PART III, ATTACHMENT 12

REPLACEMENT PAGES

CITY OF NACOGDOCHES LANDFILL
NACOGDOCHES COUNTY, TEXAS
TCEQ PERMIT NO. MSW 720

SITE DEVELOPMENT PLAN PART III

ATTACHMENT 12
FINAL CLOSURE PLAN

Prepared for:

City of Nacogdoches
P.O.Box 635030
Nacogdoches, Texas 75963

Prepared by:

CAS Engineering Services, Inc.
December 4, 2006

Revised by:

SCS ENGINEERS
TEXAS REGISTRATION NUMBER F-3407
Revision 1, December 2014
Revision 2, September 2019
Revision 3, January 2024

1/19/24
STATE OF TEXAS
JEFFREY K. REED
80103
LICENSED
PROFESSIONAL ENGINEER

FOR PERMITTING
PURPOSES ONLY

PART III, ATTACHMENT 12, APPENDIX C

REPLACEMENT PAGES

CITY OF NACOGDOCHES LANDFILL
NACOGDOCHES COUNTY, TEXAS

PART III, SITE DEVELOPMENT PLAN
ATTACHMENT 12, APPENDIX C

LINER AND FINAL COVER
STABILITY ANALYSIS

Prepared for:

Nacogdoches
the oldest town in Texas

CITY OF NACOGDOCHES
P.O. Box 635030
Nacogdoches, Texas 75963
(936) 559-2502

Prepared By:

SCS ENGINEERS
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281-293-8494

Revision 0 – June 2011
Revision 1 – July 2013
Revision 2 – September 2019/January 2020
Revision 3 – January 2024
SCS Project No. 16209006.26

STATE OF TEXAS
JEFFREY K. REED
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LICENSED
PROFESSIONAL ENGINEER
1/19/24

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APPENDICES

SCS Engineers
TBPE Reg. # F-3407

1/19/24

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80103
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1.0 SLOPE STABILITY ANALYSIS

This stability analysis has been provided to demonstrate through computerized modeling that the proposed liner system and grading configuration described in Section 1.1 will be stable under the worst case landfill configurations as defined below.

Slope stability analyses were performed to assess the stability of the proposed liner for the reconfigured Blocks P and O to be constructed at the landfill. The critical stability of mass waste and interior waste slopes of Block O and P were evaluated .

1.1 STABILITY ANALYSIS DURING FILLING

Analyses were performed to assess the stability of interior waste slopes for Block O. These analyses consider the liner systems as follows (from top to bottom):

- 24-inch thick layer of protective cover soil;
- geocomposite drainage layer;
- 60-mil high density polyethylene (HDPE) smooth (floor only) or textured (sideslope only) geomembrane; and
- 24-inch compacted clay liner (CCL) or a reinforced Geosynthetic Clay Liner (GCL).

Construction quality assurance/control procedures that will be implemented during installation of the protective cover, geocomposite, geomembrane and CCL or GCL are described in Attachment 10. Strength parameters and interface shear strengths are provided in Attachment 12, Appendix C-1.

A review of the floor grades and final cover contours was performed to determine the worst case conditions for Blocks O and P. A worst case condition was considered as a combination of greatest waste height, steepest floor grade directed downslope, or away from the interim waste slope, and interim waste slope angle. The slope of the floor liner system in Block O ranges from 2 to 5 percent towards the north as shown on Attachment 15, Drawing 15-2 of the landfill permit application. The worst case condition for an interim waste slope configuration occurs along Cross Section CC' at E12000, as shown in Figures 1 and 2 (from Drawing 2Y, titled "III.1.1.b Attachment 2 Fill Cross Section"). It is assumed that the maximum height of waste over the bottom liner system is approximately 46.2 feet as shown on Figure 2. Several worst-case scenario analyses were performed to determine the appropriate filling height and interim slope conditions for the representative floor grades along Cross Section CC'. These scenarios were listed in Table 1 of Appendix C-1. Due to steeper floor slopes in Block O, waste filling should progress from the low end to high end across the phases.

Since Block P is already filled above ground, and the entire liner area is filled, no interim waste analysis is needed.
The results of the most critical analyses are presented in Table 1 of Appendix C-1. The PCSTABL5M3 model output is provided in Appendix C-1 as well. The analyses demonstrate that smooth geomembrane/CCL or GCL liner systems on the floor is acceptable for all the phases under consideration if interior waste slopes are 3H:1V or flatter.

1.2 MASS WASTE STABILITY AT CLOSURE

Analyses were performed to assess the stability of exterior slopes at Closure. These analyses consider the same liner systems as in Section 1.1.

A review of the floor grades and final cover contours was performed to determine the worst case conditions. A worst case condition was considered as a combination of greatest waste height, steepest floor grade directed downslope, or away from the perimeter below grade sideslope, and shallowest below grade sideslope height.

The slope of the floor liner system in Block O ranges from 2 to 5 percent towards the north as shown on Attachment 15, Drawing 15-2 of the landfill permit application. The final grade sideslopes are 4:1 and 6:1. The worst case condition occurs along Cross Section AA' at E12000, as shown in Figure 2 (from Drawing 2Y, titled "III.1.1.b Attachment 2 Fill Cross Section"). The maximum height of waste over the liner system is approximately 57.5 feet along Cross Section AA'. Several worst-case scenario analyses were performed to determine the final waste filling stability for the representative floor grades along Cross Sections AA' (Figure 2, E12000) and B-B' (Figure 4, N6800). These slope section profiles are included in Appendix C-1.

For Block P, the slope of the floor liner system is approximately 2 percent towards the north as shown on Attachment 2, Drawing 2V-1 of the landfill permit application. It is assumed that the maximum height of waste over the bottom liner system is approximately 77 feet as shown on Figure 5. The worst-case scenario analysis was performed for the representative floor and fill grades along Cross Section DD'. This scenario is listed in Table 2 of Appendix C-1.

The results of the most critical analyses are presented in Table 2 of Appendix C-1. All factors of safety calculated are adequate to demonstrate the slope stability of the final waste slope conditions. The PCSTABL5M3 model output is provided in Appendix C-1 as well.

1.3 FINAL COVER VENEER STABILITY AT CLOSURE

The final cover was analyzed to ensure the prescriptive maximum slope and soil cap profile will present a stable configuration over the long term. The "worst case" slope (25%) was analyzed.

A static safety factor of 2.26 was obtained for 25-percent slopes given conservative assumptions. Calculations are included in Appendix C-2. This static safety factor listed is considered adequate to demonstrate final cover stability under dry slope condition. In the case of seismic safety factor, it was calculated to be 1.93, assuming dry slope conditions and under a seismic coefficient of 0.04g.

Under wet slope conditions of 6-inch of head, safety factors calculated for static and seismic conditions were 1.94 and 1.66, respectively. These safety factors are considered adequate to demonstrate final cover stability under wet condition.

PART III, ATTACHMENT 12, APPENDIX C-1

REPLACEMENT PAGES

APPENDIX C-1
WASTE SLOPE STABILITY CALCULATIONS AND RESULTS

SCS Engineers
TBPE Reg. # F-3407

1/19/24

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PROFESSIONAL ENGINEER

inclusive of pages C-1-1 to C-1-90.

SCS Engineers	WASTE SLOPE STABILITY-GM/CCL		
	Proj. No. 16209006.26	Made By: JKR	Date: 6/16/2011 rev 12/23
	Project: City of Nacogdoches Landfill	Checked By: JRM	Sheet 1 of 2

OBJECTIVE: Estimate the factor of safety against sliding for interior and exterior waste slopes.

GIVEN: Based on a review of the designed grades, the following worst-case conditions were identified:

Floor Grade	2.0% - 5%	
Maximum Interior Waste Slopes	33.0%	18.4 degrees
Maximum Waste Height		57.5 feet (Block O), 77 feet (Block P)
Liner System Evaluated (from top to bottom):	24" Protective Cover consisting of on-site soils Geocomposite Drainage Layer 60-mil HDPE Geomembrane 24" Compacted Clay Liner (CCL) [Block P and Block O, Cell 1 and 2 liner system. Alternate Liner for Block O, Cells 3-6]	

Based on a review of available data, the following parameters were assigned to the referenced materials.

Material	Strength Parameters		Unit Weight (pcf)		Reference
	Φ (deg)	C (psf)	moist	saturated	
Waste	33	500	65	75	Eid, et al. (2000)
Protective Cover	20	200	100	115	Est. for clay
Protective Cover/Geocomposite Interface	26	0	---	---	*
SS Geocomposite/Smooth Geomembrane Interface	8	0	---	---	*
DS Geocomposite/Textured Geomembrane Interface	28	0	---	---	*
Smooth Geomembrane/ CCL Interface	11	300	---	---	**
Textured Geomembrane/ CCL Interface	20	50	---	---	*
CCL/Subgrade Interface	20	200	100	115	Est. for clay

Notes:

* Unpublished testing data by Golder Associates, Inc. (attached)

** Based on shear strength parameters, the critical interface will be the SS geocomposite (geonet side) and smooth geomembrane.

METHOD: PCStabl5M3, Purdue University, 1985
Analyze the critical condition for block and circular failure surfaces.

RESULTS: See Tables 1 and 2, Appendix C-1

CONCLUSIONS: Using the estimated strength parameters and worst-case slopes, the analysis indicates that the interim and final waste slopes will remain stable under the configurations presented in Tables 1 and 2 for a FML/CCL liner.

SCS Engineers	WASTE SLOPE STABILITY-GM/GCL		
	Proj. No. 16209006.26	Made By: JKR	Date: 7/15/13 rev 12/23
	Project: City of Nacogdoches Landfill	Checked By: JRM	Sheet 2 of 2

OBJECTIVE: Estimate the factor of safety against sliding for interior and exterior waste slopes.

GIVEN: Based on a review of the designed grades, the following worst-case conditions were identified:

Floor Grade	2.0% - 5%	
Maximum Interior Waste Slopes	33.0%	18.4 degrees
Maximum Waste Height		57.5 feet (Block O)
Liner System Evaluated (from top to bottom):	24" Protective Cover consisting of on-site soils Geocomposite Drainage Layer 60-mil HDPE Geomembrane Reinforced Geosynthetic Clay Liner (GCL) [Alternate Block O, Cells 3-6 Liner system]	

Based on a review of available data, the following parameters were assigned to the referenced materials.

Material	Strength Parameters		Unit Weight (pcf)		Reference
	Φ (deg)	C (psf)	moist	saturated	
Waste	33	500	65	75	Eid, et al. (2000)
Protective Cover	20	200	100	115	Est. for clay
Protective Cover/Geocomposite Interface	26	0	---	---	*
SS Geocomposite/Smooth Geomembrane Interface	8	0	---	---	*
DS Geocomposite/Textured Geomembrane Interface	28	0	---	---	*
Smooth Geomembrane/ GCL Interface	10	60	---	---	**
Textured Geomembrane/ GCL Interface	20	140	---	---	**
GCL/Subgrade Interface	24	140	---	---	**

Notes:

* Unpublished testing data by Golder Associates, Inc. (attached)

** Direct shear testing data by CETCO Lining Technologies Group. (attached)

** Based on shear strength parameters, the critical interface will be the SS geocomposite (geonet side) and smooth geomembrane.

METHOD: PCStabl5M3, Purdue University, 1985
Analyze the critical condition for block and circular failure surfaces.

RESULTS: See Tables 1 and 2, Appendix C-1

CONCLUSIONS: Using the estimated strength parameters and worst-case slopes, and given the worst case friction interface remains unchanged for either a FML/CCL or a FML/GCL liner, the analysis indicates that the interim and final waste slopes will remain stable under the configurations presented in Tables 1 and 2 for a FML/GCL liner.

Table 1.
Waste Interim Slope Stability Analysis

Scenario	Section	File name	Failure Mode	Loading Condition	Factor of Safety
1 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section CC': 3:1 slope with no benches; waste height 46.2'	CCS2310	Circle	Static	2.95
		CBS2310	Block		2.73
2 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section CC': 3:1 slope with no benches; waste height 46.2'	CCE2320	Circle	Seismic = 0.04g	2.54
		CBE2320	Block		2.34
3 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section CC': 4:1 slope with no benches; waste height 46.2	CCS2330	Circle	Static	3.54
		CBS2330	Block		3.36
4 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section CC': 4:1 slope with no benches; waste height 46.2	CCE2340	Circle	Seismic = 0.04g	2.92
		CBE2340	Block		2.76

Table 2.
Mass Waste Final Slope Stability Analysis

Scenario	Section	File name	Failure Mode	Slope Modeled/Loading Condition	Factor of Safety
1 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section AA': 4:1 final slope with no benches; waste height 57.5'	ACS2310	Circle	Localized exterior waste slope / Static	3.68
		ABS2310	Block		3.35
2 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section AA': 4:1 final slope with no benches; waste height 57.5'	ACE2320	Circle	Localized exterior waste slope / Seismic = 0.04g	3.10
		ABE2320	Block		2.83
3 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section AA': 4:1 final slope with no benches; waste height 57.5'	ABS2330	Block	Global exterior waste slope / Static	13.39
		ABE2330	Block	Global exterior waste slope / Seismic = 0.04g	5.76
4 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section BB': 4:1 final slope with no benches; waste height 56.3'	BCS2340	Circle	Localized exterior waste slope / Static	4.74
		BBS2340	Block		3.79
5 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section BB': 4:1 final slope with no benches; waste height 56.3'	BCE2350	Circle	Localized exterior waste slope / Seismic = 0.04g	3.78
		BBE2350	Block		2.99
6 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section BB': 4:1 final slope with no benches; waste height 56.3'	BBS2360	Block	Global exterior waste slope / Static	9.43
		BBE2360	Block	Global exterior waste slope / Seismic = 0.04g	5.00

Scenario	Section	File name	Failure Mode	Slope Modeled/Loading Condition	Factor of Safety
7 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section DD': 4:1 final slope with no benches; waste height 77'	DCS100	Circle	Localized exterior waste slope / Static	3.85
		DBS100	Block		3.48
8 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section DD': 4:1 final slope with no benches; waste height 77'	DCE100	Circle	Localized exterior waste slope / Seismic = 0.04g	3.12
		DBE100	Block		2.82
8 Single-sided GC, FML-Smooth on base floor, FML-Tex on sideslope	Section DD': 4:1 final slope with no benches; waste height 77'	DBS200	Block	Global exterior waste slope / Static	3.93
		DBE200	Block	Global exterior waste slope / Seismic = 0.04g	3.02

SECTION LOCATION PLAN & PROFILES

Figure 1. Section Location Plan for Section CC'

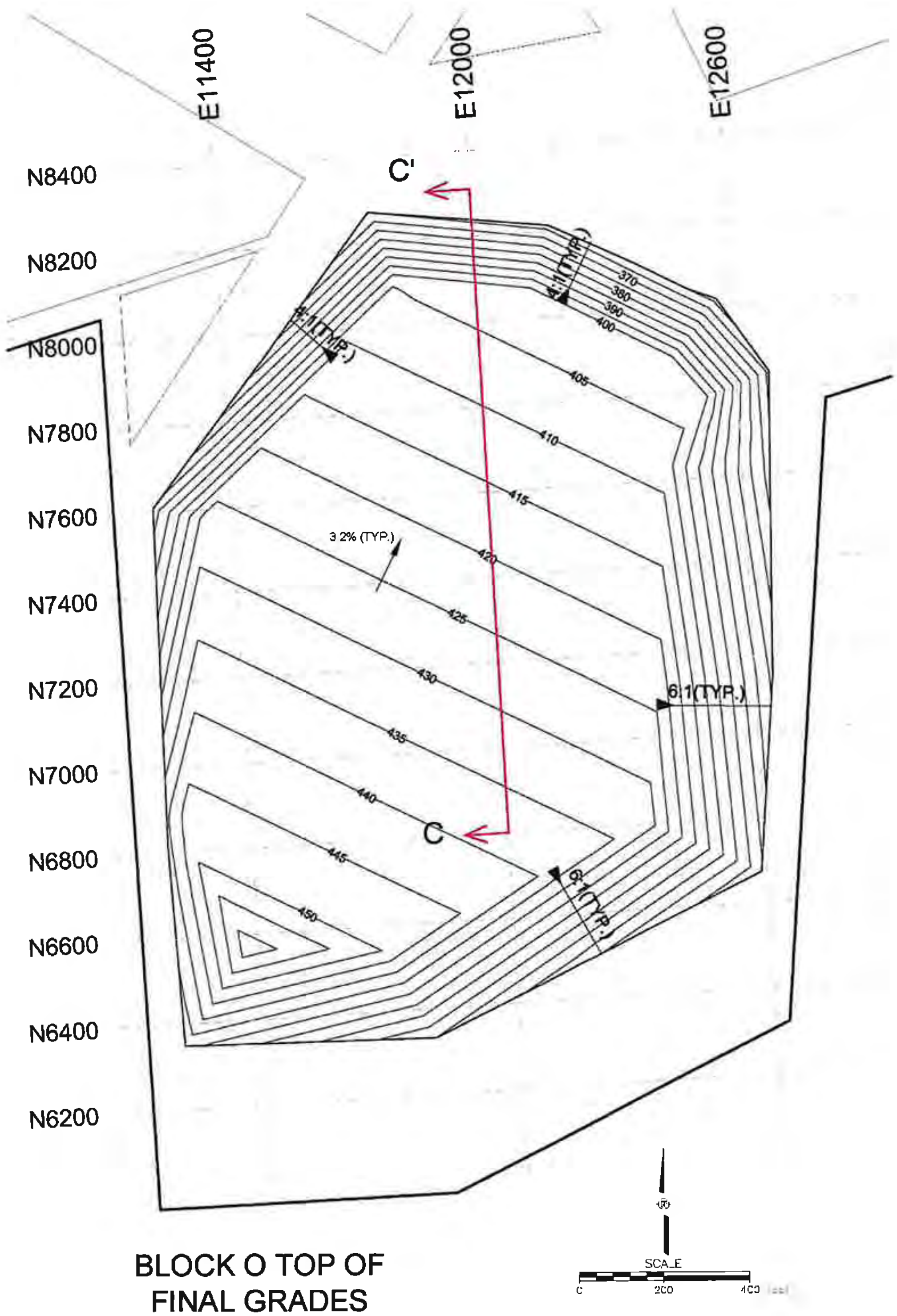


Figure 2. Section Profiles for Section AA' & CC'

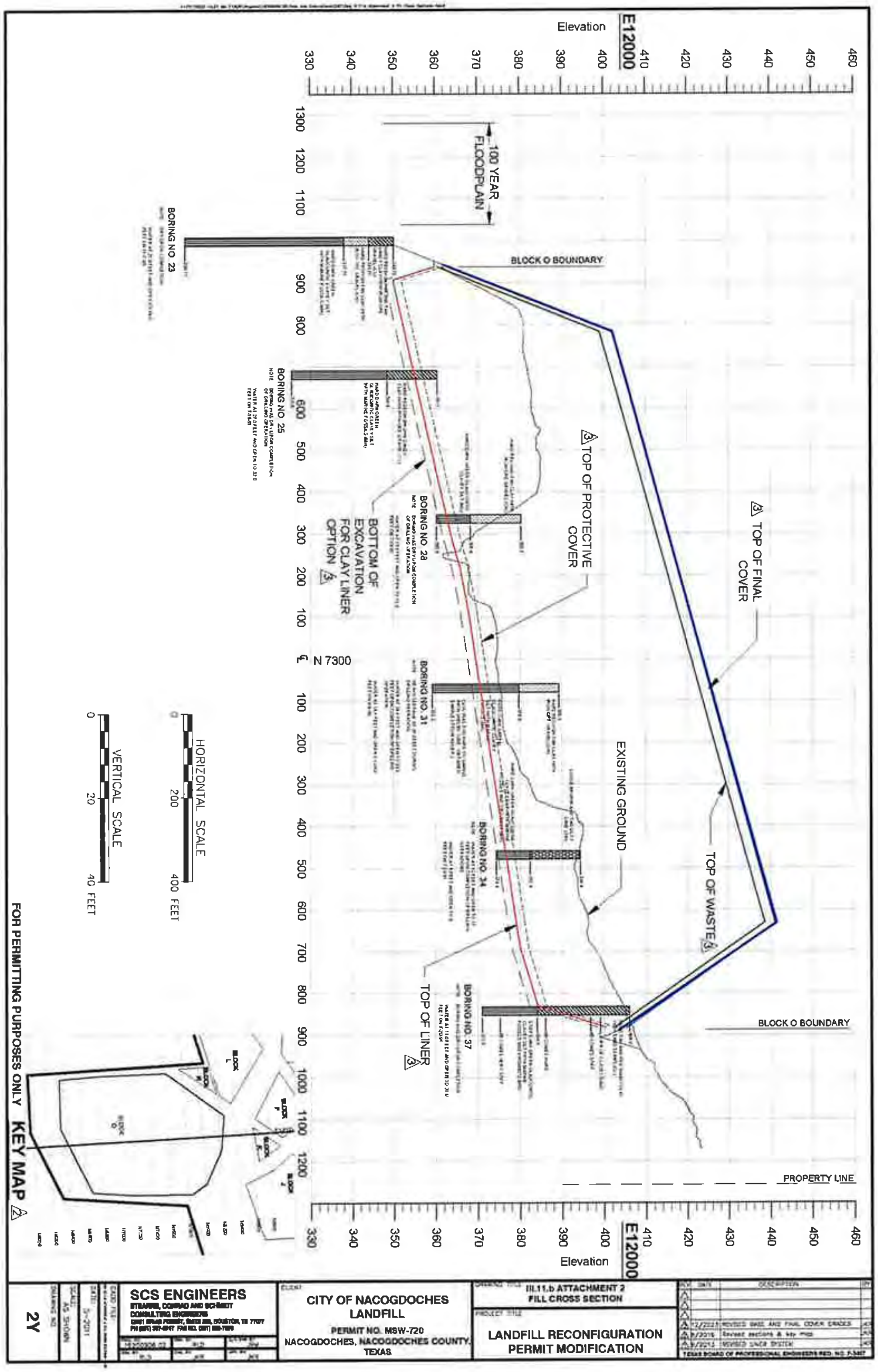


Figure 3. Section Location Plan (section AA' & BB')

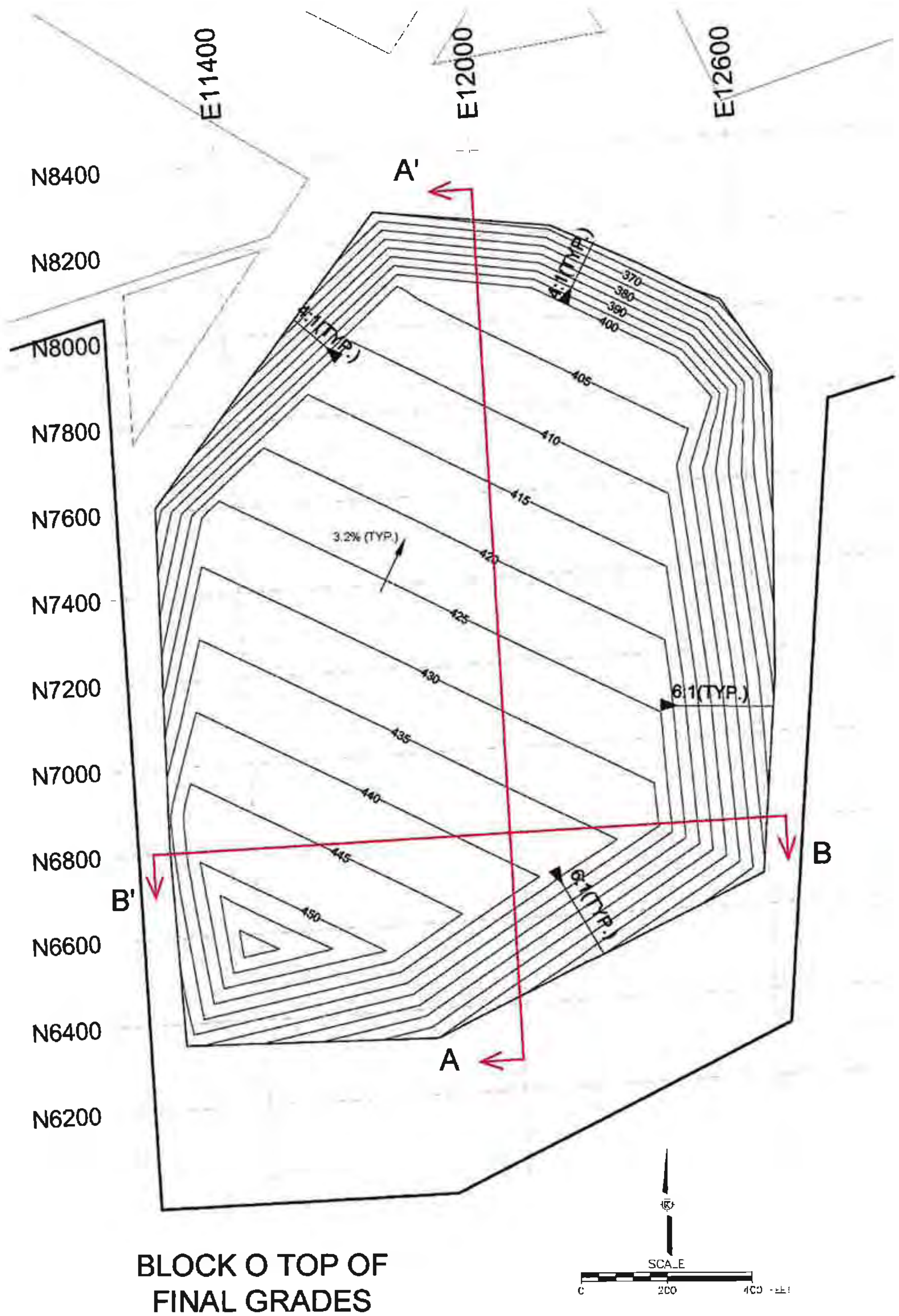


Figure 4. Section Profile BB'

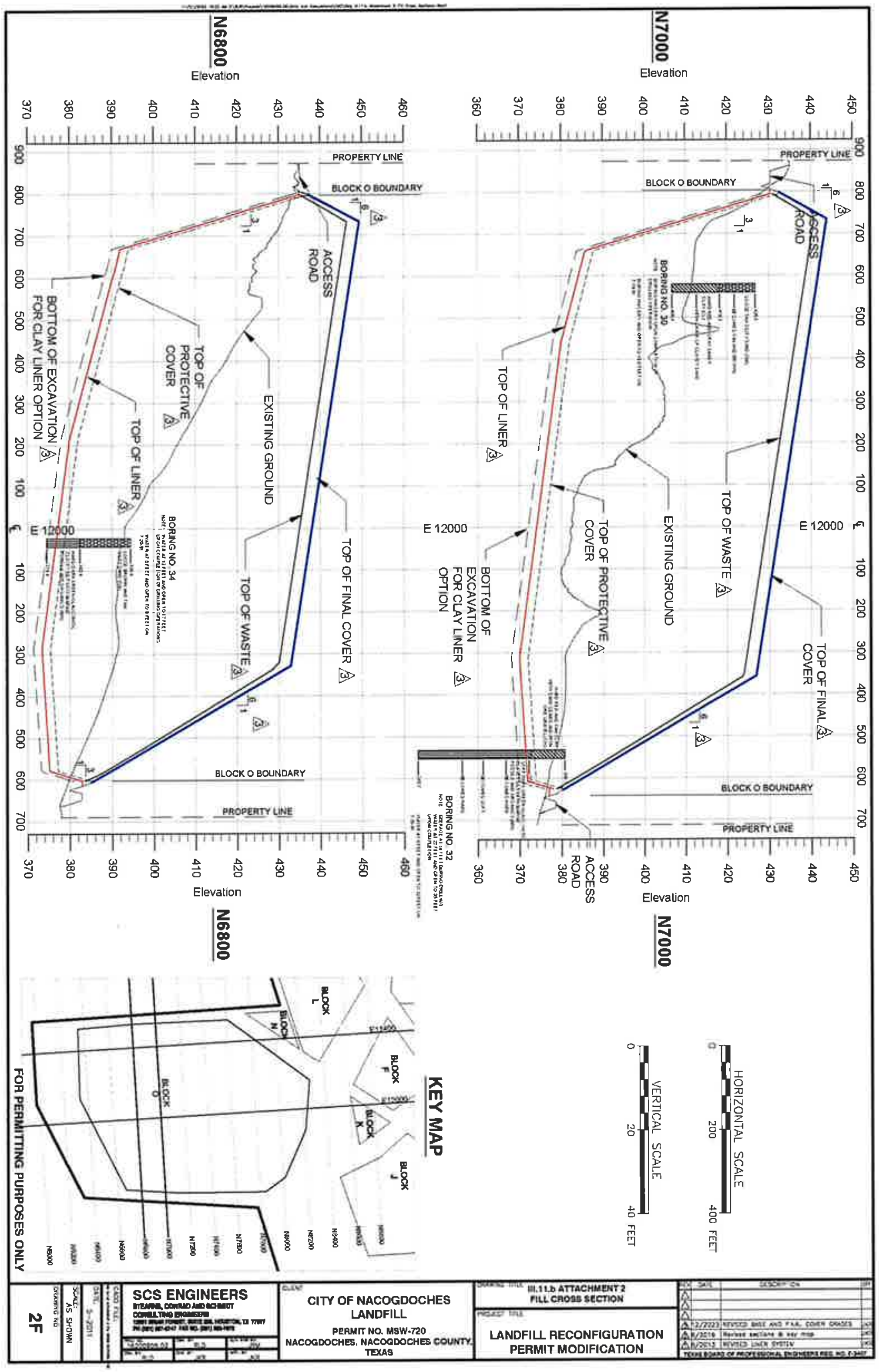
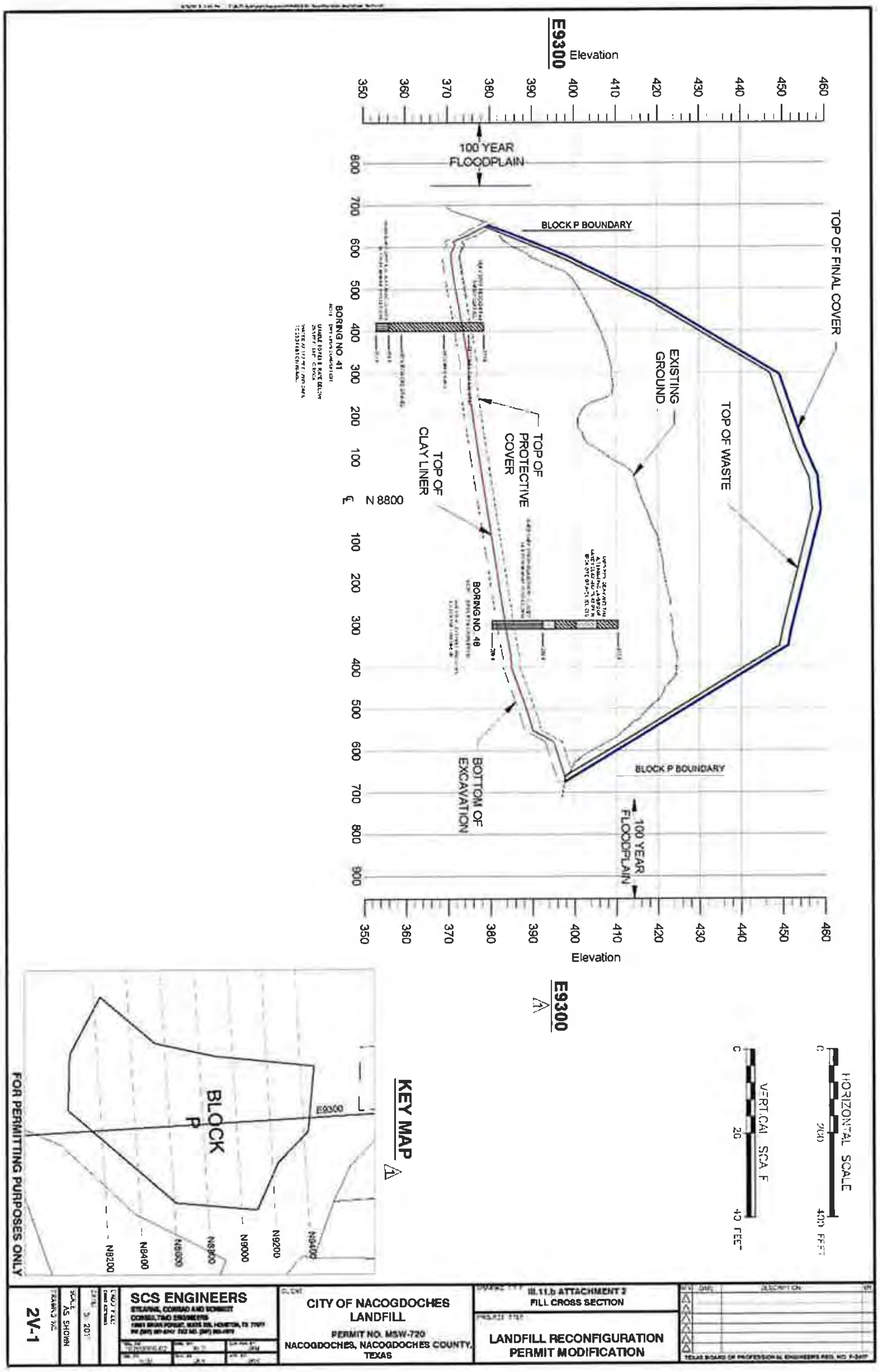


Figure 5. Section Profiles for Section DD'

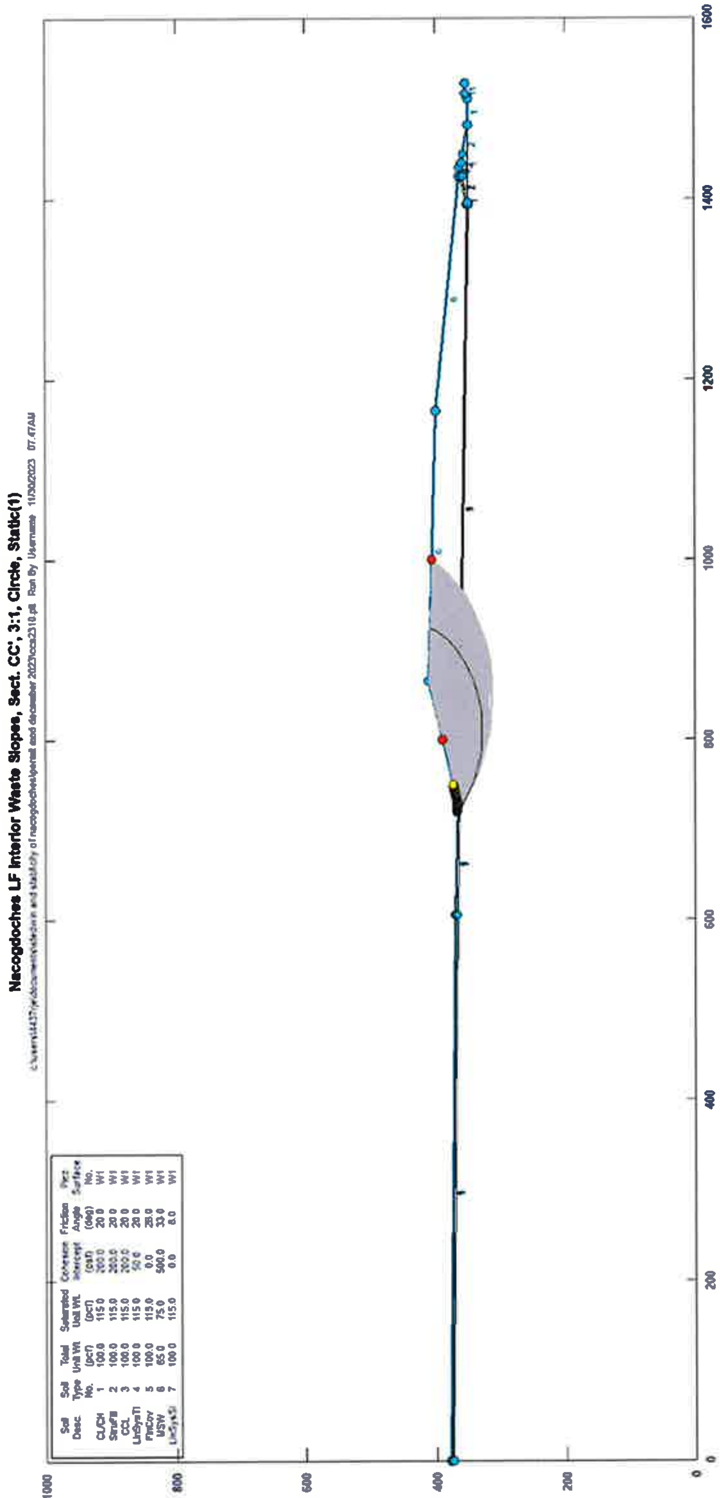


WASTE INTERIM SLOPE (3:1)

SECTION CC'

Circular Failure Surface

Static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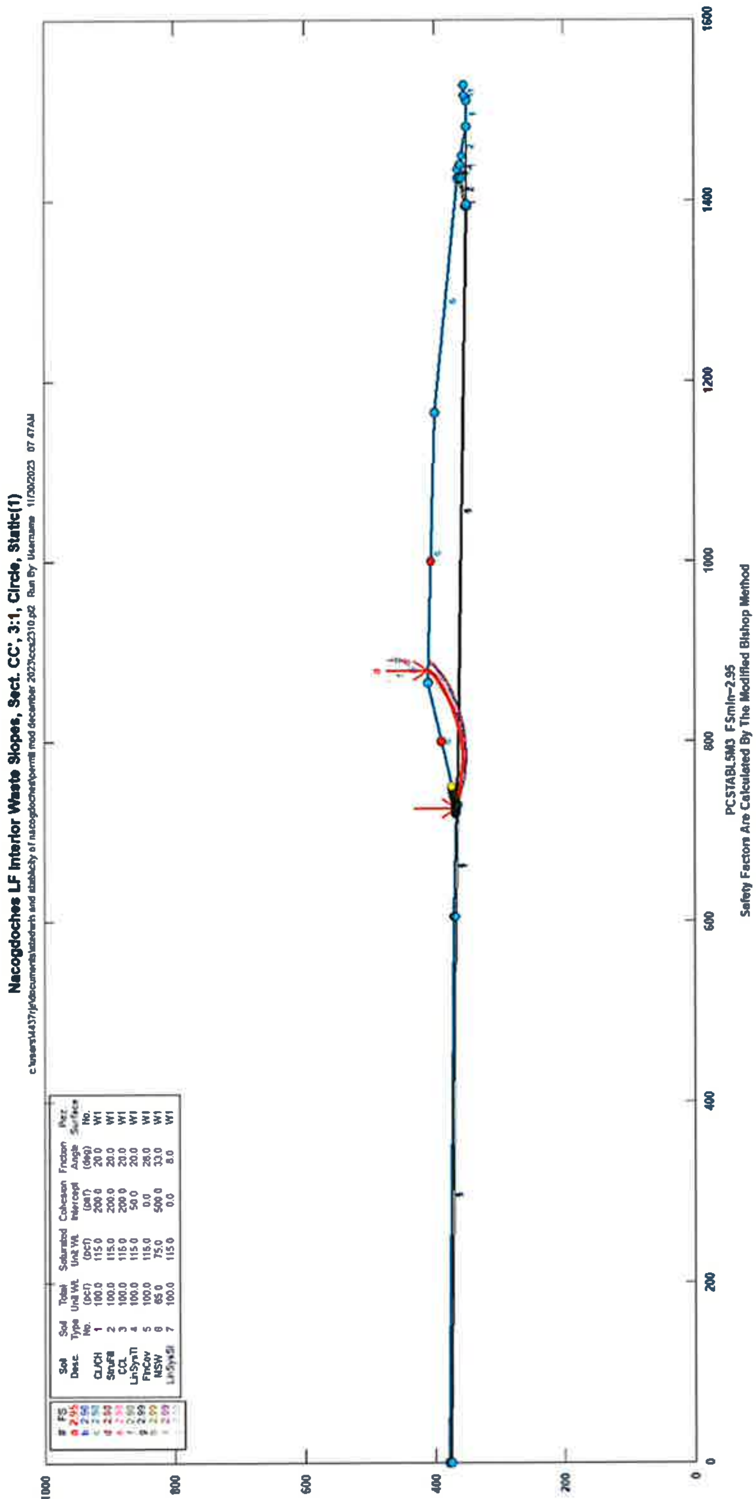
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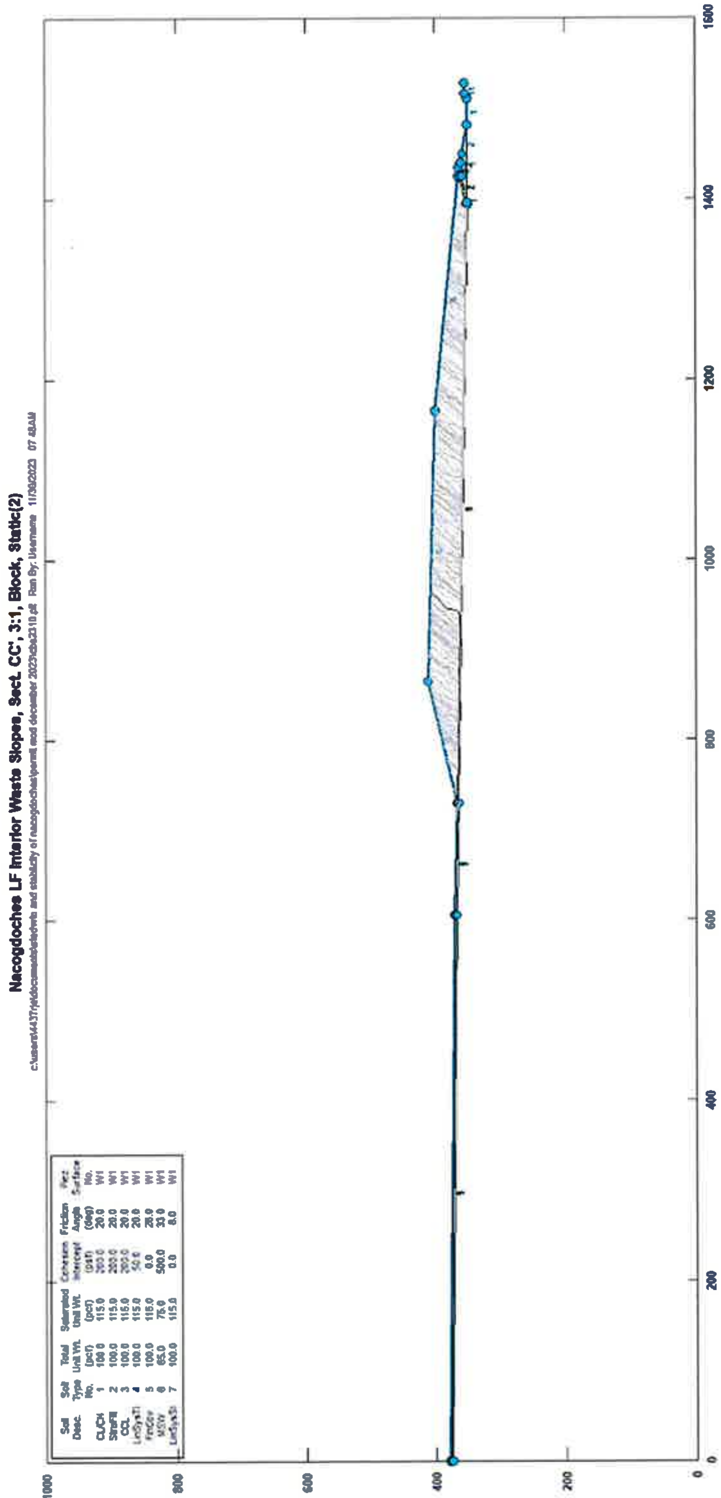
WASTE INTERIM SLOPE (3:1)

SECTION CC'

Block Failure Surface

Static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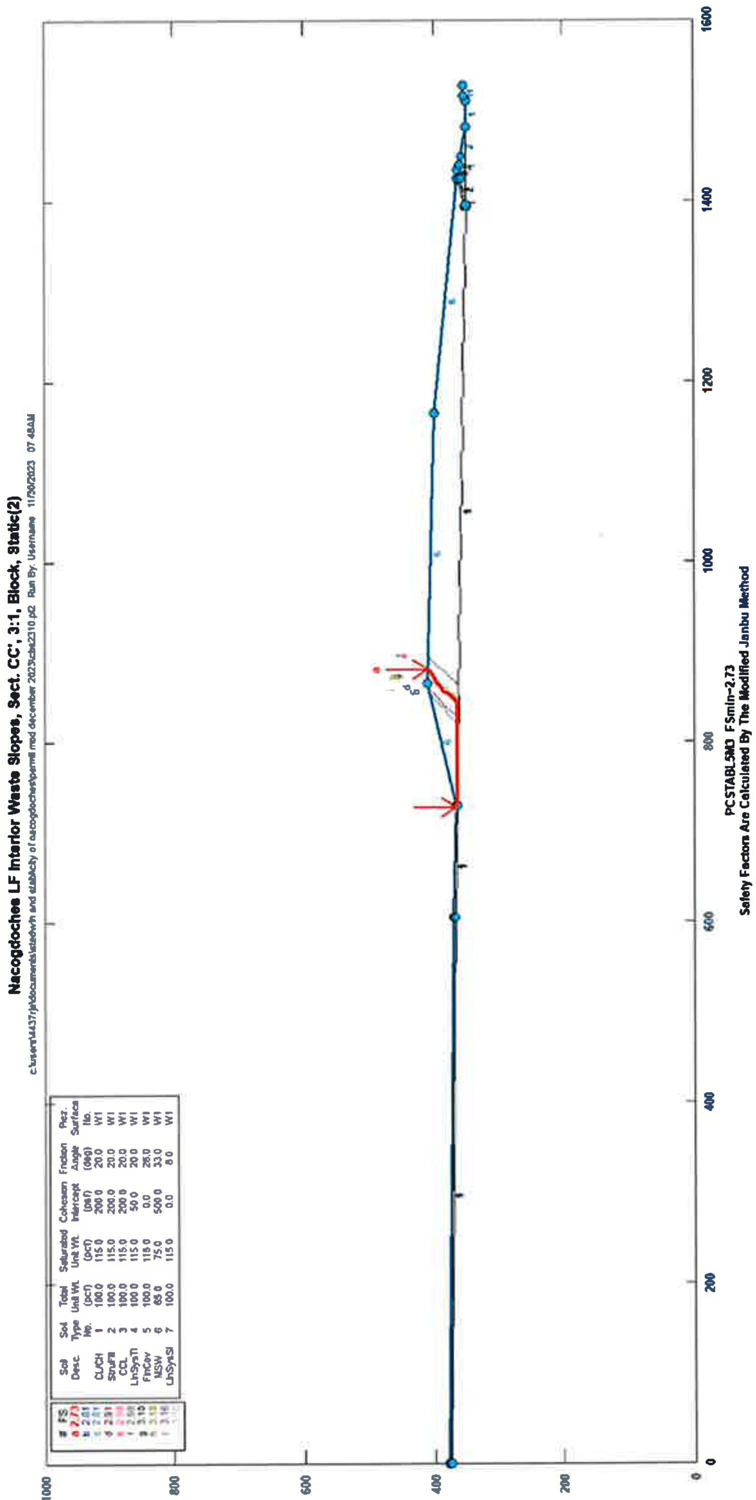
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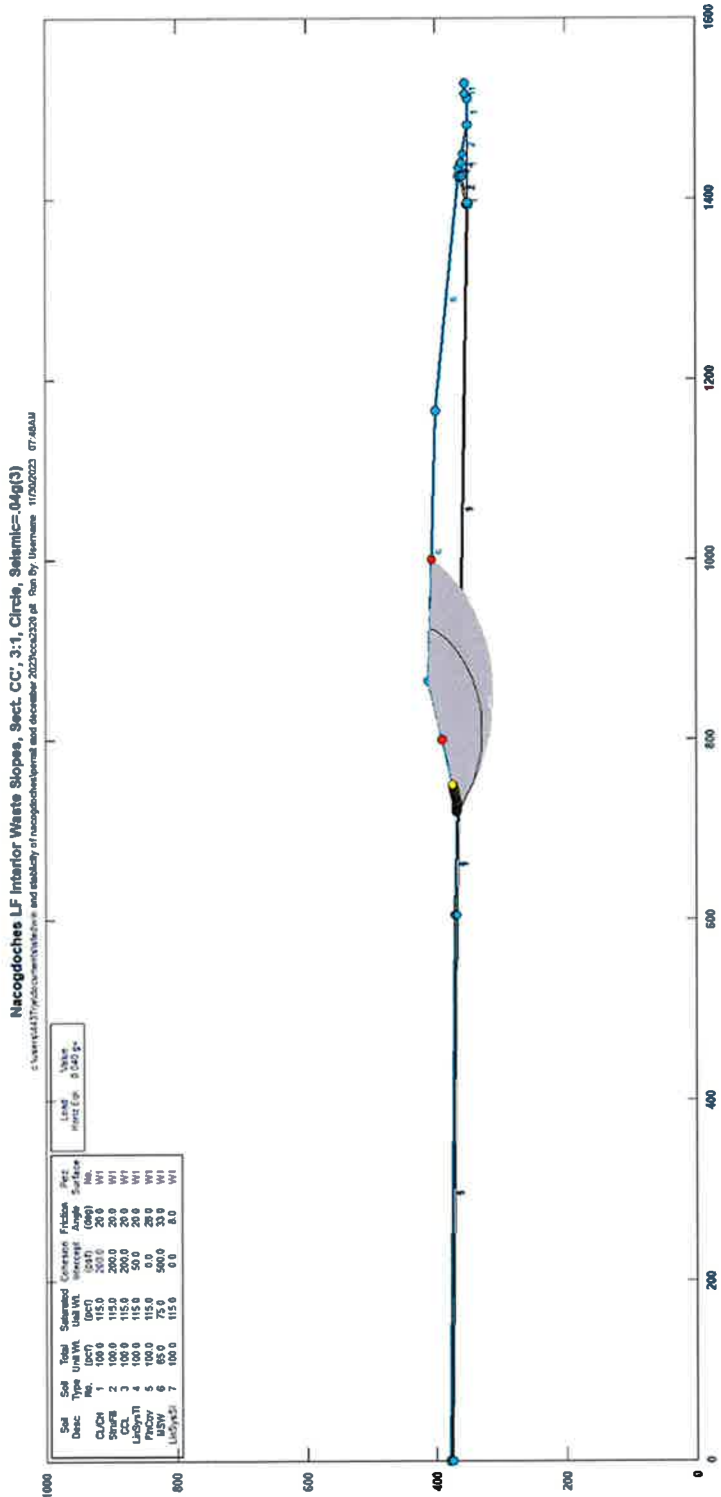
Safety Factors Are Calculated By The Modified Janbu Method

WASTE INTERIM SLOPE (3:1)

SECTION CC'

Circular Failure Surface

Seismic = 0.04g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StruFill 2 100.0 115.0 200.0 20.0 W1
CCL 3 100.0 115.0 200.0 20.0 W1
LinSysTl 4 100.0 115.0 50.0 20.0 W1
FinCov 5 100.0 115.0 0.0 28.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
LinSysSl 7 100.0 115.0 0.0 8.0 W1
Load Value
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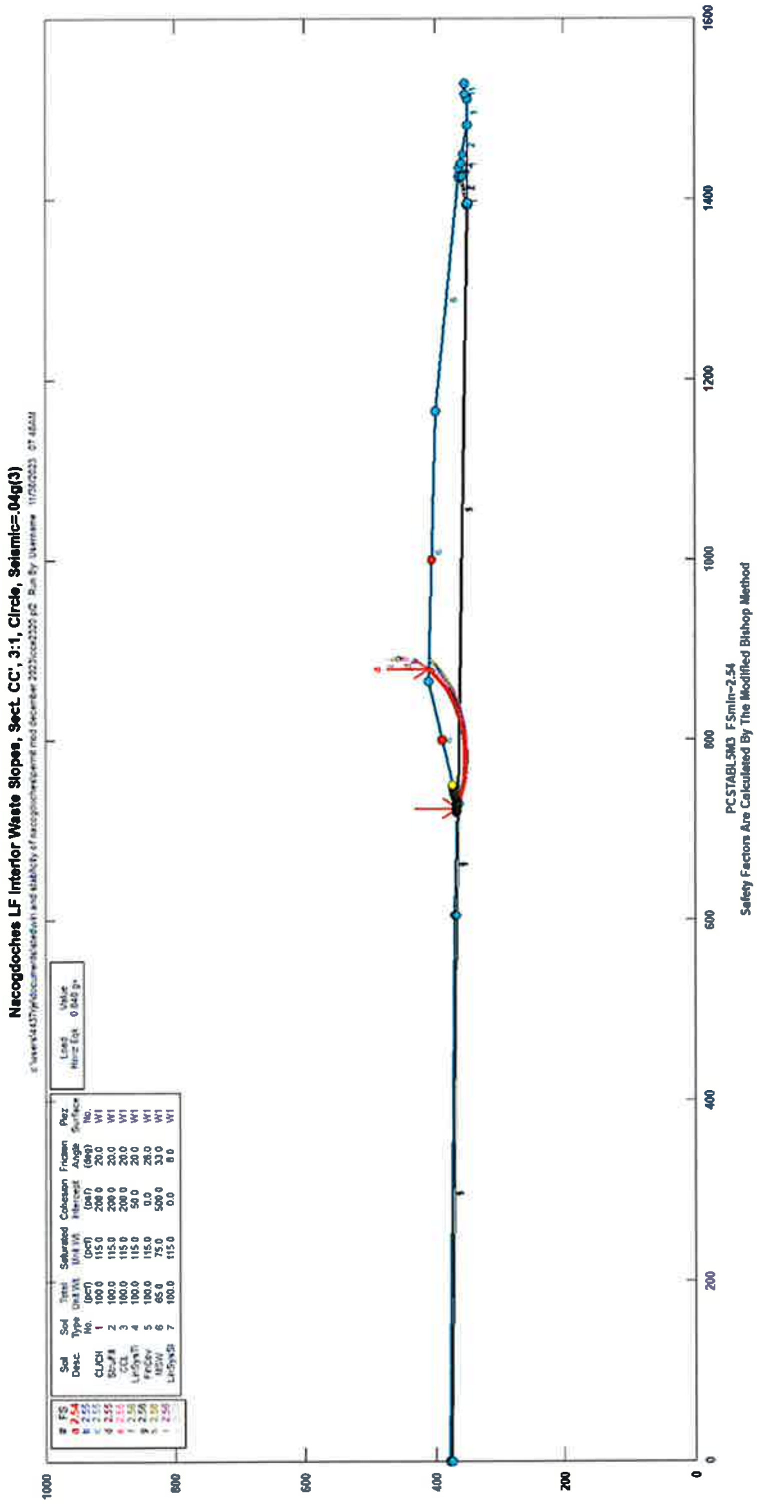
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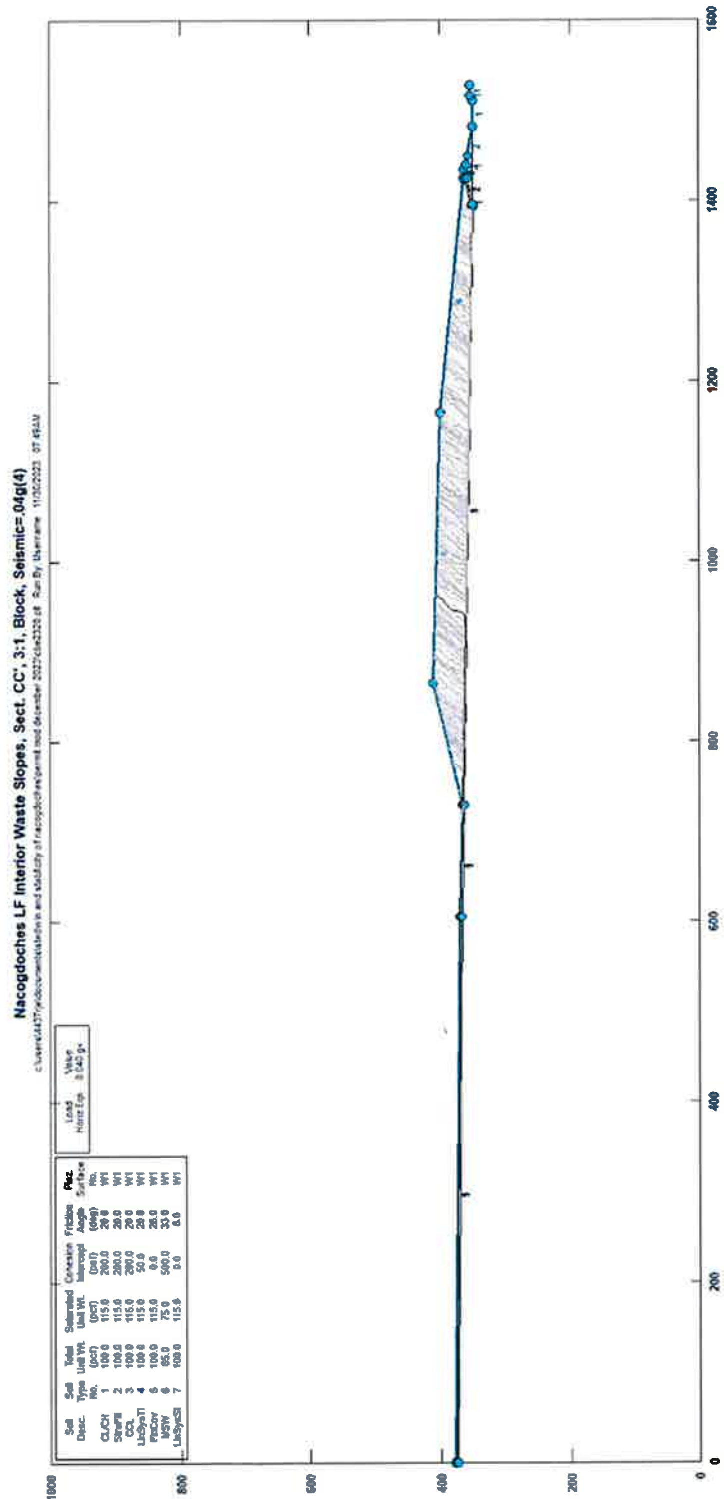
Safety Factors Are Calculated By The Modified Bishop Method

WASTE INTERIM SLOPE (3:1)

SECTION CC'

Block Failure Surface

Seismic = 0.04g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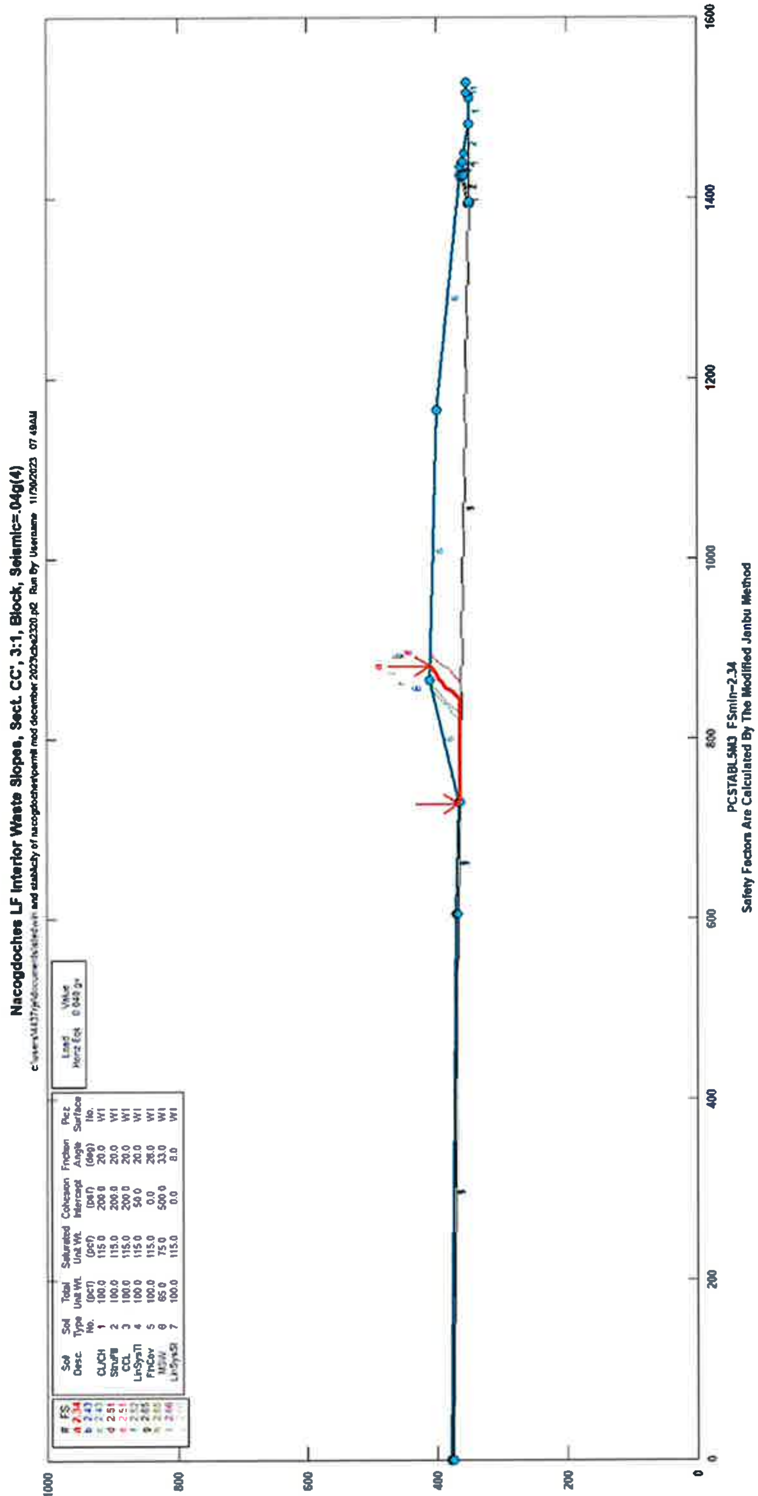
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CL/CH 1 100.0 115.0 200.0 20.0 W1
StruFill 2 100.0 115.0 200.0 20.0 W1
CCL 3 100.0 115.0 200.0 20.0 W1
LinSysTl 4 100.0 115.0 50.0 20.0 W1
FnCov 5 100.0 115.0 0.0 28.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
LinSysSl 7 100.0 115.0 0.0 8.0 W1
Load Value
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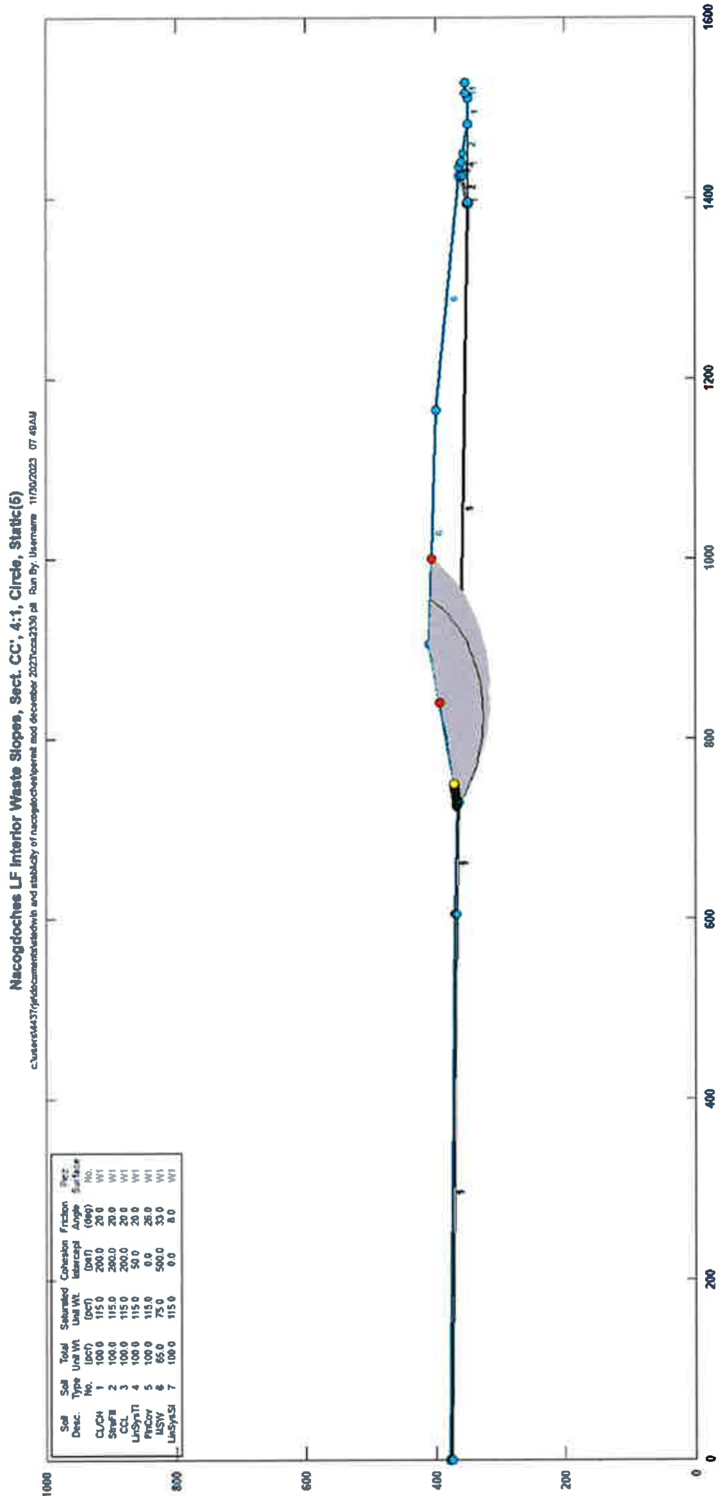
WASTE INTERIM SLOPE (4:1)

SECTION CC'

Global, Circular Failure Surface

Static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CCL 3 100.0 115.0 200.0 20.0 W1
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PtnCov 5 100.0 115.0 0.0 26.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
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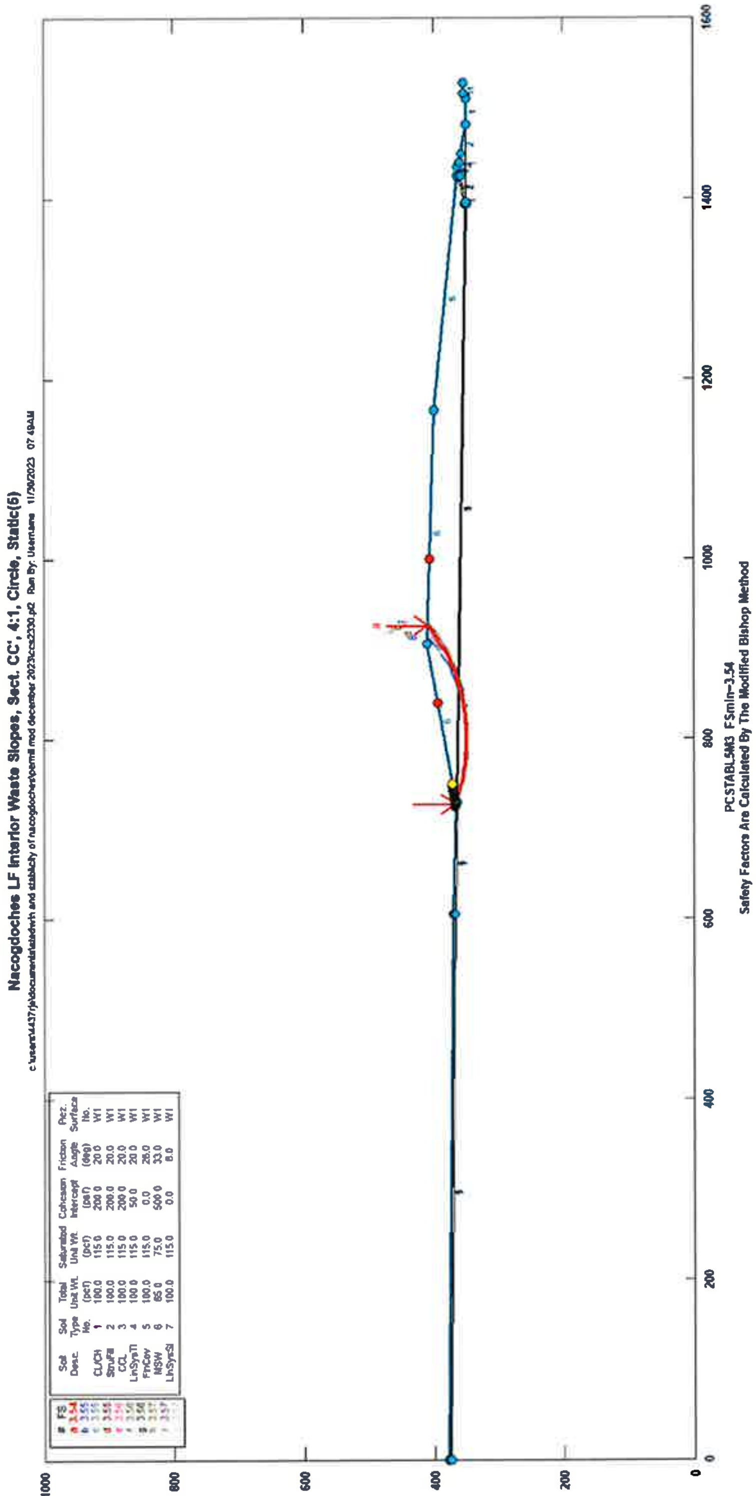
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Safety Factors Are Calculated By The Modified Bishop Method
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WASTE INTERIM SLOPE (4:1)

SECTION CC'

Global, Block Failure Surface

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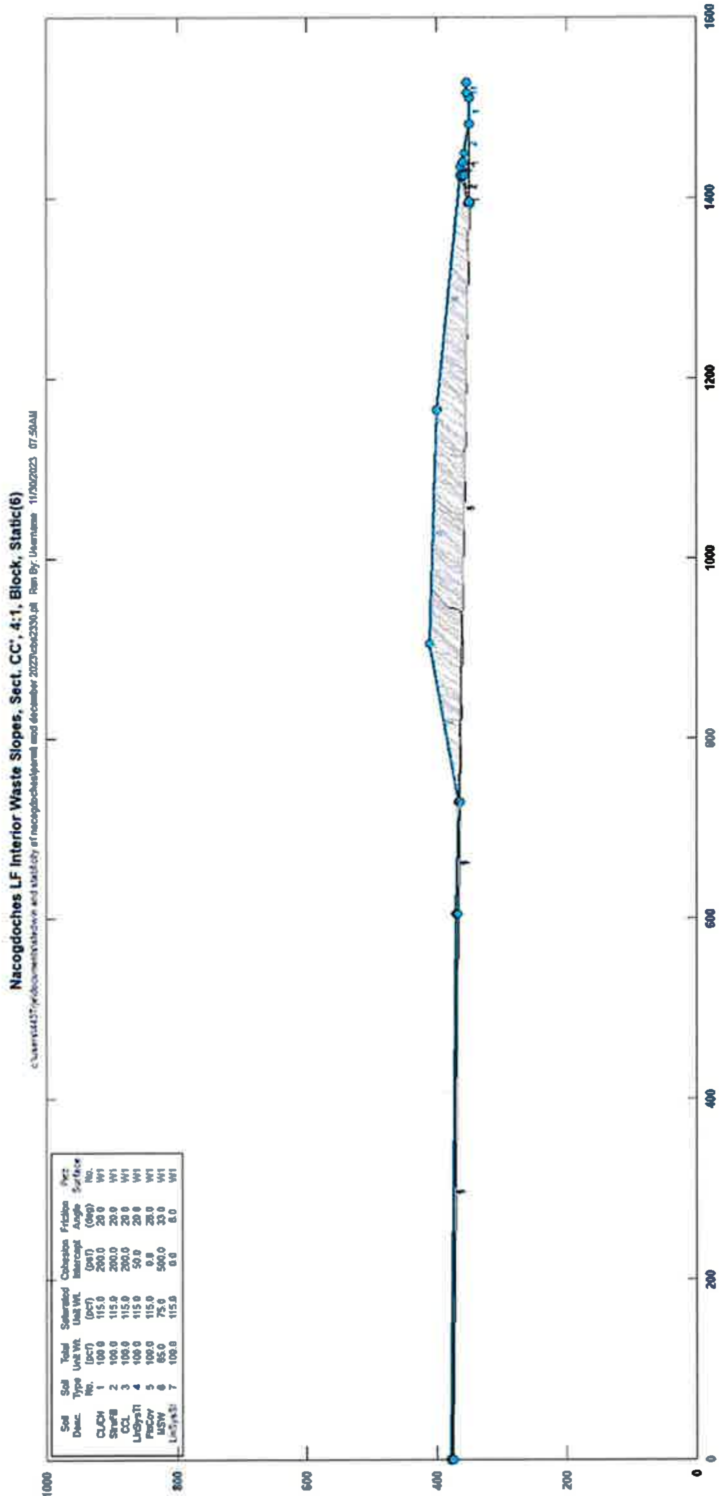
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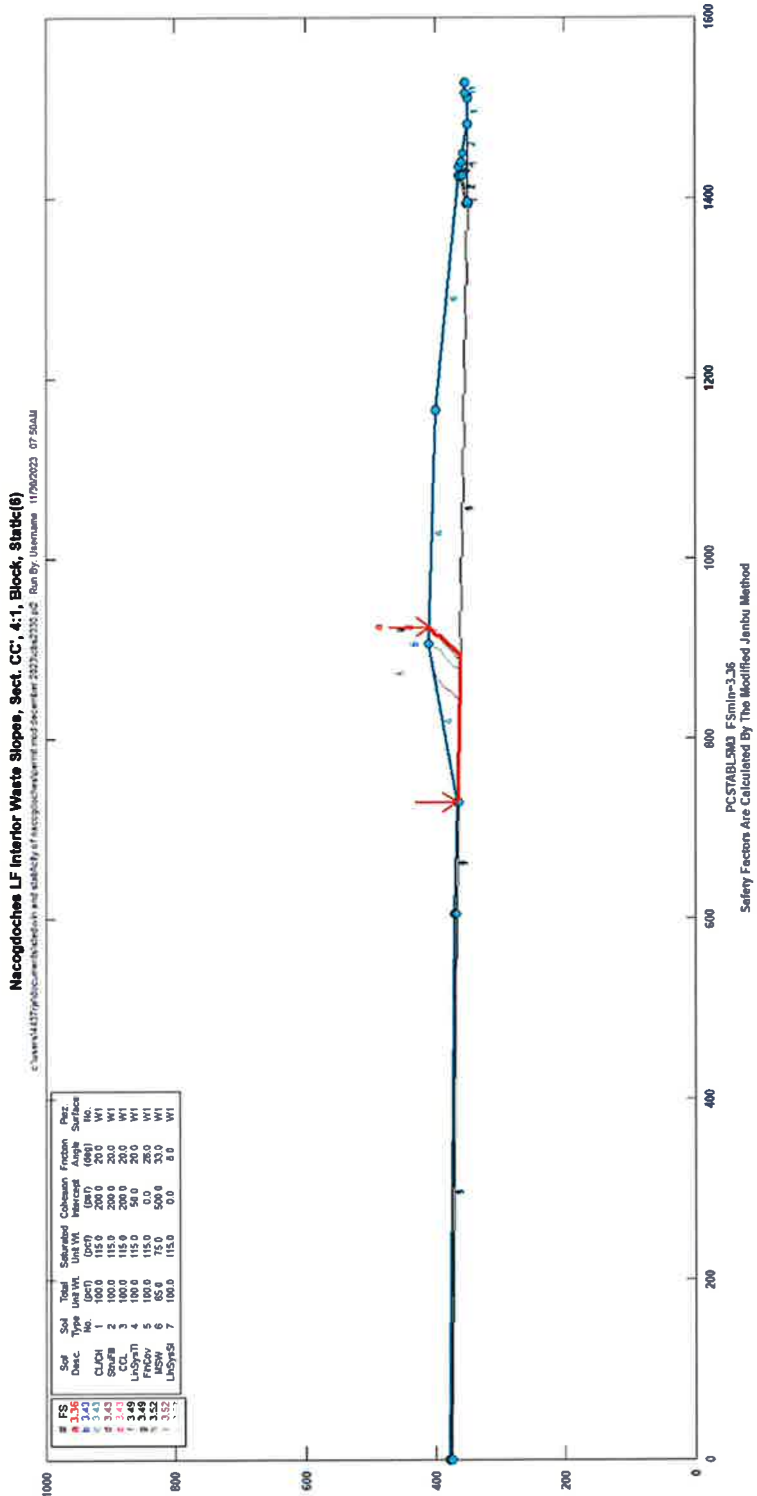
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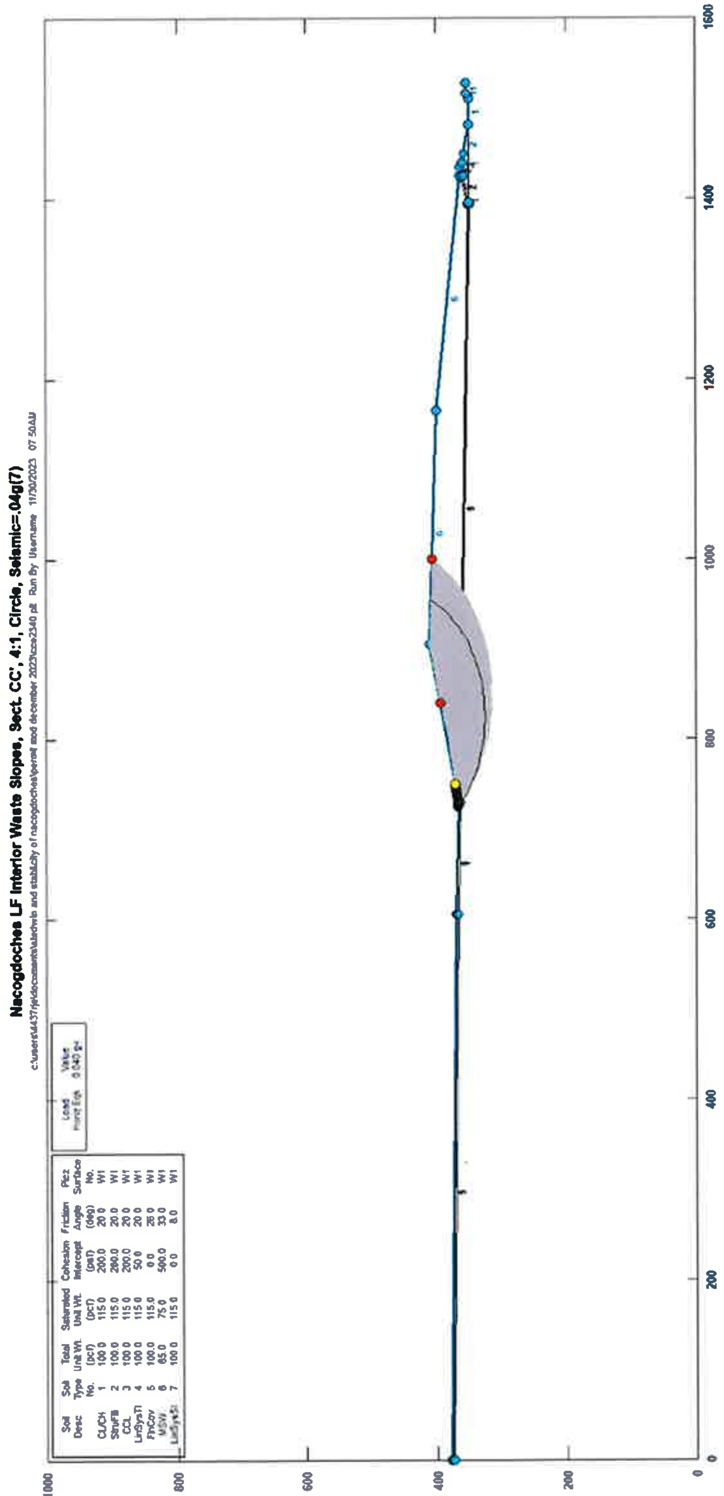
PCSTABL5M3 FSmin=3.36
Safety Factors Are Calculated By The Modified Janbu Method

WASTE INTERIM SLOPE (4:1)

SECTION CC'

Global, Circular Failure Surface

Seismic = 0.04g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Horiz Eqk 0.040 g<
Soil Desc
Soil Type No.
Total Unit Wt. (pcf)
Saturated Unit Wt. (pcf)
Cohesion Intercept (psf)
Friction Angle (deg)
Piez Surface No.
CL/CH 1 100.0 115.0 200.0 20.0 W1
StrucFill 2 100.0 115.0 200.0 20.0 W1
CCL 3 100.0 115.0 200.0 20.0 W1
LinSysTl 4 100.0 115.0 50.0 20.0 W1
FnCov 5 100.0 115.0 0.0 28.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
LinSysSl 7 100.0 115.0 0.0 8.0 W1
0
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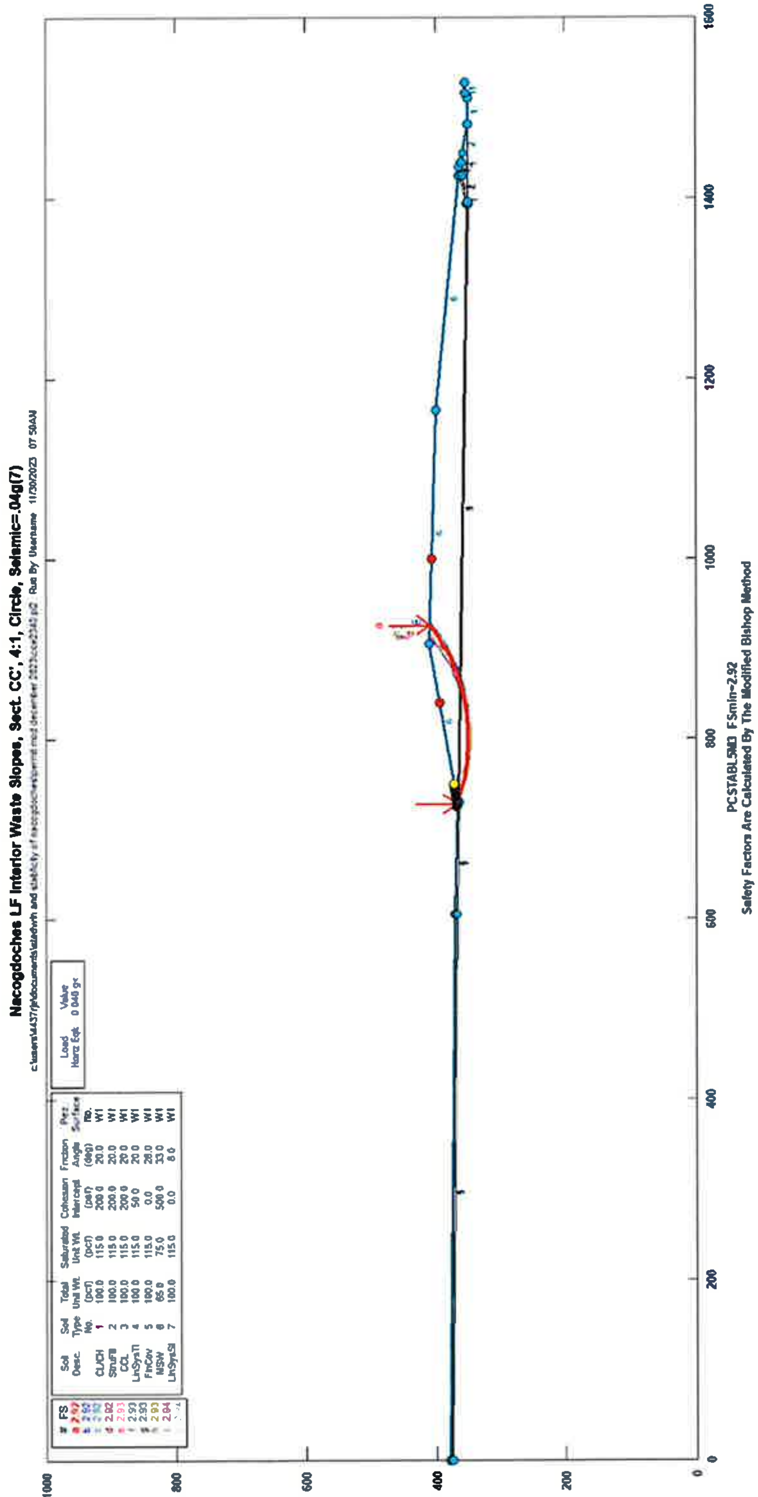
800
1000
1200
1400
1600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Horz Eqk 0.040 g<
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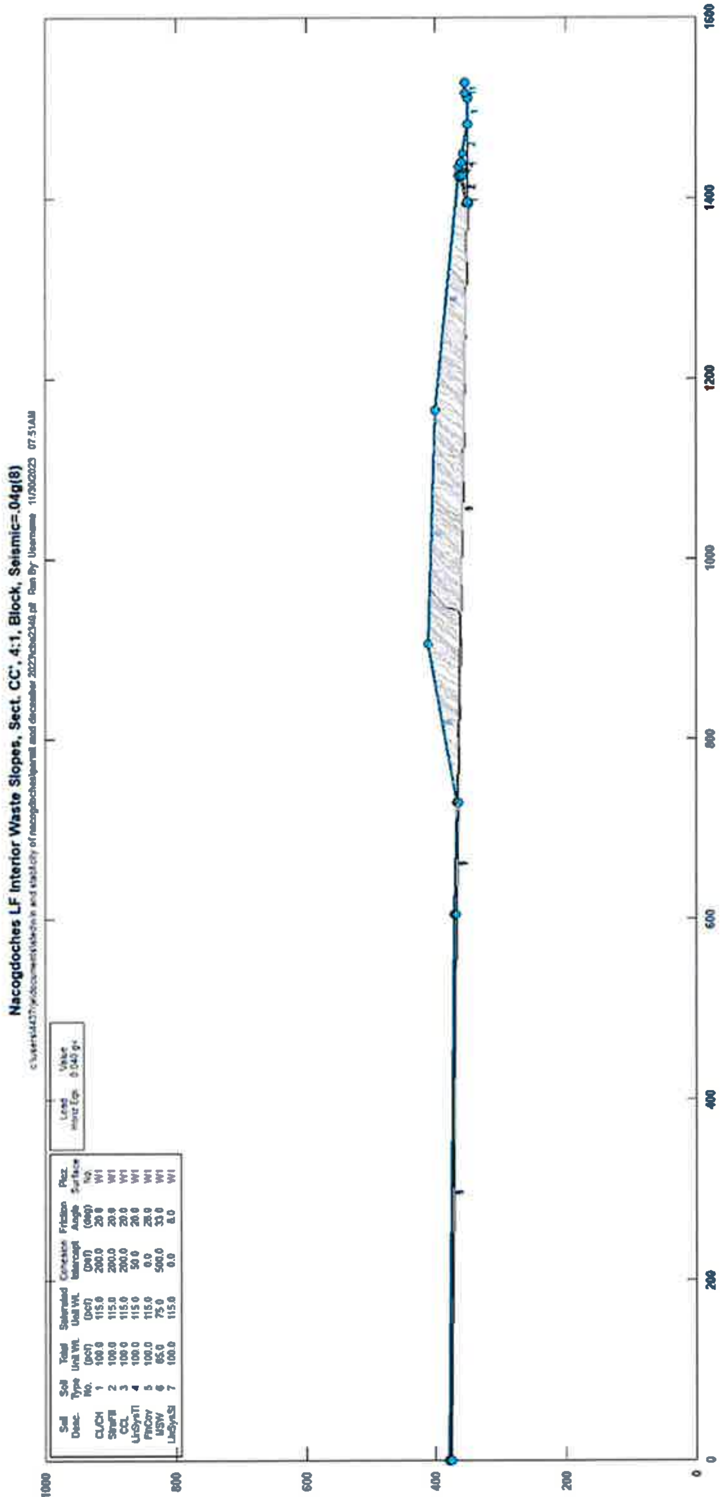
CL/CH 1 100.0 115.0 200.0 20.0 W1
StruFill 2 100.0 115.0 200.0 20.0 W1
CCL 3 100.0 115.0 200.0 20.0 W1
LinSysTl 4 100.0 115.0 50.0 20.0 W1
FinCov 5 100.0 115.0 0.0 28.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
LinSysSl 7 100.0 115.0 0.0 8.0 W1
FS
2.92
2.92
2.92
2.92
2.93
2.93
2.93
2.93
2.94
0
200
400
600
800
1000
1200
1400
1600
PCSTABL5M3 FSmin=2.92
Safety Factors Are Calculated By The Modified Bishop Method

WASTE INTERIM SLOPE (4:1)

SECTION CC'

Global, Block Failure Surface

Seismic = 0.04g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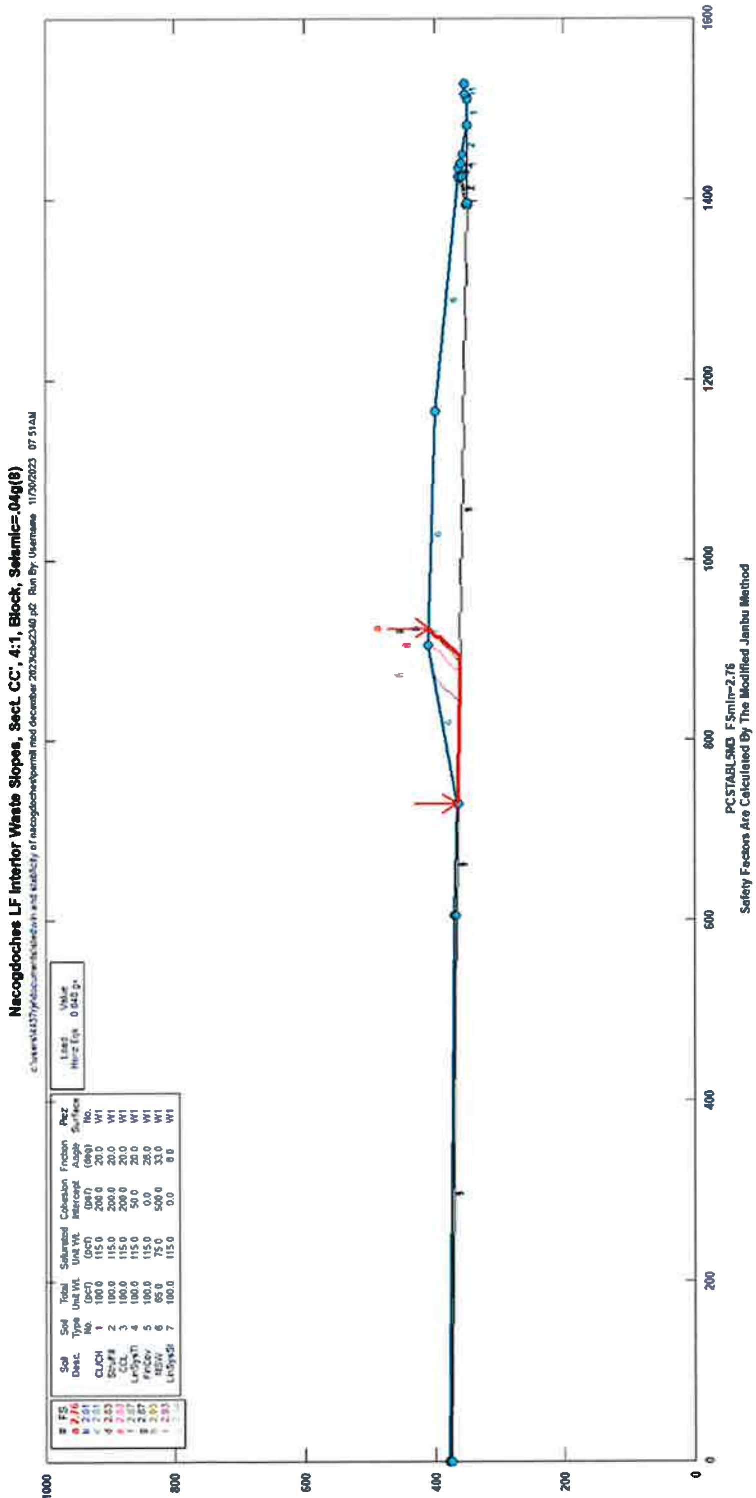
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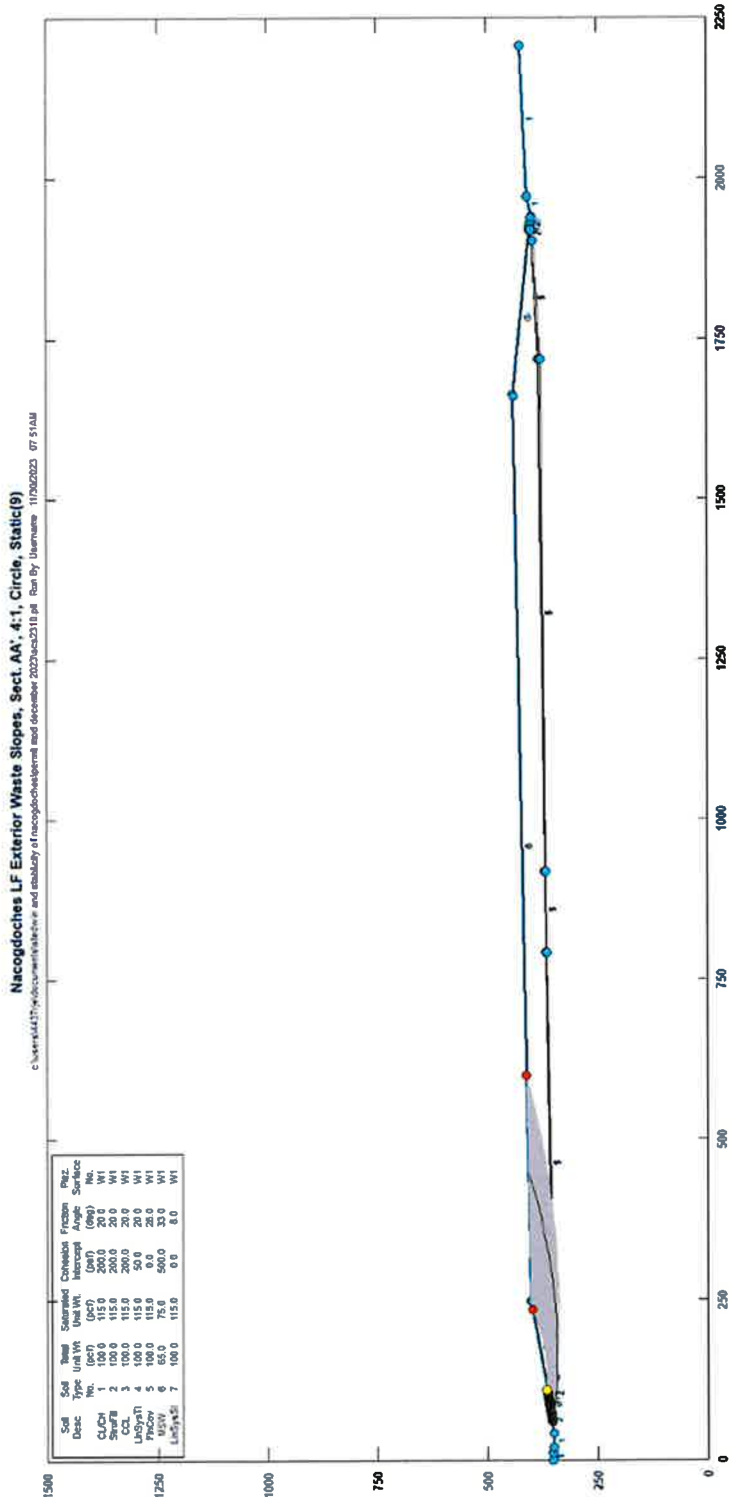
Safety Factors Are Calculated By The Modified Janbu Method
0
200
400
600
800
1000
1200
1400
1600

WASTE FINAL SLOPE

SECTION AA'

Circular Failure Surface

Static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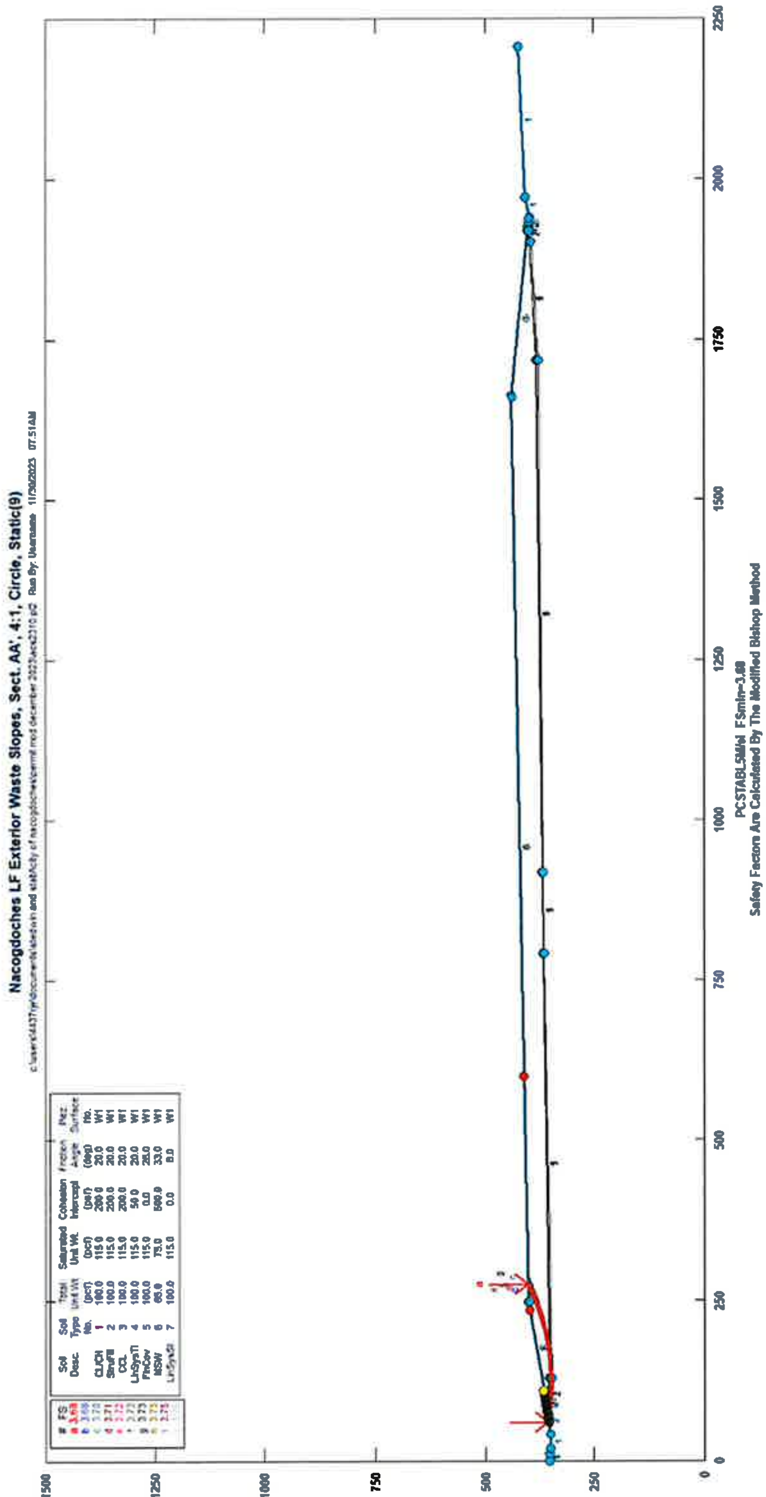
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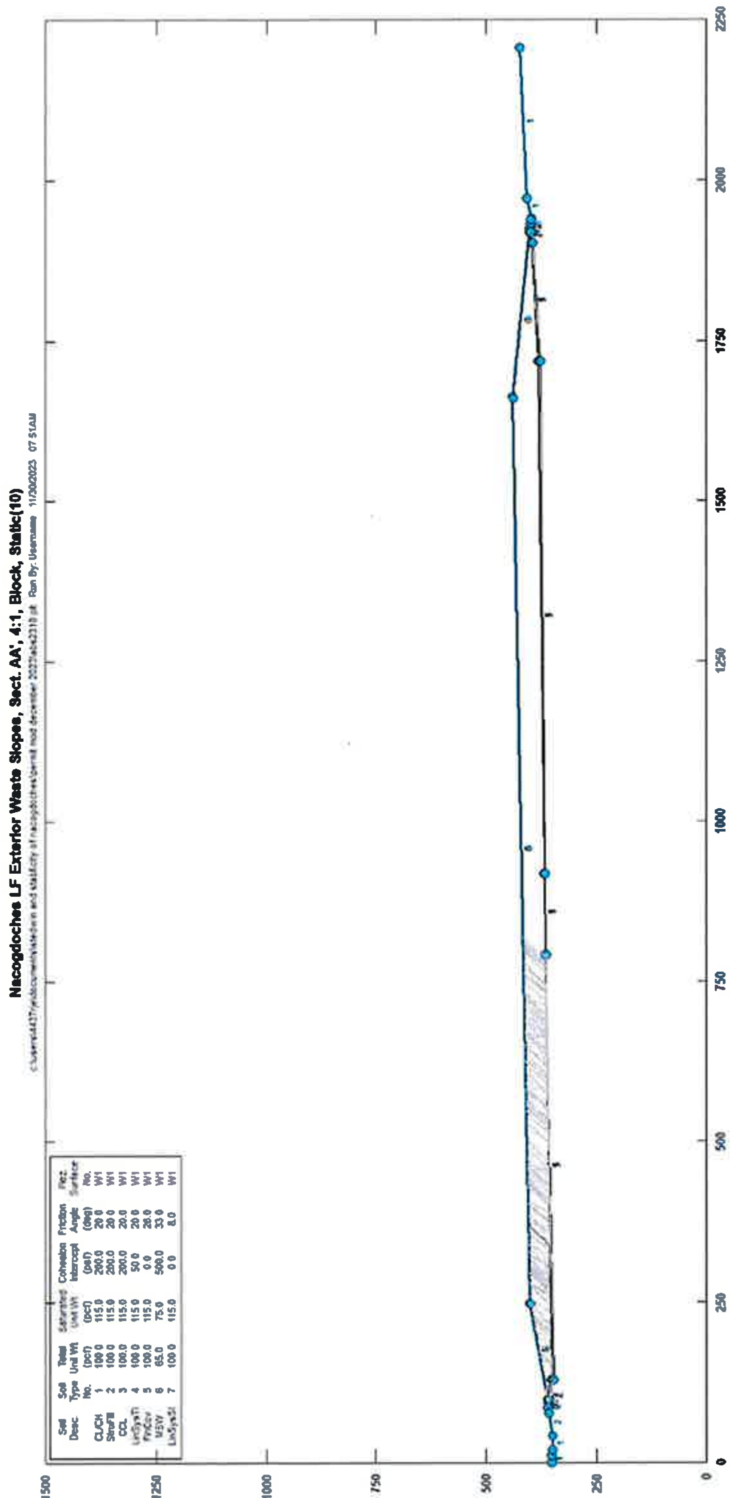
WASTE FINAL SLOPE

SECTION AA'

Block Failure Surface

Static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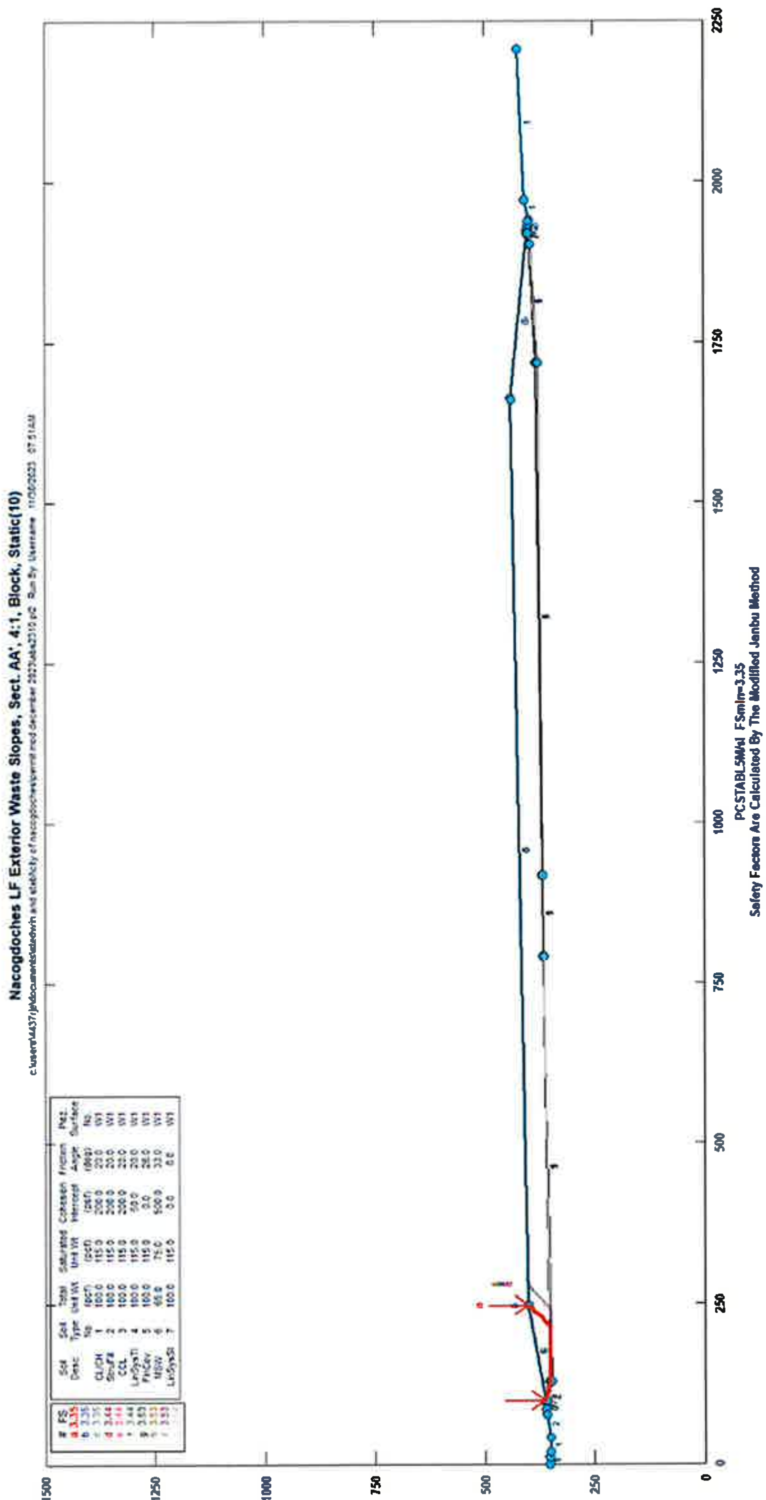
500
750
1000
1250
1500
1750
2000
2250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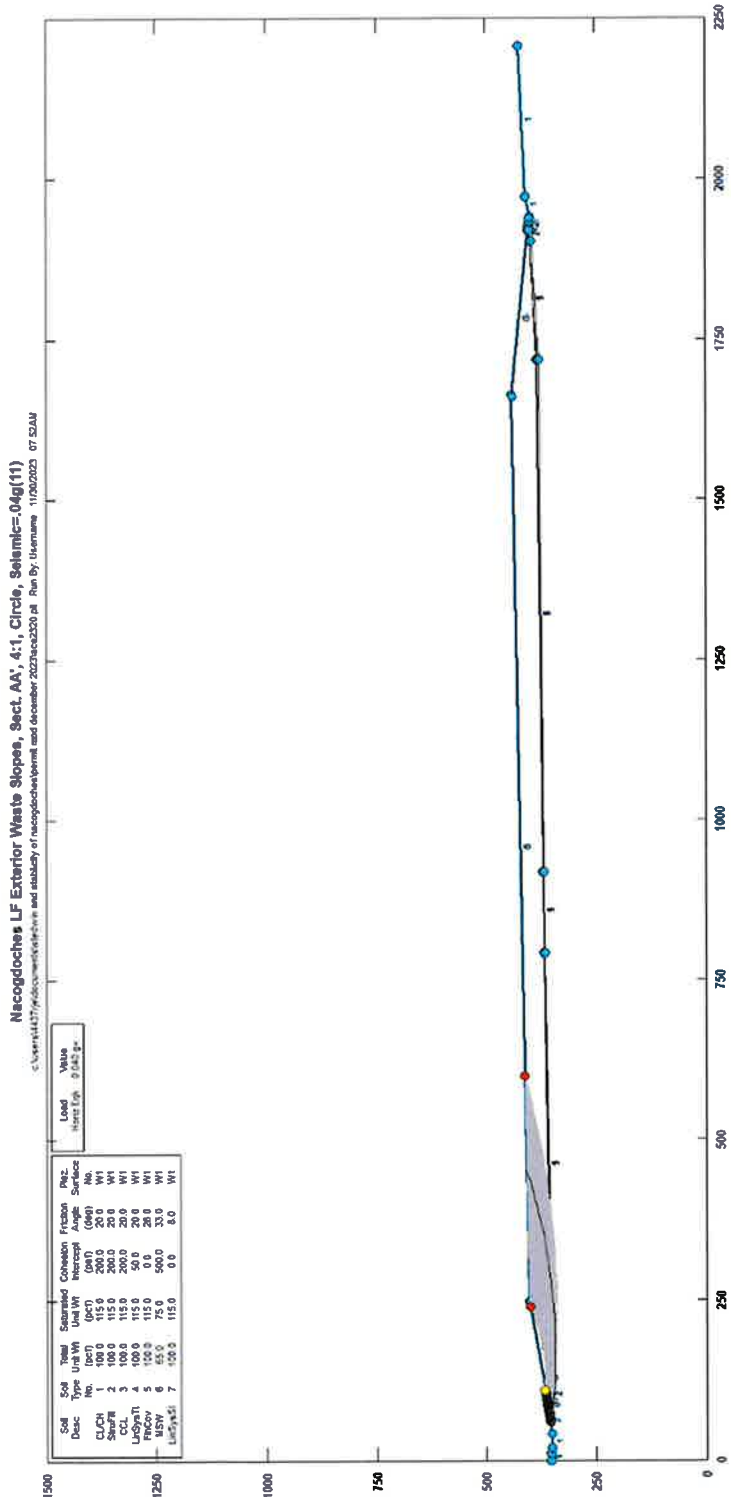
500
750
1000
1250
1500
1750
2000
2250

WASTE FINAL SLOPE

SECTION AA'

Circular Failure Surface

Seismic = 0.04g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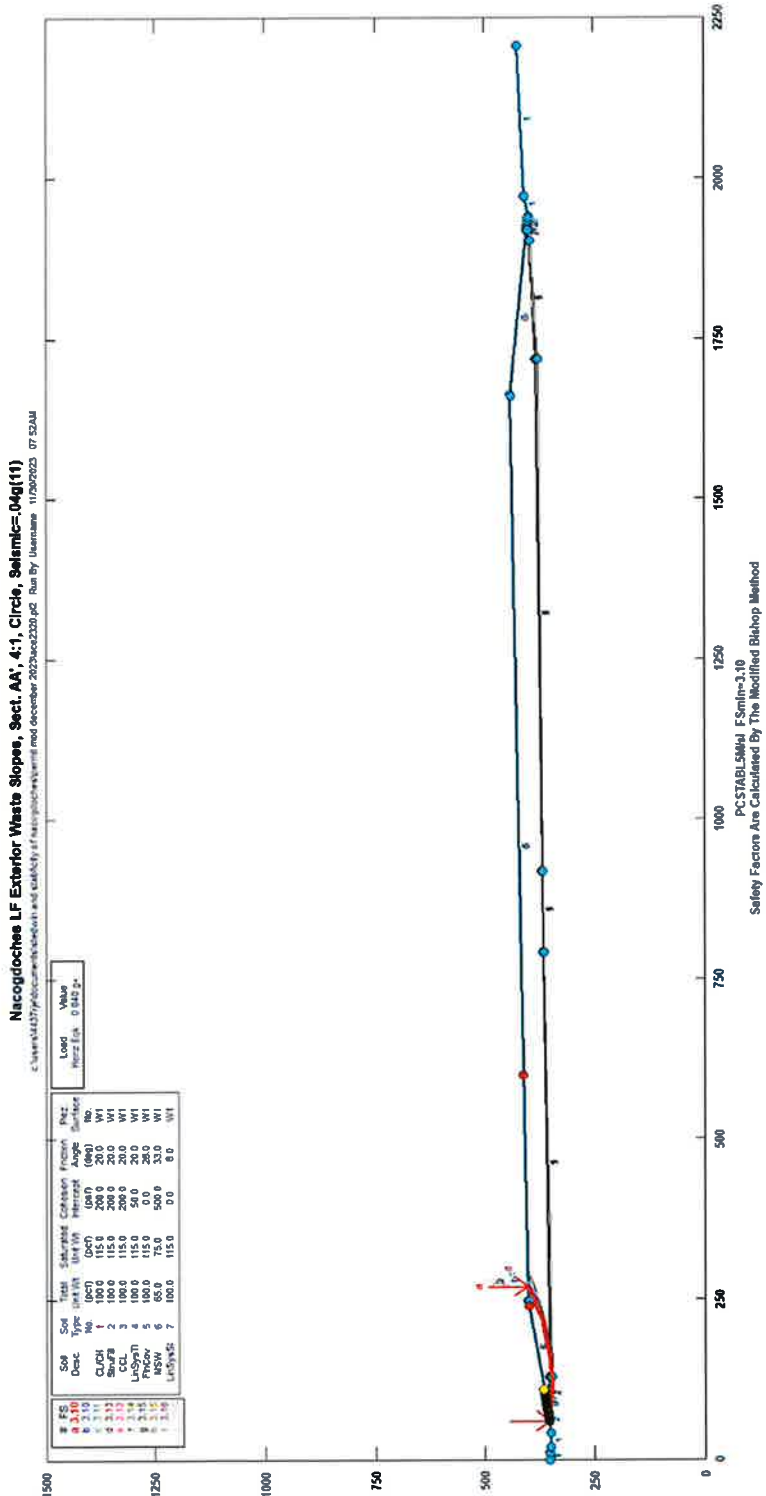
1750
2000
2250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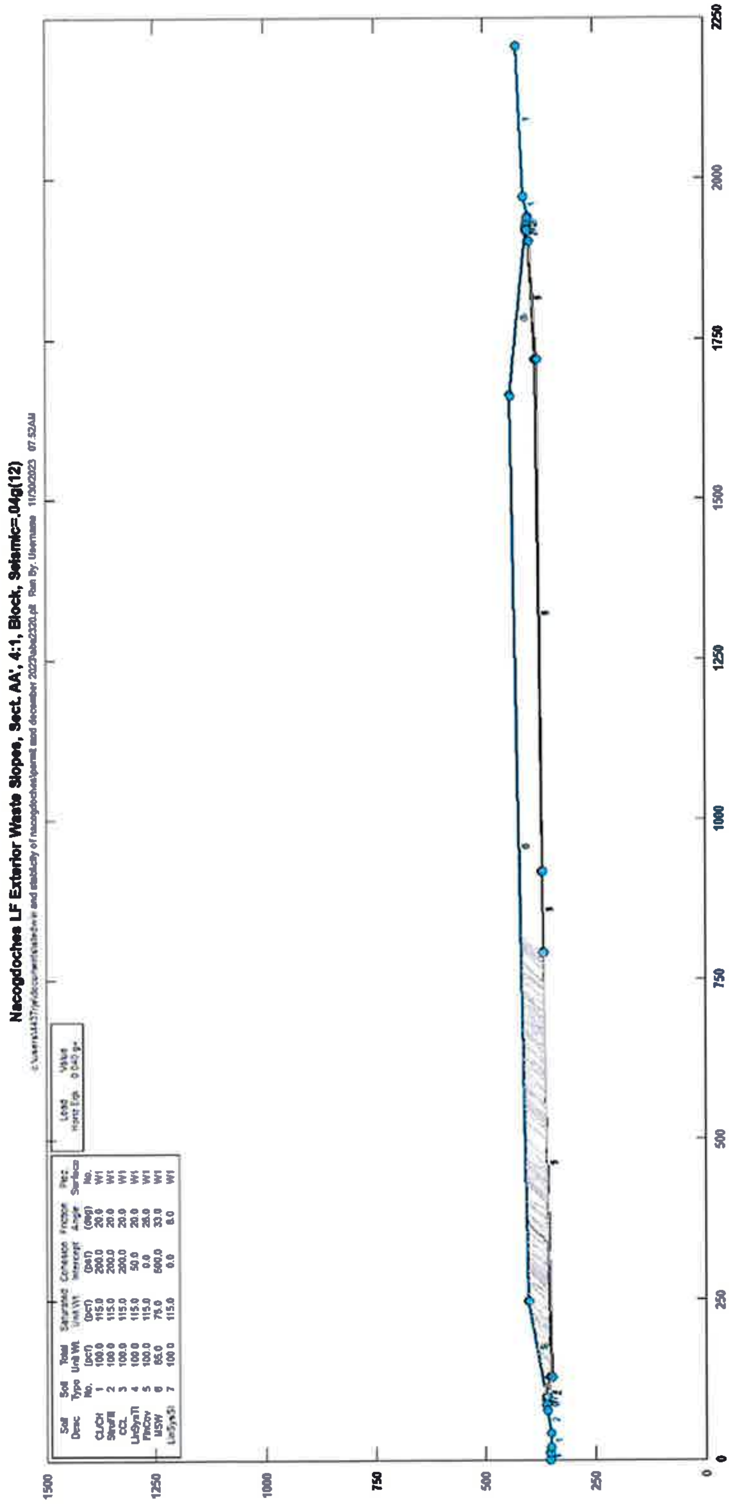
750
1000
1250
1500
1750
2000
2250

WASTE FINAL SLOPE

SECTION AA'

Block Failure Surface

Seismic = 0.04g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0
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500
750
1000
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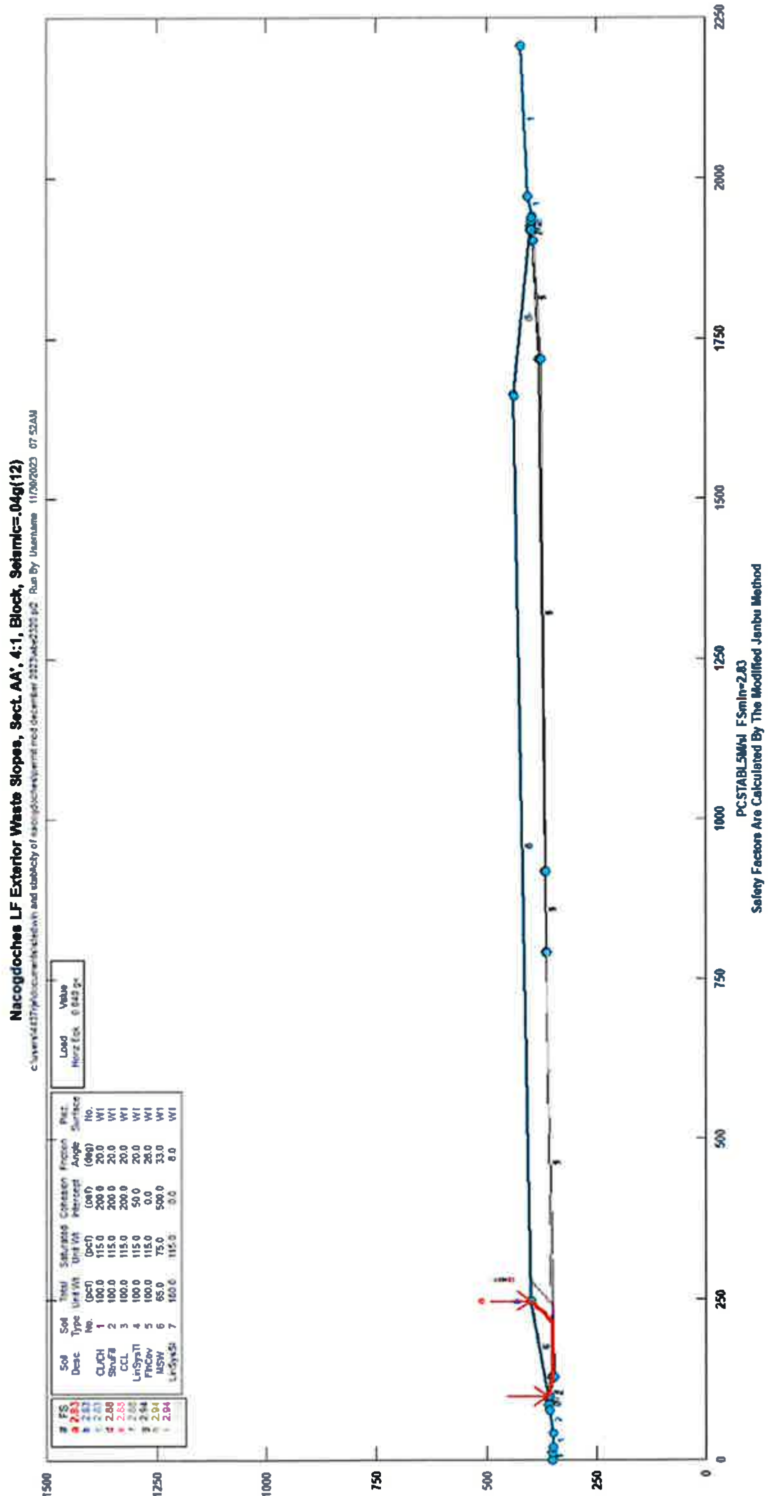
2000
2250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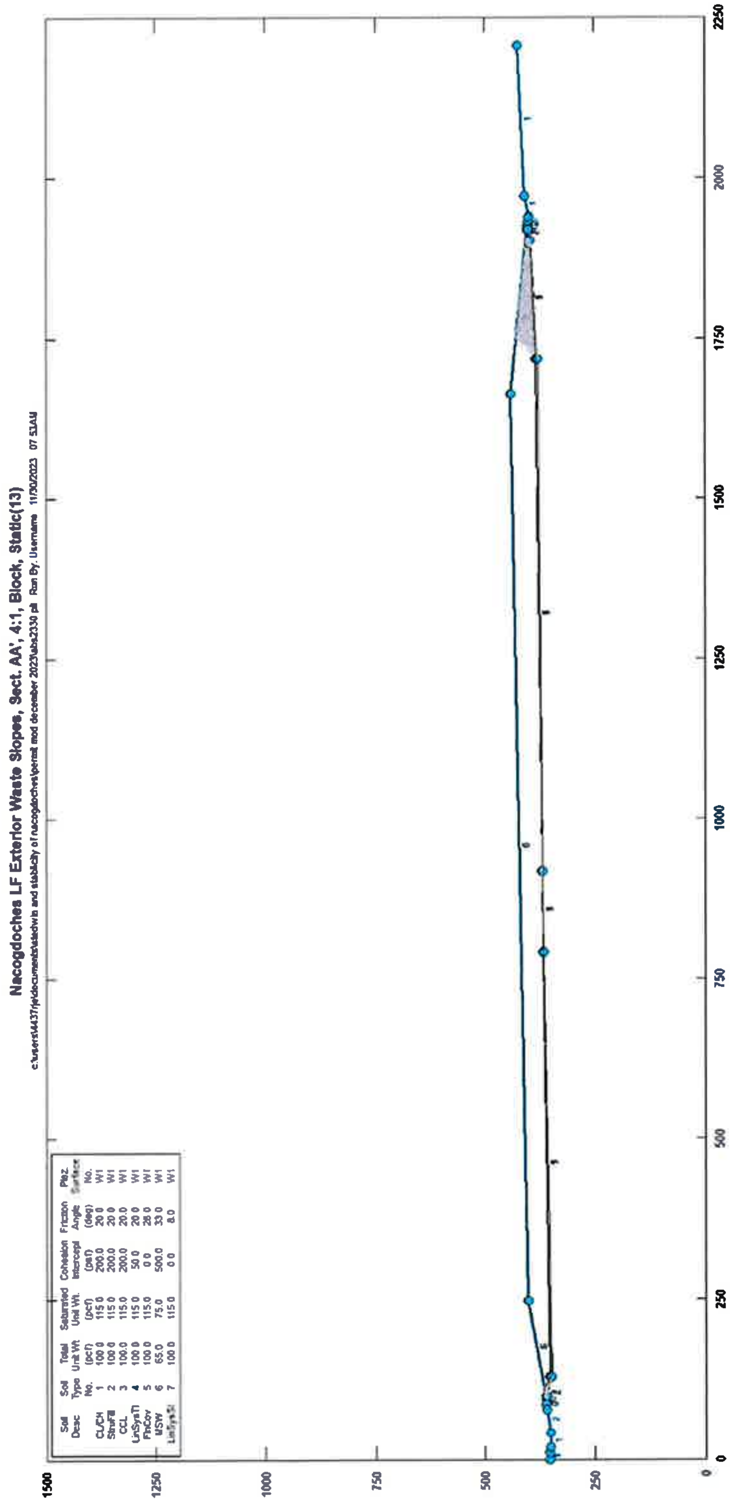
WASTE FINAL SLOPE

SECTION AA'

Global, Block Failure Surface

Static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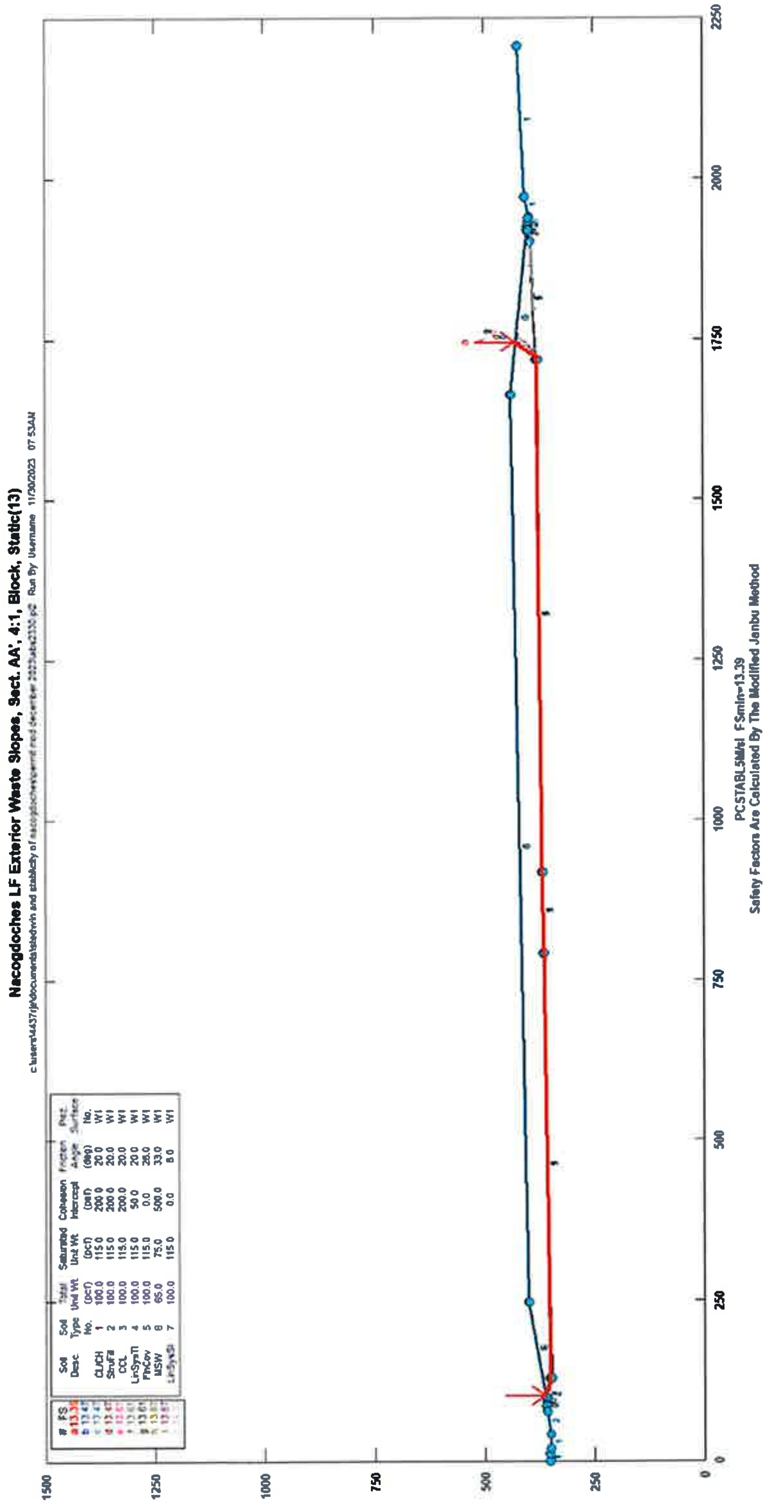
CL/CH 1 100.0 115.0 200.0 20.0 W1
StruFill 2 100.0 115.0 200.0 20.0 W1
CCL 3 100.0 115.0 200.0 20.0 W1
LinSysTl 4 100.0 115.0 50.0 20.0 W1
FinCov 5 100.0 115.0 0.0 28.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
LinSysSl 7 100.0 115.0 0.0 8.0 W1
0
250
500
750
1000
1250
1500
1750
2000
2250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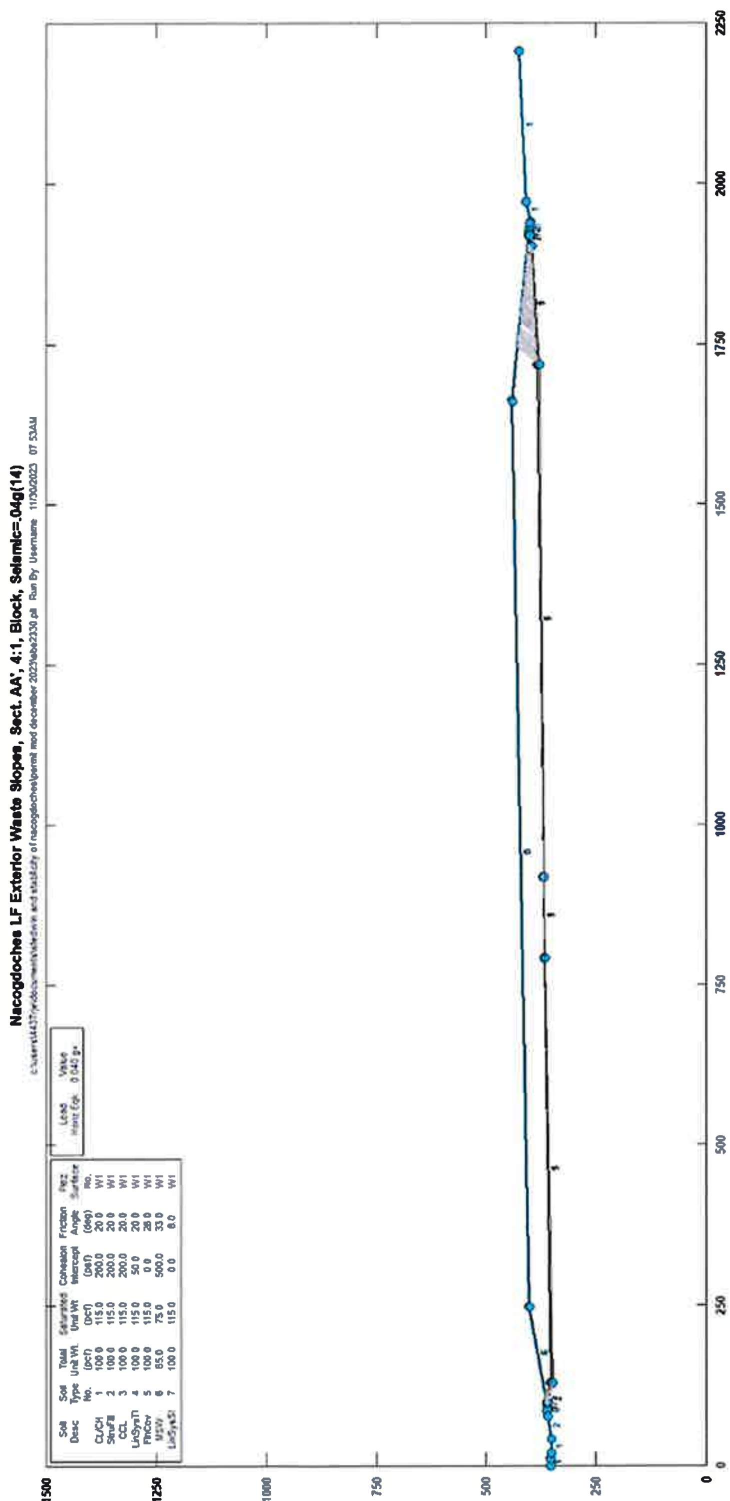
WASTE FINAL SLOPE

SECTION AA'

Global, Block Failure Surface

Seismic = 0.04g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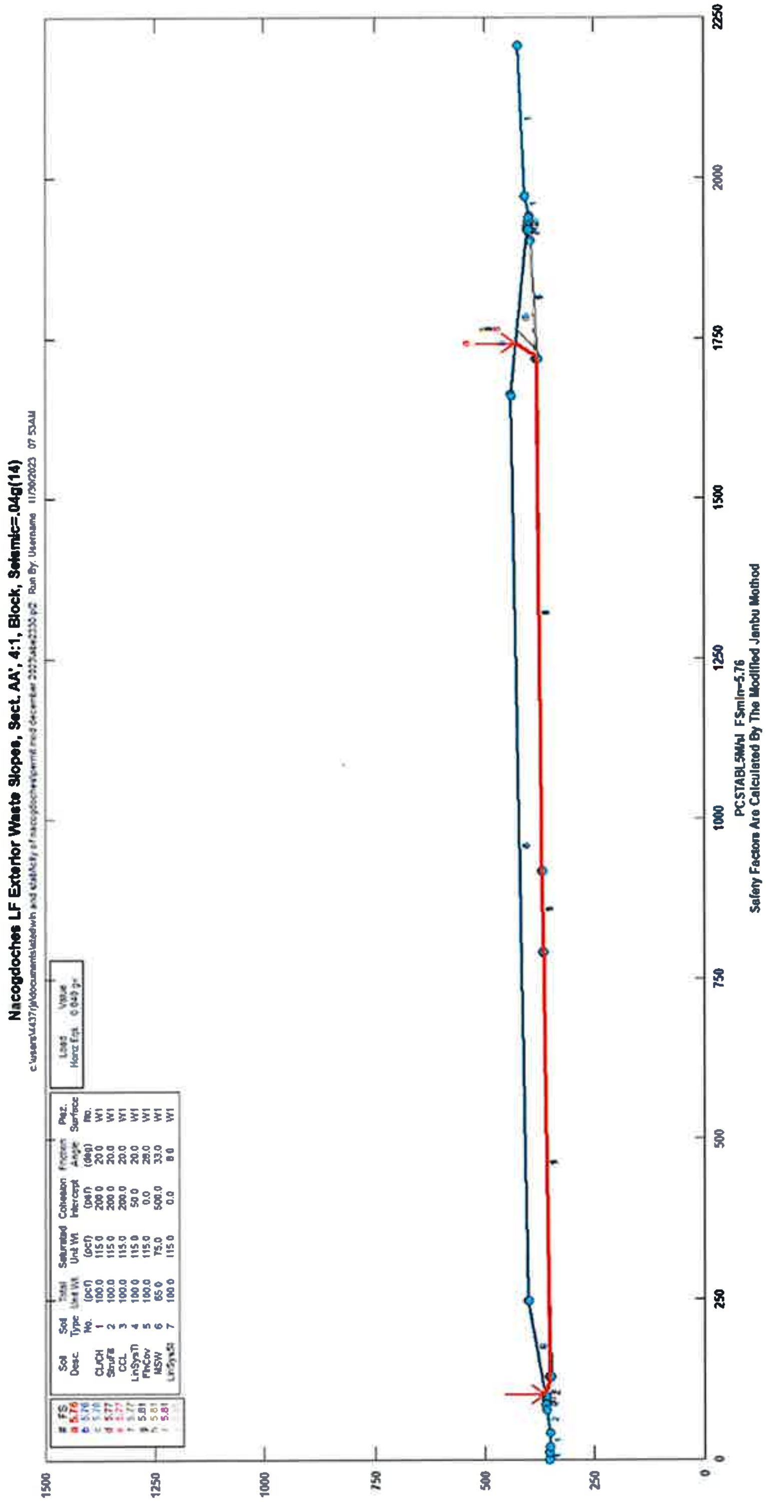
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FS
a 5.76
b 5.76
c 5.76
d 5.77
e 5.77
f 5.77
g 5.81
h 5.81
i 5.81
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CL/CH 1 100.0 115.0 200.0 20.0 W1
StruFill 2 100.0 115.0 200.0 20.0 W1
CCL 3 100.0 115.0 200.0 20.0 W1
LinSysTl 4 100.0 115.0 50.0 20.0 W1
FinCov 5 100.0 115.0 0.0 28.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
LinSysSl 7 100.0 115.0 0.0 8.0 W1
Load Value
Horiz Eqk 0.040 g<
0
250
500
750
1000
1250
1500
1750
2000
2250
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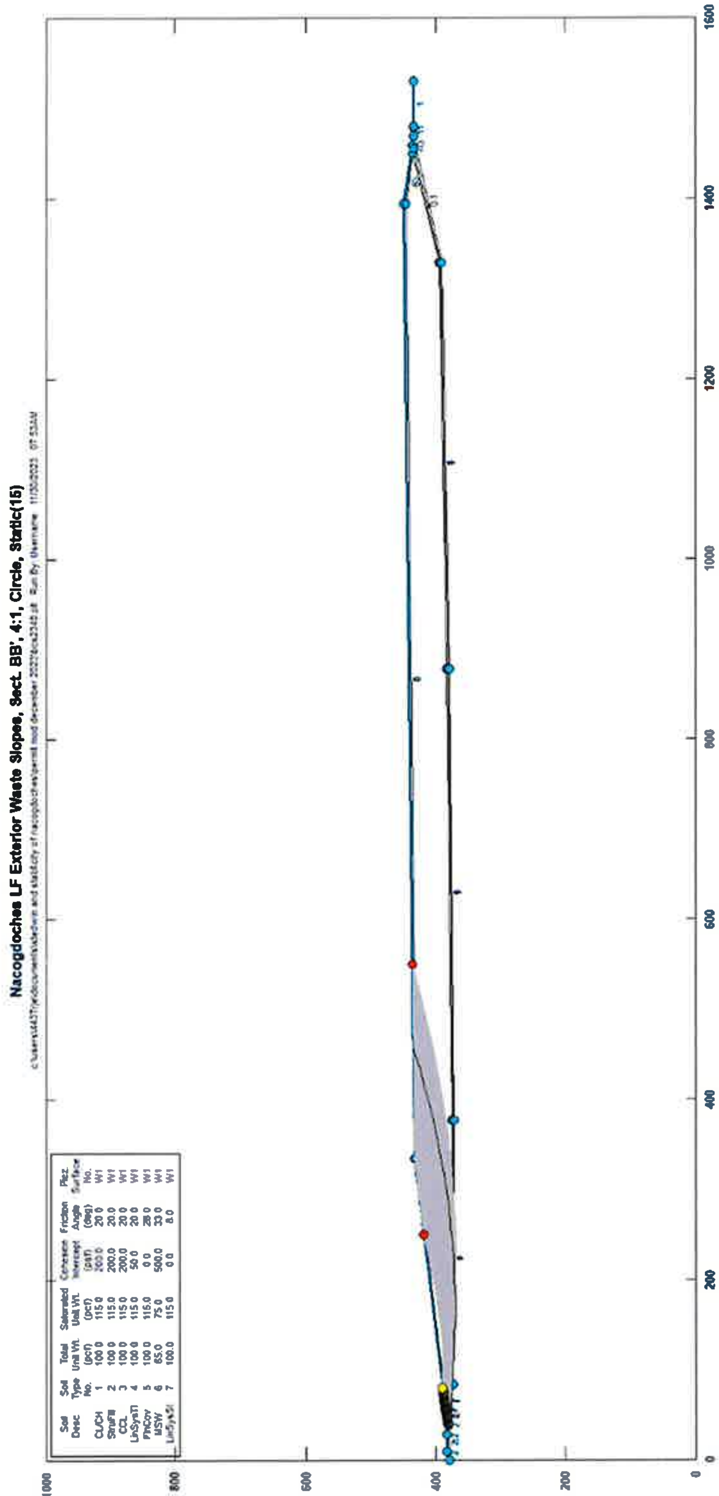
Safety Factors Are Calculated By The Modified Janbu Method

WASTE FINAL SLOPE

SECTION BB'

Circular Failure Surface

Static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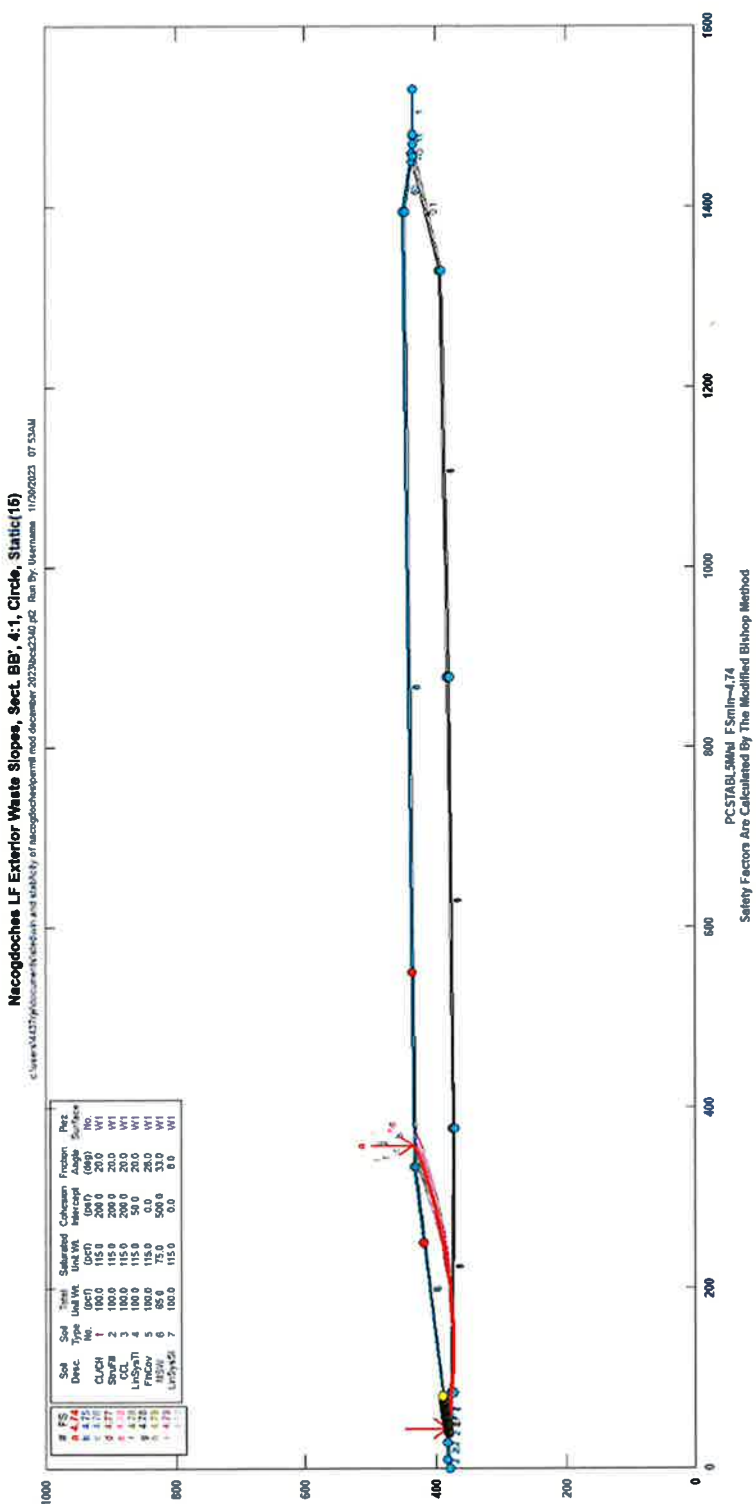
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CCL 3 100.0 115.0 200.0 20.0 W1
LinSysT1 4 100.0 115.0 50.0 20.0 W1
FinCov 5 100.0 115.0 0.0 28.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
LinSysS1 7 100.0 115.0 0.0 0.0 W1
FS
a 4.74
0
200
400
600
800
1000
1200
1400
1600
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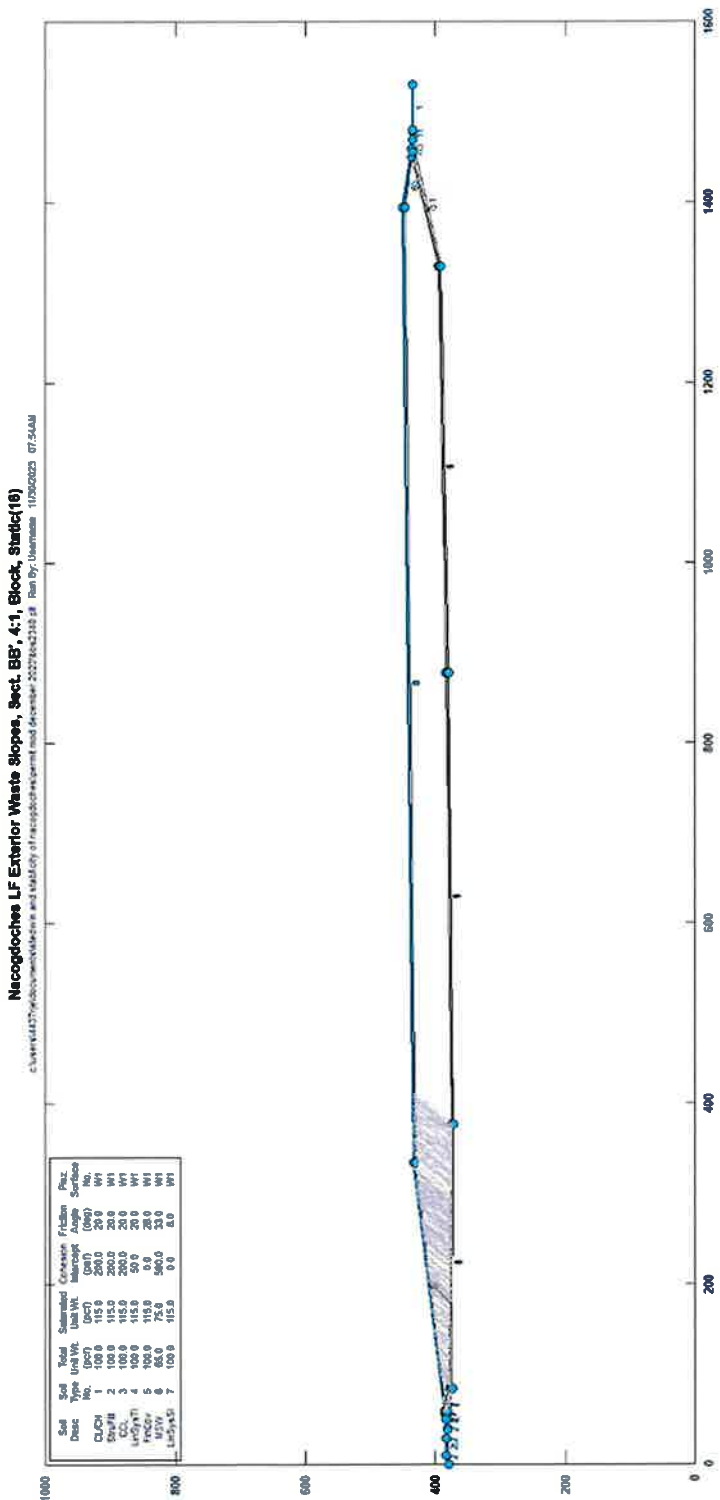
WASTE FINAL SLOPE

SECTION BB'

Block Failure Surface

Static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1000
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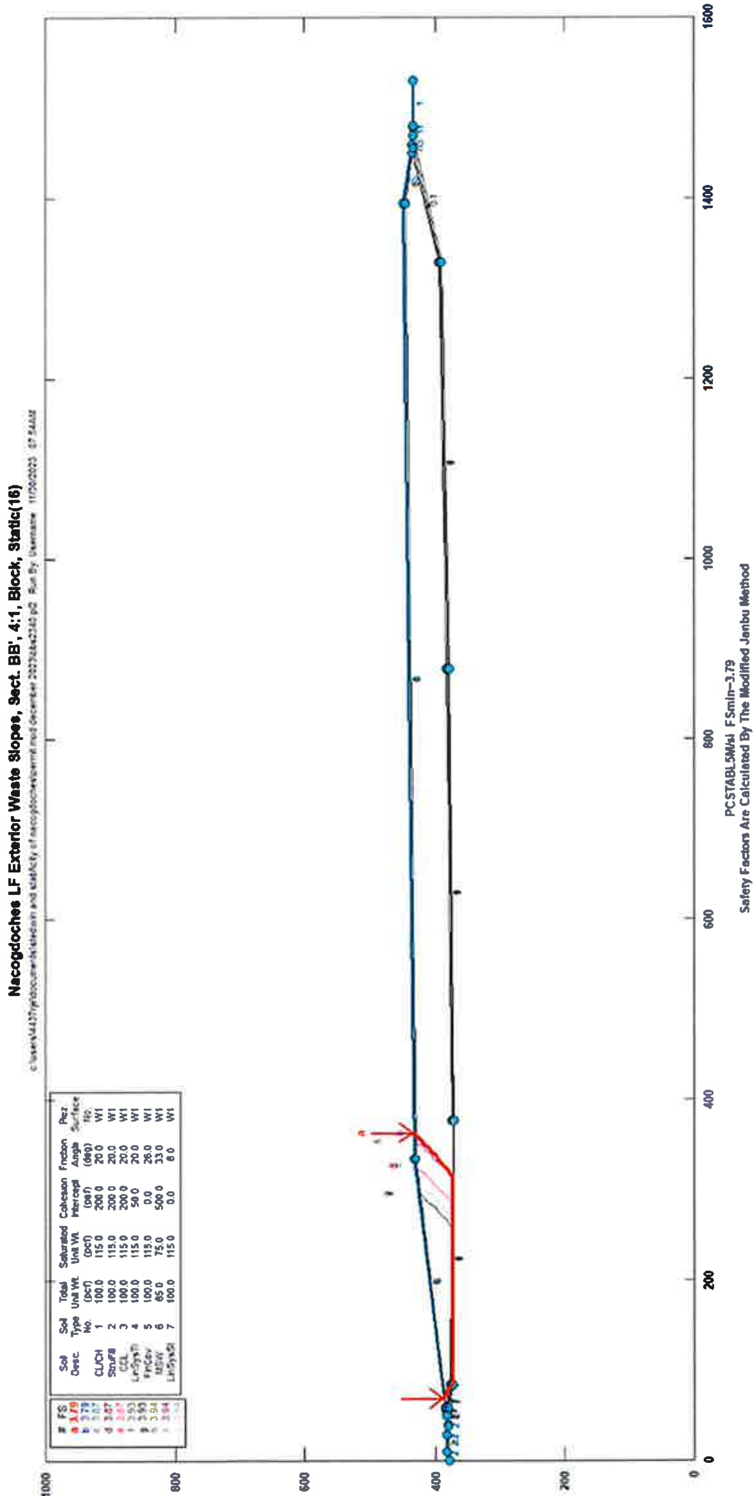
0
200
400
600
800
1000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400
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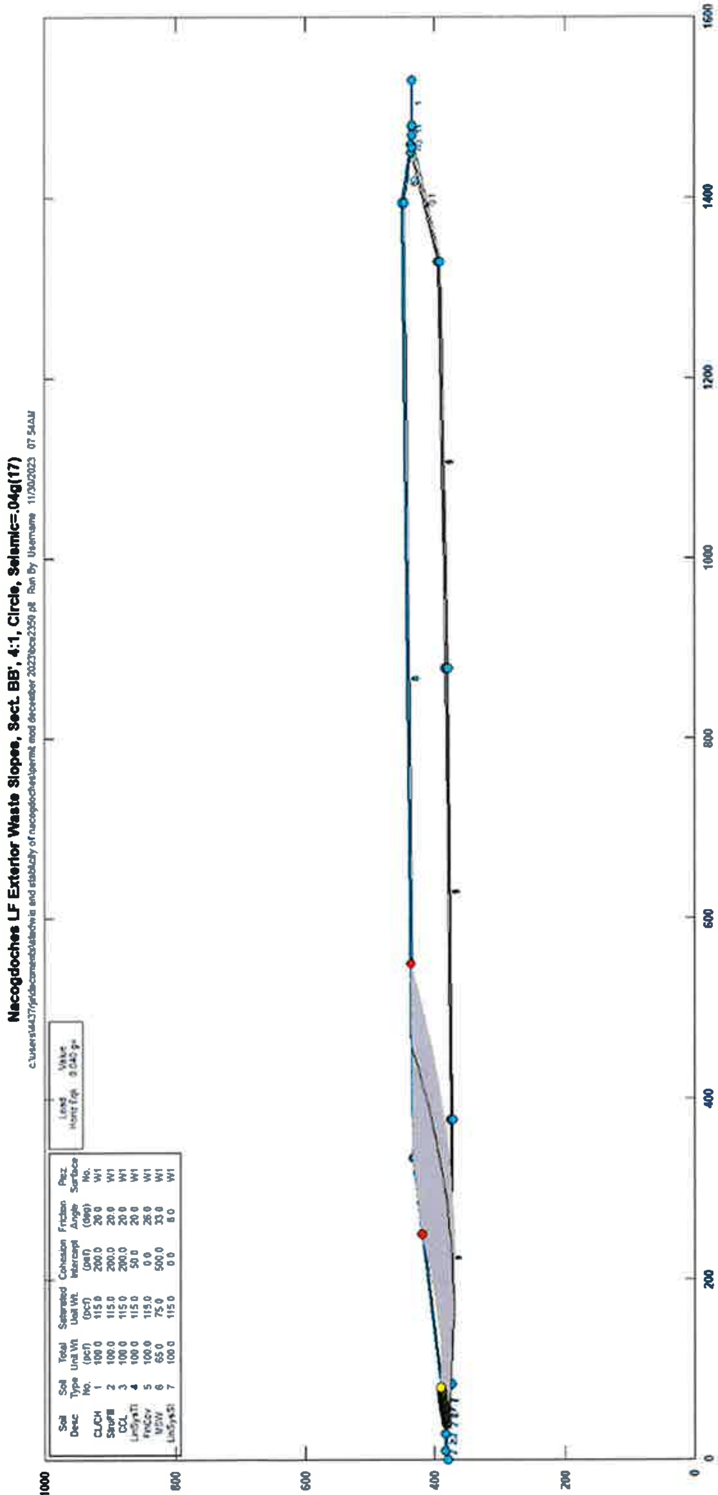
800
1000
1200
1400
1600

WASTE FINAL SLOPE

SECTION BB'

Circular Failure Surface

Seismic = 0.04g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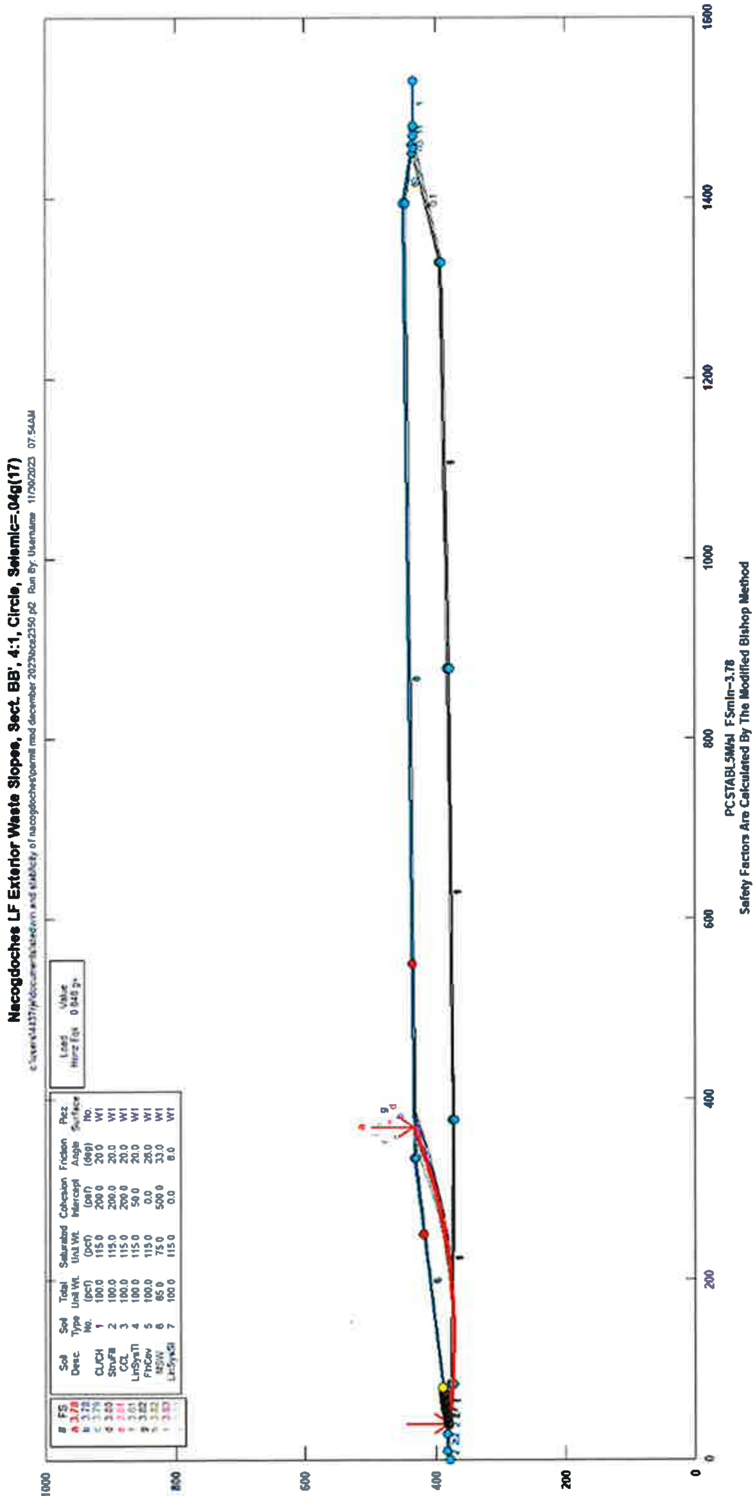
StrFill 2 100.0 115.0 200.0 20.0 W1
CCL 3 100.0 115.0 200.0 20.0 W1
4 100.0 115.0 50.0 20.0 W1
5 100.0 115.0 0.0 26.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
7 100.0 115.0 0.0 8.0 W1
Load | Value
Horiz Eqk 0.040 g<
0
200
400
600
800
1000
1200
1400
1600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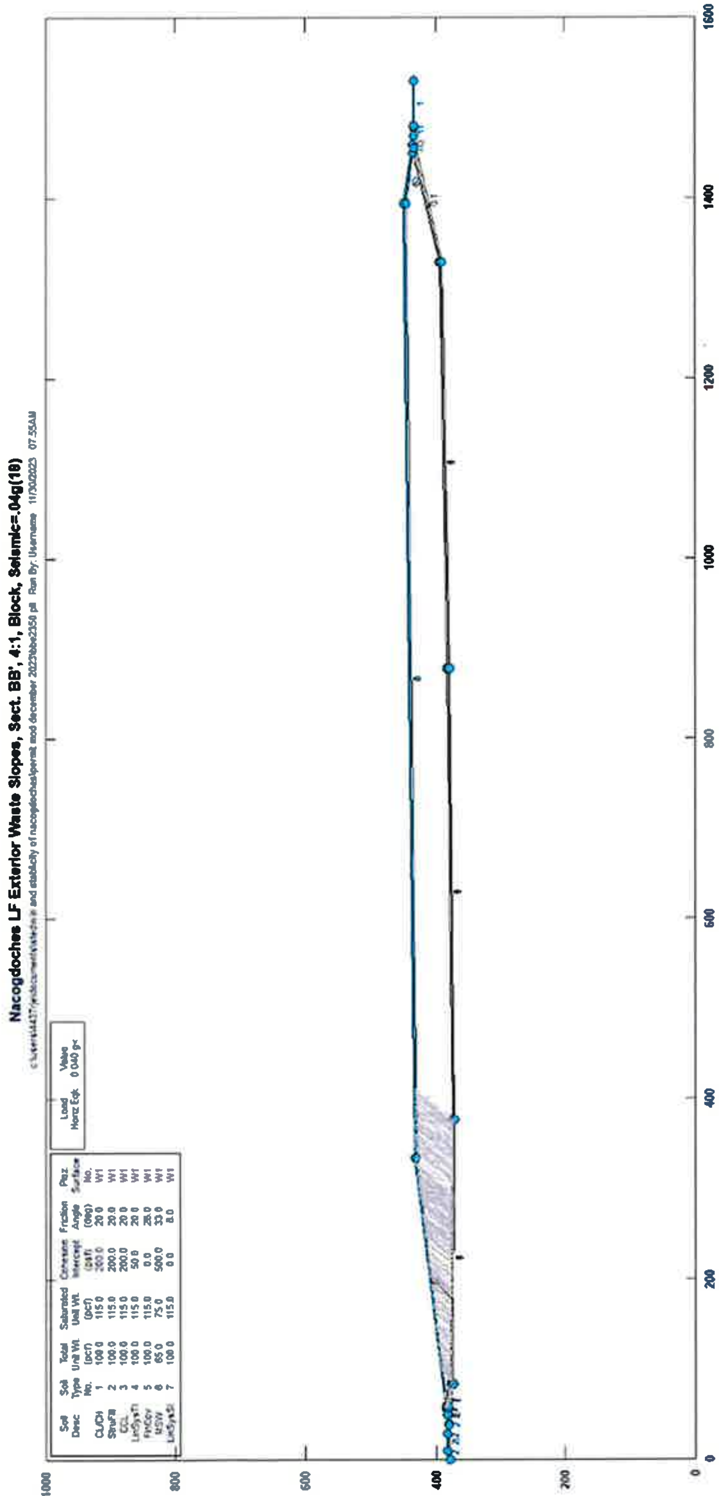
1400
1600

WASTE FINAL SLOPE

SECTION BB'

Block Failure Surface

Seismic = 0.04g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LinSysTI 4 100.0 115.0 50.0 20.0 W1
FMCov 5 100.0 115.0 0.0 28.0 W1
MSW 6 65.0 75.0 500.0 33.0 W1
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Load Value
Horiz Eqk 0.040 g<
0
200
400
600
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1000
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1400
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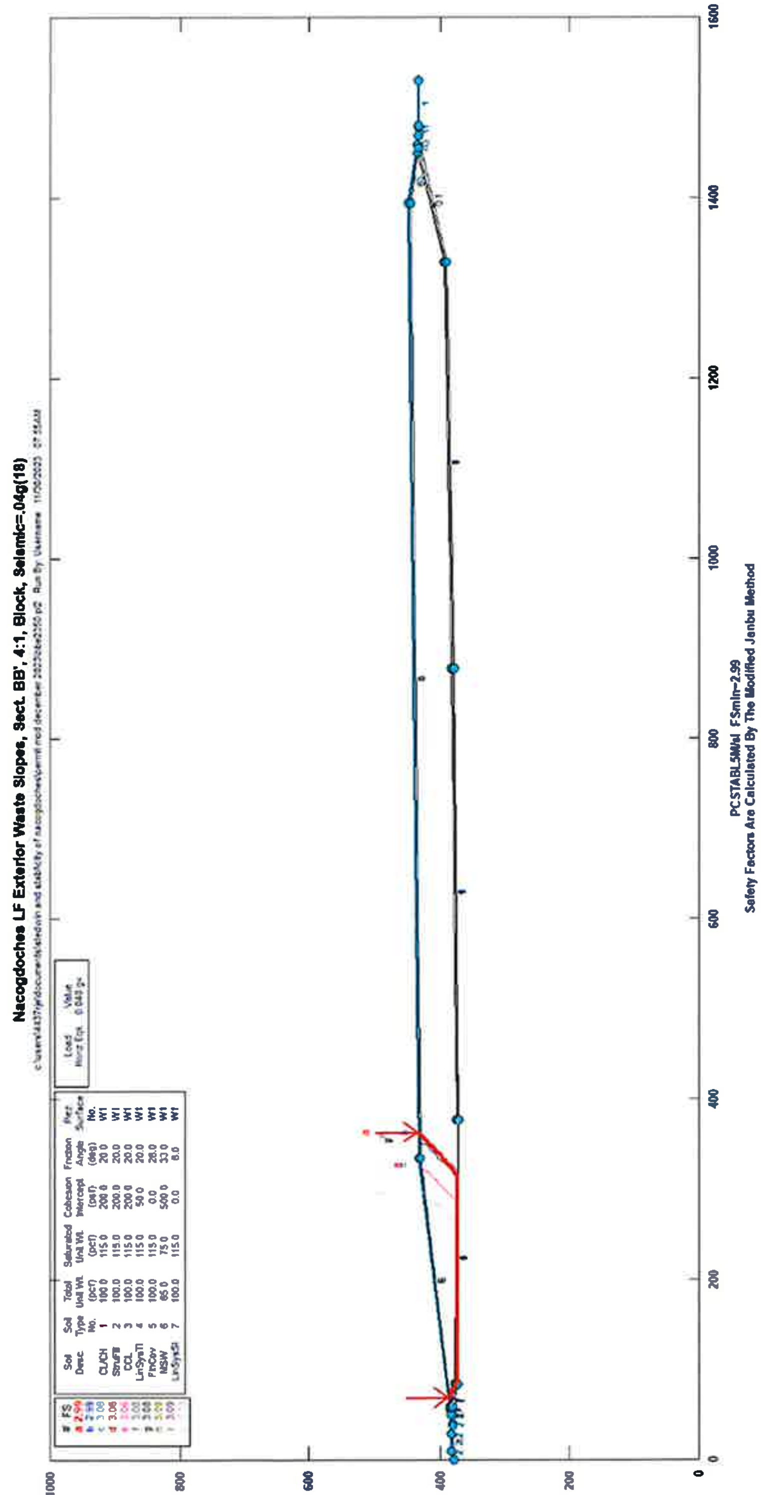
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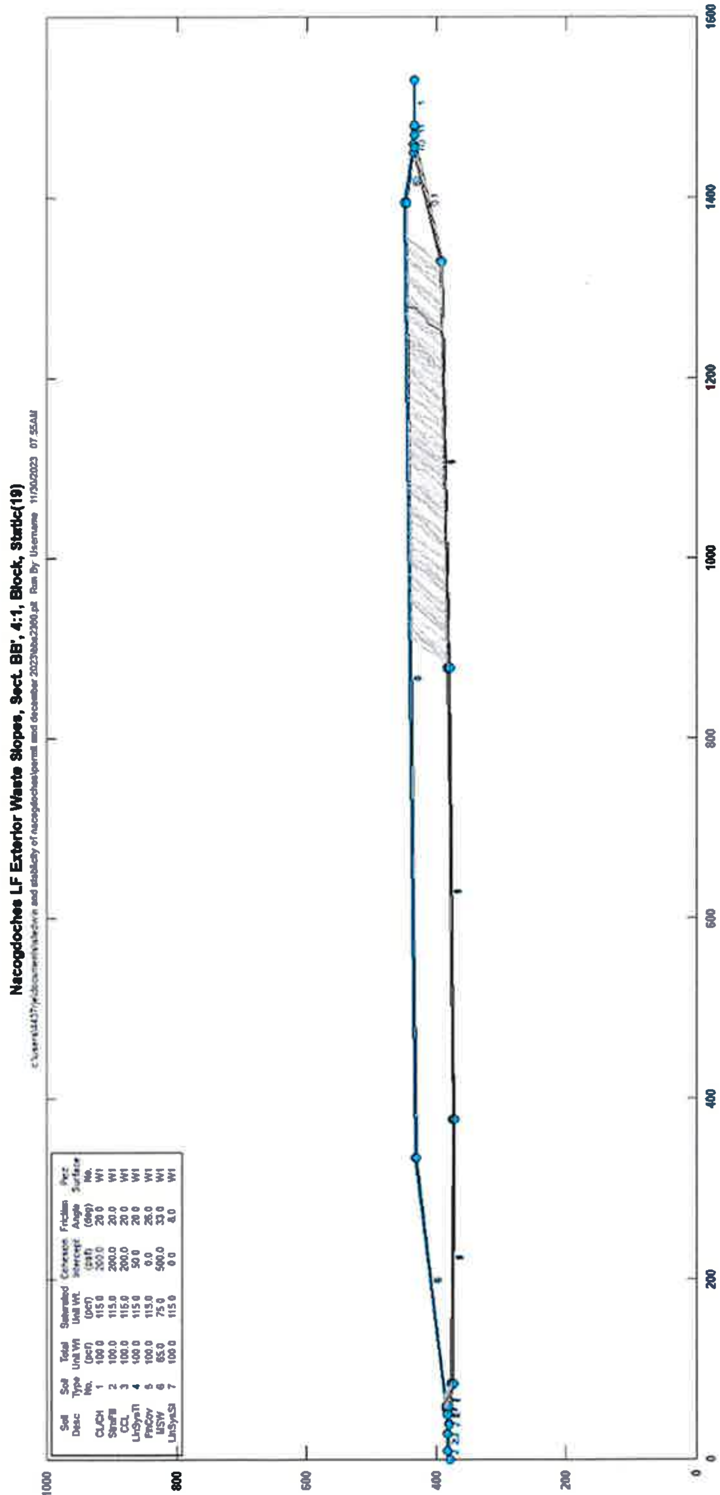
WASTE FINAL SLOPE

SECTION BB'

Global, Block Failure Surface

Static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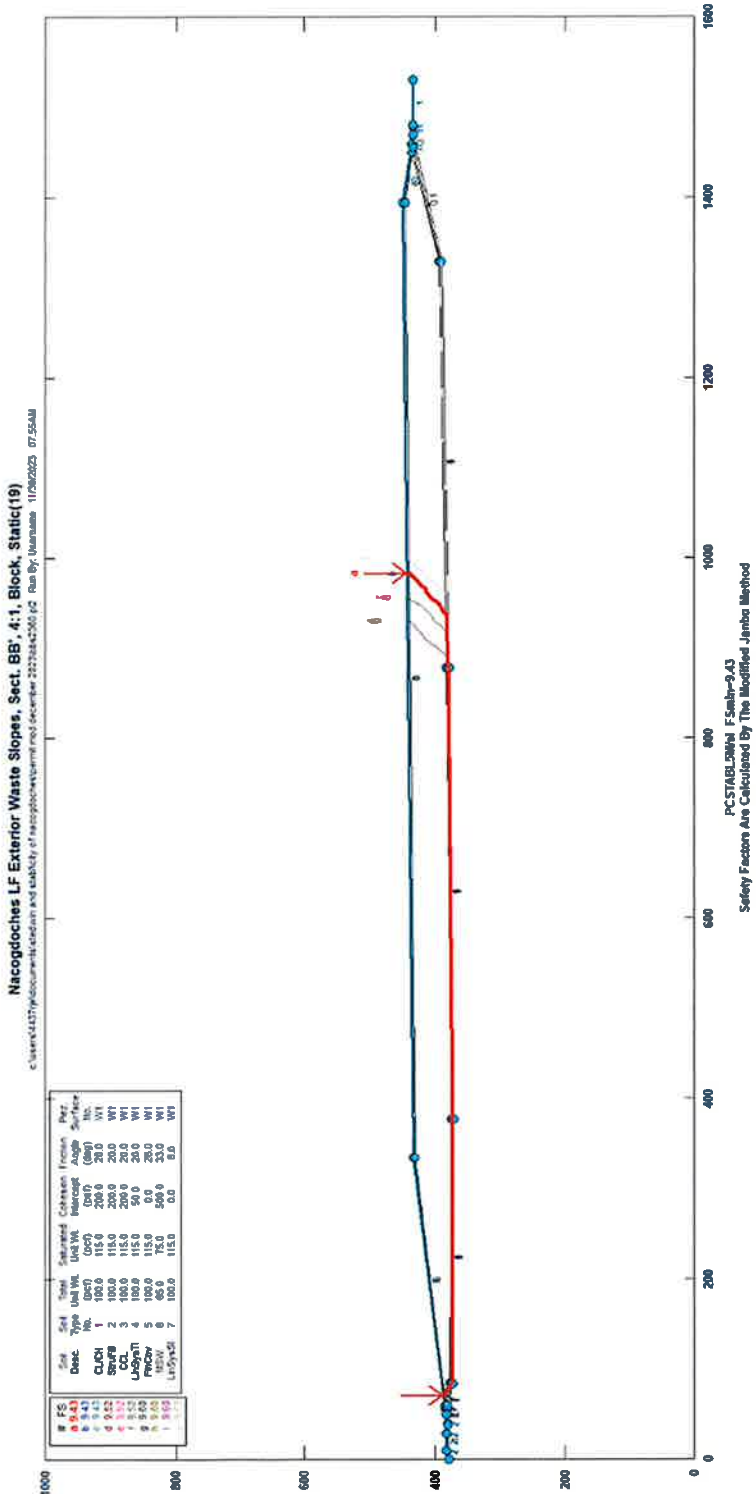
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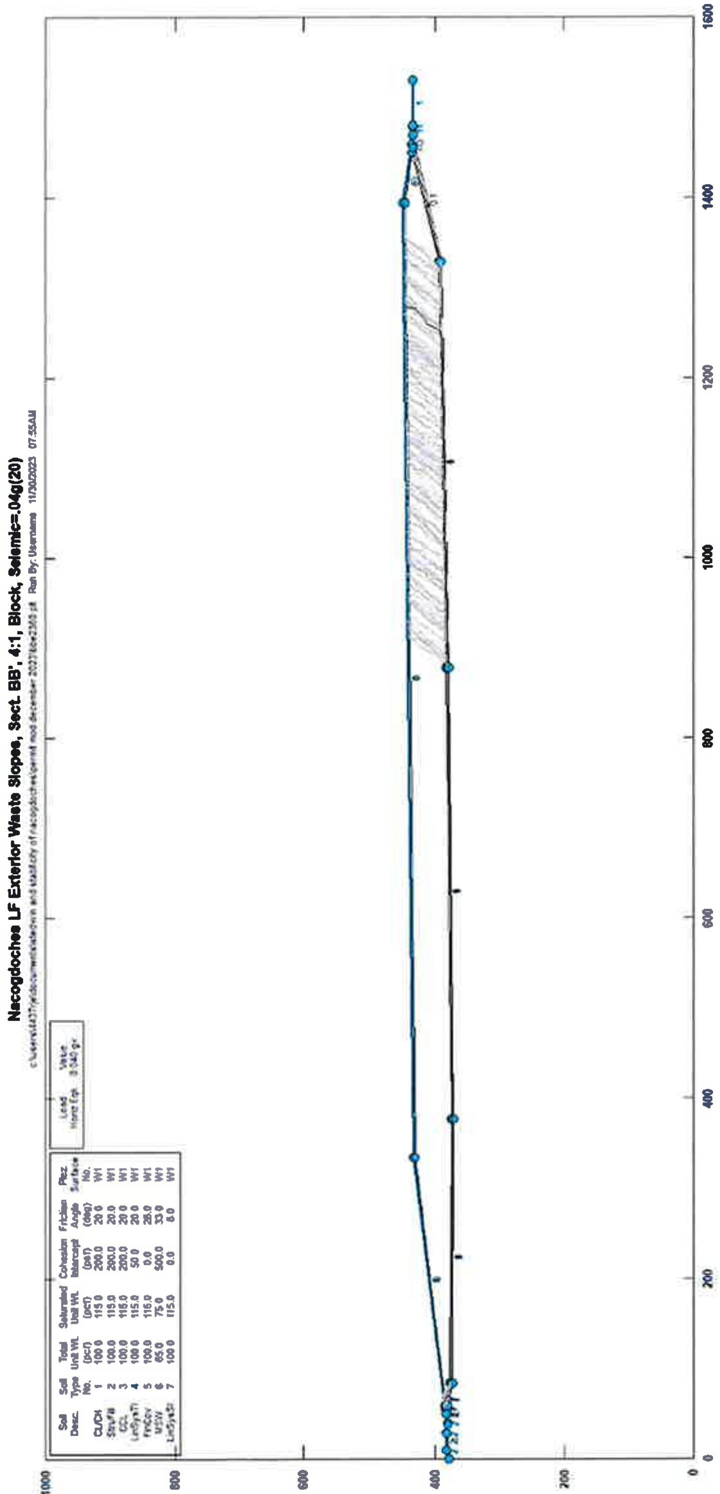
WASTE FINAL SLOPE

SECTION BB'

Global, Block Failure Surface

Seismic = 0.04g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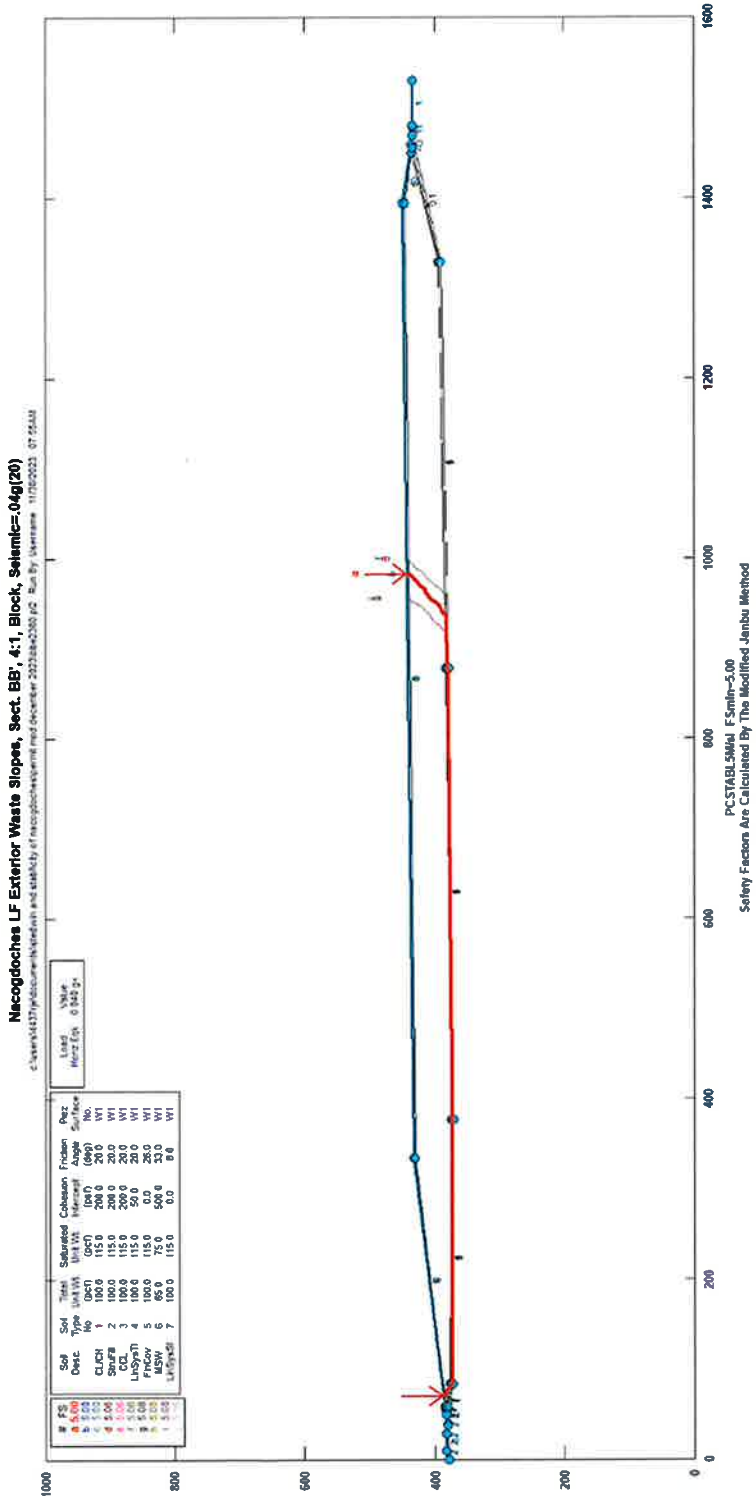
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PART III, ATTACHMENT 15

REPLACEMENT PAGES

CITY OF NACOGDOCHES LANDFILL
NACOGDOCHES COUNTY, TEXAS
TCEQ PERMIT APPLICATION NO. MSW-720

PART III - SITE DEVELOPMENT PLAN
ATTACHMENT 15

Prepared for:

CITY OF NACOGDOCHES
4602 NW Stallings Drive
Nacogdoches, TX 75964

FOR PERMITTING PURPOSES ONLY

STATE OF TEXAS
JEFFREY K. REED
80103
LICENSED
PROFESSIONAL ENGINEER
1/19/24

Prepared and Revision 1 by:

Golder Associates, Inc.
15603 West Hardy Drive, Suite 345
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Revised By:
SCS ENGINEERS
Texas Board of Professional Engineers, Reg. No. F-3407
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281/293-8494

Revision 1 – July 1994
Revision 2 – September 2019/January 2020
Revision 3 – January 2024

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SECTION **PAGE**

Figures

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1/19/24

STATE OF TEXAS
JEFFREY K. REED
80103
LICENSED
PROFESSIONAL ENGINEER

Appendices

SCS Engineers
TBPE Reg. # F-3407

The estimation of leachate generation is generally accomplished by a computerized water balance model or by using actual historical data for similar waste cells or landfills. The method used for the City of Nacogdoches Solid Waste Landfill was the U.S. EPA Hydrologic Evaluation of Landfill Performance (HELP) model. The HELP analyses for Blocks M and P are attached as Appendix A. Input parameters and assumptions used for the HELP model analyses are listed below.

1. Version 3.07 and 4.0 were used.
2. Thirty years of actual rainfall data for the Longview/Nacogdoches area (1961 through 1994) was obtained for the Nacogdoches Landfill from the Southern Regional Climate Center at Louisiana State University. This data is presented graphically in Appendix A.
3. "Fair" grass coverage was specified for the capped landfill.
4. The default SCS runoff curve number of 91.61 was used.
5. A membrane leakage fraction of 0.0001 was used for bottom liners, which is believed to be representative of an HDPE liner installed with typical QA/QC methods. A membrane leakage fraction of 0.01 was used for caps. This is a conservative assumption that will result in over estimation of precipitation infiltration and thus leachate generation, and will ensure adequate capacity of leachate collection system.
6. The HELP model analysis was performed for a 1 acre (43,560 square feet) area and a five year period. As the landfill is developed each fill area, or phase will only be active for a period of time on the order of 1 to 2 years. However, there is no way of knowing how much rainfall any active fill area will be subjected to during that period. Therefore, HELP model analyses were performed using the most severe consecutive 5 year period from the 30 years of actual rainfall data on the assumption that any similar events could conceivably occur during the active period of any of the fill areas. The 5 year period used in the analyses is identified within the 30 years of data included in Appendix A.
7. HELP model analyses were performed for three operating conditions:
    a. 5 feet of waste and 6-inches of daily cover over the area. This analysis was used to estimate the extreme worst case in terms of the rate of leachate production.
    b. 20 feet of waste with 6-inches of protective cover. These analyses were used to assess the maximum pipe spacing that would limit the head on the liner to a maximum of 1 foot. Two analyses are included; one for 0% cross slope between pipes, and one for 2% cross slope between pipes.
    c. Closed cell. These analyses are included to show the expected rate of leachate production over the long-term. Two analyses are included which show expected leachate production when a cell is half closed and when a cell is completely closed.

Results of the analyses indicate the extreme worst case rate of leachate production would be as shown on Figure 1. A more typical worst case expected rate of leachate flow is illustrated on Figures 2 and 3. These figures show rates for the Case 2 analyses which assumed 20 feet of waste in-place.

PART III, ATTACHMENT 15, APPENDIX G

REPLACEMENT PAGES

CITY OF NACOGDOCHES LANDFILL
NACOGDOCHES COUNTY, TEXAS
TCEQ PERMIT APPLICATION NO. MSW-720

PART III - SITE DEVELOPMENT PLAN
ATTACHMENT 15, APPENDIX G
BLOCK O - LEACHATE GENERATION MODEL

FOR PERMITTING PURPOSES ONLY

STATE OF TEXAS
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80103
LICENSED
PROFESSIONAL ENGINEER
1/19/24

Prepared for:

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4602 NW Stallings Drive
Nacogdoches, TX 75964

Prepared by:

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12651 Briar Forest Drive
Houston, Texas 77077
281/293-8494

Revision 0 – June 2011
Revision 1 – July 2013
Revision 2 – January 2024
SCS Project No. 16209006.26

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STATE OF TEXAS
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PROFESSIONAL ENGINEER

SCS Engineers
TBPE Reg. # F-3407

SECTION 1

LEACHATE GENERATION MODEL

1.1 OBJECTIVE

The following leachate generation modeling demonstrates that the design of the proposed leachate collection system (LCS) and the composite liner related to Block "O" at the City of Nacogdoches Landfill (landfill), complies with the requirements of 30 TAC §330.331(a)(2). Specifically, 30 TAC §330.331(a)(2) states that the LCS and composite liner shall be "…designed and constructed to maintain less than a 30 centimeters depth of leachate over the liner." The U.S. Army Corp of Engineer's Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07 and 4.0, was utilized for the purpose of demonstrating that the LCS and composite liner (herein referred to as the bottom liner system) have been designed to maintain leachate levels below the 30-centimeter (approximately 12 inches) criteria.

1.2 LEACHATE COLLECTION SYSTEM

The barrier components of the bottom liner system for Block "O" will be comprised of a 24-inch thick compacted clay liner overlain by a 60-mil high density polyethylene (HDPE) geomembrane liner. An alternate liner option consisting of a GCL overlain by a 60-mil high density polyethylene (HDPE) geomembrane liner is also proposed for Block O. The GCL/FML HELP Models are provided in Part III, Attachment 10, Appendix 10E. Above these barrier layers, the LCS will include a 200-mil lateral drainage layer (geocomposite) that will convey leachate to the LCS piping and overlain by a 24-inch-thick protective soil cover. The bottom liner system for this block will drain at varying slopes, with a minimum 2 percent and maximum 5 percent slope, towards perforated LCS piping (i.e., lateral and header pipes) located throughout the block, as shown on Drawing 15-1. This leachate generation model is based on two slope and drainage length scenarios, as follows:

1. Drainage length between LCS piping of 200 feet for slopes ranging from 2 to 2.8 percent; and

2. Drainage length between LCS piping of 325 feet for slopes greater than 2.8 percent.

In both scenarios, the minimum slope was modeled in HELP, as leachate head is inversely proportional to the slope of the bottom liner system (i.e., as the slope is decreased the leachate head increases). The two scenarios were evaluated for both the Active and Interim landfill conditions defined in Section 1.4, as these conditions of landfill development at the most critical cases for leachate generation. The Closed landfill condition was evaluated for Scenario 1 only, as the Closed landfill represents a stage of landfill development with little or no leachate generation.

Lateral piping has been positioned throughout the LCS to maintain the drainage lengths for the two minimum slope scenarios. Leachate generated at the landfill will enter the LCS piping by either: (1) infiltrating through the protective soil cover and into underlying geocomposite, which drains to the LCS piping; or (2) infiltrating through the gravel chimney drains installed over the LCS piping. Lateral piping will be sloped at a minimum 0.5 percent to drain leachate to the main header piping, which then gravity drains to the existing sanitary sewer located outside the limits of waste.

The layout and design details of the LCS are depicted on the Drawings 15-1 through 15-5.

1.3 METHOD OF ANALYSIS

The HELP model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of the disposal facility. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, field capacity, soil moisture storage, recirculation, evapotranspiration, and lateral drainage. Output includes peak daily, monthly and annual leachate generation and peak leachate depth over the liner for the respective periods.

1.4 MODEL SETUP

1.4.1 Block O Phases

The landfill was modeled as a one-acre unit area for the following conditions of landfill development:

- Active condition with 10 feet of waste, daily cover, and 0% runoff potential;
- Interim condition with 60 feet of waste (maximum waste thickness), intermediate cover, and 100% runoff potential; and
- Closed condition with 60 feet of waste, final cover, and 100% runoff potential.

In the HELP model, runoff is represented by two terms, "Runoff Potential" and "Curve Number (CN)", each of which is used differently by the model. Runoff Potential represents the percentage of the area being modeled that is sloped such that it is possible for runoff to occur.

The Curve Number (CN) is similar to the Runoff Potential in that it is used by the HELP model to estimate the volume of runoff from the landfill cover for a given storm event. The HELP model uses the CN value within a subroutine based on the Curve Number Method to calculate runoff. Unlike the Runoff Potential, the CN value incorporates the effects of soil characteristics (hydraulic conductivity), vegetative cover, and antecedent moisture content in the soil (i.e., initial soil moisture content). However, CN values and Curve Number Method (and resulting runoff values) are only applied to that portion of the landfill surface designated within the HELP model as being capable of producing runoff based on the Runoff Potential.

The Runoff Potential was user-selected as zero percent for the active condition, since precipitation contacting these areas will be contained at the working face by containment berms. For the interim and closed conditions, the Runoff Potential was user-selected as 100 percent, as these areas of the landfill will be properly graded and equipped with temporary or permanent

1.4.3.1 Compacted Clay Liner and Flexible Membrane Liner

The 24-inch-thick compacted clay liner was modeled as a barrier layer using default values from the HELP model table of soil characteristics (HELP default texture 16). The flexible geomembrane liner (60-mil HDPE), which is placed directly over the compacted clay liner, was also modeled using default values from the HELP model table of soil characteristics (HELP default texture 35). The geomembrane liner was modeled for good installation quality which is represented by four defects per acre and a pinhole density of one hole/acre (reference: HELP 3.07 and 4.0 User Manual).

1.4.3.2 Leachate Drainage System Layer

The geocomposite drainage layer is comprised of a geonet with a geotextile adhered to one side when installed on the landfill floor or both sides when installed on the below-grade sideslopes. The manufactured thickness of the geocomposite is 200-mil (approximately 0.20 inches), which was reduced for compression depending on the amount of overlying waste and soil cover for each condition modeled in HELP. The reduction in thickness of the geocomposite drainage layer, as well as reduction factors associated with creep, geotextile intrusion, and environmental conditions, were considered to account for changes in long-term performance.

To evaluate the performance of the geocomposite layer, the hydraulic conductivity value used in the HELP model was adjusted until the maximum depth of leachate in the geocomposite (for peak daily flow) was less than or generally equal to the thickness of the geocomposite. In this manner leachate flow above the geomembrane was confined in the geocomposite. The minimum allowable transmissivity was calculated based on the hydraulic conductivity, applied reduction factors, and reduced geocomposite thickness and compared to published transmissivity values for 200-mil geocomposite.

This exercise was performed to confirm that typical 200-mil geocomposites have drainage characteristics sufficient for maintaining leachate flow in the geocomposite layer. The geocomposite performance demonstration is included in Appendix G2. As presented in the demonstration, a 200-mil geocomposite has sufficient drainage capacity to meet drainage criteria during all stages of landfill development.

1.4.3.3 Covers Soils

A clay soil (CL soil classification, HELP default texture 11) was used for all cover soils, such as protective, daily, and intermediate cover soils, since this soil classification is representative of onsite soils. Default soil characteristics were used for these cover soils, including a hydraulic conductivity of 6.4×10^{-5} cm/s. Although re-compacted soil samples of onsite soils indicate permeability values less than the values assumed in the HELP model, a more permeable clay was selected to simulate more conservative leachate generation due to the uncompacted placement of these cover soils.

1.4.3.4 Waste

The waste layers described in Section 1.4.1 were utilized for the various landfill conditions in the HELP model. A default hydraulic conductivity of 1.0 x 10^{-3} cm/s was utilized in the model to represent municipal solid waste (HELP default texture 18).

1.4.3.5 Final Cover

The final cover from top to bottom will consist of a 6-inch-thick erosion layer, a 40-mil geomembrane, and an 18-inch-thick infiltration layer (compacted clay). For the purposes of this model, it has been assumed that the erosion layer will consist of a clay soil with a hydraulic conductivity of 6.4 x 10^{-5} cm/s, consistent with soil modeled for other cover soils, as described in Section 1.4.3.3. The geomembrane was modeled for good installation quality, 4 defects per acre, and a pinhole density of 1 hole/acre (reference: HELP 3.07 and 4.0 User Manual). The infiltration layer will consist of compacted soil with a hydraulic conductivity of 1.0 x 10^{-5} cm/s or less. Default soil characteristics from the HELP model were selected to represent the layers within the final cover system.

1.5 HELP MODEL RESULTS

The HELP model results are presented in the attached HELP Model Summary Sheet along with the HELP model output is provided in Appendix G1. As presented in the HELP model output, the depth of leachate over the bottom liner is predicted to be confined to the geocomposite lateral drainage layer, which is well below the 30 centimeter regulatory requirement.

PART III, ATTACHMENT 15, APPENDIX G-1

REPLACEMENT PAGES

APPENDIX G1

HELP MODEL RESULTS

SCS Engineers
TBPE Reg. # F-3407

1/19/24

STATE OF TEXAS
JEFFREY K. REED
80103
LICENSED
PROFESSIONAL ENGINEER

inclusive of pages G1-1 to G1-38.

FOR PERMITTING PURPOSES ONLY

CITY OF NACOG… …HES LANDFILL
BLOCK O - HELP MODEL SUMMARY SHEET

…By:RJE
Chkd By: JKR
Date: 01/19/2024

		ACTIVE (10' WASTE & 2.0% SLOPE)	ACTIVE (10' WASTE & 2.8% SLOPE)	INTERIM (60' WASTE & 2.0% SLOPE)	INTERIM (60' WASTE & 2.8% SLOPE)	CLOSED (60' WASTE)
GENERAL INFORMATION	Model Duration (Years)	30	30	30	30	30
	Ground Cover	BARE	BARE	FAIR	FAIR	GOOD
	SCS Runoff Curve No.	85	85	85	85	85
	Model Area (acre)	1	1	1	1	1
	Runoff Area (%)	0	0	100	100	100
	Maximum Leaf Area Index	0.0	0.0	2.0	2.0	3.5
	Evaporative Zone Depth (inch)	6	6	12	12	6
EROSION LAYER (Texture = 11)	Thickness (in)					6
	Porosity (vol/vol)					0.4640
	Field Capacity (vol/vol)					0.3100
	Wilting Point (vol/vol)					0.1870
	Init. Moisture Content (vol/vol)					0.4535
	Hyd. Conductivity (cm/s)					6.4E-05
FLEXIBLE MEMBRANE LINER (Texture = 36)	Thickness (in)					0.04
	Hyd. Conductivity (cm/s)					4.0E-13
	Pinhole Density (holes/acre)					1
	Install. Defects (holes/acre)					4
	Placement Quality					GOOD
INFILTRATION LAYER (Texture = 0)	Thickness (in)					18
	Porosity (vol/vol)					0.4270
	Field Capacity (vol/vol)					0.4180
	Wilting Point (vol/vol)					0.3670
	Init. Moisture Content (vol/vol)					0.4094
	Hyd. Conductivity (cm/s)					1.0E-05
INTERMEDIATE / DAILY COVER (Texture = 11)	Thickness (in)	6	6	12	12	6
	Porosity (vol/vol)	0.4640	0.4640	0.4640	0.4640	0.4640
	Field Capacity (vol/vol)	0.3100	0.3100	0.3100	0.3100	0.3100
	Wilting Point (vol/vol)	0.1870	0.1870	0.1870	0.1870	0.1870
	Init. Moisture Content (vol/vol)	0.3651	0.3709	0.3419	0.3419	0.3100
	Hyd. Conductivity (cm/s)	6.4E-05	6.4E-05	6.4E-05	6.4E-05	6.4E-05
WASTE (Texture = 18)	Thickness (in)	120	120	720	720	720
	Porosity (vol/vol)	0.6710	0.6710	0.6710	0.6710	0.6710
	Field Capacity (vol/vol)	0.2920	0.2920	0.2920	0.2920	0.2920
	Wilting Point (vol/vol)	0.0770	0.0770	0.0770	0.0770	0.0770
	Init. Moisture Content (vol/vol)	0.3061	0.3054	0.2946	0.2946	0.2920
	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
PROTECTIVE COVER (Texture = 11)	Thickness (in)	24	24	24	24	24
	Porosity (vol/vol)	0.4640	0.4640	0.4640	0.4640	0.4640
	Field Capacity (vol/vol)	0.3100	0.3100	0.3100	0.3100	0.3100
	Wilting Point (vol/vol)	0.1870	0.1870	0.1870	0.1870	0.1870
	Init. Moisture Content (vol/vol)	0.3445	0.3466	0.3431	0.3431	0.3100
	Hyd. Conductivity (cm/s)	6.4E-05	6.4E-05	6.4E-05	6.4E-05	6.4E-05

CITY OF NACOGDOCHES LANDFILL
BLOCK O - HELP MODEL SUMMARY SHEET

By:RJE
Chkd By: JKR
Date: 01/19/2024

		ACTIVE (10' WASTE & 2.0% SLOPE)	ACTIVE (10' WASTE & 2.8% SLOPE)	INTERIM (60' WASTE & 2.0% SLOPE)	INTERIM (60' WASTE & 2.8% SLOPE)	CLOSED (60' WASTE)
LEACHATE	Thickness (in)	0.20	0.20	0.19	0.19	0.19
COLLECTION	Porosity (vol/vol)	0.8500	0.8500	0.8500	0.8500	0.8500
(Texture = 0)	Field Capacity (vol/vol)	0.0100	0.0100	0.0100	0.0100	0.0100
	Wilting Point (vol/vol)	0.0050	0.0050	0.0050	0.0050	0.0050
	Init. Moisture Content (vol/vol)	0.0255	0.0255	0.0475	0.0555	0.0106
	Hyd. Conductivity (cm/s)	16.00	16.00	5.00	5.00	5.00
	Slope (%)	2.0	2.8	2.0	2.8	2.0
	Slope Length (ft)	200	325	200	325	200
FLEXIBLE	Thickness (in)	0.06	0.06	0.06	0.06	0.6
MEMBRANE	Hyd. Conductivity (cm/s)	2.0E-13	2.0E-13	2.0E-13	2.0E-13	2.0E-13
LINER	Pinhole Density (holes/acre)	1	1	1	1	1
(Texture = 35)	Install. Defects (holes/acre)	4	4	4	4	4
	Placement Quality	GOOD	GOOD	GOOD	GOOD	GOOD
COMPACTED	Thickness (in)	24	24	24	24	24
CLAY LINER	Porosity (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
(Texture =16)	Field Capacity (vol/vol)	0.4180	0.4180	0.4180	0.4180	0.4180
	Wilting Point (vol/vol)	0.3670	0.3670	0.3670	0.3670	0.3670
	Init. Moisture Content (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
	Hyd. Conductivity (cm/s)	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
PRECIPITATION	Average Annual (in)	45.1	45.1	45.1	45.1	45.1
RUNOFF	Average Annual (in)	0.0	0.0	3.5	3.5	14.0
EVAPOTRANSPIRATION	Average Annual (in)	26.8	26.7	31.2	31.2	31.1
LATERAL DRAINAGE (LCS)	Average Annual (cf/year)	66,382	66,989	37,077	37,076	167
LATERAL DRAINAGE (LCS)	Average Annual (cf/day)	181.9	183.5	101.6	101.6	0.5
LATERAL DRAINAGE (LCS)	Peak daily (cf/day)	1,464	1,472	713	705	1.5
HEAD ON LINER	Average daily (in)	0.04	0.05	0.07	0.08	0.0001
HEAD ON LINER	Peak daily (in)	0.09	0.10	0.14	0.16	0.0003

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Interim, 60' Waste, 2.0% Slope... **Simulated On:** 12/1/2023 10:05

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
CL - Clay Loam
Material Texture Number 11

Thickness	=	12	inches
Porosity	=	0.464	vol/vol
Field Capacity	=	0.31	vol/vol
Wilting Point	=	0.187	vol/vol
Initial Soil Water Content	=	0.3419	vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer (Waste)
Municipal Solid Waste (MSW) (900 pcy)
Material Texture Number 18

Thickness	=	720	inches
Porosity	=	0.671	vol/vol
Field Capacity	=	0.292	vol/vol
Wilting Point	=	0.077	vol/vol
Initial Soil Water Content	=	0.2945	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 1 - Vertical Percolation Layer
CL - Clay Loam
Material Texture Number 11

Thickness	=	24	inches
Porosity	=	0.464	vol/vol
Field Capacity	=	0.31	vol/vol
Wilting Point	=	0.187	vol/vol
Initial Soil Water Content	=	0.3431	vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05	cm/sec

Layer 4
Type 2 - Lateral Drainage Layer
Custom Geonet 1
Material Texture Number 123

Thickness	=	0.19	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.0475	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E+00	cm/sec
Slope	=	2	%
Drainage Length	=	200	ft

Layer 5
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	4	Holes/Acre
FML Placement Quality	=	3	Good

Layer 6
Type 3 - Barrier Soil Liner
Liner Soil (High)
Material Texture Number 16

Thickness	=	24	inches
Porosity	=	0.427	vol/vol
Field Capacity	=	0.418	vol/vol
Wilting Point	=	0.367	vol/vol
Initial Soil Water Content	=	0.427	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	85	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	12	inches
Initial Water in Evaporative Zone	=	4.103	inches
Upper Limit of Evaporative Storage	=	5.568	inches
Lower Limit of Evaporative Storage	=	2.244	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	234.625	inches
Total Initial Water	=	234.625	inches

Total Subsurface Inflow = 0 inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	31.37 Degrees
Maximum Leaf Area Index	=	2
Start of Growing Season (Julian Date)	=	55 days
End of Growing Season (Julian Date)	=	336 days
Average Wind Speed	=	11.3 mph
Average 1st Quarter Relative Humidity	=	69 %
Average 2nd Quarter Relative Humidity	=	69 %
Average 3rd Quarter Relative Humidity	=	62 %
Average 4th Quarter Relative Humidity	=	69 %

Note: Evapotranspiration data was obtained for NACOGDOCHES, TEXAS

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
4.45	3.17	3.53	3.13	5.29	4.18
2.6	3.08	4.08	4.13	4.54	4.44

Note: Precipitation was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
51.4	54.5	61	68.7	74.9	80.6
83.1	82.6	78.4	69.7	60.1	54

Note: Temperature was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS
Solar radiation was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS (Latitude: 31.37)

Average Annual Totals Summary

Title: Interim, 60' Waste, 2.0% Slope, 200' Length
Simulated on: 12/1/2023 10:06

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	45.09	[6.73]	163,658.6	100.00
Runoff	3.516	[1.61]	12,763.0	7.80
Evapotranspiration	31.213	[2.692]	113,304.1	69.23
Subprofile1				
Lateral drainage collected from Layer 4	10.2140	[3.9152]	37,076.9	22.66
Percolation/leakage through Layer 6	0.000016	[0.000005]	0.0579	0.00
Average Head on Top of Layer 5	0.0099	[0.0038]	---	---
Water storage				
Change in water storage	0.1417	[3.4507]	514.6	0.31

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Interim, 60' Waste, 2.0% Slope, 200' Length
Simulated on: 12/1/2023 10:06

	Peak Values for Years 1 - 30*	
	(inches)	(cubic feet)
Precipitation	4.62	16,770.6
Runoff	2.340	8,495.8
Subprofile1		
Drainage collected from Layer 4	0.1963	712.6
Percolation/leakage through Layer 6	0.000000	0.0009
Average head on Layer 5	0.0693	---
Maximum head on Layer 5	0.1366	---
Location of maximum head in Layer 4	2.72 (feet from drain)	
Other Parameters		
Snow water	0.7003	2,542.1
Maximum vegetation soil water	0.4516 (vol/vol)	
Minimum vegetation soil water	0.1870 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Interim, 60' Waste, 2.0% Slope, 200' Length
Simulated on: 12/1/2023 10:06
Simulation period: 30 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	3.7279	0.3107
2	215.5460	0.2994
3	9.3178	0.3882
4	0.0379	0.1993
5	0.0000	0.0000
6	10.2480	0.4270
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Interim, 60' Waste, 2.8% Slope... **Simulated On:** 12/1/2023 10:26

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
CL - Clay Loam
Material Texture Number 11

Thickness	=	12	inches
Porosity	=	0.464	vol/vol
Field Capacity	=	0.31	vol/vol
Wilting Point	=	0.187	vol/vol
Initial Soil Water Content	=	0.3419	vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05	cm/sec

Layer 2
Type 1 - Vertical Percolation Layer (Waste)
Municipal Solid Waste (MSW) (900 pcy)
Material Texture Number 18

Thickness	=	720	inches
Porosity	=	0.671	vol/vol
Field Capacity	=	0.292	vol/vol
Wilting Point	=	0.077	vol/vol
Initial Soil Water Content	=	0.2945	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03	cm/sec

Layer 3
Type 1 - Vertical Percolation Layer
CL - Clay Loam
Material Texture Number 11

Thickness	=	24	inches
Porosity	=	0.464	vol/vol
Field Capacity	=	0.31	vol/vol
Wilting Point	=	0.187	vol/vol
Initial Soil Water Content	=	0.3431	vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05	cm/sec

Layer 4
Type 2 - Lateral Drainage Layer
Custom Geonet 2
Material Texture Number 143

Thickness	=	0.19	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.0555	vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E+00	cm/sec
Slope	=	2.8	%
Drainage Length	=	325	ft

Layer 5

Type 4 - Flexible Membrane Liner

HDPE Membrane

Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	4	Holes/Acre
FML Placement Quality	=	3	Good

Layer 6

Type 3 - Barrier Soil Liner

Liner Soil (High)

Material Texture Number 16

Thickness	=	24	inches
Porosity	=	0.427	vol/vol
Field Capacity	=	0.418	vol/vol
Wilting Point	=	0.367	vol/vol
Initial Soil Water Content	=	0.427	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	85	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	12	inches
Initial Water in Evaporative Zone	=	4.103	inches
Upper Limit of Evaporative Storage	=	5.568	inches
Lower Limit of Evaporative Storage	=	2.244	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	234.627	inches
Total Initial Water	=	234.627	inches

Total Subsurface Inflow	=	0 inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	31.37 Degrees
Maximum Leaf Area Index	=	2
Start of Growing Season (Julian Date)	=	55 days
End of Growing Season (Julian Date)	=	336 days
Average Wind Speed	=	11.3 mph
Average 1st Quarter Relative Humidity	=	69 %
Average 2nd Quarter Relative Humidity	=	69 %
Average 3rd Quarter Relative Humidity	=	62 %
Average 4th Quarter Relative Humidity	=	69 %

Note: Evapotranspiration data was obtained for NACOGDOCHES, TEXAS

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
4.45	3.17	3.53	3.13	5.29	4.18
2.6	3.08	4.08	4.13	4.54	4.44

Note: Precipitation was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
51.4	54.5	61	68.7	74.9	80.6
83.1	82.6	78.4	69.7	60.1	54

Note: Temperature was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS
Solar radiation was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS (Latitude: 31.37)

Average Annual Totals Summary

Title: Interim, 60' Waste, 2.8% Slope, 325' Length
Simulated on: 12/1/2023 10:27

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	45.09	[6.73]	163,658.6	100.00
Runoff	3.516	[1.61]	12,763.0	7.80
Evapotranspiration	31.213	[2.692]	113,304.1	69.23
Subprofile1				
Lateral drainage collected from Layer 4	10.2139	[3.9155]	37,076.4	22.65
Percolation/leakage through Layer 6	0.000018	[0.000006]	0.0654	0.00
Average Head on Top of Layer 5	0.0115	[0.0044]	---	---
Water storage				
Change in water storage	0.1419	[3.4512]	515.1	0.31

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Interim, 60' Waste, 2.8% Slope, 325' Length
Simulated on: 12/1/2023 10:27

	Peak Values for Years 1 - 30*	
	(inches)	(cubic feet)
Precipitation	4.62	16,770.6
Runoff	2.340	8,495.8
Subprofile1		
Drainage collected from Layer 4	0.1943	705.2
Percolation/leakage through Layer 6	0.000000	0.0010
Average head on Layer 5	0.0796	---
Maximum head on Layer 5	0.1579	---
Location of maximum head in Layer 4	2.37 (feet from drain)	
Other Parameters		
Snow water	0.7003	2,542.1
Maximum vegetation soil water	0.4516 (vol/vol)	
Minimum vegetation soil water	0.1870 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Interim, 60' Waste, 2.8% Slope, 325' Length
Simulated on: 12/1/2023 10:27
Simulation period: 30 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	3.7279	0.3107
2	215.5460	0.2994
3	9.3178	0.3882
4	0.0437	0.2299
5	0.0000	0.0000
6	10.2480	0.4270
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Closed, 2% Slope, 200' Length **Simulated On:** 12/1/2023 10:34

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
CL - Clay Loam
Material Texture Number 11

Thickness	=	6 inches
Porosity	=	0.464 vol/vol
Field Capacity	=	0.31 vol/vol
Wilting Point	=	0.187 vol/vol
Initial Soil Water Content	=	0.4536 vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05 cm/sec

Layer 2
Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04 inches
Effective Sat. Hyd. Conductivity	=	4.00E-13 cm/sec
FML Pinhole Density	=	1 Holes/Acre
FML Installation Defects	=	4 Holes/Acre
FML Placement Quality	=	3 Good

Layer 3
Type 1 - Vertical Percolation Layer
Custom Soil 1
Material Texture Number 43

Thickness	=	18 inches
Porosity	=	0.427 vol/vol
Field Capacity	=	0.418 vol/vol
Wilting Point	=	0.367 vol/vol
Initial Soil Water Content	=	0.4094 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-05 cm/sec

Layer 4
Type 1 - Vertical Percolation Layer
CL - Clay Loam
Material Texture Number 11

Thickness	=	6 inches

Porosity	=	0.464 vol/vol
Field Capacity	=	0.31 vol/vol
Wilting Point	=	0.187 vol/vol
Initial Soil Water Content	=	0.31 vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05 cm/sec

Layer 5

Type 1 - Vertical Percolation Layer (Waste)

Municipal Solid Waste (MSW) (900 pcy)

Material Texture Number 18

Thickness	=	720 inches
Porosity	=	0.671 vol/vol
Field Capacity	=	0.292 vol/vol
Wilting Point	=	0.077 vol/vol
Initial Soil Water Content	=	0.292 vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-03 cm/sec

Layer 6

Type 1 - Vertical Percolation Layer

CL - Clay Loam

Material Texture Number 11

Thickness	=	24 inches
Porosity	=	0.464 vol/vol
Field Capacity	=	0.31 vol/vol
Wilting Point	=	0.187 vol/vol
Initial Soil Water Content	=	0.31 vol/vol
Effective Sat. Hyd. Conductivity	=	6.40E-05 cm/sec

Layer 7

Type 2 - Lateral Drainage Layer

Custom Geonet 1

Material Texture Number 123

Thickness	=	0.19 inches
Porosity	=	0.85 vol/vol
Field Capacity	=	0.01 vol/vol
Wilting Point	=	0.005 vol/vol
Initial Soil Water Content	=	0.0106 vol/vol
Effective Sat. Hyd. Conductivity	=	5.00E+00 cm/sec
Slope	=	2 %
Drainage Length	=	200 ft

Layer 8

Type 4 - Flexible Membrane Liner

HDPE Membrane

Material Texture Number 35

Thickness	=	0.06	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	4	Holes/Acre
FML Placement Quality	=	3	Good

Layer 9

Type 3 - Barrier Soil Liner

Liner Soil (High)

Material Texture Number 16

Thickness	=	24	inches
Porosity	=	0.427	vol/vol
Field Capacity	=	0.418	vol/vol
Wilting Point	=	0.367	vol/vol
Initial Soil Water Content	=	0.427	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-07	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	85	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	2.721	inches
Upper Limit of Evaporative Storage	=	2.784	inches
Lower Limit of Evaporative Storage	=	1.122	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	239.88	inches
Total Initial Water	=	239.88	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude	=	31.37	Degrees
Maximum Leaf Area Index	=	3.5	
Start of Growing Season (Julian Date)	=	55	days
End of Growing Season (Julian Date)	=	336	days
Average Wind Speed	=	11.3	mph
Average 1st Quarter Relative Humidity	=	69	%
Average 2nd Quarter Relative Humidity	=	69	%

Average 3rd Quarter Relative Humidity	=	62 %
Average 4th Quarter Relative Humidity	=	69 %

Note: Evapotranspiration data was obtained for NACOGDOCHES, TEXAS

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
4.45	3.17	3.53	3.13	5.29	4.18
2.6	3.08	4.08	4.13	4.54	4.44

Note: Precipitation was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
51.4	54.5	61	68.7	74.9	80.6
83.1	82.6	78.4	69.7	60.1	54

Note: Temperature was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS
Solar radiation was simulated using HELP v3.07 data files for the following location: HOUSTON, TEXAS (Latitude: 31.37)

Average Annual Totals Summary

Title: Closed, 2% Slope, 200' Length
Simulated on: 12/1/2023 10:35

	Average Annual Totals for Years 1 - 30*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	45.09	[6.73]	163,658.6	100.00
Runoff	13.984	[5.121]	50,761.5	31.02
Evapotranspiration	31.053	[2.761]	112,722.7	68.88
Subprofile1				
Percolation/leakage through Layer 2	0.045954	[0.006734]	166.8	0.10
Average Head on Top of Layer 2	1.7634	[0.2677]	---	---
Subprofile2				
Lateral drainage collected from Layer 7	0.0460	[0.0067]	166.8	0.10
Percolation/leakage through Layer 9	0.000001	[0]	0.0053	0.00
Average Head on Top of Layer 8	0.0000	[0]	---	---
Water storage				
Change in water storage	0.0021	[0.568]	7.5767	0.00

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: Closed, 2% Slope, 200' Length
Simulated on: 12/1/2023 10:35

	Peak Values for Years 1 - 30*	
	(inches)	(cubic feet)
Precipitation	4.62	16,770.6
Runoff	4.085	14,827.1
Subprofile1		
Percolation/leakage through Layer 2	0.000415	1.5059
Average head on Layer 2	6.0000	
Subprofile2		
Drainage collected from Layer 7	0.0004	1.4985
Percolation/leakage through Layer 9	0.000000	0.0000
Average head on Layer 8	0.0001	---
Maximum head on Layer 8	0.0003	---
Location of maximum head in Layer 7	0.00 (feet from drain)	
Other Parameters		
Snow water	0.7003	2,542.1
Maximum vegetation soil water	0.4640 (vol/vol)	
Minimum vegetation soil water	0.1870 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Closed, 2% Slope, 200' Length
Simulated on: 12/1/2023 10:35
Simulation period: 30 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	2.7840	0.4640
2	0.0000	0.0000
3	7.3688	0.4094
4	1.8600	0.3100
5	210.2400	0.2920
6	7.4400	0.3100
7	0.0020	0.0103
8	0.0000	0.0000
9	10.2480	0.4270
Snow water	0.0000	---

PART III, ATTACHMENT 15, APPENDIX G-2

REPLACEMENT PAGES

APPENDIX G2

GEOCOMPOSITE DEMONSTRATION

SCS Engineers
TBPE Reg. # F-3407

1/19/24

STATE OF TEXAS
JEFFREY K. REED
80103
LICENSED
PROFESSIONAL ENGINEER

inclusive of pgs. G2-1 to G2-4

FOR PERMITTING PURPOSES ONLY

Solution:

1. Estimate geocomposite thickness for the worst case leachate generation and loading conditions, based on an initial thickness of 200 mils:

Assume the geocomposite will undergo linear compression due to weight of soil (i.e., daily, intermediate, or final cover and protective cover) and waste

Unloaded Geocomposite Thickness =	0.20	in
Percent Thickness Retained When Subjected to 15,000 psf Surcharge =	80	%, as provided by manufacturer
Unit Weight of Waste =	65	pcf
Unit Weight of Soil Only =	120	pcf
Composite Unit Weight of Waste and Daily Cover = (80% Waste and 20% Daily Cover)	76	pcf

Table 1 - Geocomposite Thickness

Fill Condition	d_W[1] (ft)	d_S[2] (ft)	P[3] (psf)	t[4] (in)
Active	10	2.5	1,060	0.20
Interim	60	3.0	4,920	0.19
Final	60	4.5	5,100	0.19

[1] d_W is the depth of waste and daily cover soil above the geocomposite.

[2] d_S is the depth of soil (i.e., protective, daily, and intermediate) above the geocomposite.

[3] P is the pressure on the geocomposite due to the weight of the waste and soil.

[4] t is the thickness of the geocomposite after being subjected to linear compression.
t is calculated by equation (Initial Thickness) - (Max. Compression) x P/15,000.

2 Reduction Factors for Strength and Environmental Conditions

Table 2 - Reduction Factors

Environmental Condition	Range	Fill Condition		
		Active[2] (10' Waste)	Interim (60' Waste)	Closed (60' Waste)
Geotextile Intrusion [1]	1.0 - 1.2	1.00	1.10	1.20
Creep Deformation [1]	1.4 - 2.0	1.00	1.60	1.80
Chemical Clogging [1,3]	1.5 - 2.0	1.00	1.50	2.00
Biological Clogging [3]	1.1 - 1.3	1.00	1.20	1.30
Composite Reduction Factor[4]	1.00 - 5.62	1.00	3.17	5.62

Notes:

[1] Range values for geotextile intrusion, creep deformation, and chemical clogging were obtained from Giroud, J.P., Zornberg, J.G., and Zhao, A., 2000, "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", *Geosynthetics International*, Vol. 7, Nos. 4-6, pp. 285-380.

[2] Reduction factors were assumed to be negligible for the active condition due to the short duration of this landfill condition.

[3] Range values for biological clogging were obtained from GRI Standard GC8, Geosynthetic Institute, 2001, "Determination of the Allowable Flow Rate of a Drainage Geocomposite".

[4] The Composite Reduction Factor is the product of all of the factors for the respective fill condition.

3. Develop and confirm assumptions for hydraulic conductivity (k) of the geocomposite for HELP model.

Table 3 - Assumed Hydraulic Conductivity

Fill Condition	d_W[1] (ft)	P[2] (psf)	t[3] (in)	Reduction[4] Factor	k_{min}[5] (cm/s)	Peak Leachate Head (in)[6]
Active	10	1,060	0.20	1.00	16.00	0.10
Interim	60	4,920	0.19	3.17	5.00	0.16
Closed	60	5,100	0.19	5.62	2.75	0.0003

[1] d_W is the depth of waste and daily cover above the geocomposite from Table 1.

[2] P is the pressure on the geocomposite due to the weight of the waste and soil from Table 1.

[3] t is the calculated geocomposite thickness from Table 1.

[4] Reduction Factors from Table 2.

[5] k is the assumed hydraulic conductivity value for HELP model. Reduction Factors will be applied to determine required minimum manufacturer transmissivity values, below.

[6] Maximum head on the liner, as calculated by HELP model.

4. Using the hydraulic conductivity values from Table 3 (above), calculate minimum transmissivity values for use during design and specifying geocomposites.

$$T_{min} = ((t * 2.54 \text{ cm/in}) * k_{min}) * \text{Reduction Factor}$$

Table 4 - Minimum Required Transmissivity for Geocomposite Design

Fill Condition	P (psf)	t (in)	k_{min} (cm/s)	Reduction Factor	T_{min} (cm^2/sec)	**$T_{min\ Required}$ (m^3/sec/m)**
Active	1,060	0.20	16.00	1.00	8.13E+00	**8.13E-04**
Interim	4,920	0.19	5.00	3.17	7.64E+00	**7.64E-04**
Closed	5,100	0.19	2.75	5.62	7.45E+00	**7.45E-04**

5. Compare T_{min} values from Method No. 4 (above) with published manufacturer transmissivity values.

Table 5 - Comparison of Manufacturer's Reported Transmissivity to the Minimum Required Transmissivity

Fill Condition	P (psf)	T_{min} (m^2/sec) (see Table 4)	Manufacturer's Transmissivity Values P (psf)	Manufacturer's Transmissivity Values T_{man}[1,3] (m^3/sec/m)	**$T_{min} \geq T_{man}$ (Yes/No)**
Active	1,060	8.13E-04	1,000	1.00E-03	**Yes**
Interim	4,920	7.64E-04	4,920	7.34E-04	**Yes**
Closed	5,100	7.45E-04	5,100	7.21E-04	**Yes**

[1] Geocomposite Transmissivity values determined from tests with hydraulic gradient of 0.02. If higher gradient used by manufacturer to determine transmissivity, manufacturer will be required to certify that geocomposite will provide comparable drainage as described in Table 4, above.

[2] The product shown in the table is provided to demonstrate the availability of a product that will meet or exceed the required drainage characteristics. Other manufactured products, either bi-planar or tri-planar geocomposites are acceptable if confirmed to meet the minimum required transmissivity values indicated in Table 5 (above).

[3] The T_{man} value (i.e., as provided by geocomposite manufacturer), shown in the table above, is representative of the GSE 200-mil Fabrinet. The 1,000-psf asurcharge (P) was taken directly from 100-hour Transmissivity Testing performed according to ASTM D 4716. The T_{man} values for the 4,920-psf and 5,100-psf surcharge conditions were interpolated from the 100-hr Transmissivity Test results

Conclusion: As indicated in Table 5 and as shown on the HELP Model Summary Sheet, a geocomposite with drainage characteristics that meet or exceed the transmissivity values tested by the geocomposite manufacuturer will be installed for the liner system, and such geocomposite will maintain less than 30 cm of leachate over the liner system.

PART III, ATTACHMENT 15, APPENDIX H
REPLACEMENT PAGES

SCS ENGINEERS

File No. 16209006.26

Calculated By RJE Date January 19, 2024 Subject Pipe Strength Calculations: 6" Leachate Collection
Chkd By JKR Date City of Nacogdoches Landfill - Block O

Step 1 - Calculate the Total Soil Pressure (P_t) applied to the pipe. (correct P_t for slots or perforations in pipe wall)

$P_t = P_S + P_L$

CASE 1: FINAL LOADING CONDITIONS

$P_S = {}^1/_{144} * \Sigma (H_i U_i)$ (Prism Load)

Static Load Summary Table

Description of Overburden Layer	Thickness(H) (ft)	Unit Wt. (U) (pcf)	Static Load (P_S) (psi)
Drainage Coarse Aggregate	2	120	1.7
Refuse w/ Daily Cover	60	75	31.3
Final Cover	3	120	2.5
		Total Static Load (P_S):	35.4 psi

$$P_L = \frac{3 I_I W_L H_L^3}{2\pi R^5} * {}^1/_{144} + \frac{3 I_I W_L H_L^3}{2\pi H_L^5} * {}^1/_{144}$$ (Boussinesq's Equa. Ref. 1, pg. 45)

I_I = 1.5 (for unpaved road)

W_L = 48,000 lbs (loaded scraper)

H_L = 65 ft

$R = (X^2 + H_L^2)^{0.5}$

X = 11.0 ft (assumes pipe is located directly below one wheel on 11-ft axle)

R = 65.9 ft

P_L = 0.1 psi

$P_t = P_S + P_L$

$P_{t(final)}$ = 35.4 + 0.1 35.5 psi

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TBPE Reg. # F-3407

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STATE OF TEXAS
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Solution - Flow Capacity of Pipe (A):

Determine the peak daily flow rate estimate:

The following table summarizes the fill conditions that are likely to be present and have the greatest contribution of leachate into the LCS. The peak flow rate (lateral drainage in the LCS layer) is shown for each condition. All flow rates are per acre.

From the HELP model (Appendix G1):

CONDITION	PEAK DAILY	
	cf/d/ac	g/d/ac
Active, 10' Waste	1,464	10,951
Interim, 60' Waste	713	5,333

The assumed worst case condition is for Phases 1, 4, and 5 of Block O (approximately 31.3 acres), which drain to the east leachate collection header pipe.

Maximum leachate generation and drainage expected in the east leachate collection header pipe is predicted to occur assuming the following scenario:

1.	Active, 10' Waste	10.4	ac
2.	Interim, 60' Waste	20.8	ac
	Total =	31.3	ac

CONDITION	AREA	PEAK DAILY		
	ac	g/d/ac	gpd	cfs
Active, 10' Waste	10.4	10,951	114,107	0.1764
Interim, 60' Waste	20.8	5,333	111,145	0.1719
		Total =	225,251	0.3483
With applied Factor of Safety of 1.5:		Total =	337,877	0.5225

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inclusive of pgs H-8 to H-9

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CITY OF NACOGDOCHES LANDFILL
BLOCK O - LEACHATE COLLECTION
PIPING FLOW CAPACITY

Estimate the flow capacity (Q_{full}) of a 6-inch diameter perforated pipe:

$$Q_{full} = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

Where:

A = Cross-sectional area of pipe, with "d" representing the inside diameter in feet

R = Hydraulic radius of pipe in feet under full flow conditions

From Pipe Structural Stability Calculations:

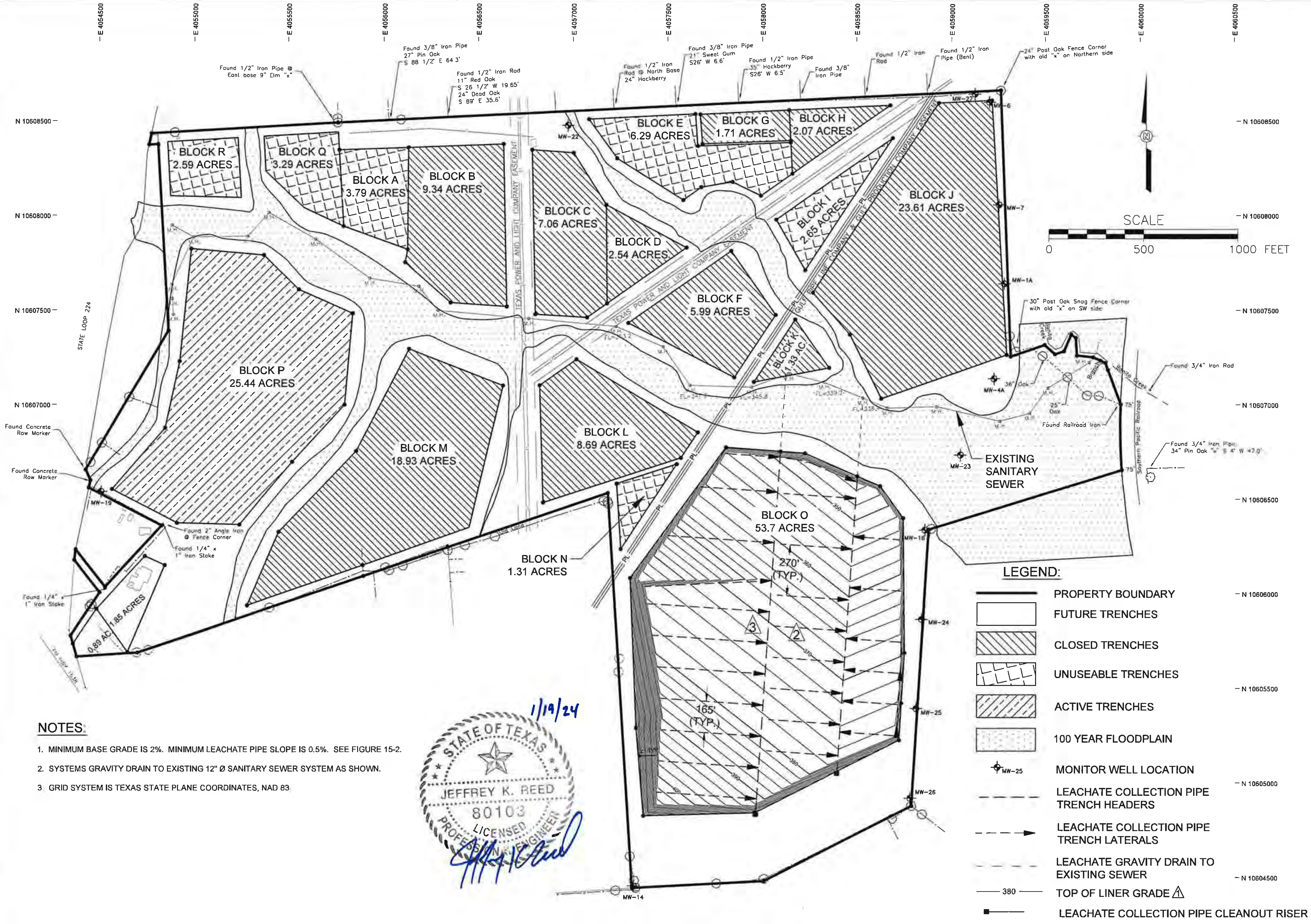
	Outside Diameter (in) =	6.625	
	Dimension Ratio (DR) =	17.0	
	Wall Thickness (t) =	0.390	
	ID =	5.846	in
	=	0.487	ft
$A = \frac{\Pi \times d^2}{4}$	A =	0.186	sq ft
$R = \frac{d}{4}$	R =	0.122	ft
S = Design slope of pipe	S =	0.0050	ft / ft
n = Manning's number	n =	0.009	for HDPE smooth pipe

Q_{full} =	0.535	cfs	or	240.3 gpm

Compare Q_{max} and Q_{full} (Peak Flow Rate):

Q_{full} =	0.535	cfs	>>	Q_{max} =	0.522	cfs

Conclusion:
The flow capacity of a 6-inch diamater HDPE pipe with a DR of 17 exceeds the maximum leachate generation (i.e., associated with the peak daily flow rate expected at the landfill).



NOTES:

1. MINIMUM BASE GRADE IS 2%. MINIMUM LEACHATE PIPE SLOPE IS 0.5%. SEE FIGURE 15-2.
2. SYSTEMS GRAVITY DRAIN TO EXISTING 12" Ø SANITARY SEWER SYSTEM AS SHOWN.
3. GRID SYSTEM IS TEXAS STATE PLANE COORDINATES, NAD 83

LEGEND:

- PROPERTY BOUNDARY
- FUTURE TRENCHES
- CLOSED TRENCHES
- UNUSEABLE TRENCHES
- ACTIVE TRENCHES
- 100 YEAR FLOODPLAIN
- MONITOR WELL LOCATION
- LEACHATE COLLECTION PIPE TRENCH HEADERS
- LEACHATE COLLECTION PIPE TRENCH LATERALS
- LEACHATE GRAVITY DRAIN TO EXISTING SEWER
- 380 TOP OF LINER GRADE 3
- LEACHATE COLLECTION PIPE CLEANOUT RISER

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1/19/24

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REV	DATE	DESCRIPTION	BY
3	12/2023	REVISE BLOCK O BASE GRADES AND LCS.	SCS
2	8/2019	REVISED BLOCKS O, LCS	SCS
1	8/2013	REVISED LEGEND	JKR

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: LEACHATE COLLECTION SYSTEM LAYOUT - BLOCK O

PROJECT TITLE: LANDFILL RECONFIGURATION PERMIT MODIFICATION

CLIENT: CITY OF NACOGDOCHES LANDFILL
PERMIT NO. MSW-720
NACOGDOCHES, NACOGDOCHES COUNTY, TEXAS

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT CONSULTING ENGINEERS
12651 BRIAR FOREST, SUITE 205, HOUSTON, TX 77077
PH (281) 397-6747 FAX NO. (281) 293-7876

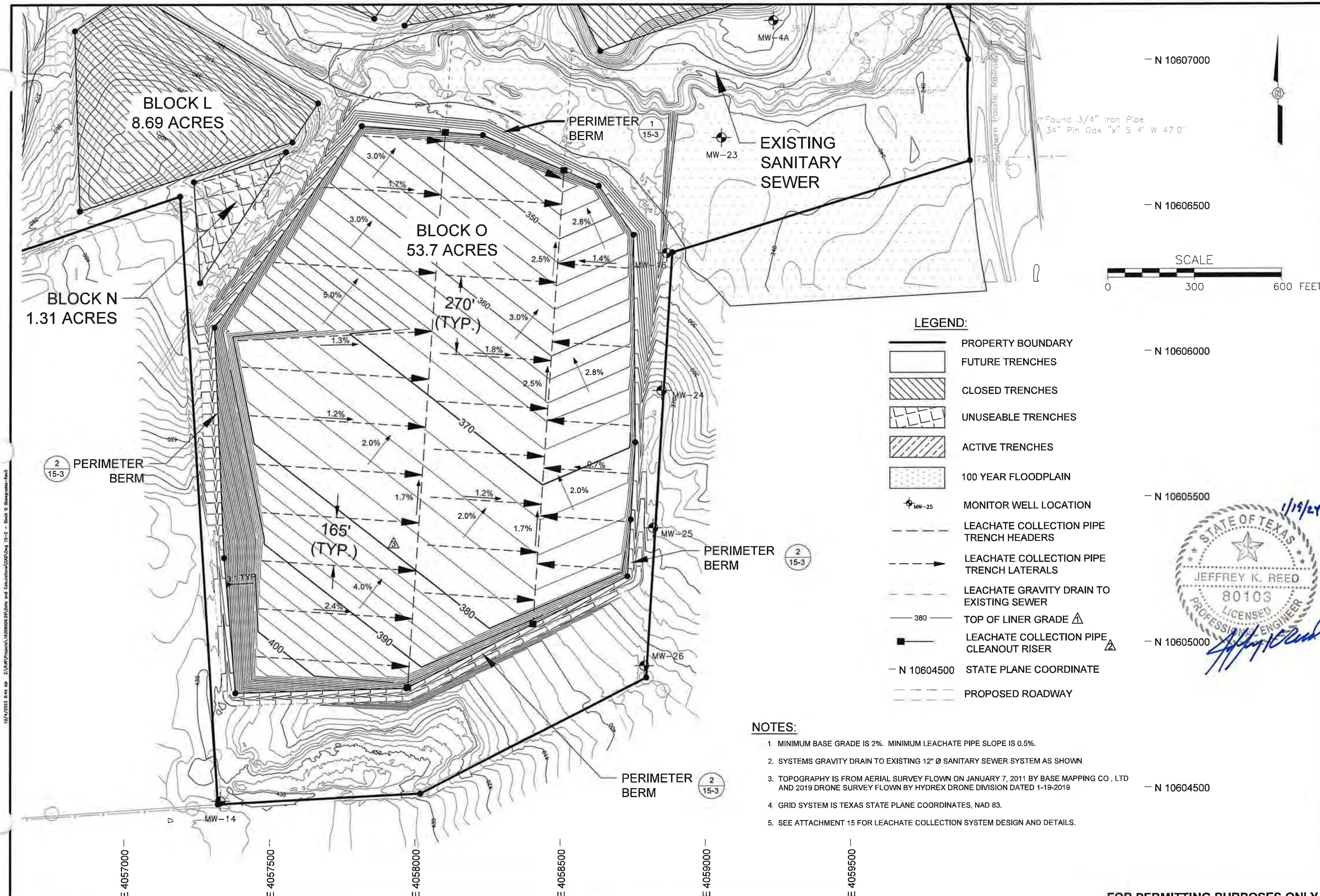
PROJ. NO. 16209006.02

CADD FILE: DWG 15-1 - LEACHATE SYSTEM LAYOUT - BLOCK O-REV3

DATE: 6-2011

SCALE: AS SHOWN

DRAWING NO. 15-1



LEGEND:

- PROPERTY BOUNDARY
- FUTURE TRENCHES
- CLOSED TRENCHES
- UNUSEABLE TRENCHES
- ACTIVE TRENCHES
- 100 YEAR FLOODPLAIN
- MONITOR WELL LOCATION (MW-25)
- LEACHATE COLLECTION PIPE TRENCH HEADERS
- LEACHATE COLLECTION PIPE TRENCH LATERALS
- LEACHATE GRAVITY DRAIN TO EXISTING SEWER
- 380 — TOP OF LINER GRADE (3)
- LEACHATE COLLECTION PIPE CLEANOUT RISER (2)
- N 10604500 STATE PLANE COORDINATE
- PROPOSED ROADWAY

NOTES:

1. MINIMUM BASE GRADE IS 2%. MINIMUM LEACHATE PIPE SLOPE IS 0.5%.
2. SYSTEMS GRAVITY DRAIN TO EXISTING 12" Ø SANITARY SEWER SYSTEM AS SHOWN
3. TOPOGRAPHY IS FROM AERIAL SURVEY FLOWN ON JANUARY 7, 2011 BY BASE MAPPING CO , LTD AND 2019 DRONE SURVEY FLOWN BY HYDREX DRONE DIVISION DATED 1-19-2019
4. GRID SYSTEM IS TEXAS STATE PLANE COORDINATES, NAD 83.
5. SEE ATTACHMENT 15 FOR LEACHATE COLLECTION SYSTEM DESIGN AND DETAILS.

STATE OF TEXAS
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LICENSED PROFESSIONAL ENGINEER
1/19/24

FOR PERMITTING PURPOSES ONLY

REV	DATE	DESCRIPTION	BY
3	12/2023	REVISE BLOCK O BASE GRADES AND LCS	SCS
2	8/2019	REVISE BLOCK O, LCS	SCS
1	8/2013	REVISED LEGEND	JKR

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: BASE GRADES - BLOCK O

PROJECT TITLE: LANDFILL RECONFIGURATION PERMIT MODIFICATION

CLIENT: CITY OF NACOGDOCHES LANDFILL
PERMIT NO. MSW-720
NACOGDOCHES, NACOGDOCHES COUNTY, TEXAS

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS
12651 BRIAR FOREST, SUITE 205, HOUSTON, TX 77077
PH (281) 397-6747 FAX NO. (281) 293-7878

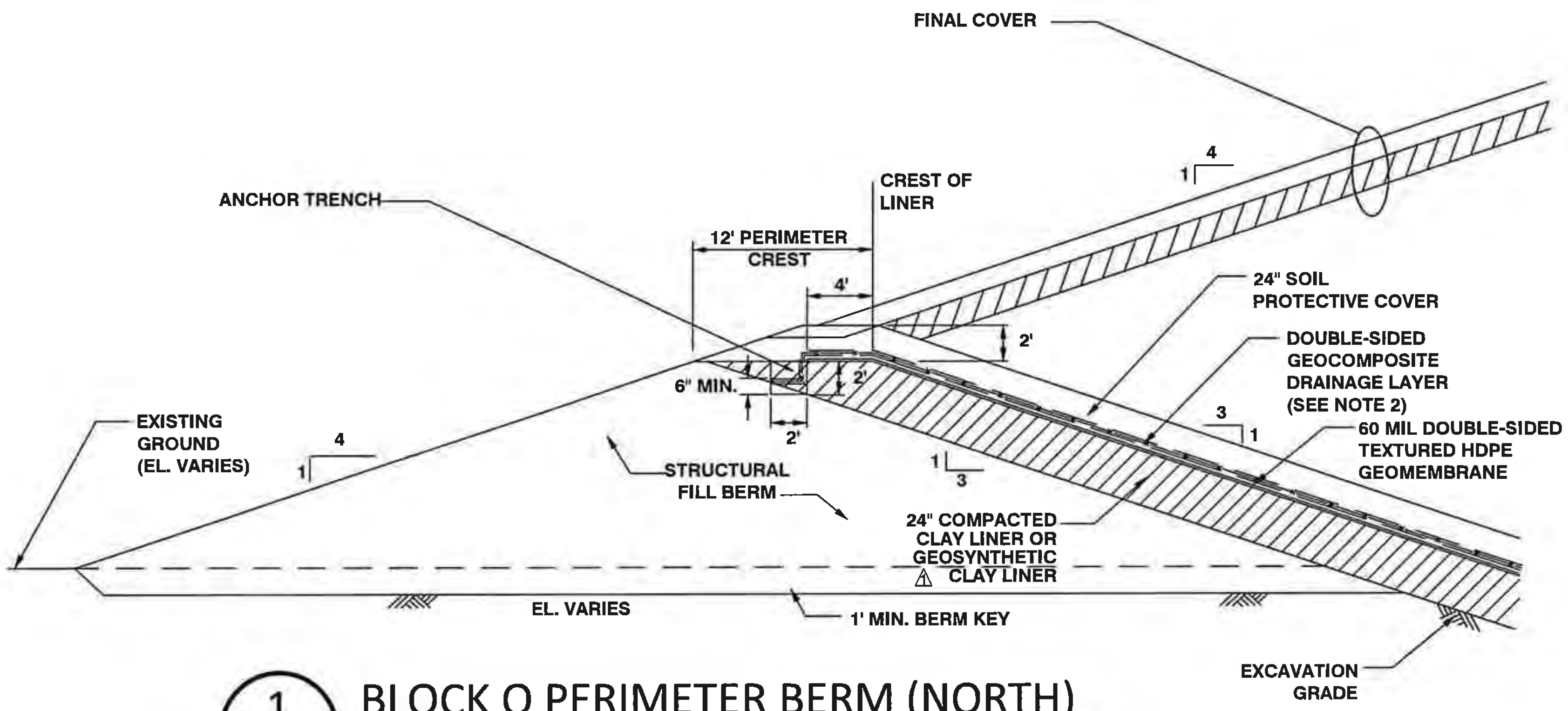
PROJ. NO.: 16209006.02 | DWN. BY: RLD | Q/A RVW BY: JRM
DSN. BY: RLD | CHK. BY: JKR | APP. BY: JKR

CADD FILE: DWG 15-2 - BLOCK O BASEGRADES-REV3

DATE: 6-2011

SCALE: AS SHOWN

DRAWING NO. 15-2

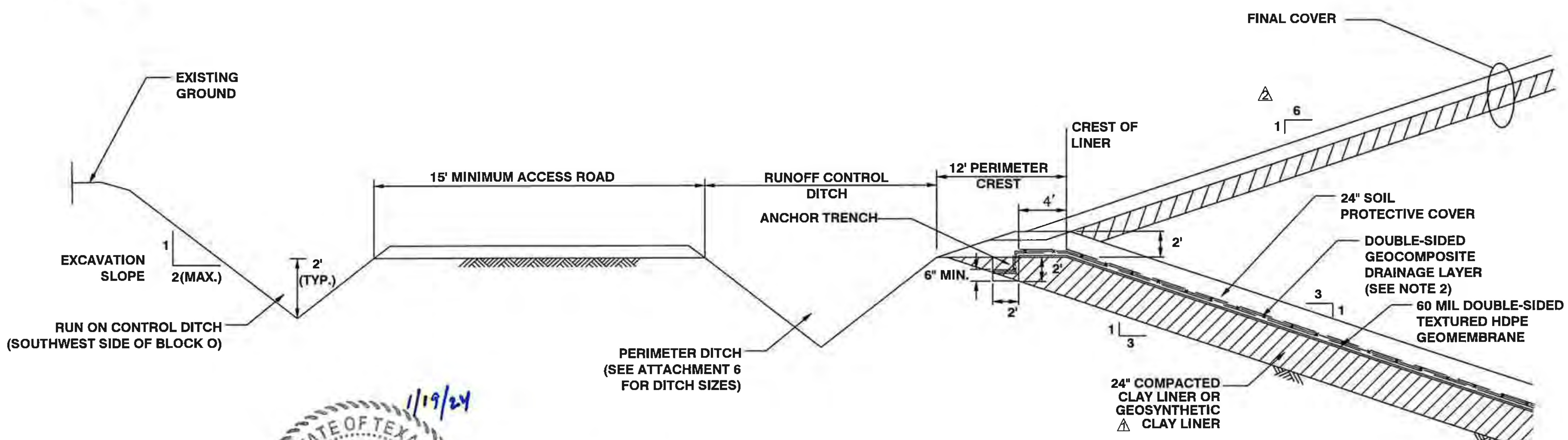


1 / 15-3 BLOCK O PERIMETER BERM (NORTH)

NOT TO SCALE

NOTES:

1. ALL DIMENSIONS INDICATE MINIMUM VALUES UNLESS OTHERWISE NOTED.
2. GEOCOMPOSITE DRAINAGE LAYER SHALL HAVE A MINIMUM TRANSMISSIVITY OF $1E^{-4}M^2$/SEC AT A GRADIENT OF 0.1 UNDER A LOAD OF 10,000 P.S.F. DOUBLE SIDED GEOCOMPOSITE SHALL BE HEAT-BONDED BOTH SIDES.
3. THE DRAINAGE LAYER ON THE CELL FLOOR SHALL CONSIST OF A SINGLE-SIDED GEOCOMPOSITE ON SMOOTH GEOMEMBRANE. TEXTURED GEOMEMBRANE MAY BE USED ON FLOOR WITH DOUBLE-SIDED GEOCOMPOSITE.
4. THE HDPE PIPE USED IN THE LEACHATE COLLECTION SYSTEM SHALL HAVE A STANDARD DIMENSION RATIO (SDR) OF 17.
5. CHIMNEY DRAINS SHALL BE USED ALONG LEACHATE COLLECTION TRENCHES AS SHOWN ON DRAWING 15-1 IF ON-SITE PROTECTIVE COVER IS USED. CHIMNEY DRAIN SHALL EXTEND A MINIMUM OF 6 INCHES ABOVE THE TOP OF PROTECTIVE COVER.
6. THE BERM SHALL BE KEYED INTO NATURAL GROUND A MINIMUM OF 1 FOOT OR AS NEEDED TO REMOVE VEGETATION, ROOT, ORGANIC MATTER OR UNSUITABLE MATERIAL SUCH AS SILT.
7. ALL GEOTEXTILE WHICH WRAPS A DRAINAGE AGGREGATE SHALL HAVE A MINIMUM 12" SEAM OVERLAP OR BE SEWN.
8. FOR BLOCK O, A REINFORCED GEOSYNTHETIC CLAY LINER MAY BE USED IN LEIU OF A 2' COMPACTED CLAY LINER



2 / 15-3 BLOCK O PERIMETER BERM (EAST, SOUTH AND WEST)

NOT TO SCALE

FOR PERMITTING PURPOSES ONLY

REV	DATE	DESCRIPTION	BY
2	12/2023	REVISED SLOPE FOR DETAIL 2	SCS
1	8/2013	ADD GCL/FML LINER OPTION	JKR

TEXAS BOARD OF PROFESSIONAL ENGINEERS REG. NO. F-3407

DRAWING TITLE: BLOCK O/PERIMETER DETAILS

PROJECT TITLE: LANDFILL RECONFIGURATION PERMIT MODIFICATION

CLIENT: CITY OF NACOGDOCHES LANDFILL
PERMIT NO. MSW-720
NACOGDOCHES, NACOGDOCHES COUNTY, TEXAS

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PROJ. NO. 16209006.26 | DWN. BY: JMG | Q/A RVW BY: | DSN. BY: | CHK. BY: RLD | APP. BY:

CADD FILE: DWG 15-3 BLOCK O PER. DET-REV2

DATE: 12/2023

SCALE: AS SHOWN

DRAWING NO. 15-3