Mine Citation/Order Continuation

U.S. Department of Labor
Mine Safety and Health Administration

Section I--Subsequent Action/Continuation Data

1. Subsequent Action	1a. Continuation	2. Dated (Original Issue) Mo Da Yr	3. Citation/ Order Number
☑	☐	01/19/2023	9154256 - 06

4. Served To	5. Operator
Robert Wagner - Vice President of Engineering	RMR AGGREGATES, INC.

6. Mine	7. Mine ID (Contractor)
MID-CONTINENT QUARRY	05-04954

Section II--Justification for Action

This 103(k) order is being modified to allow work identified in the plan titled "Eastern Production Bench Access Plan", dated June 26, 2023. The plan consists of a cover letter and 15 pages along with a 55 page document containing geotechnical data for the affected area. This will allow mine to load products into customer trucks, move stockpiled products to lower benches, build berms, construct a crusher removal ramp, move crushing equipment located within the access area to lower benches, and removal of material from the bench for rescreening/crushing.

Section III--Subsequent Action Taken

8. Extended To	A. Date Mo Da Yr	B. Time (24 Hr. Clock)	C. Vacated	D. Terminated	E. Modified
			☐	☐	☑

Section IV--Inspection Data

9. Type of Inspection	10. Event Number
E08	6465937

11. AR Name	AR Number	12. Date Mo Da Yr	13. Time (24 Hr. Clock)
Gary Joseph Polson	24766	07/07/2023	11:45

RMR Aggregates, Inc.

Mid-Continent Quarry

MSHA ID: 05-04954

Eastern Production Bench Access Plan

In response to:

Order No. 9154256

June 26, 2023

Overview

On January 18, 2023, the Mid-Continent Quarry, owned by RMR Aggregates, Inc. (RMRA), experienced a rockslide event that deposited large amounts of limestone material on the production bench. Following this event, MSHA issued a 103k order restricting access and activities on the production bench unless there was an approved plan in place with MSHA for specified activities. The order prevents RMRA from conducting normal operations on the production bench until a satisfactory operating plan is created and approved by MSHA.

RMRA is proposing a plan that seeks access to a portion of the production bench on the east and south sides. As a part of the plan, RMRA is using recommendations from a geotechnical engineering firm to develop safe working clearances and procedures.

Figure 1 – Site Map

Production Bench Access Area and Plan

The production bench access plan considers the effects of a potential second rockslide of the material on the eastern half of the production bench. The plan requests access to the area shown in Figure 2 and the removal of a portion of the Class 4 Road Base product stockpile. This area was selected based on geotechnical data and analysis provided to RMRA by our geotechnical engineering team at Kilduff Underground Engineering.

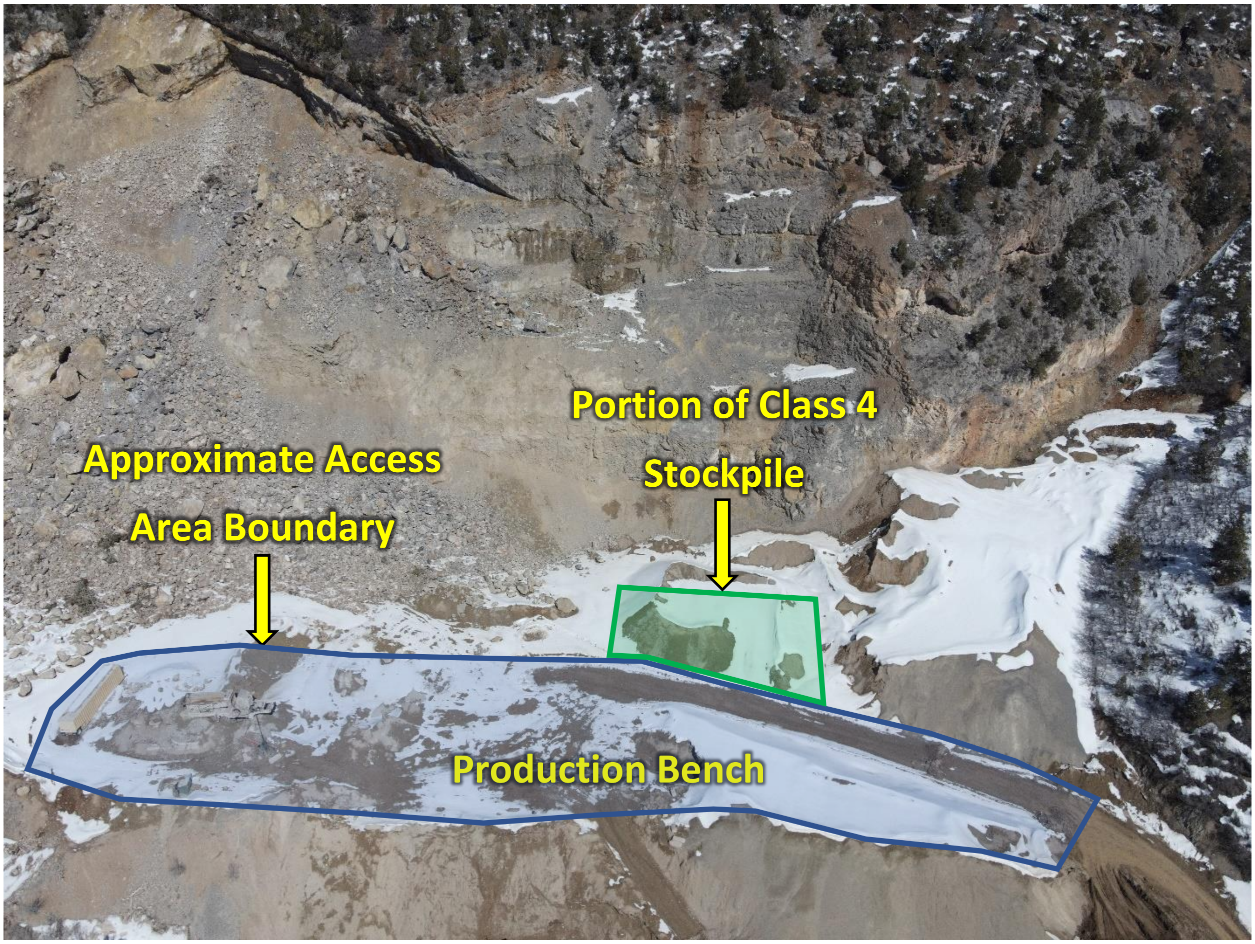


Figure 2 – Production Bench Access Area and Class 4 Stockpile

Geotechnical Analysis

Kilduff Underground Engineering made two data gathering visits to the quarry to inspect the area of the rockslide and to evaluate the eastern highwall. Based on the data they gathered and the post-slide survey data we provided to them, they created a rockfall model, in a computer software package, to simulate potential rockfall at three key points on the eastern highwall. Through running the simulations, they were able to come up with the points of maximum runout for a future rockfall event. The cross-sections of their modelling analysis are found in Appendix 1. A Google Earth view of their cross-section lines and the resulting maximum runout points (shown in red) are visible in Figure 3.

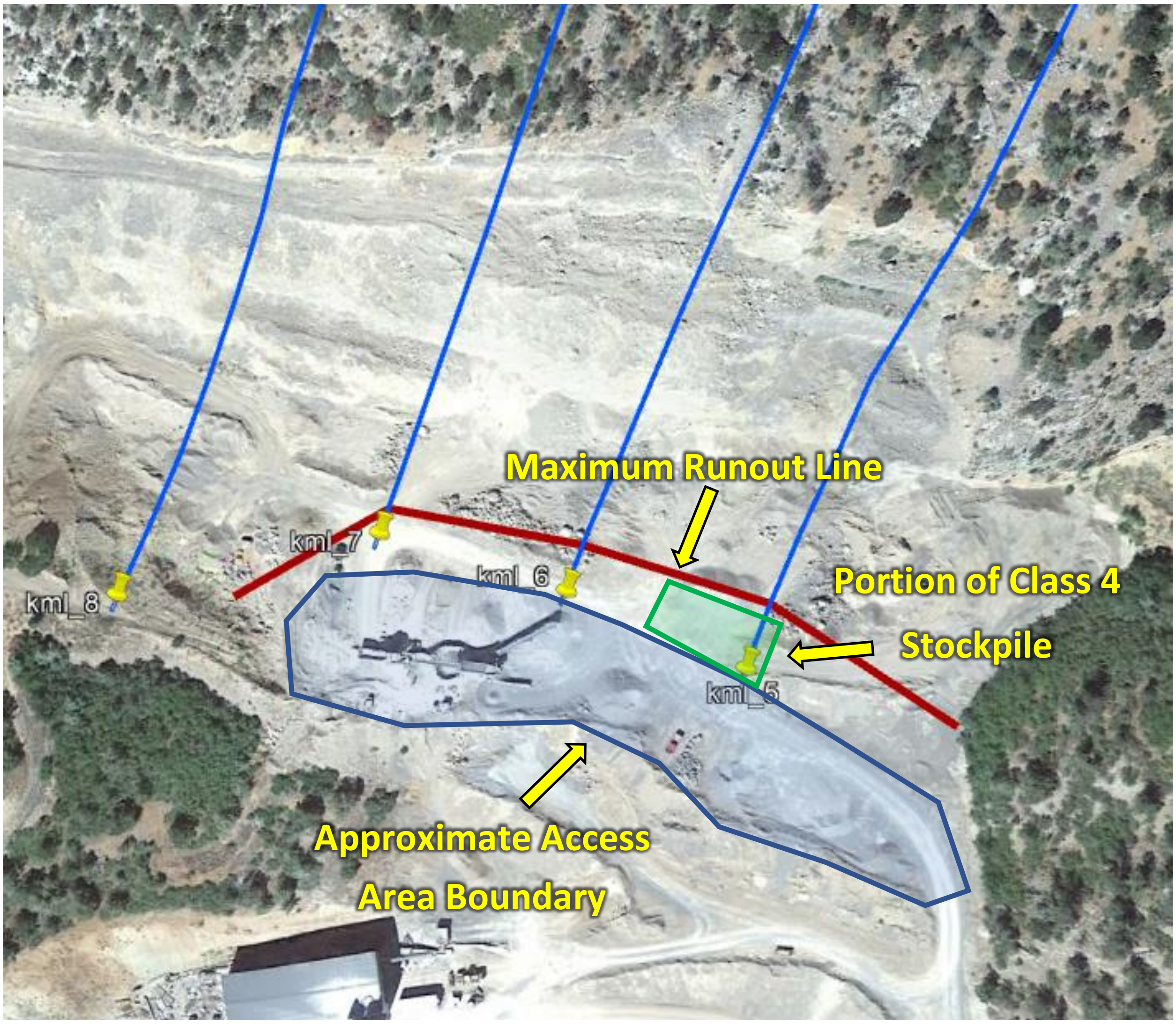


Figure 3 – Google Earth Image of Maximum Runout Points

Access Area

RMRA is requesting access to about 1.5 acres of the Production Bench (shown in Figures 2 & 3). The access area would be used for a variety of purposes, all typical to quarry operations. We are requesting permission to perform the following operations within the Access Area boundary: loading sellable products into customer trucks, moving stockpiled products to lower benches, building berms, constructing a crusher removal ramp, moving crushing equipment located within the access area to lower benches, removing material from the bench for rescreening/crushing, and any other minor activities related to the above-mentioned tasks. Blasting permission is not being requested at this time. In all cases, activities would only take place within the boundary of the Access Area. Additionally, material from the previous rockslide would not be mined.

RMRA is also requesting permission to temporarily access the green Class 4 Stockpile area to remove a portion (approximately 60-70%) of the previously produced product in that pile. The northern portion of that pile would not be removed and would act as a berm both during product removal and after 60-70% of the pile was removed. The portion of the pile would be removed by a front-end loader. The front-end loader would load its bucket with the Class 4 while facing the highwall and would not remain in the stockpile area longer than necessary to fill its bucket. Material from the pile will be moved down to either the middle bench or the mill bench by the front-end loader.

RMRA will build a 6-foot safety berm along the entire length of the northern edge of the Access Area Boundary, in places where a berm does not currently exist (see Figure 4). The location of the northern edge of the Access Area Boundary sits between 45-60 feet south of the maximum runout line, as determined by the Kilduff Underground Engineering rockfall model. The northern boundary is also between 170-200 feet away from the existing highwall. The previous slide went about a maximum of 170 feet from the highwall in areas containing material next to the highwall and without any berm in place to catch rocks.

No personnel or equipment will be allowed in the Access Area unless the berm is in place between them and the highwall. The exception to this will be the recovery of the Class 4 Stockpile which is currently acting as its own berm.

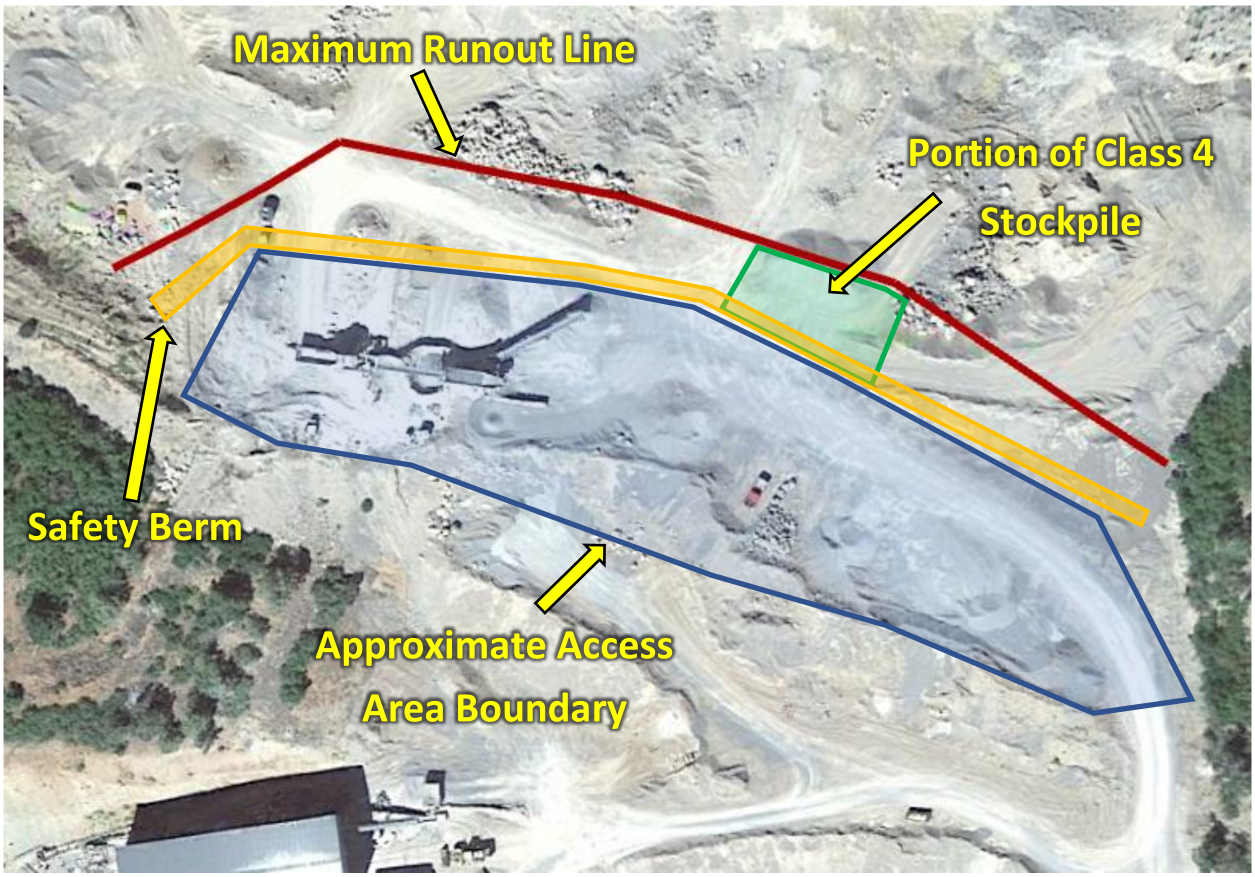


Figure 4 – Placement of Berm on North Edge of Access Area

The areas RMRA is requesting access to have improved levels of safety resulting from the existing features of the highwall. The access area sits below a portion of the highwall that includes large catch benches for any material that may fall. This is different from the western half of the highwall that had smaller catch benches (see Figure 5). In addition, the eastern highwall sits at a shallower slope than the western highwall, which improves its overall stability.

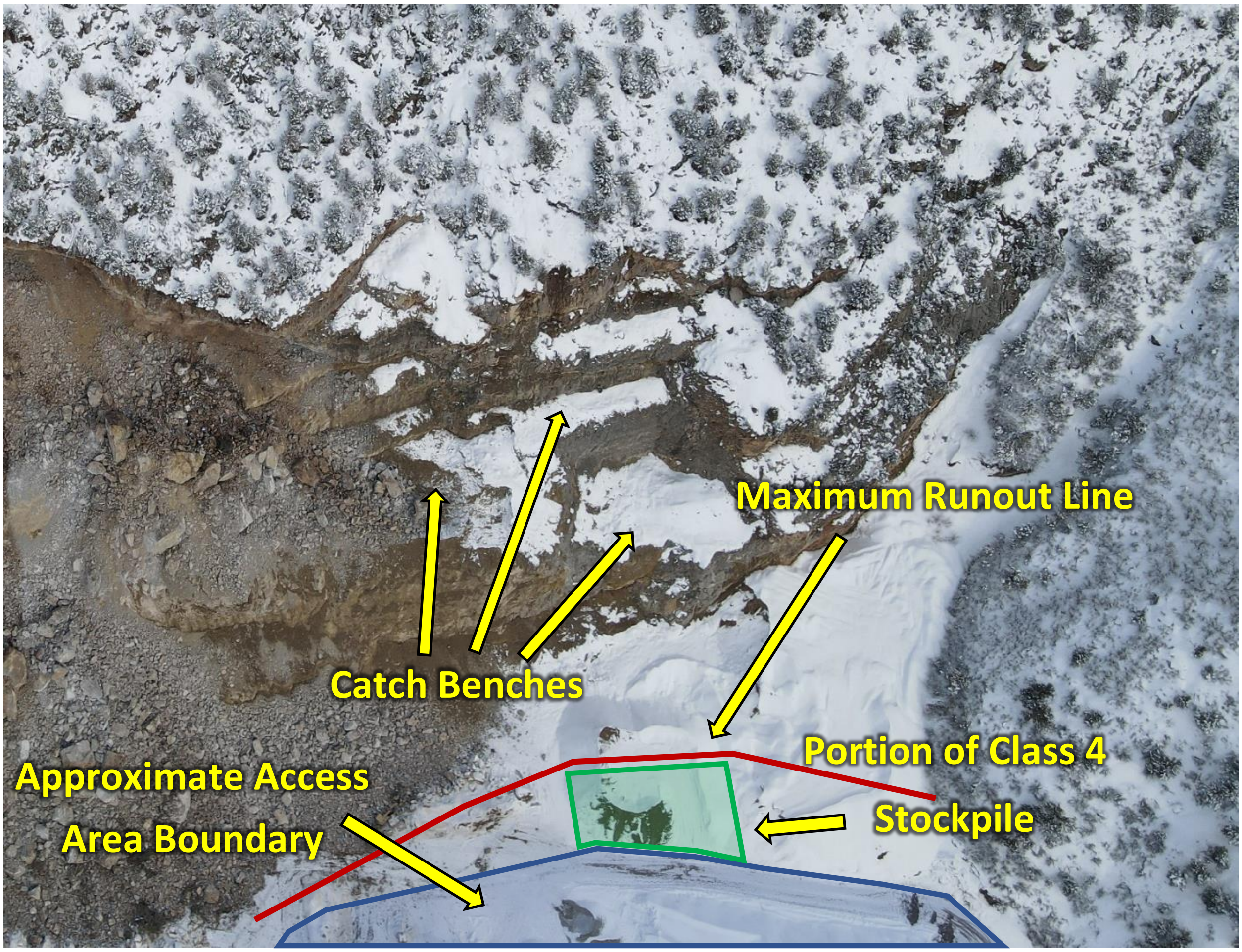


Figure 5 – Eastern Highwall Catch Benches

Access and Operating Plan

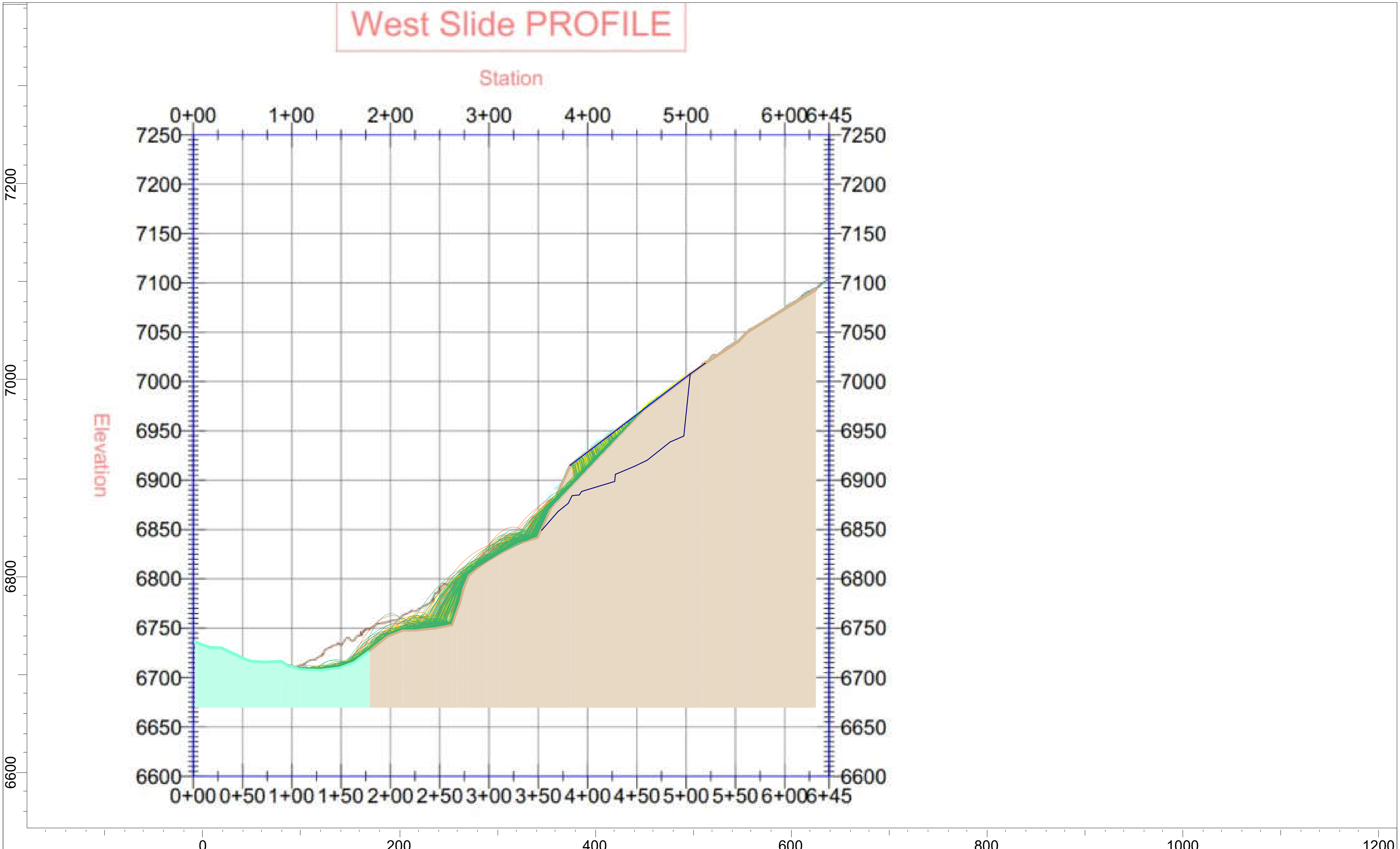
RMRA would utilize the following professional recommendations and safety procedures while working in the production bench access area.

1. Daily visual inspections of the entire highwall will be performed when personnel will be present on the production bench.
2. If rock movement is noticed, the production bench will be cleared for a minimum of 15 minutes. The wall will be observed during this time. Personnel will not be allowed to return to the production bench until a continuous 15 minutes, without rock movement, has elapsed.
3. The northern boundary of the Access Area will be marked on the production bench by a 6-foot high (minimum) safety berm to prevent access beyond it and to catch any potential stray rocks.
4. Personnel will not be allowed to cross the safety berm into other portions of the production bench, in equipment or on foot, unless future measures are approved by MSHA and put into place.
5. Equipment, both RMRA and contractors, will never be parked or allowed to stand still near the safety berm.
6. Front-end loaders and excavators will operate perpendicular to the safety berm when they are directly adjacent to it. During normal travel on the Production Bench, they will travel away from the safety berm.

Safety Requirements

1. The approved plan shall be reviewed and understood by all personnel prior to accessing the production bench area. This includes any contractors that may perform work on the bench.
2. Appropriate PPE gear shall be worn and utilized by all personnel on the production bench. This includes, but is not limited to safety glasses, steel toe boots, approved hard hat, etc.

Appendix 1 – Kilduff Underground Engineering Rockfall Model

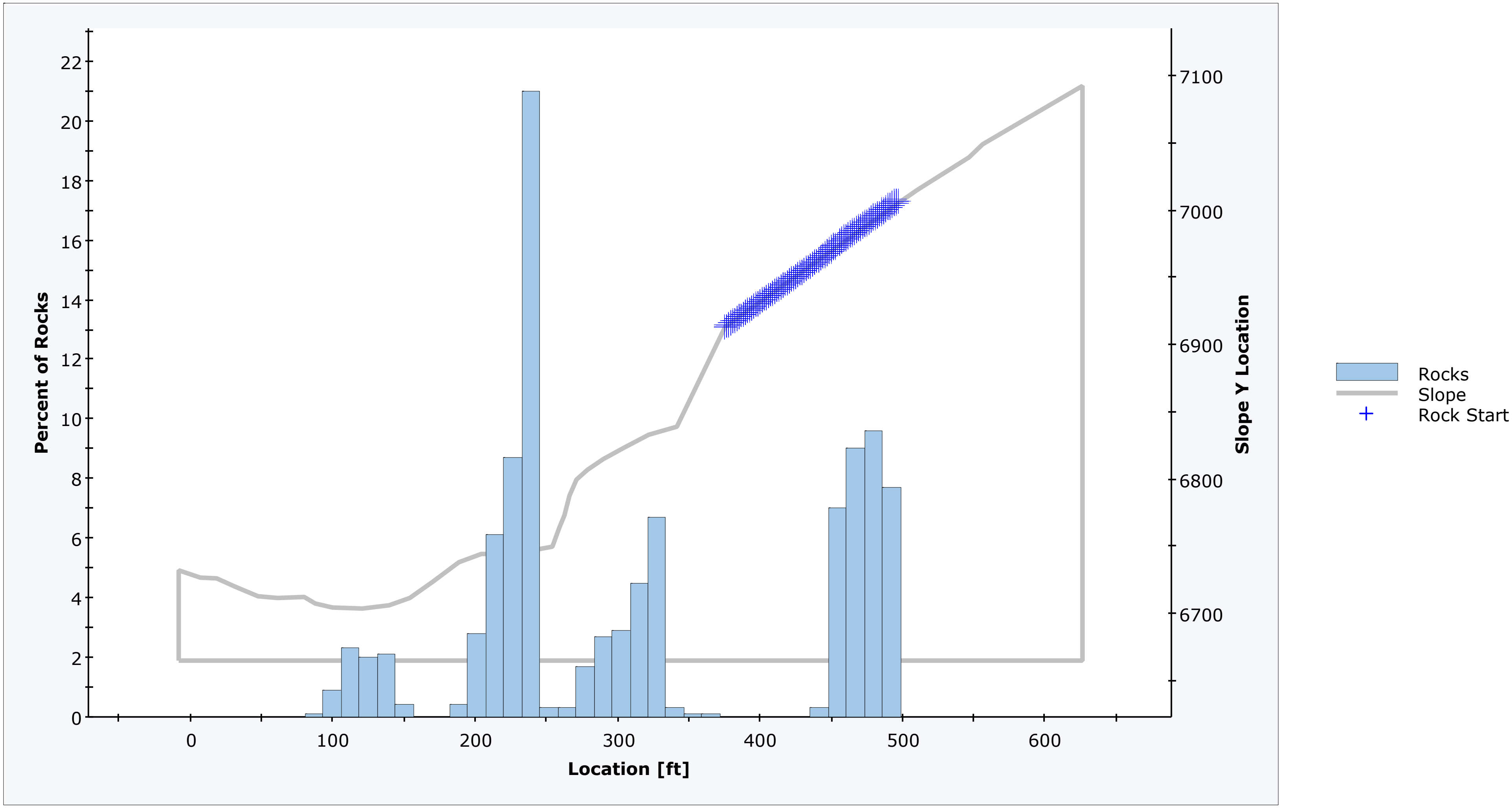


rocscience

ROCFALL 8.022

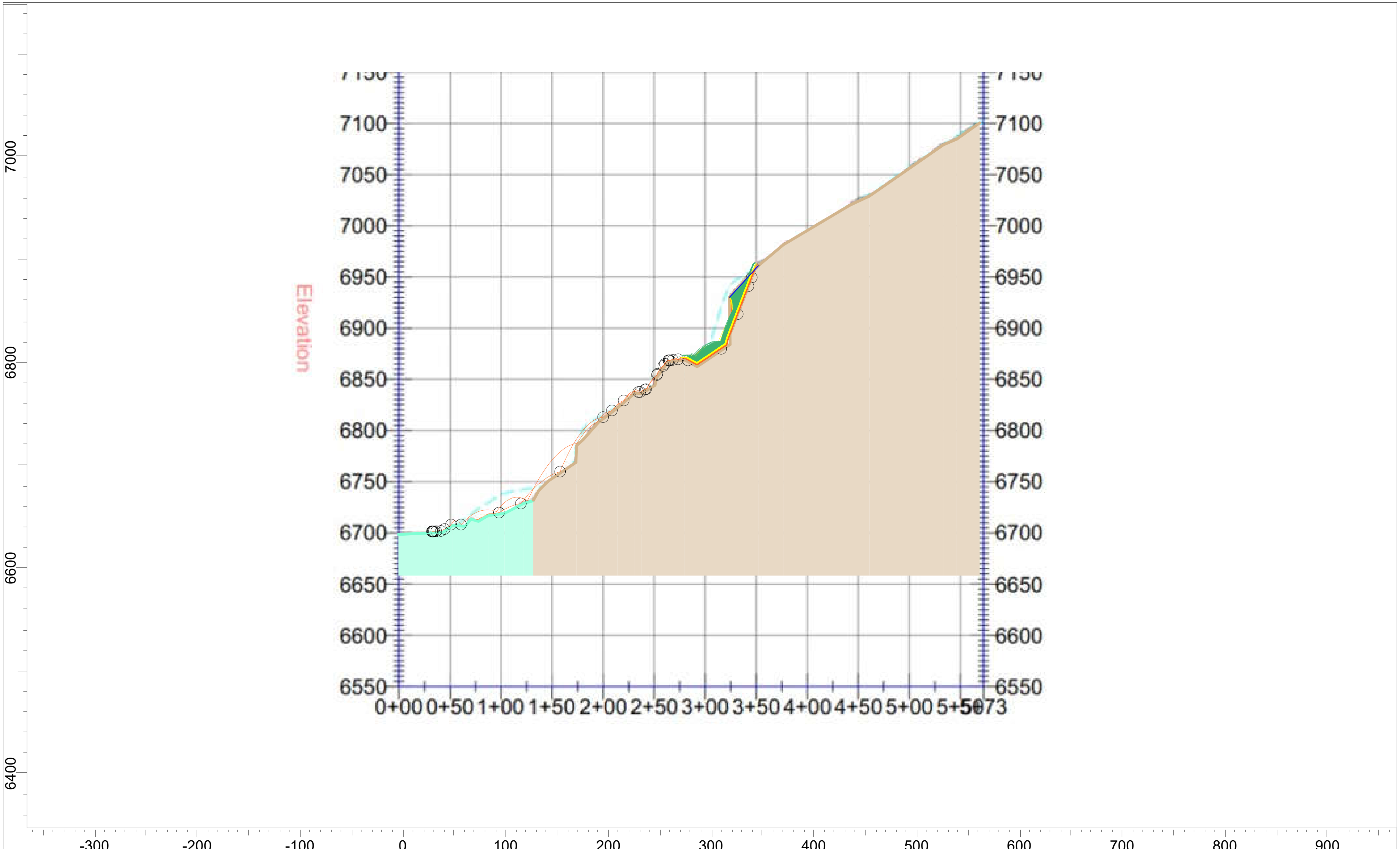
Project	Mid Continent Mine
Analysis Description	West Face Historic Topo
Drawn By	Sundermann
Company	Kilduff Underground Engineering
Date	5/26/2023, 10:21:27 AM
File Name	WestFace_Historic_CrestLoss2.fal8

Distribution of Rock Path End Locations



Total number of rock paths: 1000

rocscience	*Project* Mid Continent Mine		
	Analysis Description West Face Historic Topo		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 10:21:27 AM	*File Name* WestFace_Historic_CrestLoss2.fal8	

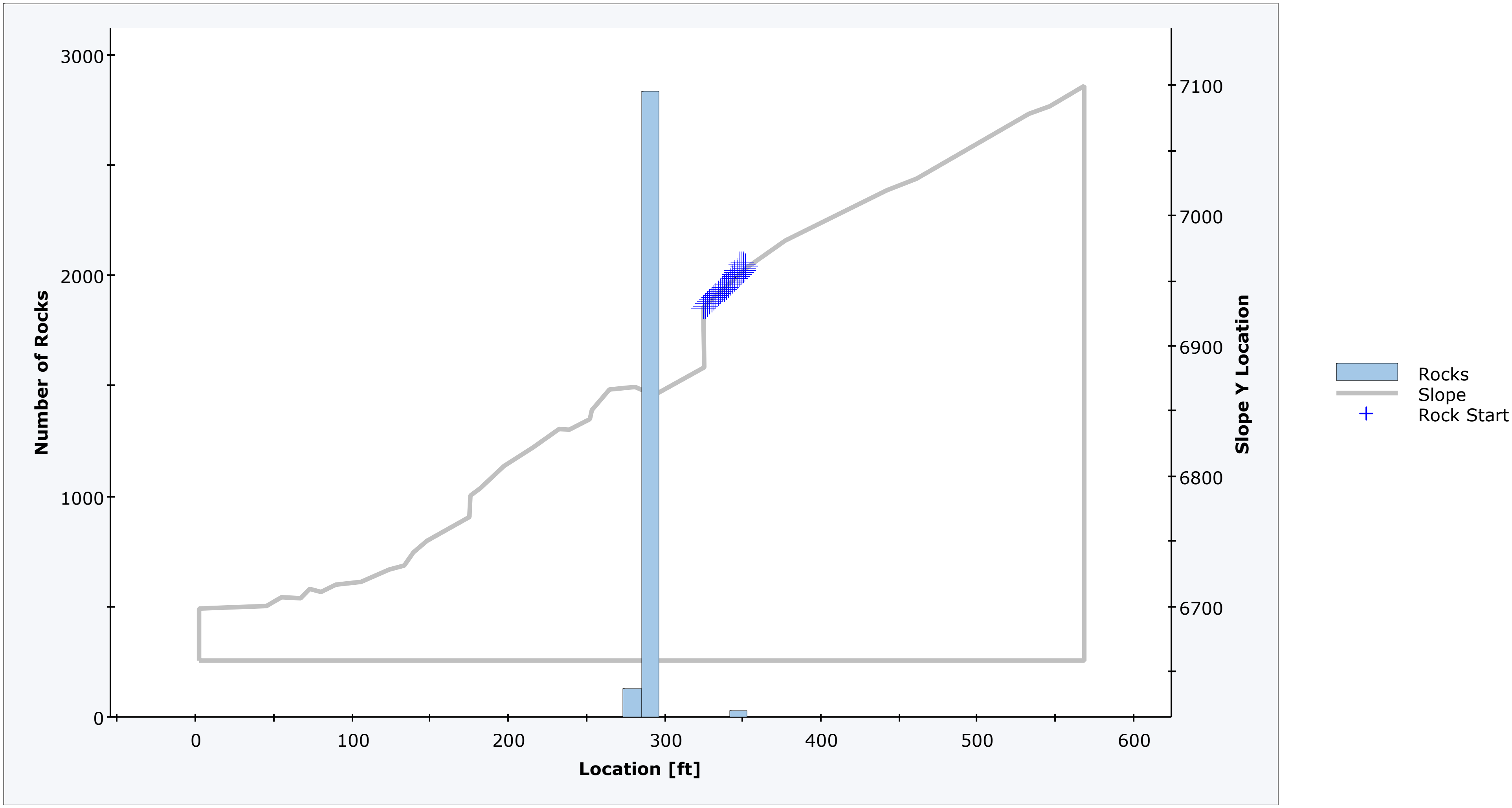


rocscience

ROCFALL 8.022

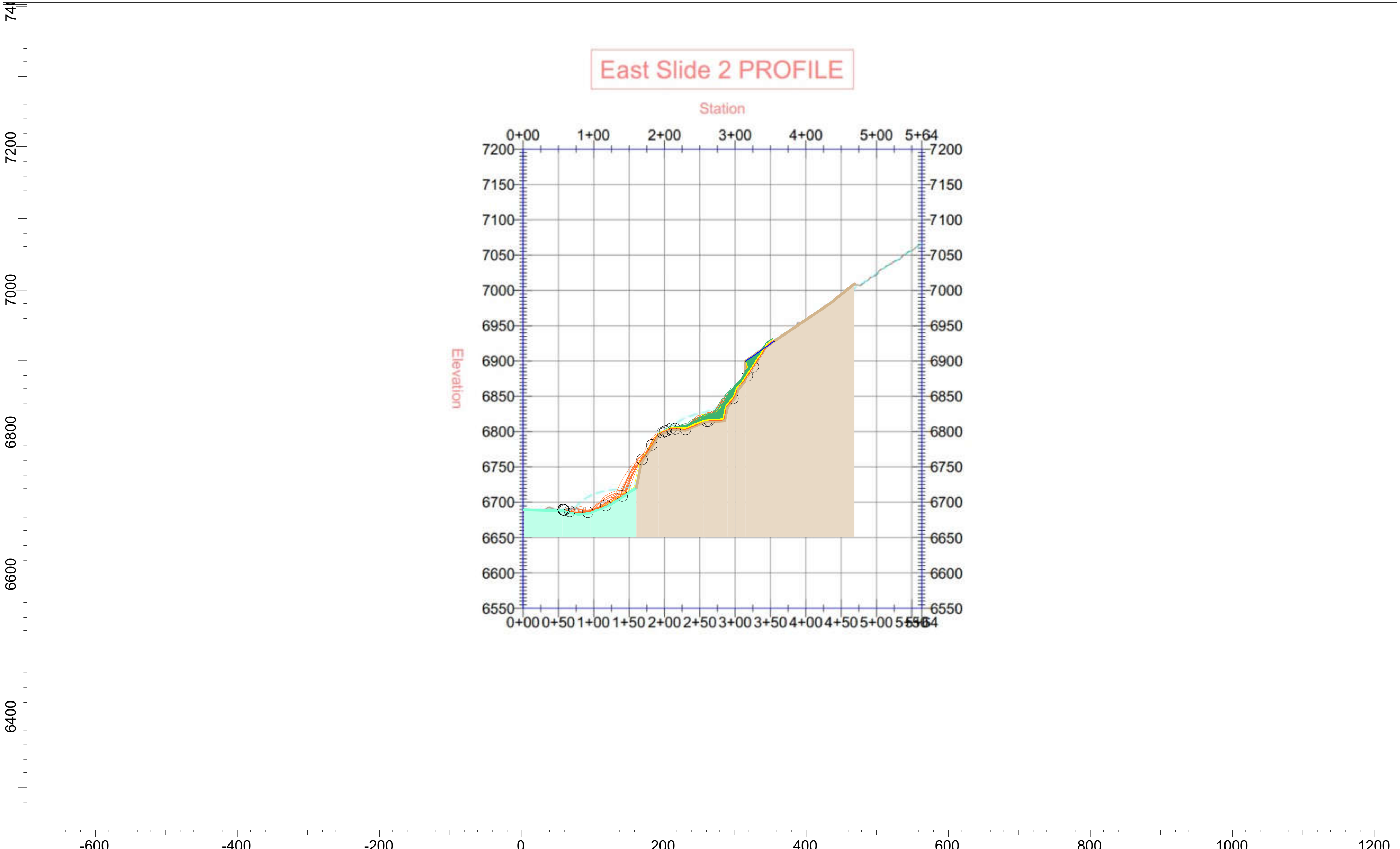
Project	Mid Continent Mine		
Analysis Description	East Face 1 - West Trend - Runout		
Drawn By	Sundermann	Company	Kilduff Underground Engineering
Date	5/26/2023, 12:24:29 PM	File Name	EastFace1_West_Runout.fal8

Distribution of Rock Path End Locations



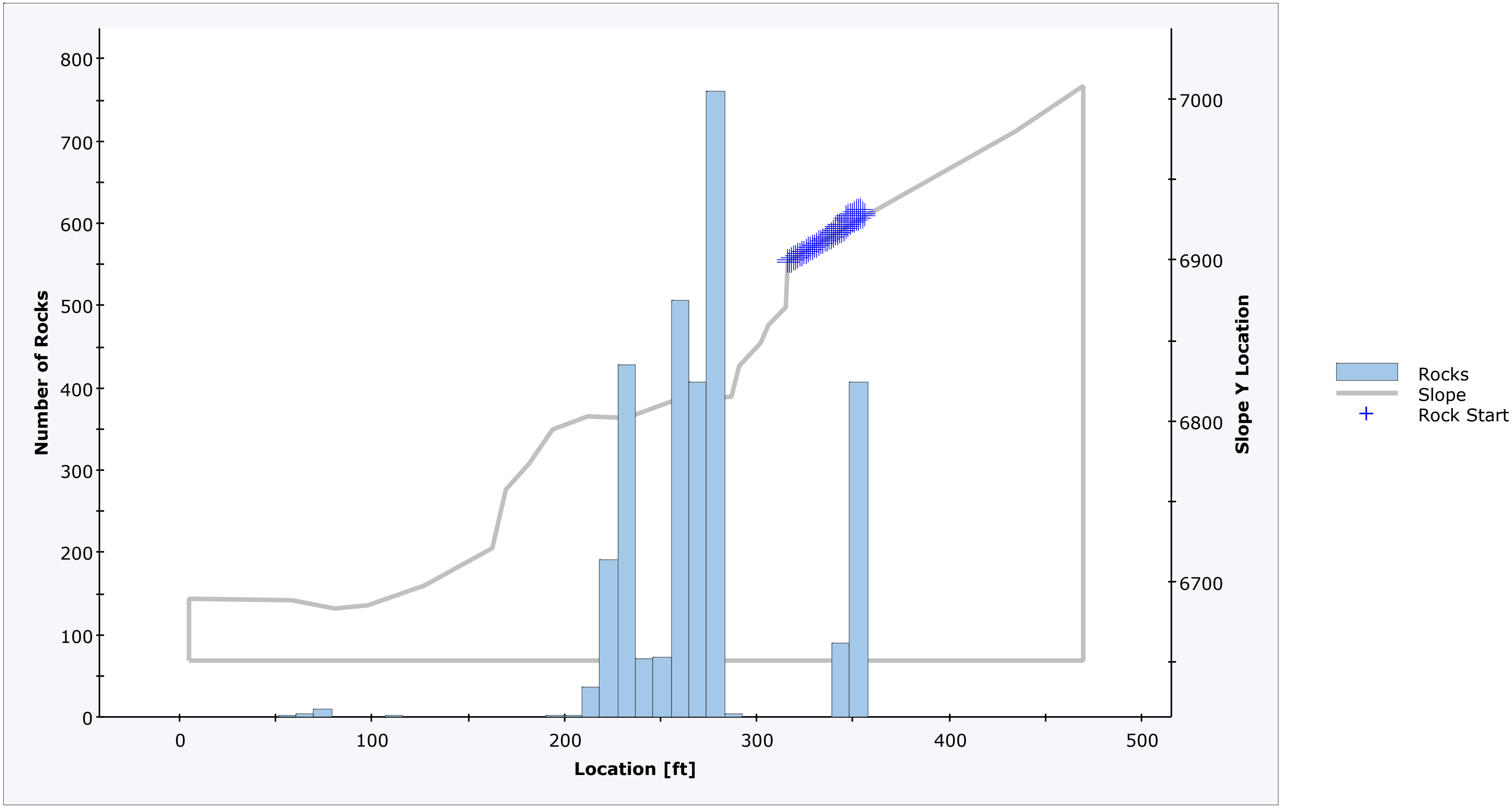
Total number of rock paths: 3000

rocscience	*Project* Mid Continent Mine		
	Analysis Description East Face 1 - West Trend - Runout		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace1_West_Runout.fal8	



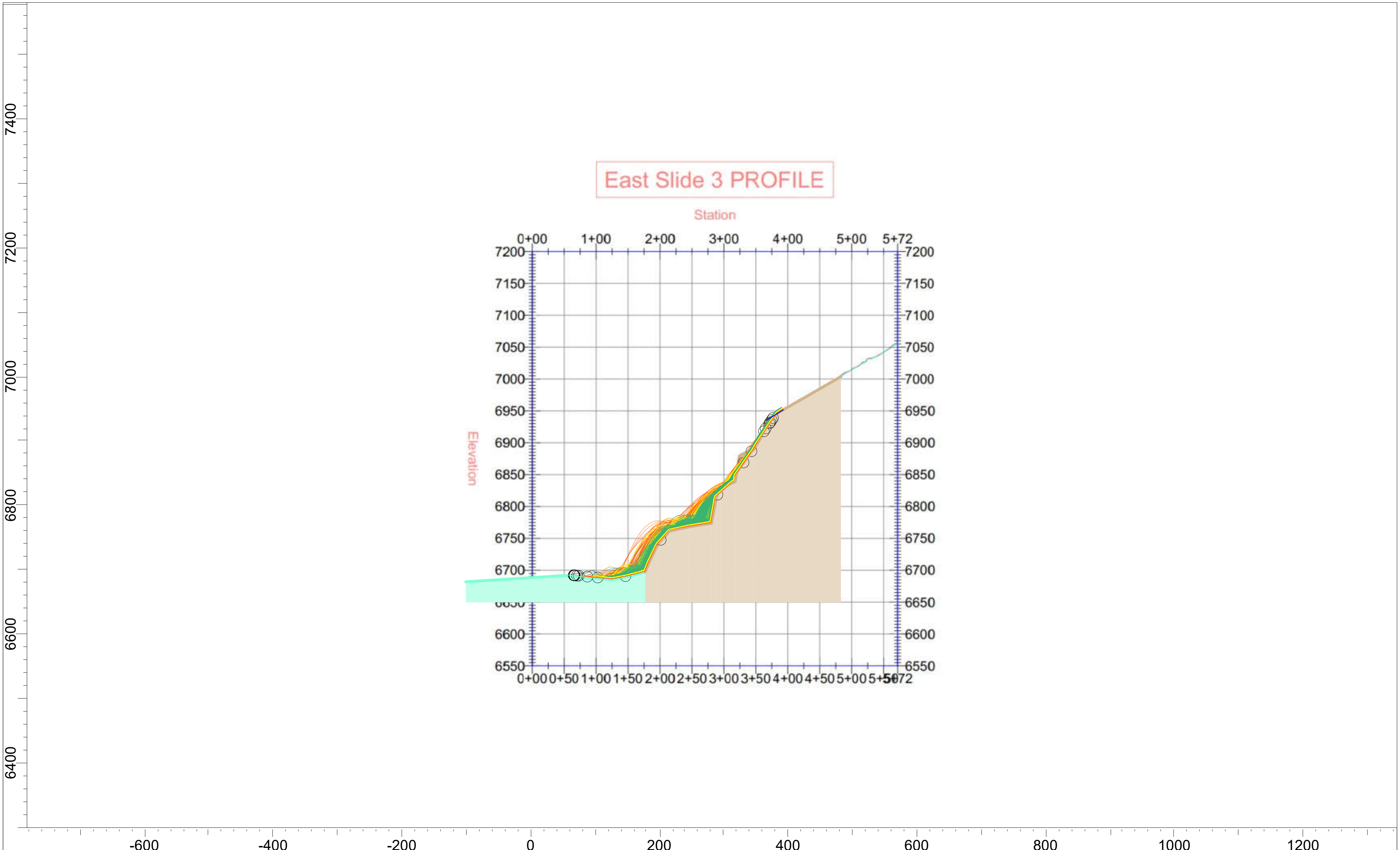
rocscience ROCFALL 8.022	*Project* Mid Continent Mine		
	Analysis Description East Face 2 - Center Trend - Runout		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
	Date 5/26/2023, 12:24:29 PM	*File Name* EastFace2_Center_Runout.fal8	

Distribution of Rock Path End Locations



Total number of rock paths: 2993

rocscience	*Project* Mid Continent Mine		
	Analysis Description East Face 2 - Center Trend - Runout		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace2_Center_Runout.fal8	

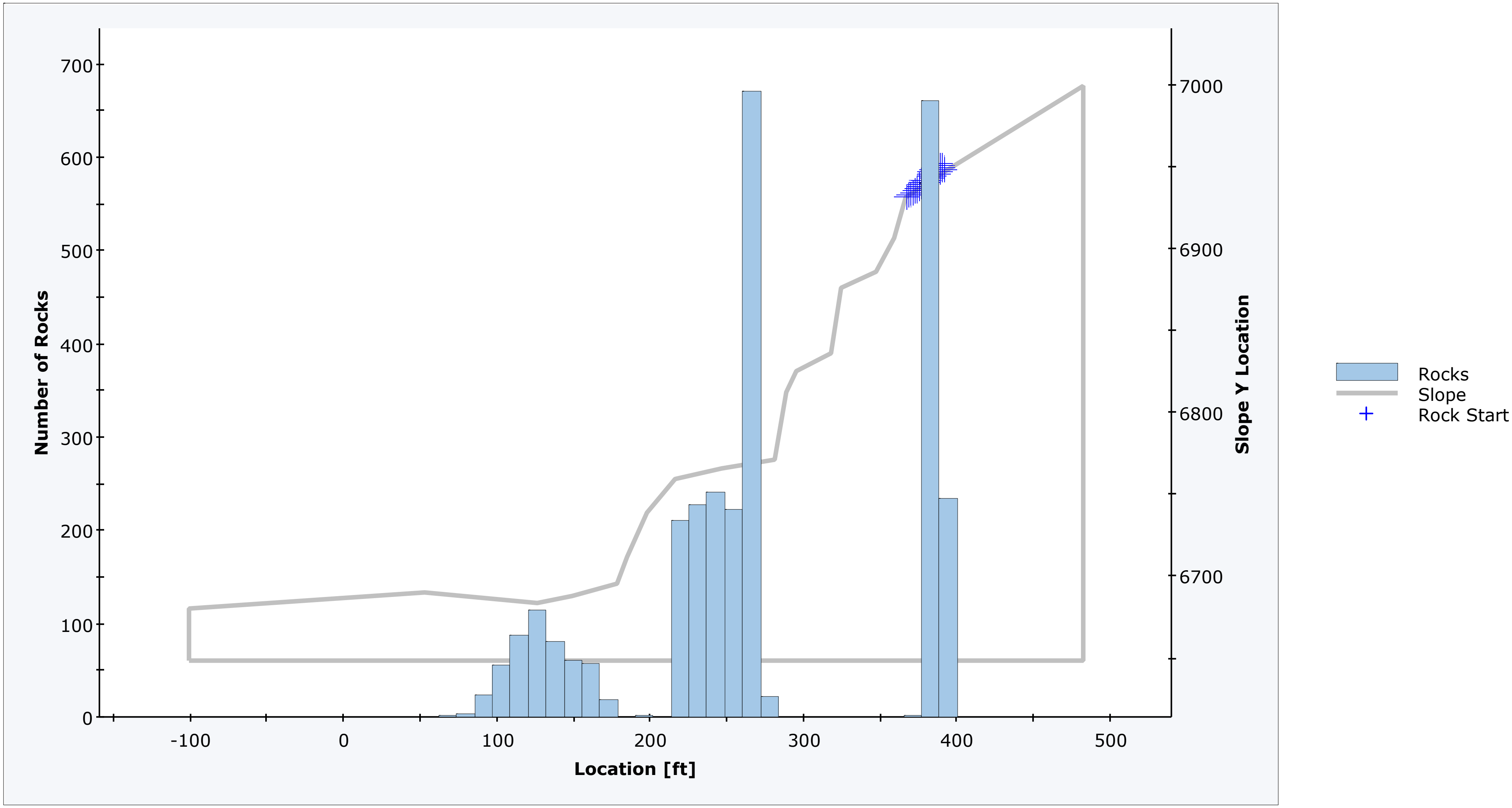


rocscience

ROCFALL 8.022

Project	Mid Continent Mine
Analysis Description	East Face 3 - East Trend - Runout
Drawn By Sundermann	*Company* Kilduff Underground Engineering
Date 5/26/2023, 12:24:29 PM	*File Name* EastFace3_East_Runout.fal8

Distribution of Rock Path End Locations



Total number of rock paths: 2996

rocscience	*Project*	Mid Continent Mine	
	Analysis Description	East Face 3 - East Trend - Runout	
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace3_East_Runout.fal8	

KILDUFF UNDERGROUND ENGINEERING, INC.

MEMORANDUM

To:	Robert Wagner	**From:**	Sean Sundermann
Company:	RMR Aggregates, Inc.	**Date:**	June 20 2023
Project:	Mid Continent Limestone Quarry	**Prj No.:**	P-23018SS
Location:	Glenwood Springs, CO	**RE:**	Rock Failure Analysis and Stability

On behalf of RMR Aggregates, Inc. (RMRA), Kilduff Underground Engineering, Inc. (KUE) has performed an evaluation of the factors that led to the West highwall ground event and to assess the long-term stability of the east highwall in its current state. The intent is not to evaluate stability during mining operations on the East Face but is intended to determine a safe work area for performing mining operations below the East Face in its current condition. This evaluation was conducted as a step in the larger evaluation of both the current and future mining areas adjacent to the highwall ground event area.

PROJECT BACKGROUND

Mr. Wagner (RMRA) reported to KUE that a headwall ground event had occurred on the West Wall of the Mid Continent Limestone Quarry on January 18, 2023. KUE Principal Geologist Sean Sundermann, PG, CEG and Senior Construction Specialist Jim Johnson performed a site walk of the site on January 26, 2023 with RMRA staff to evaluate the current condition the slope and initial assessment of the root cause of the event.

Regional 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[1]). The unit is described by Kirkham et al. as 200 feet thick in the site area. 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-foot thick calcareous sandstone (Kirkham et al., 2008), pinching out towards Glenwood Springs. The proposed expansion area is bound to the north by a mapped bedrock graben, just south of the Glenwood monocline axis, exposing the younger fossiliferous limestone unit of the Lower

[1] 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.

Pennsylvanian-age Belden formation. Outcrops of the Belden appear below the existing quarry as well, unconformably overlying the Leadville Limestone.

Mid Continent Limestone Quarry Geology

Leadville Limestone in the location of active mine operations is mapped by Kirkham et al. 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 crosscut 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.

Previous analysis of the Leadville Limestone performed for RMRA indicates the coarse crystalline rock is composed of 90% to 98% calcium carbonate and low in both magnesium chloride and silica. Boreholes completed by Colorado Fuel & Iron Corporation (CF&I) in the 1950's and 1960s were provided by RMRA to KUE as scanned hardcopy with approximate locations. Borehole Lynx 05-001 in the area of the ground event describes the upper 36 feet of the rock as follows:

> *Upper Leadville Limestone, med to dark gray, hard, fine grained, some recrystallized; numerous fractures in all directions re-cemented with w/ white, yellow, brown, & pink calcite. Some limonite stain, Good acid reaction. Porous zones at 28-0 to 28-5 and 29-9 to 30-6.*

Lower in section, thin mud seams are identified at 51-9 and 58-3, but no description of soft interbeds are included.

Also of significant note to the modeling of the recent ground event, 1966 borehole Lynx 05-099 drilled vertically in the area of the event identifies dip in the upper 40 feet of the section as 40 degrees.

Site Topography

RMR Aggregates, Inc. has developed a very detailed site topographic map, which shows a moderately-steep, south-facing slope. Slope topography decreases upslope, from south to north, along the top of the fold. The topography lays back from 1.4:1 at the southern extent at the existing quarry highwall to roughly 2.5:1 moving uphill 220 yards towards the potential area of proposed long-term stabilization.

SITE RECONNAISSANCE

January 26, 2023 - Site Reconnaissance

The aforementioned site reconnaissance performed eight days following the ground failure was primarily an overview of the event, documenting existing conditions and formulating a plan across represented disciplines to evaluate and stabilize the ground event. Photos with detailed captions from the reconnaissance are included in Appendix A. Photo 1 shows an overall view of the ground event on the west face that released along a northeast dipping joint with high to very high persistence. No other obvious cracking above the recent ground event release was observed on foot or by drone. Photos 2 and 3 highlight the upper two beds of limestone that sit on the more massive limestone below. The slide plane for the ground event occurred along bedding at these two upper beds.

Two thin interbeds of laminar bedded, shaley mudstone bound the upper two limestone beds. The observed thin interbed of laminar bedded, shaley mudstone creates a potential failure plane of lesser cohesion and fiction angle than the limestone. In addition, significant icicles had formed primarily at the basal contact of the upper limestone to the mudstone interbed. However, it is somewhat unclear if the water was draining out along this basal contact, or if seepage down the face of the limestone was dripping and causing the icicles, or most likely both.

A more detailed description and modeling of the January 18 ground event will be completed under separate cover but is mentioned here because the modeling of the ground event on the West Face was used as a back-analysis to determine appropriate input parameters for the stability modeling of the East Face.

April 14, 2023 - Site Reconnaissance

A site mapping program was performed to collect structure data on the East Face, evaluate the strength parameters of the interbed and 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. Structure measurements made during the April reconnaissance are provided in Appendix B and were supplemented with previous mapping for modeling. 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[2]). 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[3]). 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).

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

[3] 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.

On the East Face, planar, very high persistence, moderately rough to rough, south-dipping bedding planes defined the structure between the two upper limestone beds. Photo 5 in Appendix A shows this structure. The bedding plane dips 30 degrees in a 189-degree azimuth direction. Appendix A photos demonstrate the plane becomes more undulatory and rough with large crystals and second-order asperities traversing from east to west. The mudstone interbed has eroded back from the face of the outcrop face and was difficult to evaluate for strength parameters. The mudstone appears to be well cemented with clasts of limestone entrained. In areas reachable with a geologic pick the mudstone was evaluated as weak (R2). $CaCO_3$ stalactites are forming across the 4 to 7-inch aperture between the upper and lower limestone forming a connection between the two beds. The larger stalactites are forming on the face of the limestone indicating deposition from $CaCO_3$-rich surface runoff. Smaller stalactites were observed within the asperity. The stalactite connections indicate the East Face has not slid on the bedding plane over an extensive period of geologic time.

The structure dominating the limestone bed face appears to be comparable to the apparent release plane for the West Face ground event. The secondary joint set dips 45 degrees in a 055-degree azimuth direction. The joint is generally planar, slightly rough, low to medium persistence with moderately close to wide joint spacing. The secondary joint set was observed consistently across the East Face.

KINEMATIC ANALYSIS OF FAILURE MODES

Kinematic analyses incorporate the discontinuity data collected from the Mid-Continent Limestone Quarry and slope above to help identify potential rock slope failure conditions. Discontinuity data from the field mapping were compiled on stereographic projections (lower hemisphere, equal angle) and analyzed with the computer program DIPS v. 8.021 (RocScience, 2022) to evaluate trends and discontinuity sets. The resulting stereographic plots are included in Appendix C. The purpose of these analyses is to evaluate the potential for shallow failures in the cut slope walls rather than circular failure. The results are used in analyzing the stability and factor of safety for failure modes.

Characteristics of individual discontinuities identified on the East Face slope are provided in Appendix B. Global mean planes and rosette plots illustrate the East Face rock mass is controlled primarily by bedding, dipping moderately to the south-southwest, 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 44 degrees, all dipping to the south- southwest. The CGS measurements are generally consistent with data collected during the KUE April 2023 field reconnaissance that indicate a tighter cluster of dip ranging from 29 to 32 degrees, all dipping to the south-southwest (192° +/-10). The steeper CGS measurement of 44 degrees is assumed to be lower on the face where the fold is steeper. The primary discontinuities controlling rock mass stability in the slope are generally persistent and control rock mass response.

After defining the discontinuity sets, analyses for each mode of potential failure were 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 1 as a percentage of the total number of discontinuities.

Table 1. Summary Results of Kinematic Stability Analysis for East Face – Critical Failure Poles

Failure Mode		Critical Poles	Percentage of Poles
Wedge	All Intersections	4	1.33%
	Sets Only	0	0.00%
Planar Slide (No Limits)	Limestone (Bedding Only)	0	0.00%
	Mudstone (Bedding Only)	10	100.00%
Planar Slide (Lateral Limits)	Limestone (Bedding Only)	0	0.00%
	Mudstone (Bedding Only)	7	70.00%

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

Based on the kinematic analyses, there is a low probability of wedge failure. The results from the wedge stability analyses indicate a very low probability of failure.

The kinematic analyses corroborate field observations from the field reconnaissance that indicate the primary failure mode is planar sliding along the limestone bedding planes consisting of mudstone dipping adversely along the south-facing highwall. Wedge sliding of rock blocks occurs when the intersection line between two discontinuities plunges in the direction of the cut face at an angle steeper than the rock friction angle but less steep than the angle of the cut slopes (Wyllie and Mah, 2004[4]), as seen in Photo 16. Critical intersections represent wedge geometries that satisfy frictional and kinematic conditions for sliding. This point must fall outside the cut slope's great circle but within the rock friction kinematic boundary cone to be considered to have the potential for wedge sliding (red-shaded area in Appendix C figures). The thin interbed of shaley mudstone 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 ANALYSIS OF FAILURE MODES

Long Term Steady-State stability analysis along the cut slopes was performed to evaluate the potential bedrock failures along discontinuities in the rock mass. Results from these analyses

[4] Wiley, D.C. and C.W. Mah, 2004, Rock Slope Engineering, 4th Edition, Spoon Press, New York, NY.

were used to evaluate the cause of failure on the West wall and will be used to help develop conceptual design and mitigation support for the East and West faces. General limit equilibrium method slope stability analyses for the East and West face were performed using the software program RocPlane from RocScience (v.4.011). A factor of safety is calculated by modeling the effects of joint shear strength (in this case, primarily the weak interbed), water pressure within the joint, joint orientation and slope geometry intersections within a Monte Carlo sampling method. The models were checked by the limit equilibrium method of slices (Morgenstern-Price) using the software program Slope/W from Geostudio 2023.1. 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 Long Term Steady State was analyzed to consider the extended term stability of the highwall, and the rock strength is characterized by effective stress parameters.

To determine the geologic input parameters for the Mid-Continent Limestone Quarry stability modeling, characteristic values of the Leadville limestone were initially taken from empirical data in peer-reviewed publications and verified by publicly available typical values for the units encountered on the slope. Based on tests performed by the United States Bureau of Reclamation[5] 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 psi. Caltrans[6] 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. 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. And finally, a back analysis of the West Face ground event was used to corroborate these empirical values. The stability analyses parameters were manipulated to achieve a factor of safety of less than 1.0, in both RocPlane (FOS 0.99) and checked in Slope/W (FOS 0.92), indicating probable failure (Appendix D). Plane water pressure was modeled at 30% filled. The initial and properties reevaluated following the back analysis are summarized in the table below.

[5] 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.
[6] California Department of Transportation., 2013, *Rock Strength and Its Measurements.*

Table 2. Leadville Limestone and Interbed Strength Parameters				
Material	**Parameter**	**Cohesion (psf)**	**Friction Angle (deg)**	**Unit Weight (pcf)**
Leadville Limestone	Empirical	5,000	35	150
	Post-Backanalysis	10,000	35	150
Interbed Material	Empirical	40	25	150
	Post-Backanalysis	550	25	130

East Face Stability

Slope stability results of the East Face based on modeling of the above conditions indicate a factor of safety of 1.2 for the south facing highwall. This factor of safety is along a failure plane angle of 30 degrees which correlates to bedding dip of the soft interbed material. A tension crack was inserted as a release plane for the planar slide that correlates to the secondary joint set (mean set plane 45°; 055) mapped in the field on the East face. This joint set is perceived as the release plane for the West face 2023 ground event that can be seen in Photo 2 (Appendix A). Critically, water pressure was deterministically modeled as 30% filled with peak pressure at the tension crack base. Sensitivity analysis shows the factor of safety is particularly sensitive to water level assumptions.

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 KUE did not reveal any such joints beyond those previously identified.

ROCKFALL MODELING

Rockfall modeling was performed on three transects along the East face that are representative of the varying geologic and topographic conditions (Figure 1). The three slope geometries were created from LiDAR data provided by RMRA. Modeling was performed using the computer program Rockfall v.8.004 by RocScience that simulates the bounce paths of rock blocks down a slope, and calculates block velocities, end points and kinetic energies at user specified points along the slope. The rockfall simulation uses coefficient of restitution (both normal and tangential) parameters to model the loss of kinetic energy between the rockfall block and ground surface at the point of impact. Based on the site reconnaissance, two slope materials were identified: limestone headwall and Limestone Scree / Blast pile. A mean value was assigned for each property with a normal distribution of standard deviation. Similar to the slope stability analyses, input values for normal restitution, tangential restitution, dynamic friction

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and rolling friction were initially derived from desktop literature review. The values were verified under a backanalysis on the west wall along trend of the January 2023 ground event. Input values were revised until the rockfall runout and energy resembled that of the ground event, correlated to topographic data of the rockfall debris field. Summary of slope input parameters is provided in Table 3.

Table 3. Rockfall Simulation Input Parameters

Material		Normal Restitution (Rn)	Tangential Restitution (Rt)	Dynamic Friction	Rolling Friction
Leadville Limestone	Mean	0.32	0.71	0.55	0.15
	Standard Deviation	0.04	0.04	0.04	0.02
Interbed Material	Mean	0.32	0.71	0.55	0.30
	Standard Deviation	0.04	0.04	0.04	0.04

Damping was disabled for viscoplastic and forest & vegetation. Slope roughness parameters were set to 0 degrees because roughness is already accounted for by the detailed slope geometry used in the model. Three rock types were used with increasing size and mass to mimic the January ground event. The rigid body method was used to allow definition of rock size, mass and shape. The 1) Small (2022 lbm), 2) Medium (20,227 lbm), and 3) Large (93,642 lbm) blocks were assigned square, pentagon and rhombus shapes to simulate the ground event blocks.

Computational modeling was completed with a linear seeder point at the top of the upper limestone bed with a minimum of 3,000 rocks simulated. A crest loss of the overhanging limestone bed was induced to remove that geometry at point of rockfall initiation to maximize the translational velocity. Detailed results on the distribution of bounce height, velocity, and impact forces for each run were obtained by locating data collectors along the slopes. Those results were used to evaluate appropriate berm height, setback from the slope toe, and determined total energy impacting the berm.

ROCKFALL MITIGATION RECOMMENDATIONS

Based on the results of the extensive rockfall modeling along the West face and multiple East face transects, the following recommendations and descriptions of rockfall treatments are provided below.

Rockfall Runout Setback

A prescriptive setback was defined from the base of the highwall to the maximum extent of rock block endpoints across the three East face transects. The 2D sections illustrating the steps, bounce height and endpoints for the 3,000-block run are provided in Appendix E. The maximum endpoint block with the longest runout is highlighted. In all three transects, the maximum runout block was an outlier and considered a conservative estimate for probable rockfall. Figure 1 represents the setback zone from the base of the highwall that is defined by this conservative estimate for maximum rockfall runout. No man work shall be performed within the setback without additional stabilization or barriers. Figure 2 illustrates the rockfall maximum endpoints and the boundaries of the rockfall setback zone from the toe of the highwall. Coordinates of the setback and a Google Earth kmz file have been provided to RMRA to designate the setback.

Rockfall Berm

A rockfall berm was modeled on the three East face transects as a remedial measure to reduce the size of the setback zone (Figure 2), defined above. The berm size and location were defined through an iterative modeling process to minimize the size of the berm and decrease the setback from the highwall toe. Based on computational rockfall modeling, we support using the equivalent of a berm composed of limestone scree with a height of 15 feet, crest width of 5 feet and maximum slope angle of 32 degrees. Maximum kinetic energies modeled along the ten transects are all within that tolerance of maximum allowable impact energy. Rockfall analysis provided in Appendix E indicates that 100% of simulated rockfall blocks were contained by the rockfall barrier, in tandem with the catchment basin. Where the rockfall berm is impacted by larger blocks, the barrier should be repaired. The berm is considered in tandem with a setback from the highwall toe that will act as a catchment basin. A Rockfall Catchment Area Ditch (RCAD) is recommended along the entire length of the East face. Parameters contributing to RCAD effectiveness include 1) slope height and angle, 2) ditch width, depth and shape, 3) anticipated block size and quantity of rockfall, and 4) effect on rock fall trajectories of slope irregularities (Wyllie and Mah, 2004). The RCAD will also act as a retention basin for fallen rock to be cleaned over time. Rockfall modeling of the RCAD and berm design is effective at reducing the southern extent of the rockfall setback zone.

Longterm Inspection Program

An effective proactive approach to slope stabilization will require a consistent, long-term program of inspections and periodic maintenance of the berm and catchment area. Rockfall blocks should not be permitted to accumulate. Damaged portions of the berm should be repaired immediately. Periodic inspections of the slope and outcrops by an engineering geologist or geotechnical engineer will be required over time to investigate natural deterioration of the stability conditions due to 1) weathering/erosion of the surface rock, 2) increases in fracture aperture by water causing loosening of surficial blocks, 3) loss of block interlock or support following minor block failure, and 4) growth of vegetation roots.

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Inspections after seasons of significant precipitation should be a high priority, particularly with freeze-thaw potential.

LIMITATIONS

Nothing contained in this report shall be construed to create, impose, or give rise to any duty owed by KUE to any individual or entity other than RMRA. This report is for the sole use and benefit of RMRA and may not be used or relied upon by any other individual or entity without the express written approval of KUE.

CLOSURE

We appreciate the opportunity to be of service on this important project.

Sean Sundermann, PG, CEG
Principal Geologist / Vice President

Todd Kilduff, PE
Principal Engineer / President

Enclosed:
Appendix A – 2023 Field Photographs
Appendix B – Discontinuity and Structure Measurements
Appendix C – Kinematic Analyses
Appendix D – Planar Failure
Appendix E – Rockfall Modeling

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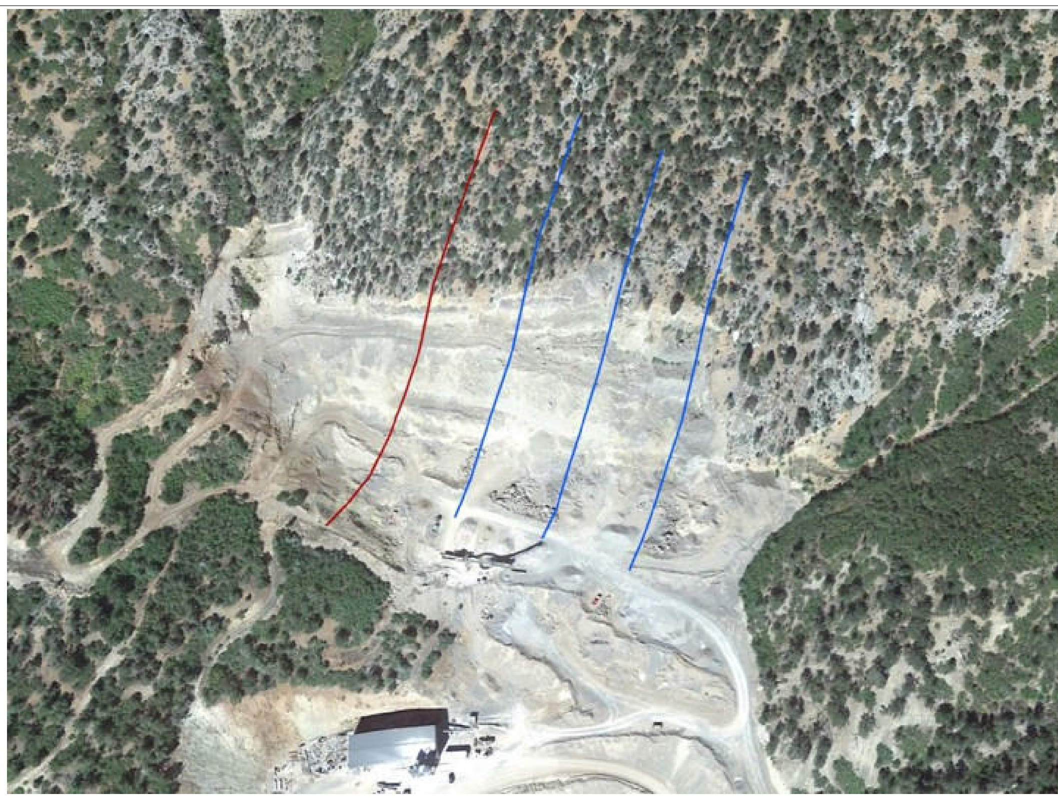

REV 0	SCALE: AS SHOWN	KILDUFF UNDERGROUND ENGINEERING, INC. 535 16TH STREET, SUITE 620 DENVER, CO 80202 (303)-732-3692	MID CONTINENT MINE - EAST FACE STABILITY GLENWOOD SPRINGS, CO	SITE LOCATION & ROCKFALL TRANSECTS	DATE 06/16/2023
DRAWN BY: IF					FIGURE 1
DESIGNED BY: SS					
CHECKED BY: SS					

N

Red line designates endpoints for maximum rockfall runout along the East face.
Gold polygon designates the rockfall setback zone from the highwall toe.
Orange line designates the front face of the design berm.

REV 1 · SCALE: AS SHOWN DRAWN BY: IF DESIGNED BY: IF CHECKED BY: RO	KILDUFF UNDERGROUND ENGINEERING, INC. 535 16TH STREET, SUITE 620 DENVER, CO 80202 (303)-732-3692	MID CONTINENT MINE - EAST FACE STABILITY GLENWOOD SPRINGS, CO	ROCKFALL SETBACK & BERM	DATE 06/16/2023 FIGURE 2

Appendix A

FIELD MAPPING PHOTOGRAPHS

Photo 1: View of the Mid Continent Mine, west face on the left and East Face on the right. The January 2023 headwall ground event can be seen on the left, releasing on a consistent, NE-dipping joint plane. (1/26/23 Photo# 0613)

Photo 2: Overview of the January 18, 2023 ground event on the West Face. Rubble path and pile at left. The two upper units of the limestone are visible with bedding acting as the slide plane. (1/26/23 Photo# 0578)

Photo 3: Side view, looking east, of the two upper units of the limestone with bedding acting as the slide plane. (1/26/23 Photo# 0598)

Photo 4: Icicles were formed particularly along the basal contact of the upper limestone bed. (1/26/23 Photo# 0584)

Photo 5: Side view, looking west, of the two upper units of the limestone of the East Face. The West Face ground event can be seen in the background along strike. (4/14/23 Photo# 2014)

Photo 6: Bedding plane of upper limestone unit exposed within the East drainage. Plane has very high persistence, planar, moderately rough, JRC 10-12. (4/14/23 Photo# 2016)

Photo 7: Bedding plane of upper limestone unit on the East face with the secondary joint release plane defining the structure of the outcrop. (4/14/23 Photo# 2023)

Photo 8: Open aperture of the upper and lower limestone bed where the interbed has been eroded back 3 – 5 feet frm the outcrop face. Asperities and direct connections between the two limestone beds creates a rough to very rough surface. (4/14/23 Photo# 2023)

Photo 9: Stalactites formed from CaCO3 water leeching down the face of the limestone and along the basal contact adhering the two beds together. Other young stalactites can be seen. (4/14/23 Photo# 2023)

Photo 10: Location of exposed interbed of Photos 11 and 12 eroded back from outcrop face approximately 3 ft (4/14/23 Photo# 2024)

Photo 11 and 12: Interbed material exposed at the East Face is a weak, cemented mudstone with clasts of limestone.
(4/14/23 Photos# 2028 and 2025)

Photo 13: Bedding plane and limestone outcrop on the western extent of the East Face with the West face ground event visible in background along strike. The Bedding plane is undulating and rough with CaCO3 stalactites and asperities of hard crystals. (4/14/23 Photo# 2032)

Photo 14: Looking up and north at the East Face. The bedding breaks defining the upper limestone beds are apparent. The East drainage on the right defines the eastern limit of operations. (4/14/23 Photo# 2002)

Appendix B

EAST FACE DISCONTINUITY MAPPING

RMI - MID CONTINENT MINE

ROCK MASS DISCONTINUITY CHARACTERIZATION FORM

Date: 4/13/2023
Sheet #: 1 of 1

Project #: P-23018SS
Logged By: S. Sundermann
Location: Glenwood Springs, CO
Domain: East Face
Slope Length: 400 ft
Slope Dip/Direction: 80 / 172
Slope Type: Natural and Mined
Friction Angle: 35
GSI Range: 65-75
Est. Comp. Strength:
Line Survey Number: window survey

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	Geologic Unit	Discontinuity Type	Dip Dir.	Dip	Persistence	Spacing	Aperature	Infilling / Weathering	JRC	Surface Shape	Roughness	Termination	Seepage Condition	Significance Rating (1-5)	Confidence (High-Low)	Notes/Failure Modes
Lower East Face	Limestone	Fault	83	76	Medium	NA	Open	Gouge		Undulating	Slickensided	0	7	5	Moderate	Parallel fault splays
Lower East Face	Limestone	Joint	67	72	Medium	Moderate to Wide	Partly	unknown	8-10	Planar	Slightly Rough	1	2	3	Low	Base of East Face
Lower East Face	Limestone	Joint	178	26	Medium	NA	Very Wide	No infill	16-18	Undulating	Rough	2	1	5	Moderate	Potential Sliding block
Lower East Face	Limestone	Joint	177	90	Low	NA	Very Wide	No infill	8-10	Planar	Mod Rough	1	1	5	Low	Release on sliding block
Lower East Face	Limestone	Joint	36	29	Low	NA	Very Wide	No infill	8-10	Planar	Mod Rough	1	1	5	Moderate	
Lower East Face	Limestone	Fault	32	50	Medium	Very Wide	Very Wide	4" weak	6-8	Planar	Slightly Rough	0	7	4	High	Interbed? Infilled with weak clay with clasts
Lower East Face	Limestone	Joint	324	48	Medium	Very Wide	Very Wide	weak infill	6-8	Planar	Slightly Rough	0	7	4	High	
Lower East Face	Limestone	Joint	238	83	High	Very Wide	Very Wide	weak infill, roots	6-8	Planar	Slightly Rough	0	7	3	High	Exfoliation in drainage
Lower East Face	Limestone	Joint	227	80	Medium	Very Wide	Wide	No infill	NR	Undulating	Slightly Rough	1	1	4	High	
Upper Limestone Beds	Limestone	Bedding	185	29	Very High	NR	NR	NR	10-12	Planar	Mod Rough	0	NR	1	High	Effervescent
Upper Limestone Beds	Limestone	Bedding	180	30	Very High	NR	NR	NR	10-12	Planar	Mod Rough	0	NR	1	High	
Upper Limestone Beds	Limestone	Bedding	191	30	Very High	Extr. Wide	Very Wide	Sandy CLAY	12-14	Planar	Mod Rough	0	8	1	High	Infill may be secondary? Roots
Upper Limestone Beds	Limestone	Joint	187	30	Very High	Extr. Wide	Very Wide	No infill	12-14	Planar	Mod Rough	0	2	2	High	
Upper Limestone Beds	Limestone	Bedding	186	30	Very High	NR	Very-Extr Wide	Signs of soil	12-14	Planar	Mod Rough	0	7	1	High	
Upper Limestone Beds	Limestone	Joint	63	40	Low	Mod Close	Open	No infill	8-10	Planar	Slightly Rough	1	1	3	High	Secondary, possible release
Upper Limestone Beds	Limestone	Joint	59	40	Low	Mod Close	Open	No infill	8-10	Planar	Slightly Rough	1	1	2	High	Secondary, possible release
Upper Limestone Beds	Limestone	Bedding	217	29	Very High	Extr. Wide	Extr. Wide	Weak Interbed	16-18	Planar	Rough	0	3	1	High	clasts of hard crystals
Upper Limestone Beds	Limestone	Bedding	202	29	Very High	Extr. Wide	Extr. Wide	Weak Interbed	16-18	Planar	Rough	0	3	1	High	clasts of hard crystals
Upper Limestone Beds	Limestone	Bedding	198	30	Very High	Extr. Wide	Extr. Wide	Weak Interbed	16-18	Planar	Rough	0	3	1	High	clasts of hard crystals
Upper Limestone Beds	Limestone	Joint	43	46	Low	Mod Close-Wide	Open	No infill	8-10	Planar	Slightly Rough	1	1	2	High	Secondary, possible release
Upper Limestone Beds	Limestone	Bedding	188	32	Very High	Extr. Wide	Very-Extr Wide	Weak Interbed	14-16	Planar	Rough	0	8	1	High	$CaCO_3$ Stalactites
Upper Limestone Beds	Limestone	Joint	57	54	Low	Mod Close	Open	No infill	8-10	Planar	Slightly Rough	1	1	2	High	Secondary, possible release
Upper Limestone Beds	Limestone	Bedding	188	31	Very High	Extr. Wide	Very-Extr Wide	Weak Interbed	14-16	Undulating	Rough	0	7	1	High	$CaCO_3$ Stalactites

Appendix C

KINEMATIC RESULTS

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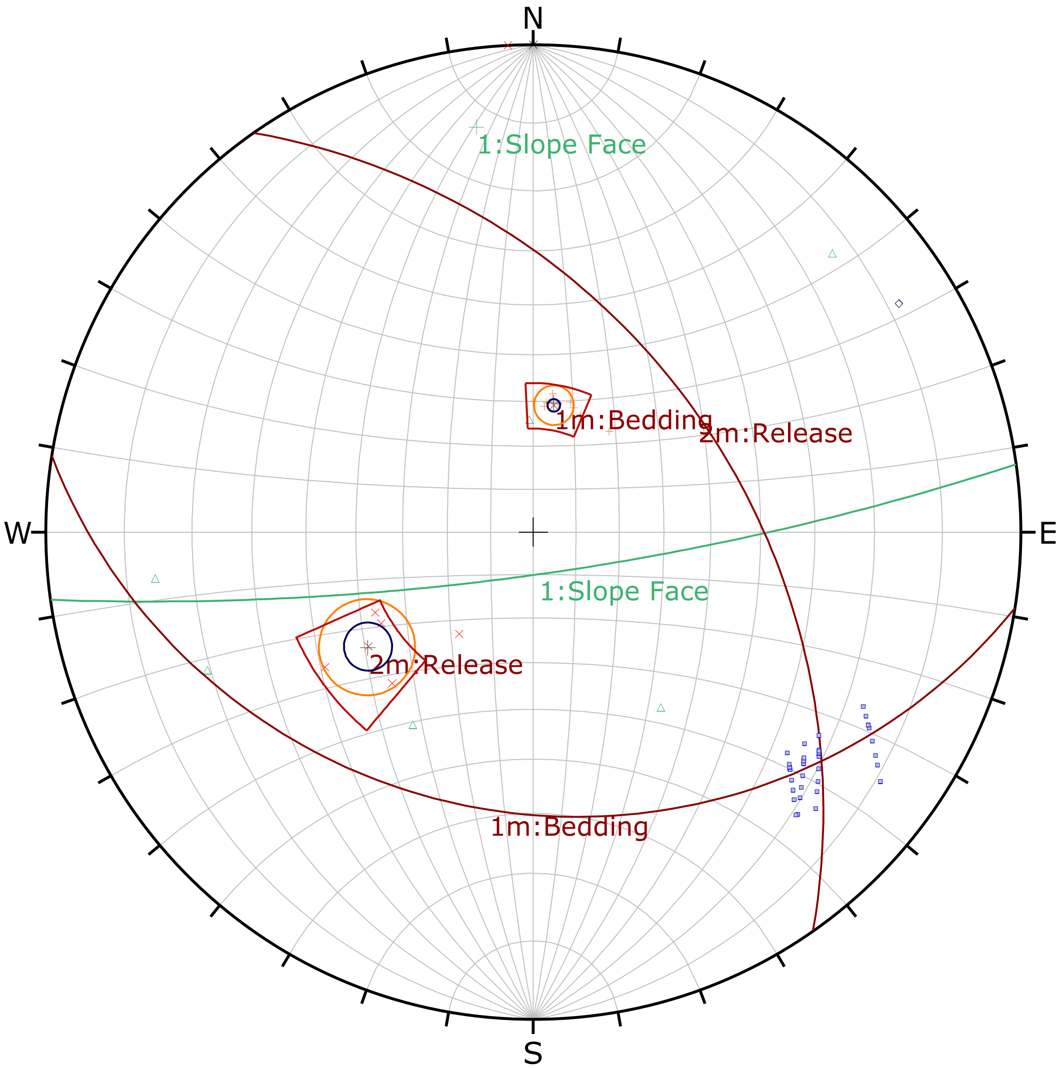


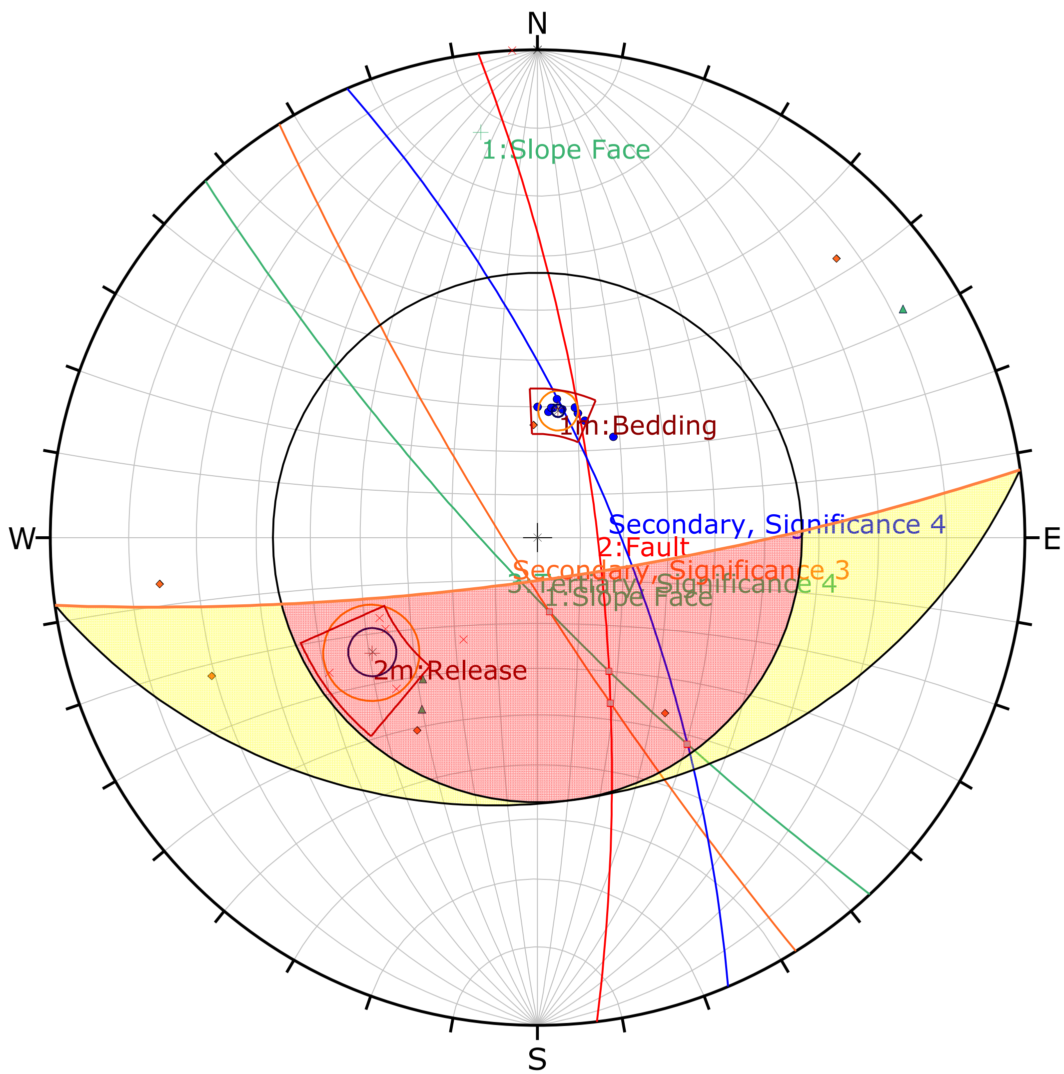
Symbol	PERSISTENCE	Quantity
◇	High	1
×	Low	6
△	Medium	6
+	Very High	10
Symbol	**Feature**	
▫	Intersection	

Plot Mode	Pole Vectors
Vector Count	23 (23 Entries)
Intersection Mode	All Set Planes
Intersections Count	40
Hemisphere	Lower
Projection	Equal Angle

rocscience

DIPS 8.021

Project	RMI Mid Continent Mine		
Analysis Description	East Face Pole Plot		
Drawn By	Sundermann	*Company*	Kilduff Underground
Date	4/27/2023, 2:35:05 PM	*File Name*	EastFace.dips8



Symbol	PERSISTENCE	Quantity
▲	High	3
×	Low	6
◆	Medium	6
●	Very High	10
Symbol	**Feature**	
■	Critical Intersection	

Kinematic Analysis	Wedge Sliding		
Slope Dip	80		
Slope Dip Direction	172		
Friction Angle	33°		
	Critical	**Total**	**%**
Wedge Sliding	4	300	1.33%

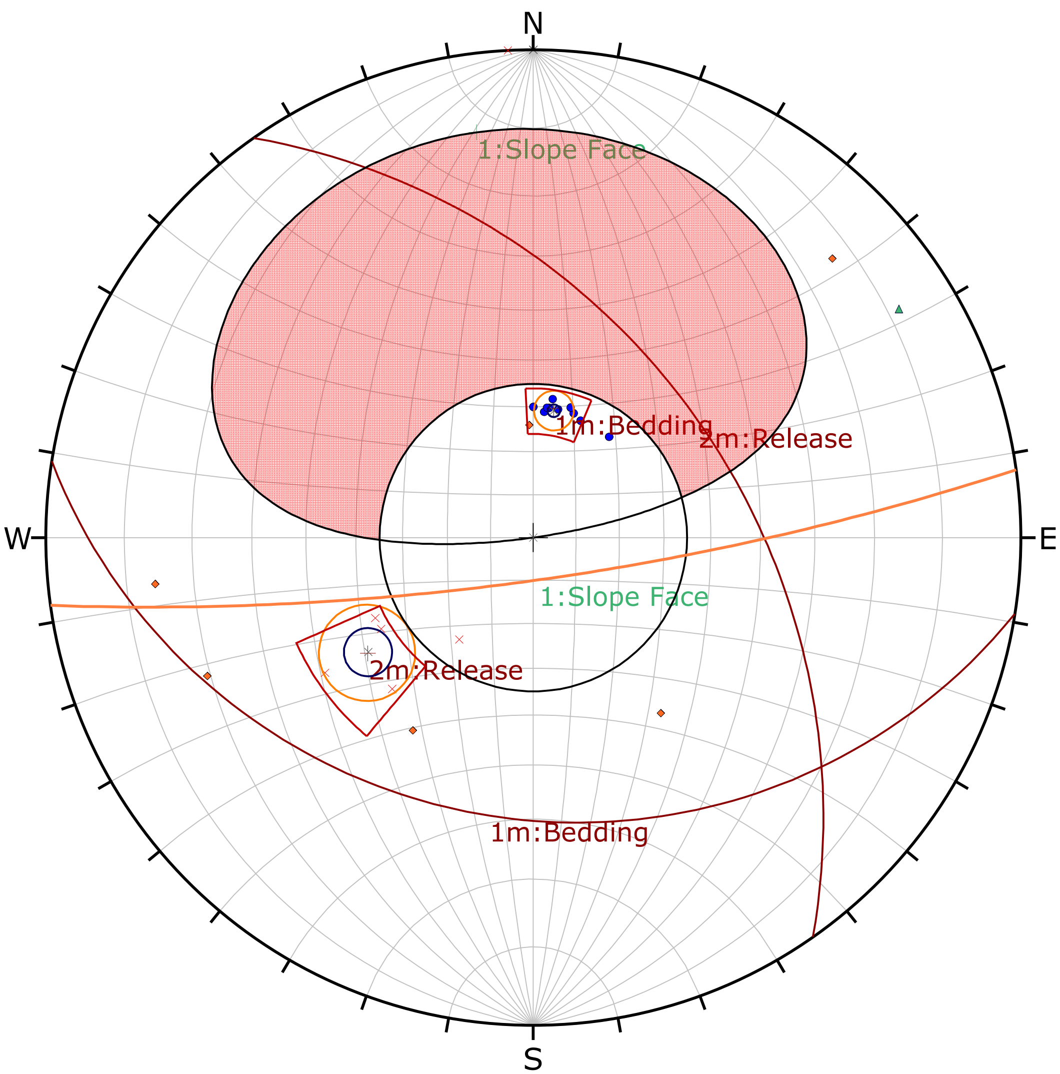
	Color	Dip	Dip Direction	Label
User Planes				
1		80	172	Slope Face
2		76	83	Fault
3		80	227	Tertiary, Signific
4		83	238	Secondary, Sigr
5		72	67	Secondary, Sigr
Mean Set Planes				
1m		30	189	Bedding
2m		45	55	Release

Plot Mode	Pole Vectors
Vector Count	25 (25 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	300
Hemisphere	Lower
Projection	Equal Angle

rocscience

DIPS 8.021

Project	RMI Mid Continent Mine		
Analysis Description	East Face - Wedge Interpreted		
Drawn By	Sundermann	*Company*	Kilduff Underground
Date	4/27/2023, 2:35:05 PM	*File Name*	EastFace_Wedge.dips8



Symbol	PERSISTENCE	Quantity
▲	High	1
×	Low	6
◆	Medium	6
●	Very High	10

Kinematic Analysis	Planar Sliding			
Slope Dip	80			
Slope Dip Direction	172			
Friction Angle	35°			
		Critical	Total	%
	Planar Sliding (All)	0	23	0.00%

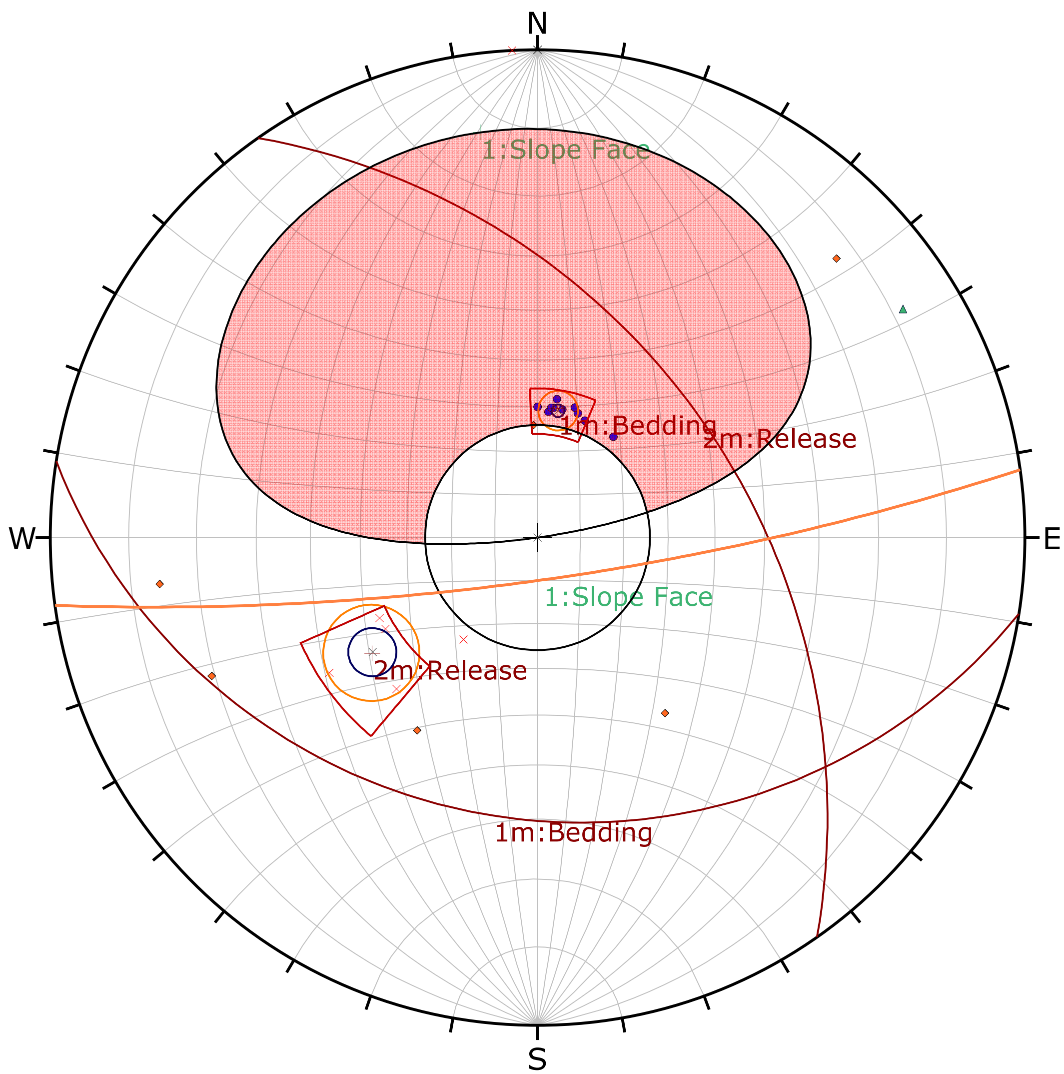
	Color	Dip	Dip Direction	Label
User Planes				
1		80	172	Slope Face
Mean Set Planes				
1m		30	189	Bedding
2m		45	55	Release

Plot Mode	Pole Vectors
Vector Count	23 (23 Entries)
Hemisphere	Lower
Projection	Equal Angle

rocscience

DIPS 8.021

Project	RMI Mid Continent Mine
Analysis Description	East Face Planar Slide - Limestone
Drawn By	Sundermann
Company	Kilduff Underground
Date	4/27/2023, 2:35:05 PM
File Name	EastFace_Planar NoLimits.dips8



Symbol	PERSISTENCE	Quantity
▲	High	1
×	Low	6
◆	Medium	6
●	Very High	10

Kinematic Analysis	Planar Sliding
Slope Dip	80
Slope Dip Direction	172
Friction Angle	26°

	Critical	Total	%
Planar Sliding (All)	11	23	47.83%
Planar Sliding (Set 1: Bedding)	10	10	100.00%

	Color	Dip	Dip Direction	Label
User Planes				
1		80	172	Slope Face
Mean Set Planes				
1m		30	189	Bedding
2m		45	55	Release

Plot Mode	Pole Vectors
Vector Count	23 (23 Entries)
Hemisphere	Lower
Projection	Equal Angle

rocscience

DIPS 8.021

Project	RMI Mid Continent Mine
Analysis Description	East Face Planar Slide - Mudstone Interbed (26 phi)
Drawn By	Sundermann
Company	Kilduff Underground
Date	4/27/2023, 2:35:05 PM
File Name	EastFace_Planar NoLimits.dips8

Appendix D

PLANAR FAILURE RESULTS

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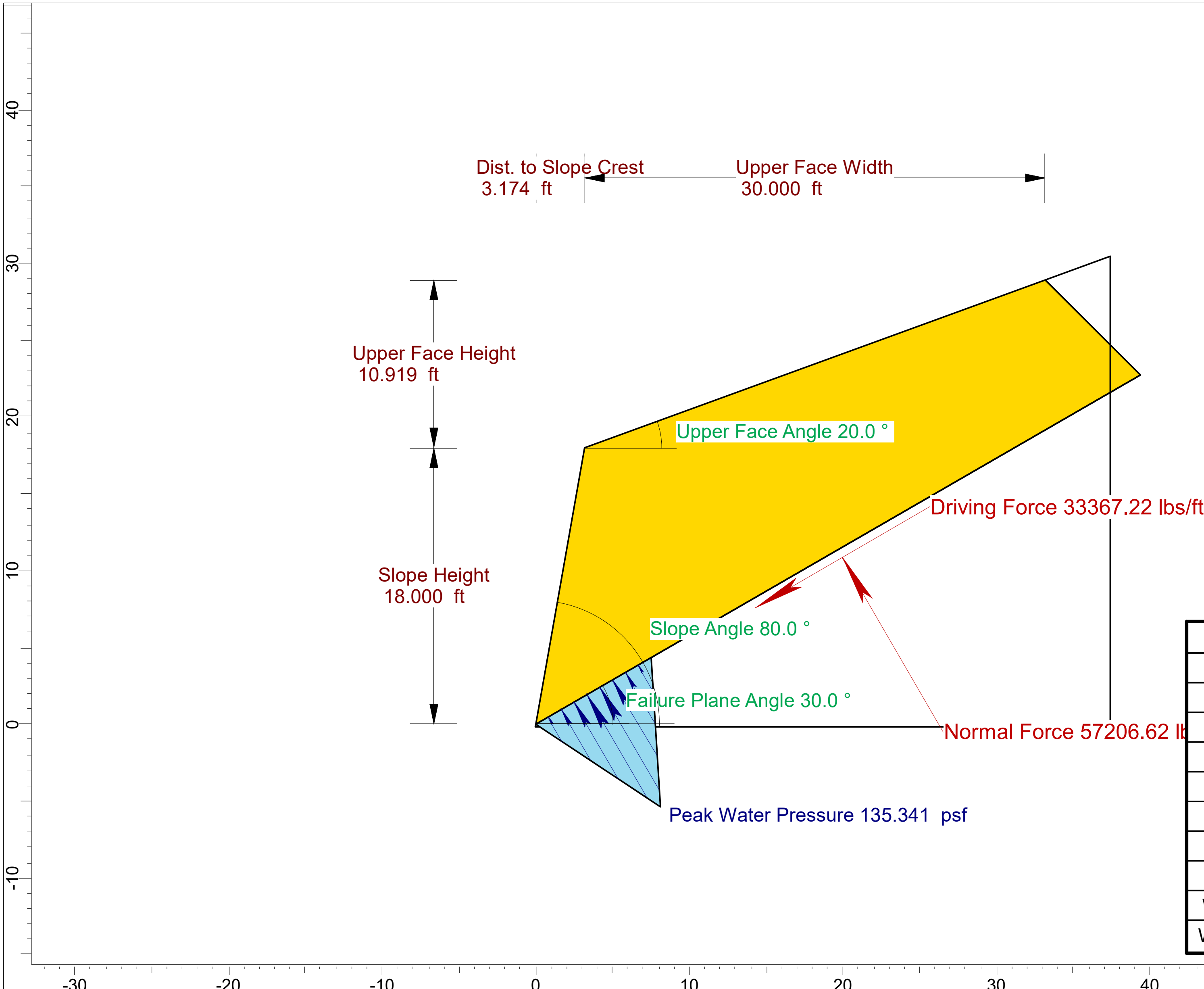
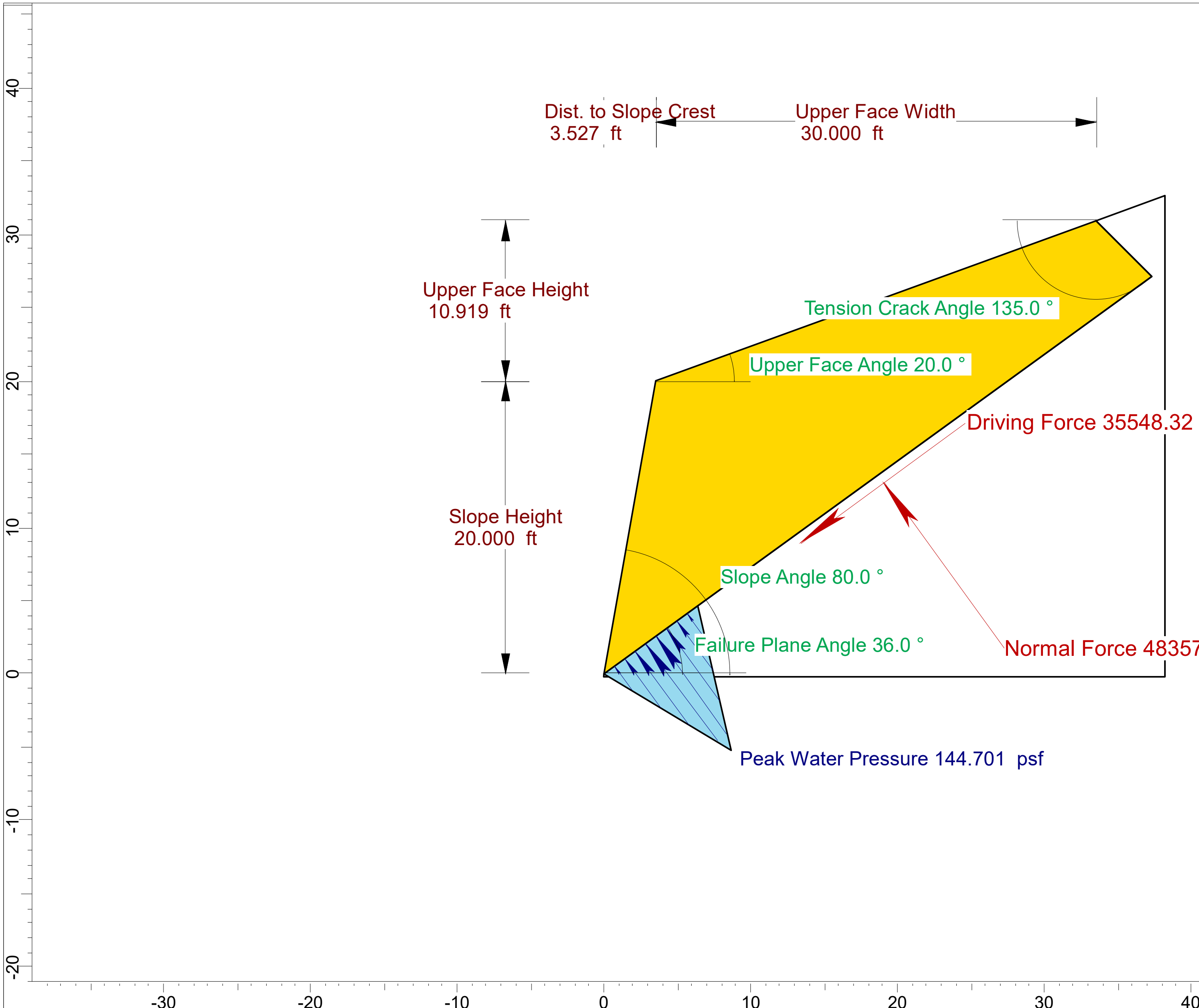


Factor of Safety	1.20
Driving Force	33367.22 lbs/ft
Resisting Force	39990.65 lbs/ft
Wedge Weight	66734.43 lbs/ft
Wedge Volume	444.90 ft^3/ ft
Shear Strength	813.82 psf
Shear Resistance	36992.58 lbs/ft
Normal Force	57206.62 lbs/ft
Plane Waviness	3.0°
Water Force on Failure Plane	587.09 lbs/ft
Water Force on Tension Crack	0.00 lbs/ft

Project	Mid Continent East Face		
Analysis Description	Planar Wedge Stability Analysis		
Drawn By	Sundermann	*Company*	Kilduff Underground Engineering
Date	5/1/2023, 7:54:04 PM	*File Name*	RocPlane_EastFace.pln4

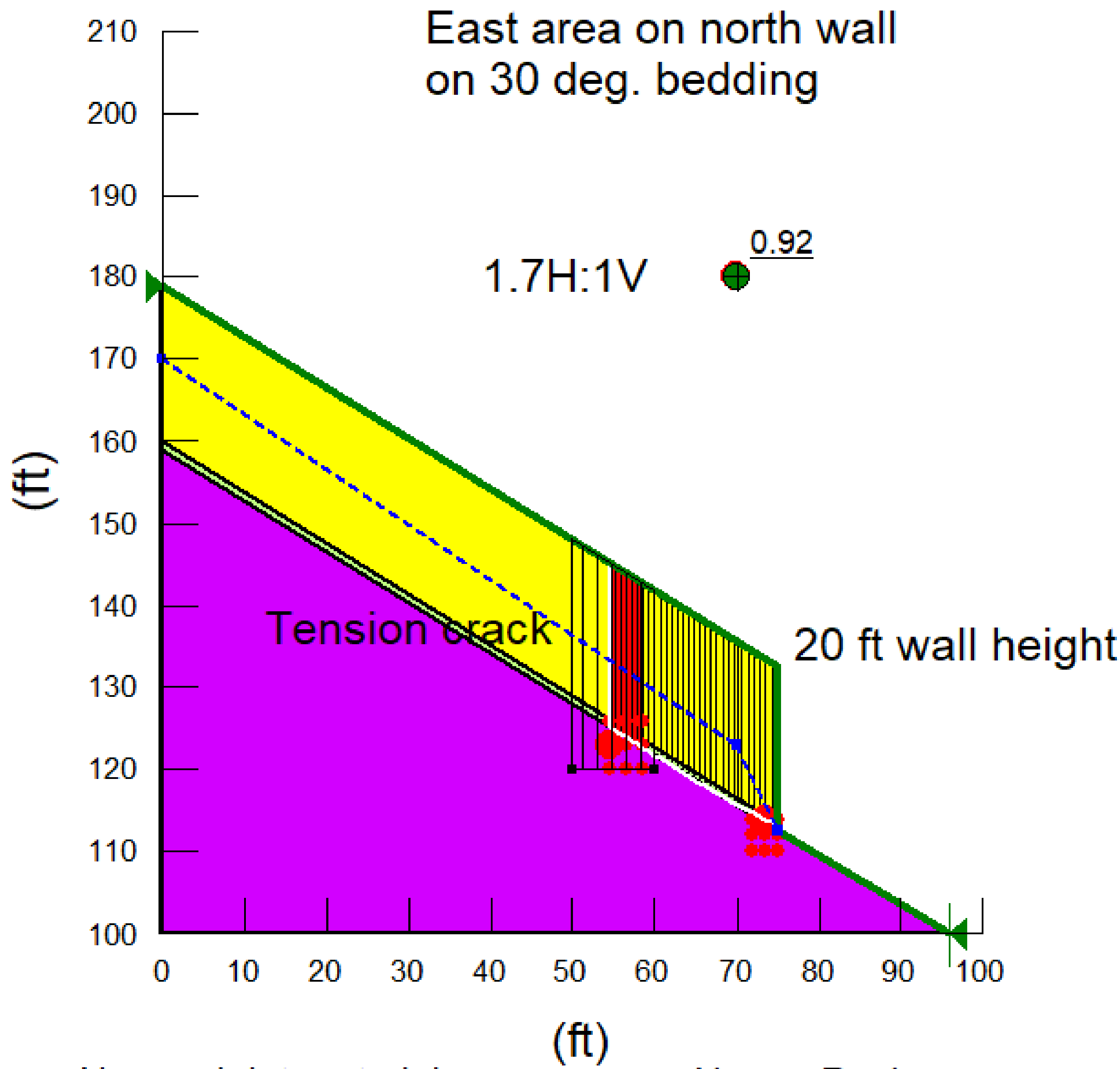
ROCPLANE 4.011



Factor of Safety	0.99
Driving Force	35548.32 lbs/ft
Resisting Force	35347.27 lbs/ft
Wedge Weight	60478.42 lbs/ft
Wedge Volume	403.19 ft^3/ ft
Shear Strength	711.19 psf
Shear Resistance	32812.98 lbs/ft
Normal Force	48357.19 lbs/ft
Plane Waviness	3.0°
Water Force on Failure Plane	570.88 lbs/ft
Water Force on Tension Crack	0.00 lbs/ft

Project	Mid Continent Mine		
Analysis Description	Planar Wedge Back Analysis - West Face		
Drawn By	Sundermann	*Company*	Kilduff Underground Engineering
Date	5/1/2023, 7:54:04 PM	*File Name*	RocPlane_WestFace_BackAnalysis.pln4

ROCPLANE 4.011



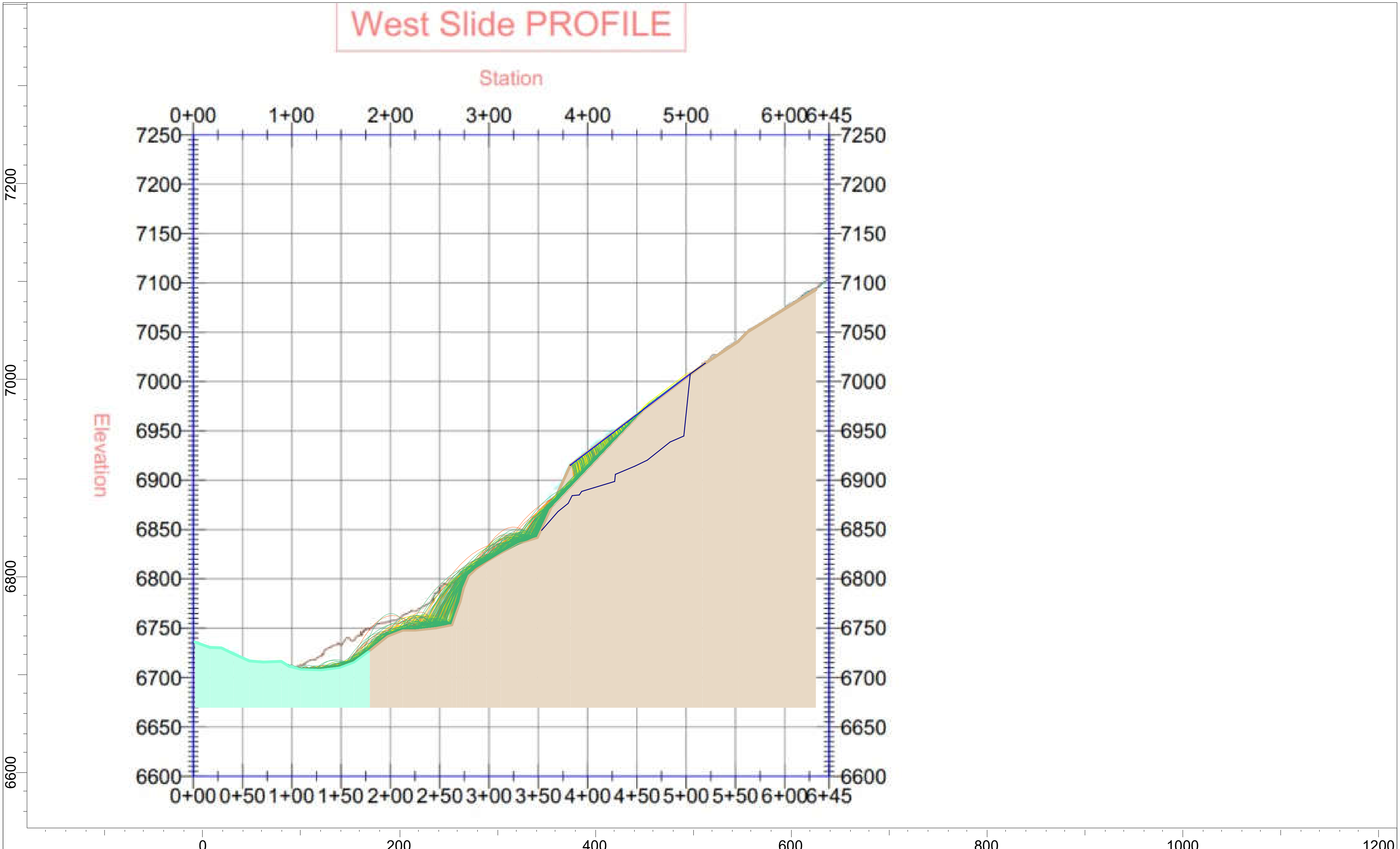
Name: Joint material
Unit Weight: 130 pcf
Cohesion': 550 psf
Phi': 25 °
Piezometric Line: 1

Name: Rock mass
Unit Weight: 150 pcf
Cohesion': 10,000 psf
Phi': 35 °
Piezometric Line: 1

KILDUFF UNDERGROUND ENGINEERING, INC.	Mid Continent Mine East Face Stability Glenwood Springs, CO	**West Face** **Slope/W Backanalyses** Appendix D

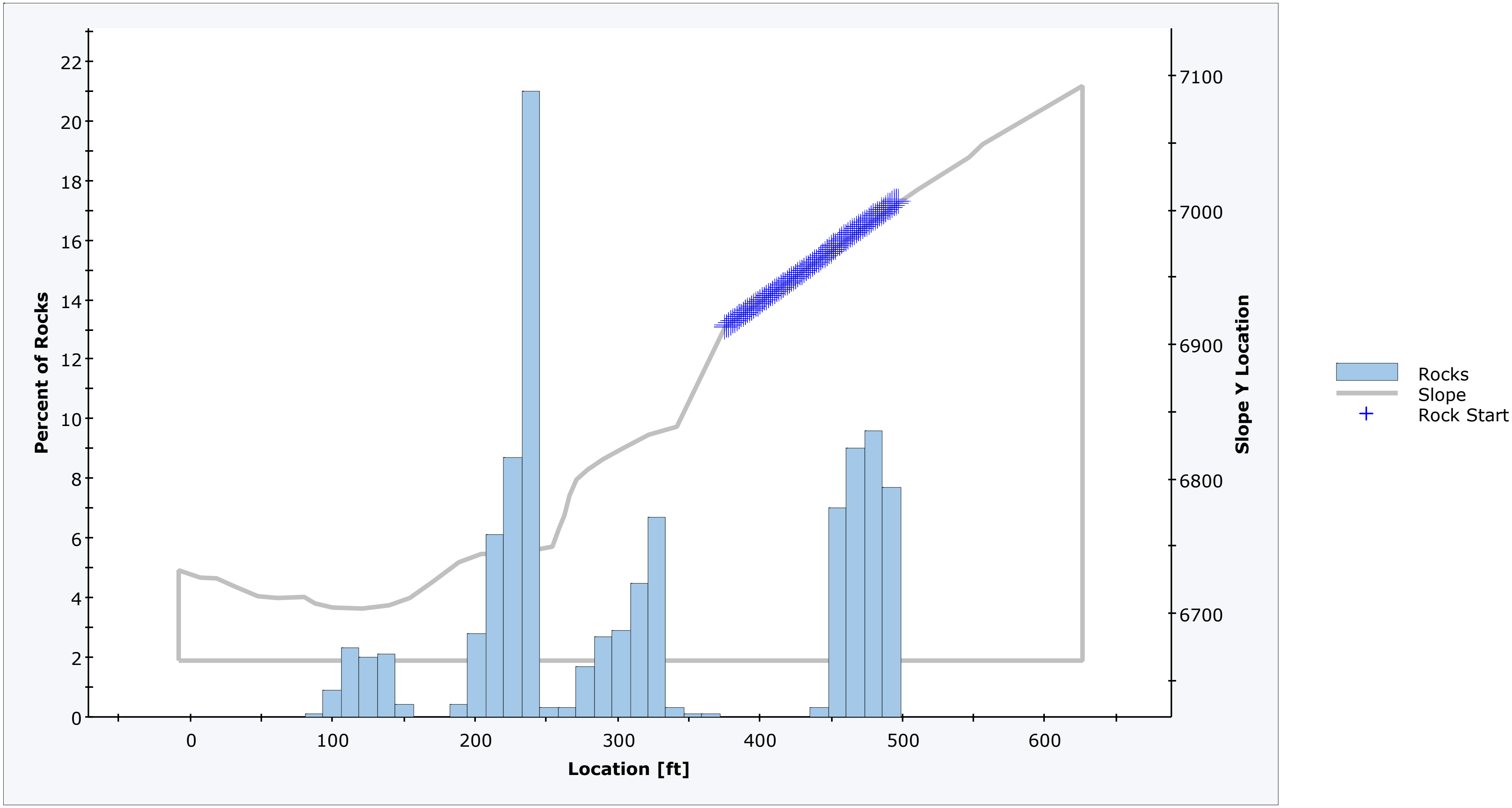
Appendix E

ROCKFALL MODELING RESULTS



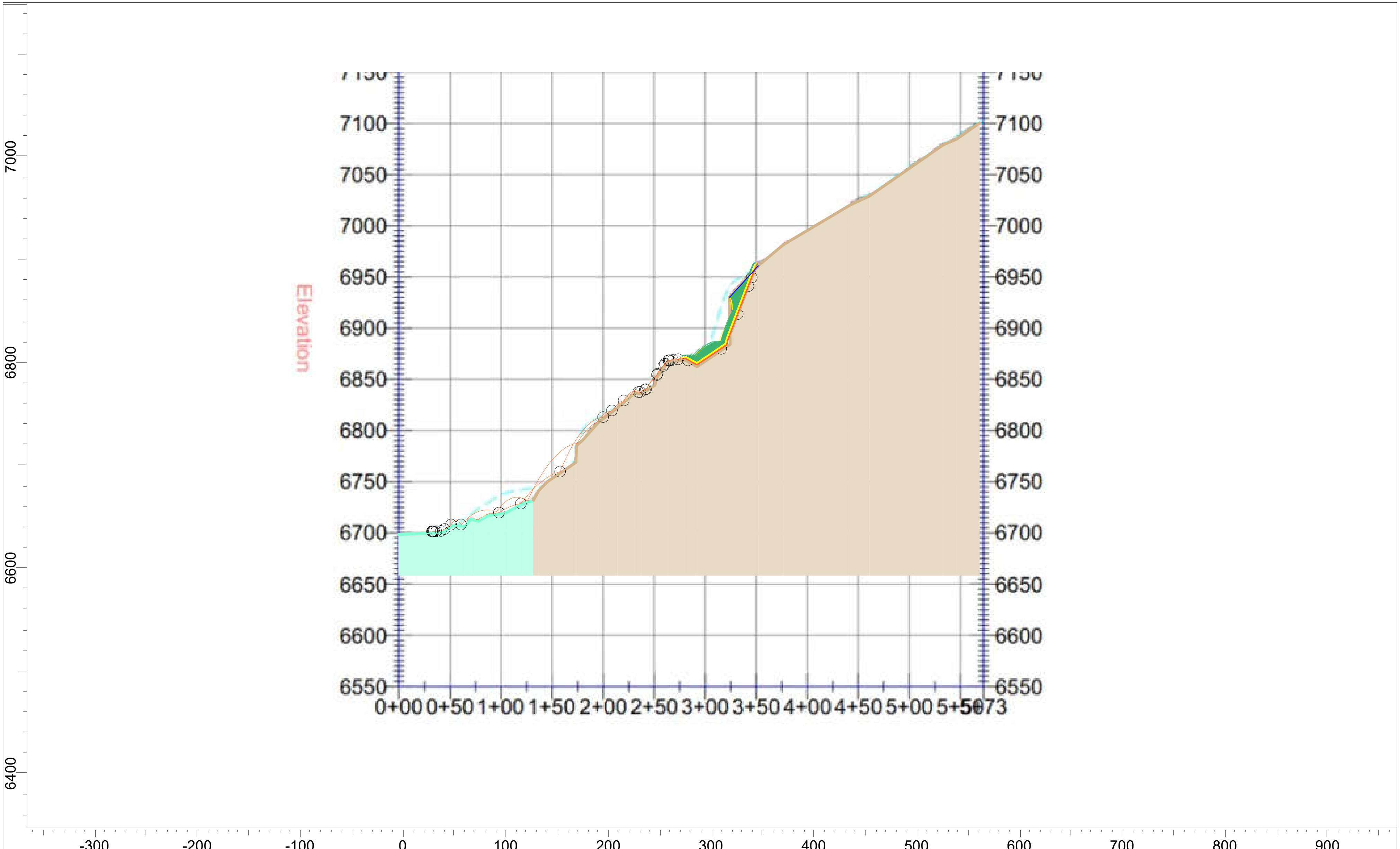
rocscience ROCFALL 8.022	*Project* Mid Continent Mine		
	Analysis Description West Face Historic Topo		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
	Date 5/26/2023, 10:21:27 AM	*File Name* WestFace_Historic_CrestLoss2.fal8	

Distribution of Rock Path End Locations



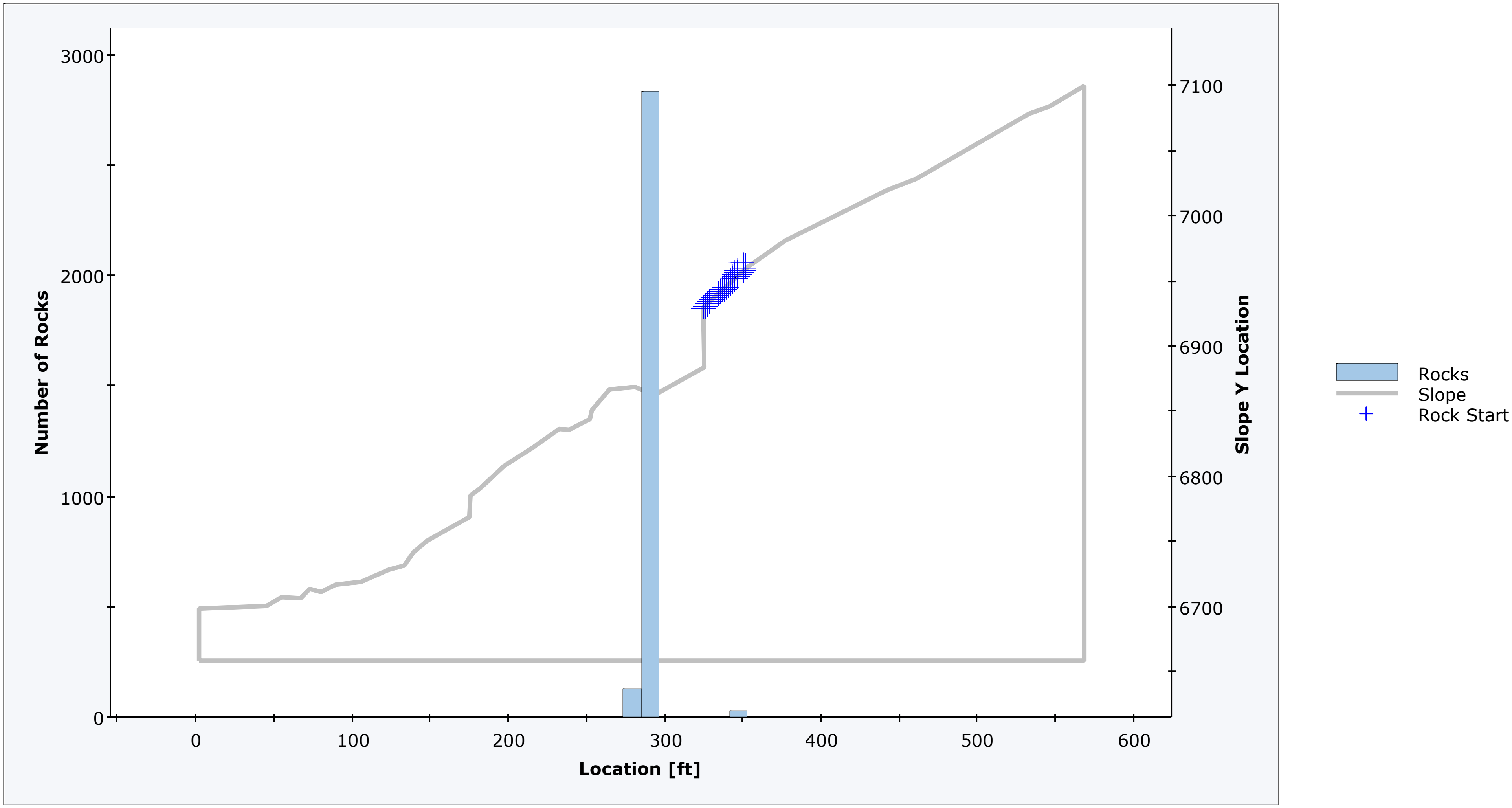
Total number of rock paths: 1000

rocscience	*Project* Mid Continent Mine		
	Analysis Description West Face Historic Topo		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 10:21:27 AM	*File Name* WestFace_Historic_CrestLoss2.fal8	



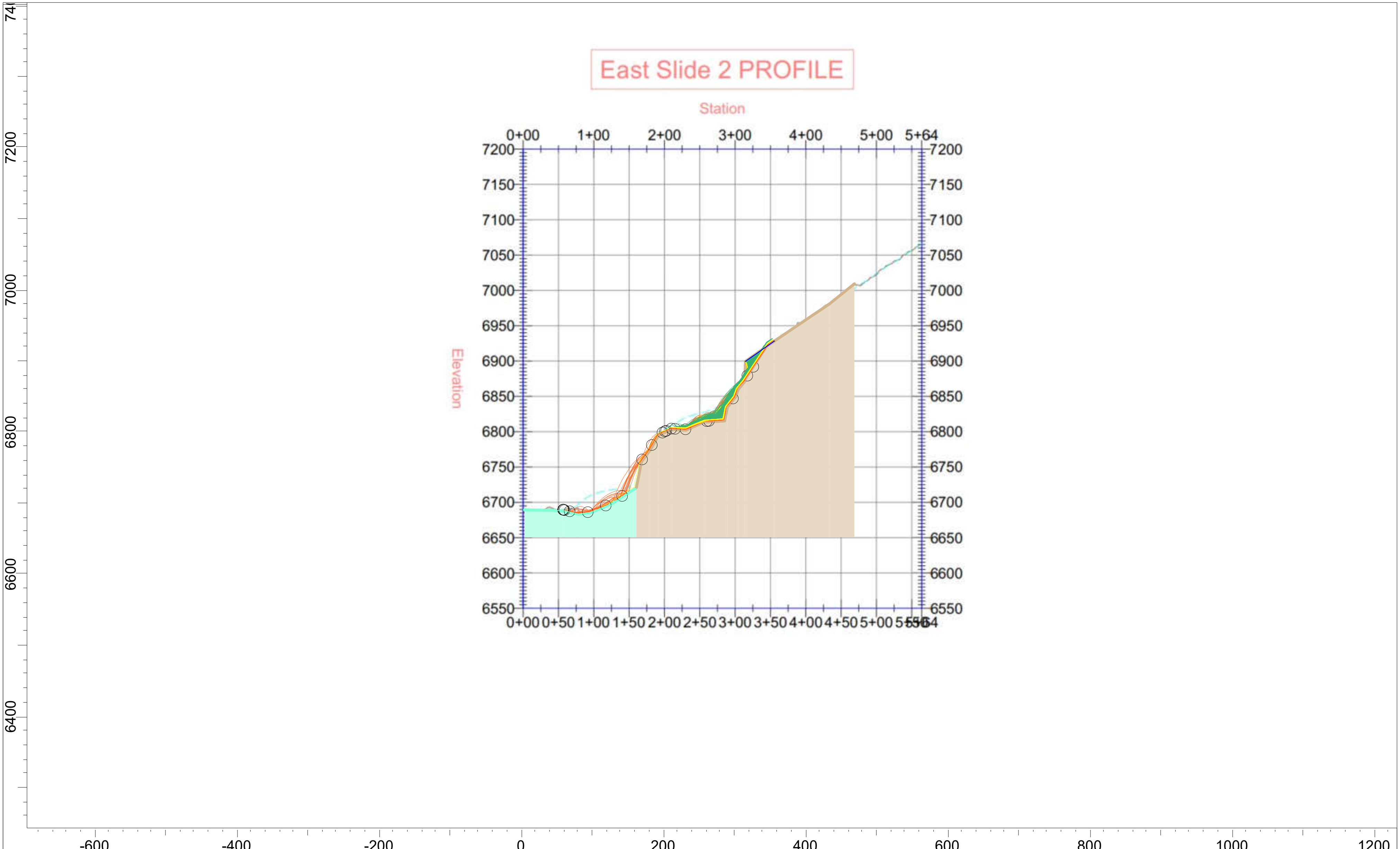
rocscience	Project	Mid Continent Mine
	Analysis Description	East Face 1 - West Trend - Runout
	Drawn By: Sundermann	Company: Kilduff Underground Engineering
ROCFALL 8.022	Date: 5/26/2023, 12:24:29 PM	File Name: EastFace1_West_Runout.fal8

Distribution of Rock Path End Locations



Total number of rock paths: 3000

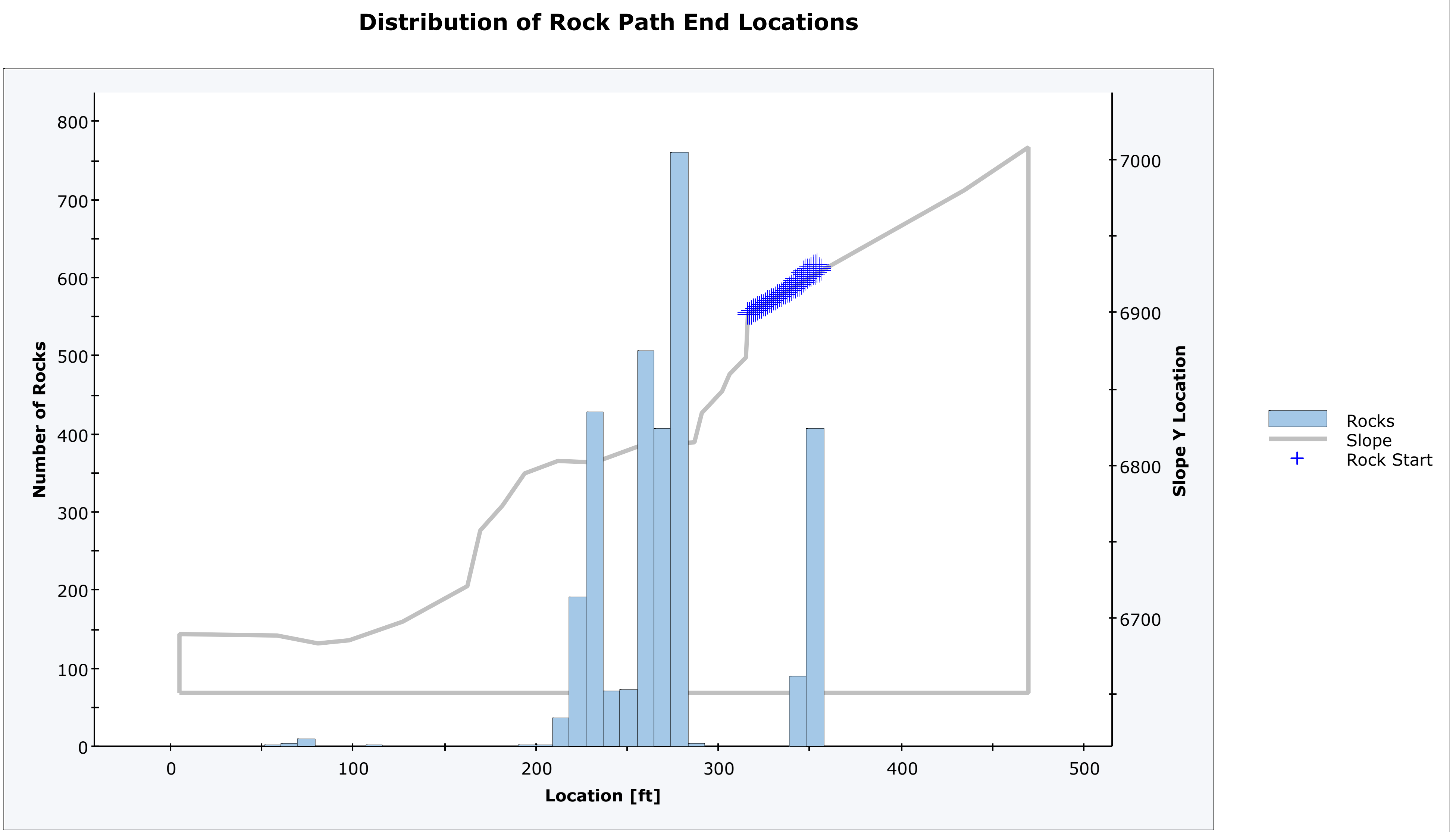
rocscience	*Project* Mid Continent Mine		
	Analysis Description East Face 1 - West Trend - Runout		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace1_West_Runout.fal8	



rocscience

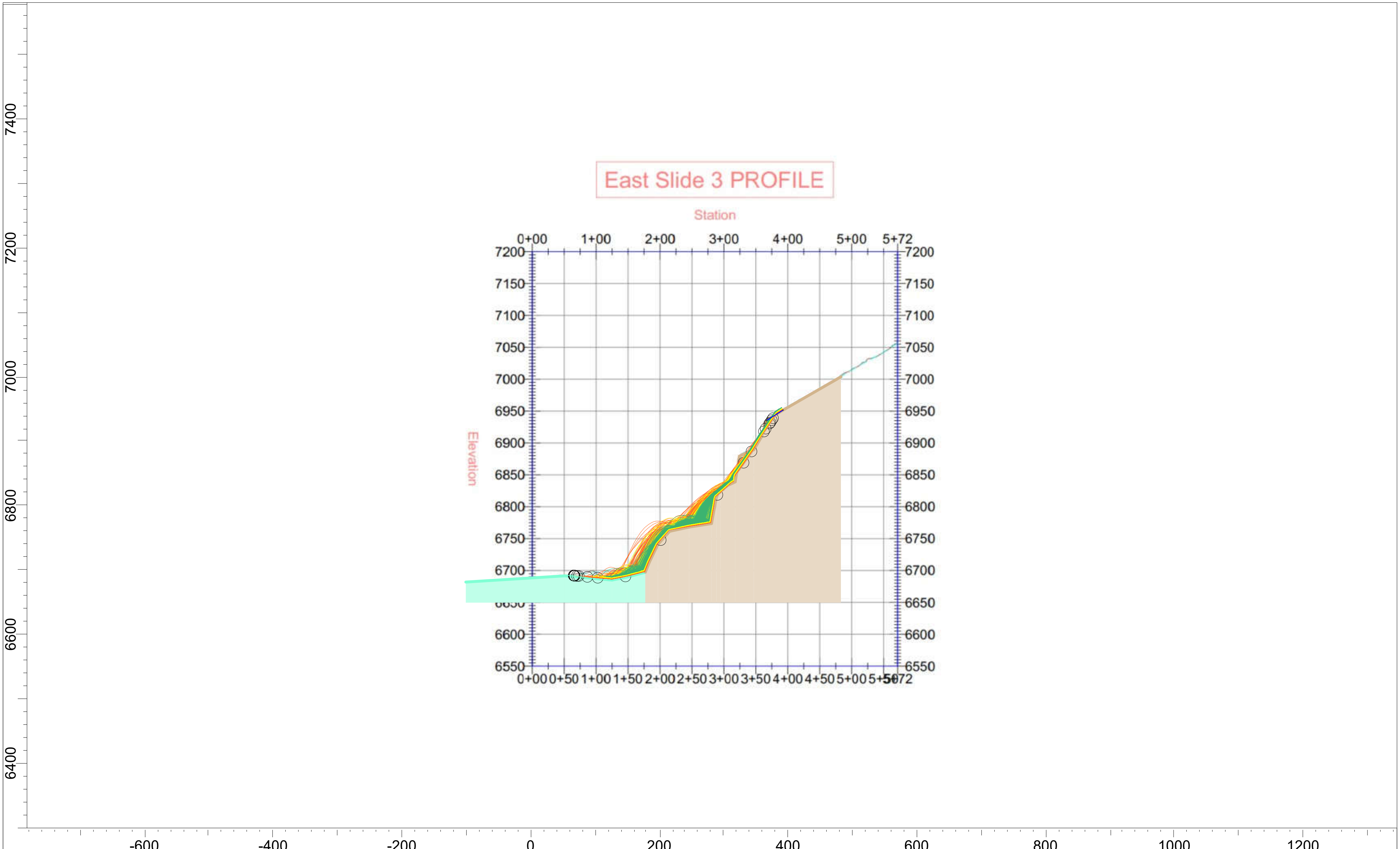
ROCFALL 8.022

Project	Mid Continent Mine		
Analysis Description	East Face 2 - Center Trend - Runout		
Drawn By	Sundermann	*Company*	Kilduff Underground Engineering
Date	5/26/2023, 12:24:29 PM	*File Name*	EastFace2_Center_Runout.fal8



Total number of rock paths: 2993

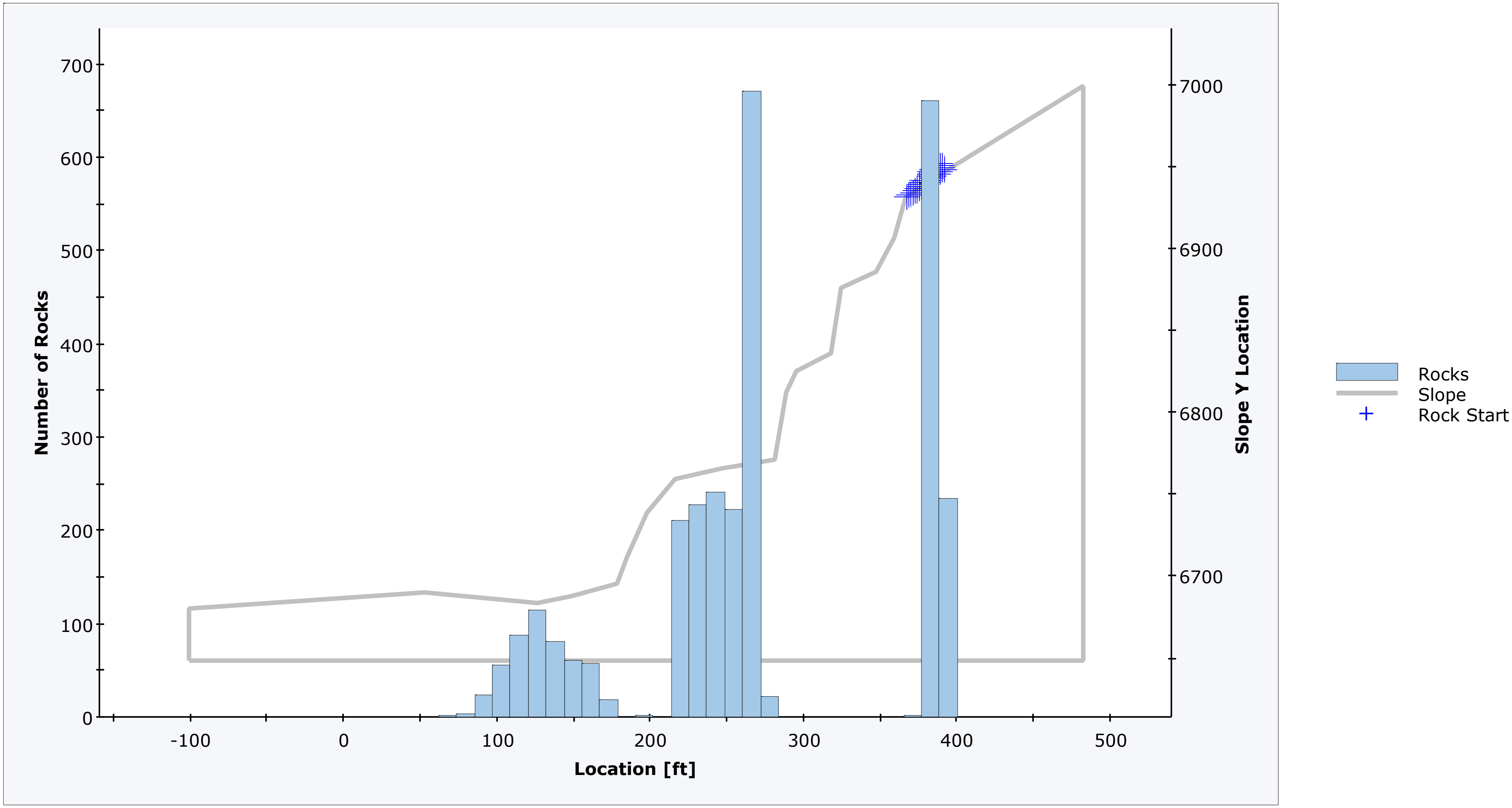
rocscience	*Project* Mid Continent Mine		
	Analysis Description East Face 2 - Center Trend - Runout		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace2_Center_Runout.fal8	



Project	Mid Continent Mine		
Analysis Description	East Face 3 - East Trend - Runout		
Drawn By	Sundermann	*Company*	Kilduff Underground Engineering
Date	5/26/2023, 12:24:29 PM	*File Name*	EastFace3_East_Runout.fal8

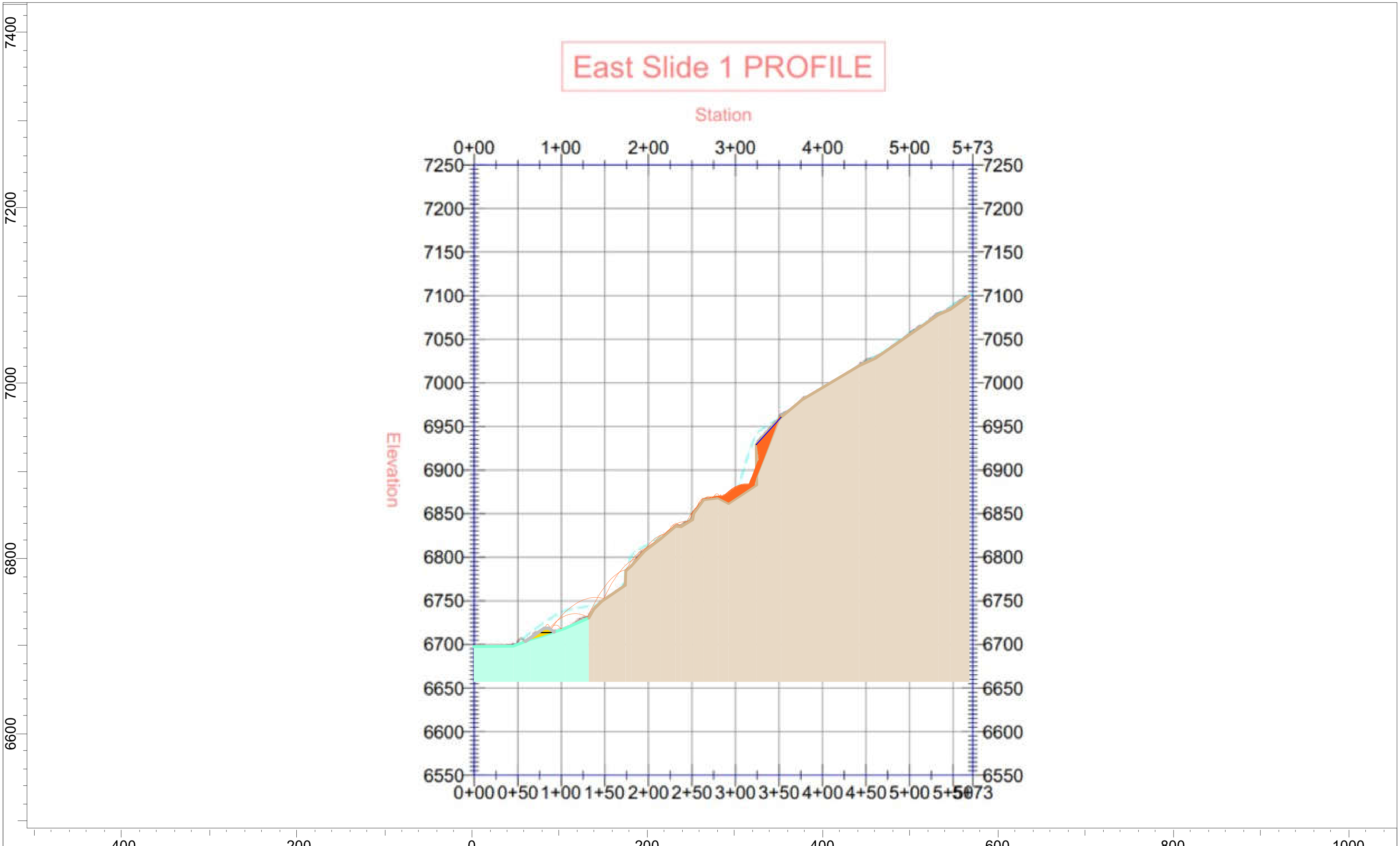
ROCFALL 8.022

Distribution of Rock Path End Locations



Total number of rock paths: 2996

rocscience	*Project* Mid Continent Mine		
	Analysis Description East Face 3 - East Trend - Runout		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace3_East_Runout.fal8	

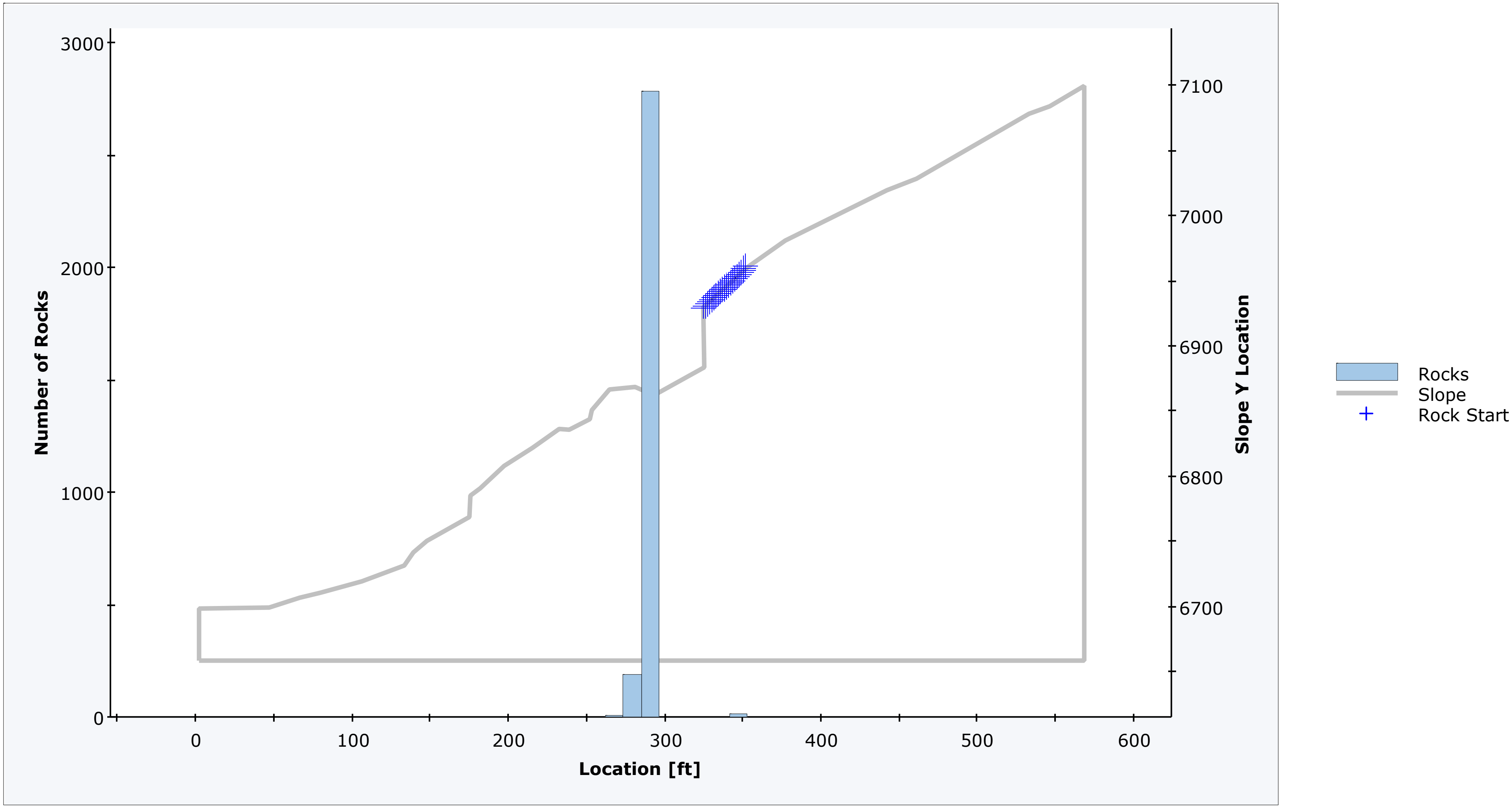


rocscience

ROCFALL 8.022

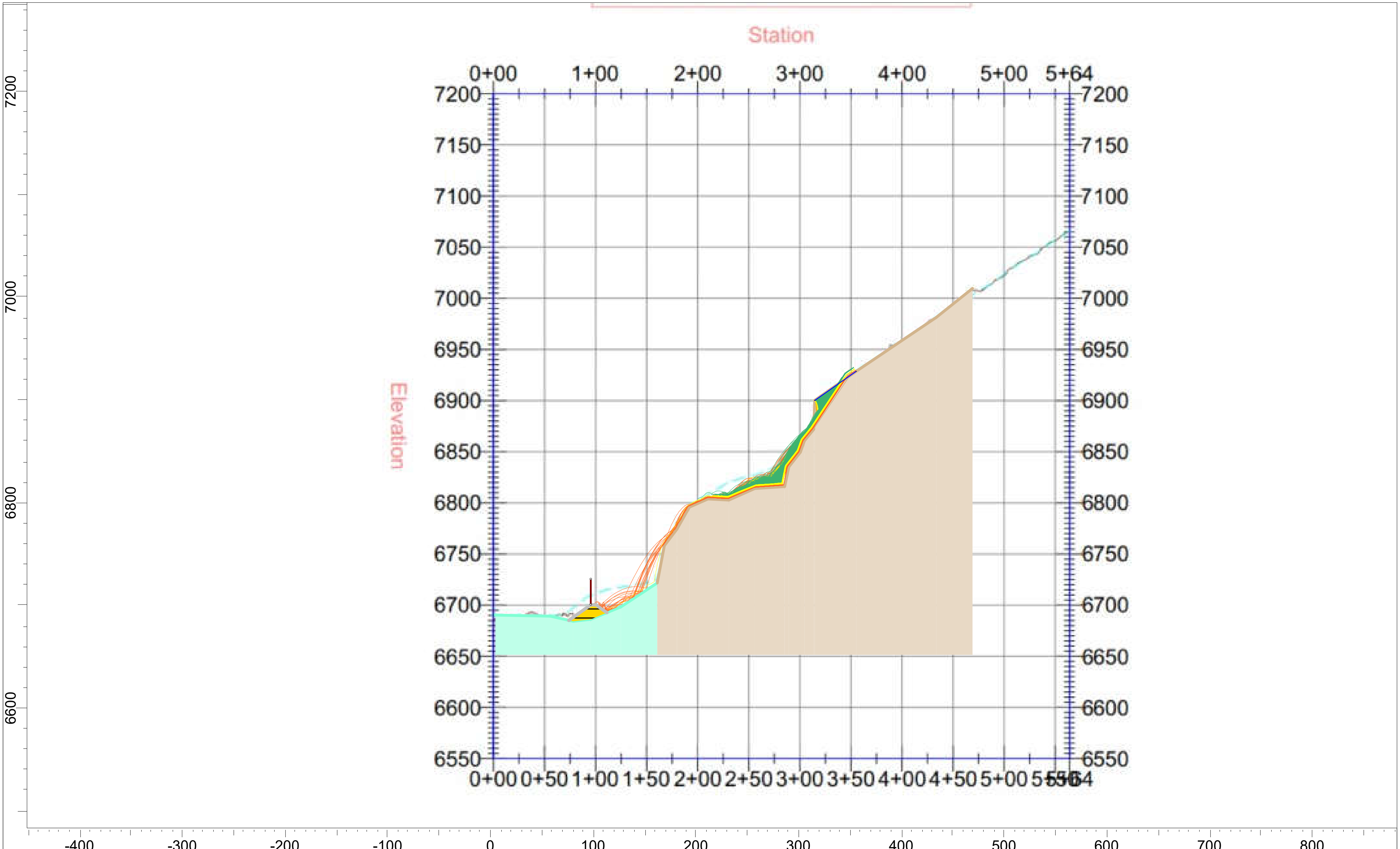
Project	Mid Continent Mine
Analysis Description	East Face 1 - West Trend - Berm
Drawn By	Sundermann
Company	Kilduff Underground Engineering
Date	5/26/2023, 12:24:29 PM
File Name	EastFace1_West.fal8

Distribution of Rock Path End Locations



Total number of rock paths: 3000

rocscience	*Project* Mid Continent Mine		
	Analysis Description East Face 1 - West Trend - Berm		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace1_West.fal8	

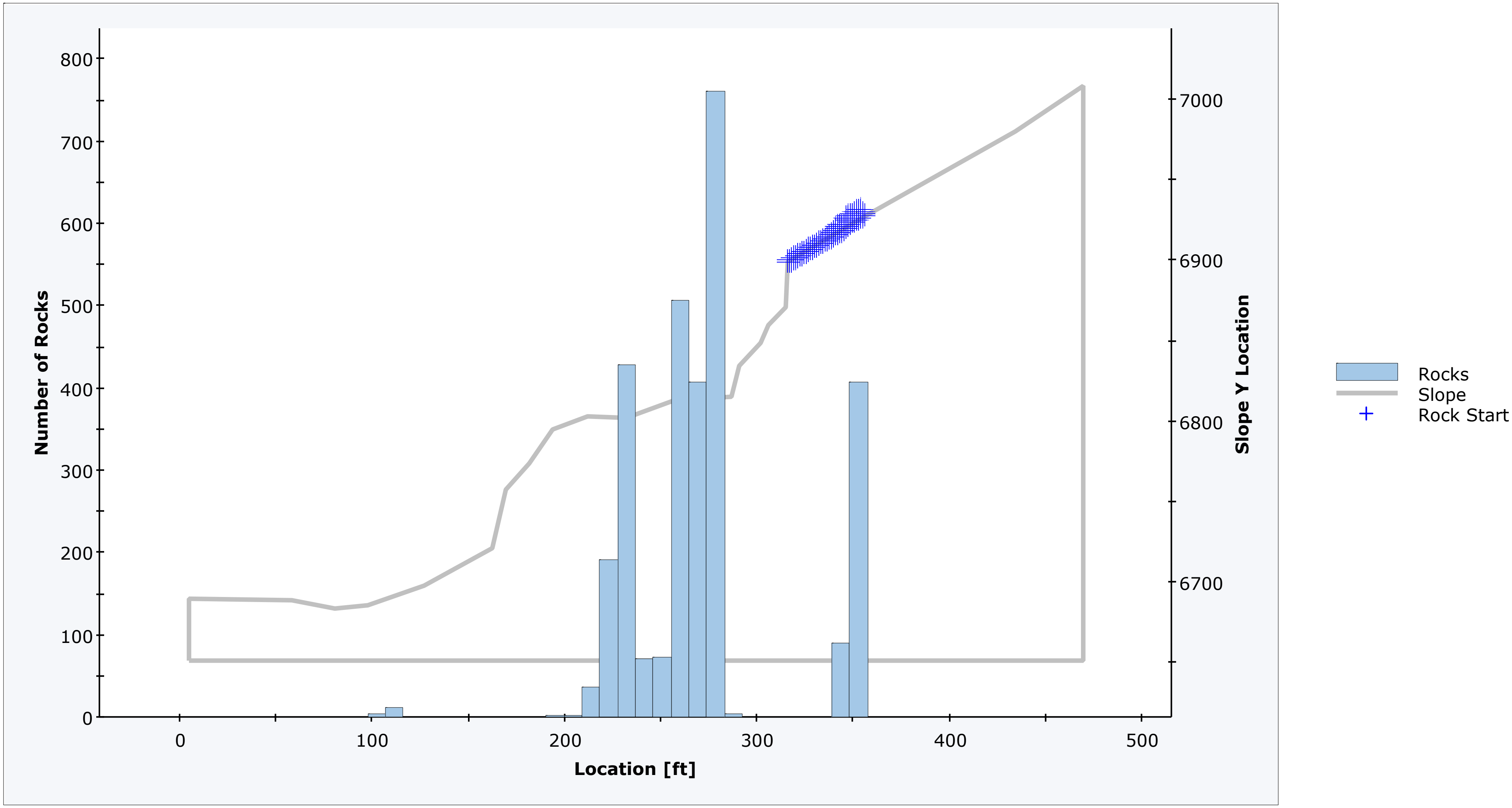


rocscience

ROCFALL 8.022

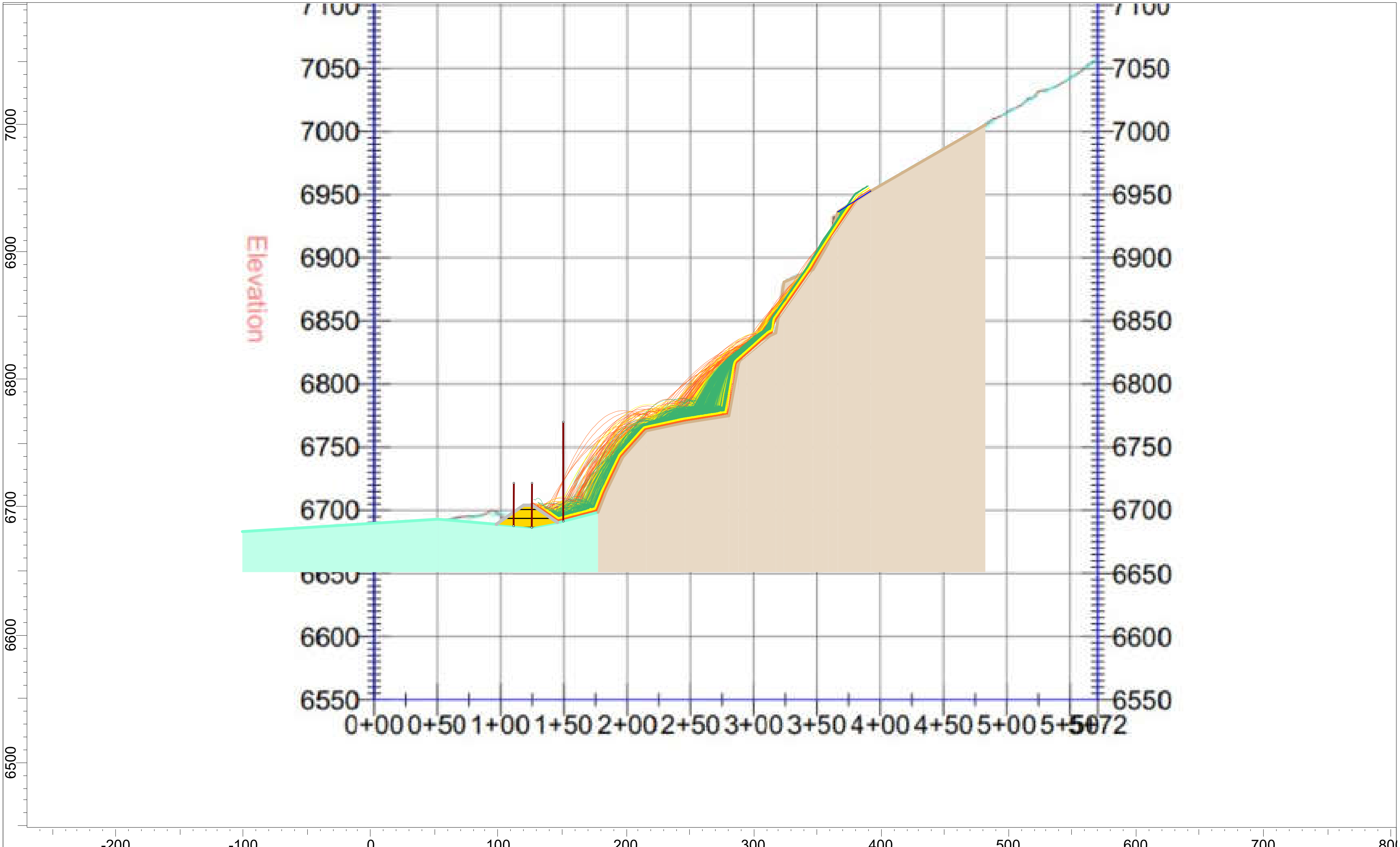
Project	Mid Continent Mine		
Analysis Description	East Face 2 - Center Trend - Berm		
Drawn By	Sundermann	Company	Kilduff Underground Engineering
Date	5/26/2023, 12:24:29 PM	File Name	EastFace2_Center_Berm.fal8

Distribution of Rock Path End Locations



Total number of rock paths: 2993

rocscience	*Project* Mid Continent Mine		
	Analysis Description East Face 2 -Center Trend - Berm		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace2_Center_Berm.fal8	

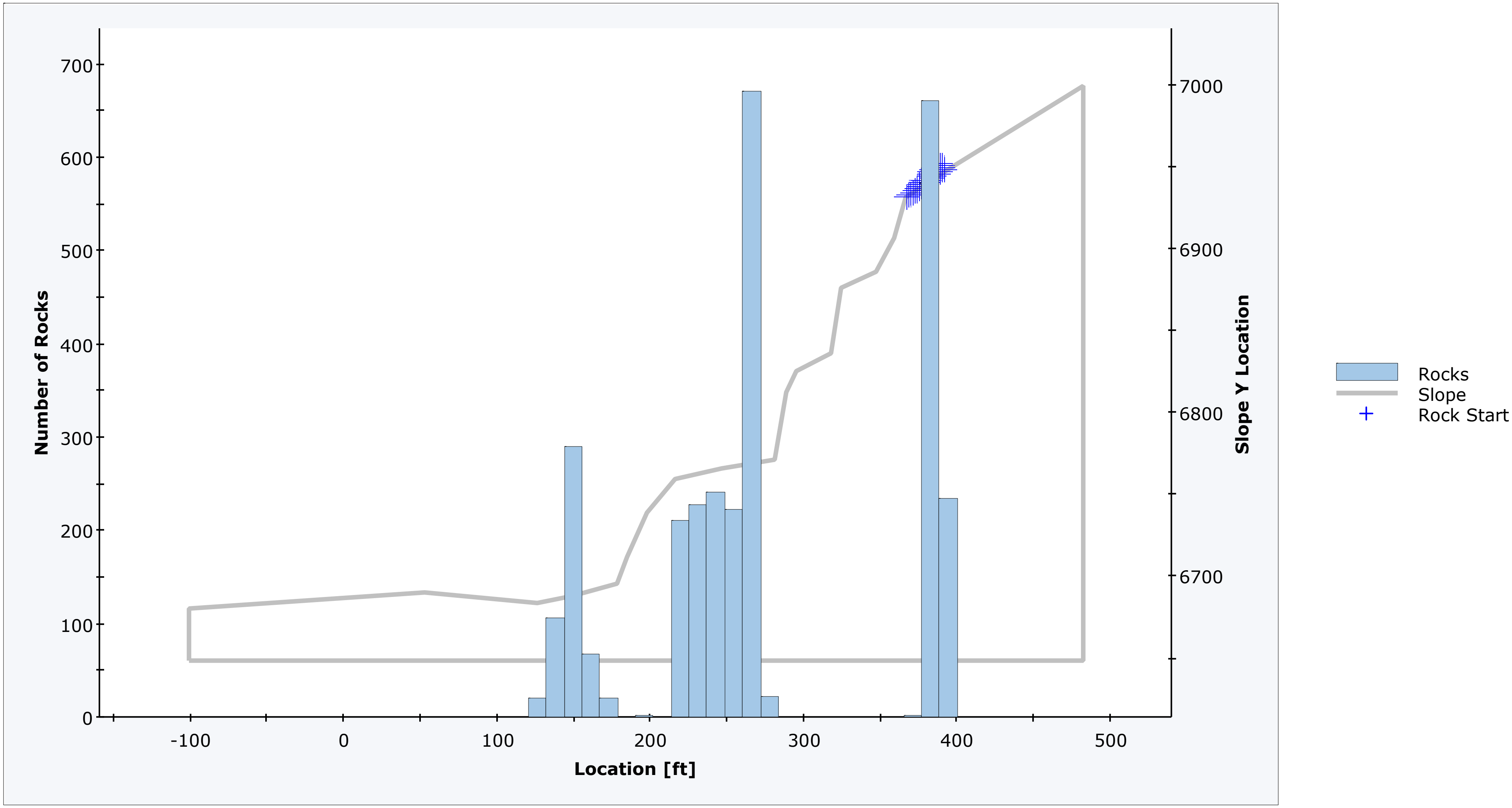


rocscience

ROCFALL 8.022

Project	Mid Continent Mine
Analysis Description	East Face 3 - East Trend - 15ft Berm
Drawn By	Sundermann
Company	Kilduff Underground Engineering
Date	5/26/2023, 12:24:29 PM
File Name	EastFace3_East_Berm3000.fal8

Distribution of Rock Path End Locations



Total number of rock paths: 2996

rocscience	*Project* Mid Continent Mine		
	Analysis Description East Face 3 - East Trend - 15ft Berm		
	Drawn By Sundermann	*Company* Kilduff Underground Engineering	
ROCFALL 8.022	*Date* 5/26/2023, 12:24:29 PM	*File Name* EastFace3_East_Berm3000.fal8	

East Face_Berm3000
Mid Continent Mine
Kilduff Underground Engineering
Date Created: 5/26/2023, 12:24:29 PM
Software Version: 8.022

East Face_Berm3000

Mid Continent Mine

Project Summary

File Name	East Face_Berm3000.fal8
File Version	8.022
Project Title	Mid Continent Mine
Analysis	East Face - 15ft Berm
Author	Sundermann
Company	Kilduff Underground Engineering
Date Created	5/26/2023, 12:24:29 PM

Project Settings

General Settings

Engine	Rigid Body
Units	Imperial Foot-Pounds (ft, lbm, ft-lbf)
Rock throw mode	Number of rocks controlled by seeder
Use tangential CRSP damping	Yes

Engine Conditions

Maximum steps per rock	40000
Normal velocity cutoff (ft/s)	0.33
Stopped velocity cutoff (ft/s)	0.33
Maximum timestep (s)	0.01
Switch velocity (ft/s)	-3.3e-09

Random Number Generation

Sampling method	Latin-Hypercube
Material Properties Sampling	Per simulation
Random seed	Pseudo-random seed: 12345234

Crest Loss

Vertex	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max
11	20	None				20	None			
13	30	None				30	None			
16	30	None				20	None			

Material Properties

Limestone Headwall

"Limestone Headwall" Properties					
Color					
	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max
Normal Restitution	0.32	Normal	0.04	0.12	0.12
Tangential Restitution	0.71	Normal	0.04	0.12	0.12
Dynamic Friction	0.55	Normal	0.04	0.12	0.12
Rolling Friction	0.15	Normal	0.02	0.06	0.06

"Limestone Headwall" Advanced Properties	
Forest and Vegetation Damping	Disabled
Scarring	Disabled
Viscoplastic Damping	Disabled

Limestone Scree / Blast Pile

"Limestone Scree / Blast Pile" Properties					
Color					
	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max
Normal Restitution	0.32	Normal	0.04	0.12	0.12
Tangential Restitution	0.71	Normal	0.04	0.12	0.12
Dynamic Friction	0.55	Normal	0.04	0.12	0.12
Rolling Friction	0.3	Normal	0.04	0.12	0.12

"Limestone Scree / Blast Pile" Advanced Properties	
Forest and Vegetation Damping	Disabled
Scarring	Disabled
Viscoplastic Damping	Disabled

Berm Properties

Berm

"Berm" Properties					
Berm Property			Calculate Impact		
	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max
Normal Restitution	0.31	Normal	0.04	0.12	0.12
Tangential Restitution	0.82	Normal	0.04	0.12	0.12
Dynamic Friction	0.55	Normal	0.04	0.12	0.12
Rolling Friction	0.6	Normal	0.01	0.03	0.03

Seeders

Seeder 1

Seeder Properties					
Name	Seeder 1				
Location	(366.167, 6931.79), (392.116, 6948.01)				
Rocks to Throw					
Number of Rocks	3000 Overall				
Rock Types	Small Blocks,	Medium Blocks,	Large Blocks		
Initial Conditions					
	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max
Horizontal Velocity (ft/s)	6	Normal	2	6	6
Vertical Velocity (ft/s)	0	None			
Rotational Velocity (deg/s)	0	None			
Initial Rotation (deg/s)	0	Uniform		0	360

Rock Types

Small Blocks

Properties					
Name	Small Blocks				
Color					
Smooth Shapes	Square,	Pentagon,	Rhombus		
Polygons	None				
	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max
Mass (lbm)	2022.2	Normal	2	6	6
Density (lbm/ft3)	150	Normal	3	9	9

Medium Blocks

Properties					
Name	Medium Blocks				
Color					
Smooth Shapes	Square,	Pentagon,	Rhombus		
Polygons	None				
	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max
Mass (lbm)	20227.2	Normal	2	6	6
Density (lbm/ft3)	150	Normal	3	9	9

Large Blocks

Properties					
Name	Large Blocks				
Color					
Smooth Shapes	Square,	Pentagon,	Rhombus		
Polygons	None				
	Mean	Distribution	Std.Dev.	Rel. Min	Rel. Max
Mass (lbm)	93642	Normal	2	6	6
Density (lbm/ft3)	156.07	None			

Collectors

Record paths' first impacts only?	No
Collector 1	
Name	Collector 1
Location	(111.848, 6685.46) to (112.031, 6718.94)
Collector 2	
Name	Collector 2
Location	(150.83, 6689.04) to (150.86, 6766.9)
Collector 3	
Name	Collector 3
Location	(126.142, 6684.2) to (126.306, 6718.94)