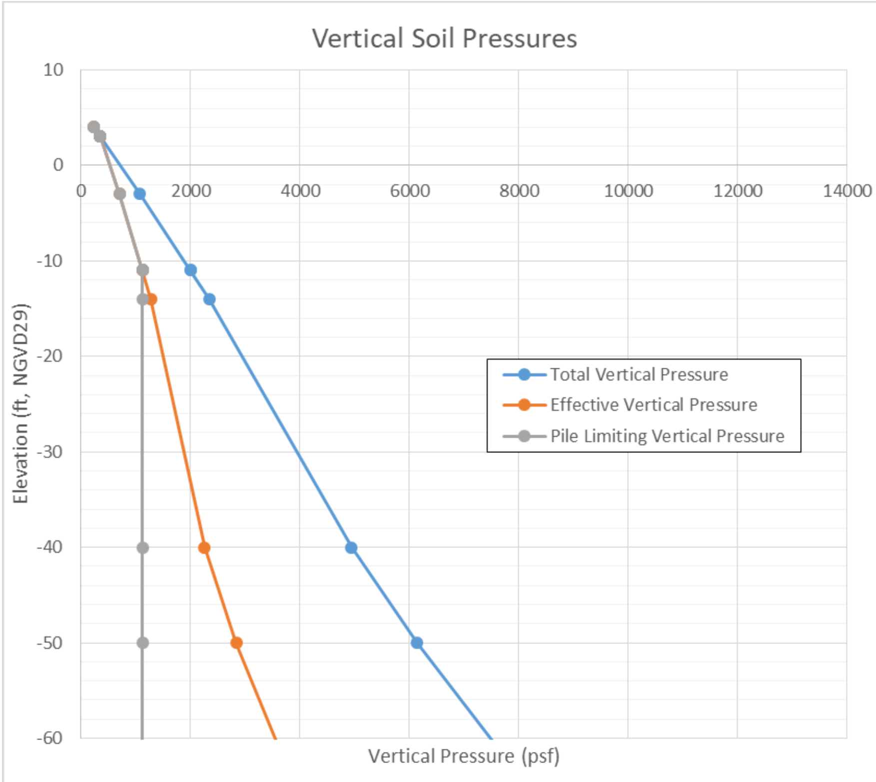


Figure 4: Vertical soil pressures

b) Skin Friction Calculations (Alpha Method)
Note: No cohesion was assumed in the organic silts drained case the alpha cancels in below equations.

$$\alpha = \alpha_1 \alpha_2$$
$$f_s = K\sigma'_v \tan\delta + \alpha c = K\sigma'_v \tan\delta$$
$$\sigma'_v = \gamma' D \quad \text{for } D < D_c$$
$$\sigma'_v = \gamma' D_c \quad \text{for } D > D_c$$
$$Q_s = f_s A_s$$

α = adhesion factor
α_1= adhesion factor for undrained strength and effective stress ratio from Fig. 4-5b in EM 1110-2-2906
α_2 = adhesion factor for pile length from Fig. 4-5b in EM 110-2-2906
K = lateral earth pressure coefficient (Kc for compression piles and Kt for tension piles)
σ'_v = effective overburden pressure
δ = angle of friction between the soil and the pile from Table 4-3 in EM 1110-2-2906
D_c = critical depth from page 4-11 of EM 1110-2-2916
Q_s = capacity due to skin resistance
A_s = surface area of pile shaft in contact with soil
f_s = average unit skin resistance

Two tables for determining values of K in compression and tension for displacement and non-displacement piles are provided in EM 1110-2-2916 (Figure 7). For displacement piles, the lower end of Table 4-4 were used as these were the more conservative values (Sand Kc=1.0, Kt=0.5; Silt Kc=1.0, Kt=0.5), and the higher K values in Table 4-5 are only recommended if testing validates those values. For the non-displacement pile calculations, the lower K tension values from Table 4-5 were used as well as the lower sand KC value from Table 4-4 (Sand Kc=1.0, Kt=0.5; Silt Kc=1.0, Kt=0.35).

Table 4-4

Values of K

Soil Type	K_c	K_t
Sand	1.00 to 2.00	0.50 to 0.70
Silt	1.00	0.50 to 0.70
Clay	1.00	0.70 to 1.00

Note: The above do not apply to piles that are prebored, jetted, or installed with a vibratory hammer. Picking K values at the upper end of the above ranges should be based on local experience. K, δ, and N_q values back calculated from load tests may be used.

Table 4-5

Common Values for Corrected K

Soil Type	Displacement Piles Compression	Displacement Piles Tension	Nondisplacement Piles Compression	Nondisplacement Piles Tension
Sand	2.00	0.67	1.50	0.50
Silt	1.25	0.50	1.00	0.35
Clay	1.25	0.90	1.00	0.70

Note: Although these values may be commonly used in some areas they should not be used without experience and testing to validate them.

Figure 5: K value table in EM 1110-2-2916

Using Table 4-3 in the EM (Figure 6), a δ of 0.67ϕ was used for steel pipe piles calculations and a δ of 0.9ϕ was used for the concrete drilled shaft calculations.

Table 4-3

Values of δ

Pile Material	δ
Steel	0.67 ϕ to 0.83 ϕ
Concrete	0.90 ϕ to 1.0 ϕ
Timber	0.80 ϕ to 1.0 ϕ

Figure 6: δ value table in EM 1110-2-2916

Allowable Compression Capacity:

$$Q_{Allow} = \frac{Q_s}{FS}$$

Note: Piles are friction based, bearing capacity not included in compression capacity

Allowable Tension Capacity:

$$Q_{Allow} = \frac{Q_{s\,\text{tension}}}{FS}$$

Q_s = capacity due to skin resistance
$Q_{s\,\text{tension}}$ = capacity due to skin resistance for pile in tension
Q_{Allow} = Allowable axial loading capacity
FS = factor of safety for compression or tension from page 4-2 of EM 1110-2-2906 shown below

As loading is due to wave loads during storms which would not be considered normal day-to-day loading a factor of safety of 2.25 was used (Figure 7).

Method of Determining Capacity	Loading Condition	Minimum Factor of Safety	
		Compression	Tension
Theoretical or empirical prediction to be verified by pile load test	Usual	2.0	2.0
	Unusual	1.5	1.5
	Extreme	1.15	1.15
Theoretical or empirical prediction to be verified by pile driving analyzer as described in Paragraph 5-4a	Usual	2.5	3.0
	Unusual	1.9	2.25
	Extreme	1.4	1.7
Theoretical or empirical prediction not verified by load test	Usual	3.0	3.0
	Unusual	2.25	2.25
	Extreme	1.7	1.7

Figure 7: Factor of Safety table from page 4-2 in EM 110-2-2906. (Note that due to uncertainty in soil conditions, a higher factor of safety was used in the pile calculations.)

Skin friction from El. 4 feet to El. -1 ft was not considered for frictional resistance due to the potential disturbance during construction.

$$f_s = K\sigma'_{v\,avg} \tan\delta + \alpha c$$
$$f_s = K\sigma'_{v\,avg} \tan\delta$$

$$Q_s = f_s A_s$$
$$Q_s = K\sigma'_{v\,avg} \tan\delta * A_s$$

El. 3 feet to El. -3 feet

$$\sigma'_{vavg} = \frac{360\,psf + 705.6\,psf}{2} = 532.8\,psf$$
$$K_{compression} = 1.0$$
$$K_{tension} = 0.5$$
$$A_s = \pi D * (Pile\ Length\ Below\ El. -1\ foot\ NGVD29) = \pi * \frac{20\,inches}{12\,\frac{inches}{ft}} * (2ft) = 10.5\,ft^2$$

$$Q_{s\,compression} = K\sigma'_{v\,avg} \tan\delta * A_s = 1.0 * 532.8\,psf * \tan(0.67 * 35°) * 10.5\,ft^2 = 2420\,lb$$

$$Q_{s\,tension} = K\sigma'_{v\,avg} \tan\delta * A_s = 0.5 * 532.8\,psf * \tan(0.67 * 35°) * 10.5\,ft^2 = 1210\,lb$$

$$Q_{s\,allow,compression} = \frac{\sum Q_{s\,compression\,@\,El.-3\,ft}}{FS} = \frac{2420\,lb}{2.25} = 1.1\,kips$$
$$Q_{s\,allow,tension} = \frac{\sum Q_{s\,tension\,@\,El.-3\,ft}}{FS} = \frac{1210\,lb}{2.25} = 0.5\,kips$$

El. -3 feet to El. -11 feet (Critical Depth)

$$\sigma'_{vavg} = \frac{705.6\,psf + 1126\,psf}{2} = 915.8\,psf$$

$$A_s = \pi D * (Pile\ Length\ Below\ El. -1\ foot\ NGVD29) = \pi * \frac{20\ inches}{12\,\frac{inches}{ft}} * (8\,ft) = 41.9\,ft^2$$

$$Q_{s\ compression} = K\sigma'_{v\ avg} \tan\delta * A_s = 1.0 * 915.8\,psf * \tan(0.67 * 32°) * 41.9\,ft^2 = 15069\,lb$$

$$Q_{s\ tension} = K\sigma'_{v\ avg} \tan\delta * A_s = 0.5 * 915.8\,psf * \tan(0.67 * 32°) * 41.9\,ft^2 = 7534\,lb$$

$$Q_{s\ allow,compression} = \frac{\sum Q_{s\ compression\ @\ El.-11\ ft}}{FS} = \frac{15069\,psf + 2420\,psf}{2.25} = 7.8\,kips$$

$$Q_{s\ allow,tension} = \frac{\sum Q_{s\ tension\ @\ El.-11\ ft}}{FS} = \frac{1210\,psf + 7534\,psf}{2.25} = 3.9\,kips$$

El. -11 feet to El. -14 feet (Below Critical)

$$\sigma'_{vavg} = 1126\,psf$$

$$A_s = \pi D * (Pile\ Length\ Below\ El. -1\ foot\ NGVD29) = \pi * \frac{20\ inches}{12\,\frac{inches}{ft}} * (3\,ft) = 15.7\,ft^2$$

$$Q_{s\ compression} = K\sigma'_{v\ avg} \tan\delta * A_s = 1.0 * 1126\,psf * \tan(0.67 * 32°) * 15.7\,ft^2 = 6948\,lb$$

$$Q_{s\ tension} = K\sigma'_{v\ avg} \tan\delta * A_s = 0.5 * 1126\,psf * \tan(0.67 * 32°) * 15.7\,ft^2 = 3474\,lb$$

$$Q_{s\ allow,compression} = \frac{\sum Q_{s\ compression\ @\ El.-14\ ft}}{FS} = \frac{15069\,lb + 2420\,lb + 6948\,lb}{2.25} = 10.9\,kips$$

$$Q_{s\ allow,tension} = \frac{\sum Q_{s\ tension\ @\ El.-14\ ft}}{FS} = \frac{1210\,lb + 7534\,lb + 3474\,lb}{2.25} = 5.4\,kips$$

El. -14 feet to El. -40 feet (Below Critical)

$$Q_{s\ compression} = K\sigma'_{v\ avg} \tan\delta * A_s = 1.0 * 1126\ psf * \tan(0.67 * 22°) * 136\ ft^2 = 40343\ lb$$

$$Q_{s\ tension} = K\sigma'_{v\ avg} \tan\delta * A_s = 0.5 * 1126\ psf * \tan(0.67 * 22°) * 136\ ft^2 = 20172\ lb$$

$$Q_{s\ allow,compression} = \sum \frac{Q_{s\ compression\ @\ El.-40\ ft}}{FS} = \frac{15069\ lb + 2420\ lb + 6948\ lb + 40343\ lb}{2.25} = 28.8\ kips$$

$$Q_{s\ allow,tension} = \frac{\sum Q_{s\ tension\ @\ El.-40\ ft}}{FS} = \frac{1210\ lb + 7534\ lb + 3474\ lb + 20172\ lb}{2.25} = 14.4\ kips$$

El. -40 feet to El. -50 feet (Below Critical)

$$Q_{s\ compression} = K\sigma'_{v\ avg} \tan\delta * A_s = 1.0 * 1126\ psf * \tan(0.67 * 35°) * 52.4\ ft^2 = 25583\ lb$$

$$Q_{s\ tension} = K\sigma'_{v\ avg} \tan\delta * A_s = 0.5 * 1126\ psf * \tan(0.67 * 35°) * 52.4\ ft^2 = 12792\ lb$$

$$Q_{s\ allow,compression} = \sum \frac{Q_{s\ compression\ @\ El.-50\ ft}}{FS} = \frac{15069\ lb + 2420\ lb + 6948\ lb + 40343\ lb + 25583\ lb}{2.25} = 40.2\ kips$$

$$Q_{s\ allow,tension} = \frac{\sum Q_{s\ tension\ @\ El.-50\ ft}}{FS} = \frac{1210\ lb + 7534\ lb + 3474\ lb + 20172\ lb + 12792\ lb}{2.25} = 20.1\ kips$$

El. -50 feet to El. -70 feet (Below Critical)

$$Q_{s\ compression} = K\sigma'_{v\ avg} \tan\delta * A_s = 1.0 * 1126\ psf * \tan(0.67 * 27°) * 104.7\ ft^2 = 38531\ lb$$

$$Q_{s\ tension} = K\sigma'_{v\ avg} \tan\delta * A_s = 0.5 * 1126\ psf * \tan(0.67 * 27°) * 104.7\ ft^2 = 19266\ lb$$

$$Q_{s\ allow,compression} = \frac{\sum Q_{s\ compression\ @\ El.-70\ ft}}{FS} = \frac{15069\ lb + 2420\ lb + 6948\ lb + 40343\ lb + 25583\ lb + 38531\ lb}{2.25} = 57.3\ kips$$

$$Q_{s\ allow,tension} = \frac{\sum Q_{s\ tension\ @\ El.-70\ ft}}{FS} = \frac{1210\ lb + 7534\ lb + 3474\ lb + 20172\ lb + 12792\ lb + 19266\ lb}{2.25} = 28.6\ kips$$

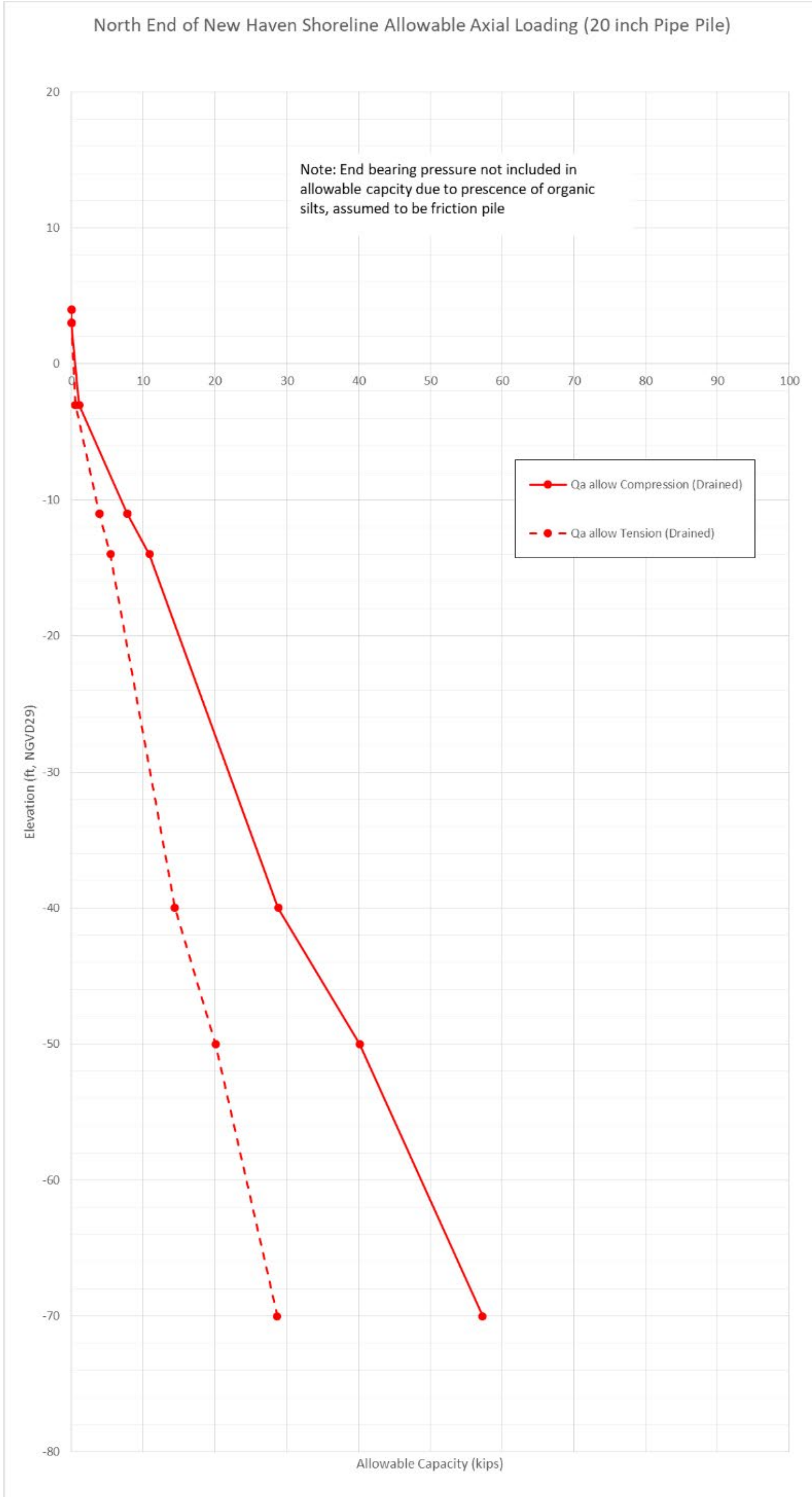


Figure 8: Example allowable axial capacities

While tip capacity was ultimately not included in the allowable compression axial loading, calculations for tip capacity were included in the excel sheet. Bearing capacity was calculated at the top and bottom of layers to indicate stratification changes. Calculations for bearing capacity used bearing capacity equations and end bearing factors from EM 1110-2-2916. A sample calculation is provided for a single elevation.

End Bearing Calculations

Sand or Silt:

$$q = \sigma'_v N_q$$

$$\sigma'_v = \gamma' D \quad \text{for } D < D_c$$

$$\sigma'_v = \gamma' D_c \quad \text{for } D > D_c$$

$$Q_t = A_t q$$

Clay:

$$q = 9c$$

$$Q_t = A_t q$$

$$Q_{t\ allow} = \frac{Q_t}{FS}$$

q = unit tip-bearing capacity
σ'_v = effective overburden pressure
N_q = Suggested bearing capacity factor determined from Fig. 4-4 in EM 1110-2-2906
A_t = effective area of the pile tip in contact with the soil

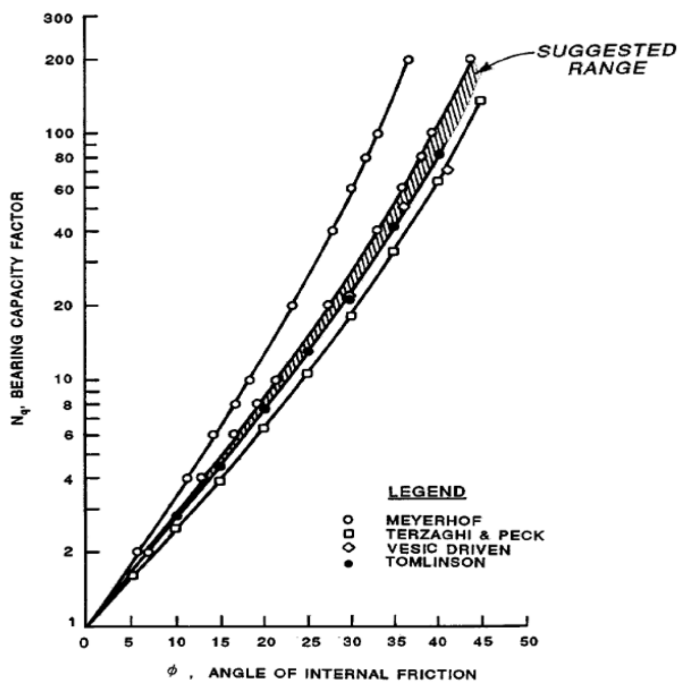


Figure 4-4. Bearing capacity factor

Figure 9: Bearing capacity figure from EM 1110-2-2916

El. -50 feet Bottom of Layer

Note: As 50 feet is below the critical depth the effective stress at the top and bottom of this layer (between -40 and -50 feet) is the same.

$$q = \sigma'_v N_q$$

$$\sigma'_v = \gamma' D_c \quad \text{for } D > D_c$$

$$Q_t = A_t \sigma'_v N_q$$

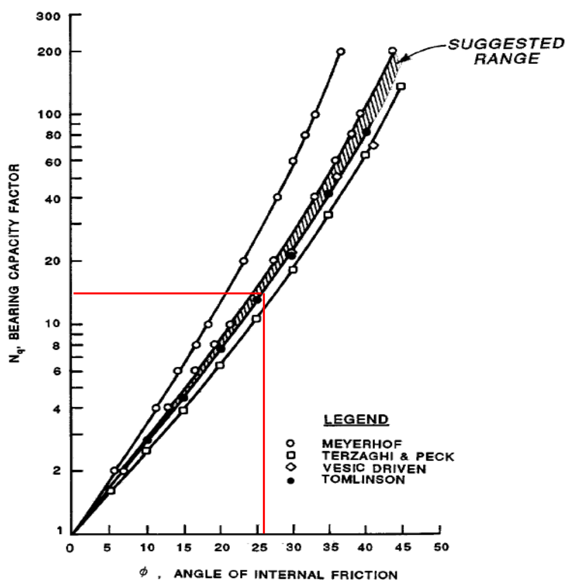


Figure 4-4. Bearing capacity factor

$$\phi = 27 \rightarrow N_q = 12$$

$$Q_t = \pi\left(\frac{(1.67\,feet)}{2}\right)^2 * 1126.4\,psf * 12 = 30.5\,kips$$

$$Q_{t\,allow} = \frac{Q_t}{FS} = \frac{30.5\,kips}{2.25} = 13\,kips$$

CONCLUSIONS:

A 20 inch pipe pile 65 feet in length will meet the 50 kip compression and 20 kip tension requirements along the north end of the New Haven shoreline. This method was applied to the attached excel sheets.

REFERENCES:

USACE EM 1110-2-2906 Design of Pile Foundations (1991)

Bowles, J.E. Physical and Geotechnical Properties of Soils 2nd Edition (1984)

Kishida, H. Ultimate Bearing Capacity of Pile Driven in Loose Sand Soils and Foundations, Vol. 7, No. 3: 20-29

ATTACHMENT 1: CALCULATIONS

New Haven Southend Near I-95	Stratification: Soil Type	Layer	Layer Top Elv. (ft)	Layer Bottom Elv. (ft)	Depth to Layer Bottom (ft)	Layer Thickness (ft)	Soil Properties: N_{60} Blow Count	γ_t (pcf)	S_u (psf)	ϕ (degrees)	c' (psf)	ϕ' (degrees)
Final Grade	Sand trace silt (Fill)	1	6	6	0							
Top of Piles (4 ft NGVD29)	Sand trace silt (Fill)	2	6	4	2	2	15	115	0	32	0	32
	Organic Silt (OH)	3	4	3	3	1	1	100	450	0	0	22
Ground Water Table		4	3	3	3	0						
	Organic Silt (OH)	5	3	-14	20	17	1	100	450	0	0	22
Critical Depth		6	-14	-14	20	0						
	Organic Silt (OH)	7	-14	-34	40	20	1	100	450	0	0	22
	Medium to Fine Sand (SP)	8	-34	-41	47	7	10	125	0	30	0	30
	Upper Silt trace Clay	9	-41	-58	64	17	12	128	0	25	0	25
	Lower Silt trace Clay	10	-58	-100	106	42	20	132	0	25	0	25

Layer	Vertical Soil Pressures at Bottom of Layer: u (psf)	σ_{vo} (psf)	σ_{vo}' (psf)	σ_{vo} critical depth (psf)	σ_{vo}' critical depth (psf)	Layer Thickness (Top 5 feet ignored) (ft)	Skin Friction Area A_s (ft^2)
1							
2	0	230	230	230	230	0	0
3	0	330	330	330	330	0	0.0
4	0	330	330	330	330	0	0.0
5	1060.8	2030	969.2	2030	969.2	13	81.7
6	1060.8	2030	969.2	2030	969.2	0	0.0
7	2308.8	4030	1721.2	2030	969.2	20	125.7
8	2745.6	4905	2159.4	2030	969.2	7	44.0
9	3806.4	7081	3274.6	2030	969.2	17	106.8
10	6427.2	12625	6197.8	2030	969.2	42	263.9

Pile Properties	
Pile Type:	Concrete Filled Steel Pipe Pile
Pile Designation:	PP 24x0.500
Diameter B (ft):	2.00
Cross Sectional Area (in^2):	36.91
Pile Weight (lb/ft):	126
Effective Area of Pile Tip (ft^2):	3.14
Perimeter:	6.28

Factor Of Safety Criteria	
Compression	Tension
2.25	2.25

From page 4-2 in EM 1110-2-2906 assumes "Theoretical or empirical prediction not verified by load testing for Unusual Loading"

Critical Depth Criteria			
Dc = 10B	20	loose silts	loose sands
Dc = 15B	30	medium silts	medium dense sand
Dc = 20B	40	dense silts	dense sand

From page 4-13 in EM 1110-2-2906, applicable to both skin friction and end bearing

Common Values for Corrected K

Soil Type	Non Displacemnt: Compression	Non Displacemnt: Tension
Sand	1.5	0.5
Silt	1	0.35
Clay	1	0.7

From Table 4-5 in EM 1110-2-2906

Values of K for Driven Piles

Soil Type	Kc	Kt
Sand	1 to 2	0.5 to 0.7
Silt	1	0.5 to 0.7
Clay	1	0.7 to 1.0

From Table 4-5 4n EM 1110-2-2906

Adhesion Factor δ	
Steel	0.67ϕ to 0.83 ϕ
Concrete	0.9 ϕ to 1.0 ϕ
Timber	0.80 ϕ to 1.0 ϕ
Factor For Calculations	0.67

Table 4-3 in EM 1110-2-2906

Water Unit Weight (pcf):	62.4

Undrained Analysis (Q case)

Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	α*c	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)
1	1	0.5												
2	1	0.5	21.44	0.0	1.0	0.0	1.0	1.0	0.0	115.0	45	0	0	0.0
3	1	0.5	0	1.4	0.5	0.5	1.0	0.5	225.0	280.0	225	0	0	0.0
4	1	0.5	0	0.0	1.0	0.5	1.0	1.0	0.0	330.0	0	0	0	0.0
5	1	0.5	0	0.5	0.9	9.0	1.0	0.9	393.1	649.6	393	32112	32112	14.3
6	1	0.5	0	0.0	1.0	9.0	1.0	1.0	0.0	969.2	0	0	32112	14.3
7	1	0.5	0	0.5	0.9	19.0	1.0	0.9	393.1	969.2	393	49402	81514	36.2
8	1	0.5	20.1	0.0	1.0	22.5	1.0	1.0	0.0	969.2	355	15600	97113	43.2
9	1	0.5	16.75	0.0	1.0	31.0	1.0	1.0	0.0	969.2	292	31157	128271	57.0
10	1	0.5	16.75	0.0	1.0	52.0	1.0	1.0	0.0	969.2	292	76977	205248	91.2

Layer	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)	Bearing Capacity Qt: Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Total Allowable Axial Capacity Qa*: Qa allow Compression (Undrained) (kips)	Qa allow Tension (Undrained) (kips)
1											
2	22.6	0.0	0	0.0	25	0	5750	0	8	0.0	0.0
3	225.0	0.0	0	0.0	0	0	0	0	0	0.0	0.0
4	0.0	0.0	0	0.0	0	0	0	0	0	0.0	0.0
5	393.1	32111.6	32112	14.3	0	0	0	0	0	14.3	14.3
6	0.0	0.0	32112	14.3	0	0	0	0	0	14.3	14.3
7	393.1	49402.4	81514	36.2	0	0	0	0	0	36.2	36.2
8	177.3	7799.8	89314	39.7	20	19384	19384	27	27	43.2	39.7
9	145.8	15578.6	104892	46.6	15	14538	14538	20	20	57.0	46.6
10	145.8	38488.4	143381	63.7	15	14538	14538	20	20	91.2	63.7

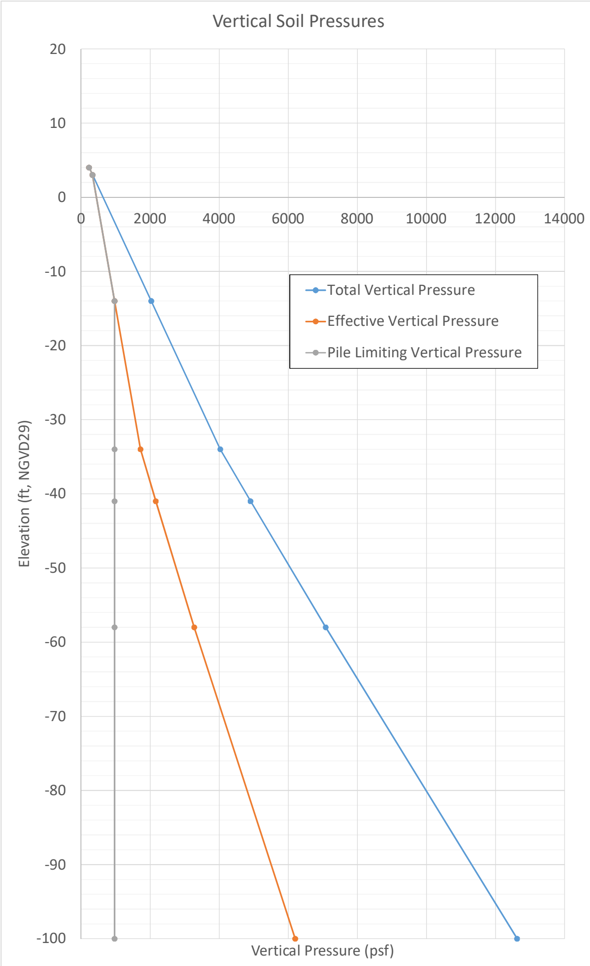
Drained Analysis (S case)

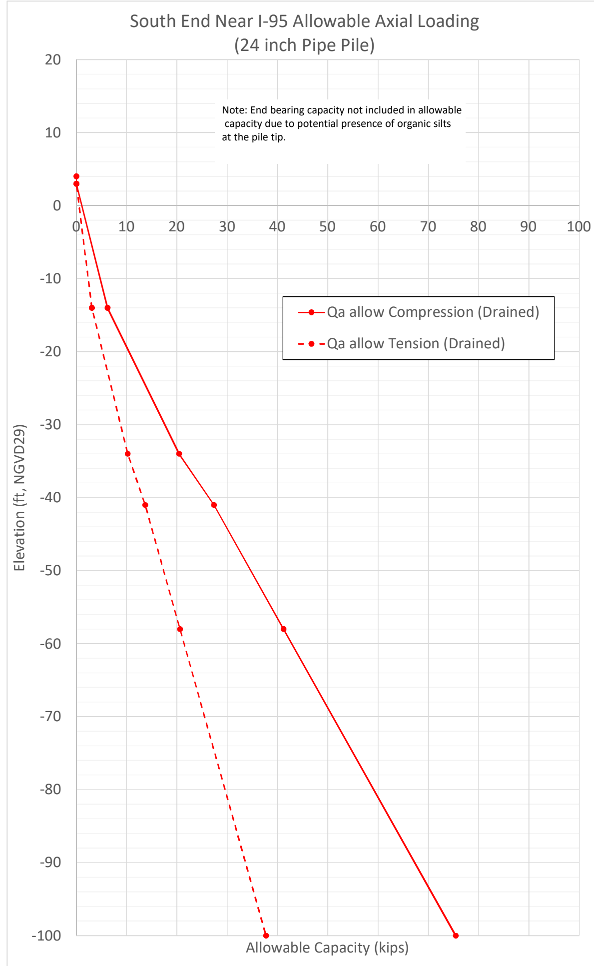
Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	αc	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)
1	1	0.5												
2	1	0.5	21.44	0.0	1.0	0.0	1.0	1.0	0.0	115.0	45	0	0	0.0
3	1	0.5	14.74	0.0	1.0	0.5	1.0	1.0	0.0	280.0	74	0	0	0.0
4	1	0.5	0	0.0	1.0	0.5	1.0	1.0	0.0	330.0	0	0	0	0.0
5	1	0.5	14.74	0.0	1.0	9.0	1.0	1.0	0.0	649.6	171	13960	13960	6.2
6	1	0.5	0	0.0	1.0	9.0	1.0	1.0	0.0	969.2	0	0	13960	6.2
7	1	0.5	14.74	0.0	1.0	19.0	1.0	1.0	0.0	969.2	255	32043	46002	20.4
8	1	0.5	20.1	0.0	1.0	22.5	1.0	1.0	0.0	969.2	355	15600	61602	27.4
9	1	0.5	16.75	0.0	1.0	31.0	1.0	1.0	0.0	969.2	292	31157	92759	41.2
10	1	0.5	16.75	0.0	1.0	52.0	1.0	1.0	0.0	969.2	292	76977	169736	75.4

Layer	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)	Bearing Capacity Qt: Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Total Allowable Axial Capacity Qa*: Qa allow Compression (Drained) (kips)	Qa allow Tension (Drained) (kips)
1											
2	22.6	0.0	0	0.0	25	0	5750	0	8	0.0	0.0
3	36.8	0.0	0	0.0	0	0	0	0	0	0.0	0.0
4	0.0	0.0	0	0.0	0	0	0	0	0	0.0	0.0
5	85.5	6979.8	6980	3.1	0	0	0	0	0	6.2	3.1
6	0.0	0.0	6980	3.1	0	0	0	0	0	6.2	3.1
7	127.5	16021.4	23001	10.2	0	0	0	0	0	20.4	10.2
8	177.3	7799.8	30801	13.7	20	19384	19384	27	27	27.4	13.7
9	145.8	15578.6	46380	20.6	15	14538	14538	20	20	41.2	20.6
10	145.8	38488.4	84868	37.7	15	14538	14538	20	20	75.4	37.7

*Bearing capacity not included in allowable axial due to organic presence.


Vertical Soil Pressures
Elevation (ft, NGVD29)
Vertical Pressure (psf)
Total Vertical Pressure
Effective Vertical Pressure
Pile Limiting Vertical Pressure
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
2000
4000
6000
8000
10000
12000
14000


South End Near I-95 Allowable Axial Loading
(24 inch Pipe Pile)
Note: End bearing capacity not included in allowable capacity due to potential presence of organic silts at the pile tip.
Elevation (ft, NGVD29)
Allowable Capacity (kips)
Qa allow Compression (Drained)
Qa allow Tension (Drained)
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
10
20
30
40
50
60
70
80
90
100

New Haven
Southend Near I-95

Stratification

	Soil Type	Layer	Layer Top Elv. (ft)	Layer Bottom Elv. (ft)	Depth to Layer Bottom (ft)	Layer Thickness (ft)
Final Grade	Sand trace silt (Fill)	1	6	6	0	
Top of Piles (4 ft NGVD29)	Sand trace silt (Fill)	2	6	4	2	2
	Organic Silt (OH)	3	4	3	3	1
Ground Water Table		4	3	3	3	0
	Organic Silt (OH)	5	3	-14	20	17
	Organic Silt (OH)	6	-14	-34	40	20
Critical Depth		7	-34	-34	40	0
	Medium to Fine Sand (SP)	8	-34	-41	47	7
	Upper Silt trace Clay	9	-41	-58	64	17
	Lower Silt trace Clay	10	-58	-100	106	42

Soil Properties

Layer	N_{60} (Blow Count)	γ_t (pcf)	S_u (psf)	ϕ (degrees)	c' (psf)	ϕ' (degrees)
1						
2	15	115	0	32	0	32
3	1	100	450	0	0	22
4						
5	1	100	450	0	0	22
6	1	100	450	0	0	22
7						
8	10	125	0	30	0	30
9	12	128	0	25	0	25
10	20	132	0	25	0	25

Vertical Soil Pressures at Bottom of Layer

Layer	u (psf)	σ_{vo} (psf)	σ_{vo}' (psf)	σ_{vo} critical depth (psf)	σ_{vo}' critical depth (psf)	Layer Thickness (Top 5 feet ignored) (ft)	Skin Friction Area A_s (ft^2)
1							
2	0	230	230	230	230	0	0
3	0	330	330	330	330	0	0.0
4	0	330	330	330	330	0	0.0
5	1060.8	2030	969.2	2030	969.2	13	163.4
6	2308.8	4030	1721.2	4030	1721.2	20	251.3
7	2308.8	4030	1721.2	4030	1721.2	0	0.0
8	2745.6	4905	2159.4	4030	1721.2	7	88.0
9	3806.4	7081	3274.6	4030	1721.2	17	213.6
10	6427.2	12625	6197.8	4030	1721.2	42	527.8

Pile Properties	
Pile Type:	Drilled Shaft
Pile Designation:	4-foot dia
Diameter B (ft):	4.00
Cross Sectional Area (in^2):	1810
Pile Weight (lb/ft):	1885
Effective Area of Pile Tip (ft^2):	12.57
Perimeter:	12.57

Factor Of Safety Criteria	
Compression	Tension
2.25	2.25

From page 4-2 in EM 1110-2-2906 assumes "Theoretical or empirical prediction not verified by load testing for Unusual Loading"

Critical Depth Criteria			
Dc = 10B	40	loose silts	loose sands
Dc = 15B	60	medium silts	medium dense sand
Dc = 20B	80	dense silts	dense sand

From page 4-13 in EM 1110-2-2906, applicable to both skin friction and end bearing

Adhesion Factor δ	
Steel	0.67ϕ to 0.83 ϕ
Concrete	0.9 ϕ to 1.0 ϕ
Timber	0.80 ϕ to 1.0 ϕ
Factor For Calculations	0.9

Table 4-3 in EM 1110-2-2906

Water Unit Weight (pcf):	62.4

Common Values for Corrected K

Soil Type	Non Displacemnt Compression	Non Displacemnt Tension
Sand	1.5	0.5
Silt	1	0.35
Clay	1	0.7

From Table 4-5 in EM 1110-2-2906

Values of K for Driven Piles

Soil Type	Kc	Kt
Sand	1 to 2	0.5 to 0.7
Silt	1	0.5 to 0.7
Clay	1	0.7 to 1.0

From Table 4-5 4n EM 1110-2-2906

Undrained Analysis (Q case)

Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	α*c	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)
1	1	0.5												
2	1	0.5	28.8	0.0	1.0	0.0	1.0	1.0	0.0	115.0	63	0	0	0.0
3	1	0.35	0	1.4	0.5	0.3	1.0	0.5	225.0	280.0	225	0	0	0.0
4	1	0.35	0	0.0	1.0	0.3	1.0	1.0	0.0	330.0	0	0	0	0.0
5	1	0.35	0	0.5	0.9	4.5	1.0	0.9	393.1	649.6	393	64223	64223	28.5
6	1	0.35	0	0.3	1.0	9.5	1.0	1.0	450.0	1345.2	450	113097	177320	78.8
7	1	0.35	0	0.0	1.0	9.5	1.0	1.0	0.0	1721.2	0	0	177320	78.8
8	1	0.5	27	0.0	1.0	11.3	1.0	1.0	0.0	1721.2	877	77145	254465	113.1
9	1	0.35	22.5	0.0	1.0	15.5	1.0	1.0	0.0	1721.2	713	152305	406770	180.8
10	1	0.35	22.5	0.0	1.0	26.0	1.0	1.0	0.0	1721.2	713	376283	783053	348.0

Layer	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)	Bearing Capacity Qt: Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Total Allowable Axial Capacity Qa*: Qa allow Compression (Undrained) (kips)	Qa allow Tension (Undrained) (kips)
1											
2	31.6	0.0	0	0.0	25	0	5750	0	32	0.0	0.0
3	225.0	0.0	0	0.0	25	5750	8250	32	46	0.0	0.0
4	0.0	0.0	0	0.0	0	0	0	0	0	0.0	0.0
5	393.1	64223.1	64223	28.5	0	0	0	0	0	28.5	28.5
6	450.0	113097.3	177320	78.8	0	0	0	0	0	78.8	78.8
7	0.0	0.0	177320	78.8	0	0	0	0	0	78.8	78.8
8	438.5	38572.3	215893	96.0	20	34424	34424	192	192	113.1	96.0
9	249.5	53306.8	269200	119.6	15	25818	25818	144	144	180.8	119.6
10	249.5	131699.1	400899	178.2	15	25818	25818	144	144	348.0	178.2

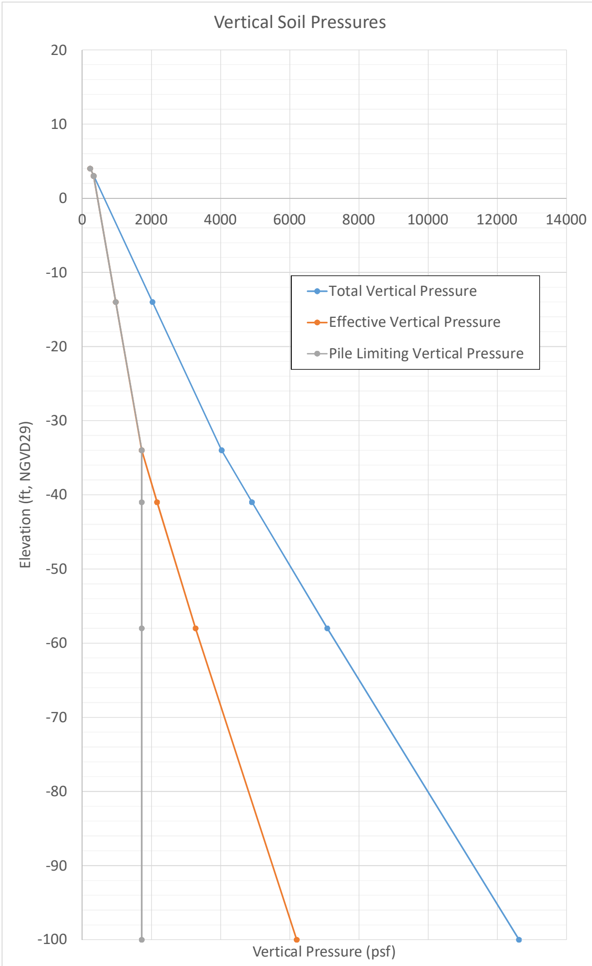
Drained Analysis (S case)

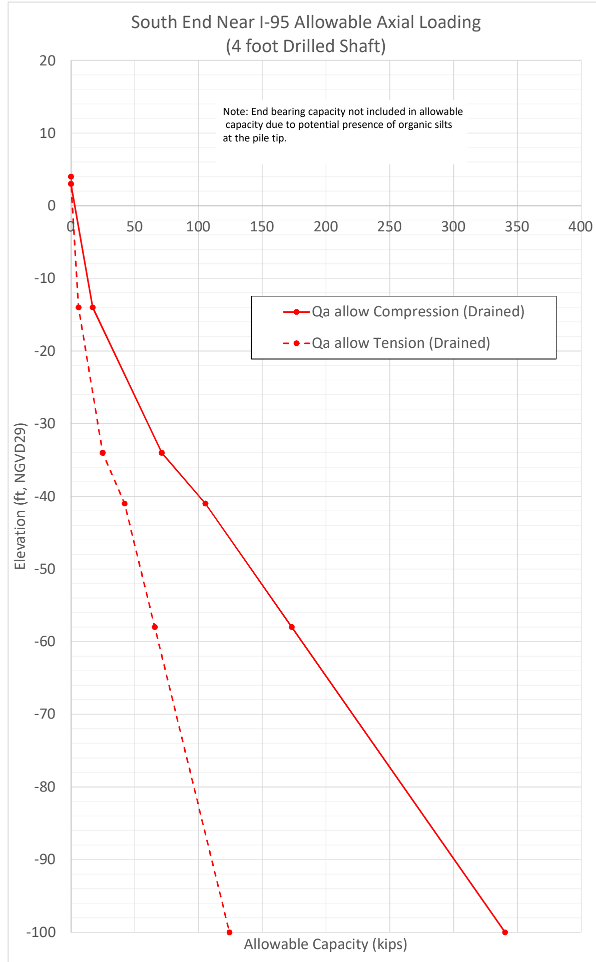
Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	αc	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)
1	1	0.5												
2	1	0.5	28.8	0.0	1.0	0.0	1.0	1.0	0.0	115.0	63	0	0	0.0
3	1	0.35	19.8	0.0	1.0	0.3	1.0	1.0	0.0	280.0	101	0	0	0.0
4	1	0.35	0	0.0	1.0	0.3	1.0	1.0	0.0	330.0	0	0	0	0.0
5	1	0.35	19.8	0.0	1.0	4.5	1.0	1.0	0.0	649.6	234	38206	38206	17.0
6	1	0.35	19.8	0.0	1.0	9.5	1.0	1.0	0.0	1345.2	484	121718	159924	71.1
7	1	0.35	0	0.0	1.0	9.5	1.0	1.0	0.0	1721.2	0	0	159924	71.1
8	1	0.5	27	0.0	1.0	11.3	1.0	1.0	0.0	1721.2	877	77145	237069	105.4
9	1	0.35	22.5	0.0	1.0	15.5	1.0	1.0	0.0	1721.2	713	152305	389374	173.1
10	1	0.35	22.5	0.0	1.0	26.0	1.0	1.0	0.0	1721.2	713	376283	765657	340.3

Layer	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)	Bearing Capacity Qt: Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Total Allowable Axial Capacity Qa*: Qa allow Compression (Drained) (kips)	Qa allow Tension (Drained) (kips)
1											
2	31.6	0.0	0	0.0	25	0	5750	0	32	0.0	0.0
3	35.3	0.0	0	0.0	25	5750	8250	32	46	0.0	0.0
4	0.0	0.0	0	0.0	0	0	0	0	0	0.0	0.0
5	81.9	13372.0	13372	5.9	0	0	0	0	0	17.0	5.9
6	169.5	42601.4	55973	24.9	0	0	0	0	0	71.1	24.9
7	0.0	0.0	55973	24.9	0	0	0	0	0	71.1	24.9
8	438.5	38572.3	94546	42.0	20	34424	34424	192	192	105.4	42.0
9	249.5	53306.8	147852	65.7	15	25818	25818	144	144	173.1	65.7
10	249.5	131699.1	279552	124.2	15	25818	25818	144	144	340.3	124.2

*Bearing capacity not included in allowable axial due to organic presence.


Vertical Soil Pressures
Elevation (ft, NGVD29)
Vertical Pressure (psf)
Total Vertical Pressure
Effective Vertical Pressure
Pile Limiting Vertical Pressure
0
2000
4000
6000
8000
10000
12000
14000
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100


South End Near I-95 Allowable Axial Loading
(4 foot Drilled Shaft)
Note: End bearing capacity not included in allowable capacity due to potential presence of organic silts at the pile tip.
Elevation (ft, NGVD29)
Allowable Capacity (kips)
Qa allow Compression (Drained)
Qa allow Tension (Drained)
0
50
100
150
200
250
300
350
400
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100

New Haven Southend Near Shoreline	Stratification						Soil Properties						Vertical Soil Pressures at Bottom of Layer						
	Soil Type	Layer	Layer Top Elv. (ft)	Layer Bottom Elv. (ft)	Depth to Layer Bottom (ft)	Layer Thickness (ft)	N_{60} Blow Count	γ_t (pcf)	S_u (psf)	φ (degrees)	c' (psf)	φ' (degrees)	u (psf)	σ_{vo} (psf)	σ_{vo}' (psf)	σ_{vo} critical depth (psf)	σ_{vo}' critical depth (psf)	Layer Thickness (Top 5 feet ignored) (ft)	Skin Friction Area A_s (ft^2)
Final Grade	Sand trace silt (Fill)	1	6	6	0														
Top of Piles (4 ft NGVD29)	Sand trace silt (Fill)	2	6	4	2	2	15	115	0	32	0	32	0	230	230	230	230	0	0
	Sand trace silt (Fill)	3	4	3	3	1	15	115	0	32	0	32	0	345	345	345	345	0	0.0
Ground Water Table		4	3	3	3	0							0	345	345	345	345	0	0.0
	Sand trace silt (Fill)	5	3	0	6	3	15	115	0	32	0	32	187.2	690	502.8	690	502.8	0	0.0
	Coarse to Fine Sand (SW)	6	0	-9	15	9	20	120	0	35	0	35	748.8	1770	1021.2	1770	1021.2	8	41.9
	Organic Silt (OH)	7	-9	-11	17	2	1	100	450	0	0	22	873.6	1970	1096.4	1970	1096.4	2	10.5
Critical Depth		8	-11	-11	17	0							873.6	1970	1096.4	1970	1096.4	0	0.0
	Organic Silt (OH)	9	-11	-20	26	9	1	100	450	0	0	22	1435.2	2870	1434.8	1970	1096.4	9	47.1
	Organic Silt (OH)	10	-20	-37	43	17	1	100	450	0	0	22	2496	4570	2074	1970	1096.4	17	89.0
	Sand	11	-37	-47	53	10	20	120	0	35	0	35	3120	5770	2650	1970	1096.4	10	52.4
	Upper Silt trace Clay	12	-47	-75	81	28	12	128	0	25	0	25	4867.2	9354	4486.8	1970	1096.4	28	146.6
	Lower Silt trace Clay	13	-75	-100	106	25	20	132	0	25	0	25	6427.2	12654	6226.8	1970	1096.4	25	130.9

Pile Properties	
Pile Type:	Concrete Filled Steel Pipe Pile
Pile Designation:	PP 20x0.500
Diameter B (ft):	1.67
Cross Sectional Area (in^2):	30.63
Pile Weight (lb/ft):	104
Effective Area of Pile Tip (ft^2):	2.18
Perimeter:	5.24

Factor Of Safety Criteria	
Compression	Tension
2.25	2.25

From page 4-2 in EM 1110-2-2906 assumes "Theoretical or empirical prediction not verified by load testing for Unusual Loading"

Critical Depth Criteria			
Dc = 10B	17	loose silts	loose sands
Dc = 15B	25	medium silts	medium dense sand
Dc = 20B	33	dense silts	dense sand

From page 4-13 in EM 1110-2-2906, applicable to both skin friction and end bearing

Common Values for Corrected K

Soil Type	Non Displacemnt	
	Compression	Tension
Sand	1.5	0.5
Silt	1	0.35
Clay	1	0.7

From Table 4-5 in EM 1110-2-2906

Values of K for Driven Piles

Soil Type	Kc	Kt
Sand	1 to 2	0.5 to 0.7
Silt	1	0.5 to 0.7
Clay	1	0.7 to 1.0

From Table 4-5 4n EM 1110-2-2906

Adhesion Factor δ	
Steel	0.67φ to 0.83 φ
Concrete	0.9 φ to 1.0 φ
Timber	0.80 φ to 1.0 φ
Factor For Calculations	0.67

Table 4-3 in EM 1110-2-2906

Water Unit Weight (pcf):	62.4

Undrained Analysis (Q case)

Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	α*c	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)
1	1	0.5																
2	1	0.5	21.44	0.0	1.0	0.0	1.0	1.0	0.0	115.0	45	0	0	0.0	22.6	0.0	0	0.0
3	1	0.5	21.44	0.0	1.0	0.6	1.0	1.0	0.0	287.5	113	0	0	0.0	56.5	0.0	0	0.0
4	1	0.5	0	0.0	1.0	0.6	1.0	1.0	0.0	345.0	0	0	0	0.0	0.0	0.0	0	0.0
5	1	0.5	21.44	0.0	1.0	2.4	1.0	1.0	0.0	423.9	166	0	0	0.0	83.2	0.0	0	0.0
6	1	0.5	23.45	0.0	1.0	7.8	1.0	1.0	0.0	762.0	331	13845	13845	6.2	165.3	6922.7	6923	3.1
7	1	0.5	0	0.4	0.9	9.0	1.0	0.9	420.0	1058.8	420	4399	18244	8.1	420.0	4398.6	11321	5.0
8	1	0.5	0	0.0	1.0	9.0	1.0	1.0	0.0	1096.4	0	0	18244	8.1	0.0	0.0	11321	5.0
9	1	0.5	0	0.4	0.9	14.4	1.0	0.9	420.0	1096.4	420	19794	38038	16.9	420.0	19793.8	31115	13.8
10	1	0.5	0	0.4	0.9	24.6	1.0	0.9	420.0	1096.4	420	37388	75426	33.5	420.0	37388.3	68504	30.4
11	1	0.5	23.45	0.0	1.0	30.6	1.0	1.0	0.0	1096.4	476	24902	100328	44.6	237.8	12450.9	80954	36.0
12	1	0.5	16.75	0.0	1.0	47.4	1.0	1.0	0.0	1096.4	330	48377	148706	66.1	165.0	24188.7	105143	46.7
13	1	0.5	16.75	0.0	1.0	62.4	0.9	0.9	0.0	1096.4	330	43194	191900	85.3	165.0	21597.1	126740	56.3

Layer	Bearing Capacity Qt					Total Allowable Axial Capacity Qa*	
	Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Qa allow Compression (Undrained) (kips)	Qa allow Tension (Undrained) (kips)
1							
2	25	0	5750	0	6	0.0	0.0
3	25	5750	8625	6	8	0.0	0.0
4	25	8625	8625	8	8	0.0	0.0
5	25	8625	12570	8	12	0.0	0.0
6	40	20112	40848	20	40	6.2	3.1
7	0	0	0	0	0	8.1	5.0
8	0	0	0	0	0	8.1	5.0
9	0	0	0	0	0	16.9	13.8
10	0	0	0	0	0	33.5	30.4
11	40	43856	43856	43	43	44.6	36.0
12	15	16446	16446	16	16	66.1	46.7
13	15	16446	16446	16	16	85.3	56.3

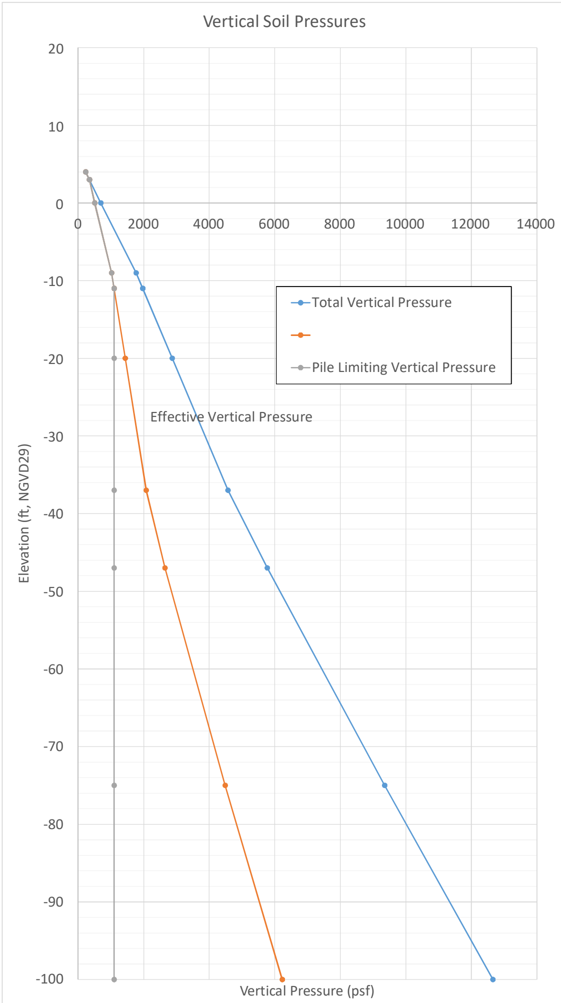
Drained Analysis (S case)

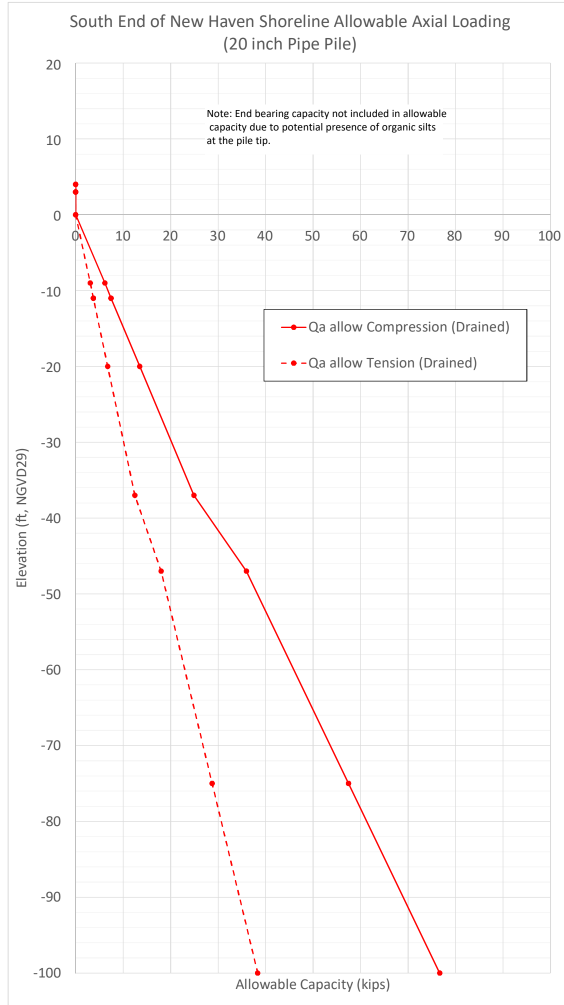
Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	αc	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)
1	1	0.5																
2	1	0.5	21.44	0.0	1.0	0.0	1.0	1.0	0.0	115.0	45	0	0	0.0	22.6	0.0	0	0.0
3	1	0.5	21.44	0.0	1.0	0.6	1.0	1.0	0.0	287.5	113	0	0	0.0	56.5	0.0	0	0.0
4	1	0.5	0	0.0	1.0	0.6	1.0	1.0	0.0	345.0	0	0	0	0.0	0.0	0.0	0	0.0
5	1	0.5	21.44	0.0	1.0	2.4	1.0	1.0	0.0	423.9	166	0	0	0.0	83.2	0.0	0	0.0
6	1	0.5	23.45	0.0	1.0	7.8	1.0	1.0	0.0	762.0	331	13845	13845	6.2	165.3	6922.7	6923	3.1
7	1	0.5	14.74	0.0	1.0	9.0	1.0	1.0	0.0	1058.8	279	2917	16763	7.5	139.3	1458.5	8381	3.7
8	1	0.5	0	0.0	1.0	9.0	1.0	1.0	0.0	1096.4	0	0	16763	7.5	0.0	0.0	8381	3.7
9	1	0.5	14.74	0.0	1.0	14.4	1.0	1.0	0.0	1096.4	288	13593	30356	13.5	144.2	6796.5	15178	6.7
10	1	0.5	14.74	0.0	1.0	24.6	1.0	1.0	0.0	1096.4	288	25676	56031	24.9	144.2	12837.9	28016	12.5
11	1	0.5	23.45	0.0	1.0	30.6	1.0	1.0	0.0	1096.4	476	24902	80933	36.0	237.8	12450.9	40467	18.0
12	1	0.5	16.75	0.0	1.0	47.4	1.0	1.0	0.0	1096.4	330	48377	129311	57.5	165.0	24188.7	64655	28.7
13	1	0.5	16.75	0.0	1.0	62.4	0.9	0.9	0.0	1096.4	330	43194	172505	76.7	165.0	21597.1	86252	38.3

Layer	Bearing Capacity Qt					Total Allowable Axial Capacity Qa*	
	Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Qa allow Compression (Drained) (kips)	Qa allow Tension (Drained) (kips)
1							
2	25	0	5750	0	6	0.0	0.0
3	25	5750	8625	6	8	0.0	0.0
4	25	8625	8625	8	8	0.0	0.0
5	25	8625	12570	8	12	0.0	0.0
6	40	20112	40848	20	40	6.2	3.1
7	0	0	0	0	0	7.5	3.7
8	0	0	0	0	0	7.5	3.7
9	0	0	0	0	0	13.5	6.7
10	0	0	0	0	0	24.9	12.5
11	40	43856	43856	43	43	36.0	18.0
12	15	16446	16446	16	16	57.5	28.7
13	15	16446	16446	16	16	76.7	38.3

***Bearing capacity not included in allowable axial due to organic presence.**


Vertical Soil Pressures
Elevation (ft, NGVD29)
Vertical Pressure (psf)
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
2000
4000
6000
8000
10000
12000
14000
Total Vertical Pressure
Pile Limiting Vertical Pressure
Effective Vertical Pressure


South End of New Haven Shoreline Allowable Axial Loading (20 inch Pipe Pile)
Note: End bearing capacity not included in allowable capacity due to potential presence of organic silts at the pile tip.
Elevation (ft, NGVD29)
Allowable Capacity (kips)
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
10
20
30
40
50
60
70
80
90
100
Qa allow Compression (Drained)
Qa allow Tension (Drained)

U.S. Army Corps of Engineers
® New England District

PROJECT: New Haven General Investigation
SUBJECT: New Haven Allowable Axial Pile Loading

COMPUTED BY: DPFransioli Date: 3/15/2019
CHECKED BY: WGG Date: 4/11/2019

Stratification							Soil Properties						Vertical Soil Pressures at Bottom of Layer						
New Haven Northend Near Shoreline	Soil Type	Layer	Layer Top Elv.	Layer Bottom Elv.	Depth to Layer Bottom	Layer Thickness	N_{60}	γ_t	S_u	ϕ	c'	ϕ'	u	σ_{vo}	σ_{vo}'	σ_{vo} critical depth	σ_{vo}' critical depth	Layer Thickness (Top 5 feet ignored)	Skin Friction Area A_s
			(ft)	(ft)	(ft)	(ft)	Blow Count	(pcf)	(psf)	(degrees)	(psf)	(degrees)	(psf)	(psf)	(psf)	(psf)	(psf)	(ft)	(ft^2)
Final Grade	Sand trace silt (Fill)	1	6	6	0														
Top of Piles (4 ft NGVD29)	Sand trace silt (Fill)	2	6	4	2	2	20	120	0	35	0	35	0	240	240	240	240	0	0
	Sand trace silt (Fill)	3	4	3	3	1	20	120	0	35	0	35	0	360	360	360	360	0	0.0
Ground Water Table		4	3	3	3	0							0	360	360	360	360	0	0.0
	Sand trace silt (Fill)	5	3	-3	9	6	20	120	0	35	0	35	374.4	1080	705.6	1080	705.6	2	10.5
	Sand trace silt (SP/SW)	6	-3	-11	17	8	15	115	0	32	0	32	873.6	2000	1126.4	2000	1126.4	8	41.9
Critical Depth		7	-11	-11	17	0							873.6	2000	1126.4	2000	1126.4	0	0.0
	Sand trace silt (SP/SW)	8	-11	-14	20	3	15	115	0	32	0	32	1060.8	2345	1284.2	2345	1126.4	3	15.7
	Organic Silt (OH)	9	-14	-40	46	26	1	100	450	0	0	22	2683.2	4945	2261.8	2345	1126.4	26	136.1
	Medium to Fine Sand (SP)	10	-40	-50	56	10	20	120	0	35	0	35	3307.2	6145	2837.8	2345	1126.4	10	52.4
	Silt trace Clay	11	-50	-100	106	50	25	134	0	27	0	27	6427.2	12845	6417.8	2345	1126.4	50	261.8

Pile Properties	
Pile Type:	Concrete Filled Steel Pipe Pile
Pile Designation:	PP 20x0.500
Diameter B (ft):	1.67
Cross Sectional Area (in^2):	30.63
Pile Weight (lb/ft):	104
Effective Area of Pile Tip (ft^2):	2.18
Perimeter:	5.24

Factor Of Safety Criteria	
Compression	Tension
2.25	2.25

From page 4-2 in EM 1110-2-2906 assumes "Theoretical or empirical prediction not verified by load testing for Unusual Loading"

Critical Depth Criteria			
Dc = 10B	17	loose silts	loose sands
Dc = 15B	25	medium silts	medium dense sand
Dc = 20B	33	dense silts	dense sand

From page 4-13 in EM 1110-2-2906, applicable to both skin friction and end bearing

Common Values for Corrected K

Soil Type	Non Displacemnt	
	Compression	Tension
Sand	1.5	0.5
Silt	1	0.35
Clay	1	0.7

From Table 4-5 in EM 1110-2-2906

Values of K for Driven Piles

Soil Type	Kc	Kt
Sand	1 to 2	0.5 to 0.7
Silt	1	0.5 to 0.7
Clay	1	0.7 to 1.0

From Table 4-5 4n EM 1110-2-2906

Adhesion Factor δ	
Steel	0.67ϕ to 0.83 ϕ
Concrete	0.9 ϕ to 1.0 ϕ
Timber	0.80 ϕ to 1.0 ϕ
Factor For Calculations	0.67

Table 4-3 in EM 1110-2-2906

Water Unit Weight (pcf):	62.4

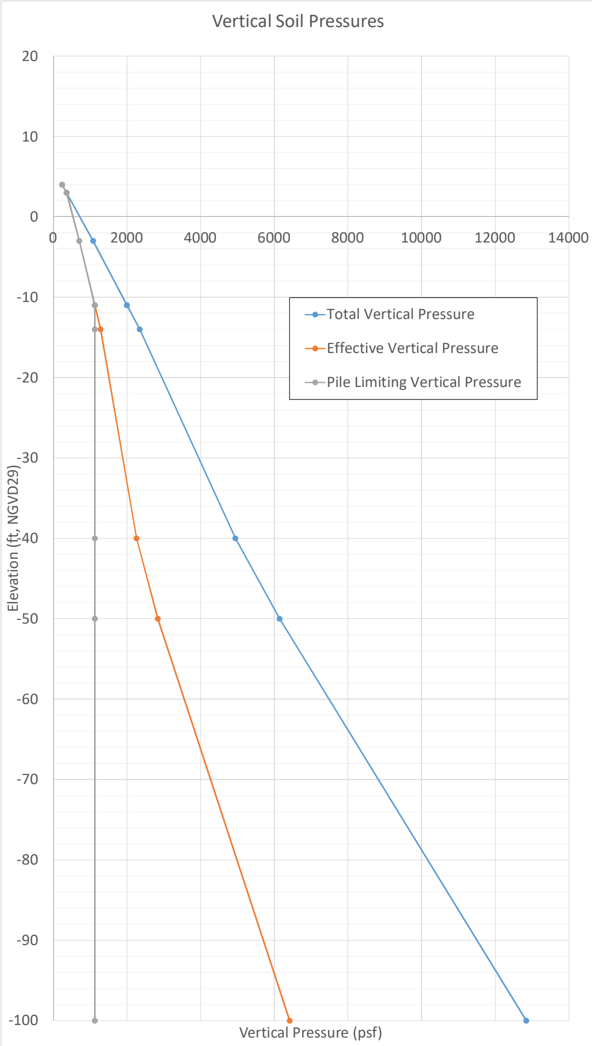
Undrained Analysis (Q case)

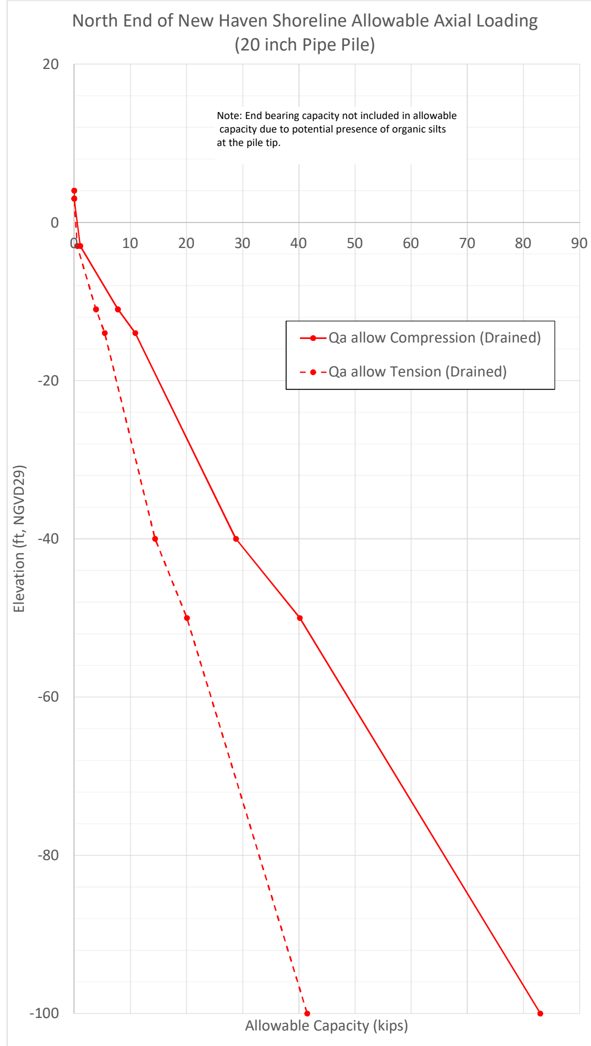
	Side Friction Qs																		Bearing Capacity Qt					Total Allowable Axial Capacity Qa*	
Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	α*c	σvo' avg	fs compression avg	Qs compression	ΣQs compression	Qs allow compression	fstens avg	Qs tension	ΣQs tension	Qs allow tension	Nq	q at Top of Layer	q at Bottom of Layer	Qt allow at Top of Layer	Qt allow Bottom of Layer	Qa allow Compression (Undrained)	Qa allow Tension (Undrained)
												(lbs)	(lbs)	(kips)		(lbs)	(lbs)	(kips)		(psf)	(psf)	(kips)	(kips)	(kips)	(kips)
1	1	0.5																							
2	1	0.5	23.45	0.0	1.0	0.0	1.0	1.0	0.0	120.0	52	0	0	0.0	26.0	0.0	0	0.0	40	0	9600	0	9	0.0	0.0
3	1	0.5	23.45	0.0	1.0	0.6	1.0	1.0	0.0	300.0	130	0	0	0.0	65.1	0.0	0	0.0	40	9600	14400	9	14	0.0	0.0
4	1	0.5	0	0.0	1.0	0.6	1.0	1.0	0.0	360.0	0	0	0	0.0	0.0	0.0	0	0.0	40	14400	14400	14	14	0.0	0.0
5	1	0.5	23.45	0.0	1.0	4.2	1.0	1.0	0.0	532.8	231	2420	2420	1.1	115.6	1210.1	1210	0.5	40	14400	28224	14	27	1.1	0.5
6	1	0.5	21.44	0.0	1.0	9.0	1.0	1.0	0.0	916.0	360	15068	17488	7.8	179.9	7533.8	8744	3.9	25	17640	28160	17	27	7.8	3.9
7	1	0.5	0	0.0	1.0	9.0	1.0	1.0	0.0	1126.4	0	0	17488	7.8	0.0	0.0	8744	3.9	25	28160	28160	27	27	7.8	3.9
8	1	0.5	21.44	0.0	1.0	10.8	1.0	1.0	0.0	1126.4	442	6948	24436	10.9	221.2	3474.1	12218	5.4	25	28160	28160	27	27	10.9	5.4
9	1	0.5	0	0.4	0.9	26.4	1.0	0.9	425.5	1126.4	425	57926	82362	36.6	425.5	57925.5	70144	31.2	0	0	0	0	0	36.6	31.2
10	1	0.5	23.45	0.0	1.0	32.4	1.0	1.0	0.0	1126.4	489	25583	107945	48.0	244.3	12791.6	82935	36.9	40	45056	45056	44	44	48.0	36.9
11	1	0.5	18.09	0.0	1.0	62.4	0.9	0.9	0.0	1126.4	368	96328	204273	90.8	184.0	48164.1	131099	58.3	12	13516.8	13516.8	13	13	90.8	58.3

Drained Analysis (S case)

	Side Friction Qs																		Bearing Capacity Qt					Total Allowable Axial Capacity Qa*	
Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	αc	σvo' avg	fs compression avg	Qs compression	ΣQs compression	Qs allow compression	fstens avg	Qs tension	ΣQs tension	Qs allow tension	Nq	q at Top of Layer	q at Bottom of Layer	Qt allow at Top of Layer	Qt allow Bottom of Layer	Qa allow Compression (Drained)	Qa allow Tension (Drained)
												(lbs)	(lbs)	(kips)		(lbs)	(lbs)	(kips)		(psf)	(psf)	(kips)	(kips)	(kips)	(kips)
1	1	0.5																							
2	1	0.5	23.45	0.0	1.0	0.0	1.0	1.0	0.0	120.0	52	0	0	0.0	26.0	0.0	0	0.0	40	0	9600	0	9	0.0	0.0
3	1	0.5	23.45	0.0	1.0	0.6	1.0	1.0	0.0	300.0	130	0	0	0.0	65.1	0.0	0	0.0	40	9600	14400	9	14	0.0	0.0
4	1	0.5	0	0.0	1.0	0.6	1.0	1.0	0.0	360.0	0	0	0	0.0	0.0	0.0	0	0.0	40	14400	14400	14	14	0.0	0.0
5	1	0.5	23.45	0.0	1.0	4.2	1.0	1.0	0.0	532.8	231	2420	2420	1.1	115.6	1210.1	1210	0.5	40	14400	28224	14	27	1.1	0.5
6	1	0.5	21.44	0.0	1.0	9.0	1.0	1.0	0.0	916.0	360	15068	17488	7.8	179.9	7533.8	8744	3.9	25	17640	28160	17	27	7.8	3.9
7	1	0.5	0	0.0	1.0	9.0	1.0	1.0	0.0	1126.4	0	0	17488	7.8	0.0	0.0	8744	3.9	25	28160	28160	27	27	7.8	3.9
8	1	0.5	21.44	0.0	1.0	10.8	1.0	1.0	0.0	1126.4	442	6948	24436	10.9	221.2	3474.1	12218	5.4	25	28160	28160	27	27	10.9	5.4
9	1	0.5	14.74	0.0	1.0	26.4	1.0	1.0	0.0	1126.4	296	40343	64779	28.8	148.2	20171.6	32390	14.4	0	0	0	0	0	28.8	14.4
10	1	0.5	23.45	0.0	1.0	32.4	1.0	1.0	0.0	1126.4	489	25583	90363	40.2	244.3	12791.6	45181	20.1	40	45056	45056	44	44	40.2	20.1
11	1	0.5	18.09	0.0	1.0	62.4	0.9	0.9	0.0	1126.4	368	96328	186691	83.0	184.0	48164.1	93345	41.5	12	13516.8	13516.8	13	13	83.0	41.5

*Bearing capacity not included in allowable axial due to organic presence.


Vertical Soil Pressures
Elevation (ft, NGVD29)
Vertical Pressure (psf)
Total Vertical Pressure
Effective Vertical Pressure
Pile Limiting Vertical Pressure
0
2000
4000
6000
8000
10000
12000
14000
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100


North End of New Haven Shoreline Allowable Axial Loading
(20 inch Pipe Pile)
Note: End bearing capacity not included in allowable capacity due to potential presence of organic silts at the pile tip.
Qa allow Compression (Drained)
Qa allow Tension (Drained)
Elevation (ft, NGVD29)
Allowable Capacity (kips)
0
10
20
30
40
50
60
70
80
90
20
0
-20
-40
-60
-80
-100

New Haven Northend Near I-95	Stratification: Soil Type	Layer	Layer Top Elv. (ft)	Layer Bottom Elv. (ft)	Depth to Layer Bottom (ft)	Layer Thickness (ft)	Soil Properties: N_{60} Blow Count	γ_t (pcf)	S_u (psf)	ϕ (degrees)	c' (psf)	ϕ' (degrees)	Vertical Soil Pressures at Bottom of Layer: u (psf)	σ_{vo} (psf)	σ_{vo}' (psf)	σ_{vo} critical depth (psf)	σ_{vo}' critical depth (psf)	Layer Thickness (Top 5 feet ignored) (ft)	Skin Friction Area A_s (ft^2)
Final Grade	Sand trace silt (Fill)	1	6	6	0														
Top of Piles (4 ft NGVD29)	Sand trace silt (Fill)	2	6	4	2	2	15	115	0	32	0	32	0	230	230	230	230	0	0
	Sand trace silt (Fill)	3	4	3	3	1	15	115	0	32	0	32	0	345	345	345	345	0	0.0
Ground Water Table		4	3	3	3	0							0	345	345	345	345	0	0.0
	Sand trace silt (Fill)	5	3	1	5	2	15	115	0	32	0	32	124.8	575	450.2	575	450.2	0	0.0
	Organic Silt (OH)	6	1	-14	20	15	1	100	450	0	0	22	1060.8	2075	1014.2	2075	1014.2	13	81.7
Critical Depth		7	-14	-14	20	0							1060.8	2075	1014.2	2075	1014.2	0	0.0
	Organic Silt (OH)	8	-14	-39	45	25	1	100	450	0	0	22	2620.8	4575	1954.2	2075	1014.2	25	157.1
	Medium to Fine Sand (SP)	9	-39	-50	56	11	30	125	0	35	0	35	3307.2	5950	2642.8	2075	1014.2	11	69.1
	Silt trace Clay	10	-50	-100	106	50	20	132	0	25	0	25	6427.2	12550	6122.8	2075	1014.2	50	314.2

Pile Properties	
Pile Type:	Concrete Filled Steel Pipe Pile
Pile Designation:	PP 24x0.500
Diameter B (ft):	2.00
Cross Sectional Area (in^2):	36.91
Pile Weight (lb/ft):	126
Effective Area of Pile Tip (ft^2):	3.14
Perimeter:	6.28

Factor Of Safety Criteria	
Compression	Tension
2.25	2.25

From page 4-2 in EM 1110-2-2906 assumes "Theoretical or empirical prediction not verified by load testing for Unusual Loading"

Critical Depth Criteria			
Dc = 10B	20	loose silts	loose sands
Dc = 15B	30	medium silts	medium dense sand
Dc = 20B	40	dense silts	dense sand

From page 4-13 in EM 1110-2-2906, applicable to both skin friction and end bearing

Common Values for Corrected K

Soil Type	Non Displacemnt: Compression	Tension
Sand	1.5	0.5
Silt	1	0.35
Clay	1	0.7

From Table 4-5 in EM 1110-2-2906

Values of K for Driven Piles

Soil Type	Kc	Kt
Sand	1 to 2	0.5 to 0.7
Silt	1	0.5 to 0.7
Clay	1	0.7 to 1.0

From Table 4-5 4n EM 1110-2-2906

Adhesion Factor δ	
Steel	0.67ϕ to 0.83 ϕ
Concrete	0.9 ϕ to 1.0 ϕ
Timber	0.80 ϕ to 1.0 ϕ
Factor For Calculations	0.67

Table 4-3 in EM 1110-2-2906

Water Unit Weight (pcf):	62.4

Undrained Analysis (Q case)

Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	α*c	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)
1	1	0.5																
2	1	0.5	21.44	0.0	1.0	0.0	1.0	1.0	0.0	115.0	45	0	0	0.0	22.6	0.0	0	0.0
3	1	0.5	21.44	0.0	1.0	0.5	1.0	1.0	0.0	287.5	113	0	0	0.0	56.5	0.0	0	0.0
4	1	0.5	0	0.0	1.0	0.5	1.0	1.0	0.0	345.0	0	0	0	0.0	0.0	0.0	0	0.0
5	1	0.5	21.44	0.0	1.0	1.5	1.0	1.0	0.0	397.6	156	0	0	0.0	78.1	0.0	0	0.0
6	1	0.5	0	0.4	0.9	9.0	1.0	0.9	403.4	732.2	403	32952	32952	14.6	403.4	32952.1	32952	14.6
7	1	0.5	0	0.0	1.0	9.0	1.0	1.0	0.0	1014.2	0	0	32952	14.6	0.0	0.0	32952	14.6
8	1	0.5	0	0.4	0.9	21.5	1.0	0.9	403.4	1014.2	403	63369	96321	42.8	403.4	63369.4	96321	42.8
9	1	0.5	23.45	0.0	1.0	27.0	1.0	1.0	0.0	1014.2	440	30406	126728	56.3	220.0	15203.1	111525	49.6
10	1	0.5	16.75	0.0	1.0	52.0	1.0	1.0	0.0	1014.2	305	95894	222621	98.9	152.6	47946.9	159471	70.9

Layer	Bearing Capacity Qt: Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Total Allowable Axial Capacity Qa*: Qa allow Compression (Undrained) (kips)	Qa allow Tension (Undrained) (kips)
1							
2	25	0	5750	0	8	0.0	0.0
3	25	5750	8625	8	12	0.0	0.0
4	25	8625	8625	12	12	0.0	0.0
5	25	8625	11255	12	16	0.0	0.0
6	0	0	0	0	0	14.6	14.6
7	0	0	0	0	0	14.6	14.6
8	0	0	0	0	0	42.8	42.8
9	40	40568	40568	57	57	56.3	49.6
10	15	15213	15213	21	21	98.9	70.9

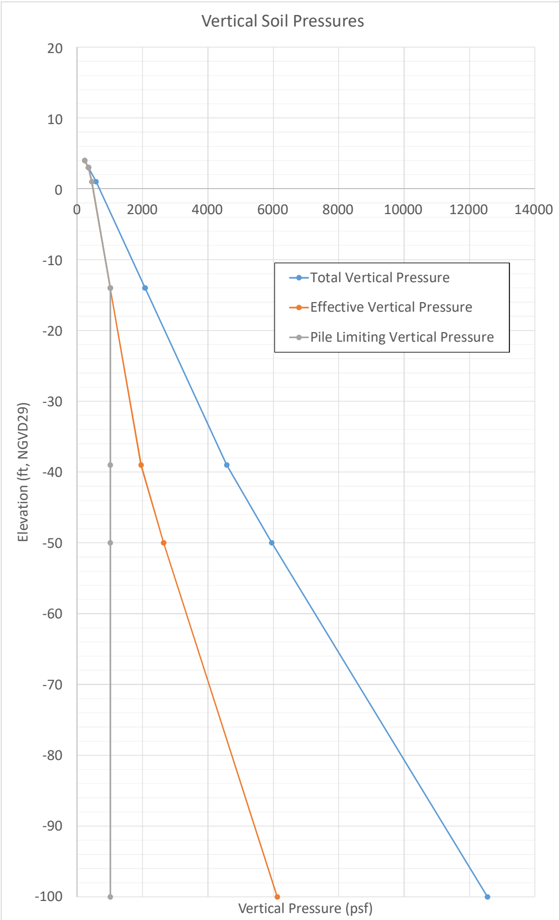
Drained Analysis (S case)

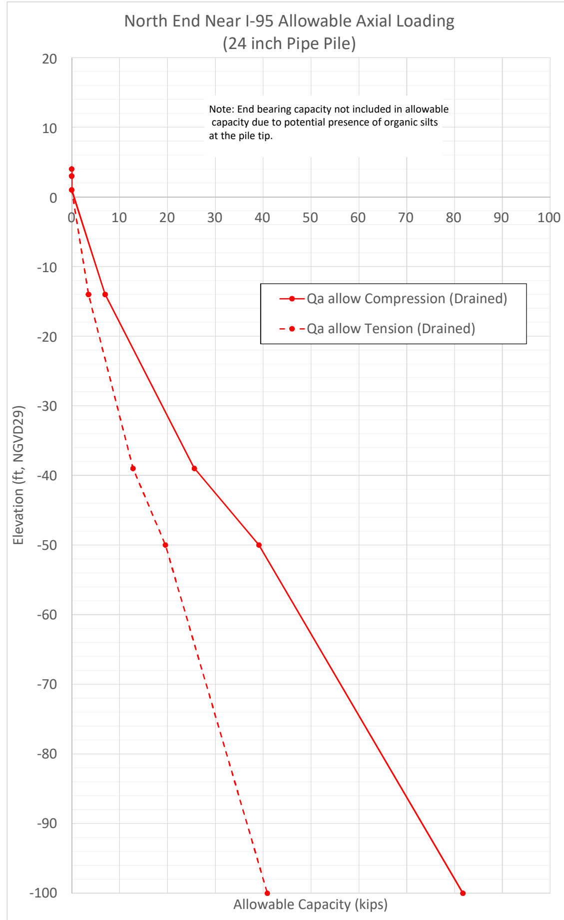
Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	αc	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)
1	1	0.5																
2	1	0.5	21.44	0.0	1.0	0.0	1.0	1.0	0.0	115.0	45	0	0	0.0	22.6	0.0	0	0.0
3	1	0.5	21.44	0.0	1.0	0.5	1.0	1.0	0.0	287.5	113	0	0	0.0	56.5	0.0	0	0.0
4	1	0.5	0	0.0	1.0	0.5	1.0	1.0	0.0	345.0	0	0	0	0.0	0.0	0.0	0	0.0
5	1	0.5	21.44	0.0	1.0	1.5	1.0	1.0	0.0	397.6	156	0	0	0.0	78.1	0.0	0	0.0
6	1	0.5	14.74	0.0	1.0	9.0	1.0	1.0	0.0	732.2	193	15735	15735	7.0	96.3	7867.4	7867	3.5
7	1	0.5	0	0.0	1.0	9.0	1.0	1.0	0.0	1014.2	0	0	15735	7.0	0.0	0.0	7867	3.5
8	1	0.5	14.74	0.0	1.0	21.5	1.0	1.0	0.0	1014.2	267	41913	57648	25.6	133.4	20956.6	28824	12.8
9	1	0.5	23.45	0.0	1.0	27.0	1.0	1.0	0.0	1014.2	440	30406	88054	39.1	220.0	15203.1	44027	19.6
10	1	0.5	16.75	0.0	1.0	52.0	1.0	1.0	0.0	1014.2	305	95894	183948	81.8	152.6	47946.9	91974	40.9

Layer	Bearing Capacity Qt: Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Total Allowable Axial Capacity Qa*: Qa allow Compression (Drained) (kips)	Qa allow Tension (Drained) (kips)
1							
2	25	0	5750	0	8	0.0	0.0
3	25	5750	8625	8	12	0.0	0.0
4	25	8625	8625	12	12	0.0	0.0
5	25	8625	11255	12	16	0.0	0.0
6	0	0	0	0	0	7.0	3.5
7	0	0	0	0	0	7.0	3.5
8	0	0	0	0	0	25.6	12.8
9	40	40568	40568	57	57	39.1	19.6
10	15	15213	15213	21	21	81.8	40.9

***Bearing capacity not included in allowable axial due to organic presence.**


Vertical Soil Pressures
Elevation (ft, NGVD29)
Vertical Pressure (psf)
Total Vertical Pressure
Effective Vertical Pressure
Pile Limiting Vertical Pressure
0
2000
4000
6000
8000
10000
12000
14000
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100


North End Near I-95 Allowable Axial Loading
(24 inch Pipe Pile)
Note: End bearing capacity not included in allowable capacity due to potential presence of organic silts at the pile tip.
Elevation (ft, NGVD29)
Allowable Capacity (kips)
Qa allow Compression (Drained)
Qa allow Tension (Drained)
0
10
20
30
40
50
60
70
80
90
100
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100

PROJECT: New Haven General Investigation
SUBJECT: New Haven Allowable Axial Pile Loading

New Haven Northend Near I-95	Soil Type	Layer	Layer Top Elv. (ft)	Layer Bottom Elv. (ft)	Depth to Layer Bottom (ft)	Layer Thickness (ft)	N_{60} (Blow Count)	γ_t (pcf)	S_u (psf)	ϕ (degrees)	c' (psf)	ϕ' (degrees)	u (psf)	σ_{vo} (psf)	σ_{vo}' (psf)	σ_{vo} critical depth (psf)	σ_{vo}' critical depth (psf)	Layer Thickness (Top 5 feet ignored) (ft)	Skin Friction Area A_s (ft^2)
	Stratification						Soil Properties						Vertical Soil Pressures at Bottom of Layer						
Final Grade	Sand trace silt (Fill)	1	6	6	0														
Top of Piles (4 ft NGVD29)	Sand trace silt (Fill)	2	6	4	2	2	15	115	0	32	0	32	0	230	230	230	230	0	0
	Sand trace silt (Fill)	3	4	3	3	1	15	115	0	32	0	32	0	345	345	345	345	0	0.0
Ground Water Table		4	3	3	3	0							0	345	345	345	345	0	0.0
	Sand trace silt (Fill)	5	3	1	5	2	15	115	0	32	0	32	124.8	575	450.2	575	450.2	0	0.0
	Organic Silt (OH)	6	1	-34	40	35	1	100	450	0	0	22	2308.8	4075	1766.2	4075	1766.2	33	414.7
Critical Depth		7	-34	-34	40	0							2308.8	4075	1766.2	4075	1766.2	0	0.0
	Organic Silt (OH)	8	-34	-39	45	5	1	100	450	0	0	22	2620.8	4575	1954.2	4075	1766.2	5	62.8
	Medium to Fine Sand (SP)	9	-39	-50	56	11	30	125	0	35	0	35	3307.2	5950	2642.8	4075	1766.2	11	138.2
	Silt trace Clay	10	-50	-100	106	50	20	132	0	25	0	25	6427.2	12550	6122.8	4075	1766.2	50	628.3

Pile Properties	
Pile Type:	Drilled Shaft
Pile Designation:	4-foot dia
Diameter B (ft):	4.00
Cross Sectional Area (in^2):	1810
Pile Weight (lb/ft):	1885
Effective Area of Pile Tip (ft^2):	12.57
Perimeter:	12.57

Factor Of Safety Criteria	
Compression	Tension
2.25	2.25

From page 4-2 in EM 1110-2-2906 assumes "Theoretical or empirical prediction not verified by load testing for Unusual Loading"

Critical Depth Criteria			
Dc = 10B	40	loose silts	loose sands
Dc = 15B	60	medium silts	medium dense sand
Dc = 20B	80	dense silts	dense sand

From page 4-13 in EM 1110-2-2906, applicable to both skin friction and end bearing

Common Values for Corrected K

Soil Type	Non Displacemnt Compression	Non Displacemnt Tension
Sand	1.5	0.5
Silt	1	0.35
Clay	1	0.7

From Table 4-5 in EM 1110-2-2906

Values of K for Driven Piles

Soil Type	Kc	Kt
Sand	1 to 2	0.5 to 0.7
Silt	1	0.5 to 0.7
Clay	1	0.7 to 1.0

From Table 4-5 4n EM 1110-2-2906

Adhesion Factor δ	
Steel	0.67ϕ to 0.83 ϕ
Concrete	0.9 ϕ to 1.0 ϕ
Timber	0.80 ϕ to 1.0 ϕ
Factor For Calculations	0.9

Table 4-3 in EM 1110-2-2906

Water Unit Weight (pcf):	62.4

Undrained Analysis (Q case)

Side Friction Qs

Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	α*c	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)
1	1	0.5																
2	1	0.5	28.8	0.0	1.0	0.0	1.0	1.0	0.0	115.0	63	0	0	0.0	31.6	0.0	0	0.0
3	1	0.5	28.8	0.0	1.0	0.3	1.0	1.0	0.0	287.5	158	0	0	0.0	79.0	0.0	0	0.0
4	1	0.5	0	0.0	1.0	0.3	1.0	1.0	0.0	345.0	0	0	0	0.0	0.0	0.0	0	0.0
5	1	0.5	28.8	0.0	1.0	0.8	1.0	1.0	0.0	397.6	219	0	0	0.0	109.3	0.0	0	0.0
6	1	0.35	0	0.3	1.0	9.5	1.0	1.0	450.0	1108.2	450	186611	186611	82.9	450.0	186610.6	186611	82.9
7	1	0.35	0	0.0	1.0	9.5	1.0	1.0	0.0	1766.2	0	0	186611	82.9	0.0	0.0	186611	82.9
8	1	0.35	0	0.3	1.0	10.8	1.0	1.0	450.0	1766.2	450	28274	214885	95.5	450.0	28274.3	214885	95.5
9	1	0.5	31.5	0.0	1.0	13.5	1.0	1.0	0.0	1766.2	1082	149610	364495	162.0	541.2	74805.2	289690	128.8
10	1	0.35	22.5	0.0	1.0	26.0	1.0	1.0	0.0	1766.2	732	459668	824163	366.3	256.1	160883.7	450574	200.3

Bearing Capacity Qt / Total Allowable Axial Capacity Qa*

Layer	Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Qa allow Compression (Undrained) (kips)	Qa allow Tension (Undrained) (kips)
1							
2	25	0	5750	0	32	0.0	0.0
3	25	5750	8625	32	48	0.0	0.0
4	25	8625	8625	48	48	0.0	0.0
5	25	8625	11255	48	63	0.0	0.0
6	0	0	0	0	0	82.9	82.9
7	0	0	0	0	0	82.9	82.9
8	0	0	0	0	0	95.5	95.5
9	40	70648	70648	395	395	162.0	128.8
10	15	26493	26493	148	148	366.3	200.3

Drained Analysis (S case)

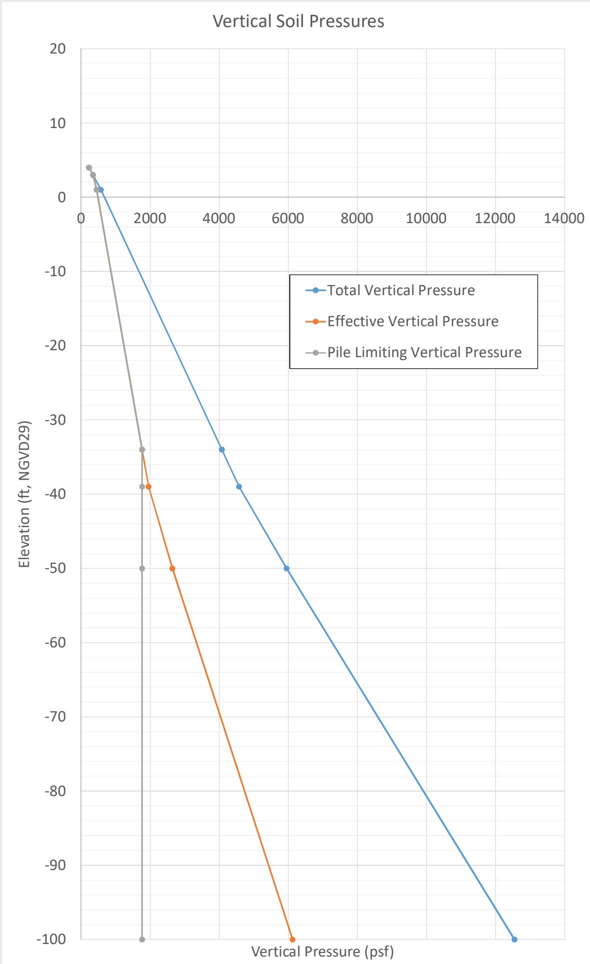
Side Friction Qs

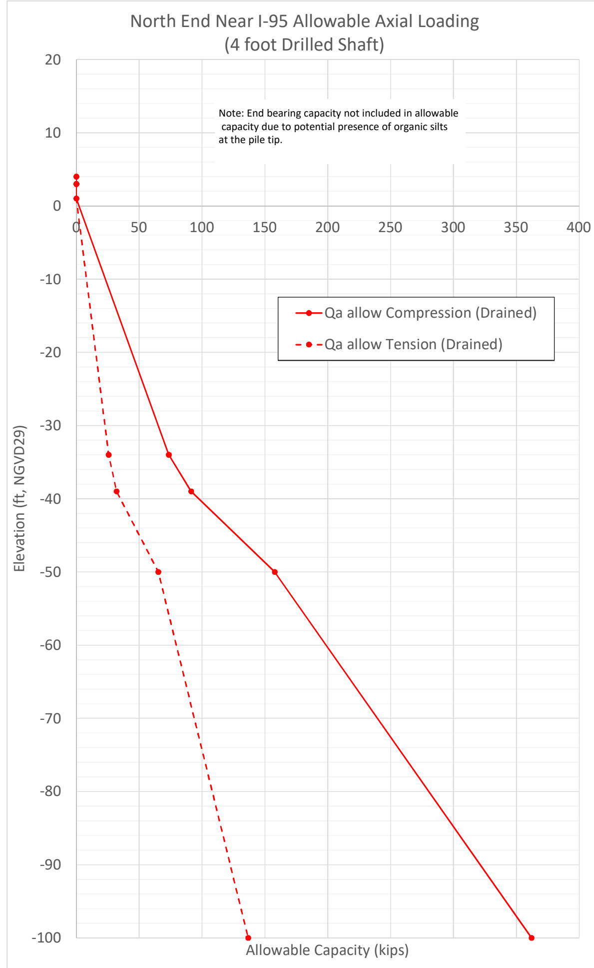
Layer	K_c	K_t	δ	Su/σ_{vo}'	α_1	L/B	α_2	α	αc	σvo' avg	fs compression avg	Qs compression (lbs)	ΣQs compression (lbs)	Qs allow compression (kips)	fstens avg	Qs tension (lbs)	ΣQs tension (lbs)	Qs allow tension (kips)
1	1	0.5																
2	1	0.5	28.8	0.0	1.0	0.0	1.0	1.0	0.0	115.0	63	0	0	0.0	31.6	0.0	0	0.0
3	1	0.5	28.8	0.0	1.0	0.3	1.0	1.0	0.0	287.5	158	0	0	0.0	79.0	0.0	0	0.0
4	1	0.5	0	0.0	1.0	0.3	1.0	1.0	0.0	345.0	0	0	0	0.0	0.0	0.0	0	0.0
5	1	0.5	28.8	0.0	1.0	0.8	1.0	1.0	0.0	397.6	219	0	0	0.0	109.3	0.0	0	0.0
6	1	0.35	19.8	0.0	1.0	9.5	1.0	1.0	0.0	1108.2	399	165452	165452	73.5	139.6	57908.1	57908	25.7
7	1	0.35	0	0.0	1.0	9.5	1.0	1.0	0.0	1766.2	0	0	165452	73.5	0.0	0.0	57908	25.7
8	1	0.35	19.8	0.0	1.0	10.8	1.0	1.0	0.0	1766.2	636	39953	205405	91.3	222.6	13983.5	71892	32.0
9	1	0.5	31.5	0.0	1.0	13.5	1.0	1.0	0.0	1766.2	1082	149610	355015	157.8	541.2	74805.2	146697	65.2
10	1	0.35	22.5	0.0	1.0	26.0	1.0	1.0	0.0	1766.2	732	459668	814683	362.1	256.1	160883.7	307581	136.7

Bearing Capacity Qt / Total Allowable Axial Capacity Qa*

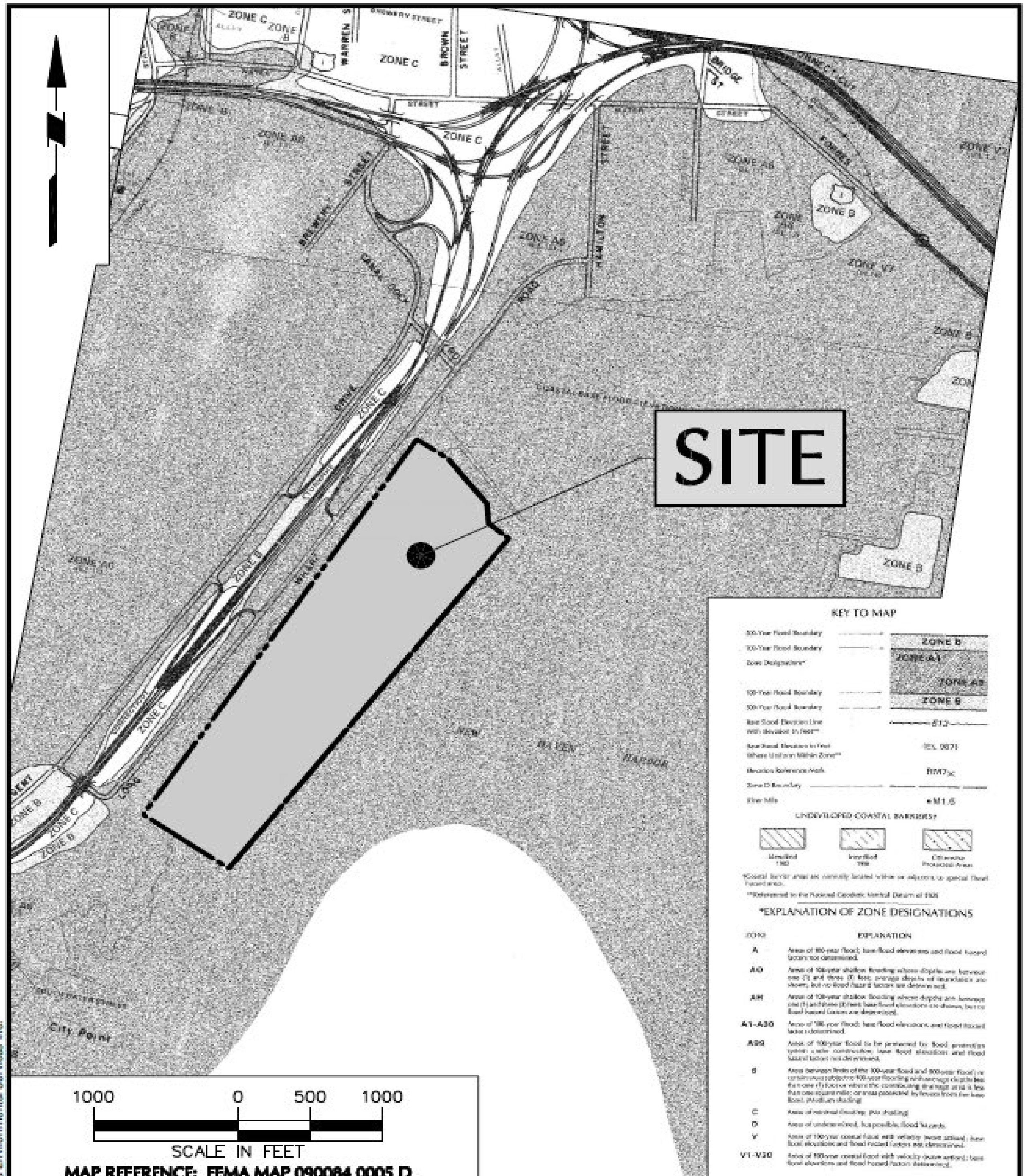
Layer	Nq	q at Top of Layer (psf)	q at Bottom of Layer (psf)	Qt allow at Top of Layer (kips)	Qt allow Bottom of Layer (kips)	Qa allow Compression (Drained) (kips)	Qa allow Tension (Drained) (kips)
1							
2	25	0	5750	0	32	0.0	0.0
3	25	5750	8625	32	48	0.0	0.0
4	25	8625	8625	48	48	0.0	0.0
5	25	8625	11255	48	63	0.0	0.0
6	0	0	0	0	0	73.5	25.7
7	0	0	0	0	0	73.5	25.7
8	0	0	0	0	0	91.3	32.0
9	40	70648	70648	395	395	157.8	65.2
10	15	26493	26493	148	148	362.1	136.7

***Bearing capacity not included in allowable axial due to organic presence.**


Vertical Soil Pressures
Elevation (ft, NGVD29)
Vertical Pressure (psf)
Total Vertical Pressure
Effective Vertical Pressure
Pile Limiting Vertical Pressure
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
2000
4000
6000
8000
10000
12000
14000


North End Near I-95 Allowable Axial Loading
(4 foot Drilled Shaft)
Note: End bearing capacity not included in allowable capacity due to potential presence of organic silts at the pile tip.
Elevation (ft, NGVD29)
Allowable Capacity (kips)
Qa allow Compression (Drained)
Qa allow Tension (Drained)
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
50
100
150
200
250
300
350
400

ATTACHMENT B: BORING LOGS

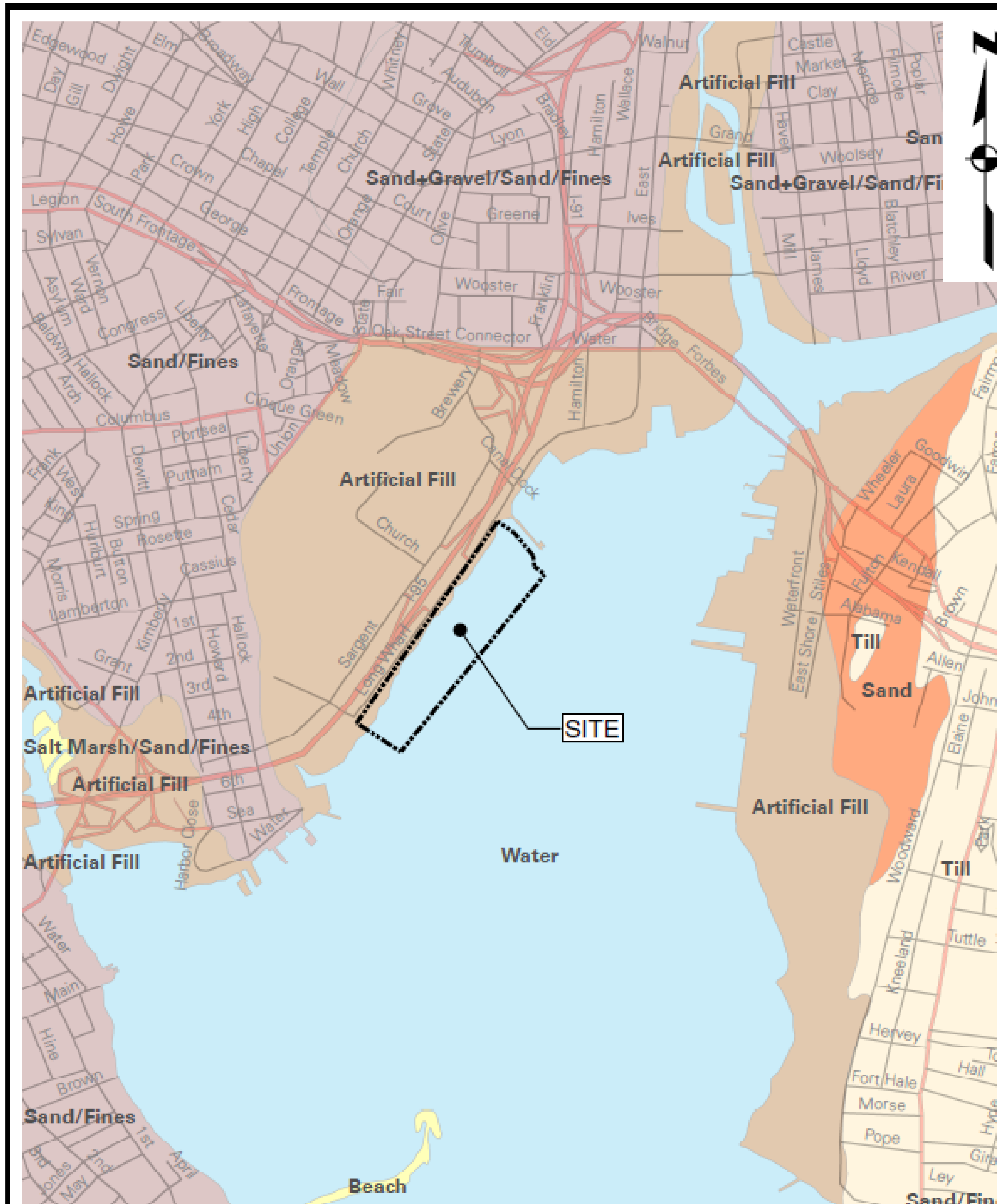


MAP REFERENCE: FEMA MAP 090084 0005 D

LANGAN
ENGINEERING & ENVIRONMENTAL SERVICES
555 Long Wharf Drive New Haven, CT 06511
P: 203.562.5771 F: 203.789.6142
www.langan.com
NEW JERSEY PENNSYLVANIA NEW YORK CONNECTICUT FLORIDA NEVADA VIRGINIA CALIFORNIA

Project
FEMA MAP
LONG WHARF PARK
NEW HAVEN CONNECTICUT

Project No.	Date	Scale	Fig. No.
140034415	11/1/10	1"=1,000'	2



REFERENCES: SURFICIAL MATERIALS MAP OF CONNECTICUT, DATED 1992, CONNECTICUT GEOLOGICAL AND NATURAL HISTORY SURVEY

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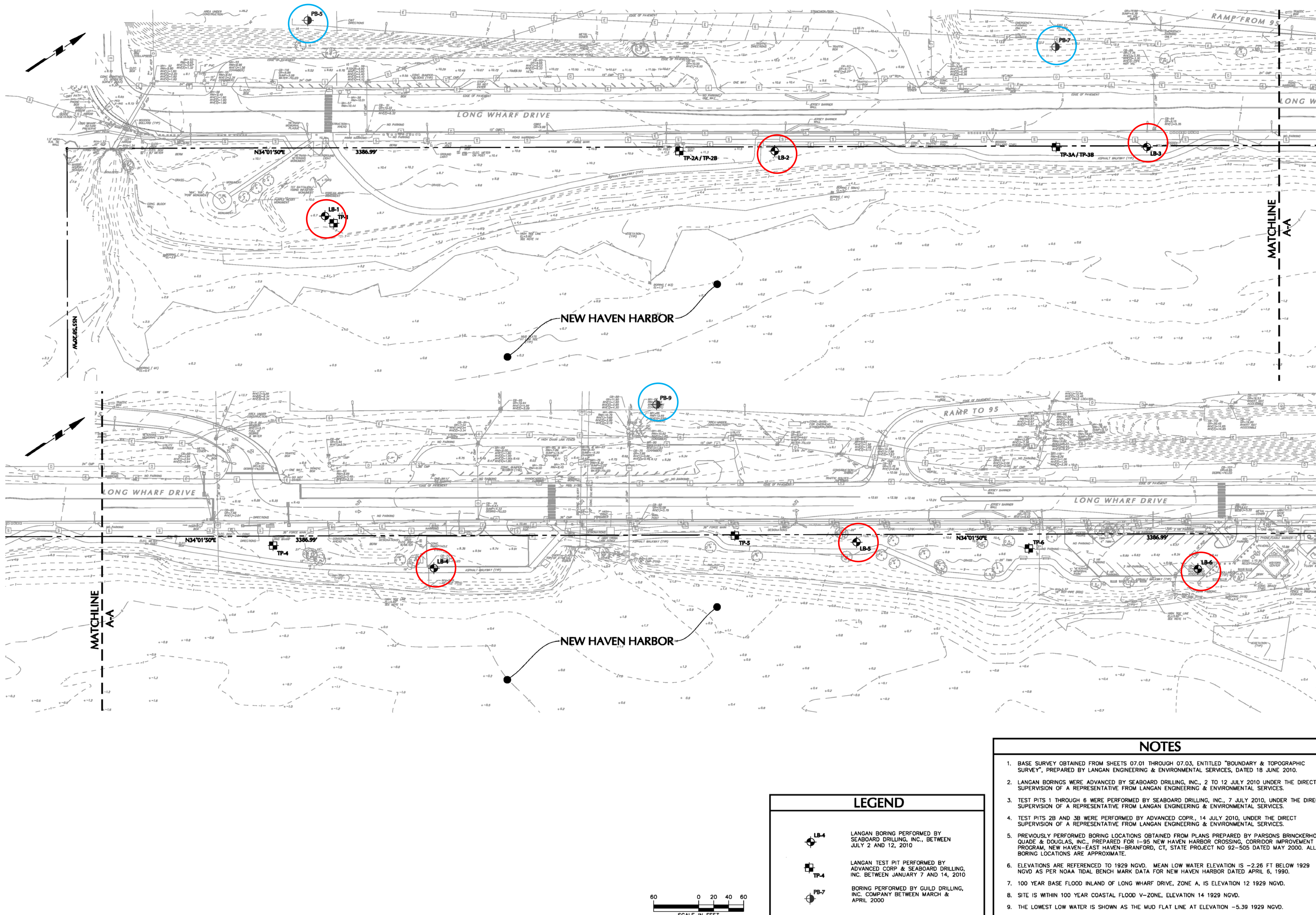
Project
LONG WHARF PARK
SURFICIAL SOILS MAP
NEW HAVEN CONNECTICUT

Project No.	Date	Scale	Dwg. No.
140034415	11/1/10	1:24,000	FIG. 3



LEGEND

LB-4	LANGAN BORING PERFORMED BY SEABOARD DRILLING, INC., BETWEEN JULY 2 AND 12, 2010
TP-4	LANGAN TEST PIT PERFORMED BY ADVANCED CORP & SEABOARD DRILLING, INC. BETWEEN JANUARY 7 AND 14, 2010
PB-7	BORING PERFORMED BY GUILD DRILLING, INC. COMPANY BETWEEN MARCH & APRIL 2000

NOTES

1. BASE SURVEY OBTAINED FROM SHEETS 07.01 THROUGH 07.03, ENTITLED "BOUNDARY & TOPOGRAPHIC SURVEY", PREPARED BY LANGAN ENGINEERING & ENVIRONMENTAL SERVICES, DATED 18 JUNE 2010.
2. LANGAN BORINGS WERE ADVANCED BY SEABOARD DRILLING, INC., 2 TO 12 JULY 2010 UNDER THE DIRECT SUPERVISION OF A REPRESENTATIVE FROM LANGAN ENGINEERING & ENVIRONMENTAL SERVICES.
3. TEST PITS 1 THROUGH 6 WERE PERFORMED BY SEABOARD DRILLING, INC., 7 JULY 2010, UNDER THE DIRECT SUPERVISION OF A REPRESENTATIVE FROM LANGAN ENGINEERING & ENVIRONMENTAL SERVICES.
4. TEST PITS 2B AND 3B WERE PERFORMED BY ADVANCED COPR., 14 JULY 2010, UNDER THE DIRECT SUPERVISION OF A REPRESENTATIVE FROM LANGAN ENGINEERING & ENVIRONMENTAL SERVICES.
5. PREVIOUSLY PERFORMED BORING LOCATIONS OBTAINED FROM PLANS PREPARED BY PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC., PREPARED FOR I-95 NEW HAVEN HARBOR CROSSING, CORRIDOR IMPROVEMENT PROGRAM, NEW HAVEN-EAST HAVEN-BRANFORD, CT, STATE PROJECT NO 92-505 DATED MAY 2000. ALL BORING LOCATIONS ARE APPROXIMATE.
6. ELEVATIONS ARE REFERENCED TO 1929 NGVD. MEAN LOW WATER ELEVATION IS -2.26 FT BELOW 1929 NGVD AS PER NOAA TIDAL BENCH MARK DATA FOR NEW HAVEN HARBOR DATED APRIL 6, 1990.
7. 100 YEAR BASE FLOOD INLAND OF LONG WHARF DRIVE, ZONE A, IS ELEVATION 12 1929 NGVD.
8. SITE IS WITHIN 100 YEAR COASTAL FLOOD V-ZONE, ELEVATION 14 1929 NGVD.
9. THE LOWEST LOW WATER IS SHOWN AS THE MUD FLAT LINE AT ELEVATION -5.39 1929 NGVD.

IMPROVEMENTS AT
LONG WHARF PARK
NEW HAVEN, CT 06511

STATE PROJECT NO.
92-571

FEDERAL AID PROJECT NO.
1092 (121)

OWNER/CLIENT:
CITY OF NEW HAVEN
165 CHURCH STREET
NEW HAVEN, CT 06510

CONNECTICUT DEPT. OF
TRANSPORTATION
2800 BERLIN TURNPIKE
NEWINGTON, CT 06111
MAILING ADDRESS:
P.O. BOX 317546
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NEW JERSEY PENNSYLVANIA NEW YORK CONNECTICUT FLORIDA NEVADA VIRGINIA CALIFORNIA

INVESTIGATION PHASE

Date	Revisions / Description	No.

NAME LICENSE NO.

DRAWING TITLE
INVESTIGATION LOCATION PLAN

SCALE	PROJECT NUMBER
1"=60'	140034435
DRAWN BY/CHECKED BY	DATE
DEB/CBW	11/1/10

DRAWING NUMBER
4

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ENGINEERING & ENVIRONMENTAL SERVICES

Log of Boring **LB-1** Sheet 1 of 3

Project: Long Wharf Park		Project No.: 140034435	
Location: Long Wharf Drive, New Haven, CT		Elevation and Datum: Approx. 9.7 (1929 NGVD)	
Drilling Agency: Seaboard Drilling, Inc.		Date Started: 0910 hrs 7/12/10	Date Finished: 1400 hrs 7/12/10
Drilling Equipment: Mobile Drill B-53 Truck-mounted		Completion Depth: 52 ft	Rock Depth: N/E
Size and Type of Bit: 4-1/4" Hollow Stem Auger, 2-15/16" Tri-cone roller bit		Number of Samples: Disturbed 16; Undisturbed 2; Core -	
Casing Diameter (in): 4" OD Steel Casing	Casing Depth (ft): 20	Water Level (ft.): First 7; Completion -; 24 HR. -	
Casing Hammer: Auto; Weight (lbs): 300	Drop (in): 30	Drilling Foreman: Jeff Nitsch	
Sampler: 2" OD Split Spoon, 3" OD Shelby Tube		Inspecting Engineer: Lee Chrisman	
Sampler Hammer: Auto; Weight (lbs): 140	Drop (in): 30		

Material Symbol	Elev. (ft) +9.7	Sample Description	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
	+9.5	3-in Topsoil [TOPSOIL] (dry)	0						Boring started at 0910 hrs
		Light-brown f-SAND, tr. f-gravel, tr. brick, tr. concrete, sm. silt [FILL] (dry)	0–2	S-1	SS	15	16, 22, 33, 23		
		Brown f-SAND, tr. brick, tr. f-gravel, sm. silt [FILL] (dry)	2–4	S-2	SS	19	12, 21, 34, 29		
		Light-brown m-f SAND, tr. f-gravel, tr. granite, tr. asphalt [FILL] (dry)	4–6	S-3	SS	18	25, 22, 30, 19		Auger 0 to 4-ft Light to Heavy grinding
		Light-brown f-SAND, tr. roots, tr. f-gravel, sm. asphalt [FILL] (wet)	6–8	S-4	SS	14	19, 17, 12, 12	29	Auger 4 to 6.5-ft Augers removed from borehole Hammer casing to 8-ft Drill with water and clean out hole to 8-ft
		Black c-f SAND, sm. f-gravel [FILL] (wet)	8–10	S-5	SS	10	22, 14, 4, 7	18	Hammer casing 8 to 12-ft Drill with water and clean out hole to 8-ft
	-0.3	Dark-grey c-f SAND, tr. shells [SW] (wet)	10–12	S-6	SS	11	15, 13, 10, 10	23	
		Dark-grey c-f SAND, tr. shells [SW] (wet)	12–14	S-7	SS	8	11, 11, 8, 6	19	Hammer casing 12 to 14-ft Drill with water and clean out hole to 14-ft
		Dark-grey c-f SAND, sm. shells, sm. f-gravel [SW] (wet)	14–16	S-8	SS	5	11, 6, 8, 6	14	Hammer casing 14 to 20-ft Drill with water and clean out hole to 20-ft
		Dark-grey m-f SAND, sm. f-gravel, tr. shells [SP] (wet)	16–18	S-9	SS	11	4, 3, 5, 3	8	
	-9.3	? ? ? ?	19						Wash turned grey at 19-ft
			20						

Project	Project No.
Long Wharf Park	140034435
Location	**Elevation and Datum**
Long Wharf Drive, New Haven, CT	Approx. 9.7 (1929 NGVD)

Material Symbol	Elev. (ft)	Sample Description	Depth Scale	Sample Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		Dark-grey Organic Clayey SILT, tr. shells, tr. f-gravel [OH] (wet)	20–22	S-10	SS	24	1, WOH, WOH, 1	0	Casing remains at 20-ft. Drill with water and clean out hole to 22-ft
		Dark-grey Organic Clayey SILT, tr. shells [OH] (wet)	22–24	ST-1	ST	24	PUSH		
		Dark-grey Organic Clayey SILT, tr. shells [OH] (wet)	24–26	S-11	SS	24	WOH, WOH, WOH, WOH	0	Casing remains at 20-ft. Drill with water and clean out hole to 30-ft
		Dark-grey Organic Clayey SILT, tr. shells [OH] (wet)	30–32	S-12	SS	24	1, 1, 1, 1	2	Casing remains at 20-ft. Drill with water and clean out hole to 35-ft
		Grey Organic Clayey SILT, tr. shells, tr. wood [OH] (wet)	35–37	S-13	SS	24	1, 1, 1, 1	2	Casing remains at 20-ft. Drill with water and clean out hole to 40-ft
		Grey Organic Clayey SILT, tr. shells [OH] (wet)	40–42	S-14	SS	24	1, 1, 1, 1	2	Casing remains at 20-ft. Drill with water and clean out hole to 42-ft
		Grey Organic Clayey SILT, tr. shells [OH] (wet)	42–44	ST-2	ST	24	PUSH		
		Grey Clayey SILT, tr. shells [OH] (wet)	44–45	S-15	SS	19	1, 2	5	Casing remains at 20-ft. Drill with water and clean out hole to 50-ft

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Project: Long Wharf Park	Project No.: 140034435
Location: Long Wharf Drive, New Haven, CT	Elevation and Datum: Approx. 9.7 (1929 NGVD)

Elev. (ft)	Sample Description	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		45	S-15	SS	19	3 / 3	5	
-37.3	? ? ? ?	47						
	Brown m-f SAND, sm. silt [SP] (wet)	50	S-16	SS	8	8 / 13 / 13 / 14	26	
-42.3	Bottom of Boring 52-ft 0-in	52						Borehole backfilled with grout and soil cuttings upon completion
		68						Casing Remains at 22-ft Drill with water and clean out hole to 35-ft

Depth scale: 45–70

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Log of Boring LB-4

Project: Long Wharf Park	Project No.: 140034435
Location: Long Wharf Drive, New Haven, CT	Elevation and Datum: Approx. 8.75 (1929 NGVD)
Drilling Agency: Seaboard Drilling, Inc.	Date Started: 0900 hrs 7/2/10 ; Date Finished: 1430 hrs 7/2/10
Drilling Equipment: Mobile Drill B-53 Truck-mounted	Completion Depth: 52 ft ; Rock Depth: N/E
Size and Type of Bit: 4-1/4" Hollow Stem Auger, 2-15/16" Tri-cone roller bit	Number of Samples: Disturbed 19 ; Undisturbed 1 ; Core -
Casing Diameter (in): 4" OD Steel Casing ; Casing Depth (ft): 22	Water Level (ft.): First ∇ 8 ; Completion ▼ - ; 24 HR ▼ -
Casing Hammer: Auto ; Weight (lbs): 300 ; Drop (in): 30	Drilling Foreman: Jeff Nitsch
Sampler: 2" OD Split Spoon, 3" OD Shelby Tube	Inspecting Engineer: Dan Bearse
Sampler Hammer: Auto ; Weight (lbs): 140 ; Drop (in): 30	

Elev. (ft)	Sample Description	Casing Blows/ft	Depth Scale (ft)	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
+8.8 / +8.4	4-in Asphalt Pavement [ASPHALT] (dry)		0						Boring started at 0900 hrs
	Brown m-f SAND, tr. f-gravel, tr. shells, tr. silt [FILL] (dry)	14, 21	0–2	S-1	SS	14	5, 5, 5, 5	10	
	Brown m-f SAND, tr. f-gravel, tr. shells, tr. silt [FILL] (dry)	22, 30	2–4	S-2	SS	10	9, 7, 10, 13	17	
	Brown m-f SAND, tr. f-gravel, tr. silt [FILL] (wet)		4–6	S-3	SS	6	6, 6, 5, 4	11	Hammer Casing to 4-ft Drill with water and clean out hole to 4-ft
	No Recovery		6–8	S-4	SS	0	4, 4, 1, 1	5	
	No Recovery (∇ at 8 ft)		8–10	S-5	SS	0	2, 1, WOH, 1	1	Hammer Casing to 8-ft Drill with water and clean out hole to 8-ft
-1.3	Light Brown c-f SAND, sm. shells, tr. silt [SP] (dry)		10–12	S-6	SS	18	8, 9, 9, 9	18	
	Light Brown m-f SAND, tr. silt [SP] (dry)		12–14	S-7	SS	8	7, 5, 6, 11	11	Hammer Casing to 12-ft Drill with water and clean out hole to 12-ft
	Brown m-f SAND, tr. silt [SP] (wet)		14–16	S-8	SS	6	8, 8, 9, 11	17	Hammer Casing to 14-ft Drill with water and clean out hole to 14-ft
-7.3	Gray Organic and Clayey SILT, sm. f-sand seams, tr. shells [OH] (moist)		16–18	S-9	SS	12	6, 2, 1, 3	3	
-9.3	Brown/Grey Silty m-f SAND, sm. f-sand seams, tr. shells [SM] (moist)		18–20	S-10	SS	18	10, 5, 3, 3	8	Hammer Casing to 18-ft Drill with water and clean out hole to 18-ft

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Project: Long Wharf Park	Project No.: 140034435
Location: Long Wharf Drive, New Haven, CT	Elevation and Datum: Approx. 8.75 (1929 NGVD)

Elev. (ft)	Sample Description	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
	Brownish-red m-f SAND, sm. gray silty clay, tr. shells [SM] (wet)	20–22	S-11	SS	11	3 / 2 / 4 / 10	6	
-13.3	Gray Organic Clayey SILT, sm. shells [OH] (moist)	22–24	S-12	SS	18	1 / 1 / 1 / 2	2	Hammer Casing to 22-ft. Drill with water and clean out hole to 22-ft
	Gray Organic Clayey SILT, tr. shells [OH] (moist)	24–26	S-13	SS	24	WOH / 1 / 1 / 1	2	
	Gray Organic Clayey SILT, tr. shells [OH] (moist)	26–28	ST-1	ST	24	PUSH		Casing Remains at 22-ft. Drill with water and clean out hole to 26-ft
	Gray Organic Clayey SILT, tr. shells [OH] (moist)	28–30	S-14	SS	21	1 / 1 / 1 / 1	2	
	Gray Organic Clayey SILT, tr. shells [OH] (moist)	30–32	S-15	SS	16	1 / 1 / 1 / 1	2	Casing Remains at 22-ft. Drill with water and clean out hole to 30-ft
	Gray Organic Clayey SILT, tr. shells [OH] (moist)	35–37	S-16	SS	24	1 / 1 / 1 / 1	2	Casing Remains at 22-ft. Drill with water and clean out hole to 35-ft
	Gray Organic Clayey SILT, tr. shells [OH] (moist)	40–42	S-17	SS	24	1 / 1 / 1 / 1	2	Casing Remains at 22-ft. Drill with water and clean out hole to 40-ft
-34.8	? ? ? ?							

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Project	Long Wharf Park	Project No.	140034435
Location	Long Wharf Drive, New Haven, CT	Elevation and Datum	Approx. 8.75 (1929 NGVD)

Material Symbol	Elev. (ft)	Sample Description	Casing blws/ ft	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		Light Brown m-f SAND, sm. shells, tr. silt [SP] (wet)		45	S-18	SS	16	1 / 3 / 9 / 11	12	Casing Remains at 22-ft Drill with water and clean out hole to 45-ft
		Brown c-f SAND, sm. silt, tr. shells [SP] (wet)		50	S-19	SS	12	9 / 11 / 14 / 11	25	Casing Remains at 22-ft Drill with water and clean out hole to 50-ft
	-43.3	Bottom of Boring 52-ft 0-in		52						Borehole backfilled with soil cuttings and grout and patched with asphalt upon completion.

Depth scale: 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70

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Project: Long Wharf Park	Project No.: 140034435
Location: Long Wharf Drive, New Haven, CT	Elevation and Datum: Approx. 10.5 (1929 NGVD)
Drilling Agency: Seaboard Drilling, Inc.	Date Started: 0930 hrs 7/6/10 / Date Finished: 0930 hrs 7/7/10
Drilling Equipment: Mobile Drill B-53 Truck-mounted	Completion Depth: 54 ft / Rock Depth: N/E
Size and Type of Bit: 4-1/4" Hollow Stem Auger, 2-15/16" Tri-cone roller bit	Number of Samples: Disturbed 17 / Undisturbed - / Core -
Casing Diameter (in): 4" OD Steel Casing / Casing Depth (ft): 45	Water Level (ft.): First ∇ 8 / Completion ▼ - / 24 HR. ▼ -
Casing Hammer: Auto / Weight (lbs): 300 / Drop (in): 30	Drilling Foreman: Jeff Nitsch
Sampler: 2" OD Split Spoon	
Sampler Hammer: Auto / Weight (lbs): 140 / Drop (in): 30	Inspecting Engineer: Dan Bearse

Elev. (ft)	Sample Description	Casing blows/ft	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
+10.5 / +10.2	4-in Topsoil, sm. grass, sm. roots [TOPSOIL] (dry); Brownish-tan m-f SAND, tr. silt, tr. f-gravel [FILL] (dry)		0–2	S-1	SS	12	9, 19, 18, 21	37	Drilling begins at 0930 hrs on 7/6/10.
	Light Brown m-f SAND, tr. f-gravel, tr. silt, tr. shells [FILL] (dry)		2–4	S-2	SS	14	22, 18, 13, 12	31	
	No Recovery	22, 21	4–6	S-3	SS	0	9, 10, 11, 13	21	Auger to 4-ft Augers removed from borehole
	No Recovery	13, 12	6–8	S-4	SS	0	15, 9, 4, 3	13	
	Brown to Light Brown f-SAND, sm. silt [FILL] (moist)	15, 33	8–10	S-5	SS	8	8, 5, 8, 11	13	Hammer Casing to 8-ft Drill with water and clean out hole to 8-ft
+0.5	Light Brown f-SAND, sm. silt, tr. shells [SP] (moist)	15, 16	10–12	S-6	SS	12	13, 12, 11, 9	23	
	No Recovery		12–14	S-7	SS	0	10, 7, 6, 7	13	Hammer Casing to 12-ft Drill with water and clean out hole to 12-ft
	No Recovery		14–16	S-8	SS	0	6, 6, 5, 5	11	Hammer Casing to 14-ft Drill with water and clean out hole to 14-ft
	Light Brown c-f SAND, sm. f-gravel, tr. silt, tr. shells [SP] (wet)		16–18	S-9	SS	6	4, 4, 4, 5	8	
	Light Brown m-f SAND, tr. f-gravel, tr. silt, tr. shells [SP] (wet)		18–20	S-10	SS	7	5, 3, 3, 5	6	Hammer Casing to 18-ft Drill with water and clean out hole to 18-ft

Project	Project No.
Long Wharf Park	140034435
Location	**Elevation and Datum**
Long Wharf Drive, New Haven, CT	Approx. 10.5 (1929 NGVD)

Elev. (ft)	Sample Description	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
	Light Brown m-f SAND, tr. f-gravel, tr. silt, tr.shells [SP] (wet)	20–22	S-11	SS	16	4, 5, 6, 5	11	
	Light Brown c-f SAND, sm. f-gravel, tr. silt, tr. shells [SP] (wet)	22–24	S-12	SS	7	6, 7, 7, 7	14	Hammer Casing to 22-ft Drill with water and clean out hole to 22-ft
	Light Brown c-f SAND, sm. f-gravel, tr. silt, tr. shells [SP] (wet)	24–26	S-13	SS	2	7, 7, 9, 8	16	
	Light Brown m-f SAND, tr. f-gravel, tr. silt, tr. shells [SP] (wet)	26–28	S-14	SS	15	5, 8, 8, 8	16	Hammer Casing to 26-ft Drill with water and clean out hole to 26-ft
	Light Brown c-f SAND, sm. f-gravel, tr. silt, tr. shells [SP] (wet)	28–30	S-15	SS	5	10, 10, 9, 8	19	
	Light Brown c-f SAND, tr. f-gravel, tr. silt, tr. shells [SP] (wet)	30–32	S-16	SS	16	9, 9, 7, 9	16	Hammer Casing to 30-ft Drill with water and clean out hole to 30-ft
	Light Brown m-f SAND, tr. silt, tr. shells [SP] (wet)	35–37	S-17	SS	7	13, 11, 12, 13	23	Hammer Casing to 35-ft Drill with water and clean out hole to 35-ft
-28.5	? ? ? ?	39						
	Dark Grey Organic Clayey SILT, sm. shells [OH] (moist)	40–42	S-18	SS	8	8, 6, 7, 7	13	Hammer Casing to 40-ft Drill with water and clean out hole to 40-ft
		44						Loss of drilling fluid at approximately 44-ft
		45						

LANGAN ENGINEERING & ENVIRONMENTAL SERVICES

Log of Boring LB-5 Sheet 3 of 3

Project: Long Wharf Park	Project No.: 140034435
Location: Long Wharf Drive, New Haven, CT	Elevation and Datum: Approx. 10.5 (1929 NGVD)

Elev. (ft)	Sample Description	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
	Dark Grey Organic Clayey SILT, tr. shells [OH] (moist)	45–47	S-19	SS	24	4, 4, 4, 6	8	Casing Remains at 40-ft. Drill with water and clean out hole to 45-ft
	No Recovery	50–52	S-20	SS	0	4, 7, 14, 24	21	Hammer Casing to 45-ft. Drill with water and clean out hole to 50-ft
-42.5	Brown Organic Clayey SILT, tr. shells [OH] (wet)	52–54	S-21 a,b	SS	20	3, 5, 14, 14	19	Borehole backfilled with soil cuttings and grout upon completion
-43.5	Brown m-f SAND, sm. silt, tr. shells [SM] (wet)							
	Bottom of Boring 54-ft 0-in	54						

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ENGINEERING & ENVIRONMENTAL SERVICES

Log of Boring **LB-6** Sheet 1 of 3

Project: Long Wharf Park	Project No.: 140034435
Location: Long Wharf Drive, New Haven, CT	Elevation and Datum: Approx. 9 (1929 NGVD)
Drilling Agency: Seaboard Drilling, Inc.	Date Started: 1015 hrs 7/7/10 — Date Finished: 0900 hrs 7/12/10
Drilling Equipment: Mobile Drill B-53 Truck-mounted	Completion Depth: 47 ft — Rock Depth: N/E
Size and Type of Bit: 4-1/4" Hollow Stem Auger, 2-15/16" Tri-cone roller bit	Number of Samples: Disturbed 14 — Undisturbed 1 — Core -
Casing Diameter (in): 4" OD Steel Casing — Casing Depth (ft): 30	Water Level (ft.): First ∇ 5.5 — Completion ▼ - — 24 HR. ▼ -
Casing Hammer: Auto — Weight (lbs): 300 — Drop (in): 30	Drilling Foreman: Jeff Nitsch
Sampler: 2" OD Split Spoon, 3" OD Shelby Tube	
Sampler Hammer: Auto — Weight (lbs): 140 — Drop (in): 30	Inspecting Engineer: Dan Bearse

Elev. (ft)	Sample Description	Casing blows/ft	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
+9.0			0						
+8.7	4-in Asphalt								
	Brown c-f SAND, tr. silt, tr. f-gravel [FILL] (dry)		0–2	S-1	SS	6	19, 24, 20, 18	44	
	Brown m-f SAND, tr. silt [FILL] (dry)		2–4	S-2	SS	6	18, 26, 33, 23		
	Tan to Brown m-f SAND, tr. silt [FILL] (dry)	5, 15	4–6	S-3	SS	21	7, 8, 10, 10	18	Auger to 4-ft
	∇ (water level, 5.5 ft)								
	Brown c-f SAND, tr. silt, tr. shells [FILL] (wet)	13, 12	6–8	S-4	SS	20	9, 10, 8, 7	18	
	Brown m-f SAND, tr. silt, tr. shells [FILL] (wet)	18, 33	8–10	S-5	SS	8	12, 5, 5, 5	10	Hammer Casing to 8-ft. Drill with water and clean out hole to 8-ft
	No Recovery	20, 22	10–12	S-6	SS	0	20, 30, 23, 16		
-3.0	Brown m-f SAND, tr. silt, tr. shells, tr. f-gravel [SP] (wet)		12–14	S-7	SS	8	13, 11, 11, 11	22	Hammer Casing to 12-ft. Drill with water and clean out hole to 12-ft
	Brown c-f SAND, sm. shells, tr. silt, tr. f-gravel [SW] (wet)		14–16	S-8	SS	8	12, 10, 7, 10	17	Hammer Casing to 14-ft. Drill with water and clean out hole to 14-ft
	Brown m-f SAND, tr. silt, tr. f-gravel, tr. shells [SP] (wet)		16–18	S-9	SS	12	5, 7, 7, 8	14	
			20						

Project	Project No.
Long Wharf Park	140034435
Location	**Elevation and Datum**
Long Wharf Drive, New Haven, CT	Approx. 9 (1929 NGVD)

Material Symbol	Elev. (ft)	Sample Description	Casing blows/ft	Depth Scale	Sample Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
SAND		Brown c-f SAND, tr. silt, tr. f-gravel, sm. shells [SW] (wet)		20–22	S-10	SS	4	6 / 5 / 4 / 4	9	Hammer Casing to 20-ft Drill with water and clean out hole to 20-ft
	-14.0	? — ? — ? — ?		23						
SILT		Dark Grey Organic Clayey SILT, tr. shells [OH] (moist)		25–27	S-11	SS	21	1 / 1 / 1 / 2	2	
		Dark Grey Organic Clayey SILT, tr. shells [OH] (moist)		30–32	S-12	SS	24	WOH / 1 / 1 / 1	2	Hammer Casing to 30-ft Drill with water and clean out hole to 30-ft
		Dark Grey Organic Clayey SILT [OH] (moist)		32–34	ST-1	ST	24	PUSH		Clean out hole to 32-ft Casing remains at 30-ft
		Dark Grey Silty CLAY, tr. shells [OH] (moist)		34–36	S-13	SS	24	1 / 2 / 2 / 2	4	
		Dark Grey Organic Clayey SILT, tr. shells [OH] (moist)		40–42	S-14	SS	24	1 / 1 / 2 / 2	3	Drill with water and clean out hole to 40-ft Casing remains at 30-ft
	-35.0	? — ? — ? — ?		44						
SAND				45						

Project	Project No.
Long Wharf Park	140034435
Location	Elevation and Datum
Long Wharf Drive, New Haven, CT	Approx. 9 (1929 NGVD)

Material Symbol	Elev. (ft)	Sample Description	Casing blows/ft	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		Dark Grey m-f. SAND, tr. shells [SP] (wet)		45	S-15	SS	11	10 10 12 10	22	Drill with water and clean out hole to 45-ft Casing remains at 30-ft
	-38.0	Bottom of Boring 47-ft 0-in		47						Borehole backfilled with soil cuttings and grout upon completion. Concrete patch installed at pavement elevation.

FORM NO. SM-1 ED. 1/71
STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
BORING REPORT

T. Paquette BORING FOREMAN		SHEET 1 OF 4
		LOCATION Long Wharf Drive
J. Freitas/J. O'Brien INSPECTOR	TOWN New Haven, Connecticut	Guild Drilling Co. BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME I-95 New Haven Harbor Program Management	Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER
	PROJECT NO. 92-505	

LOCATION Long Wharf Drive adjacent to the Long Wharf Nature Preserve

		AUGER	CASING	SAMPLER	CORE BAR	
SURFACE ELEV. 18.6						HOLE NO. PB-5
DATE FINISHED 3/29/00	TYPE		HW	SS	N/A	LINE & STATION
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET
AT 8.8 FT. 48 HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE 165,475.0
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE 551,963.2

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE: DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		0.0' - 2.0'	1	24	19	D	1	3	5	6		Red-brown f SAND, trace c gravel, some silt, dry. (FILL)
5		4.0' - 6.0'	2	24	17	D	8	7	15	15		Red-brown f SAND, some silt. (FILL)
10		9.0' - 11.0'	3	24	19	D	5	12	12	11		Red-brown f SAND, some silt. (FILL)
15		14.0' - 16.0'	4	24	13	D	10	12	14	15		Red-brown m-c SAND, little f gravel, trace shells. (FILL)
											19.0	Top 3": Gray-brown f-c SAND, trace f-m gravel, little silt. (FILL)
20		19.0' - 21.0'	5	24	9	D	9	7	4	4	-0.4	Dark green-gray ORGANIC CLAY, some silt, trace peat fibers.
25		24.0' - 26.0'	6	24	13	D	3	7	17	12		Dark green-gray ORGANIC SILT, some f-c gravel, little f-m sand, shells, organic odor.
30		29.0' - 31.0'	7	24	12	D	1	0	0	0		Dark green-gray ORGANIC SILT, trace f-c sand, little clay, trace shells, slight organic odor, pp= 0.5 TSF
35		34.0' - 36.0'	8	24	7	D	WOR	WOR	WOH	WOH		Dark green-gray ORGANIC SILT, trace f-c sand, little clay, trace shells, slight organic odor, pp= 0.4 TSF

FROM GROUND SURFACE TO 33.5 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 88.5 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D NO. OF SAMPLES 25 HOLE NO. PB-5

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

T. Paquette BORING FOREMAN	FORM NO. SM-1 ED. 1/71 STATE OF CONNECTICUT DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS BORING REPORT	SHEET 2 OF 4 LOCATION Long Wharf Drive
J. Freitas/J. O'Brien INSPECTOR	TOWN New Haven, Connecticut	Guild Drilling Co. BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME I-95 New Haven Harbor Program Management PROJECT NO. 92-505	Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER

LOCATION Long Wharf Drive adjacent to the Long Wharf Nature Preserve

		AUGER	CASING	SAMPLER	CORE BAR	
SURFACE ELEV. 18.6						HOLE NO. PB-5
DATE FINISHED 3/29/00	TYPE		HW	SS	N/A	LINE & STATION
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET
AT 8.8 FT. 48 HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE 165,475.0
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE 551,963.2

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE: DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		40.0' - 42.0'	9	24	14	D	WOH	WOH	1	0		Dark green-gray ORGANIC SILT, trace f-c sand, little clay, trace shells, slight organic odor, pp= 0.15 TSF
45		45.0' - 47.0'	10	24	16	D	WOH	WOH	1	1		Dark green-gray ORGANIC SILT, trace f-c sand, little clay, trace shells, slight organic odor, pp= 0.25, 0.25 TSF
50		50.0' - 52.0'	11	24	20	D	1	1	1	2		Dark green-gray ORGANIC SILT, trace f-c sand, little clay, trace shells, slight organic odor, pp= 0.25, 0.35 TSF
											52.5 -33.9	Driller noted cobble at 52.7 to 52.9'.
55		55.0' - 57.0'	12	24	19	D	8	4	2	1		Brown f-m SAND, some silt, trace wood.
60		60.0' - 62.0'	13	24	20	D	4	4	3	4	60.0 -41.4	Red-brown mottled with black SILT, little f sand, trace black clay layer 1/16" thick.
65		65.0' - 67.0'	14	24	23	D	3	3	8	11		Red-brown SILT, little f sand, trace clay, rapid dilatancy.
70		70.0' - 72.0'	15	24	21	D	3	3	3	7		Red-brown SILT, little f sand, trace clay, rapid dilatancy.
75		75.0' - 77.0'	16	24	20	D	2	4	3	6		Red-brown SILT, little f sand, trace clay, rapid dilatancy.

FROM GROUND SURFACE TO 33.5 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 88.5 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D NO. OF SAMPLES 25 HOLE NO. PB-5

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

T. Paquette	FORM NO. SM-1 ED. 1/71
BORING FOREMAN	STATE OF CONNECTICUT
J. Freitas/J. O'Brien	DEPARTMENT OF TRANSPORTATION
INSPECTOR	BUREAU OF HIGHWAYS
R. Borjeson	BORING REPORT
SOILS ENGINEER	

SHEET 3 OF 4
LOCATION Long Wharf Drive
Guild Drilling Co. — BORING CONTRACTOR
Parsons Brinckerhoff Quade & Douglas, Inc. — CONTRACTING ENGINEER

TOWN New Haven, Connecticut
PROJECT NAME I-95 New Haven Harbor Program Management
PROJECT NO. 92-505

LOCATION Long Wharf Drive adjacent to the Long Wharf Nature Preserve

SURFACE ELEV. 18.6		AUGER	CASING	SAMPLER	CORE BAR	HOLE NO.	PB-5
DATE FINISHED 3/29/00	TYPE		HW	SS	N/A	LINE & STATION	
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET	
AT 8.8 FT. 48 HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE	165,475.0
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE	551,963.2

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		80.0' - 82.0'	17	24	20	D	7	7	11	12		Red-brown SILT, trace clay, 1/4" clay layer, rapid dilitancy.
85		85.0' - 87.0'	18	24	18	D	4	4	9	10		Red-brown SILT, trace clay, 1/4" clay layer, rapid dilitancy.
90		90.0' - 92.0'	19	24	22	D	6	5	9	15		Red-brown SILT, trace clay, 1/4" clay layer, rapid dilitancy.
95		95.0' - 97.0'	20	24	21	D	5	5	7	11		Red-brown SILT, little clay, 1/4" clay layer, rapid dilitancy.
100		100.0' - 102.0'	21	24	23	D	4	6	10	17		Red-brown SILT, trace clay, rapid dilatancy.
105		105.0' - 107.0'	22	24	22	D	5	5	10	15		Red-brown SILT, trace clay, few 1/4" clay layers, rapid dilitancy.
110		110.0' - 112.0'	23	24	24	D	3	5	9	11		Red-brown SILT, trace clay, rapid dilatancy.
115		115.0' - 117.0'	24	24	21	D	7	9	13	17		Red-brown SILT, trace clay, 1/4" clay layer, rapid dilatancy.

FROM GROUND SURFACE TO 33.5 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 88.5 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D NO. OF SAMPLES 25 HOLE NO. PB-5

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

T. Paquette BORING FOREMAN	FORM NO. SM-1 ED. 1/71 STATE OF CONNECTICUT DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS BORING REPORT	SHEET 4 OF 4 LOCATION Long Wharf Drive
J. Freitas/J. O'Brien INSPECTOR	TOWN **New Haven, Connecticut**	**Guild Drilling Co.** BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME **I-95 New Haven Harbor Program Management** PROJECT NO. **92-505**	**Parsons Brinckerhoff Quade & Douglas, Inc.** CONTRACTING ENGINEER

LOCATION **Long Wharf Drive adjacent to the Long Wharf Nature Preserve**

		AUGER	CASING	SAMPLER	CORE BAR		
SURFACE ELEV. 18.6						HOLE NO.	PB-5
DATE FINISHED 3/29/00	TYPE		HW	SS	N/A	LINE & STATION	
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET	
AT 8.8 FT. 48 HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE	165,475.0
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE	551,963.2

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE: DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		120.0' - 122.0'	25	24	23	D	11	14	21	21		Red-brown SILT, trace clay, few 1/4" clay layers, rapid dilitancy.
											122.0	
											-103.4	Bottom of boring at 122.0 ft
125												
130												
135												
140												
145												
150												
155												

FROM GROUND SURFACE TO 33.5 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 88.5 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D NO. OF SAMPLES 25 HOLE NO. PB-5

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

FORM NO. SM-1 ED. 1/71
STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
BORING REPORT

T. Paquette BORING FOREMAN		SHEET 1 OF 4
		LOCATION Long Wharf Drive
J. Freitas/J. O'Brien INSPECTOR	TOWN New Haven, Connecticut	Guild Drilling Co. BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME I-95 New Haven Harbor Program Management PROJECT NO. 92-505	Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER

LOCATION Long Wharf Drive adjacent to Exit 46 off ramp from I-95 North

		AUGER	CASING	SAMPLER	CORE BAR		
SURFACE ELEV. 11.1						HOLE NO.	PB-7
DATE FINISHED 3/30/00	TYPE		HW	SS	N/A	LINE & STATION	
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET	
AT 8.1 FT. 24 HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE	166,379.9
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE	552,603.9

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		0.0' - 2.0'	1	24	13	D	4	8	9	7		Top 3": Dark brown SILT, some f sand. (TOPSOIL) Bottom 10": Red-brown f SAND, some silt. (FILL)
5		5.0' - 7.0'	2	24	15	D	5	4	3	1		Top 14": Red-brown f SAND, some silt. Bottom 1": Dark gray ORGANIC SILT.
10		10.0' - 12.0'	3	24	10	D	4	2	3	4		Red-gray-brown f-c SAND, trace silt, trace shells. (FILL)
											0.9	
15		15.0' - 17.0'	4	24	20	D	WOH	1	2	1		Dark green-gray ORGANIC SILT, organic odor. pp= 0.75, 0.4, 0.5 TSF
20		20.0' - 22.0'	5	24	6	D	3	2	1	1		Dark gray-brown f SAND, little silt, petroleum odor.
25		25.0' - 27.0'	6	24	18	D	-	-	-	1		Dropped rods to 26.5 ft. Dark green-gray ORGANIC SILT, trace peat fibers, shells, organic odor. pp= 0.35, 0.25, 0.35 TSF
30		30.0' - 32.0'	7	24	24	D	WOR	WOH	WOH	WOH		Dark green-gray ORGANIC SILT, trace peat fibers, shells, organic odor. pp= 0.25 TSF
35		35.0' - 37.0'	8	24	22	D	WOR	1	0	1		Dark green-gray ORGANIC SILT, trace peat fibers, shells, organic odor. pp= 0.25 TSF

FROM GROUND SURFACE TO 39 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 83 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D NO. OF SAMPLES 25 HOLE NO. PB-7

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER U=UNDISTURBED, PISTON V=VANE TEST
PROPORTIONS USED: TRACE = 0 - 10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

T. Paquette BORING FOREMAN	FORM NO. SM-1 ED. 1/71 STATE OF CONNECTICUT DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS BORING REPORT	SHEET 2 OF 4 LOCATION Long Wharf Drive
J. Freitas/J. O'Brien INSPECTOR	TOWN New Haven, Connecticut	Guild Drilling Co. BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME I-95 New Haven Harbor Program Management PROJECT NO. 92-505	Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER

LOCATION Long Wharf Drive adjacent to Exit 46 off ramp from I-95 North

		AUGER	CASING	SAMPLER	CORE BAR		
SURFACE ELEV. 11.1						HOLE NO.	PB-7
DATE FINISHED 3/30/00	TYPE		HW	SS	N/A	LINE & STATION	
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET	
AT 8.1 FT. 24 HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE	166,379.9
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE	552,603.9

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE: DEPTH ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		40.0' - 42.0'	9	24	18	D	WOH	WOH	WOH	1		Dark green-gray ORGANIC SILT, trace peat fibers, shells, organic odor. pp= 0.5, 0.5, 0.5 TSF
45		45.0' - 47.0'	10	24	24	D	1	0	0	1		Top 18": Dark green-gray ORGANIC SILT, as above. Bottom 6": Dark green-gray SILT, some f sand, trace peat fibers, shells, organic odor.
50		50.0' - 52.0'	11	24	24	D	WOH	1	1	5	50.5 -39.4	Top 6": Dark green-gray SILT, as above. Bottom 18": Dark brown PEAT and ORGANIC SILT, fibrous, organic odor.
											54.0 -42.9	
55		55.0' - 57.0'	12	24	16	D	8	10	14	11		Red-brown f SAND, trace silt.
60		60.0' - 62.0'	13	24	12	D	6	7	6	3		Red-brown m-c SAND, little f gravel, trace silt.
											64.0 -52.9	
65		65.0' - 67.0'	14	24	20	D	5	8	11	12		Red-brown SILT and f SAND, trace clay, 1/4" gray clay layer, rapid dilatancy.
70		70.0' - 72.0'	15	24	16	D	5	5	12	15		Red-brown SILT and f SAND, trace clay, rapid dilatancy.
75		75.0' - 77.0'	16	24	22	D	6	3	7	8		Red-brown SILT, some f sand, trace clay, 1/4" clay layer, rapid dilatancy.

FROM GROUND SURFACE TO 39 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 83 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D NO. OF SAMPLES 25 HOLE NO. PB-7

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

T. Paquette BORING FOREMAN	FORM NO. SM-1 ED. 1/71 STATE OF CONNECTICUT DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS BORING REPORT	SHEET 3 OF 4 LOCATION Long Wharf Drive
J. Freitas/J. O'Brien INSPECTOR	TOWN New Haven, Connecticut	Guild Drilling Co. BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME I-95 New Haven Harbor Program Management PROJECT NO. 92-505	Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER

LOCATION Long Wharf Drive adjacent to Exit 46 off ramp from I-95 North

			AUGER	CASING	SAMPLER	CORE BAR	
SURFACE ELEV. 11.1							HOLE NO. PB-7
DATE FINISHED 3/30/00	TYPE			HW	SS	N/A	LINE & STATION
GROUND WATER OBSERVATIONS	SIZE I.D.			4"	1 3/8"		OFFSET
AT 8.1 FT. 24 HRS.	HAMMER WT.			300#	140#	BIT	N. COORDINATE 166,379.9
AT FT. HRS.	HAMMER FALL			24"	30"		E. COORDINATE 552,603.9

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE: DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		80.0' - 82.0'	17	24	21	D	3	6	11	16		Red-brown SILT, some f sand, trace clay, rapid dilatancy.
85		85.0' - 87.0'	18	24	15	D	5	5	9	12		Red-brown SILT, some f sand, trace clay, rapid dilatancy.
90		90.0' - 92.0'	19	24	21	D	5	8	11	19		Red-brown SILT, trace clay, few 1/4" clay layers, rapid dilatancy.
95		95.0' - 97.0'	20	24	22	D	9	8	11	11		Red-brown SILT, trace clay, 1/8" clay layer, rapid dilatancy.
100		100.0' - 102.0'	21	24	21	D	6	9	13	16		Red-brown SILT, trace clay, 1/4" clay layer, rapid dilatancy.
105		105.0' - 107.0'	22	24	19	D	5	6	8	18		Red-brown SILT, trace clay, 1/4" clay layer, rapid dilatancy.
110		110.0' - 112.0'	23	24	23	D	2	6	10	20		Red-brown SILT, little clay, few 1/4" to 1/8" clay layers, rapid dilatancy.
115		115.0' - 117.0'	24	24	21	D	4	7	10	21		Red-brown SILT, trace clay, 1/8" clay layer, rapid dilatancy.

FROM GROUND SURFACE TO 39 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 83 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D NO. OF SAMPLES 25 HOLE NO. PB-7

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

T. Paquette BORING FOREMAN	FORM NO. SM-1 ED. 1/71 STATE OF CONNECTICUT DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS BORING REPORT	SHEET 4 OF 4
		LOCATION Long Wharf Drive
J. Freitas/J. O'Brien INSPECTOR	TOWN New Haven, Connecticut	Guild Drilling Co. BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME I-95 New Haven Harbor Program Management PROJECT NO. 92-505	Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER

LOCATION Long Wharf Drive adjacent to Exit 46 off ramp from I-95 North

		AUGER	CASING	SAMPLER	CORE BAR		
SURFACE ELEV. 11.1						HOLE NO.	PB-7
DATE FINISHED 3/30/00	TYPE		HW	SS	N/A	LINE & STATION	
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET	
AT 8.1 FT. 24 HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE	166,379.9
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE	552,603.9

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE: DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		120.0' - 122.0'	25	24	15	D	2	6	13	18	122.0 -110.9	Red-brown SILT, trace clay, 1/4" clay layer, rapid dilatancy.
												Bottom of boring at 122.0 ft
125												Note: Hole grouted to 23', observation well installed, screened from 10' to 20'.
130												
135												
140												
145												
150												
155												

FROM GROUND SURFACE TO 39 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 83 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D NO. OF SAMPLES 25 HOLE NO. PB-7

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

FORM NO. SM.1 ED. 1/71
STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
BORING REPORT

A. Mason BORING FOREMAN	TOWN: New Haven, Connecticut	SHEET 1 OF 4
J. Freitas INSPECTOR	PROJECT NAME: I-95 New Haven Harbor Program Management	LOCATION: Long Wharf Drive
R. Borjeson SOILS ENGINEER	PROJECT NO. 92-505	Guild Drilling Co. BORING CONTRACTOR
		Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER

LOCATION: Long Wharf Drive

		AUGER	CASING	SAMPLER	CORE BAR		
SURFACE ELEV.	10.0					HOLE NO.	PB-9
DATE FINISHED	4/5/00	TYPE	HW	SS	N/A	LINE & STATION	
GROUND WATER OBSERVATIONS		SIZE I.D.	4"	1 3/8"		OFFSET	
AT – FT.	HRS.	HAMMER WT.	300#	140#	BIT	N. COORDINATE	167,179.4
AT FT.	HRS.	HAMMER FALL	24"	30"		E. COORDINATE	553,106.3

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		0.0' - 2.0'	1	24	20	D	2	2	4	7		Top 5": Brown SILT, trace f sand, some organic matter-grass, roots. (TOPSOIL) Bottom 15": Red-brown f SAND and SILT, trace f gravel, dry. (FILL)
5		4.0' - 6.0'	2	24	20	D	7	9	11	14		Red brown m-c SAND, trace f gravel, trace silt, wet. (FILL)
											9.0	
10		9.0' - 11.0'	3	24	24	D	2	1	1	1	1.0	Green-gray ORGANIC SILT, trace f sand, trace shells; top 2" black with slight sheen.
15		14.0' - 16.0'	4	24	24	D	1	0	WOH	WOH		Black ORGANIC SILT, trace shells, slight organic odor, slight petroleum odor. pp= 0.0, 0.0, 0.0 TSF
20		19.0' - 21.0'	5	24	24	D	WOR	WOH	WOH	WOH		Black ORGANIC SILT, trace shells, slight organic odor. pp= 0.0, 0.0 TSF
		22.0' - 24.0'	1	24	24	UP	PUSH					Black ORGANIC SILT, slight organic odor. pp= 0.3, 0.5, 0.4 TSF
25		24.0' - 26.0'	6	24	24	D	WOH	1	1	1		Black ORGANIC SILT, slight organic odor. pp= 0.0, 0.25 TSF
30		29.0' - 31.0'	7	24	24	D	1	1	1	1		Black ORGANIC SILT, slight organic odor. pp= 0.25, 0.3, 0.25 TSF
35		34.0' - 36.0'	8	24	24	D	WOH	WOH	WOH	2		Black ORGANIC SILT, slight organic odor. pp= 0.25 TSF
		39.0' - 41.0'	9	24	24	D	WOH	WOH	1	1		Black ORGANIC SILT, slight organic odor.

FROM GROUND SURFACE TO 49 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 73 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D/UP NO. OF SAMPLES 25/1 HOLE NO. PB-9

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED. PISTON V=VANE TEST

PROPORTIONS USED: TRACE = 0 - 10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

A. Mason BORING FOREMAN	FORM NO. SM-1 ED. 1/71 STATE OF CONNECTICUT DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS BORING REPORT	SHEET 2 OF 4 LOCATION Long Wharf Drive
J. Freitas INSPECTOR	TOWN New Haven, Connecticut	Guild Drilling Co. BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME I-95 New Haven Harbor Program Management PROJECT NO. 92-505	Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER

LOCATION Long Wharf Drive

		AUGER	CASING	SAMPLER	CORE BAR	
SURFACE ELEV. 10.0						HOLE NO. PB-9
DATE FINISHED 4/5/00	TYPE		HW	SS	N/A	LINE & STATION
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET
AT -- FT. HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE 167,179.4
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE 553,106.3

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN INCH	REC INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE: DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
45		44.0' - 46.0'	10	24	24	D	1	2	2	3		Olive-gray ORGANIC SILT, little f sand, trace shells.
50		49.0' - 51.0'	11	24	10	D	16	12	15	17	49.0 -39.0	Brown f-c SAND, little f gravel, trace silt.
55		54.0' - 56.0'	12	24	14	D	9	12	15	17		Brown f-c SAND, little f gravel, trace silt.
60		59.0' - 61.0'	13	24	19	D	10	13	18	23	59.1 -49.1	Top 1": Brown f-c SAND, little f gravel, trace silt. Bottom 18": Red-brown f SAND and SILT, rapid dilatancy.
65		64.0' - 66.0'	14	24	14	D	22	12	17	22		Red-brown SILT, trace f sand, medium dilatancy.
70		69.0' - 71.0'	15	24	20	D	12	16	16	20		Red-brown f SAND and SILT, medium to rapid dilatancy.
75		74.0' - 76.0'	16	24	23	D	5	7	16	22		Red-brown SILT, little clay, few 1/8" clay layers, rapid dilatancy.
		79.0' - 81.0'	17	24	20	D	7	9	11	19		Red-brown SILT, little clay, rapid dilatancy.

FROM GROUND SURFACE TO 49 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 73 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D/UP NO. OF SAMPLES 25/1 HOLE NO. PB-9

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

FORM NO. SM-1 ED. 1/71
STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
BORING REPORT

SHEET 3 OF 4
LOCATION Long Wharf Drive

A. Mason
BORING FOREMAN

J. Freitas
INSPECTOR

R. Borjeson
SOILS ENGINEER

TOWN New Haven, Connecticut
PROJECT NAME I-95 New Haven Harbor Program Management
PROJECT NO. 92-505

Guild Drilling Co.
BORING CONTRACTOR

Parsons Brinckerhoff Quade & Douglas, Inc.
CONTRACTING ENGINEER

LOCATION Long Wharf Drive

		AUGER	CASING	SAMPLER	CORE BAR		
SURFACE ELEV. 10.0						HOLE NO.	PB-9
DATE FINISHED 4/5/00	TYPE		HW	SS	N/A	LINE & STATION	
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET	
AT – FT. HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE	167,179.4
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE	553,106.3

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE: DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
85		84.0' - 86.0'	18	24	22	D	6	9	14	22		Red-brown SILT, trace f sand, trace clay, rapid dilatancy.
90		89.0' - 91.0'	19	24	16	D	7	10	15	18		Red-brown SILT and f SAND, medium dilatancy.
95		94.0' - 96.0'	20	24	20	D	5	9	13	21		Red-brown SILT, trace f sand, trace clay.
100		99.0' - 101.0'	21	24	18	D	10	15	16	27		Red-brown SILT, trace f sand, trace clay, rapid dilatancy.
105		104.0' - 106.0'	22	24	16	D	9	13	17	22		Red-brown SILT, trace f sand, trace clay, rapid dilatancy.
110		109.0' - 111.0'	23	24	16	D	10	14	16	23		Red brown SILT, trace f sand, trace clay.
115		114.0' - 116.0'	24	24	20	D	8	11	17	23		Red brown SILT, trace f sand, trace clay.

FROM GROUND SURFACE TO 49 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 73 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D/UP NO. OF SAMPLES 25/1 HOLE NO. PB-9

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

A. Mason BORING FOREMAN	FORM NO. SM-1 ED. 1/71 STATE OF CONNECTICUT DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS BORING REPORT	SHEET 4 OF 4 LOCATION Long Wharf Drive
J. Freitas INSPECTOR	TOWN New Haven, Connecticut	Guild Drilling Co. BORING CONTRACTOR
R. Borjeson SOILS ENGINEER	PROJECT NAME I-95 New Haven Harbor Program Management PROJECT NO. 92-505	Parsons Brinckerhoff Quade & Douglas, Inc. CONTRACTING ENGINEER

LOCATION Long Wharf Drive

		AUGER	CASING	SAMPLER	CORE BAR	
SURFACE ELEV. 10.0						HOLE NO. PB-9
DATE FINISHED 4/5/00	TYPE		HW	SS	N/A	LINE & STATION
GROUND WATER OBSERVATIONS	SIZE I.D.		4"	1 3/8"		OFFSET
AT – FT. HRS.	HAMMER WT.		300#	140#	BIT	N. COORDINATE 167,179.4
AT FT. HRS.	HAMMER FALL		24"	30"		E. COORDINATE 553,106.3

DEPTH	CASING BLOWS PER FOOT	SAMPLE DEPTHS FROM - TO	NO.	PEN. INCH	REC. INCH	TYPE	BLOWS PER 6 INCHES ON SAMPLER 0-6	6-12	12-18	18-24	STRATA CHANGE DEPTH, ELEV.	FIELD IDENTIFICATION OF SOIL, REMARKS (INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.)
		120.0' - 122.0'	25	24	24	D	8	14	24	29	122.0 -112.0	Red-brown SILT, trace f sand, trace clay, clay layers up to 1" thick, rapid dilatancy. Bottom of boring at 122.0 ft
125												
130												
135												
140												
145												
150												
155												

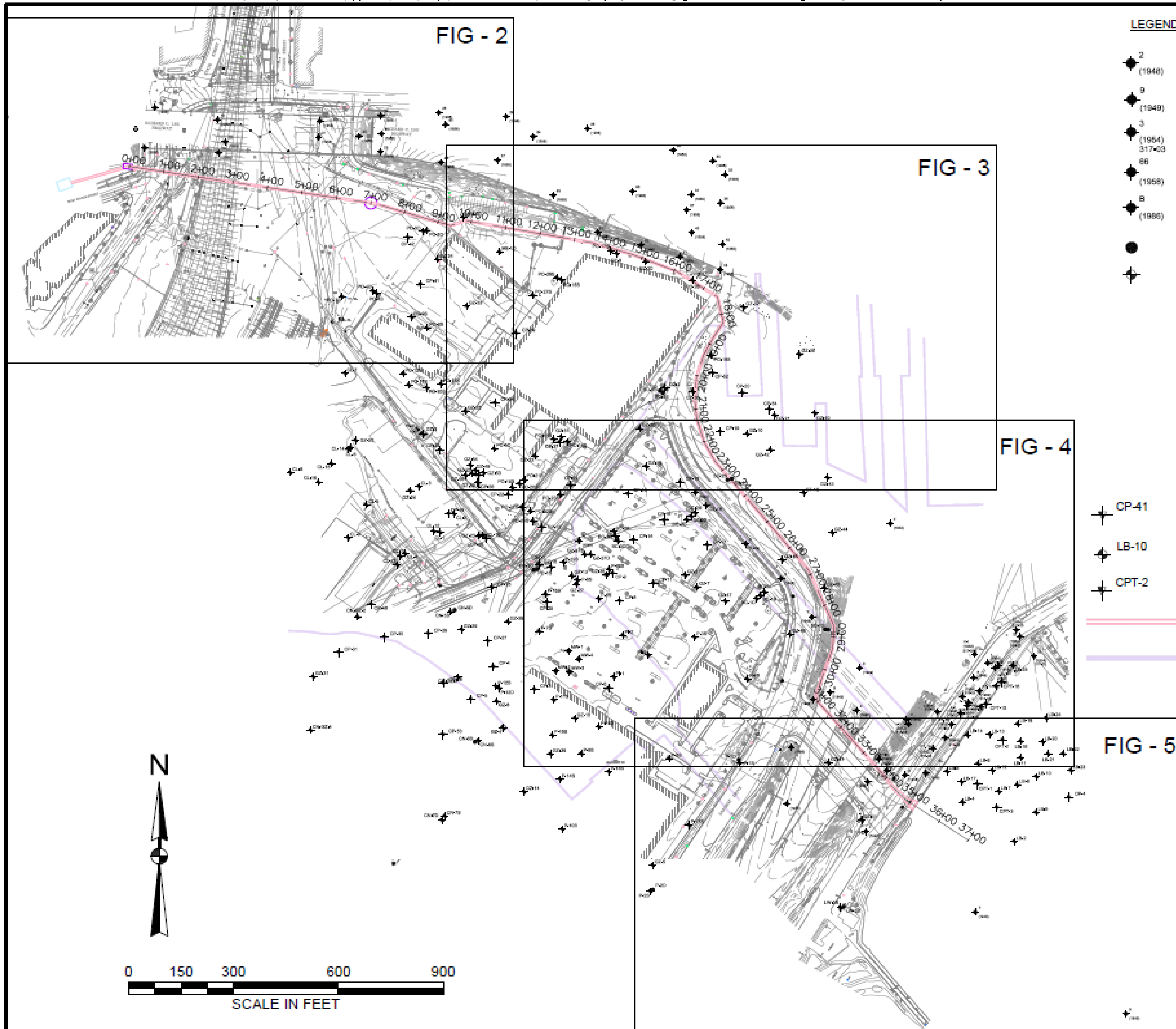
FROM GROUND SURFACE TO 49 FEET USED 4 INCH CASING THEN OPEN HOLE FOR 73 FEET

FOOTAGE IN EARTH 122.0 FOOTAGE IN ROCK 0 TYPE D/UP NO. OF SAMPLES 25/1 HOLE NO. PB-9

SAMPLE TYPE CODING: D=DRY C=CORE A=AUGER UP=UNDISTURBED, PISTON V=VANE TEST

PROPORTIONS USED: TRACE =0 -10% LITTLE = 10 - 20% SOME = 20 - 35% AND = 35 - 50%

c 2019 – GZA GeoEnvironmental, Inc. GZA–C:\Users\marc.chmura\appdata\local\temp\AcPublish_14872\GZA_BoringMapLayout2.0.dwg [FIG 1 11x17 OPTION 2] January 24, 2019 – 2:40pm marc.chmura



LEGEND:

2 (1948)	FILE# 0092-0060, 1948 BORINGS - HYDRAULIC FILL ON SECTIONS OF HARBORFRONT RELOCATION OF ROUTE US 1
9 (1949)	FILE# 0092-0053, 1949 BORINGS - BOX CULVERT AND PIPE CULVERTS ON HARBORFRONT RELOCATION OF US ROUTE NO1
3 (1954) 317-03	FILE# 317-03, 1948-1954 BORINGS - BULKHEAD AT BREWERY STREET CHANNEL GREENWICH - KILLINGLY EXPRESSWAY
66 (1958)	FILE# 0092-0093, 1958 BORINGS - RELOCATION OF ROUTE 34
8 (1986)	FILE# 0092-0313, 1986 BORINGS - ROUTE I-95 NORTHBOUND & SOUTHBOUND OVER CANAL DOCK ROAD BRIDGE REHABILITATION
●	INDICATES MICROWELL TEST BORING/MONITORING WELL
✦	INDICATES TEST BORING AND/OR MONITORING WELL
CN-GZ-3:	PERFORMED BY GZA DURING DECEMBER, 1994
CN, SD, & P-1S, 1D: P-2S, 2D:	PERFORMED BY GZA DURING MAY, 1997
P, PI, BC:	PERFORMED BY GZA DURING SEPTEMBER/OCTOBER 1997
GZ (1-11):	PERFORMED BY NEW ENGLAND BORING OR GZA DURING JANUARY, 1997 THROUGH JUNE, 1998
GZ (13-56):	PERFORMED BY GZA DURING FEBRUARY AND MARCH, 1999
MW:	TEST BORINGS/MONITORING WELLS PERFORMED BY OTHERS AS PART OF THE CLOSURE INVESTIGATION OF THE EXISTING UNDERGROUND STORAGE TANK
PO, MF:	PERFORMED BY GZA DURING FEBRUARY/MARCH, 1998
CP-41 / CP:	CONE PENETROMETER PERFORMED BY CPT DATABASE SERVIES IN MARCH, 1999
LB-10 / LB:	LANGAN BOATHOUSE BORINGS - 2009 & 2010
CPT-2 / CPT:	LANGAN BOATHOUSE CONE PENETRATION TEST - 2009 & 2010
(pink line)	PROPOSED STORM WATER FORCE MAIN
(purple line)	APPROXIMATE LOCATION OF PRE-1923 SHORELINE

NOTE: FIGURE 6 NOT DISPLAYED

NO.	ISSUE/DESCRIPTION	BY	DATE

NEW HAVEN STORM WATER IMPROVMENTS

NEW HAVEN, CONNECTICUT

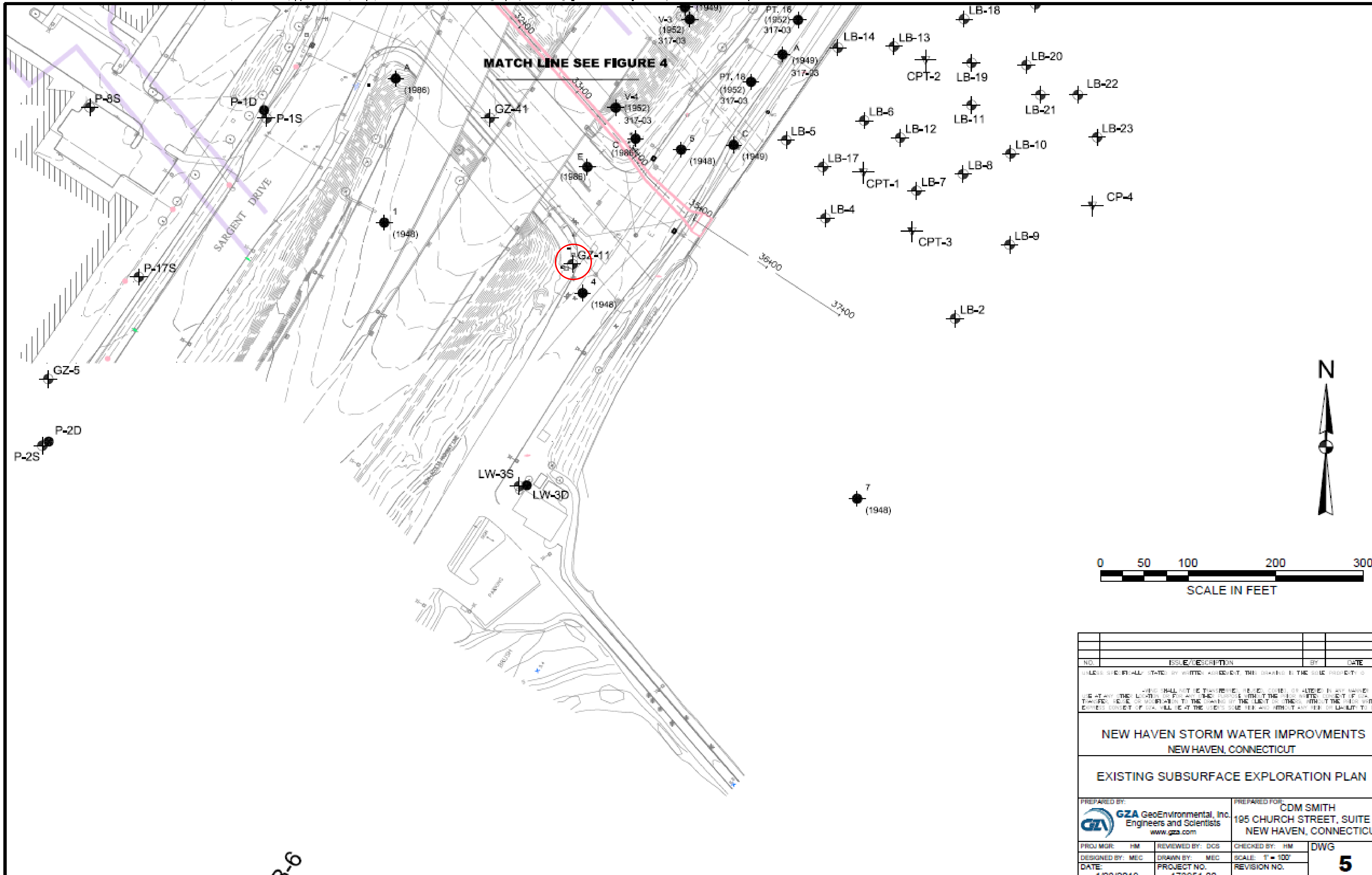
EXISTING SUBSURFACE EXPLORATION PLAN

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com

PREPARED FOR: CDM SMITH, 195 CHURCH STREET, SUITE 7A, NEW HAVEN, CONNECTICUT

PROJ MGR: HM	REVIEWED BY: DCS	CHECKED BY: HM	DWG 1
DESIGNED BY: MEC	DRAWN BY: MEC	SCALE: 1" = 300'	
DATE: 1/23/2019	PROJECT NO. 173951.00	REVISION NO.	SHEET NO. 1-OF-6

© 2019 — GZA GeoEnvironmental, Inc. GZA—C:\Users\marc.chmura\appdata\local\temp\AcPublish_14872\GZA_BoringMapLayout2.0.dwg [FIG 5 11x17] January 24, 2019 — 2:40pm marc.chmura



NO.	ISSUE/DESCRIPTION	BY	DATE

NEW HAVEN STORM WATER IMPROVMENTS
NEW HAVEN, CONNECTICUT

EXISTING SUBSURFACE EXPLORATION PLAN

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com

PREPARED FOR: CDM SMITH 195 CHURCH STREET, SUITE 7A NEW HAVEN, CONNECTICUT

PROJ MGR: HM	REVIEWED BY: DCS	CHECKED BY: HM	DWG
DESIGNED BY: MEC	DRAWN BY: MEC	SCALE: 1" = 100'	5
DATE: 1/23/2019	PROJECT NO. 173951.00	REVISION NO.	SHEET NO. 5-OF-6

GZA GEOENVIRONMENTAL, INC.
Engineers and Scientists
27 Naek Road
Vernon, Connecticut 06066
(860) 875-7655

EXPLORATION DATA
PROPERTY OF GZA
GEOENVIRONMENTAL, INC.

Boring No.: GZ-11
age: 1 OF 2
File No.: 41802
hecked By: AJ

Boring Co.	GZA GeoEnvironmental			Casing	Sampler
Foreman	R. Holman		Type	Steel	S.S.
GZA Representat	A. Augustine		I.D./O.D.	4"	2" O.D.
Date Start	6/29/98	Date En 6/29/98	Hammer	300 lb	140 lb
Location	See Plan		Hammer F	30"	30"
G.S. Elevation	NA	Datum	Other	Shelby	Tube

Groundwater Readings

Date	Time	Depth	Casing	Stab. Time
6/29/98				

Depth	Casing Blows	No.	Pen./Rec.	Depth (ft)	Blows/6"	Field Test Data	Sample Description and Classification	Stratum Description	Remarks
	Push	S-1	24/16	0-2	6-11		Medium dense, red/brown fine SAND, some fine Gravel, trace Silt.	FILL	
	22				14-12				
	31								
	24								
5	15								
	Push	S-2	24/0	5-7	2-1		No Recovery		
	Push				2-1				
	Push								
	Push								
10	Push								
	Push	S-3	24/0	10-12	2-1		No Recovery		
	Push				1-1				
	Push	S-4	24/12	12-14	4-4		Medium dense, red/ brown fine to medium SAND, trace Silt (has odor)		
	166				10-8				
15	35							15'	
	Push	S-5	24/14	15-17	5-3		Soft, grey, Organic CLAY, trace Sea Shells	ORGANIC CLAY	
	Push				1-2				
	Push								
	Push								
20	Push								
	Push	S-6	24/14	20-22	WOH-1		Very soft, grey, Organic CLAY, trace Sea Shells		
	Push				1-1				
	Push								
	Push								
25	Push								
	Push	S-7	24/24	25-27	WOH-		Very soft, grey, Organic CLAY, trace Sea Shells		
	Push				-/24"				
	Push	S.T.	24/23	27-29					
	Push								
30	Push	S-8	24/24	29-31	1-2		Very soft, grey, Organic CLAY, trace Sea Shells.		
					1-1				

REMARKS

Stratification lines represent approximate boundaries between soil types, transitions may be gradual. Water level readings have been made at times and unde conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were madeBoring No.: GZ-11

GZA GEOENVIRONMENTAL, INC.
Engineers and Scientists
27 Naek Road
Vernon, Connecticut 06066
(860) 875-7655

EXPLORATION DATA
PROPERTY OF GZA GEOENVIRONMENTAL, INC.

Boring No.:	GZ-11
Page:	2 OF 2
File No.:	41802
Checked By:	AJ

Boring Co.	GZA GeoEnvironmental		
Foreman	R. Holman		
GZA Representativ	A. Augustine		
Date Start	6/29/98	Date End	6/29/98
Location	See Plan		
G.S. Elevation		Datum	

	Casing	Sampler
Type	Steel	S.S.
I.D./O.D.	4"	2" O.D.
Hammer	300 lbs	140 lb
Hammer F	24"	30"
Other	Shelby	Tube

Groundwater Readings

Date	Time	Depth	Casing	Stab. Time
6/29/98				

Depth	Casing Blows	Sample Information: No.	Pen./Rec.	Depth (ft)	Blows/6"	Field Test Data	Sample Description and Classification	Stratum Description	Remarks
35								ORGANIC CLAY	
	89	S-9	24/24	35-37	WOH/-		Very loose, grey, Organic CLAY, trace		
	73				24"		Sea Shells, 1/8" loose fine Sand.		
	74								
	92								
40	81							40'	
	130	S-10	24/14	40-42	5-4		Medium dense grey/brown fine to medium		
	82				6-11		SAND, trace Silt.		
	72								
	72							STRATIFIED DRIFT	
45	79								
		S-11	24/16	45-47	5-7		Medium dense red/brown fine SAND,		
					6-7		trace Silt.	47'	
								END OF EXPLORATION	
50									
55									
60									

REMARKS

Stratification lines represent approximate boundaries between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: GZ-11

ATTACHMENT C: LABORATORY ANALYSES

LABORATORY TESTING DATA SHEET

Project Name: I-95 NEW HAVEN HARBOR PROJECT
NEW HAVEN, CT.

Project No.: L16173
Assigned By: R. BORJESON
Reviewed By:

Project Engineer: D. SCHULZE
Date: May-00
Date Reviewed:

Boring/ Test Pit No.	Sample No.	Depth ft.	Lab No.	Identification Tests: Water Content %	LL %	PL %	Sieve -200 %	Hyd -2μ %	ORG %	G_s	Dry unit wt. pcf	Density: γ_d MAX (pcf) W_{opt} (%)	Perme-ability cm/sec	Strength Tests: Torvane or Type Test	σ_c psf	Failure Criteria	$\sigma_1 - \sigma_3$ or τ psf	Strain %	Consol.: $\frac{C_c}{1+e_0}$	Laboratory Log and Soil Description
PB-5	SS-9	40-42	133		71	35	92	22												Grey Organic SILT, trace Sand
	SS-16	75-77	134				82	3												Red-Brown SILT, little (+) fine Sand
	SS-22	105-107	135				98	3												Red-Brown SILT

LABORATORY TESTING DATA SHEET

Project Name I-95 NEW HAVEN HARBOR PROJECT
NEW HAVEN, CT.
Project No. L16173 Assigned By R. BORJESON Reviewed By
Project Engineer D. SCHULZE Date May-00 Date Reviewed

Boring/ Test Pit No.	Sample No.	Depth ft.	Lab No.	Identification Tests: Water Content %	LL %	PL %	Sieve -200 %	Hyd -2μ %	ORG %	G_s	Dry unit wt. pcf	Density: γ_d MAX (pcf) W_{opt} (%)	Perme-ability cm/sec	Strength Tests: Torvane or Type Test	σ_c psf	Failure Criteria	$\sigma_1 - \sigma_3$ or τ psf	Strain %	Consol.: $\frac{C_c}{1+e_0}$	Laboratory Log and Soil Description
PB-9	SS-6	24-26	160		118	47	100	43												Grey Organic SILT of very high plasiticy
	SS-12	54-56	161				8													Brown f-c SAND, little Gravel, trace (+) Silt
	SS-21	99-101	162				90	7												Red-Brown Clayey SILT, trace (+) Sand
	SS-25	120-122	163				95	8												Red-Brown Clayey SILT, trace Sand

LABORATORY TESTING DATA SHEET

Project Name I-95 NEW HAVEN HARBOR PROJECT
NEW HAVEN, CT.

Project No. L16173 Assigned By R. BORJESON Reviewed By

Project Engineer D. SCHULZE Date May-00 Date Reviewed

				Identification Tests								Density		Strength Tests					Consol.	
Boring/ Test Pit No.	Sample No.	Depth ft.	Lab No.	Water Content %	LL %	PL %	Sieve -200 %	Hyd -2μ %	ORG %	G_s	Dry unit wt. pcf	γ_d MAX (pcf) W_{opt} (%)	Perme-ability cm/sec	Torvane or Type Test	σ_c psf	Failure Criteria	$\sigma_1 - \sigma_3$ or τ psf	Strain %	$\frac{C_c}{1+e_0}$	Laboratory Log and Soil Description
PB-7	SS-17	80-82	154				77	5												Red-Brown Clayey SILT, some fine Sand
	SS-20	95-97	155				97	8												Red-Brown Clayey SILT

LABORATORY TESTING DATA SHEET

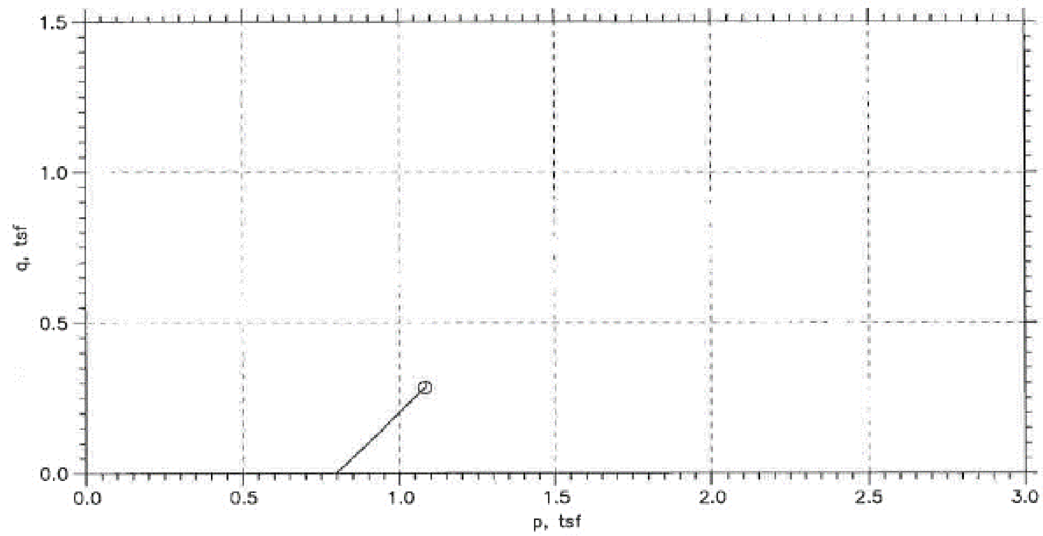
Project Name: I-95 NEW HAVEN HARBOR PROJECT
NEW HAVEN, CT.

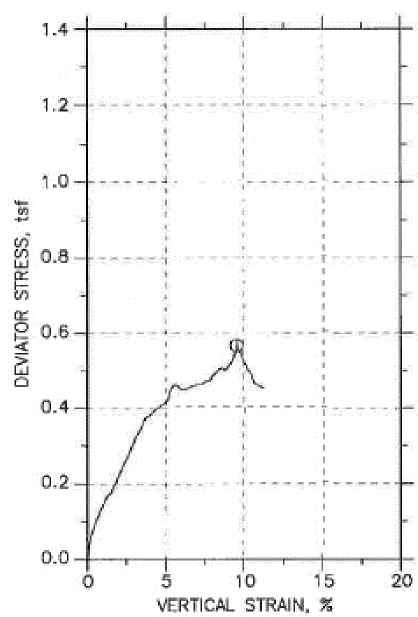
Project No.: L16173   Assigned By: R. BORJESON   Reviewed By:

Project Engineer: D. SCHULZE   Date: May-00   Date Reviewed:

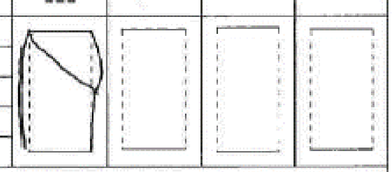
				Identification Tests								Density		Strength Tests					Consol.	
Boring/ Test Pit No.	Sample No.	Depth ft.	Lab No.	Water Content %	LL %	PL %	Sieve -200 %	Hyd -2μ %	ORG %	G_s	Dry unit wt. pcf	γ_d MAX (pcf) W_{opt} (%)	Perme-ability cm/sec	Torvane or Type Test	σ_c psf	Failure Criteria	$\sigma_1 - \sigma_3$ or τ psf	Strain %	$\frac{C_c}{1+e_0}$	Laboratory Log and Soil Description
PB-9	UP-1	22-24	153		Average Total Unit Weight (22.0-23.9') = 88.2 Pcf															
		22.2		98.9										Tv= 0.15 tsf						Dk.Grey Organic SILT of very high plasticity, soft consisteny, trace fine Sand, trace Shell
		22.4-22.6		95.4	117	52														
		22.6-22.7		97.8							46.6								0.27	
		22.7		95.7										Tv= 0.17 tsf						
		22.7-23.2		94.4							47.5			UU	1800	P/A MAX	845	7.0		
		23.3		95.7										Tv= 0.17 tsf						
		23.3-23.8		Save																

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D2850





Symbol	⊙				
Sample No.	U-1				
Test No.	UU-2				
Depth	22-24 ft				
Tested by	md				
Test Date	07/30/10				
Checked by	jdt				
Check Date	08/03/10				
Diameter, in	2.87				
Height, in	5.8				
Water Content, %	68.8				
Dry Density, pcf	56.63				
Saturation, %	94.0				
Void Ratio	1.98				
Confining Stress, tsf	0.8				
Undrained Strength, tsf	0.2827				
Max. Dev. Stress, tsf	0.5653				
Strain at Failure, %	9.55				
Strain Rate, %/min	1				
Estimated Specific Gravity	2.7				
Liquid Limit	---				
Plastic Limit	---				
Plasticity Index	---				

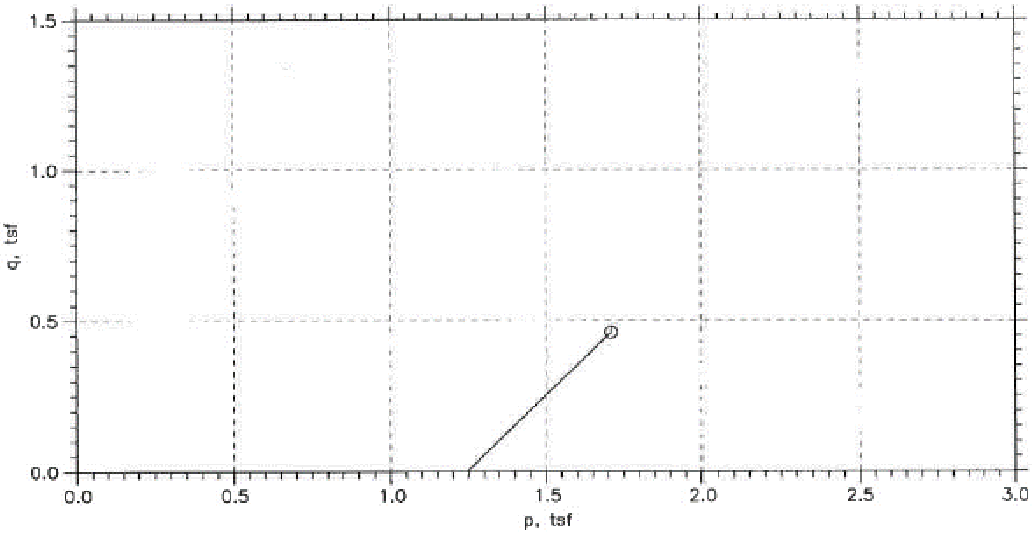


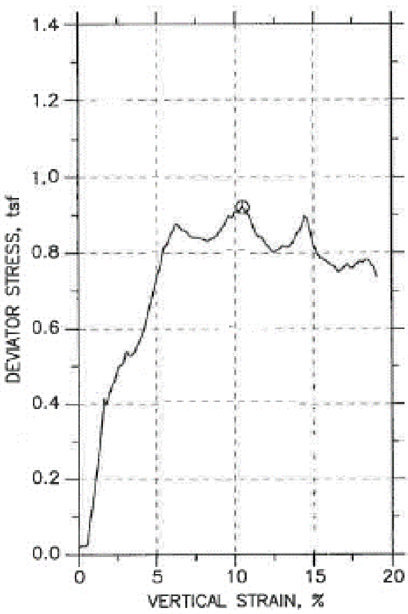
GeoTesting express
a subsidiary of Geocomp Corporation

Project: Long Wharf Park
Location: New Haven, CT
Project No.: GTX-10042
Boring No.: LB-1
Sample Type: tube
Description: Moist, dark gray silt
Remarks: System A
Phase calculations based on start and end of test.

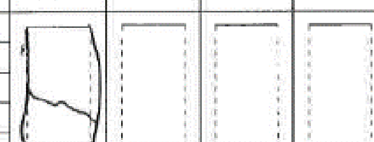
Tue, 03-AUG-2010 11:46:07

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D2850





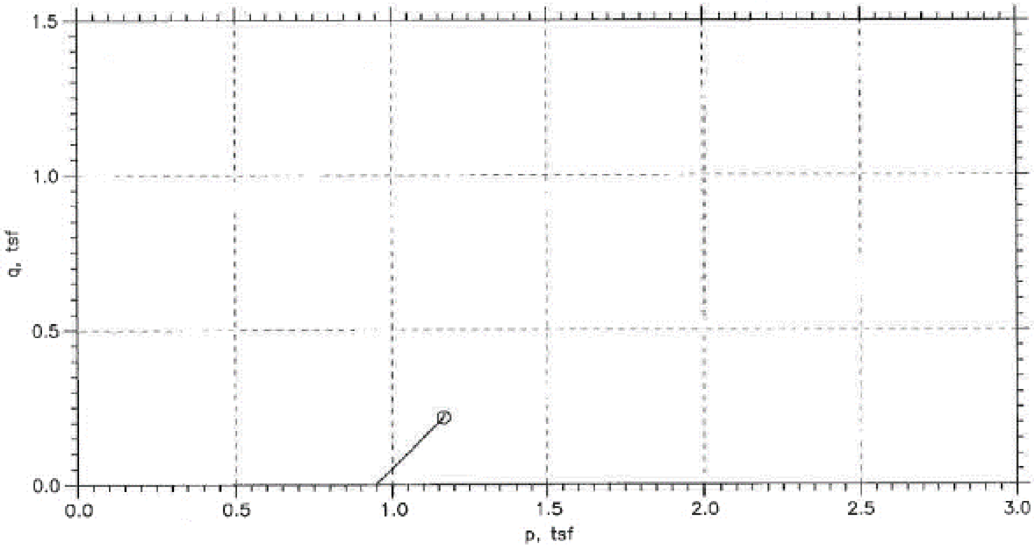
Symbol	⦶			
Sample No.	U-2			
Test No.	UU-3			
Depth	40-42 ft			
Tested by	md			
Test Date	07/30/10			
Checked by	jdt			
Check Date	08/03/10			
Diameter, in	2.87			
Height, in	5.99			
Water Content, %	52.1			
Dry Density, pcf	66.49			
Saturation, %	91.7			
Void Ratio	1.54			
Confining Stress, tsf	1.25			
Undrained Strength, tsf	0.4592			
Max. Dev. Stress, tsf	0.9185			
Strain at Failure, %	10.5			
Strain Rate, %/min	1			
Estimated Specific Gravity	2.7			
Liquid Limit	---			
Plastic Limit	---			
Plasticity Index	---			

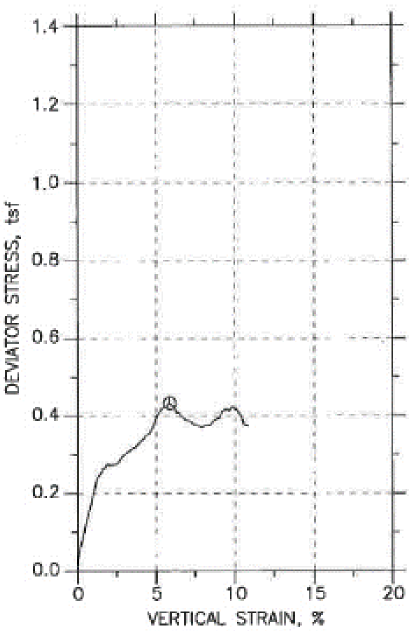


GeoTesting express, a subsidiary of Geocomp Corporation	Project: Long Wharf Park
	Location: New Haven, CT
	Project No.: GTX-10042
	Boring No.: LB-1
	Sample Type: tube
	Description: Moist, dark gray silt
	Remarks: System A
	Phase calculations based on start and end of test.

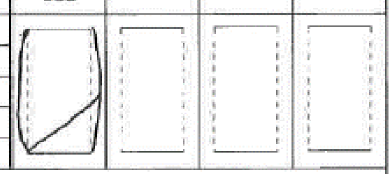
Tue, 03-AUG-2010 11:46:38

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D2850





Symbol	⊘			
Sample No.	U-1			
Test No.	UU-1			
Depth	26-28 ft			
Tested by	md			
Test Date	07/30/10			
Checked by	jdt			
Check Date	08/03/10			
Diameter, in	2.87			
Height, in	5.98			
Water Content, %	76.1			
Dry Density, pcf	52.51			
Saturation, %	93.0			
Void Ratio	2.21			
Confining Stress, tsf	0.95			
Undrained Strength, tsf	0.216			
Max. Dev. Stress, tsf	0.4319			
Strain at Failure, %	5.88			
Strain Rate, %/min	1			
Estimated Specific Gravity	2.7			
Liquid Limit	---			
Plastic Limit	---			
Plasticity Index	---			



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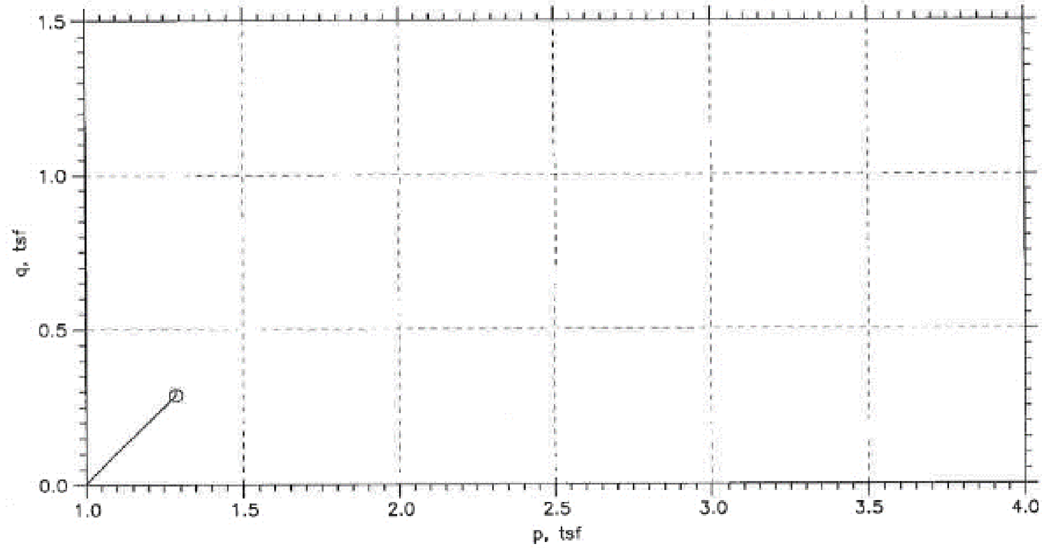
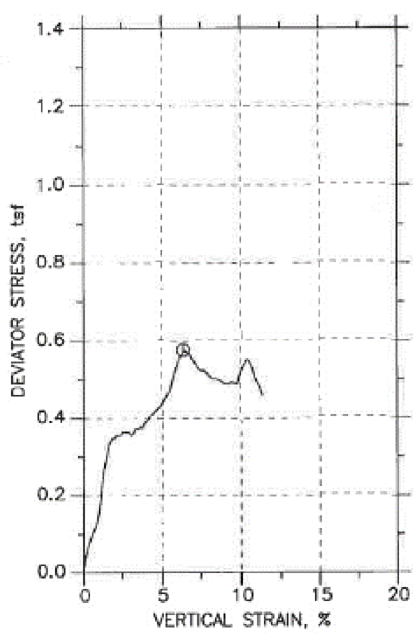
Project: Long Wharf Park
Location: New Haven, CT
Project No.: GTX-10042
Boring No.: LB-4
Sample Type: tube
Description: Moist, dark gray silt
Remarks: System A

Phase calculations based on start and end of test.

Tue, 03-AUG-2010 11:45:34

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D2850





Symbol	①			
Sample No.	U-1			
Test No.	UU-4			
Depth	32-34 ft			
Tested by	md			
Test Date	07/30/10			
Checked by	jdt			
Check Date	08/03/10			
Diameter, in	2.87			
Height, in	5.75			
Water Content, %	74.9			
Dry Density, pcf	52.63			
Saturation, %	91.9			
Void Ratio	2.2			
Confining Stress, tsf	1			
Undrained Strength, tsf	0.2866			
Max. Dev. Stress, tsf	0.5733			
Strain at Failure, %	6.35			
Strain Rate, %/min	1			
Estimated Specific Gravity	2.7			
Liquid Limit	---			
Plastic Limit	---			
Plasticity Index	---			

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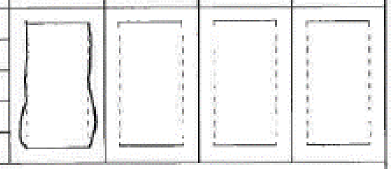
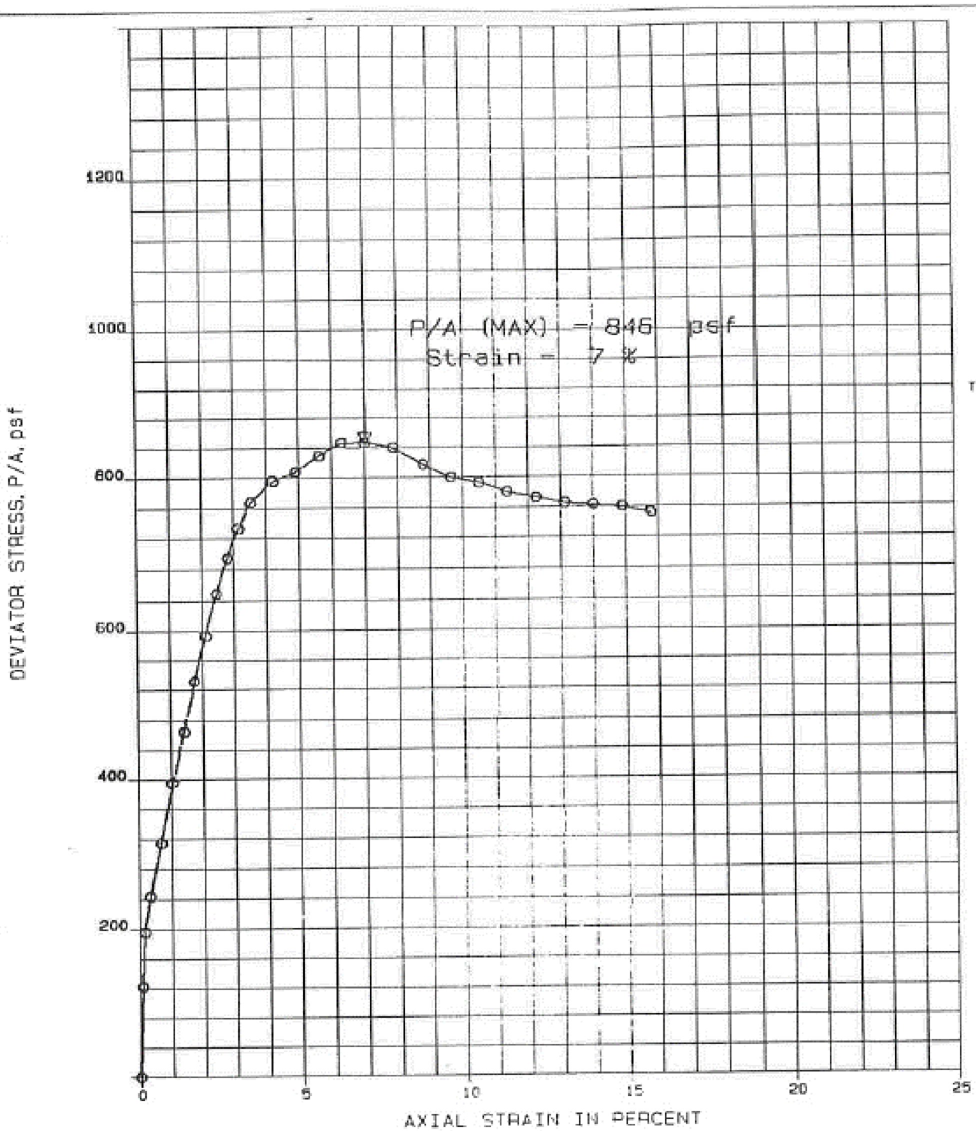
Project: Long Wharf Park
Location: New Haven, CT
Project No.: GTX-10042
Boring No.: LB-6
Sample Type: tube
Description: Moist, dark gray silt
Remarks: System A



Phase calculations based on start and end of test.

Tue, 03-AUG-2010 11:47:31



SKETCH AT FAILURE

TEST NO. 153.0.1

TEST NO./SYMBOL	INITIAL CONDITIONS			CONDITIONS BEFORE SHEAR				FINAL CONDITIONS		RATE OF STRAIN, PERCENT PER MINUTE
	INITIAL WATER CONTENT, %	INITIAL DRY UNIT WEIGHT, pcf	SAMPLE HEIGHT & DIAMETER, IN.	CONFINING STRESS, psf	FINAL BACK PRESSURE	VOLUMETRIC STRAIN, %	PORE PRESSURE RESPONSE, %	FINAL WATER CONTENT, %	FINAL DRY UNIT WEIGHT	
153.0	94.4	47.5	5.71 2.83	1800.	-	-	-	92.2	-	0.50

SOIL DESCRIPTION: **Grey Organic SILT**

LIQUID LIMIT 117 % PLASTIC LIMIT 52 % SPECIFIC GRAVITY 2.62

I-95 NEW HAVEN HARBOR PROJECT
NEW HAVEN, CT.
TRIAXIAL COMPRESSION TESTS (UU)

BORING NO. PB-9
SAMPLE UP-1
DEPTH 22.7-23.2'
TECH MST
REVIEWER

TEST SERIES NO 153
DATE MAY 00
FILE L16173

FIGURE

GZA GEOENVIRONMENTAL, INC.
ENGINEERS AND SCIENTISTS