SAFETY FACTOR ASSESSMENT

SAFETY FACTOR ASSESSMENT

Bremo Power Station CCR Surface Impoundment: North Ash Pond

Dominion

Submitted To: Bremo Power Station
1038 Bremo Bluff Road
Bremo Bluff, VA 23022

Submitted By: Golder Associates Inc.
2108 W. Laburnum Avenue, Suite 200
Richmond, VA 23227

October 2016 **Project No. 15-20347**

Golder Associates

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1.0 CERTIFICATION

This Safety Factor Assessment for the Bremo Power Station's North Ash Pond was prepared by Golder Associates Inc. (Golder). The document and Certification/Statement of Professional Opinion are based on and limited to information that Golder has relied on from Dominion and others, but not independently verified, as well as work products produced by Golder.

On the basis of and subject to the foregoing, it is my professional opinion as a Professional Engineer licensed in the Commonwealth of Virginia that this document has been prepared in accordance with good and accepted engineering practices as exercised by other engineers practicing in the same discipline(s), under similar circumstances, at the same time, and in the same locale. It is my professional opinion that the document was prepared consistent with the requirements in §257.73(e) of the United States Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments," published in the Federal Register on April 17, 2015, with an effective date of October 19, 2015 [40 CFR §257.73(e)].

The use of the word "certification" and/or "certify" in this document shall be interpreted and construed as a Statement of Professional Opinion, and is not and shall not be interpreted or construed as a guarantee, warranty, or legal opinion.

James R. DiFrancesco, P.E.
Print Name

Principal and Practice Leader
Title

Signature

10/13/2016
Date

COMMONWEALTH OF VIRGINIA
JAMES R. DIFRANCESCO
Lic. No. 025260
10-13-16
PROFESSIONAL ENGINEER

2.0 INTRODUCTION

This Safety Factor Assessment was prepared for the Bremo Power Station's (Station) existing Coal Combustion Residuals (CCR) surface impoundment known as the North Ash Pond (NAP). This Safety Factor Assessment was prepared in accordance with 40 CFR Part §257, Subpart D and is consistent with the requirements of 40 CFR §257.73(e).

The Station, owned and operated by Virginia Electric and Power Company d/b/a Dominion Virginia Power (Dominion), is located in Fluvanna County at 1038 Bremo Road, east of Route 15 (James Madison Highway) and north of the James River. The Station includes an existing CCR surface impoundment, the NAP, as defined by the Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule (40 CFR §257; the CCR rule).

3.0 SAFETY FACTOR ASSESSMENT

A slope stability analysis of the NAP dam was conducted to determine whether the calculated factors of safety meet or exceed the minimum safety factors specified in 40 CFR §257.73(e)(1).

3.1 Methodology

Stability safety factors were evaluated using a general limit equilibrium (GLE) method and the computer program SLIDE 7.0 Version 7.017. Specifically, the method developed by Morgenstern and Price was used in SLIDE to evaluate the stability of potential failure surfaces. For each surface, the method calculates the shear strengths that would be required to maintain equilibrium and then calculates a factor of safety by dividing the available shear strength by the shear strength required to maintain stability. The slip surface producing the minimum factor of safety is reported as the critical slip surface. Golder evaluated both circular and block type slip surfaces for the critical (maximum height) section of the NAP, shown in Figure 1 in Appendix A. Material properties and slope geometry for the NAP dam were taken from previous Golder investigations, analyses, and reports included in Golder's March 2016 Virginia Department of Conservation and Recreation (DCR) Impounding Structure Geotechnical Design Report Supporting Documents (Golder 2016). The four loading scenarios required by the CCR rule are discussed in the following sections.

3.2 Long-Term Maximum Storage Pool Conditions

The water level in the ash pond behind the dam for the maximum pool storage scenario was set equal to the NAP's emergency spillway elevation [330.4 feet above mean sea level (ft amsl)]. This is an elevated pool elevation that considers the principal spillway to be out of service, as is the current condition.

3.3 Maximum Surcharge Pool Conditions

The peak water level calculated to exist during the probable maximum flood (PMF) was used to evaluate stability for this elevated (surcharge pool) water level. The maximum pool surcharge corresponds to a water level at elevation 331.6 ft amsl. For further details, refer to the hydraulic and hydrologic stormwater routing analysis included in Appendix B of the Inflow Design Flood Control System Plan.

3.4 Seismic Loading Conditions

Factors of safety for stability under seismic loading conditions were calculated based on the earthquake hazard corresponding to a probability of exceedance of 2% in 50 years (2,475-year return period). The Bray and Travasarou displacement-based seismic slope stability screening method, as described in Golder 2016, was used. For this method, a pseudo-static coefficient (0.07) corresponding to a seismic event having a probability of occurrence of 2% in 50 years was used in the analysis. For further details on the site seismic hazard and/or the application of the Bray and Travasarou method, refer to Golder 2016.

3.5 Post-Seismic Liquefaction Loading Conditions

Golder completed an evaluation of the liquefaction susceptibility of the site soils and CCR materials, as presented in Golder 2016. Based on the liquefaction evaluations, the foundation and embankment materials of the NAP dam and compacted CCR were calculated to not be susceptible to liquefaction under the design earthquake hazard. Because the dam/dikes of the NAP are not constructed of or on materials calculated to be susceptible to liquefaction, no post-liquefaction demonstration is required in the CCR rule. However, being that the sluiced ash within the NAP is calculated to be susceptible to liquefaction, Golder completed a demonstration of stability considering the sluiced ash behind the NAP to have a conservative lower-bound liquefied strength, as described in Golder 2016.

3.6 Results

The table below presents the results of the slope stability assessments of the existing NAP for the analysis cases required in 40 CFR §257.73(e)(i) to (iv) of the CCR rule. For all four cases, the calculated factors of safety for both circular and block slip surfaces meet the target factors of safety presented in the CCR rule. For further details, see the stability figures in Appendix A.

Table 1: North Ash Pond – Factors of Safety

Case	Pool Elevation (ft amsl)	Target Factor of Safety (FS)	Circular FS	Block FS
Max Storage Pool	330.4	1.5	1.6	1.6
Max Surcharge Pool	331.6	1.4	1.6	1.5
Seismic	310.0	1.0	1.3	1.2
Liquefied Ash	310.0	1.2	1.6	1.6

Established in 1960, Golder Associates is a global, employee-owned organization that helps clients find sustainable solutions to the challenges of finite resources, energy and water supply and management, waste management, urbanization, and climate change. We provide a wide range of independent consulting, design, and construction services in our specialist areas of earth, environment, and energy. By building strong relationships and meeting the needs of clients, our people have created one of the most trusted professional services organizations in the world.

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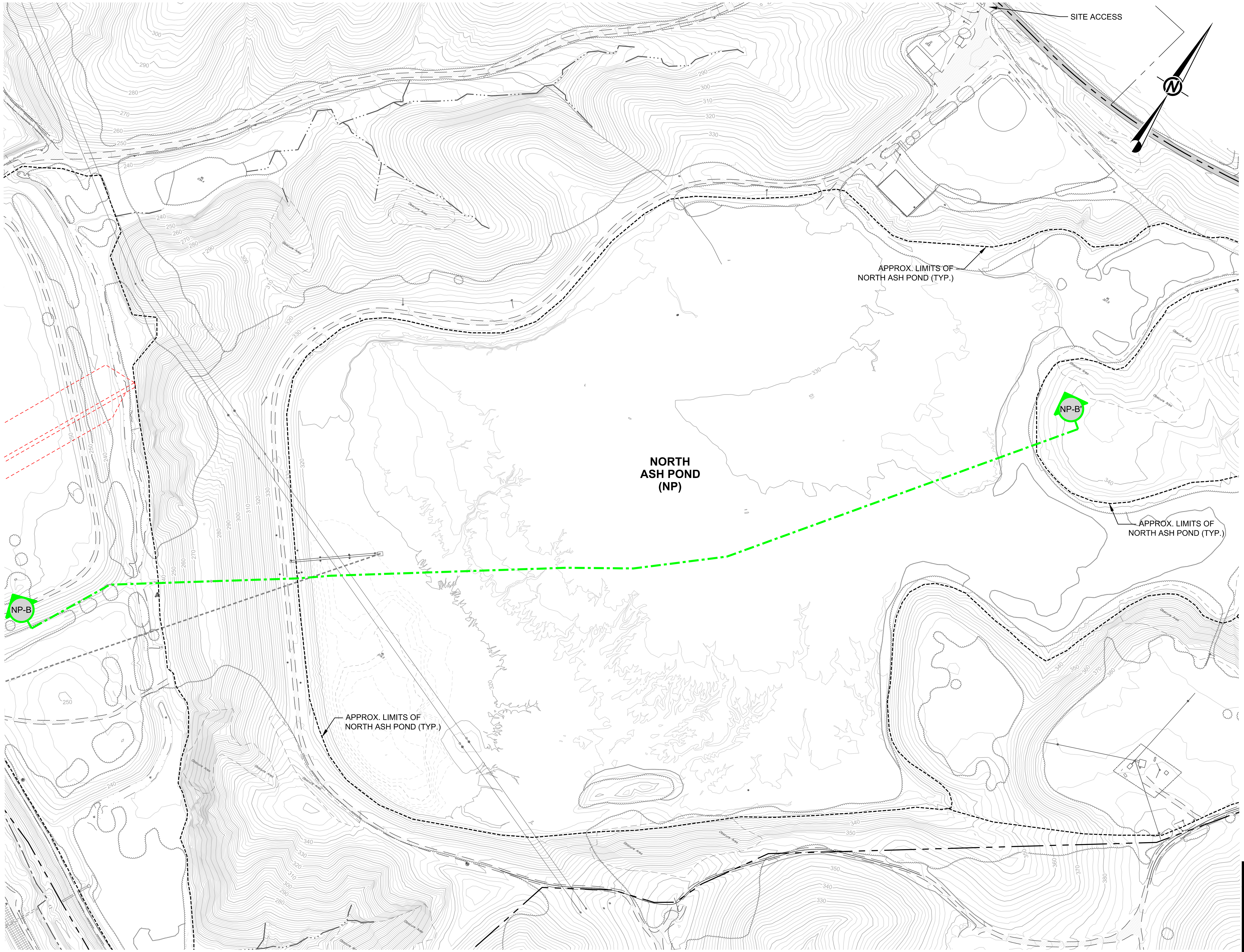
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

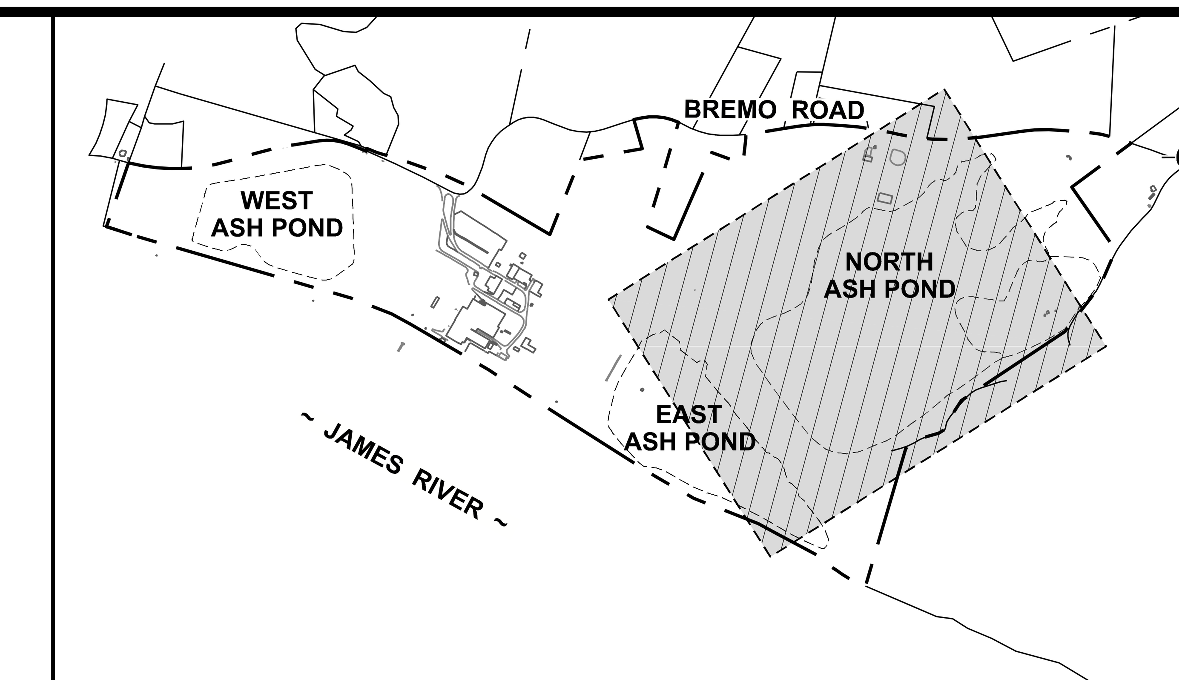
solutions@golder.com
www.golder.com

Golder Associates Inc.
2108 W. Laburnum Avenue, Suite 200
Richmond, VA 23227 USA
Tel: (804) 358-7900
Fax: (804) 358-2900

Appendix A

North Ash Pond Stability Analysis





SITE KEY

NOT TO SCALE

LEGEND

- DOMINION PROPERTY BOUNDARY
- ADJACENT PROPERTY BOUNDARY
- APPROXIMATE LIMITS OF EXISTING ASH PONDS
- 300 EXISTING TOPOGRAPHIC CONTOURS (2' INTERVALS)
- 300 EXISTING BATHYMETRIC SURFACE CONTOURS (2' INTERVALS)
- 220 DESIGN SURFACE CONTOURS (2' INTERVALS)
- EXISTING PAVED ROAD
- EXISTING UNPAVED ROAD
- EXISTING RAILROAD
- CREEK CENTERLINE
- EXISTING TREE LINE
- EXISTING FENCE
- GAS EXISTING GAS LINE
- Obscure Area DENOTES AREAS OF TOPOGRAPHY THAT DO NOT MEET MINIMUM ACCURACY STANDARDS FOR AERIAL SURVEYING

REFERENCES

1. AERIAL TOPOGRAPHIC SURVEY PREPARED BY McKENZIE SNYDER, INC., DATE OF AERIAL PHOTO: 01/16/15 [CONTROL PREPARED BY H&B SURVEYING & MAPPING (H&B)].

2. BATHYMETRIC SURVEYS PREPARED BY H&B, SURVEYS PERFORMED IN FEBRUARY 2015.

120 0 120 240
SCALE FEET

REV	DATE	REVISION DESCRIPTION	DES	CADD	CHK	RVW
△	-	-	-	-	-	-

PROJECT
DOMINION
BREMO POWER STATION
CCR IMPOUNDMENT CLOSURE
FLUVANNA COUNTY, VIRGINIA

TITLE
EXISTING CONDITIONS GEOTECHNICAL STABILITY PLAN (NORTH POND)

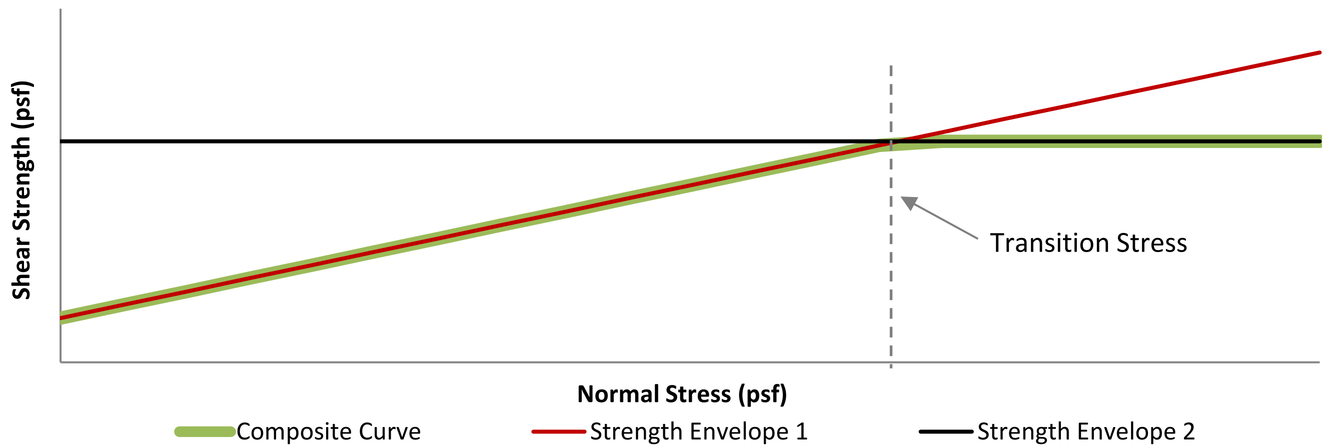
Golder Associates

PROJECT No.		15-20347	FILE No.	1520347AD01
DESIGN	-	-	SCALE	AS SHOWN
CADD	CCP	2016/09/27	FIGURE 1	
CHECK	JGM	2016/09/27		
REVIEW	GLH	2016/09/27		

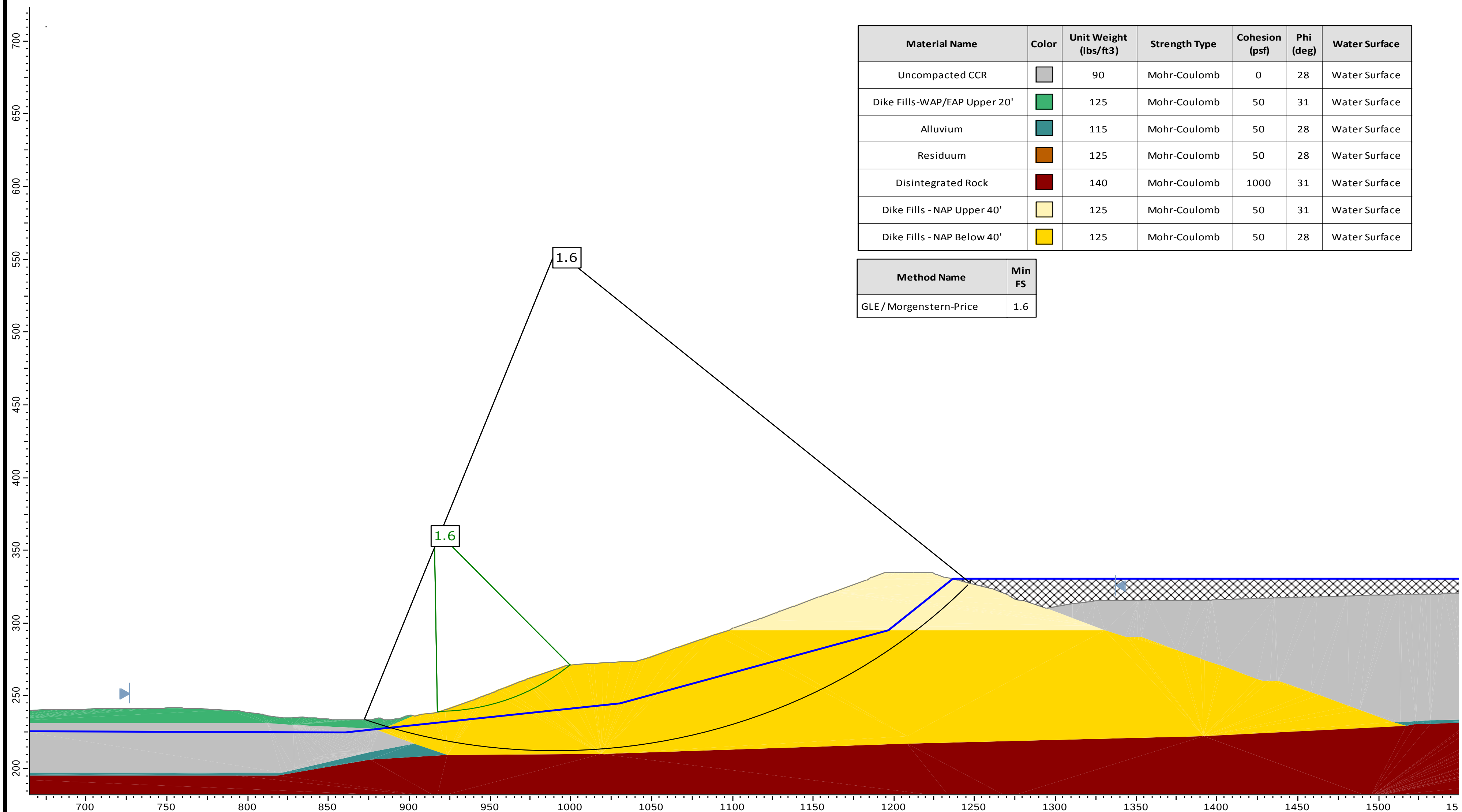
G:\Plan Production Data Files\Drawing Data Files\15-20347\A - Bremo Pond Closure (Conceptual Plan)\Active Drawings\Geotech Stability\Sept 2016\1520347AD01.dwg | Layout: GD-5A | Modified: ccpowell 09/27/2016 2:51 PM | Plotted: ccpowell 09/28/2016

Material properties assessed in the previous report were used in the following analyses (Golder 2015). For long-term, drained conditions, the effective stress strength (Strength Envelope 1) was used. For seismic loading conditions, 80% of the undrained strength (Strength Envelope 2) was used for the alluvium, and for all other materials, a composite curve was developed by taking the minimum of 80% of the undrained shear strength and the effective strength for a given normal stress. Composite curves can be represented with two Mohr-Coulomb curves. The figure below illustrates the composite curves, and the table below shows the strengths used for the stability calculations.

Material	Shear Strengths Used in Pseudo-Static Seismic Analyses				
	Transition Stress (psf)	Strength Envelope 1		Strength Envelope 2	
		ϕ (deg)	c (psf)	ϕ (deg)	c (psf)
Uncompacted CCR	1505	28	0	0	800
Dike Fills - WAP/EAP Upper 20'	3911	31	50	0	2400
Alluvium	N/A	0	1600	N/A	N/A
Residuum	3911	31	50	0	2400
Disintegrated Rock	N/A	31	0	N/A	N/A
Dike Fills - NAP Upper 40'	5242	31	50	0	3200
Dike Fills - NAP Below 40'	5924	28	50	0	3200
CCR Fill	3558	34	0	0	2400



Golder Associates Inc.	SCALE: AS SHOWN	PROJECT	**Bremo Power Station Ash Pond Closure**
	DATE: Sep 2016	TITLE	**Summary of Properties**
	MADE BY: JGM		
	CAD:		
FILE: STABILITY	CHECK: NNNY	CLIENT: **Dominion**	FIGURE: **2**
PROJECT No. 1520347 / REV. 0	REVIEW: GLH		



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Uncompacted CCR		90	Mohr-Coulomb	0	28	Water Surface
Dike Fills-WAP/EAP Upper 20'		125	Mohr-Coulomb	50	31	Water Surface
Alluvium		115	Mohr-Coulomb	50	28	Water Surface
Residuum		125	Mohr-Coulomb	50	28	Water Surface
Disintegrated Rock		140	Mohr-Coulomb	1000	31	Water Surface
Dike Fills - NAP Upper 40'		125	Mohr-Coulomb	50	31	Water Surface
Dike Fills - NAP Below 40'		125	Mohr-Coulomb	50	28	Water Surface

Method Name	Min FS
GLE / Morgenstern-Price	1.6

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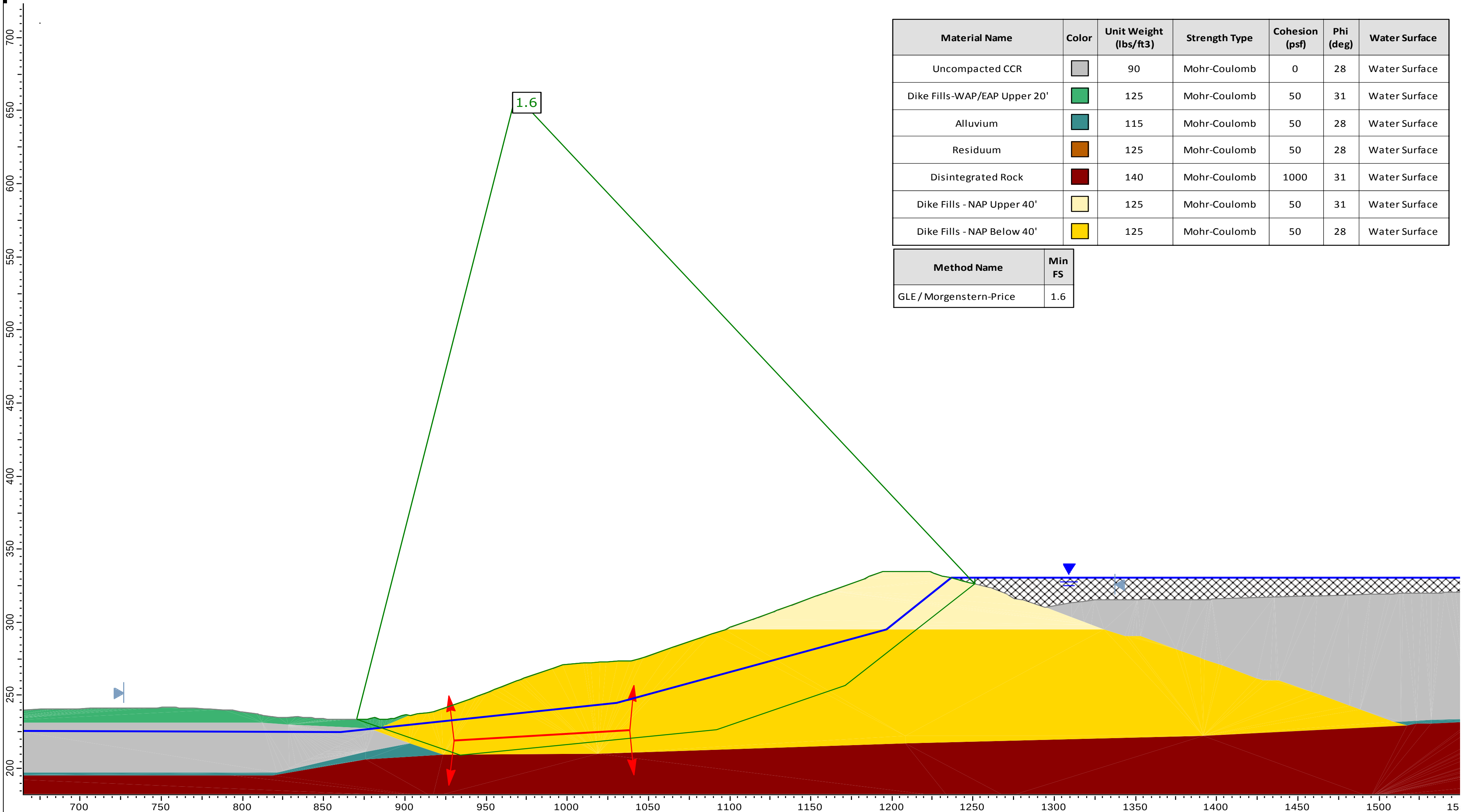
SCALE	AS SHOWN	PROJECT	**Bremo Power Station Ash Pond Closure**
DATE	Sep 2016	TITLE	**NP-B, South Left - Pre-Closure Configuration Maximum Pool Storage Circular Slip Surface Search**
MADE BY	JGM		
CAD			
CHECK	NNNY	CLIENT	**Dominion**
REVIEW	GLH	FIGURE	**3**

FILE: STABILITY

PROJECT No. 1520347 REV. 0



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Uncompacted CCR		90	Mohr-Coulomb	0	28	Water Surface
Dike Fills-WAP/EAP Upper 20'		125	Mohr-Coulomb	50	31	Water Surface
Alluvium		115	Mohr-Coulomb	50	28	Water Surface
Residuum		125	Mohr-Coulomb	50	28	Water Surface
Disintegrated Rock		140	Mohr-Coulomb	1000	31	Water Surface
Dike Fills - NAP Upper 40'		125	Mohr-Coulomb	50	31	Water Surface
Dike Fills - NAP Below 40'		125	Mohr-Coulomb	50	28	Water Surface

Method Name	Min FS
GLE / Morgenstern-Price	1.6

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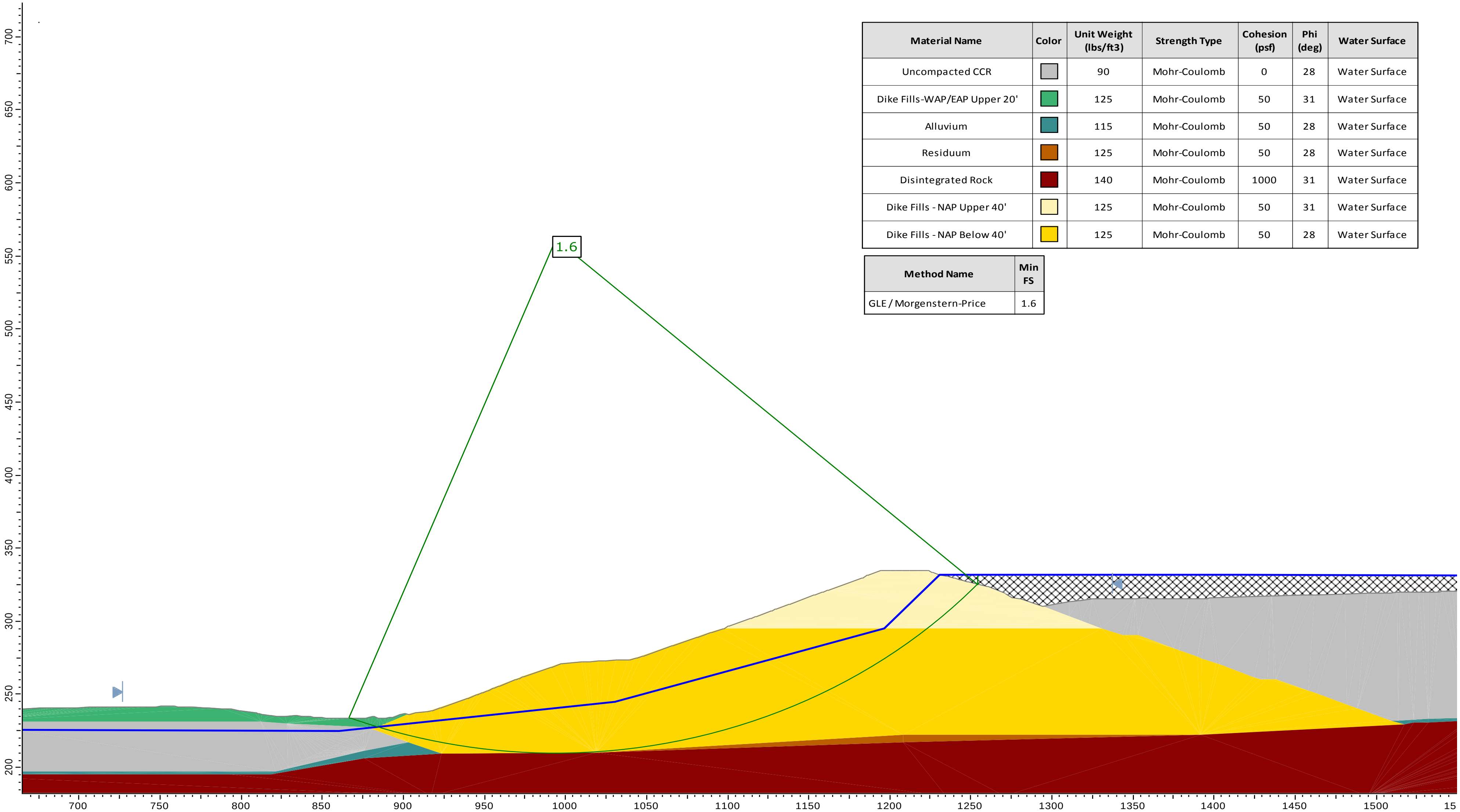
SCALE	AS SHOWN	PROJECT	**Bremo Power Station Ash Pond Closure**
DATE	Sep 2016	TITLE	**NP-B, South Left - Pre-Closure Configuration Maximum Pool Storage Block Slip Surface Search**
MADE BY	JGM		
CAD			
CHECK	NNNY	CLIENT	**Dominion**
REVIEW	GLH	FIGURE	4

FILE	STABILITY		
PROJECT No.	1520347	REV.	0



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Uncompacted CCR		90	Mohr-Coulomb	0	28	Water Surface
Dike Fills-WAP/EAP Upper 20'		125	Mohr-Coulomb	50	31	Water Surface
Alluvium		115	Mohr-Coulomb	50	28	Water Surface
Residuum		125	Mohr-Coulomb	50	28	Water Surface
Disintegrated Rock		140	Mohr-Coulomb	1000	31	Water Surface
Dike Fills - NAP Upper 40'		125	Mohr-Coulomb	50	31	Water Surface
Dike Fills - NAP Below 40'		125	Mohr-Coulomb	50	28	Water Surface

Method Name	Min FS
GLE / Morgenstern-Price	1.6

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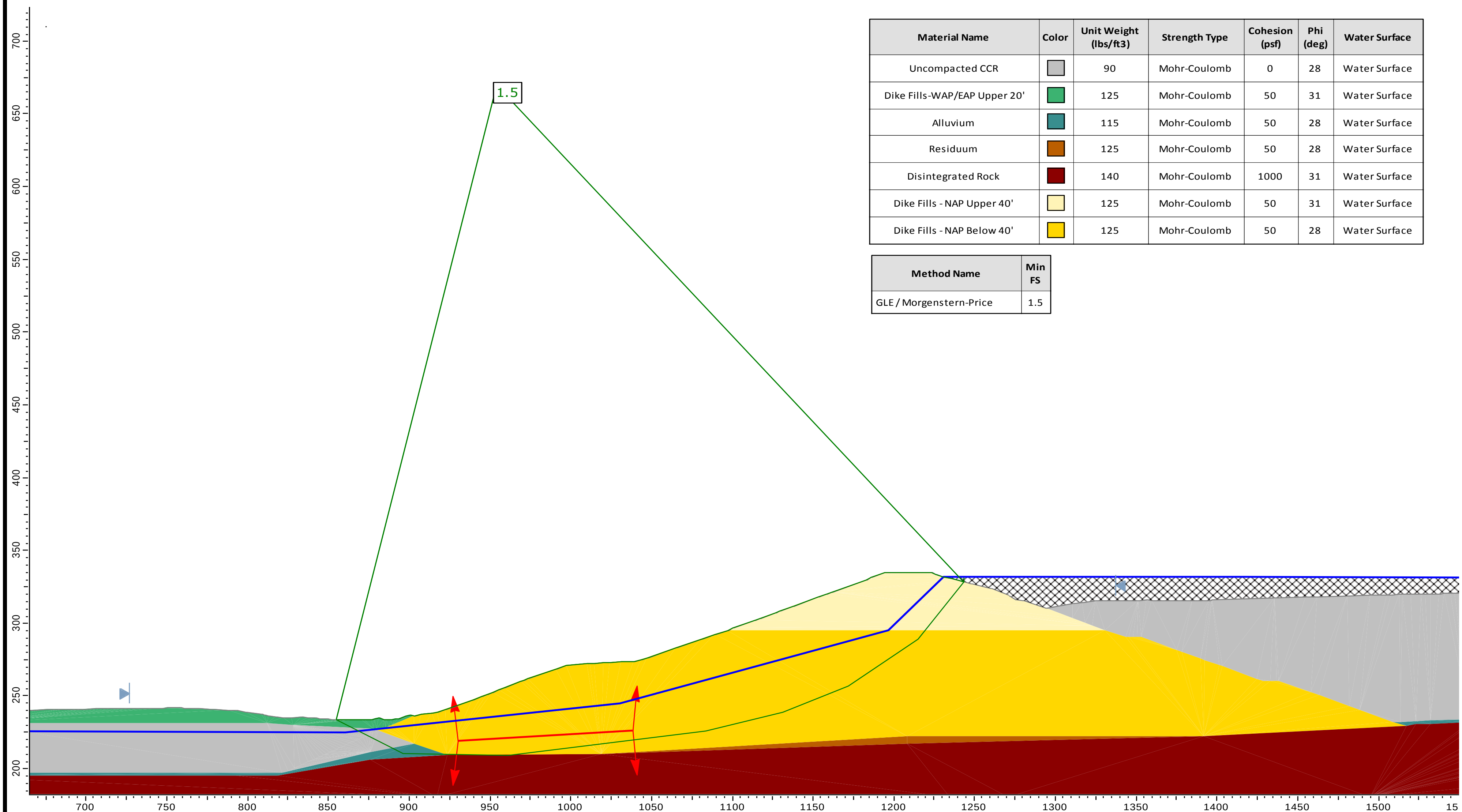
SCALE	AS SHOWN	PROJECT	**Bremo Power Station Ash Pond Closure**
DATE	Sep 2016	TITLE	**NP-B, South Left - Pre-Closure Configuration Maximum Pool Surcharge Circular Slip Surface Search**
MADE BY	JGM		
CAD			
CHECK	NNNY	CLIENT	**Dominion**
REVIEW	GLH	FIGURE	**5**

FILE STABILITY

PROJECT No. 1520347 REV. 0



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Uncompacted CCR		90	Mohr-Coulomb	0	28	Water Surface
Dike Fills-WAP/EAP Upper 20'		125	Mohr-Coulomb	50	31	Water Surface
Alluvium		115	Mohr-Coulomb	50	28	Water Surface
Residuum		125	Mohr-Coulomb	50	28	Water Surface
Disintegrated Rock		140	Mohr-Coulomb	1000	31	Water Surface
Dike Fills - NAP Upper 40'		125	Mohr-Coulomb	50	31	Water Surface
Dike Fills - NAP Below 40'		125	Mohr-Coulomb	50	28	Water Surface

Method Name	Min FS
GLE / Morgenstern-Price	1.5

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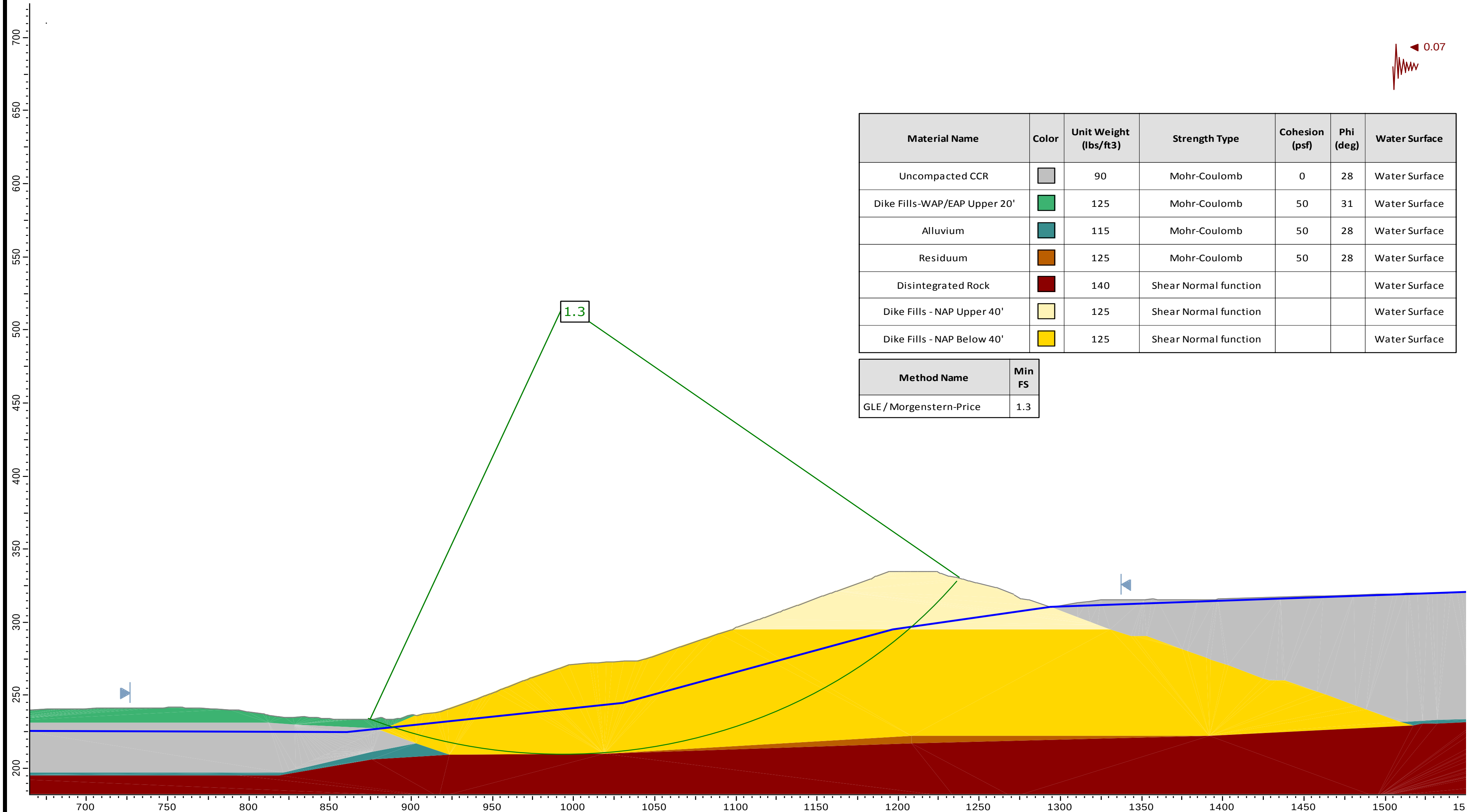
SCALE	AS SHOWN	PROJECT	**Bremo Power Station Ash Pond Closure**
DATE	Sep 2016	TITLE	**NP-B, South Left - Pre-Closure Configuration Maximum Pool Surcharge Block Slip Surface Search**
MADE BY	JGM		
CAD			
CHECK	NNNY	CLIENT	**Dominion**
REVIEW	GLH	FIGURE	6

FILE STABILITY

PROJECT No. 1520347 REV. 0



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Uncompacted CCR		90	Mohr-Coulomb	0	28	Water Surface
Dike Fills-WAP/EAP Upper 20'		125	Mohr-Coulomb	50	31	Water Surface
Alluvium		115	Mohr-Coulomb	50	28	Water Surface
Residuum		125	Mohr-Coulomb	50	28	Water Surface
Disintegrated Rock		140	Shear Normal function			Water Surface
Dike Fills - NAP Upper 40'		125	Shear Normal function			Water Surface
Dike Fills - NAP Below 40'		125	Shear Normal function			Water Surface

Method Name	Min FS
GLE / Morgenstern-Price	1.3

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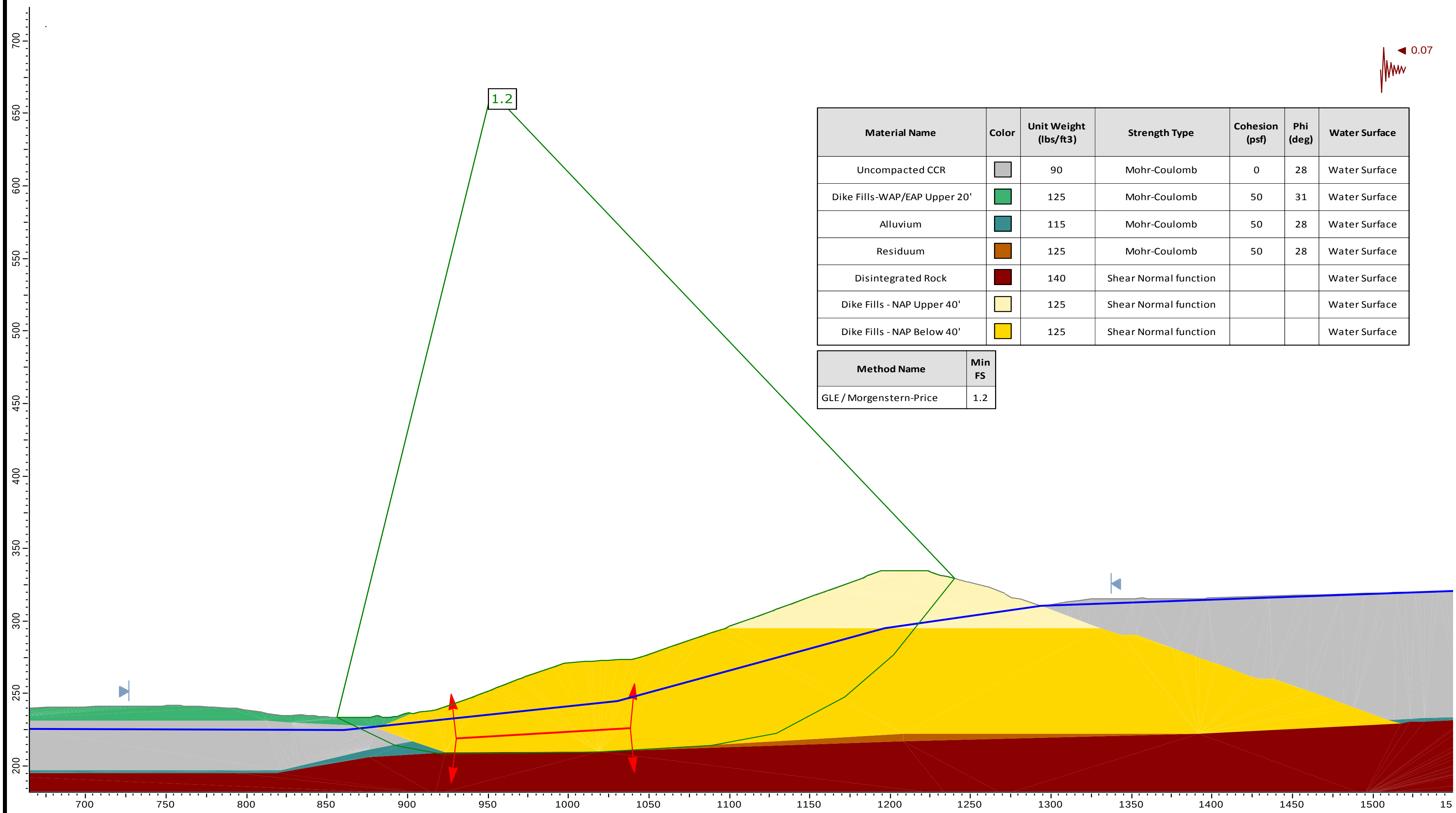
SCALE	AS SHOWN	PROJECT	Bremo Power Station Ash Pond Closure
DATE	Sep 2016	TITLE	NP-B, South Left - Pre-Closure Configuration Bray & Travasarou Displacement Based Screening Method 2014 Seismic Hazard - Circular Slip Surface Search
MADE BY	JGM		
CAD			
CHECK	NNNY	CLIENT	Dominion
REVIEW	GLH	FIGURE	7

FILE: STABILITY
PROJECT No. 1520347 REV. 0



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Uncompacted CCR		90	Mohr-Coulomb	0	28	Water Surface
Dike Fills-WAP/EAP Upper 20'		125	Mohr-Coulomb	50	31	Water Surface
Alluvium		115	Mohr-Coulomb	50	28	Water Surface
Residuum		125	Mohr-Coulomb	50	28	Water Surface
Disintegrated Rock		140	Shear Normal function			Water Surface
Dike Fills - NAP Upper 40'		125	Shear Normal function			Water Surface
Dike Fills - NAP Below 40'		125	Shear Normal function			Water Surface

Method Name	Min FS
GLE / Morgenstern-Price	1.2

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SCALE	AS SHOWN	PROJECT	**Bremo Power Station Ash Pond Closure**
DATE	Sep 2016	TITLE	**NP-B, South Left - Pre-Closure Configuration Bray & Travasarou Displacement Based Screening Method 2014 Seismic Hazard - Block Slip Surface Search**
MADE BY	JGM		
CAD			
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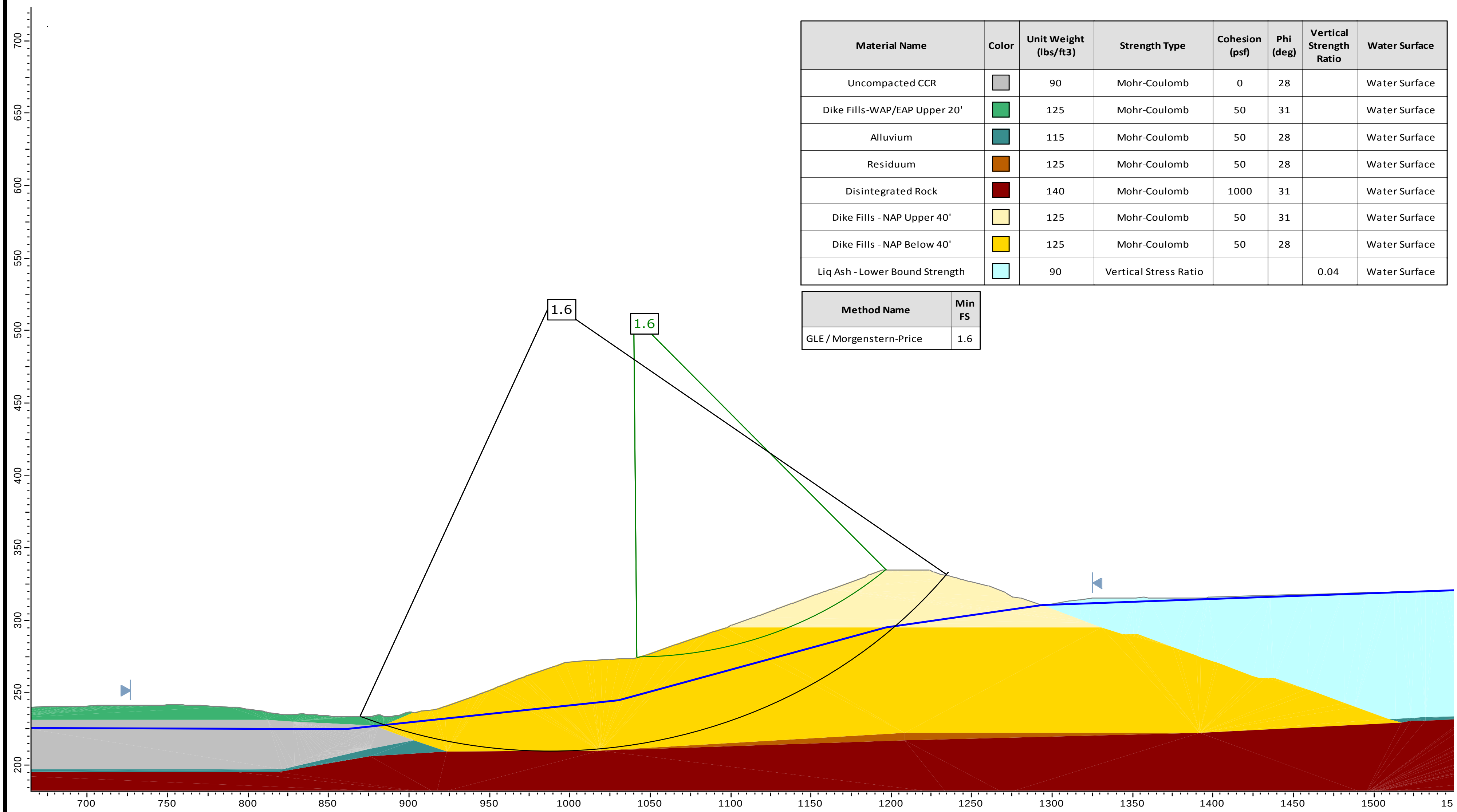
PROJECT No.	1520347	REV.	0
REVIEW	GLH	CLIENT	**Dominion**
FIGURE	8		



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Strength Ratio	Water Surface
Uncompacted CCR		90	Mohr-Coulomb	0	28		Water Surface
Dike Fills-WAP/EAP Upper 20'		125	Mohr-Coulomb	50	31		Water Surface
Alluvium		115	Mohr-Coulomb	50	28		Water Surface
Residuum		125	Mohr-Coulomb	50	28		Water Surface
Disintegrated Rock		140	Mohr-Coulomb	1000	31		Water Surface
Dike Fills - NAP Upper 40'		125	Mohr-Coulomb	50	31		Water Surface
Dike Fills - NAP Below 40'		125	Mohr-Coulomb	50	28		Water Surface
Liq Ash - Lower Bound Strength		90	Vertical Stress Ratio			0.04	Water Surface

Method Name	Min FS
GLE / Morgenstern-Price	1.6

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SCALE	AS SHOWN	PROJECT	Bremo Power Station Ash Pond Closure
DATE	Sep 2016	TITLE	NP-B, South Left - Pre-Closure Configuration Post-Liquefaction - Lower Bound Strengths Circular Slip Surface Search
MADE BY	JGM		
CAD			
CHECK	NNNY	CLIENT	Dominion
REVIEW	GLH	FIGURE	9

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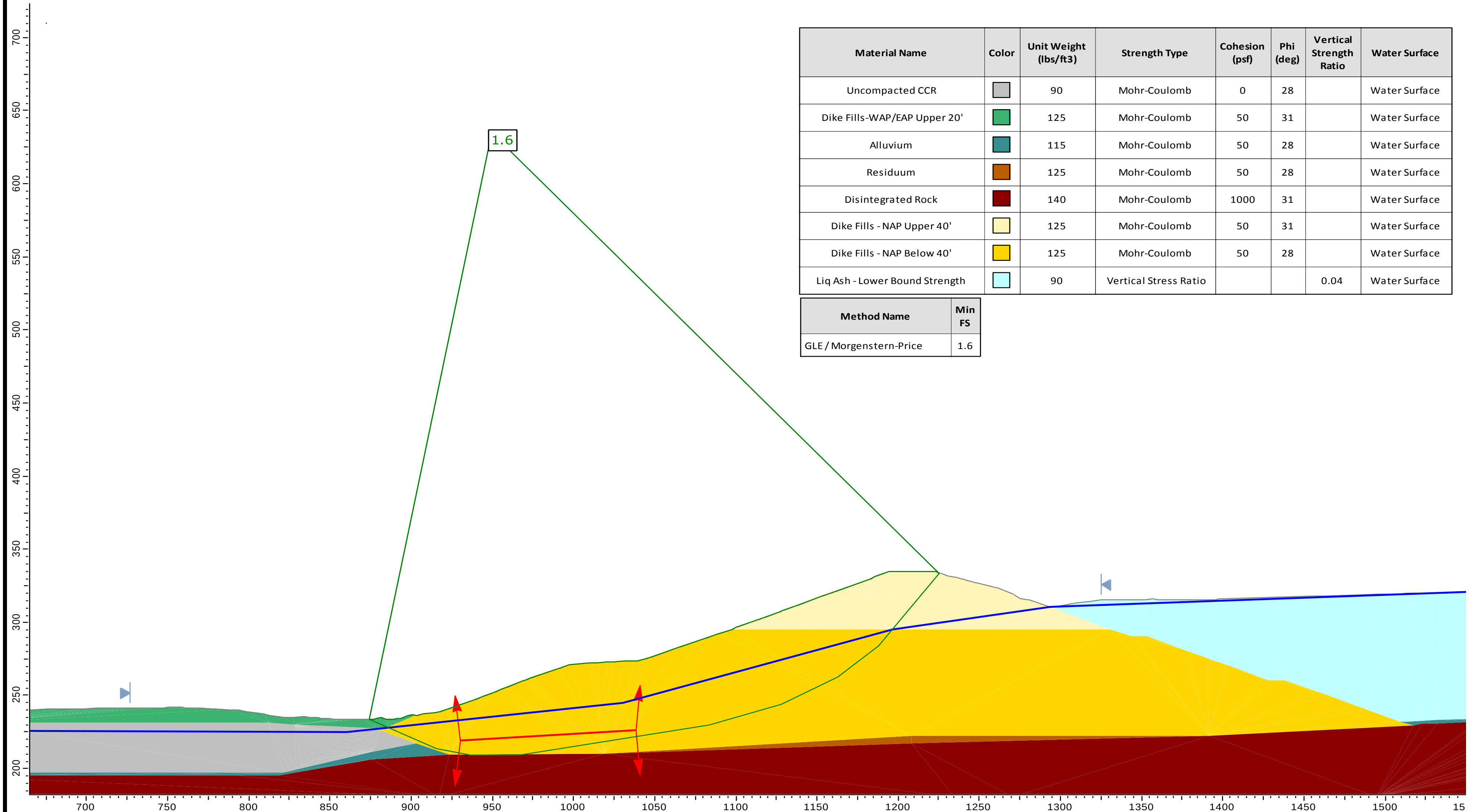
PROJECT No. 1520347 REV. 0



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Vertical Strength Ratio	Water Surface
Uncompacted CCR		90	Mohr-Coulomb	0	28		Water Surface
Dike Fills-WAP/EAP Upper 20'		125	Mohr-Coulomb	50	31		Water Surface
Alluvium		115	Mohr-Coulomb	50	28		Water Surface
Residuum		125	Mohr-Coulomb	50	28		Water Surface
Disintegrated Rock		140	Mohr-Coulomb	1000	31		Water Surface
Dike Fills - NAP Upper 40'		125	Mohr-Coulomb	50	31		Water Surface
Dike Fills - NAP Below 40'		125	Mohr-Coulomb	50	28		Water Surface
Liq Ash - Lower Bound Strength		90	Vertical Stress Ratio			0.04	Water Surface

Method Name	Min FS
GLE / Morgenstern-Price	1.6

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SCALE	AS SHOWN	PROJECT	Bremo Power Station Ash Pond Closure
DATE	Sep 2016	TITLE	NP-B, South Left - Pre-Closure Configuration Post-Liquefaction - Lower Bound Strengths Block Slip Surface Search
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CAD			
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REVIEW	GLH	FIGURE	10

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