COLORADO
Division of Reclamation, Mining and Safety
Department of Natural Resources
1313 Sherman Street, Room 215
Denver, CO 80203

MEMORANDUM

Date: April 23, 2020

To: Brock Bowles; Division of Reclamation, Mining & Safety

From: Peter Hays; Division of Reclamation, Mining & Safety

Re: Adequacy Review of Exhibit 6.5 – Geotechnical Stability Review
Colorado Sand Company LLC; Keenesburg No. 2; File No. M-2019-058

The Division of Reclamation, Mining and Safety (Division/DRMS) has reviewed the Geotechnical Evaluations submitted by CTL Thompson; Exhibit T-1 – Geotechnical Evaluation – Pipelines and Other Structures Setback dated November 20, 2019, Exhibit T-2 – Geotechnical Evaluation – Transmission Line Foundation Setback dated November 25, 2019 and Exhibit T-3 – Additional Geotechnical Evaluation dated March 27, 2020 for the Keenesburg No. 2 Mine 112c permit application.

The following list describes the information used by the Division as presented in the permit application to evaluate slope stability for the proposed site:

- Geotechnical boring and sampling data is available for the site. The data was provided by the Applicant in Appendix 1 and Appendix F.
- Topsoil consists for a thin veneer at the site. No topsoil was modeled by the Applicant. The upper 12 inches of sand will be salvaged as growth medium.
- The site will be mined to a nominal maximum depth of 30 feet below grade.
- Bedrock was encountered in two borings at depths of 24 and 35 feet below grade.
- A typical 50-foot setback from the top of slope to an easement or structure was modeled and will be maintained by the Applicant.
- Groundwater was measured in 11 of the 24 borings at erratic locations and depths across the site.
- The groundwater elevation was modeled at 17 feet and 27 feet below grade to provide a conservative model.
- The soil strength parameters were determined based on standard penetration testing and correlations with gradations and Atterberg limit testing.
- The Applicant used conservative soil parameters for the soil types encountered;
    - Sand - 120 pcf, 30° friction angle, 0 psf cohesion
    - Clay - 120 pcf, 20° friction angle, 100 psf cohesion
- The perimeter slopes will be mined at a minimum 3H:1V slope and will be reclaimed to as shallow as 5H:1V.

- The final reclamation slopes were modeled conservatively at a 3H:1V slope.
- Pipelines were assumed to be 10 feet below grade. If deeper pipelines are known to exist or are determined to be deeper, the recommendations will be reevaluated by the geotechnical engineer.
- If seepage into excavations is encountered, shallower slopes than 3H:1V may be necessary and would be determined on a case-by-case basis.
- Stockpiles of soil and equipment should not be placed within a horizontal distance equal to one-half the excavation depth, from the edge of the excavation.
- The depth of transmission line foundations were not provided and therefore were not included in the models.
- A factor of safety of 1.7 was calculated by the Applicant for a 30 foot high, 3H:1V slope.

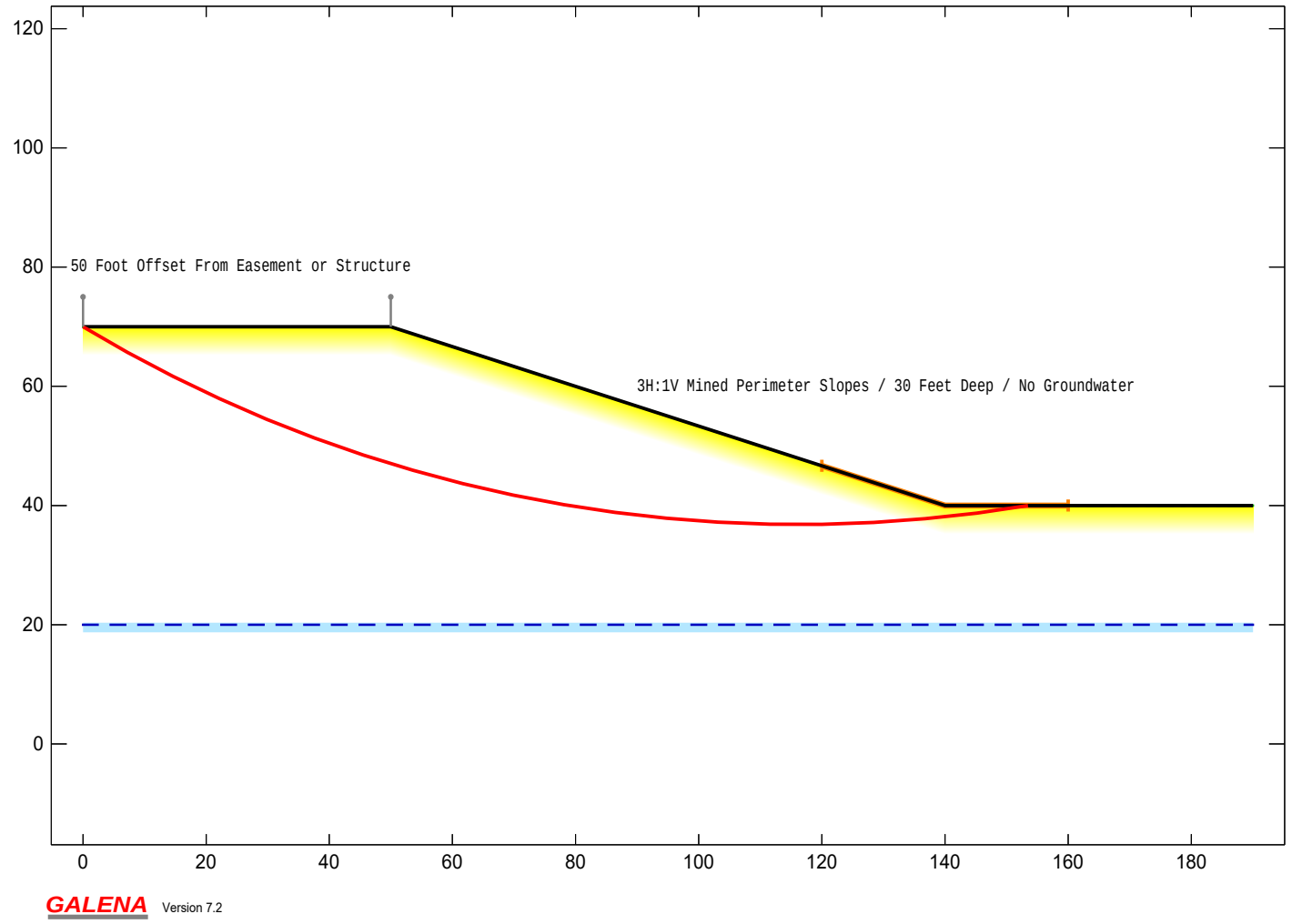
In accordance with Table 1 - Recommended Factors of Safety for Slope Stability Analysis for Operations and Reclamation within Section 30.4 of the Policies of the Mined Land Reclamation Board (MLRB) effective May 16, 2018, the Division will require the Applicant to comply with the factor of safety (FOS) of 1.5 for critical structures in static conditions since the Applicant utilized generalized strength measurements in the analysis.

The Division replicated the Applicant's slope stability analysis using Clover Technologies Galena Slope Stability Analysis System, Version 7.2 with the X-Left coordinate maintained at the edge of easement and/or structure. A table of the Applicant's and the Division's analysis results are below:

Analysis Name	**Applicant's FOS**	**DRMS FOS**
30-Foot Excavation, 3H:1V Slope, Sand, No Groundwater	1.73	2.66
30-Foot Excavation, 3H:1V Slope, Clay at 20', Groundwater at 27'	1.42	1.79
30-Foot Excavation, 3H:1V Slope, Clay at 20', Groundwater at 17'	1.43	1.50
20-Foot Excavation, 3H:1V Slope, Clay at 20', Groundwater at 17'	1.53	2.20

The Division accepts the proposed mining plan setback at the Keenesburg No. 2 Mine. If groundwater is intercepted shallower than expected and/or the soils differ from the expected profile, the Applicant must contact the DRMS immediately and reevaluate the stability analysis based on the updated information. Please note any transgression of the proposed setback and sloping will be considered a permit violation if the permit is approved and issued. A copy Division's stability analysis results is attached.

If you have any questions regarding these adequacy items, please contact me at peter.hays@state.co.us or (303) 866-3567, Ext. 8124.



Material Keys

1: Sand

Analysis 1

Multiple Stability Analysis

Method: Spencer-Wright

Surface: Circular

Results

Critical Factor of Safety: 2.66

Interslice Force (Final) Angle: 11.9°

Edited: 17 Apr 2020 *Processed:* 17 Apr 2020

Project Keenesburg No. 2 Mine

50 Foot Offset / 30 Foot / 3H:1V Slope / No Groundwater

File: G:\My Drive\1 - My Projects Google\8 Galena - Stability Analysis Models\Keenesburg No 2\Keenesburg Profile 1.gmf

Dept of the Interior - Office of Surface Mining

Project: Keenesburg No. 2 Mine
File: G:\My Drive\1 - My Projects Google\8 Galena - Stability Analysis Models\Keenesburg No 2\Keenesburg Profile 1.gmf
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DATA: Analysis 1 - 50 Foot Offset / 30 Foot / 3H:1V Slope / No Groundwater

Material Properties (2 materials)

Material: 1 (Mohr-Coulomb Isotropic) - Sand

Cohesion	Phi	UnitWeight	Ru
0.00	30.0	120.00	Auto

Material: 2 (Mohr-Coulomb Isotropic) - Clay

Cohesion	Phi	UnitWeight	Ru
100.00	20.0	120.00	Auto

Water Properties

Unit weight of water: 62.400 Unit weight of water/medium above ground: 0.000

Material Profiles (1 profile)

Profile: 1 (2 points) Material beneath: 1 - Sand

0.00	70.00	190.00	70.00

Slope Surface (4 points)

0.00	70.00	50.00	70.00	140.00	40.00	190.00	40.00

Phreatic Surface (2 points)

0.00	20.00	190.00	20.00

Failure Surface

Initial circular surface for critical search defined by: XL,XR,R
Intersects: XL: 0.00 YL: 70.00 XR: 140.00 YR: 40.00
Centre: XC: 109.13 YC: 237.60 Radius: R: 200.00

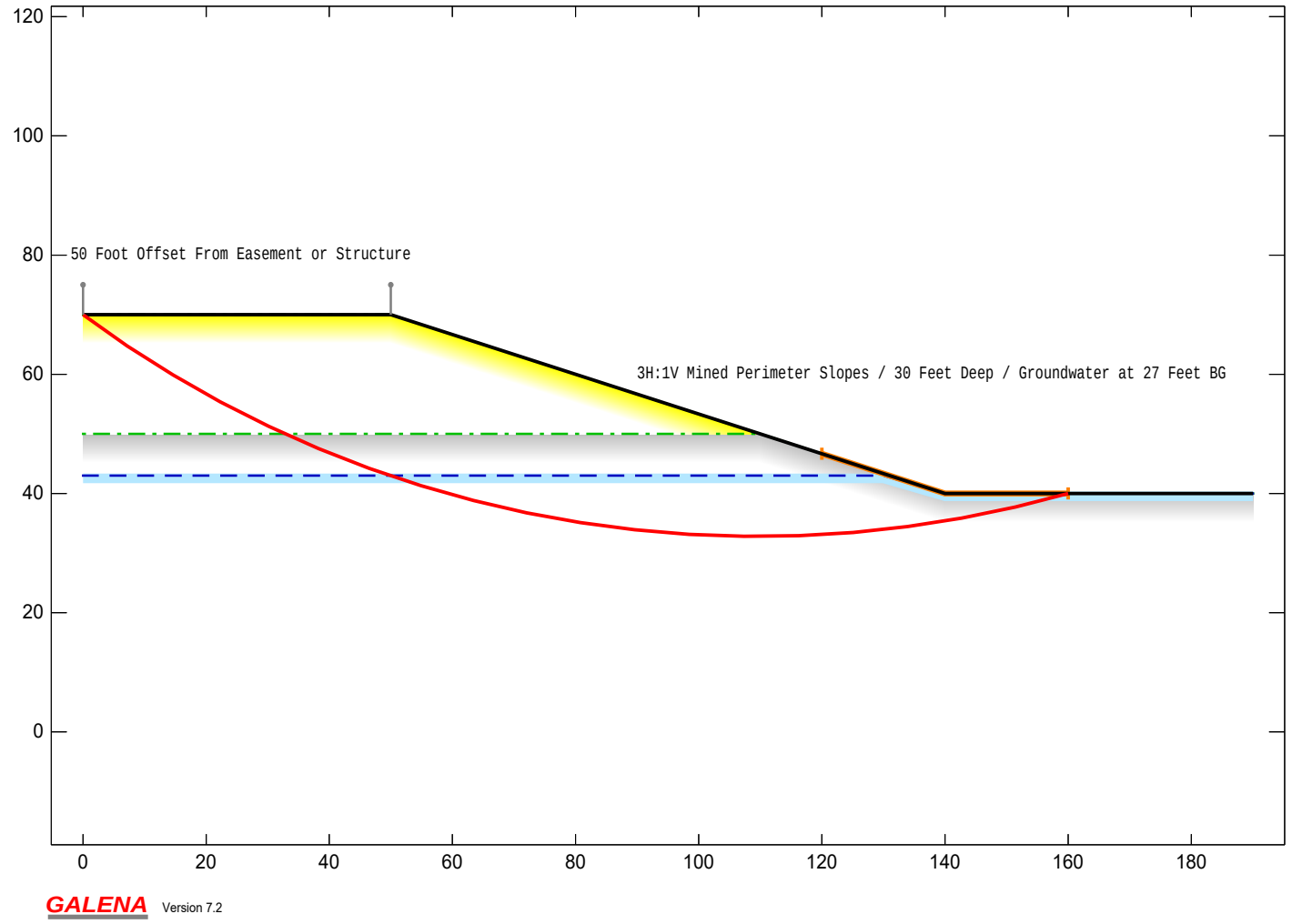
Variable Restraints

	XL	XR	R
Parameter descriptor:	XL	XR	R
Range of variation:	0.00	40.00	40.00
Trial positions within range:	1	50	50

RESULTS: Analysis 1 - 50 Foot Offset / 30 Foot / 3H:1V Slope / No Groundwater

Spencer-Wright Method of Analysis - Circular Failure Surface

Critical Failure Surface Search using Multiple Circle Generation Techniques



GALENA Version 7.2

Material Keys

1: Sand

2: Clay

Analysis 1

Multiple Stability Analysis

Method: Spencer-Wright

Surface: Circular

Results

Critical Factor of Safety: 1.79

Interslice Force (Final) Angle: 11.1 °

Edited: 17 Apr 2020 *Processed:* 17 Apr 2020

Project Keenesburg No. 2 Mine

50 Foot Offset / 30 Foot / 3H:1V Slope / Groundwater at 27 Feet BG

File: G:\My Drive\1 - My Projects Google\8 Galena - Stability Analysis Models\Keenesburg No 2\Keenesburg Profile 2.gmf

Dept of the Interior - Office of Surface Mining

Project: Keenesburg No. 2 Mine
File: G:\My Drive\1 - My Projects Google\8 Galena - Stability Analysis Models\Keenesburg No 2\Keenesburg Profile 2.gmf
Processed: 17 Apr 2020 15:38:22

DATA: Analysis 1 - 50 Foot Offset / 30 Foot / 3H:1V Slope / Groundwater at 27 Feet BG

Material Properties (2 materials)

Material: 1 (Mohr-Coulomb Isotropic) - Sand

Cohesion	Phi	UnitWeight	Ru
0.00	30.0	120.00	Auto

Material: 2 (Mohr-Coulomb Isotropic) - Clay

Cohesion	Phi	UnitWeight	Ru
100.00	20.0	120.00	Auto

Water Properties

Unit weight of water: 62.400 Unit weight of water/medium above ground: 0.000

Material Profiles (2 profiles)

Profile: 1 (2 points) Material beneath: 1 - Sand

0.00	70.00	190.00	70.00

Profile: 2 (2 points) Material beneath: 2 - Clay

0.00	50.00	190.00	50.00

Slope Surface (4 points)

0.00	70.00	50.00	70.00	140.00	40.00	190.00	40.00

Phreatic Surface (4 points)

0.00	43.00	130.00	43.00	140.00	40.00	190.00	40.00

Failure Surface

Initial circular surface for critical search defined by: XL,XR,R
Intersects: XL: 0.00 YL: 70.00 XR: 140.00 YR: 40.00
Centre: XC: 109.13 YC: 237.60 Radius: R: 200.00

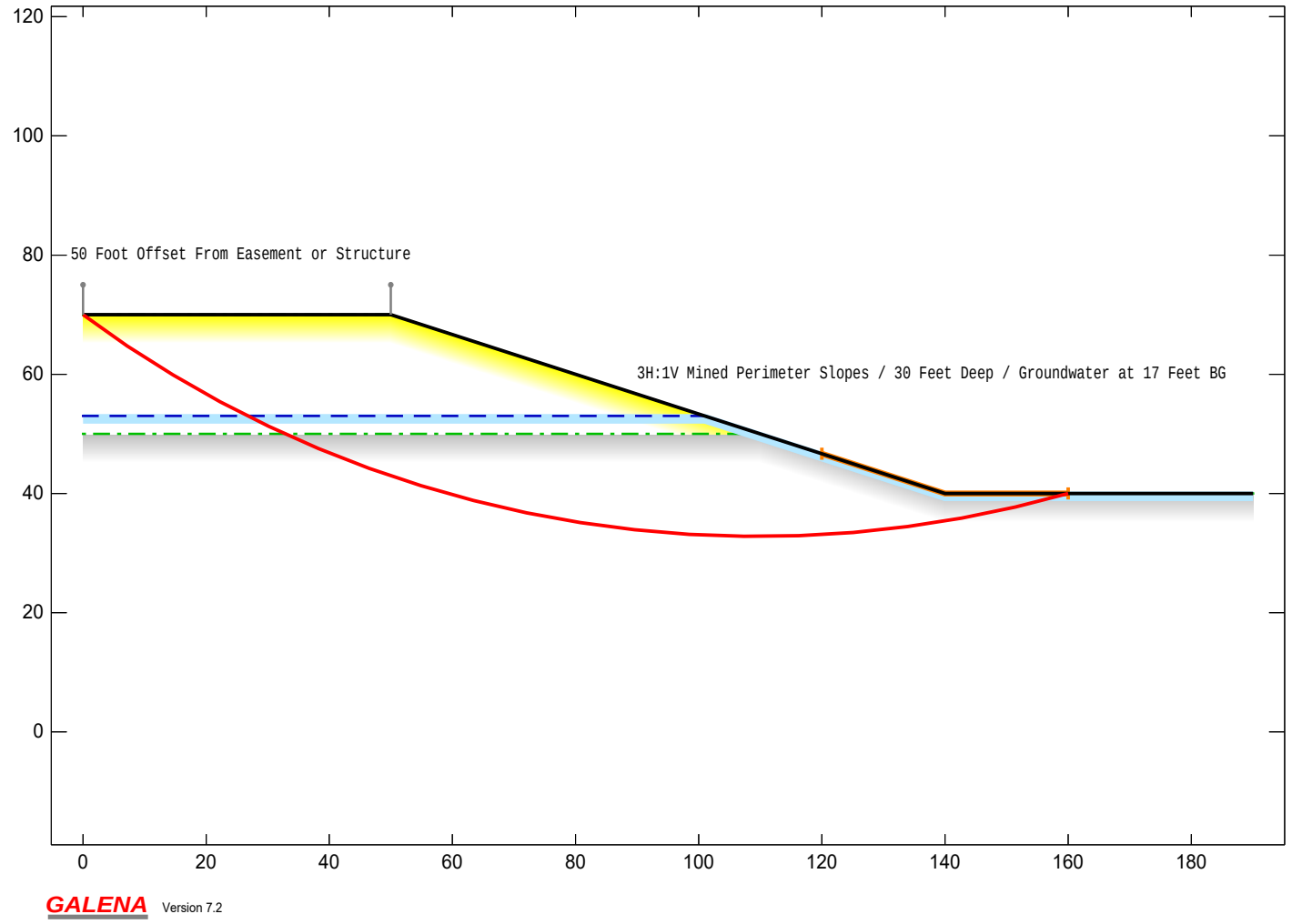
Variable Restraints

Parameter descriptor:	XL	XR	R
Range of variation:	0.00	40.00	40.00
Trial positions within range:	1	50	50

RESULTS: Analysis 1 - 50 Foot Offset / 30 Foot / 3H:1V Slope / Groundwater at 27 Feet BG

Spencer-Wright Method of Analysis - Circular Failure Surface

Critical Failure Surface Search using Multiple Circle Generation Techniques



GALENA Version 7.2

Material Keys

1: Sand

2: Clay

Analysis 1

Multiple Stability Analysis

Method: Spencer-Wright

Surface: Circular

Results

Critical Factor of Safety: 1.50

Interslice Force (Final) Angle: 10.1 °

Edited: 17 Apr 2020 *Processed:* 17 Apr 2020

Project Keenesburg No. 2 Mine

50 Foot Offset / 30 Foot / 3H:1V Slope / Groundwater at 17 Feet BG

File: G:\My Drive\1 - My Projects Google\8 Galena - Stability Analysis Models\Keenesburg No 2\Keenesburg Profile 3.gmf

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Project: Keenesburg No. 2 Mine
File: G:\My Drive\1 - My Projects Google\8 Galena - Stability Analysis Models\Keenesburg No 2\Keenesburg Profile 3.gmf
Processed: 17 Apr 2020 15:39:40

DATA: Analysis 1 - 50 Foot Offset / 30 Foot / 3H:1V Slope / Groundwater at 17 Feet BG

Material Properties (2 materials)

Material: 1 (Mohr-Coulomb Isotropic) - Sand

Cohesion	Phi	UnitWeight	Ru
0.00	30.0	120.00	Auto

Material: 2 (Mohr-Coulomb Isotropic) - Clay

Cohesion	Phi	UnitWeight	Ru
100.00	20.0	120.00	Auto

Water Properties

Unit weight of water: 62.400   Unit weight of water/medium above ground: 0.000

Material Profiles (2 profiles)

Profile: 1 (2 points)   Material beneath: 1 - Sand

0.00	70.00	190.00	70.00

Profile: 2 (2 points)   Material beneath: 2 - Clay

0.00	50.00	190.00	50.00

Slope Surface (4 points)

0.00	70.00	50.00	70.00	140.00	40.00	190.00	40.00

Phreatic Surface (4 points)

0.00	53.00	101.00	53.00	140.00	40.00	190.00	40.00

Failure Surface

Initial circular surface for critical search defined by: XL,XR,R

Intersects: XL:	0.00	YL:	70.00	XR:	140.00	YR:	40.00
Centre: XC:	109.13	YC:	237.60			Radius: R:	200.00

Variable Restraints

Parameter descriptor:	XL	XR	R
Range of variation:	0.00	40.00	40.00
Trial positions within range:	1	50	50

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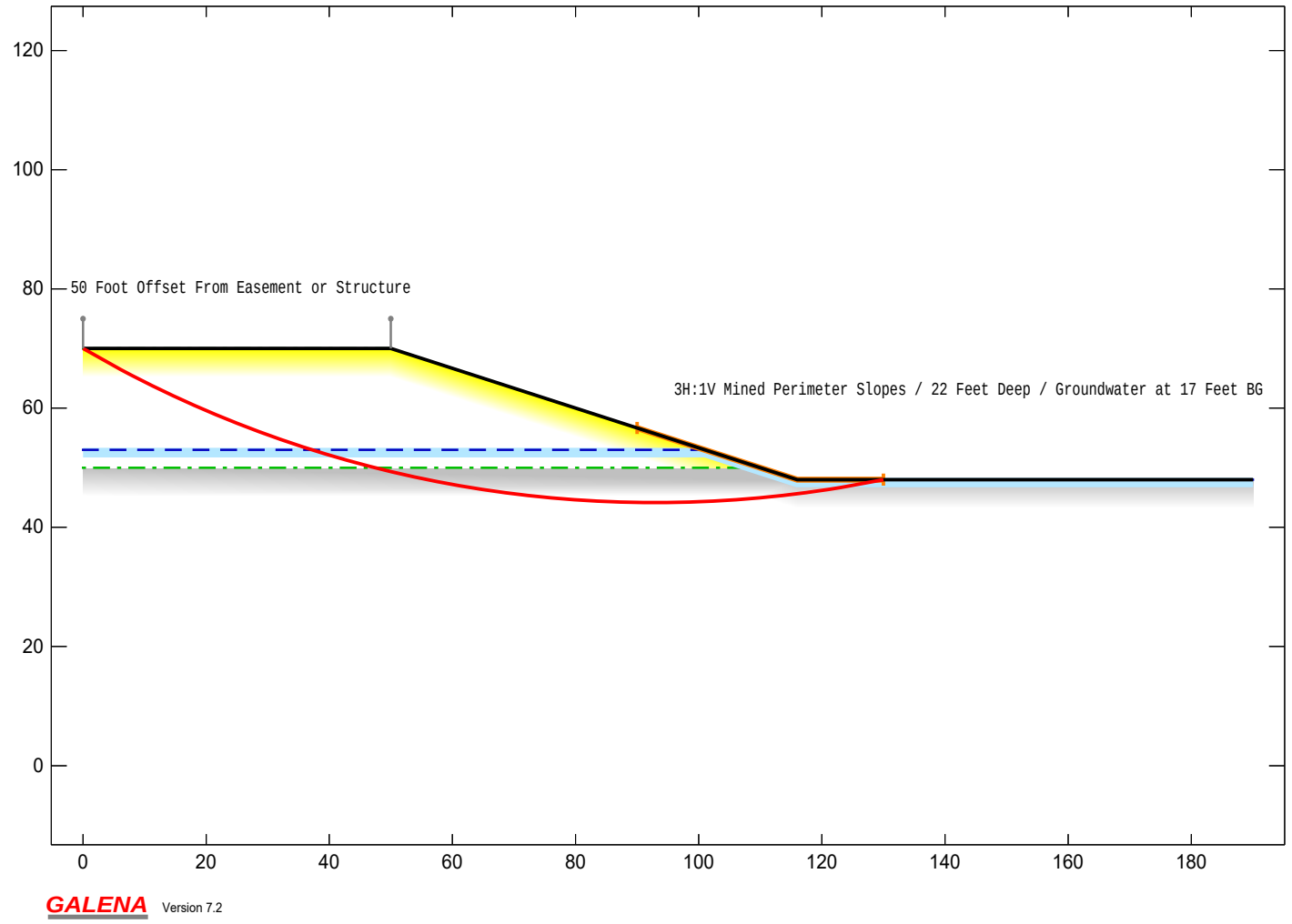
RESULTS: Analysis 1 - 50 Foot Offset / 30 Foot / 3H:1V Slope / Groundwater at 17 Feet BG

Spencer-Wright Method of Analysis - Circular Failure Surface

Critical Failure Surface Search using Multiple Circle Generation Techniques



GALENA Version 7.2

Material Keys

1: Sand

2: Clay

Analysis 1

Multiple Stability Analysis

Method: Spencer-Wright

Surface: Circular

Results

Critical Factor of Safety: 2.20

Interslice Force (Final) Angle: 9.8 °

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Project Keenesburg No. 2 Mine

50 Foot Offset / 22 Foot / 3H:1V Slope / Groundwater at 17 Feet BG

File: G:\My Drive\1 - My Projects Google\8 Galena - Stability Analysis Models\Keenesburg No 2\Keenesburg Profile 4.gmf

Dept of the Interior - Office of Surface Mining

Project: Keenesburg No. 2 Mine
File: G:\My Drive\1 - My Projects Google\8 Galena - Stability Analysis Models\Keenesburg No 2\Keenesburg Profile 4.gmf
Processed: 17 Apr 2020 15:40:46

DATA: Analysis 1 - 50 Foot Offset / 22 Foot / 3H:1V Slope / Groundwater at 17 Feet BG

Material Properties (2 materials)

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Material:  1 (Mohr-Coulomb Isotropic) - Sand
   Cohesion   Phi   UnitWeight   Ru
      0.00   30.0     120.00    Auto
Material:  2 (Mohr-Coulomb Isotropic) - Clay
   Cohesion   Phi   UnitWeight   Ru
    100.00   20.0     120.00    Auto
```

Water Properties

```
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Unit weight of water: 62.400          Unit weight of water/medium above ground:   0.000
```

Material Profiles (2 profiles)

```
-----------------
Profile:  1 (2 points)   Material beneath:  1 - Sand
      0.00      70.00        190.00      70.00
Profile:  2 (2 points)   Material beneath:  2 - Clay
      0.00      50.00        190.00      50.00
```

Slope Surface (4 points)

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      0.00      70.00         50.00      70.00        116.00      48.00        190.00      48.00
```

Phreatic Surface (4 points)

```
----------------
      0.00      53.00        101.00      53.00        116.00      48.00        190.00      48.00
```

Failure Surface

```
---------------
Initial circular surface for critical search defined by: XL,XR,R
  Intersects:  XL:      0.00     YL:     70.00     XR:    110.00     YR:     50.00
      Centre:  XC:     89.35     YC:    248.93               Radius:  R:    200.00
```

Variable Restraints

```
-------------------
Parameter descriptor:             XL        XR        R
Range of variation:              0.00      40.00     40.00
Trial positions within range:      1        50        50
```

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RESULTS: Analysis 1 - 50 Foot Offset / 22 Foot / 3H:1V Slope / Groundwater at 17 Feet BG

Spencer-Wright Method of Analysis - Circular Failure Surface

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Critical Failure Surface Search using Multiple Circle Generation Techniques
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