PART III, ATTACHMENT 3

APPENDIX III-3C

STABILITY ANALYSIS

APPENDIX III-3C-1

Excavation Stability Analysis

Prepared:	**PKP**
Checked:	**JBF**
Reviewed:	**CGD**

EXCAVATION STABILITY ANALYSIS

STATE OF TEXAS
2/12/21
CHARLES G. DOMINGUEZ
83247
LICENSED PROFESSIONAL ENGINEER

GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

INTENDED FOR PERMITTING PURPOSES ONLY

For sheets 1 and 2; Figures III-3C1-1 and III-3C1-2

1.0 OBJECTIVE

Evaluate the factor of safety against failure of the excavated slopes.

2.0 GIVEN

Based on a review of the design grades, the deepest proposed excavation (EXCV) occurs within the proposed expansion area located northeast of the existing Center Block landfill. The cross-section in this area consists of a 3H:1V slope from an approximate elevation of 108 ft to the toe at design elevation of 76 ft (Section B-B', shown in Figure 1 below and on Figure III-3-4).

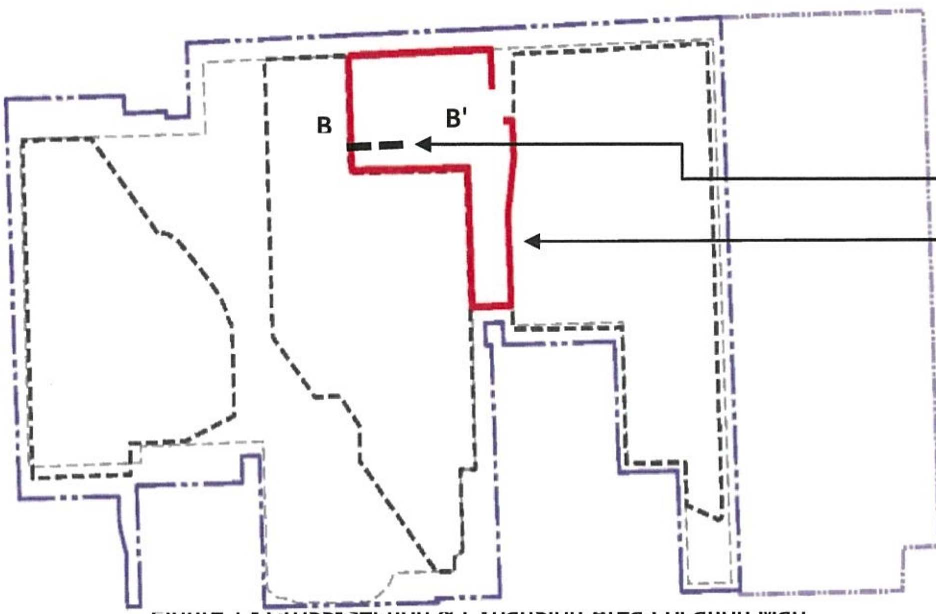

Figure 1 - Cross-Section & Expansion Area Location Map

3.0 ASSUMPTIONS

▪ SOIL CONDITIONS

Subsurface stratigraphies previously developed by Biggs & Matthews Environmental (BME) were used to determine the soil strata in the future expansion area. The results of the subsurface investigation and previous studies show that the site is underlain by four distinct layers listed below (from top to bottom):

- Layer I: Clays and sandy clays with minor amounts of sand and silt
- Layer II: Channel fill deposits consisting predominantly of fine sands with gradations to silty fine sands and silts and is considered the uppermost groundwater-bearing unit of the site
- Layer III: Primarily low permeability clay with sand and silt forming internal transmissive zones
- Layer IV: Fine sands with some interbedded clays

For this analysis,the subsurface stratigraphy along cross-section B-B' excludes Layer IV due to insuffticent data in determining an approximate starting location and range.

Table 1 below summarizes the soil parameters used in the analysis. Laboratory tests were performed by Golder on select soil samples collected by BME.

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Table 1 - Material Properties For Excavation Stability Analysis

Layer	Unit Weight			Strength Parameters		Reference
	γ_{DRY} (psf)	γ_{MOIST} (pcf)	γ_{SAT} (pcf)	ϕ (degrees)	c (psf)	
I	Two Strength Types Analyzed - See Table 2					Golder (1)
II	-	120	130	35	0	Estimate
III	-	120	130	16	300	Golder (1)

Notes: (1) - Conservative estimates based on data from tests performed in Golder's laboratory and experience.

Table 2 - Stratum I Material Properties for Various Strength Types

Strength Type	Strength Type	Unit Weight		Strength Parameters			
		γ_{MOIST} (pcf)	γ_{SAT} (pcf)	τ / σ'_v Ratio	τ_{MIN} (psf)	ϕ (degrees)	c' (psf)
Drained Analysis	Mohr-Coulomb	**120**	**130**	-	-	**400**	**16**
Undrained Analysis	Vertical Stress Ratio	**120**	**130**	**0.35**	**400**	-	-

A potentiometric elevation of approximately 95 ft was assumed within Layer II based on the subsurface stratigraphy data along cross-section B-B'. The depressurization system will reduce this value. The water surface was assumed to be 10 feet within the existing landfill cell and to correspond to the excavation grade in the adjacent disposal cell.

4.0 METHOD

The stability analyses were performed using SLIDE2, a 2-dimensional limit equilibrium analysis software, developed by Rocscience. Circular failure surfaces were evaluated. The minimum factor of safety for the cross-section and failure mode was calculated using the General Limit Equilibrium/Morgenstern-Price and Spencer Methods.

5.0 RESULTS

The results are presented in Table 3 below and the SLIDE2 output attached to this appendix.

Table 3 - Stability Analysis Results

Configuration	Strength Type	Failure Type	Analysis Methods	FS	Figure
Excavation Slope	Drained	Circular	Spencer	1.42	III-3C1-1
			GLE / Morgenstern-Price	1.43	III-3C1-1
	Undrained	Circular	Spencer	1.31	III-3C1-2
			GLE / Morgenstern-Price	1.33	III-3C1-2

Note: See SLIDE output attached to this appendix for results.

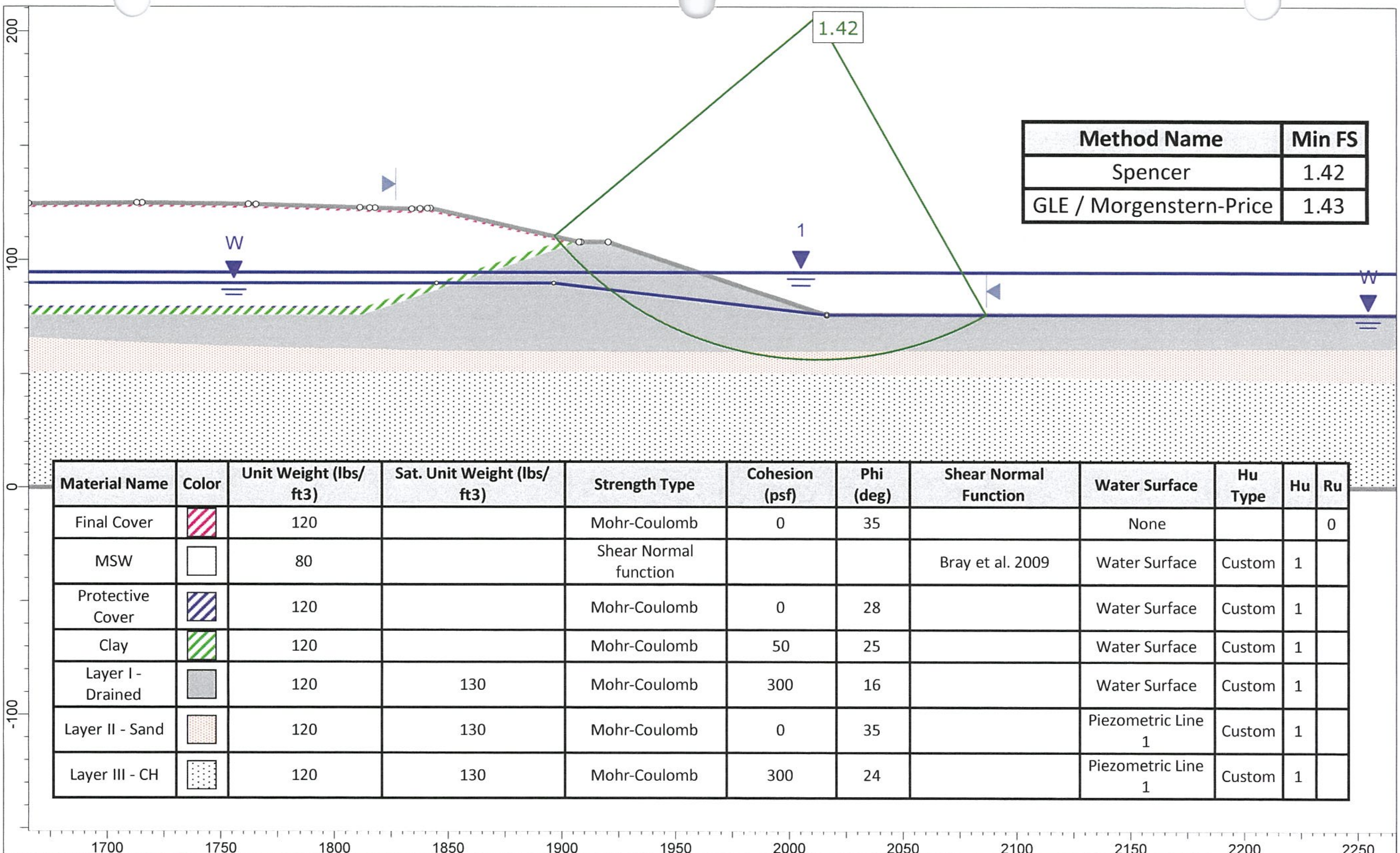
FS EXCAVATED WASTE SLOPE = 1.31

6.0 CONCLUSION

Using a generalized cross-section and strength parameters from laboratory tests, the analysis indicates that the excavated slopes will be stable.

7.0 REFERENCE

Bray, J.D., D. Zekkos, E. Kavazanjian, Jr., G.A. Athanasopoulos, and F. Riemer. 2009. Shear strength of municipal solid waste. J. Geotech. and Geoenviron. Eng. (ASCE) No. 6, Vol. 135, pp. 709–722.



Method Name	Min FS
Spencer	1.42
GLE / Morgenstern-Price	1.43

Material Name	Color	Unit Weight (lbs/ ft3)	Sat. Unit Weight (lbs/ ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface	Hu Type	Hu	Ru
Final Cover		120		Mohr-Coulomb	0	35		None			0
MSW		80		Shear Normal function			Bray et al. 2009	Water Surface	Custom	1	
Protective Cover		120		Mohr-Coulomb	0	28		Water Surface	Custom	1	
Clay		120		Mohr-Coulomb	50	25		Water Surface	Custom	1	
Layer I - Drained		120	130	Mohr-Coulomb	300	16		Water Surface	Custom	1	
Layer II - Sand		120	130	Mohr-Coulomb	0	35		Piezometric Line 1	Custom	1	
Layer III - CH		120	130	Mohr-Coulomb	300	24		Piezometric Line 1	Custom	1	

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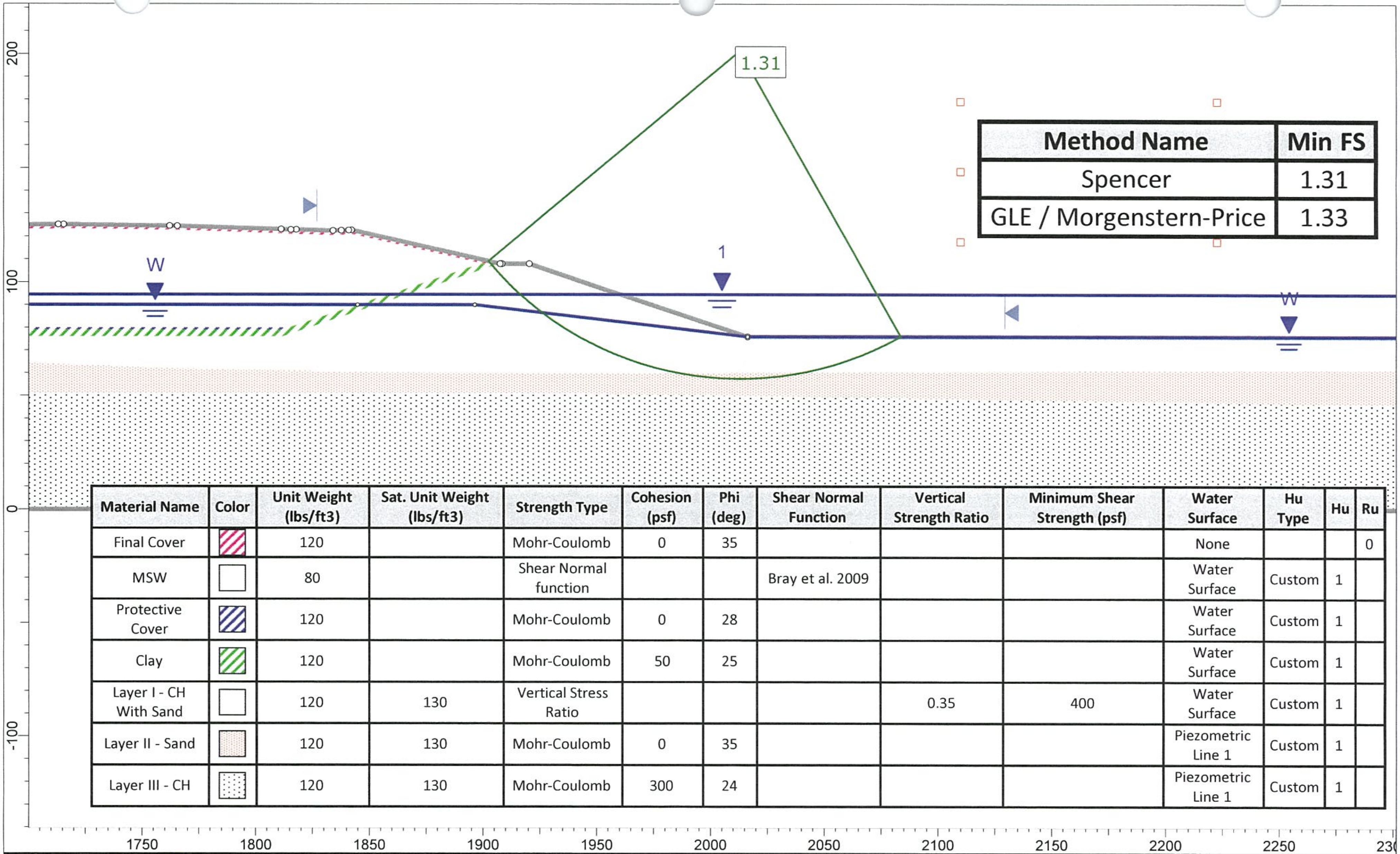
Figure Title	01 III-3C1_ExcavationStability Drained - Long-Term Conditions		
Drawn By PKP	*Scale* 1:700	*Location*	Hawthorn Park RDF
Date 11/19/2020		*Figure*	III-3C1-1



Method Name	Min FS
Spencer	1.31
GLE / Morgenstern-Price	1.33

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Vertical Strength Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
Final Cover		120		Mohr-Coulomb	0	35				None			0
MSW		80		Shear Normal function			Bray et al. 2009			Water Surface	Custom	1	
Protective Cover		120		Mohr-Coulomb	0	28				Water Surface	Custom	1	
Clay		120		Mohr-Coulomb	50	25				Water Surface	Custom	1	
Layer I - CH With Sand		120	130	Vertical Stress Ratio				0.35	400	Water Surface	Custom	1	
Layer II - Sand		120	130	Mohr-Coulomb	0	35				Piezometric Line 1	Custom	1	
Layer III - CH		120	130	Mohr-Coulomb	300	24				Piezometric Line 1	Custom	1	

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Figure Title
01 III-3C1_ExcavationStability
Undrained - Short-Term Conditions

Drawn By PKP	*Scale* 1:700	*Location*	Hawthorn Park RDF
Date 11/19/2020		*Figure*	III-3C1-2

APPENDIX III-3C-2

Interior Waste Slope Stability Analysis

Prepared:	PKP
Checked:	JBF
Reviewed:	CGD

INTERIOR WASTE SLOPE STABILITY ANALYSIS

STATE OF TEXAS
CHARLES G. DOMINGUEZ
83247
LICENSED PROFESSIONAL ENGINEER
2/12/21
For Sheets 1 and 2; Figures III-3C2-1 and III-3C2-2

GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

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1.0 OBJECTIVE

Investigate the stability of the interior waste slopes against failing through or sliding along the proposed liner system.

2.0 GIVEN

The most critical interior waste slope cross-section is dependent on operations procedures. For this analysis we have conservatively assumed that a 3H:1V temporary waste slope will exist from near the maximum height of the landfill to a point on the floor in the northern portion of the expansion area between the West and Center Blocks. This cross-section is shown on Figure III-3-4 as Section C-C'.

The cell liner system consists of (from top to bottom):
1 -ft of Protective Cover (PCOV)
3 -ft of Clay Liner

The following parameters were assigned to the materials based on available data:

Table 1 - Material Properties For Interior Waste Slope Stability Analysis

Material	γ Dry (pcf)	Strength Param. ϕ (degrees)	Strength Param. c (psf)	Reference / Comment
Waste	80	Shear / Normal		Bray et al. 2009
PCOV	120	28	0	Estimate
Clay	120	25	50	Estimate

Refer to Table 1 in Appendix III-3C1 - Excavation Stability Analysis, for soil parameters used in the analysis.

Table 2 - Bray et al. 2009 Recommended Modern MSW Strength Parameters

Normal Stress (psf)	Shear Stress (psf)
0	310
600	810
5,200	3,840
6,300	4,480
7,300	5,120
8,400	5,740
16,700	10,550

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3.0 METHOD

The stability analyses were performed using SLIDE2, a 2-dimensional limit equilibrium analysis software, developed by Rocscience. Circular and block failure surfaces were evaluated. The minimum factors of safety for the cross-section and failure mode were calculated using the General Limit Equilibrium/Morgenstern-Price and Spencer Methods.

4.0 ASSUMPTIONS

- 5 ft of liquid above the liner system
- Lowest strength applied along the floor and sideslope interfaces simultaneously
- Minimum allowable factor of safety for interior waste slope ($FS_{INTERIOR\ WASTE\ SLOPE}$) is 1.3.

The results are presented in Table 3 below and the SLIDE2 output attached to this appendix.

Table 3 - Stability Analysis Results

Configuration	Type	Analysis Methods	FS	Figure
Interior Waste Slope	Circular	Spencer	2.24	III-3C2-1
		GLE / Morgenstern-Price	2.24	
	Block	Spencer	1.94	III-3C2-2
		GLE / Morgenstern-Price	1.95	

Note: See SLIDE output attached to this appendix for results.

$FS_{INTERIOR\ WASTE\ SLOPE\ |\ CIRCULAR\ FAILURE}$ = **2.24**

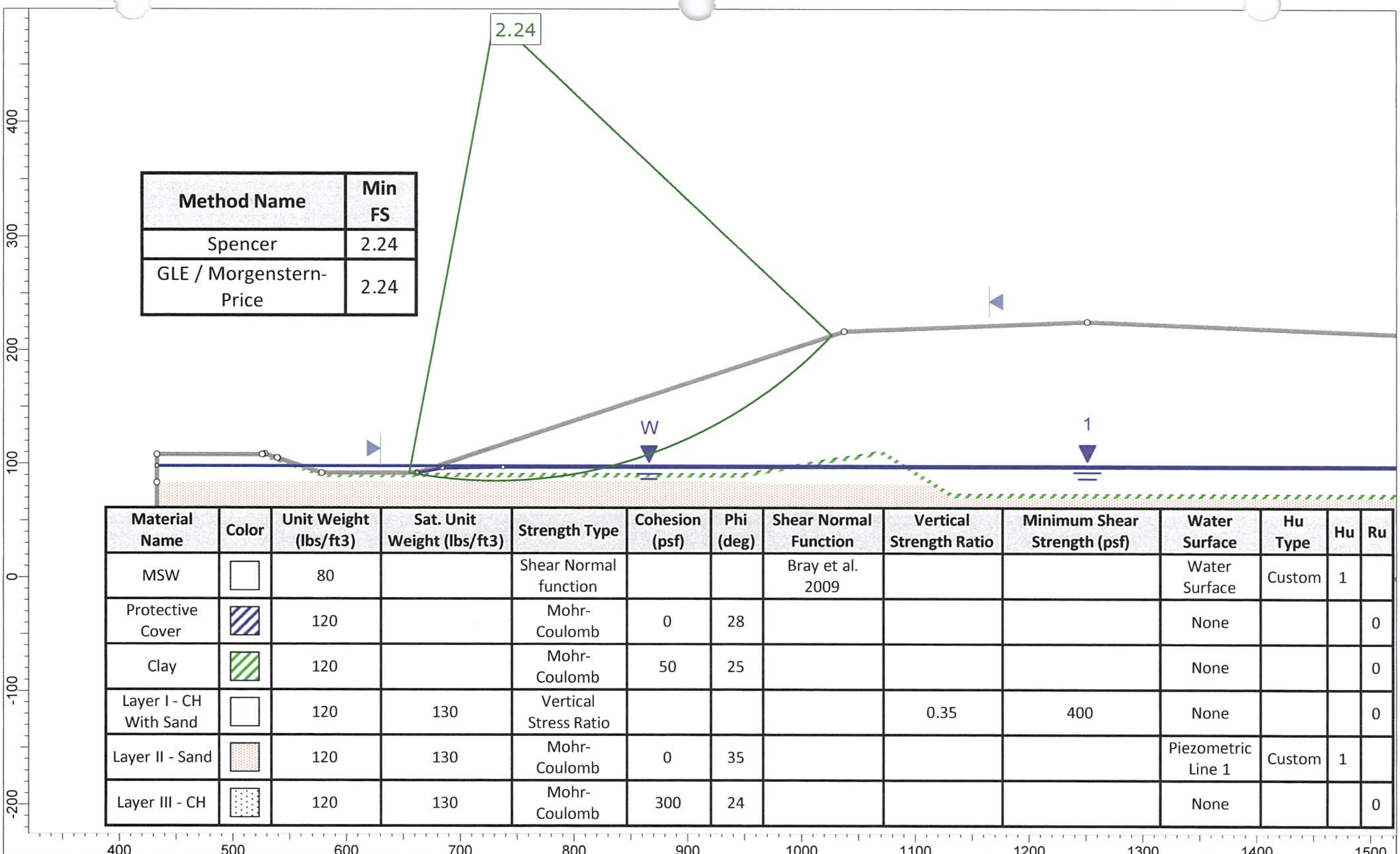
$FS_{INTERIOR\ WASTE\ SLOPE\ |\ BLOCK\ FAILURE}$ = **1.94**

6.0 CONCLUSION

Using a generalized cross-section and strength parameters from published literature and based on experience, the analysis indicates that the interior waste slopes will be stable.

7.0 REFERENCES

Bray, J.D., D. Zekkos, E. Kavazanjian, Jr., G.A. Athanasopoulos, and F. Riemer. 2009. Shear strength of municipal solid waste. J. Geotech. and Geoenviron. Eng. (ASCE) No. 6, Vol. 135, pp. 709–722.

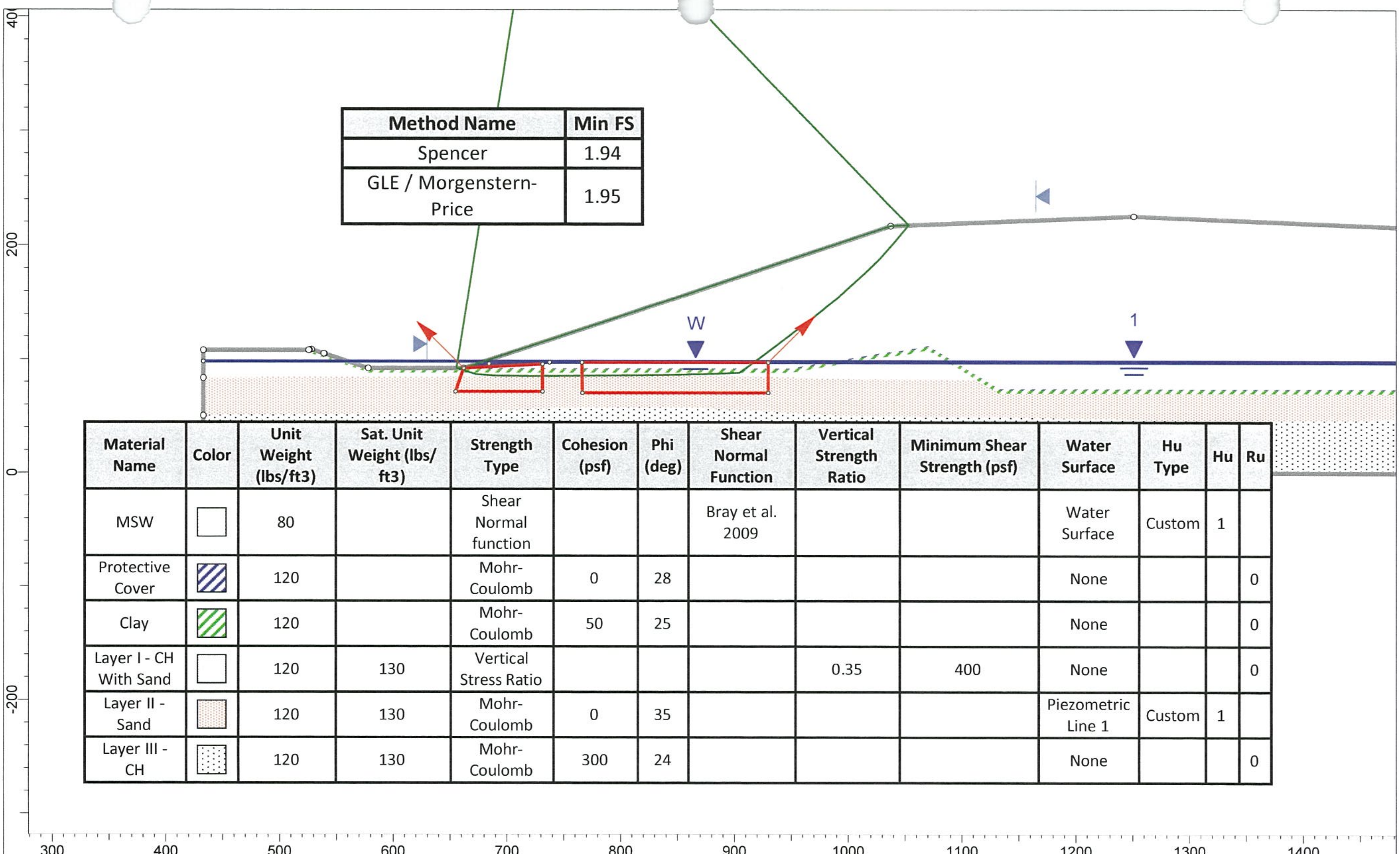


Method Name	Min FS
Spencer	2.24
GLE / Morgenstern-Price	2.24

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Vertical Strength Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
MSW		80		Shear Normal function			Bray et al. 2009			Water Surface	Custom	1	
Protective Cover		120		Mohr-Coulomb	0	28				None			0
Clay		120		Mohr-Coulomb	50	25				None			0
Layer I - CH With Sand		120	130	Vertical Stress Ratio				0.35	400	None			0
Layer II - Sand		120	130	Mohr-Coulomb	0	35				Piezometric Line 1	Custom	1	
Layer III - CH		120	130	Mohr-Coulomb	300	24				None			0

GOLDER

Figure Title	02 III-3C2_InteriorWasteSlope Failure - Circular		
Drawn By PKP	*Scale* 1:1400	*Location* Hawthorn Park RDF	
Date 11/25/2020		*Figure* III-3C2-1	



Method Name	Min FS
Spencer	1.94
GLE / Morgenstern-Price	1.95

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Vertical Strength Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
MSW		80		Shear Normal function			Bray et al. 2009			Water Surface	Custom	1	
Protective Cover		120		Mohr-Coulomb	0	28				None			0
Clay		120		Mohr-Coulomb	50	25				None			0
Layer I - CH With Sand		120	130	Vertical Stress Ratio				0.35	400	None			0
Layer II - Sand		120	130	Mohr-Coulomb	0	35				Piezometric Line 1	Custom	1	
Layer III - CH		120	130	Mohr-Coulomb	300	24				None			0

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Figure Title	02 III-3C2_InteriorWasteSlope Failure - Block
Drawn By	PKP
Scale	1:1400
Location	Hawthorn Park RDF
Date	11/25/2020
Figure	III-3C2-2

APPENDIX III-3C-3

Final-Filled Configuration Stability Analysis

Prepared:	**PKP**
Checked:	**JBF**
Reviewed:	**CGD**

FINAL-FILLED CONFIGURATION STABILITY ANALYSIS

STATE OF TEXAS
CHARLES G. DOMINGUEZ
83247
LICENSED PROFESSIONAL ENGINEER
2/12/21
For Sheets 1 and 2; Figures III-3C3-1 and III-3C3-2

GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

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1.0 OBJECTIVE

Estimate the factors of safety against sliding and global stability for the final-filled configuration.

2.0 GIVEN

The most critical configuration cross-section occurs where waste slope length is greatest and where the perimeter berm sideslope is shortest. Based on a review of the design grades the expansion area between the West and Center Blocks was determined to contain the critical section. This cross-section is shown on Figure III-3-4 as Section D-D'.

The cell liner system consists of (from top to bottom):

1 -ft of Protective Cover (PCOV)
3 -ft of Clay Liner

The following parameters were assigned to the materials based on available data:

Table 1 - Material Properties For Final-Filled Configuration Stability Analysis

Material	γ Dry (pcf)	Strength Param. φ (degrees)	Strength Param. c (psf)	Reference / Comment
Waste	80	Shear / Normal Function		Bray et al. 2009
PCOV	120	28	0	Estimate
Clay	120	25	50	Estimate

Refer to Table 1 in Appendix III-3C1 - Excavation Stability Analysis, for soil parameters used in the analysis.

▪ DESIGN CONFIGURATIONS

- 12 ft of liquid above the liner system
- Lowest strength applied along the floor and sideslope interfaces simultaneously
- Minimum allowable factor of safety for permanent slopes is 1.5.

3.0 METHOD

The stability analyses were performed using SLIDE2, a 2-dimensional limit equilibrium analysis software, developed by Rocscience. Circular and block failure surfaces were evaluated. The minimum factor of safety the cross-section and failure mode was calculated using the General Limit Equilibrium/Morgenstern-Price and

4.0 RESULTS

The results are presented in Table 2 below and the SLIDE2 output attached to this appendix.

Table 2 - Stability Analysis Results

Configuration	Failure Type	Analysis Methods	FS	Figure
Final-Filled Waste Slope	Circular	Spencer	2.76	III-3C3-1
		GLE / Morgenstern-Price	2.75	
	Block	Spencer	2.46	III-3C3-2
		GLE / Morgenstern-Price	2.45	

Note: See SLIDE output attached to this appendix for results.

$FS_{\text{FINAL-FILLED WASTE SLOPE} \mid \textit{CIRCULAR FAILURE}} =$ **2.75**

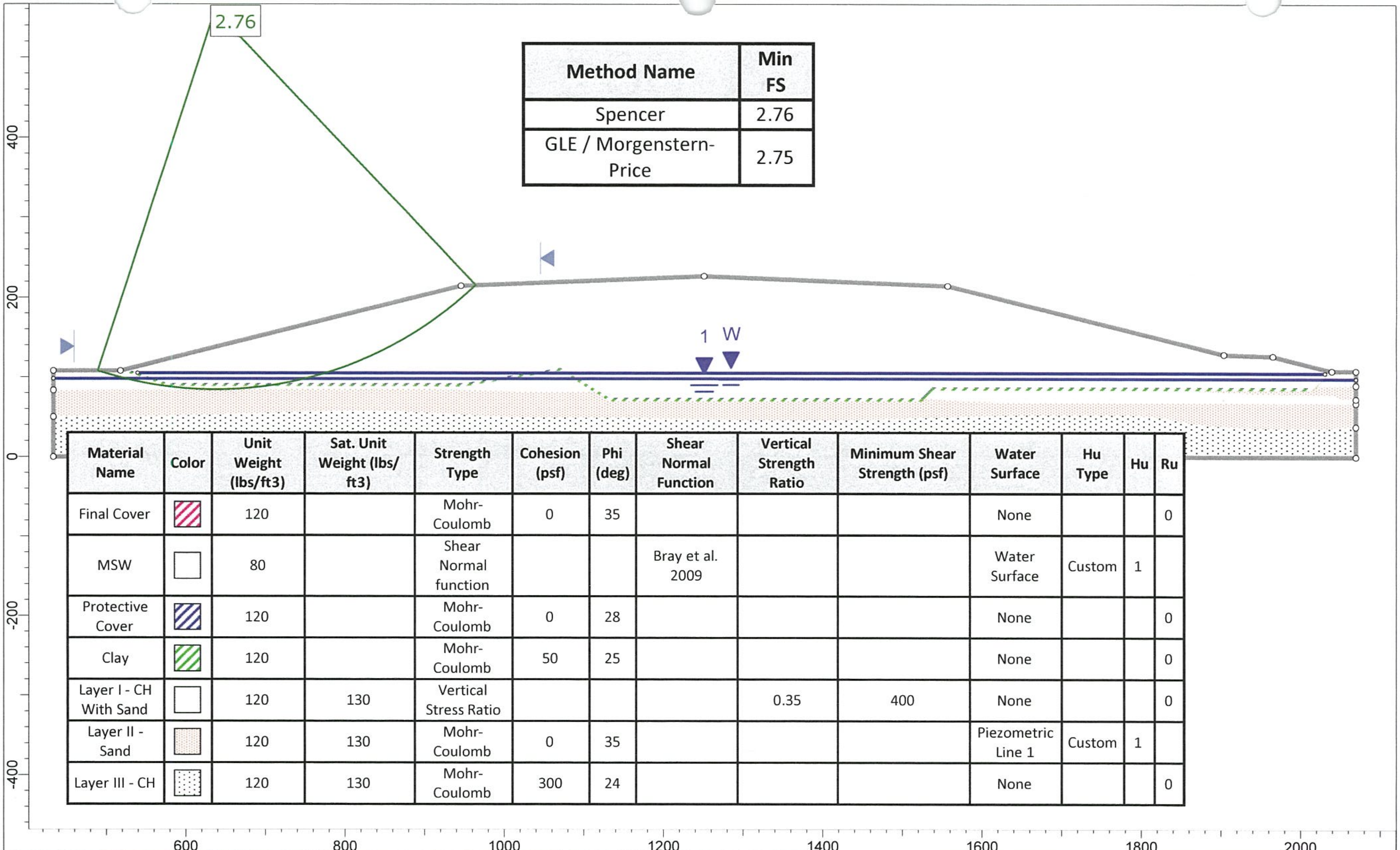
$FS_{\text{FINAL-FILLED WASTE SLOPE} \mid \textit{BLOCK FAILURE}} =$ **2.45**

6.0 CONCLUSION

Using a generalized cross-section and strength parameters from laboratory tests, the analysis indicates that the final-filled waste slopes will be stable.

7.0 REFERENCES

Bray, J.D., D. Zekkos, E. Kavazanjian, Jr., G.A. Athanasopoulos, and F. Riemer. 2009. Shear strength of municipal solid waste. J. Geotech. and Geoenviron. Eng. (ASCE) No. 6, Vol. 135, pp. 709–722.



Method Name	Min FS
Spencer	2.76
GLE / Morgenstern-Price	2.75

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Vertical Strength Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
Final Cover		120		Mohr-Coulomb	0	35				None			0
MSW		80		Shear Normal function			Bray et al. 2009			Water Surface	Custom	1	
Protective Cover		120		Mohr-Coulomb	0	28				None			0
Clay		120		Mohr-Coulomb	50	25				None			0
Layer I - CH With Sand		120	130	Vertical Stress Ratio				0.35	400	None			0
Layer II - Sand		120	130	Mohr-Coulomb	0	35				Piezometric Line 1	Custom	1	
Layer III - CH		120	130	Mohr-Coulomb	300	24				None			0

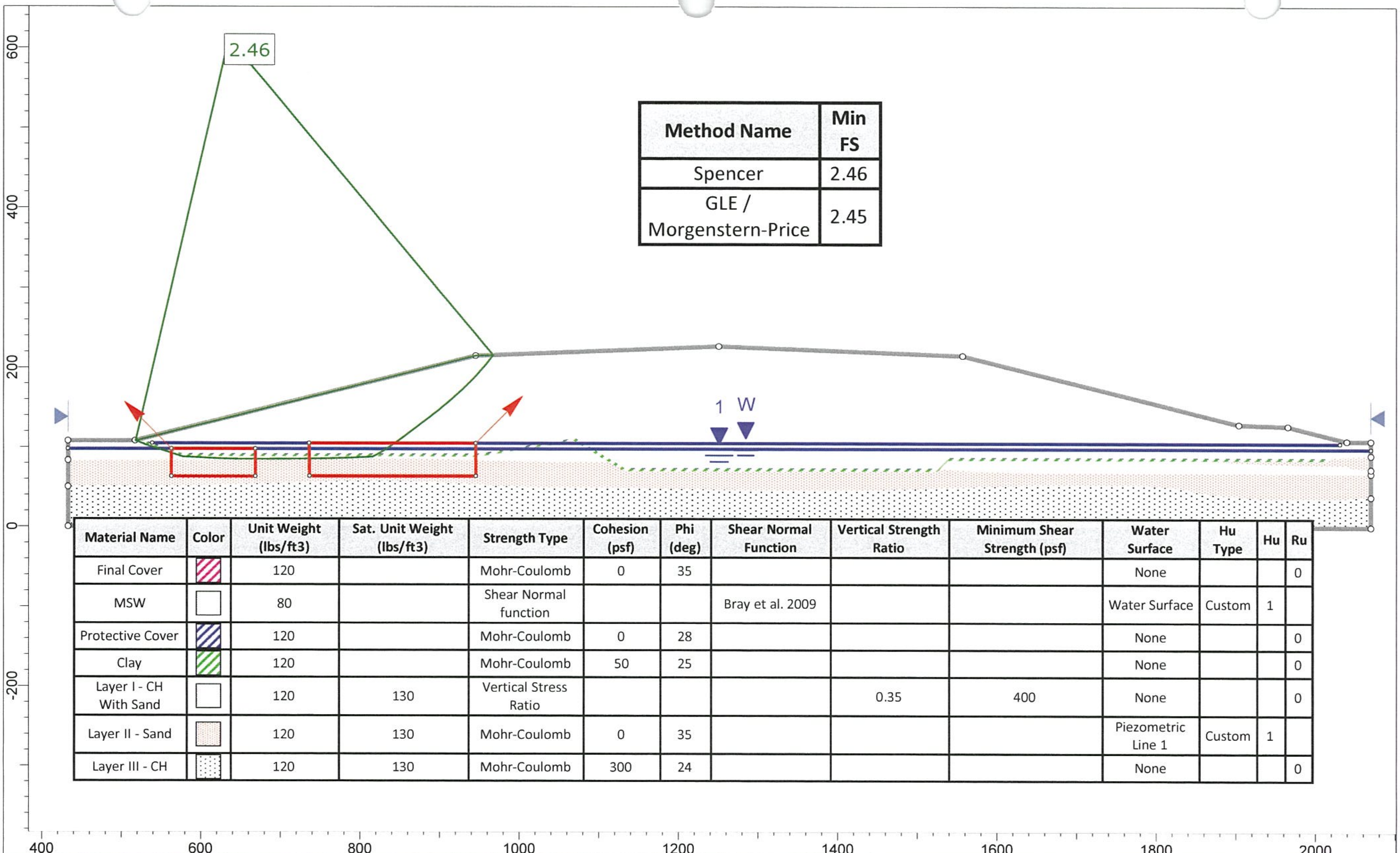
GOLDER

Figure Title

03 III-3C3_FinalFilledConfiguration
Failure - Circular

Drawn By PKP | *Scale* 1:2000 | *Location* Hawthorn Park RDF

Date 11/25/2020 | *Figure* III-3C3-1



Method Name	Min FS
Spencer	2.46
GLE / Morgenstern-Price	2.45

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Vertical Strength Ratio	Minimum Shear Strength (psf)	Water Surface	Hu Type	Hu	Ru
Final Cover		120		Mohr-Coulomb	0	35				None			0
MSW		80		Shear Normal function			Bray et al. 2009			Water Surface	Custom	1	
Protective Cover		120		Mohr-Coulomb	0	28				None			0
Clay		120		Mohr-Coulomb	50	25				None			0
Layer I - CH With Sand		120	130	Vertical Stress Ratio				0.35	400	None			0
Layer II - Sand		120	130	Mohr-Coulomb	0	35				Piezometric Line 1	Custom	1	
Layer III - CH		120	130	Mohr-Coulomb	300	24				None			0

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Figure Title	03 III-3C3_FinalFilledConfiguration Failure - Block
Drawn By	PKP
Scale	1:2000
Location	Hawthorn Park RDF
Date	11/25/2020
Figure	III-3C3-2