ALLIANT ENERGY
Wisconsin Power and Light Company
Columbia Energy Center

CCR SURFACE IMPOUNDMENT

SAFETY FACTOR ASSESSMENT

Report Issued: September 19, 2016
Revision 0

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EXECUTIVE SUMMARY

This Safety Factor Assessment (Report) is prepared in accordance with the requirements of the United States Environmental Protection Agency (USEPA) published Final Rule for Hazardous and Solid Waste Management System – Disposal of Coal Combustion Residual (CCR) from Electric Utilities (40 CFR Parts 257 and 261, also known as the CCR Rule) published on April 17, 2015 and effective October 19, 2015.

This Report assesses the safety factors of each CCR unit at Columbia Energy Center in Pardeeville, Wisconsin in accordance with §257.73(b) and §257.73(e) of the CCR Rule. For purposes of this Report, "CCR unit" refers to existing CCR surface impoundments.

Primarily, this Report is focused on assessing if each CCR surface impoundment achieves the minimum safety factors, which include:

- Static factor of safety under long-term, maximum storage pool loading condition,
- Static factor of safety under the maximum surcharge pool loading condition,
- Seismic factor of safety; and,
- Post-Liquefaction factor of safety for embankments constructed of soils that have susceptibility to liquefaction.

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1 Introduction

The owner or operator of the Coal Combustion Residual (CCR) unit must conduct an initial and periodic safety factor assessments to determine if each CCR surface impoundment achieves the minimum safety factors, which include:

- Static factor of safety under long-term, maximum storage pool loading condition,
- Static factor of safety under the maximum surcharge pool loading condition,
- Seismic factor of safety; and,
- Post-Liquefaction factor of safety for embankments constructed of soils that have susceptibility to liquefaction.

This Report has been prepared in accordance with the requirements of §257.73(b) and §257.73(e) of the CCR Rule.

1.1 CCR Rule Applicability

The CCR Rule requires a periodic safety factor assessment by a qualified professional engineer (PE) for existing CCR surface impoundments with a height of 5 feet or more and a storage volume of 20 acre-feet or more; or the existing CCR surface impoundment has a height of 20 feet or more.

1.2 Safety Factor Assessment Applicability

The Columbia Energy Center (COL) in Pardeeville, Wisconsin (Figure 1) has one existing and one inactive CCR surface impoundments, identified as follows:

- COL Primary Ash Pond (existing)
- COL Secondary Ash Pond (inactive)

2 FACILITY DESCRIPTION

COL is located southeast of the City of Portage on the eastern shore of the Wisconsin River in Columbia County at W8375 Murray Road, Pardeeville, Wisconsin (Figure 1). Wisconsin River backwaters are located north of the generating station, while Lake Columbia, south of the generating plant, is a 480-acre non-contact cooling water pond.

COL is a fossil-fueled electric generating station that initiated operations in 1975. COL consists of two steam electric generating units. Sub-bituminous coal is the primary fuel for producing steam. The burning of coal produces a by-product of CCR. The CCR at COL includes bottom ash, fly ash, and spray dryer absorber waste from scrubbers. The fly ash can also be subdivided into two types, economizer fly ash and precipitator fly ash.

General Facility Information:

Date of Initial Facility Operations:	1975	
WPDES Permit Number:	WI-0002780-08-0	
Latitude / Longitude:	43° 29′ 9.73″ N	89° 25′ 8.40″ W
Unit Nameplate Ratings:	Unit 1 (1975): 512 MW	
	Unit 2 (1978): 511 MW	

2.1 COL Primary Ash Pond

The COL Primary Ash Pond is located north of the generating plant and west of the COL Secondary Pond. The COL Primary Ash Pond is the primary receiver of process flows from the generating plant. Process flows include CCR sluice water (bottom ash and economizer fly ash), boiler/precipitator wash water, plant floor drains, ash line freeze protection flows, bottom ash area sump water, demineralizer area sump water, and air heater sump water. Additionally, the COL Primary Ash Pond receives storm water runoff from the surrounding area, inclusive of the closed ash landfill, located south of the CCR surface impoundments.

The western half of the COL Primary Ash Pond is a CCR handling area. A shallow narrow drainage channel is located along the south, west, and north sides of the CCR handling area. The sluiced CCR is discharged into the southeast corner of the western half of the COL Primary Ash Pond. The sluiced CCR settles out through the water column as it follows the flow of the narrow channel around the southern, western, and northern sides of the existing CCR surface impoundment. The water in the channel flows to the east and discharges through a narrow cut-out of an interior dike into the northwest corner of the large open area in the eastern half of the COL Primary Ash Pond.

The majority of the CCR that is discharged into the COL Primary Ash Pond is removed during routine maintenance dredging activities of the shallow narrow channel. The CCR that is dredged is stockpiled in the western half of the COL Primary Ash Pond for dewatering. Once dewatered the CCR is run through a sieve shaker machine to separate the coarsely graded CCR from the finely graded CCR. The CCR is then transported off-site for beneficial reuse or to the on-site active dry ash landfill.

The water in the COL Primary Ash Pond is recirculated to the generating plant via effluent pumps located in the ash recirculating pump house in the northeast corner of the eastern half of the COL Primary Ash Pond. The recirculating pumps return water to the generating plant for reuse and/or treatment and disposal per the facility's Wisconsin Pollution Discharge Elimination System (WPDES) permit. Instrumentation associated with the pump house in the northeast corner of the COL Primary Ash Pond includes a submersible hydrostatic level transducer, as well as a visual staff gauge, for monitoring water elevations in the COL Primary Ash Pond. An 18-inch diameter corrugated metal pipe is located immediately south of the pump house, in the interior dike between the COL Primary Ash Pond and COL Secondary Pond. The pipe drains to the Secondary Ash Pond and is no longer used. The influent end of the hydraulic structure, on the COL Primary Ash Pond side, consists of a manually operated gate valve which is closed.

The surface area of the COL Primary Ash Pond is approximately 14.7 acres and has an embankment height of approximately 23 feet from the crest to the toe of the downstream slope. The interior storage depth of the COL Primary Ash Pond is approximately 15 feet. The total volume of impounded CCR and water within the COL Primary Ash Pond is approximately 330,000 cubic yards.

2.2 COL Secondary Ash Pond

The COL Secondary Pond is located north of the generating plant and east of the COL Primary Ash Pond. The COL Secondary Ash Pond was previously a downstream receiver of influent flows from the COL Primary Ash Pond. The water within the COL Secondary Pond, prior to 2004, was pumped to a surface impoundment identified as the polishing pond. The polishing pond was located east of the generating plant. The water pumped to the polishing pond would flow to the south through the facility's WPDES Outfall 002 into "Mint Ditch" and eventually flow into the backwaters of the Wisconsin River. Presently, the COL Secondary Pond acts as a storm water detention impoundment with the only influent sources being precipitation and storm water runoff from the surrounding area. The water within the COL Secondary Pond either infiltrates or evaporates. The water elevation within the COL Secondary Pond is normally the same as the ground water elevation under the CCR Ponds approximately 10 feet lower than the COL Primary Ash Pond.

The surface area of the COL Secondary Ash Pond is approximately 9.6 acres and has an embankment height of approximately 23 feet from the crest to the toe of the downstream slope. The interior storage depth of the COL Secondary Ash Pond is approximately 12 feet. The total volume of impounded CCR and water within the COL Secondary Ash Pond is approximately 185,000 cubic yards.

3 SAFETY FACTOR ASSESSMENT- §257.73(e)

This Report documents if each CCR surface impoundment achieves the minimum safety factors, which are identified on the table below.

Safety Factor Assessment	Minimum Safety Factor
Static Safety Factor Under Maximum Storage Pool Loading	1.50
Static Safety Factor Under Maximum Surcharge Pool Loading	1.40
Seismic Safety Factor	1.00
Liquefaction Safety Factor	1.20

3.1 Safety Factor Assessment Methods

The safety factor assessment is completed with the two dimensional limit-equilibrium slope stability analyses program STABL5M (1996)[1]. The program analyzes many potential failure circles or block slides by random generation of failure surfaces using the toe and crest search boundaries set for each analysis. The solution occurs by balancing the resisting forces along the failure plane due to the Mohr-Columb failure strength parameters of friction angle and cohesion. The gravity driving forces are divided by the resisting forces to produce a safety factor for the slope. The minimum of hundreds of searches is presented as the applicable safety factor.

There are both total stress and effective stress friction angle and cohesion values for soil. In the case of cohesionless soil (gravel, sand and silt) the friction angle value is the same for total stress and effective stress analysis and there is no cohesion. At the COL Primary Ash Pond and COL Secondary Ash Pond only cohesionless soil is present in and under the embankments.

[1] STABL User Manual by Ronald A. Siegal, Purdue University, June 4, 1975 and STABL5 – The Spencer Method of Slices: Final Report by J. R. Carpenter, Purdue University, August 28, 1985

3.1.1 Soil Conditions in and under the impoundments

The COL Primary Ash Pond and COL Secondary Ash Pond are subdivided from a larger outer embankment constructed of compacted fine sand. The soil below the foundation of the embankment is loose fine sand from backwaters of the Wisconsin River underlain by very dense fine sand deposited by glaciation. Borings taken in 1971 indicated that rock is located at approximately 90 feet below the top of the embankments, Appendix A.

In addition to the 1971 borings, borings were taken in the embankment in June of 2011 and indicate the embankment soil is dense fine sand (SP). Recent 2015 borings taken in the embankment between the COL Primary Ash Pond and COL Secondary Ash Pond for the installation of monitoring wells also indicates the embankments are dense sand, Appendix A.

The boring logs from 1971 indicate that the foundation soil is the same as the embankment soil. However, the boring logs indicate that the upper part of the foundation sand is loose and transitions to very dense with depth. The results of the borings taken in 2015 indicate the embankment sand is dense to very dense.

The density observations from the soil borings were used to assign soil properties to the embankment and foundation soils using NAVFACS DM-7[2], Appendix B. The internal friction angles selected based on the Standard Split Spoon (SPT) results reported on the borings are:

Soil Type	Internal Friction Angle °	Total Unit Weight (lb/ft3)
Embankment Sand	35	120
Foundation Sand	30	110

The very dense sand found below the loose sand was not included in the modeled soil

[2] Naval Facilities Engineering Command Design Manual DM-7, Figure 3-7 "Density versus Angle of Internal Friction for Cohesionless Soils", March 1971

profile, since its exact depth in the foundation of the embankments is unknown. Ignoring the very dense sand will produce a conservative slope safety factor.

3.1.2 Design water surface in impoundments maximum normal pool and maximum pool under design inflow storm

The COL Primary Ash Pond receives process water from the facility at the rate of approximately 1.5 MGD. The water is recycled back to the facility whenever the water elevation in the impoundment reaches 795 feet. The COL Primary Ash Pond is therefore assigned a normal pool elevation of 795 feet. The COL Primary Ash Pond does not have an outlet structure and would overflow across the interior embankment into the COL Secondary Ash Pond at elevation 802 feet, Figure 2. During the design 100 year return period the impoundment water would rise to elevation 799 feet by accumulating all of the runoff from the COL Primary Ash Pond watershed, Inflow Flood Control Plan §257.82.

The COL Secondary Ash Pond is no longer used for COL process water handling and operates as a zero liquid discharge pond accumulating only the rainfall from its watershed. The normal impoundment water elevation is equivalent to the ground water elevation at 785 feet and the accumulated design storm water elevation is 787 feet, Inflow Flood Control Plan §257.82. Accumulated storm water will exfiltrate from the impoundment due to the permeable nature of the impoundment foundation soil SCS Engineers[3]

3.1.3 Selection of Seismic Design Parameters and Description of Method

The design earthquake ground acceleration is selected from the United States Geologic Survey (USGS) detailed seismic design maps based on the latitude and longitude of the COL. The peak ground acceleration (PGA) value is selected for a 2% probability of exceedance in 50 years (2500 year return period) as required by §257.53. Since the site soils with the exception of a thin loose sand foundation layer are dense to very dense

[3] SCS Engineers, "Columbia Energy Center – Monitoring Well Documentation Report", February 9, 2016.

sand and extend to bedrock at 90 feet, the site class as defined in the 2009 International Building Code 1613.5.5 is Site Class D. For Site Class D the ground surface PGA for slope stability and liquefaction assessment is 0.055 g, Appendix C.

3.1.4 Liquefaction Assessment Method and Parameters

Certain soils may have zero effective stress (liquefaction) during an earthquake of from static shear of a saturated embankment slope. Soils that will liquefy include loose or very loose uniform fine sand or silt, and low plasticity clay (plastic index of less than 12). The liquefaction resistance of a soil is based on its strength and effective confining stress. The strength of the saturated embankment and foundation sand is measured by the SPT results shown on the borings in Appendix A.

The test results for Boring MW-304 on the interior embankment and 112 at the toe of the COL Primary Ash Pond embankment, Figure 2, are indicative of the soil resistance to liquefaction.

The simplified assessment of liquefaction procedure as first proposed by Seed and most recently updated and published by Idriss and Boulanger[4] is used to assess the potential for liquefaction of the river silt. The procedure uses the strengths determined by the SPT test adjusted to normalize for overburden pressure and for fines content to determine the cyclic resistance ratio for the soil at earthquake magnitude 7.5 and at 1 atmosphere pressure. The cyclic resistance ratio is then adjusted for the actual earthquake magnitude of the design event which is 7.7 for a New Madrid Fault source earthquake[5]. The cyclic stress ratio caused by the design surface PGA is then used to determine the actual cyclic stress ratio at 65% of maximum strain at depth in the soil profile. The cyclic resistance ratio is divided by the cyclic stress ratio to determine the factor of safety for liquefaction.

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[4] Idriss I. M. and R. W. Boulanger, "Soil Liquefaction During Earthquakes", EERI MNO-12, 2008.
[5] Elnashi et al, "Impact of Earthquakes on the Central USA", FEMA Report 8-02, Mid-American Earthquake Center, 2002

The results for the soil profile typical of the COL Primary Ash Pond and COL Secondary Ash Pond is shown in Appendix C. The results indicate that the loose foundation sand will not liquefy during the site design earthquake.

3.2 COL Primary Ash Pond

The COL Primary Ash Pond is incised on the east and south sides of the impoundment. On the north and west sides the impoundment is created by construction of on-site fine sand embankments constructed with an outer slope of 4 horizontal to 1 vertical. The northern end of the embankment has the greatest height with the toe located in the floodplain of the Wisconsin River at elevation 782 feet and is selected as the critical cross-section, Figure2. The crest elevation of the embankment is 804 feet.

3.2.1 Static Safety Factor Assessment Under Maximum Storage Pool Loading - §257.73(e)(1)(i)

The critical cross-section is analyzed with the maximum storage pool under normal operations at elevation 795 feet. The phreatic surface in the embankment is calculated to exist at the toe of the embankment based on Huang[6] and using a permeability of 10^{-2} $^{cm}/_{sec}$. Analysis for both a circular and block sliding surface, Appendix D, show a minimum factor of safety of 1.9 for the circular slide surface.

3.2.2 Static Safety Factor Assessment Under Maximum Surcharge Pool Loading - §257.73(e)(1)(ii)

The COL Primary Ash Pond storm water elevation at the end of the design 100 year storm is elevation 799 feet. The increase in water elevation is considered without exfiltration loss through the permeable impoundment bottom and assumes the plant recovers all process water discharged to the impoundment. Analysis for both a circular and block slide surface, Appendix D, show a minimum factor of safety of 1.8 for a circular slide surface.

[6] Huang Yuag H., Stability Analysis of Earth Slopes, Van Nostrand Rienhold, 1983

3.2.3 Seismic Safety Factor Assessment - §257.73(e)(1)(iii)

The COL Primary Ash Pond was assigned a pseudo-static earthquake coefficient equal to 0.055 g and a vertical downward component equal to $^{2}/_{3}$ of the horizontal component (0.04 g) as recommended by Newmark[7]. Analysis for both circular and block slide surfaces, Appendix D, show a minimum factor of safety of 1.5 for a circular slide surface.

3.2.4 Liquefaction Safety Factor Assessment - §257.73(e)(1)(iv)

The embankment and foundation soils of the COL Primary Ash Pond will not liquefy during the design earthquake. No post-liquefaction slope stability assessment is required.

3.3 COL Secondary Ash Pond

The COL Secondary Ash Pond is incised on the east and south sides of the impoundment. The north side the impoundment is created by construction of on-site fine sand embankments constructed with an outer slope of 4 horizontal to 1 vertical. The west side is an interior embankment that separates the COL Secondary Ash Pond from the COL Primary Ash Pond. The northern end of the embankment has the greatest height with the toe located in the floodplain of the Wisconsin River at elevation 783 feet and is selected as the critical cross-section, Figure 2. The crest elevation of the embankment is 804 feet.

3.3.1 Static Safety Factor Assessment Under Maximum Storage Pool Loading - §257.73(e)(1)(i)

The critical cross-section is analyzed with the maximum storage pool under normal operations at elevation 785 feet. The phreatic surface in the embankment is assumed to be at the toe of the outer slope only two foot below the water elevation in the impoundment. Analysis for both a circular and block sliding surface, Appendix D, show a minimum factor of safety of 2.2 for the circular slide surface.

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[7] Newmark, N. M. and W. J. Hall, "Earthquake Spectra and Design", EERI Monograph, Earthquake Engineering Research Institute, Berkeley, California, 1982

3.3.2 Static Safety Factor Assessment Under Maximum Surcharge Pool Loading - §257.73(e)(1)(ii)

The COL Secondary Ash Pond storm water elevation at the end of the design 100 year storm is elevation 787 feet. The increase in water elevation is considered without exfiltration loss through the permeable impoundment bottom. Analysis for both a circular and block slide surface, Appendix D, show a minimum factor of safety of 2.2 for a circular slide surface.

3.3.3 Seismic Safety Factor Assessment - §257.73(e)(1)(iii)

The COL Secondary Ash Pond was assigned a pseudo-static earthquake coefficient equal to 0.055 g and a vertical downward component equal to $^2/_3$ of the horizontal component (0.04 g) as recommended by Newmark[8]. Analysis for both circular and block slide surfaces, Appendix D, show a minimum factor of safety of 1.7 for a circular slide surface.

3.3.4 Liquefaction Safety Factor Assessment - §257.73(e)(1)(iv)

The embankment and foundation soils of the COL Secondmary Ash Pond will not liquefy during the design earthquake. No post-liquefaction slope stability assessment is required.

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[8] Newmark, N. M. and W. J. Hall, "Earthquake Spectra and Design", EERI Monograph, Earthquake Engineering Research Institute, Berkeley, California, 1982

4 Results Summary

The results of the safety factor assessment indicate that the embankment of the COL Primary Ash Pond and COL Secondary Ash Pond meets the requirements of §257.73(e). The results are summarized as:

	Static Stability Normal Water Elevation	Static Stability Flood Water Elevation	Pseudo Static Earthquake with Normal Water Elevation	Liquefaction Potential	Post Earthquake Static Stability Normal Water Elevation
Required Safety Factor	1.5	1.4	1.0		1.2
COL Primary Ash Pond	1.9	1.8	1.5	no	Not Applicable
COL Secondary Ash Pond	2.2	2.2	1.7	no	Not Applicable

5 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

To meet the requirements of 40 CFR 257.73(e)(2), I Mark W. Loerop hereby certify that I am a licensed professional engineer in the State of Wisconsin; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in 40 CFR 257.73(b) and 40 CFR 257.73(e).

WISCONSIN
MARK W.
LOEROP
E-43783-6
NAPERVILLE
IL
PROFESSIONAL ENGINEER

By: [signature]

Name: Mark Loerop

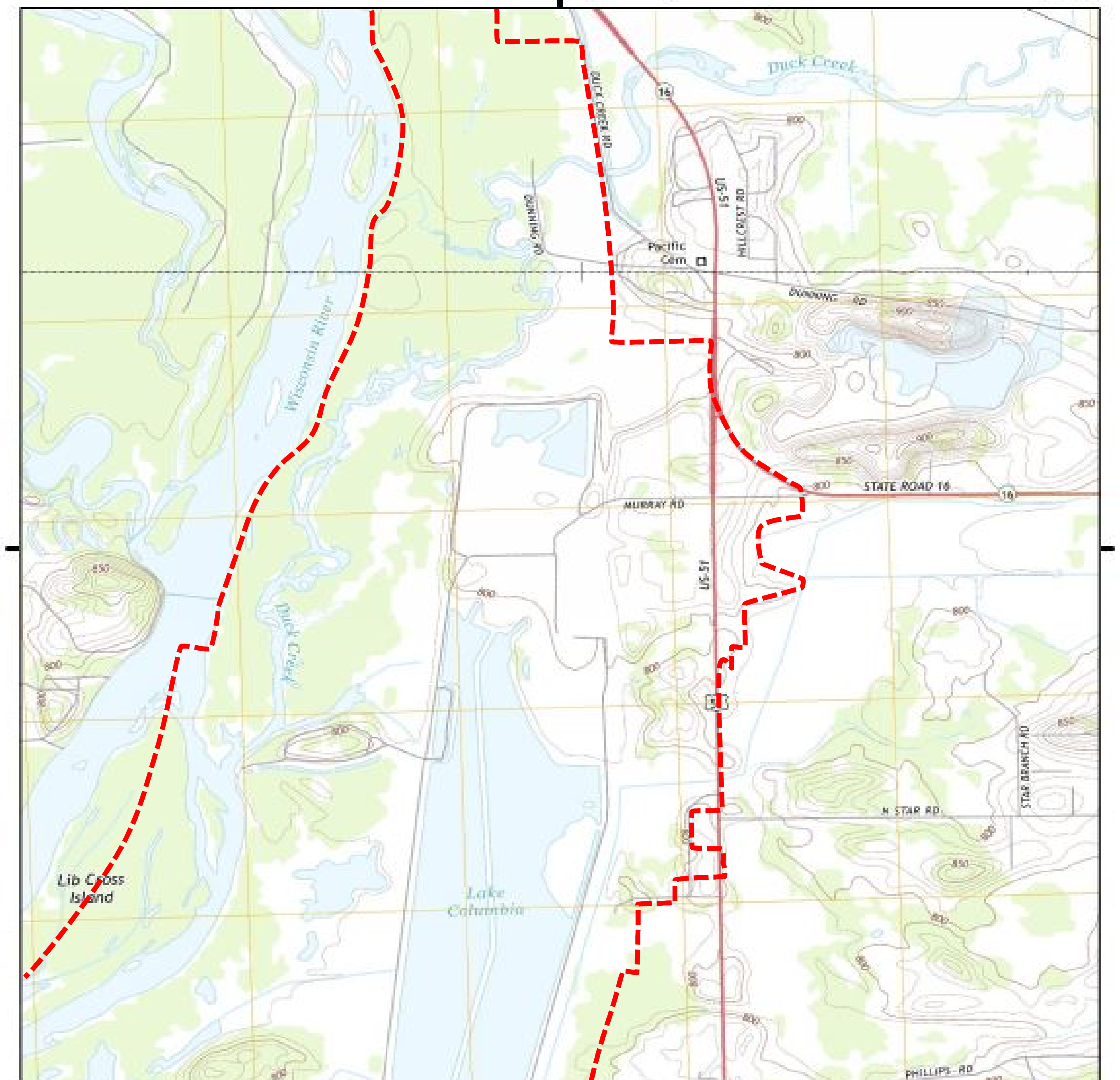
Date: Sep. 19, 2016

FIGURES

Alliant Energy
Wisconsin Power and Light Company
Columbia Energy Center
Pardeeville, Wisconsin

Safety Factor Assessment

Historical Topo Map 2013



Miles 0.25 0.5 1 1.5

This report includes information from the following map sheet(s).

NW N NE
W E
SW S SE

TP, Poynette, 2013, 7.5-minute

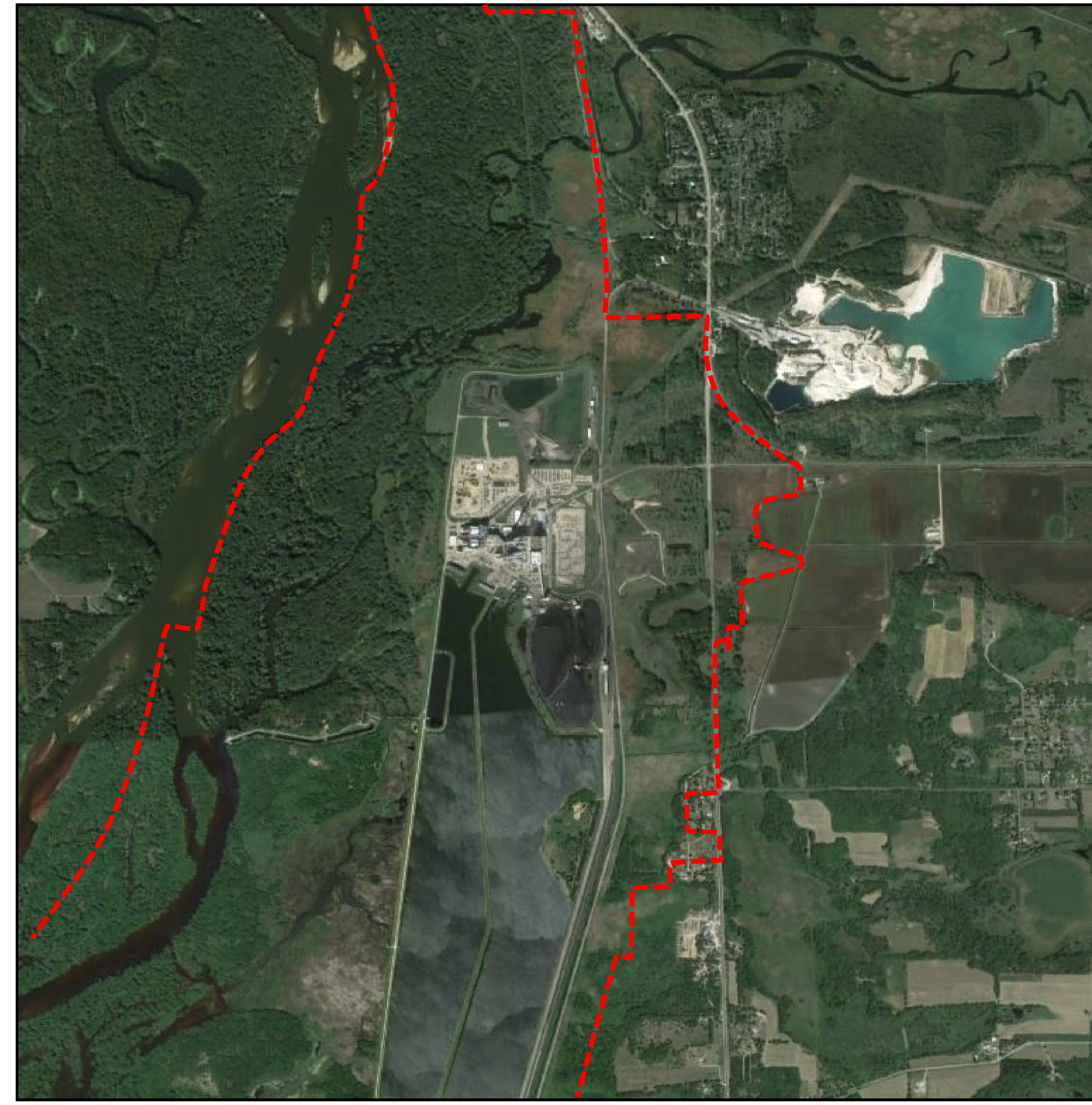
N, Portage, 2013, 7.5-minute

SITE NAME: Columbia Energy Center
ADDRESS: W8375 Murray Road
Pardeeville, WI 53954
CLIENT: Environmental Site Assessors

N

4555570 - 7 page 4

Historical Aerial Photo 6/12/2014



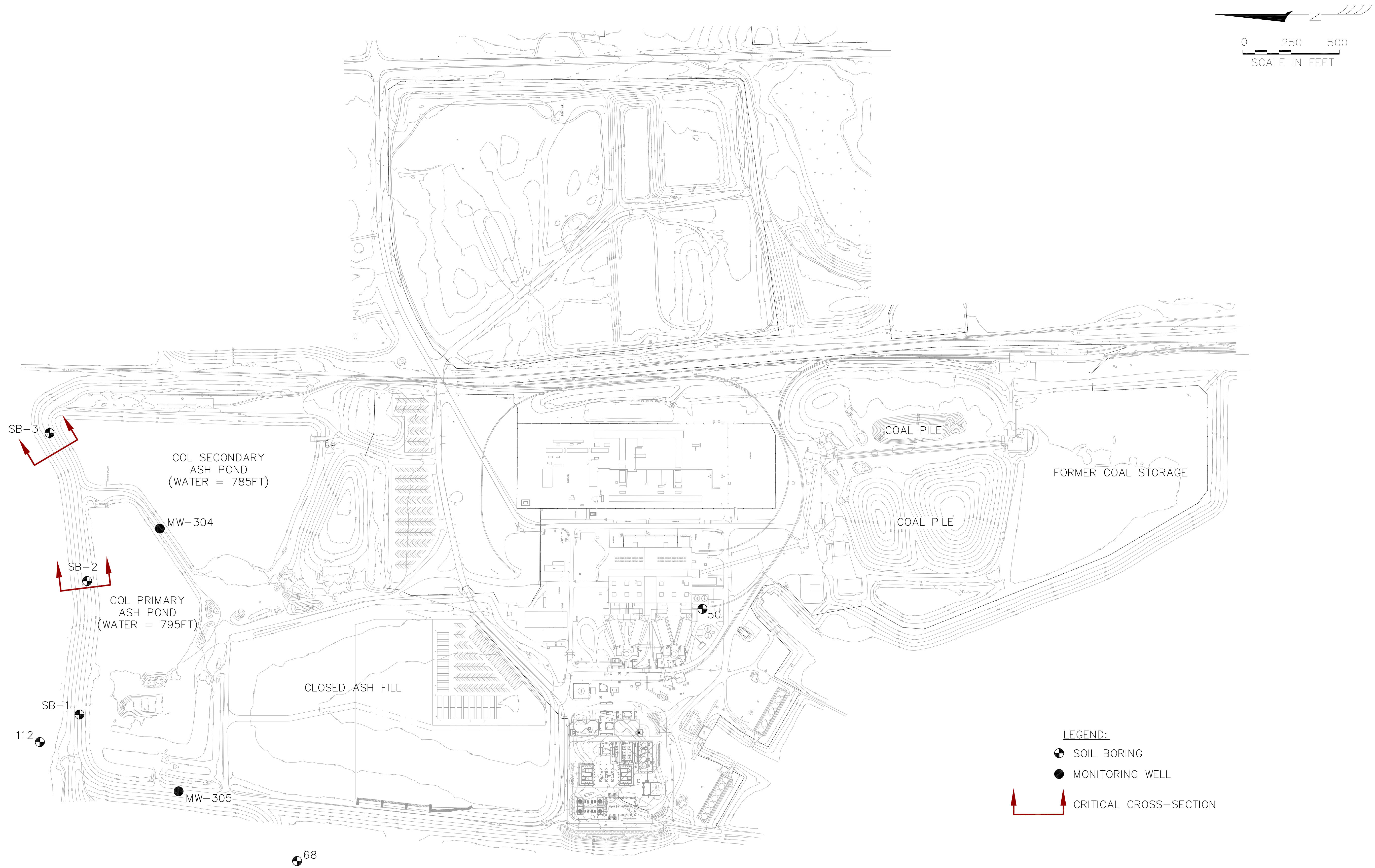
Approximate Property Boundary

HARD HAT SERVICES ™
Engineering, Construction and Management Solutions

Site Location
Columbia Energy Center
Wisconsin Power and Light Company

Drawing
Figure 1

Date
7/12/2016



REV	DATE	BY	DESCRIPTION
5			
4			
3			
2			
1			

hard hat™ SERVICES

SCALE:	AS SHOWN
DATE:	8-22-16
DRAWN BY:	JFD
CHKD BY:	TJH
APRVD BY:	MWL

CLIENT / LOCATION
WISCONSIN POWER AND LIGHT (WPL) COMPANY
COLUMBIA ENERGY CENTER
PARDEEVILLE, WISCONSIN

DRAWING DESCRIPTION
SAFETY FACTOR ASSESSMENT REPORT
SITE PLAN

JOB 154.010.025
SHT. FIGURE 2
DWG. 154.010.025-SFA

APPENDIX A – Soil Borings

Alliant Energy
Wisconsin Power and Light Company
Columbia Energy Center
Pardeeville, Wisconsin

Safety Factor Assessment

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name: WPL-Columbia SCS#: 25215135.00		License/Permit/Monitoring Number		Boring Number: MW-304	
Boring Drilled By: Name of crew chief (first, last) and Firm: Kevin Durst, Badger State Drilling		Date Drilling Started: 11/12/2015	Date Drilling Completed: 11/12/2015	Drilling Method: hollow stem auger	
WI Unique Well No.: VY703	DNR Well ID No.	Common Well Name	Final Static Water Level: Feet	Surface Elevation: 802.50 Feet	Borehole Diameter: 8.5 in.
Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒ State Plane 544671 N, 2122897 E /C/N 1/4 of 1/4 of Section 27, T 12 N, R 9 E		Lat ° ' " Long ° ' "	Local Grid Location ☐ N ☐ S Feet; ☐ E ☐ W Feet		
Facility ID	County: Columbia	County Code: 11	Civil Town/City/ or Village: Portage		

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Pocket Penetration (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				TOPSOIL.	TOPSOIL									
			1	SILTY SAND, mostly fine, brown/tan (10YR 5/6).										
S1	24	7 8 10 12	2							M				
			3											
S2	24	14 22 26 31	4–5	Same as above except, trace gravel, brown tan to grey (top to bottom) 10YR 5/4.						M				
S3	24	16 18 22 24	6–7	Same as above except, brown/tan/grey assorted coloring.						M				
			8		SM									
S4	24	11 15 15 14	9–10	Same as above except, black/grey/brown, saturated area about 2" thick.						M				
S5	24	23 31 30 29	11–12	Same as above except, 10YR 5/3.						M				
			13											
S6	20	9 10 7 5	14–15	trace gravel.						M				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature] for Zach Watson

Firm: SCS Engineers, 2830 Dairy Drive Madison, WI 53711 Tel: (608) 224-2830 Fax:

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION SUPPLEMENT
Form 4400-122A

Boring Number MW-304 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Pocket Penetration (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			16	SILTY SAND, mostly fine, brown/tan (10YR 5/6).										
S7	4		17							W				dropped spoon
			18	Same as above except, 10YR 6/3.										
			19		SM									
S8			20							W				
			21											
			22											
			23	End of boring at 23 ft bgs.										

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION

Form 4400-122 Rev. 7-98

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
WPL-Columbia SCS#: 25215135.00		MW-305

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Kevin Durst Badger State Drilling	11/13/2015	11/13/2015	hollow stem auger

WI Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
VY716			Feet	803.95 Feet	8.5 in.

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 544776.1 N, 2121537 E S/C/N
1/4 of 1/4 of Section 27, T 12 N, R 9 E
Lat ° ' "
Long ° ' "
Local Grid Location Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	County Code	Civil Town/City/ or Village
	Columbia	11	Portage

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Pocket Penetration (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–1	TOPSOIL	TOPSOIL									
			1	SILTY SAND, mostly fine, brown/tan 10YR 5/8.	SM									
S1	18	5 8 9 7	2							M				
S2	18	2 3 3 4	4–5							M				
			6	Same as above except, trace gravel, tan 10YR 6/8 at bottom.										
S3	18	2 8 9 8	7							M				
			9	Same as above except, light tan 10YR 6/6, trace gravel, some large gravel chunks.										
S4	20	5 7 6 5	9–10							M				
			11	POORLY GRADED SAND, tan (10YR 6/8), trace gravel, some saturated areas.	SP									
S5	20	9 12 17 22	12							M				
			13.5	SILTY SAND, trace gravel, tan (10YR 5/6).	SM									
S6	24	16 19 22 34	15							W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature] for Zach Watson	SCS Engineers 2830 Dairy Drive Madison, WI 53711	Tel: (608) 224-2830 Fax:

This form is authorized by Chapters 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats. Completion of this form is mandatory. Failure to file this form may result in forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on this form is not intended to be be used for any other purpose. NOTE: See instructions for more information, including where the completed form should be sent.

SOIL BORING LOG INFORMATION SUPPLEMENT

Form 4400-122A

Boring Number MW-305 Use only as an attachment to Form 4400-122.

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Pocket Penetration (tsf)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
S7		31 30 41 50/2	16–18	SILTY SAND, trace gravel, tan (10YR 5/6), some large dolomite chunks.	SM					W				
			18	End of boring at 18 ft bgs.										

Boring Log Legend

Sample
No: (Number) Soil samples are numbered consecutively from the ground surface. Core samples are numbered consecutively from the first core run.

Type: A= Auger Cuttings CR= Core Run MS= Modified Spoon PB= Pitcher Barrel
PT= Piston Tube ST= Shelby Tube SS= Split Spoon (2" O.D.) WC= Wash Cuttings

Interval: The depth of sampling interval in feet below ground surface

Blow Count
The number of blows required to drive a 2-inch O.D. split-spoon sampler with a 140 pound hammer falling 30-inches. When appropriate, the sampler is driven 18 inches and blow counts are reported for each 6-inch interval. The sum of blow counts for the last two 6-inch intervals is designated as the standard penetration resistance (N) expressed as blows per foot.

Recovery in Inches
The length of sample recovered by the sampling device.

U.S.C.S. Soil Type
The Unified Soil Classification System symbol for recovered soil samples determined by visual examination or laboratory tests. Refer to ASTM D2487-69 for a detailed description of procedure and symbols. Underlined symbols denote classifications based on laboratory tests (i.e. ML), all others are based on visual classification only.

Percent Moisture
Natural moisture content of sample expressed as percent of dry weight.

q_u TSF
Unconfined compressive strength in tons per square foot obtained by hand penetrometer. Laboratory compression test values are indicated by underlining.

Contact Depth
The contact depth between soil layers is interpreted from significant changes in recovered samples and observations during drilling. Actual changes between soil layers often occur gradually and the contact depths shown on the boring logs should be considered as approximate.

Soil Description and Remarks
Soil descriptions include consistency or density, color, predominant soil types and modifying constituents.

Cohesive Soils			Cohesionless Soils	
Consistency	q_u (TSF)	Blows/ft.	Density	Blows/ft.
Very Soft	less than 0.25	0-1	Very Loose	4 or less
Soft	0.25 to 0.50	2-4	Loose	5 to 10
Medium Stiff	0.50 to 1.00	5-8	Medium Dense	11 to 30
Stiff	1.00 to 2.00	9-15	Dense	30 to 50
Very Stiff	2.00 to 4.00	15-30	Very Dense	Over 50
Hard	more than 4.00	Over 30		

Particle Size Description		Definition of Terms	
Boulder =	Larger than 12 inches	Trace =	5 to 12 percent by weight
Cobble =	3 to 12 inches	Some =	12 to 30 percent by weight
Gravel =	0.187 to 3 inches	And =	Approximately equal fractions
Sand =	0.074 to 4.76 mm	( ) =	Driller's observation
Silt and Clay =	smaller than 0.074 mm		

Piezo.
(Piezometer) Screened interval of the piezometer installation is denoted by cross-hatching.

General Note
The boring log and related information depicted subsurface conditions only at the specified locations and date indicated. Soil conditions and water levels at other locations may differ from conditions occurring at these boring locations. Also the passage of time may result in a change in the conditions at these boring locations.

Soil Test Boring Refusal
Defined as any material causing a blow count greater that 50 blows/6 inches. Such material may include bedrock, "floating" rock slabs, boulders, dense gravel seams, hard pan clay, or cemented soils. Refusal is usually indicated in fractional notation showing number of blows as the numerator and inches of penetration as the denominator.

CABENO
Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

PROJECT: Alliant Columbia Station

BORING NO.: *SB1*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *06-01-11*
DATE FINISHED: *06-01-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)	CONSISTENCY vs. DEPTH	DEPTH IN FEET	PROFILE	DESCRIPTION
						0		SAND & GRAVEL; light brown to orange; fine to coarse grained; well graded; dry to moist. (Fill)
	SP1	4.7'/5'						SAND; light brown; fine grained; poorly graded; moist. (Fill)
						-5		
▽	SP2	5'/5'						@ 8.5' grades wet
						-10		
	SP3	4'/5'						@ 13' grades yellow to light tan
						-15		@ 15' grades fine to coarse, well graded
	SP4	5'/5'						@ 17' grades fine sand w/ well rounded gravels, trace silt/clay
						-20		Bottom of boring @ 19'
						-25		

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

PROJECT: Alliant Columbia Station

BORING NO.: *SB2*

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *06-01-11*
DATE FINISHED: *06-01-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)	CONSISTENCY vs. DEPTH	DEPTH IN FEET	PROFILE	DESCRIPTION
						0		SAND; light brown to orange; fine grained; poorly graded; dry to moist; trace gravels. (Fill)
	SP1	5'/5'						
						-5		@ 5' grades trace silt
	SP2	5'/5'						
						-10		@ 10' to 13', very hard & dense; seems overconsolidated; more recovery than push
	SP3	5'/3'						
						-15		Bottom of boring @ 13' Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 06-1-11.
						-20		

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Aether dbs

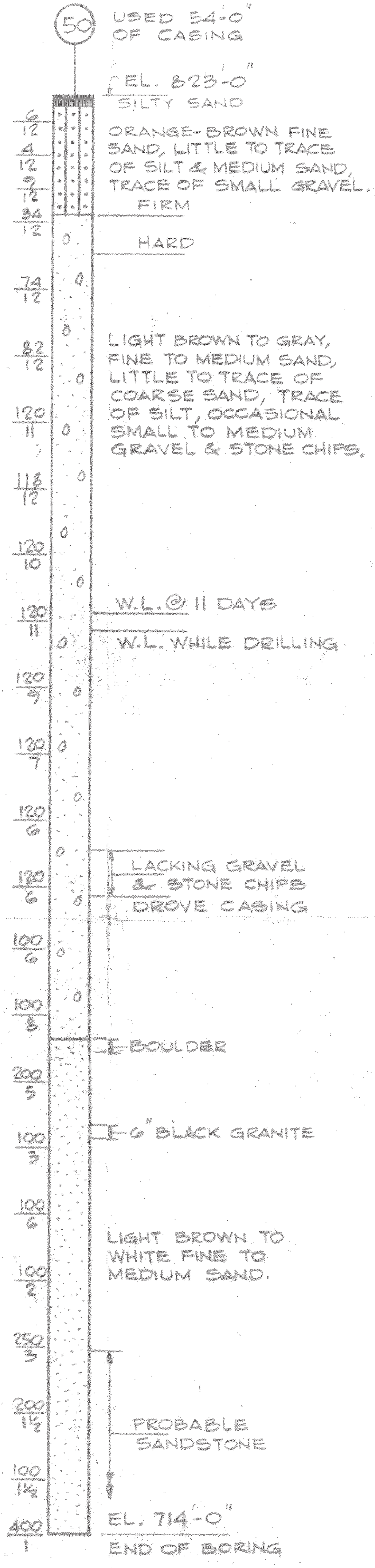
COORDINATES: *N NOT SURVEYED* / *E NOT SURVEYED*

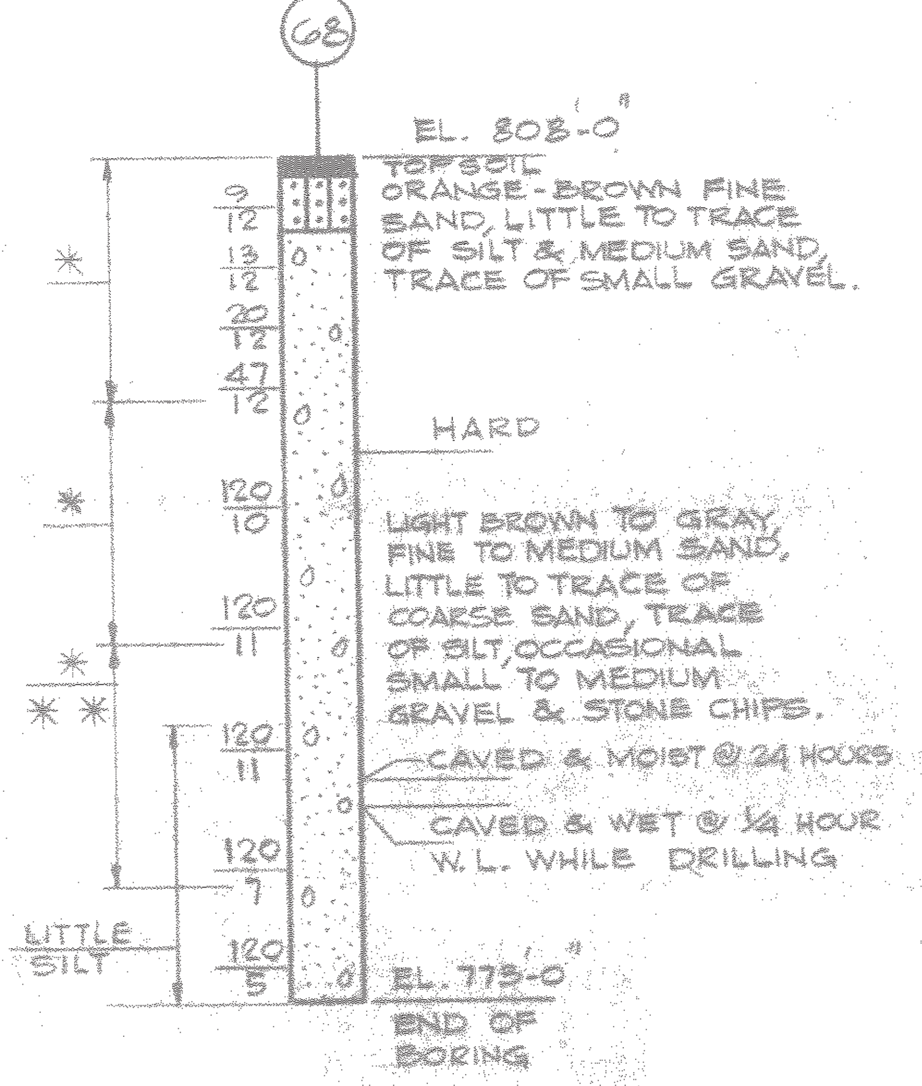
PROJECT: Alliant Columbia Station

BORING NO.: *SB3*

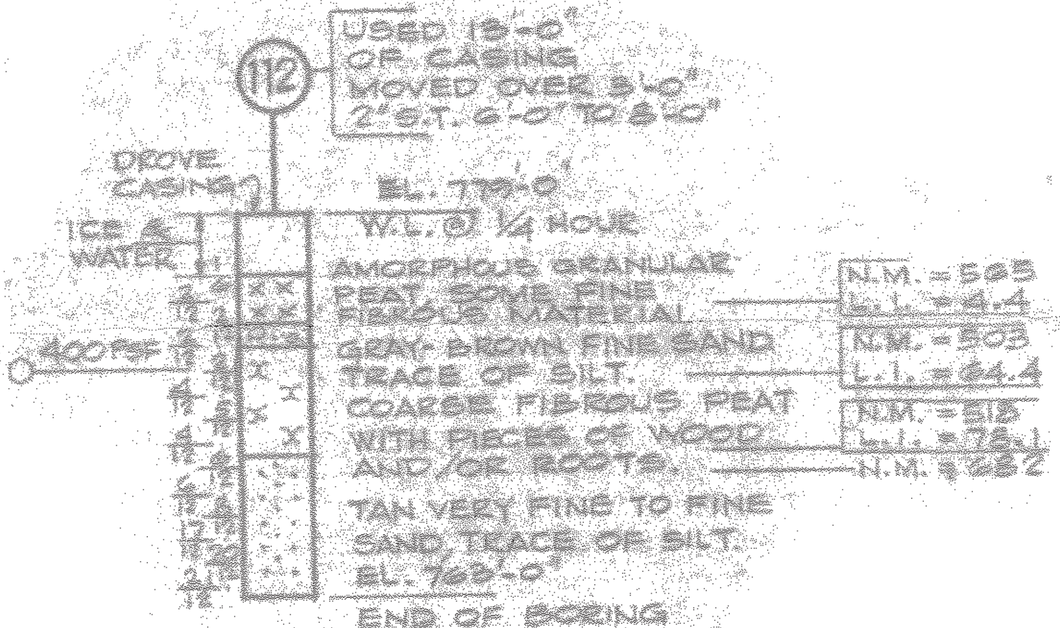
LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Chris Sullivan*
DATE BEGAN: *06-01-11*
DATE FINISHED: *06-01-11*
GROUND SURFACE ELEVATION:

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER (TONS/FT2)	CONSISTENCY vs. DEPTH	DEPTH IN FEET	PROFILE	DESCRIPTION
						0		SAND; light brown to orange; fine grained; poorly graded; dry to moist; trace gravels. (Fill)
	SP1	5'/5'						
						-5		
	SP2	5'/5'						
						-10		
	SP3	5'/5'						
						-15		
▽								@ 16' grades gray and wet.
	SP4	5'/5'						
						-20		
	SP5	5'/5'						
						-25		PEAT; brown; dry; non-plastic. (PT)
	SP6	1'/1'						Clayey SILT; gray; non-plastic; hard; moist. (ML)
								Bottom of boring @ 26' Boring advanced W/ Geoprobe Model 6610DT using 60-inch Macrocore sampling system. Boring backfilled to groundsurface w/ bentonite chips on 06-1-11.
						-30		


50
USED 54'-0" OF CASING
EL. 823'-0"
SILTY SAND
ORANGE-BROWN FINE SAND, LITTLE TO TRACE OF SILT & MEDIUM SAND, TRACE OF SMALL GRAVEL.
FIRM
HARD
LIGHT BROWN TO GRAY, FINE TO MEDIUM SAND, LITTLE TO TRACE OF COARSE SAND, TRACE OF SILT, OCCASIONAL SMALL TO MEDIUM GRAVEL & STONE CHIPS.
W.L. @ 11 DAYS
W.L. WHILE DRILLING
LACKING GRAVEL & STONE CHIPS
DROVE CASING
BOULDER
6" BLACK GRANITE
LIGHT BROWN TO WHITE FINE TO MEDIUM SAND.
PROBABLE SANDSTONE
EL. 714'-0"
END OF BORING
6/12
4/12
9/12
34/12
74/12
82/12
120/11
118/12
120/10
120/11
120/9
120/7
120/6
120/6
100/6
100/8
200/5
100/3
100/6
100/2
250/3
200/1½
100/1½
400/1



68
EL. 808'-0"
TOPSOIL
ORANGE-BROWN FINE SAND, LITTLE TO TRACE OF SILT & MEDIUM SAND, TRACE OF SMALL GRAVEL.
9/12
13/12
20/12
47/12
HARD
120/10
LIGHT BROWN TO GRAY, FINE TO MEDIUM SAND, LITTLE TO TRACE OF COARSE SAND, TRACE OF SILT, OCCASIONAL SMALL TO MEDIUM GRAVEL & STONE CHIPS.
120/11
120/11
CAVED & MOIST @ 24 HOURS
CAVED & WET @ 1/4 HOUR
W.L. WHILE DRILLING
120/7
LITTLE SILT
120/5
EL. 779'-0"
END OF BORING


112
USED 18'-0" OF CASING
MOVED OVER 3'-0"
2" S.T. 6'-0" TO 8'-0"
DROVE CASING
EL. 779-0
W.L. @ 1/4 HOUR
ICE & WATER
400 PSF
AMORPHOUS GRANULAR PEAT SOME FINE FIBROUS MATERIAL
GRAY-BROWN FINE SAND TRACE OF SILT.
COARSE FIBROUS PEAT WITH PIECES OF WOOD AND/OR ROOTS.
TAN VERY FINE TO FINE SAND TRACE OF SILT.
EL. 763-0
END OF BORING
N.M. = 565
L.I. = 4.4
N.M. = 503
L.I. = 64.4
N.M. = 512
L.I. = 78.1
N.M. = 28.2

APPENDIX B – Strength of Embankment Soil

Alliant Energy
Wisconsin Power and Light Company
Columbia Energy Center
Pardeeville, Wisconsin

Safety Factor Assessment

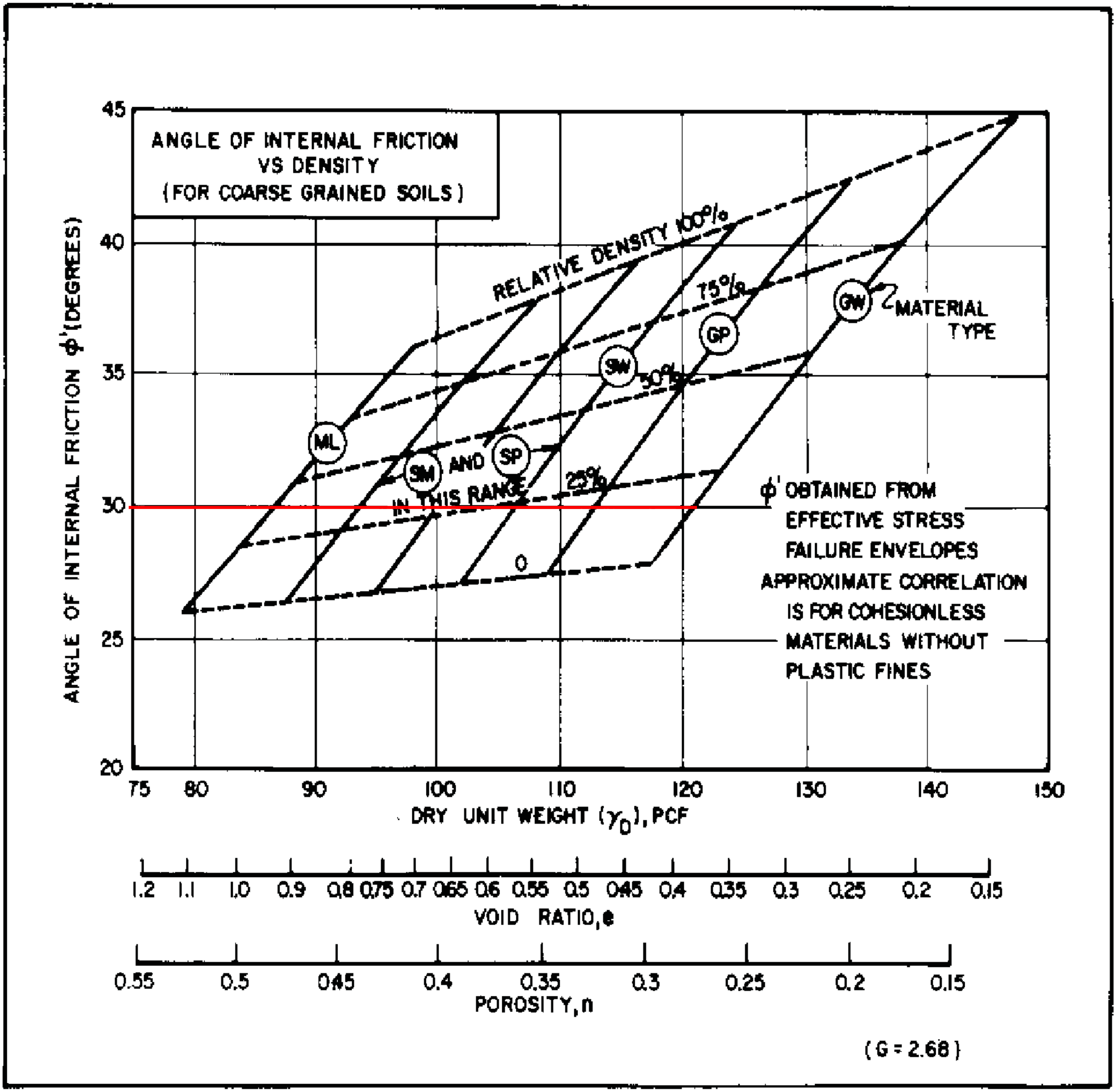


FIGURE 7
Correlations of Strength Characteristics for Granular Soils

APPENDIX C – Earthquake and Liquefaction Analysis

Alliant Energy
Wisconsin Power and Light Company
Columbia Energy Center
Pardeeville, Wisconsin

Safety Factor Assessment

USGS Design Maps Detailed Report

ASCE 7-10 Standard (43.489°N, 89.418°W)

Site Class D – "Stiff Soil", Risk Category I/II/III

Section 11.4.1 — Mapped Acceleration Parameters

Note: Ground motion values provided below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_S) and 1.3 (to obtain S_1). Maps in the 2010 ASCE-7 Standard are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

From Figure 22-1 [1]	S_S = 0.072 g
From Figure 22-2 [2]	S_1 = 0.041 g

Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class D, based on the site soil properties in accordance with Chapter 20.

Table 20.3–1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index *PI* > 20, • Moisture content *w* ≥ 40%, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 11.4.3 — Site Coefficients and Risk–Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Table 11.4–1: Site Coefficient F_a

Site Class	Mapped MCE $_R$ Spectral Response Acceleration Parameter at Short Period				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_S

For Site Class = D and S_S = 0.072 g, F_a = 1.600

Table 11.4–2: Site Coefficient F_v

Site Class	Mapped MCE $_R$ Spectral Response Acceleration Parameter at 1–s Period				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_1

For Site Class = D and S_1 = 0.041 g, F_v = 2.400

Equation (11.4–1): $S_{MS} = F_aS_S = 1.600 \times 0.072 = 0.116$ g

Equation (11.4–2): $S_{M1} = F_vS_1 = 2.400 \times 0.041 = 0.099$ g

Section 11.4.4 — Design Spectral Acceleration Parameters

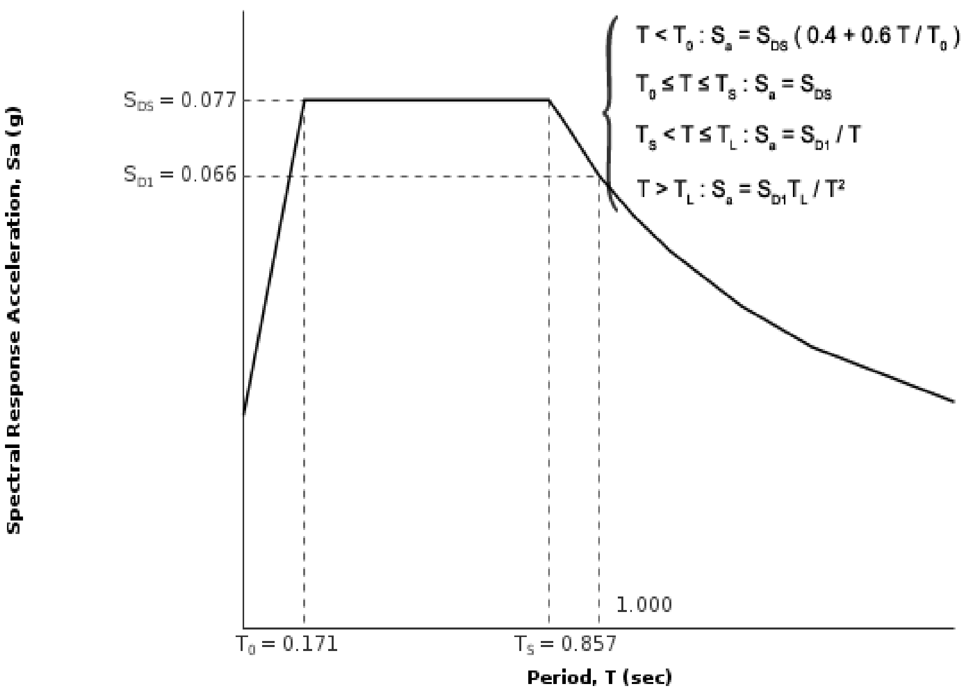
Equation (11.4–3): $S_{DS} = ⅔ S_{MS} = ⅔ \times 0.116 = 0.077$ g

Equation (11.4–4): $S_{D1} = ⅔ S_{M1} = ⅔ \times 0.099 = 0.066$ g

Section 11.4.5 — Design Response Spectrum

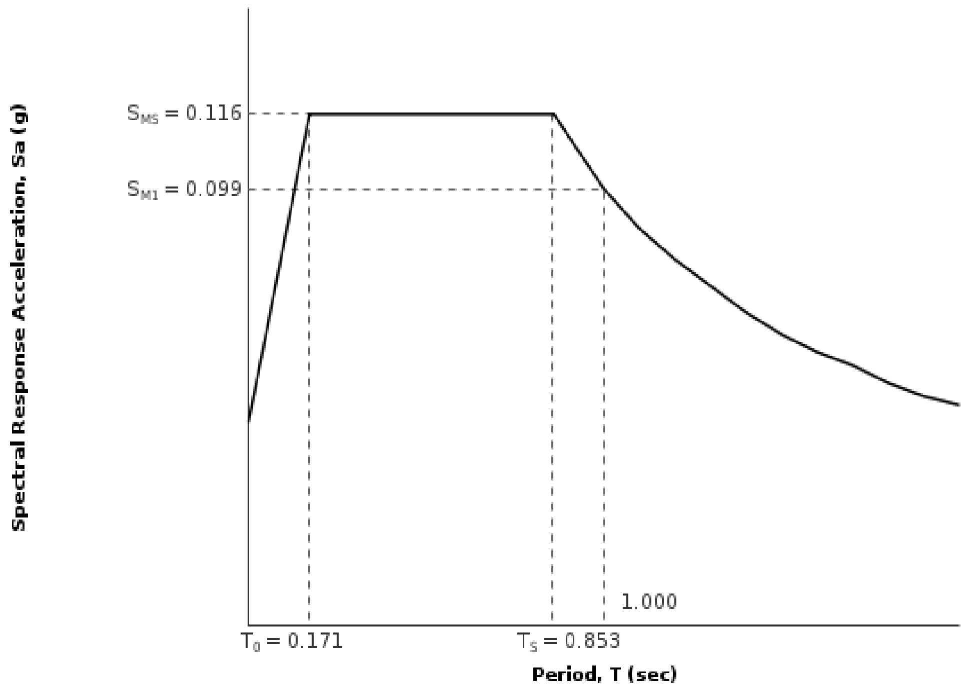
From Figure 22-12 [3] $T_L = 12$ seconds

Figure 11.4–1: Design Response Spectrum



Section 11.4.6 — Risk-Targeted Maximum Considered Earthquake (MCE_R) Response Spectrum

The MCE_R Response Spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

From Figure 22-7 [4] PGA = 0.034

Equation (11.8–1): $PGA_M = F_{PGA}PGA = 1.600 \times 0.034 = 0.055$ g

Table 11.8–1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of PGA

For Site Class = D and PGA = 0.034 g, F_{PGA} = 1.600

Section 21.2.1.1 — Method 1 (from Chapter 21 – Site-Specific Ground Motion Procedures for Seismic Design)

From Figure 22-17 [5] C_{RS} = 0.905

From Figure 22-18 [6] C_{R1} = 0.868

Section 11.6 — Seismic Design Category

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

VALUE OF S_{DS}	RISK CATEGORY		
	I or II	III	IV
S_{DS} < 0.167g	A	A	A
0.167g ≤ S_{DS} < 0.33g	B	B	C
0.33g ≤ S_{DS} < 0.50g	C	C	D
0.50g ≤ S_{DS}	D	D	D

For Risk Category = I and S_{DS} = 0.077 g, Seismic Design Category = A

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

VALUE OF S_{D1}	RISK CATEGORY		
	I or II	III	IV
S_{D1} < 0.067g	A	A	A
0.067g ≤ S_{D1} < 0.133g	B	B	C
0.133g ≤ S_{D1} < 0.20g	C	C	D
0.20g ≤ S_{D1}	D	D	D

For Risk Category = I and S_{D1} = 0.066 g, Seismic Design Category = A

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is **E** for buildings in Risk Categories I, II, and III, and **F** for those in Risk Category IV, irrespective of the above.

Seismic Design Category ≡ "the more severe design category in accordance with Table 11.6-1 or 11.6-2" = A

Note: See Section 11.6 for alternative approaches to calculating Seismic Design Category.

References

1. *Figure 22-1*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-1.pdf
2. *Figure 22-2*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-2.pdf
3. *Figure 22-12*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-12.pdf
4. *Figure 22-7*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-7.pdf
5. *Figure 22-17*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-17.pdf
6. *Figure 22-18*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-18.pdf

Simplified Seed and Idriss Liquefaction Analysis
SPT Based Analysis
Lansing Generating Station
Interstate Electric Power - Columbia Energy Center
Equations from "Soil Liquefaction During Earthqakes" Idriss & Boulanger
SPT values at Boring MW-304 & 112 (sand starting at top elevation 782)

Input Parameters:

Peak Ground Acceleration (g) =	0.055
Earthquake Magnitude, M =	7.7
Water Table Depth (ft) =	16
Average Soil Density above water table (lb/ft^3) =	115.0
Average Soil Density below water table (lb/ft^3) =	120.0
Borehole Diameter (mm) =	100

Rod Lengths assumed equal to depth plus 5.0 feet (for the above ground extension)

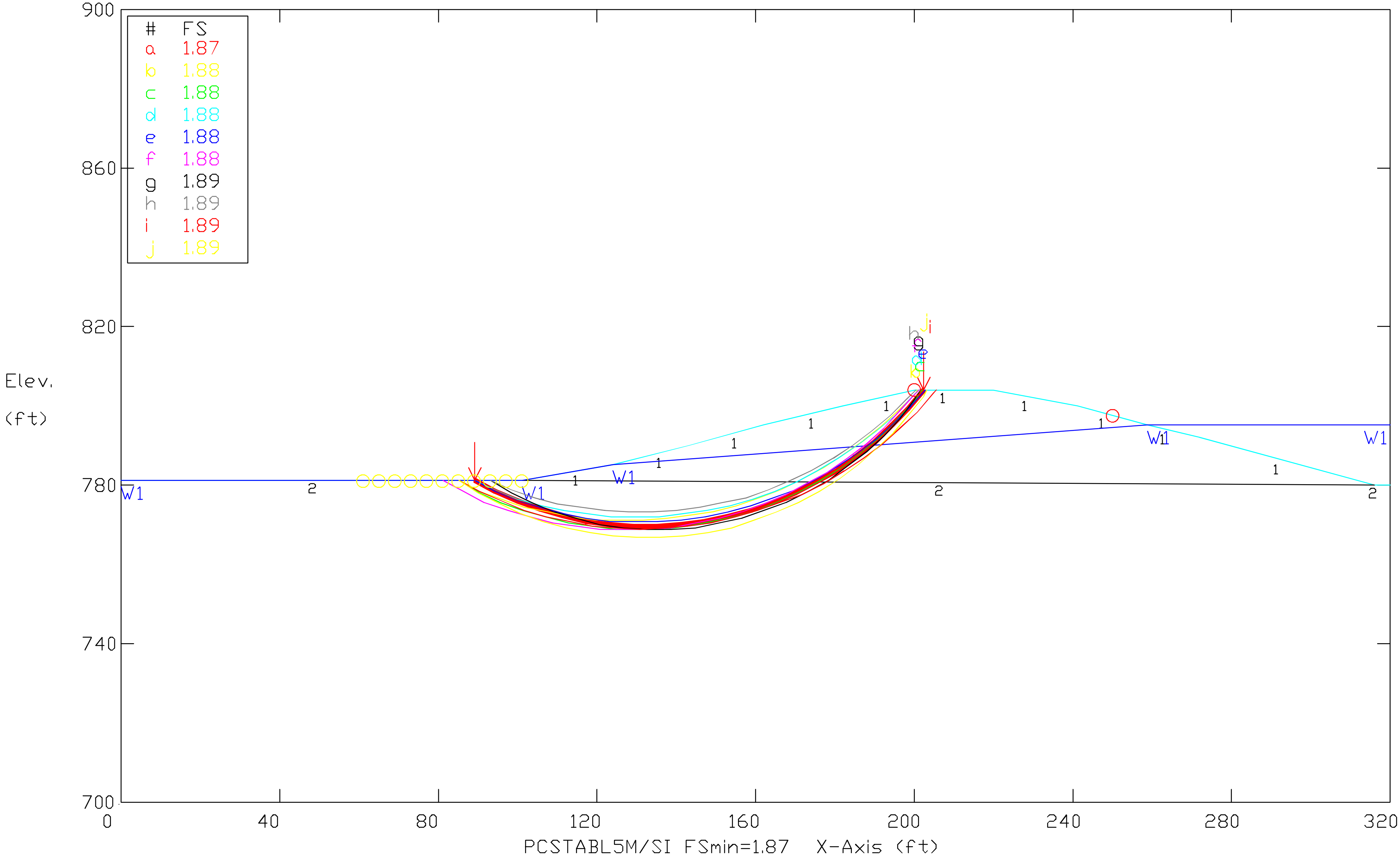
SPT #	Depth (ft)	Measured N	Soil Type (USCS)	Flag "Clay" "Unsaturated"	Fines Content (%)	Energy Ratio, ER (%)	C_e	C_b	C_r	N_{60}	σ_{vc} (lb/ft^2)	σ_{vc}' (lb/ft^2)	C_n	$(N_1)_{60}$	ΔN for fines content	$(N_1)_{60\text{-}cs}$	Stress Reduction Coeff, r_d	CSR	MSF for sand	k_σ for sand	CRR 7.5M & 1 atm	CRR	Factor of Safety
1	2	18	SP	Unsaturated	5	75%	1.25	1	0.75	16.9	230	230	1.70	28.7	0.0	28.7	1.00	0.036	0.95	1.10	0.414	n.a.	n.a.
2	4.5	48	SP	Unsaturated	5	75%	1.25	1	0.75	45.0	518	518	1.70	76.5	0.0	76.5	1.00	0.036	0.95	1.10	2.000	n.a.	n.a.
3	7	40	SP	Unsaturated	5	75%	1.25	1	0.8	40.0	805	805	1.62	64.9	0.0	64.9	0.99	0.035	0.95	1.10	2.000	n.a.	n.a.
4	9.5	30	SP	Unsaturated	5	75%	1.25	1	0.85	31.9	1093	1093	1.39	44.4	0.0	44.4	0.99	0.035	0.95	1.10	2.000	n.a.	n.a.
5	12	61	SP	Unsaturated	5	75%	1.25	1	0.85	64.8	1380	1380	1.24	80.3	0.0	80.3	0.98	0.035	0.95	1.10	2.000	n.a.	n.a.
6	14.5	17	SP	Unsaturated	5	75%	1.25	1	0.85	18.1	1668	1668	1.13	20.4	0.0	20.4	0.97	0.035	0.95	1.03	0.210	n.a.	n.a.
7	17	6	SP		5	75%	1.25	1	0.95	7.1	1960	1898	1.06	7.5	0.0	7.5	0.96	0.036	0.95	1.01	0.102	0.097	2.00
8	19.5	6	SP		5	75%	1.25	1	0.95	7.1	2260	2042	1.02	7.3	0.0	7.3	0.96	0.038	0.95	1.00	0.100	0.095	2.00
9	22	6	SP		5	75%	1.25	1	0.95	7.1	2560	2186	0.98	7.0	0.0	7.0	0.95	0.040	0.95	1.00	0.098	0.093	2.00
10	25	20	SP		5	75%	1.25	1	0.95	23.8	2920	2358	0.95	22.5	0.0	22.5	0.94	0.042	0.95	0.98	0.241	0.225	2.00
11	30	47	SP		5	75%	1.25	1	1	58.8	3520	2646	0.89	52.5	0.0	52.5	0.92	0.044	0.95	0.93	2.000	1.772	2.00

APPENDIX D – Slope Stability Analysis

Alliant Energy
Wisconsin Power and Light Company
Columbia Energy Center
Pardeeville, Wisconsin

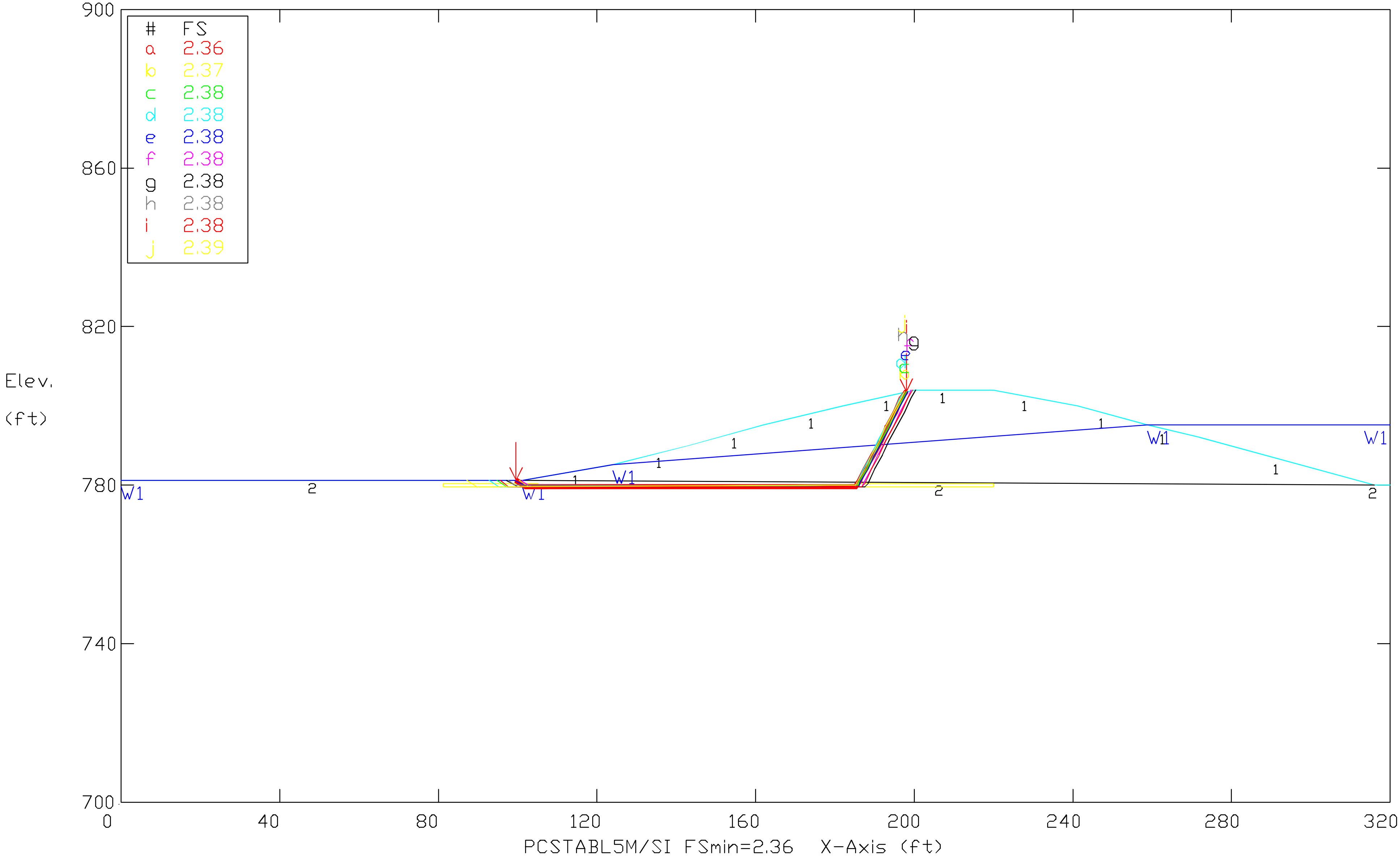
Safety Factor Assessment

COL Primary Impoundment Outer Dike Static Case & Normal Water Levels
Ten Most Critical. E:COL31C.PLT 07-29-16 11:06am



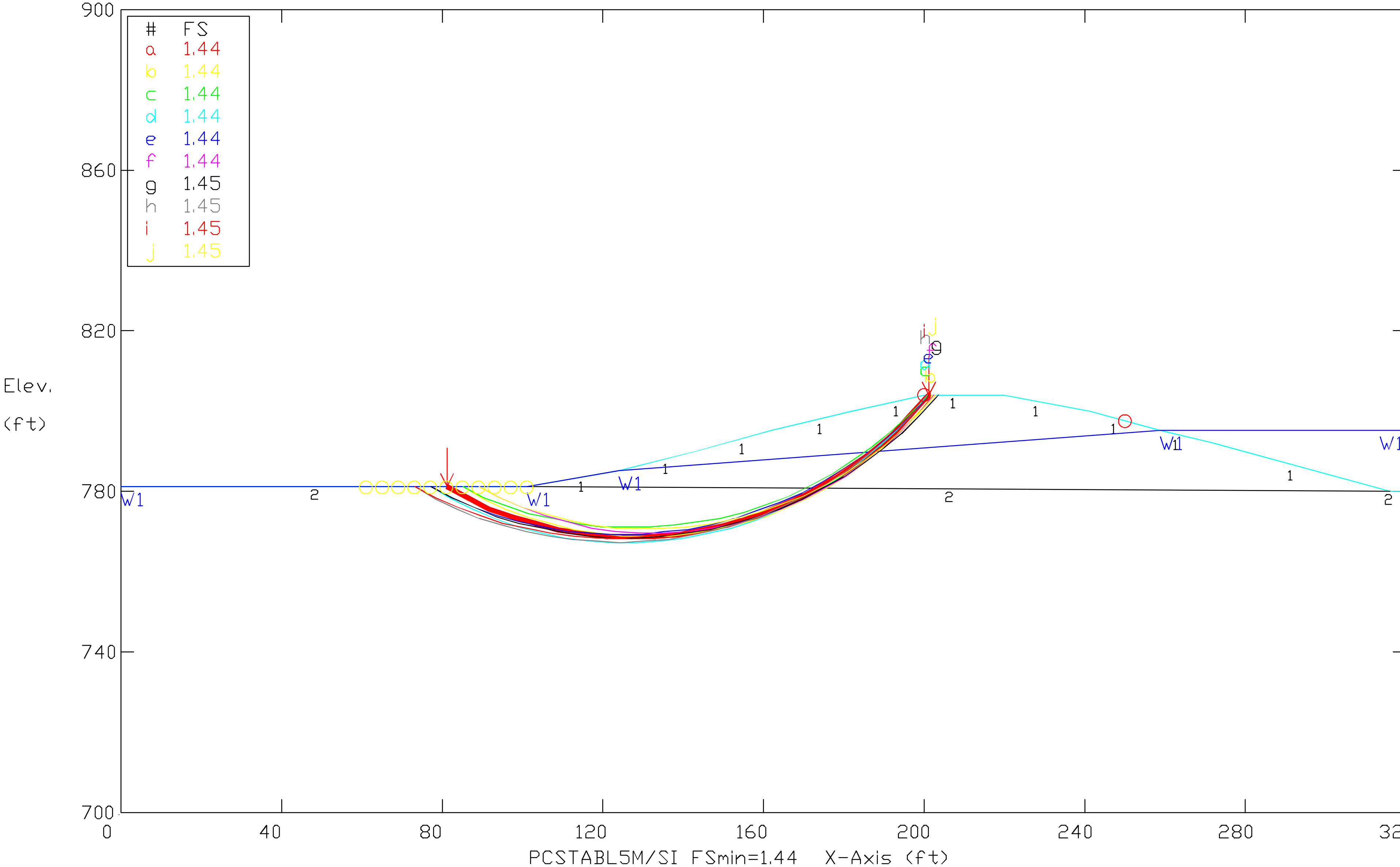
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Sand	120	120	0	35	0	0	W1
2 Sand	110	110	0	30	0	0	W1

COL Primary Impoundment Outer Dike Static Case & Normal Water Levels
Ten Most Critical. E:COL31B.PLT 07-29-16 11:04am



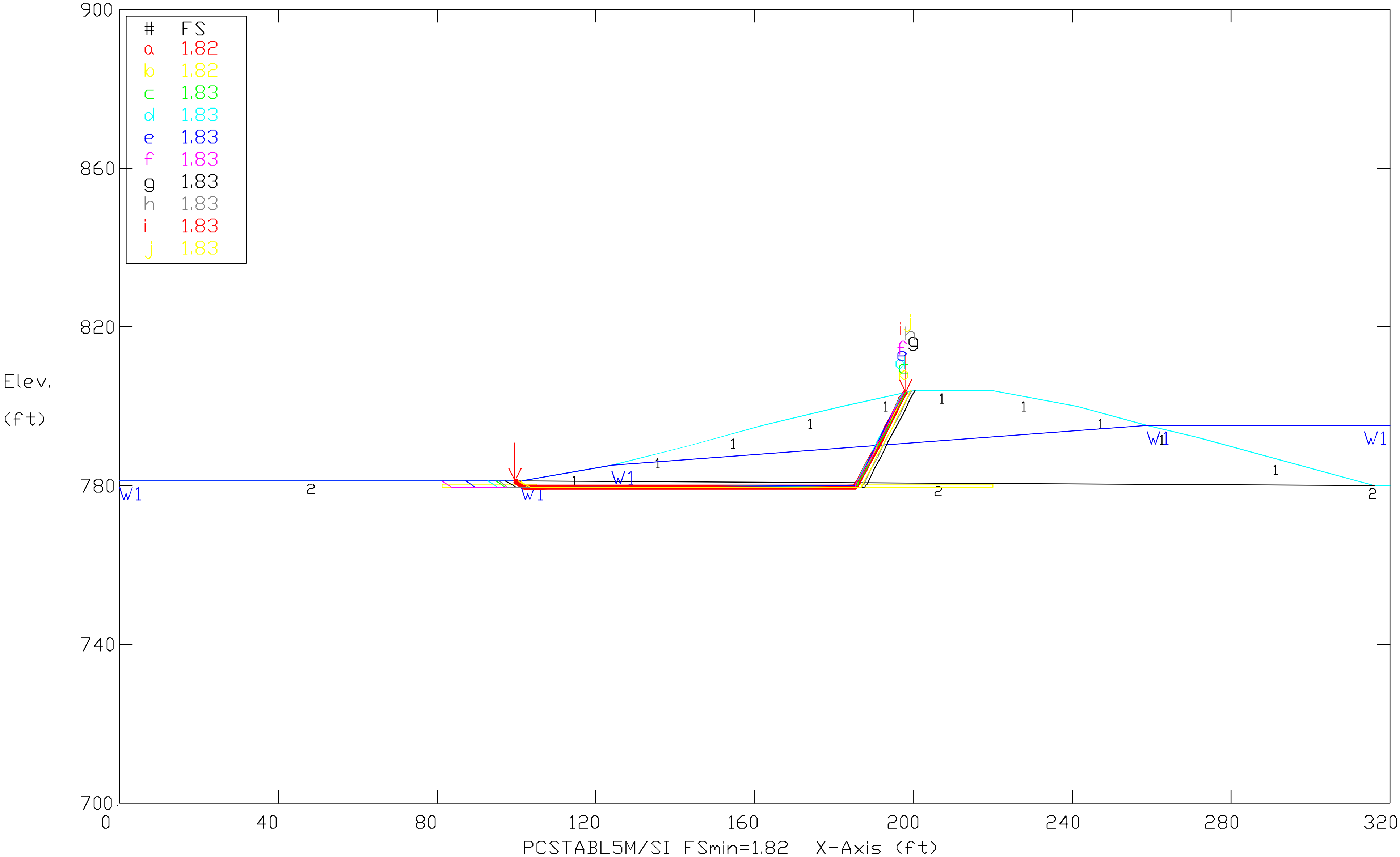
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Sand	120	120	0	35	0	0	W1
2 Sand	110	110	0	30	0	0	W1

COL Primary Impoundment Outer Dike Earthquake Case & Normal Water Levels
Ten Most Critical. E:COL31CEQ.PLT 07-29-16 11:07am



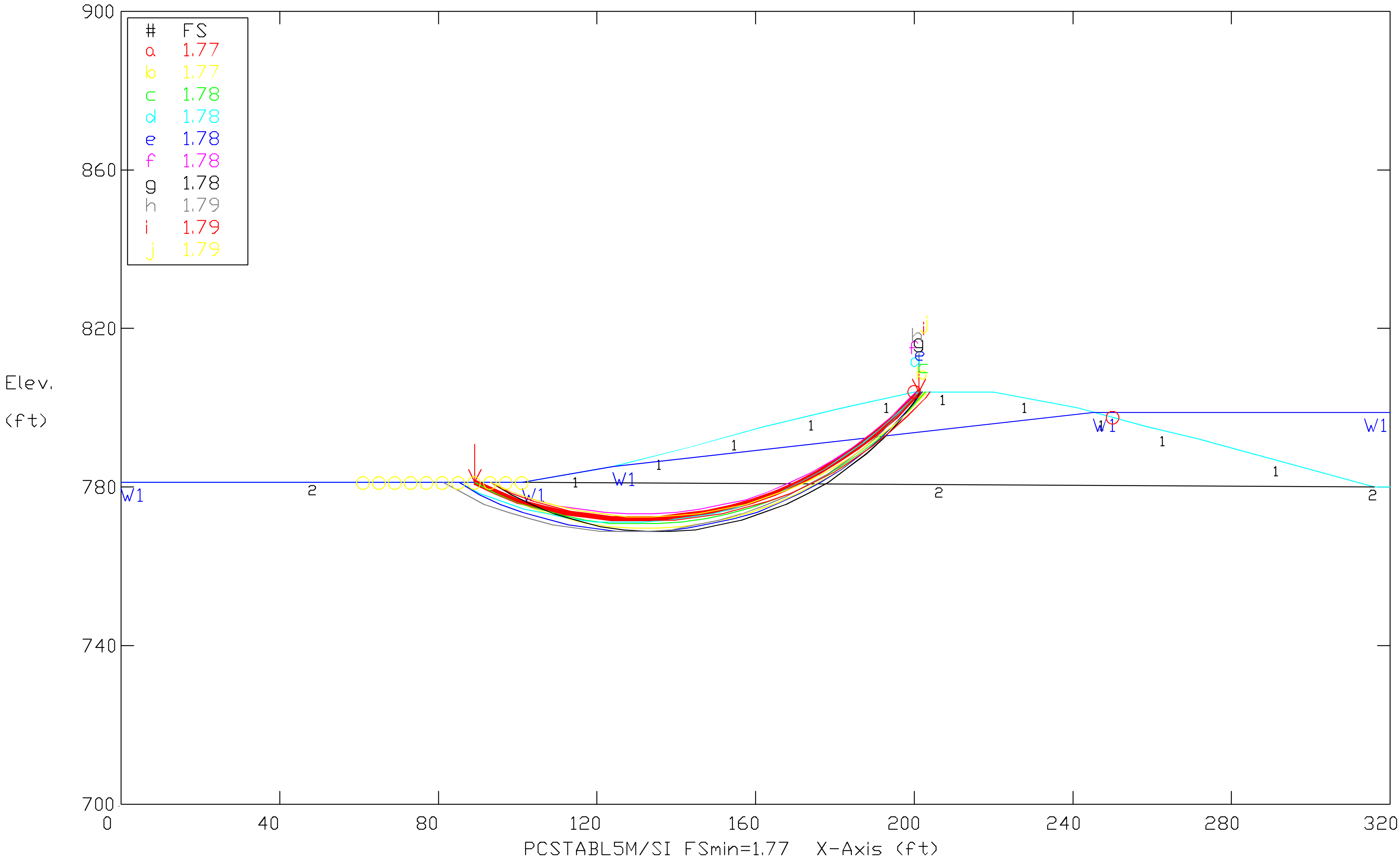
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Sand	120	120	0	35	0	0	W1
2 Sand	110	110	0	30	0	0	W1

COL Primary Impoundment Outer Dike Earthquake Case & Normal Water Levels
Ten Most Critical. E:COL31BEQ.PLT   07-29-16   11:05am



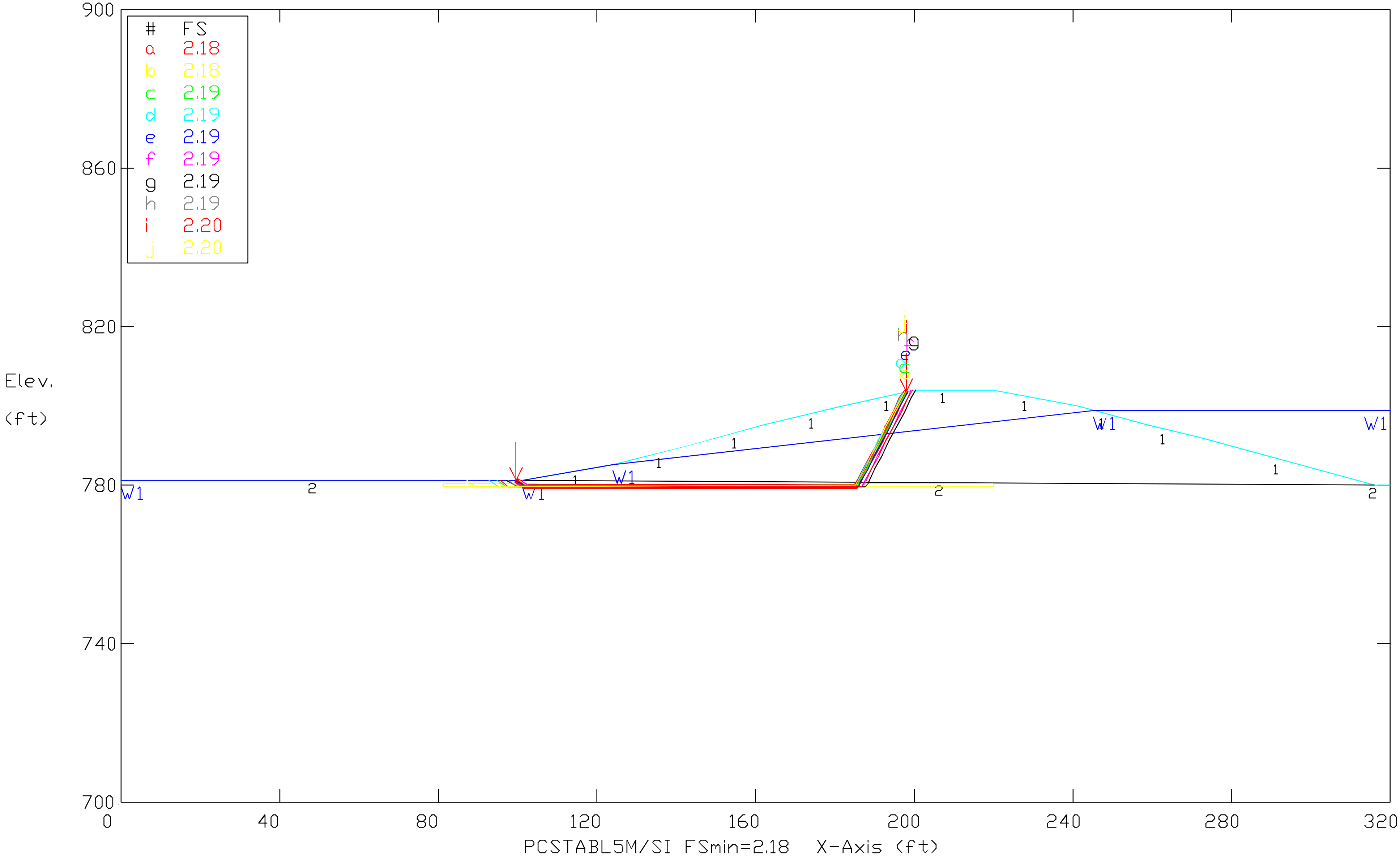
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Sand	120	120	0	35	0	0	W1
2 Sand	110	110	0	30	0	0	W1

COL Primary Impoundment Outer Dike Static Case & 100-Year Water Levels
Ten Most Critical. E:COL32C.PLT 07-29-16 11:09am



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Sand	120	120	0	35	0	0	W1
2	Sand	110	110	0	30	0	0	W1

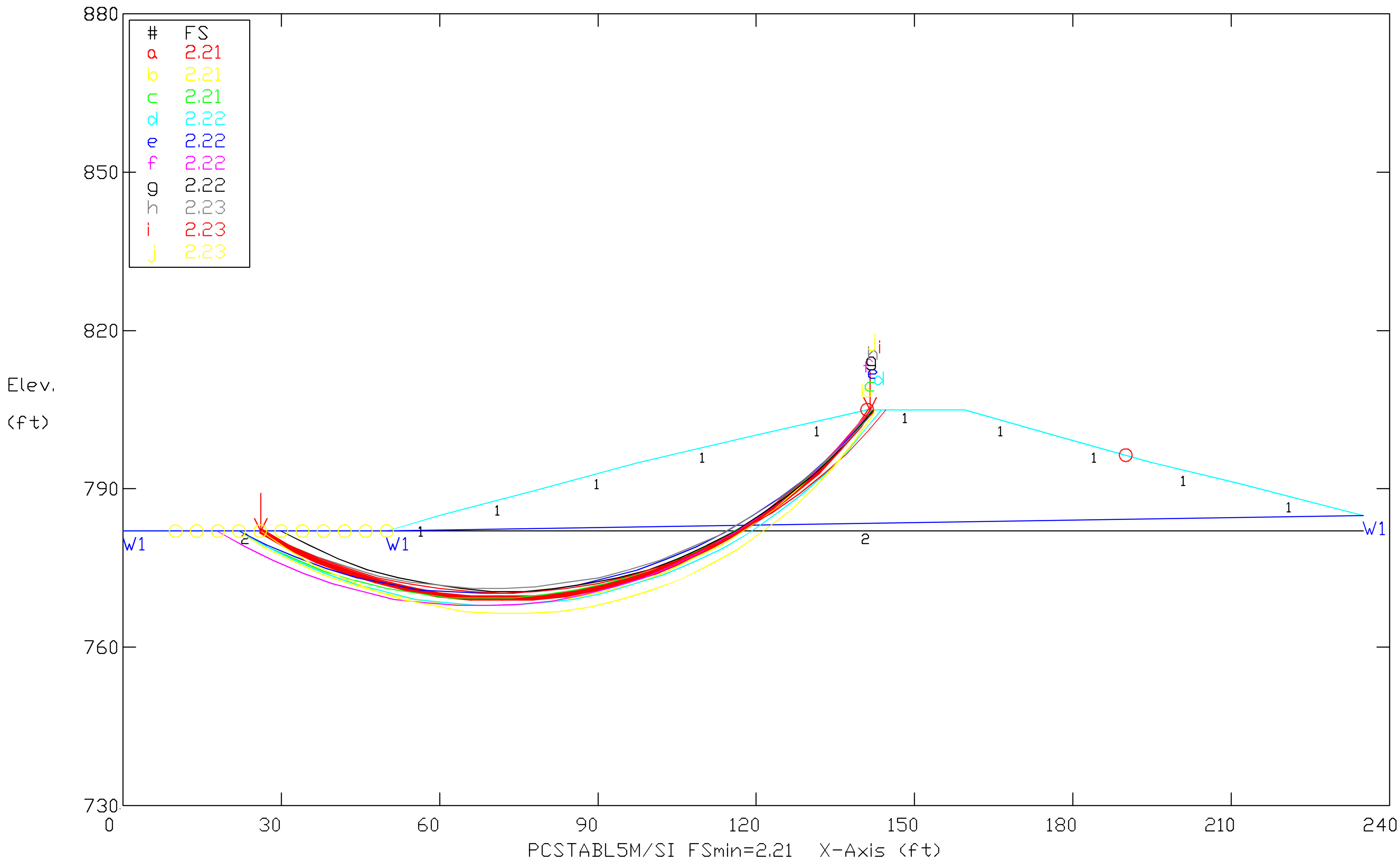
COL Primary Impoundment Outer Dike Static Case & 100-Year Water Levels
Ten Most Critical. E:COL32B.PLT 07-29-16 11:08am



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Sand	120	120	0	35	0	0	W1
2	Sand	110	110	0	30	0	0	W1

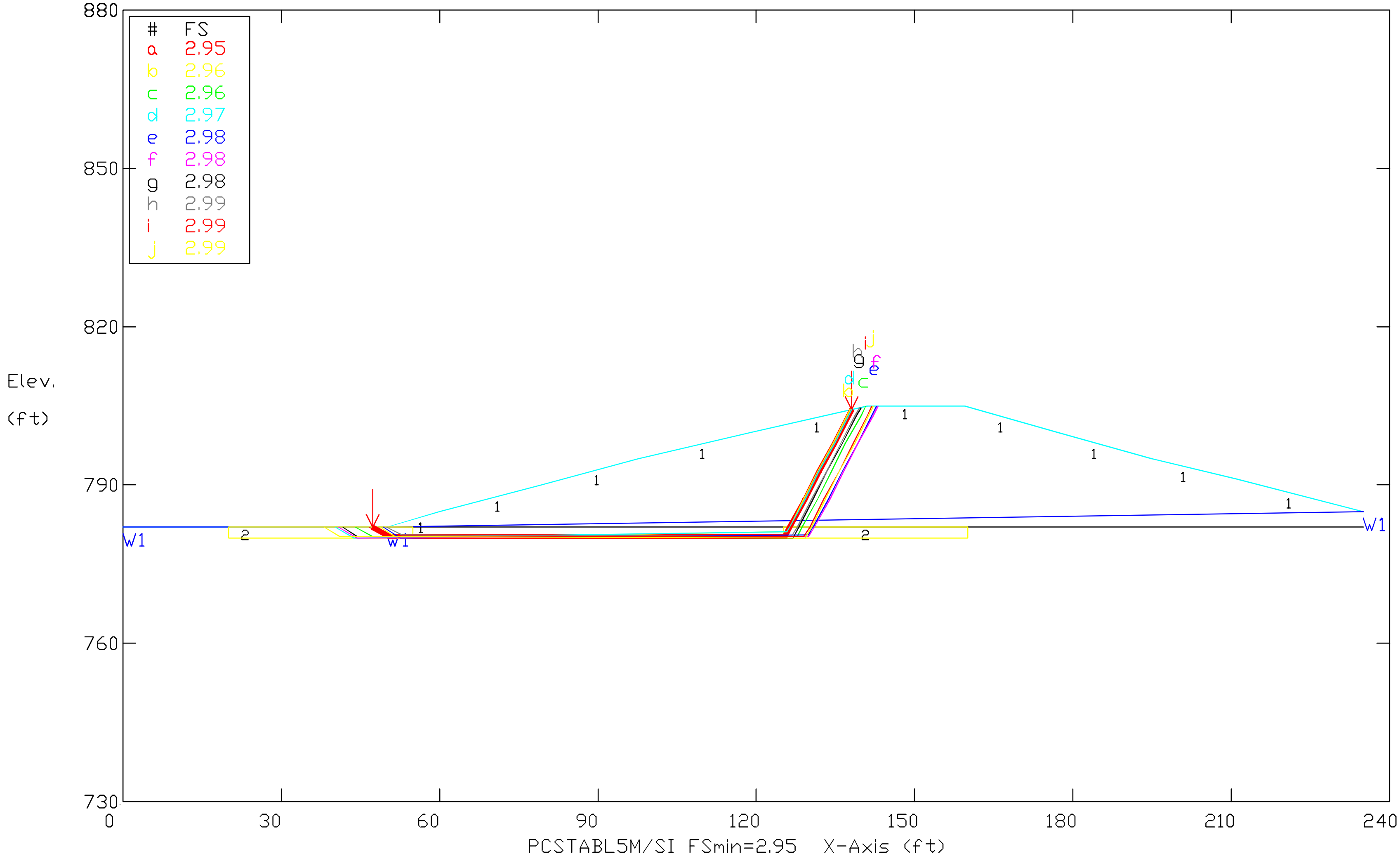
COL Secondary Impoundment Outer Dike Static Case & Normal Water Levels

Ten Most Critical. E:COL41C.PLT   07-29-16   9:47am



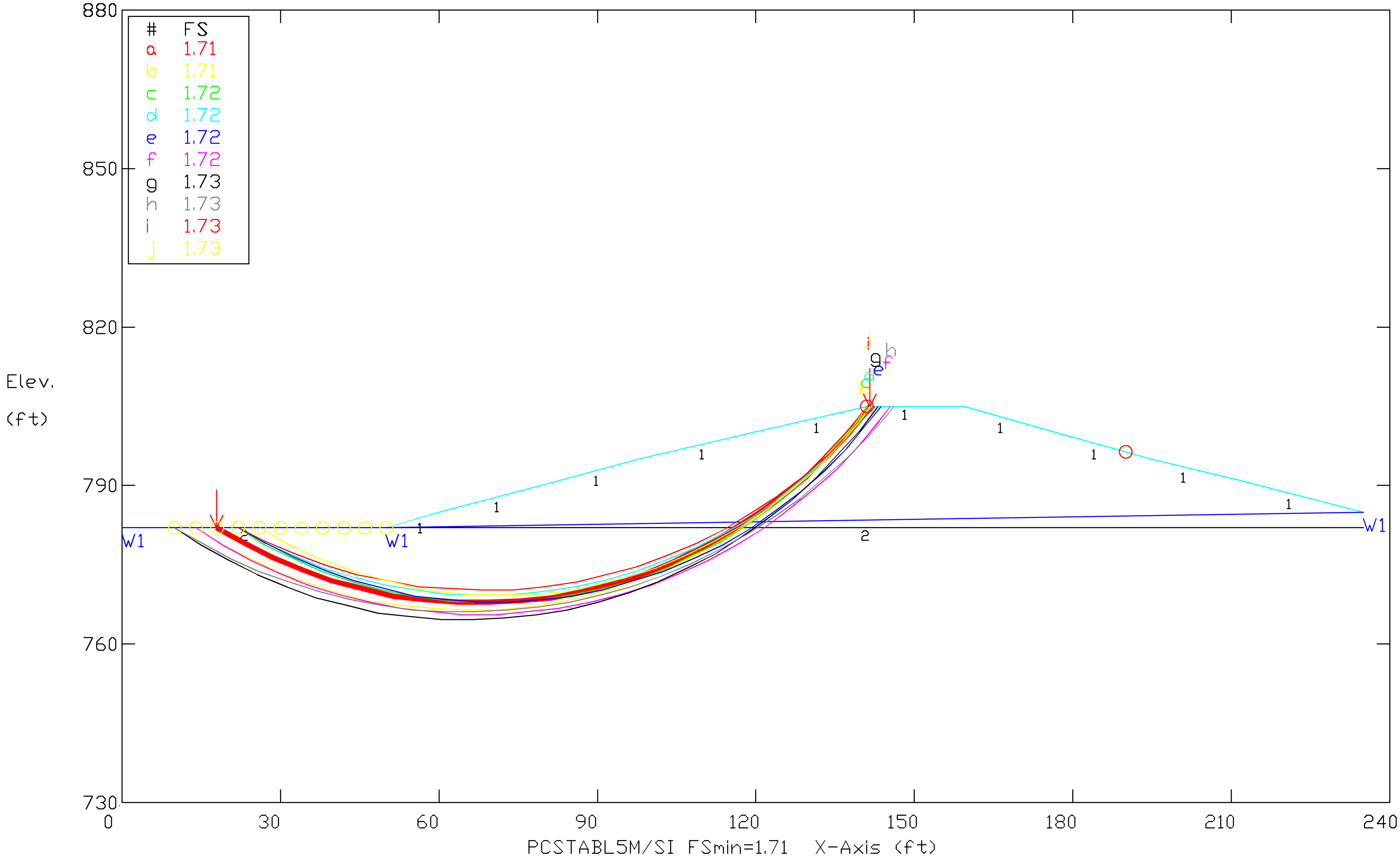
Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Sand	120	120	0	35	0	0	W1
2	Sand	110	110	0	30	0	0	W1

CDL Secondary Impoundment Outer Dike Static Case & Normal Water Levels
Ten Most Critical. E:CDL41B.PLT 07-29-16 9:45am



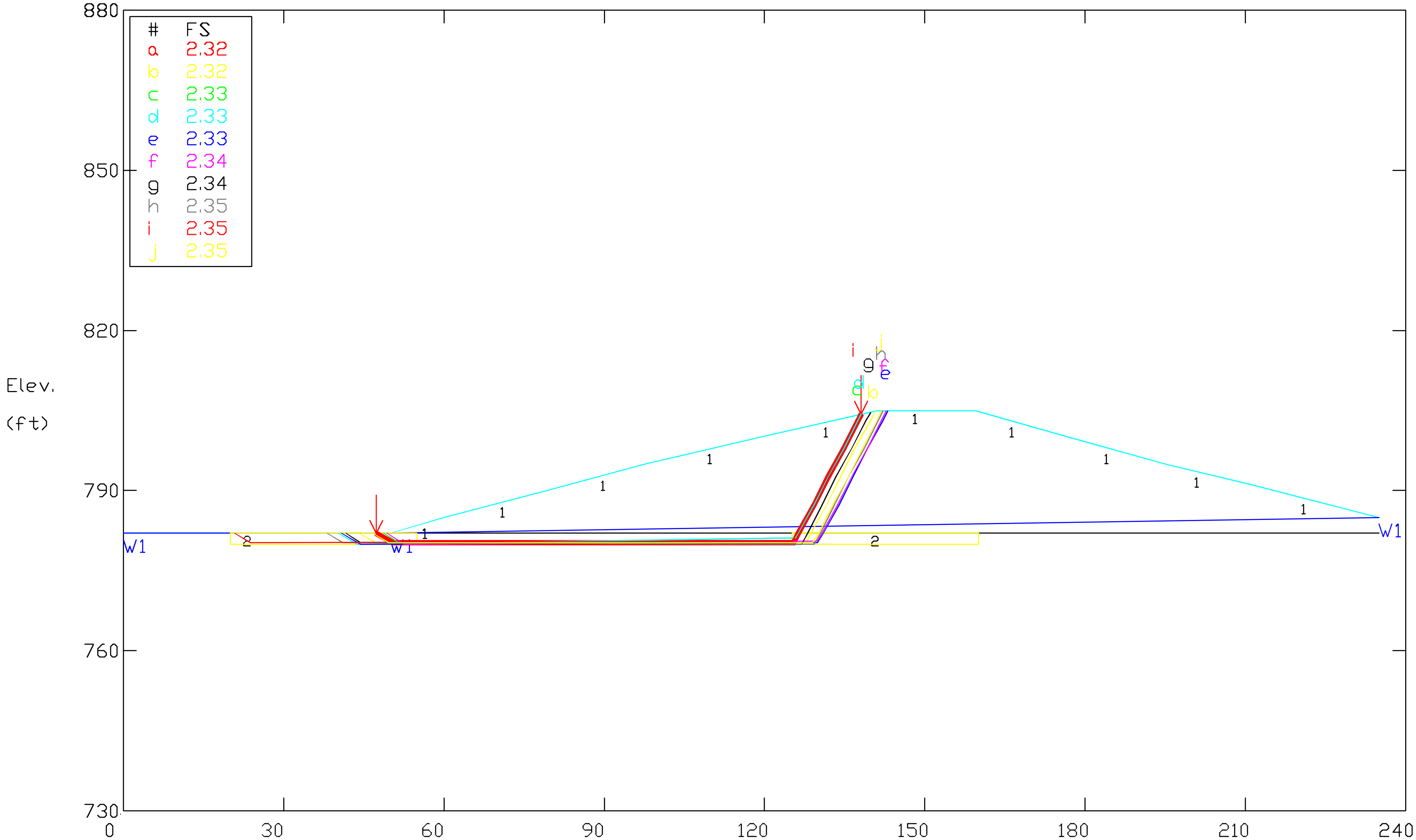
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Sand	120	120	0	35	0	0	W1
2 Sand	110	110	0	30	0	0	W1

COL Secondary Impoundment Outer Dike Earthquake Case & Normal Water Levels
Ten Most Critical. E:COL41CEQ.PLT 07-29-16 9:48am



Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Sand	120	120	0	35	0	0	W1
2 Sand	110	110	0	30	0	0	W1

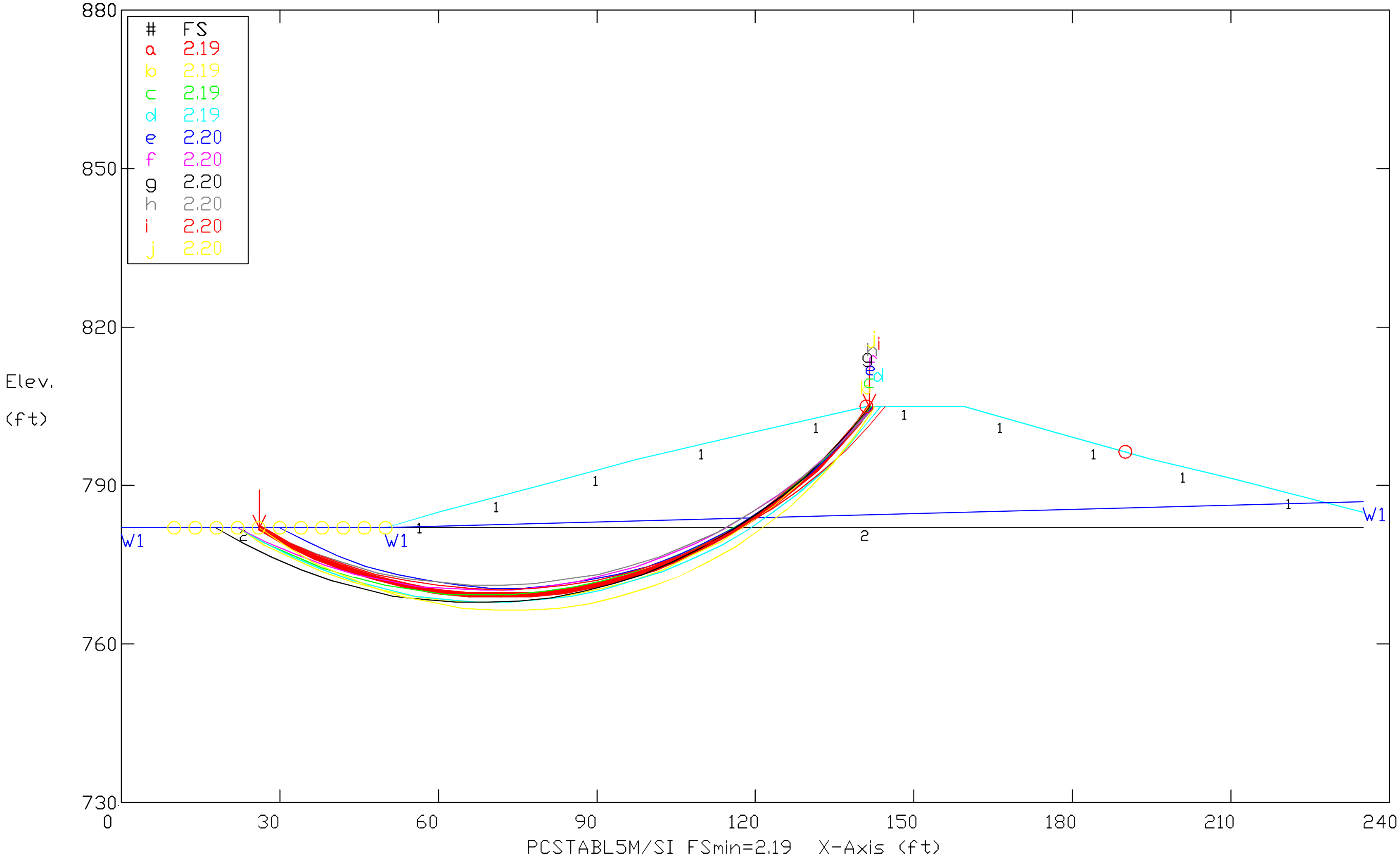
COL Secondary Impoundment Outer Dike Earthquake Case & Normal Water Levels
Ten Most Critical. E:COL41BEQ.PLT 07-29-16 9:46am



PCSTABL5M/SI FSmin=2.32 X-Axis (ft)

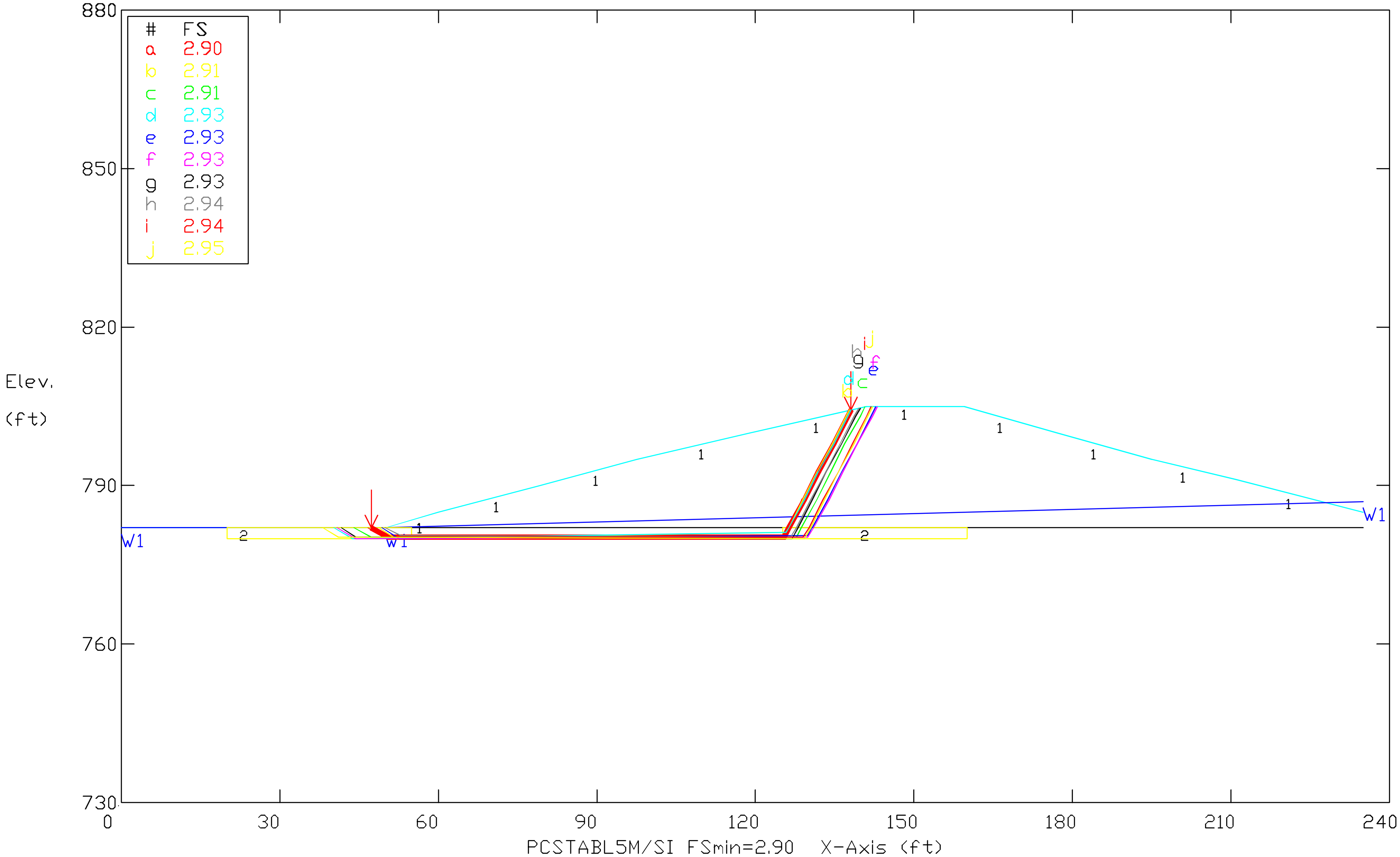
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Sand	120	120	0	35	0	0	W1
2 Sand	110	110	0	30	0	0	W1

COL Secondary Impoundment Outer Dike Static Case & 100-Year Water Levels
Ten Most Critical. E:COL42C.PLT 07-29-16 10:00am



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Sand	120	120	0	35	0	0	W1
2	Sand	110	110	0	30	0	0	W1

COL Secondary Impoundment Outer Dike Static Case & 100-Year Water Levels
Ten Most Critical. E:COL42B.PLT 07-29-16 9:58am



Soil Type No.	Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	Sand	120	120	0	35	0	0	W1
2	Sand	110	110	0	30	0	0	W1