Date: 09-16-2019

MEMORANDUM FOR RECORD

SUBJECT: Coastal Texas Study: Documentation of PDT & Vertical Team Meeting Discussion on Adequacy of Available Geotechnical Data.
MEETING TYPE: WEBEX Meeting
DATE: 09-06-2019
TIME: 1200-1300 (CT)
ATTENDEES: Cepero, Carlos E CIV USARMY CESWD (USA); Bateman, Vanessa C CIV USARMY CEHQ (USA); Boothby, David B Jr CIV USARMY CESWG (US); Sterling, Michael C CIV USARMY CESWD (US); Mike Diaz CIV USARMY CESWG (US), Harper, Brian K CIV USARMY CESWF (USA); Das, Himangshu S CIV USARMY CESWG (USA); Tharmendira, Ratnam I CIV USARMY CESWG (USA).

DISCUSSION SUMMARY: The Project Technical Lead hosted the meeting. The Project Geotechnical Lead conducted a power point presentation as the opening event of the subject discussion. The pdf copy of the powerpoint slides is attached with this document. At the end of the presentation the attendees provided suggestions and conclusions as summarized below;
COMMENTS AND CONCLUSION FROM ATTENDEES:

<u>PDT Inputs on Subject Discussion (See Attachment for more details)</u>.

- PD The available geotechnical data is adequate for the subject study level design. This will allow the PDT to perform acceptable study level design and to develop an acceptable study level cost estimate.
- The Geotechnical Risk levels evaluated on Project Cost Estimate as follows for major structural components:
  a) Surge Barrier System - Medium level risk
  b) Dune System - Low
  C) Ring Levee System - Medium level risk
- The current study level geotechnical design adopts appropriate risk mitigation strategies, including reasonable engineering assumptions and considerations to meet the subject study requirements. Therefore, the actual foundation cost should be within the acceptable study level cost estimate, when considering a contingency commensurate with the associated risk.
- Geotechnical Risk mitigation strategies will be as follows:
  a) Adopting the lower-bound soil strength data from available soil borings within the vicinity of the proposed structure for Axial pile capacity estimate.
  b) Pile type selection will consider the upper bound evaluation of potential hard-driving conditions.
  c) Study level design's Lateral pile resistance will be relying on capacity of battered piles only.
  d) Sensitivity analysis on using upper - and lower – bound geotechnical parameters for pile foundation design will be performed to estimate the potential change in final pile length to support the project cost estimate at the study level.
- Comprehensive level geotechnical investigations and pile drivability/ pile load testing during the PED phase will be specified as mandatory requirements in the final study report.

<u>Cepero, Carlos E CIV USARMY CESWD (USA):</u>

- The risk levels chosen by the PDT for the foundation cost estimate is acceptable (not lower than moderate).
- PED phase shall consider additional geotechnical investigations for the deep foundation design. Pile drivability study and vibration monitoring (Example: Near Fort Travis) shall be part of the PED, and it should be specified in the final study report.
- Vibrations impacts on wild animals (dolphins, manatees, etc.) in the area
- Sensitivity analysis evaluating different geologic cross sections, representative of variations in site conditions across the bay entrance (in essence, at least two geologic cross sections will be modeled)
- Evaluation, during PED, of slightly different (smaller) size piles, e.g. 60", 54", 48" because of potential installation issues and contractors' limitations (i.e. experience, equipment, etc.) when installing very large diameter driven piles.

Bateman, Vanessa C CIV USARMY CEHQ (USA):

- The current geotechnical team's design approach is considered as reasonable and acceptable to meet the study requirements.
- The Geotechnical team shall provide inputs to the cost engineer to estimate potential cost change for the foundation elements based on upper- and lower- bound geotechnical parameters.

ATTACHMENT: Coastal Texas Study Geotechnical Presentation 09-06-19

Prepared by: THARMENDIRA.RATNAM.I.1534262511 Digitally signed by THARMENDIRA.RATNAM.I.1534262511 Date: 2020.12.14 15:15:04 -06'00'

Ratnam I. Tharmendira, P.E., G.E., PMP

Reviewed by: CEPERO.CARLOS.ENRIQUE.1258332748 Digitally signed by CEPERO.CARLOS.ENRIQUE.1258332748 Date: 2020.12.16 08:33:37 -06'00'

Carlos E. Cepero, P.E.

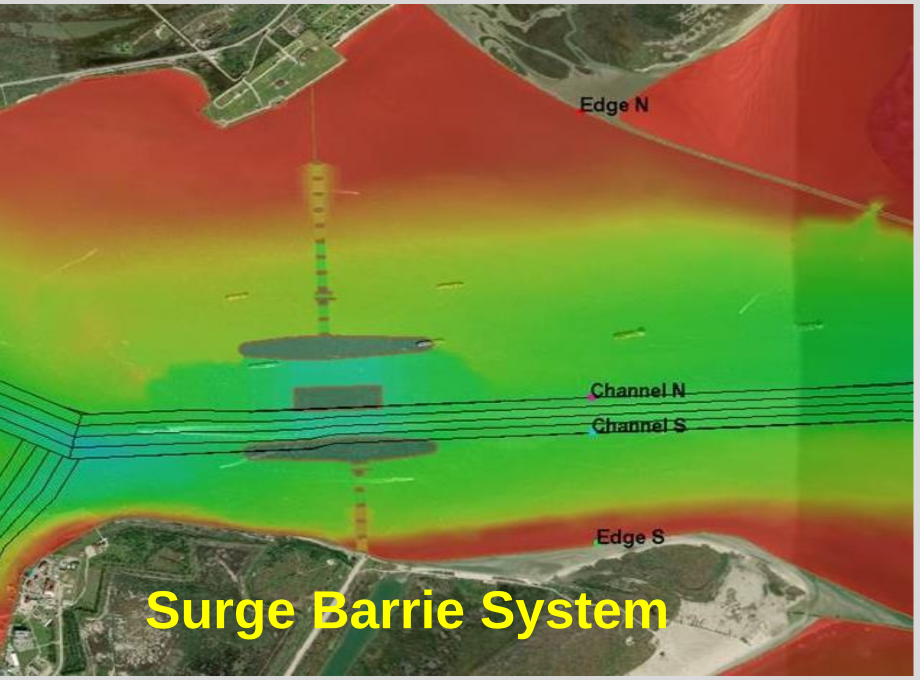
BATEMAN.VANESSA.C.1403662417 Digitally signed by BATEMAN.VANESSA.C.1403662417 Date: 2020.12.18 11:17:27 -05'00'

Vanessa C. Bateman, P.E., P.G, D.GE

ATTACHMENT: Coastal Texas Study Geotechnical Presentation 09-06-19

COASTAL TEXAS STUDY

RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR THE STUDY LEVEL GEOTECHNICAL DESIGN



By

Ratnam. I. Tharmendira, P.E., G.E., PMP, SWG & the PDT

Sept 06, 2019

COASTAL TEXAS STUDY

RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR THE STUDY LEVEL GEOTECHNICAL DESIGN

OBJECTIVE OF THE PRESENTATION:

- RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA
- RISK MITIGATION STRATEGY FOR THE STUDY LEVEL GEOTECHNICAL DESIGN

GEOTECHNICAL RISK ASSESSMENT FINDINGS

- Design of Deep Foundation system using available geotechnical data is one of the critical tasks for the subject study.
- The current feasibility level geotechnical design is performed based on a limited (preliminary level) geotechnical data due to the nature of the current design type (Feasibility Level).
- The available geotechnical data is adequate for the subject study level design. This will allow the PDT to perform acceptable study level design and to develop an acceptable study level cost estimate.
- The current study level geotechnical design adopts appropriate risk mitigation strategies, including reasonable engineering assumptions and considerations to meet the subject study requirements.
- The current design associates with a medium level risk induced by potential uncertainties on subsurface conditions. This risk level is acceptable, and a similar risk level which is encountered commonly in feasibility studies for large-scale civil projects.
- In general, Large-scale civil projects are associated with a significant level of risk induced by the change in subsurface conditions regardless of the availability of a comprehensive level of geotechnical investigation data. Applying pile drivability/ pile load testing (Static and CAPWAP) during the construction phase can minimize the subject risk on deep foundation design.
- Comprehensive level geotechnical investigations and pile drivability/ pile load testing during the PED will be specified as mandatory requirements in the final study report.

DETAILS FOR SUBJECT RISK ASSESSMENT

- As Summarized in the Remaining Presentation slides

COASTAL TEXAS STUDY

RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR THE STUDY LEVEL GEOTECHNICAL DESIGN

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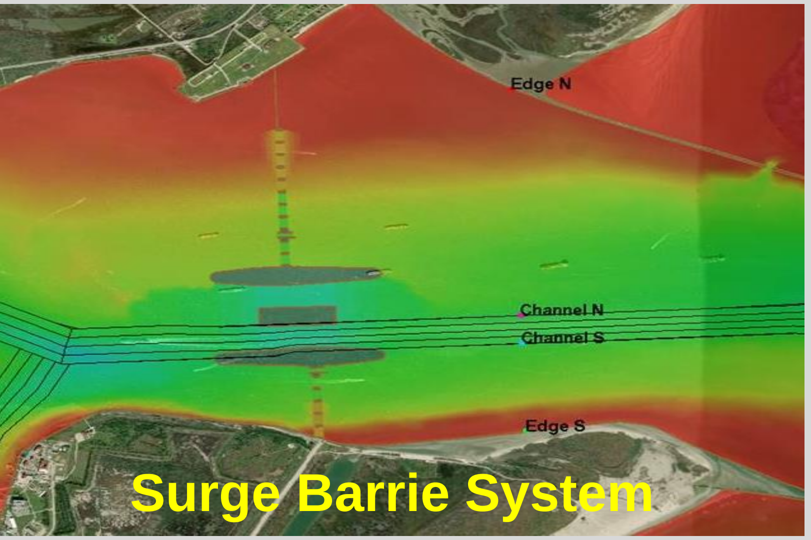

Major Components	Proposed Structural Elements	Considered Foundation Elements	Major Reference Document for Geology & Geotechnical Data
Surge Barrier System	Combi-wall, Cutoff El.- variable Vertical Lift Gate, sill El. -20.0, Deep Vertical Lift Gate, sill El. -40.0, 125' Sector Gate, Sill El. -40.0, 650' Navigation Gate, Sill El. -60.0, Shallow Water Combi Walls	Deep Foundation System 24- to 36- inch Steel Pipe Piles (Vertical and Battered) 48- to 66- inch dia. Precast- Pre-Stressed Pipe Piles Cellular bulkhead structure using Sheet Piles for Artificial Islands for 650’ Navigation Gates	• GCCPRD Phase 4 Report dated October 18, 2017 • Texas Coast Hurricane Study Galveston Harbor Channel Crossing October 31, 1967
Dune System	N/A	Engineered Earth Fill for Foundation Preparation (if needed)	• GCCPRD Phase 4 Report dated October 18, 2017
Ring Levee System	T-Wall, Combi-Wall, Levees, Sea Wall, Road/Railroad Crossings, Navigation/Circulation/Access Gates, Pump Stations, Drainage Structures	Deep Foundation System 24- to 36- inch Steel Pipe Piles (Vertical and Battered)	• GCCPRD Phase 4 Report dated October 18, 2017

GCCPRD: Gulf Coast Community Protection and Recovery District (GCCPRD)
Coastal Texas Protection and Restoration Feasibility Study report refers to the Appendix H (FUGRO 2017) of the GCCPRD Phase 4 Report dated October 18, 2017 as the primary reference material for the available Geotechnical data for the subject study project.

COASTAL TEXAS STUDY

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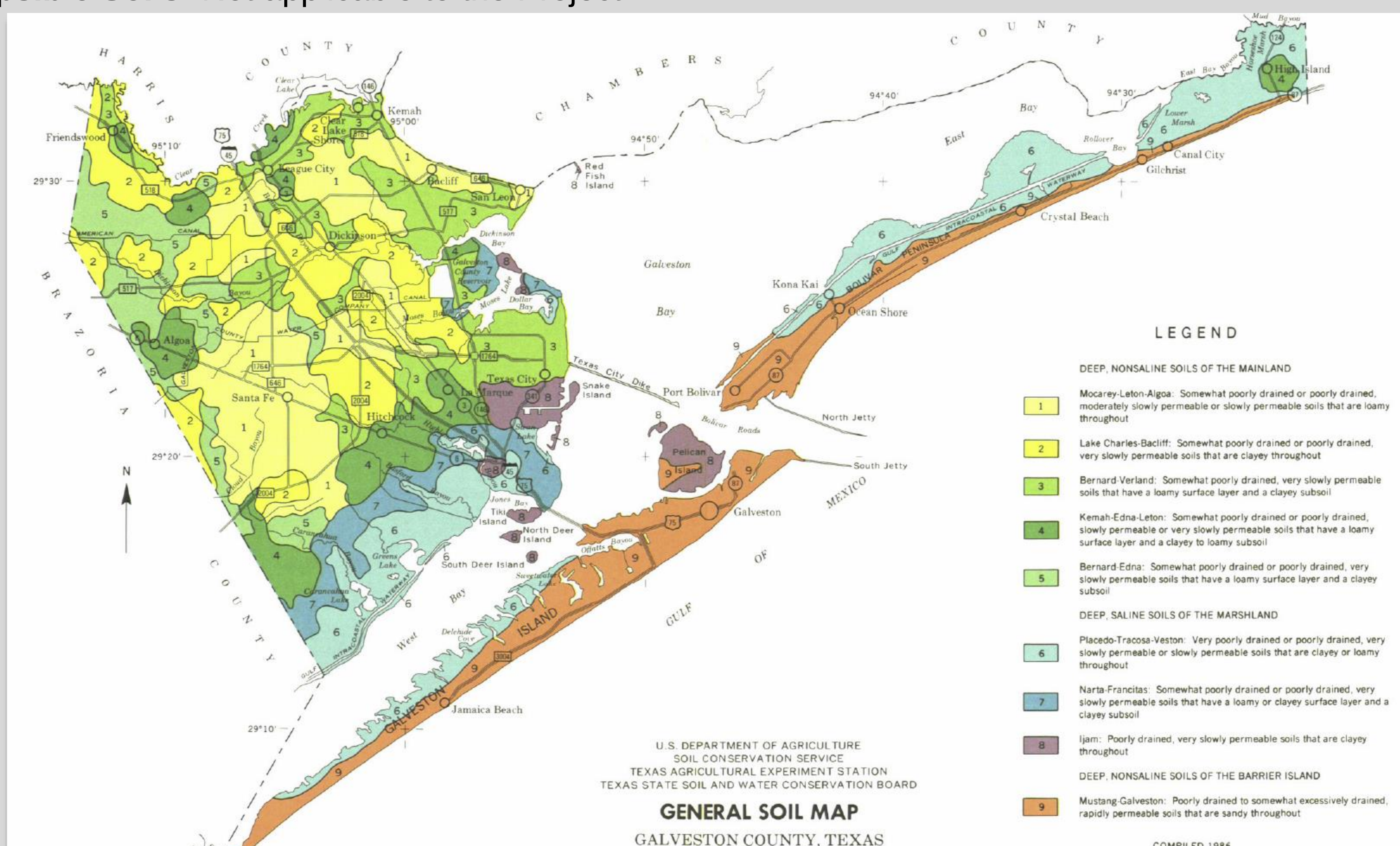
Engineering Geology for the Project is Adequately Evaluated and Documented

- Coastal Texas Protection and Restoration Feasibility Study report refers to the Appendix H (FUGRO 2017) of the GCCPRD Phas 4 Report dated October 18, 2017as the primary reference material for the available Geotechnical data for the subject study project.
- The Relevant Engineering Geology for the study area including **Potential Geologic Hazards** were evaluated and are presented in the subject reference report.

Surface Faulting – No Seismic hazards, and the project site is not in proximity to known growth faults.
Subsidence – No significant subsidence in the future if groundwater pumpage and oil and gas withdrawal are maintained at current levels.
Expansive Soils – Applicable to Shallow Foundation elements, replace upper 2-foot of soils with engineered fill.
Karst - Not applicable to the Project
Collapsible Soils- Not applicable to the Project



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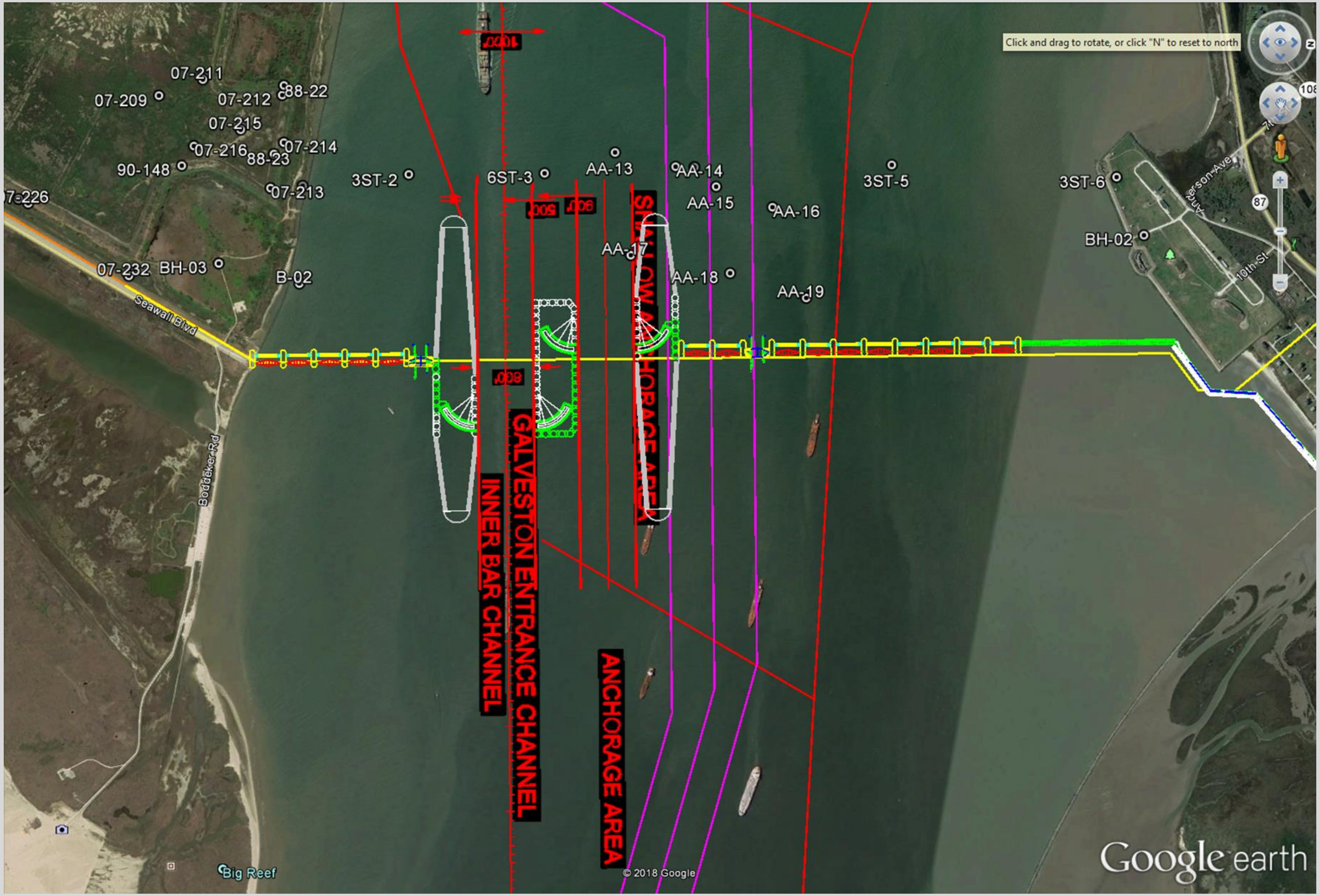

Surge Barrier System- Available Geotechnical Borings

COASTAL TEXAS STUDY

RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR THE STUDY LEVEL GEOTECHNICAL DESIGN

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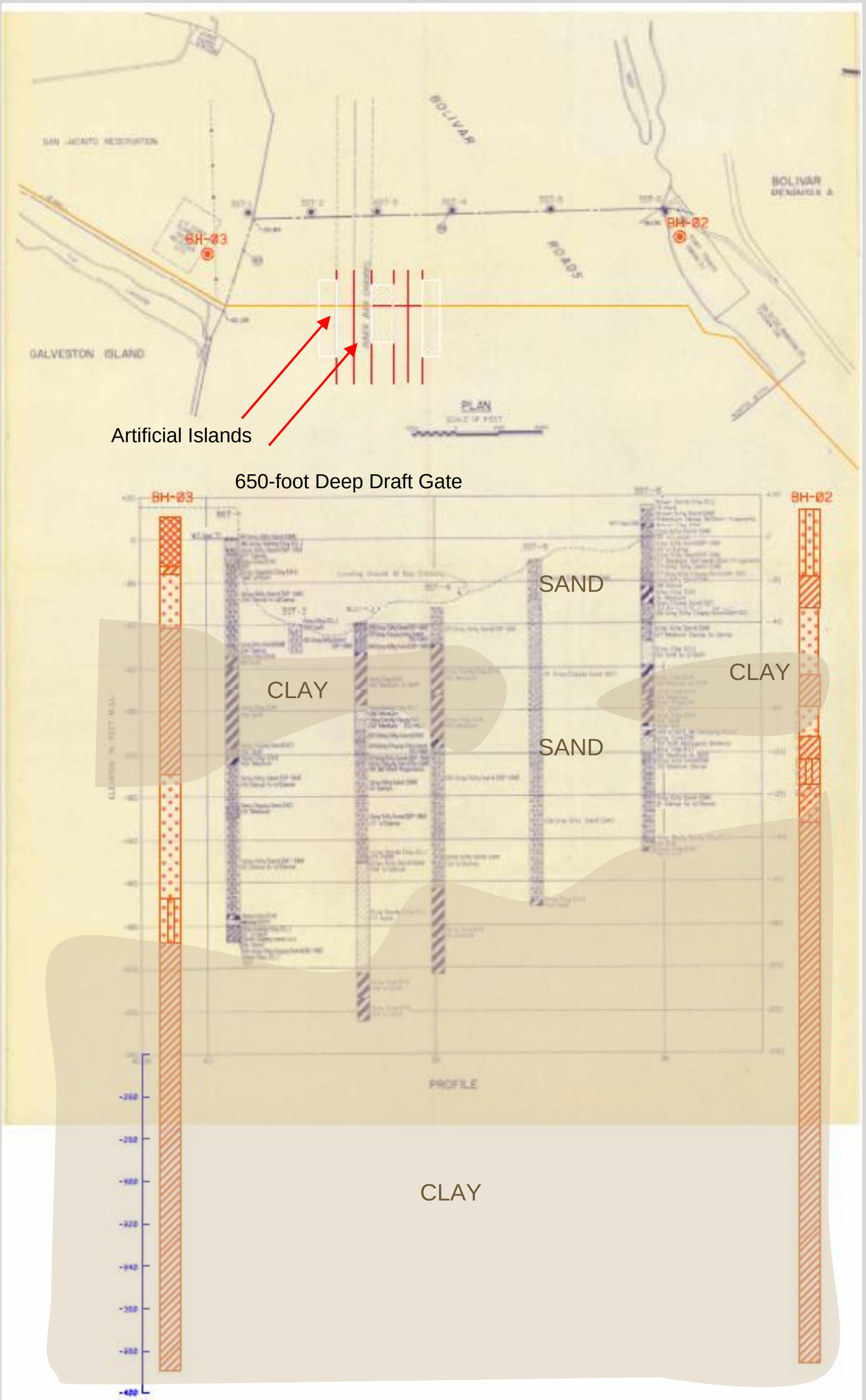
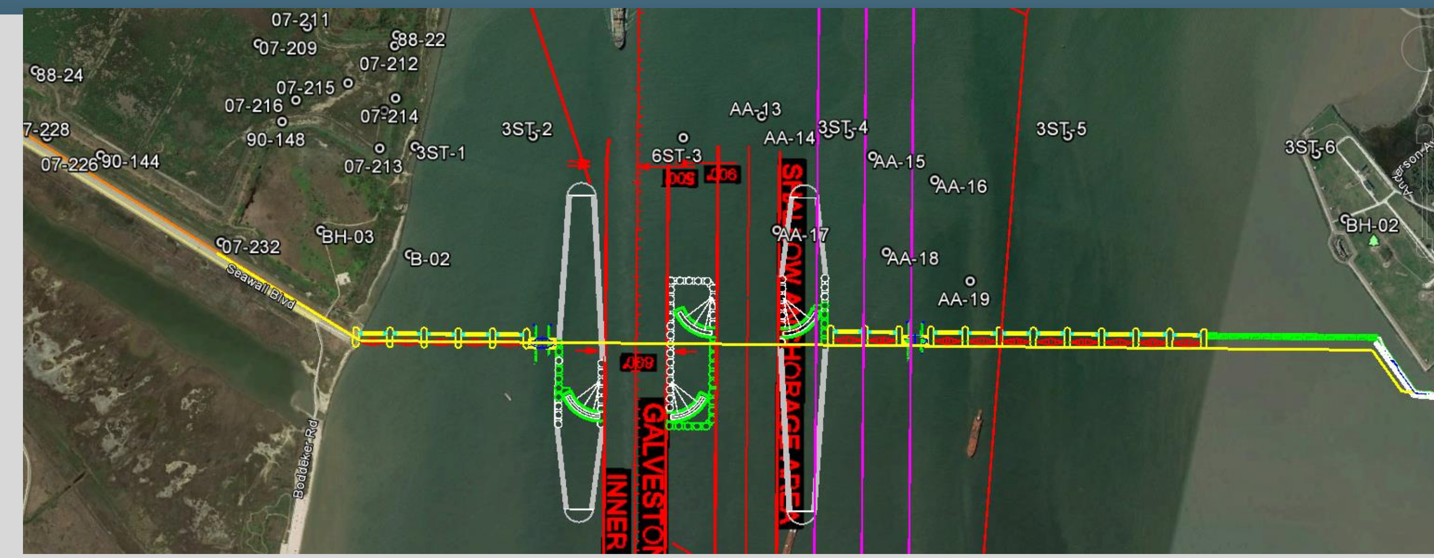
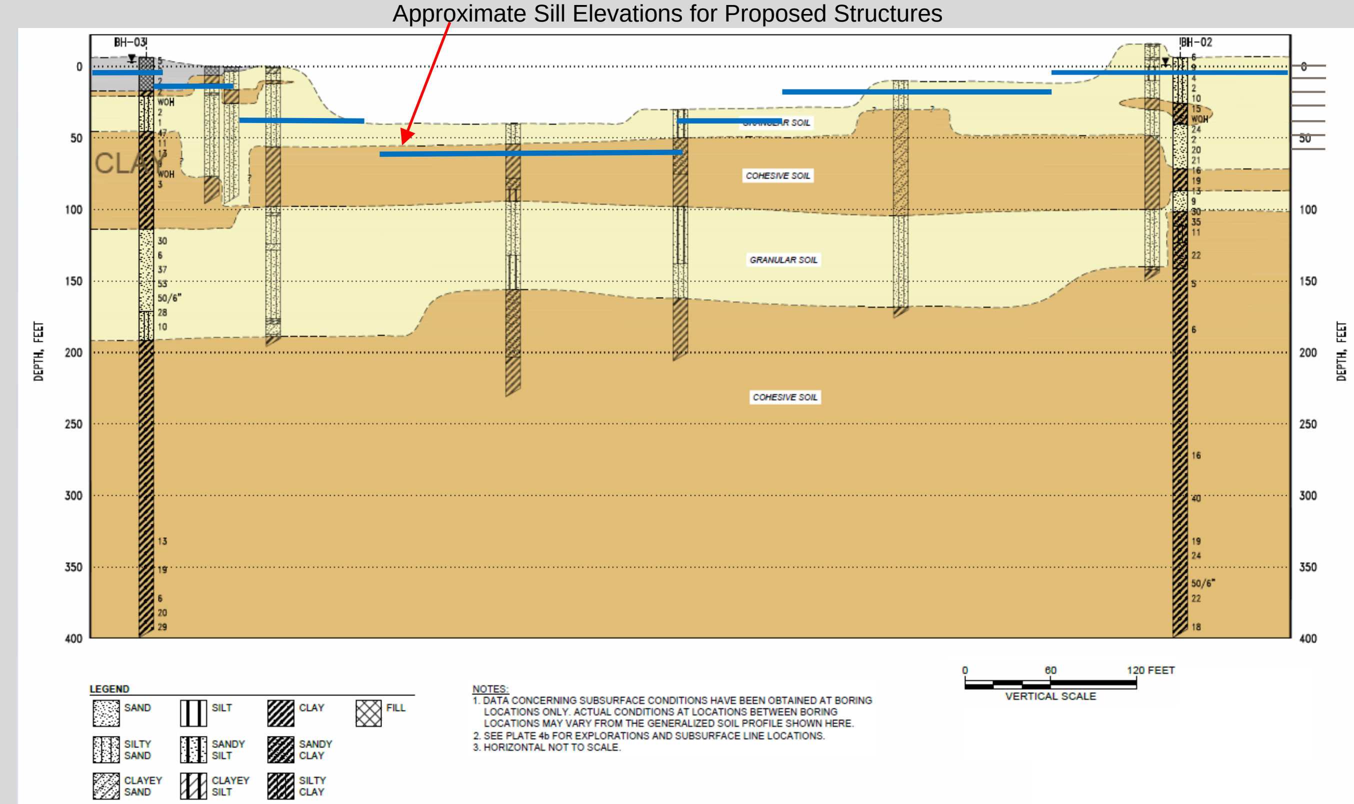




Approximate Sill Elevations for Proposed Structures



- **Approximate length of the Surge barrier System is 11 000 feet, Available deep soil borings (depths vary between 140 to 400 feet) are 7; adequate number of deep borings for the current study level geotechnical design.**
- **Geotechnical Soil Borings including Laboratory Testing Results are available from the following sources.**

a) 3ST-1, 3ST-2, 6ST-3, 3ST-4, 3ST-5, 3ST-6 Soil Borings (Galveston Entrance Channel Structure1972), Depths up to 200-foot
b) BH-03 and BH-02, Appendix H (FUGRO 2017) of the GCCPRD Phase 4 Report dated October 18, 2017, Depths up to 400-foot

Surge Barrier System- Geotechnical Subsurface Profile and Parameters

COASTAL TEXAS STUDY

RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR THE STUDY LEVEL GEOTECHNICAL DESIGN

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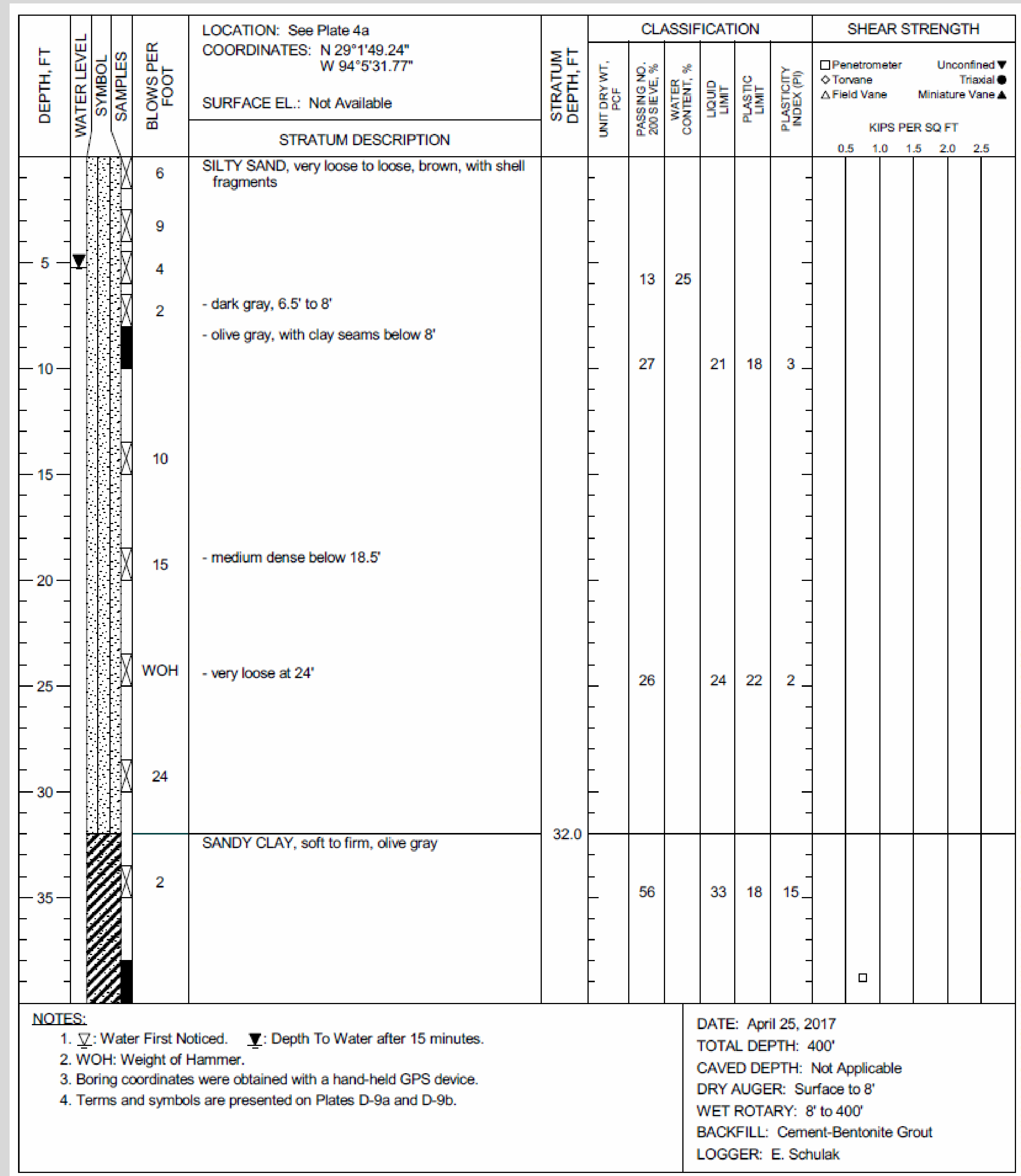
Reference Boring	Depth (feet)	Soil Description	Total Unit Weight (pcf)	Shear Strength Parameters: Undrained Shear Strength (psf)	Shear Strength Parameters: Friction Angle (degrees)	Laboratory Data: Liquid Limit (%)	Laboratory Data: Plasticity Index (%)	Laboratory Data: Water Content (%)	Raw SPT Blow count
BH-02	0 to 47	Loose Sand/Soft Clay	110	N/A	N/A	21 to 33	2 to 15	25	2 to 24
	47 to 73	Medium dense Sand	120		32				13 to 21
	73 to 78	Loose Sand	120		30				9
	78 to 93	Firm to very stiff Clay	120	550 to 2,000		57	43	13	
	93 to 108	Medium dense to dense Clayey Sand	120		32				30 to 35
	108 to 400	Stiff to very stiff Clay	120	1,000 to 2,000		24 to 84	9 to 64	20 to 34	
BH-03	0 to 60	Loose to medium dense Sand /Soft Clay	110	N/A	N/A				
	60 to 120	Firm to very stiff Clay	120	500 to 1,900		60 to 95	44 to 74	28 to 56	
	120 to 178	Medium dense to very dense Sand	120		32				28 to more than 50
	178 to 198	Loose to medium dense Sand	120		30				10 to 28
	198 to 400	Stiff to very stiff Clay	120	1,200 to 2,000		30 to 87	17 to 68	19 to 37	

Appendix H (FUGRO 2017) of the GCCPRD Phase 4 Report dated October 18, 2017

SAMPLE SOIL BORING LOG FROM GCCPRD PHASE 4 REPORT DATED OCTOBER 18, 2017



Surge Barrier System - Geotechnical Subsurface Profile & Geotechnical Parameters

Sample Lab Results from Texas Coast Hurricane Study Galveston Harbor Channel Crossing October 31, 1967

SWG Form 267(C)
28 Jan 1965

PROJECT: Texas coast Hurricane study

LOCATION: Galveston Harbor Channel Crossing

TEST DATA SUMMARY

BORING NO. 6st-3

DATE DRILLED 18 Mar 1966

ELEVATION TOP BORING ______

FIELD NO.	DEPTH	CLASSIFICATION	SYMBOL	CONSISTENCY	POCKET (1) PENETROMETER	STAN. PENET. BLOWS/FT (2)	MOISTURE CONTENT %	DRY DENSITY p.c.f.	L.L.	P.L.	BAR L.S.	SIEVE ANALYSIS: PERCENT GRVL	SAND	FINES	INIT. WT.	ACC. WT. RTND. SIEVE NO. (3): NO. 4	NO. 10	NO. 40	NO. 200
	0.0 to 40.0	Water																	
J-1	40.0 to 41.5	Gray silty sand 40-43	SM SP				25.3				0.0	0	94	6	50	0	0	1	47
X	41.5 to 45.0																		
C-1	45.0 to 47.0	Gray clayey silty sand 43-48	SC SM	S	0.25		37.1	84			3.0	0	56	44	50	0	0	0	28
X	47.0 to 50.0																		
C-2	50.0 to 52.0			VS	0.0		25.9				0.0	5	86	9	701	38	92	173	603
X	52.0 to 55.0																		
C-3	55.0 to 57.0	Gray clay, shell fragments	CH	M	0.75		61.2	65			26.0	0	0	100	50	0	0	0	0
X	57.0 to 60.0	55-78.5																	
C-4	60.0 to 62.0			ST	1.0		60.6	63			25.0	0	0	100	50	0	0	0	0
X	62.0 to 65.0																		
C-5	65.0 to 67.0			ST	1.0		61.9	62			25.0	0	0	100	50	0	0	0	0
X	67.0 to 70.0																		
C-6	70.0 to 72.0			ST	1.0		63.2	62			25.0	0	0	100	50	0	0	0	0
X	72.0 to 75.0																		
C-7	75.0 to 77.0			ST	1.0		61.2	62			23.0	0	4	96	50	0	0	0	2
X	77.0 to 80.0																		
C-8	80.0 to 82.0	Gray sandy clay 78.5-85	CL	M	0.75		25.5	84			9.0	0	44	56	50	0	0	0	33
X	82.0 to 85.0																		
C-9	85.0 to 87.0	Gray sandy clayey silt	CL ML	M	0.75		22.1	104			4.0	0	42	58	50	0	0	0	21
X	87.0 to 90.0	85-90																	
C-10	90.0 to 92.0	Gray silty sand 90-95	SM	M	0.75		20.4	105			0.0	0	78	22	50	0	0	0	39
X	92.0 to 95.0																		
C-11	95.0 to 97.0	Gray clayey silty sand 95-100	SC SM	M	0.5		24.2	98			4.0	0	50	50	50	0	0	0	25
X	97.0 to 100.0																		
C-12	100.0 to 102.0	Gray silty sand 100-105	SP	M	0.5		21.0	105			0.0	0	88	12	50	0	0	0	44
X	102.0 - 105.0																		
C-13	105.0 - 107.0	Gray clayey sand, w/shell	SC SM	S	0.25		32.5	87			7.0	4	60	40	618	25	85	137	371
X	107.0 - 110.0	fragments 105-110																	
J-2	110.0 - 112.0	Gray silty sand 110-124	SM	D		34	21.5				0.0	0	74	26	50	0	1	4	37

KEY: CONSISTENCY — COHESIVE SOILS: VS Very Soft, S Soft, M Medium, ST Stiff, VST Very Stiff, H Hard. CONSISTENCY — COHESIONLESS SOILS: VL Very Loose, L Loose, M Medium, D Dense, VD Very Dense

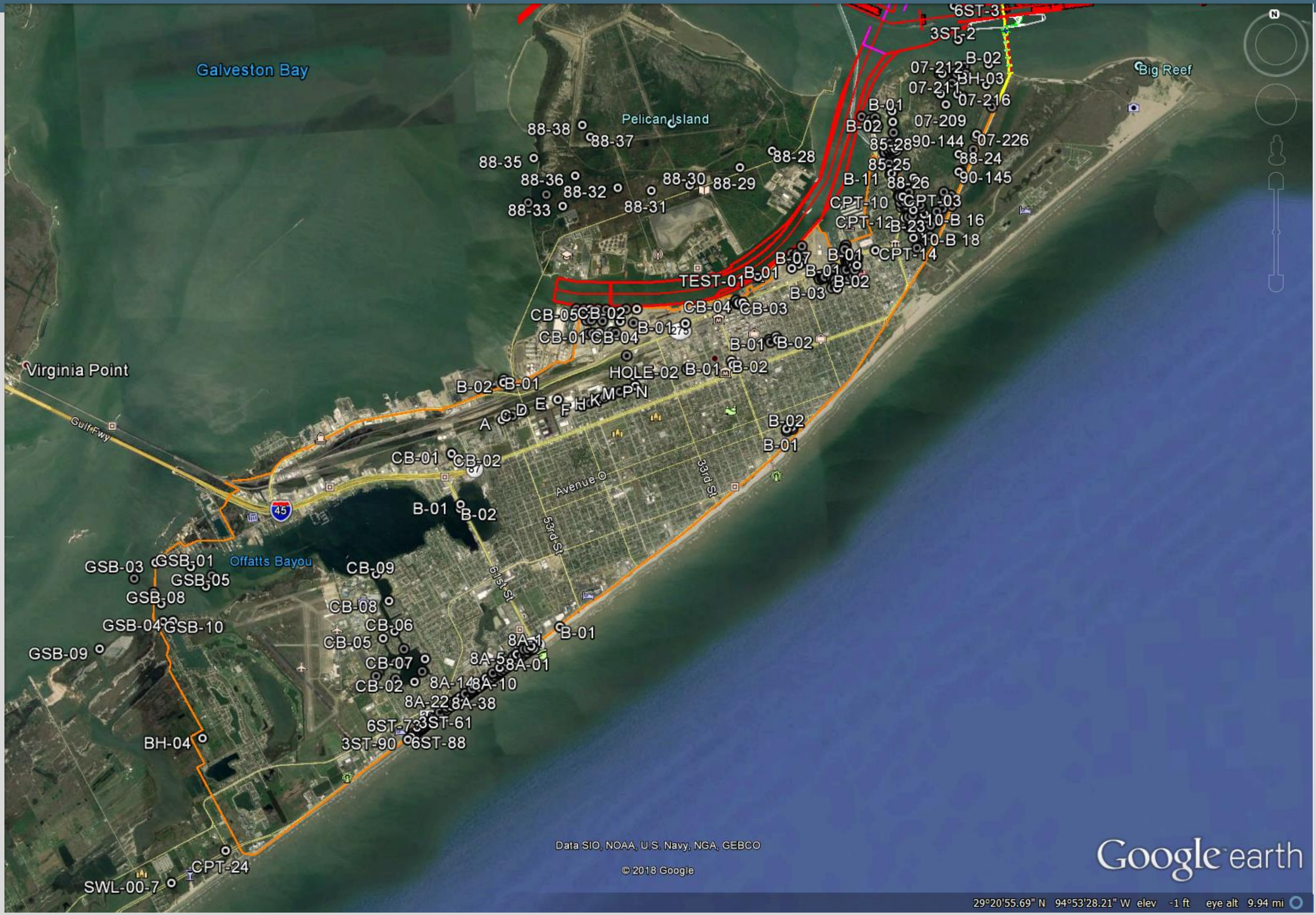
(1) Tons/Sq.Ft. Unconfined Compressive Strength
(2) Split Barrel Sampler
(3) Acc. Wt. Rtnd ÷ Init. Wt. x 100 = % Rtnd.

BORING NO. 6st-3

COASTAL TEXAS STUDY

RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR THE STUDY LEVEL GEOTECHNICAL DESIGN

US Army Corps of Engineers



Geotechnical Soil Borings including Laboratory Results are available from the following sources.

a) CPTs, Appendix H (FUGRO 2017) of the GCCPRD Phase 4 Report dated October 18, 2017, Depths up to 60-foot

Ring Levee System – Available Geotechnical Borings and CPTs

COASTAL TEXAS STUDY

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Geotechnical Soil Borings including Laboratory Results are available from the following sources.

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Southern Dune System – Available Geotechnical Borings and CPTs

COASTAL TEXAS STUDY

RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR THE STUDY LEVEL GEOTECHNICAL DESIGN

US Army Corps of Engineers

Soil Parameters for Slope Stability Analysis – Galveston Ring Levee/ Floodwall Reach and West Galveston Island Reach

Depth (feet)	Soil	Total Unit Weight (pcf)	Short-term (Undrained) Cohesion (psf)	Short-term (Undrained) Friction Angle (degrees)	Long-term (Drained) Cohesion (psf)	Long-term (Drained) Friction Angle (degrees)	Rapid Drawdown Cohesion (psf)	Rapid Drawdown Friction Angle (degrees)
0 to 8	Sand	115	0	25	0	25	0	25
8 to 16	Soft Clay	105	300	0	50	17	75	12
16 to 20	Sand	115	0	30	0	30	0	30
20 to 45	Soft to Firm Clay	105	Top: 300 Bottom: 800	0	Top: 50 Bottom: 200	Top: 17 Bottom: 21	Top: 75 Bottom: 250	Top: 12 Bottom: 16
45 to 60	Stiff Clay	125	1,200	0	250	21	300	16

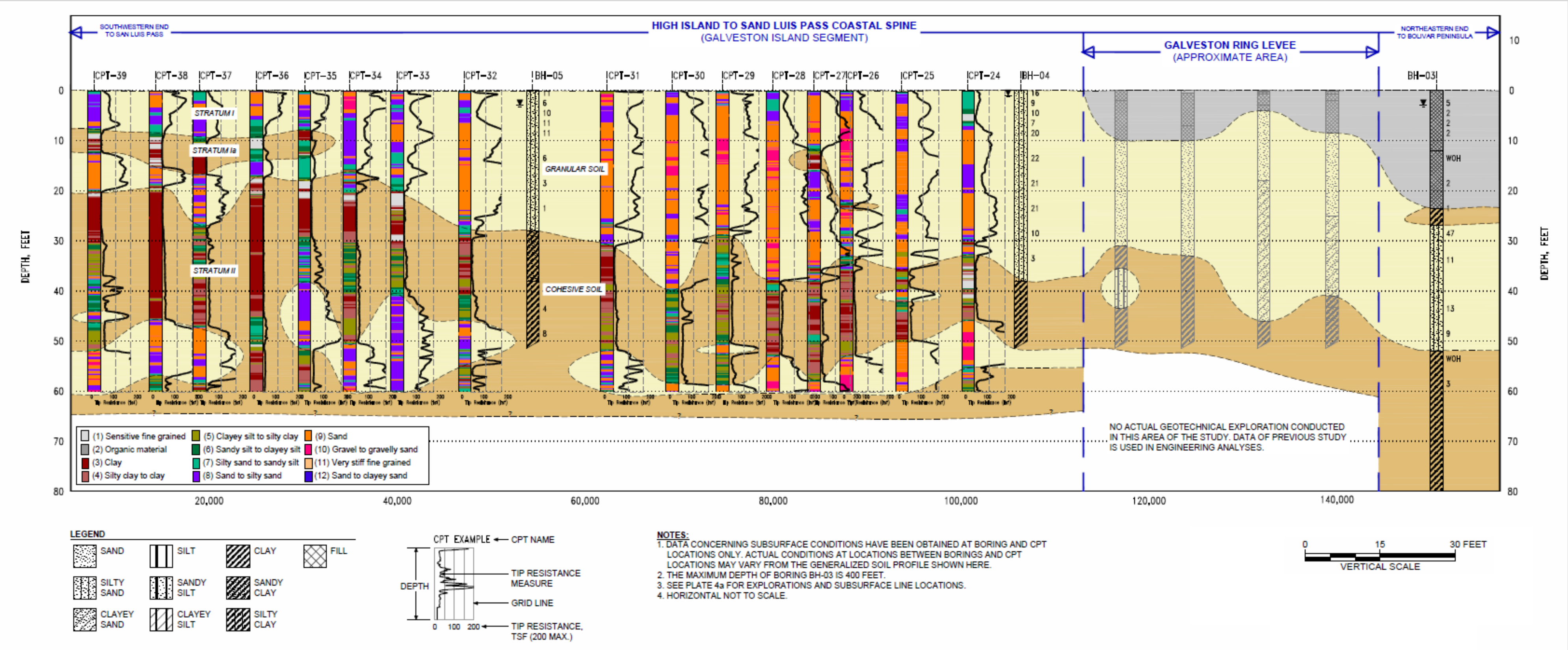
Soil Parameters for Slope Stability Analysis – Compacted Clay (Fat Clay or Lean Clay) Fill

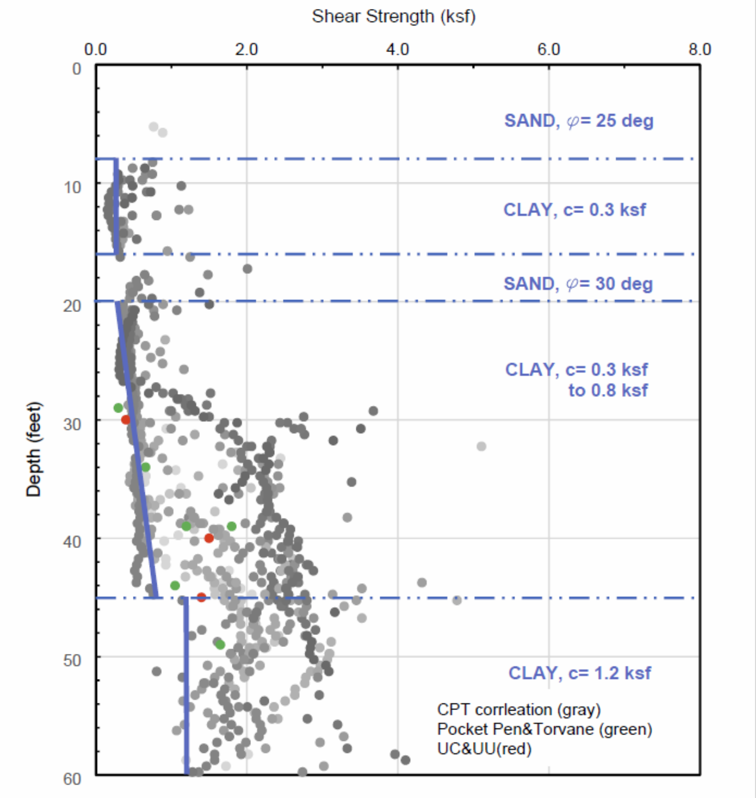
Depth (feet)	Total Unit Weight (pcf)	Short-term (Undrained) Cohesion (psf)	Short-term (Undrained) Friction Angle (degrees)	Long-term (Drained) Cohesion (psf)	Long-term (Drained) Friction Angle (degrees)	Rapid Drawdown Cohesion (psf)	Rapid Drawdown Friction Angle (degrees)
Varies	115	600	0	120	20	170	15

Soil Parameters for Settlement Analysis – Galveston Ring Levee/ Floodwall Reach and West Galveston Island Reach

Depth (feet)	Soil Description	Total Unit Weight (pcf)	Compressibility Parameters CR[1]	RR[2]	OCR[3]	Cv[4] (feet/year)
0 to 8	Loose Sand	115	E[5]: 300 ksf	--	--	300
8 to 16	Soft Clay	105	0.15	0.03	10	7
16 to 20	Medium Dense Sand	115	E[5]: 450 ksf	--	--	300
20 to 45	Soft to Firm Clay	105	0.20	0.02	3	7
45 to 60	Stiff Clay	125	0.20	0.02	3	7

[1] Strained-based compression index.
[2] Strained-based re-compression index.
[3] Over-consolidation ratio.
[4] Coefficient of Consolidation
[5] Modulus of Elasticity





Appendix H (FUGRO 2017) of the GCCPRD Phase 4 Report dated October 18, 2017

Ring Levee & Southern Dune System – Geotechnical Subsurface Profile & Geotechnical Parameters

COASTAL TEXAS STUDY

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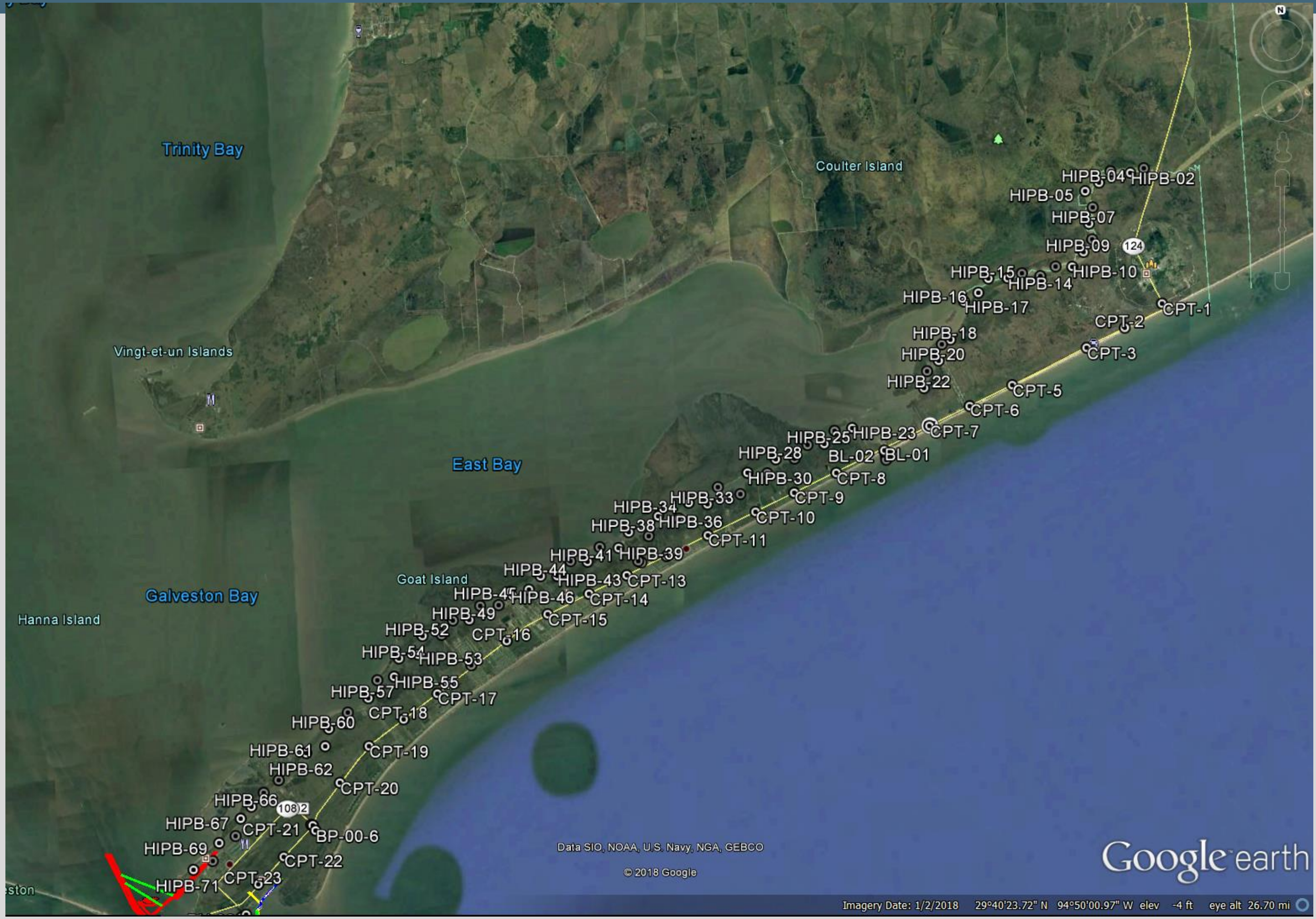

Geotechnical Soil Borings including Laboratory Results are available from the following sources.
a) CPTs, Appendix H (FUGRO 2017) of the GCCPRD Phase 4 Report dated October 18, 2017, Depths up to 60-foot

Northern Dune System – Available Geotechnical Borings and CPTs

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US Army Corps of Engineers

Soil Parameters for Slope Stability Analysis – Bolivar Peninsula Reach

Depth (feet)	Soil	Total Unit Weight (pcf)	Short-term (Undrained) Cohesion (psf)	Short-term (Undrained) Friction Angle (degrees)	Long-term (Drained) Cohesion (psf)	Long-term (Drained) Friction Angle (degrees)	Rapid Drawdown Cohesion (psf)	Rapid Drawdown Friction Angle (degrees)
0 to 5	Sand	115	0	25	0	25	0	25
5 to 15	Soft Clay	105	300	0	50	17	75	12
15 to 60	Soft to Stiff Clay	125	Top: 300 Bottom: 1,000	0	Top: 50 Bottom: 200	Top: 17 Bottom: 21	Top: 75 Bottom: 250	Top: 12 Bottom: 16

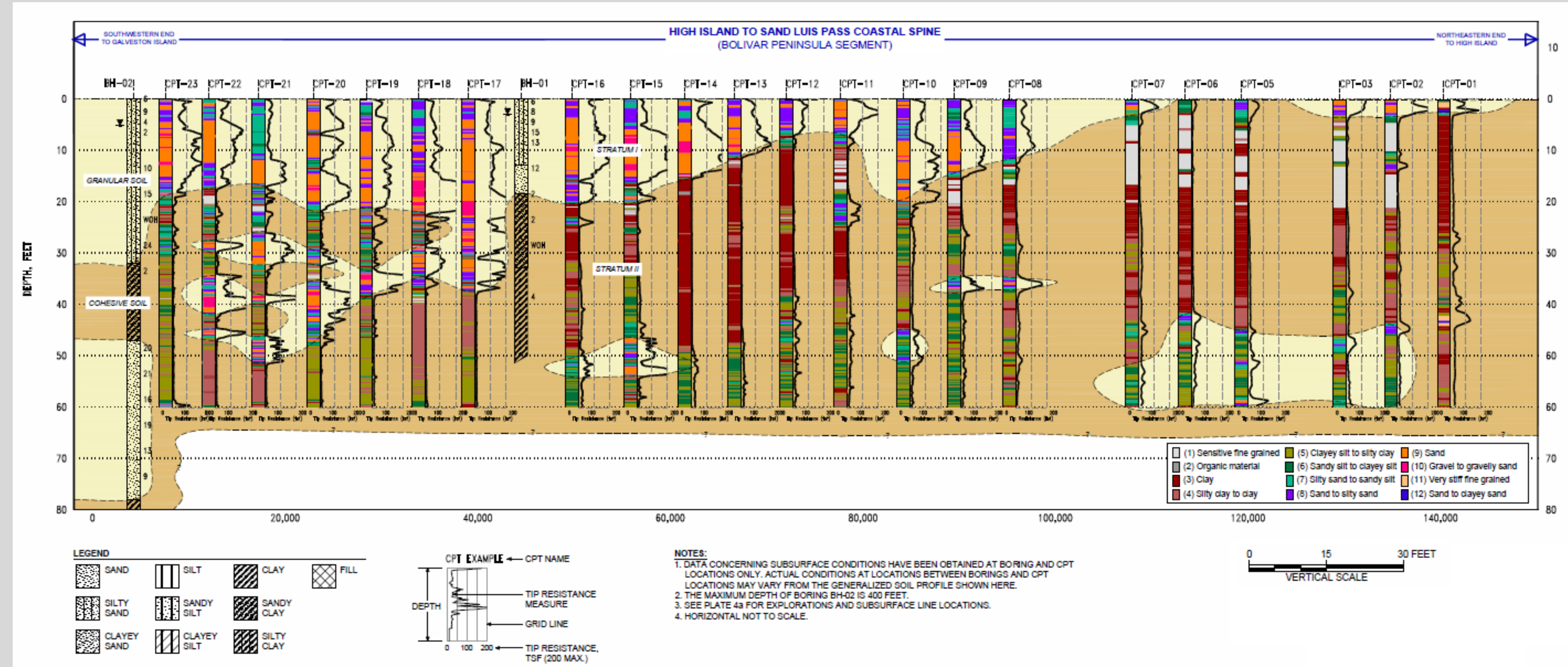
Soil Parameters for Slope Stability Analysis – Compacted Clay (Fat Clay or Lean Clay) Fill

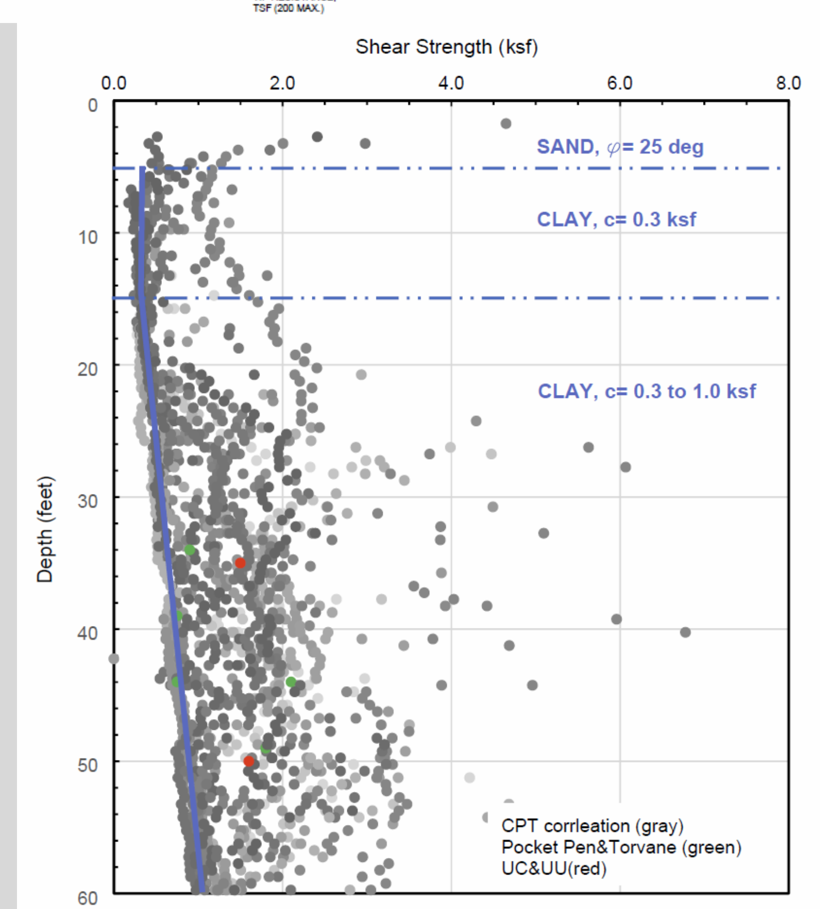
Depth (feet)	Total Unit Weight (pcf)	Short-term (Undrained) Cohesion (psf)	Short-term (Undrained) Friction Angle (degrees)	Long-term (Drained) Cohesion (psf)	Long-term (Drained) Friction Angle (degrees)	Rapid Drawdown Cohesion (psf)	Rapid Drawdown Friction Angle (degrees)
Varies	115	600	0	120	20	170	15

Soil Parameters for Settlement Analysis – Bolivar Peninsula Reach

Depth (feet)	Soil Description	Total Unit Weight (pcf)	Compressibility Parameters CR[1]	RR[2]	OCR[3]	Cv[4] (feet/year)
0 to 5	Loose Sand	115	E[5]: 300 ksf	--	--	300
5 to 15	Soft Clay	105	0.15	0.03	10	7
15 to 60	Soft to Stiff Clay	125	0.20	0.02	3	7

[1] Strained-based compression index.
[2] Strained-based re-compression index.
[3] Over-consolidation ratio.
[4] Coefficient of Consolidation
[5] Modulus of Elasticity





Appendix H (FUGRO 2017) of the GCCPRD Phase 4 Report dated October 18, 2017

Northern Dune System – Geotechnical Subsurface Profile & Geotechnical Parameters

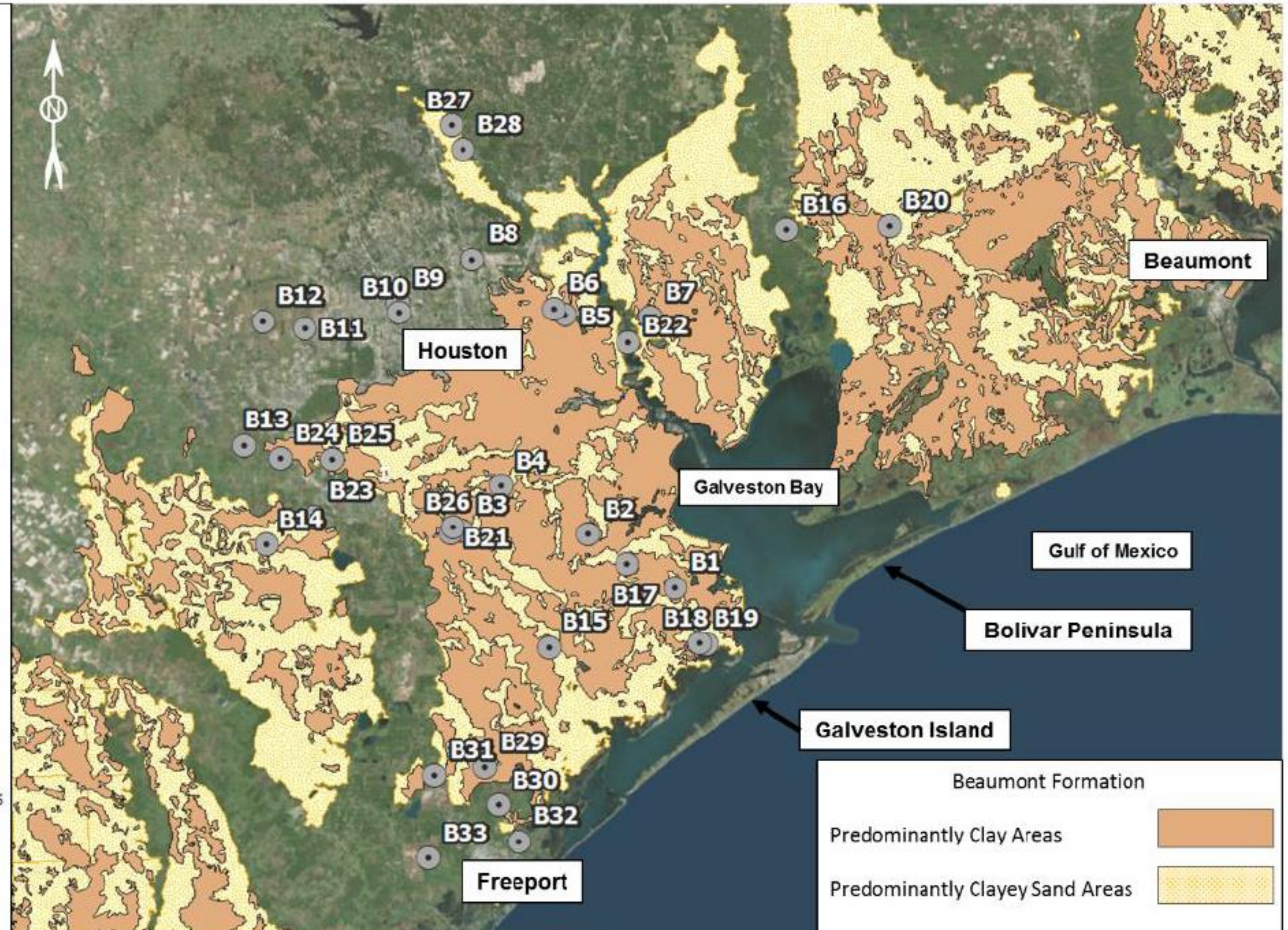
COASTAL TEXAS STUDY

RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR THE STUDY LEVEL GEOTECHNICAL DESIGN

US Army Corps of Engineers

Commercial Borrow Sources Pits

B1	Sprint Sand and Clay
B2	Sprint Sand and Clay
B3	Sprint Sand and Clay
B4	Sprint Sand and Clay
B5	Sprint Sand and Clay
B6	Sprint Sand and Clay
B8	Sprint Sand and Clay
B9	Sprint Sand and Clay
B10	Sprint Sand and Clay
B11	Sprint Sand and Clay
B12	Sprint Sand and Clay
B13	Sprint Sand and Clay
B14	Sprint Sand and Clay
B15	Clear Lake Sand
B16	Smart Materials
B17	Jadina Sand & Gravel
B18	Mabe's Hauling & Sand Pit
B19	Baulch Sand Pit
B20	ALS Affordable Land Services
B21	Gulf Coast Stabilized Material
B22	Gulf Coast Stabilized Material
B23	Gulf Coast Stabilized Material
B24	Gulf Coast Stabilized Material
B25	Gulf Coast Stabilized Material
B26	Gulf Coast Stabilized Material
B27	Gulf Coast Stabilized Material
B28	Gulf Coast Stabilized Material
B29	Sorrell Construction, Equipment, and Materials
B30	Vernor Material & Equipment
B31	Vernor Material & Equipment
B32	Vernor Material & Equipment
B33	Vernor Material & Equipment



CSRM – Potential Commercial Borrow Sources

Note: Off-shore borrow sources are not shown in this slide.

Geotechnical Engineering Tasks and Study Level Limitations

Elements	Tentative Start Date	Tentative Completion Date	Details of Technical Task	Limitations
Closure at Bolivar Inlet - Combi-Wall	6/10/2019	8/9/2019	Developing sub-surface profiles and geotechnical parameters for analyses including deep foundation and stability evaluation for foundation piles, sheet piles for cofferdams, assessing the constructability of foundation elements, selection of suitable foundation types, developing the quantity spreadsheet to support project Cost Estimate.	Uncertainties associated with preliminary level decision on CSRM alignment, proposed structural types, construction assumptions, foundation configurations (pile cap, footing size, cutoff elevations), structural loads (dead, wind, wave, live), subsurface geotechnical parameters developed based on available soil borings within the vicinity of the proposed foundation elements' locations.
Closure at Bolivar Inlet - Culverts	6/10/2019	11/23/2019		
Closure at Bolivar Inlet - Vertical Lift Gates	6/10/2019	9/14/2019		
Closure at Bolivar Inlet - 125-foot Recreation Navigation Sector Gate	6/10/2019	10/5/2019		
Closure at Bolivar Inlet - 650-foot Deep Draft Gate	6/10/2019	11/2/2019		
Galveston Ring Levee - Levees & Flood Walls, Offats Gate design	6/10/2019	11/7/2019		

SUMMARY OF GEOTECHNICAL RISK ASSESSMENT AND RISK MITIGATION STRATEGY

Major Components	Level of Geotechnical Risk on Project Cost Estimate based on available soil borings & subsurface geotechnical parameters
Surge Barrier System	**Medium level risk** – Adequate number of deep soil borings (seven) including geotechnical laboratory testing data are available within the vicinity of Surge Barrier System. The potential risk on study level geotechnical design can be classified as medium level due to the nature of the deep foundation system and size of the project. **Risk mitigation strategies** will be as follows: a) adopting the lower-bound soil strength data from available soil borings within the vicinity of the proposed structure for Axial pile capacity estimate. b) Pile type selection will consider the upper bound evaluation of potential hard-driving conditions. c) Study level design's Lateral pile resistance will be relying on battered piles only. d) Sensitivity analysis on using upper - and lower – bound geotechnical parameters for pile foundation design will be performed to estimate the potential change in final pile length to support the project cost estimate at the study level. (See example on next slide). **Projected Risk Management Results: The actual foundation cost will be within the acceptable study level cost estimate.** •Study level design lengths of the piles will be longer than detail design/ actual construction pile length. Study level Pile lengths will be optimized by obtaining comprehensive level geotechnical investigation data during detail level (PED phase) design. •Study level pile numbers will be higher than the detail level design/ actual construction pile numbers. Lateral resistance of the vertical pile will be evaluated during PED phase based on comprehensive level geotechnical data. The additional lateral resistance contribution from the group of vertical piles will reduce the number of vertical piles.
Dune System	**Low** – Adequate number of soil borings and CPTs are available along the alignment of the Dune System. The potential risk on developing geotechnical parameters for shallow foundation system can be classified as low level due to nature of shallow foundation system. **Projected Risk Management Results:** The actual foundation cost will be within the acceptable study level cost estimate.
Ring Levee System	**Medium level risk :** Adequate number of soil borings and CPTs are available along the alignment of the Ring Levee System. The development of geotechnical parameters for deep foundation system will be associated with medium level of risk due to nature of the deep foundation system and size of the project. **Risk Mitigation Strategy:** Same as Surge Barrier System. **Projected Risk Management Results:** Same as Surge Barrier System.

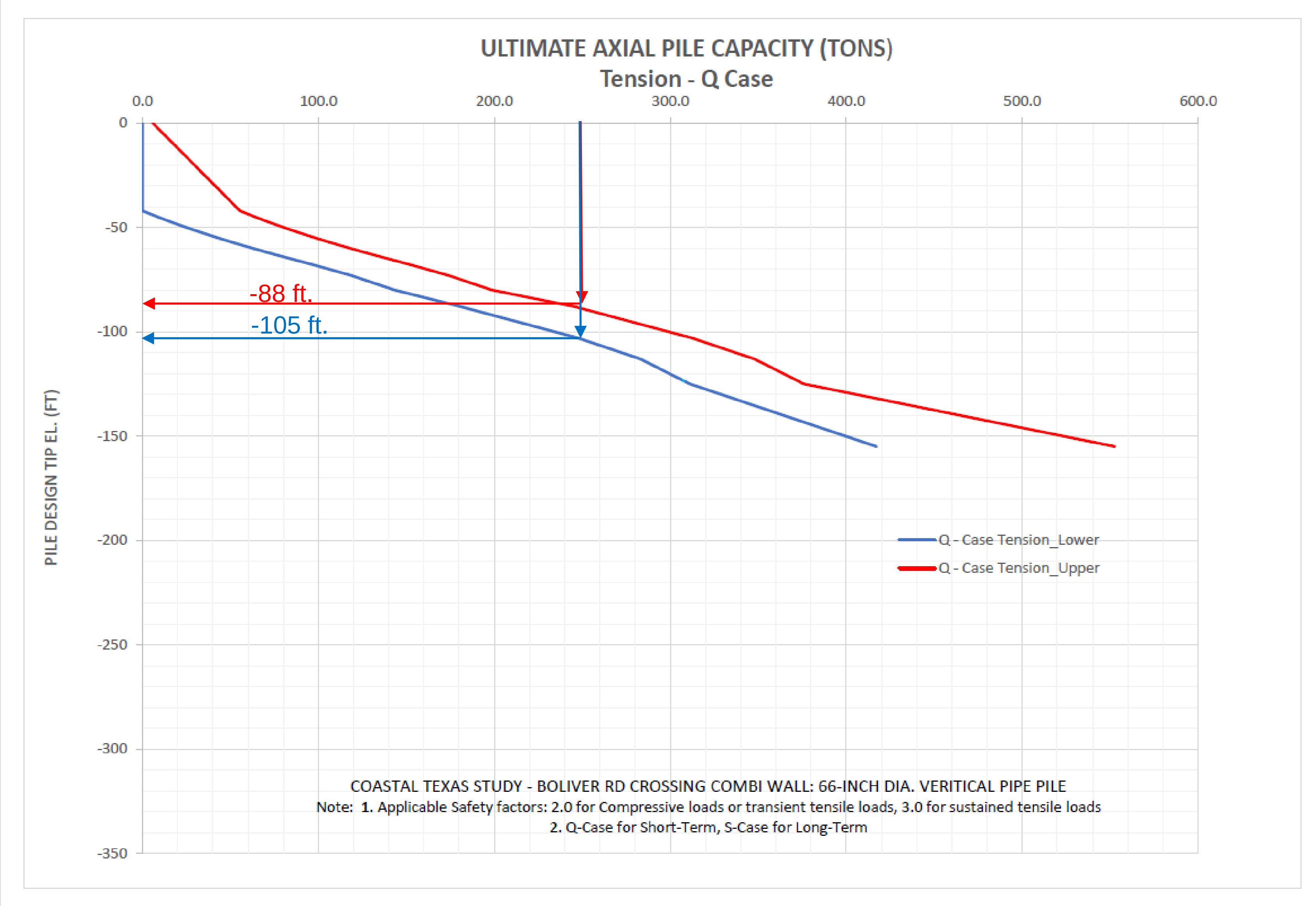
COASTAL TEXAS STUDY

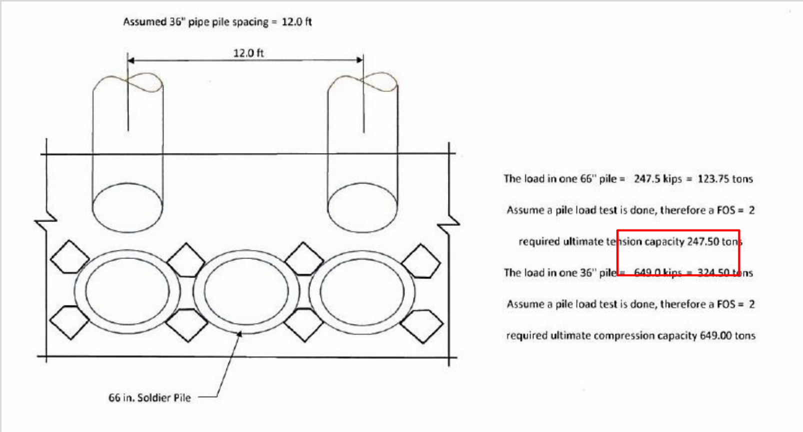
RISK ASSESSMENT ON ADEQUACY OF AVAILABLE GEOTECHNICAL DATA & MITIGATION STRATEGY BASED ON ADOPTING APPROPRIATE ENGINEERING ASSUMPTIONS AND CONSIDERATIONS FOR STUDY LEVEL GEOTECHNICAL DESIGN

US Army Corps of Engineers

TEXAS GENERAL LAND OFFICE ESTABLISHED 1836

EXAMPLE: SENSITIVITY ANALYSIS USING UPPER - AND LOWER – BOUND GEOTECHNICAL PARAMETERS FOR PILE FOUNDATION DESIGN TO ESTIMATE THE POTENTIAL CHANGE IN FINAL PILE LENGTH @ Boliver Road Crossing Combiwall 66 in. Soldier Pile





UPPER-BOUND GEOTECHNICAL PARAMETERS.

Q-CASE STRATIFICATION DONE | Fill Kc, Kt, Nc, Nq — Fills Table with HSDRRSG values. | Clear Contents — Clears Table Contents.

NOTES: A MAXIMUM OF TWENTY (20) STRATA CAN BE USED WITH THIS SPREADSHEET!

Stratum Number	Bottom EL. (ft)	Total Unit Weight (pcf)	Submerged Unit Weight (pcf)	Cohesion Top (psf)	Cohesion Bottom (psf)	ϕ (degrees)	δ (degrees)	Kc	Kt	Nc	Nq	End Bearing?	Soil Type	Maximum Unit Friction* (psf)	Maximum Unit End Bearing* (psf)
1	-42	110	47.5	250	250	0	0	1	1	9	1	☐	CL		
2	-68	120	57.5	0	0	32	21	1.25	0.7	0	22.5	☐	SP		
3	-73	120	57.5	0	0	30	20	1.25	0.7	0	22.5	☐	SP		
4	-80	120	57.5	1000	1000	0	0	1	1	9	1	☐	CH		
5	-88	120	57.5	2500	2500	0	0	1	1	9	1	☐	CH		
6	-103	120	57.5	0	0	32	21	1.25	0.7	0	22.5	☐	SP		
7	-113	120	57.5	1000	1000	0	0	1	1	9	1	☐	CH		
8	-125	120	57.5	500	500	0	0	1	1	9	1	☐	CL		
9	-155	120	57.5	2500	2500	0	0	1	1	9	1	☑	CH		
10												☐			
11												☐			
12												☐			
13												☐			
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18												☐			
19												☐			
20												☐			

LOWER-BOUND GEOTECHNICAL PARAMETERS.

Q-CASE STRATIFICATION DONE | Fill Kc, Kt, Nc, Nq — Fills Table with HSDRRSG values. | Clear Contents — Clears Table Contents.

NOTES: A MAXIMUM OF TWENTY (20) STRATA CAN BE USED WITH THIS SPREADSHEET!

Stratum Number	Bottom EL. (ft)	Total Unit Weight (pcf)	Submerged Unit Weight (pcf)	Cohesion Top (psf)	Cohesion Bottom (psf)	ϕ (degrees)	δ (degrees)	Kc	Kt	Nc	Nq	End Bearing?	Soil Type	Maximum Unit Friction* (psf)	Maximum Unit End Bearing* (psf)
1	-42	110	47.5	0	0	0	0	1	1	9	1	☐	CL		
2	-68	120	57.5	0	0	32	21	1.25	0.7	0	22.5	☐	SP		
3	-73	120	57.5	0	0	30	20	1.25	0.7	0	22.5	☐	SP		
4	-80	120	57.5	1000	1000	0	0	1	1	9	1	☐	CH		
5	-88	120	57.5	2000	2000	0	0	1	1	9	1	☐	CH		
6	-103	120	57.5	0	0	32	21	1.25	0.7	0	22.5	☐	SP		
7	-113	120	57.5	1000	1000	0	0	1	1	9	1	☐	CH		
8	-125	120	57.5	500	500	0	0	1	1	9	1	☐	CL		
9	-155	120	57.5	1500	1500	0	0	1	1	9	1	☑	CH		
10												☐			
11												☐			
12												☐			
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19												☐			
20												☐			

<u>Estimated Potential Pile Length Changes to 66-inch Dia. Pile:</u>

Required Pile length using Lower-bound design parameters = Pile tip at -105 ft EL.

Required Pile length using Lower-bound design parameters = Pile tip at -88 ft EL.

Potential Pile Length change percentage = (105-88)/105 x 100% = 16.2 %

Conclusion:

- The available geotechnical data is adequate for the subject study level design. This will allow the PDT to perform acceptable study level design and to develop an acceptable study level cost estimate.

- The current study level geotechnical design adopts appropriate risk mitigation strategies, including reasonable engineering assumptions and considerations to meet the subject study requirements.

- Comprehensive level geotechnical investigations and pile drivability/ pile load testing during the PED will be specified as mandatory requirements in the final study report.

QUESTIONS & COMMENTS