BRIERLEY ASSOCIATES
Creating Space Underground

MEMORANDUM

DATE: May 14, 2018

TO: Robert Wagner, Rocky Mountain Resources

FROM: Sean Sundermann, P.G.

SUBJECT: Mid-Continent Quarry Preliminary Stability Analyses

On behalf of Rocky Mountain Resources, Brierley Associates Corporation (Brierley) has prepared this memorandum as a portion of the Mining and Reclamation Permit Application to obtain the Regular (112) Mining and Reclamation Permit for the Mid-Continent Quarry. The full permit application will be prepared and submitted by Greg Lewicki and Associates. In compliance with the Rules and Regulations established by the State of Colorado through the Mined Land Reclamation Act, the Division of Reclamation, Mining and Safety (DRMS), and the Mined Land Reclamation Board (Board), the following materials outline Rocky Mountain Resources' proposed mining and reclamation plans for the subject affected land. Specifically, this report provides rock mass characterization and a preliminary geotechnical stability evaluation for permitting the proposed Mid-Continent Quarry expansion, north of Glenwood Springs, CO. This evaluation satisfies the Colorado Division of Reclamation Mining & Safety (DRMS) 112 permit for the extraction of construction materials[1], Rule 6.5 requirements for a Geotechnical Stability Exhibit.

The subject facility is located approximately 1.25 miles North-Northwest of Glenwood Springs, Colorado, and encompasses the south-facing slope immediately north of Rocky Mountain Resources' active mining operations. The Mid-Continent Quarry expansion will increase the total disturbed land from approximately 38 acres to 300 acres. Calculations by Brierley evaluated the stability of rock slopes and the stability of interbeds daylighting on individual benches as part of mine reclamation. Calculation sets for both these evaluations are attached. The base map for the quarry was provided by Rocky Mountain Resources on March 14, 2018. The base map was used in the preparation of this memorandum, including conducting geotechnical evaluations of pit slope stability of the future mined areas.

Background

The current Rocky Mountain Resources mining plan is to expand the existing mine operations (covering roughly 38 acres) northward to encompass additional approximate 265 acres. The target of the proposed expansion is to extend northward to mine the 150-175 ft of combined limestone and dolomite of the Leadville formation for rock dust and aggregate. Based on the drawings provided, the quarry will ultimately excavate to a surface mimicking the existing

[1] Colorado Mined Land Reclamation Board, 2006, Mineral rules and regulations of the Colorado Mined Land Reclamation Board for the extraction of construction materials, available online: http://mining.state.co.us/SiteCollectionDocuments/Revised-ConstrMatadoptedAug92006indexed.pdf

topography with steeper, benched sides excavated on the western (offset from Oasis Creek) and eastern extents (offset from Cascade Creek). A north-facing, benched slope on the southern mine limit will provide a privacy berm as mining progresses down the slope. Based on initial requests from the Bureau of Land Management (BLM), part of the current reclamation plan is to leave a series of random cliff faces during mining of the generally slope-parallel quarry surface to break up the topography of the mined surface for visual purposes.

General Geology/ Bedrock and Surficial Geology

The quarry lies primarily within the Mississippian-age Leadville Limestone, a very fossiliferous, massive, coarse to finely crystalline limestone and dolomite formation, as mapped by the Colorado Geological Survey (Kirkham et al., 2008[2]). The unit is described by Kirkham et al. (2008)[2] as 200 ft thick in the site area. Rocky Mountain Resources anticipates mining 150-175 ft of combined limestone and dolomite. The Leadville Limestone formation consists of gray to bluish-gray, coarse to finely crystalline limestone underlain by Dolomitic limestone with 20 feet to 30 feet of varying amounts of sand expected in the basal unit. Underlying the Leadville Limestone is the Upper Devonian-age Chaffee Group. Near the southeast flank of the White River Uplift, the Gilman Sandstone, the upper unit of the Chaffee Group, is predominantly a 16-ft thick calcareous sandstone (Kirkham et al., 2008), pinching out towards Glenwood Springs. The proposed expansion area is bound to the north by a mapped[2] bedrock graben, just south of the Glenwood monocline axis, exposing the younger fossiliferous limestone unit of the Lower Pennsylvanian-age Belden formation. Outcrops of the Belden appear below the existing quarry as well, unconformably overlying the Leadville Limestone. Bedrock in the location of the proposed expansion is mapped[2] as dipping between 24 and 38 degrees to the south-southwest, which forms dip slopes and tends to control hillside slope topography. A series of roughly east-west trending normal faults cross cut the area, but are not mapped as continuous across the proposed expansion area. These structures are likely a westward extension of the normal-oblique Grizzly Creek Shear Zone, and the secondary influence on the site's rock mass, outside bedding.

Site Topography

Rocky Mountain Resources has developed a very detailed site topographic map, which shows a moderately-steep, south-facing slope. The slope increases from 3.3:1 near the top of the proposed mine extent to 2.3:1 around mid-slope and steepening to 2:1 at the southern extent, adjacent to the existing quarry. A copy of the new detailed topographic map showing existing conditions is provided elsewhere in the application submittal.

Test Borings or Core Samples

No test borings were performed and no core samples have yet been obtained as part of the preliminary site permitting efforts. There are ample bedrock exposures within the existing quarry and encompassing the proposed expansion area to preclude the need for test drilling to identify site lithologies. Topsoil and overburden thicknesses are negligible, varying from less than a foot to approximately 3 ft thick. Where exposed, the limestone in outcrop is largely intact and

[2] Kirkham, R., Streufert, R., Cappa, J., Shaw, C., Allen, J., and J. Jones, 2008, Geologic map of the Glenwood Springs quadrangle, Garfield County, Colorado; Colorado Geological Survey, Map Series 38, scale 1:24,000.

unweathered. Bedrock exposures at the site have been mapped for geologic structure and these data are included in the slope stability section below.

Slope Stability

Rock Mass Characterization

A field reconnaissance was performed to provide an initial assessment of the overall geologic/rock mass conditions and stability of the south-facing slope. During the field reconnaissance, the bedrock conditions were evaluated and classified by visual examination of surficial deposits and outcrops. Bedrock joints, structure, fractures and weathering were assessed and classified, and the geometry of discontinuities (dip and dip direction) were measured with a Brunton compass. Measurements were made of rock mass discontinuities along the entirety of the slope to evaluate the range and variability of discontinuity geometry and character. The collected datasets are believed to be representative of the exposed rock mass. Exposed outcrops were characterized using the Hoek-Brown rock mass classification system to assess in-situ strength properties (Hoek, 2000[3]). Joint surface conditions, such as continuity, spacing, aperture, infilling, roughness, seepage, and a rating of significance were characterized, and collated on data tables. The degree of roughness and larger-scale waviness of joint surfaces was evaluated using the Joint Roughness Coefficient (JRC) methodology of Barton (1977[4]). Digital photos were taken to document rock identification, typical and atypical rock conditions, locations of measurements, zones of localized weakness, and/or locations of geologic interest. Field measurements, mapping control, and feature location were recorded using a hand-held Global Positioning System (GPS) unit (Garmin™60 Cx), with typical degree of positional uncertainty of +/- 9 feet (as calculated by the GPS device).

Rock Mass Discontinuity Sets

Discontinuity data from the field mapping were compiled on stereographic projections (lower hemisphere, equal angle) and analyzed with the computer program DIPS v. 6.0 (RocScience, 2012) to evaluate trends and discontinuity sets. The resulting stereographic plots are included in Appendix B. General characteristics of the discontinuities identified on the slope above the existing quarry are provided in Table 1.

Table 1. Discontinuity Global Characteristics

Type	Typical Spacing	Lateral Continuity	Surface Roughness	Infill / Bonding
Bedding	>10 ft	>100 ft	Slightly rough	Laminar shaley claystone interbed
Strike Joint	0.5 to 3 ft	5 to 20 ft	Smooth	None
Conjugate Joint 1	0.5 to 3 ft	3 to 15 ft	Smooth to slightly rough	None
Conjugate Joint 2	0.2 to 3 ft	3 to 15 ft	Smooth to slightly rough	None

[3] Hoek, E., 2000, Practical rock engineering: on-line document, rocscience.com

[4] Barton, N.R. and Choubey, V., 1977, The shear strength of rock joints in theory and practice: Rock Mechanics, Vol. 10 (1-2), pp. 1-54.

Additional details and modeling parameters are provided below. The discontinuities controlling rock mass stability on the slope are presented in Table 2. The sequence of the set designations below does not infer a hierarchy of set frequency or importance.

Table 2. Mid-Continent Discontinuity Sets

Set Name	Set #	Dip	Dip Direction	Waviness
Bedding	1	27°	197°	3°
Strike Joint	2	59°	354°	3°
Conjugate Joint 1	3	53°	029°	13°
Conjugate Joint 2	4	63°	059°	4°

Global mean planes and rosette plots (Appendix A) illustrate the rock mass is controlled primarily by bedding, dipping moderately to the south, creating dip slopes that dictate slope topography. Nine bedding structure measurements from the CGS throughout the quarry expansion area are presented on Kirkham et al., 2008, ranging from 24° to 34°, all dipping to the south- southwest (+/- 25°). The CGS measurements are consistent with data collected during the Brierley field reconnaissance that indicate a dip ranging from 24° to 34°, all dipping to the southwest (197° +/-19). The primary discontinuities controlling rock mass stability in the slope are generally persistent and control rock mass response.

Kinematic Analysis of Failure Modes

Kinematic analyses incorporate the discontinuity data collected from the Mid-Continent quarry and slope above to help identify potential rock slope failure conditions. Data from the field mapping investigation were compiled for stereographic plotting and kinematic stability evaluation using the Rocscience, Inc. Dips 7.0 program. Discrete discontinuity sets, such as bedding, joints and shear zones, were plotted and defined by examination of the stereographic plots. The purpose of these analyses is to evaluate the potential for shallow failures (approximately less than 10-20 ft) in the cut slope walls. The results are used in analyzing the stability and factor of safety for failure modes.

Kinematic analysis involves stereographic projection of rock mass bedding and fractures measured in the field, and comparing the discontinuity geometry against the proposed slope excavation direction and inclination. Stereographic projections of fracture data are tools commonly used to predict the types of discontinuity-controlled rock slope failures that are possible for given cut slope configurations and rock friction angles. The analysis of the discontinuity data allows for the recognition of potential rock slope stability failures by examining the geometric relationships between discontinuity surfaces and the rock face. Discontinuity data (joints, shears, and bedding) collected during the geologic mapping were used as the basis for our kinematic stability analyses.

Kinematic analyses consider three primary failure modes:

(1) Topple failure of rock blocks and slabs. Topple failures occur as blocks or slabs, which are bounded by discontinuities that dip steeply into the face at angles such that the center of mass falls outside the toe of the block and causes outward rotation and topple out of the cut face.

(2) Planar sliding of rock on a single discontinuity or single discontinuity set. Planar sliding failure occurs when a rock mass slides along a single, optimally-oriented surface that dips out of the slope face.

(3) Wedge sliding of rock along the intersection of two discontinuities. Wedge failures involve block sliding along two favorably oriented intersecting fractures in the direction of the plunge of the intersection line.

Only the geometric relationships between the discontinuities and the cut slopes are used in the kinematic analyses. The kinematic analyses assume no rock reinforcement to the slope. External forces, such as seismic loads, cohesion, joint surface character and hydrostatic pressures, are not considered in the kinematic analyses. These factors increase the risk of slope failure identified in the kinematic analyses, but do not directly affect the geometric analysis.

After defining the discontinuity sets, analyses for each mode of potential failure was performed. The number of the discontinuity stereonet poles that meet the kinematic criteria of lying within the critical zone for failure are represented on Table 3 as a percentage of the total number of discontinuities.

Table 3. Summary Results of Kinematic Stability Analysis for North Highwall – Critical Failure Poles

Failure Mode		Critical Poles	Percentage of Poles
Direct Topple	All Intersections	98	15.6%
	Sets Planes Only	44	19.4%
Oblique Topple		0	0.0%
Flexural Topple	All Poles	10	27.8%
	Strike Joint Only (Set 2)	7	100%
Wedge	All Intersections	38	6.0%
	Sets Only	6	2.6%
Planar Slide	All Sets	5	13.9%
	Bedding Only	5	62.5%

Note: Failure mode numbers in table represent the percentage of total discontinuity poles that kinematically lie within the critical zone for failure.

All stereonet plots and sensitivity plots are provided as Appendix A.

For the vertical and sub-vertical jointing, there is the potential for direct and flexural toppling, but these are expected to be limited to individual benches and highwalls. Large scale instabilities involving multiple benches and the overall quarry slopes are not expected as a result of these joints.

Based on the kinematic analyses, there is a low probability of wedge. However, small wedges along non-characteristic joint sets were observed within the quarry along the blast line, indicating wedge remains a hazard. To further evaluate the potentially hazardous wedge geometries identified in the kinematic analyses, limit equilibrium models were run that included variations in joint surface shear strength, water conditions, and the presence of a tension cracks in the slope behind the rock face. The results from the wedge stability analyses indicate a very low probability of failure, as summarized in tables 4A and 4B below. Where a wedge geometry exists a minimum factor of safety is provided.

Table 4A. Wedge Factor of Safety

	Bedding	Strike Joint	Conjugate Joint 1	Conjugate Joint 2
Strike Joint	1.92		No Wedge	No Wedge
Conjugate Joint 1	No Wedge	No Wedge		No Wedge
Orthogonal Joint	4.06	No Wedge	No Wedge	

Table 4B. Wedge Basal Slide Factor of Safety

	Conjugate Joint 1	Conjugate Joint 2
Primary Joint	No Wedge	No Wedge
Conjugate Joint 1		6.42
Conjugate Joint 2	6.42	

The kinematic analyses corroborate field observations from the field reconnaissance that indicate the primary failure mode is planar sliding along the limestone bedding planes dipping adversely along the south-facing highwall. The thin interbed of laminar-bedded, shaley claystone observed along some of the limestone bedding planes creates a potential failure plane of lesser cohesion and fiction angle than the limestone. Stability modeling was completed to evaluate this geometry for potential failure.

Stability Modeling

To determine the geologic input parameters for the Mid-Continent Quarry stability modeling, characteristic values of the Leadville limestone were taken from empirical data in peer-reviewed publications and verified by publicly available typical values for the units encountered on the slope. Based on back analysis from the stability modeling of the existing slopes, the Leadville Limestone is considered a medium to strong material[5]. Based on tests performed by the United States Bureau of Reclamation[6] on the Leadville Limestone in the Paradox Valley, the friction angle of the limestone is approximately 40 degrees and the cohesion is approximately 3,050

[5] United States Bureau of Reclamation, 1998, *Engineering Geology Field Manual*, Second edition.

[6] Ake, J., Mahrer, K., O'Connell, D., Block, L., 2005, *Deep Injection and Closely Monitored Induced Seismicity at Paradox Valley, Colorado.*, United States Bureau of Reclamation.

psi. Caltrans[7] estimates for hard rock masses, like limestone, the friction angle of the rock mass varies from 35 degrees to 45 degrees and the friction angle of the joint areas can vary from 35 degrees to 40 degrees.

The slope stability analyses were performed using the general limit equilibrium method of slices (Morgenstern-Price) using the software program Slope/W from Geostudio 2012. Using this methodology, the factor of safety for a given geometry is determined by calculating the ratio of resisting forces to driving forces on trial failure surfaces. Slip surface scenarios analyzed for this report were block specified. The slip surface with the lowest factor of safety against sliding is described as the minimum factor of safety for the defined conditions.

The critical cross-section was selected for analysis. Two stability cases were analyzed for the proposed quarry: 1) Long Term Steady-State and 2) Long Term Pseudo-Static. Long Term Steady State considers the extended term stability of the highwall and the rock strength is characterized by effective stress parameters. Pseudo-Static introduces seismic loading to the Long-Term Steady-State model.

Soil parameters for the Leadville limestone and the joint material observed on-site were back-calculated based on current dimensions of the existing Mid-Continent Quarry. No site-specific strength testing has been completed. Mohr-Coulomb strength criterion framework was utilized to define bedrock and joint material strengths. Mohr-Coulomb assumes an inherent cohesion in over-consolidated fine-grained or cemented soils and bedrock. The properties are summarized in the table below.

Table 5. Leadville Limestone Strength Parameters

Soil	Cohesion (psf)	Friction Angle (degrees)	Unit Weight (pcf)
Leadville Limestone	5,000	35	150
Joint Material	40	25	150

Slope stability results based on modeling of the above conditions along with the associated minimum factors of safety are provided in the table below. Slope stability results are presented in Appendix B.

Table 6. Modeled Factor of Safety

Loading Condition		Factor of Safety	
		Minimum Recommended	Quarry Slope Stability Result
I	Long Term Steady State	1.5	1.55
II	Pseudo-Static Seismic Loading	1.1	1.32

Preliminary stability analyses indicate the overall global stability of the slope is stable at a factor of safety of 1.55 along the south-facing northern highwall, the most adverse slope geometry for the south-dipping limestone bedding.

[7] California Department of Transportation., 2013, *Rock Strength and Its Measurements.*

For any rock mass there is the possibility of large scale random joints with a low strength such as from weathering, historic sliding, or clay infilling. If such a joint or several joints exist and if these joints have a disadvantageous orientation and location, then there could be a large-scale slope instability. However, field observations by Brierley did not reveal any such joints.

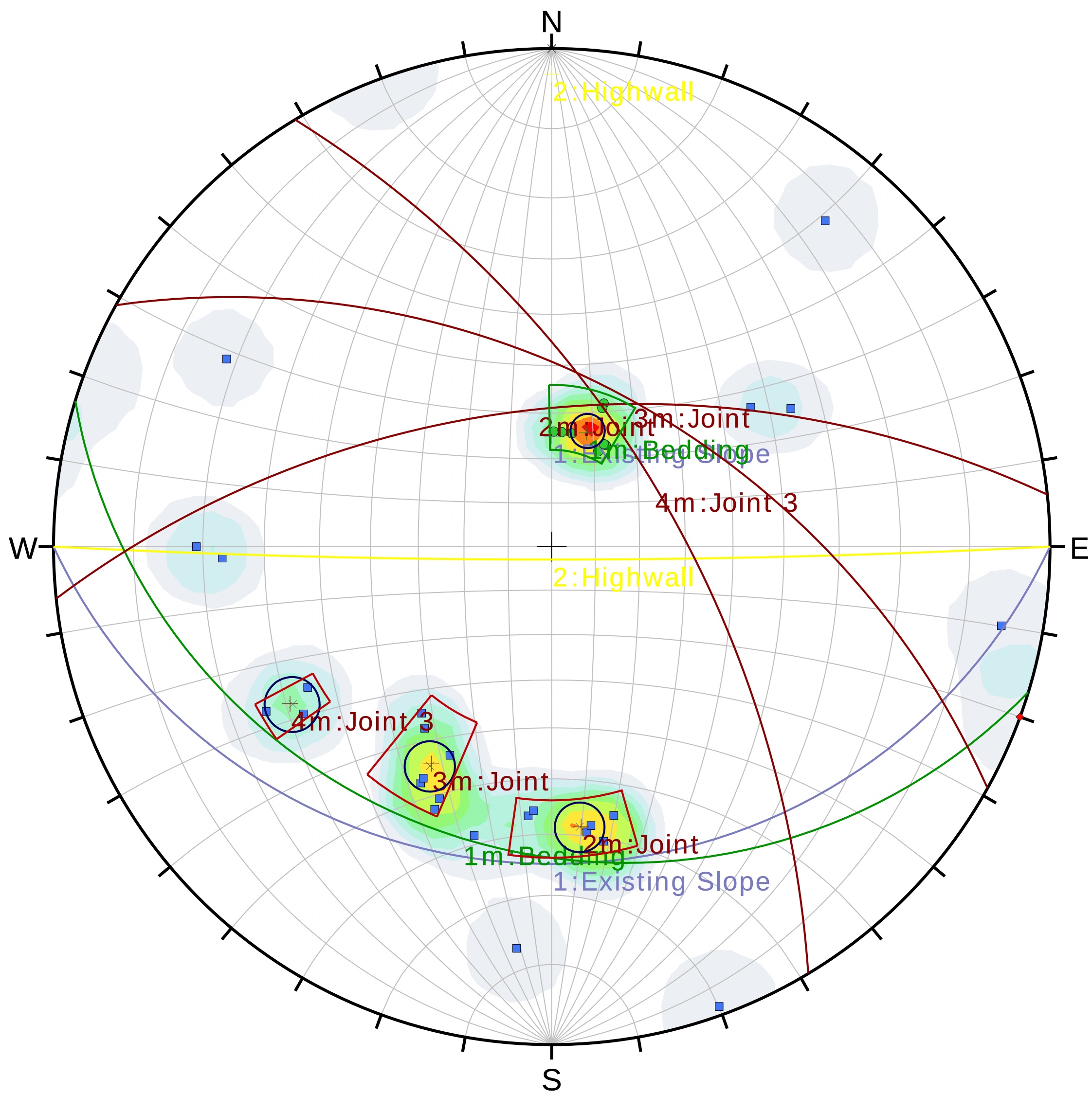
Conclusions and Recommendations

Based on presently available information, it is not practical to model the rock mass in sufficient detail to predetermine absolute final slope configurations. Therefore, the “observational method” approach to determining stability of final cut slopes will be employed. The observational method is a rigorous series of interactive steps of excavating rock, observing the condition of the rock mass and behavior of rock slopes, and refining the design based upon observed conditions. Based on the observations and evaluations at a given stage, the next stage of the operation is designed and implemented. Using this approach, Rocky Mountain Resources will perform an experimental / trial initial excavation well within the mining limits to observe actual ground conditions and the actual performance of the benches and highwalls in multiple orientations. Providing that observed conditions are consistent with the basis of these slope stability evaluations and that the rock slopes do not show unexpected behavior, the mine will be developed to the maximum extents as proposed in the mine plan. Preliminary recommended maximum build-out benches and highwalls will consist of 15-ft wide benches and 25-ft highwalls from the highest elevation in the north extent of the mining limits down to elevation of the existing quarry. The trial excavation will be used to establish the basic design for the benches and highwalls. Evaluations and changes to the highwalls and benches will be made as necessary over time based on continuous observations of bench and highwall performance.

Rocky Mountain Resources will submit a report to the DRMS after the initial trial excavation is complete. This report will detail actual observed bench and highwall performance and present recommendations for the future development of slopes, benches, and highwalls in the mine. It is anticipated that subsequent annual reports will not be necessary. However, the DRMS will be notified by Rocky Mountain Resources of any significant changes to the mine plan.

As part of the site reclamation plan, the U.S. Bureau of Land Management has requested random cliffs remain as part of the permanent surface to create a more naturally-erratic slope. The cliffs should not exceed the recommended maximum build-out bench and highwall geometry described above, consisting of 15 ft wide-benches and 25-ft highwalls. An Observational approach should be taken to verify the free-standing cliffs will not be intersected by the laminar-bedded, shaley claystone interbeds with weak shear strength. These interbeds are very continuous, traceable where exposed across the length of the existing quarry.

APPENDIX A: KINEMATIC ANALYSES



Symbol	TYPE	Quantity
●	Bedding	8
■	Joint	27
◆	Shear	1

Color	Density Concentrations
	0.00 - 1.80
	1.80 - 3.60
	3.60 - 5.40
	5.40 - 7.20
	7.20 - 9.00
	9.00 - 10.80
	10.80 - 12.60
	12.60 - 14.40
	14.40 - 16.20
	16.20 - 18.00
Contour Data	Pole Vectors
Maximum Density	17.91%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
User Planes				
1		25	180	Existing Slope
2		87	180	Highwall
Mean Set Planes				
1m		27	197	Bedding
2m		59	354	Joint
3m		53	29	Joint
4m		63	59	Joint 3

Plot Mode	Pole Vectors
Vector Count	36 (36 Entries)
Hemisphere	Lower
Projection	Equal Angle

Project	Mid Continent Quarry	
Analysis Description	Surface Mapping Pole Plot	
Drawn By	Sundermann	*Company* Brierley
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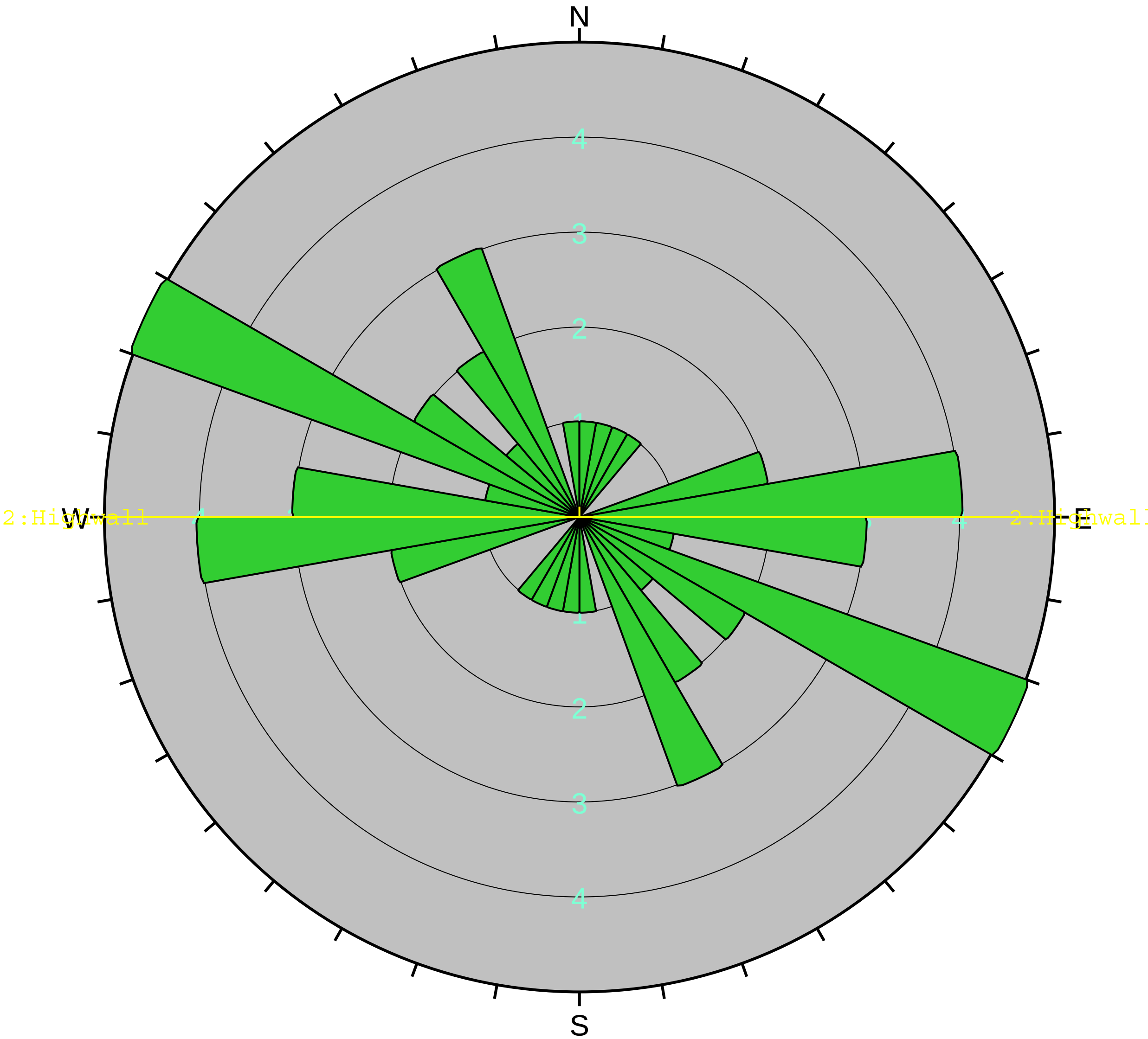
DIPS 7.012

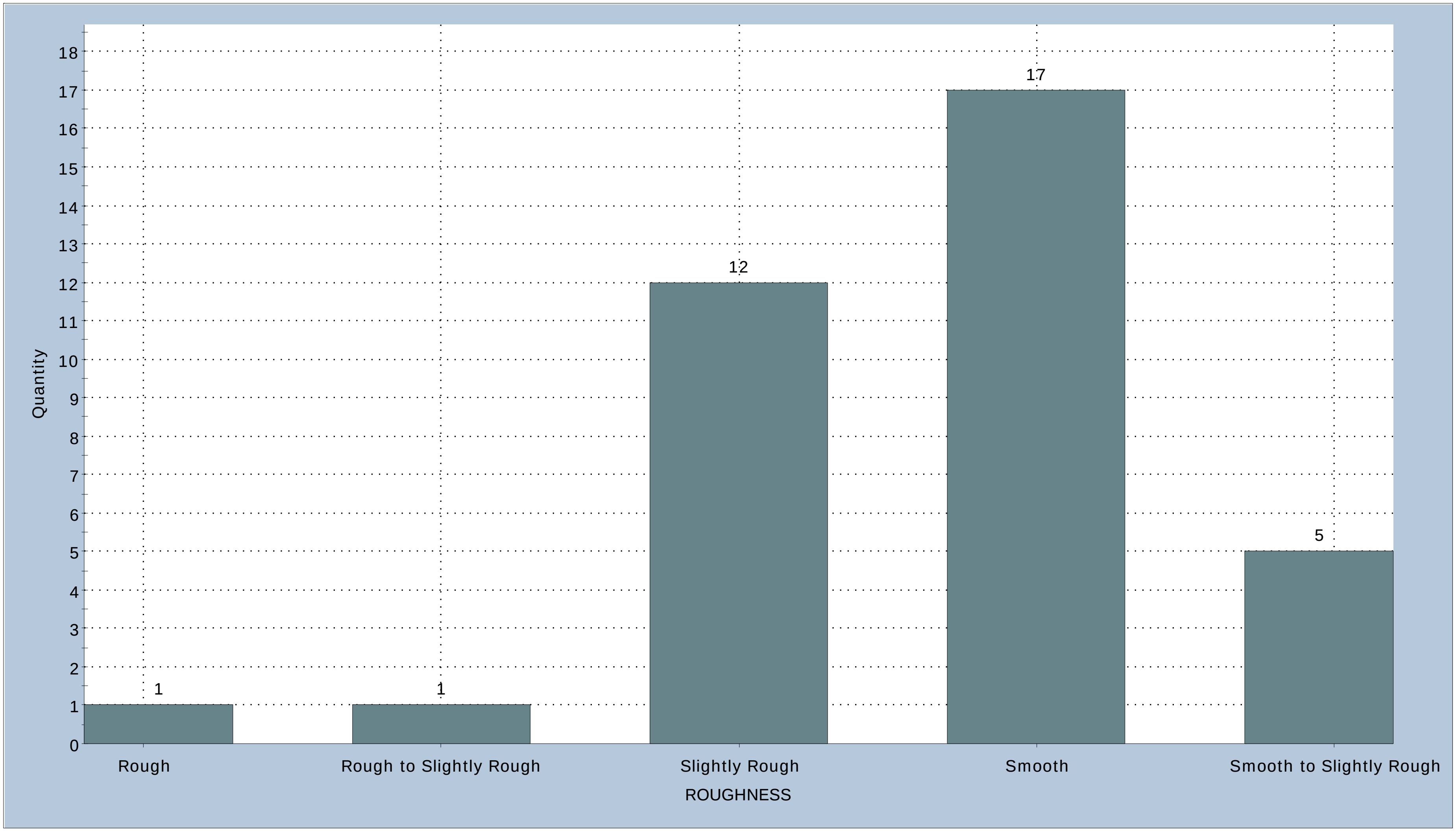


Plot Mode	Rosette
Plot Data	Apparent Strike
Face Normal Trend	0.0
Face Normal Plunge	90.0
Bin Size	10°
Outer Circle	5 planes per arc
Planes Plotted	28
Minimum Angle To Plot	45.0°
Maximum Angle To Plot	90.0°

Project	Mid Continent Quarry		
Analysis Description	Surface Mapping Rosette Plot		
Drawn By	Sundermann	*Company*	Brierley
Date	4/23/2018, 11:38:37 AM	*File Name*	MidContinent_Quarry.dips7

DIPS 7.012

Qualitative Chart of ROUGHNESS



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Analysis Description	Surface Mapping Surface Roughness		
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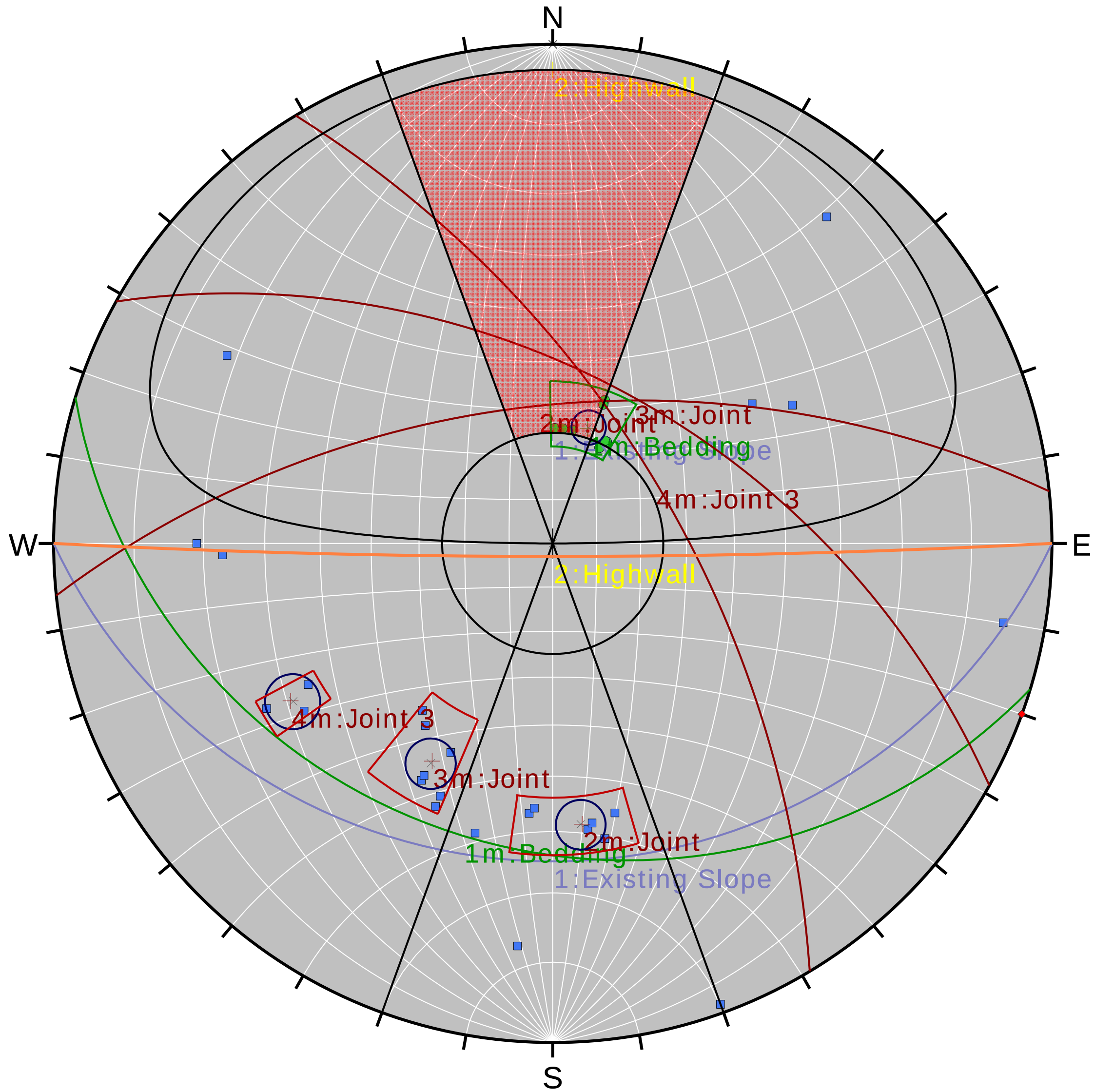
DIPS 7.012



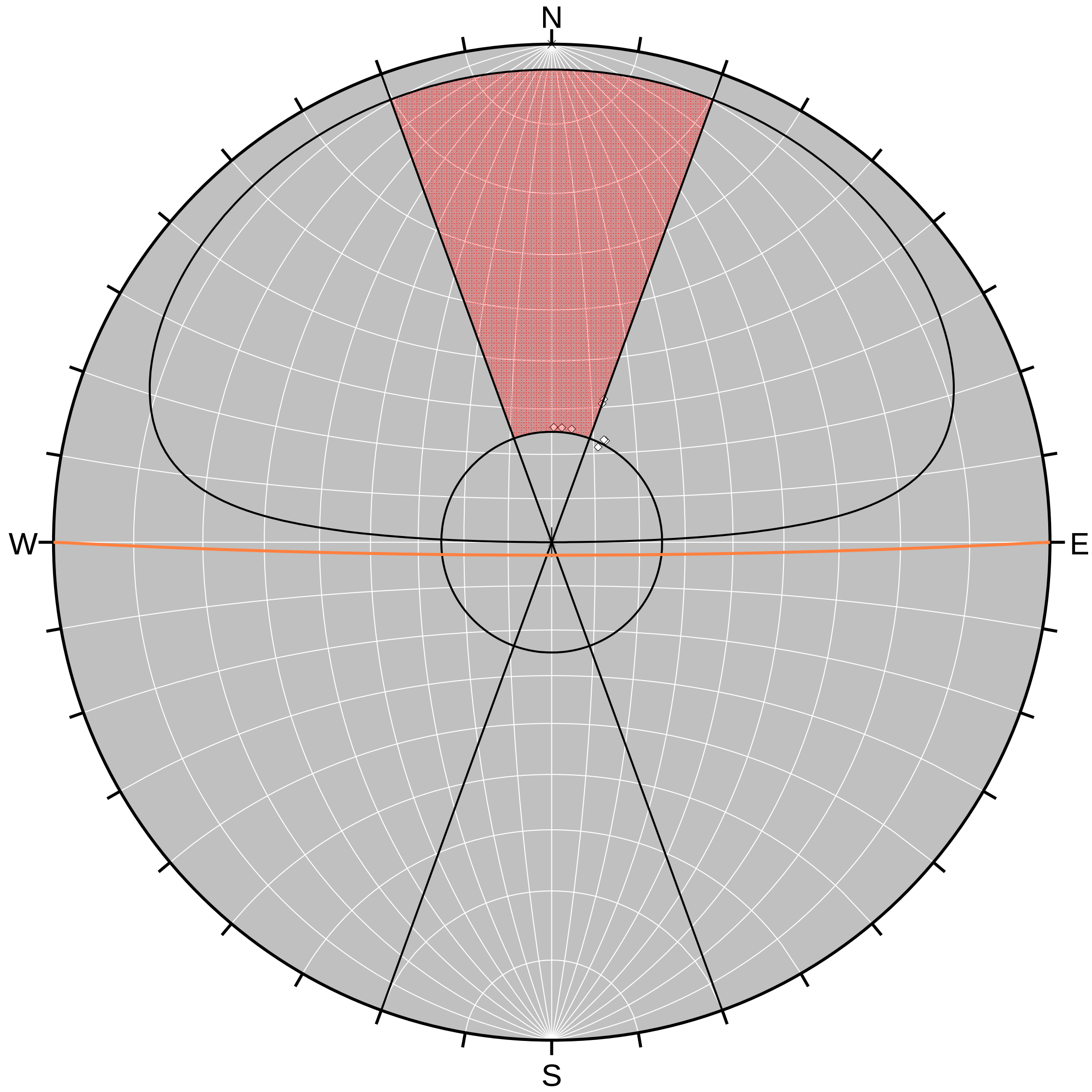
Symbol	TYPE	Quantity
●	Bedding	8
■	Joint	27
◆	Shear	1

Kinematic Analysis	Planar Sliding
Slope Dip	87
Slope Dip Direction	180
Friction Angle	25°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	5	36	13.89%
Planar Sliding (Set 1: Bedding)	5	8	62.50%

Plot Mode	Pole Vectors
Vector Count	36 (36 Entries)
Hemisphere	Lower
Projection	Equal Angle

rocscience	*Project*	Mid Continent Quarry	
	Analysis Description	Surface Mapping Planar Slide	
	Drawn By Sundermann	*Company* Brierley	
DIPS 7.012	*Date* 4/23/2018, 11:38:37 AM	*File Name* MidContinent_Quarry.dips7	



Symbol	Feature
◇	Pole Vectors

Kinematic Analysis	Planar Sliding
Slope Dip	87
Slope Dip Direction	180
Friction Angle	25°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	5	8	62.50%

Plot Mode	Pole Vectors
Vector Count	8 (8 Entries)
Hemisphere	Lower
Projection	Equal Angle

Project	Mid Continent Quarry	
Analysis Description	Surface Mapping Planar Slide - Bedding (Set 1)	
Drawn By	Sundermann	*Company* Brierley
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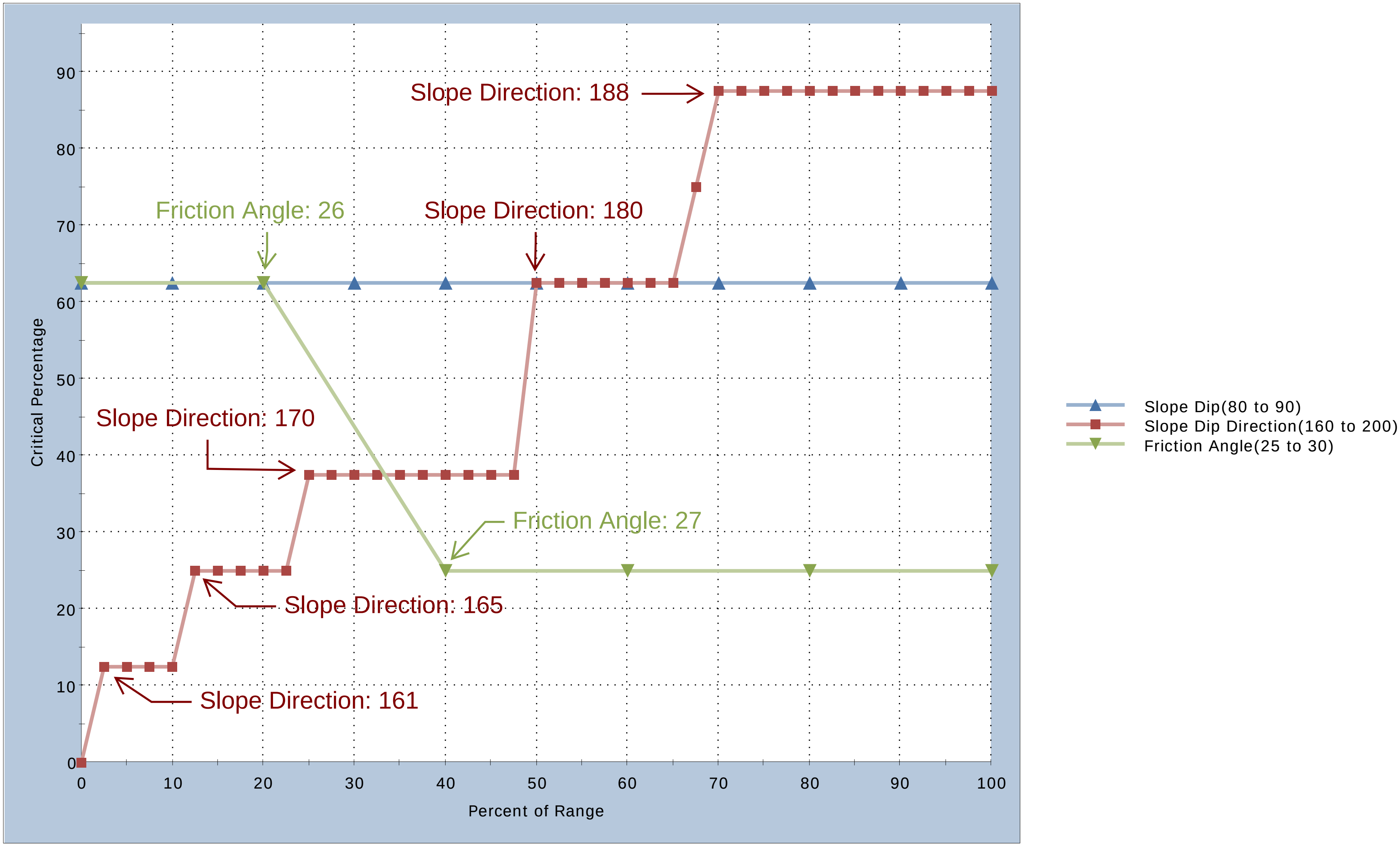
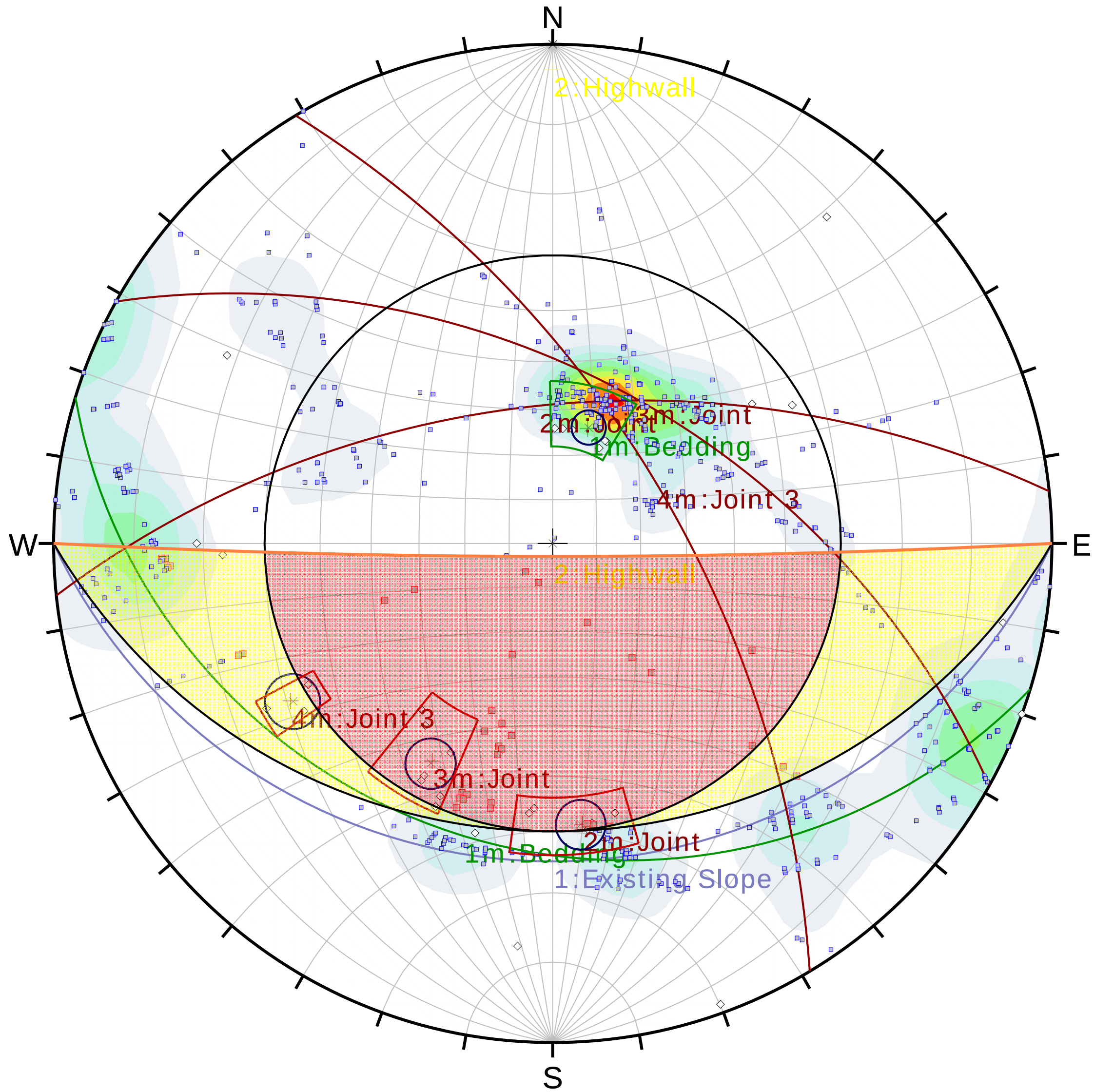
Planar Sliding: Critical Percentage vs. Percent of Range



Mean Values

Slope Dip = 87 Slope Dip Direction = 180 Friction Angle = 25 Lateral Limit = 20



Symbol	Feature
◇	Pole Vectors
▫	Critical Intersection
▫	Intersection

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	1.50 - 3.00
	3.00 - 4.50
	4.50 - 6.00
	6.00 - 7.50
	7.50 - 9.00
	9.00 - 10.50
	10.50 - 12.00
	12.00 - 13.50
	13.50 - 15.00

Contour Data	Intersections
Maximum Density	14.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding		
Slope Dip	87		
Slope Dip Direction	180		
Friction Angle	30°		
	Critical	**Total**	**%**
Wedge Sliding	38	629	6.04%

Plot Mode	Pole Vectors
Vector Count	36 (36 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	629
Hemisphere	Lower
Projection	Equal Angle

Project	Mid Continent Quarry		
Analysis Description	Surface Mapping Wedge Failure		
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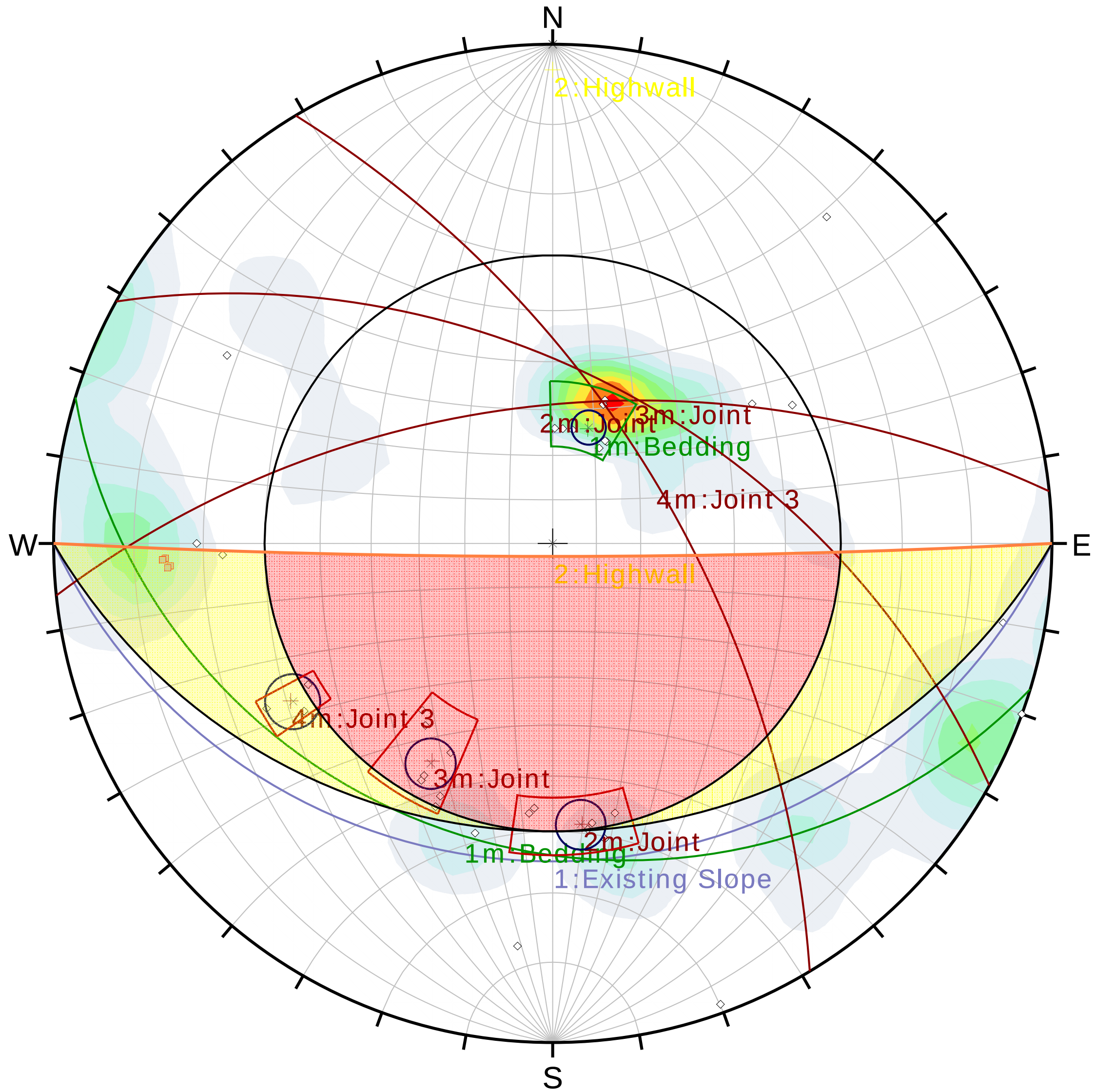
DIPS 7.012



Symbol	Feature
◇	Pole Vectors
■	Critical Intersection

Color	Density Concentrations
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	1.50 - 3.00
	3.00 - 4.50
	4.50 - 6.00
	6.00 - 7.50
	7.50 - 9.00
	9.00 - 10.50
	10.50 - 12.00
	12.00 - 13.50
	13.50 - 15.00

Contour Data	Intersections
Maximum Density	14.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

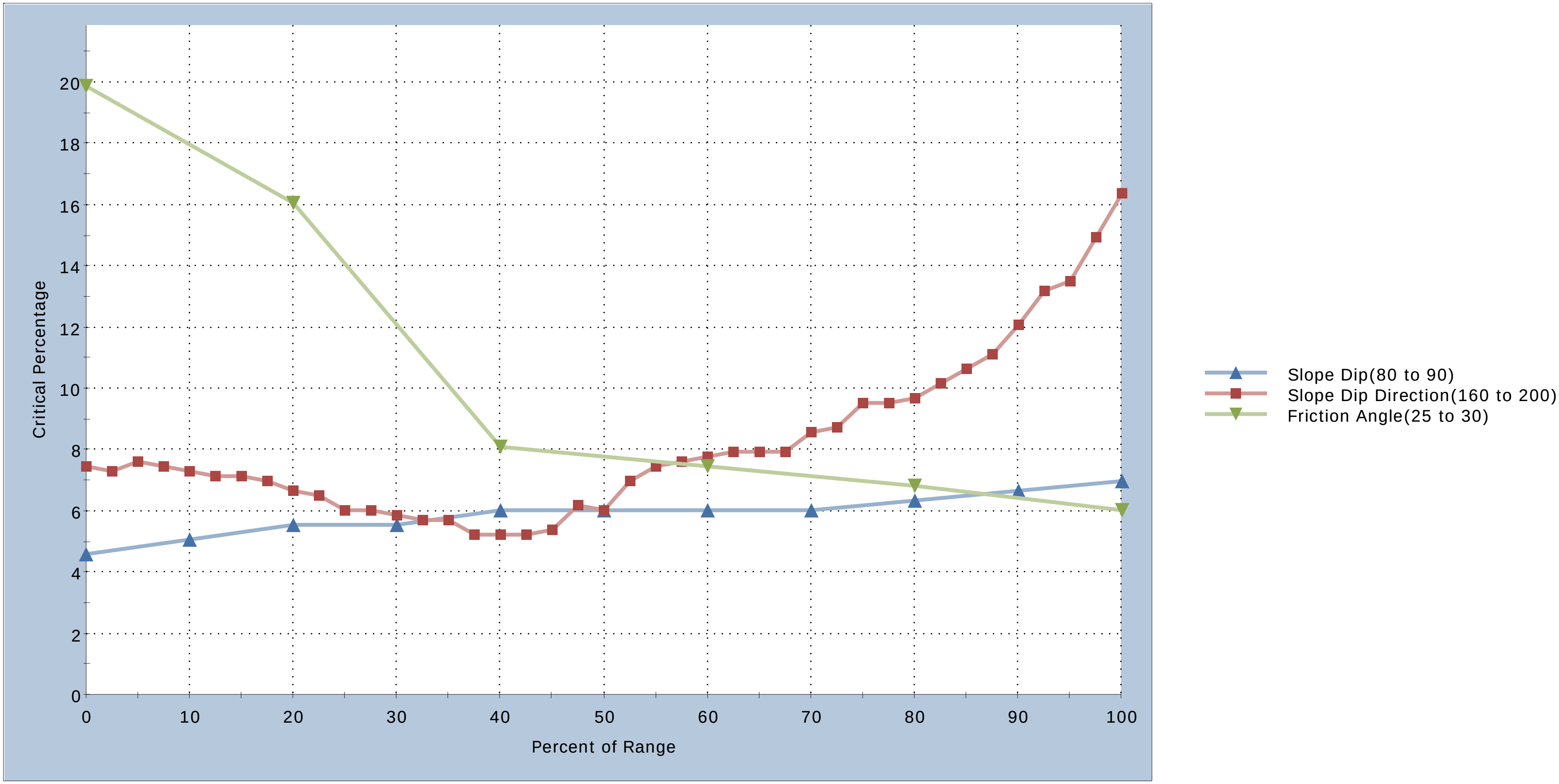
Kinematic Analysis	Wedge Sliding		
Slope Dip	87		
Slope Dip Direction	180		
Friction Angle	30°		
	Critical	**Total**	**%**
Wedge Sliding	6	227	2.64%

Plot Mode	Pole Vectors
Vector Count	36 (36 Entries)
Intersection Mode	All Set Planes
Intersections Count	227
Hemisphere	Lower
Projection	Equal Angle

Project	Mid Continent Quarry		
Analysis Description	Surface Mapping Wedge Failure - Sets Only		
Drawn By	Sundermann	*Company*	Brierley
Date	4/23/2018, 11:38:37 AM	*File Name*	MidContinent_Quarry.dips7

DIPS 7.012

Wedge Sliding: Critical Percentage vs. Percent of Range



Mean Values

Slope Dip = 87   Slope Dip Direction = 180   Friction Angle = 30   Lateral Limit = 20

rocscience	*Project*	Mid Continent Quarry	
	Analysis Description	Surface Mapping Wedge Failure	
	Drawn By Sundermann	*Company* Brierley	
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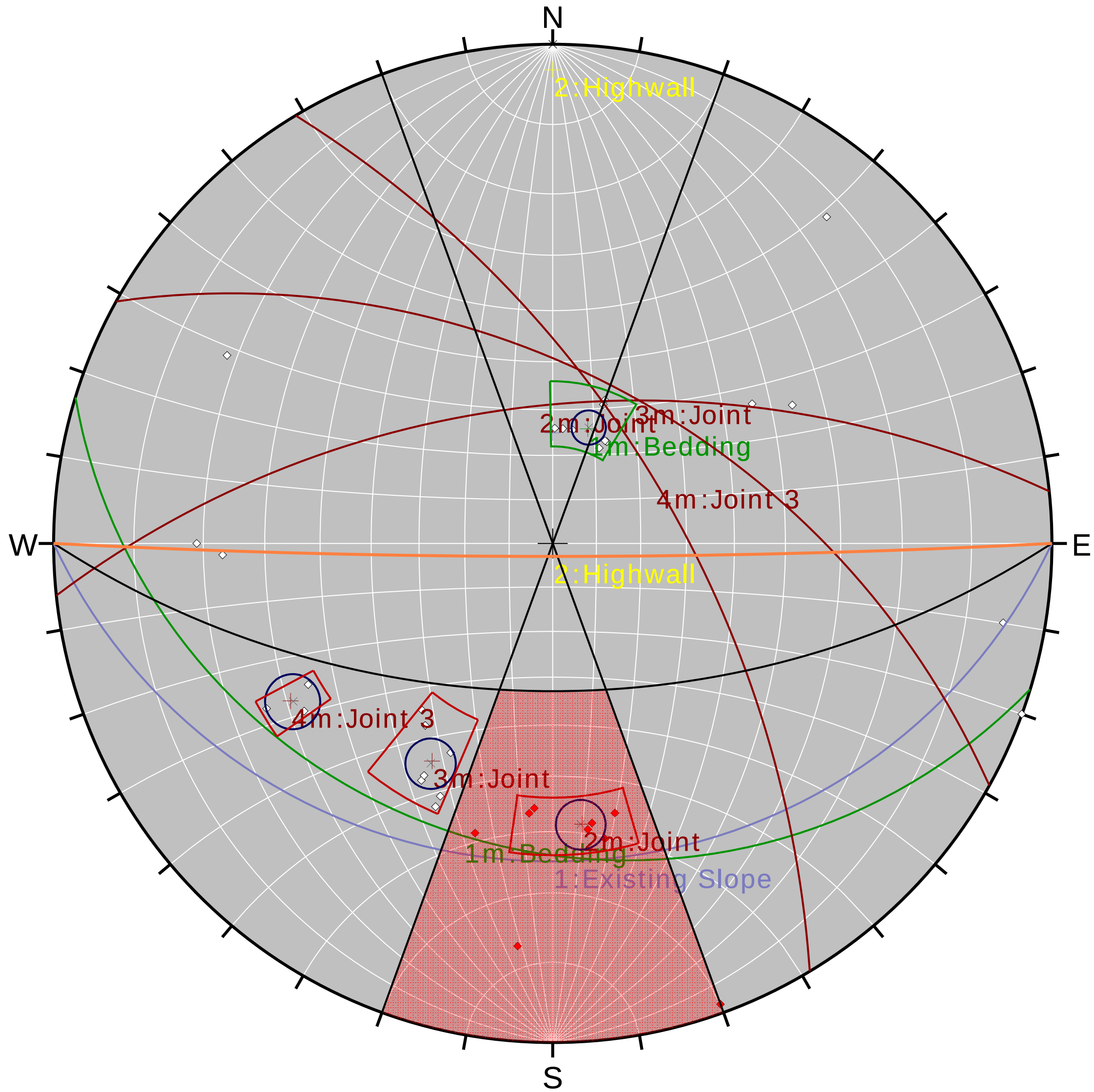


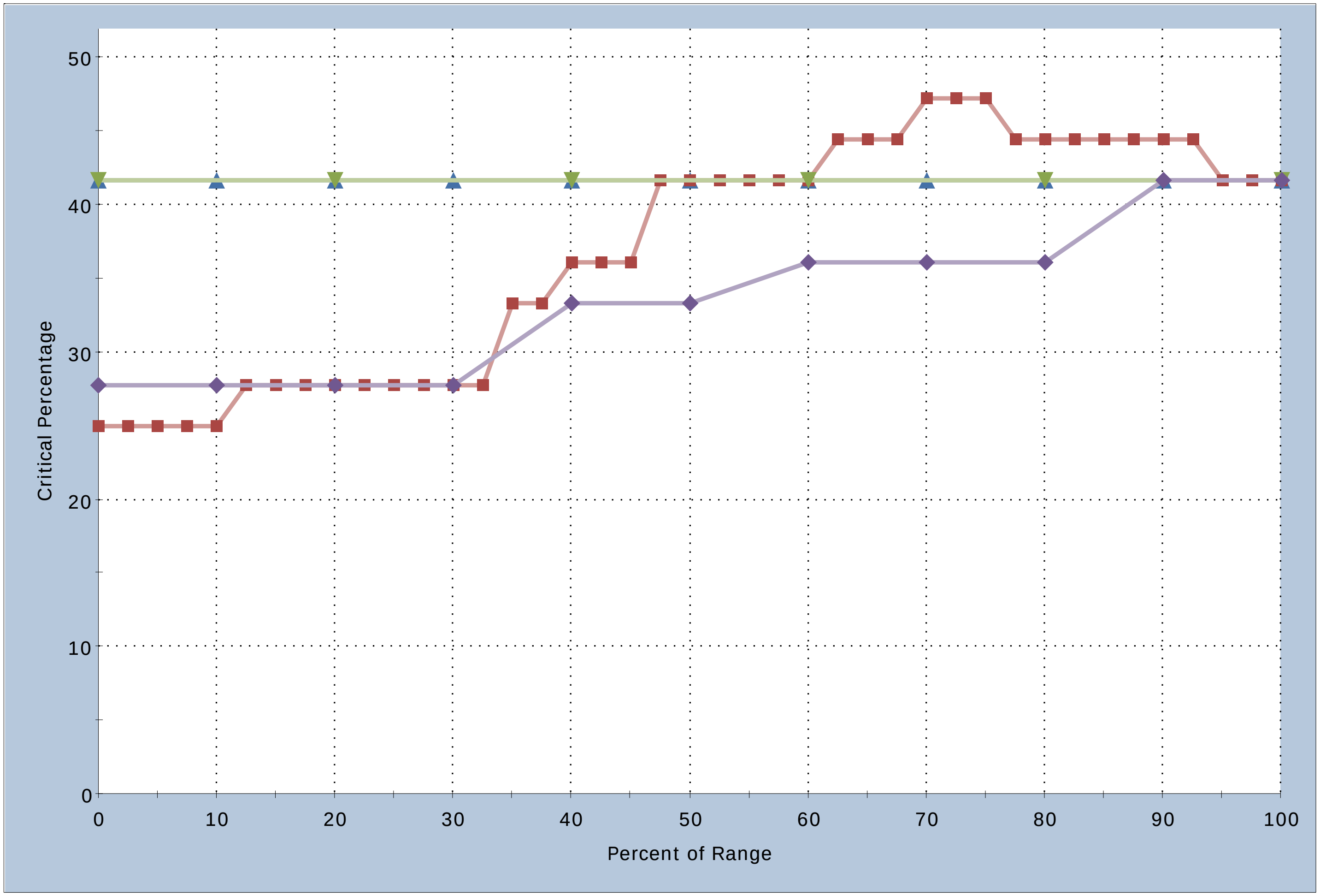
Symbol	Feature
◇	Pole Vectors
◆	Critical Vectors

Kinematic Analysis	Flexural Toppling		
Slope Dip	87		
Slope Dip Direction	180		
Friction Angle	30°		
Lateral Limits	20°		
	Critical	**Total**	**%**
Flexural Toppling (All)	10	36	27.78%
Flexural Toppling (Set 2: Joint)	7	7	100.00%

Plot Mode	Pole Vectors
Vector Count	36 (36 Entries)
Hemisphere	Lower
Projection	Equal Angle

DIPS 7.012	*Project* Mid Continent Quarry		
	Analysis Description Surface Mapping Flexural Topple		
	Drawn By Sundermann	*Company* Brierley	
	Date 4/23/2018, 11:38:37 AM	*File Name* MidContinent_Quarry_Wedge.dips7	

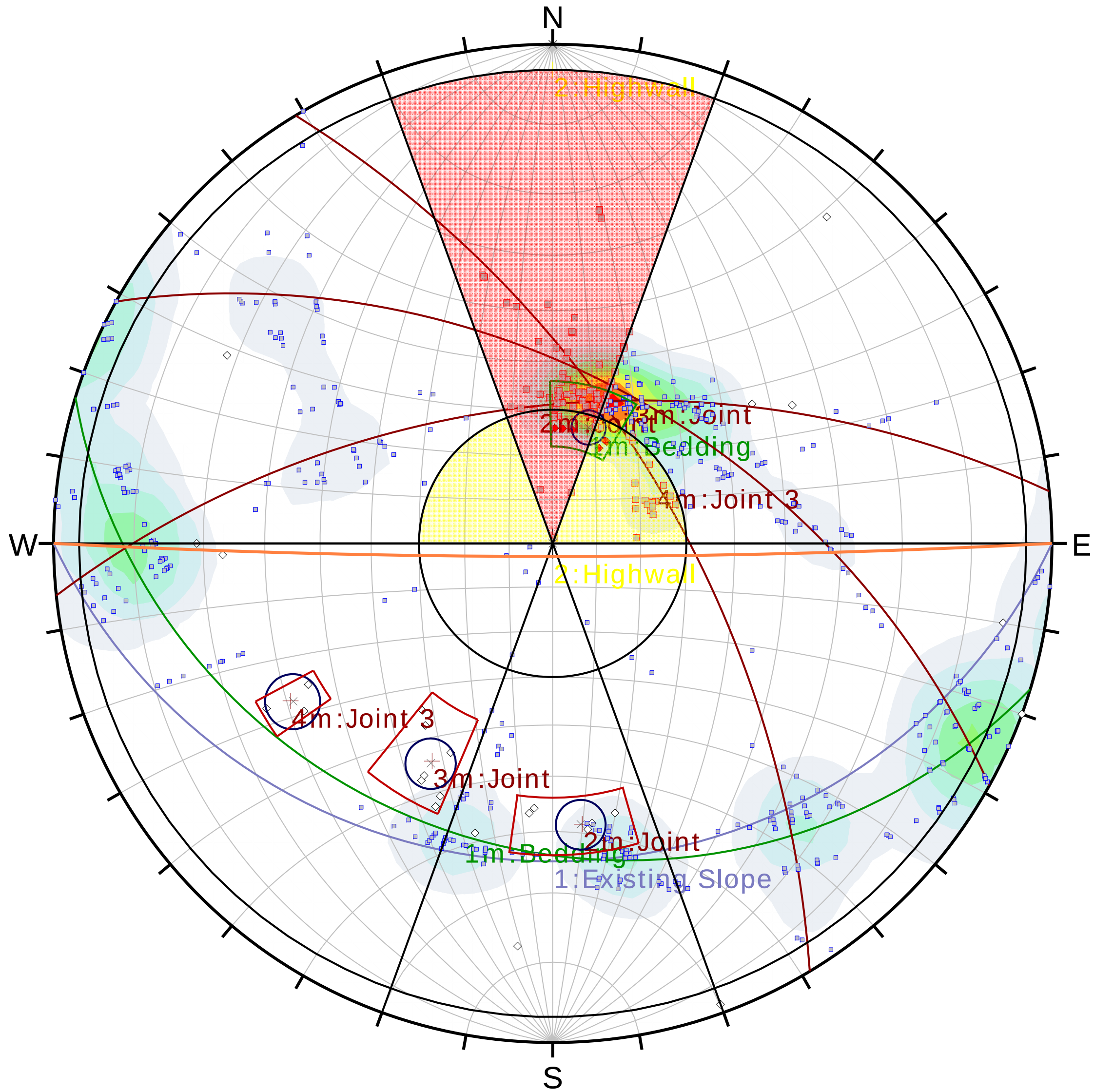
Flexural Toppling: Critical Percentage vs. Percent of Range



Mean Values

Slope Dip = 87 **Slope Dip Direction = 180** **Friction Angle = 30** **Lateral Limit = 30**

rocscience	*Project*	Mid Continent Quarry	
	Analysis Description	Surface Mapping Flexural Topple	
	Drawn By Sundermann	*Company* Brierley	
DIPS 7.012	*Date* 4/23/2018, 11:38:37 AM	*File Name* MidContinent_Quarry_Flexural.dips7	



Symbol	Feature
◇	Pole Vectors
◆	Critical Vectors
■	Critical Intersection
▫	Intersection

Color	Density Concentrations
	0.00 - 1.50
	1.50 - 3.00
	3.00 - 4.50
	4.50 - 6.00
	6.00 - 7.50
	7.50 - 9.00
	9.00 - 10.50
	10.50 - 12.00
	12.00 - 13.50
	13.50 - 15.00

Contour Data	Intersections
Maximum Density	14.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

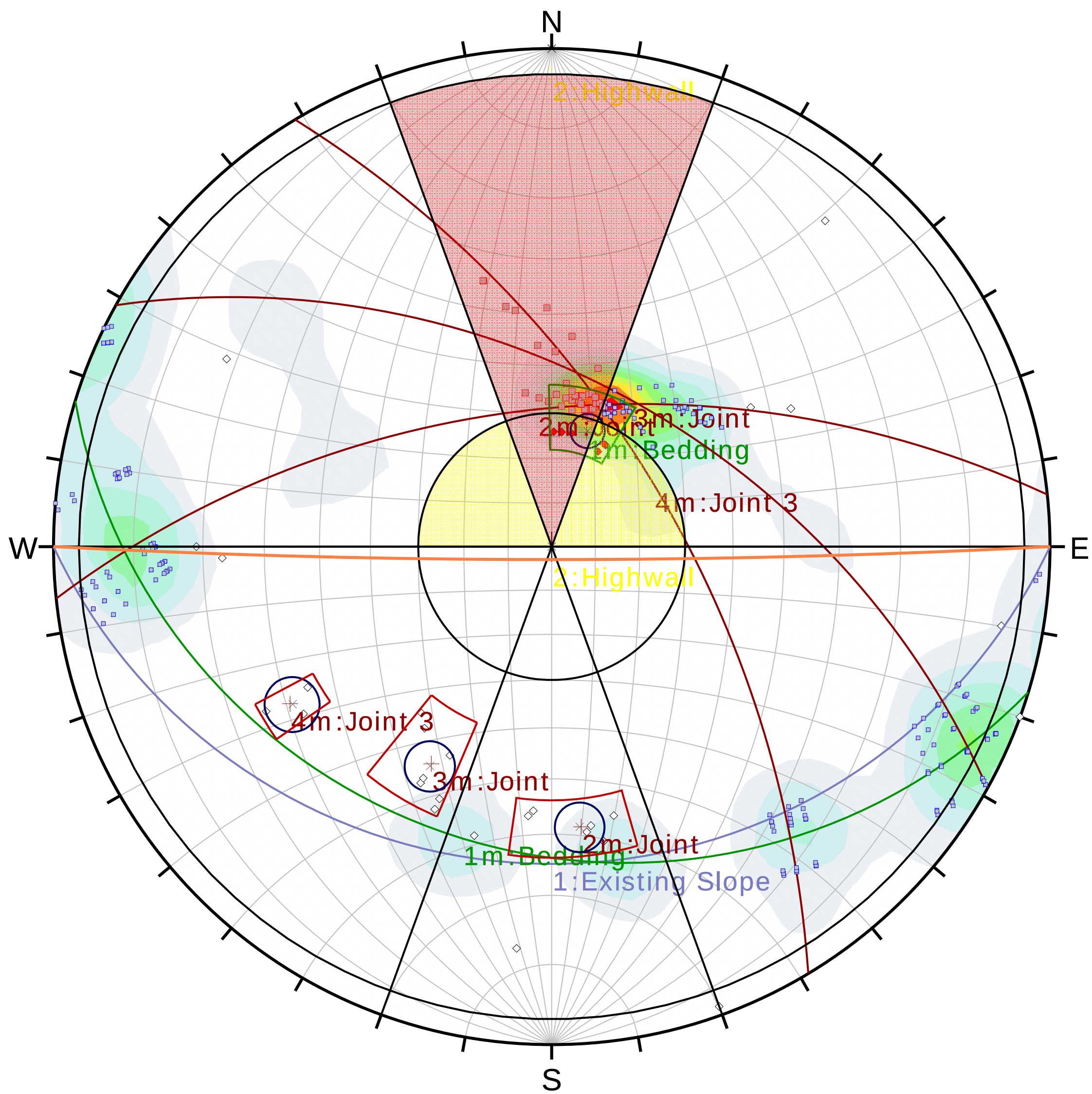
Kinematic Analysis	Direct Toppling
Slope Dip	87
Slope Dip Direction	180
Friction Angle	30°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	98	629	15.58%
Oblique Toppling (Intersection)	22	629	3.50%
Base Plane (All)	8	36	22.22%
Base Plane (Set 1: Bedding)	8	8	100.00%

Plot Mode	Pole Vectors
Vector Count	36 (36 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	629
Hemisphere	Lower
Projection	Equal Angle

Project	Mid Continent Quarry		
Analysis Description	Surface Mapping Direct Topple		
Drawn By	Sundermann	*Company*	Brierley
Date	4/23/2018, 11:38:37 AM	*File Name*	MidContinent_Quarry_Direct.dips7

DIPS 7.012



Symbol	Feature
◇	Pole Vectors
◆	Critical Vectors
■	Critical Intersection
□	Intersection

Color	Density Concentrations
	0.00 - 1.50
	1.50 - 3.00
	3.00 - 4.50
	4.50 - 6.00
	6.00 - 7.50
	7.50 - 9.00
	9.00 - 10.50
	10.50 - 12.00
	12.00 - 13.50
	13.50 - 15.00
Contour Data	Intersections
Maximum Density	14.33%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Direct Toppling
Slope Dip	87
Slope Dip Direction	180
Friction Angle	30°
Lateral Limits	20°

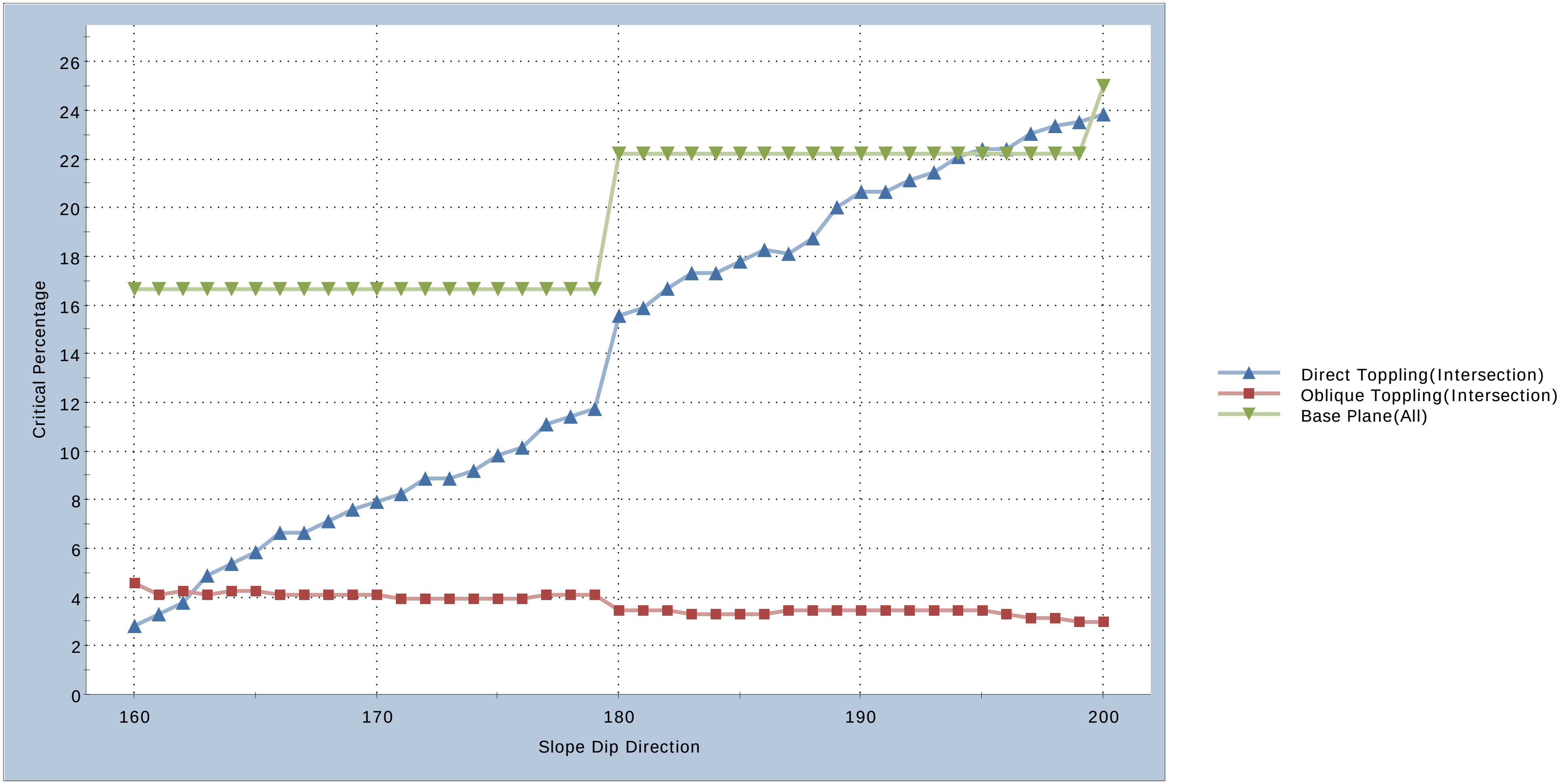
	Critical	Total	%
Direct Toppling (Intersection)	44	227	19.38%
Oblique Toppling (Intersection)	0	227	0.00%
Base Plane (All)	8	36	22.22%
Base Plane (Set 1: Bedding)	8	8	100.00%

Plot Mode	Pole Vectors
Vector Count	36 (36 Entries)
Intersection Mode	All Set Planes
Intersections Count	227
Hemisphere	Lower
Projection	Equal Angle

DIPS 7.012

Project	Mid Continent Quarry		
Analysis Description	Surface Mapping Direct Topple - Set Planes		
Drawn By	Sundermann	*Company*	Brierley
Date	4/23/2018, 11:38:37 AM	*File Name*	MidContinent_Quarry_Direct.dips7

Direct Toppling: Critical Percentage vs. Slope Dip Direction

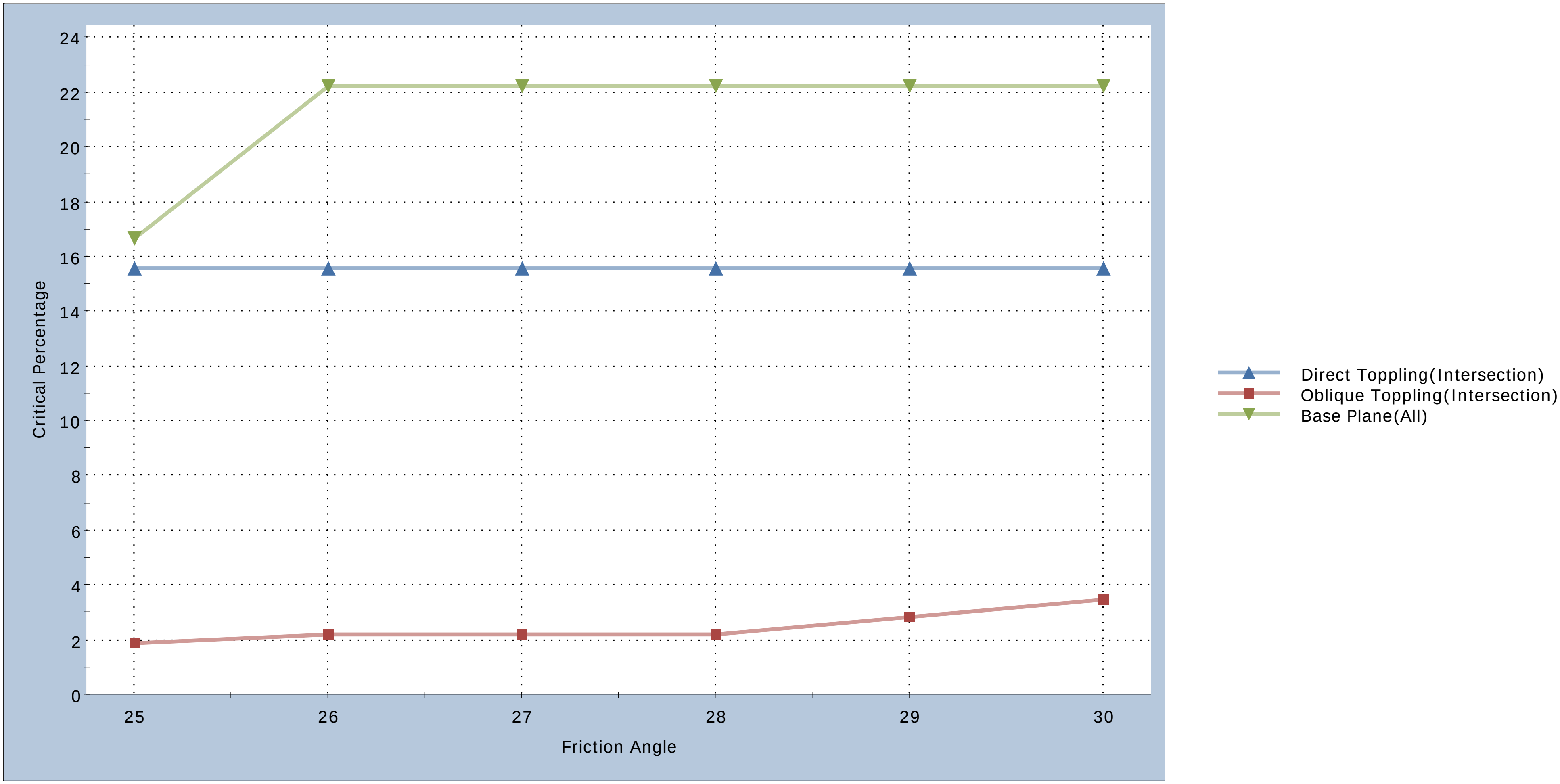


Mean Values

Slope Dip = 87 Slope Dip Direction = 180 Friction Angle = 30 Lateral Limit = 20

DIPS 7.012	*Project* Mid Continent Quarry		
	Analysis Description Surface Mapping Direct Topple		
	Drawn By Sundermann	*Company* Brierley	
	Date 4/23/2018, 11:38:37 AM	*File Name* MidContinent_Quarry_Direct.dips7	

Direct Toppling: Critical Percentage vs. Friction Angle



Mean Values

Slope Dip = 87 **Slope Dip Direction = 180** **Friction Angle = 30** **Lateral Limit = 20**

	Project Mid Continent Quarry		
	Analysis Description Surface Mapping Direct Topple		
	Drawn By Sundermann	*Company* Brierley	
DIPS 7.012	*Date* 4/23/2018, 11:38:37 AM	*File Name* MidContinent_Quarry_Direct.dips7	

Dips Analysis Information
Mid Continent Quarry

Project Summary

File Name: MidContinent_Quarry
Last saved with Dips version: 7.012
Project Title: Mid Continent Quarry
Analysis: Surface Mapping Planar Slide - Bedding (Set 1)
Author: Sundermann
Company: Brierley
Date Created: 4/23/2018, 11:38:37 AM

General Settings

Data Format: Dip / Dip Direction
Magnetic Declination (E pos): 0°
Multiple Data Flag (Quantity): OFF
Distance Column: OFF
Extra Data Columns: 4
Units: Imperial
Poles: 8
Entries: 8

Traverses

No traverse information available.

Global Mean

	Dip	Dip Direction
Unweighted	27.30	197.25
Weighted	27.30	197.25

Global Best Fit

Unweighted			
	Dip	Dip Direction	Eigenvalue
S1	27.29	197.25	0.990496
S2	79.66	86.54	0.005865
S3	65.04	351.66	0.003640

Woodcock S1 / S3 = 272.134
Woodcock K = 10.753
Woodcock C = 5.606

Weighted			
	Dip	Dip Direction	Eigenvalue
S1	27.29	197.25	0.990496
S2	79.66	86.54	0.005865
S3	65.04	351.66	0.003640

Woodcock S1 / S3 = 272.134
Woodcock K = 10.753
Woodcock C = 5.606

Intersections

Intersection Type	Number
Grid Data Planes	28
User and Mean Set (Unweighted) Planes	0
User Planes	0
Mean Set (Unweighted) Planes	0

Kinematic Analysis

Slope Dip: 87
Slope Dip Direction: 180
Friction Angle: 25°
Lateral Limit Angle: 20°

Planar Sliding

Planar Sliding	Critical	%	Total
All Vectors	5	62.50%	8

Planar Sliding (No Limits)

Planar Sliding	Critical	%	Total
All Vectors	7	87.50%	8

Wedge Sliding

Critical 1 = Wedge Sliding (Both Planes)
Critical 2 = Wedge Sliding (One Plane)

Intersection Type	Critical 1	%	Critical 2	%	Total
Grid Data Plane Intersections	0	0.00%	16	57.14%	28
User and Mean Set (Unweighted) Plane Intersections	No results				
User Plane Intersections	No results				
Mean Set Plane (Unweighted) Intersections	No results				

Flexural Toppling

Flexural Toppling	Critical	%	Total
All Vectors	0	0.00%	8

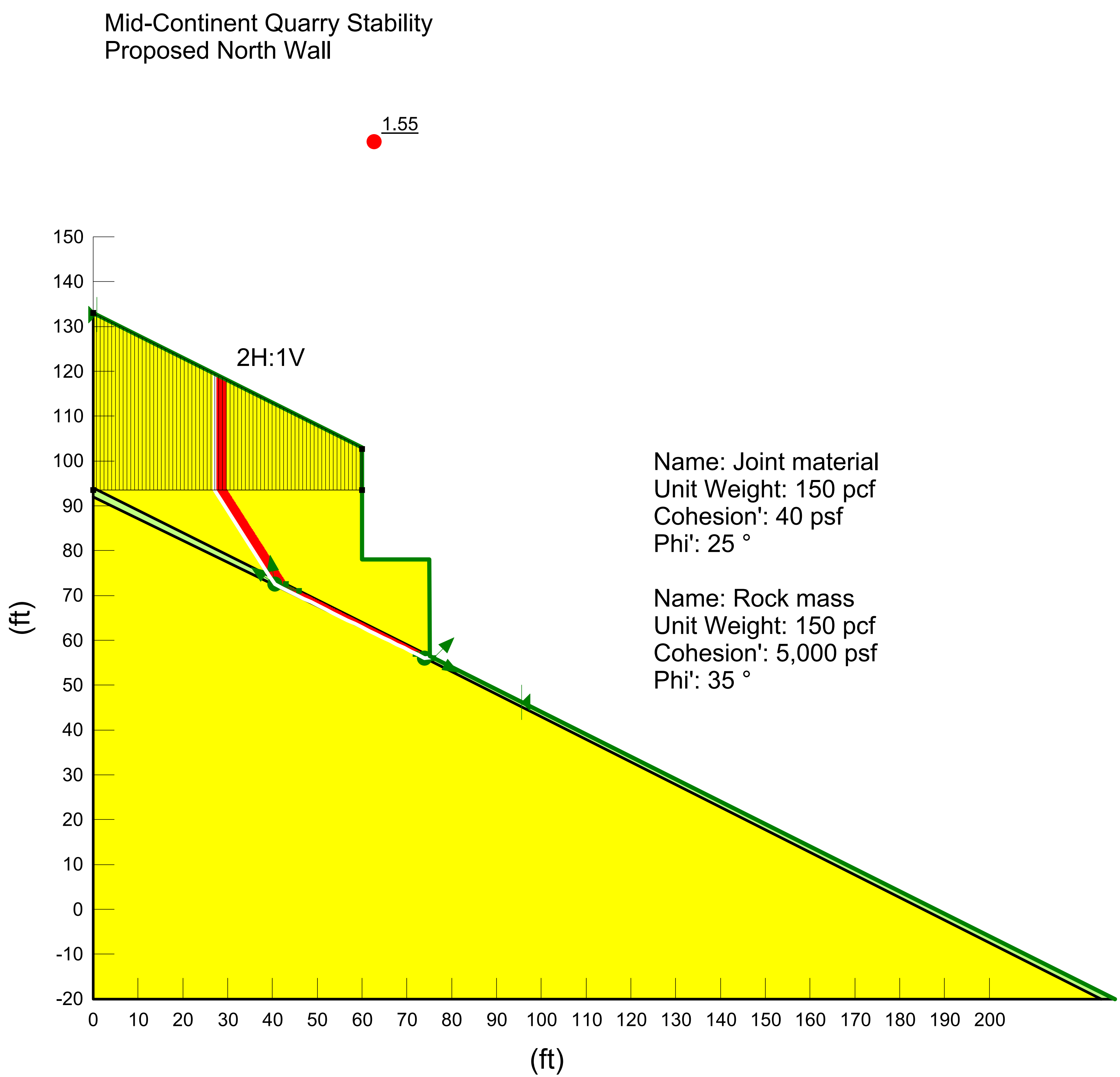
Direct Toppling

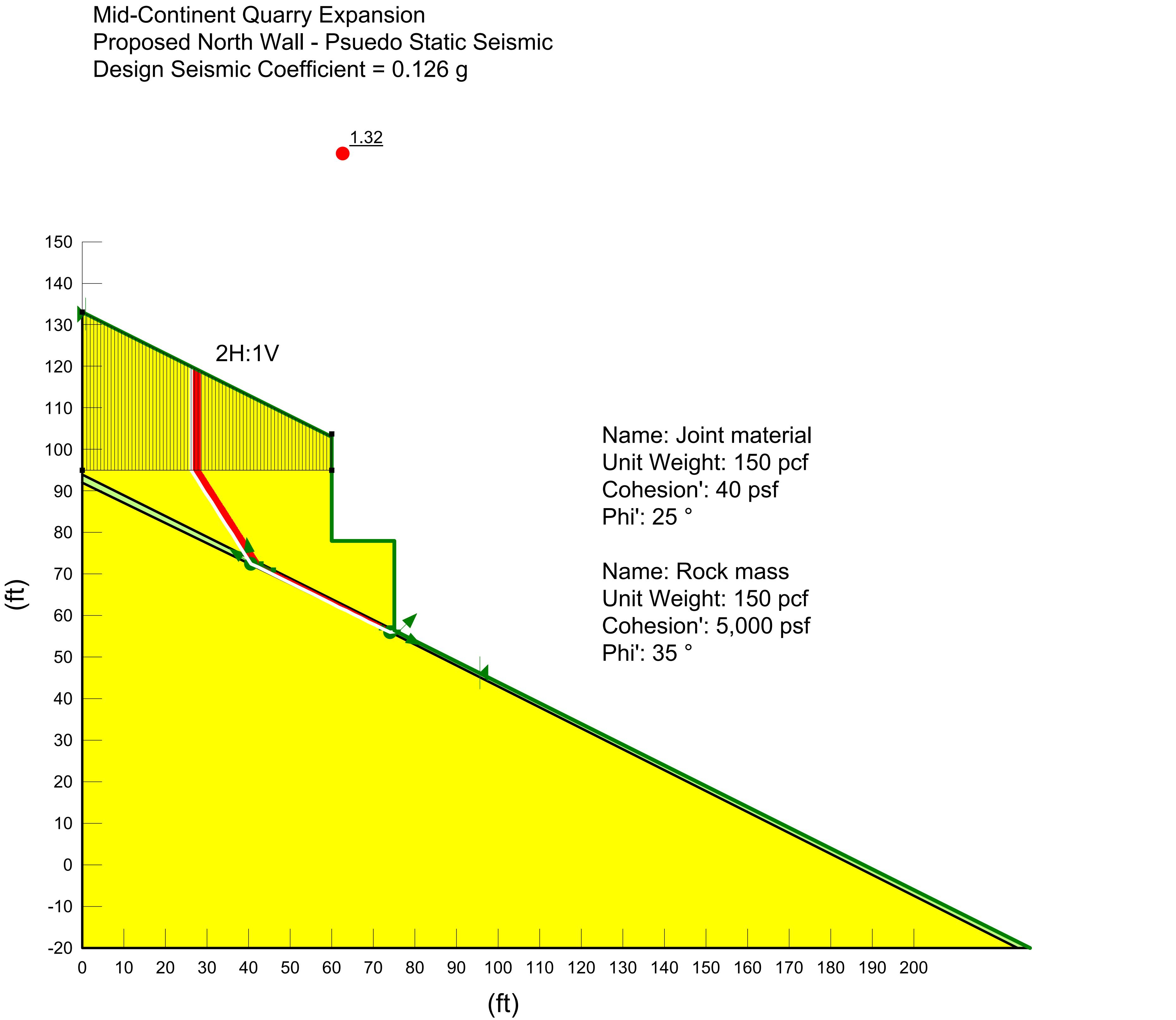
Base Plane	Critical	%	Total
All Vectors	6	75.00%	8

Critical 1 = Direct Toppling (Intersection)
Critical 2 = Oblique Toppling (Intersection)

Intersection Type	Critical 1	%	Critical 2	%	Total
Grid Data Plane Intersections	0	0.00%	0	0.00%	28
User and Mean Set (Unweighted) Plane Intersections	No results				
User Plane Intersections	No results				
Mean Set Plane (Unweighted) Intersections	No results				

APPENDIX B: STABILITY ANALYSES


Mid-Continent Quarry Stability
Proposed North Wall
1.55
2H:1V
Name: Joint material
Unit Weight: 150 pcf
Cohesion': 40 psf
Phi': 25 °
Name: Rock mass
Unit Weight: 150 pcf
Cohesion': 5,000 psf
Phi': 35 °
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
(ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
(ft)


Mid-Continent Quarry Expansion
Proposed North Wall - Psuedo Static Seismic
Design Seismic Coefficient = 0.126 g
1.32
2H:1V
Name: Joint material
Unit Weight: 150 pcf
Cohesion': 40 psf
Phi': 25 °
Name: Rock mass
Unit Weight: 150 pcf
Cohesion': 5,000 psf
Phi': 35 °
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
(ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
(ft)