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); Tharmendra, 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:

PDT Inputs on Subject Discussion (See Attachment for more details).

- 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.

Cepero, Carlos E CIV USARMY CESWD (USA):

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

Reviewed by: Carlos E. Cepero, P.E.

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

Surge Barrie System

Natural/Fortified Dune System

Ring Levee System

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

Sept 06, 2019
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
## Major Components

### Surge Barrier System
- **Proposed Structural Elements:** 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
- **Considered Foundation Elements:** Deep Foundation System 24- to 36-inch Steel Pipe Piles (Vertical and Battered) 48- to 66-inch dia. Precast- Pre-Stressed Pipe Piles
- **Artificial Islands for 650’ Navigation Gates:** Cellular bulkhead structure using Sheet Piles
- **Major Reference Document for Geology & Geotechnical Data:**
  - GCCPRD Phase 4 Report dated October 18, 2017
  - Texas Coast Hurricane Study Galveston Harbor Channel Crossing October 31, 1967

### Dune System
- **Proposed Structural Elements:** N/A
- **Considered Foundation Elements:** Engineered Earth Fill for Foundation Preparation (if needed)
- **Major Reference Document for Geology & Geotechnical Data:**
  - GCCPRD Phase 4 Report dated October 18, 2017

### Ring Levee System
- **Proposed Structural Elements:** T-Wall, Combi-Wall, Levees, Sea Wall, Road/Railroad Crossings, Navigation/Circulation/Access Gates, Pump Stations, Drainage Structures
- **Considered Foundation Elements:** Deep Foundation System 24- to 36-inch Steel Pipe Piles (Vertical and Battered)
- **Major Reference Document for Geology & Geotechnical Data:**
  - GCCPRD Phase 4 Report dated October 18, 2017

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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.
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 Phase 4 Report dated October 18, 2017 as 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
Surge Barrier System- Available Geotechnical Borings
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 Structure 1972), 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
### 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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#### SAMPLE SOIL BORING LOG FROM GCCPRD PHASE 4 REPORT DATED OCTOBER 18, 2017

<table>
<thead>
<tr>
<th>Reference Boring</th>
<th>Depth (feet)</th>
<th>Soil Description</th>
<th>Total Unit Weight (pcf)</th>
<th>Undrained Shear Strength (psf)</th>
<th>Friction Angle (degrees)</th>
<th>Liquid Limit (%)</th>
<th>Plasticity Index (%)</th>
<th>Water Content (%)</th>
<th>Raw SPT Blow count</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH-02</td>
<td>0 to 47</td>
<td>Loose Sand/Soft Clay</td>
<td>110</td>
<td>N/A</td>
<td>N/A</td>
<td>21 to 33</td>
<td>2 to 15</td>
<td>25</td>
<td>2 to 24</td>
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<tr>
<td></td>
<td>47 to 73</td>
<td>Medium dense</td>
<td>120</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13 to 21</td>
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<tr>
<td></td>
<td>73 to 78</td>
<td>Loose Sand</td>
<td>120</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>78 to 93</td>
<td>Firm to very stiff Clay</td>
<td>120</td>
<td>550 to 2,000</td>
<td>32</td>
<td>57</td>
<td>43</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>93 to 108</td>
<td>Medium dense to dense Clayey Sand</td>
<td>120</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30 to 35</td>
</tr>
<tr>
<td></td>
<td>108 to 400</td>
<td>Stiff to very stiff Clay</td>
<td>120</td>
<td>1,000 to 2,000</td>
<td>32</td>
<td>24 to 84</td>
<td>9 to 64</td>
<td>20 to 34</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference Boring</th>
<th>Depth (feet)</th>
<th>Soil Description</th>
<th>Total Unit Weight (pcf)</th>
<th>Undrained Shear Strength (psf)</th>
<th>Friction Angle (degrees)</th>
<th>Liquid Limit (%)</th>
<th>Plasticity Index (%)</th>
<th>Water Content (%)</th>
<th>Raw SPT Blow count</th>
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<tbody>
<tr>
<td>BH-03</td>
<td>0 to 60</td>
<td>Loose to medium dense Sand/Soft Clay</td>
<td>110</td>
<td>N/A</td>
<td>N/A</td>
<td>60 to 95</td>
<td>44 to 74</td>
<td>28 to 56</td>
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<tr>
<td></td>
<td>60 to 120</td>
<td>Firm to very stiff Clay</td>
<td>120</td>
<td>500 to 1,900</td>
<td>32</td>
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<td></td>
<td>28 to more than 50</td>
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<td>120 to 178</td>
<td>Medium dense to very dense Sand</td>
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<td>32</td>
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<td>15 to 24</td>
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<td>178 to 198</td>
<td>Loose to medium dense Sand</td>
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<td>10 to 28</td>
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<td>198 to 400</td>
<td>Stiff to very stiff Clay</td>
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<td>1,200 to 2,000</td>
<td>30 to 87</td>
<td>17 to 68</td>
<td>19 to 37</td>
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Appendix H (FUGRO 2017) of the GCCPRD Phase 4 Report dated October 18, 2017

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Surge Barrier System - Geotechnical Subsurface Profile & Geotechnical Parameters
Sample Lab Results from Texas Coast Hurricane Study Galveston Harbor Channel Crossing October 31, 1967

<table>
<thead>
<tr>
<th>FIELD NO.</th>
<th>DEPTH</th>
<th>CLASSIFICATION</th>
<th>ELEVATION TOP BORING</th>
<th>CONSISTENCY</th>
<th>SIEVE ANALYSIS</th>
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<tr>
<td>1</td>
<td>0-2</td>
<td>Gray sandy clay</td>
<td>Water</td>
<td>25%</td>
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<tr>
<td></td>
<td>49-58</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>59-69</td>
<td>Gray clayey sand</td>
<td></td>
<td>50%</td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>117-120</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>121-127</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>128-135</td>
<td></td>
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</tbody>
</table>

**BOREING NO. 6ST-3**

**DATE DRILLED:** 13 MARCH 1968

**PROJECT:** Texas Coast Hurricane Study

**LOCATION:** Galveston Harbor Channel Crossing

**TEST DATA SUMMARY**

**SIEVE ANALYSIS**

**PERCENT**

<table>
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<tr>
<th>%</th>
<th>No. 4</th>
<th>No. 8</th>
<th>No. 16</th>
<th>No. 20</th>
<th>No. 40</th>
<th>No. 60</th>
<th>No. 80</th>
<th>No. 200</th>
</tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**ACCU. WT. RND. SIEVE NO. (2)**

**NO. 4 | NO. 8 | NO. 16 | NO. 20 | NO. 40 | NO. 60 | NO. 80 | NO. 200 |
<table>
<thead>
<tr>
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<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**BOREING NO. 6ST-3**
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
Southern Dune System – Available Geotechnical Borings and CPTs

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

Ring Levee & Southern Dune System – Geotechnical Subsurface Profile & Geotechnical Parameters
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
COASTAL TEXAS STUDY
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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
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CSRM – Potential Commercial Borrow Sources

Note: Off-shore borrow sources are not shown in this slide.
## Geotechnical Engineering Tasks and Study Level Limitations

<table>
<thead>
<tr>
<th>Elements</th>
<th>Tentative Start Date</th>
<th>Tentative Completion Date</th>
<th>Details of Technical Task</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closure at Bolivar Inlet - Combi-Wall</td>
<td>6/10/2019</td>
<td>8/9/2019</td>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td>Closure at Bolivar Inlet - Vertical Lift Gates</td>
<td>6/10/2019</td>
<td>9/14/2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closure at Bolivar Inlet - 125-foot Recreation Navigation Sector Gate</td>
<td>6/10/2019</td>
<td>10/5/2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closure at Bolivar Inlet - 650-foot Deep Draft Gate</td>
<td>6/10/2019</td>
<td>11/2/2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Galveston Ring Levee - Levees &amp; Flood Walls, Offats Gate design</td>
<td>6/10/2019</td>
<td>11/7/2019</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## SUMMARY OF GEOTECHNICAL RISK ASSESSMENT AND RISK MITIGATION STRATEGY

<table>
<thead>
<tr>
<th>Major Components</th>
<th>Level of Geotechnical Risk on Project Cost Estimate based on available soil borings &amp; subsurface geotechnical parameters</th>
</tr>
</thead>
</table>
| **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. |
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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

Estimated Potential Pile Length Changes to 66-inch Dia. Pile:
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