Appendix B. Geotechnical Evaluation of Retaining Wall Concepts Memorandum

To	Bob Beduhn, PE		
From	Brian Havens, PE		
CC	Project file		
Date	July 7, 2014	Job No.	BA 153-01

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 armoring 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 underseepage 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

System configuration	Equivalent width (feet)	Cell diameter (feet)	Sheet pile tip elevation (feet)	Sheet pile length (feet)	Factor of safety (overturning)
Inlet Station 21+00; in-the-dry	80	91–98	–67	89	1.4
Inlet Station 28+00; in-the-dry[c]	80	91–98[a]	–70	92	1.5
Inlet Station 21+00; in-the-wet	50	57–61	–67	89	1.6
Inlet Station 28+00; in-the-wet	65	74–80	–70	92	1.5
Diversion structure; in-the-wet	80	91–98	–85	100	1.5
Back structure; in-the-wet	50	57–61	–78	80	<1[b]

[a] with 20-foot-tall interior stability berm

[b] requires ground improvement

[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

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

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

HDR. 2013. *Mid-Barataria Sediment Diversion, Draft Preliminary Foundation Report*. November.

———. 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."*

———. 2014. *Mid-Barataria Sediment Diversion, 30% Design – Geotechnical Evaluation of Retaining Wall Concepts*. January 16.

U.S. Army Corps of Engineers (USACE). 1989. *Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures*. Engineering Manual 1110-2-2503. September 29.

Attachment A. Site Plans and Profiles

PHASE 1 SITE PLAN

SCALE: 1" = 200'

NOTES:

PHASE 1A - DEEP SOIL MIXING CUTOFF WALL 3' WIDE TO EL -100 FT FOR SEEPAGE CONTROL.

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

PHASE 1C - CIRCULAR DIAPHRAGM SHEET PILE COFFERDAM 80' WIDE W/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 W/FILTER MATERIAL FOR TEMP. DEWATERING AND PERMANENT PASSIVE DEWATERING 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 BERMS FOR SURCHARGING.

0 1" 2"

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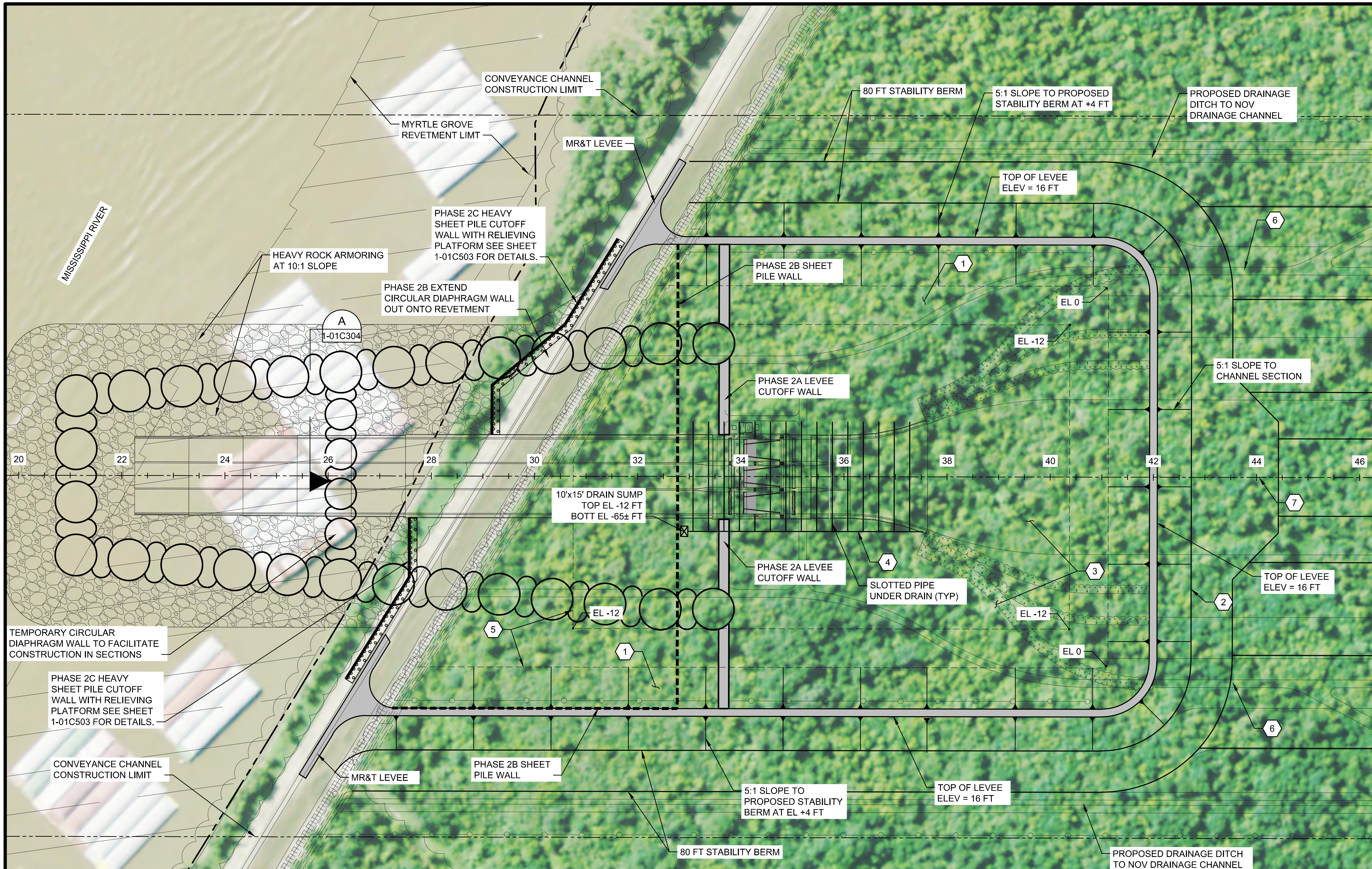
REV.	DATE	DESCRIPTION	BY

COASTAL PROTECTION & RESTORATION AUTHORITY
ENGINEERING DIVISION
450 LAUREL STREET
BATON ROUGE, LOUISIANA 70801

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

MID-BARATARIA SEDIMENT DIVERSION
STATE PROJECT NUMBER: BA-153
FEDERAL PROJECT NUMBER: BA-153
APPROVED BY:

VOLUME 1
CIVIL
DIVERSION STRUCTURE
PHASE 1 CONSTRUCTION
DATE: MARCH 2014
DWG 1-01C107 SHT 44



NOTES:

PHASE 2A - LEVEE CUTOFF TO ALLOW TRANSITION WALLS AND CHANNEL ARMORING TO BE CONSTRUCTED W/SHEETING/SHORING AS REQ'D.

PHASE 2B - CIRCULAR DIAPHRAGM SHEET PILE COFFERDAM 80' WIDE. ADD DEWATERING SYSTEM INSIDE EXCAVATION AND COFFERDAMS. REMOVE WALL ACROSS APPROACH CHANNEL, STOPLOGS NOW IN PLACE TO SEAL GATE STRUCTURE, TOP EL +10 FT TYP. HEAVY 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 SEEPAGE/STABILITY. ADD RELIEVING PLATFORMS AND PILES TO ANCHOR SHEET PILE WALL AND TO REDUCE SECTION MODULUS REQUIRED. TOP OF WALL AT EL +17.5 FT.

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 W/FILTER MATERIAL FOR TEMP. DEWATERING AND PERMANENT PASSIVE DEWATERING SYSTEM.
5. PROJECTED LEVEE SLOPE CONTOURS AT 5:1 GRADE SHOWN FOR INFORMATION PURPOSES ONLY.
6. SITE ACCESS ROAD AND RAMPS AS REQ'D TO ACCESS CONSTRUCTION SITE. DETAILS TBD.
7. PHASE 1 MECHANICAL EXCAVATION IN CHANNEL AND PLACEMENT ON STABILITY BERMS FOR SURCHARGING.

PHASE 2 SITE PLAN

SCALE: 1" = 200'

0 1" 2"

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FEDERAL PROJECT NUMBER: BA-153

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PHASE 2 CONSTRUCTION

DATE: MARCH 2014

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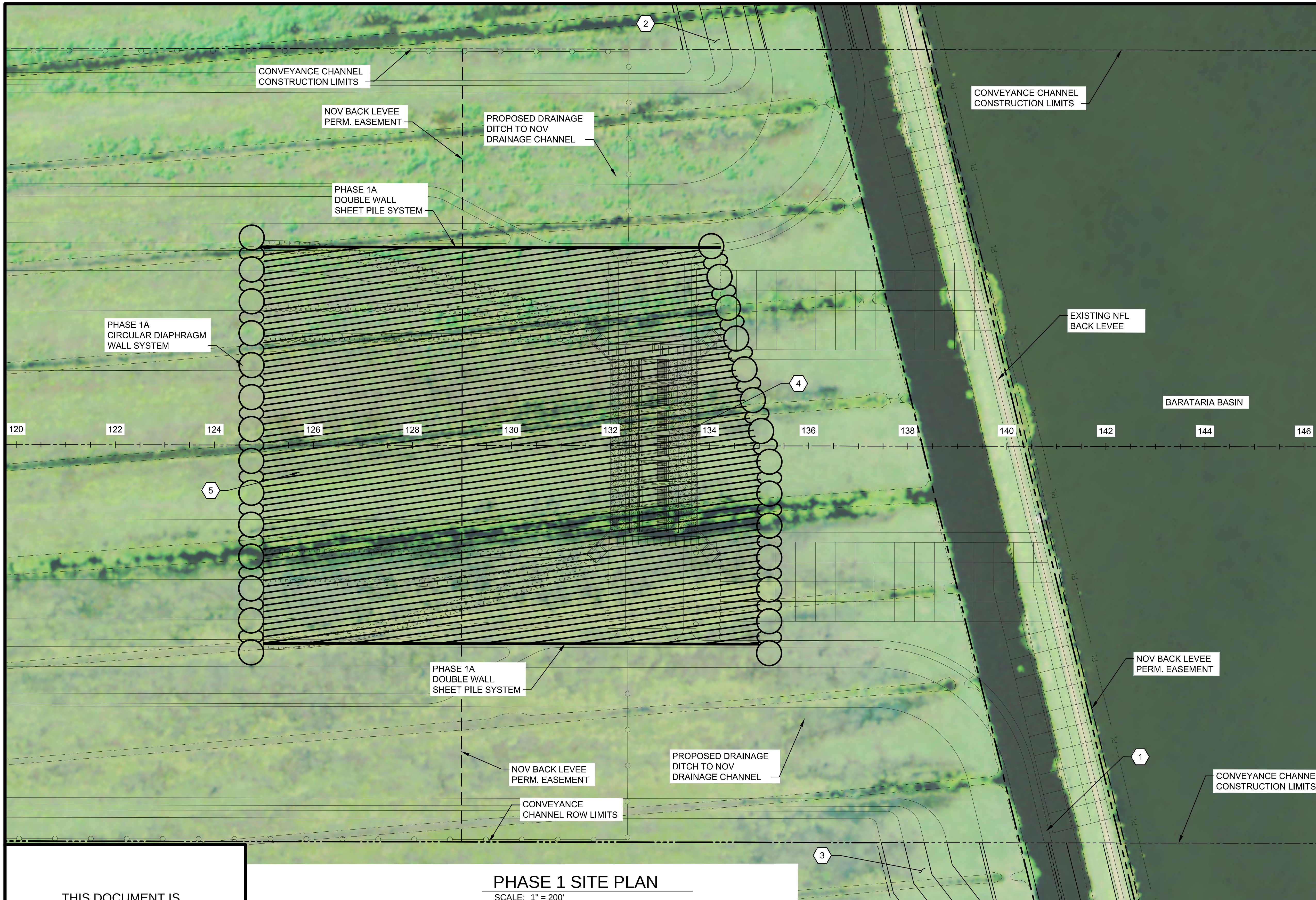

PHASE 1 SITE PLAN

SCALE: 1" = 200'

NOTES:

PHASE 1A - DOUBLE WALL SHEET PILE COFFERDAM 15 FT WIDE WITH TOP AT EL +15 FT WITH DEEP SOIL MIXING FROM EL X FT TO EL X FT.

PHASE 1A - CIRCULAR DIAPHRAGM CUTOFF WALL 50 FT WIDE WITH TOP AT EL +2FT - DEEP SOIL MIXING FROM EL X FT TO EL X FT - DEMOLISH TO FINISH GRADE ONCE BACK STRUCTURE IS COMPLETE.

KEY NOTES:

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 INSIDE 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 CENTERS 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.

0 1" 2"

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STATE PROJECT NUMBER: BA-153

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BACK STRUCTURE
PHASE 1 CONSTRUCTION

DATE: MARCH 2014

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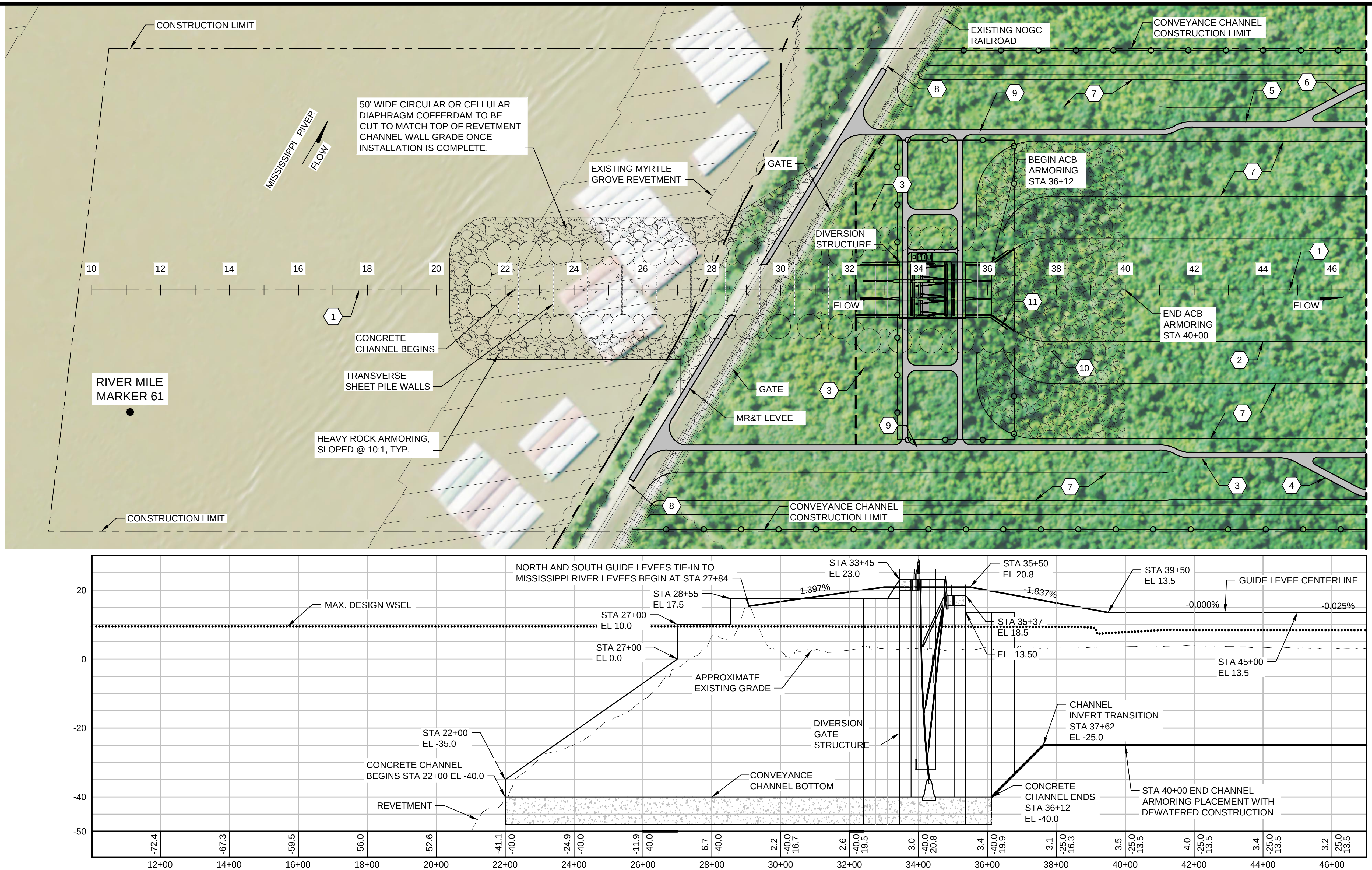

300' CHANNEL - PLAN AND PROFILE

HORIZ SCALE: 1" = 300'
VERT SCALE: 1" = 30'

NOTES:

1. STANDARD CHANNEL ARMORING APPLIES STA 40+00 TO 132+00.
2. COFFERDAM TO REMAIN, NOT SHOWN IN PROFILE VIEW.

KEY NOTES:

1. PROJECT CONVEYANCE BASELINE
2. CONVEYANCE CHANNEL TOE
3. NORTH GUIDE LEVEE
4. NORTH GUIDE LEVEE MAINTENANCE RD
5. SOUTH GUIDE LEVEE
6. SOUTH GUIDE LEVEE MAINTENANCE RD
7. STABILITY BERM
8. MR&T LEVEE
9. SETBACK LEVEE TO REMAIN
10. ACB ARMORING
11. WINGWALL (TBD)

LEGEND

APPROX EXISTING GRADE EL — -4.2
CONVEYANCE CHANNEL EL — -25.0
GUIDE LEVEE EL — 13.0
STATION VALUE — 44+00

0 1" 2"

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MID-BARATARIA SEDIMENT DIVERSION

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FEDERAL PROJECT NUMBER: BA-153

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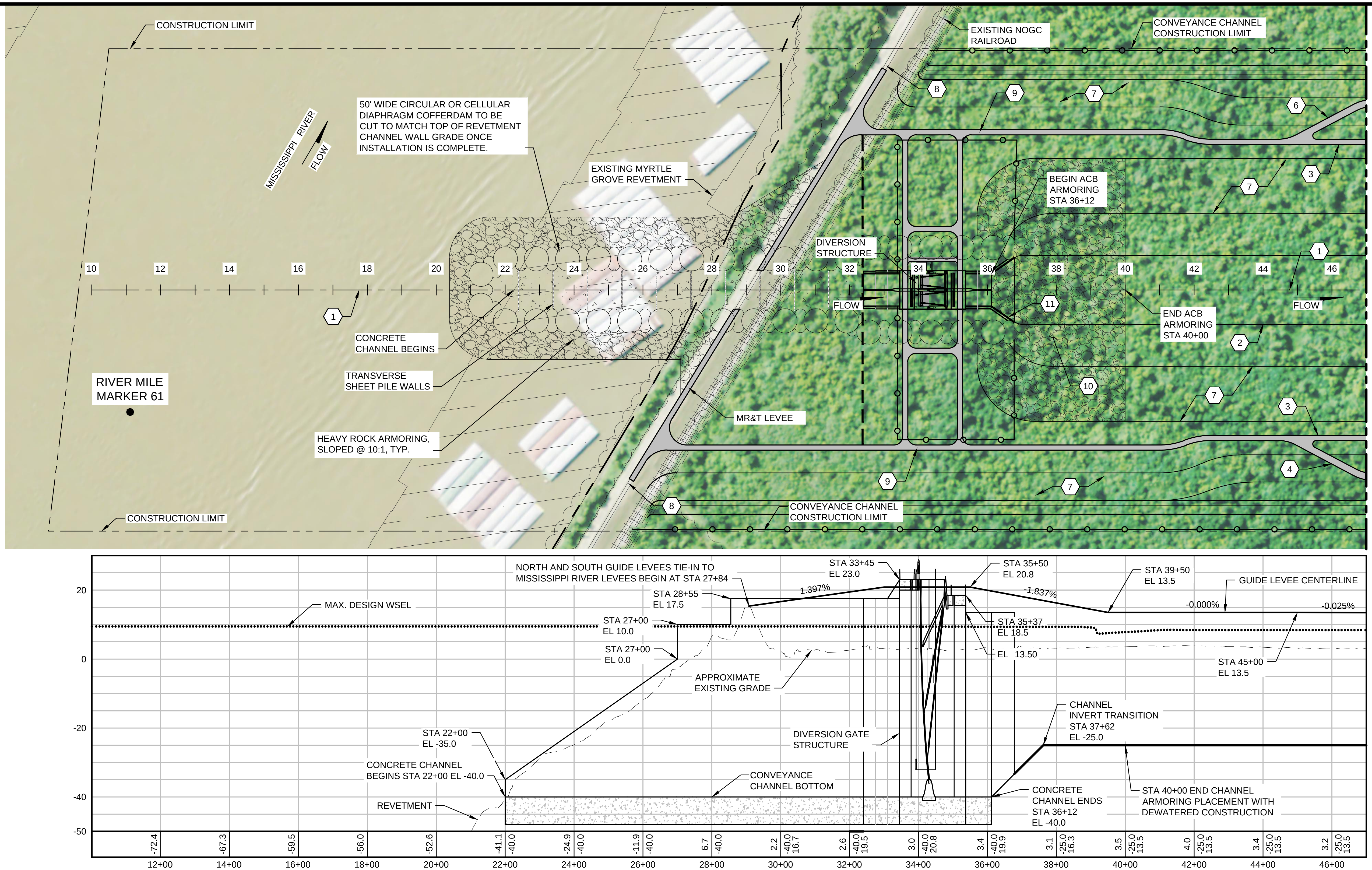
DESIGNED BY: G. PENNISON
APPROVED BY:

VOLUME 1D
CIVIL
CONVEYANCE CHANNLE PLAN AND PROFILE (VE 1.2)
DATE: JUNE 2014
DWG 1D-03C201 SHT 2



200' CHANNEL - PLAN AND PROFILE

HORIZ SCALE: 1" = 300'
VERT SCALE: 1" = 30'

NOTES:

1. STANDARD CHANNEL ARMORING APPLIES STA 42+00 TO 132+00.
2. COFFERDAM TO REMAIN, NOT SHOWN IN PROFILE VIEW.

KEY NOTES:

1. PROJECT CONVEYANCE BASELINE
2. CONVEYANCE CHANNEL TOE
3. NORTH GUIDE LEVEE
4. NORTH GUIDE LEVEE MAINTENANCE RD
5. SOUTH GUIDE LEVEE
6. SOUTH GUIDE LEVEE MAINTENANCE RD
7. STABILITY BERM
8. MR&T LEVEE
9. SETBACK LEVEE TO REMAIN
10. ACB ARMORING
11. WINGWALL (TBD)

LEGEND

APPROX EXISTING GRADE EL -4.2
CONVEYANCE CHANNEL EL -25.0
GUIDE LEVEE EL 13.0
STATION VALUE 44+00

0 1" 2"

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STATE PROJECT NUMBER: BA-153
FEDERAL PROJECT NUMBER: BA-153
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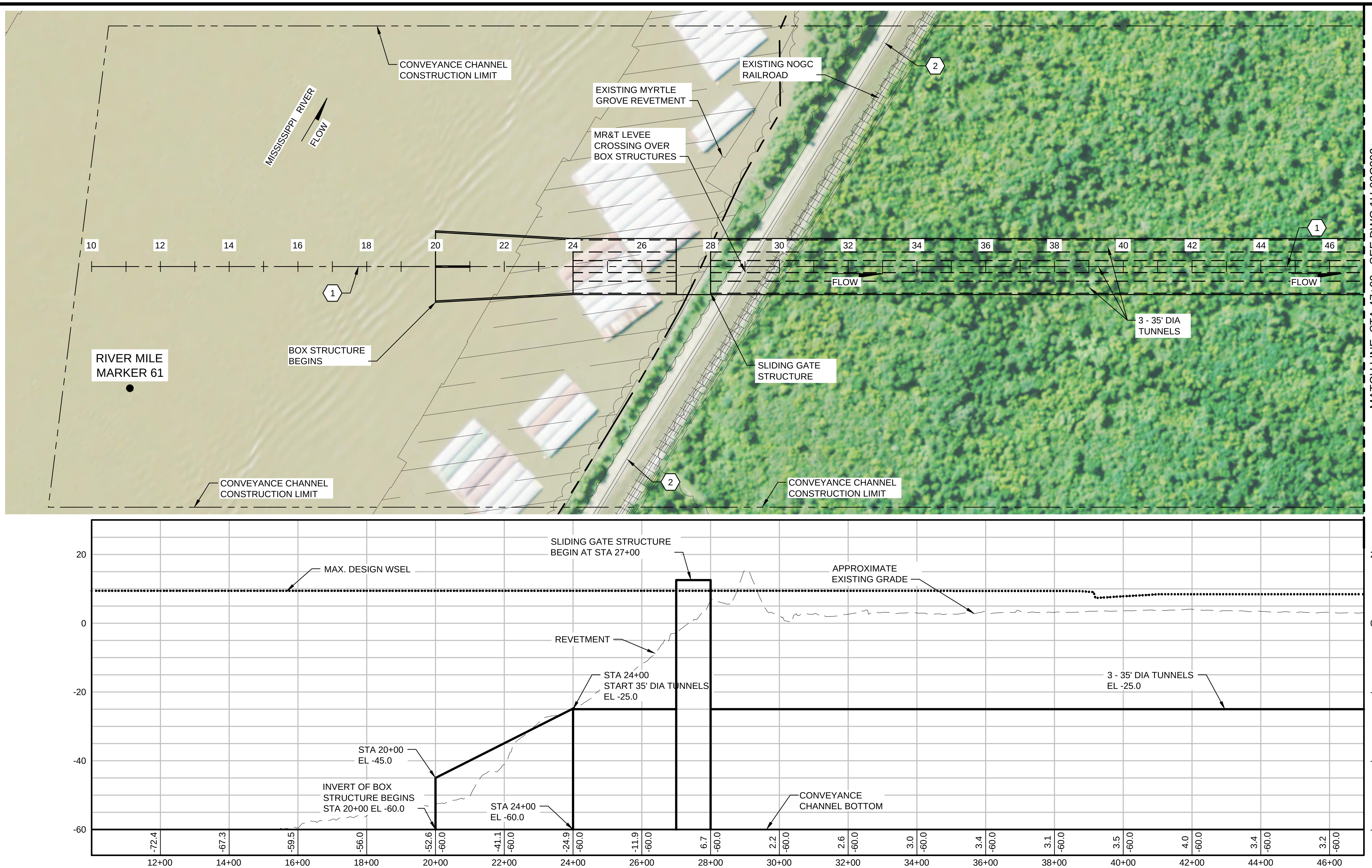
CONVEYANCE CHANNLE PLAN AND PROFILE (VE 2.2)
DATE: JUNE 2014
DWG 1E-03C201 SHT 2



100' CHANNEL - PLAN AND PROFILE

HORIZ SCALE: 1" = 300'
VERT SCALE: 1" = 30'

NOTES:

1. NOGC RAILROAD CROSSING PROFILE DESIGN TBD.

KEY NOTES:

1. PROJECT CONVEYANCE BASELINE
2. MR&T LEVEE

LEGEND

APPROX EXISTING GRADE EL -4.2

CONVEYANCE CHANNEL EL -25.0

GUIDE LEVEE EL 13.0

STATION VALUE 44+00

0 1" 2"

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MID-BARATARIA SEDIMENT DIVERSION

STATE PROJECT NUMBER: BA-153

FEDERAL PROJECT NUMBER: BA-153

VOLUME 1H
CIVIL
CONVEYANCE CHANNLE PLAN AND PROFILE (VE 5.2)

DATE: JULY 2014

DRAWN BY: H. GARCIA

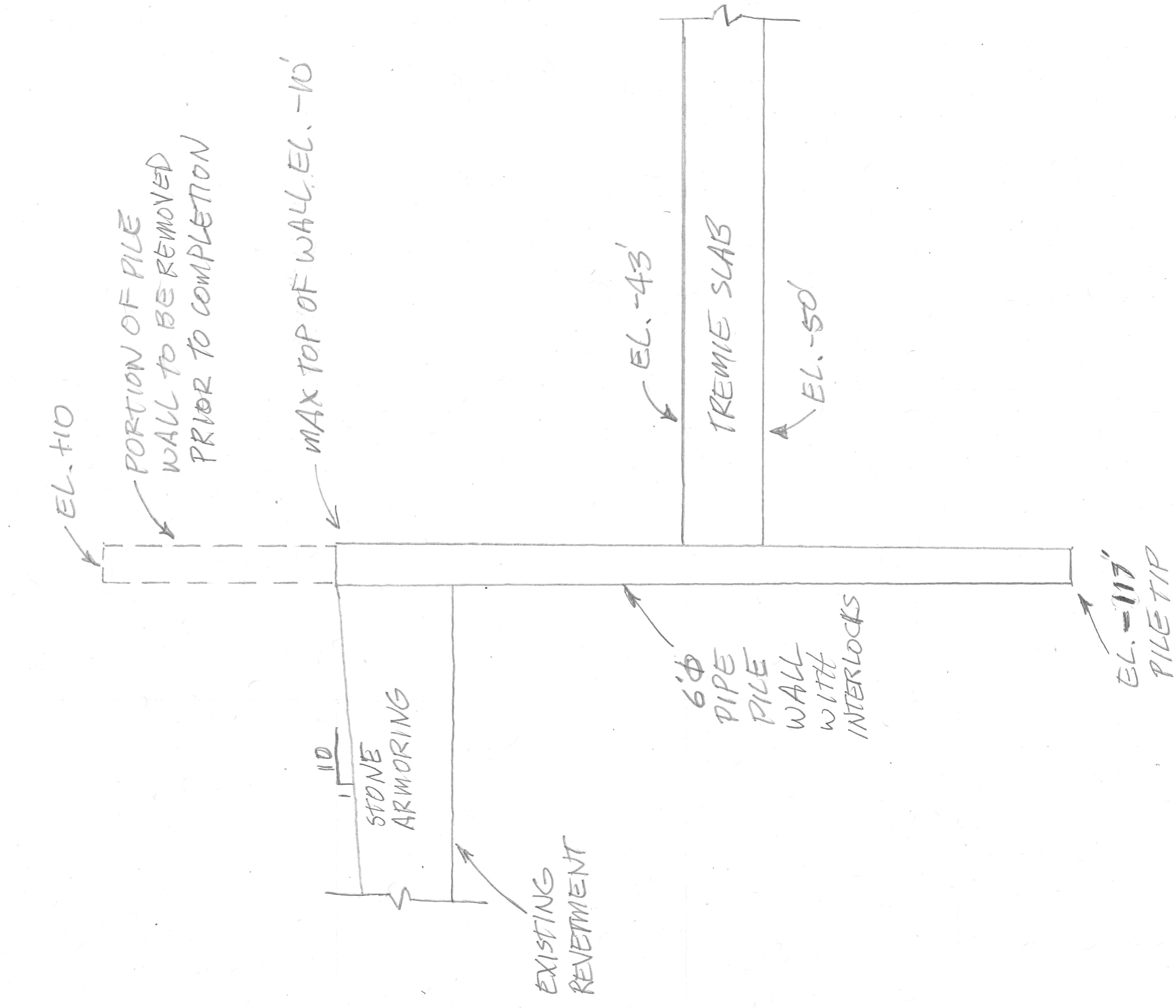
DESIGNED BY: G. PENNISON

APPROVED BY:

DWG 1H-03C201 SHT 2

Project:	MBSD	Computed:	BTH	Date:	5/30/14
Subject:	INLET	Checked:		Date:	
Task:		Page:		of:	
Job #:		No:			

ALTERNATIVES 1.2b, 2.2b (IN-THE-WET)



Project: MBSD		Computed: BHH	Date: 5/30/14
Subject: INLET		Checked:	Date:
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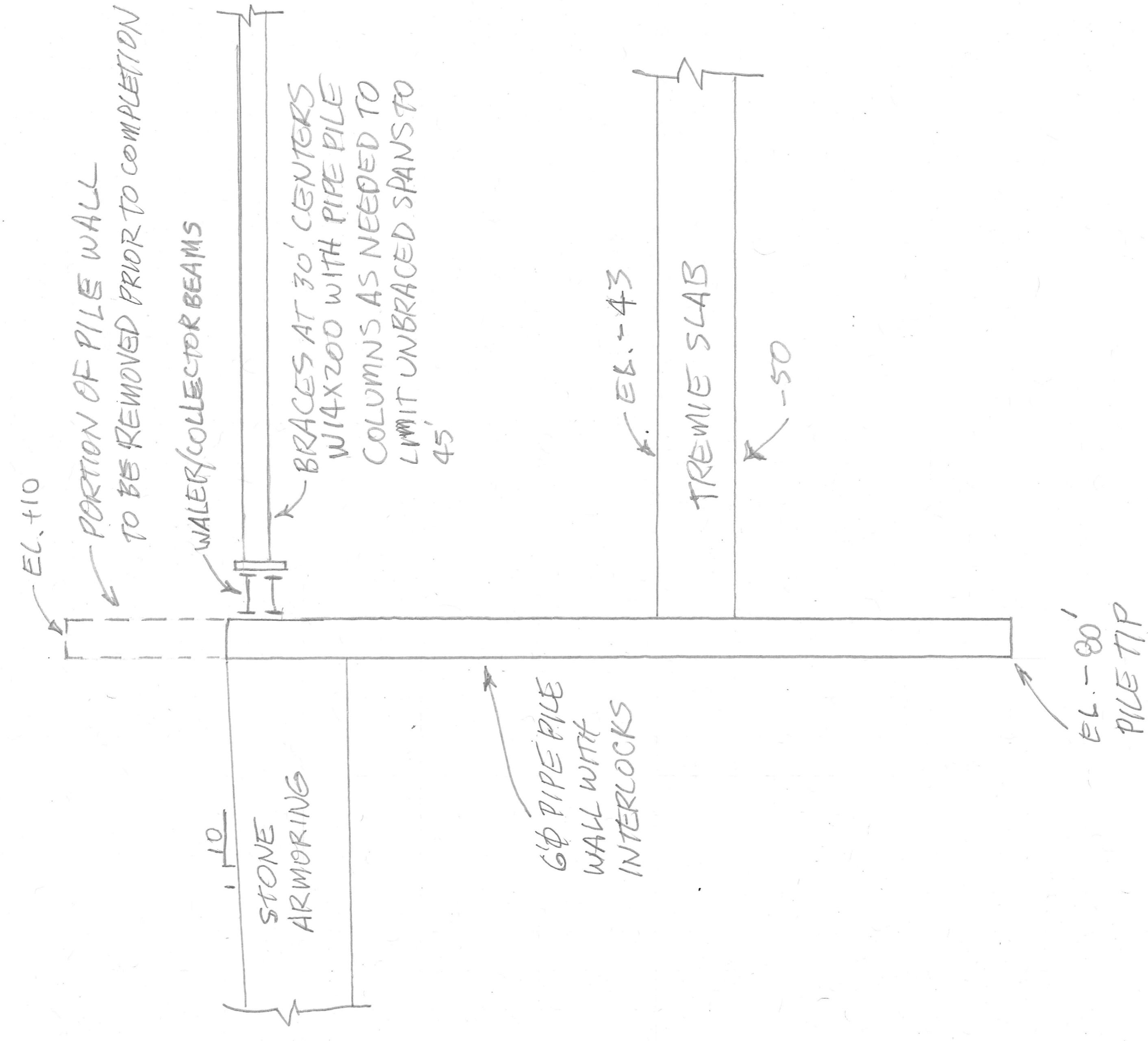
ALTERNATIVES 1.2b, 2.2b (IN-THE-WET)



Project: MBSD	Computed: BHH	Date: 5/30/14
Subject: INLET	Checked:	Date:
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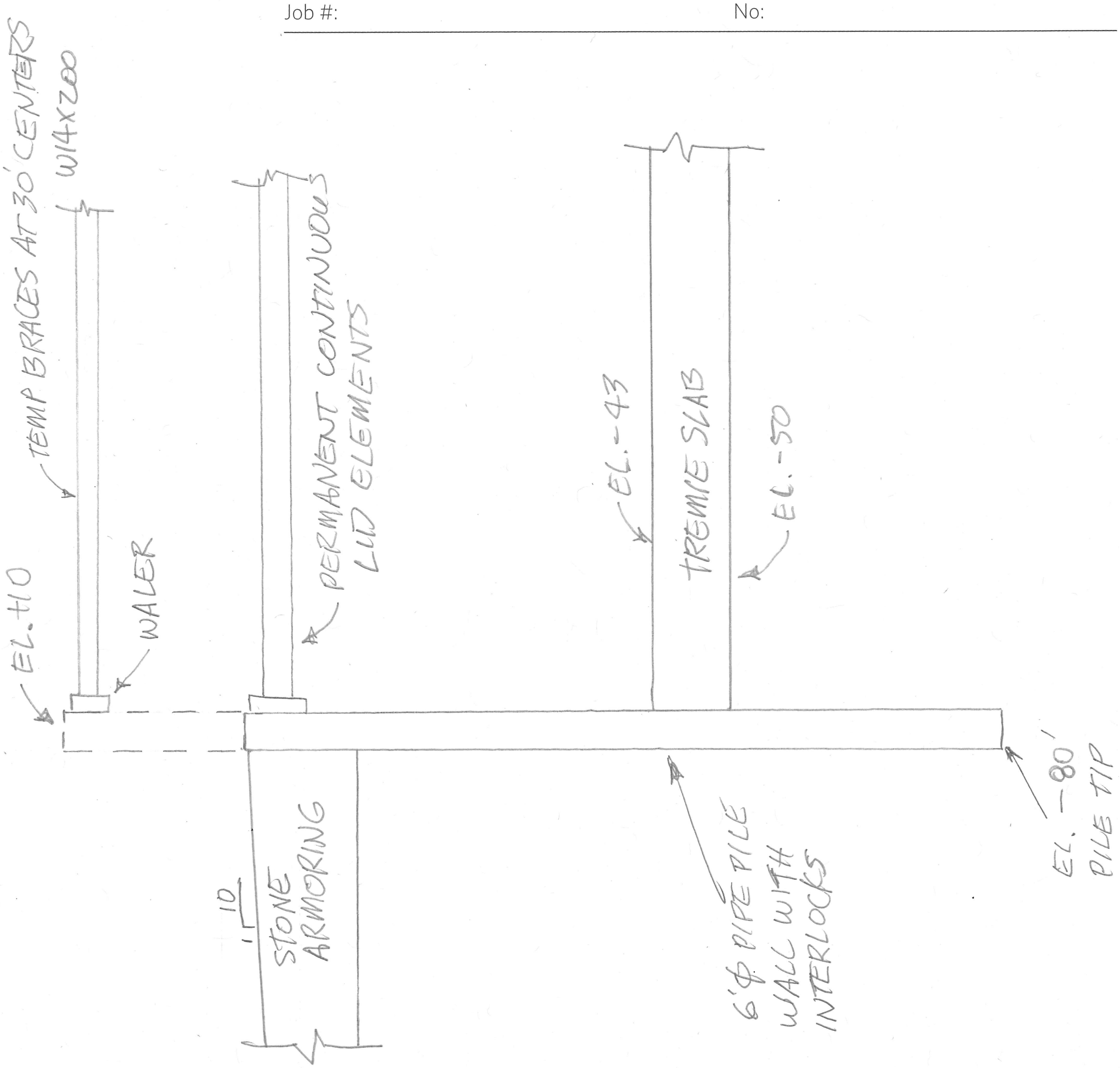
Job #:	No:	

ALTERNATIVE 4.2 (IN-THE-WET)



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

Stratigraphic Unit	Elevation [Thickness], ft	Description	ASTM/USACE NO District Classification [1]	Moisture Content (%)	% Fines	Unit Weight (pcf) [2]	SPT N60 [5]	Strength Parameters[2]				Explorations
								Drained		Undrained[6]		
								Cohesion (psf)[3]	Friction Angle [4]	Cohesion (psf)	Friction Angle	
Recent Deposits	-47.5 to -50 [2.5]	Very soft **CLAY** (recent river sediments) with shell fragments	CL6	57	>50	100	0	50	15	150	0	Borings R-1 through R-6 (with R-3 Primary)
	-50 to -62.5 [12.5]	Medium dense poorly graded **SAND**	SP	21 to 28	6.6	122	14	0	30	0	30	
	-62.5 to -67.5 [5]	Medium dense to dense silty **SAND**	SM	29	12 % Silt 0.8% clay	122	45@-63 ft 16 @-66 ft	0	28	0	28	
Intra Delta	-67.5 to -82.5 [15]	Dense poorly graded **SAND**	SP	26	6	128	46	0	39	0	39	
	-82.5 to -107.5 [25]	Very dense poorly graded **SAND**	SP	24	6	128	74	0	41	0	41	
Near Shore Gulf	-107.5 to -127.5 [20]	Very dense poorly graded **SAND**	SP	25	7	130	91	0	41	0	41	
Pleistocene	-127.5 to -129.5 [2]	Very stiff **CLAY**	CH2		>50	125	19	200	22	2700	0	
	-131.5 to -139.5 [8]	Very stiff **CLAY**	CL6	24	>50	125	19	250	24	3150	0	
	-139.5 to -141.5 [2]	Medium dense sandy **SILT**	ML	26	>50	117	--	0	30	200	25	
	-141.5 to -146.0 [5.5]	Medium dense silty **SAND**	SM	24	--	122	--	0	30	0	30	
	-146.5 to -162.5 [16]	Very stiff to hard Interbedded Lean **CLAY**	CL4, CL6, CH2, CH3	43	>50	116	19 to 35	200	22	1200	0	
	-162.5 to -170 [7.5]	Very dense clayey **SILT**	ML	34	>50	125	80+	0	25	0	25	
	-170 to -199.5 [29.5]	Very stiff **CLAY**	CH3	41	>50	110	26	200	22	2100	0	

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

Stratigraphic Unit	Elevation (Thickness), ft	Description	ASTM/USACE NO District Classification [1]	Moisture Content (%)	% Fines	Unit Weight (pcf) [2]	SPT N60 [5]	Strength Parameters[2]				Explorations
								Drained		Undrained[6]		
								Cohesion[3]	Friction Angle[4]	Cohesion (psf)	Friction Angle	
Natural Levee	5.5 to -4.8 [9.3]	Medium **CLAY**	CL4, CL6, CH2	35	>50	123		100	26	700	0	Borings – B-1A, B2-A and IS-7A, R-2A and R3A
	-4.8 to -7.8 [2]	Soft to medium **CLAY**	CL4	35	>50	117	--	10	26	300	0	
Upper Point Bar	-7.8 to-13.8 [6]	Medium dense **SILT**	ML	31	72	115	--	50	30	200	8	
	-13.8 to -37.8 [24]	Very loose to loose **SILT**	ML	36	+80	115	1 to 2	50	26	200	6	
	-37.8 to -40.5 [2.7]	Soft **CLAY**	CL4	38		115	3	20	26	150	0	
Middle Point Bar	-40.5 to -62 [21.5]	Medium dense **SILT**	ML	33	62 to 84	117	--	50	30	200	8	
	-46.7 to -67.5 [20.8] Boring B-1A only	Medium dense silty **SAND**	SM	--	9 to 23	122	37	0	33	0	33	
	-62 to -64.5 [2.5]	Medium CLAY	CL6	45	75	118	9	35	24	450	0	
	-64.5 to -75 [10.5]	Medium dense silty **SAND**	SM	31	59 to 74	117	31	0	33	0	33	
	-75 to -80 [5]	Dense to very dense **SAND** and silty **SAND**	SP-SM	30	20 (SP) 40 (SM)	130	31 to 55	0	33	0	33	
	-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)

Conveyance Channel Geotechnical Parameters
Ground Surface Elevation +3.5 feet at NL-9A

Stratigraphic Unit	Elevation (Thickness), ft	Description	ASTM/USACE NO District Classification [1]	Moisture Content (%)	% Fines	Unit Weight (pcf) [2]	SPT N60 [5]	Strength Parameters[2]				Reference Explorations
								Drained		Undrained[6]		
								Cohesion (psf)[3]	Friction Angle[4]	Cohesion (psf)	Friction Angle	
Natural Levee	+3.5 to -0.5 [4]	Medium **CLAY**	CL4, CL6	26	>50	90	--	25	24	500	0	Borings: NL-9A and PT-2
	-0.5 to -4.5 [4]	Soft to medium **CLAY**	CL4, CL6	33	>50	90	<3	50	22	200	8	
	-4.5 to -24 [20.5feet]	Interbedded soft **CLAY** and loose clayey **SILT**	CL4, ML	36	79	90	Weight of Hammer	15	22	125	8	
Upper Point Bar	-24 to -37 [13]	Loose to medium **SILT** silty sand lenses	ML with SM lenses	27	53 to 77	113	--	0	26	200	8	
	-37 to -48	Medium dense sandy **SILT /Silty SAND**	ML/SM	32	70 to 74/30 to 35	115	--	0	30	200	10	
Middle Point Bar	-48 to -63 [15]	Loose to very loose **SILT** and loose clayey **SAND**	ML/SC	31	74 to 82	118	<10	0	28	200	8	
	-63 to -76 [13]	Medium dense silty S**AND** with clay strata and lenses	SM	--	32 to 64	120	15	0	30	0	30	
	-76 to –93 [17]	Medium dense sandy **SILT** and clayey **SAND**	SM/SC	37	56 to 66	120	57, 73	0	33	0	33	
	-93 to -106 [13]	Medium dense silty **SAND** and medium dense sandy **SILT**	SM/ML	--	11	124	30, 53	0	33	0	33	
Pro Delta	-106 to -112 [6]	Very stiff high plasticity **CLAY**	CH4	55	>50	110	36	250	24	1100	0	
Gulf Near Shore?	-112 to -118 [6]	Very stiff high plasticity **CLAY with sand strata**	CH2	30	>50	110	--	250	24	1100	0	
Pleistocene	-118 to -130 [12]	Very stiff high plasticity **CLAY with shells**	CH4	50	>50	110	20	250	26	1100	0	

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

Stratigraphic Unit	Elevation [Thickness], ft	Description	ASTM/USACE NO District Classification [1]	Moisture Content (%)	% Fines	Unit Weight (pcf) [2]	SPT N60[5]	Strength Parameters[2]				Reference Explorations
								Drained		Undrained[6]		
								Cohesion (psf)[3]	Friction Angle[4]	Cohesion (psf)	Friction Angle	
Marsh, Intra Delta and Interdistributary	-3.5 to -22 [18.5]	Very soft **Organic Clay**	CHOA, CHOC, CH3, CH2, Peat, CH4	47 to 172	>90	85 to 105	--	0	22	150	0	Borings: NL-3A, PZ-13, PZ-14, PT-1
	-22 to -38 [18]	Highly Variable sequence of very soft **CLAY**, loose **SILT**, silty **SAND** and **SAND**	ML, SM, SP, CH4, CL4	44 to 92	Varies	105	--	0	22	150	0	
Interdistributary (Lower)	-38 to -50 [12]	Soft **CLAY** with silt lenses and shells	CH4	42 to 73	>90	95	--	15	22	200	0	
	-50 to -70 [20]	Soft **CLAY** with increasing strength with depth	CH4	55 to 74	>90	103	--	50	22	Linearly increasing from 375 psf @ 9 psf/ft	0	
Pro-Delta	-70 to –110 [40]	Soft to medium **CLAY**	CH2, CH4	55 to 66	.90	103	--	50	24	Linearly increasing from 555 psf @ 9 psf/ft	0	
Gulf Near Shore	-110 to -116 [6]	Very stiff high plasticity **CLAY with shells**	CH4	60	>50	100	--	150	26	1300	0	
	-116 to -120 [4]	medium dense **SAND** and clayey **SAND**	SP, SC	25, 34	28 (SC)	122	39 (SC)	0	30	0	30	
Pleistocene	-120+ [BOH – 124]	Stiff Clay with shells	CH4	63	>90	100	--	250	24	1100	0	

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

Design of Sheet Pile Cellular Structures, USACE EM 1110-2-2503, 1989.
Pile Buck Steel Sheet Piling Design Manual, 1987.
Design & Execution Manual AS 500 Straight Web Steel Sheet Piles, ArcelorMittal, 2009.
Steel Sheet Piling Design Manual, US Steel, 1984.

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. 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 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.

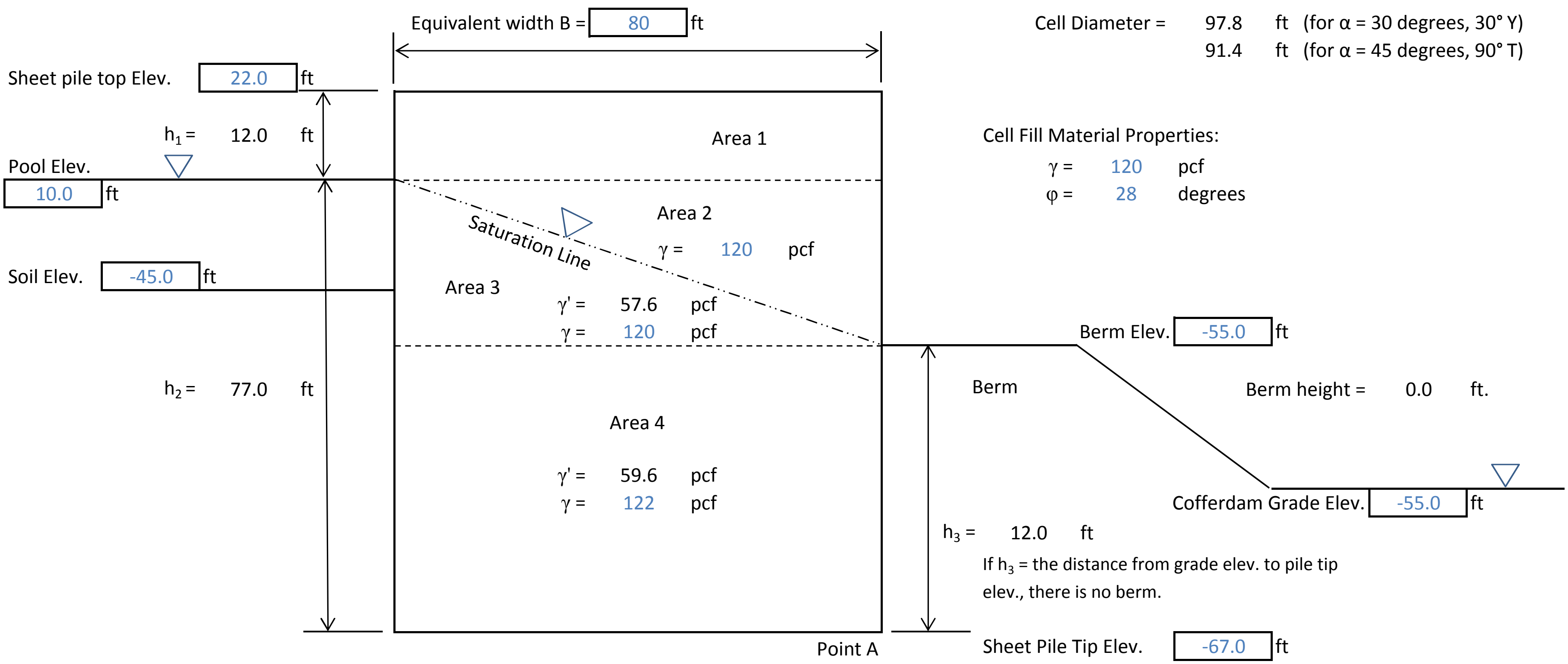
Hansen's Method:
Hansen's method produces an area between the log spiral failure surface and the toe of the cell. The force resultant of this region is commonly referred to as "G". The area of this region is partly based on the internal friction angle of the soil encompassed by the failure surface and 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.

Project:	CPRA Mid-Barataria Sediment Diversion	Computed:	RLJ	Date:	07/06/14
Subject:	Sediment Diversion Structure	Checked:	JPW	Date:	07/07/14
Task:	Station 21+00 Cofferdam Design - Preliminary (30% Design)	Page:	4	of	13
Job #:	099-209442	No:			

Circular Sheet Pile Cofferdam



Total Sheet Pile length: 89.0 ft

Foundation Soil Material Properties:

γ = 128 pcf

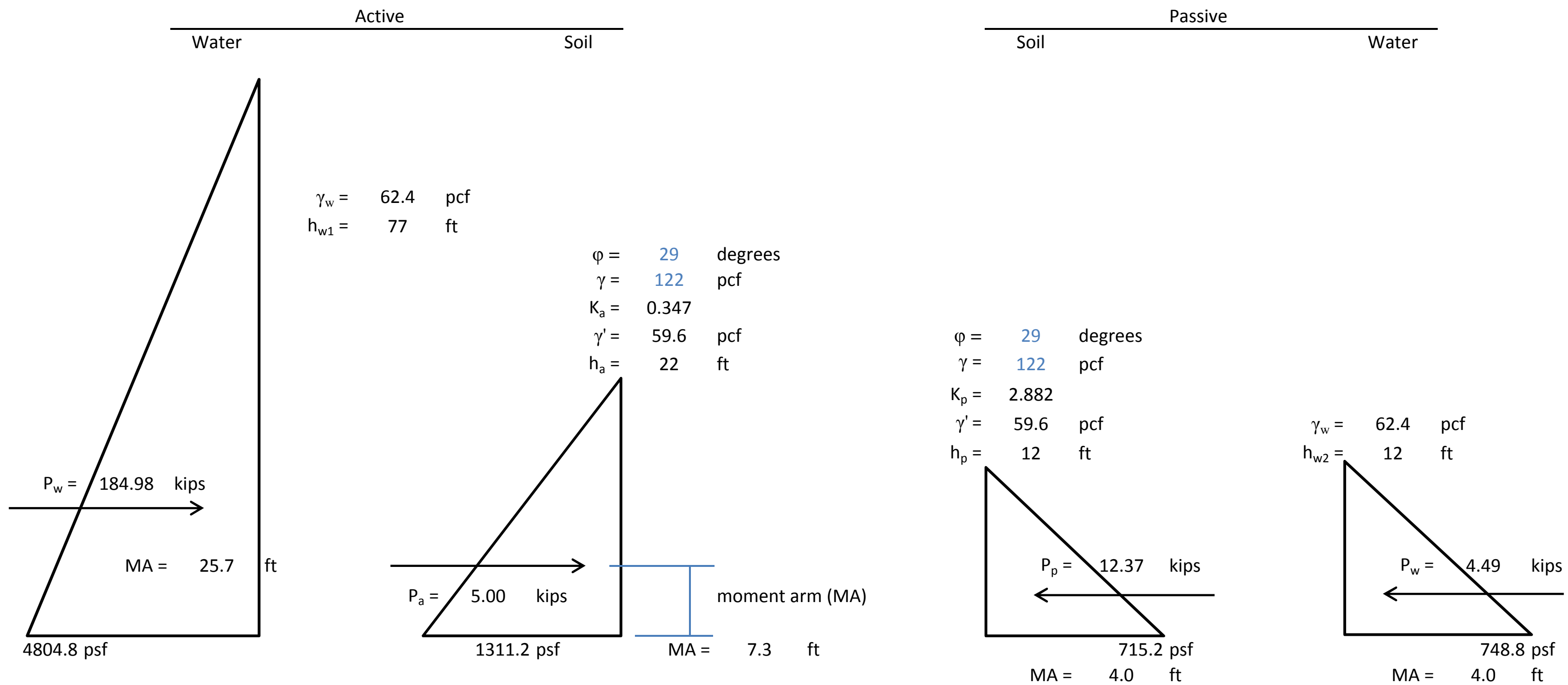
φ = 39 degrees

c = 0 psf

Station 21+00

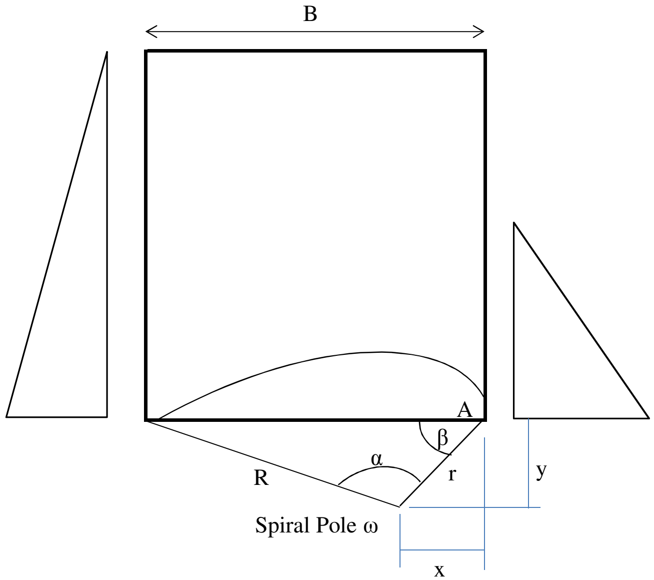
Not to Scale

Pressure Diagram for Active and Passive Pressures



NOT TO SCALE

Generation of Log Spiral curve for failure surface.



Log Spiral equation:

$$R = r\, e^{\alpha \tan \varphi}$$

α = angle between segments R and r.
φ = angle of internal friction of cell fill or foundation soil.

Input values:

Constants:

B = 80 feet (equivalent width)

φ = (see below) degrees

Variables:

α (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 sovle for r.

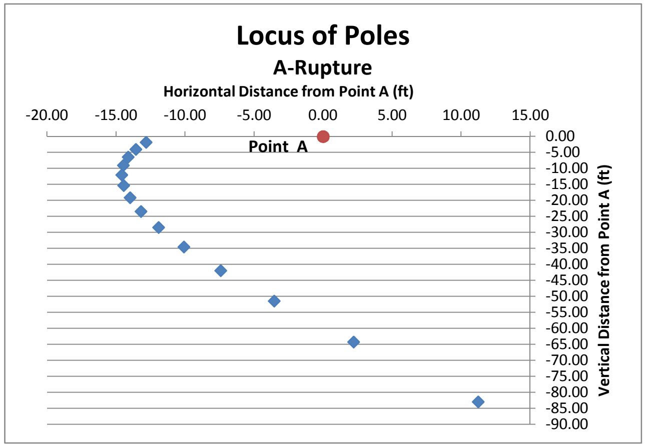
Solve for R using Log Spiral equation.

Failure surface within cell fill (A-rupture).

Internal friction angle of cell granular soil, ϕ: 29 degrees

Calculation:

Pole	α	$e^{\alpha \tan \phi}$	R/r	r (ft)	R (ft)	x (ft)	y (ft)	β
						Coordinates from Point A		
1	170	5.18	5.18	12.97	67.19	12.83	1.89	8.4
2	160	4.70	4.70	14.15	66.55	13.57	4.03	16.5
3	150	4.27	4.27	15.51	66.19	14.12	6.42	24.4
4	140	3.87	3.87	17.08	66.16	14.46	9.08	32.1
5	130	3.52	3.52	18.91	66.52	14.58	12.05	39.6
6	120	3.19	3.19	21.09	67.34	14.44	15.38	46.8
7	110	2.90	2.90	23.71	68.73	13.99	19.14	53.8
8	100	2.63	2.63	26.91	70.81	13.19	23.46	60.7
9	90	2.39	2.39	30.89	73.79	11.93	28.50	67.3
10	80	2.17	2.17	35.96	77.98	10.08	34.52	73.7
11	70	1.97	1.97	42.59	83.84	7.41	41.94	80.0
12	60	1.79	1.79	51.57	92.16	3.54	51.45	86.1
13	50	1.62	1.62	64.34	104.37	-2.21	64.30	92.0
14	40	1.47	1.47	83.76	123.33	-11.23	83.00	97.7

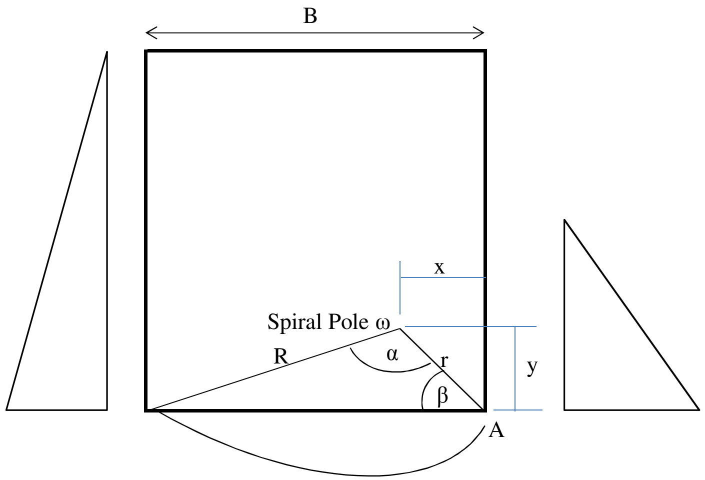


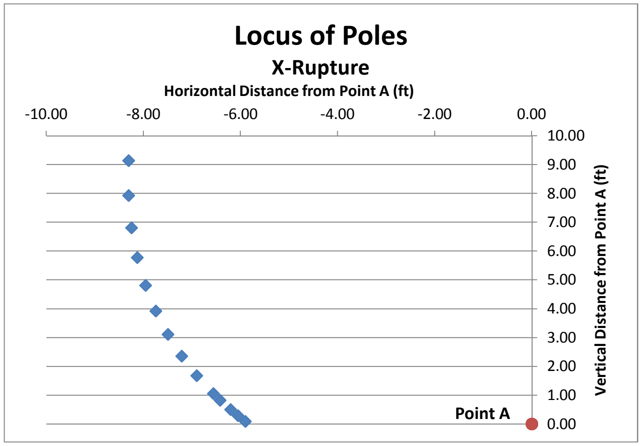
Failure surface within foundation soil (X-rupture).

Internal friction angle of foundation soil, ϕ: 39 degrees

Calculation:

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





Overturning

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

Overturning Moments

Water	h =	77.0	ft
	Y' =	62.4	pcf
	Ka =	1	
	Resultant =	184.98	kips
	moment arm =	25.7	ft (from Point A)
		Input:	
Soil	h =	22	ft
	Y' =	59.6	pcf
	Ka =	0.347	
	Resultant =	5.00	kips
	moment arm =	7.3	ft (from Point A)

Resisting Moments

Water	h =	12.0	ft
	Y' =	62.4	pcf
	Ka =	1	
	Resultant =	4.49	kips
	moment arm =	4.0	ft (from Point A)
		Input:	
Soil	h =	12	ft
	Y' =	59.6	pcf
	Kp =	2.88	
	Resultant =	12.37	kips
	moment arm =	4.0	ft (from Point A)

Drained Cell Fill		Area 1 =	960	sq. ft.	(rectangular area)				
		Area 2 =	2600	sq. ft.	(triangular area)				
		Y' =	120	pcf					
	Resultants:	Area 1 =	115.20	kips	Area 2 =	312.00	kips		
	moment arms:	Area 1 =	40	ft	Area 2 =	26.7	ft	ft (from Point A)	
Saturated Cell Fill		Area 3 =	2600	sq. ft.	(triangular area)				
		Area 4 =	960	sq. ft.	(rectangular area)				
		Y'_3 =	57.6	pcf	Y'_4 =	59.6	pcf		
	Resultants:	Area 3 =	149.76	kips	Area 4 =	57.22	kips		
	moment arms:	Area 3 =	53.3	ft	Area 4 =	40	ft	ft (from Point A)	

A-Rupture Failure Mode

(Within cell fill)

Moments about Poles - pole is below the cell therefore add pole y-coord. to moment arm from point A to get total arm, subtract x-coord.

G = Aγ   A = [(R^2 - r^2)/4*tan φ] - B*γ/2

Y' = 59.6 pcf   ϕ = 29 degrees

Overturning Moments

Pole	Pole y-coord.	Water Total Moment Arm	Water Resultant kips	Water Moment kip-ft	Soil Total Moment Arm	Soil Resultant kips	Soil Moment kip-ft	Total Moment kip-ft
1	1.89	27.6	184.98	5097.955	9.23	5.00	46.17	5144.12
2	4.03	29.7	184.98	5492.962	11.36	5.00	56.85	5549.82
3	6.42	32.1	184.98	5934.793	13.75	5.00	68.81	6003.60
4	9.08	34.7	184.98	6427.185	16.41	5.00	82.13	6509.31
5	12.05	37.7	184.98	6976.4	19.38	5.00	96.99	7073.39
6	15.38	41.0	184.98	7592.095	22.71	5.00	113.64	7705.74
7	19.14	44.8	184.98	8288.646	26.47	5.00	132.49	8421.13
8	23.46	49.1	184.98	9087.267	30.79	5.00	154.09	9241.36
9	28.50	54.2	184.98	10019.57	35.83	5.00	179.32	10198.88
10	34.52	60.2	184.98	11133.8	41.85	5.00	209.46	11343.26
11	41.94	67.6	184.98	12506.52	49.28	5.00	246.60	12753.11
12	51.45	77.1	184.98	14265.94	58.79	5.00	294.19	14560.13
13	64.30	90.0	184.98	16643.39	71.64	5.00	358.51	17001.90
14	83.00	108.7	184.98	20101.95	90.33	5.00	452.08	20554.03

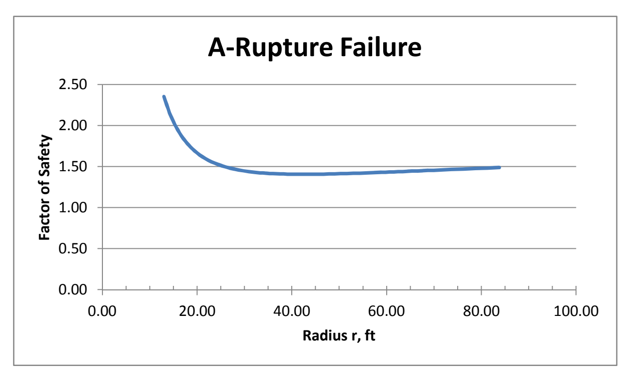
Resisting Moments

Pole y-coord.	Water Total Moment Arm	Water Resultant kips	Water Moment kip-ft	Soil Total Moment Arm	Soil Resultant kips	Soil Moment kip-ft	Pole x-coord.
1.89	5.9	4.49	26.47208	5.89	12.37	72.87	12.83
4.03	8.0	4.49	36.06576	8.03	12.37	99.28	13.57
6.42	10.4	4.49	46.79668	10.42	12.37	128.82	14.12
9.08	13.1	4.49	58.75562	13.08	12.37	161.74	14.46
12.05	16.0	4.49	72.09463	16.05	12.37	198.46	14.58
15.38	19.4	4.49	87.04827	19.38	12.37	239.62	14.44
19.14	23.1	4.49	103.9657	23.14	12.37	286.19	13.99
23.46	27.5	4.49	123.3621	27.46	12.37	339.58	13.19
28.50	32.5	4.49	146.0052	32.50	12.37	401.91	11.93
34.52	38.5	4.49	173.067	38.52	12.37	476.41	10.08
41.94	45.9	4.49	206.4068	45.94	12.37	568.18	7.41
51.45	55.5	4.49	249.1386	55.45	12.37	685.81	3.54
64.30	68.3	4.49	306.8807	68.30	12.37	844.76	-2.21
83.00	87.0	4.49	390.8802	87.00	12.37	1075.99	-11.23

Pole x-coord.	Drained Cell Fill Area 1 Total Moment Arm	Area 1 Resultant kips	Area 1 Moment kip-ft	Area 2 Total Moment Arm	Area 2 Resultant kips	Area 2 Moment kip-ft	Saturated Cell Fill Area 3 Total Moment Arm	Area 3 Resultant kips	Area 3 Moment kip-ft	Area 4 Total Moment Arm	Area 4 Resultant kips	Area 4 Moment kip-ft	G (subtracted from Area 4) Total Moment Arm	G Resultant kips	G Moment kip-ft	Total Moment kip-ft	Factor of Safety
12.83	27.17	115.2	3129.46	13.83	312	4315.63	40.50	149.76	6065.10	27.17	57.216	1554.30	27.17	112.32	3051.33	12112.51	2.35
13.57	26.43	115.2	3044.75	13.10	312	4086.20	39.76	149.76	5954.98	26.43	57.216	1512.23	26.43	104.07	2750.60	11982.90	2.16
14.12	25.88	115.2	2981.47	12.55	312	3914.83	39.21	149.76	5872.72	25.88	57.216	1480.80	25.88	96.01	2484.93	11940.51	1.99
14.46	25.54	115.2	2941.82	12.20	312	3807.44	38.87	149.76	5821.17	25.54	57.216	1461.11	25.54	88.19	2252.03	12000.01	1.84
14.58	25.42	115.2	2928.45	12.09	312	3771.22	38.75	149.76	5803.79	25.42	57.216	1454.46	25.42	80.61	2049.17	12179.30	1.72
14.44	25.56	115.2	2944.85	12.23	312	3815.64	38.90	149.76	5825.11	25.56	57.216	1462.61	25.56	73.29	1873.46	12501.41	1.62
13.99	26.01	115.2	2995.90	12.67	312	3953.89	39.34	149.76	5891.47	26.01	57.216	1487.96	26.01	66.22	1722.05	12997.32	1.54
13.19	26.81	115.2	3088.64	13.48	312	4205.07	40.14	149.76	6012.03	26.81	57.216	1534.03	26.81	59.39	1592.24	13710.47	1.48
11.93	28.07	115.2	3233.59	14.74	312	4597.63	41.40	149.76	6200.46	28.07	57.216	1606.01	28.07	52.78	1481.60	14704.01	1.44
10.08	29.92	115.2	3446.89	16.59	312	5175.32	43.25	149.76	6477.76	29.92	57.216	1711.95	29.92	46.39	1387.95	16073.45	1.42
7.41	32.59	115.2	3754.42	19.26	312	6008.22	45.92	149.76	6877.55	32.59	57.216	1864.70	32.59	40.18	1309.41	17970.06	1.41
3.54	36.46	115.2	4199.84	23.12	312	7214.57	49.79	149.76	7456.59	36.46	57.216	2085.92	36.46	34.13	1244.36	20647.52	1.42
-2.21	42.21	115.2	4862.38	28.87	312	9008.96	55.54	149.76	8317.90	42.21	57.216	2414.98	42.21	28.23	1191.45	24564.41	1.44
-11.23	51.23	115.2	5901.28	37.89	312	11822.63	64.56	149.76	9668.46	51.23	57.216	2930.97	51.23	22.44	1149.59	30640.61	1.49

Factor of Safety for failure within cell fill:

Min. Factor of Safety = 1.41



X-Rupture Failure Mode on next page

Overturning (continued)

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

X-Rupture Failure Mode

(Below cell in foundation soil)

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

G = Aγ   A = [(R^2 - r^2)/4*tan φ] - B*y/2

ϒ' = 65.6 pcf   ϕ = 39 degrees

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.

Overturning Moments

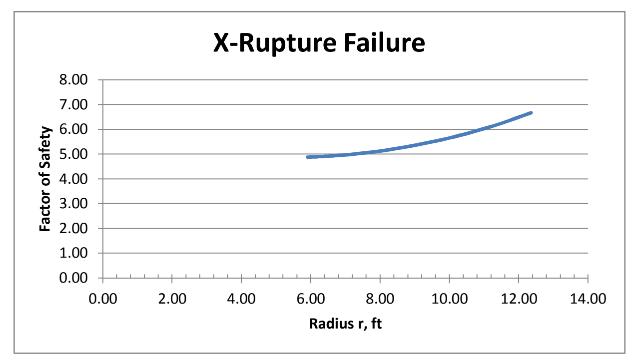
		Water			Soil			
Pole	Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment kip-ft
1	0.10	25.6	184.98	4730.291	7.24	5.00	36.22	4766.51
2	0.29	25.4	184.98	4693.711	7.04	5.00	35.23	4728.94
3	0.50	25.2	184.98	4655.41	6.83	5.00	34.20	4689.61
4	0.83	24.8	184.98	4594.678	6.50	5.00	32.55	4627.23
5	1.06	24.6	184.98	4551.968	6.27	5.00	31.40	4583.37
6	1.68	24.0	184.98	4437.241	5.65	5.00	28.29	4465.53
7	2.36	23.3	184.98	4310.839	4.97	5.00	24.87	4335.71
8	3.11	22.6	184.98	4172.35	4.22	5.00	21.13	4193.48
9	3.93	21.7	184.98	4021.323	3.41	5.00	17.04	4038.36
10	4.81	20.9	184.98	3857.25	2.52	5.00	12.60	3869.85
11	5.78	19.9	184.98	3679.546	1.56	5.00	7.80	3687.34
12	6.81	18.9	184.98	3487.522	0.52	5.00	2.60	3490.12
13	7.93	17.7	184.98	3280.363	-0.60	5.00	-3.00	3277.36
14	9.14	16.5	184.98	3057.087	-1.81	5.00	-9.04	3048.04

Resisting Moments

	Water			Soil				Drained Cell Fill: Area 1			Drained Cell Fill: Area 2			Saturated Cell Fill: Area 3			Saturated Cell Fill: Area 4			G (added to Area 4)				
Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Pole x-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment kip-ft	Factor of Safety
0.10	3.9	4.49	17.54	3.90	12.37	48.29	5.90	34.10	115.2	3928.03	20.76	312	6478.42	47.43	149.76	7103.24	34.10	57.216	1950.92	34.10	110.24	3758.85	23285.30	4.89
0.29	3.7	4.49	16.65	3.71	12.37	45.84	6.05	33.95	115.2	3910.68	20.61	312	6431.43	47.28	149.76	7080.69	33.95	57.216	1942.31	33.95	109.23	3708.06	23135.66	4.89
0.50	3.5	4.49	15.72	3.50	12.37	43.28	6.20	33.80	115.2	3893.60	20.47	312	6385.16	47.13	149.76	7058.48	33.80	57.216	1933.82	33.80	108.21	3657.26	22987.32	4.90
0.83	3.2	4.49	14.25	3.17	12.37	39.22	6.42	33.58	115.2	3868.54	20.25	312	6317.31	46.91	149.76	7025.91	33.58	57.216	1921.38	33.58	106.64	3581.13	22767.73	4.92
1.06	2.9	4.49	13.21	2.94	12.37	36.37	6.56	33.44	115.2	3852.27	20.11	312	6273.22	46.77	149.76	7004.75	33.44	57.216	1913.29	33.44	105.58	3530.49	22623.59	4.94
1.68	2.3	4.49	10.43	2.32	12.37	28.70	6.90	33.10	115.2	3813.29	19.77	312	6167.66	46.43	149.76	6954.08	33.10	57.216	1893.93	33.10	102.85	3404.61	22272.70	4.99
2.36	1.6	4.49	7.36	1.64	12.37	20.25	7.21	32.79	115.2	3777.17	19.45	312	6069.85	46.12	149.76	6907.13	32.79	57.216	1876.00	32.79	100.04	3280.27	21938.01	5.06
3.11	0.9	4.49	3.99	0.89	12.37	10.99	7.50	32.50	115.2	3744.43	19.17	312	5981.18	45.84	149.76	6864.56	32.50	57.216	1859.74	32.50	97.16	3158.05	21622.94	5.16
3.93	0.1	4.49	0.32	0.07	12.37	0.89	7.75	32.25	115.2	3715.61	18.92	312	5903.11	45.59	149.76	6827.09	32.25	57.216	1845.42	32.25	94.21	3038.49	21330.93	5.28
4.81	-0.8	4.49	-3.66	-0.81	12.37	-10.08	7.96	32.04	115.2	3691.26	18.71	312	5837.15	45.38	149.76	6795.43	32.04	57.216	1833.32	32.04	91.19	2922.05	21065.47	5.44
5.78	-1.8	4.49	-7.98	-1.78	12.37	-21.96	8.13	31.87	115.2	3671.96	18.54	312	5784.90	45.21	149.76	6770.35	31.87	57.216	1823.74	31.87	88.13	2809.14	20830.16	5.65
6.81	-2.8	4.49	-12.64	-2.81	12.37	-34.80	8.24	31.76	115.2	3658.36	18.42	312	5748.06	45.09	149.76	6752.67	31.76	57.216	1816.99	31.76	85.02	2700.08	20628.72	5.91
7.93	-3.9	4.49	-17.67	-3.93	12.37	-48.65	8.31	31.69	115.2	3651.13	18.36	312	5728.47	45.03	149.76	6743.27	31.69	57.216	1813.39	31.69	81.88	2595.16	20465.10	6.24
9.14	-5.1	4.49	-23.10	-5.14	12.37	-63.58	8.31	31.69	115.2	3651.00	18.36	312	5728.14	45.03	149.76	6743.11	31.69	57.216	1813.33	31.69	78.71	2494.58	20343.49	6.67

Factor of Safety for failure below cell fill:

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, $\beta = 45 + \varphi/2$ degrees

$\beta =$ 59.5 degrees

Minimum width of berm:

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

= 0.0 feet

No Stability Berm is Required

Bearing Capacity at Toe (Terzaghi)

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

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

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

Factor of Safety = 23.28

Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:

P_w = 184.98 kips

P_a = 5.00 kips

Resisting Forces:

P_w = 4.49 kips

P_p = 12.37 kips

Cell Fill:

Area 1	P_1 =	115.20	kips
Area 2	P_2 =	312.00	kips
Area 3	P_3 =	149.76	kips
Area 4	P_4 =	57.22	kips

P_C = $P_1 + P_2 + P_3 + P_4$ = 634.18 kips

Friction angle of soil against soil at cell toe, $\delta = \phi'$: 28 degrees

Effective cohesion along faliure 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 kips

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

Factor of Safety = 1.86

Interlock Tension

Cell diameter, D = 91.4 ft

Cell Fill Material Properties:

γ = 120 pcf

φ = 28 degrees

γ' = 57.6 pcf

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

$$\sigma_T = K_a * \Upsilon * (H - H_1) + K_a * \Upsilon' * (H_1 - H/4) + \Upsilon_W * (H_3 - H/4)$$

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 suggeted by Terzaghi)

σ_T = 1197.84 pounds/sq. ft.

Maximum Interlock tension = σ_T * cell radius = 54.76 kips/ft

4.56 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
Design of Sheet Pile Cellular Structures, USACE EM 1110-2-2503, 1989.
Pile Buck Steel Sheet Piling Design Manual, 1987.
Design & Execution Manual AS 500 Straight Web Steel Sheet Piles, ArcelorMittal, 2009.
Steel Sheet Piling Design Manual, US Steel, 1984.

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 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 – 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

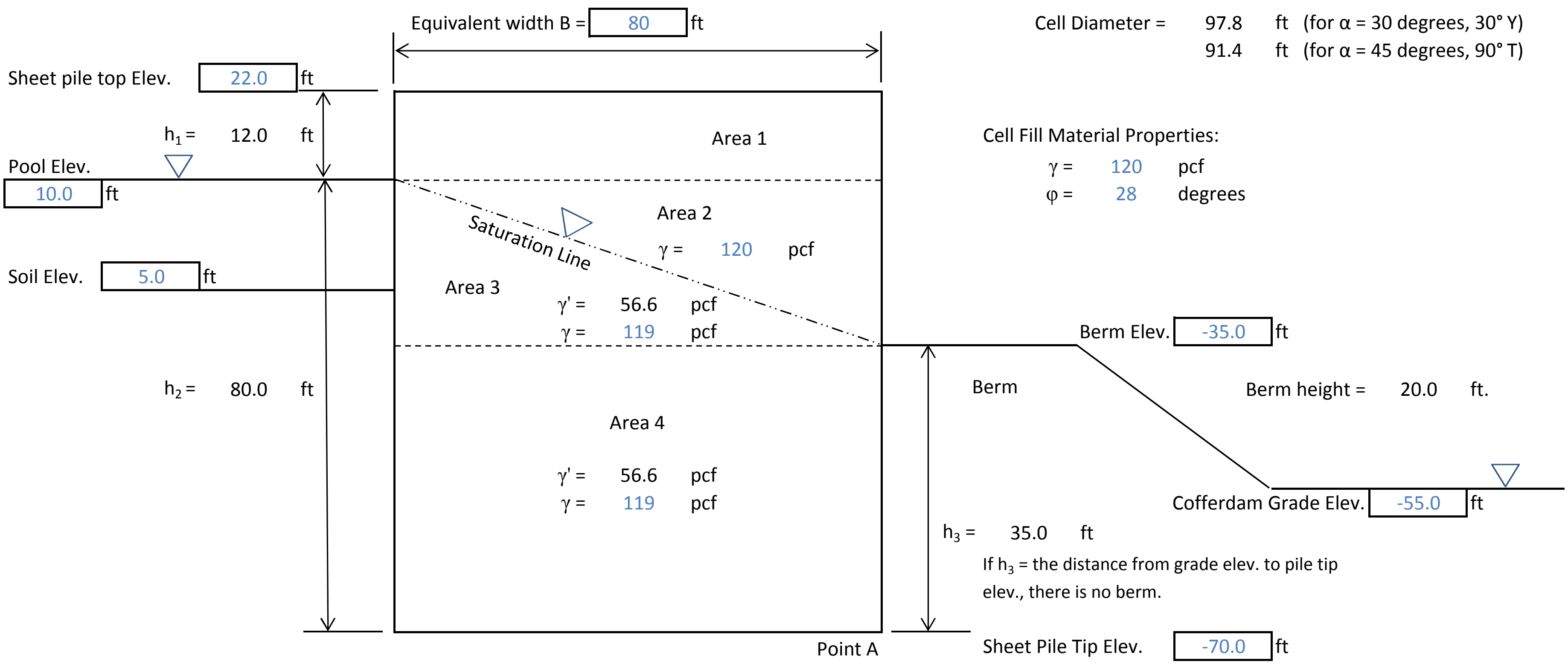
Cell Diameter = 97.8 ft (for α = 30 degrees, 30° Y)

91.4 ft (for α = 45 degrees, 90° T)

Cell Fill Material Properties:

γ = 120 pcf

φ = 28 degrees



Total Sheet Pile length: 92.0 ft

Foundation Soil Material Properties:

γ = 128 pcf

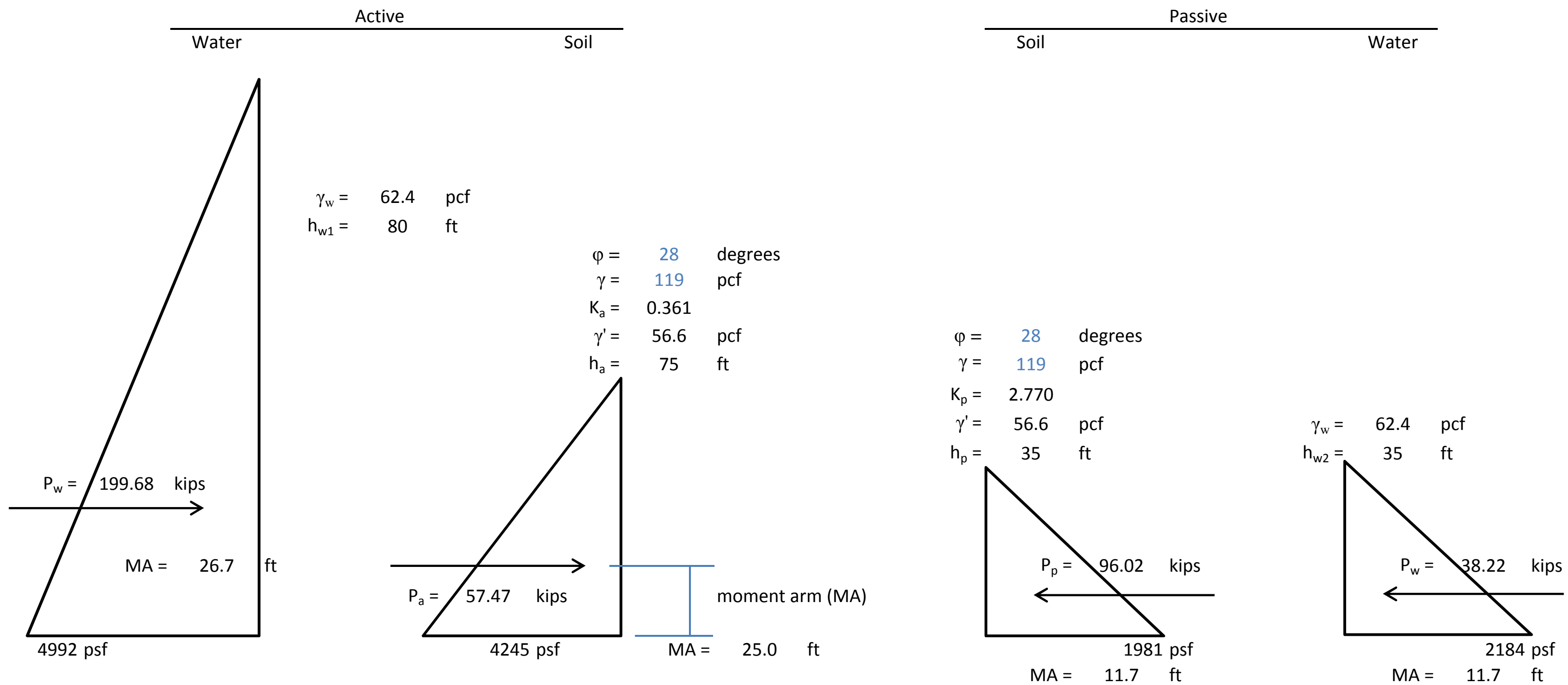
φ = 33 degrees

c = 0 psf

Station 28+00

Not to Scale

Pressure Diagram for Active and Passive Pressures



NOT TO SCALE

Project:	CPRA Mid-Barataria Sediment Diversion	Computed:	RLJ	Date:	07/01/14
Subject:	Sediment Diversion Structure	Checked:	JPW	Date:	07/07/14
Task:	Station 28+00 Cofferdam Design - Preliminary (30% Design)	Page:	6	of	15
Job #:	099-209442	No:			

Generation of Log Spiral curve for failure surface.

Log Spiral equation:

$$R = r\, e^{\alpha \tan \varphi}$$

α = angle between segments R and r.
φ = angle of internal friction of cell fill or foundation soil.

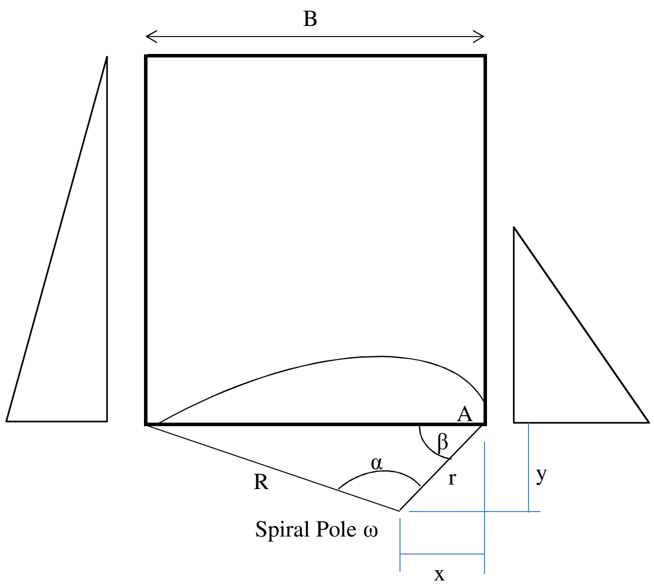
Input values:

Constants:

B = 80 feet (equivalent width)
φ = (see below) degrees

Variables:

α (entered below)



Law of Cosines:

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

or

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

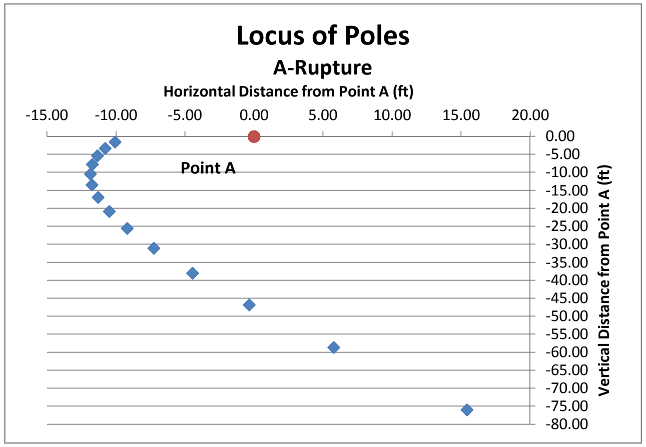
put R in terms of r, then sovle for r.
Solve for R using Log Spiral equation.

Failure surface within cell fill (A-rupture).

Internal friction angle of cell granular soil, ϕ: 33 degrees

Calculation:

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



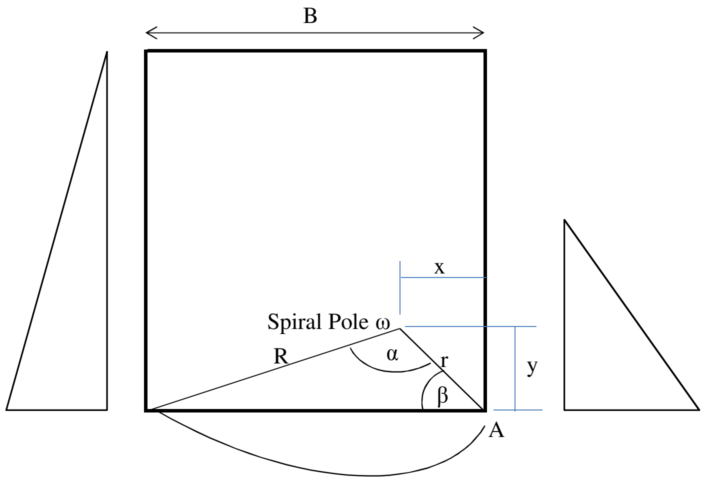
Failure surface within foundation soil (X-rupture).

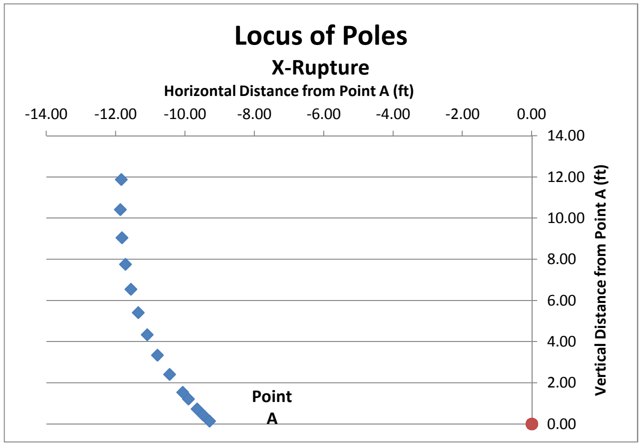
Internal friction angle of foundation soil, ϕ: 33 degrees

Calculation:

Coordinates from Point A

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





Overturning

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

Overturning Moments

Water	h =	80.0	ft
	Y' =	62.4	pcf
	Ka =	1	
	Resultant =	199.68	kips
	moment arm =	26.7	ft (from Point A)
		Input:	
Soil	h =	75	ft
	Y' =	56.6	pcf
	Ka =	0.361	
	Resultant =	57.47	kips
	moment arm =	25.0	ft (from Point A)

Resisting Moments

Water	h =	35.0	ft
	Y' =	62.4	pcf
	Ka =	1	
	Resultant =	38.22	kips
	moment arm =	11.7	ft (from Point A)
		Input:	
Soil	h =	35	ft
	Y' =	56.6	pcf
	Kp =	2.77	
	Resultant =	96.02	kips
	moment arm =	11.7	ft (from Point A)

Drained Cell Fill		Area 1 =	960	sq. ft.	(rectangular area)				
		Area 2 =	1800	sq. ft.	(triangular area)				
		Y' =	120	pcf					
	Resultants:	Area 1 =	115.20	kips		Area 2 =	216.00	kips	
	moment arms:	Area 1 =	40	ft		Area 2 =	26.7	ft	ft (from Point A)
Saturated Cell Fill		Area 3 =	1800	sq. ft.	(triangular area)				
		Area 4 =	2800	sq. ft.	(rectangular area)				
		Y'_3 =	56.6	pcf		Y'_4 =	56.6	pcf	
	Resultants:	Area 3 =	101.88	kips		Area 4 =	158.48	kips	
	moment arms:	Area 3 =	53.3	ft		Area 4 =	40	ft	ft (from Point A)

A-Rupture Failure Mode

(Within cell fill)

Moments about Poles - pole is below the cell therefore add pole y-coord. to moment arm from point A to get total arm, subtract x-coord.

G = Aγ A = [(R^2 - r^2)/4*tan φ] - B*γ/2

Y' = 56.6 pcf ϕ = 33 degrees

Overturning Moments

Pole	Pole y-coord.	Water Total Moment Arm	Water Resultant kips	Water Moment kip-ft	Soil Total Moment Arm	Soil Resultant kips	Soil Moment kip-ft	Total Moment kip-ft
1	1.55	28.2	199.68	5633.599	26.55	57.47	1525.68	7159.28
2	3.35	30.0	199.68	5993.186	28.35	57.47	1629.18	7622.36
3	5.41	32.1	199.68	6405.692	30.41	57.47	1747.90	8153.60
4	7.76	34.4	199.68	6874.765	32.76	57.47	1882.91	8757.68
5	10.42	37.1	199.68	7406.289	35.42	57.47	2035.90	9442.19
6	13.44	40.1	199.68	8009.351	38.44	57.47	2209.47	10218.82
7	16.89	43.6	199.68	8697.633	41.89	57.47	2407.57	11105.20
8	20.87	47.5	199.68	9491.571	45.87	57.47	2636.08	12127.65
9	25.53	52.2	199.68	10421.93	50.53	57.47	2903.86	13325.79
10	31.11	57.8	199.68	11536.03	56.11	57.47	3224.52	14760.54
11	37.98	64.7	199.68	12909.32	62.98	57.47	3619.78	16529.10
12	46.79	73.5	199.68	14668.6	71.79	57.47	4126.14	18794.73
13	58.69	85.4	199.68	17043.03	83.69	57.47	4809.55	21852.58
14	75.96	102.6	199.68	20491.88	100.96	57.47	5802.20	26294.08

Resisting Moments (Water, Soil)

Pole	Pole y-coord.	Water Total Moment Arm	Water Resultant kips	Water Moment kip-ft	Soil Total Moment Arm	Soil Resultant kips	Soil Moment kip-ft	Pole x-coord.
1	1.55	13.2	38.22	505.0061	13.21	96.02	1268.76	10.07
2	3.35	15.0	38.22	573.8333	15.01	96.02	1441.68	10.79
3	5.41	17.1	38.22	652.7896	17.08	96.02	1640.05	11.35
4	7.76	19.4	38.22	742.573	19.43	96.02	1865.62	11.72
5	10.42	22.1	38.22	844.31	22.09	96.02	2121.22	11.86
6	13.44	25.1	38.22	959.7399	25.11	96.02	2411.23	11.75
7	16.89	28.6	38.22	1091.481	28.56	96.02	2742.21	11.31
8	20.87	32.5	38.22	1243.446	32.53	96.02	3124.00	10.50
9	25.53	37.2	38.22	1421.522	37.19	96.02	3571.40	9.20
10	31.11	42.8	38.22	1634.767	42.77	96.02	4107.15	7.27
11	37.98	49.7	38.22	1897.624	49.65	96.02	4767.54	4.46
12	46.79	58.5	38.22	2234.361	58.46	96.02	5613.55	0.36
13	58.69	70.4	38.22	2688.842	70.35	96.02	6755.38	-5.78
14	75.96	87.6	38.22	3348.973	87.62	96.02	8413.88	-15.43

Resisting Moments (Drained Cell Fill: Area 1, Area 2)

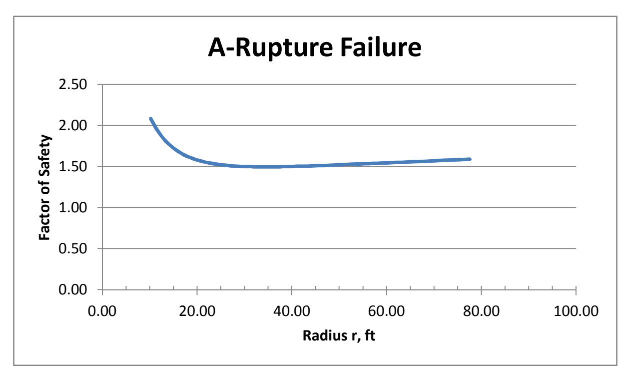
Pole	Area 1 Total Moment Arm	Area 1 Resultant kips	Area 1 Moment kip-ft	Area 2 Total Moment Arm	Area 2 Resultant kips	Area 2 Moment kip-ft
1	29.93	115.2	3448.25	16.60	216	3585.48
2	29.21	115.2	3364.68	15.87	216	3428.78
3	28.65	115.2	3300.10	15.31	216	3307.69
4	28.28	115.2	3257.72	14.95	216	3228.23
5	28.14	115.2	3241.17	14.80	216	3197.19
6	28.25	115.2	3254.86	14.92	216	3222.86
7	28.69	115.2	3304.57	15.35	216	3316.06
8	29.50	115.2	3398.31	16.17	216	3491.82
9	30.80	115.2	3547.71	17.46	216	3771.95
10	32.73	115.2	3770.42	19.40	216	4189.53
11	35.54	115.2	4094.46	22.21	216	4797.12
12	39.64	115.2	4566.99	26.31	216	5683.12
13	45.78	115.2	5273.43	32.44	216	7007.69
14	55.43	115.2	6385.34	42.10	216	9092.52

Resisting Moments (Saturated Cell Fill: Area 3, Area 4; G (subtracted from Area 4))

Pole	Area 3 Total Moment Arm	Area 3 Resultant kips	Area 3 Moment kip-ft	Area 4 Total Moment Arm	Area 4 Resultant kips	Area 4 Moment kip-ft	G Total Moment Arm	G Resultant kips	G Moment kip-ft	Total Moment kip-ft	Factor of Safety
1	43.27	101.88	4407.95	29.93	158.48	4743.74	29.93	100.85	3018.78	14940.42	2.09
2	42.54	101.88	4334.04	29.21	158.48	4628.78	29.21	94.25	2752.67	15019.13	1.97
3	41.98	101.88	4276.93	28.65	158.48	4539.93	28.65	87.61	2509.86	15207.62	1.87
4	41.61	101.88	4239.45	28.28	158.48	4481.63	28.28	81.01	2290.97	15524.26	1.77
5	41.47	101.88	4224.81	28.14	158.48	4458.86	28.14	74.49	2095.68	15991.89	1.69
6	41.59	101.88	4236.92	28.25	158.48	4477.69	28.25	68.06	1923.04	16640.25	1.63
7	42.02	101.88	4280.88	28.69	158.48	4546.07	28.69	61.76	1771.71	17509.56	1.58
8	42.83	101.88	4363.78	29.50	158.48	4675.03	29.50	55.60	1640.10	18656.28	1.54
9	44.13	101.88	4495.90	30.80	158.48	4880.56	30.80	49.57	1526.59	20162.45	1.51
10	46.06	101.88	4692.86	32.73	158.48	5186.94	32.73	43.68	1429.58	22152.09	1.50
11	48.88	101.88	4979.44	35.54	158.48	5632.73	35.54	37.91	1347.58	24821.34	1.50
12	52.98	101.88	5397.34	39.64	158.48	6282.79	39.64	32.27	1279.23	28498.92	1.52
13	59.11	101.88	6022.09	45.78	158.48	7254.63	45.78	26.73	1223.37	33778.70	1.55
14	68.76	101.88	7005.44	55.43	158.48	8784.28	55.43	21.27	1179.01	41851.43	1.59

Factor of Safety for failure within cell fill:

Min. Factor of Safety = 1.50



X-Rupture Failure Mode on next page

Overturning (continued)

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

X-Rupture Failure Mode
(Below cell in foundation soil)

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

G = Aγ   A = [(R^2 - r^2)/4*tan φ] - B*y/2

ϒ' = 67.6 pcf   ϕ = 33 degrees

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.

Overturning Moments

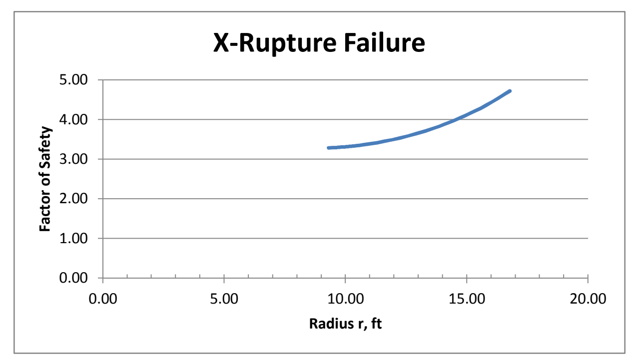
		Water			Soil			
Pole	Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment kip-ft
1	0.14	26.5	199.68	5296.166	24.86	57.47	1428.56	6724.73
2	0.44	26.2	199.68	5237.409	24.56	57.47	1411.65	6649.06
3	0.74	25.9	199.68	5176.658	24.26	57.47	1394.16	6570.82
4	1.22	25.4	199.68	5081.775	23.78	57.47	1366.85	6448.63
5	1.55	25.1	199.68	5016.001	23.45	57.47	1347.92	6363.92
6	2.41	24.3	199.68	4842.661	22.59	57.47	1298.03	6140.69
7	3.35	23.3	199.68	4656.414	21.65	57.47	1244.43	5900.84
8	4.35	22.3	199.68	4456.961	20.65	57.47	1187.02	5643.98
9	5.41	21.3	199.68	4243.908	19.59	57.47	1125.70	5369.60
10	6.55	20.1	199.68	4016.748	18.45	57.47	1060.32	5077.06
11	7.76	18.9	199.68	3774.835	17.24	57.47	990.69	4765.52
12	9.05	17.6	199.68	3517.359	15.95	57.47	916.58	4433.94
13	10.42	16.2	199.68	3243.311	14.58	57.47	837.70	4081.02
14	11.89	14.8	199.68	2951.449	13.11	57.47	753.70	3705.15

Resisting Moments

	Water			Soil				Drained Cell Fill: Area 1			Drained Cell Fill: Area 2			Saturated Cell Fill: Area 3			Saturated Cell Fill: Area 4			G (added to Area 4)				
Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Pole x-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment kip-ft	Factor of Safety
0.14	11.5	38.22	440.42	11.52	96.02	1106.50	9.30	30.70	115.2	3537.14	17.37	216	3752.13	44.04	101.88	4486.56	30.70	158.48	4866.02	30.70	127.46	3913.53	22102.30	3.29
0.44	11.2	38.22	429.17	11.23	96.02	1078.24	9.48	30.52	115.2	3516.39	17.19	216	3713.23	43.86	101.88	4468.21	30.52	158.48	4837.48	30.52	125.91	3843.40	21886.13	3.29
0.74	10.9	38.22	417.54	10.92	96.02	1049.03	9.65	30.35	115.2	3496.19	17.02	216	3675.36	43.68	101.88	4450.34	30.35	158.48	4809.69	30.35	124.36	3774.20	21672.36	3.30
1.22	10.4	38.22	399.38	10.45	96.02	1003.40	9.90	30.10	115.2	3466.97	16.76	216	3620.58	43.43	101.88	4424.51	30.10	158.48	4769.50	30.10	122.02	3672.21	21356.55	3.31
1.55	10.1	38.22	386.79	10.12	96.02	971.77	10.07	29.93	115.2	3448.25	16.60	216	3585.48	43.27	101.88	4407.95	29.93	158.48	4743.74	29.93	120.45	3605.47	21149.46	3.32
2.41	9.3	38.22	353.62	9.25	96.02	888.41	10.45	29.55	115.2	3404.29	16.22	216	3503.04	42.88	101.88	4369.07	29.55	158.48	4683.26	29.55	116.52	3443.18	20644.87	3.36
3.35	8.3	38.22	317.97	8.32	96.02	798.85	10.79	29.21	115.2	3364.68	15.87	216	3428.78	42.54	101.88	4334.04	29.21	158.48	4628.78	29.21	112.56	3287.64	20160.75	3.42
4.35	7.3	38.22	279.79	7.32	96.02	702.94	11.10	28.90	115.2	3329.82	15.57	216	3363.42	42.24	101.88	4303.21	28.90	158.48	4580.82	28.90	108.60	3139.09	19699.09	3.49
5.41	6.3	38.22	239.01	6.25	96.02	600.48	11.35	28.65	115.2	3300.10	15.31	216	3307.69	41.98	101.88	4276.93	28.65	158.48	4539.93	28.65	104.64	2997.65	19261.79	3.59
6.55	5.1	38.22	195.53	5.12	96.02	491.25	11.56	28.44	115.2	3275.92	15.10	216	3262.36	41.77	101.88	4255.54	28.44	158.48	4506.67	28.44	100.69	2863.36	18850.63	3.71
7.76	3.9	38.22	149.23	3.90	96.02	374.91	11.72	28.28	115.2	3257.72	14.95	216	3228.23	41.61	101.88	4239.45	28.28	158.48	4481.63	28.28	96.76	2736.21	18467.38	3.88
9.05	2.6	38.22	99.94	2.61	96.02	251.10	11.82	28.18	115.2	3245.97	14.84	216	3206.19	41.51	101.88	4229.05	28.18	158.48	4465.46	28.18	92.85	2616.12	18113.83	4.09
10.42	1.2	38.22	47.49	1.24	96.02	119.31	11.86	28.14	115.2	3241.17	14.80	216	3197.19	41.47	101.88	4224.81	28.14	158.48	4458.86	28.14	88.96	2502.97	17791.80	4.36
11.89	-0.2	38.22	-8.37	-0.22	96.02	-21.04	11.84	28.16	115.2	3243.91	14.83	216	3202.34	41.49	101.88	4227.24	28.16	158.48	4462.63	28.16	85.11	2396.58	17503.29	4.72

Factor of Safety for failure below cell fill:

Min. Factor of Safety = 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, $\beta = 45 + \varphi/2$ degrees

$\beta =$ 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)

$$\text{Factor of Safety} = \frac{c*N_c + 0.5*\gamma'*B*N_\gamma}{(6*M/B^2) + \gamma*H}$$ (From "Pile Buck Steel Sheet Piling Design Manual", 1987)

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

Factor of Safety = 6.22

Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:

$P_w =$ 199.68 kips

$P_a =$ 57.47 kips

Resisting Forces:

$P_w =$ 38.22 kips

$P_p =$ 96.02 kips

Cell Fill:

Area 1	$P_1 =$	115.20	kips
Area 2	$P_2 =$	216.00	kips
Area 3	$P_3 =$	101.88	kips
Area 4	$P_4 =$	158.48	kips

$P_C = P_1 + P_2 + P_3 + P_4 =$ 591.56 kips

Friction angle of soil against soil at cell toe, $\delta = \phi'$:	33	degrees
Effective cohesion along faliure 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

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

Factor of Safety = 2.02

Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:

$P_w =$ 199.68 kips

$P_a =$ 57.47 kips

Resisting Forces:

$P_w =$ 38.22 kips

$P_p =$ 96.02 kips

Cell Fill:

Area 1	$P_1 =$	115.20	kips
Area 2	$P_2 =$	216.00	kips
Area 3	$P_3 =$	101.88	kips
Area 4	$P_4 =$	158.48	kips

$P_C = P_1 + P_2 + P_3 + P_4 =$ 591.56 kips

Friction angle of soil against soil at cell toe, $\delta = \phi'$:	24	degrees
Effective cohesion along faliure 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	kips

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

Factor of Safety = 1.49

Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:

P_w = 199.68 kips

P_a = 57.47 kips

Resisting Forces:

P_w = 38.22 kips

P_p = 96.02 kips

Cell Fill:

Area 1	P_1 =	115.20	kips
Area 2	P_2 =	216.00	kips
Area 3	P_3 =	101.88	kips
Area 4	P_4 =	158.48	kips

P_C = $P_1 + P_2 + P_3 + P_4$ = 591.56 kips

Friction angle of soil against soil at cell toe, $\delta = \phi$:	0	degrees
Cohesion along faliure 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	kips

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

Factor of Safety = 0.66

Interlock Tension

Cell diameter, D = 91.4 ft

Cell Fill Material Properties:

γ = 120 pcf

φ = 28 degrees

γ' = 57.6 pcf

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

$$\sigma_T = K_a * \Upsilon * (H - H_1) + K_a * \Upsilon' * (H_1 - H/4) + \Upsilon_W * (H_3 - H/4)$$

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 suggeted by Terzaghi)

$\sigma_T =$ 2638.08 pounds/sq. ft.

Maximum Interlock tension = σ_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

PURPOSE

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

REFERENCES

Design of Sheet Pile Cellular Structures, USACE EM 1110-2-2503, 1989.
Pile Buck Steel Sheet Piling Design Manual, 1987.
Design & Execution Manual AS 500 Straight Web Steel Sheet Piles, ArcelorMittal, 2009.
Steel Sheet Piling Design Manual, US Steel, 1984.

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.

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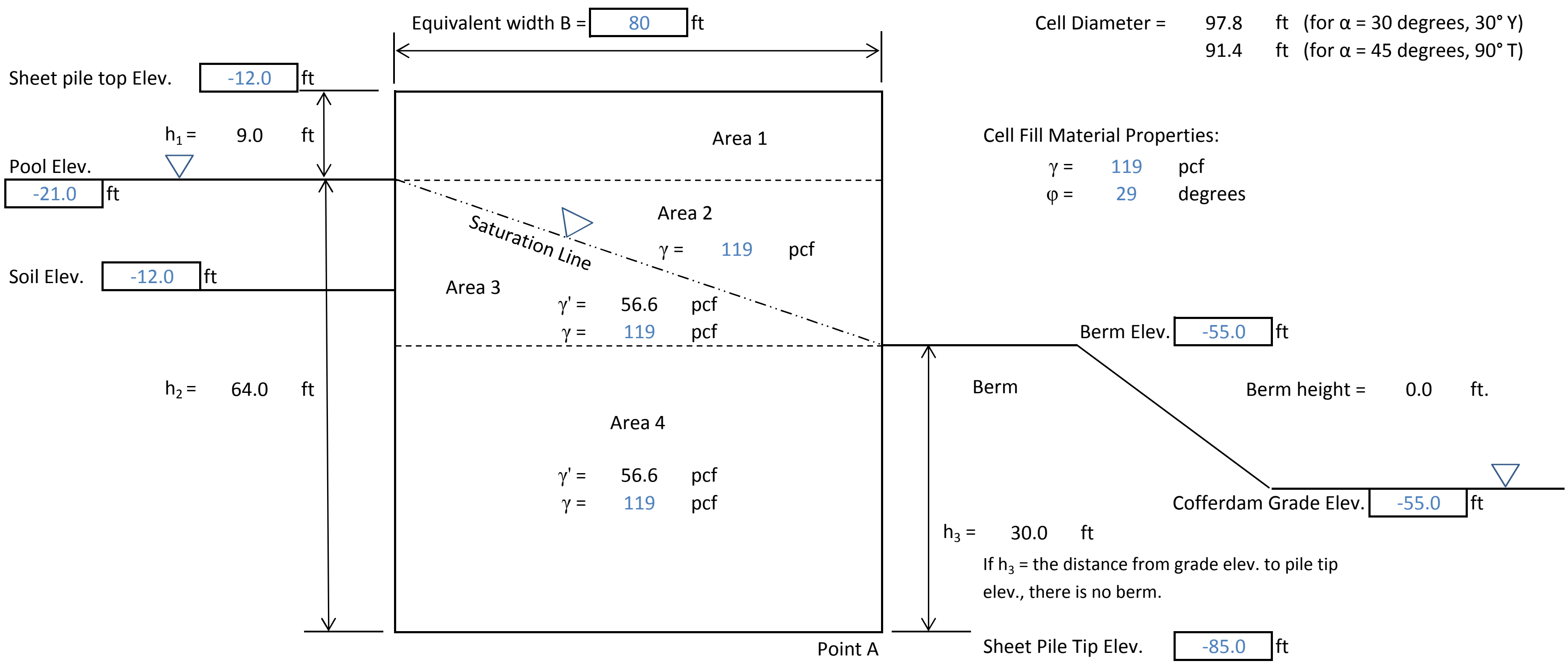
Circular Sheet Pile Cofferdam



Foundation Soil Material Properties:

γ = 122.5 pcf

φ = 33 degrees

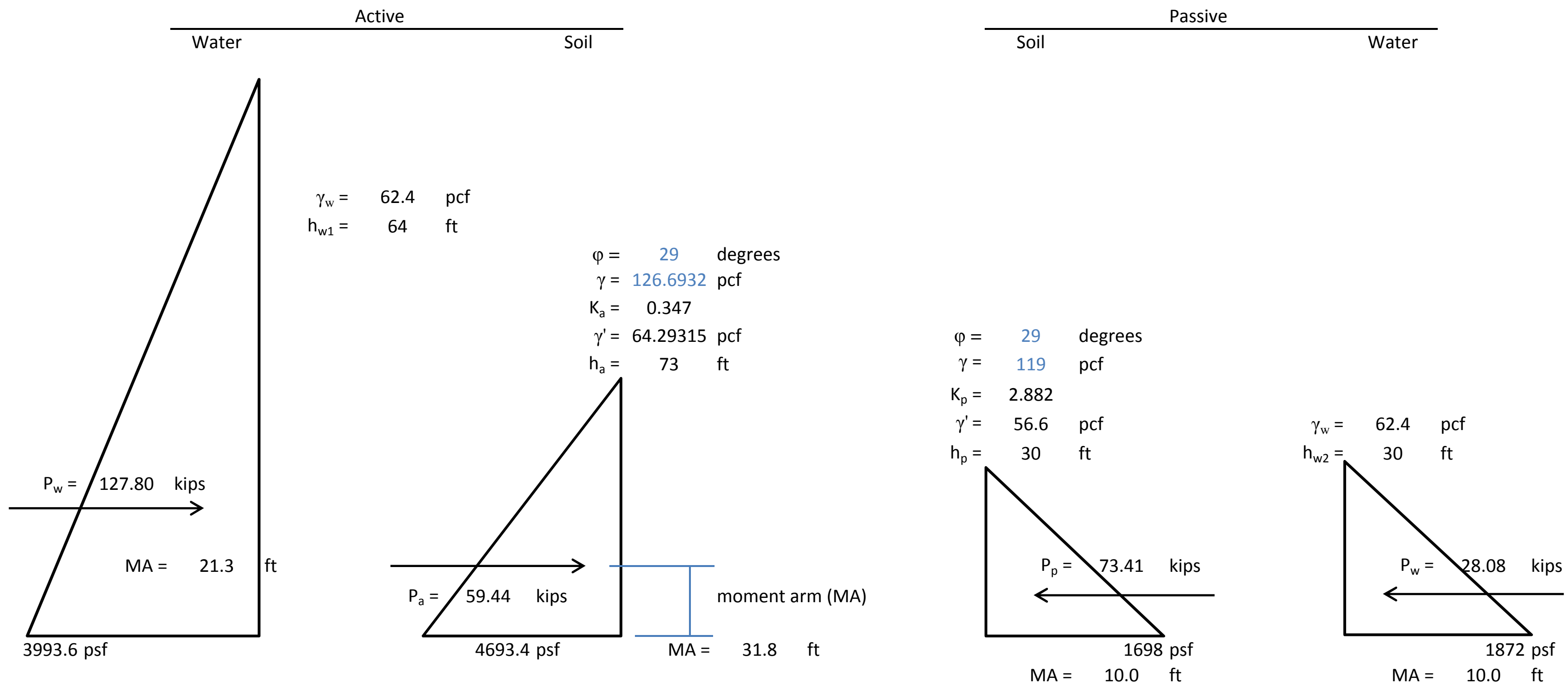
c = 0 psf

Total Sheet Pile length: 73.0 ft

Station 32+00 to 39+00

Not to Scale

Pressure Diagram for Active and Passive Pressures



NOT TO SCALE

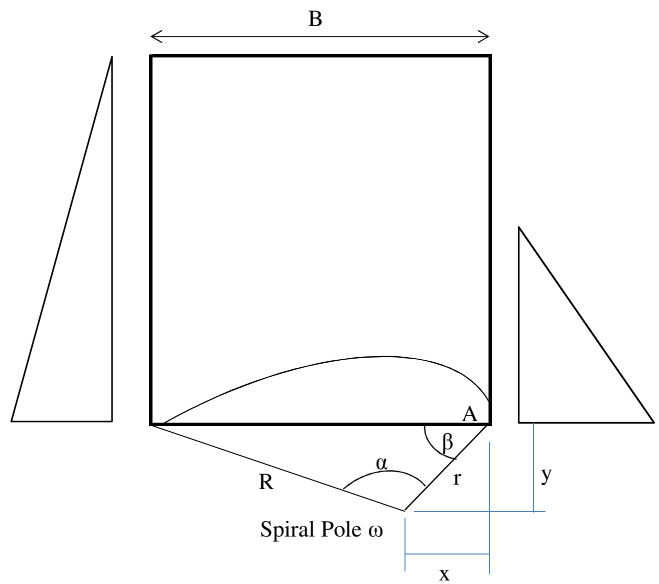
Generation of Log Spiral curve for failure surface.

Log Spiral equation:

$$R = r\,e^{\alpha \tan \varphi}$$

α = angle between segments R and r.
φ = angle of internal friction of cell fill or foundation soil.

Input values:
Constants:
B = 80 feet (equivalent width)
φ = (see below) degrees
Variables:
α (entered below)



Law of Cosines:

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

or

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

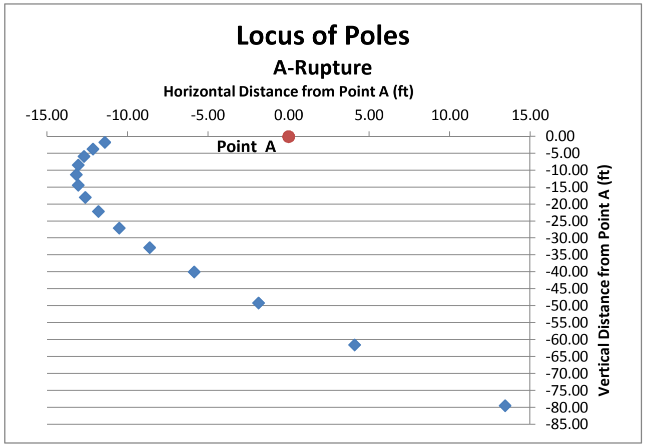
put R in terms of r, then sovle for r.
Solve for R using Log Spiral equation.

Failure surface within cell fill (A-rupture).

Internal friction angle of cell granular soil, ϕ: 31 degrees

Calculation:

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

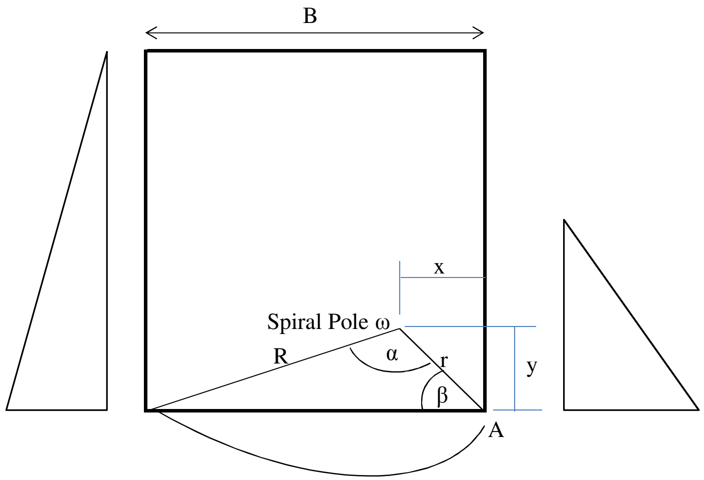


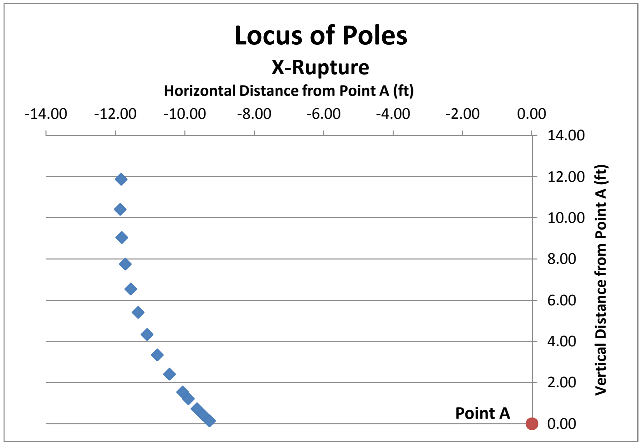
Failure surface within foundation soil (X-rupture).

Internal friction angle of foundation soil, ϕ: 33 degrees

Calculation:

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





Project:	CPRA Mid-Barataria Sediment Diversion	Computed:	RLJ	Date:	07/06/14
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Overturning

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

Overturning Moments

Water	h =	64.0	ft
	Y' =	62.4	pcf
	Ka =	1	
	Resultant =	127.80	kips
	moment arm =	21.3	ft (from Point A)
		Input:	
Soil	h =	73	ft
	Y' =	64.293151	pcf
	Ka =	0.347	
	Resultant =	59.44	kips
	moment arm =	31.8	ft (from Point A)

Resisting Moments

Water	h =	30.0	ft
	Y' =	62.4	pcf
	Ka =	1	
	Resultant =	28.08	kips
	moment arm =	10.0	ft (from Point A)
		Input:	
Soil	h =	30	ft
	Y' =	56.6	pcf
	Kp =	2.88	
	Resultant =	73.41	kips
	moment arm =	10.0	ft (from Point A)

Drained Cell Fill	Area 1 =	720	sq. ft.	(rectangular area)				
	Area 2 =	1360	sq. ft.	(triangular area)				
	Y' =	119	pcf					
Resultants:	Area 1 =	85.68	kips	Area 2 =	161.84	kips		
moment arms:	Area 1 =	40	ft	Area 2 =	26.7	ft		ft (from Point A)
Saturated Cell Fill	Area 3 =	1360	sq. ft.	(triangular area)				
	Area 4 =	2400	sq. ft.	(rectangular area)				
	Y'_3 =	56.6	pcf	Y'_4 =	56.6	pcf		
Resultants:	Area 3 =	76.98	kips	Area 4 =	135.84	kips		
moment arms:	Area 3 =	53.3	ft	Area 4 =	40	ft		ft (from Point A)

A-Rupture Failure Mode
(Within cell fill)

Moments about Poles - pole is below the cell therefore add pole y-coord. to moment arm from point A to get total arm, subtract x-coord.

G = Aγ   A = [(R^2 - r^2)/4*tan φ] - B*y/2
Y' = 57.6 pcf   ϕ = 31 degrees

Overturning Moments

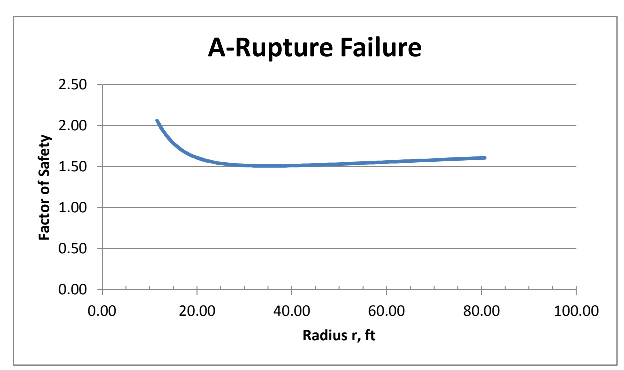
		Water			Soil			
Pole	Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment kip-ft
1	1.72	23.1	127.80	2945.9	33.47	59.44	1989.60	4935.50
2	3.69	25.0	127.80	3197.514	35.44	59.44	2106.63	5304.14
3	5.92	27.2	127.80	3482.394	37.67	59.44	2239.13	5721.53
4	8.42	29.8	127.80	3802.948	40.18	59.44	2388.23	6191.18
5	11.24	32.6	127.80	4163.184	43.00	59.44	2555.78	6718.96
6	14.42	35.8	127.80	4569.318	46.18	59.44	2744.68	7314.00
7	18.03	39.4	127.80	5030.681	49.79	59.44	2959.27	7989.95
8	22.18	43.5	127.80	5561.138	53.94	59.44	3205.99	8767.13
9	27.04	48.4	127.80	6181.461	58.79	59.44	3494.52	9675.98
10	32.84	54.2	127.80	6923.481	64.60	59.44	3839.64	10763.13
11	40.00	61.3	127.80	7837.831	71.75	59.44	4264.92	12102.75
12	49.17	70.5	127.80	9009.439	80.92	59.44	4809.86	13819.30
13	61.55	82.9	127.80	10591.67	93.30	59.44	5545.78	16137.45
14	79.54	100.9	127.80	12891.68	111.30	59.44	6615.56	19507.24

Resisting Moments

		Water			Soil				Drained Cell Fill: Area 1			Drained Cell Fill: Area 2			Saturated Cell Fill: Area 3			Saturated Cell Fill: Area 4			G (subtracted from Area 4)				
Pole	Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Pole x-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment kip-ft	Factor of Safety
1	1.72	11.7	28.08	329.0525	11.72	73.41	860.20	11.41	28.59	85.68	2449.62	15.26	161.84	2469.19	41.92	76.976	3227.12	28.59	135.84	3883.71	28.59	105.67	3021.15	10197.74	2.07
2	3.69	13.7	28.08	384.3387	13.69	73.41	1004.73	12.14	27.86	85.68	2386.69	14.52	161.84	2350.32	41.19	76.976	3170.58	27.86	135.84	3783.94	27.86	98.32	2738.72	10341.87	1.95
3	5.92	15.9	28.08	446.9344	15.92	73.41	1168.37	12.70	27.30	85.68	2338.90	13.96	161.84	2260.06	40.63	76.976	3127.64	27.30	135.84	3708.17	27.30	91.04	2485.30	10564.77	1.85
4	8.42	18.4	28.08	517.3687	18.42	73.41	1352.49	13.06	26.94	85.68	2308.27	13.61	161.84	2202.21	40.27	76.976	3100.13	26.94	135.84	3659.62	26.94	83.89	2260.14	10879.96	1.76
5	11.24	21.2	28.08	596.5221	21.24	73.41	1559.41	13.19	26.81	85.68	2297.14	13.48	161.84	2181.18	40.14	76.976	3090.13	26.81	135.84	3641.97	26.81	76.90	2061.76	11304.61	1.68
6	14.42	24.4	28.08	685.7606	24.42	73.41	1792.70	13.06	26.94	85.68	2308.45	13.61	161.84	2202.53	40.28	76.976	3100.28	26.94	135.84	3659.89	26.94	70.08	1888.25	11861.36	1.62
7	18.03	28.0	28.08	787.1343	28.03	73.41	2057.71	12.62	27.38	85.68	2346.14	14.05	161.84	2273.74	40.72	76.976	3134.15	27.38	135.84	3719.66	27.38	63.45	1737.52	12581.01	1.57
8	22.18	32.2	28.08	903.6898	32.18	73.41	2362.40	11.80	28.20	85.68	2415.84	14.86	161.84	2405.38	41.53	76.976	3196.76	28.20	135.84	3830.15	28.20	57.01	1607.42	13506.80	1.54
9	27.04	37.0	28.08	1039.991	37.04	73.41	2718.72	10.52	29.48	85.68	2525.77	16.15	161.84	2613.03	42.81	76.976	3295.53	29.48	135.84	4004.44	29.48	50.74	1495.91	14701.56	1.52
10	32.84	42.8	28.08	1203.033	42.84	73.41	3144.94	8.62	31.38	85.68	2688.53	18.05	161.84	2920.46	44.71	76.976	3441.75	31.38	135.84	4262.48	31.38	44.65	1401.10	16260.10	1.51
11	40.00	50.0	28.08	1403.94	50.00	73.41	3670.15	5.87	34.13	85.68	2924.20	20.80	161.84	3365.63	47.46	76.976	3653.49	34.13	135.84	4636.13	34.13	38.71	1321.29	18332.26	1.51
12	49.17	59.2	28.08	1661.373	59.17	73.41	4343.12	1.87	38.13	85.68	3266.65	24.79	161.84	4012.46	51.46	76.976	3961.14	38.13	135.84	5179.05	38.13	32.92	1254.99	21168.81	1.53
13	61.55	71.5	28.08	2009.03	71.55	73.41	5251.96	-4.09	44.09	85.68	3777.23	30.75	161.84	4976.89	57.42	76.976	4419.85	44.09	135.84	5988.54	44.09	27.24	1200.95	25222.56	1.56
14	79.54	89.5	28.08	2514.405	89.54	73.41	6573.10	-13.45	53.45	85.68	4579.26	40.11	161.84	6491.84	66.78	76.976	5140.41	53.45	135.84	7260.11	53.45	21.67	1158.11	31401.01	1.61

Factor of Safety for failure within cell fill:

Min. Factor of Safety = 1.51



X-Rupture Failure Mode on next page

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Overturning (continued)

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

X-Rupture Failure Mode

(Below cell in foundation soil)

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

$G = A\gamma$ $A = [(R^2 - r^2)/4*\tan\varphi] - B*y/2$

ϒ' = 60.1 pcf   ϕ = 33 degrees

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.

Overturning Moments

		Water			Soil			
Pole	Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment kip-ft
1	0.14	21.2	127.80	2707.972	31.61	59.44	1878.94	4586.91
2	0.44	20.9	127.80	2670.367	31.32	59.44	1861.45	4531.81
3	0.74	20.6	127.80	2631.487	31.01	59.44	1843.36	4474.85
4	1.22	20.1	127.80	2570.762	30.54	59.44	1815.12	4385.88
5	1.55	19.8	127.80	2528.666	30.21	59.44	1795.54	4324.20
6	2.41	18.9	127.80	2417.729	29.34	59.44	1743.94	4161.67
7	3.35	18.0	127.80	2298.531	28.41	59.44	1688.50	3987.03
8	4.35	17.0	127.80	2170.88	27.41	59.44	1629.13	3800.01
9	5.41	15.9	127.80	2034.526	26.34	59.44	1565.70	3600.23
10	6.55	14.8	127.80	1889.144	25.20	59.44	1498.08	3387.23
11	7.76	13.6	127.80	1734.32	23.99	59.44	1426.07	3160.39
12	9.05	12.3	127.80	1569.535	22.70	59.44	1349.43	2918.96
13	10.42	10.9	127.80	1394.145	21.33	59.44	1267.85	2662.00
14	11.89	9.4	127.80	1207.353	19.87	59.44	1180.97	2388.32

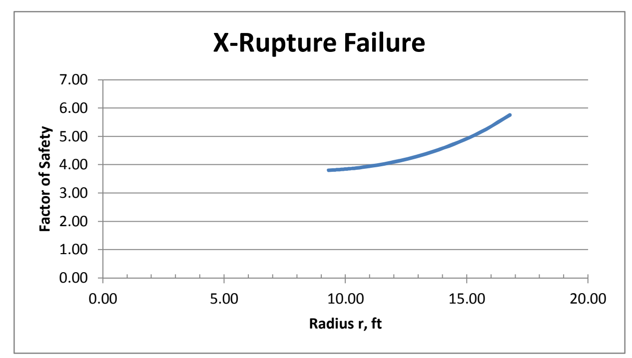
Resisting Moments

	Water			Soil				Drained Cell Fill: Area 1			Drained Cell Fill: Area 2		
Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Pole x-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft
0.14	9.9	28.08	276.77	9.86	73.41	723.53	9.30	30.70	85.68	2630.75	17.37	161.84	2811.32
0.44	9.6	28.08	268.51	9.56	73.41	701.93	9.48	30.52	85.68	2615.32	17.19	161.84	2782.17
0.74	9.3	28.08	259.97	9.26	73.41	679.60	9.65	30.35	85.68	2600.29	17.02	161.84	2753.80
1.22	8.8	28.08	246.62	8.78	73.41	644.72	9.90	30.10	85.68	2578.56	16.76	161.84	2712.75
1.55	8.5	28.08	237.38	8.45	73.41	620.54	10.07	29.93	85.68	2564.64	16.60	161.84	2686.45
2.41	7.6	28.08	213.00	7.59	73.41	556.82	10.45	29.55	85.68	2531.94	16.22	161.84	2624.69
3.35	6.7	28.08	186.81	6.65	73.41	488.35	10.79	29.21	85.68	2502.48	15.87	161.84	2569.05
4.35	5.7	28.08	158.76	5.65	73.41	415.03	11.10	28.90	85.68	2476.56	15.57	161.84	2520.07
5.41	4.6	28.08	128.80	4.59	73.41	336.70	11.35	28.65	85.68	2454.45	15.31	161.84	2478.32
6.55	3.4	28.08	96.86	3.45	73.41	253.20	11.56	28.44	85.68	2436.47	15.10	161.84	2444.35
7.76	2.2	28.08	62.84	2.24	73.41	164.26	11.72	28.28	85.68	2422.93	14.95	161.84	2418.78
9.05	0.9	28.08	26.63	0.95	73.41	69.61	11.82	28.18	85.68	2414.19	14.84	161.84	2402.27
10.42	-0.4	28.08	-11.91	-0.42	73.41	-31.13	11.86	28.14	85.68	2410.62	14.80	161.84	2395.53
11.89	-1.9	28.08	-52.95	-1.89	73.41	-138.43	11.84	28.16	85.68	2412.66	14.83	161.84	2399.38

	Saturated Cell Fill: Area 3			Saturated Cell Fill: Area 4			G (added to Area 4)				
Pole y-coord.	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment Arm	Resultant kips	Moment kip-ft	Total Moment kip-ft	Factor of Safety
0.14	44.04	76.976	3389.84	30.70	135.84	4170.87	30.70	113.32	3479.34	17482.43	3.81
0.44	43.86	76.976	3375.98	30.52	135.84	4146.41	30.52	111.94	3416.99	17307.31	3.82
0.74	43.68	76.976	3362.48	30.35	135.84	4122.59	30.35	110.56	3355.46	17134.19	3.83
1.22	43.43	76.976	3342.96	30.10	135.84	4088.14	30.10	108.48	3264.79	16878.55	3.85
1.55	43.27	76.976	3330.45	29.93	135.84	4066.07	29.93	107.09	3205.45	16710.98	3.86
2.41	42.88	76.976	3301.07	29.55	135.84	4014.23	29.55	103.59	3061.17	16302.91	3.92
3.35	42.54	76.976	3274.61	29.21	135.84	3967.52	29.21	100.07	2922.89	15911.72	3.99
4.35	42.24	76.976	3251.32	28.90	135.84	3926.42	28.90	96.55	2790.82	15538.97	4.09
5.41	41.98	76.976	3231.46	28.65	135.84	3891.37	28.65	93.03	2665.07	15186.16	4.22
6.55	41.77	76.976	3215.30	28.44	135.84	3862.86	28.44	89.52	2545.68	14854.71	4.39
7.76	41.61	76.976	3203.14	28.28	135.84	3841.40	28.28	86.02	2432.64	14545.99	4.60
9.05	41.51	76.976	3195.28	28.18	135.84	3827.54	28.18	82.55	2325.87	14261.38	4.89
10.42	41.47	76.976	3192.08	28.14	135.84	3821.88	28.14	79.09	2225.27	14002.34	5.26
11.89	41.49	76.976	3193.91	28.16	135.84	3825.11	28.16	75.67	2130.69	13770.38	5.77

Factor of Safety for failure below cell fill:

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, $\beta = 45 + \varphi/2$ degrees

$\beta =$ 59.5 degrees

Minimum width of berm:

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

= 0.0 feet

No Stability Berm is Required

Bearing Capacity at Toe (Terzaghi)

$$\text{Factor of Safety} = \frac{c*N_c + 0.5*\gamma'*B*N_\gamma}{(6*M/B^2) + \gamma*H}$$ (From "Pile Buck Steel Sheet Piling Design Manual", 1987)

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

Factor of Safety = 8.85

Sliding

From the Pressure Diagrams page and the Overturning page:

Driving Forces:

P_w = 127.80 kips

P_a = 59.44 kips

Resisting Forces:

P_w = 28.08 kips

P_p = 73.41 kips

Cell Fill:

Area 1	P_1 =	85.68	kips
Area 2	P_2 =	161.84	kips
Area 3	P_3 =	76.98	kips
Area 4	P_4 =	135.84	kips

P_C = $P_1 + P_2 + P_3 + P_4$ = 460.34 kips

Friction angle of soil against soil at cell toe, $\delta = \phi'$:	33	degrees
Effective cohesion along faliure 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 kips

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

Factor of Safety = 2.14

Interlock Tension

Cell diameter, D = 91.4 ft

Cell Fill Material Properties:

γ = 119 pcf

φ = 29 degrees

γ' = 56.6 pcf

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

$$\sigma_T = K_a * \Upsilon * (H - H_1) + K_a * \Upsilon' * (H_1 - H/4) + \Upsilon_W * (H_3 - H/4)$$

H = length of sheet pile	=	73	ft
H_1 = height of water on the outboard sheeting	=	64	ft
H_3 = height of water on the inboard sheeting	=	30	ft

Assume K_a = 0.4 (minimum value suggeted by Terzaghi)

$\sigma_T =$ 2197.38 pounds/sq. ft.

Maximum Interlock tension = σ_T * cell radius = 100.45 kips/ft

8.37 kips/in.

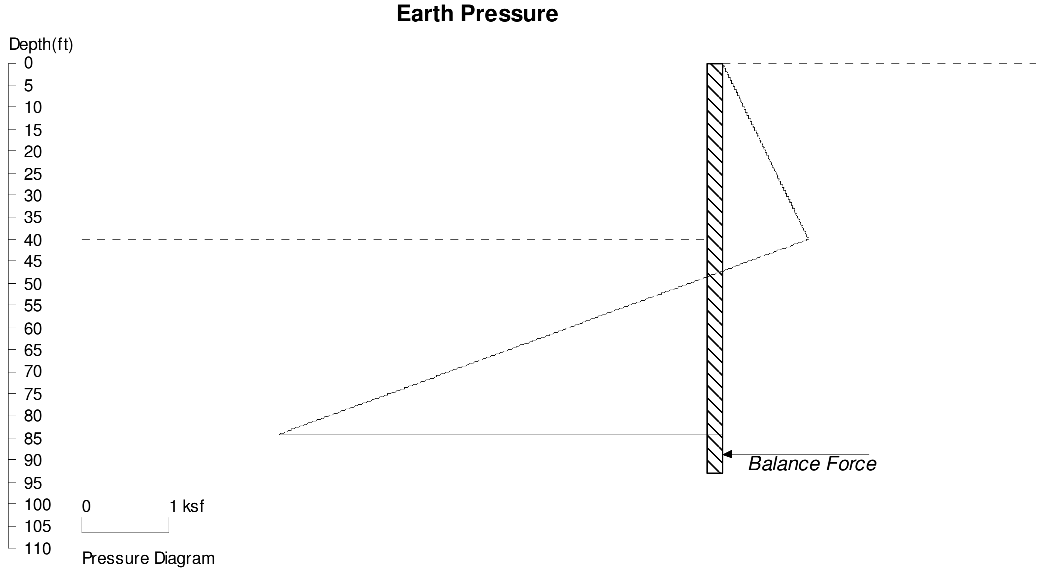
Sheet pile: AS 500 12.7

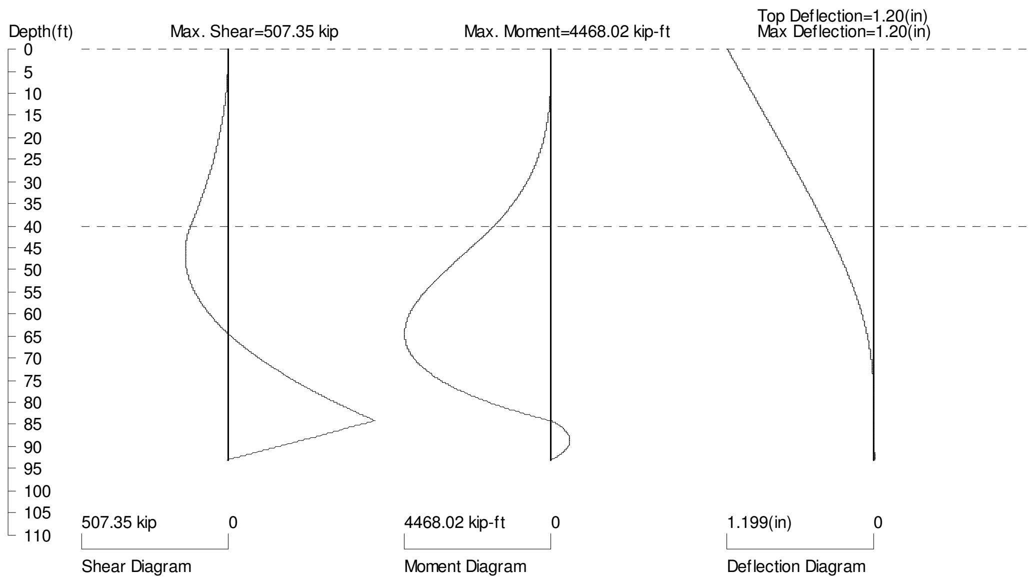
Max. Interlock Strength = 31.4 kips/in. (Skyline Steel technical data sheet)

Approximate Factor of Safety = 3.75

Attachment D. Design Calculations for Pipe Pile Retaining Structures (Shoring Suite Software)

MBSD Inlet Walls - Pipe Pile Alternative





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

: 6/20/2014 File Name: G:\Projects\099 - 209444 - Mid Barataria Sedimentation Diversion\06.00 Proj_Engr\Inlet Wall Analysis\PP 6 ft_Cantilever\PP_6ft_Cantilever.sl

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*****************************************************************
                 EARTH PRESSURE ANALYSIS SUMMARY
                          <EarthPres>
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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:

Line	Z1	Xp1	Z2	Xp2	Soil No.
1	40.0	0.0	40.0	150.0	1
2	40.0	150.0	0.0	80000.0	1

Water Table at Passive Side:

Point	Z-water	X-water
1	0.0	0.0
2	0.0	80000.0

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

No	Z1	P1	Z2	P2	Slope
0	0.0	0.00	40.0	0.99	0.0248

Driving Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope
0	40.0	0.99	200.0	4.95	0.0248

Passive Pressure below Base - Output to Shoring

No	Z1	P1	Z2	P2	Slope
0	40.0	0.00	200.0	25.98	0.1624

****
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

****

ShoringSuite 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
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
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

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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_6ft_Cantilever.sh8

Title: MBSD Inlet Walls - Pipe Pile Alternative
Subtitle: Earth Pressure

*********************************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:

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

No.	Z2 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	0.00	0.00	40.00	0.99	0.0248
2	40.00	0.99	200.00	4.95	0.0248

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	40.01	0.00	200.00	25.99	0.1624

* ACTIVE SPACE *

No.	Z depth	Spacing
1	0.00	6.60
2	40.00	6.00

* PASSIVE SPACE *

No.	Z depth	Spacing
1	40.00	6.60

*For Tieback: Input1 = Diameter; Input2 = Bond Stength
*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, fist 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, fist 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

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 EASTIMENTION **********************
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:

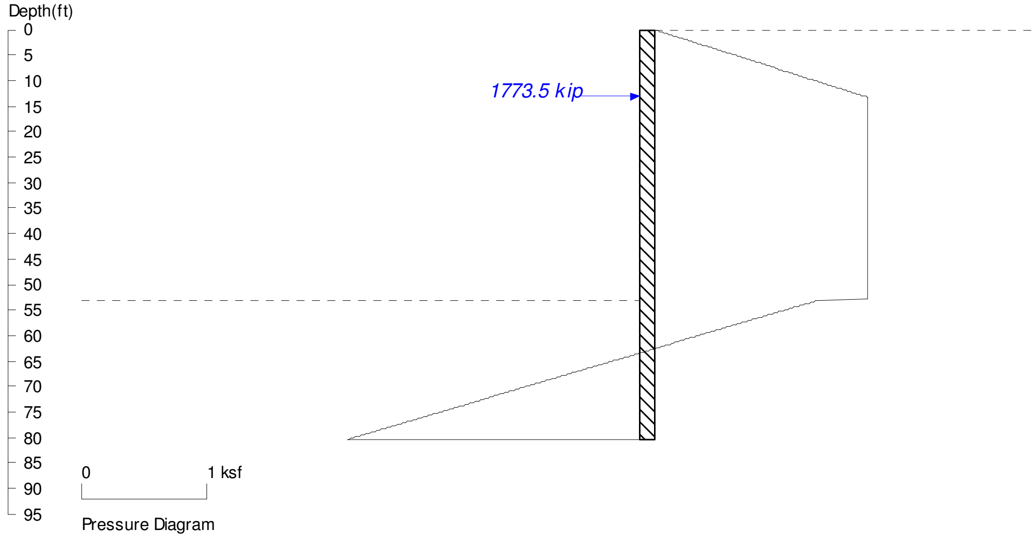
User Input Pile:
Elastic Module, E (ksi)= 29000.00
Moment of Inertia, I (in4)/foot= 140579

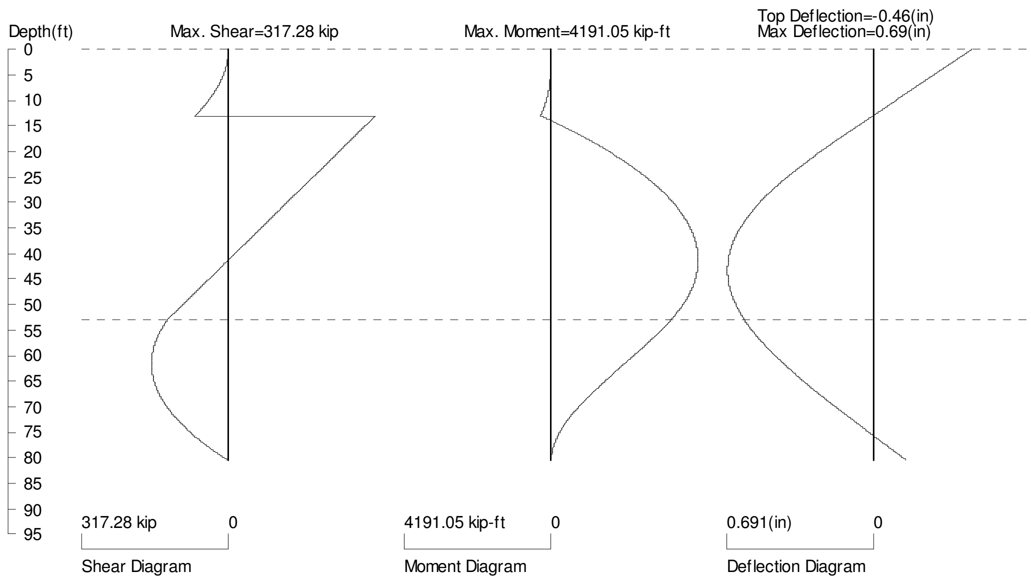
PRESS. - Sum of all pressures on wall. Driving (Active) direction is positive
LOAD - Liner load (force per unit depth) = Pressures multiply by acting space

No	DEPTH ft	PRESS. ksf	LOAD kip/ft	SHEAR kip	MOMENT kip-ft	DEFLECTION in
1	0.00	0.00	0.00	0.00	0.00	1.199
2	0.12	0.00	0.02	0.00	0.00	1.196
3	0.23	0.01	0.04	0.00	0.00	1.194
4	0.35	0.01	0.06	0.01	0.00	1.192
5	0.47	0.01	0.08	0.02	0.00	1.189
6	0.58	0.01	0.10	0.03	0.01	1.187
7	0.70	0.02	0.11	0.04	0.01	1.185
8	0.82	0.02	0.13	0.05	0.01	1.182
9	0.93	0.02	0.15	0.07	0.02	1.180
10	1.05	0.03	0.17	0.09	0.03	1.177
11	1.17	0.03	0.19	0.11	0.04	1.175

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)/pile=140579.0

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

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Diversion\06.00 Proj_Engr\Inlet Wall Analysis\PP 6 ft_Braced\PP 6ft_Braced.ep8

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
Apparent Pressure Envelope: 4. Trapezoid Envelope (Braced, Soft-Med. Clay)
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, Hmax = 265.00
        Analysis Segment, dz = 1.32
        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 = 53.00
        Active Depth at Hmax, Z = 265.00
        Passive Depth at Hmax, Zp = 265.00
        Max. Pressure = 34.44

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:

Line	Z1	Xp1	Z2	Xp2	Soil No.
1	53.0	0.0	53.0	150.0	1
2	53.0	150.0	0.0	80000.0	1

Water Table at Passive Side:

Point	Z-water	X-water
1	0.0	0.0
2	0.0	80000.0

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

****
ShoringSuite 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
5. DESIGN OF SHEET PILE WALLS, EM 1110-2-2504, U.S. Army Corps of Engineers, 31 March 1994
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

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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) *

No.	Z2 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	0.00	0.00	13.25	1.71	0.1287
2	13.25	1.71	53.00	1.71	0.0000
3	53.00	1.31	265.00	6.56	0.0248

* PASSIVE PRESSURE *

No.	Z1 top	Top Pres.	Z2 bottom	Bottom Pres.	Slope
1	53.03	0.00	265.00	34.44	0.1625

```
* ACTIVE SPACE *
 No.    Z depth          Spacing
----------------------------------------------------------------------------
 1      0.00             6.60
 2      53.00            6.00
----------------------------------------------------------------------------

* PASSIVE SPACE *
 No.    Z depth          Spacing
----------------------------------------------------------------------------
 1      53.00            6.60
----------------------------------------------------------------------------

* BRACE: STRUT, TIEBACK, ANCHOR PLATE, OR DEADMAN *
 No.    Z brace          Angle            Spacing          Input1*          Input2*          Type
----------------------------------------------------------------------------------------------------
------------
 1      13.00            0.0              30.00            4.00             0.35             Strut
----------------------------------------------------------------------------------------------------
------------
*For Tieback:  Input1 = Diameter;  Input2 = Bond Stength
*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*****************************************
```

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

* MOMENT IN PILE (per pile spacing)*
 No.    Depth           M @ Brace       Mmax in Span    Depth of Mmax
-----------------------------------------------------------------------------
 1      13.00           303.84          4191.05         41.31
-----------------------------------------------------------------------------
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.

 No.    DEPTH           Tangle          SPACING         HORIZONTAL      VERTICAL     TOTAL
LOAD
---------------------------------------------------------------------------------------------
-
 1      13.00           0.0             30.00           1773.52         0.00
1773.52

 No.    DEPTH           Free length     Type and Data
---------------------------------------------------------------------------------------------
-
 1      13.00           0.00            Strut
---------------------------------------------------------------------------------------------
-

* 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 EASTIMENTION ***********************
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
     Pile Spacing =6.6, Max. Moment in lagging = 4.64
     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
     Pile Spacing =6.6, Max. Moment in lagging = 2.79
     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

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