Appendix B. Geotechnical Evaluation of Retaining Wall Concepts Memorandum
RE: Geotechnical Evaluation of Retaining Wall Concepts – 30% Design

Primary Mid-Barataria Sediment Diversion (MBSD) project features include an inlet in the Mississippi River, a diversion structure near the Mississippi River to control flow into the system, a conveyance channel, and a back structure near the Barataria Basin to provide hurricane surge protection. The existing Mississippi River and Tributary (MR&T) levee would be connected to the diversion structure, while the existing Non-Federal Levee (NFL) along the Barataria Basin would be connected to the back structure. Given the challenges associated with dewatering at this site, it is anticipated that the conveyance channel would be excavated in the wet by dredging methods. The MBSD site is located in an area of the Mississippi River where the river side slopes are covered with revetment (referred to as the Myrtle Grove Revetment), placed by the U.S. Army Corps of Engineers (USACE) to limit erosion. The revetment consists of roughly 4-inch-thick precast concrete panels interconnected in a grid pattern with wires that extend down the side slope to approximately elevation –50 feet.

The MBSD would feature various permanent retaining wall systems, as shown on the plans in Attachment A. HDR prepared a memorandum dated January 16, 2014, that summarized the geotechnical evaluation of several wall systems including sheet pile transition walls between the diversion structure and the conveyance channel, sheet pile guide walls as an alternative to earthen levees on both sides of the conveyance channel, and an outlet armorining wall system at Barataria Basin consisting of sheet piles, pipe piles, and gravel infill.

This memorandum addresses HDR’s geotechnical evaluation of temporary and permanent retaining wall systems to facilitate construction of the inlet structure, diversion structure, and back structure, as well as permanent inlet wall systems that would be constructed in the wet.

Geology and Geomorphology

The project team developed a general description of the site geology and geomorphology based on review of preliminary boring logs, laboratory testing from 30% design investigations, and available USACE exploration data in the site vicinity. Available published reports describing local geomorphology were also reviewed by the project team. This description is presented in Section 3 of the Draft Preliminary Foundation Report prepared by HDR in November 2013.

Description of Inlet Wall Systems (Base Design and VE Alternatives)

The following list identifies proposed inlet wall configurations for the base design and four VE alternatives:
- **Alternative 1.1** (base design) – 75,000 cubic feet per second (cfs) design flow, inlet with open top
  - cellular sheet pile coffer walls to permit in-the-dry construction from Station 21+00 to Station 32+50
  - permanent cast-in-place concrete inlet structure with top of slab at elevation –40 feet from Station 21+00 to Station 32+50

- **Alternative 1.2** (VE alternative) – 75,000 cfs design flow, inlet with open top
  - In-the-wet portion (Station 21+00 to Station 28+00):
    - cellular sheet pile coffer walls
    - pipe pile cantilever wall system with bracing as needed
    - tremie concrete slab base at elevation –40 feet
  - In-the-dry portion (Station 28+00 to Station 32+50):
    - cellular sheet pile coffer walls
    - permanent cast-in-place concrete inlet structure with top of slab at elevation –40 feet

- **Alternative 2.2** (VE alternative) – 50,000 cfs design flow, inlet with open top
  - In-the-wet portion (Station 21+00 to Station 28+00):
    - cellular sheet pile coffer walls
    - pipe pile cantilever wall system with bracing as needed
    - tremie concrete base slab
  - In-the-dry portion (Station 28+00 to Station 32+50):
    - cellular sheet pile coffer walls
    - permanent cast-in-place concrete inlet structure

- **Alternative 4.2** (VE alternative) – 35,000 cfs design flow, inlet with continuous lid
  - In-the-wet portion (Station 21+00 to Station 28+00):
    - pipe pile cantilever wall with continuous cover
    - tremie concrete base slab
  - In-the-dry portion (Station 28+00 to Station 32+50):
    - cellular sheet pile coffer walls
    - permanent reinforced concrete box pressure conduits

- **Alternative 5.2** (VE alternative) – 25,000 cfs design flow, three 35-foot-diameter tunnels (Station 21+00 to Station 80+00)
  - receiving pit constructed with coffer cells at Station 8+00 to receive tunnel machine and to construct submerged inlet
  - coffer cells at approximately Station 28+00 to construct gated closure structure
  - coffer cells at approximately Station 80+00 to receive tunnel machine and to construct gated transition to open channel
permanent precast tunnel lining system with invert at elevation –60 feet

**Engineering Analyses**

**Cellular Sheet Pile Wall Systems**

Cellular sheet pile coffer walls were selected for use in the base design and several VE alternatives based on their past use on other in-the-wet projects and contractor familiarity. Circular cells (rather than diaphragm cells) were selected because each cell is independent of adjacent cells, because each cell can be filled as soon as it is constructed, and because the cells are easier to form using templates. The base design cell layout was selected by the project team to provide sufficient dry working space for construction of the permanent wall systems. The VE design cell layout was selected to form permanent walls for the inlet system from the Mississippi River.

Design of the cellular systems was completed using guidance from USACE Engineer Manual 1110-2-2503, *Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures*. Some cases involve dewatering inside the area bounded by the cells, while some cases involve only in-the-wet construction. Because this design effort is at the 30% level, the calculations focused on critical potential failure modes that control the size of the coffer wall systems (typically overturning). Some potential failure modes related to undereepage uplift or heave would be mitigated by using sheet pile walls and slurry walls for seepage control. These seepage control measures have been included in the Opinion of Probable Construction Cost (OPCC) that is contained within the Draft Value Engineering Report (30% Basis of Design). Detailed calculations of all failure modes and interlock stresses were not completed for this effort. Geotechnical parameters for design were based on the summaries of geotechnical design parameters shown in Attachment B. Design calculations are presented in Attachment C.

**Pipe Pile Wall Systems**

Pipe piles with interlocking connections that form a wall were selected for use in several VE alternatives. Use of these systems results in a smaller footprint in the river and avoids the need for extensive excavation and backfill when compared with cellular systems. Six-foot-diameter pipes were selected because significant bending capacity is needed, and this is approximately the largest pipe size that is driven by three contractors working in the Gulf Coast area. The VE design cell layout was selected to form permanent walls for the inlet system from the Mississippi River.

Design of the pipe pile walls was completed using the Shoring Suite software (2007, Version 8.8b). All cases involve in-the-wet construction of the walls. HDR analyzed cases where the pipe pile walls are installed in a cantilever fashion and cases where permanent bracing spans across the inlet channel to limit wall deflections for greater differential soil heights. Geotechnical parameters for design were based on the summaries of geotechnical design parameters shown in Attachment B. Design calculations are presented in Attachment D.

**River Flow Pressure on Inlet Wall Systems**

In general, water loads from the Mississippi River on the inlet channel walls (sheet pile systems and pipe pile systems) were assumed to be hydrostatic for this 30% design effort, based on hydraulic modeling with FLOW-3D software completed by the project team. Pressures from dynamic velocities are not expected to have a significant impact on walls at the inlet location.
Constructibility Considerations

- The inlet wall systems would be installed in an area of the Mississippi River where the river side slopes are covered by the Myrtle Grove Revetment, which extends down the side slopes to an approximate elevation of −50 feet. The revetment would be removed to facilitate construction of the inlet channel, but removal of the revetment would increase the risk of scouring. Thus, careful planning would be needed during final design and construction to limit the time between removal of the revetment and construction of the inlet channel features.

- Construction of the sheet pile inlet wall systems for in-the-dry construction would require that the walls extend above the highest river elevation expected during the construction period. This obstruction in the river flow would increase the risk of riverbed scour adjacent to the wall systems and could be mitigated through the use of stone armoring. Following construction of the cast-in-place inlet channels and backfilling of the gap between the temporary and permanent wall systems, the sheet pile systems would be cut down closer to the revetment level and the stone armoring would be redistributed over the sheet pile systems and backfill zone. Sheet piles or pipe piles that are driven for in-the-wet construction may be stopped above the river surface for constructibility reasons and then be cut off at the revetment elevation.

- The inlet wall systems would likely require protection from barge impacts during construction with some type of temporary barriers. Design and construction of these temporary features would likely be the responsibility of the contractor because they are not part of the permanent construction. The cost for these features is expected to be within the contingency portion of the OPCC.

- Input provided by one contractor (Traylor Brothers) suggests that sheet pile lengths greater than 80 feet are less practical and significantly more costly for installation.

- The pipe pile wall alternatives involving bracing (either intermittent braces or a continuous lid) would require careful consideration given the challenges of underwater installation, including alignment of braces and connection of braces using welded or bolted connections.

Summary of Findings from Retaining Wall Design Evaluations

Cellular Sheet Pile Wall Systems

Table 1 summarizes the design analyses completed for the cellular sheet pile wall systems.
Table 1. Summary of design analyses for cellular sheet pile wall systems

<table>
<thead>
<tr>
<th>System configuration</th>
<th>Equivalent width (feet)</th>
<th>Cell diameter (feet)</th>
<th>Sheet pile tip elevation (feet)</th>
<th>Sheet pile length (feet)</th>
<th>Factor of safety (overturning)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet Station 21+00; in-the-dry</td>
<td>80</td>
<td>91–98</td>
<td>–67</td>
<td>89</td>
<td>1.4</td>
</tr>
<tr>
<td>Inlet Station 28+00; in-the-dry</td>
<td>80</td>
<td>91–98\textsuperscript{a}</td>
<td>–70</td>
<td>92</td>
<td>1.5</td>
</tr>
<tr>
<td>Inlet Station 21+00; in-the-wet</td>
<td>50</td>
<td>57–61</td>
<td>–67</td>
<td>89</td>
<td>1.6</td>
</tr>
<tr>
<td>Inlet Station 28+00; in-the-wet</td>
<td>65</td>
<td>74–80</td>
<td>–70</td>
<td>92</td>
<td>1.5</td>
</tr>
<tr>
<td>Diversion structure; in-the-wet</td>
<td>80</td>
<td>91–98</td>
<td>–85</td>
<td>100</td>
<td>1.5</td>
</tr>
<tr>
<td>Back structure; in-the-wet</td>
<td>50</td>
<td>57–61</td>
<td>–78</td>
<td>80</td>
<td>&lt;1\textsuperscript{b}</td>
</tr>
</tbody>
</table>

\textsuperscript{a} with 20-foot-tall interior stability berm  
\textsuperscript{b} requires ground improvement  
\textsuperscript{c} Factor of Safety against sliding failure in sand is 2.0, but Factor of Safety for a deep clay layer in the cell just above the base of the excavation could be less than 1

Pipe Pile Wall Systems

Table 2 summarizes the design analyses completed for the pipe pile wall systems.

Table 2. Summary of design analyses for pipe pile wall systems

<table>
<thead>
<tr>
<th>System configuration</th>
<th>Maximum lateral deflection (inches)</th>
<th>Pile diameter/wall thickness (feet/inches)</th>
<th>Pipe pile tip elevation (feet)</th>
<th>Bracing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential height less than 40 feet (cantilever); in-the-wet</td>
<td>1.2</td>
<td>6/1</td>
<td>–117</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Differential height greater than 40 feet (braced); in-the-wet</td>
<td>0.7</td>
<td>6/1</td>
<td>–80</td>
<td>W14 × 200 (wide flange beam) at 30-foot centers; intermediate pipe pile supports as needed to limit spans to 45 feet</td>
</tr>
</tbody>
</table>
Conclusions and Recommendations

Based on our evaluations and engineering analyses, we have developed the following conclusions and recommendations for the project:

Cellular Sheet Pile Wall Systems

Use of cellular sheet pile wall systems to allow for construction in the dry appears to be the “tried and true” technique that is most familiar to contractors working in the project area. These systems are feasible for use on the MBSD for construction in the dry or in the wet, but the cell sizes for in-the-dry scenarios are relatively large. Additional evaluation is needed during the next design phase to evaluate the following items:

- Determine whether the cell sizes can be reduced.
- Identify likely borrow sources for the cell fill.
- Obtain more definition of the deep clay layer(s) between Stations 21+00 and 28+00 to better define the risk of sliding failure through these materials.
- Review the configuration of the tapered stability berm between Stations 21+00 to 28+00 as more information becomes available about the strength and unit weight properties of the available berm materials.
- Review the geotechnical conditions and construction sequence at the back structure. The foundation soils are very weak at this location, and ground improvement would likely be needed to construct a stable wall system.

Pipe Pile Wall Systems

Use of pipe pile wall systems to form the permanent inlet channel walls is feasible, but apparently less familiar to contractors working in this area and is perceived to involve a higher level of risk during construction. As a result, this alternative was not considered further in the value engineering report.

Limitations

This memorandum presents the findings, conclusions, and recommendations from our geotechnical engineering evaluation of the MBSD retaining wall concepts at the 30% design level. It has been prepared in accordance with generally accepted engineering practice and in a manner consistent with the level of care and skill for this type of project within this geographical area. No warranty, expressed or implied, is made.

The conclusions and recommendations presented here are based on research and available literature, the results of field exploration and laboratory materials testing by others, and the results of preliminary engineering analyses.

Geotechnical engineering and the geologic sciences are characterized by uncertainty. Professional judgments presented here are based partly on our understanding of the proposed construction, partly on our general experience, and on the state of the practice at the time of this evaluation.
References


———. 2014. *Geotechnical Design Parameters for “River Bottom,” “West River Bank at North Tie-In,” “Conveyance Channel Station 32+00 to 45+00,” and “Conveyance Channel Station 90+00 to 140+00.”*


Attachment A. Site Plans and Profiles
NOTES:

PHASE 1A - DEEP SOIL MIXING CUTOFF WALL 3" WIDE TO EL -150' FT FOR SEEPAGE CONTROL.

PHASE 1B - TEMPORARY SETBACK LEVEE REPLACES MRT LEVEE AS PRIMARY PROTECTION DURING PHASE 1 CONSTRUCTION. MRT LEVEE TO REMAIN IN PHASE 1.

PHASE 1C - CIRCULAR DIAPHRAGM SHEET PILE COFFERDAM BY WIDTH TOP OF WALL AT EL -22 FT WITH LIMESTONE CAP.

KEY NOTES:

1. AREA BETWEEN GUIDE LEVEE AND TEMPORARY SETBACK LEVEE TO REMAIN AFTER PHASE 1 COMPLETION.

2. TEMPORARY SETBACK LEVEE BETWEEN GUIDE LEVEES TO BE DEGRADED DURING FINAL DREDGING AND CHANNEL CONSTRUCTION PHASE.

3. CONTRACTOR DESIGNED WELL POINT Dewatering SYSTEM INSIDE CUTOFF WALL.

4. HORIZONTAL UNDERDRAIN INfiltrator MATERIAL FOR TEMP. DWATERING AND PERMANENT PASSIVE DWATERING SYSTEM.

5. PROJECTED LEVEE SLOPE CONTOURS AT 5:1 GRADE SHOWN FOR INFORMATION PURPOSES ONLY.

6. CONSTRUCTION WORKING BENCH BEGINS AT TOE OF LEVEE SLOPE EL -12' FT GRADED TO EL -15' FT AT COFFERDAM.

7. SITE ACCESS ROAD AND RAMPS AS REQ'D TO ACCESS CONSTRUCTION SITE. DETAILS TBD.

8. PHASE 1 MECHANICAL EXCAVATION IN CHANNEL AND PLACEMENT ON STABILITY BERM FOR SURCHARGING.

COASTAL PROTECTION & RESTORATION AUTHORITY ENGINEERING DIVISION

DIVERSION STRUCTURE PHASE 1 CONSTRUCTION

VOLUME 1 CIVIL DIVISION

STATE PROJECT NUMBER: BA-152
FEDERAL PROJECT NUMBER: BA-153
DATE: MARCH 2014

DRAWN BY: H. GARCIA
DESIGNED BY: G. PENNISON
APPROVED BY:

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF REVIEW IT IS NOT TO BE USED FOR CONSTRUCTION OR ANY OTHER PURPOSE.
NOTES:

PHASE 2A - LEVEE CUTOFF TO ALLOW TRANSITION WALLS AND CHANNEL ARMOR TO BE CONSTRUCTED (W/ SHEETING/ShORING AS NOTED)

PHASE 2B - CIRCULAR DIAPHRAGM SHEET PILE COFFERDAM AT WIDE: ADD Dewatering SYSTEM INSIDE EXCAVATION AND DIAPHRAGM. REMOVE WALL ACROSS APPROACH CHANNEL. STOPLOGS NOW IN PLACE TO SEAL GATE STRUCTURE. TOP EL +10 FT TOP SHEET PILE CUTOFF WALL, TOP OF WALL AT EL +17.5 FT. TEMPORARY SETBACK LEVEE TO REMAIN UNTIL CONSTRUCTION COMPLETE ON INLET.

PHASE 2C - SHEET PILE FOR STRUCTURE TO LEVEE PERMANENT CONNECTION DESIGNED BY CONTRACTOR. ADD SHEETING PLATFORMS AND PILES TO ANCHOR SHEET PILE WALL AND TO REDUCE SECTION MODULUS REQUIRED. TOP OF WALL AT EL +17.5 FT.

KEY NOTES:

AREA BETWEEN GUIDE LEVEES AND TEMPORARY SETBACK LEVEE TO REMAIN AFTER PHASE 1 COMPLETION.

TEMPORARY SETBACK LEVEE BETWEEN GUIDE LEVEES TO BE SEGREGATED DURING FINAL DRESSING AND CHANNEL CONSTRUCTION PHASE.

CONTRACTOR DESIGNED WELL POINT DEWATERING SYSTEM INSIDE CUTOFF WALL.

HORIZONTAL UNDERDRAIN WITH FILTER MATERIAL FOR TEMP Dewatering AND PERMANENT PASSIVE DEWATERING SYSTEM.

PROJECTED LEVEE SLOPE CONTOURS AT 5:1 GRADE SHOWN FOR INFORMATION PURPOSES ONLY.

SITE ACCESS ROAD AND RAMPS AS REQUIRED TO ACCESS CONSTRUCTION SITE. DETAILS TBD.

PHASE 1 MECHANICAL EXCAVATION IN CHANNEL AND Placement ON Stability BERM 4 FOR SURCHARGING.
PHASE 1A - DOUBLE WALL SHEET PILE COFFERDAM 15 FT WIDE WITH TOP AT EL +10 FT WITH DEEP SOIL MIXING FROM EL X FT TO EL X FT.

PHASE 1A - CIRCULAR DIAPHRAGM CUTOFF WALL 5 FT WIDE WITH TOP AT EL +10 FT - DEEP SOIL MIXING FROM EL X FT TO EL X FT.

PROPOSED GATED BACK STRUCTURE - SEE VOLUME 6

SURCHARGE SEQUENCE - SEE SURCHARGE SEQUENCE NOTES THIS SHEET.

1. PROPOSED NFL BACK LEVEE STRUCTURE.
2. FUTURE NFL BACK LEVEE DRAINAGE CHANNEL.
3. CTB PUMP STATION BUILT DURING PHASE 1 TO ALLOW CHANNEL FILL AT CONVEYANCE CHANNEL - SEE VOLUME 3.
4. PROPOSED GATED BACK STRUCTURE - SEE VOLUME 6
5. SURCHARGE SEQUENCE - SEE SURCHARGE SEQUENCE NOTES THIS SHEET.

SURCHARGE SEQUENCE:
1. PLACE 4 FT OF SAND OVER PROTECTED AREA.
2. INSTALL SLOTTED DRAIN PILES IN EXISTING DRAINAGE DITCHES AT 200 FT CENTERS.
3. INSTALL WICK DRAINS TO EL -55 FT AT 6 FT CENTER TRIANGULAR PATTERN INSIDE PROTECTED AREA.
4. PLACE 2 FT OF SAND OVER WICK DRAINS AND CONSOLIDATE 2 MONTHS.
5. PLACE ADDITIONAL SURCHARGE TO MIN. EL +5 FT.
ALTERNATIVES 12b, 2.28 (in-the-wet)

- EL. 0.0
- STONE ARMORING
- EXISTING REVENUE
- MAX TOP OF WALL EL. -10'
- PORTION OF PILE WALL TO BE REMOVED PRIOR TO COMPLETION
- TREMIE SLABS
- EL. -11' 1/2
- PIPE PILE WALL WITH INTERLOCKS

EL. 0'
ALTERNATIVES 1.2b, 2.2b (IN-THE-WET)

- 10' PORTION OF PILE WALL TO BE REMOVED PRIOR TO COMPLETION
- WALES/COLECTOR BEAMS
- BRACERS AT 30' CEINTERS W14x200 WITH PIPE PILE COLUMNS AS NEEDED TO LIMIT UNBRACED SPANS TO 45

TREMLE SLAB

EL. = -43

EL. = -50

- 10' STONE ARMORING

- 6" PIPE PILE WALL WITH INTERLOCKS
ALTERNATIVE 4.2 (IN-THE-WET)

EL. +10
TEMP BRACES AT 30' CENTERS
W14x200

WALER

PERMANENT CONTINUOUS LID ELEMENTS

STONE ARMORING

10

6'-6" PIPE PILE WALL WITH INTERLOCKS

EL.-80'
PILE TIP

EL.-43
TREMIE SLAB

EL.-50
Attachment B. Summary of Geotechnical Design Parameters
### Table 1-1 – River Bottom – (Station 10+00 to 22+00)

**River Bottom Geotechnical Parameters**

*Ground Surface Elevation -47.5 feet at R-3A on Conveyance centerline (Range -46.4 to -54.4 ft)*

**Borings drilled near toe of slope outside of revetment**

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Location [Thickness], ft</th>
<th>Description</th>
<th>ASTM/USACE NO District Classification</th>
<th>Moisture Content (%)</th>
<th>% Fines</th>
<th>Unit Weight (pcf)</th>
<th>SPT N60</th>
<th>Explorations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recent Deposits</strong></td>
<td>-47.5 to -50 [2.5]</td>
<td>Very soft CLAY (recent river sediments) with shell fragments</td>
<td>CL6</td>
<td>57</td>
<td>&gt;50</td>
<td>100</td>
<td>0</td>
<td>50 15 150 0</td>
</tr>
<tr>
<td></td>
<td>-50 to -62.5 [12.5]</td>
<td>Medium dense poorly graded SAND</td>
<td>SP</td>
<td>21 to 28</td>
<td>6.6</td>
<td>122</td>
<td>14</td>
<td>0 30 0 30</td>
</tr>
<tr>
<td></td>
<td>-62.5 to -67.5 [5]</td>
<td>Medium dense to dense silty SAND</td>
<td>SM</td>
<td>29</td>
<td>12 % Silt 0.8% clay</td>
<td>122</td>
<td>45 @-63 ft 16 @-66 ft</td>
<td>0 28 0 28</td>
</tr>
<tr>
<td><strong>Intra Delta</strong></td>
<td>-67.5 to -82.5 [15]</td>
<td>Dense poorly graded SAND</td>
<td>SP</td>
<td>26</td>
<td>6</td>
<td>128</td>
<td>46</td>
<td>0 39 0 39</td>
</tr>
<tr>
<td></td>
<td>-82.5 to -107.5 [25]</td>
<td>Very dense poorly graded SAND</td>
<td>SP</td>
<td>24</td>
<td>6</td>
<td>128</td>
<td>74</td>
<td>0 41 0 41</td>
</tr>
<tr>
<td><strong>Near Shore Gulf</strong></td>
<td>-107.5 to -127.5 [20]</td>
<td>Very dense poorly graded SAND</td>
<td>SP</td>
<td>25</td>
<td>7</td>
<td>130</td>
<td>91</td>
<td>0 41 0 41</td>
</tr>
<tr>
<td><strong>Pleistocene</strong></td>
<td>-127.5 to -129.5 [2]</td>
<td>Very stiff CLAY</td>
<td>CH2</td>
<td>&gt;50</td>
<td>125</td>
<td>19</td>
<td>200</td>
<td>22 2700 0</td>
</tr>
<tr>
<td></td>
<td>-131.5 to -139.5 [8]</td>
<td>Very stiff CLAY</td>
<td>CL6</td>
<td>24</td>
<td>&gt;50</td>
<td>125</td>
<td>19</td>
<td>250 24 3150 0</td>
</tr>
<tr>
<td></td>
<td>-139.5 to -141.5 [2]</td>
<td>Medium dense sandy SILT</td>
<td>ML</td>
<td>26</td>
<td>&gt;50</td>
<td>117</td>
<td>--</td>
<td>0 30 200 25</td>
</tr>
<tr>
<td></td>
<td>-141.5 to -146.0 [5.5]</td>
<td>Medium dense silty SAND</td>
<td>SM</td>
<td>24</td>
<td>--</td>
<td>122</td>
<td>--</td>
<td>0 30 0 30</td>
</tr>
<tr>
<td></td>
<td>-146.5 to -162.5 [16]</td>
<td>Very stiff to hard Interbedded Lean CLAY</td>
<td>CL4, CL6, CH2, CH3</td>
<td>43</td>
<td>&gt;50</td>
<td>116</td>
<td>19 to 35</td>
<td>200 22 1200 0</td>
</tr>
<tr>
<td></td>
<td>-162.5 to -170 [7.5]</td>
<td>Very dense clayey SILT</td>
<td>ML</td>
<td>34</td>
<td>&gt;50</td>
<td>125</td>
<td>80+</td>
<td>0 25 0 25</td>
</tr>
<tr>
<td></td>
<td>-170 to -199.5 [29.5]</td>
<td>Very stiff CLAY</td>
<td>CH3</td>
<td>41</td>
<td>&gt;50</td>
<td>110</td>
<td>26</td>
<td>200 22 2100 0</td>
</tr>
</tbody>
</table>

1 - Refer to Table 3-2 for fine grained soils descriptions
2 - Refer to Table 3-3 for estimated coarse grained soils properties
3 - Cohesion intercept for soft clay soils calculated as 1 percent of the effective overburden pressure
4 - Drained friction angle for clay soils based upon a measured mean Liquid Limit of clay soils of approximately 40 for both CL4 and CL6 soils and 45 for CH2 (Refer to Table 3-2)
5 - “—” indicates soil sampled with 5-inch diameter piston stapler. Single value represents average N60 over the soil layer
6 - Undrained shear strength of clays determined from laboratory testing, Refer to Geotechnical Data Report
Table 2-1– River Bank Slope at North Tie-in - (Station 22+00 to 28+00)

River Bottom Geotechnical Parameters
Ground Surface Elevation +5 feet at B- 2A

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Elevation (Thickness), ft</th>
<th>Description</th>
<th>ASTM/USACE NO District Classification</th>
<th>Moisture Content (%)</th>
<th>% Fines</th>
<th>Unit Weight (pcf)</th>
<th>SPT N60</th>
<th>Strength Parameters</th>
<th>Explorations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Drained</td>
<td>Undrained</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cohesion^1</td>
<td>Cohesion (pf)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Levee</td>
<td>5.5 to -4.8 [9.3]</td>
<td>Medium CLAY</td>
<td>CL4, CL6, CH2</td>
<td>35</td>
<td>&gt;50</td>
<td>123</td>
<td>100</td>
<td>26</td>
<td>700</td>
</tr>
<tr>
<td></td>
<td>-4.8 to -7.8 [2]</td>
<td>Soft to medium CLAY</td>
<td>CL4</td>
<td>35</td>
<td>&gt;50</td>
<td>117</td>
<td>--</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>Upper Point Bar</td>
<td>-7.8 to-13.8 [6]</td>
<td>Medium dense SILT</td>
<td>ML</td>
<td>31</td>
<td>72</td>
<td>115</td>
<td>--</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>-13.8 to -37.8 [24]</td>
<td>Very loose to loose SILT</td>
<td>ML</td>
<td>36</td>
<td>+80</td>
<td>115</td>
<td>1 to 2</td>
<td>50</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>-37.8 to -40.5 [2.7]</td>
<td>Soft CLAY</td>
<td>CL4</td>
<td>38</td>
<td></td>
<td>115</td>
<td>3</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Middle Point Bar</td>
<td>-40.5 to -62 [21.5]</td>
<td>Medium dense SILT</td>
<td>ML</td>
<td>33</td>
<td>62 to 84</td>
<td>117</td>
<td>--</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>-46.7 to -67.5 [20.8]</td>
<td>Medium dense silty SAND</td>
<td>SM</td>
<td>--</td>
<td>9 to 23</td>
<td>122</td>
<td>37</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>-62 to -64.5 [2.5]</td>
<td>Medium CLAY</td>
<td>CL6</td>
<td>45</td>
<td>75</td>
<td>118</td>
<td>9</td>
<td>35</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>-64.5 to -75 [10.5]</td>
<td>Medium dense silty SAND</td>
<td>SM</td>
<td>31</td>
<td>59 to 74</td>
<td>117</td>
<td>31</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>-75 to -80 [5]</td>
<td>Dense to very dense SAND and silty SAND</td>
<td>SP-SM</td>
<td>30</td>
<td>20 (SP) 40 (SM)</td>
<td>130</td>
<td>31 to 55</td>
<td>0</td>
<td>33</td>
</tr>
</tbody>
</table>

-80+ Below an elevation of -80 refer to Table 1-1 for river borings.

1 – Refer to Table 2-2 for fine grained soils descriptions
2- Refer to Table 2-3 for estimated coarse grained soils properties
3- Cohesion intercept for soft clay soils calculated as 1 percent of the effective overburden pressure
4 – Drained friction angle for clay soils based upon a measured mean Liquid Limit of clay soils of approximately 40 for both CL4 and CL6 soils and 45 for CH2 soils (Refer to Table 2-2)
5 – “—”indicates soil sampled with 5-inch diameter piston stapler. Single value represents average N60 over the soil layer
6 – Undrained shear strength of clays determined from laboratory testing, Refer to Geotechnical Data Report
Table 4-1 – Conveyance Channel (Station 32+00 to 45+00)

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Elevation (Thickness), ft</th>
<th>Description</th>
<th>ASTM/USACE NO District Classification</th>
<th>Moisture Content (%)</th>
<th>% Fines</th>
<th>Unit Weight (pcf)</th>
<th>SPT N60</th>
<th>Drained Cohesion (psf)</th>
<th>Drained Friction Angle°</th>
<th>Undrained Cohesion (psf)</th>
<th>Undrained Friction Angle°</th>
<th>Reference Explorations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Levee</td>
<td>+3.5 to -0.5 [4]</td>
<td>Medium CLAY</td>
<td>CL4, CL6</td>
<td>26</td>
<td>&gt;50</td>
<td>90</td>
<td>–</td>
<td>25</td>
<td>24</td>
<td>500</td>
<td>0</td>
<td>Borings: NL-9A and PT-2</td>
</tr>
<tr>
<td></td>
<td>-0.5 to -4.5 [4]</td>
<td>Soft to medium CLAY</td>
<td>CL4, CL6</td>
<td>33</td>
<td>&gt;50</td>
<td>90</td>
<td>&lt;3</td>
<td>50</td>
<td>22</td>
<td>200</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-4.5 to -24 [20.5feet]</td>
<td>Interbedded soft CLAY and loose clayey SILT</td>
<td>CL4, ML</td>
<td>36</td>
<td>79</td>
<td>90</td>
<td>Weight of Hammer</td>
<td>15</td>
<td>22</td>
<td>125</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Upper Point Bar</td>
<td>-24 to -37 [13]</td>
<td>Loose to medium SILT silty sand lenses</td>
<td>ML with SM lenses</td>
<td>27</td>
<td>53 to 77</td>
<td>113</td>
<td>–</td>
<td>0</td>
<td>26</td>
<td>200</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-37 to -48</td>
<td>Medium dense sandy SILT /Silty SAND</td>
<td>ML/SM</td>
<td>32</td>
<td>70 to 74/30 to 35</td>
<td>115</td>
<td>–</td>
<td>0</td>
<td>30</td>
<td>200</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Middle Point Bar</td>
<td>-48 to -63 [15]</td>
<td>Loose to very loose SILT and loose clayey SAND</td>
<td>ML/SC</td>
<td>31</td>
<td>74 to 82</td>
<td>118</td>
<td>&lt;10</td>
<td>0</td>
<td>28</td>
<td>200</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-63 to -76 [13]</td>
<td>Medium dense silty SAND with clay strata and lenses</td>
<td>SM</td>
<td>--</td>
<td>32 to 64</td>
<td>120</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-76 to -93 [17]</td>
<td>Medium dense sandy SILT and clayey SAND</td>
<td>SM/SC</td>
<td>37</td>
<td>56 to 66</td>
<td>120</td>
<td>57, 73</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-93 to -106 [13]</td>
<td>Medium dense sandy SAND and medium dense sandy SILT</td>
<td>SM/ML</td>
<td>--</td>
<td>11</td>
<td>124</td>
<td>30, 53</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Pro Delta</td>
<td>-106 to -112 [6]</td>
<td>Very stiff high plasticity CLAY</td>
<td>CH4</td>
<td>55</td>
<td>&gt;50</td>
<td>110</td>
<td>36</td>
<td>250</td>
<td>24</td>
<td>1100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pleistocene</td>
<td>-118 to -130 [12]</td>
<td>Very stiff high plasticity CLAY with shells</td>
<td>CH4</td>
<td>50</td>
<td>&gt;50</td>
<td>110</td>
<td>20</td>
<td>250</td>
<td>26</td>
<td>1100</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

1 – Refer to Table 4-2 for fine grained soils descriptions
2 - Refer to Table 4-3 for estimated coarse grained soils properties
3- Cohesion intercept for soft clay soils calculated as 1 percent of the effective overburden pressure
4 – Drained friction angle for clay soils based upon a measured mean Liquid Limit of clay soils of approximately 40 for both CL4 and CL6 soils and 45 for CH2 soils (Refer to Table 4-2)
5 – “—” indicates soil sampled with 5-inch diameter piston stapler. Single value represents average N60 over the soil layer
6 – Undrained shear strength of clays determined from laboratory testing. Refer to Geotechnical Data Report.
### Table 6-1: Conveyance Channel (Station 90+00 to 140+00)

**Conveyance Channel Geotechnical Parameters**  
Ground Surface Elevation +1.0 feet at NL-8A

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Elevation [Thickness], ft</th>
<th>Description</th>
<th>ASTM/USACE NO District Classification</th>
<th>Moisture Content (%)</th>
<th>% Fines</th>
<th>Unit Weight (pcf)</th>
<th>SPT N60</th>
<th>Strength Parameters</th>
<th>Reference Explorations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Marsh, Intra Delta and Interdistributary</strong></td>
<td>-3.5 to -22 [18.5]</td>
<td>Very soft Organic Clay</td>
<td>CHOA, CHOC, CH2, CH3, Peat, CH4</td>
<td>47 to 172</td>
<td>&gt;90</td>
<td>85 to 105</td>
<td>--</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>-22 to -38 [18]</td>
<td>Highly Variable sequence of very soft CLAY, loose SILT, silty SAND and SAND</td>
<td>ML, SM, SP, CH4, CL4</td>
<td>44 to 92</td>
<td>Varies</td>
<td>105</td>
<td>--</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td><strong>Interdistributary (Lower)</strong></td>
<td>-38 to -50 [12]</td>
<td>Soft CLAY with silt lenses and shells</td>
<td>CH4</td>
<td>42 to 73</td>
<td>&gt;90</td>
<td>95</td>
<td>--</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>-50 to -70 [20]</td>
<td>Soft CLAY with increasing strength with depth</td>
<td>CH4</td>
<td>55 to 74</td>
<td>&gt;90</td>
<td>103</td>
<td>--</td>
<td>50</td>
<td>22</td>
</tr>
<tr>
<td><strong>Pro-Delta</strong></td>
<td>-70 to -110 [40]</td>
<td>Soft to medium CLAY</td>
<td>CH2, CH4</td>
<td>55 to 66</td>
<td>.90</td>
<td>103</td>
<td>--</td>
<td>50</td>
<td>24</td>
</tr>
<tr>
<td><strong>Gulf Near Shore</strong></td>
<td>-110 to -116 [6]</td>
<td>Very stiff high plasticity CLAY with shells</td>
<td>CH4</td>
<td>60</td>
<td>&gt;50</td>
<td>100</td>
<td>--</td>
<td>150</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>-116 to -120 [4]</td>
<td>medium dense SAND and clayey SAND</td>
<td>SP, SC</td>
<td>25, 34</td>
<td>28 (SC)</td>
<td>122</td>
<td>39 (SC)</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td><strong>Pleistocene</strong></td>
<td>-120+ [BOH – 124]</td>
<td>Stiff Clay with shells</td>
<td>CH4</td>
<td>63</td>
<td>&gt;90</td>
<td>100</td>
<td>--</td>
<td>250</td>
<td>24</td>
</tr>
</tbody>
</table>

1 – Refer to Table 1-2 for fine grained soils descriptions  
2 – Refer to Table 1-3 for estimated coarse grained soils properties  
3 – Cohesion intercept for soft clay soils calculated as 1 percent of the effective overburden pressure  
4 – Drained friction angle for clay soils based upon a measured mean Liquid Limit of clay soils of approximately 40 for both CL4 and CL6 and 45 for CH2 soils (refer to Table 6-2)  
5 – “—” indicates soil sampled with 5-inch diameter piston stapler. Single value represents average N60 over the soil layer. Friction angle for granular soils estimated from values listed in Table 6-2.  
6 – Undrained shear strength of clays determined from laboratory testing. Refer to Geotechnical Data Report.
Attachment C. Design Calculations for Cellular Sheet Pile Retaining Structures
PURPOSE
Preliminary design of a cellular cofferdam at the inlet structure of the Mid-Barataria Sediment Diversion structure.

REFERENCES

LOCATION
The sediment diversion structure will be located South of New Orleans, LA connecting the Mississippi River and the Barataria Basin to the west.

CALCULATIONS
Soil Profile and Soil Model:
Soil parameters were taken from Table 1-1 – River Bottom (Station 10+00 to 22+00).

The generalized soil column at the inlet structure consisted of about 2½ ft. of very soft, low plasticity clays, elevation -47.5 ft. to -50.0 ft., then medium dense sand to elevation -62.5 ft., then medium dense to dense sand to elevation -67.5 ft., then dense and very dense sand to elevation -107.5 ft.

In order to simplify the design for the 30% design level, the upper 2½ ft. of very soft clay was modeled with the medium dense and dense sands as a uniform granular material with the strength parameters adjusted to account for the relatively lower strength parameters of the clays. It was also considered reasonable to use the drained condition soil strength parameters for the sand.

Overall or Global Stability Soil Model:
Equivalent cell diameter was limited to 80 feet.
Sheet pile tip: elevation -67 feet. Total sheet pile length: 89 ft.
Imported cell fill was assumed to be granular material with a Total Unit Weight = 120 pcf and an internal friction angle = 28 degrees. The 28 degrees was assumed to be the value after being placed through water.

It was assumed that after the sheet piles were driven that the native clay within the cell would not be excavated, and the cell fill would be placed directly on the native soil. As a result, the soil within the cell would have a profile of multiple layers of sands and clays each with significantly
different unit weights and internal friction angles. In order to simplify the 30% design level calculations, the soil profile within the cell was generalized and divided into areas, each area becoming a uniform soil.

Page 4 shows the general cell geometry and the areas of uniform soil parameters. Area 1 and 2 simply use the imported cell fill parameters. The soil parameters in Area 3 and 4 were developed by reviewing the soil layers within each region and taking an average or weighted average of the unit weights and internal friction angles.

Area 3 had a weighted average unit weight = 120.6 pcf. Since the area is triangular the weighted average was calculated using the area of each different unit weight material. Area 4 had a weighted average unit weight equal to 122 pcf by inspection of Table 1-1. The weighted averages for the internal friction angles were: from elevation -47.5 ft. to -62.5 ft. was 30.0 degrees, and from elevation -62.5 ft. to -67 ft. was 28.0 degrees. A value of 29 degrees was chosen for the soil model for both the active and passive soil calculations to simplify the calculation procedure.

The soil parameters below the pile tip elevation used in calculations were evaluated in a similar way as the cell fill. The soil profile below the pile tip elevation was evaluated to a depth of ½B (approximately 40 ft.) below the cell toe. The depth of ½ B was chosen simply for ease of calculation. A depth equal to the cell diameter should be evaluated for final design. The weighted average unit weight = 128 pcf. An internal friction angle = 39 degrees was chosen by inspection.

**Log Spiral Curves:**
The poles for the log spirals are dependent on the angle of internal friction of the soil that the failure surface is passing through. For failure within the cell, the angle chosen for the calculations was 29 degrees. This was based on the fact that the internal friction angle of the soil within the cell and near the toe of the cell had an internal friction angle of 28 degrees extending from the toe to 5 ft. above the toe. It was assumed that the majority of the trial failure surfaces would not be within that region and would extend up into the 30 degree material. For failure within the foundation soil, the soil angle of internal friction was 39 degrees to a depth of 15.5 ft. below the cell toe then increased to 41 degrees to an elevation -127.5 ft., 60.5 ft. below the cell toe. Thirty-nine degrees was chosen to develop the log spiral curves below the cell toe and is a conservative value.

The alpha values used for developing the log spirals within the foundation soil were chosen so that the pole of the log spirals would not cross the lateral pressure resultant centroid which would produce a negative moment arm and negative moment. This negative moment would
produce a false Factor of Safety for the log spiral pole. The cut-off value was determined by trail and error and was found to be 120 degrees.

**Hansen’s Method:**
Hansen’s method produces an area between the log spiral failure surface and the toe of the cell. The force resultant of this region is commonly referred to as “G”. The area of this region is partly based on the internal friction angle of the soil encompassed by the failure surface and the toe of the cell. The angle of internal friction and unit weight chosen for this region was based on observation of the native soil parameters near the toe of the cell and may differ from the overall unit weight and friction angle used to develop the active and passive pressures. The internal friction angles for calculating “G”, within the cell fill and within the foundation soil should be the same as used to develop the log spirals. The unit weight and internal friction angle chosen were: failure within cell fill – 122 pcf and 29 degrees, failure within foundation soil – 128 pcf and 39 degrees.

**Stability Berm Width:**
The cofferdam at this location does not require a stability berm.

**Sliding:**
The Factor of Safety against sliding was evaluated for the cell sliding on sand located at the toe of the cell. The friction angle chosen for the analysis was 28 degrees. This angle was chosen because it was the angle of internal friction of the sand above and below the cell toe.
Circular Sheet Pile Cofferdam

Equivalent width $B = 80$ ft

Cell Diameter = 97.8 ft (for $\alpha = 30$ degrees, $30^\circ Y$)
91.4 ft (for $\alpha = 45$ degrees, $90^\circ T$)

Cell Fill Material Properties:
- $\gamma = 120$ pcf
- $\varphi = 28$ degrees

Foundation Soil Material Properties:
- $\gamma = 128$ pcf
- $\varphi = 39$ degrees
- $c = 0$ psf

Total Sheet Pile length: 89.0 ft
Pressure Diagram for Active and Passive Pressures

Active

- $\gamma_w = 62.4$ pcf
- $h_{w1} = 77$ ft

- $\phi = 29$ degrees
- $\gamma = 122$ pcf
- $K_a = 0.347$
- $\gamma'_a = 59.6$ pcf
- $h_a = 22$ ft

- $P_w = 184.98$ kips
- MA = 25.7 ft

Passive

- $\gamma_w = 62.4$ pcf
- $h_{w2} = 12$ ft

- $\phi = 29$ degrees
- $\gamma = 122$ pcf
- $K_p = 2.882$
- $\gamma'_p = 59.6$ pcf
- $h_p = 12$ ft

- $P_p = 12.37$ kips
- MA = 7.3 ft

- $P_w = 4.49$ kips
- MA = 4.0 ft

NOT TO SCALE
Generation of Log Spiral curve for failure surface.

Log Spiral equation:

\[ R = r \ e^{\alpha \tan \phi} \]

\( \alpha \) = angle between segments R and r.
\( \phi \) = angle of internal friction of cell fill or foundation soil.

Input values:

Constants:
- \( B = 80 \) feet (equivalent width)
- \( \phi = \) [see below] degrees

Variables:
- \( \alpha \) (entered below)

Law of Cosines:

\[ c^2 = a^2 + b^2 - 2ab \cos \theta \]

or

\[ B^2 = R^2 + r^2 - 2Rr \cos \alpha \]

put R in terms of r, then solve for r.
Solve for R using Log Spiral equation.

Failure surface within cell fill (A-rupture).

Internal friction angle of cell granular soil, \( \phi \): 29 degrees

<table>
<thead>
<tr>
<th>Pole</th>
<th>( \alpha )</th>
<th>( e^{\alpha \tan \phi} )</th>
<th>( R/r )</th>
<th>( r ) (ft)</th>
<th>( R ) (ft)</th>
<th>( x ) (ft)</th>
<th>( y ) (ft)</th>
<th>( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>170</td>
<td>5.18</td>
<td>5.18</td>
<td>12.97</td>
<td>67.19</td>
<td>12.83</td>
<td>1.89</td>
<td>8.4</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>4.70</td>
<td>4.70</td>
<td>14.15</td>
<td>66.55</td>
<td>13.57</td>
<td>4.03</td>
<td>16.5</td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>4.27</td>
<td>4.27</td>
<td>15.51</td>
<td>66.19</td>
<td>14.12</td>
<td>6.42</td>
<td>24.4</td>
</tr>
<tr>
<td>4</td>
<td>140</td>
<td>3.87</td>
<td>3.87</td>
<td>17.08</td>
<td>66.16</td>
<td>14.46</td>
<td>9.08</td>
<td>32.1</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
<td>3.52</td>
<td>3.52</td>
<td>18.91</td>
<td>66.52</td>
<td>14.58</td>
<td>12.05</td>
<td>39.6</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>3.19</td>
<td>3.19</td>
<td>21.09</td>
<td>67.34</td>
<td>14.44</td>
<td>15.38</td>
<td>46.8</td>
</tr>
<tr>
<td>7</td>
<td>110</td>
<td>2.90</td>
<td>2.90</td>
<td>23.71</td>
<td>68.73</td>
<td>13.99</td>
<td>19.14</td>
<td>53.8</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>2.63</td>
<td>2.63</td>
<td>26.91</td>
<td>70.81</td>
<td>13.19</td>
<td>23.46</td>
<td>66.7</td>
</tr>
<tr>
<td>9</td>
<td>90</td>
<td>2.39</td>
<td>2.39</td>
<td>30.89</td>
<td>73.79</td>
<td>11.93</td>
<td>28.50</td>
<td>67.3</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>2.17</td>
<td>2.17</td>
<td>35.96</td>
<td>77.98</td>
<td>10.08</td>
<td>34.52</td>
<td>73.7</td>
</tr>
<tr>
<td>11</td>
<td>70</td>
<td>1.97</td>
<td>1.97</td>
<td>42.59</td>
<td>83.84</td>
<td>7.41</td>
<td>41.94</td>
<td>80.0</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>1.79</td>
<td>1.79</td>
<td>51.57</td>
<td>92.16</td>
<td>3.54</td>
<td>51.45</td>
<td>86.1</td>
</tr>
<tr>
<td>13</td>
<td>50</td>
<td>1.62</td>
<td>1.62</td>
<td>64.34</td>
<td>104.37</td>
<td>-2.21</td>
<td>64.30</td>
<td>92.0</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>1.47</td>
<td>1.47</td>
<td>83.76</td>
<td>123.33</td>
<td>-11.23</td>
<td>83.00</td>
<td>97.7</td>
</tr>
</tbody>
</table>
Failure surface within foundation soil (X-rupture).

Internal friction angle of foundation soil, \( \phi \): 39 degrees

Calculation:

<table>
<thead>
<tr>
<th>Pole</th>
<th>( \alpha )</th>
<th>( e^{\alpha \tan \phi} )</th>
<th>( R/r )</th>
<th>( r ) (ft)</th>
<th>( R ) (ft)</th>
<th>( x ) (ft)</th>
<th>( y ) (ft)</th>
<th>( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>179</td>
<td>12.55</td>
<td>12.55</td>
<td>5.90</td>
<td>74.10</td>
<td>5.90</td>
<td>0.10</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td>177</td>
<td>12.20</td>
<td>12.20</td>
<td>6.06</td>
<td>73.95</td>
<td>6.05</td>
<td>0.29</td>
<td>2.8</td>
</tr>
<tr>
<td>3</td>
<td>175</td>
<td>11.86</td>
<td>11.86</td>
<td>6.22</td>
<td>73.80</td>
<td>6.20</td>
<td>0.50</td>
<td>4.6</td>
</tr>
<tr>
<td>4</td>
<td>172</td>
<td>11.37</td>
<td>11.37</td>
<td>6.47</td>
<td>73.59</td>
<td>6.42</td>
<td>0.83</td>
<td>7.4</td>
</tr>
<tr>
<td>5</td>
<td>170</td>
<td>11.05</td>
<td>11.05</td>
<td>6.65</td>
<td>73.45</td>
<td>6.56</td>
<td>1.06</td>
<td>9.2</td>
</tr>
<tr>
<td>6</td>
<td>165</td>
<td>10.30</td>
<td>10.30</td>
<td>7.10</td>
<td>73.12</td>
<td>6.90</td>
<td>1.68</td>
<td>13.7</td>
</tr>
<tr>
<td>7</td>
<td>160</td>
<td>9.60</td>
<td>9.60</td>
<td>7.59</td>
<td>72.83</td>
<td>7.21</td>
<td>2.36</td>
<td>18.1</td>
</tr>
<tr>
<td>8</td>
<td>155</td>
<td>8.94</td>
<td>8.94</td>
<td>8.12</td>
<td>72.57</td>
<td>7.50</td>
<td>3.11</td>
<td>22.5</td>
</tr>
<tr>
<td>9</td>
<td>150</td>
<td>8.33</td>
<td>8.33</td>
<td>8.69</td>
<td>72.36</td>
<td>7.75</td>
<td>3.93</td>
<td>26.9</td>
</tr>
<tr>
<td>10</td>
<td>145</td>
<td>7.76</td>
<td>7.76</td>
<td>9.30</td>
<td>72.20</td>
<td>7.96</td>
<td>4.81</td>
<td>31.2</td>
</tr>
<tr>
<td>11</td>
<td>140</td>
<td>7.23</td>
<td>7.23</td>
<td>9.97</td>
<td>72.11</td>
<td>8.13</td>
<td>5.78</td>
<td>35.4</td>
</tr>
<tr>
<td>12</td>
<td>135</td>
<td>6.74</td>
<td>6.74</td>
<td>10.69</td>
<td>72.08</td>
<td>8.24</td>
<td>6.81</td>
<td>39.6</td>
</tr>
<tr>
<td>13</td>
<td>130</td>
<td>6.28</td>
<td>6.28</td>
<td>11.49</td>
<td>72.13</td>
<td>8.31</td>
<td>7.93</td>
<td>43.7</td>
</tr>
<tr>
<td>14</td>
<td>125</td>
<td>5.85</td>
<td>5.85</td>
<td>12.35</td>
<td>72.27</td>
<td>8.31</td>
<td>9.14</td>
<td>47.7</td>
</tr>
</tbody>
</table>

Diagram showing the locus of poles and the spiral pole.
### Overturning Moments

#### Hansen's Method:

**Moments about Log Spiral Poles**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Water</th>
<th>Soil</th>
<th>Water</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>2</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>3</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>4</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
</tbody>
</table>

#### Resisting Moments

**Overturning Moments**

- **Water**
- **Soil**
- **Resultant**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Water</th>
<th>Soil</th>
<th>Resultant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>2</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>3</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>4</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
</tbody>
</table>

### A-Rupture Failure Mode (Within cell fill)

- **Overturning Moments**
- **Resisting Moments**
- **Saturated Cell Fill**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Water</th>
<th>Soil</th>
<th>Resultant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>2</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>3</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>4</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
</tbody>
</table>

### A-Rupture Failure Mode on next page

- **Factor of Safety**
- **Safety**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Water</th>
<th>Soil</th>
<th>Resultant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>2</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>3</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>4</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
</tbody>
</table>
Moments about Log Spiral Poles (Hansen’s Method):

For soil below elev. -65 ft., use φ = 39° and ϒ = 128 pcf.

\[ \gamma = \frac{-r}{4 \tan \phi} \]

Moments about Poles: pole is within the cell therefore subtract pole y coord. from moment arm from point A to get total arm, subtract x coord. inside cell.

### Overturning Moments

<table>
<thead>
<tr>
<th>Pole</th>
<th>y coord.</th>
<th>x coord.</th>
<th>Radius r, ft</th>
<th>Radius ( r ) pole</th>
<th>Moment in</th>
<th>Moment out</th>
<th>Resultant Moment</th>
<th>Moment in</th>
<th>Moment out</th>
<th>Resultant Moment</th>
<th>Moment in</th>
<th>Moment out</th>
<th>Resultant Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10</td>
<td>25.6</td>
<td>184.88</td>
<td>184.88</td>
<td>37.24</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>2</td>
<td>0.29</td>
<td>25.4</td>
<td>184.88</td>
<td>184.88</td>
<td>7.04</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>3</td>
<td>0.50</td>
<td>25.2</td>
<td>184.88</td>
<td>184.88</td>
<td>6.83</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>4</td>
<td>0.65</td>
<td>24.8</td>
<td>184.88</td>
<td>184.88</td>
<td>6.62</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>5</td>
<td>1.06</td>
<td>24.6</td>
<td>184.88</td>
<td>184.88</td>
<td>6.27</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>6</td>
<td>1.48</td>
<td>24.0</td>
<td>184.88</td>
<td>184.88</td>
<td>6.05</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>7</td>
<td>2.38</td>
<td>23.3</td>
<td>184.88</td>
<td>184.88</td>
<td>6.07</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>8</td>
<td>3.11</td>
<td>22.6</td>
<td>184.88</td>
<td>184.88</td>
<td>6.32</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>9</td>
<td>3.83</td>
<td>21.7</td>
<td>184.88</td>
<td>184.88</td>
<td>7.04</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>10</td>
<td>4.61</td>
<td>20.8</td>
<td>184.88</td>
<td>184.88</td>
<td>7.91</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>11</td>
<td>5.71</td>
<td>19.9</td>
<td>184.88</td>
<td>184.88</td>
<td>7.81</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>12</td>
<td>6.81</td>
<td>18.9</td>
<td>184.88</td>
<td>184.88</td>
<td>7.81</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>13</td>
<td>7.91</td>
<td>17.7</td>
<td>184.88</td>
<td>184.88</td>
<td>7.81</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
<tr>
<td>14</td>
<td>8.81</td>
<td>16.5</td>
<td>184.88</td>
<td>184.88</td>
<td>7.81</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
<td>7.46</td>
<td>30.22</td>
<td>7.46</td>
</tr>
</tbody>
</table>

### X-Rupture Failure

<table>
<thead>
<tr>
<th>X-Rupture Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor of Safety = 4.89</td>
</tr>
</tbody>
</table>

| Min. Factor of Safety | 4.89 |
Stability Berm Minimum Width

Distance from cell toe to top of berm = 12 feet
Angle of internal friction of passive soil = 29 degrees

Coulomb’s Theory:
Angle of failure wedge from wall, \( \beta = 45 + \frac{\phi}{2} \) degrees

\[ \beta = 59.5 \text{ degrees} \]

Minimum width of berm:

Width = distance from cell toe to top of berm \( \times \) tan \( \beta \)

= 0.0 feet

No Stability Berm is Required
Bearing Capacity at Toe (Terzaghi)

\[
\text{Factor of Safety} = \frac{c*N_c + 0.5*\gamma'*B*N_r}{(6*M/B^2) + \gamma*H} \\
\]

- \( c = 0 \text{ psf} \) Cohesion of bearing stratum.
- \( N_c = 5.7 \) [from Pile Buck, 1987 (after Terzaghi and Peck, 1967)]
- \( \phi = 39 \) degrees
- \( N_r = 95 \) [from Pile Buck, 1987 (after Terzaghi and Peck, 1967)]
- \( \gamma' = 65.6 \text{ pcf} \) average effective uint weight of bearing stratum within a depth \( H \).
- \( \gamma = 120.3 \text{ pcf} \) Average unit weight of cell fill.
- \( B = 80 \text{ ft} \) Equivalent width of cell \( (B = 0.818*D, \text{TVA}) \).
- \( H = 89 \text{ ft} \) Height of cell from sheet pile tip.
- \( M = 4717.2 \text{ kip-ft} \) Net overturning moment.

\[
\text{Factor of Safety} = 23.28
\]
Sliding

From the Pressure Diagrams page and the Overturning page:

**Driving Forces:**

\[
P_w = 184.98 \text{ kips} \\
P_a = 5.00 \text{ kips}
\]

**Resisting Forces:**

\[
P_w = 4.49 \text{ kips} \\
P_p = 12.37 \text{ kips}
\]

**Cell Fill:**

\[
\begin{align*}
\text{Area 1} & : P_1 = 115.20 \text{ kips} \\
\text{Area 2} & : P_2 = 312.00 \text{ kips} \\
\text{Area 3} & : P_3 = 149.76 \text{ kips} \\
\text{Area 4} & : P_4 = 57.22 \text{ kips}
\end{align*}
\]

\[
P_C = P_1 + P_2 + P_3 + P_4 = 634.18 \text{ kips}
\]

Friction angle of soil against soil at cell toe, \( \delta = \phi' \): 28 degrees
Effective cohesion along failure plane, \( c' \): 0 psf
Width of cofferdam, \( B \): 80 ft

If the sliding surface is within the cell, deduct the area below the sliding surface from Area 4.

Distance from cell toe to top of sliding surface = 0 feet
Revised Area 4, \( P_4 = 57.22 \text{ kips} \)

\[
\text{Factor of Safety} = \frac{\text{Resisting Forces}}{\text{Driving Forces}} = \frac{P_w + P_p + P_p \cdot \tan \delta + c' \cdot B}{P_w + P_a}
\]

**Factor of Safety** = 1.86
Interlock Tension

Cell diameter, \( D = 91.4 \) ft

Cell Fill Material Properties:
\[
\begin{align*}
\gamma &= 120 \text{pcf} \\
\phi &= 28 \text{ degrees} \\
\gamma' &= 57.6 \text{pcf}
\end{align*}
\]

From "Pile Buck Steel Sheet Piling Design Manual", 1987:

\[
\sigma_T = K_a \gamma \left( H - H_1 \right) + K_a \gamma' \left( H_1 - H/4 \right) + \gamma_w \left( H_3 - H/4 \right)
\]

\( H = \) length of sheet pile = 89 ft
\( H_1 = \) height of water on the outboard sheeting = 77 ft
\( H_3 = \) height of water on the inboard sheeting = 12 ft

Assume \( K_a = 0.4 \) (minimum value suggested by Terzaghi)

\[
\sigma_T = 1197.84 \text{ pounds/sq. ft.}
\]

Maximum Interlock tension = \( \sigma_T \times \) cell radius = 54.76 kips/ft

\[
4.56 \text{ kips/in.}
\]

Sheet pile: AS 500 12.7
Max. Interlock Strength = 31.4 kips/in. (Skyline Steel technical data sheet)

**Approximate Factor of Safety** = 6.88
PURPOSE
Preliminary design of a cellular cofferdam at the inlet structure of the Mid-Barataria Sediment Diversion structure.

REFERENCES

LOCATION
The sediment diversion structure will be located South of New Orleans, LA connecting the Mississippi River and the Barataria Basin to the west.

CALCULATIONS
Soil Profile and Soil Model:
Soil parameters were taken from Table 2-1 – River Bank Slope at North Tie-in (Station 22+00 to 28+00) and Table 1-1 – River Bottom (Station 10+00 to 22+00).

The generalized soil column at the inlet structure-river bank tie-in consisted of about 11 ft. of soft to medium, low plasticity clays, elevation 5.5 ft. to -7.8 ft., then very loose to medium dense silt to elevation -37.8 ft., then a soft clay to elevation -40.5 ft., then medium dense silt to elevation -62 ft. (or a medium dense sand to elevation -67.5 ft. encountered only in Boring 1A), then a medium dense to very dense silty sand to elevation -80 ft. Below elevation -80 ft. the soil parameters are from Table 1-1 – River Bottom (Station 10+00 to 22+00). The soil profile from elevation -82.5 ft. to -107.5 ft. consisted of very dense, poorly graded sand.

In order to simplify the design for the 30% design level, the upper 11 ft. of soft to medium clay and the two clay layers at elevations -37.8 ft. and -62 ft., each about 2 ft. thick, were modeled with the medium dense and very dense sands as a uniform granular material with the strength parameters adjusted to account for the relatively lower strength parameters of the clays and silts. It was also considered reasonable to use the drained condition soil strength parameters for the sand and silt.

Overall or Global Stability Soil Model:
Equivalent cell diameter was limited to 80 feet.
Sheet pile tip elevation: -70 feet. Total sheet pile length: 92 ft.
Imported cell fill was assumed to be granular material with a Total Unit Weight = 120 pcf and an internal friction angle = 28 degrees. The 28 degrees was assumed to be the value after being placed through water.

It was assumed that after the sheet piles were driven that the native clay and silt within the cell would not be excavated, and the cell fill would be placed directly on the native soil. As a result, the soil within the cell would have a profile of multiple layers of sands, silts, and clays each with significantly different unit weights and internal friction angles. In order to simplify the 30% design level calculations, the soil profile within the cell was generalized and divided into areas, each area becoming a uniform soil.

Page 4 shows the general cell geometry and the areas of uniform soil parameters. Area1 and 2 simply use the imported cell fill parameters. The soil parameters in Area 3 and 4 were developed by reviewing the soil layers within each region and taking an average or weighted average of the unit weights and internal friction angles.

Area 3 had a weighted average unit weight = 120.6 pcf. Since the area is triangular and the higher unit weight material is at the top, elevation 10 ft. to -4.8 ft. the unit weight used in the calculations was adjusted downward to 119 pcf to account for less higher unit weight material in the triangular area. Area 4 had a weighted average unit weight equal to 119 pcf. The weighted averages for the internal friction angles were: from elevation 5.5 ft to -70 ft. was 27.0 degrees, and from elevation -37.8 ft. to -70 ft. was 29.2 degrees. A value of 28 degrees was chosen for the soil model for both the active and passive soil calculations to simplify the calculation procedure.

The soil parameters below the pile tip elevation used in calculations were evaluated in a similar way as the cell fill. The soil profile below the pile tip elevation was evaluated to a depth of ½B (approximately 40 ft.) below the cell toe. The depth of ½ B was chosen simply for ease of calculation. A depth equal to the cell diameter should be evaluated for final design. The weighted average unit weight = 128 pcf. An internal friction angle = 33 degrees was chosen by inspection.

**Log Spiral Curves:**

The poles for the log spirals are dependent on the angle of internal friction of the soil that the failure surface is passing through. For failure within the cell, the angle chosen for the calculations was 33 degrees. This was based on the fact that the internal friction angle of the soil within the cell and near the toe of the cell had an internal friction angle of 33 degrees extending from the toe to 24 ft. above the toe. It was assumed that the majority of the trial failure surfaces would be within that region. For failure within the foundation soil, the soil angle
of internal friction was 33 degrees to a depth of 10 ft. below the cell toe then increased to 41 degrees to an elevation -127 ft., 57 ft. below the cell toe. Thirty-three degrees was chosen to develop the log spiral curves below the cell toe and is a conservative value.

The alpha values used for developing the log spirals within the foundation soil were chosen so that the pole of the log spirals would not cross the lateral pressure resultant centroid which would produce a negative moment arm and negative moment. This negative moment would produce a false Factor of Safety for the log spiral pole. The cut-off value was determined by trial and error and was found to be 120 degrees.

**Hansen’s Method:**
Hansen’s method produces an area between the log spiral failure surface and the toe of the cell. The force resultant of this region is commonly referred to as “G”. The area of this region is partly based on the internal friction angle of the soil encompassed by the failure surface and the toe of the cell. The angle of internal friction and unit weight chosen for this region was based on observation of the native soil parameters near the toe of the cell and may differ from the overall unit weight and friction angle used to develop the active and passive pressures. The internal friction angles for calculating “G”, within the cell fill and within the foundation soil should be the same as used to develop the log spirals. The unit weight and internal friction angle chosen were: failure within cell fill – 119 pcf and 33 degrees, failure within foundation soil – 130 pcf and 33 degrees.

**Stability Berm Width:**
The cofferdam at this location required a stability berm. The preliminary berm width was approximately 58 feet. This assumed a soil-sheetpile friction angle of 0 degrees and a berm constructed of the native material. The width may be reduced by constructing the berm using a higher unit weight material and accounting for friction between the sheet pile and soil.

**Sliding:**
The generalized soil profile shown in Table 2-1 indicates that there is a 2½ foot thick clay layer within the cell approximately 5 feet from the toe of the cell. The cofferdam cell design for this station has the sheet piles tipping out in the sand layer below this clay layer. Since the toe of the cell is founded in sand, the Factor of Safety against sliding was evaluated for the condition where sand inside the cell was sliding on sand just below the cell toe. This was considered the “base condition.” Since the clay layer could potentially impact the location of the sliding surface and therefore the Factor of Safety against sliding, a sensitivity analysis was conducted by changing the strength of the soil in which potential sliding could occur. The sensitivity analysis involved evaluating the Factor of Safety against sliding if the sliding surface moved to within the clay layer. In the analysis, both the drained and undrained conditions for the clay
were analyzed. The results are included in the calculation package. Additional evaluations of Failure due to sliding should be conducted during final design when information regarding the areal extent and strength parameters of the clay is available.
Circular Sheet Pile Cofferdam

Equivalent width \( B = 80 \) ft

Cell Diameter = \( 97.8 \) ft (for \( \alpha = 30 \) degrees, \( 30^\circ Y \))

\( 91.4 \) ft (for \( \alpha = 45 \) degrees, \( 90^\circ T \))

Cell Fill Material Properties:

- \( \gamma = 120 \) pcf
- \( \phi = 28 \) degrees

Soil Elev. \( 5.0 \) ft

\( \gamma' = 56.6 \) pcf

\( \gamma = 119 \) pcf

Berm Elev. \( -35.0 \) ft

Berm height = \( 20.0 \) ft.

Cofferdam Grade Elev. \( -55.0 \) ft

Sheet Pile Tip Elev. \( -70.0 \) ft

Foundation Soil Material Properties:

- \( \gamma = 128 \) pcf
- \( \phi = 33 \) degrees
- \( c = 0 \) psf

Total Sheet Pile length: \( 92.0 \) ft

Station 28+00

Not to Scale
Pressure Diagram for Active and Passive Pressures

<table>
<thead>
<tr>
<th>Water</th>
<th>Soil</th>
<th>Active</th>
<th>Passive</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_w$ = 62.4 pcf</td>
<td>$\phi$ = 28 degrees</td>
<td>$\gamma_a$ = 119 pcf</td>
<td>$\phi$ = 28 degrees</td>
</tr>
<tr>
<td>$h_{w1}$ = 80 ft</td>
<td>$\gamma$ = 119 pcf</td>
<td>$h_a$ = 75 ft</td>
<td>$\gamma$ = 119 pcf</td>
</tr>
<tr>
<td>$P_w = 199.68$ kips</td>
<td>$P_a = 57.47$ kips</td>
<td>$P_p = 1981$ psf</td>
<td>$P_p = 96.02$ kips</td>
</tr>
<tr>
<td>MA = 26.7 ft</td>
<td>MA = 25.0 ft</td>
<td>MA = 25.0 ft</td>
<td>MA = 11.7 ft</td>
</tr>
</tbody>
</table>

CPRA Mid-Barataria Sediment Diversion
Sediment Diversion Structure
Station 28+00 Cofferdam Design - Preliminary (30% Design)

NOT TO SCALE
Generation of Log Spiral curve for failure surface.

Log Spiral equation:

\[ R = r e^{\alpha \tan \phi} \]

\( \alpha \) = angle between segments R and r.
\( \phi \) = angle of internal friction of cell fill or foundation soil.

Input values:

Constants:
- \( B = 80 \) feet (equivalent width)
- \( \phi \) = [see below] degrees

Variables:
- \( \alpha \) (entered below)

Law of Cosines:

\[ c^2 = a^2 + b^2 - 2ab \cos \theta \]

or

\[ B^2 = R^2 + r^2 - 2Rr \cos \alpha \]

put R in terms of r, then solve for r.

Solve for R using Log Spiral equation.

Failure surface within cell fill (A-rupture).

Internal friction angle of cell granular soil, \( \phi \): 33 degrees

Calculation:

<table>
<thead>
<tr>
<th>Pole</th>
<th>( \alpha )</th>
<th>( e^{\alpha \tan \phi} )</th>
<th>( R/r )</th>
<th>( r ) (ft)</th>
<th>( R ) (ft)</th>
<th>( x ) (ft)</th>
<th>( y ) (ft)</th>
<th>( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>170</td>
<td>6.87</td>
<td>6.87</td>
<td>10.19</td>
<td>69.95</td>
<td>10.07</td>
<td>1.55</td>
<td>8.7</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>6.13</td>
<td>6.13</td>
<td>11.30</td>
<td>69.29</td>
<td>10.79</td>
<td>3.35</td>
<td>17.2</td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>5.47</td>
<td>5.47</td>
<td>12.58</td>
<td>68.86</td>
<td>11.35</td>
<td>5.41</td>
<td>25.5</td>
</tr>
<tr>
<td>4</td>
<td>140</td>
<td>4.89</td>
<td>4.89</td>
<td>14.06</td>
<td>68.72</td>
<td>11.72</td>
<td>7.76</td>
<td>33.5</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
<td>4.36</td>
<td>4.36</td>
<td>15.79</td>
<td>68.93</td>
<td>11.86</td>
<td>10.42</td>
<td>41.3</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>3.90</td>
<td>3.90</td>
<td>17.85</td>
<td>69.57</td>
<td>11.75</td>
<td>13.44</td>
<td>48.9</td>
</tr>
<tr>
<td>7</td>
<td>110</td>
<td>3.48</td>
<td>3.48</td>
<td>20.33</td>
<td>70.73</td>
<td>11.31</td>
<td>16.89</td>
<td>56.2</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>3.11</td>
<td>3.11</td>
<td>23.36</td>
<td>72.56</td>
<td>10.50</td>
<td>20.87</td>
<td>63.3</td>
</tr>
<tr>
<td>9</td>
<td>90</td>
<td>2.77</td>
<td>2.77</td>
<td>27.14</td>
<td>75.26</td>
<td>9.20</td>
<td>25.53</td>
<td>70.2</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>2.48</td>
<td>2.48</td>
<td>31.94</td>
<td>79.10</td>
<td>7.27</td>
<td>31.11</td>
<td>76.8</td>
</tr>
<tr>
<td>11</td>
<td>70</td>
<td>2.21</td>
<td>2.21</td>
<td>38.24</td>
<td>84.55</td>
<td>4.46</td>
<td>37.98</td>
<td>83.3</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>1.97</td>
<td>1.97</td>
<td>46.80</td>
<td>92.37</td>
<td>0.36</td>
<td>46.79</td>
<td>89.6</td>
</tr>
<tr>
<td>13</td>
<td>50</td>
<td>1.76</td>
<td>1.76</td>
<td>58.97</td>
<td>103.93</td>
<td>-5.78</td>
<td>58.69</td>
<td>95.6</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>1.57</td>
<td>1.57</td>
<td>77.51</td>
<td>121.97</td>
<td>-15.43</td>
<td>75.96</td>
<td>101.5</td>
</tr>
</tbody>
</table>
Failure surface within foundation soil (X-rupture).

Internal friction angle of foundation soil, $\phi$: 33 degrees

<table>
<thead>
<tr>
<th>Pole</th>
<th>$\alpha$</th>
<th>$e^{\alpha}$ tan $\phi$</th>
<th>$r$</th>
<th>$r$ (ft)</th>
<th>$R$ (ft)</th>
<th>$x$ (ft)</th>
<th>$y$ (ft)</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>179</td>
<td>7.61</td>
<td>7.61</td>
<td>9.30</td>
<td>70.70</td>
<td>9.30</td>
<td>0.14</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td>177</td>
<td>7.43</td>
<td>7.43</td>
<td>9.49</td>
<td>70.53</td>
<td>9.48</td>
<td>0.44</td>
<td>2.6</td>
</tr>
<tr>
<td>3</td>
<td>175</td>
<td>7.27</td>
<td>7.27</td>
<td>9.68</td>
<td>70.35</td>
<td>9.65</td>
<td>0.74</td>
<td>4.4</td>
</tr>
<tr>
<td>4</td>
<td>172</td>
<td>7.03</td>
<td>7.03</td>
<td>9.98</td>
<td>70.11</td>
<td>9.90</td>
<td>1.22</td>
<td>7.0</td>
</tr>
<tr>
<td>5</td>
<td>170</td>
<td>6.87</td>
<td>6.87</td>
<td>10.19</td>
<td>69.95</td>
<td>10.07</td>
<td>1.55</td>
<td>8.7</td>
</tr>
<tr>
<td>6</td>
<td>165</td>
<td>6.49</td>
<td>6.49</td>
<td>10.72</td>
<td>69.59</td>
<td>10.45</td>
<td>2.41</td>
<td>13.0</td>
</tr>
<tr>
<td>7</td>
<td>160</td>
<td>6.13</td>
<td>6.13</td>
<td>11.30</td>
<td>69.29</td>
<td>10.79</td>
<td>3.35</td>
<td>17.2</td>
</tr>
<tr>
<td>8</td>
<td>155</td>
<td>5.79</td>
<td>5.79</td>
<td>11.92</td>
<td>69.04</td>
<td>11.10</td>
<td>4.35</td>
<td>21.4</td>
</tr>
<tr>
<td>9</td>
<td>150</td>
<td>5.47</td>
<td>5.47</td>
<td>12.58</td>
<td>68.86</td>
<td>11.35</td>
<td>5.41</td>
<td>25.5</td>
</tr>
<tr>
<td>10</td>
<td>145</td>
<td>5.17</td>
<td>5.17</td>
<td>13.29</td>
<td>68.75</td>
<td>11.56</td>
<td>6.55</td>
<td>29.5</td>
</tr>
<tr>
<td>11</td>
<td>140</td>
<td>4.89</td>
<td>4.89</td>
<td>14.06</td>
<td>68.72</td>
<td>11.72</td>
<td>7.76</td>
<td>33.5</td>
</tr>
<tr>
<td>12</td>
<td>135</td>
<td>4.62</td>
<td>4.62</td>
<td>14.89</td>
<td>68.78</td>
<td>11.82</td>
<td>9.05</td>
<td>37.4</td>
</tr>
<tr>
<td>13</td>
<td>130</td>
<td>4.36</td>
<td>4.36</td>
<td>15.79</td>
<td>68.93</td>
<td>11.86</td>
<td>10.42</td>
<td>41.3</td>
</tr>
<tr>
<td>14</td>
<td>125</td>
<td>4.12</td>
<td>4.12</td>
<td>16.78</td>
<td>69.19</td>
<td>11.84</td>
<td>11.89</td>
<td>45.1</td>
</tr>
</tbody>
</table>
### Overturning

**Moments about Log Spiral Poles (Hansen's Method):**

**Moment Inputs:**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Moment arm</th>
<th>Soil</th>
<th>Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>3</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>1</td>
<td>0.40</td>
<td>1342.4</td>
<td>1342.4</td>
<td>2684.8</td>
</tr>
<tr>
<td>2</td>
<td>1.14</td>
<td>5390.7</td>
<td>5390.7</td>
<td>10781.5</td>
</tr>
<tr>
<td>4</td>
<td>1.18</td>
<td>3139.5</td>
<td>3139.5</td>
<td>6279.0</td>
</tr>
<tr>
<td>6</td>
<td>1.21</td>
<td>2737.3</td>
<td>2737.3</td>
<td>5474.6</td>
</tr>
</tbody>
</table>

**Drained Cell Fill:**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Moment arm</th>
<th>Soil</th>
<th>Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>3</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>1</td>
<td>0.40</td>
<td>1342.4</td>
<td>1342.4</td>
<td>2684.8</td>
</tr>
<tr>
<td>2</td>
<td>1.14</td>
<td>5390.7</td>
<td>5390.7</td>
<td>10781.5</td>
</tr>
<tr>
<td>4</td>
<td>1.18</td>
<td>3139.5</td>
<td>3139.5</td>
<td>6279.0</td>
</tr>
<tr>
<td>6</td>
<td>1.21</td>
<td>2737.3</td>
<td>2737.3</td>
<td>5474.6</td>
</tr>
</tbody>
</table>

**Saturated Cell Fill:**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Moment arm</th>
<th>Soil</th>
<th>Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>3</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>1</td>
<td>0.40</td>
<td>1342.4</td>
<td>1342.4</td>
<td>2684.8</td>
</tr>
<tr>
<td>2</td>
<td>1.14</td>
<td>5390.7</td>
<td>5390.7</td>
<td>10781.5</td>
</tr>
<tr>
<td>4</td>
<td>1.18</td>
<td>3139.5</td>
<td>3139.5</td>
<td>6279.0</td>
</tr>
<tr>
<td>6</td>
<td>1.21</td>
<td>2737.3</td>
<td>2737.3</td>
<td>5474.6</td>
</tr>
</tbody>
</table>

### Overturning Moments

<table>
<thead>
<tr>
<th>Pole</th>
<th>Moment arm</th>
<th>Soil</th>
<th>Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>3</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>1</td>
<td>0.40</td>
<td>1342.4</td>
<td>1342.4</td>
<td>2684.8</td>
</tr>
<tr>
<td>2</td>
<td>1.14</td>
<td>5390.7</td>
<td>5390.7</td>
<td>10781.5</td>
</tr>
<tr>
<td>4</td>
<td>1.18</td>
<td>3139.5</td>
<td>3139.5</td>
<td>6279.0</td>
</tr>
<tr>
<td>6</td>
<td>1.21</td>
<td>2737.3</td>
<td>2737.3</td>
<td>5474.6</td>
</tr>
</tbody>
</table>

### Overturning Failure Mode

**Within cell fill:**

\[ G = A \times \left( \sin^2 \phi \cdot \tan \phi \right) \]

\[ G = 56.6 \text{ pcf} \]

\[ \phi = 33 \text{ degrees} \]

\[ A = \text{Factor of Safety} \]

\[ \text{Factor of Safety} = \frac{G}{2A} \]

**Min. Factor of Safety = 1.50**

---

**Drilled Cell Fill:**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Moment arm</th>
<th>Soil</th>
<th>Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>3</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>1</td>
<td>0.40</td>
<td>1342.4</td>
<td>1342.4</td>
<td>2684.8</td>
</tr>
<tr>
<td>2</td>
<td>1.14</td>
<td>5390.7</td>
<td>5390.7</td>
<td>10781.5</td>
</tr>
<tr>
<td>4</td>
<td>1.18</td>
<td>3139.5</td>
<td>3139.5</td>
<td>6279.0</td>
</tr>
<tr>
<td>6</td>
<td>1.21</td>
<td>2737.3</td>
<td>2737.3</td>
<td>5474.6</td>
</tr>
</tbody>
</table>

**Saturated Cell Fill:**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Moment arm</th>
<th>Soil</th>
<th>Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>3</td>
<td>2.37</td>
<td>3131.1</td>
<td>3288.7</td>
<td>6419.8</td>
</tr>
<tr>
<td>1</td>
<td>0.40</td>
<td>1342.4</td>
<td>1342.4</td>
<td>2684.8</td>
</tr>
<tr>
<td>2</td>
<td>1.14</td>
<td>5390.7</td>
<td>5390.7</td>
<td>10781.5</td>
</tr>
<tr>
<td>4</td>
<td>1.18</td>
<td>3139.5</td>
<td>3139.5</td>
<td>6279.0</td>
</tr>
<tr>
<td>6</td>
<td>1.21</td>
<td>2737.3</td>
<td>2737.3</td>
<td>5474.6</td>
</tr>
</tbody>
</table>

---

**Overturning Failure Mode**

\[ A = \text{Factor of Safety} \]

\[ \text{Factor of Safety} = \frac{G}{2A} \]

\[ G = 56.6 \text{ pcf} \]

\[ \phi = 33 \text{ degrees} \]
### Overturning (continued)

Moments about Log Spiral (Hansen's Method):

### X-Rupture Failure Mode

(Below cell in foundation soil)

For soil below revet - 65 ft, use $\phi = 30^\circ$ and $\gamma = 128$ pf

\[ G = \gamma \left( \frac{R}{2} - \frac{h}{2} \right) \]

\[ F' = \frac{\gamma}{\gamma + \phi} \]

### Overturning Moments

<table>
<thead>
<tr>
<th>Pole</th>
<th>y-coord</th>
<th>Moment (kips)</th>
<th>Area 1</th>
<th>Area 2</th>
<th>Area 3</th>
<th>Area 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pole</td>
<td>coord.</td>
<td>x-coord</td>
<td>Pole</td>
<td>coord.</td>
<td>x-coord</td>
<td>Pole</td>
</tr>
<tr>
<td>1</td>
<td>0.14</td>
<td>26.1</td>
<td>199.68</td>
<td>1394.16</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>2</td>
<td>0.44</td>
<td>29.9</td>
<td>199.68</td>
<td>1394.43</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>3</td>
<td>0.74</td>
<td>33.6</td>
<td>199.68</td>
<td>1394.69</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>4</td>
<td>1.22</td>
<td>37.4</td>
<td>199.68</td>
<td>1394.95</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>5</td>
<td>1.55</td>
<td>41.2</td>
<td>199.68</td>
<td>1395.21</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>6</td>
<td>2.41</td>
<td>50.1</td>
<td>199.68</td>
<td>1395.47</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>7</td>
<td>3.35</td>
<td>53.9</td>
<td>199.68</td>
<td>1395.73</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>8</td>
<td>4.35</td>
<td>57.7</td>
<td>199.68</td>
<td>1396.00</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>9</td>
<td>5.41</td>
<td>61.5</td>
<td>199.68</td>
<td>1396.26</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>10</td>
<td>6.55</td>
<td>65.4</td>
<td>199.68</td>
<td>1396.52</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>11</td>
<td>7.76</td>
<td>69.2</td>
<td>199.68</td>
<td>1396.78</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>12</td>
<td>9.05</td>
<td>73.0</td>
<td>199.68</td>
<td>1397.05</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>13</td>
<td>10.34</td>
<td>76.8</td>
<td>199.68</td>
<td>1397.31</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>14</td>
<td>11.63</td>
<td>80.6</td>
<td>199.68</td>
<td>1397.58</td>
<td>216</td>
<td>216</td>
</tr>
</tbody>
</table>

### Safety Factor for failure below cell (RF)

\[ \text{Safety Factor} = 3.29 \]
Stability Berm Minimum Width

Distance from cell toe to top of berm = 35 feet
Angle of internal friction of passive soil = 28 degrees

Coulomb’s Theory:
Angle of failure wedge from wall, β = 45 + φ/2 degrees

β = 59 degrees

Minimum width of berm:

Width = distance from cell toe to top of berm * tan β

= 58.2 feet
Bearing Capacity at Toe (Terzaghi)

\[
\text{Factor of Safety} = \frac{c*N_c + 0.5*\gamma'\gamma B*N_{\gamma}}{(6*M/B^2) + \gamma\gamma'}
\]

From "Pile Buck Steel Sheet Piling Design Manual", 1987

- \(c = 0 \text{ psf}\) Cohesion of bearing stratum.
- \(N_c = 5.7\) [from Pile Buck, 1987 (after Terzaghi and Peck, 1967)]
- \(N_{\gamma} = 30\) (assume \(\phi = 33\) degrees)
- \(\gamma' = 57.0 \text{ pcf}\) average effective unit weight of bearing stratum within a depth \(H\).
- \(\gamma = 119.4 \text{ pcf}\) Average unit weight of cell fill.
- \(B = 80 \text{ ft}\) Equivalent width of cell (\(B = 0.818*D, \text{TVA}\)).
- \(H = 92 \text{ ft}\) Height of cell from sheet pile tip.
- \(M = 5195.4 \text{ kip-ft}\) Net overturning moment.

\[
\text{Factor of Safety} = 6.22
\]
Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:

\[ P_w = 199.68 \text{ kips} \]
\[ P_a = 57.47 \text{ kips} \]

Resisting Forces:

\[ P_w = 38.22 \text{ kips} \]
\[ P_p = 96.02 \text{ kips} \]

Cell Fill:

Area 1 \[ P_1 = 115.20 \text{ kips} \]
Area 2 \[ P_2 = 216.00 \text{ kips} \]
Area 3 \[ P_3 = 101.88 \text{ kips} \]
Area 4 \[ P_4 = 158.48 \text{ kips} \]

\[ P_c = P_1 + P_2 + P_3 + P_4 = 591.56 \text{ kips} \]

Friction angle of soil against soil at cell toe, \( \delta = \phi' \): 33 degrees
Effective cohesion along failure plane, \( c' \): 0 psf
Width of cofferdam, \( B \): 80 ft

If the sliding surface is within the cell, deduct the area below the sliding surface from Area 4.

Distance from cell toe to top of sliding surface = 0 feet
Revised Area 4, \( P_4 \) = 158.48 kips

Factor of Safety = \( \frac{\text{Resisting Forces}}{\text{Driving Forces}} = \frac{P_w + P_p + P_c \cdot \tan \delta + c' \cdot B}{P_w + P_a} \)

Factor of Safety = 2.02
Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:
\[ P_w = 199.68 \text{ kips} \]
\[ P_a = 57.47 \text{ kips} \]

Resisting Forces:
\[ P_w = 38.22 \text{ kips} \]
\[ P_p = 96.02 \text{ kips} \]

Cell Fill:
\[ P_1 = 115.20 \text{ kips} \]
\[ P_2 = 216.00 \text{ kips} \]
\[ P_3 = 101.88 \text{ kips} \]
\[ P_4 = 158.48 \text{ kips} \]
\[ P_C = P_1 + P_2 + P_3 + P_4 = 591.56 \text{ kips} \]

Friction angle of soil against soil at cell toe, \( \delta = \phi' \): 24 degrees
Effective cohesion along failure plane, \( c' \): 35 psf
Width of cofferdam, \( B \): 80 ft

If the sliding surface is within the cell, deduct the area below the sliding surface from Area 4.
Distance from cell toe to top of sliding surface = 8 feet
Revised Area 4, \( P_4 = 122.26 \text{ kips} \)

\[ \text{Factor of Safety} = \frac{R}{D} = \frac{P_w + P_p + P_C \tan \delta + c' B}{P_w + P_a} \]

\[ \text{Factor of Safety} = 1.49 \]
Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:

\[ P_w = 199.68 \text{ kips} \]
\[ P_a = 57.47 \text{ kips} \]

Resisting Forces:

\[ P_w = 38.22 \text{ kips} \]
\[ P_p = 96.02 \text{ kips} \]

Cell Fill:

Area 1 \[ P_1 = 115.20 \text{ kips} \]
Area 2 \[ P_2 = 216.00 \text{ kips} \]
Area 3 \[ P_3 = 101.88 \text{ kips} \]
Area 4 \[ P_4 = 158.48 \text{ kips} \]

\[ P_c = P_1 + P_2 + P_3 + P_4 = 591.56 \text{ kips} \]

Friction angle of soil against soil at cell toe, \( \delta = \phi \): 0 degrees
Cohesion along failure plane, \( c \): 450 psf
Width of cofferdam, \( B \): 80 ft

If the sliding surface is within the cell, deduct the area below the sliding surface from Area 4.
Distance from cell toe to top of sliding surface = 8 feet
Revised Area 4, \( P_4 = 122.26 \text{ kips} \)

\[ \text{Factor of Safety} = \frac{\text{Resisting Forces}}{\text{Driving Forces}} = \frac{P_w + P_p + P_c \cdot \tan \delta + c' \cdot B}{P_w + P_a} \]

\[ \text{Factor of Safety} = 0.66 \]
Interlock Tension

Cell diameter, \( D = 91.4 \) ft

Cell Fill Material Properties:
- \( \gamma = 120 \) pcf
- \( \varphi = 28 \) degrees
- \( \gamma' = 57.6 \) pcf

From "Pile Buck Steel Sheet Piling Design Manual", 1987:

\[
\sigma_T = K_a * \gamma * (H - H_1) + K_a * \gamma' * (H_1 - H/4) + \gamma_w * (H_3 - H/4)
\]

where:
- \( H = \) length of sheet pile = 92 ft
- \( H_1 = \) height of water on the outboard sheeting = 80 ft
- \( H_3 = \) height of water on the inboard sheeting = 35 ft

Assume \( K_a = 0.4 \) (minimum value suggested by Terzaghi)

\[
\sigma_T = 2638.08 \text{ pounds/sq. ft.}
\]

Maximum Interlock tension = \( \sigma_T * \) cell radius = 120.60 kips/ft

\( 10.05 \) kips/in.

Sheet pile: AS 500 12.7

Max. Interlock Strength = 31.4 kips/in. (Skyline Steel technical data sheet)

Approximate Factor of Safety = 3.12
<table>
<thead>
<tr>
<th>Project</th>
<th>Mid-Barataria Sediment Diversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>Gate Structure Cofferdam – Sta. 32+00 to 39+00</td>
</tr>
<tr>
<td>Task</td>
<td>Cellular Cofferdam Design – 30% Design</td>
</tr>
</tbody>
</table>

**PURPOSE**

Preliminary design of a cellular cofferdam at the inlet structure of the Mid-Barataria Sediment Diversion structure.

**REFERENCES**


**LOCATION**

The sediment diversion structure will be located South of New Orleans, LA connecting the Mississippi River and the Barataria Basin to the west.

**CALCULATIONS**

**Soil Profile and Soil Model:**
Soil parameters were taken from Table 4-1 – Conveyance Channel (Station 32+00 to 45+00).

After the sheet piles have been driven for the cofferdam cellular structures the soil on the outside of the cofferdam will be excavated to an elevation of -12 ft. and the inner cofferdam soil to elevation -55 ft. The cofferdam from station 32+00 to 39+00 has been analyzed for this condition. Starting at the post excavation elevation of -12 ft. the generalized soil column at the gate structure consisted of about 12 ft. of interbedded soft clays and clayey silt, elevation -12 ft. to -24 ft., then loose to medium dense silt to elevation -37 ft., then medium dense silt and silty sand to elevation -48 ft., then loose to very loose silt and clayey sand to elevation -63 ft., then a medium dense silty sand to elevation -76 ft., then medium dense sandy silt to elevation -93 ft. From elevation -93 ft. to -106 ft. was medium dense silty sand.

In order to simplify the design for the 30% design level, the upper 12 ft. of soft clay and loose silt were modeled with the sands and silts as a uniform granular material with the strength parameters adjusted to account for the relatively lower strength parameters of the clays and silts. It was also considered reasonable to use the drained condition soil strength parameters for the sand and silt.
Overall or Global Stability Soil Model:
Equivalent cell diameter was limited to 80 feet.
Sheet pile tip elevation: -85 feet. Total sheet pile length: of 73 ft.

It was assumed that after the sheet piles were driven that the native clay and silt within the cell would not be excavated and any cell fill placed would be placed directly on the native soil. As a result, the soil within the cell would have a profile of multiple layers of sands, silts, and clays each with significantly different unit weights and internal friction angles. In order to simplify the 30% design level calculations, the soil profile within the cell was generalized and divided into areas, each area becoming a uniform soil.

Page 4 shows the general cell geometry and the areas of uniform soil parameters. Since no imported fill would be required, the soil parameters in Area 1, 2, 3 and 4 were developed by reviewing the soil layers within each region and taking an average or weighted average of the unit weights and internal friction angles.

Area 1, 2, and 3 had a weighted average unit weight = 119 pcf. Area 4 had a weighted average unit weight equal to 119.5 pcf. The unit weight used to estimate the lateral earth pressure was 119.0 pcf. The weighted averages for the internal friction angles were: from elevation -12 ft. to -85 ft. was 29 degrees, and from elevation -55 ft. to -85 ft. was 30 degrees. A value of 29 degrees was chosen for the soil model for both the active and passive soil calculations to simplify the calculation procedure.

The soil parameters below the pile tip elevation used in calculations were evaluated in a similar way as the cell fill. The soil profile below the pile tip elevation was evaluated to a depth of ¼B (approximately 20 ft.) below the cell toe. The depth of ¼B was chosen simply for ease of calculation. A depth equal to the cell diameter should be evaluated for final design. The weighted average unit weight = 122.5 pcf. An internal friction angle = 33 degrees was chosen by inspection.

Log Spiral Curves:
The poles for the log spirals are dependent on the angle of internal friction of the soil that the failure surface is passing through. For failure within the cell, the angle chosen for the calculations was 31 degrees. This was based on the fact that the internal friction angle of the soil within the cell and near the toe of the cell had an internal friction angle of 33 degrees extending from the toe to 9 ft. above the toe. It was assumed that the majority of the trial failure surfaces would not be within that region and some would extend into the 30 degree material. For failure within the foundation soil, the soil angle of internal friction was 33 degrees.
to a depth of 21 ft., elevation -106 ft., below the cell toe. It was assumed that the majority of failure surfaces would occur within this region. Thirty-three degrees was chosen to develop the log spiral curves below the cell toe.

The alpha values used for developing the log spirals within the foundation soil were chosen so that the pole of the log spirals would not cross the lateral pressure resultant centroid which would produce a negative moment arm and negative moment. This negative moment would produce a false Factor of Safety for the log spiral pole. The cut-off value was determined by trail and error and was found to be 120 degrees.

Hansen’s Method:
Hansen’s method produces an area between the log spiral failure surface and the toe of the cell. The force resultant of this region is commonly referred to as “G”. The area of this region is partly based on the internal friction angle of the soil encompassed by the failure surface and the toe of the cell. The angle of internal friction and unit weight chosen for this region was based on observation of the native soil parameters near the toe of the cell and may differ from the overall unit weight and friction angle used to develop the active and passive pressures. The internal friction angles for calculating “G”, within the cell fill and within the foundation soil should be the same as used to develop the log spirals. The unit weight and internal friction angle chosen were: failure within cell fill – 120 pcf and 31 degrees, failure within foundation soil – 122.5 pcf and 33 degrees.

Stability Berm Width:
The cofferdam at this location does not require a stability berm.

Sliding:
The Factor of Safety against sliding was evaluated for the cell sliding on sand located at the toe of the cell. The friction angle chosen for the analysis was 33 degrees. This angle was chosen because it was the angle of internal friction of the sand above and below the cell toe.
Circular Sheet Pile Cofferdam

Sheet pile top Elev.  -12.0 ft
Pool Elev.  -21.0 ft
Soil Elev.  -12.0 ft
h₁ = 9.0 ft
h₂ = 64.0 ft
h₃ = 30.0 ft
h₄ = 30.0 ft

Equivalent width B = 80 ft

Cell Diameter = 97.8 ft (for α = 30 degrees, 30° Y)
91.4 ft (for α = 45 degrees, 90° T)

Cell Fill Material Properties:
γ = 119 pcf
φ = 29 degrees

γ' = 56.6 pcf
γ = 119 pcf

γ' = 56.6 pcf
γ = 119 pcf

Sheet Pile Tip Elev.  -85.0 ft
Berm Elev.  -55.0 ft
Berm height = 0.0 ft.
Cofferdam Grade Elev.  -55.0 ft

Foundation Soil Material Properties:
γ = 122.5 pcf
φ = 33 degrees
c = 0 psf

Total Sheet Pile length: 73.0 ft

Station 32+00 to 39+00
Not to Scale
Pressure Diagram for Active and Passive Pressures

**Active**
- \( \gamma_w = 62.4 \text{ pcf} \)
- \( h_{w1} = 64 \text{ ft} \)

\[ \varphi = 29 \text{ degrees} \]
\[ \gamma = 126.6932 \text{ pcf} \]
\[ K_a = 0.347 \]
\[ \gamma' = 64.29315 \text{ pcf} \]
\[ h_a = 73 \text{ ft} \]

\[ P_a = 59.44 \text{ kips} \]
\[ \text{Moment arm (MA)} = 31.8 \text{ ft} \]

\[ P_w = 127.80 \text{ kips} \]
\[ \text{MA} = 21.3 \text{ ft} \]

\[ 3993.6 \text{ psf} \]

**Passive**
- \( \gamma_w = 62.4 \text{ pcf} \)
- \( h_{w2} = 30 \text{ ft} \)

\[ \varphi = 29 \text{ degrees} \]
\[ \gamma = 119 \text{ pcf} \]
\[ K_p = 2.882 \]
\[ \gamma' = 56.6 \text{ pcf} \]
\[ h_p = 30 \text{ ft} \]

\[ P_p = 73.41 \text{ kips} \]
\[ \text{MA} = 10.0 \text{ ft} \]

\[ 1698 \text{ psf} \]

\[ 1872 \text{ psf} \]

---

*NOT TO SCALE*
Generation of Log Spiral curve for failure surface.

Log Spiral equation:

\[ R = r e^{\alpha \tan \varphi} \]

\( \alpha \) = angle between segments R and r.
\( \varphi \) = angle of internal friction of cell fill or foundation soil.

Input values:

Constants:
- \( B = 80 \) feet (equivalent width)
- \( \varphi = \) [see below] degrees

Variables:
- \( \alpha \) (entered below)

Law of Cosines:

\[ c^2 = a^2 + b^2 - 2ab \cos \theta \]

or

\[ B^2 = R^2 + r^2 - 2Rr \cos \alpha \]

put \( R \) in terms of \( r \), then solve for \( r \).

Solve for \( R \) using Log Spiral equation.

Failure surface within cell fill (A-rupture).

Internal friction angle of cell granular soil, \( \varphi \): 31 degrees

Calculation:

<table>
<thead>
<tr>
<th>Pole</th>
<th>( \alpha )</th>
<th>( e^{\alpha \tan \varphi} )</th>
<th>( R/r )</th>
<th>( r ) (ft)</th>
<th>( R ) (ft)</th>
<th>( x ) (ft)</th>
<th>( y ) (ft)</th>
<th>( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>170</td>
<td>5.95</td>
<td>5.95</td>
<td>11.54</td>
<td>68.61</td>
<td>11.41</td>
<td>1.72</td>
<td>8.6</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>5.35</td>
<td>5.35</td>
<td>12.69</td>
<td>67.96</td>
<td>12.14</td>
<td>3.69</td>
<td>16.9</td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>4.82</td>
<td>4.82</td>
<td>14.01</td>
<td>67.56</td>
<td>12.70</td>
<td>5.92</td>
<td>25.0</td>
</tr>
<tr>
<td>4</td>
<td>140</td>
<td>4.34</td>
<td>4.34</td>
<td>15.54</td>
<td>67.47</td>
<td>13.06</td>
<td>8.42</td>
<td>32.8</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
<td>3.91</td>
<td>3.91</td>
<td>17.33</td>
<td>67.75</td>
<td>13.19</td>
<td>11.24</td>
<td>40.4</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>3.52</td>
<td>3.52</td>
<td>19.45</td>
<td>68.48</td>
<td>13.06</td>
<td>14.42</td>
<td>47.8</td>
</tr>
<tr>
<td>7</td>
<td>110</td>
<td>3.17</td>
<td>3.17</td>
<td>22.01</td>
<td>69.75</td>
<td>12.62</td>
<td>18.03</td>
<td>55.0</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>2.85</td>
<td>2.85</td>
<td>25.13</td>
<td>71.71</td>
<td>11.80</td>
<td>22.18</td>
<td>62.0</td>
</tr>
<tr>
<td>9</td>
<td>90</td>
<td>2.57</td>
<td>2.57</td>
<td>29.01</td>
<td>74.55</td>
<td>10.52</td>
<td>27.04</td>
<td>68.7</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>2.31</td>
<td>2.31</td>
<td>33.96</td>
<td>78.57</td>
<td>8.62</td>
<td>32.84</td>
<td>75.3</td>
</tr>
<tr>
<td>11</td>
<td>70</td>
<td>2.08</td>
<td>2.08</td>
<td>40.43</td>
<td>84.23</td>
<td>5.87</td>
<td>40.00</td>
<td>81.7</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>1.88</td>
<td>1.88</td>
<td>49.20</td>
<td>92.31</td>
<td>1.87</td>
<td>49.17</td>
<td>87.8</td>
</tr>
<tr>
<td>13</td>
<td>50</td>
<td>1.69</td>
<td>1.69</td>
<td>61.68</td>
<td>104.20</td>
<td>-4.09</td>
<td>61.55</td>
<td>93.8</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>1.52</td>
<td>1.52</td>
<td>80.67</td>
<td>122.72</td>
<td>-13.45</td>
<td>79.54</td>
<td>99.6</td>
</tr>
</tbody>
</table>
Failure surface within foundation soil (X-rupture).

Internal friction angle of foundation soil, $\phi$: 33 degrees

<table>
<thead>
<tr>
<th>Pole</th>
<th>$\alpha$</th>
<th>$e^{\alpha \tan \phi}$</th>
<th>$R/r$</th>
<th>$r$ (ft)</th>
<th>$R$ (ft)</th>
<th>$x$ (ft)</th>
<th>$y$ (ft)</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>179</td>
<td>7.61</td>
<td>7.61</td>
<td>9.30</td>
<td>70.70</td>
<td>9.30</td>
<td>0.14</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td>177</td>
<td>7.43</td>
<td>7.43</td>
<td>9.49</td>
<td>70.53</td>
<td>9.48</td>
<td>0.44</td>
<td>2.6</td>
</tr>
<tr>
<td>3</td>
<td>175</td>
<td>7.27</td>
<td>7.27</td>
<td>9.68</td>
<td>70.35</td>
<td>9.65</td>
<td>0.74</td>
<td>4.4</td>
</tr>
<tr>
<td>4</td>
<td>172</td>
<td>7.03</td>
<td>7.03</td>
<td>9.98</td>
<td>70.11</td>
<td>9.90</td>
<td>1.22</td>
<td>7.0</td>
</tr>
<tr>
<td>5</td>
<td>170</td>
<td>6.87</td>
<td>6.87</td>
<td>10.19</td>
<td>69.95</td>
<td>10.07</td>
<td>1.55</td>
<td>8.7</td>
</tr>
<tr>
<td>6</td>
<td>165</td>
<td>6.49</td>
<td>6.49</td>
<td>10.72</td>
<td>69.59</td>
<td>10.45</td>
<td>2.41</td>
<td>13.0</td>
</tr>
<tr>
<td>7</td>
<td>160</td>
<td>6.13</td>
<td>6.13</td>
<td>11.30</td>
<td>69.29</td>
<td>10.79</td>
<td>3.35</td>
<td>17.2</td>
</tr>
<tr>
<td>8</td>
<td>155</td>
<td>5.79</td>
<td>5.79</td>
<td>11.92</td>
<td>69.04</td>
<td>11.10</td>
<td>4.35</td>
<td>21.4</td>
</tr>
<tr>
<td>9</td>
<td>150</td>
<td>5.47</td>
<td>5.47</td>
<td>12.58</td>
<td>68.86</td>
<td>11.35</td>
<td>5.41</td>
<td>25.5</td>
</tr>
<tr>
<td>10</td>
<td>145</td>
<td>5.17</td>
<td>5.17</td>
<td>13.29</td>
<td>68.75</td>
<td>11.56</td>
<td>6.55</td>
<td>29.5</td>
</tr>
<tr>
<td>11</td>
<td>140</td>
<td>4.89</td>
<td>4.89</td>
<td>14.06</td>
<td>68.72</td>
<td>11.72</td>
<td>7.76</td>
<td>33.5</td>
</tr>
<tr>
<td>12</td>
<td>135</td>
<td>4.62</td>
<td>4.62</td>
<td>14.89</td>
<td>68.78</td>
<td>11.82</td>
<td>9.05</td>
<td>37.4</td>
</tr>
<tr>
<td>13</td>
<td>130</td>
<td>4.36</td>
<td>4.36</td>
<td>15.79</td>
<td>68.93</td>
<td>11.86</td>
<td>10.42</td>
<td>41.3</td>
</tr>
<tr>
<td>14</td>
<td>125</td>
<td>4.12</td>
<td>4.12</td>
<td>16.78</td>
<td>69.19</td>
<td>11.84</td>
<td>11.89</td>
<td>45.1</td>
</tr>
</tbody>
</table>

Locus of Poles

[Diagram of Locus of Poles]

X-Rupture

Horizontal Distance from Point A (ft)

Vertical Distance from Point A (ft)
### Overturning

#### Moments about Log Spiral Poles (Hansen's Method):

<table>
<thead>
<tr>
<th>Water</th>
<th>Pole Moment</th>
<th>Resultant Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y = 62.4 pcf</td>
<td>56.6 pcf</td>
<td>1168.37 kips</td>
</tr>
<tr>
<td>Pole = 1</td>
<td>127.80 kips</td>
<td>3653.49 kips</td>
</tr>
<tr>
<td>Moment arm = 21.8 ft (from Point A)</td>
<td>361.3 ft (from Point A)</td>
<td>26.7 ft</td>
</tr>
</tbody>
</table>

#### Soil Input:

<table>
<thead>
<tr>
<th>Soil h</th>
<th>Xf</th>
<th>Saturated Cell Fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>73 ft</td>
<td>64,393.33 pcf</td>
<td>2400.00 ft</td>
</tr>
<tr>
<td>Pole y = 0.06</td>
<td>56.6 pcf</td>
<td>56.6</td>
</tr>
<tr>
<td>Pole y = 0.98</td>
<td>2.88</td>
<td>56.6 pcf</td>
</tr>
<tr>
<td>Resultant = 56.6 kips</td>
<td>73.41 kips</td>
<td>127.80 kips</td>
</tr>
<tr>
<td>Moment arm = 21.8 ft (from Point A)</td>
<td>361.3 ft (from Point A)</td>
<td>26.7 ft</td>
</tr>
</tbody>
</table>

#### A-Rupture Failure Mode (Within cell fill):

\[ G = A \times (g - y') + \frac{4K_b}{e_y} \]

### Overturning Moments

<table>
<thead>
<tr>
<th>Water</th>
<th>Pole Moment</th>
<th>Resultant Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y = 62.4 pcf</td>
<td>56.6 pcf</td>
<td>1168.37 kips</td>
</tr>
<tr>
<td>Pole = 1</td>
<td>127.80 kips</td>
<td>3653.49 kips</td>
</tr>
<tr>
<td>Moment arm = 21.8 ft (from Point A)</td>
<td>361.3 ft (from Point A)</td>
<td>26.7 ft</td>
</tr>
</tbody>
</table>

#### Moment arms:

- Rectangular area:
  - Area 1 = 28.08 ft
  - Area 2 = 85.68 ft
  - Area 3 = 26.7 ft

- Triangular area:
  - Area 4 = 53.3 ft

### Overturning Summary

- Water
- Soil
- Design Cell Fill
- Resultant

### A-Rupture Failure Mode on next page
Overturning (continued):

Moments about Log Spiral Poles (Hansen's Method):

Overturning Moments

<table>
<thead>
<tr>
<th>Pole</th>
<th>y-coord.</th>
<th>Moment</th>
<th>Resultant</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.14</td>
<td>21.3</td>
<td>127.80</td>
<td>1277.72</td>
</tr>
<tr>
<td>2</td>
<td>0.64</td>
<td>20.8</td>
<td>128.70</td>
<td>2670.87</td>
</tr>
<tr>
<td>3</td>
<td>0.74</td>
<td>20.6</td>
<td>128.70</td>
<td>2651.49</td>
</tr>
<tr>
<td>4</td>
<td>1.22</td>
<td>20.1</td>
<td>128.70</td>
<td>2570.72</td>
</tr>
<tr>
<td>5</td>
<td>1.55</td>
<td>19.8</td>
<td>128.70</td>
<td>2526.60</td>
</tr>
<tr>
<td>6</td>
<td>2.41</td>
<td>18.8</td>
<td>128.70</td>
<td>2417.70</td>
</tr>
<tr>
<td>7</td>
<td>3.35</td>
<td>18.0</td>
<td>128.70</td>
<td>2286.53</td>
</tr>
<tr>
<td>8</td>
<td>4.35</td>
<td>17.0</td>
<td>128.70</td>
<td>2179.08</td>
</tr>
<tr>
<td>9</td>
<td>5.41</td>
<td>15.0</td>
<td>128.70</td>
<td>2034.52</td>
</tr>
<tr>
<td>10</td>
<td>6.55</td>
<td>14.8</td>
<td>128.70</td>
<td>1899.14</td>
</tr>
<tr>
<td>11</td>
<td>7.76</td>
<td>13.6</td>
<td>128.70</td>
<td>1784.12</td>
</tr>
<tr>
<td>12</td>
<td>9.05</td>
<td>12.3</td>
<td>128.70</td>
<td>1655.55</td>
</tr>
<tr>
<td>13</td>
<td>10.42</td>
<td>10.9</td>
<td>128.70</td>
<td>1494.34</td>
</tr>
<tr>
<td>14</td>
<td>11.89</td>
<td>9.4</td>
<td>128.70</td>
<td>1207.35</td>
</tr>
</tbody>
</table>

X-Rupture Failure Mode

For soil below rivett: 65 ft., φ = 30° and γ = 128 pcf.

\[ G = \phi \gamma \]

\[ A = [R - r]/4 \tan \theta \]

Overturning Moments

<table>
<thead>
<tr>
<th>Overturning</th>
<th>Resultant</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Water</td>
<td>Soil</td>
</tr>
<tr>
<td>Area 1</td>
<td>Area 2</td>
<td>Area 3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pole</th>
<th>y-coord.</th>
<th>Moment</th>
<th>Resultant</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.14</td>
<td>21.3</td>
<td>127.80</td>
<td>1277.72</td>
</tr>
<tr>
<td>2</td>
<td>0.64</td>
<td>20.8</td>
<td>128.70</td>
<td>2670.87</td>
</tr>
<tr>
<td>3</td>
<td>0.74</td>
<td>20.6</td>
<td>128.70</td>
<td>2651.49</td>
</tr>
<tr>
<td>4</td>
<td>1.22</td>
<td>20.1</td>
<td>128.70</td>
<td>2570.72</td>
</tr>
<tr>
<td>5</td>
<td>1.55</td>
<td>19.8</td>
<td>128.70</td>
<td>2526.60</td>
</tr>
<tr>
<td>6</td>
<td>2.41</td>
<td>18.8</td>
<td>128.70</td>
<td>2417.70</td>
</tr>
<tr>
<td>7</td>
<td>3.35</td>
<td>18.0</td>
<td>128.70</td>
<td>2286.53</td>
</tr>
<tr>
<td>8</td>
<td>4.35</td>
<td>17.0</td>
<td>128.70</td>
<td>2179.08</td>
</tr>
<tr>
<td>9</td>
<td>5.41</td>
<td>15.0</td>
<td>128.70</td>
<td>2034.52</td>
</tr>
<tr>
<td>10</td>
<td>6.55</td>
<td>14.8</td>
<td>128.70</td>
<td>1899.14</td>
</tr>
<tr>
<td>11</td>
<td>7.76</td>
<td>13.6</td>
<td>128.70</td>
<td>1784.12</td>
</tr>
<tr>
<td>12</td>
<td>9.05</td>
<td>12.3</td>
<td>128.70</td>
<td>1655.55</td>
</tr>
<tr>
<td>13</td>
<td>10.42</td>
<td>10.9</td>
<td>128.70</td>
<td>1494.34</td>
</tr>
<tr>
<td>14</td>
<td>11.89</td>
<td>9.4</td>
<td>128.70</td>
<td>1207.35</td>
</tr>
</tbody>
</table>

X-Rupture Failure

Min. Factor of Safety = 3.81
Stability Berm Minimum Width

Distance from cell toe to top of berm = 30 feet
Angle of internal friction of passive soil = 29 degrees

Coulomb’s Theory:
Angle of failure wedge from wall, $\beta = 45 + \phi/2$ degrees

$\beta = 59.5$ degrees

Minimum width of berm:

Width = distance from cell toe to top of berm * tan $\beta$

= 0.0 feet

No Stability Berm is Required
Bearing Capacity at Toe (Terzaghi)

\[ \text{Factor of Safety} = \frac{cN_c + 0.5\gamma'H}{{6M/B^2} + \gamma'H} \]

- \(c = 0\) psf  Cohesion of bearing stratum.
- \(N_c = 5.7\) [from Pile Buck, 1987 (after Terzaghi and Peck, 1967)]
- \(\phi = 33\) degrees
- \(N_r = 32\) [from Pile Buck, 1987 (after Terzaghi and Peck, 1967)]
- \(\gamma' = 60.1\) pcf  average effective unit weight of bearing stratum within a depth \(H\).
- \(\gamma = 119.0\) pcf  Average unit weight of cell fill.
- \(B = 80\) ft  Equivalent width of cell \((B = 0.818D, \text{TVA})\).
- \(H = 73\) ft  Height of cell from sheet pile tip.
- \(M = 3598.9\) kip-ft  Net overturning moment.

\[ \text{Factor of Safety} = 8.85 \]
Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:

\[ P_w = 127.80 \text{ kips} \]
\[ P_a = 59.44 \text{ kips} \]

Resisting Forces:

\[ P_w = 28.08 \text{ kips} \]
\[ P_p = 73.41 \text{ kips} \]

Cell Fill:

Area 1  \[ P_1 = 85.68 \text{ kips} \]
Area 2  \[ P_2 = 161.84 \text{ kips} \]
Area 3  \[ P_3 = 76.98 \text{ kips} \]
Area 4  \[ P_4 = 135.84 \text{ kips} \]

\[ P_C = P_1 + P_2 + P_3 + P_4 = 460.34 \text{ kips} \]

Friction angle of soil against soil at cell toe, \( \delta = \phi' \): 33 degrees

Effective cohesion along failure plane, \( c' \): 0 psf

Width of cofferdam, \( B \): 80 ft

If the sliding surface is within the cell, deduct the area below the sliding surface from Area 4.

Distance from cell toe to top of sliding surface = 0 feet

Revised Area 4, \( P_4 = 135.84 \text{ kips} \)

\[ \text{Factor of Safety} = \frac{\text{Resisting Forces}}{\text{Driving Forces}} = \frac{P_w + P_p + P_C \cdot \tan \delta + c' \cdot B}{P_w + P_a} \]

\[ \text{Factor of Safety} = 2.14 \]
Interlock Tension

Cell diameter, D = 91.4 ft

Cell Fill Material Properties:
\[ \gamma = 119 \text{ pcf} \]
\[ \phi = 29 \text{ degrees} \]
\[ \gamma' = 56.6 \text{ pcf} \]

From "Pile Buck Steel Sheet Piling Design Manual", 1987:

\[ \sigma_T = K_a \cdot \gamma \cdot (H - H_1) + K_a \cdot \gamma' \cdot (H_1 - H/4) + \gamma_w \cdot (H_3 - H/4) \]

\[ H = \text{length of sheet pile} = 73 \text{ ft} \]
\[ H_1 = \text{height of water on the outboard sheeting} = 64 \text{ ft} \]
\[ H_3 = \text{height of water on the inboard sheeting} = 30 \text{ ft} \]

Assume \( K_a = 0.4 \) (minimum value suggested by Terzaghi)

\[ \sigma_T = 2197.38 \text{ pounds/sq. ft.} \]

Maximum Interlock tension = \( \sigma_T \cdot \text{cell radius} = 100.45 \text{ kips/ft} \)
\[ = 8.37 \text{ kips/in.} \]

Sheet pile: AS 500 12.7
Max. Interlock Strength = 31.4 kips/in. (Skyline Steel technical data sheet)

Approximate Factor of Safety = 3.75
Attachment D. Design Calculations for Pipe Pile Retaining Structures (Shoring Suite Software)
MBSD Inlet Walls - Pipe Pile Alternative
Earth Pressure

PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.6 feet or meter
Pile: No Pile can't be found in Pile list. User input properties: E (ksi)=29000.0, I (in4)/foot=140579.0

Balance Force

Max. Shear=507.35 kip
Max. Moment=4468.02 kip-ft
Top Deflection=1.20(in)

0 1 ksf

Pressure Diagram

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110

Depth(ft)

507.35 kip 0

Max. Shear=507.35 kip
Max. Moment=4468.02 kip-ft
Top Deflection=1.20(in)

Max. Shear=507.35 kip
Max. Moment=4468.02 kip-ft
Top Deflection=1.20(in)

507.35 kip 0

4468.02 kip-ft 0

1.199(in) 0

Shear Diagram

Moment Diagram

Deflection Diagram
EARTH PRESSURE ANALYSIS SUMMARY

Software Copyright by CivilTech Software
www.civiltechsoftware.com

Licensed to 4324324234 3424343
Date: 6/20/2014 File: G:\Projects\099 - 209444 - Mid Barataria Sedimentation Diversion\06.00 Proj_Engr\Inlet Wall Analysis\PP 6 ft_Cantilever\PP_6 ft_Cantilever.ep8

Title 1: MBSD Inlet Walls - Pipe Pile Alternative
Title 2: Earth Pressure

Input data: *************************************************

Wall Height = 40.00
Depth of Ground at Active Side = 0.00
Depth of Ground at Passive Side = 40.00
Apparent Pressure Envelope: 1. Triangular Envelope (No-braced, all soils)
Pressure Type: 1. Active, Ka*
Earthquake Loading Apply to: 1. No Earthq. Loads
  Earthquake Horizontal Acceleration, Kh = 0
  Earthquake Vertical Acceleration, Kv = 0
Calculation Methods: 1. Numerical Solution (Wedge Analysis)
Wall Friction Options: 1. No wall friction
Apparent Pressure Conversion: 1. Default (Terzaghi and Peck)*
Water Density = 62.4
Water Pressure: 1. No seepage at wall tip*
User's Settings
  Ignore Passive from Depth = 0
  Multiplier of Active Pressure = 1
  Multiplier of Passive Pressure = 1
  Multiplier of Water Pressure = 1
  Multiplier of Earthq. Pressure = 1
  Estimate Embedment: Default: 3H
Program's Settings
  Max. Height, Hmax = 200.00
  Analysis Segment, dz = 1.00
  No. of Active Segment at H, nz0 = 1
  No. of Active Segment at Hmax, nz = 2
  No. of Passive Segment, nzp = 1
  Active Depth at H, Zh = 40.00
  Active Depth at Hmax, Z = 200.00
  Passive Depth at Hmax, Zp = 200.00
  Max. Pressure = 25.98

Total Soil Types= 3
Soil Weight W(S) Phi Cohesion Nspt Type Description
1 115.5 125.8 26.0 0.0 0 1 Eqv. Clay
2 114.9 125.3 26.0 0.0 0 1 Eqv. Clay
3 115.2 125.0 30.0 0.0 0 1 Eqv. Clay

Ground Surface at Active Side:
Line Z1 Xa1 Z2 Xa2 Soil No.
1 0.0 0.0 0.0 80000.0 1

Water Table at Active Side:
Point Z-water X-water
1 0.0 0.0
2 0.0 80000.0
Ground Surface at Passive Side:

<table>
<thead>
<tr>
<th>Line</th>
<th>Z1</th>
<th>Xp1</th>
<th>Z2</th>
<th>Xp2</th>
<th>Soil No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.0</td>
<td>0.0</td>
<td>40.0</td>
<td>150.0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>40.0</td>
<td>150.0</td>
<td>0.0</td>
<td>80000.0</td>
<td>1</td>
</tr>
</tbody>
</table>

Water Table at Passive Side:

<table>
<thead>
<tr>
<th>Point</th>
<th>Z-water</th>
<th>X-water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>80000.0</td>
</tr>
</tbody>
</table>

Output data: *************************************************

Eae (Active/At-Rest Force above Base) = 19.80
Ea (Total Static Force above Base) = 19.80
Ee (Total Earthquake Force above Base) = 0.00

Apparent Pressure above Base - Output to Shoring
Active/At-Rest Force above Base, Ea = 19.80

<table>
<thead>
<tr>
<th>No</th>
<th>Z1</th>
<th>P1</th>
<th>Z2</th>
<th>P2</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
<td>0.00</td>
<td>40.0</td>
<td>0.99</td>
<td>0.0248</td>
</tr>
</tbody>
</table>

Driving Pressure below Base - Output to Shoring

<table>
<thead>
<tr>
<th>No</th>
<th>Z1</th>
<th>P1</th>
<th>Z2</th>
<th>P2</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40.0</td>
<td>0.99</td>
<td>200.0</td>
<td>4.95</td>
<td>0.0248</td>
</tr>
</tbody>
</table>

Passive Pressure below Base - Output to Shoring

<table>
<thead>
<tr>
<th>No</th>
<th>Z1</th>
<th>P1</th>
<th>Z2</th>
<th>P2</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40.0</td>
<td>0.00</td>
<td>200.0</td>
<td>25.98</td>
<td>0.1624</td>
</tr>
</tbody>
</table>

*****************************************************************

DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip, PRESSURE: ksf, SLOPE: kcf

---

Z, Xa, Xp - Coordinates of ground lines
Z- Depth measured from wall top
Xa - Distance measure from wall to active side.
Xp - Distance measure from wall to passive side

Z1, P1, Z2, P2 - Four values to define a pressure diagram
Z1- Top depth of the diagram
P1- Top pressure of the diagram
Z2- Bottom depth of the diagram
P2- Bottom pressure of the diagram
Slope - (P2-P1)/(Z2-Z1), Slope of the diagram. It also called Equivalent fluid density. It equals to Ka*Gamma or Kp*Gamma
Shoring Suite Software is developed by CivilTech Software, Bellevue, WA, USA. The calculation method is based on the following references:
1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
6. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITs: Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft, Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft^3, Deflection - in

**INPUT DATA**

Wall Type: 3. Soldier Pile, Driving
Wall Height: 40.00
Pile Diameter: 6.00
Pile Spacing: 6.60
Factor of Safety (F.S.): 1.00
Lateral Support Type (Braces): 1. No
Top Brace Increase (Multi-Bracing): Add 15%
Embedment Option: 1. Yes
Friction at Pile Tip: No
Pile Properties:
- Allowable Fb/Fy: 0.66
- Steel Strength, Fy: 36 ksi = 248 MPa
- Elastic Module, E: 29000.00
- Moment of Inertia, I: 140579

User Input Pile:

<table>
<thead>
<tr>
<th>No.</th>
<th>Z2 top</th>
<th>Top Pres.</th>
<th>Z2 bottom</th>
<th>Bottom Pres.</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>40.00</td>
<td>0.99</td>
<td>0.0248</td>
</tr>
<tr>
<td>2</td>
<td>40.00</td>
<td>0.99</td>
<td>200.00</td>
<td>4.95</td>
<td>0.0248</td>
</tr>
</tbody>
</table>

* PASSIVE PRESSURE *

<table>
<thead>
<tr>
<th>No.</th>
<th>Z1 top</th>
<th>Top Pres.</th>
<th>Z2 bottom</th>
<th>Bottom Pres.</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.01</td>
<td>0.00</td>
<td>200.00</td>
<td>25.99</td>
<td>0.1624</td>
</tr>
</tbody>
</table>

* ACTIVE SPACE *
**report.out**

<table>
<thead>
<tr>
<th>No.</th>
<th>Z depth</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>6.60</td>
</tr>
<tr>
<td>2</td>
<td>40.00</td>
<td>6.00</td>
</tr>
</tbody>
</table>

* PASSIVE SPACE *

<table>
<thead>
<tr>
<th>No.</th>
<th>Z depth</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.00</td>
<td>6.60</td>
</tr>
</tbody>
</table>

*For Tieback: Input1 = Diameter; Input2 = Bond Strength
For Plate: Input1 = Diameter; Input2 = Allowable Pressure
For Deaman: Input1 = Horz. Width; Input2 = Allowable Pressure; Angle = 0

******************************CALCULATION******************************

The calculated moment and shear are per pile spacing. Sheet piles are per one feet or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

```
D1=0.00
==
D2=40.00
==
D3=93.14
```

D1 - TOP DEPTH
D2 - EXCAVATION BASE
D3 - PILE TIP (20% increased, see EMBEDMENT Notes below)

MOMENT BALANCE: M=0.00 AT DEPTH=84.29 WITH EMBEDMENT OF 44.29
FORCE BALANCE: F=0.00 AT DEPTH=93.14 WITH EMBEDMENT OF 53.14

The program calculates an embedment for moment equilibrium, then increase the embedment by
20% to reach force equilibrium.
A Balance Force=515.23 is developed from depth=84.29 to depth=93.14
Total Passive Pressure = Total Active Pressure, OK!

******************************RESULTS******************************

* EMBEDMENT Notes *
Based on USS Design Manual, first calculate embedment for moment equilibrium, then increased
by 20 to 40 % to reach force equilibrium.
The embedment for moment equilibrium is 44.29
The 20% increased embedment for force equilibrium is 53.14 (Used by Program)
The 30% increased embedment for force equilibrium is 57.57
The 40% increased embedment for force equilibrium is 62.00

Based on AASHTO Standard Specifications, first calculate embedment for moment equilibrium,
then add safety factor of 30% for temporary shoring; add safety factor of 50% for permanent
shoring.
The embedment for moment equilibrium is 44.29
Add 30% embedment for temporary shoring (FS=1.3) is 57.57
Add 50% embedment for permanent shoring (FS=1.5) is 66.43

Page 2
PROGRAM RECOMMENDED MINIMUM EMBEDMENT = 53.14
TOTAL MINIMUM PILE LENGTH = 93.14

* MOMENT IN PILE (per pile spacing)*
Overall Maximum Moment = 4468.02 at 64.47
Maximum Shear = 507.35
Moment and Shear are per pile spacing: 6.6 feet or meter

* VERTICAL LOADING *
Vertical Loading from Braces = 0.00
Vertical Loading from External Load = 0.00
Total Vertical Loading = 0.00

*****************************SPECIFIED PILE ***********************************
Specified Pile: No Pile can't be found in Pile Database.

*********************** LAGGING DESIGN ESTIMATION ***********************
Max. Pressure above base = 0.99
Piles are more rigid than timber lagging, only portion of pressures are acting to lagging,
30-50% arching is suggested.
If 50% arching is used for lagging design, Design Pressure = 0.49
  Pile Spacing = 6.6, Max. Moment in lagging = 2.70
  For 4"x12" Timber, Section Modules S = 23.47 in3. The request allowable bending strength,
  fb = M/S = 1.38
  For 6"x12" Timber, Section Modules S = 57.98 in3. The request allowable bending strength,
  fb = M/S = 0.56

If 30% arching is used for lagging design, Design Pressure = 0.30
  Pile Spacing = 6.6, Max. Moment in lagging = 1.62
  For 4"x12" Timber, Section Modules S = 23.47 in3. The request allowable bending strength,
  fb = M/S = 0.83
  For 6"x12" Timber, Section Modules S = 57.98 in3. The request allowable bending strength,
  fb = M/S = 0.33

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

********PRESSURE, LOAD, SHEAR, MOMENT, AND DEFLECTION v.s. DEPTH**************
The shear and moment are per single soldier pile (secant/tangent pile) or one foot
of sheet pile (concrete wall). The deflection is based on users input pile below:
User Input Pile:
  Elastic Module, E (ksi) = 29000.00
  Moment of Inertia, I (in4)/foot = 140579

PRESS. - Sum of all pressures on wall. Driving (Active) direction is positive
LOAD - Liner load (force per unit depth) = Pressures multiply by acting space

<table>
<thead>
<tr>
<th>No</th>
<th>DEPTH</th>
<th>PRESS.</th>
<th>LOAD</th>
<th>SHEAR</th>
<th>MOMENT</th>
<th>DEFLECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.199</td>
</tr>
<tr>
<td>2</td>
<td>0.12</td>
<td>0.00</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>1.196</td>
</tr>
<tr>
<td>3</td>
<td>0.23</td>
<td>0.01</td>
<td>0.04</td>
<td>0.00</td>
<td>0.00</td>
<td>1.194</td>
</tr>
<tr>
<td>4</td>
<td>0.35</td>
<td>0.01</td>
<td>0.06</td>
<td>0.01</td>
<td>0.00</td>
<td>1.192</td>
</tr>
<tr>
<td>5</td>
<td>0.47</td>
<td>0.01</td>
<td>0.08</td>
<td>0.02</td>
<td>0.00</td>
<td>1.189</td>
</tr>
<tr>
<td>6</td>
<td>0.58</td>
<td>0.01</td>
<td>0.10</td>
<td>0.03</td>
<td>0.01</td>
<td>1.187</td>
</tr>
<tr>
<td>7</td>
<td>0.70</td>
<td>0.02</td>
<td>0.11</td>
<td>0.04</td>
<td>0.01</td>
<td>1.185</td>
</tr>
<tr>
<td>8</td>
<td>0.82</td>
<td>0.02</td>
<td>0.13</td>
<td>0.05</td>
<td>0.01</td>
<td>1.182</td>
</tr>
<tr>
<td>9</td>
<td>0.93</td>
<td>0.02</td>
<td>0.15</td>
<td>0.07</td>
<td>0.02</td>
<td>1.180</td>
</tr>
<tr>
<td>10</td>
<td>1.05</td>
<td>0.03</td>
<td>0.17</td>
<td>0.09</td>
<td>0.03</td>
<td>1.177</td>
</tr>
<tr>
<td>11</td>
<td>1.17</td>
<td>0.03</td>
<td>0.19</td>
<td>0.11</td>
<td>0.04</td>
<td>1.175</td>
</tr>
</tbody>
</table>
MBSD Inlet Walls - Pipe Pile Alternative

Earth Pressure

Date: 5/29/2014     File Name: G:\Projects\099 - 209444 - Mid Barataria Sedimentation Diversion\06.00 Proj_Engr\Inlet Wall Analysis\PP 6 ft_Braced\PP_6ft.sh8

Licensed to 4324324234     3424343

PRESSURE, SHEAR, MOMENT, AND DEFLECTION DIAGRAMS

Based on pile spacing: 6.6 feet or meter

Pile: No Pile can’t be found in Pile list. User input properties:  
E (ksi)=29000.0,     I (in4)/pile= 140579.0

Max. Shear=317.28 kip

Max. Moment=4191.05 kip-ft

Top Deflection=0.69(in)

Pressure Diagram

Shear Diagram

Moment Diagram

Deflection Diagram

Date: 5/29/2014     File Name: G:\Projects\099 - 209444 - Mid Barataria Sedimentation Diversion\06.00 Proj_Engr\Inlet Wall Analysis\PP 6 ft_Braced\PP_6ft.sh8

<ShoringSuite> CIVILTECH SOFTWARE USA www.civiltechsoftware.com
Licensed to 4324324234     3424343
**Title 1: MBSD Inlet Walls - Pipe Pile Alternative**

**Title 2: Earth Pressure**

**Input data:************

- **Wall Height = 53.00**
- **Depth of Ground at Active Side = 0.00**
- **Depth of Ground at Passive Side = 53.00**
- **Pressure Type: 2. At rest, Ko**
- **Earthquake Loading Apply to: 1. No Earthq. Loads**
  - Earthquake Horizontal Acceleration, \( Kh = 0 \)
  - Earthquake Vertical Acceleration, \( Kv = 0 \)
- **Calculation Methods: 1. Numerical Solution (Wedge Analysis)**
- **Wall Friction Options: 1. No wall friction**
- **Apparent Pressure Conversion: 1. Default (Terzaghi and Peck)**
- **Water Density = 62.4**
- **Water Pressure: 1. No seepage at wall tip**

**User's Settings**
- Ignore Passive from Depth = 0
- Multiplier of Active Pressure = 1
- Multiplier of Passive Pressure = 1
- Multiplier of Water Pressure = 1
- Multiplier of Earthq. Pressure = 1
- Estimate Embedment: Default: 3H

**Program's Settings**
- Max. Height, \( H_{max} = 265.00 \)
- Analysis Segment, \( dz = 1.32 \)
- No. of Active Segment at H, \( n_{z0} = 1 \)
- No. of Active Segment at Hmax, \( n_{z} = 2 \)
- No. of Passive Segment, \( n_{zp} = 1 \)
- Active Depth at H, \( Z_h = 53.00 \)
- Active Depth at Hmax, \( Z = 265.00 \)
- Passive Depth at Hmax, \( Z_p = 265.00 \)
- Max. Pressure = 34.44

**Total Soil Types** = 3

<table>
<thead>
<tr>
<th>Soil</th>
<th>Weight</th>
<th>( W(S) )</th>
<th>( \Phi )</th>
<th>Cohesion</th>
<th>Nspt</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>115.5</td>
<td>125.8</td>
<td>26.0</td>
<td>0.0</td>
<td>0</td>
<td>1</td>
<td>Eqv. Clay</td>
</tr>
<tr>
<td>2</td>
<td>114.9</td>
<td>125.3</td>
<td>26.0</td>
<td>0.0</td>
<td>0</td>
<td>1</td>
<td>Eqv. Clay</td>
</tr>
<tr>
<td>3</td>
<td>115.2</td>
<td>125.0</td>
<td>30.0</td>
<td>0.0</td>
<td>0</td>
<td>1</td>
<td>Eqv. Clay</td>
</tr>
</tbody>
</table>

**Ground Surface at Active Side:**

<table>
<thead>
<tr>
<th>Line</th>
<th>( Z_1 )</th>
<th>( X_a1 )</th>
<th>( Z_2 )</th>
<th>( X_a2 )</th>
<th>Soil No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>80000.0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Water Table at Active Side:**

<table>
<thead>
<tr>
<th>Point</th>
<th>Z-water</th>
<th>X-water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>80000.0</td>
</tr>
</tbody>
</table>
Ground Surface at Passive Side:

<table>
<thead>
<tr>
<th>Line</th>
<th>Z1</th>
<th>Xp1</th>
<th>Z2</th>
<th>Xp2</th>
<th>Soil No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53.0</td>
<td>0.0</td>
<td>53.0</td>
<td>150.0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>53.0</td>
<td>150.0</td>
<td>0.0</td>
<td>80000.0</td>
<td>1</td>
</tr>
</tbody>
</table>

Water Table at Passive Side:

<table>
<thead>
<tr>
<th>Point</th>
<th>Z-water</th>
<th>X-water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>80000.0</td>
</tr>
</tbody>
</table>

Output data: *************************************************

Eae (Active/At-Rest Force above Base)= 45.20
Ea (Total Static Force above Base)= 45.20
Ee (Total Earthquake Force above Base)= 0.00

Apparent Pressure above Base - Output to Shoring
Active/At-Rest Force above Base, Ea = 45.20
No Z1 P1 Z2 P2 Slope
0 0.0 0.00 13.3 1.71 0.1287
1 13.3 1.71 53.0 1.71 0.0000

Driving Pressure below Base - Output to Shoring
No Z1 P1 Z2 P2 Slope
0 53.0 1.31 265.0 6.56 0.0248

Passive Pressure below Base - Output to Shoring
No Z1 P1 Z2 P2 Slope
0 53.0 0.00 265.0 34.44 0.1625

*****************************************************************

DEPTH/DISTANCE: ft, UNIT WEIGHT: pcf, FORCE: kip, PRESSURE: ksf, SLOPE: kcf

Z, Xa, Xp - Coordinates of ground lines
Z - Depth measured from wall top
Xa - Distance measure from wall to active side.
Xp - Distance measure from wall to passive side

Z1, P1, Z2, P2 - Four values to define a pressure diagram
Z1 - Top depth of the diagram
P1 - Top pressure of the diagram
Z2 - Bottom depth of the diagram
P2 - Bottom pressure of the diagram
Slope - (P2-P1)/(Z2-Z1), Slope of the diagram. It also called
   Equivalent fluid density. It equals to Ka*Gamma or Kp*Gamma
SHORING WALL CALCULATION SUMMARY

The leading shoring design and calculation software
Software Copyright by CivilTech Software
www.civiltechsoftware.com

This calculation method is based on the following references:
1. FHWA 98-011, FHWA-RD-97-130, FHWA SA 96-069, FHWA-IF-99-015
2. STEEL SHEET PILING DESIGN MANUAL by Pile Buck Inc., 1987
3. DESIGN MANUAL DM-7 (NAVFAC), Department of the Navy, May 1982
4. TRENCHING AND SHORING MANUAL Revision 12, California Department of Transportation, January 2000
5. EARTH SUPPORT SYSTEM & RETAINING STRUCTURES, Pile Buck Inc. 2002
7. EARTH RETENTION SYSTEMS HANDBOOK, Alan Macnab, McGraw-Hill. 2002
8. AASHTO HB-17, American Association of State and Highway Transportation Officials, 2 September 2002

UNITS:   Width/Spacing/Diameter/Length/Depth - ft, Force - kip, Moment - kip-ft,
Friction/Bearing/Pressure - ksf, Pres. Slope - kip/ft3, Deflection - in

Licensed to   4324324234     3424343
Date: 5/29/2014  File: G:\Projects\099 - 209444 - Mid Barataria Sedimentation Diversion\06.00 Proj_Engr\Inlet Wall Analysis\PP 6 ft_Braced\PP_6ft.sh8
Title: MBSD Inlet Walls - Pipe Pile Alternative
Subtitle: Earth Pressure

* INPUT DATA ***********************************************

Wall Type: 3. Soldier Pile, Driving
  Wall Height: 53.00
  Pile Diameter: 6.00
  Pile Spacing: 6.60
  Factor of Safety (F.S.): 1.00

Lateral Support Type (Braces): 2. Strut, Raker
  Top Brace Increase (Multi-Bracing): Add 15%
  Brace Position (One Brace Case): Normal Brace

Embedment Option: 1. Yes
  Friction at Pile Tip: No

Pile Properties:
  Allowable Fb/Fy: 0.66
  Steel Strength, Fy: 36 ksi = 248 MPa
  Elastic Module, E: 29000.00
  Moment of Inertia, I: 140579

User Input Pile:

* DRIVING PRESSURE (ACTIVE, WATER, & SURCHARGE) *

<table>
<thead>
<tr>
<th>No.</th>
<th>Z2 top</th>
<th>Top Pres.</th>
<th>Z2 bottom</th>
<th>Bottom Pres.</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>13.25</td>
<td>1.71</td>
<td>0.1287</td>
</tr>
<tr>
<td>2</td>
<td>13.25</td>
<td>1.71</td>
<td>53.00</td>
<td>1.71</td>
<td>0.0000</td>
</tr>
<tr>
<td>3</td>
<td>53.00</td>
<td>1.31</td>
<td>265.00</td>
<td>6.56</td>
<td>0.0248</td>
</tr>
</tbody>
</table>

* PASSIVE PRESSURE *

<table>
<thead>
<tr>
<th>No.</th>
<th>Z1 top</th>
<th>Top Pres.</th>
<th>Z2 bottom</th>
<th>Bottom Pres.</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53.03</td>
<td>0.00</td>
<td>265.00</td>
<td>34.44</td>
<td>0.1625</td>
</tr>
</tbody>
</table>
**ACTIVE SPACE**

<table>
<thead>
<tr>
<th>No.</th>
<th>Z depth</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>6.60</td>
</tr>
<tr>
<td>2</td>
<td>53.00</td>
<td>6.00</td>
</tr>
</tbody>
</table>

**PASSIVE SPACE**

<table>
<thead>
<tr>
<th>No.</th>
<th>Z depth</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53.00</td>
<td>6.60</td>
</tr>
</tbody>
</table>

**BRACE: STRUT, TIEBACK, ANCHOR PLATE, OR DEADMAN**

<table>
<thead>
<tr>
<th>No.</th>
<th>Z brace</th>
<th>Angle</th>
<th>Spacing</th>
<th>Input1*</th>
<th>Input2*</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.00</td>
<td>0.0</td>
<td>30.00</td>
<td>4.00</td>
<td>0.35</td>
<td>Strut</td>
</tr>
</tbody>
</table>

*For Tieback: Input1 = Diameter; Input2 = Bond Strength
*For Plate: Input1 = Diameter; Input2 = Allowable Pressure
*For Deaman: Input1 = Horz. Width; Input2 = Allowable Pressure; Angle = 0

****************************CALCULATION****************************

The calculated moment and shear are per pile spacing. Sheet piles are per one feet or meter; Soldier piles are per pile.

Top Pressures start at depth = 0.00

NUMBER OF BRACE LEVEL = 1

D1=0.00
D2=13.00  R1=390.17
D3=53.00
D4=80.51

D1 - TOP DEPTH
D2 - BRACE DEPTH  R1 - REACTION
D3 - EXCAVATION BASE
D4 - PILE TIP

TOTAL REACTION: R1 = 390.17
TOTAL PRESSURES ACTING ON WALL = 390.17
Total Reactions = Total Pressures, OK!

BRACE NO.1 AT DEPTH = 13.00
R1 = Brace Load = 390.17

****************************RESULTS****************************
* EMBEDMENT *
MINIMUM EMBEDMENT = 27.51
TOTAL MINIMUM PILE LENGTH = 80.51

* MOMENT IN PILE (per pile spacing)*

<table>
<thead>
<tr>
<th>No.</th>
<th>Depth</th>
<th>M @ Brace</th>
<th>Mmax in Span</th>
<th>Depth of Mmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.00</td>
<td>303.84</td>
<td>4191.05</td>
<td>41.31</td>
</tr>
</tbody>
</table>

Overall Maximum Moment = 4191.05 at 41.31
Maximum Shear = 317.28
Moment and Shear are per pile spacing: 6.6 feet or meter

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, OR DEADMAN *
The calculated brace force are per brace spacing.

<table>
<thead>
<tr>
<th>No.</th>
<th>DEPTH</th>
<th>Tangle</th>
<th>SPACING</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.00</td>
<td>0.00</td>
<td>30.00</td>
<td>1773.52</td>
<td>0.00</td>
<td>1773.52</td>
</tr>
</tbody>
</table>

* VERTICAL LOADING *
Vertical Loading from Braces = 0.00
Vertical Loading from External Load = 0.00
Total Vertical Loading = 0.00

***********************SPECIFIED PILE***********************
Specified Pile: No Pile can't be found in Pile Database.

*****************************LAGGING DESIGN EASIMENTION*****************************
Max. Pressure above base = 1.71
Piles are more rigid than timber lagging, only portion of pressures are acting to lagging, 30-50% arching is suggested.
   If 50% arching is used for lagging design, Design Pressure = 0.85
   For 4"x12" Timber, Section Modules S=23.47 in3.  The request allowable bending strength, fb=M/S=2.37
   For 6"x12" Timber, Section Modules S=57.98 in3.  The request allowable bending strength, fb=M/S=0.96

   If 30% arching is used for lagging design, Design Pressure = 0.51
   For 4"x12" Timber, Section Modules S=23.47 in3.  The request allowable bending strength, fb=M/S=1.42
   For 6"x12" Timber, Section Modules S=57.98 in3.  The request allowable bending strength, fb=M/S=0.58

Unit: Pressure: ksf, Spacing: ft, Moment: kip-ft, Bending Strength, fb: ksi

*******PRESSURE, LOAD, SHEAR, MOMENT, AND DEFLECTION V.S. DEPTH*******
The shear and moment are per single soldier pile (secant/tangent pile) or one foot
of sheet pile (concrete wall). The deflection is based on users input pile below:

User Input Pile:
Elastic Module,  \( E \) (ksi)= 29000.00
Moment of Inertia,  \( I \) (in4)/pile= 140579

PRESS. - Sum of all pressures on wall. Driving (Active) direction is positive LOAD - Liner load (force per unit depth) = Pressures multiply by acting space

<table>
<thead>
<tr>
<th>No</th>
<th>DEPTH ft</th>
<th>PRESS. ksf</th>
<th>LOAD kip/ft</th>
<th>SHEAR kip</th>
<th>MOMENT kip-ft</th>
<th>DEFLECTION in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.459</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
<td>0.01</td>
<td>0.09</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.455</td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
<td>0.03</td>
<td>0.17</td>
<td>0.02</td>
<td>0.00</td>
<td>-0.452</td>
</tr>
<tr>
<td>4</td>
<td>0.30</td>
<td>0.04</td>
<td>0.26</td>
<td>0.04</td>
<td>0.00</td>
<td>-0.448</td>
</tr>
<tr>
<td>5</td>
<td>0.40</td>
<td>0.05</td>
<td>0.34</td>
<td>0.07</td>
<td>0.01</td>
<td>-0.445</td>
</tr>
<tr>
<td>6</td>
<td>0.50</td>
<td>0.06</td>
<td>0.43</td>
<td>0.11</td>
<td>0.02</td>
<td>-0.441</td>
</tr>
<tr>
<td>7</td>
<td>0.60</td>
<td>0.08</td>
<td>0.51</td>
<td>0.16</td>
<td>0.03</td>
<td>-0.438</td>
</tr>
<tr>
<td>8</td>
<td>0.71</td>
<td>0.09</td>
<td>0.60</td>
<td>0.21</td>
<td>0.05</td>
<td>-0.434</td>
</tr>
<tr>
<td>9</td>
<td>0.81</td>
<td>0.10</td>
<td>0.68</td>
<td>0.28</td>
<td>0.07</td>
<td>-0.430</td>
</tr>
<tr>
<td>10</td>
<td>0.91</td>
<td>0.12</td>
<td>0.77</td>
<td>0.35</td>
<td>0.11</td>
<td>-0.427</td>
</tr>
<tr>
<td>11</td>
<td>1.01</td>
<td>0.13</td>
<td>0.86</td>
<td>0.43</td>
<td>0.14</td>
<td>-0.423</td>
</tr>
<tr>
<td>12</td>
<td>1.11</td>
<td>0.14</td>
<td>0.94</td>
<td>0.52</td>
<td>0.19</td>
<td>-0.420</td>
</tr>
<tr>
<td>13</td>
<td>1.21</td>
<td>0.16</td>
<td>1.03</td>
<td>0.62</td>
<td>0.25</td>
<td>-0.416</td>
</tr>
<tr>
<td>14</td>
<td>1.31</td>
<td>0.17</td>
<td>1.11</td>
<td>0.73</td>
<td>0.32</td>
<td>-0.413</td>
</tr>
<tr>
<td>15</td>
<td>1.41</td>
<td>0.18</td>
<td>1.20</td>
<td>0.85</td>
<td>0.40</td>
<td>-0.409</td>
</tr>
<tr>
<td>16</td>
<td>1.51</td>
<td>0.19</td>
<td>1.28</td>
<td>0.97</td>
<td>0.49</td>
<td>-0.405</td>
</tr>
<tr>
<td>17</td>
<td>1.61</td>
<td>0.21</td>
<td>1.37</td>
<td>1.10</td>
<td>0.59</td>
<td>-0.402</td>
</tr>
<tr>
<td>18</td>
<td>1.71</td>
<td>0.22</td>
<td>1.46</td>
<td>1.25</td>
<td>0.71</td>
<td>-0.398</td>
</tr>
<tr>
<td>19</td>
<td>1.81</td>
<td>0.23</td>
<td>1.54</td>
<td>1.40</td>
<td>0.84</td>
<td>-0.395</td>
</tr>
<tr>
<td>20</td>
<td>1.91</td>
<td>0.25</td>
<td>1.63</td>
<td>1.56</td>
<td>0.99</td>
<td>-0.391</td>
</tr>
<tr>
<td>21</td>
<td>2.02</td>
<td>0.26</td>
<td>1.71</td>
<td>1.73</td>
<td>1.16</td>
<td>-0.388</td>
</tr>
<tr>
<td>22</td>
<td>2.12</td>
<td>0.27</td>
<td>1.80</td>
<td>1.90</td>
<td>1.34</td>
<td>-0.384</td>
</tr>
<tr>
<td>23</td>
<td>2.22</td>
<td>0.29</td>
<td>1.88</td>
<td>2.09</td>
<td>1.54</td>
<td>-0.380</td>
</tr>
<tr>
<td>24</td>
<td>2.32</td>
<td>0.30</td>
<td>1.97</td>
<td>2.28</td>
<td>1.76</td>
<td>-0.377</td>
</tr>
<tr>
<td>25</td>
<td>2.42</td>
<td>0.31</td>
<td>2.05</td>
<td>2.48</td>
<td>2.00</td>
<td>-0.373</td>
</tr>
<tr>
<td>26</td>
<td>2.52</td>
<td>0.32</td>
<td>2.14</td>
<td>2.70</td>
<td>2.26</td>
<td>-0.370</td>
</tr>
<tr>
<td>27</td>
<td>2.62</td>
<td>0.34</td>
<td>2.23</td>
<td>2.92</td>
<td>2.55</td>
<td>-0.366</td>
</tr>
<tr>
<td>28</td>
<td>2.72</td>
<td>0.35</td>
<td>2.31</td>
<td>3.14</td>
<td>2.85</td>
<td>-0.362</td>
</tr>
<tr>
<td>29</td>
<td>2.82</td>
<td>0.36</td>
<td>2.40</td>
<td>3.38</td>
<td>3.18</td>
<td>-0.359</td>
</tr>
<tr>
<td>30</td>
<td>2.92</td>
<td>0.38</td>
<td>2.48</td>
<td>3.63</td>
<td>3.53</td>
<td>-0.355</td>
</tr>
<tr>
<td>31</td>
<td>3.02</td>
<td>0.39</td>
<td>2.57</td>
<td>3.88</td>
<td>3.91</td>
<td>-0.352</td>
</tr>
<tr>
<td>32</td>
<td>3.12</td>
<td>0.40</td>
<td>2.65</td>
<td>4.15</td>
<td>4.32</td>
<td>-0.348</td>
</tr>
<tr>
<td>33</td>
<td>3.22</td>
<td>0.42</td>
<td>2.74</td>
<td>4.42</td>
<td>4.75</td>
<td>-0.345</td>
</tr>
<tr>
<td>34</td>
<td>3.33</td>
<td>0.43</td>
<td>2.83</td>
<td>4.70</td>
<td>5.21</td>
<td>-0.341</td>
</tr>
<tr>
<td>35</td>
<td>3.43</td>
<td>0.44</td>
<td>2.91</td>
<td>4.99</td>
<td>5.69</td>
<td>-0.337</td>
</tr>
<tr>
<td>36</td>
<td>3.53</td>
<td>0.45</td>
<td>3.00</td>
<td>5.28</td>
<td>6.21</td>
<td>-0.334</td>
</tr>
<tr>
<td>37</td>
<td>3.63</td>
<td>0.47</td>
<td>3.08</td>
<td>5.59</td>
<td>6.76</td>
<td>-0.330</td>
</tr>
<tr>
<td>38</td>
<td>3.73</td>
<td>0.48</td>
<td>3.17</td>
<td>5.91</td>
<td>7.34</td>
<td>-0.327</td>
</tr>
<tr>
<td>39</td>
<td>3.83</td>
<td>0.49</td>
<td>3.25</td>
<td>6.23</td>
<td>7.95</td>
<td>-0.323</td>
</tr>
<tr>
<td>40</td>
<td>3.93</td>
<td>0.51</td>
<td>3.34</td>
<td>6.56</td>
<td>8.59</td>
<td>-0.320</td>
</tr>
<tr>
<td>41</td>
<td>4.03</td>
<td>0.52</td>
<td>3.42</td>
<td>6.90</td>
<td>9.27</td>
<td>-0.316</td>
</tr>
<tr>
<td>42</td>
<td>4.13</td>
<td>0.53</td>
<td>3.51</td>
<td>7.25</td>
<td>9.99</td>
<td>-0.312</td>
</tr>
<tr>
<td>43</td>
<td>4.23</td>
<td>0.54</td>
<td>3.60</td>
<td>7.61</td>
<td>10.73</td>
<td>-0.309</td>
</tr>
<tr>
<td>44</td>
<td>4.33</td>
<td>0.56</td>
<td>3.68</td>
<td>7.98</td>
<td>11.52</td>
<td>-0.305</td>
</tr>
<tr>
<td>45</td>
<td>4.43</td>
<td>0.57</td>
<td>3.77</td>
<td>8.35</td>
<td>12.34</td>
<td>-0.302</td>
</tr>
<tr>
<td>46</td>
<td>4.53</td>
<td>0.58</td>
<td>3.85</td>
<td>8.73</td>
<td>13.20</td>
<td>-0.298</td>
</tr>
<tr>
<td>47</td>
<td>4.64</td>
<td>0.60</td>
<td>3.94</td>
<td>9.13</td>
<td>14.10</td>
<td>-0.294</td>
</tr>
<tr>
<td>48</td>
<td>4.74</td>
<td>0.61</td>
<td>4.02</td>
<td>9.53</td>
<td>15.04</td>
<td>-0.291</td>
</tr>
<tr>
<td>49</td>
<td>4.84</td>
<td>0.62</td>
<td>4.11</td>
<td>9.94</td>
<td>16.02</td>
<td>-0.287</td>
</tr>
<tr>
<td>50</td>
<td>4.94</td>
<td>0.64</td>
<td>4.19</td>
<td>10.36</td>
<td>17.05</td>
<td>-0.284</td>
</tr>
<tr>
<td>51</td>
<td>5.04</td>
<td>0.65</td>
<td>4.28</td>
<td>10.78</td>
<td>18.11</td>
<td>-0.280</td>
</tr>
<tr>
<td>52</td>
<td>5.14</td>
<td>0.66</td>
<td>4.37</td>
<td>11.22</td>
<td>19.22</td>
<td>-0.277</td>
</tr>
</tbody>
</table>