RULE 6.5 GEOTECHNICAL STABILITY EXHIBIT
MARTIN MARIETTA MATERIALS
SPECIFICATION AGGREGATES QUARRY AMENDMENT
DRMS PERMIT NO. M1974-004
JEFFERSON COUNTY, COLORADO

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Martin Marietta Manager of Geology/Survey

April 5, 2022

Introduction

The Specification Aggregates Quarry is located in Jefferson County, Colorado, to the north of Interstate 70 near Jackson Gulch on the east flank of the Rocky Mountain Front Range (Figure 1), approximately 3 miles south of downtown Golden, Colorado. The natural topography of the property increases significantly in elevation to the west, with elevations within the current and planned mining pit that vary from approximately mean sea level elevation (EL) 6,425 feet (ft) along the quarry's eastern boundary to approximate EL 7,110 ft on the western boundary. Aggregate reserves mined from the Specification Aggregates Quarry site are derived from Precambrian metamorphic rocks.

The Specification Aggregates Quarry was initially owned and mined by Holloway Companies, who operated the quarry from 1971 until 1979. The quarry was purchased by Mobile Premix, a part of Western Mobile, Inc., in 1979, who operated the quarry until 2002 when Western Mobile, Inc. was purchased by Lafarge West, Inc. The quarry is currently operated by Martin Marietta who acquired the quarry in 2012. Geotechnical monitoring of the quarry was started in 1996 by Lachel & Associates (a Schnabel Engineering company), and has been conducted biannually since that time. The planned reclamation program includes water storage, as approved by Technical Revision Number 3 to permit No. M1974-004, and open space.

Martin Marietta is submitting a 2022 application to amend the Specification Aggregates Quarry mining permit to expand the mining area to the south onto land currently owned by Jefferson County Open Space and to increase the depth of mining to EL 5,400 ft. As part of that amendment process, the Colorado Department of Reclamation, Mining and Safety (DRMS) requires that the applicant submit a geotechnical stability report for the quarry meeting the requirements of Rule 6.5 of the Mineral Rules and Regulations of the Colorado Mined Land Reclamation Board for the Extraction of Construction Materials as amended in 2019 (Rule 6.5). As required by Rule 6.5, this update addresses the following issues:

- Geologic hazards that have the potential to affect any proposed impoundment, slope, embankment, highwall, or waste pile within the affected area;

- Engineering stability analyses for proposed final reclaimed slopes, highwalls, waste piles and embankments;
- Operational slope configurations; and
- Information to demonstrate that off-site areas will not be adversely affected by blasting.

A Geotechnical Stability Report that includes analysis of proposed final reclaimed slopes, highwalls, and embankments (no final reclaimed waste plies are planned for the site), as well as operational slope configurations for the proposed expansion has been prepared by Schnabel Engineering (Schnabel Report), which is included in **Appendix A** of this report. A Blast Impact Analysis was prepared by Vibra-Tech Engineers, Inc. (Vibra-Tech) for the quarry and proposed expansion area to obtain information to demonstrate that off-site areas will not be adversely affected by blasting. The Vibra-Tech report is included in **Appendix B**.

Site Geology

Geologic information presented in this report is taken from the geology section of the Schnabel Report. The Specification Aggregates Quarry is located on the east flank of the Rocky Mountain Front Range Uplift, at the boundary with the Denver Basin to the east. This region of the Rocky Mountain Front Range Uplift was deformed during the Laramide orogeny in the late Cretaceous and early Tertiary periods. The gneissic bedrock within the quarry is believed to have undergone two to three episodes of deformation during Precambrian time (Gable, 1968). During this time, the bedrock material was intruded by several distinct igneous bodies and dikes. The gneisses are mapped as a series of folds, which are oriented roughly east-west, and have been broken and displaced by faults believed to range in age from Precambrian to Tertiary.

The bedrock within the mined portions of the quarry is mapped as migmatitic quartzo-felspathic gneiss with intrusions of granitic pegmatite veins (Scott, 1972). The granitic gneiss found in the quarry is generally hard and relatively competent. The gneiss varies in color from grayish orange to dark gray, with occasional banding visible along the foliation of the rock. The term foliation refers to the realignment of minerals into a parallel orientation as a result of the intense heat and/or pressure of metamorphism. The rock mass tends to be weakest along the foliation planes, which ultimately results in a discontinuity set parallel to the orientation of the foliation. The foliation orientation is the most prominent discontinuity set identified in the quarry. The foliation undulates across rock exposures in some locations. The rock mass also exhibits several other joint sets that are locally prominent and varied with elevations as mining progress to lower elevation. However, the joints are generally not as regular or as laterally continuous at the foliation.

Two regional fault trends with orientations approximately east-west and north-south, have been mapped within the property by others (Gable, 1968; Scott 1972), and multiple fault orientation measurements have been recorded during Schnabel's site visits since monitoring started in 1996, as shown in Figure 3 of the Schnabel Report. An approximately east-west trending fault is mapped by Gable (1968) across the northern margin of the quarry. This fault is exposed in the northern portion of the main quarry pit (Figure 3 of the Schnabel Report). A second approximately east-west trending fault was previously identified by Schnabel in Jackson Gulch (informally named the Jackson Gulch fault). However, this fault is not mapped by Schnabel due to the uncertainty in the orientation of the fault trace. A mapped fault trending roughly north-south is located within the quarry property and constitutes the boundary between the metamorphosed Precambrian bedrock of the Rocky Mountain Front Range Uplift to the west and Pennsylvanian sedimentary rocks of the Denver Basin to the east (Smith, 1964; Scott, 1972). The quarry property straddles this boundary, with the majority of the processing plant and the entire asphalt plant located east of the fault (Figure 3 of the Schnabel Report). The bedrock material east of the fault is dominantly composed of upturned sandstones and shales of the Fountain Formation (Scott, 1972). West of this fault, the material is mapped as migmatitic quartzo-felspathic gneiss with intrusions of granitic pegmatite veins (Scott, 1972).

Two other approximately north-south trending faults have been exposed in the northern quarry walls, as shown on Figure 3 of the Schnabel Report, and as discussed in a 2013 Lachel report (Lachel, 2013). They roughly parallel the Golden Fault, which is a major fault that bounds the east side of the north-northwest trending hogback immediately east of the quarry property. The exposure of these two faults has remained unchanged since discovery because there are no mining activities in the main pit area.

In the Southern Expansion Area, Gable (1968) mapped a third fault that also trends roughly east-west. This fault was initially exposed during Lachel's 2006 investigation, and was noted by a distinct pegmatite vein that was surrounded by decomposed weak biotite rich gneiss. The fault was exposed in temporary excavation walls along the southwestern and southern margin of the Southern Expansion Area during previous annual inspection site visits by Lachel.

Geologic Hazards

Rule 6.5 requires the identification of geologic hazards that have the potential to affect any proposed impoundment, slope, embankment, highwall, or waste pile within the affected area. A geologic hazard as defined in Rule 6.5 is one of several types of adverse geologic conditions capable of causing damage or loss of property and life. Geologic hazards that may be considered include landslides and debris flows, subsidence, earthquakes and seismicity, tsunamis and seiches, and volcanic activity.

Landslides and Debris Flows

We visually evaluated landslide and debris flow hazards that have the potential to affect any proposed impoundment, slope, embankment, highwall, or waste pile within the affected area. The geologic materials present on slopes at the Specification Aggregates Quarry and adjacent Jefferson County Open Space area proposed for mining are Precambrian migmatitic quartzo-feldspathic gneiss. Some small-scale localized natural rockfalls occur in the area due to weathering and erosion. However, no evidence of natural landslides or debris flows were observed within or adjacent to the mining and expansion areas that would be indicative of a potential hazard to proposed structures. If improperly designed, failures of mine slopes can affect proposed impoundments, embankments, highwalls, or waste piles. Mine slopes are being designed with ultimate factors of safety appropriate to minimize potential adverse impacts. Reclamation slopes are being designed with a static factor of safety of 1.5 or greater, and a seismic factor of safety of 1.3 or greater. Working slopes are being designed with a static factor of safety of 1.3 or greater, and a seismic factor of safety of 1.1 or greater. Mining activities are unlikely to decrease global stability outside of the mining area.

Earthquakes and Seismicity

There is no evidence that the faults on or within one-mile of the Specification Aggregates Quarry and expansion area are active (evidence of movement in the past 10,000 years) or potentially active (evidence of movement in the last 1.6-million years). The design Peak Ground Acceleration (PGA) for the site was derived from the 2021 USGS online Unified Hazard. The USGS Unified Hazard Tool predicted a PGA of 0..1337g for an earthquake with a return period of 2475 years (2% chance of occurrence in 50 years). The predicted PGAs are unlikely to affect proposed impoundments, slopes, embankments, highwalls, or waste pile within the affected area.

Volcanic Activity

There are no known active volcanic features in the region with the potential to affect any proposed impoundment, slope, embankment, highwall, or waste pile within the affected area.

Tsunamis and Seiches

Tsunamis and seiches are not a potential hazard since there are no bodies of water in the vicinity of the site large enough to generate those phenomena.

Subsidence

There has not been documented underground mining under the site, and the subsurface geology is not conducive to the formation of karst features, so subsidence is unlikely.

Engineering Stability Analyses

Schnabel Engineering prepared a Geotechnical Stability Report, included in **Appendix A** of this report, that includes analysis of proposed final reclaimed slopes, highwalls, and embankments (no final reclaimed waste plies are planned for the site), as well as operational slope configurations for the quarry. Schnabel performed kinematic structural discontinuity analyses and limit equilibrium slope analysis for the Specification Aggregates Quarry to predict the stability of the planned quarry slopes. Schnabel's analysis focused on the northern portion of the expansion area (Area 1), but also considered the predicted stability for the balance of the expansion area (Area 2).

Schnabel's analysis for the Spec-Agg Quarry Area 1 Expansion does not indicate any immediate concerns with respect to large-scale instabilities in the planned final quarry wall faces. They concluded that while the 1:1 (Horizontal:Vertical) slope configuration indicates fewer kinematically admissible failures and a higher global factor of safety, the steeper ½:1 (H:V) slope angle also indicates that global stability is met. Given the planned 35 -foot bench height to be used during excavation, Schnabel does not anticipate either of the slope angles as having large-scale instabilities.

Schnabel went on to write that while their field observations and analysis of structural discontinuities presented in the Schnabel Report consider Area 1, they anticipate similar geologic conditions and structure to be present in Area 2. However, the conditions present in Area 2 must be verified prior to mining below the point where permanent benches will be left. Additionally, the zone of Area 1 may be subject to expansion if similar conditions are observed between observations discussed in their report and Area 2.

The Schnabel Report states that stability of the slopes is anticipated to be enhanced by the absence of significant hydrostatic pressure, by planned mining procedures to be used in Area 1, and by the planned reclamation process being implemented by Martin Marietta in the active mining portion of the site. While large-scale failures are not anticipated, the slopes will likely experience minor raveling as a result of small-scale planar, wedge, and toppling failures, particularly in the bench faces prior to reclamation. They recommended that excavation into Area 1 be observed by Schnabel personnel to confirm the assumptions used in their analyses.

The operator of the Specification Aggregates Quarry has continuously monitored the geologic conditions at the quarry since at least 1998 to ensure that the required factors of safety for slope stability are met as the mine progresses. Martin Marietta will continue to provide a Structural Geology Evaluation annually to DRMS. Martin Marietta will verify the conditions in Area 2 once safe entry can be made into the area and prior to mining below the point where permanent benches will be left (approximately mean sea level 6,500 feet in elevation). Any supplemental data and design changes, if needed, will be submitted to DRMS as a technical revision.

Off-site Impacts from Blasting

Blasting is currently being performed at the Specification Aggregates Quarry. All blasting is currently performed by a United States Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATFE) licensed third-party blasting contractor. A blast plan prepared in accordance with Code of Federal Regulations (CFR) 30, Part 56 Subpart E - Explosives and Office of Surface Mining Reclamation and Enforcement (OSM) Blasting Performance Standards is in place for blasting operations. Martin Marietta has performed in excess of 500 blasts on the site since acquiring it in 2012, with no reports of offsite damage and no recorded exceedances of allowable vibration limits.

General Blasting Procedures

Blast holes are typically loaded the day a blast is scheduled. Explosives are transported to the site by the blasting contractor on the day a blast is scheduled, any excess explosives are transported from the site after all blast holes are loaded, and no explosives are stored on the site. Personnel at the quarry prepare each area to be drilled and blasted according to the mining plan for the quarry development. The quarry manager works with the blasting contractor to design an appropriate drill pattern to ensure safe and efficient production in each area of the quarry. The drill pattern design includes burden and spacing, hole depth, number of holes, explosive densities, shot sequencing, stemming, and other factors. Drilling is performed using a rotary hammer shothole drill using either a top-hammer or down-hole-hammer. Drilling is conducted using a Martin Marietta employed driller and drill or an outside drilling contractor. Blasting is performed using conventional mining-type bulk explosives to include ammonium nitrate and fuel oil (ANFO); an emulsion of liquid ammonium nitrate and diesel fuel; or a blend of the two. Blasts are initiated using computer-controlled electronic detonators that are programable and require that a unique code be sent to them to detonate.

A blast notification sign is present at the quarry entrance to notify personnel entering the site as to whether a blast is scheduled for that day. On days when a blast is scheduled, onsite personnel are notified as to the scheduled blast time. Additionally, the quarry manager contacts the local fire and police department dispatch prior to a blast.

Prior to blasting, quarry personnel, visitors, vendors, and customers are removed from the mining area. The site manager or lead blaster inspect the mining area to confirm all personnel have cleared from the blast area. Blast guards are posted at the entrance to the blasting area to make sure that access corridors through the active mining area are secure during the blast process. Blast guards are in contact with the lead blaster via radio on a channel to be determined at the time the blasting operation begins. Blast guards have the authority to stop the blast at any time, up to the time when the blast is initiated. Audible blast signals are utilized prior to the blast according to the following schedule:

- 2 minutes before the blast
- 30 seconds before blast

Once all personnel are accounted for, all blast guards are in place, and the blast area has been confirmed to be clear, the lead blaster initiates the blast.

After the blast, the lead blaster re-enters the blast area to inspect it and verify that all holes were detonated. No one is allowed back into the mining area until the lead blaster has inspected the blast and confirmed that it is safe to resume work. At that time the 'All Clear' audible signal sounds and the blast guards release their blocks. Personnel are then be allowed back into the mining area and operations return to normal.

A misfire is the complete or partial failure of a blast hole to detonate as planned. Due to advancements in blast technology, misfires rarely happen. However, in the event of a misfire the lead blaster will not allow normal activities to resume in the blast area. The lead blaster will wait 30 minutes before completing a more thorough investigation of the cause of the misfire. Depending on the location of the blast, the lead blaster, at their discretion, can release areas not in the immediate area of the blast while waiting the required 30 minutes.

If it is found that the misfired detonator can be re-shot, the blast area will be cleared again, blast guards reestablished, the blast warning procedure will be reinitiated, and the detonator blasted. If the detonator cannot be blasted, the area will be secured, and all mining personnel warned of the hazard. The area will be carefully excavated under the supervision of the lead blaster or Quarry Manager until the blasting cap and booster is located and rendered safe.

Vibration Monitoring

Regulatory limits have been set for ground vibration, expressed as peak particle velocity (PPV) and air overpressure (AO) to control potential damage to offsite structures due to blasting. Blasts are monitored to verify that these limits are not exceeded. Each blast at the Specification Aggregates Quarry is monitored through a combination of a drone equipped with a video camera and six seismic monitoring stations located at or outside the Specification Aggregates Quarry property boundary, between the mining area and the structures closest to the quarry at the locations in Table 1, and as shown on Figure 1. The six seismic monitors are monitored by VibraTech, a third-party consultant. The blasting limits established for the site are as follows:

Limits on ground vibration (i.e., peak particle velocity) – 0.50 inches per second

Limit on air blast (i.e., peak air pressure) – 133 decibels

Table 1 – Seismic Monitoring Station Locations

Station Name	Latitude	Longitude
Gateway Plaza	N39^{O} 42" 13.2'	W105^{O} 12" 23'
Highway 40 Exxon	N39^{O} 41" 53.6'	W105^{O} 12" 30'
Avalanche Harley	N39^{O} 42" 17.3'	W105^{O} 12" 23'
Mother Cabrini	N39^{O} 42" 12.29'	W105^{O} 13" 31"
Heritage Farms	N39^{O} 42" 39.87'	W105^{O} 12" 45'
Isern Residence	N39^{O} 41" 40.3'	W105^{O} 12" 34'

Using the current blasting techniques, the predicted PPV and AO at the sites closest to the existing and proposed mining areas (Avalanche Harley and Highway 40 Exxon) will not exceed PPV and AO limits, based on modeling and analysis of blasts from January 2020 to January 2021.

Pre-Blast Survey

Blasting is currently being conducted on the site. Vibra-Tech's Blast Impact Analysis includes an evaluation of the likely effects of vibration and air overpressure from blasting in the expansion area on neighboring structures based on data from the current blasting.

Blast Reports

MARTIN MARIETTA will generate and keep blast reports on file for each blast performed at the quarry. The blasting report will be prepared by the blasting contractor or Martin Marietta blaster, within two business days after the blast. At a minimum, the blast report will include the following:

- Blast number, blast date, and blast time;
- Location of the blast within the quarry;
- Weather at the time of the blast;
- Location of the nearest non-owned structure;
- Seismograph data for the blast; and
- Blast data to include number of blast holes, hole depth, amount and type of explosives used, and cubic yards of material blasted.

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Rule 6.5 Exhibit
Appendix A

Schnabel ENGINEERING
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GEOTECHNICAL STABILITY REPORT

Expansion Area 1 – Slope Stability Specifications Aggregate Quarry Golden, Colorado

Schnabel Reference #21C18002.000
April 12, 2022

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April 12, 202212

Mr. Phillip J. Courtney
Martin Marietta Materials, Inc.
1627 Cole Blvd, Suite 200
Lakewood, CO 80401

Subject: Geotechnical Stability Report, Expansion Area 1 – Slope Stability Specifications Aggregate Quarry, Golden, Colorado; Schnabel Reference 21C18002.000

Dear Mr. Courtney:

SCHNABEL ENGINEERING, LLC is pleased to submit our report for this project. This report includes tables, figures, and appendices with relevant data collected for this study. This study was performed in accordance with our proposal dated November 1, 2021, as authorized by Phillip Courtney on November 12, 2021.

We appreciate the opportunity to be of service for this project. Please call us if you have any questions regarding this report.

Sincerely,

SCHNABEL ENGINEERING, LLC

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KAMI DEPUTY GARDELLA
0048175
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PROFESSIONAL ENGINEER

Ryan L. Coe, PG
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GEOTECHNICAL STABILITY REPORT
EXPANSION AREA 1 – SLOPE STABILITY
SPECIFICATIONS AGGREGATE QUARRY
GOLDEN, COLORADO

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APPENDICES

1.0 INTRODUCTION

Schnabel Engineering (Schnabel) has prepared this Geotechnical Stability Report for the Specification Aggregates (Spec-Agg) Quarry located in Golden, Colorado for the Southern Expansion Area 1 (Area 1). The location of Spec-Agg Quarry is shown in **Figure 1**. The layout of Area 1 and the future planned Area 2 is presented on **Figure 2**. The evaluation of Area 2 will be performed at a later date. This study was conducted at the request of Martin Marietta Materials, Inc. (Martin Marietta), the owner of the quarry, as a requirement for the State of Colorado, Permit Number M-74-004 to expand the quarry beyond the current mine limits. Expansion will generally occur along the southern side of the existing open pit. The evaluation presented herein includes observations and measurements from the quarry that have been obtained annually by Lachel & Associates (a Schnabel Engineering company) staff over the past 24 years (1997-2021), as well as results of the site reconnaissance conducted by Schnabel on December 13, 2021.

2.0 PURPOSE AND SCOPE OF WORK

The purpose of this report is to evaluate the bedrock structural geology and develop preliminary pit wall stability parameters so mining can occur within Area 1 as outlined in the Phase 1 portion of our proposal dated November 1, 2021. This report also presents anticipated slope designs for Area 2. The purpose of this study is as follows:

- Conduct a desktop review of existing data.
- Conduct a site reconnaissance and rock structure mapping of accessible outcrops.
- Conduct digital rock structure mapping using point cloud data provided by Martin Marietta.
- Perform kinematic rock slope stability analyses to identify potential structure-controlled failure modes based on the results of rock structure mapping and domain analysis.
- Perform global limit equilibrium stability analyses to develop estimated factors of safety.
- Develop recommended global slope layback angles for slope sections that do not meet the minimum factor of safety criteria of 1.5.
- Summarize the field observations, mapping data, and structural discontinuity analyses results in a report.

Phase 2 of our work is anticipated to include additional analysis of Area 2, that may include advancing borings to complete downhole measurements, laboratory testing and additional mapping. This work will be completed after Martin Marietta completes the land exchange with Jefferson County, achieves safe access to Area 2 and before pit excavation is below mean sea level Elevation (EL) 6,500 feet in the Southern Expansion Area. This work will be completed to verify our understanding of this area and will be supplemented by ongoing observations of the active mine in similar manner as has been completed over the past 24 years.

3.0 LOCATION AND GEOLOGIC SETTING

The Spec-Agg Quarry is located to the north of Interstate 70 near Jackson Gulch on the east flank of the Rocky Mountain Front Range, approximately 3 miles south of downtown Golden, Colorado (**Figure 1**). The natural topography of the property increases significantly in elevation to the west, with elevations within the planned mining pit area that vary from approximately EL 6,425 feet (ft) along the mine's eastern boundary to EL 7,110 ft on the western boundary.

This region of the Rocky Mountain Front Range was deformed during the Laramide orogeny in the late Cretaceous and early Tertiary periods. The gneissic bedrock within the quarry is believed to have undergone two to three episodes of deformation during Precambrian time (Gable, 1968). During this time, the bedrock material was intruded by several distinct igneous bodies and dikes. The gneisses are mapped as a series of folds, which are oriented roughly east-west, and have been broken and displaced by faults believed to range in age from Precambrian to Tertiary.

The bedrock within the mined portions of the quarry is mapped as migmatitic quartzo-felspathic gneiss with intrusions of granitic pegmatite veins (Scott, 1972). The granitic gneiss found in the quarry is generally hard and relatively competent. The gneiss varies in color from grayish orange to dark gray, with occasional banding visible along the foliation of the rock. The term foliation refers to the realignment of minerals into a parallel orientation as a result of the intense heat and/or pressure of metamorphism. The rock mass tends to be weakest along the foliation planes, which ultimately results in a discontinuity set parallel to the orientation of the foliation. The foliation orientation is the most prominent discontinuity set identified in the quarry. The foliation undulates across rock exposures in some locations. The rock mass also exhibits several other joint sets that are locally prominent and varied with elevations as mining progress to lower elevation. However, the joints are generally not as regular or as laterally continuous at the foliation.

Two regional fault orientations, trending approximately east-west and north-south, have been mapped within the property by others (Gable, 1968; Scott 1972), and multiple fault orientation measurements have been recorded in Schnabel's site visits over the last 24 years, as shown in **Figure 3**.

An approximately east-west trending fault is mapped by Gable (1968) across the northern margin of the quarry. This fault is exposed in the northern portion of the main quarry pit (**Figure 3**).

A second approximately east-west trending fault was previously identified in Jackson Gulch (informally named the Jackson Gulch fault). However, this fault is not mapped due to the uncertainty in the orientation of the fault trace.

A mapped reverse fault trending roughly north-south is located within the quarry property and constitutes the boundary between the metamorphosed Precambrian bedrock to the west and the Pennsylvanian sedimentary rocks to the east (Smith, 1964; Scott, 1972). The quarry property straddles this boundary, with the majority of the processing plant and the entire asphalt plant located east of the fault (**Figure 3**). The bedrock material east of the fault is dominantly composed of upturned sandstones and shales of the Fountain Formation (Scott, 1972). West of this fault, the material is mapped as migmatitic quartzo-felspathic gneiss with intrusions of granitic pegmatite veins (Scott, 1972).

Two other approximately north-south trending faults have been exposed in the northern quarry walls, as shown on **Figure 3** and discussed in a 2013 Lachel report (Lachel, 2013). They roughly parallel the

Golden Fault, which is a major fault that forms the north-northwest trending hogback immediately east of the quarry property. The exposures of these two faults remain unchanged since there are no mining activities in the main pit area.

In the Southern Expansion Area, Gable (1968) mapped a third fault that also trends roughly east-west. This fault was initially exposed during a 2006 investigation, and was noted by a distinct pegmatite vein that was surrounded by decomposed weak biotite rich gneiss. The fault was exposed in temporary excavation walls along the southwestern and southern margin of the Southern Expansion Area during previous annual inspection site visits by Lachel. No apparent large shear zones were observed during our site reconnaissance in Area 1.

All faults observed on the site appear to be inactive.

4.0 PHOTOGRAMMETRY AND POINT CLOUD DATA REVIEW

Aerial photogrammetry and point cloud survey data was reviewed as part of our scope. Aerial photogrammetry and point cloud survey data was provided by Martin Marietta for our review and consideration in our analysis. The following point cloud files were provided:

- Spec_Agg_Spec_Agg_6_21_21_LAZ_WGS_84_UTM_zone_13N_85_765_879_points
- Spec_Agg_Spec_Agg_6_21_21_LAZ_WGS_84_UTM_zone_13N_85_765_879_points
- Spec_Agg_Spec_Agg_Quarry_1_21_22_LAZ_NAD83_2011_Colorado_Central_ftUS_48_023_419_points

The files were inspected in PointStudio software by MAPTEK. The point clouds were analyzed for point density and visually inspected for notable rock structures. Unfortunately, the clouds yielded insufficient point density to accurately pick out notable rock structures and conduct digital kinematic analysis. However, it was discussed with Martin Marietta that they will continue to collect this data and work with Schnabel to refine it for use on future inspections of the active mining area as well as for use in the planned Southern Expansion Area 1 and Area 2.

5.0 FIELD OBSERVATIONS

Field observations were collected on December 13, 2021 and were performed along the ridge south of the quarry within Area 1 and along the northern edge of Area 2, as shown on **Figure 2**. Collection of information included observing rock types and collecting dip and dip direction of outcropping rock. A geological compass was used to obtain discontinuity measurements by directly measuring the discontinuity surfaces. A handheld GPS was used to record the location of data collection points (**Figure 2**).

A total of 111 discontinuity measurements were collected at 22 data collection points (**Figure 2**) and were added to the measurements from previous years. When combined with data collected from previous reports, a total of 3,900 discontinuity orientation measurements were plotted. **Figure 5** presents these data. Contours of data collected during our field observation is shown in **Figure 6**. **Figure 7** represents the mean sets as interpreted from a cluster analysis of the December 13, 2021 data. **Figure 8** represents the December 13, 2021 data with only the East Point data shown. The East Point were separated into their own stereonet during our domain analysis and the data indicating different data sets present.

During our site visit, no major shear zone or fault exposure was observed in the surficial exposures.

No seepage or ponded water was observed during our site reconnaissance.

6.0 ANALYSIS OF STRUCTURAL DISCONTINUITIES

The stability of the rock mass that will form the quarry walls is primarily controlled by the presence of rock discontinuities, such as joints, foliation, and faults. Discontinuities can create surfaces for toppling, sliding, and the intersections of multiple discontinuities can define the boundaries of wedges or blocks that have the potential to slide. The orientations of discontinuity sets vary considerably throughout the quarry. Therefore, it is possible that discontinuity orientations in a specific location of the quarry could deviate from the discontinuity orientations assumed for the analyses presented in this report.

6.1 Evaluation of Discontinuity Measurements

Representative discontinuity orientations for the quarry walls are required in order to evaluate the stability of the rock mass that will form the mine walls. Representative orientations for each discontinuity set observed were developed by analyzing data collected during our field observation. For this expansion report, we evaluated how the data collected during our December 13, 2021 field observation compares with Schnabel's historic dataset and the representative orientations of observed discontinuity sets previously selected for analysis.

We analyzed the discontinuity orientation data using DIPS by Rocscience (2021, version 8.016). The program enables plotting of individual data points, and offers several methods of data analysis, including contouring and cluster analyses.

We plotted the individual data points collected during our field observation over contours for the entire dataset (from all previous years, Lachel, 1998-2022). These comparisons show that the data collected on December 13, 2021 is generally consistent with the representative orientations of discontinuity sets observed in the active mining area collected during annual inspections since 1998. However, based on our cluster analysis of the December 13, 2021 data, there are some deviations from the historic data (**Figure 9**). Joint Sets P-5, P-6 and Foliation Set F-1 emerged strongly from the December 13, 2021 data. Based on the field measurements, P-6's dip decreased from about 63° to 41° relative to previous mean set data. The dip of F-1 decreased from about 33° to 28°. The dip of P-5 increased from about 68° to 73°.

Ultimately, a total of nine (9) discontinuity sets (two foliation sets and seven joint sets) were identified and analyzed for this structural discontinuity analysis. The discontinuity orientations are shown in **Figure 7** and summarized in **Table 6-1** below.

Table 6-1: Representative Discontinuity Orientations

Discontinuity Set	Representative Orientation (Dip/Dip Direction)	
	Previous Data	12/13/21 Data
F-1 (Foliation)	33°/171°	28°/211°
F-2 (Foliation)	22°/300°	15°/101°
P-1 (Joint)	72°/174°	84°/159°
P-2 (Joint)	58°/085°	59°/086°
P-3 (Joint)	68°/256°	86°/256°
P-4 (Joint)	74°/299°	65°/290°
P-5 (Joint)	68°/354°	73°/005°
P-6 (Joint)	63°/029°	41°/032°
P-7 (Joint)	61°/215°	75°/209°

6.2 Slope Geometry

Wall orientations used in this report are based on the mine plan developed by Martin Marietta in December 2003. The wall designations, slope angles, and slope dip directions used to represent the final quarry walls are presented in **Table 6-2** below. The wall orientations are anticipated to be similar in Areas 1 and 2.

Table 6-2: Representative Quarry Wall Orientations

Wall Designation	Slope Angles(1)	Slope Direction of Wall(2)
Southwest Wall 2	45° / 63°	036°
South Wall	45° / 63°	000°
Southeast Wall	45° / 63°	335°
East Wall 2	45° / 63°	270°
East Wall 1	45° / 63°	242°

1 Slope angles are measured relative to the horizontal.
2 Slope orientations are presented as dip directions measured from true north (0°).

6.3 Friction Angle

A representative angle of friction ($\phi + i$) = 33° was used for our kinematic analysis, where "ϕ" is the basic friction angle and "*i*" is the surface roughness angle (Hoek and Bray, 1977). The surface roughness angle is the angle between the basic plane of the joint and the planes representing the surface of undulations on the joint surface. This value was based on the results of the direct shear testing performed as part of the 2003 geotechnical investigation (Lachel, 2003). The test results produced only a basic friction angle, ϕ, and results indicated that the basic friction angle of the discontinuities ranged from 13.7° to 49.3° with a mean value of 28°. These results do not include the two direct shear tests conducted on samples with clay material along the foliation plane, which produced an average friction angle of 5°. A generally accepted and conservative value of 5° was selected for the surface roughness angle, "*i*"

6.4 Kinematic Analysis

We performed kinematic structural discontinuity analyses for each of the representative quarry wall orientations presented in Table 6-2. The analyses were performed to evaluate potential rock slope failure modes controlled by planar rock mass discontinuities based exclusively on the geometric relationships of the discontinuities measured. Potential rock slope failure modes include sliding of wedges formed in the slope by the intersection of two discontinuity planes, sliding of rock blocks along a single planar discontinuity, and toppling rock blocks. The computer program DIPS by Rocscience (2021; version 8.016*)*, was used for the kinematic stability analysis. Inputs for the analyses include the following:

1. Representative discontinuity orientations (dip and dip direction) based on the cluster analysis performed on data collected during the December 13, 2021 site visit (**Table 6-1**).
2. Mine Slope Orientations (dip and dip direction) as presented in **Table 6-2** and shown in **Figure 2**. A total of 5 slope orientations were considered.
3. Estimated Rock Mass Discontinuity Interface Friction Angle. A typical interface friction angle of 33 degrees was considered in all cases for the kinematic analysis, as discussed in Section 6.3.

The kinematic analysis stereonet plots are presented in **Figures 5** through **19**. Representative discontinuity orientations are shown as red lines. The representative discontinuity orientations are based on a cluster analysis performed on the discontinuity measurements made on 12/13/21. The orientation of the slope face for the considered wall is shown as an orange great circle. The friction circle is shown as a black line. The limits of the “critical zone” are defined by the area of overlap between the friction circle and the great circle representing the plane of the slope face and is shown as a light red shaded area. Each kinematic analysis plot is evaluated based on where discontinuities plot in relation to the critical zone. If discontinuities plot within the critical zone they are considered “kinematically admissible” and therefore could slide when the slope face is exposed at the evaluated orientation.

Due to locally varying cut slope geometry within each domain, scatter in the discontinuity data, and assumed friction angle, observed failures may differ from those evaluated in the kinematic analysis.

It should be noted that the slope faces and the discontinuity planes can and do vary and that stereonets provide a general relationship of the plotted discontinuities.

6.4.1 Potential Failure Modes

6.4.1.1 <u>Planar Failure</u>

The following four conditions, defined by Hoek & Bray (1977) and Wyllie & Mah (2004), must be met in order for planar failure to occur:

1. The plane on which sliding occurs must strike parallel or nearly parallel to the slope face. Typically, discontinuity planes with a dip direction within 20 degrees of the slope dip direction are considered.
2. The failure plane must “daylight” in the slope face (i.e., the dip of the failure plane must be smaller than the dip of the slope face).
3. The dip of the failure plane must be greater than the angle of friction of the plane.
4. Release surfaces, which provide negligible resistance to sliding, must be present in the rock mass to define the lateral boundaries of the slide.

On the stereonets, criteria for planar sliding are satisfied when the dip vector of a discontinuity plots within the critical zone (and the dip direction of the discontinuity plane is within 20 degrees of the slope dip direction).

6.4.1.2 <u>Wedge Failure</u>

Wedge failure is characterized by sliding that occurs along the line of intersection of two discontinuities (Hoek & Bray, 1977). According to the analysis method developed by Markland (1972), a wedge failure can occur when the following criteria are satisfied:

1. The plunge of the lines of intersection is less than the dip of the slope face.
2. The plunge of the lines of intersection exceeds the angle of friction.

On the stereonets, Markland’s criteria for wedge sliding are satisfied when the intersection of two discontinuities plot within the critical zone.

6.4.1.3 <u>Toppling Failure</u>

Toppling failures can occur where planes share a similar dip direction to the slope face and where they dip relatively steeply into the slope face. We consider that toppling failures may occur when the dip direction of the discontinuity planes are within about 20 degrees of the cut slope dip direction (lateral limits = 20 degrees). Flexural toppling occurs when layers striking nearly parallel to and dipping into the slope can fail in flexure due to the absence of a sliding plane. Direct toppling occurs when discrete blocks formed by intersecting discontinuities plunging into the slope can overturn like a series of columns. Failure is initiated when the shorter columns near the toe of the slope are allowed to slide due to overturning loads produced by longer columns above. Oblique toppling is likely to occur when the plunge of discontinuity intersections approach vertical and blocks can topple outside of the lateral limits.

6.4.2 Results and Discussion – Area 1

The slope configurations considered in our analysis are shown in **Table 6-2**. We consider these configurations to be most significant from a stability standpoint. P-6 was observed in our field observation. Based on the field measurements, P-6's dip decreased from about 63° to 41° relative to previous mean set data. Set P-6 presents risk to the Southwest Wall 2 configuration contributing to both planar and multiple wedge failures in that domain. The persistence of Set P-6 appears relatively short based on field observations. Longer persistence of Set P-6 could contribute to larger scale instability, particularly in Southwest Wall 2. The persistence of Set P-6 should be verified during excavation at Area 1.

In general, the slope configurations indicate fewer kinematically admissible failures with the 1:1 (H:V) slope angle. The steeper ½:1 (H:V) slope angle indicates more kinematically admissible failures. Given the planned 35 foot bench height to be used during excavation, we do not anticipate either of the slope angles as having large-scale instabilities. However, a Schnabel engineer should be engaged as mining activities begin to confirm the assumptions in our analyses are correct.

Results of our kinematic analysis are shown in **Table 6-3** and in **Figures 10-19**. The table presents the results based on the number of identified sets contributing to the specific failure type.

Table 6-3: Summary of Kinematic Analysis

Wall Designation	Slope Angle	Planar Sliding	Wedge Sliding	Toppling (flexural)	Comments
Southwest Wall 2	45°	1	3	0	Planar sliding comes from Set P-6. Wedge intersections were formed between Sets P-6 and P-4, P-2, and P-1.
	63°	1	5	1	Planar sliding comes from Set P-6. Wedge intersections were formed between Sets P-6 and P-4, P-2, and P-1, Sets P-5 and P-1, and Sets P-2 and P-5. Toppling comes from Set P-7.
South Wall	45°	0	2	0	Wedge failure was formed by the intersections of Set P-6 with P-4 and P-2. No planar or toppling failure plotted as kinematically admissible.
	63°	0	3	0	Wedge failure was formed by the intersections of Set P-6 with P-4 and P-2 and Sets P-4 and P-3. No planar or toppling failure plotted as kinematically admissible.
Southeast Wall	45°	0	1	1	Potential wedge failure comes from the intersection of Sets P-6 and P-4. Toppling is kinematically admissible in Set P-1. No planar sliding plotted as kinematically admissible.
	63°	0	4	1	Potential wedge failure comes from the intersection between Sets P-6 and P-4 and Sets P-2, P-7 and P-5, and Sets P-4 and P-3. Toppling is kinematically admissible in Set P-1. No planar sliding plotted as kinematically admissible.

Table 6-3: Summary of Kinematic Analysis

Wall Designation	Slope Angle	Planar Sliding	Wedge Sliding	Toppling (flexural)	Comments
East Wall 2	45°	0	1	0	One wedge failure is formed between Sets P-5 and P-7. No planar or toppling failure plotted as kinematically admissible.
	63°	0	2	0	Two wedges are formed by the intersection of Sets P-5 and P-7, and Sets P-4 and P-1. No planar or toppling failure plotted as kinematically admissible.
East Wall 1	45°	0	0	0	No planar, wedge, or toppling plotted as kinematically admissible.
	63°	0	2	0	Two wedges are formed by the intersection of Sets P-5 and P-7, and Sets P-4 and P-1. No planar or toppling plotted as kinematically admissible.

6.4.3 Preliminary Results and Discussion – Area 2

While the wall orientations are anticipated to be similar for Areas 1 and 2, additional data is needed to expand the limits of Area 1 or to fully evaluate Area 2. Area 2 expands across a drainage feature and may indicate a fault or shear feature that could alter the orientations seen within the main pit, southern expansion area, and the ridgeline mapped for Area 1.

Despite limited data in Area 2 we have used correlations from our current field mapping and the previous data collected for 24 years within the active mining areas, we have assumed that the orientations in Area 2 are similar to those evaluated for Area 1 therefore yielding the same results presented in **Table 6-3** above and anticipated slope angles. Further evaluation of Area 2 will be performed in Phase 2 to confirm the orientations in Area 2.

7.0 LIMIT EQUILIBRIUM SLOPE ANALYSIS

7.1 Mechanics of Stability

Limit equilibrium analysis take into consideration, material strength, presence and orientation of subsurface materials, surcharge loads, and the slope geometry. The analysis is typically conducted by dividing a potential failure mass into a number of vertical slices and solving the static equilibrium for each slice, resulting in an overall Factor of Safety (FS) for the slope. Slope stability software can consider many variations of a potential failure mass and will report the lowest FS.

7.2 Slope Configuration and Material Properties

Analysis was conducted on the final planned mine configurations. Final mine plan configurations were provided by Martin Marietta in CAD files. It should be noted that the final mine plan considers that both Area 1 and Area 2 have been fully excavated, therefore our analysis evaluates both areas. Three cross sections were taken from the final mine plan along the south and east planned slopes and were analyzed for stability (Sections E, F, and G shown on **Figures 3** and **4** and in Appendices A and B). Two slope configurations were considered in the analysis: a ½:1 (H:V) slope and a 1:1 (H:V) slope. A final water surface elevation of 6,405 feet above mean sea level (msl) was used based on Martin Marietta's provided drawings.

The material strength was considered using the Generalized Hoek-Brown criterion. Inputs for this criterion include the unit weight, unconfined compressive strength (UCS), Geologic Strength Index (GSI), a material constant (m_i), and a disturbance factor. The unit weight and UCS values were taken from the 2003 Lachel Report. A harmonic mean of the 2003 UCS values was used to determine the material UCS. An arithmetic mean was used to determine the unit weight. The GSI is a rock mass classification scheme that uses two inputs, joint surface quality and overall rock structure, to arrive at a value between 0 and 100 with a value of 100 representing the highest quality rock. A GSI of 55 was used in our analysis based on field observations of exposed rock and past photographs. A material constant typical of Gneiss was used. A disturbance factor of 1 was assumed given that the final slope geometry will be created by production blasting and that presplitting of final slopes is not planned.

Seismic slope stability was considered using a pseudo-static approach based on Seed, 1979. In the pseudo-static analysis, a ground motion parameter, k, is selected based on earthquake magnitudes expected at the site. The USGS online Unified Hazard Tool[1] was used to compute earthquake deaggregations based on the Dynamic: Conterminous U.S. 2014 (v4.1.4) edition deaggregations and a 2% exceedance in 50 years over a 2,475-year return period. The location used was latitude 39.700 N, longitude 105.215 W. The seismic site class considered was a B/C boundary (based on ASCE 7-10). The tool returned a PGA of 0.137 and a mean earthquake magnitude of 5.52. Based on Seed, 1979 and the resulting ground motion expected at the site, a k value of 0.1 was considered in the pseudo-static analysis.

7.3 Analysis and Results

A FS of 1.5 was selected based on requirements in the DRMS guidelines for "critical structures". A FS of 1.15 or greater is considered acceptable for short term loading from a seismic event. **Table 7-1** below

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[1] (https://earthquake.usgs.gov/hazards/interactive/)

provides a summary of our global slope stability analyses. For all scenarios evaluated, the FS was met and exceeded.

Table 7-1: Limit Equilibrium Slope Stability

Slope Section	Slope Configuration	Minimum Calculated Factor of Safety[1]		
		Static	Static with Ponded Water Load	Seismic Load
E	1:1 (H:V)	2.6	3.3	2.2
	½:1 (H:V)	1.9	2.3	1.6
F	1:1 (H:V)	2.7	3.6	2.3
	½:1 (H:V)	1.9	2.2	1.6
G	1:1 (H:V)	2.1	3.1	1.8
	½:1 (H:V)	1.6	2.1	1.4

1. A geologist or engineer from Schnabel should observe the cut slopes to verify the conditions used in our analysis.

It should be noted that reducing the GSI to a value of 50 reduces the FS observed in our analyses. We should be contacted as excavation of Area 1 proceeds so as to verify conditions used in our analyses.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The results of the kinematic structural discontinuity analyses and limit equilibrium slope analysis for the Spec-Agg Quarry Area 1 Expansion do not indicate any immediate concerns with respect to large-scale instabilities in the planned final quarry wall faces. While the 1:1 (H:V) slope configuration indicates fewer kinematically admissible failures and a higher global FS, the steeper ½:1 (H:V) slope angle also indicates that global stability is met. Given the planned 35 foot bench height to be used during excavation, we do not anticipate either of the slope angles as having large-scale instabilities.

While our field observations and analysis of structural discontinuities presented in this report consider Area 1, we anticipate similar geologic conditions and structure to be present in Area 2. However, the conditions present in Area 2 must be verified as outlined in the Phase 2 portion of our November 1, 2021 proposal prior to mining below the point where permanent benches will be left. Additionally, the zone of Area 1 may be subject to expansion if similar conditions are observed between observations discussed in this report and the Phase 2 scope of work.

The stability of the slopes is anticipated to be enhanced by the absence of significant hydrostatic pressure, by planned mining procedures to be used in Area 1, and by the planned reclamation process being implemented by Martin Marietta in the active mining portion of the site. While large-scale failures are not anticipated, the slopes will likely experience minor raveling as a result of small-scale failures planar, wedge, and toppling, particularly in the bench faces prior to reclamation. Excavation into Area 1 should be observed by Schnabel to confirm the assumptions used in our analyses.

9.0 LIMITATIONS

We based the analyses and recommendations submitted in this report on the information revealed by our data review, site reconnaissance, and experience with the Spec-Agg Quarry. We attempted to provide for normal contingencies, but the possibility remains that unexpected conditions may be encountered during excavation of Area 1.

This report has been prepared to aid in the evaluation of this site and to assist in the design of the project. It is intended for use concerning this specific project. We based our recommendations on information on the site and proposed excavation as described in this report. Substantial changes in loads, locations, or grades should be brought to our attention so we can modify our recommendations as needed. We would appreciate an opportunity to review the plans and specifications as they pertain to the recommendations contained in this report, and to submit our comments to you based on this review.

We have endeavored to complete the services identified herein in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality and under similar conditions as this project. No other representation, express or implied, is included or intended, and no warranty or guarantee is included or intended in this report, or other instrument of service.

The data and recommendations provided in this report are based on the information obtained from our field observation and data review. However, conditions on the site may vary between the discrete locations observed at the time of our field observation. The nature and extent of variations with subsurface materials may not become evident until during excavation.

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FIGURES

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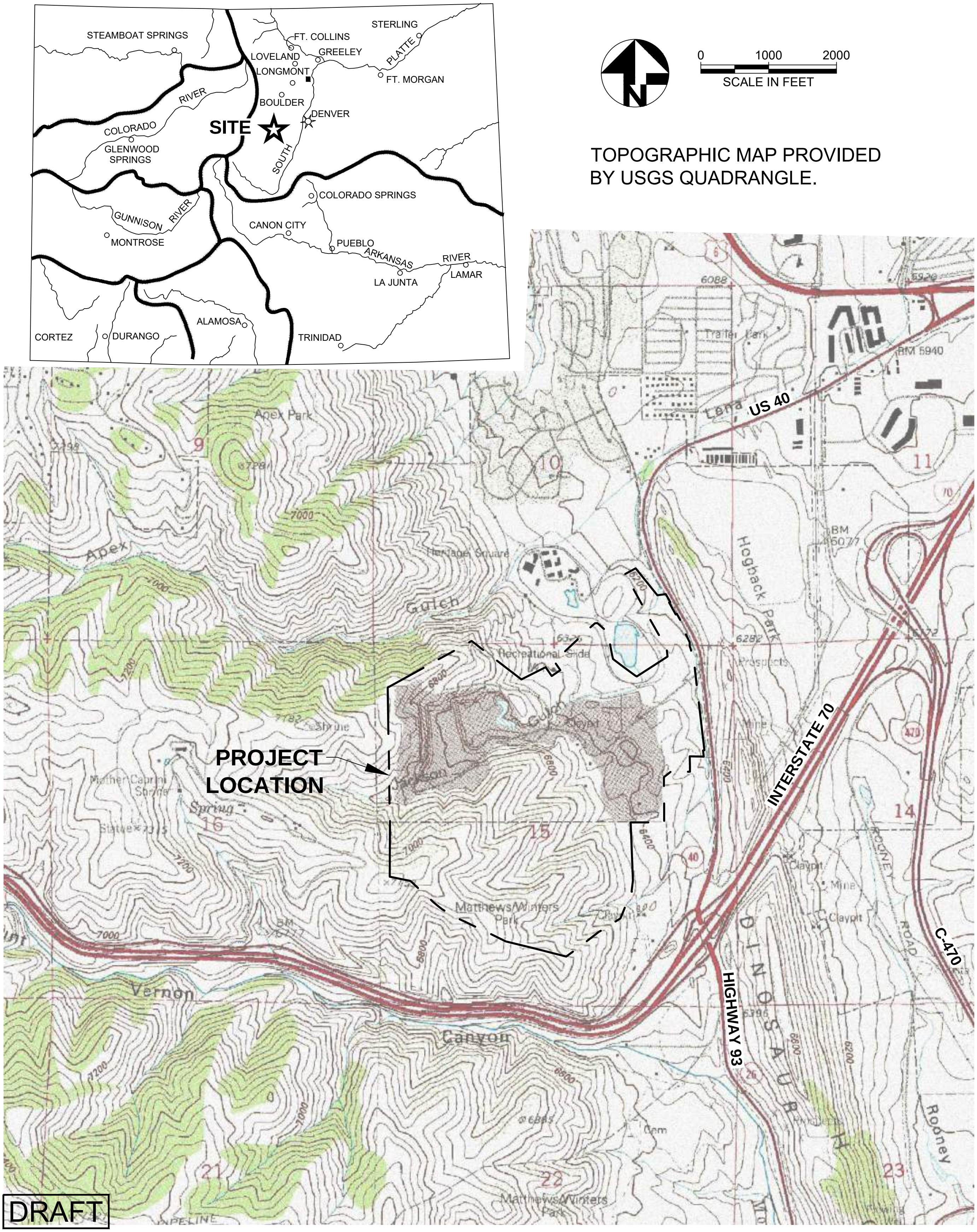

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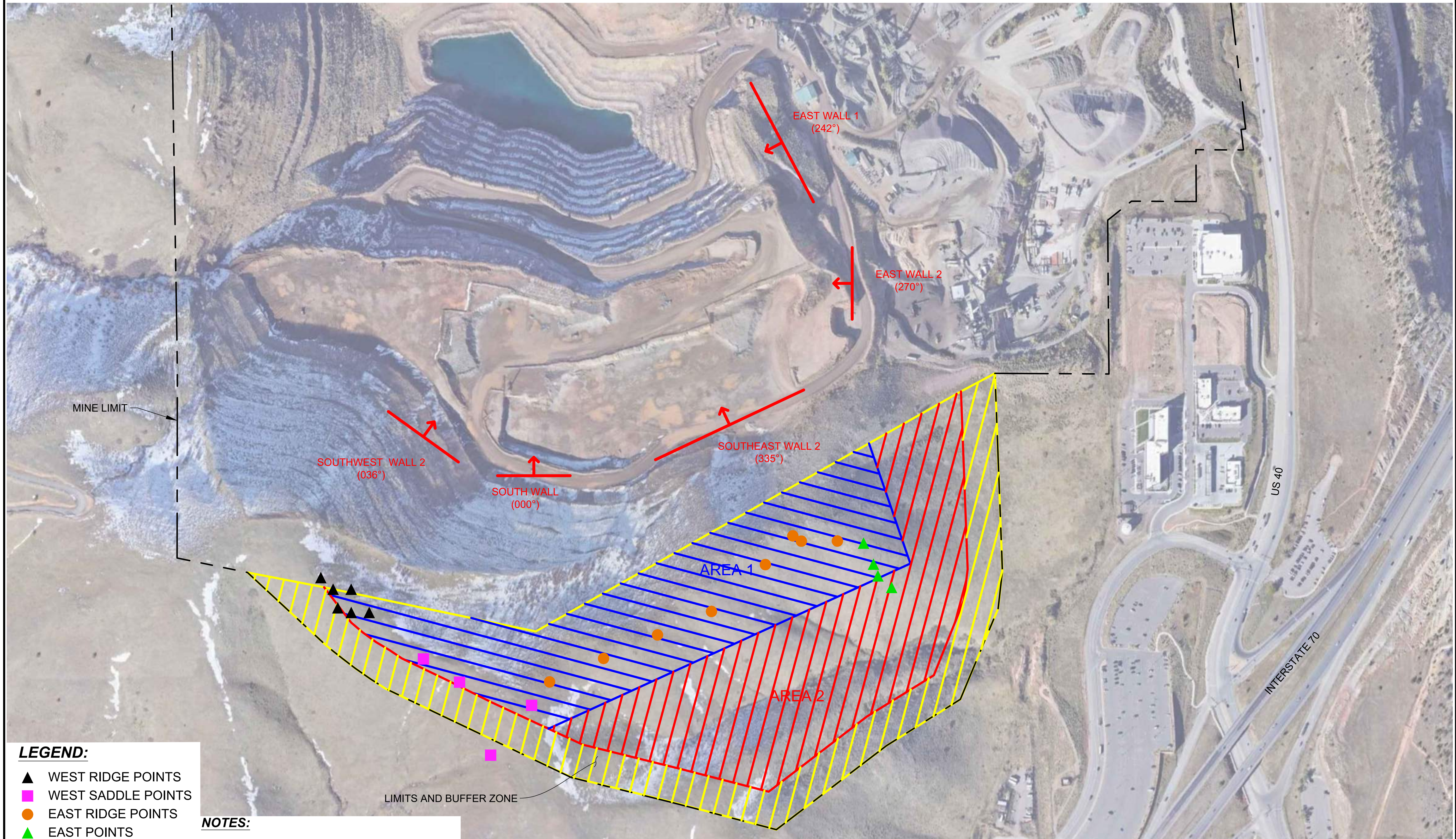
Schnabel ENGINEERING

SPECIFICATIONS AGGREGATE QUARRY
GOLDEN, COLORADO
PROJECT NO. 21C18002.000

SITE VICINITY MAP

FIGURE 1

Rule 6.5 Exhibit
Appendix A



LEGEND:

- WEST RIDGE POINTS
- WEST SADDLE POINTS
- EAST RIDGE POINTS
- EAST POINTS
- WALL ORIENTATION

DRAFT

NOTES:

1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH PRO DATED 10-3-19.
2. AREAS, LIMITS AND BUFFER ZONE PRESENTED IN SCHNABEL ENGINEERING'S PROPOSAL, DATED NOVEMBER 1, 2021.

Schnabel ENGINEERING	SPECIFICATIONS AGGREGATE QUARRY GOLDEN, COLORADO PROJECT NO. 21C18002.000	EXPANSION AREAS FIGURE 2

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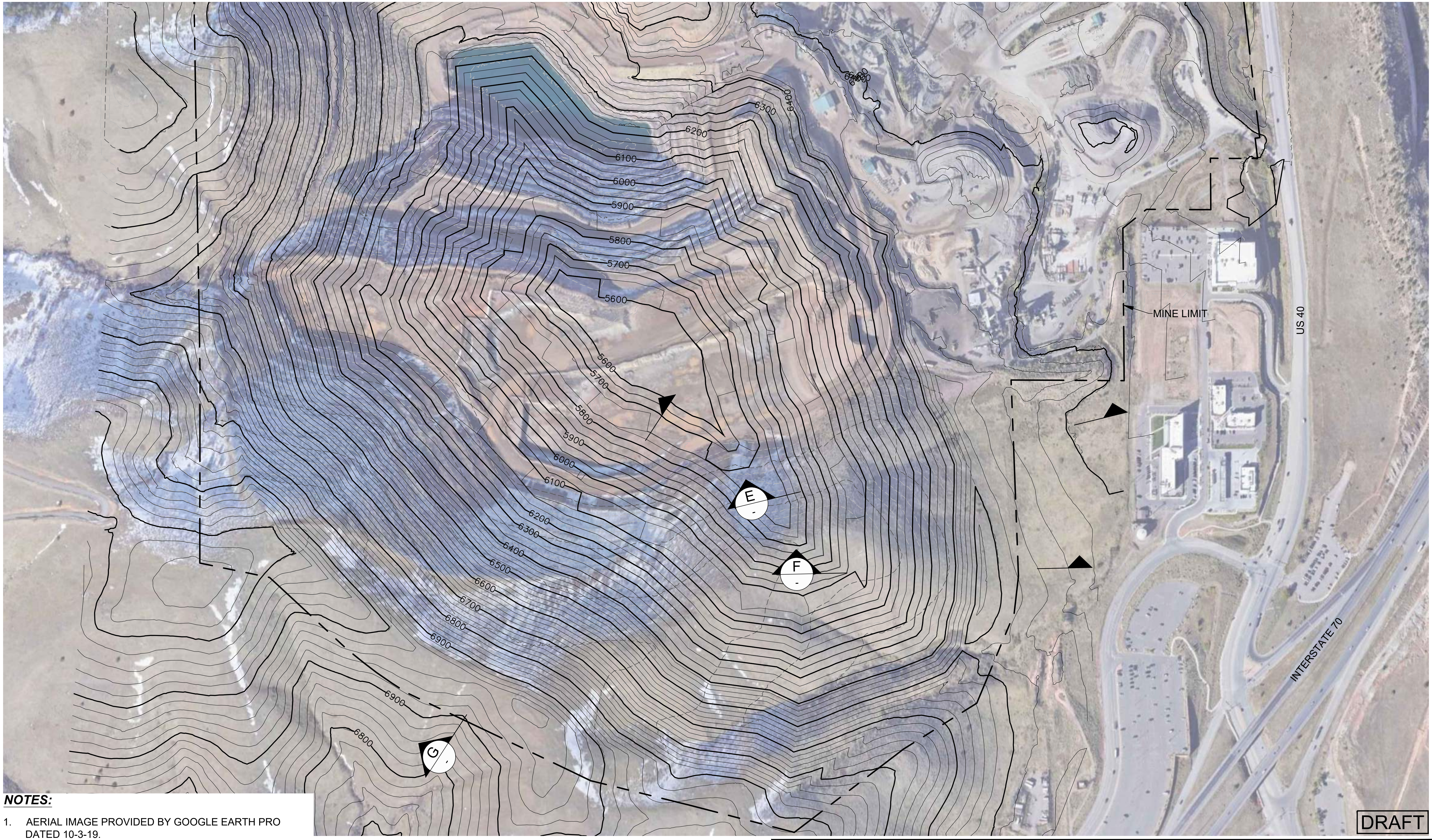


NOTES:

1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH PRO DATED 10-3-19.
2. EXISTING GROUND CONTOURS, MINE CONTOURS AND MINE LIMIT PROVIDED BY MARTIN MARIETTA.
3. 1:1 (H:V) CROSS SECTIONS ARE SHOWN IN THE SLOPE STABILITY SECTIONS PRESENTED IN APPENDIX A.

0 200 400
SCALE IN FEET

Schnabel ENGINEERING

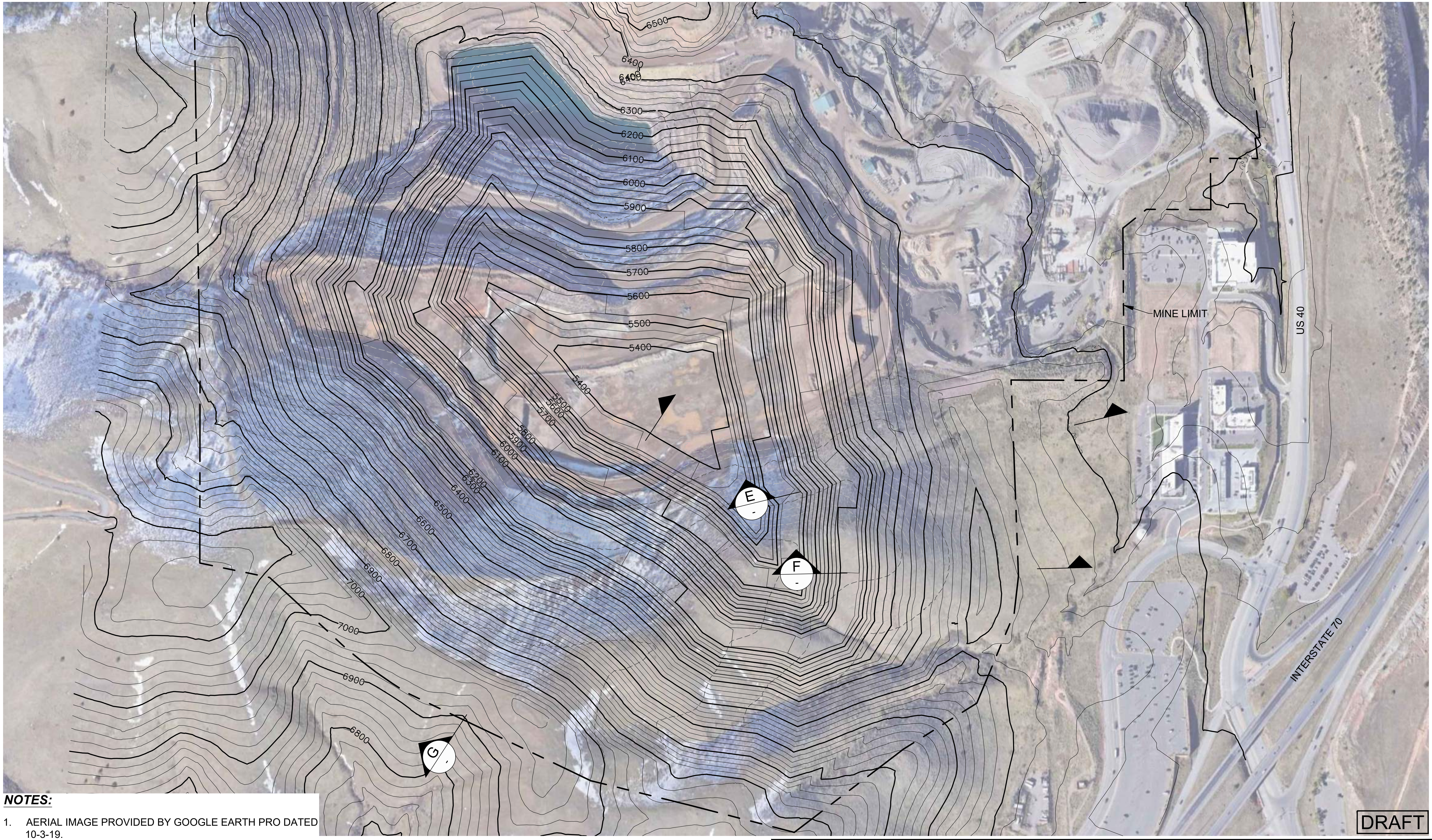
SPECIFICATIONS AGGREGATE QUARRY
GOLDEN, COLORADO
PROJECT NO. 21C18002.000

1:1 (H:V) MINING SLOPES

FIGURE 3

K:\2021\DENVER\21C18002.00_SPEC AGG QUARRY EXPANSION\03_SE_PRODUCTS\08-CAD\04-CONTRACT_DWGS\SPEC AGG XS.DWG

IRECK 2/14/2022 3:51:32 PM



NOTES:

1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH PRO DATED 10-3-19.
2. EXISTING GROUND CONTOURS, MINE CONTOURS AND MINE LIMIT PROVIDED BY MARTIN MARIETTA.
3. 1/2:1 (H:V) CROSS SECTIONS ARE SHOWN IN THE SLOPE STABILITY SECTIONS PRESENTED IN APPENDIX B.

0 200 400
SCALE IN FEET

Schnabel ENGINEERING

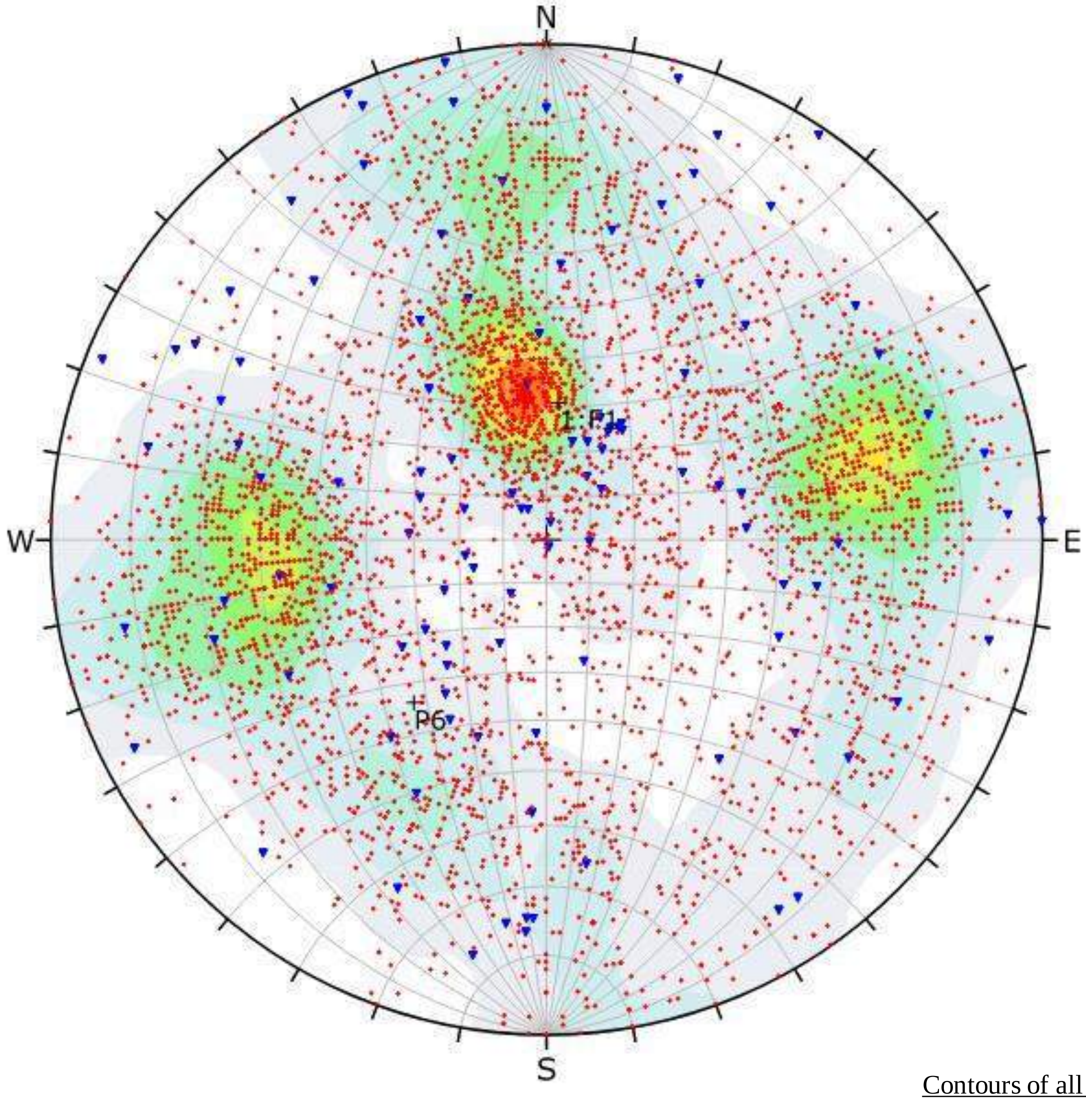
SPECIFICATIONS AGGREGATE QUARRY
GOLDEN, COLORADO
PROJECT NO. 21C18002.000

1/2:1 (H:V) MINING SLOPES

FIGURE 4

K:\2021\DENVER\21C18002.00_SPEC AGG QUARRY EXPANSION\03_SE_PRODUCTS\08-CAD\04-CONTRACT_DWGS\SPEC AGG XS.DWG

IRECK 2/14/2022 3:51:32 PM



Contours of all data
(1997 - 2021, 3900 data points)

Color	Density Concentrations
	0.00 - 0.45
	0.45 - 0.90
	0.90 - 1.35
	1.35 - 1.80
	1.80 - 2.25
	2.25 - 2.70
	2.70 - 3.15
	3.15 - 3.60
	3.60 - 4.05
	4.05 - 4.50
Contour Data	Pole Vectors
Maximum Density	4.16%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	3900 (3900 Entries)
Hemisphere	Lower
Projection	Equal Angle

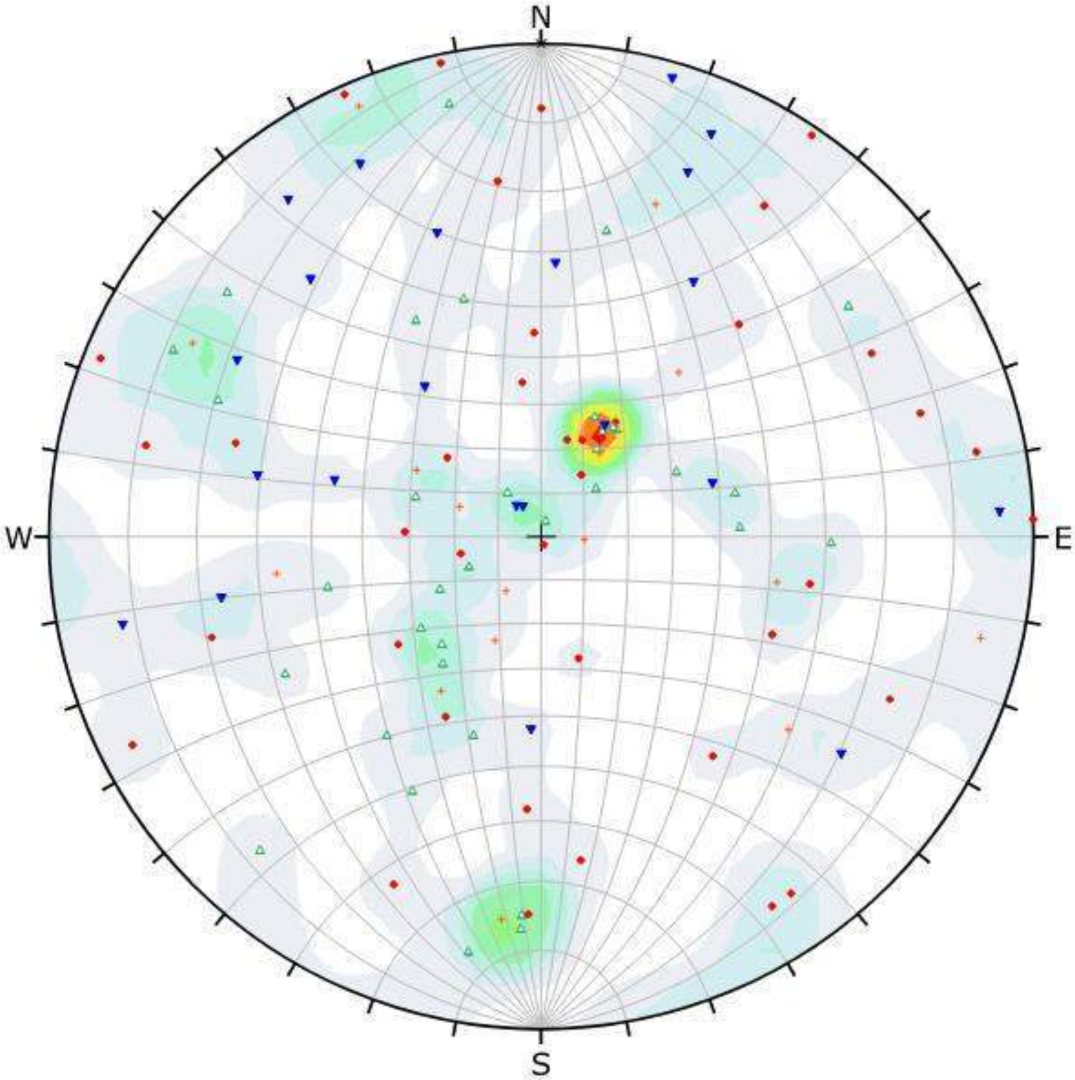
Legend

Equal Area, Lower Hemisphere Stereonet Plot

▲ Measurements taken 12/13/21

● Previous Measurements from Annual Inspections

Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 5 COMPILED DATA PROJECT NO. 21C18002



Contours of 12/13/21 data

Color	Density Concentrations
	0.00 - 0.80
	0.80 - 1.60
	1.60 - 2.40
	2.40 - 3.20
	3.20 - 4.00
	4.00 - 4.80
	4.80 - 5.60
	5.60 - 6.40
	6.40 - 7.20
	7.20 - 8.00

Contour Data	Pole Vectors
Maximum Density	7.60%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	111 (111 Entries)
Hemisphere	Lower
Projection	Equal Angle

Legend

Equal Area, Lower Hemisphere Stereonet Plot

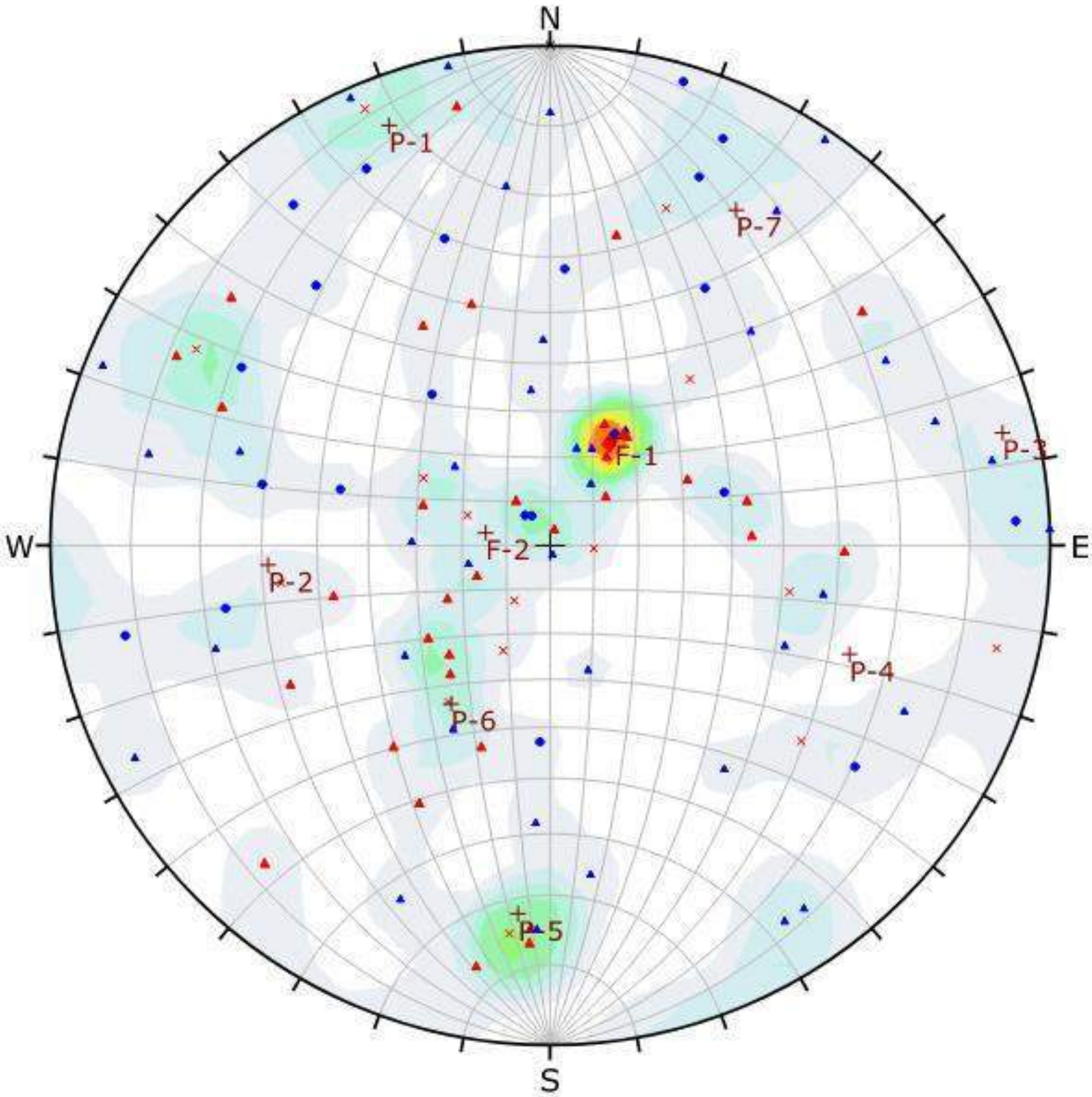
- East Point Measurements
- East Ridge Measurements
- West Ridge Measurements
- West Saddle Measurements

Schnabel ENGINEERING

SPEC-AGG QUARRY EXPANSION
GOLDEN, CO

Martin Marietta

FIGURE 6
12/13/21 DATA
PROJECT NO. 21C18002



Representative Discontinuity Orientations

Discontinuity Set	Set Data
F-1 (Foliation)	28°/211°
F-2 (Foliation)	15°/101°
P-1 (Joint)	84°/159°
P-2 (Joint)	59°/086°
P-3 (Joint)	86°/256°
P-4 (Joint)	65°/290°
P-5 (Joint)	73°/005°
P-6 (Joint)	41°/032°
P-7 (Joint)	75°/209°

Legend

Equal Area, Lower Hemisphere Stereonet Plot

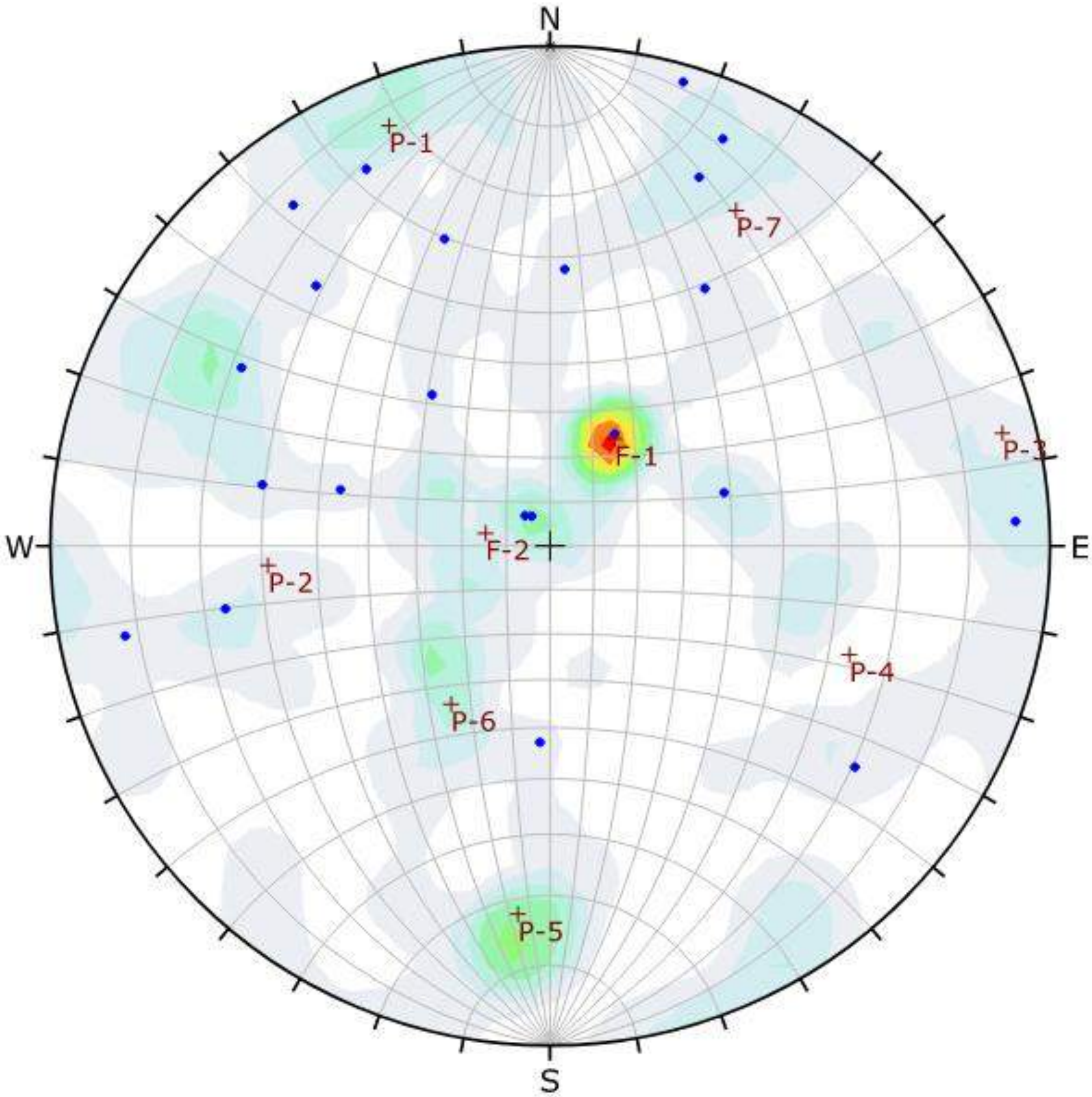
- P-1 Mean Discontinutiy Sets
- East Point Measurements
- East Ridge Measurements
- West Ridge Measurements
- West Saddle Measurements

Schnabel ENGINEERING

SPEC-AGG QUARRY EXPANSION
GOLDEN, CO

Martin Marietta

FIGURE 7
MEAN SET DATA 12/13/21
PROJECT NO. 21C18002



Contours of 12/13/21 data

Color	Density Concentrations
	0.00 - 0.80
	0.80 - 1.60
	1.60 - 2.40
	2.40 - 3.20
	3.20 - 4.00
	4.00 - 4.80
	4.80 - 5.60
	5.60 - 6.40
	6.40 - 7.20
	7.20 - 8.00
Contour Data	Pole Vectors
Maximum Density	7.60%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	111 (111 Entries)
Hemisphere	Lower
Projection	Equal Angle

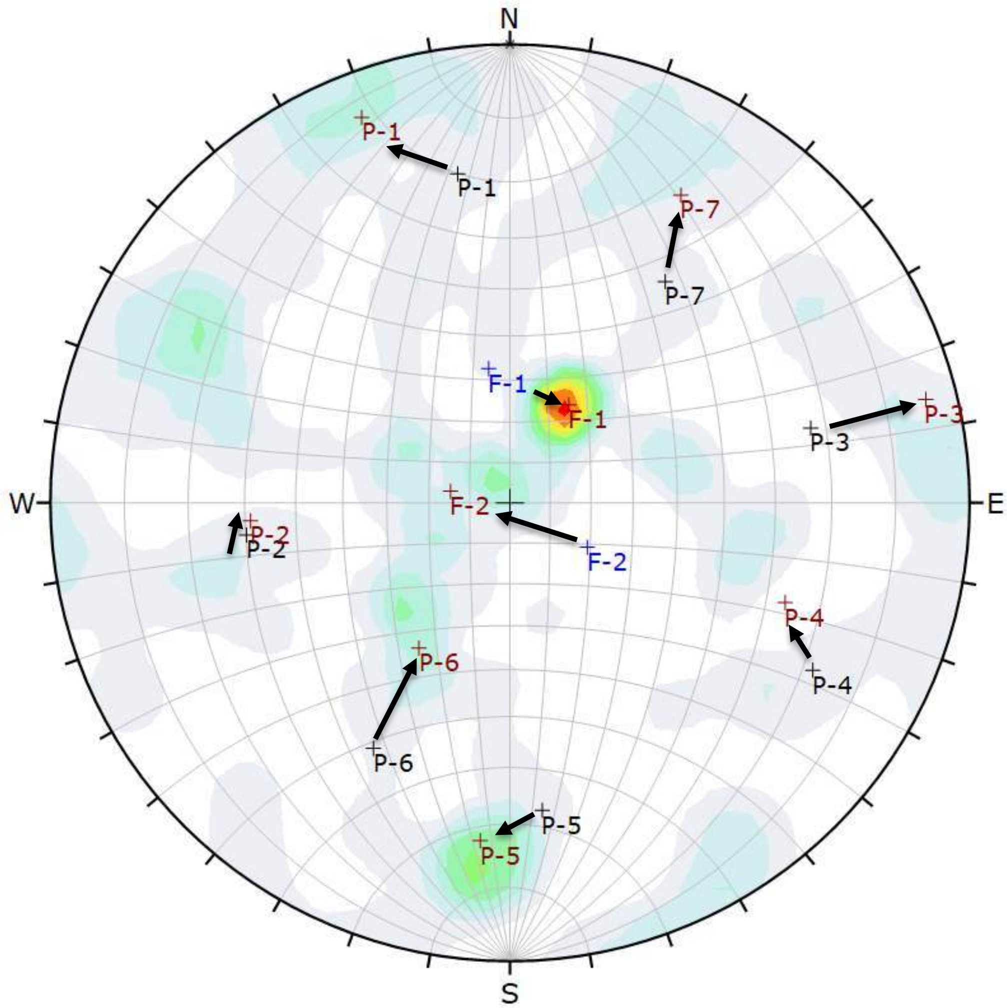
Legend

Equal Area, Lower Hemisphere Stereonet Plot

P-1 Mean Joint and Foliation Sets

● East Point Measurements

Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 8 EAST POINT DATA PROJECT NO. 21C18002



Legend

Equal Area, Lower Hemisphere Stereonet Plot

P-1 Previous Mean Joint Set Data

P-1 12/13/21 Mean Set Data

F-1 Previous Mean Foliation Set Data

← Deviation from Previous Data

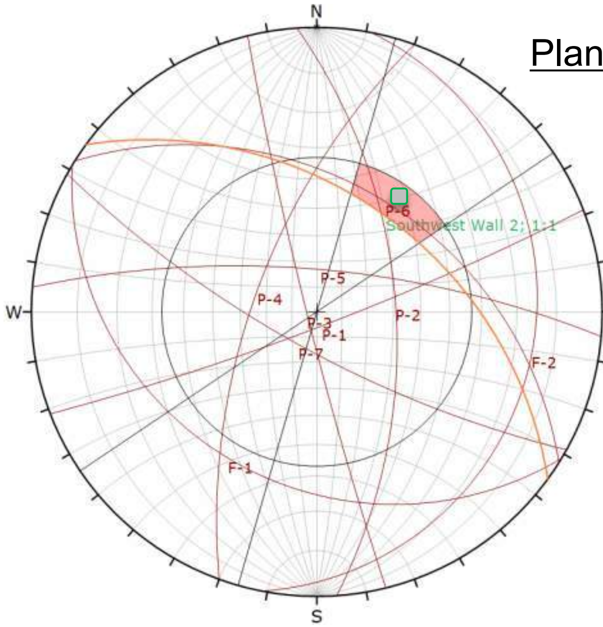
Contours of 12/13/21 data

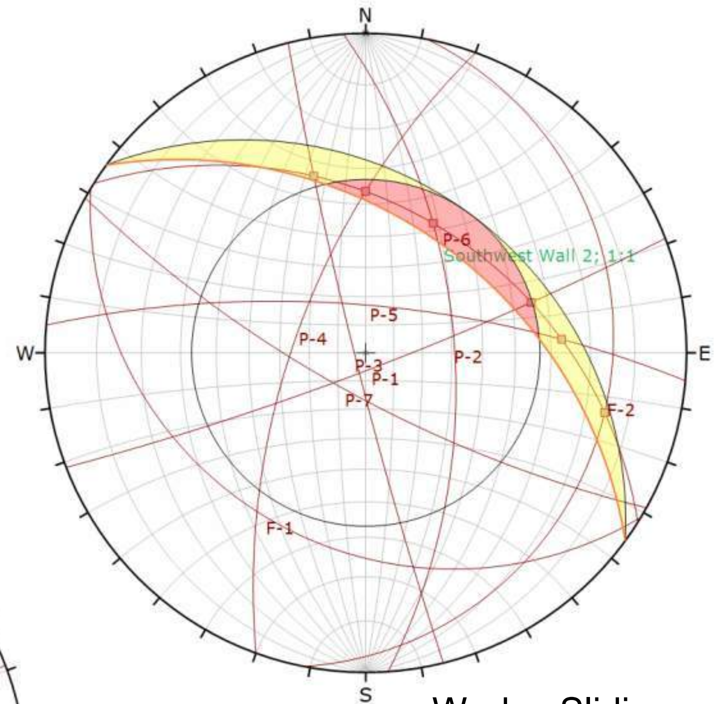
Color	Density Concentrations
	0.00 - 0.80
	0.80 - 1.60
	1.60 - 2.40
	2.40 - 3.20
	3.20 - 4.00
	4.00 - 4.80
	4.80 - 5.60
	5.60 - 6.40
	6.40 - 7.20
	7.20 - 8.00
Contour Data	Pole Vectors
Maximum Density	7.60%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Plot Mode	Pole Vectors
Vector Count	111 (111 Entries)
Hemisphere	Lower
Projection	Equal Angle

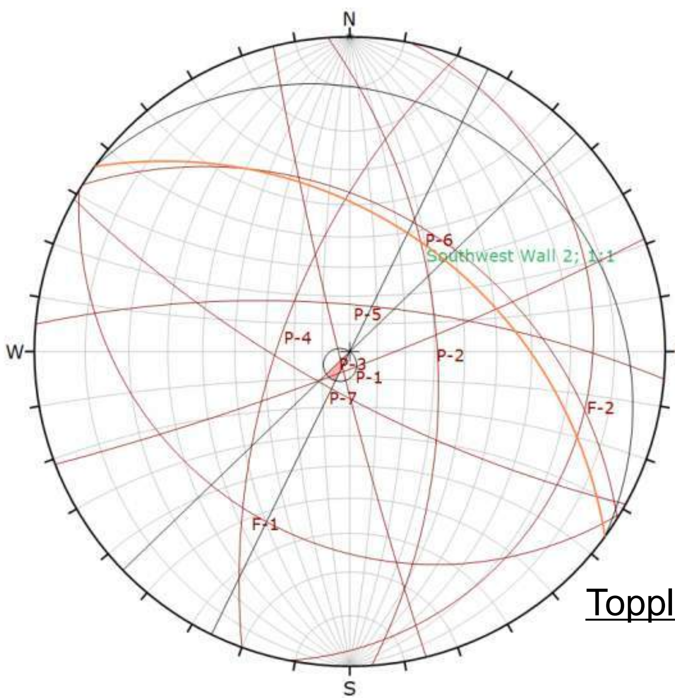
Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 9 DEVIATION OF MEAN SETS PROJECT NO. 21C18002

Planar Sliding





Wedge Sliding



Toppling

Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

Domain

Southwest Wall 2
(45º/036º)

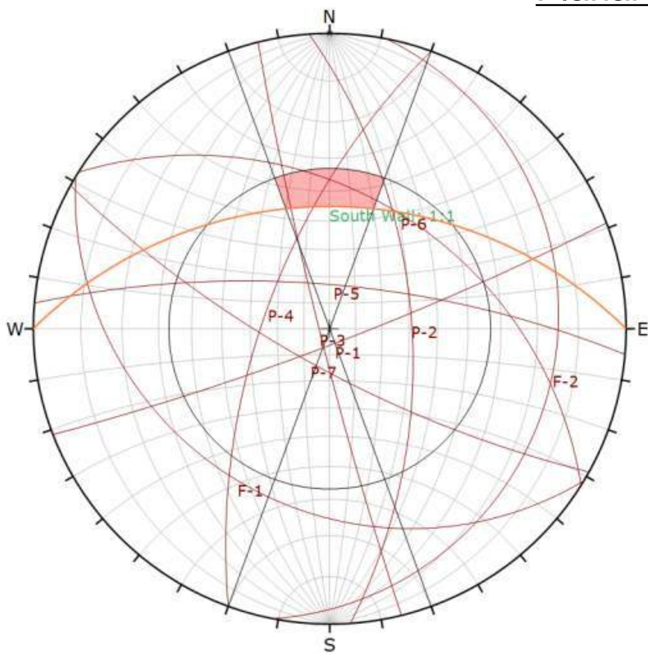
Schnabel ENGINEERING

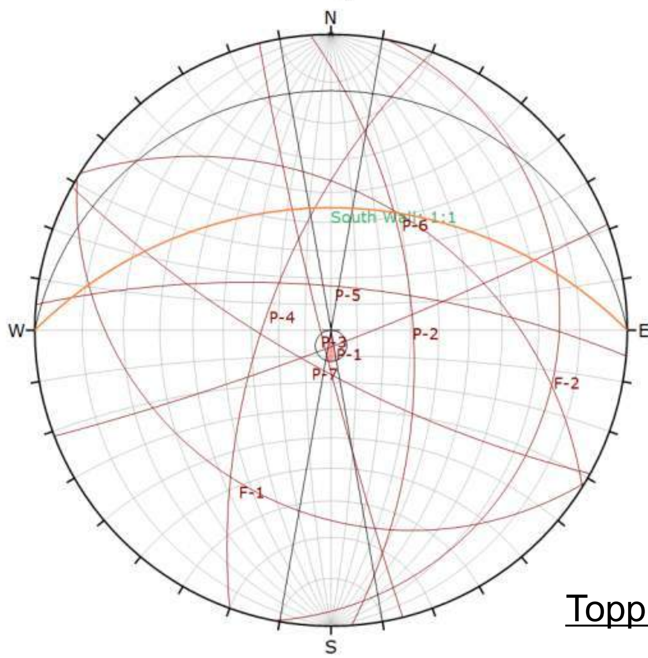
SPEC-AGG QUARRY EXPANSION
GOLDEN, CO

Martin Marietta

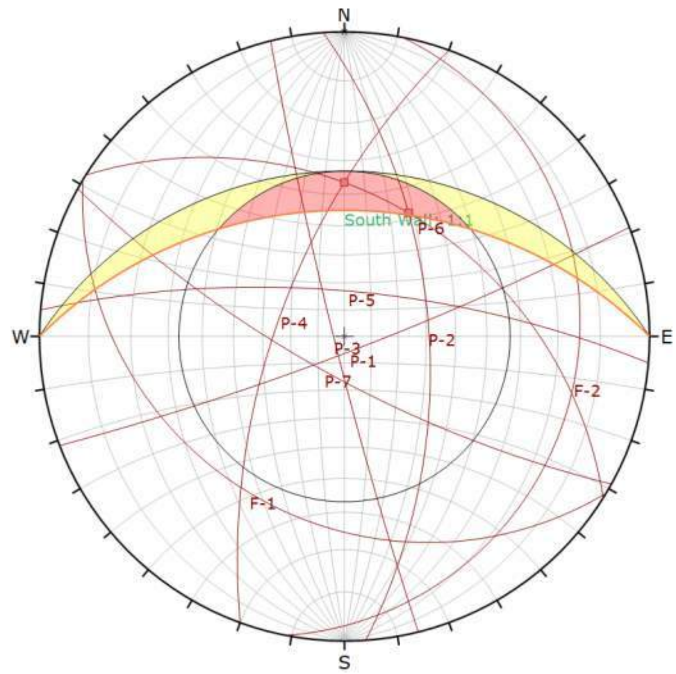
FIGURE 10
KINEMATIC ANALYSIS:
SOUTHWEST WALL 2, 45°
PROJECT NO. 21C18002

Planar Sliding





Wedge Sliding



Toppling

Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33˚

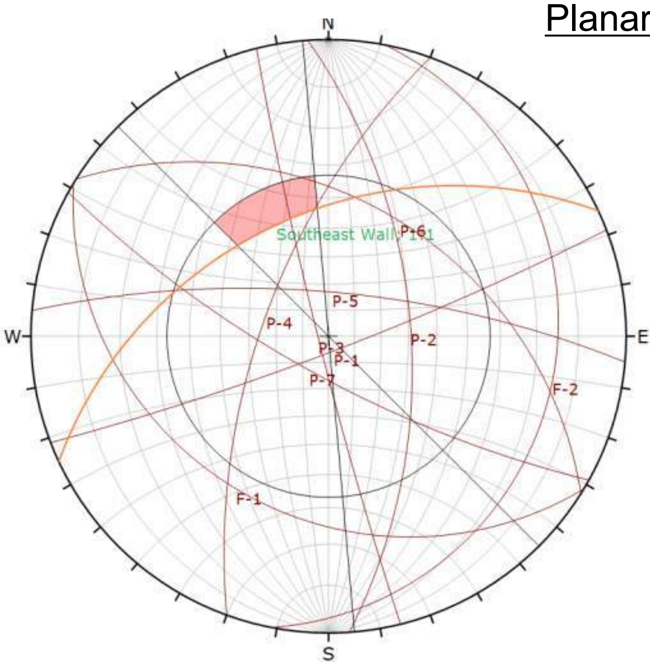
- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

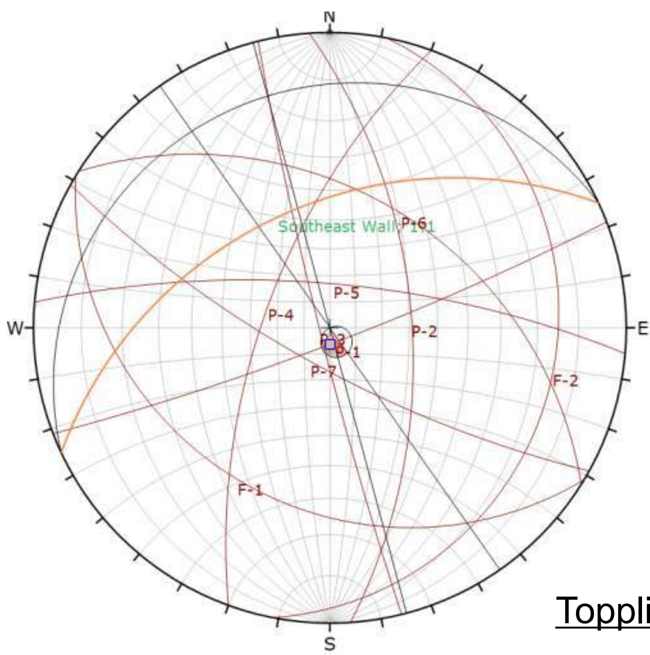
Domain

South Wall
(45º/000º)

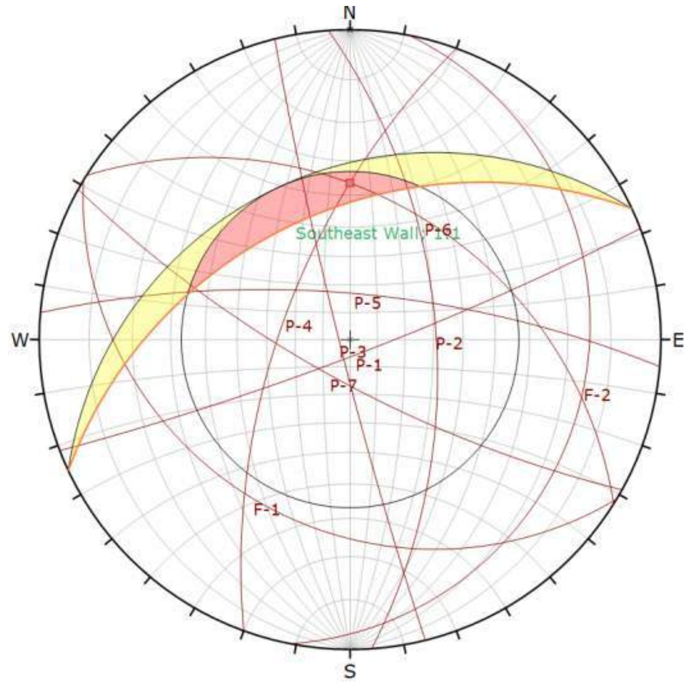
Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 11 KINEMATIC ANALYSIS: SOUTH WALL , 45˚ PROJECT NO. 21C18002

Planar Sliding





Wedge Sliding



Toppling

Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33˚

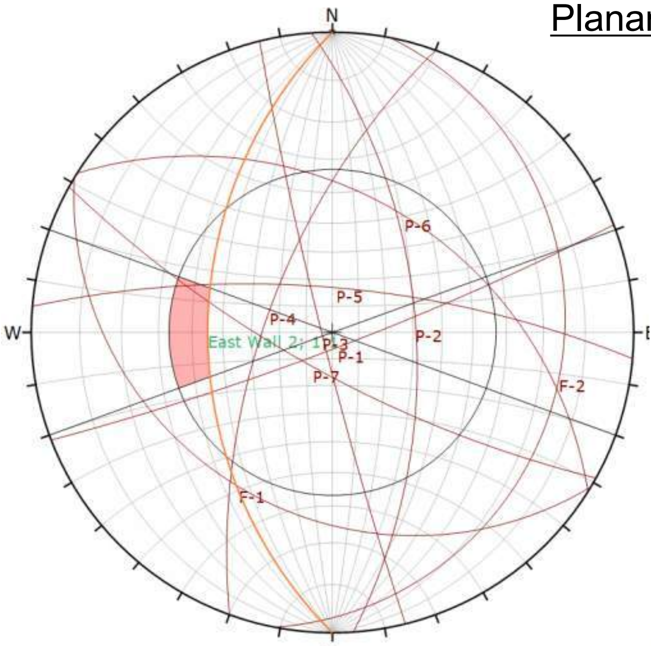
- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

Domain

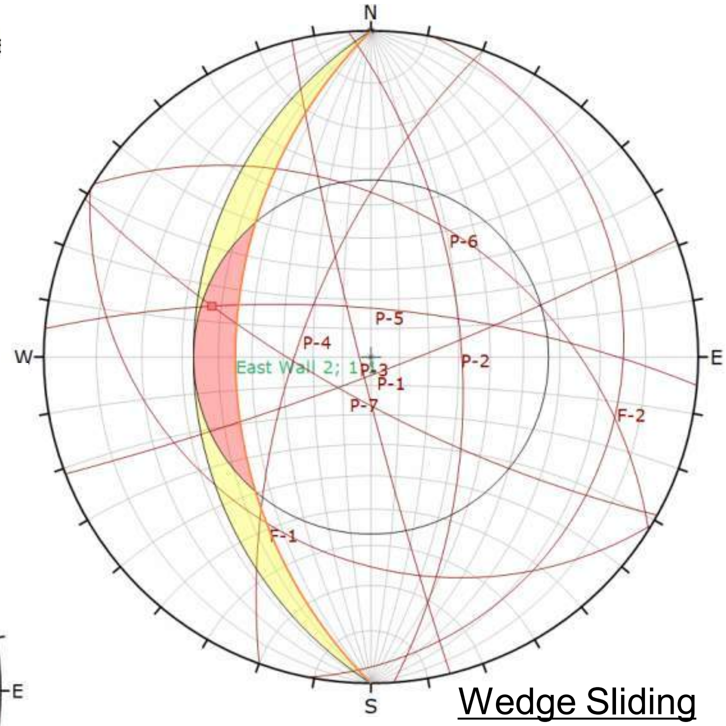
Southeast Wall
(45º/335º)

Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 12 KINEMATIC ANALYSIS: SOUTHEAST WALL, 45˚ PROJECT NO. 21C18002

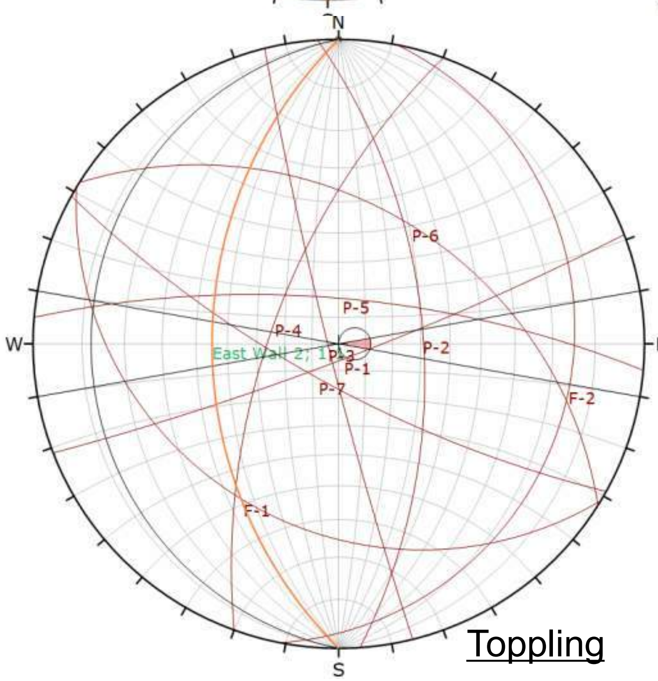
Planar Sliding



Wedge Sliding



Toppling



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33˚

- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

Domain

East Wall 2
(45º/270º)

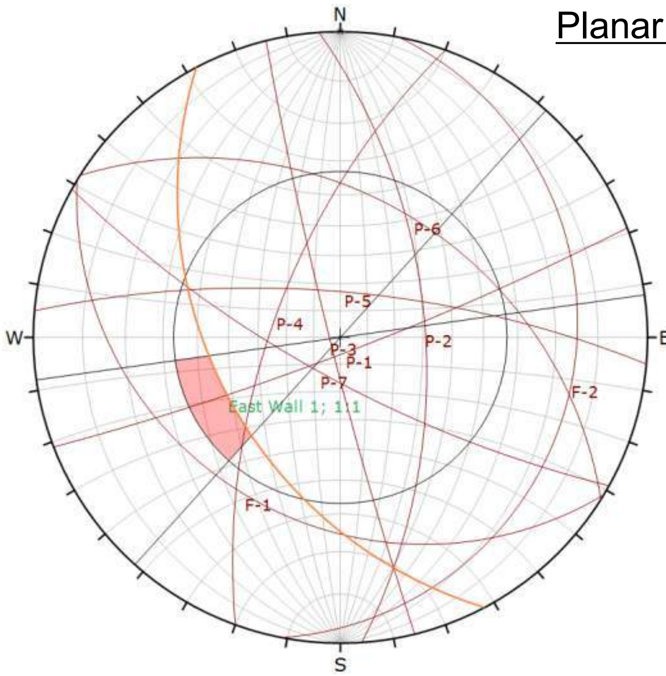
Schnabel ENGINEERING

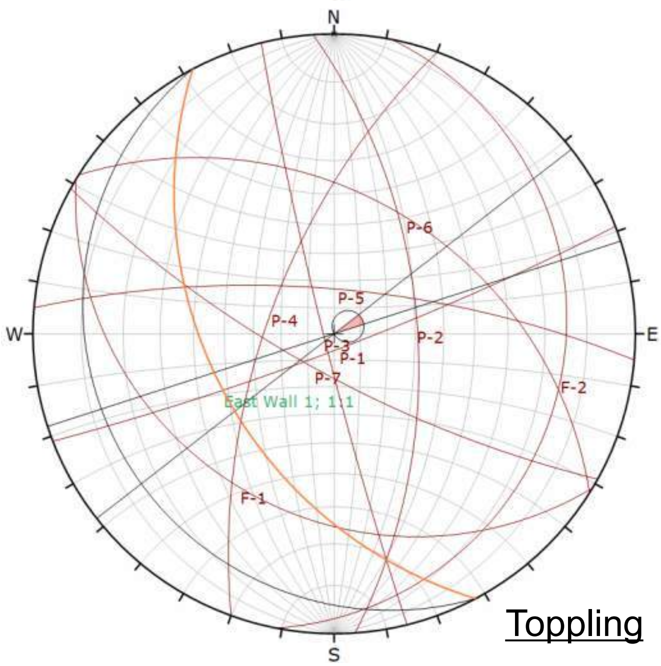
SPEC-AGG QUARRY EXPANSION
GOLDEN, CO

Martin Marietta

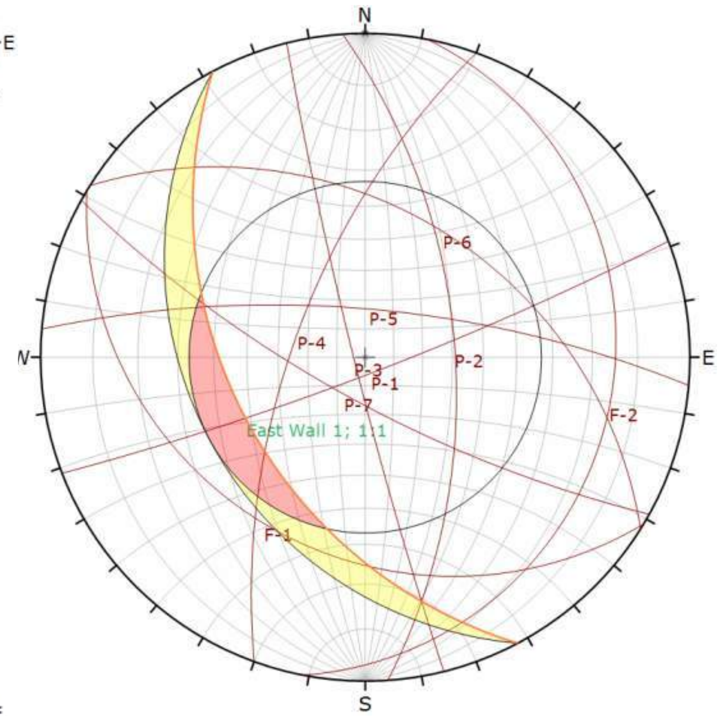
FIGURE 13
KINEMATIC ANALYSIS:
EAST WALL 2, 45˚
PROJECT NO. 21C18002

Planar Sliding





Wedge Sliding



Toppling

Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33˚

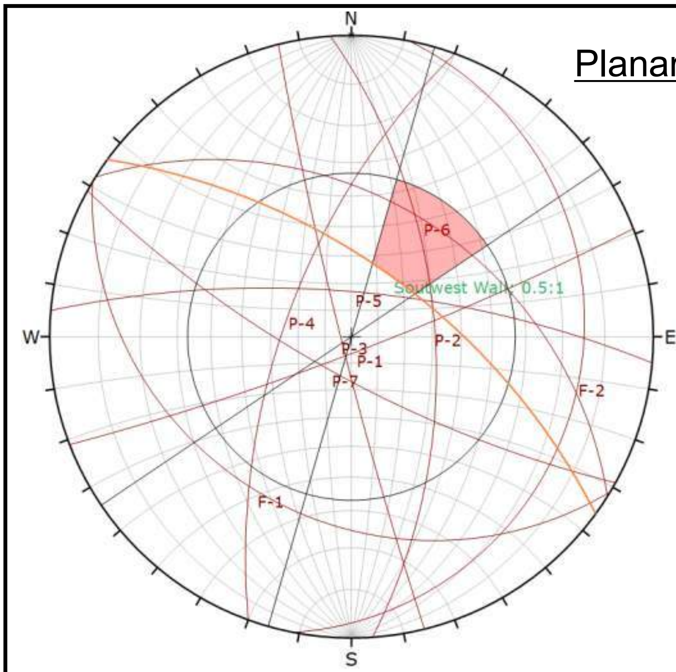
- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

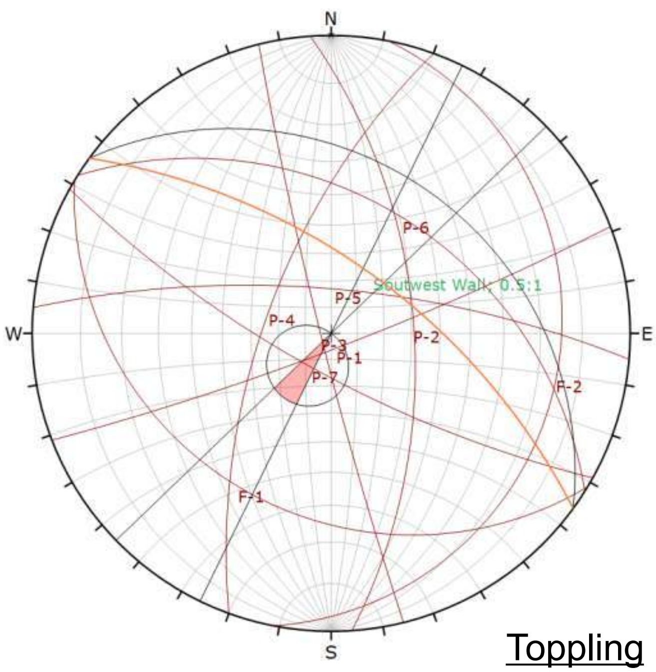
Domain

East Wall 1
(45º/242º)

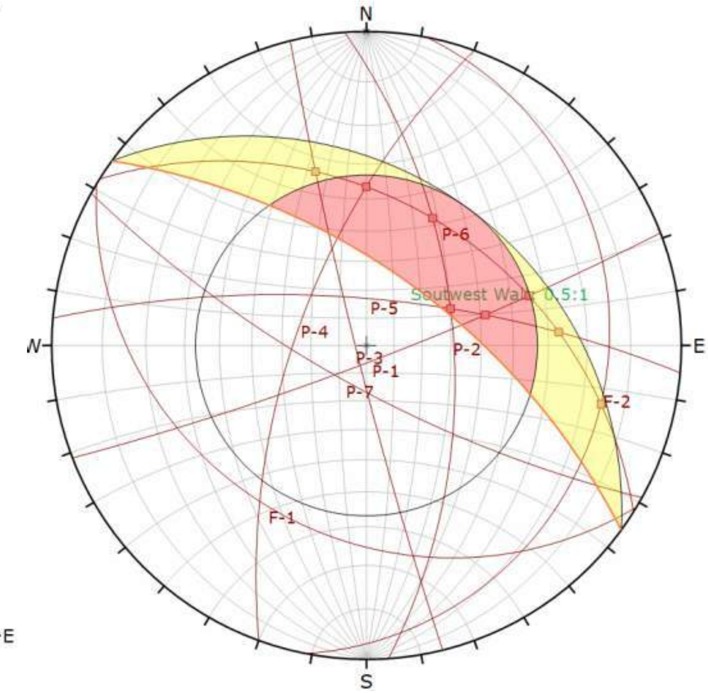
Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 14 KINEMATIC ANALYSIS: EAST WALL 1, 45˚ PROJECT NO. 21C18002

Planar Sliding





Wedge Sliding



Toppling

Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

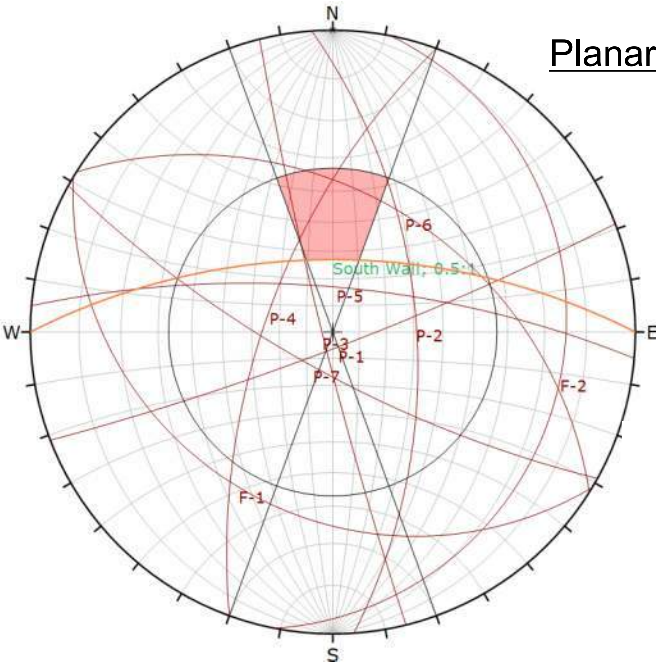
- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

Domain

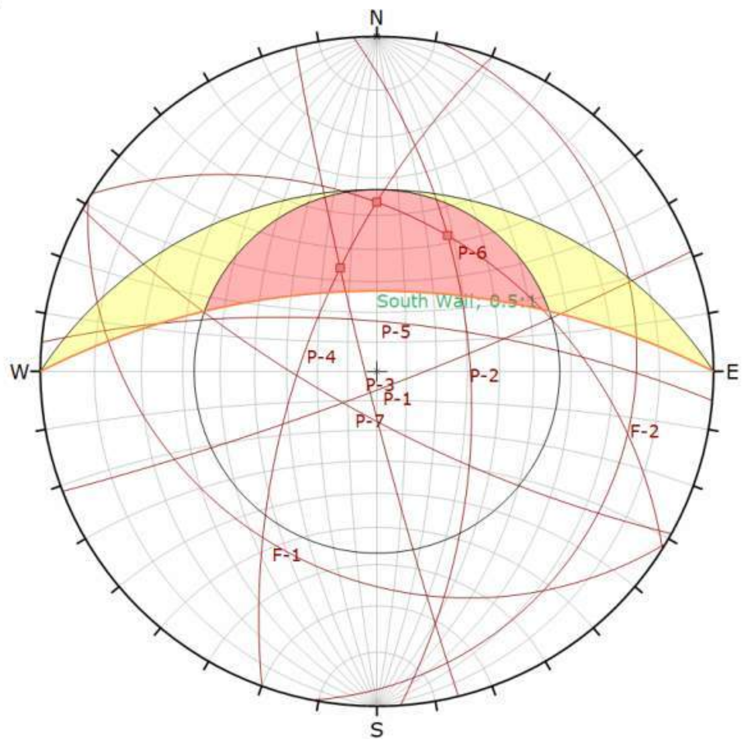
Southwest Wall 2
(63º/036º)

Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 15 KINEMATIC ANALYSIS: SOUTHWEST WALL 2, 63° PROJECT NO. 21C18002

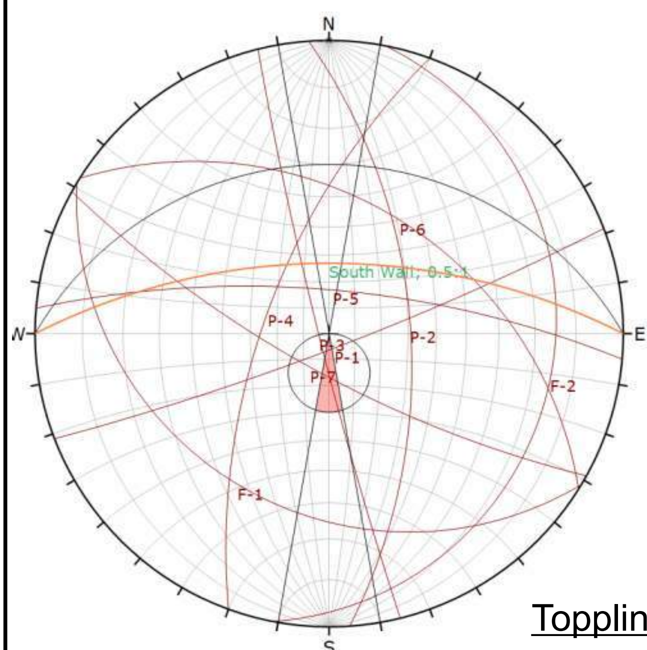
Planar Sliding



Wedge Sliding



Toppling



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

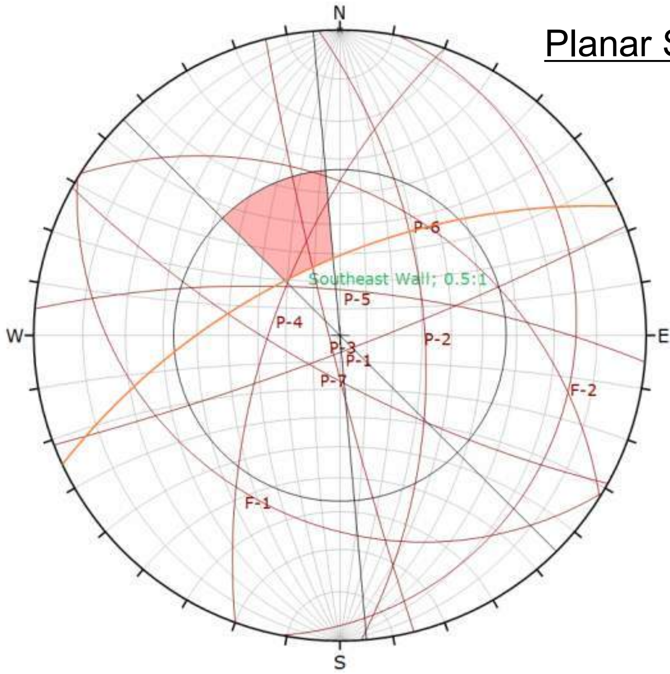
- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

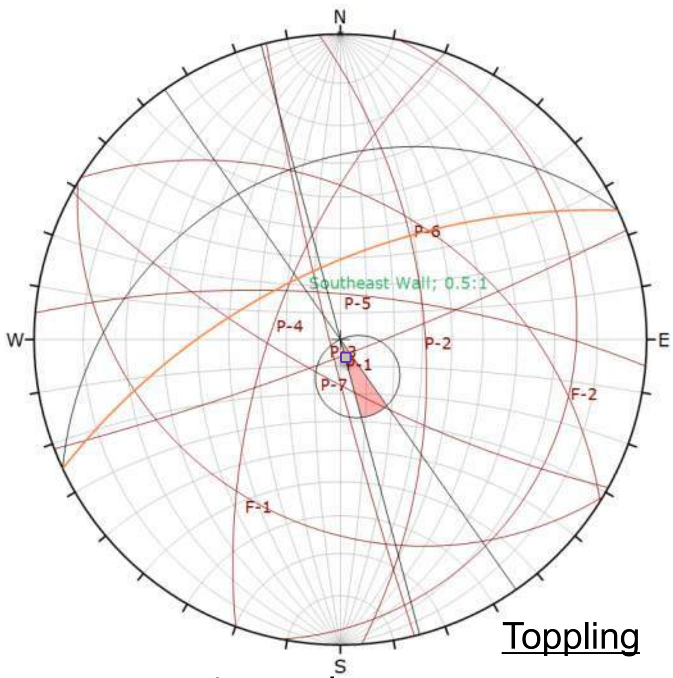
Domain

South Wall
(63º/000º)

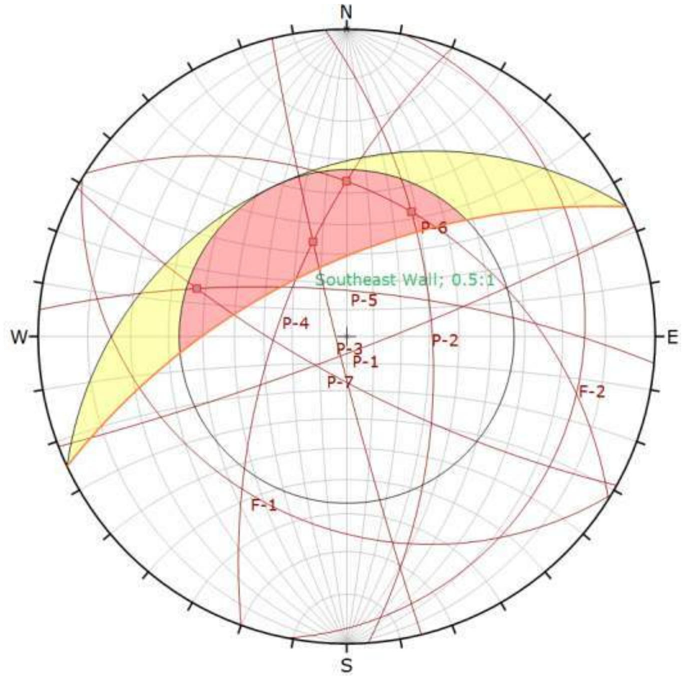
Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 16 KINEMATIC ANALYSIS: SOUTH WALL, 63° PROJECT NO. 21C18002

Planar Sliding





Wedge Sliding



Toppling

Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

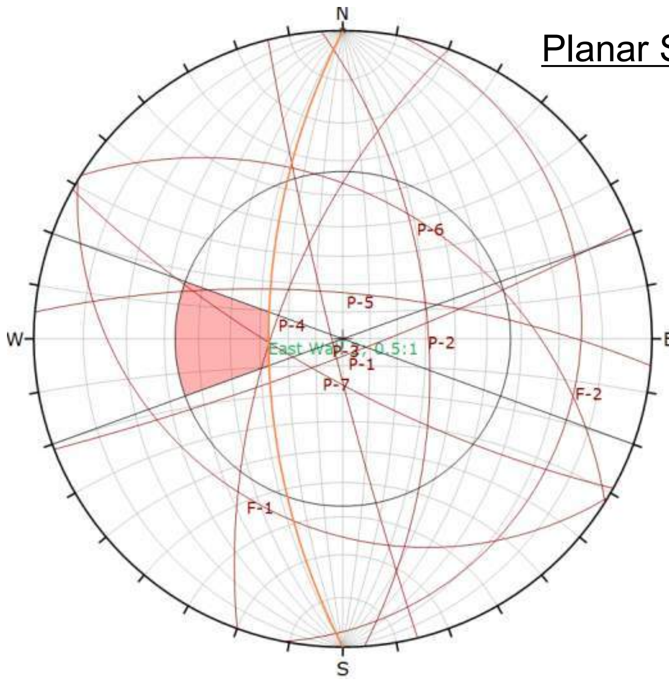
- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

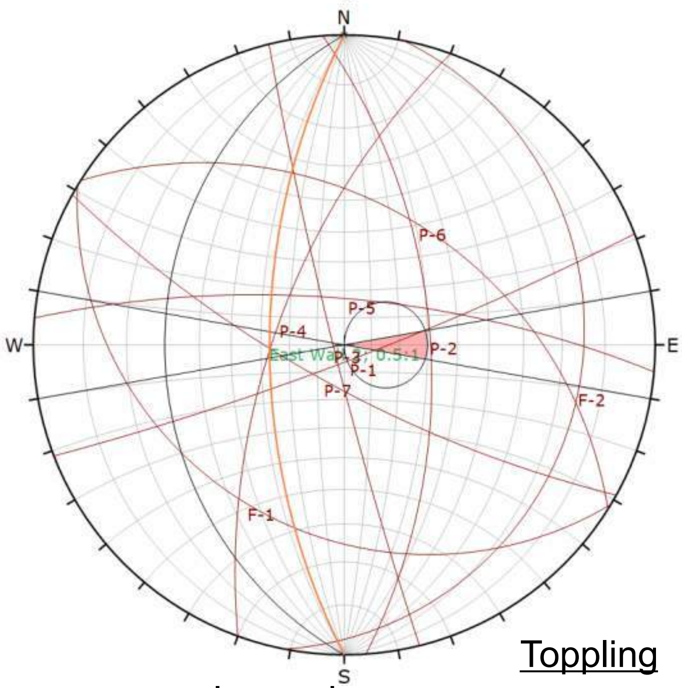
Domain

Southeast Wall
(63º/335º)

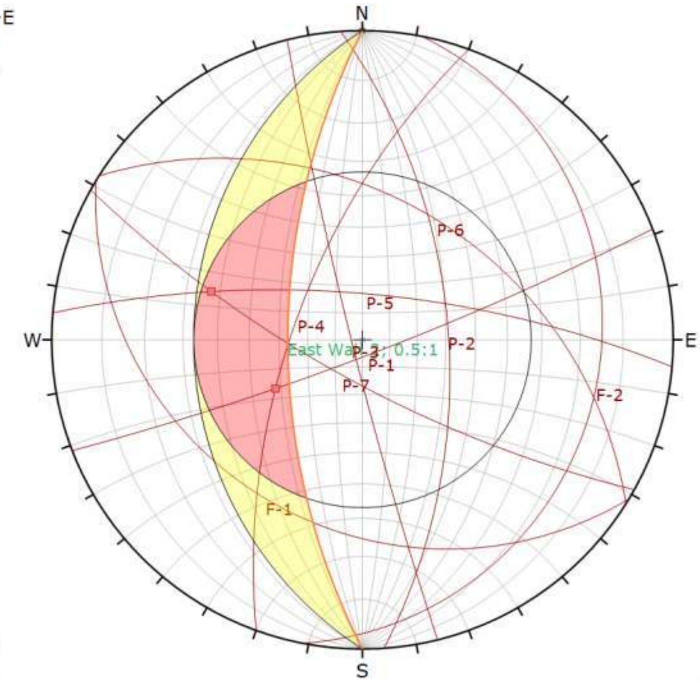
Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 17 KINEMATIC ANALYSIS: SOUTHEAST WALL, 63° PROJECT NO. 21C18002

Planar Sliding





Wedge Sliding



Toppling

Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33˚

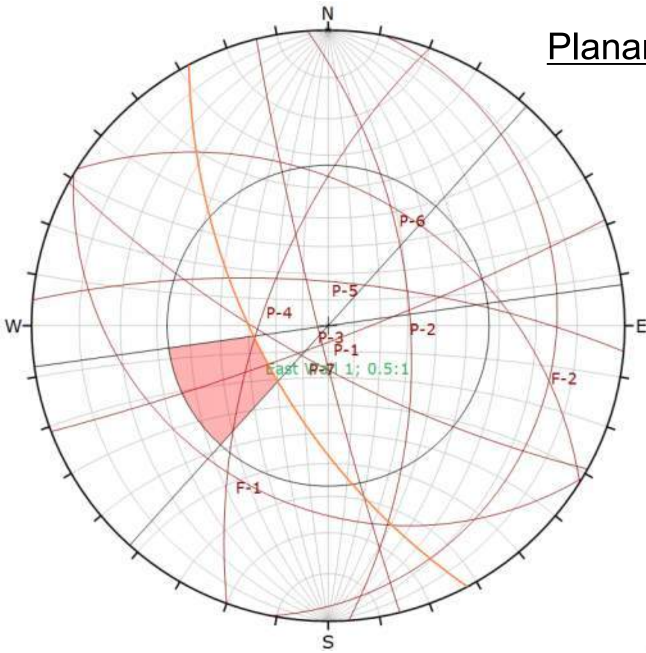
- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

Domain

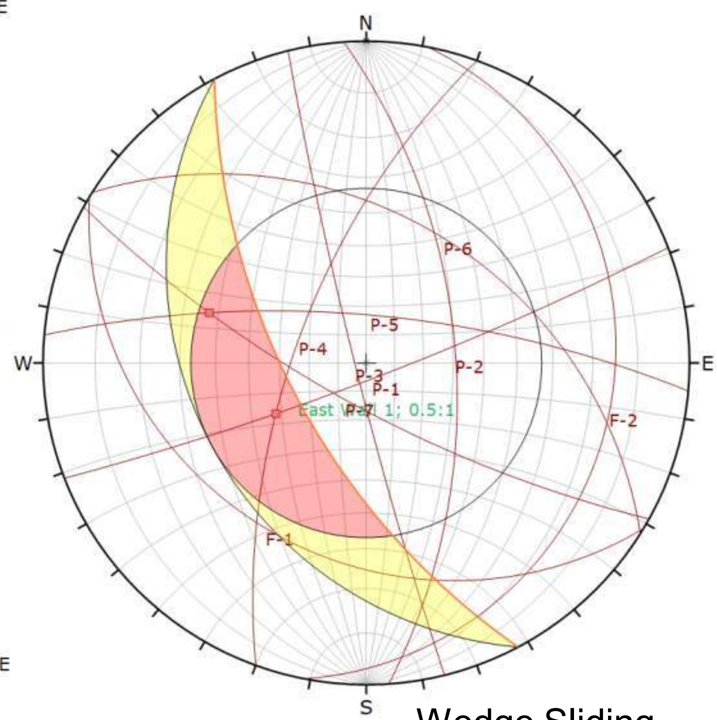
East Wall 2
(63º/270º)

Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 18 KINEMATIC ANALYSIS: EAST WALL 2, 63˚ PROJECT NO. 21C18002

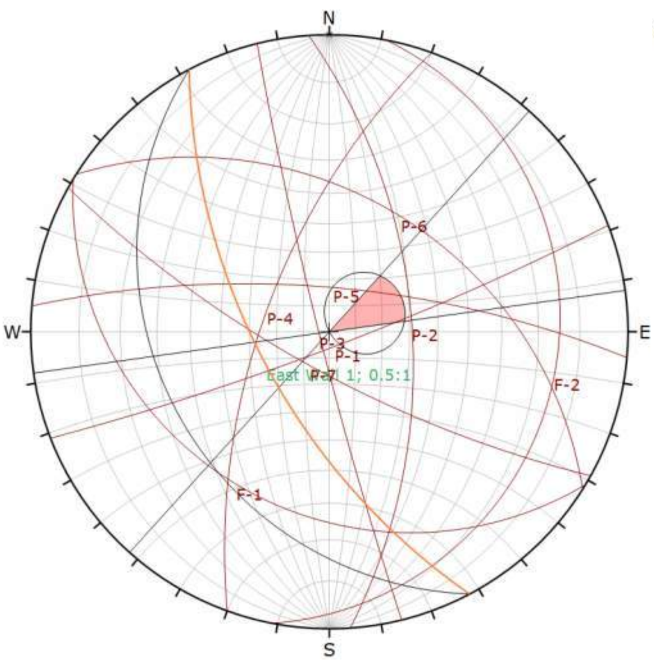
Planar Sliding



Wedge Sliding



Toppling



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33˚

- Planes of Discontinuity Sets
- Wall Orientation
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone
- Flexural toppling vector within the critical zone

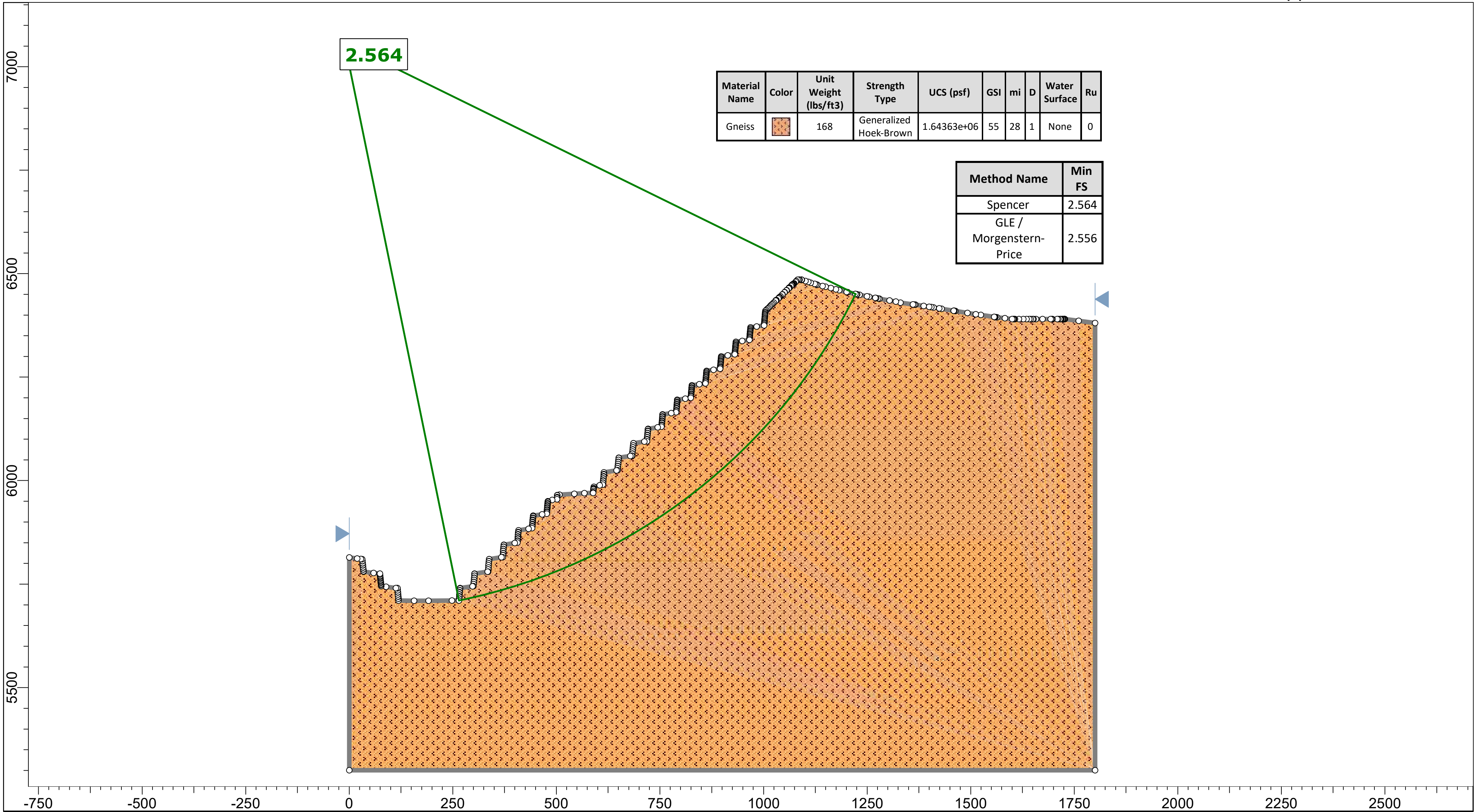
Domain

East Wall 1
(63º/242º)

Schnabel ENGINEERING	SPEC-AGG QUARRY EXPANSION GOLDEN, CO Martin Marietta	FIGURE 19 KINEMATIC ANALYSIS: EAST WALL 1, 63˚ PROJECT NO. 21C18002

APPENDIX A

Slope Stability 1:1 (H:V) Configuration



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Method Name	Min FS
Spencer	2.564
GLE / Morgenstern-Price	2.556

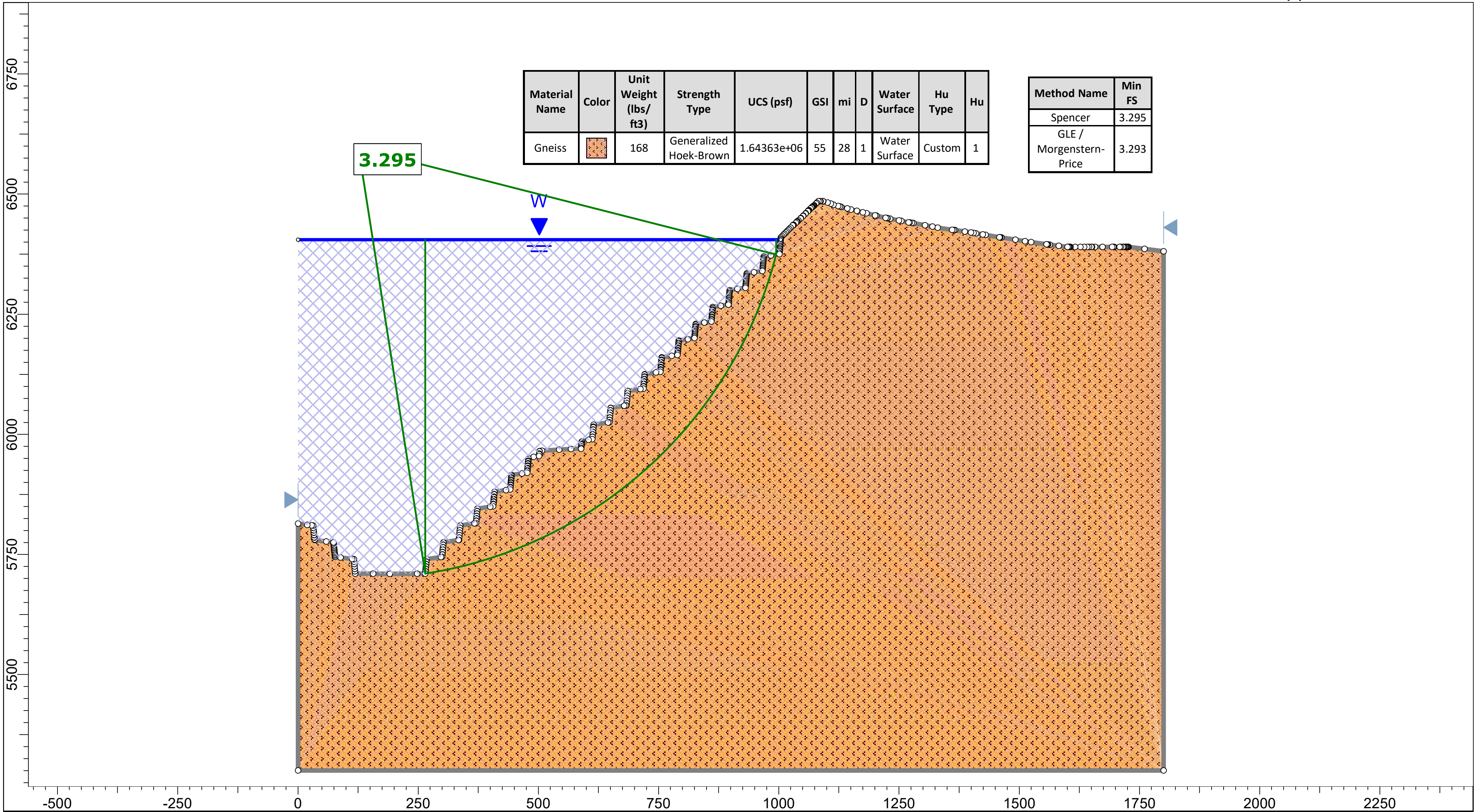
Schnabel ENGINEERING

SLIDEINTERPRET 9.019

Project	Spec Agg - Quarry Expansion
Analysis Description	Section E
Drawn By	RLC
Project No.	20C18002.00
Date	2/4/2022, 5:07:48 PM
File Name	Spec Agg - Section E_1 to 1.slmd

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Hu Type	Hu
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	Water Surface	Custom	1

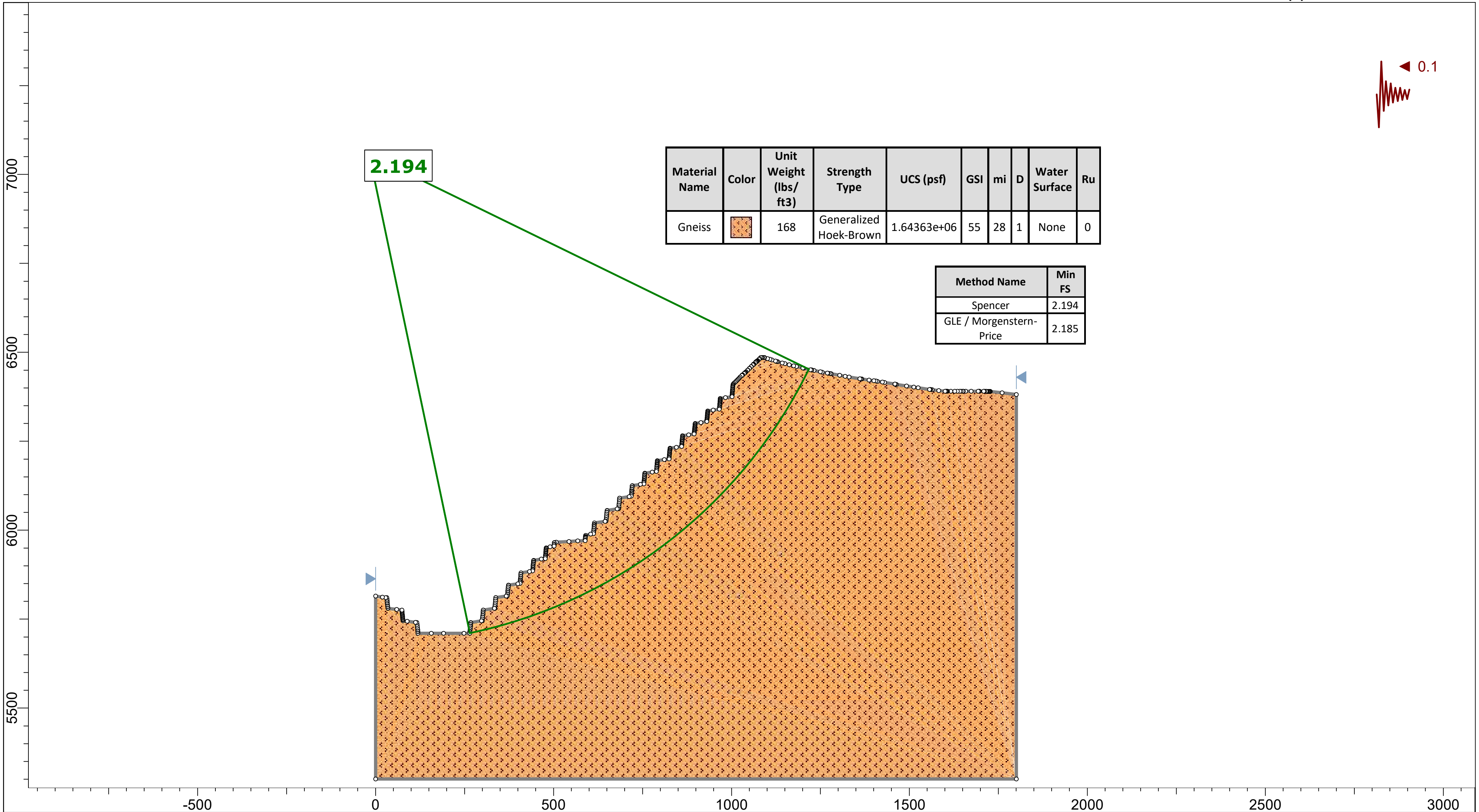
Method Name	Min FS
Spencer	3.295
GLE / Morgenstern-Price	3.293



Schnabel ENGINEERING

SLIDEINTERPRET 9.019

Project	Spec Agg - Quarry Expansion
Analysis Description	Section E - Ponded Water
Drawn By	RLC
Project No.	20C18002.00
Date	2/4/2022, 5:07:48 PM
File Name	Spec Agg - Section E_1 to 1.slmd



Material Name	Color	Unit Weight (lbs/ ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Method Name	Min FS
Spencer	2.194
GLE / Morgenstern-Price	2.185

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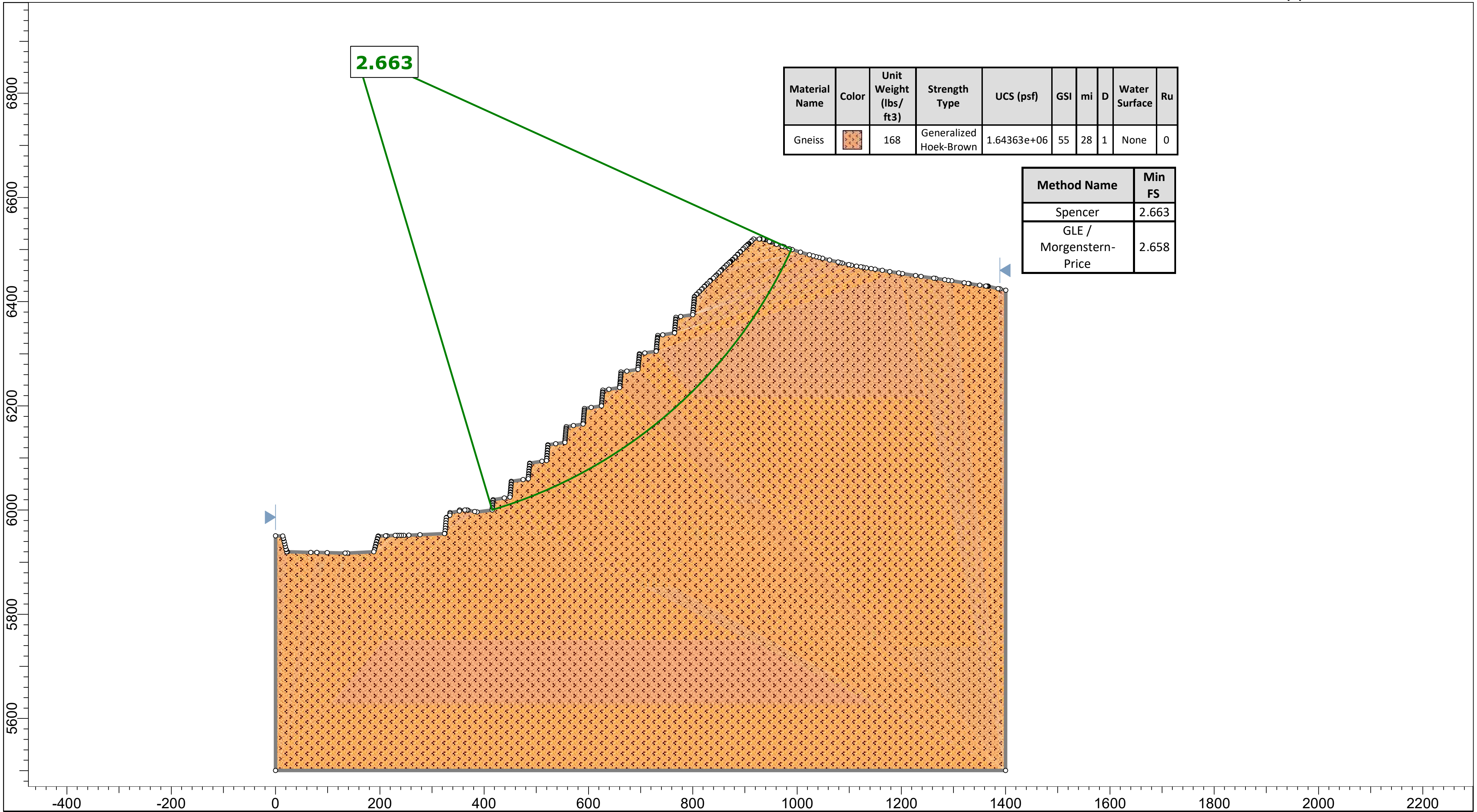
SLIDEINTERPRET 9.019

Project	Spec Agg - Quarry Expansion		
Analysis Description	Section E - Seismic		
Drawn By	RLC	*Project No.*	20C18002.00
Date	2/4/2022, 5:07:48 PM	*File Name*	Spec Agg - Section E_1 to 1.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Method Name	Min FS
Spencer	2.663
GLE / Morgenstern-Price	2.658

Project	Spec Agg - Quarry Expansion		
Analysis Description	Section F		
Drawn By	RLC	*Project No.*	20C18002.00
Date	2/4/2022, 5:07:48 PM	*File Name*	Spec Agg - Section F_1 to 1.slmd

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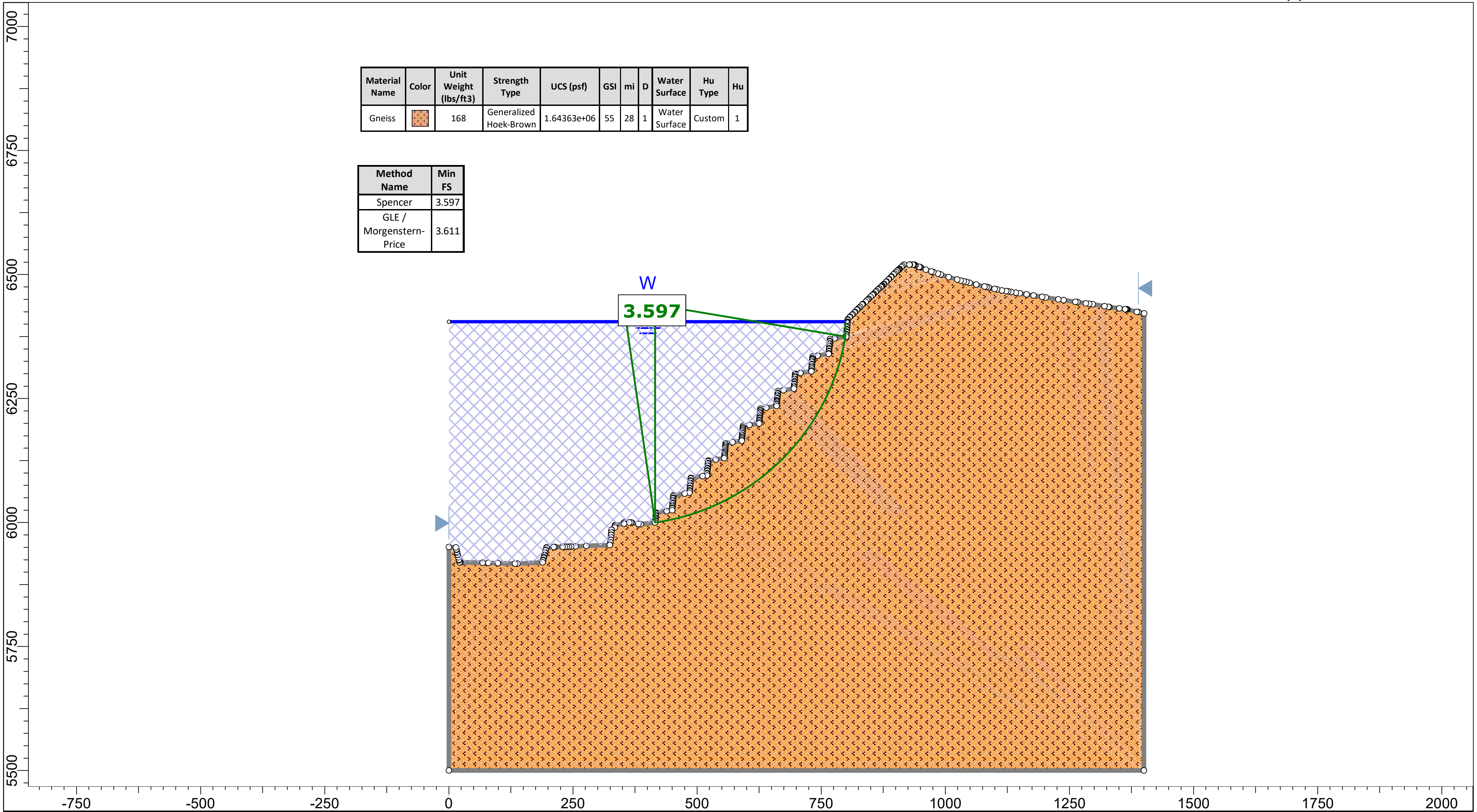
SLIDEINTERPRET 9.019



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Hu Type	Hu
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	Water Surface	Custom	1

Method Name	Min FS
Spencer	3.597
GLE / Morgenstern-Price	3.611

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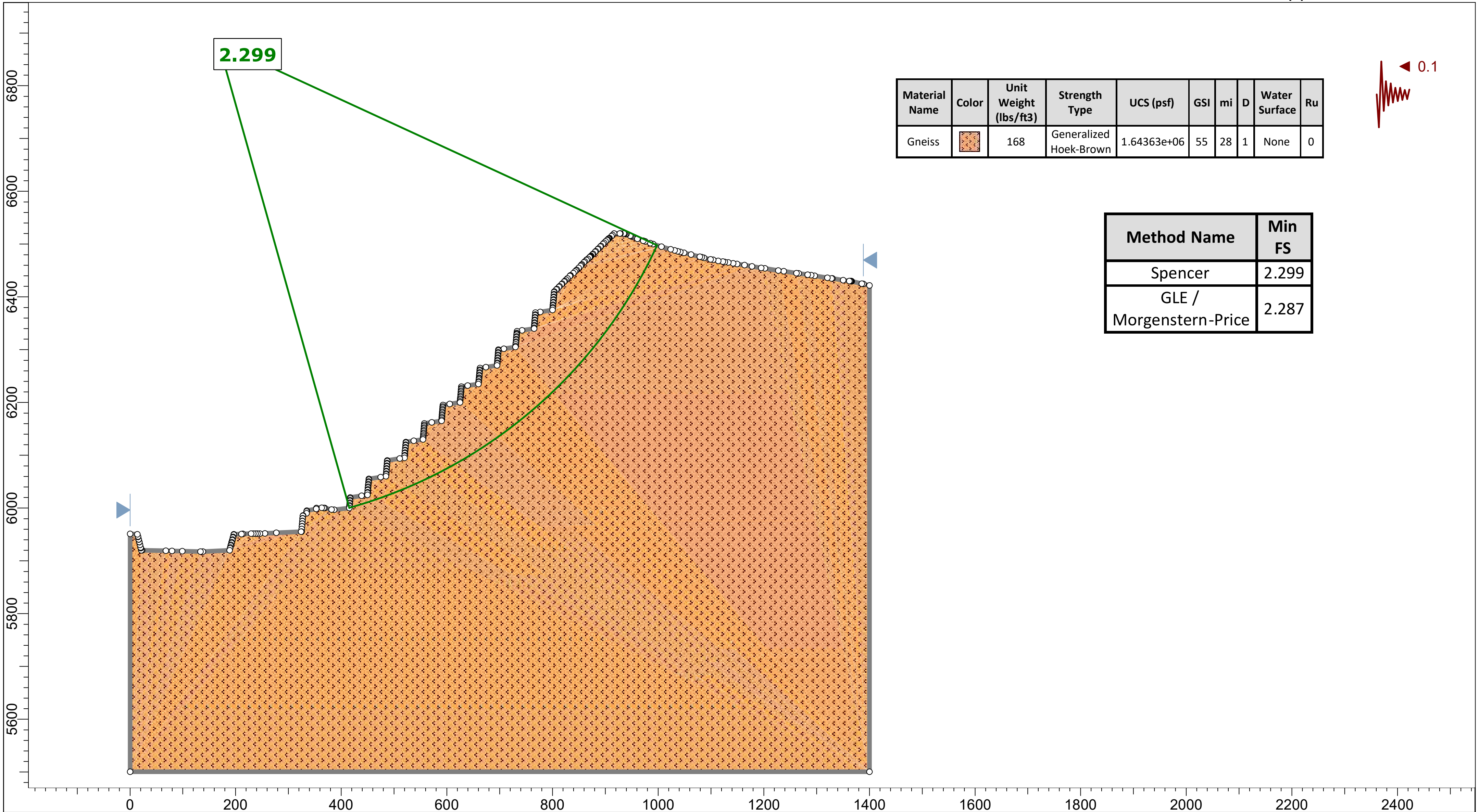
SLIDEINTERPRET 9.019

Project	Spec Agg - Quarry Expansion		
Analysis Description	Section F - Ponded Water		
Drawn By	RLC	*Project No.*	20C18002.00
Date	2/4/2022, 5:07:48 PM	*File Name*	Spec Agg - Section F_1 to 1.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Method Name	Min FS
Spencer	2.299
GLE / Morgenstern-Price	2.287

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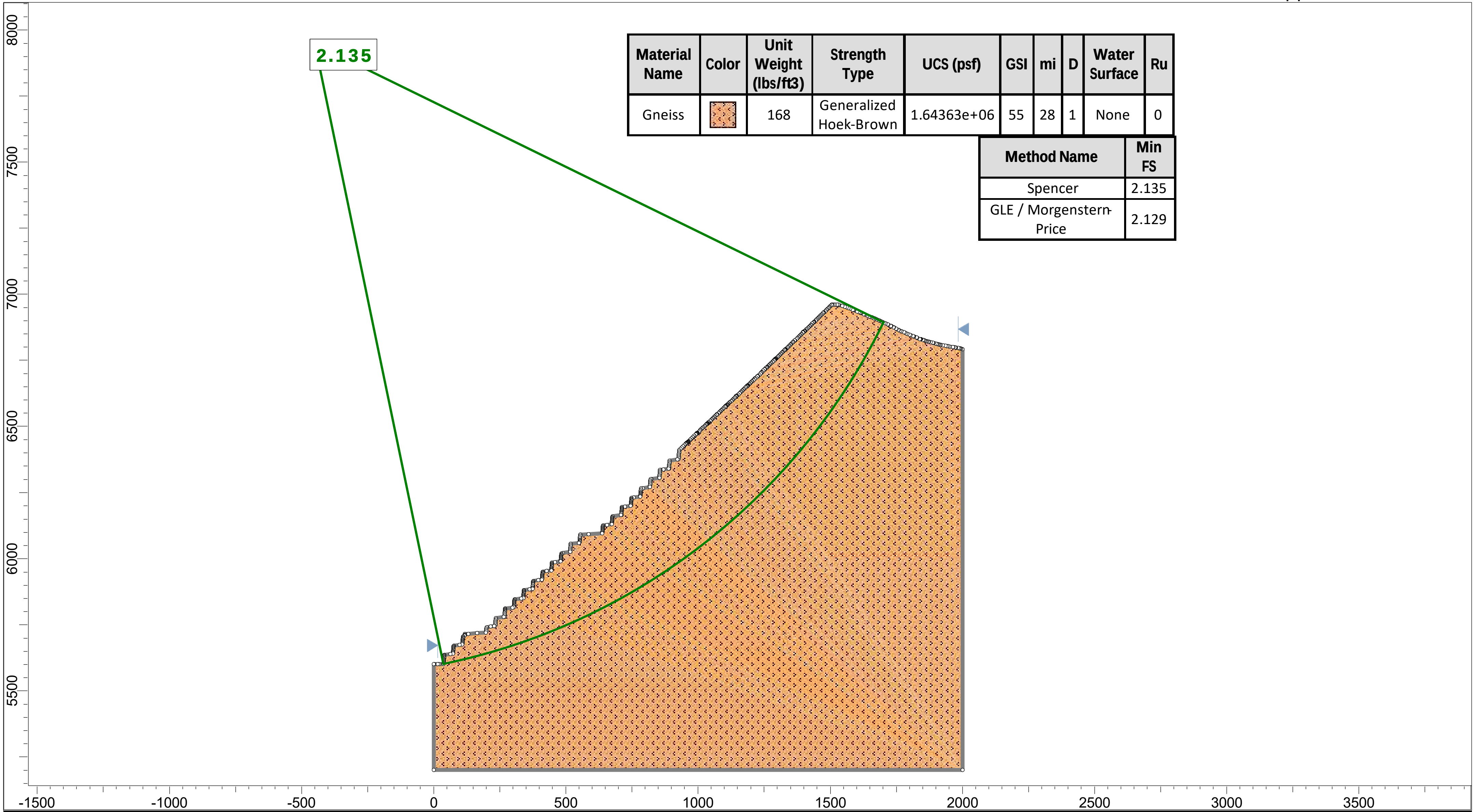
SLIDEINTERPRET 9.019

Project	Spec Agg - Quarry Expansion
Analysis Description	Section F - Seismic
Drawn By	RLC
Project No.	20C18002.00
Date	2/4/2022, 5:07:48 PM
File Name	Spec Agg - Section F_1 to 1.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Method Name	Min FS
Spencer	2.135
GLE / Morgenstern-Price	2.129

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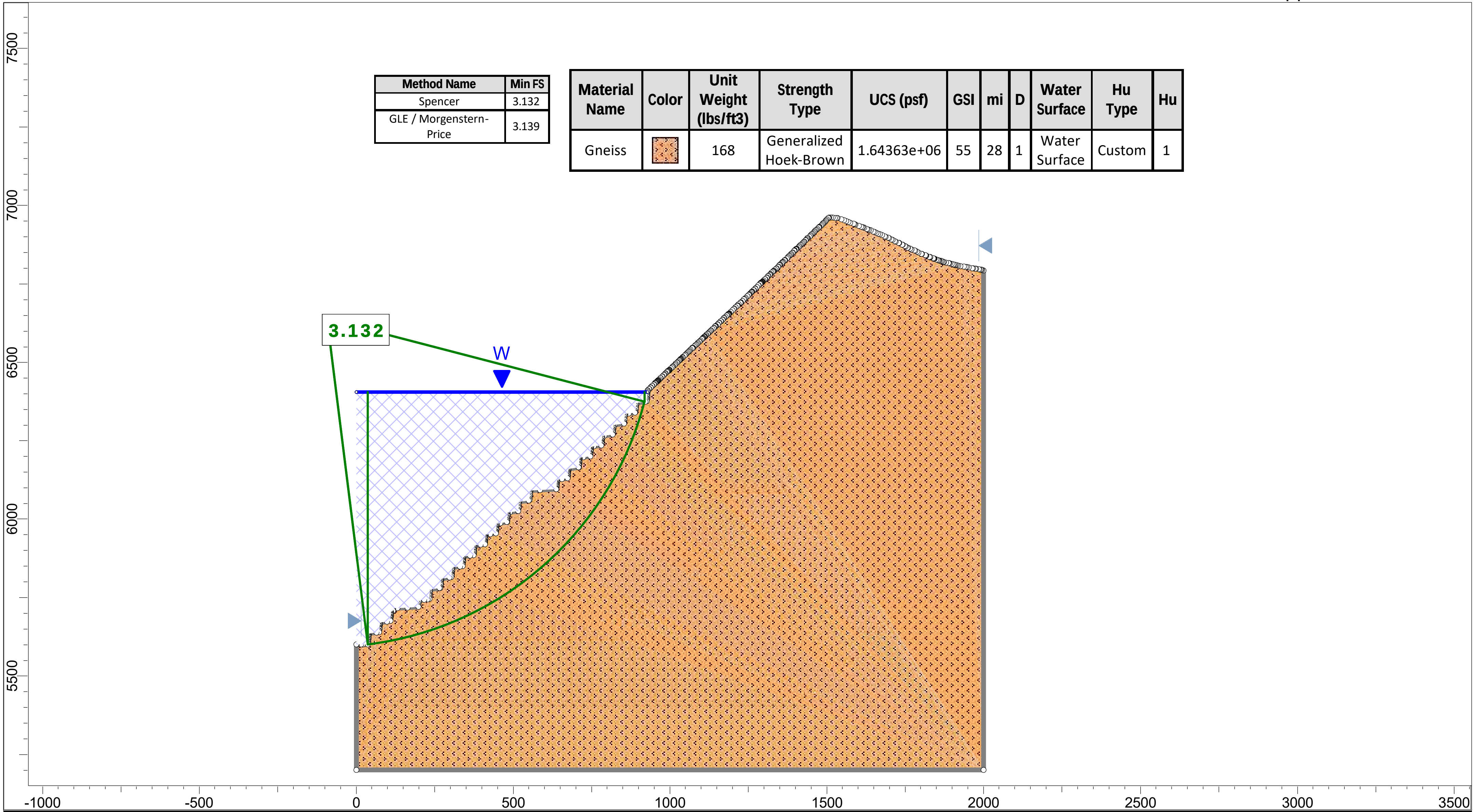
SLIDEINTERPRET 9.019

Project	Spec Agg - Quarry Expansion
Analysis Description	Section G
Drawn By	RLC
Project No.	20C18002.00
Date	2/4/2022, 5:07:48 PM
File Name	Spec Agg - Section G_1 to 1.slmd

Method Name	Min FS
Spencer	3.132
GLE / Morgenstern-Price	3.139

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Hu Type	Hu
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	Water Surface	Custom	1



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	Analysis Description: Section G - Ponded Water		
	Drawn By: RLC	Project No.: 20C18002.00	
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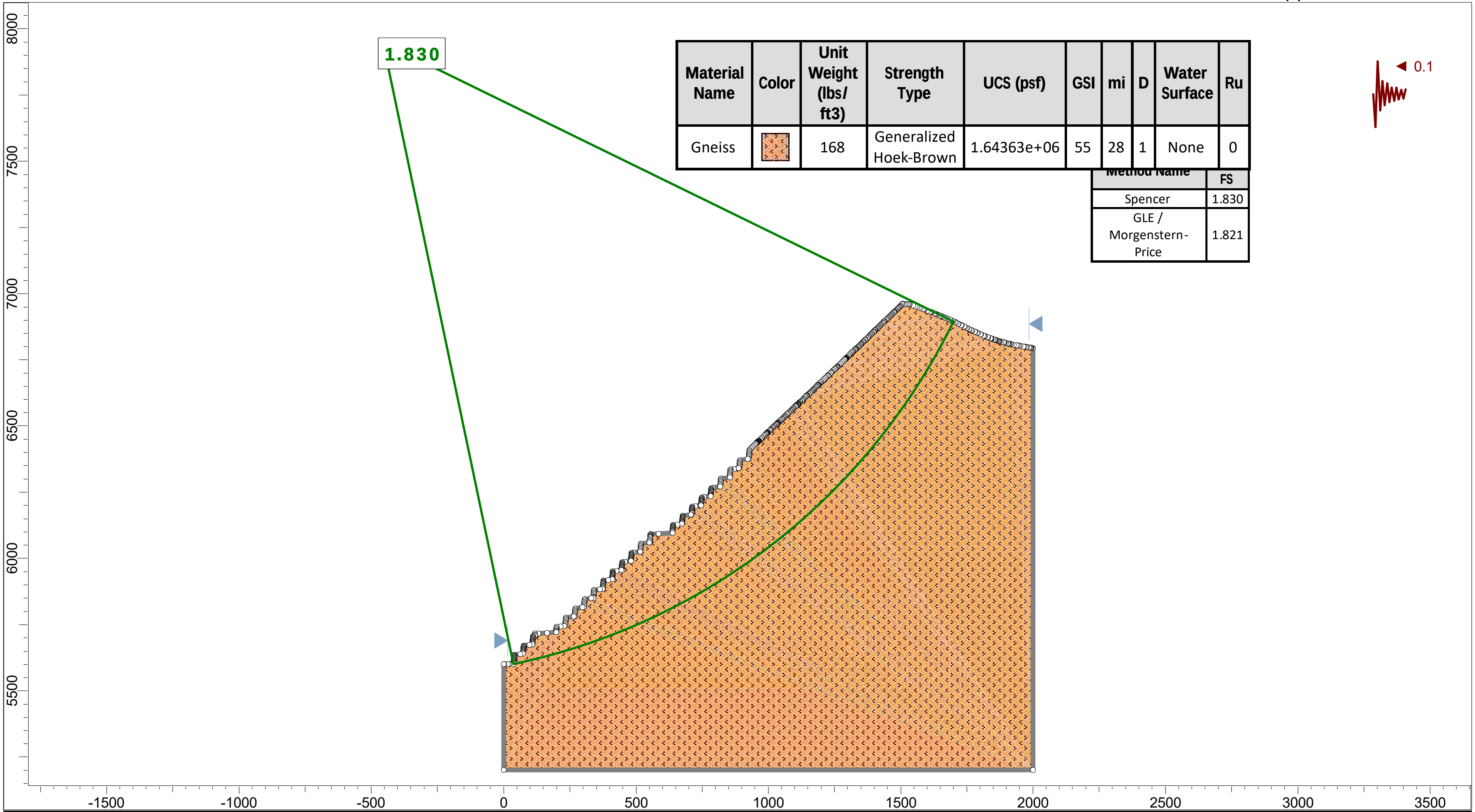


Material Name	Color	Unit Weight (lbs/ ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Method Name	FS
Spencer	1.830
GLE / Morgenstern-Price	1.821

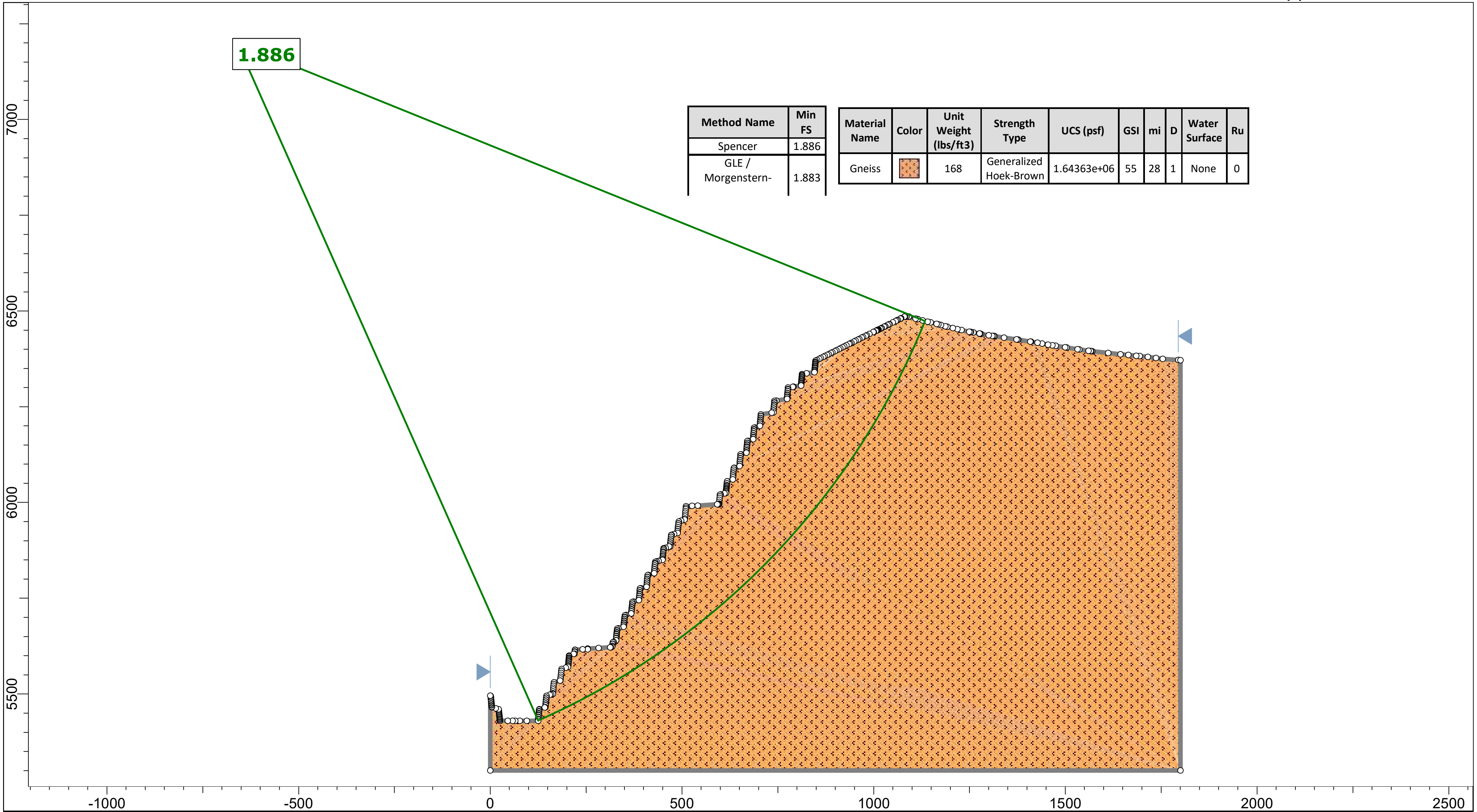
Schnabel ENGINEERING

SLIDEINTERPRET 9.019

Project	Spec Agg - Quarry Expansion		
Analysis Description	Section G - Seismic		
Drawn By	RLC	*Project No.*	20C18002.00
Date	2/4/2022, 5:07:48 PM	*File Name*	Spec Agg - Section G_1 to 1.slmd

APPENDIX B

Slope Stability ½:1 (H:V) Configuration



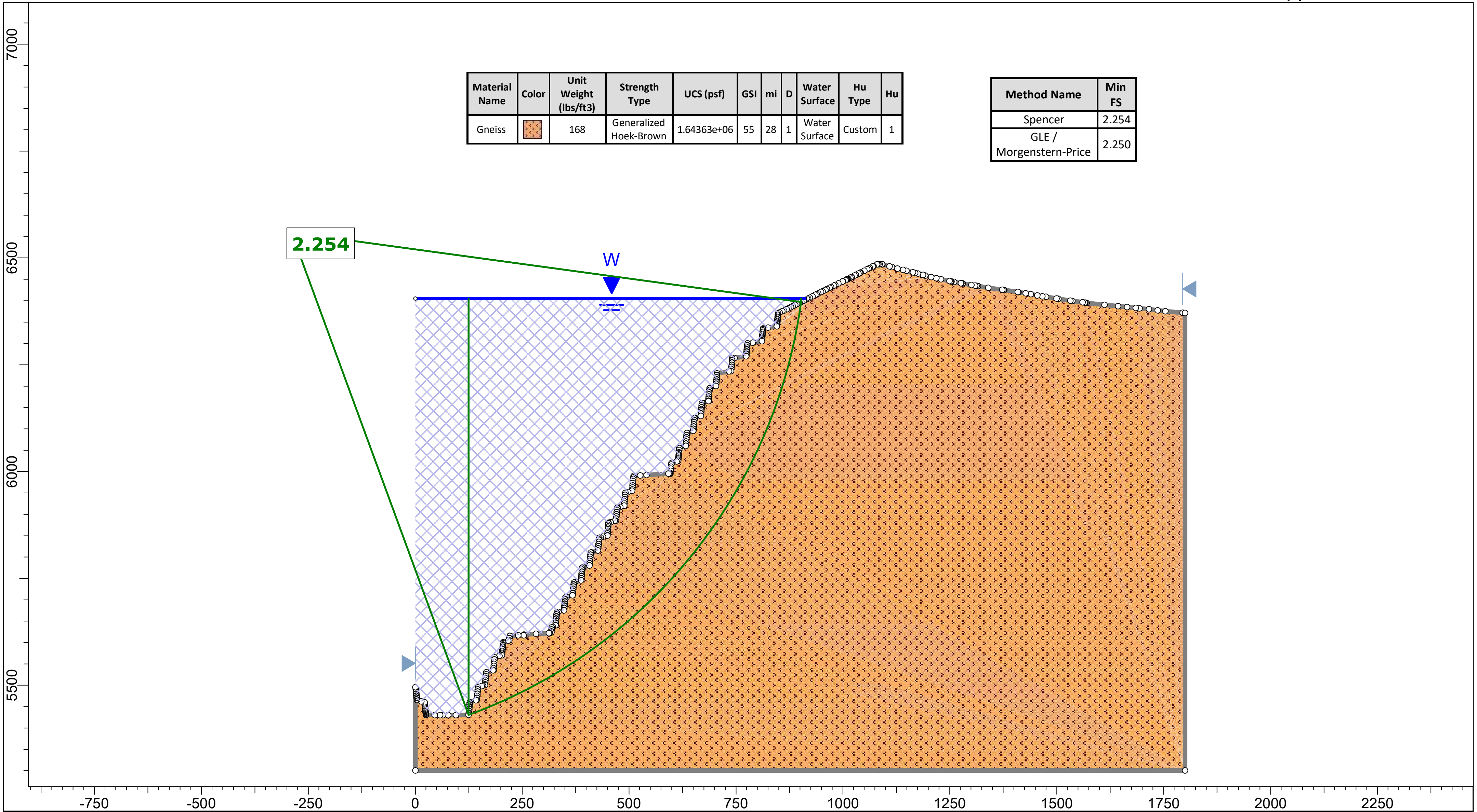
Method Name	Min FS
Spencer	1.886
GLE / Morgenstern-	1.883

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Schnabel ENGINEERING

SLIDEINTERPRET 9.019

Project	Spec Agg Quarry Expansion		
Analysis Description	Section E		
Drawn By	RLC	*Project No.*	21C18002.00
Date	2/7/2022, 10:25:45 AM	*File Name*	Spec Agg - Section E.slmd



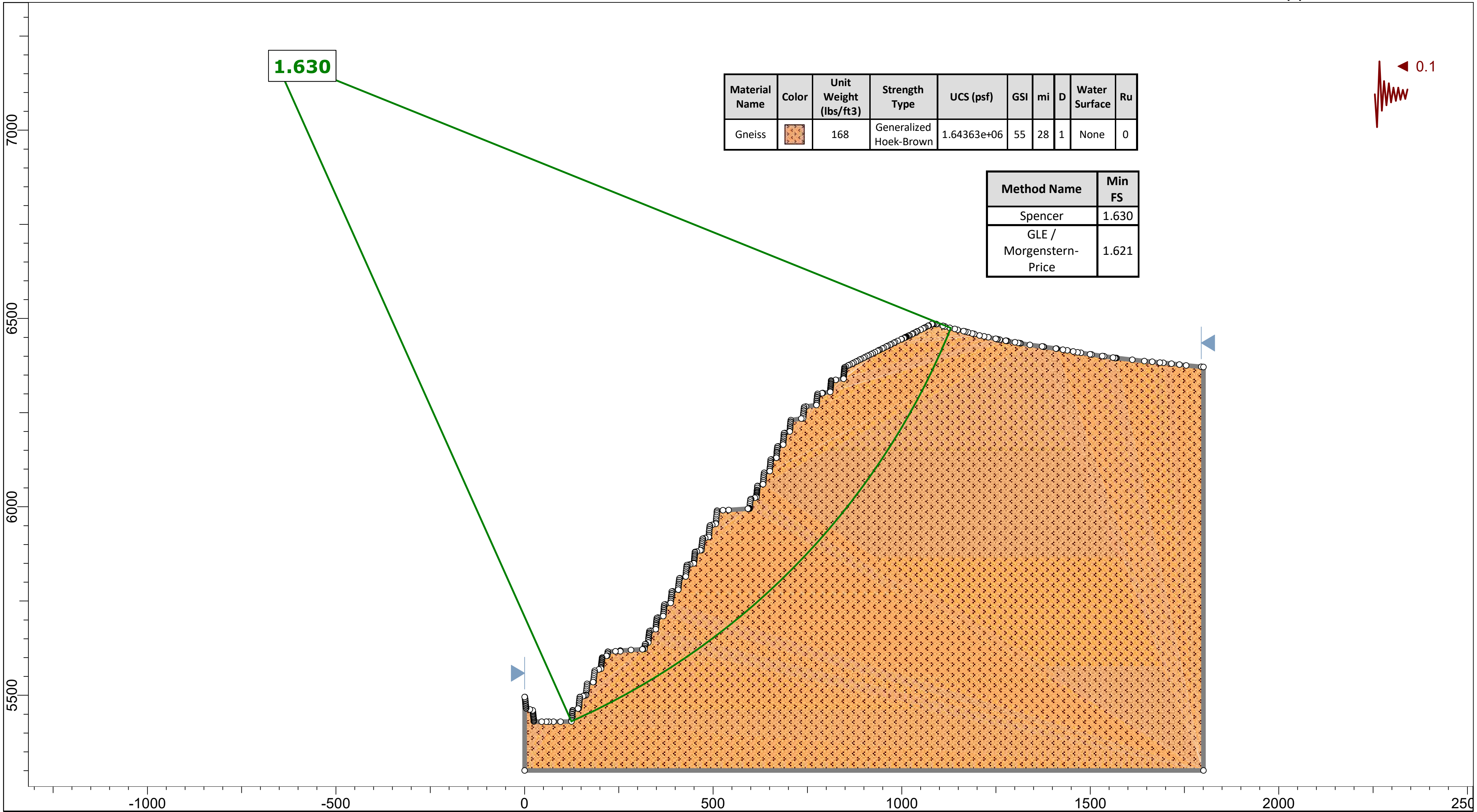
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Hu Type	Hu
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	Water Surface	Custom	1

Method Name	Min FS
Spencer	2.254
GLE / Morgenstern-Price	2.250

Project	Spec Agg Quarry Expansion		
Analysis Description	Section E - Ponded Water		
Drawn By	RLC	*Project No.*	21C18002.00
Date	2/7/2022, 10:25:45 AM	*File Name*	Spec Agg - Section E.slmd

Schnabel ENGINEERING

SLIDEINTERPRET 9.019



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Method Name	Min FS
Spencer	1.630
GLE / Morgenstern-Price	1.621

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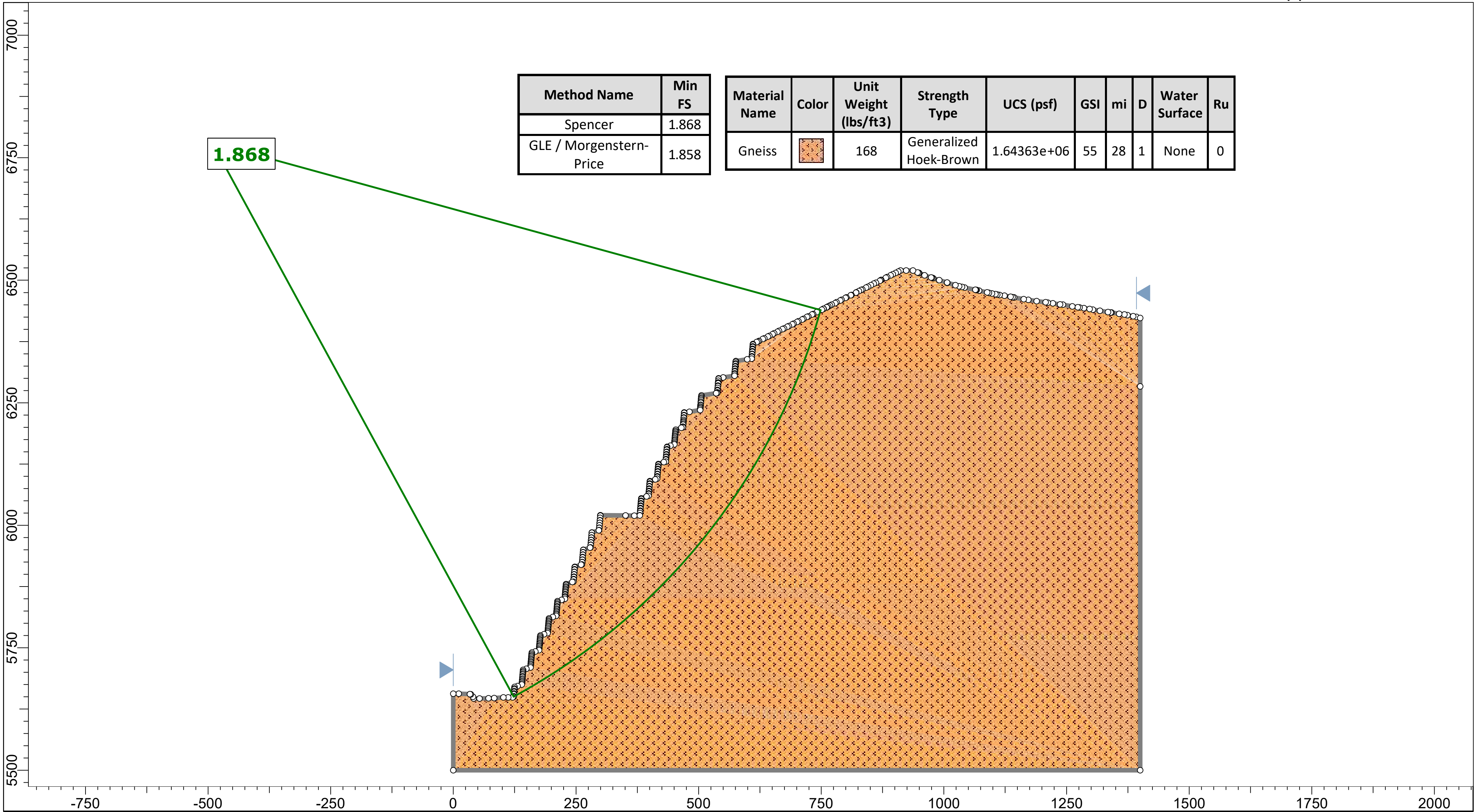
SLIDEINTERPRET 9.019

Project	Spec Agg Quarry Expansion
Analysis Description	Section E - Seismic
Drawn By	RLC
Project No.	21C18002.00
Date	2/7/2022, 10:25:45 AM
File Name	Spec Agg - Section E.slmd

Method Name	Min FS
Spencer	1.868
GLE / Morgenstern-Price	1.858

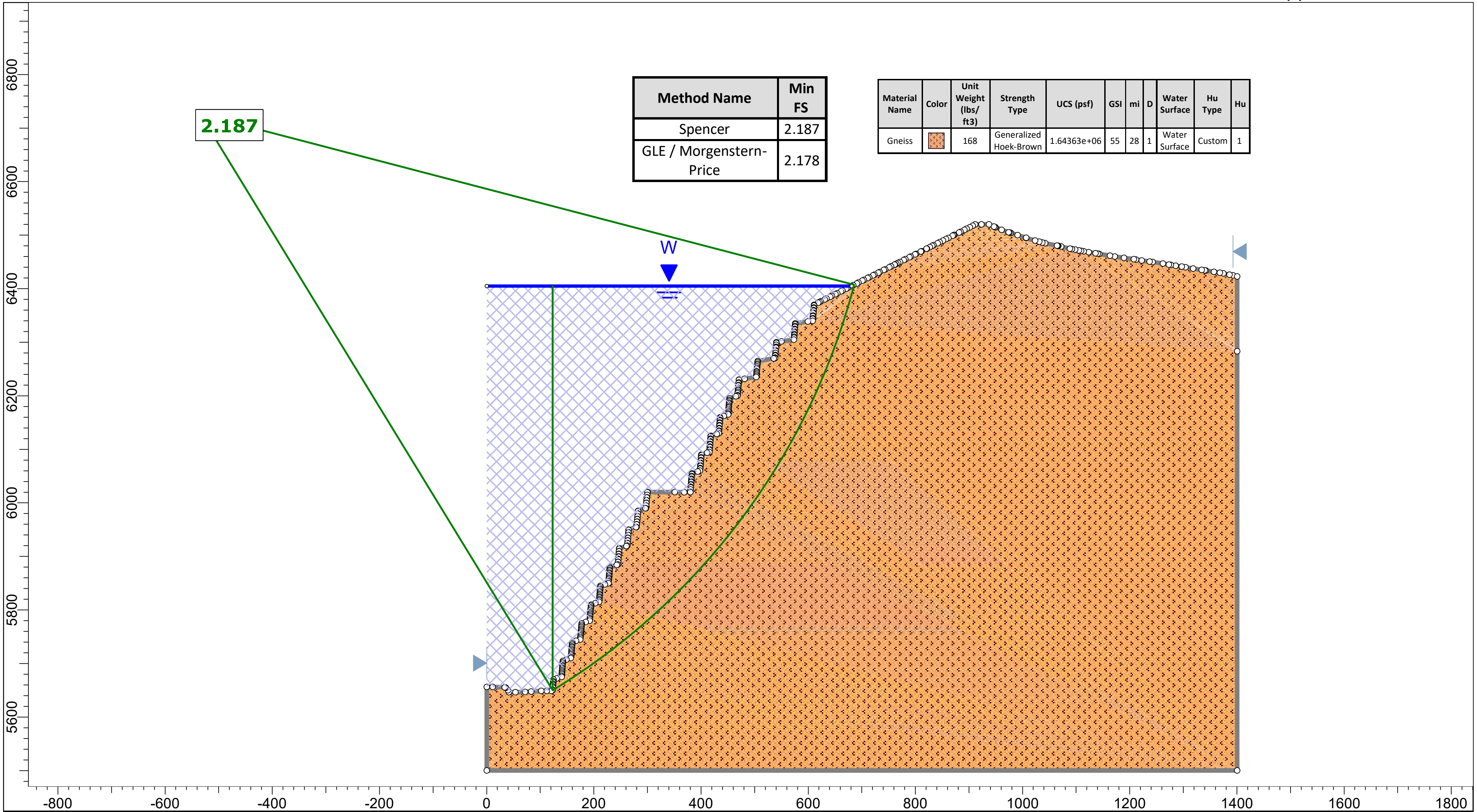
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0



Schnabel ENGINEERING

SLIDEINTERPRET 9.019

Project	Spec Agg Quarry Expansion
Analysis Description	Section F
Drawn By	RLC
Project No.	21C18002.00
Date	2/7/2022, 10:25:45 AM
File Name	Spec Agg - Section F.slmd



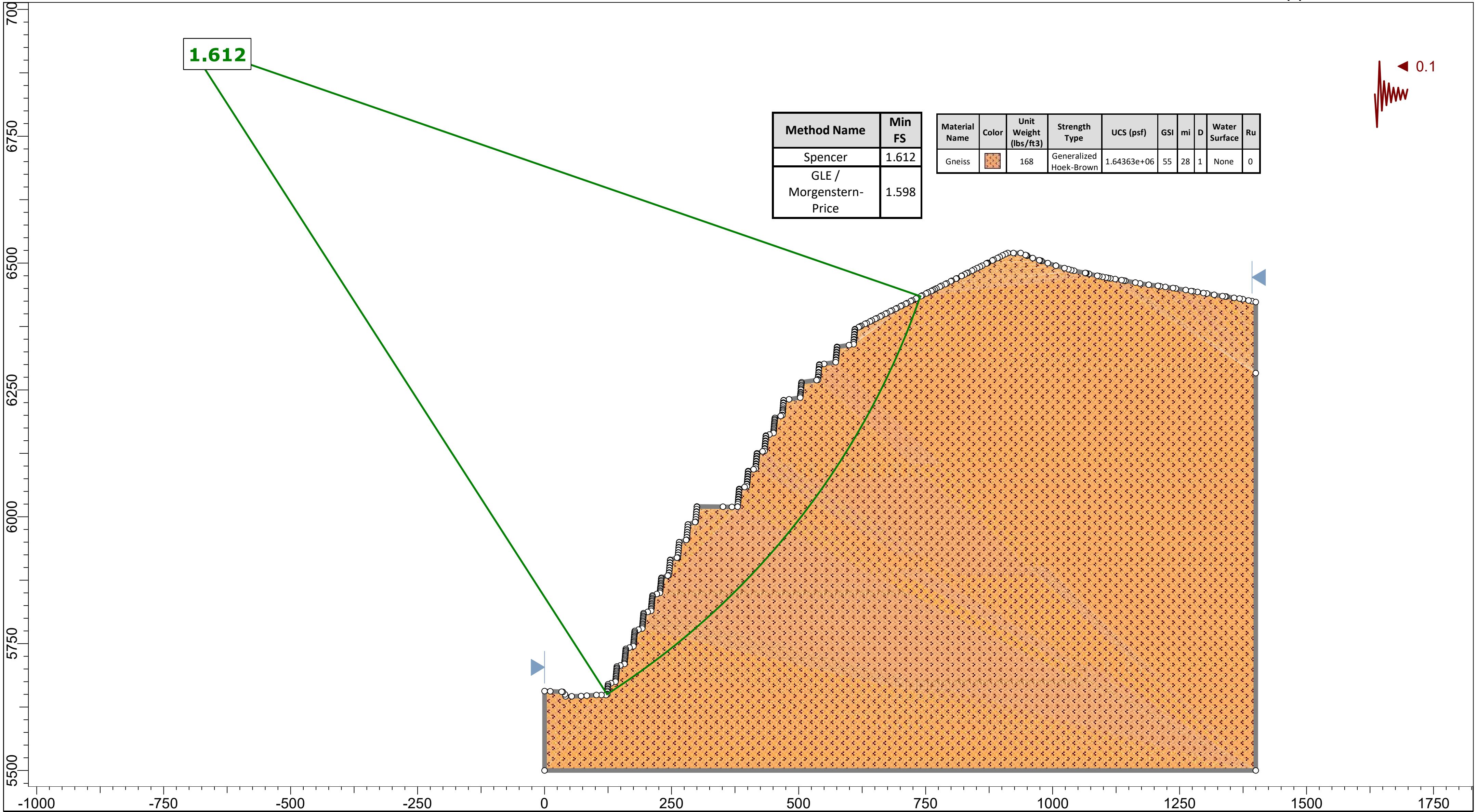
Method Name	Min FS
Spencer	2.187
GLE / Morgenstern-Price	2.178

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Hu Type	Hu
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	Water Surface	Custom	1

Schnabel ENGINEERING

SLIDEINTERPRET 9.019

Project	Spec Agg Quarry Expansion		
Analysis Description	Section F - Ponded Water		
Drawn By	RLC	*Project No.*	21C18002.00
Date	2/7/2022, 10:25:45 AM	*File Name*	Spec Agg - Section F.slmd



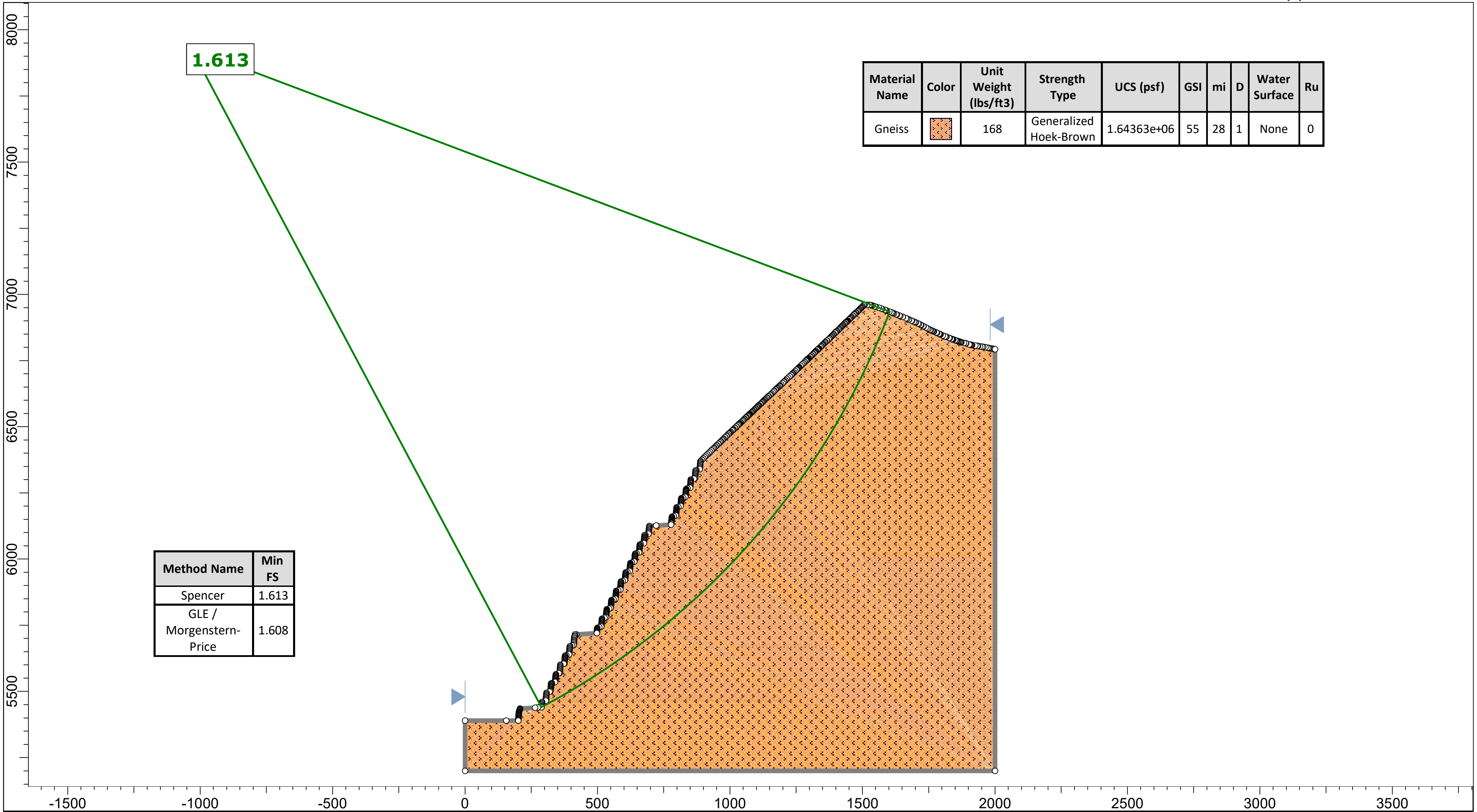
Method Name	Min FS
Spencer	1.612
GLE / Morgenstern-Price	1.598

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Schnabel ENGINEERING

SLIDEINTERPRET 9.019

Project	Spec Agg Quarry Expansion		
Analysis Description	Section F - Seismic		
Drawn By	RLC	*Project No.*	21C18002.00
Date	2/7/2022, 10:25:45 AM	*File Name*	Spec Agg - Section F.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Method Name	Min FS
Spencer	1.613
GLE / Morgenstern-Price	1.608

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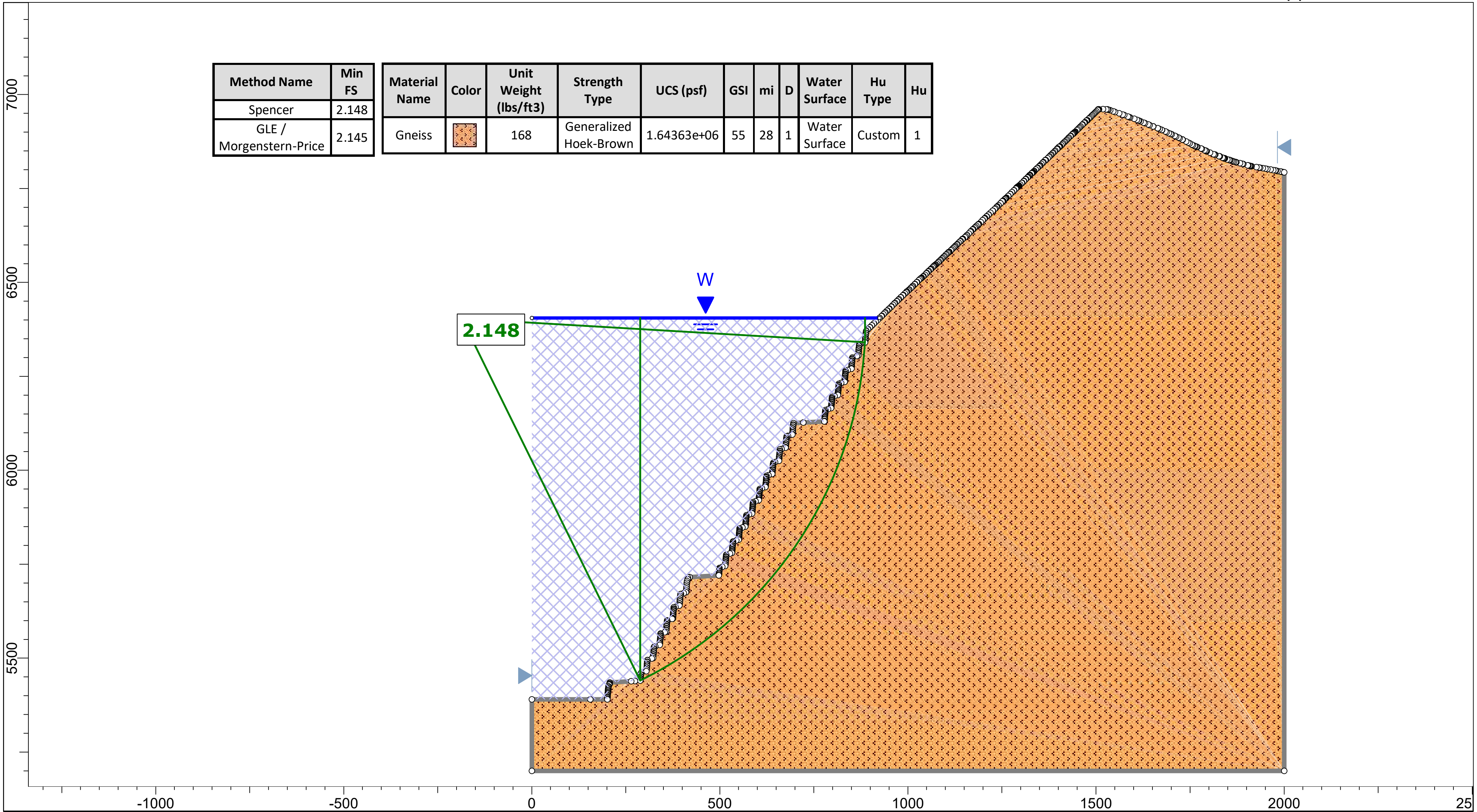
SLIDEINTERPRET 9.019

Project	Spec Agg Quarry Expansion		
Analysis Description	Section G		
Drawn By	RLC	*Project No.*	21C18002.00
Date	2/7/2022, 10:25:45 AM	*File Name*	Spec Agg - Section G.slmd

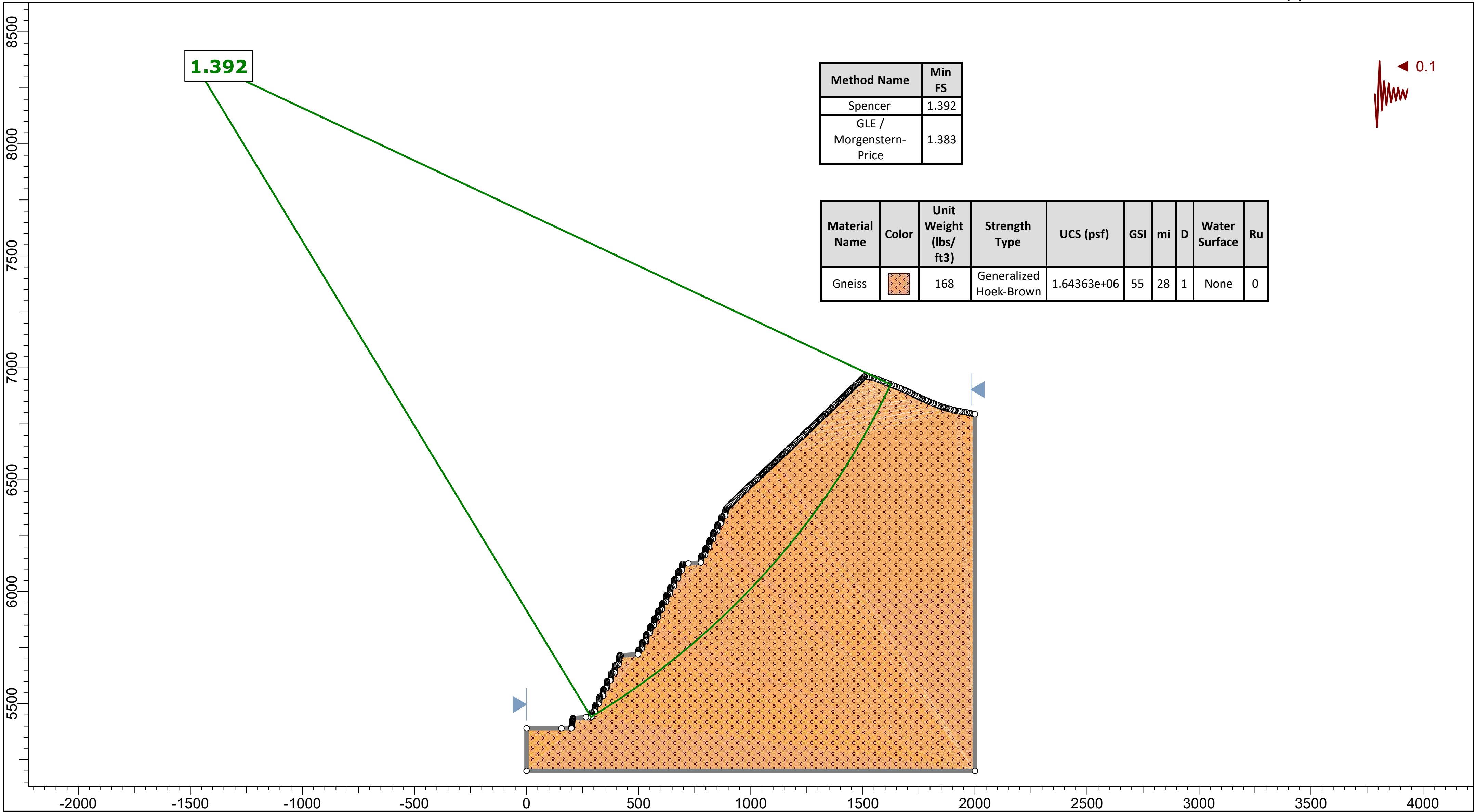
Rule 6.5 Exhibit
Appendix A

Method Name	Min FS
Spencer	2.148
GLE / Morgenstern-Price	2.145

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Hu Type	Hu
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	Water Surface	Custom	1



Schnabel ENGINEERING	*Project* Spec Agg Quarry Expansion		
	Analysis Description Section G - Ponded Water		
	Drawn By RLC	*Project No.* 21C18002.00	
SLIDEINTERPRET 9.019	*Date* 2/7/2022, 10:25:45 AM	*File Name* Spec Agg - Section G.slmd	



Method Name	Min FS
Spencer	1.392
GLE / Morgenstern-Price	1.383

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	UCS (psf)	GSI	mi	D	Water Surface	Ru
Gneiss		168	Generalized Hoek-Brown	1.64363e+06	55	28	1	None	0

Schnabel ENGINEERING

SLIDEINTERPRET 9.019

Project	Spec Agg Quarry Expansion		
Analysis Description	Section G - Seismic		
Drawn By	RLC	*Project No.*	21C18002.00
Date	2/7/2022, 10:25:45 AM	*File Name*	Spec Agg - Section G.slmd

Blast Impact Analysis
Martin Marietta – Spec Agg Quarry
Golden, Colorado

Prepared for:

Martin Marietta
Spec Agg Quarry
18401 West Colfax Ave
Golden, CO 80401

Prepared by:

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Suite 202
Austin, TX 78741
512-442-6464

April 19, 2021

Table of Contents

Executive Summary

Vibra-Tech has evaluated the potential impact from blasting in order to assist Martin Marietta in developing strategies for conducting the excavation and removal of materials with minimal disturbance to areas of concern in the vicinity of the Spec Agg Quarry.

The Spec Agg Quarry is in the permitting process to expand its mining area an additional 48 acres to the south. Vibra-Tech analyzed existing blasting data from January 2020 through January 2021 to make vibration and air overpressure predictions for the proposed new extraction area. A total of twenty-seven predictions were made for each location based on their respective distance to the proposed new extraction area boundary. Additional predictions were made for each location based on the quarry's phasing plan over the next twenty-five years. Vibra-Tech compared these predictions to appropriate vibration and/or air overpressure criteria for each receptor.

Avalanche Harley Davidson is located approximately 1181 feet to the closest point on the proposed mine boundary. Based upon this distance and the historical vibration data, the worst-case ground vibration would be a predicted particle velocity of 0.10 in/sec. The Highway 40 Exxon is located approximately 836 feet to the closest point on the proposed mine boundary. Based upon this distance and the historical vibration data, the worst-case ground vibration would be a predicted particle velocity of 0.18 in/sec. These levels of ground vibration are below the acceptable limits established by the USBM.

Predictions were also made for air overpressure using the same methodology and distances mentioned above. The worst-case predicted air overpressure at Avalanche Harley Davidson and Highway 40 Exxon were 0.00844 and 0.01234 psi respectively. Based upon the historical air overpressure data, these predicted air overpressure levels are below the acceptable limits established by the USBM.

Vibra-Tech has been monitoring ground vibration and air overpressure with digital seismographs near the Gateway Plaza and two other locations around the Spec Agg Quarry for a number of years now. Vibra-Tech recently added two additional digital seismographs. One located near the Avalanche Harley Davidson in the Gateway Plaza and the other near the Highway 40 Exxon gas station. Data from all five digital seismographs will continue to be reviewed and blast designs will be adjusted before vibration levels reach the applicable criteria limits. In our opinion, Martin Marietta can develop the Spec Agg Quarry mining area further to the south with no adverse effect on surrounding structures and residents from ground or air vibrations.

Purpose

Martin Marietta requested a review of current blasting process and the modification to process to ensure that mining taking place in the new extraction area will comply with Martin Marietta's internal controls related to vibration and air overpressure and minimized as much as possible. Martin Marietta's internal controls are stricter than state and federal requirements.

Permitting Description

Martin Marietta's Spec Agg Quarry is in the permitting process to permit 64 acres of adjacent property of which 16 acres will be buffer and a 48-acre extraction area. Drilling and blasting activities within the 48-acre extraction area will require continued application of modern blast designs to ensure all activities occur within established internal and state and federal thresholds.

Discussion on Blasting and Vibrations

In order to understand the nature of this issue the following pages are dedicated to educating the reader about mineral recovery via blasting, the effects of blasting operations on the earth, the causes of blast vibrations, why people feel vibrations, and how vibrations are measured.

Since blasting can sometimes produce perceptible ground vibrations beyond the quarry property, attempts to control vibrations have been accomplished via laws, regulations, and industry standards. Maximum permissible levels have been established based on academic and government studies of the effects of vibration on nearby property and people. Seismographs are used to measure the vibrations and ensure that the permissible levels are not exceeded. The seismograph may measure how far the ground moves from rest (displacement), how fast it moves (velocity), or how fast the velocity changes (acceleration). These three parameters are related by the frequency of the vibrations.

Frequency is a measure of how many times the ground will vibrate through its original position in one second. The seismograph also measures frequency, which is commonly reported in cycles per second or hertz (Hz). Standards limit the maximum amount of vibration that can occur at any point, or particle, on the ground surface. The limit is therefore commonly referred to as a peak particle displacement, peak particle velocity, or peak particle acceleration. Nearly all residential vibration standards limit the peak particle velocity.

Operators must have a method of estimating ground vibrations from a blast during its planning to confidently adhere to vibration limits. Since the amplitude of ground vibration is determined by how much energy is present to create vibration and how far the vibrations have propagated, researchers devised a single number to relate these parameters. This number, called the Square Root Scaled Distance, or simply Scaled Distance, relates ground vibration amplitude to explosive charge weight and distance from the blast. The scaled distance requires the explosive charge weight to decrease as the distance from the blast decreases in order to adhere to ground vibration peak particle velocity limits. The scaled distance provides a convenient method of comparing the ground vibration potential of different blast designs. Some regulations do not require the use of seismographs if the scaled distance from the blast is large enough.

In response to quarry operator desires to minimize ground vibrations and still operate efficiently, explosive manufacturers developed millisecond delayed blasting caps. Research has shown that several charges detonated only a few thousandths of a second apart would not only produce less ground vibration but are also more effective at fracturing and moving rock than a simultaneous detonation of all charges. All quarry blasts today consist of many charges detonated several hundredths or thousandths of a second apart. The scale distance equation defines maximum charge weight per delay as the total weight of explosives detonated within a certain period of time, rather than the total weight of explosives in the blast.

Air-borne vibration may also be produced by blasting. These vibrations may occur within the audible range of the human ear (sound), or at frequencies below those humans can hear (infrasonic). Many sources for air vibration exist in a typical blast, but all can be traced back to either the venting of the detonation and explosion pressures or the fractured rock pushing air out of the quarry. Seismographs are equipped with microphones and measure these changes in air pressure occurring as the air vibration passes to determine if permissible limits are exceeded.

The weight of the air in Earth's atmosphere produces pressure upon everything on Earth. This pressure, known as atmospheric pressure, is commonly reported in daily weather reports in millibars (mbar, metric) or inches of mercury (in.Hg, USCS). The air vibrations produced by blasting cause the normal air pressure to fluctuate. Changes in normal air pressure due to the airblast are referred to as overpressure, as in pressure over atmospheric pressure. Air overpressure resulting from blasting is measured by microphones attached to seismographs.

Changes in air pressure due to wind are many times greater than the changes in pressure produced by blasting. This is why a gust of wind may push a garbage can down the street, but the air overpressure from a quarry cannot. The frequency of the changes in air pressure produced by wind is much lower than the frequency of the air pressure wave produced by blasting. Two important effects can be traced to this difference in frequency. First, wind remains inaudible, while air overpressure from blasting may rumble or boom. Second, higher frequency changes in air pressure due to blasting means forces on the structure's exterior change quickly. A window pane may be alternately pushed and pulled fast enough to make it rattle as a result of a blast. Wind force, on the other hand, does not change direction quickly. Wind can therefore push or pull on a window pane with a much greater force without producing audible sounds.

Most air overpressures from blasting are measured in thousandths or ten thousandths of pounds per square inch (psi). Rather than reporting air overpressures in psi, most regulations specify decibels (dB). Since a decibel is a measure of change, it must be with respect to some value. The reference pressure for air overpressure monitoring is 2.9×10^{-9} psi. A small change in decibels can represent a very large change in pressure. Doubling of the overpressure in psi yields a 6 dB increase; a tenfold increase in overpressure equates to a 20 dB increase.

Established Vibration Criteria

Ground Vibration Criteria from USBM RI-8507

The U.S. Bureau of Mines has studied various aspects of ground vibration and air blast since 1930. In 1980, the culmination of over 50 years of research was compiled into RI-8507[1] entitled "Structure

[1] Siskind, D.E., Stagg, M.S., Kopp, J.W. & Dowding, C.H. (1980). Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting (Report of Investigation 8507). U.S. Bureau of Mines, Washington, D.C.

Response and Damage Produced by Ground Vibrations from Surface Mine Blasting". In this study direct measurements of structural response and damage from actual surface-mine production blasting was observed in 76 residences for 219 production blasts. This data along with damage data from six additional studies were combined with the historical data from an earlier report entitled Bulletin 656. Particular emphasis was placed on the frequency dependence of structure response and its relationship to damage.

The culmination of this study was the Appendix B curve which was entitled "Alternative Blasting Level Criteria". The Appendix B curve used both measured structure amplification and damage evaluations to develop criteria that involved both displacement and velocity.

The curve in Figure 1 below shows that above 40 Hz, a constant peak particle velocity of 2.0 in/sec is the maximum safe value. This level was established to protect the interior walls and ceilings of structures, regardless of construction material.

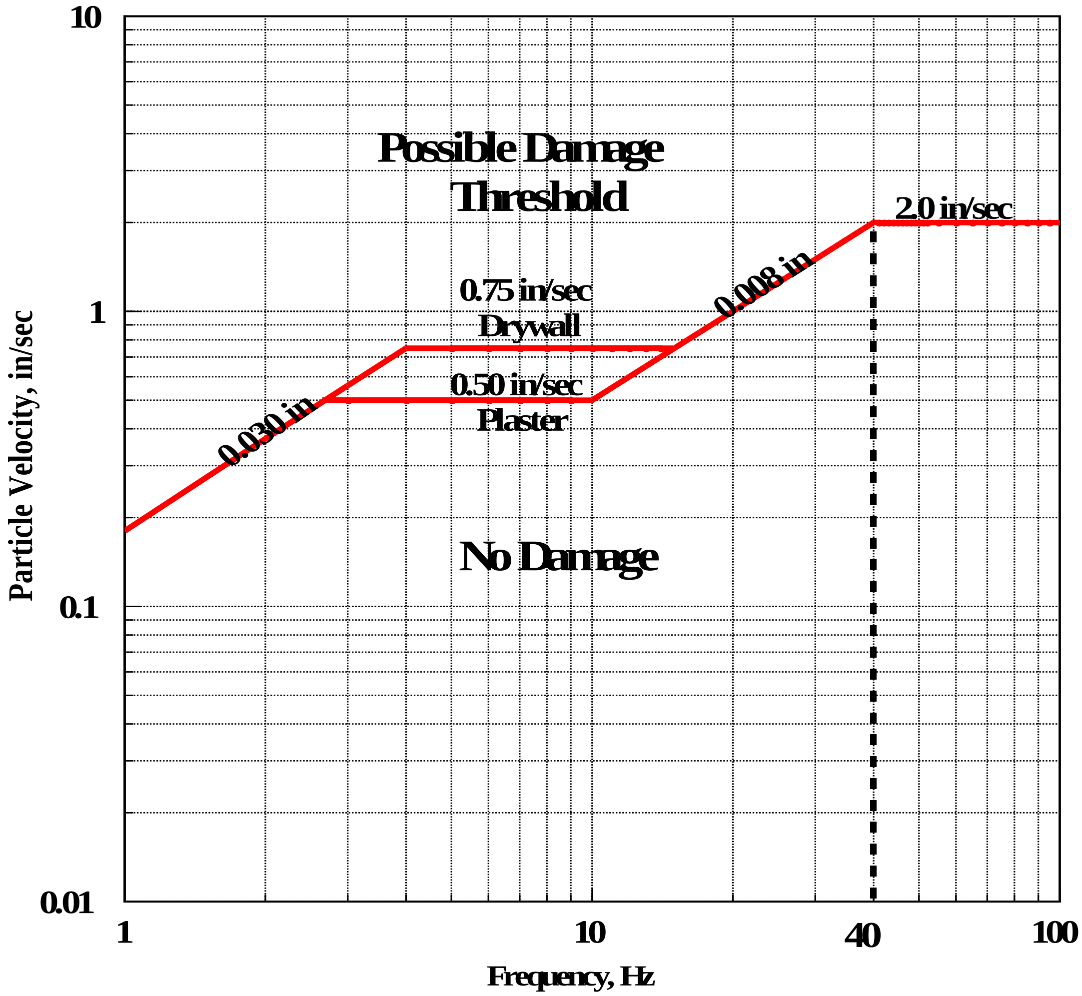

Figure 1. U.S. Bureau of Mines Vibration Criteria. Maximum Safe Values for Peak Particle Velocity (From RI-8507)

Below 40 Hz however, the maximum velocity decreases at a rate equivalent to a constant peak displacement of 0.008 inches. For intermediate frequencies (4 to 12 Hz), a 0.5 inch per second maximum particle velocity is the accepted level to preclude 'threshold' damage to the plaster-on-wood-lath interior portions of older structures. Threshold damage is defined by the USBM as the loosening of paint, small plaster cracks at joints between construction elements or the lengthening of old plaster cracks. A maximum of 0.75 inch per second is the accepted level for the protection of modern drywall interior construction between 4 and 12 Hz. The damage threshold is normally considerably higher for load-bearing or other structural portions of a house.

Air Vibration Criteria from USBM RI-8485

The USBM has also set forth air overpressure limits in its Report of Investigation RI-8485[2] "Structure Response and Damage Produced by Airblast from Surface Mining". The safe air-blast limits recommended by the USBM were determined by analyzing structural response and damage from many applicable studies. Based on a minimal probability of the most superficial type of damage in residential-type structures, any of the following represent safe maximum air overpressure levels:

Table 1. Air Borne Vibration Criteria recommended in USBM RI-8485

Lower Frequency Limits of Measuring System	Maximum Level in dB
0.1 Hz high-pass system	134 dB
2 Hz high-pass system	133 dB
5 or 6 Hz high-pass system	129 dB
c- slow (events not exceeding 2 sec duration)	105 dB

The USBM concluded that the single best air overpressure descriptor is the 2 Hz system. These recommendations have been accepted by many states. The maximum safe air overpressure level set forth by USBM RI-8485 for this type of system is 133 dB (0.01295 psi).

The recommended limits listed in Table 1 were compared to a composite of five impulsive noise studies for human tolerance in the USBM report. Based upon these studies, the USBM concluded that these recommended air overpressure limits would provide annoyance acceptability to 95% of the population for 1 to 2 events per day.

Structural damage as a result of air overpressure is generally conceded to not be possible without extensive window breakage, as the glass is the weakest portion of a structure's exterior where this pressure acts. Windowpanes are designed to safely withstand changes of 1.0 psi (170 dB) when properly installed, and even in the worst situation a pane should be able to withstand 0.1 lbs/in^2 (150 dB). Air overpressures from blasting rarely exceed 0.01 psi (130 dB). This level is about one one-hundredth of the overpressure that a window can safely withstand.

[2] Siskind, David et. al. (1980). Structural Response and Damage Produced by Airblast from Surface Mining (Report of Investigation 8485). U.S. Bureau of Mines, Washington, D.C.

Projected Ground and Air Vibration Levels

The previous sections have presented research on vibration levels for the protection of structures around the perimeter of the site. Since the new mining area will be further to the south, it will be necessary to predict the level of blast-induced ground and air vibration levels from the blasting data to date for comparison to this research. Over the years several authors have published prediction formulae or graphs for this purpose. These prediction formulae relate the existing blasting data peak particle velocity values to the ratio of known distances to local monitoring receptors.

Ground vibrations or seismic waves decay with distance. Ground vibrations from typical blasting in most geologic settings decay or attenuate to about 1/3 their former value for each doubling of distance. For example, at 200 feet the vibration is about 1/3 as intense as it is at 100 feet. Because vibration waves attenuate in a fairly regular manner it is possible to predict them within acceptable accuracy.

Peak particle velocity prediction formulas exist to calculate vibration intensity levels at a particular location based upon attenuation factors, known peak particle velocity values at existing digital seismographs, and distances from the blast to the digital seismographs. Using these formulas, it is possible to utilize the ground vibrations and air overpressure levels from the blasts that occurred from January 2020 to January 2021 to estimate the resulting vibration levels at the closest off-site receptors. Distances from the extraction area to the off-site receptors were taken from the aerial photos showing the mining extraction boundary over a time period of 25 years. Figures A-1 through A-6 in Appendix A show aerial views of the site including the proposed mining extraction area, five-year phasing plan boundaries through twenty-five years, the closest digital seismographs and the off-site receptors of concern.

Projected Levels

Utilizing the existing ground vibration and air overpressure data from the Gateway Plaza digital seismograph from January 2020 to January 2021 and the ratio of the known distances Figures B-1, B-3, B-5, B-7, B-9 and B-11 in Appendix B show the predicted peak particle velocity values for each blast from 2020 compared to the USBM RI-8507 ground vibration criteria curve. This prediction would be as if the same shot had originated at the boundary of the new mining extraction area.

The Avalanche Harley Davidson is 1181 feet from the final mining extraction area boundary. The Highway 40 Exxon is 836 feet from the final mining extraction area boundary. The highest predicted peak particle velocity calculated at the Avalanche Harley Davidson was 0.10 in/s. The highest predicted peak particle velocity calculated at the Highway 40 Exxon digital seismograph was 0.18 in/s. When comparing our highest predicted values to the established criteria for maximum safe values of ground vibration (0.75 in/sec PPV for the residential/commercial structures) we find that the ground vibration criteria would not be exceeded.

We can also input the ratio of the known distances and the measured air overpressure to estimate the air overpressure at the off-site receptors of concern. Figures B-2, B-4, B-6, B-8, B-10 and B-12 in Appendix B show the predicted air overpressure values for each blast from 2020 compared to the USBM RI-8485 airborne vibration criteria. We found the highest predicted air overpressure at the Avalanche Harley Davidson and the Highway 40 Exxon to be 0.00844 psi (129.3 dB) and 0.01234 psi (132.6 dB) respectively.

Comparing the predicted values to the established criteria for maximum safe values of air overpressure 0.01295 psi (133 dB) air overpressure for the residential/commercial structures) we find that the air overpressure criteria would not be exceeded. Table 2 below is a summary of the highest predicted ground vibration and air overpressure based on the closest mining boundary distance to each receptor for each mining phase.

Table 2. Summary of Predicted Ground Vibration and Air Overpressure Levels for Each Phase

Mining Extraction Boundary	**Avalanche Harley**			**Highway 40 Exxon**		
	Distance (ft)	**Predicted PPV (in/sec)**	**Predicted AO (dB)**	**Distance (ft)**	**Predicted PPV (in/sec)**	**Predicted AO (dB)**
5-Year	1939	0.04	124	1034	0.12	130
10-Year	1528	0.06	126	836	0.18	132
15-Year	1367	0.08	127	875	0.16	132
20-Year	1387	0.08	127	948	0.14	131
25-Year	1457	0.07	127	990	0.13	130
Final	1181	0.10	129	836	0.18	132

It should be noted that on May 20, 2020, an abnormal level of air overpressure was measured at the Gateway Plaza digital seismograph. This resulted in the higher predicted values given in table 2 above. Review of Figures B-2, B-4, B-6, B-8, B-10 and B-12 in Appendix B shows that typical levels are below 0.005157 psi (125 dB). If elevated levels of air overpressure begin to occur as blasting advances closer to the new mining area boundary, adjustments will be made to ensure that the air overpressure levels remain below the applicable criteria.

Conclusion

The analysis has shown that based upon the ground vibration and air overpressure levels that were recorded in 2020, if those blasts were migrated to the closest point on the mining extraction boundary, the ground vibration and air overpressure levels would meet the criteria discussed in this report. Predicted ground vibration levels were found to be at 0.18 in./sec or lower which is 36% of the allowable limit at 0.5 in/sec. Average air overpressure levels were found to be below 0.005157 psi (125 dB) which is 39.8% of the allowable limit of 0.01295 psi (133 dB). In our opinion, Martin Marietta can blast in the proposed extraction area to the south of the current Spec Agg quarry with no adverse effect on surrounding structures and residents from ground or air vibrations.

Respectfully submitted,
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Project Manager

Nick Reittinger
Area Manager

Douglas Rudenko
Vice President

APPENDIX A

Description: The teal polygon outlines the final proposed mining extraction area. The red icons designate the nearby seismograph locations and the yellow icons designate the off-site receptors of concern.

FIGURE A-1

Description: The teal polygon outlines the final proposed mining extraction area and the yellow polygon outlines the five-year phasing boundary. The red icons designate the nearby seismograph locations and the yellow icons designate the off-site receptors of concern.

FIGURE A-2

Description: The teal polygon outlines the final proposed mining extraction area and the yellow polygon outlines the ten-year phasing boundary. The red icons designate the nearby seismograph locations and the yellow icons designate the off-site receptors of concern.

FIGURE A-3

Description: The teal polygon outlines the final proposed mining extraction area and the yellow polygon outlines the fifteen-year phasing boundary. The red icons designate the nearby seismograph locations and the yellow icons designate the off-site receptors of concern.

FIGURE A-4

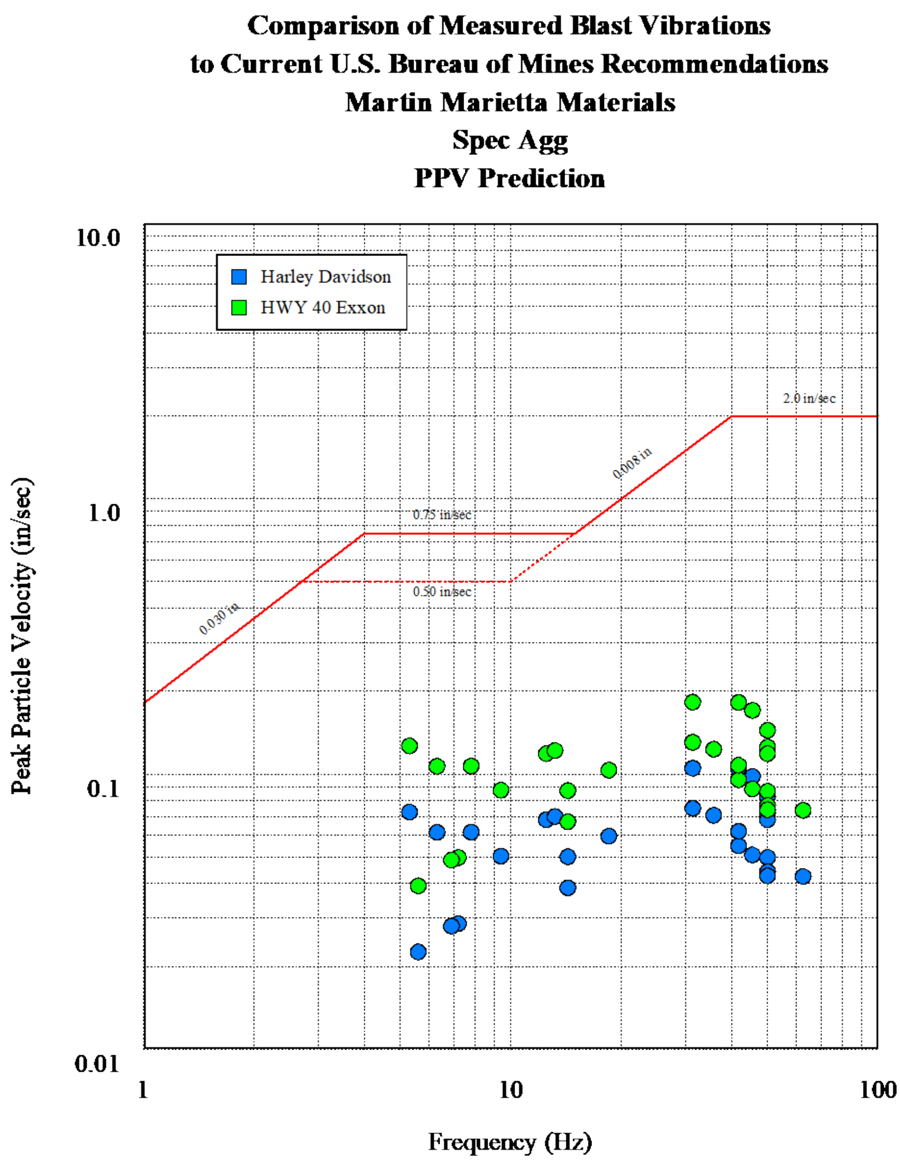
Description: The teal polygon outlines the final proposed mining extraction area and the yellow polygon outlines the twenty-year phasing boundary. The red icons designate the nearby seismograph locations and the yellow icons designate the off-site receptors of concern.

FIGURE A-5

Description: The teal polygon outlines the final proposed mining extraction area and the yellow polygon outlines the twenty-five-year phasing boundary. The red icons designate the nearby seismograph locations and the yellow icons designate the off-site receptors of concern.

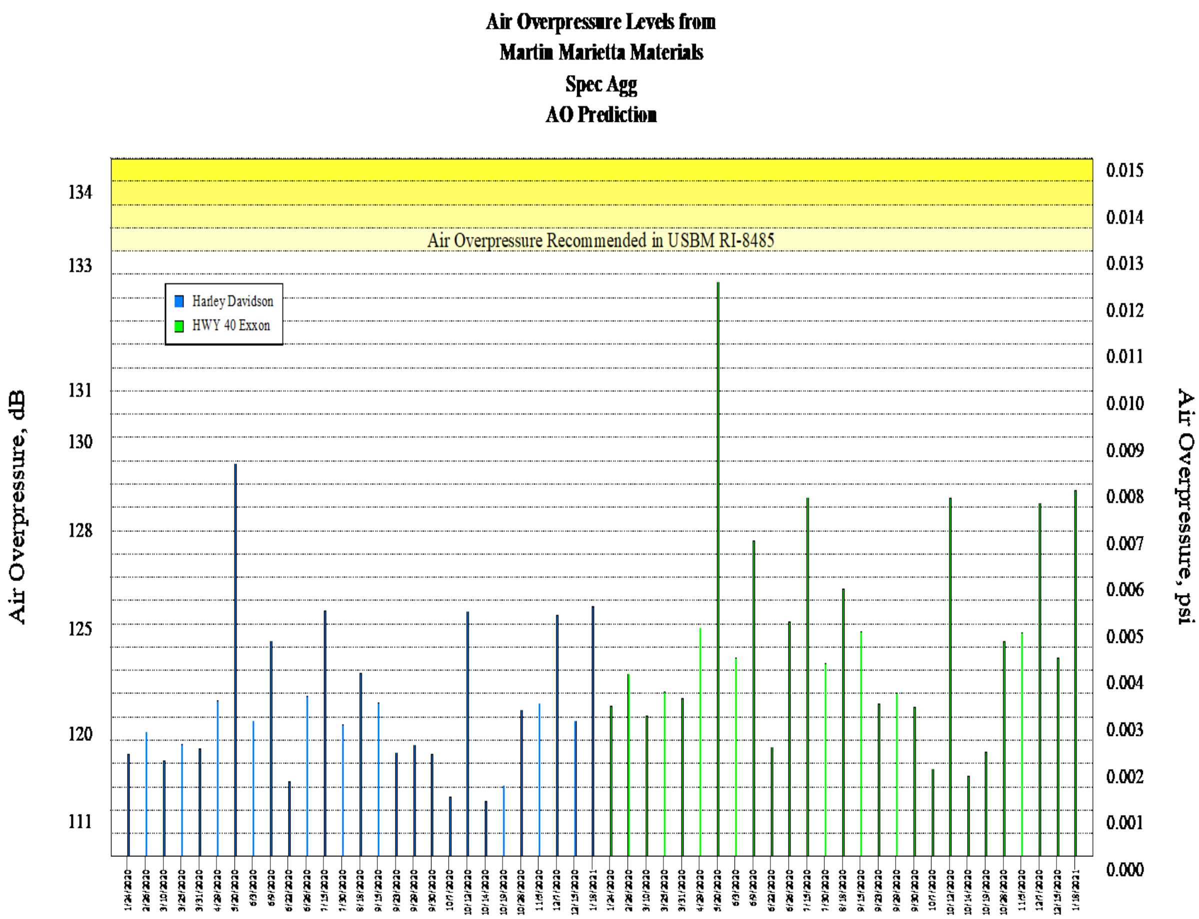
FIGURE A-6

APPENDIX B



Description: The green and blue dots represent the 2020 predicted peak particle velocity values from the final mining extraction boundary to the off-site receptors of concern. The red line represents the USBM RI-8507 ground vibration criteria curve.

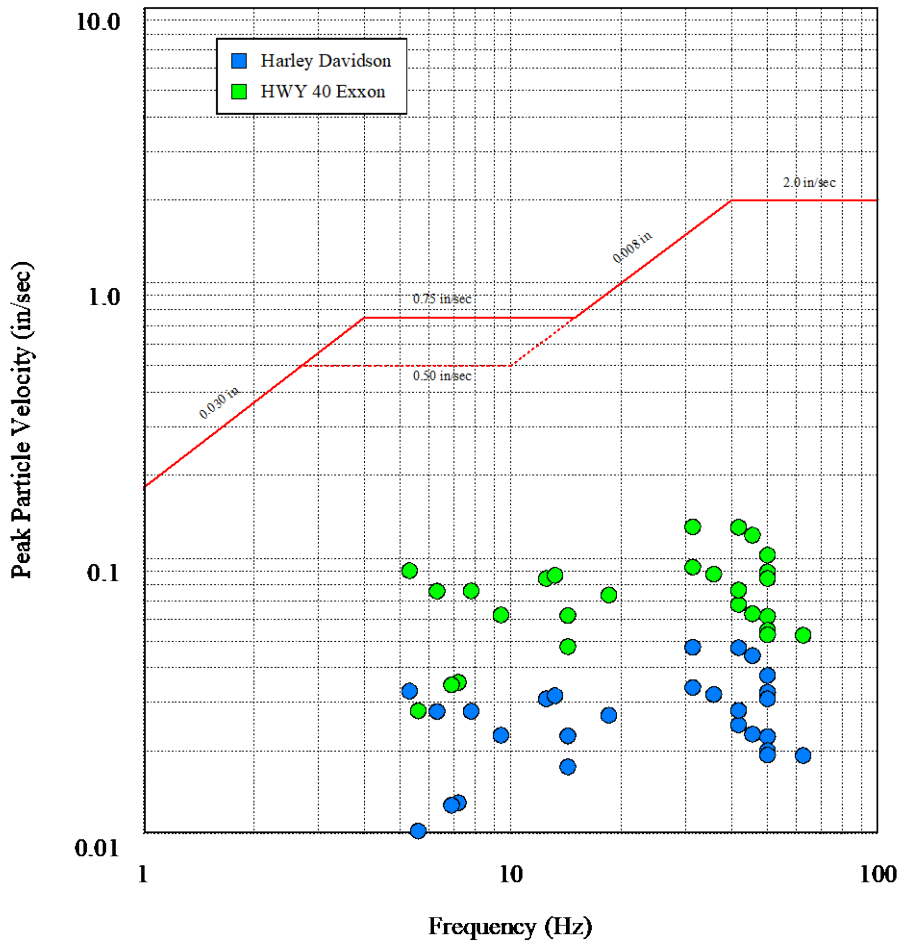
FIGURE B-1



Description: The green and blue bars represent the 2020 predicted air overpressure values from the final mining extraction boundary to the off-site receptors of concern. The yellow area represents the USBM RI-8485 air overpressure exceedance limit beginning at 133dB.

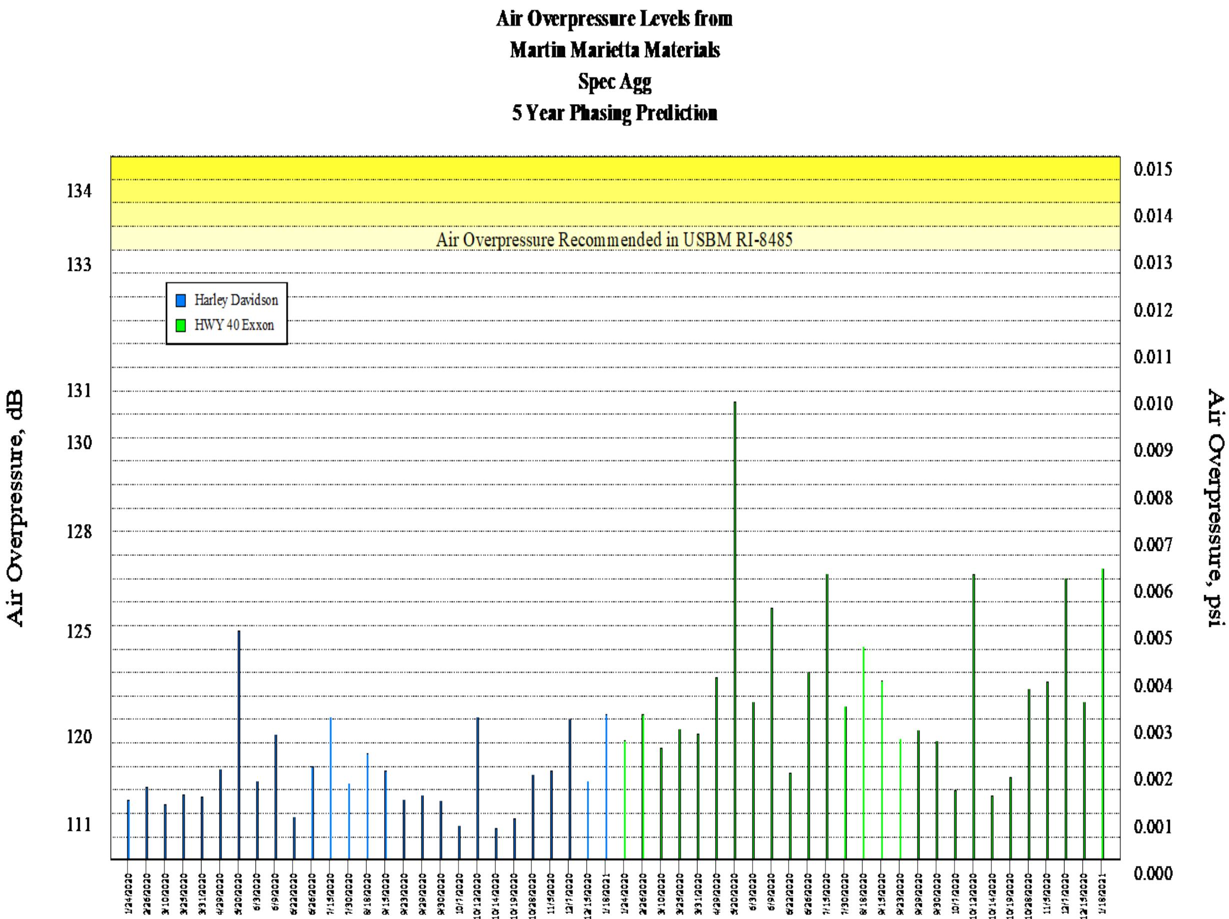
FIGURE B-2

**Comparison of Measured Blast Vibrations
to Current U.S. Bureau of Mines Recommendations
Martin Marietta Materials
Spec Agg
5 Year Phasing Prediction**



Description: The green and blue dots represent the 2020 predicted peak particle velocity values from the five-year phasing boundary to the off-site receptors of concern. The red line represents the USBM RI-8507 ground vibration criteria curve.

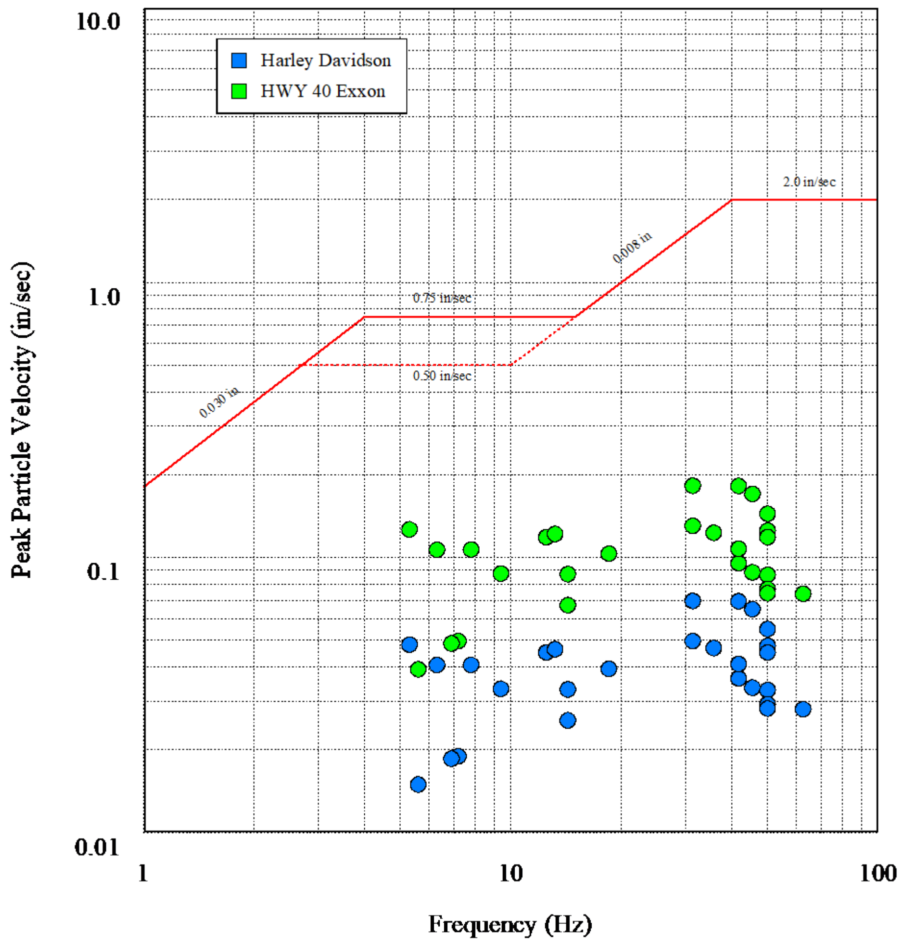
FIGURE B-3



Description: The green and blue bars represent the 2020 predicted air overpressure values from the five-year phasing boundary to the off-site receptors of concern. The yellow area represents the USBM RI-8485 air overpressure exceedance limit beginning at 133dB.

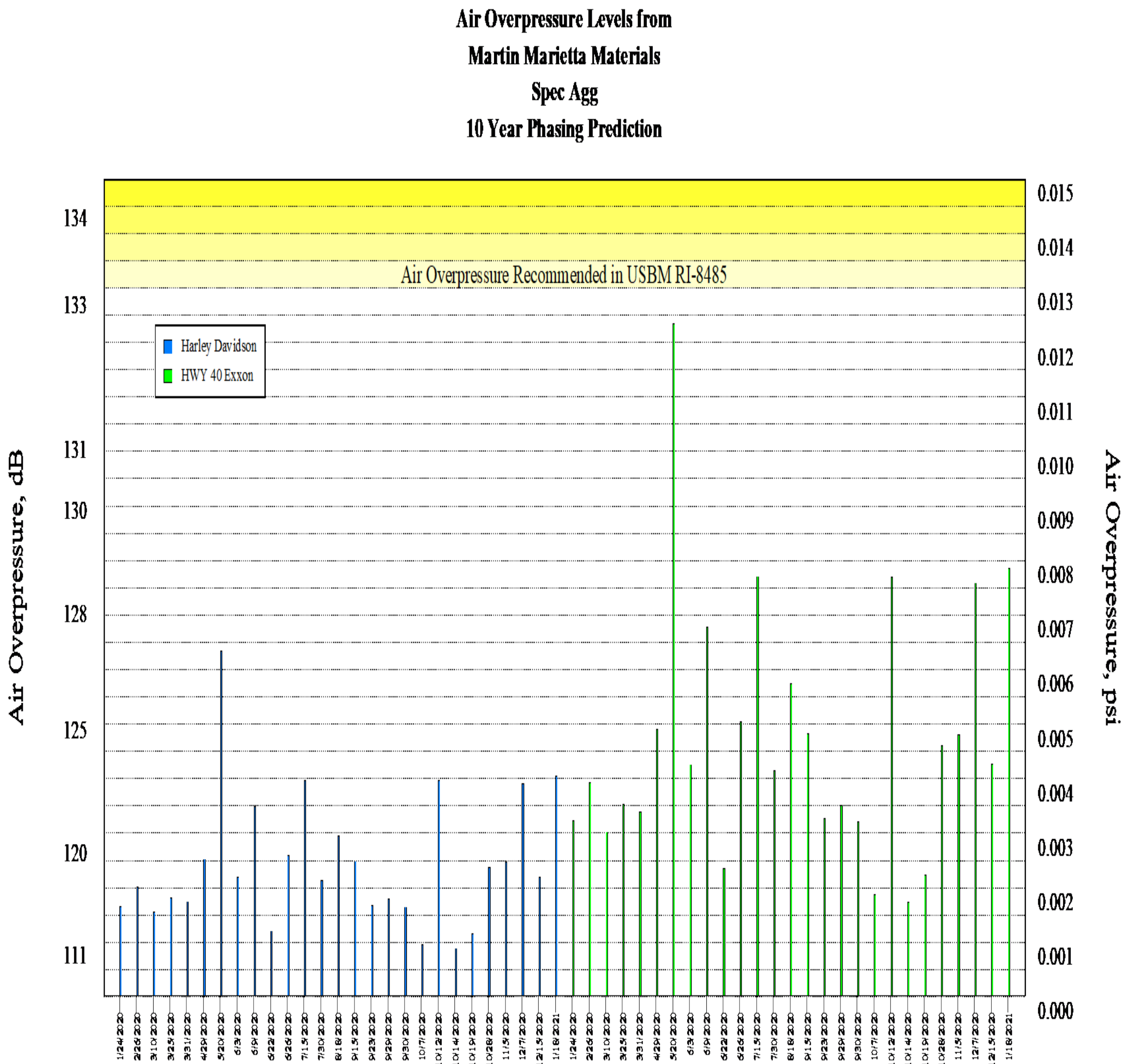
FIGURE B-4

**Comparison of Measured Blast Vibrations
to Current U.S. Bureau of Mines Recommendations
Martin Marietta Materials
Spec Agg
10 Year Phasing Prediction**



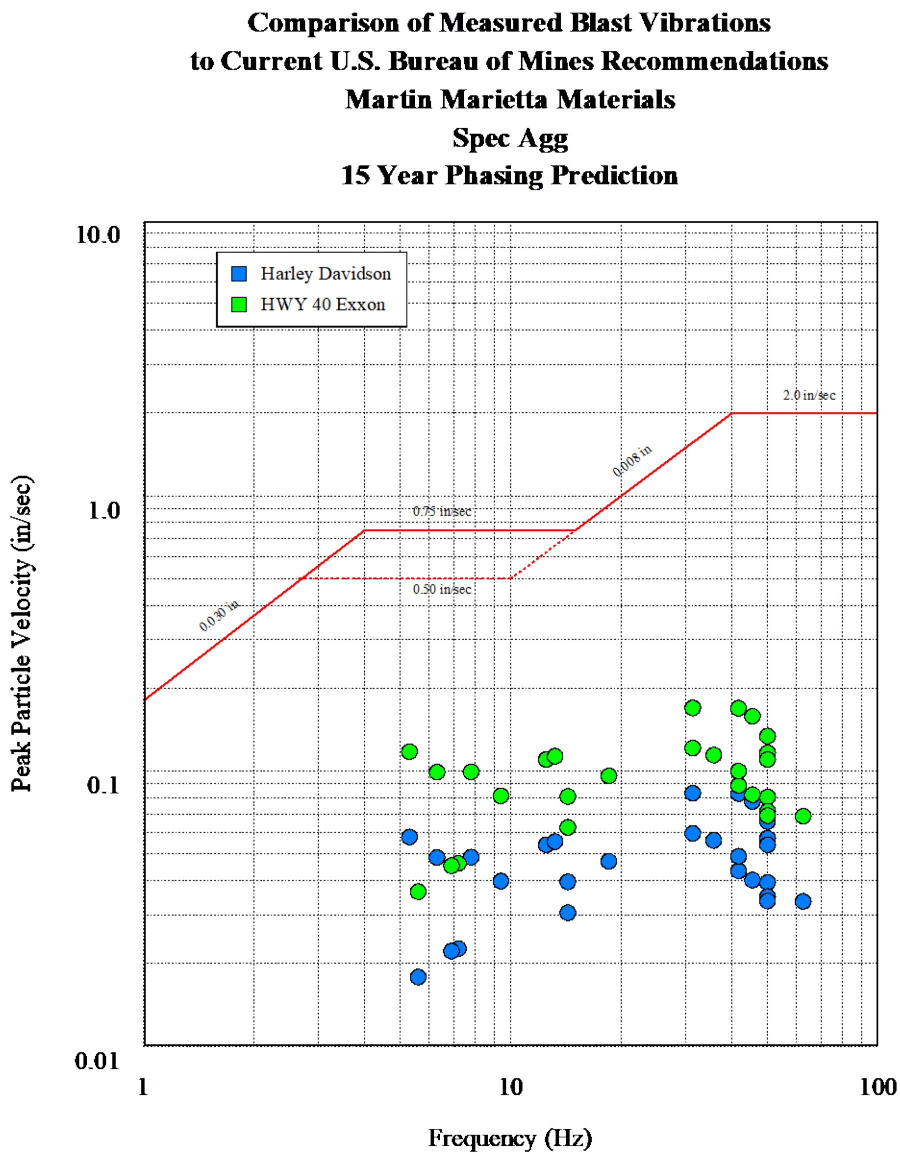
Description: The green and blue dots represent the 2020 predicted peak particle velocity values from the ten-year phasing boundary to the off-site receptors of concern. The red line represents the USBM RI-8507 ground vibration criteria curve.

FIGURE B-5



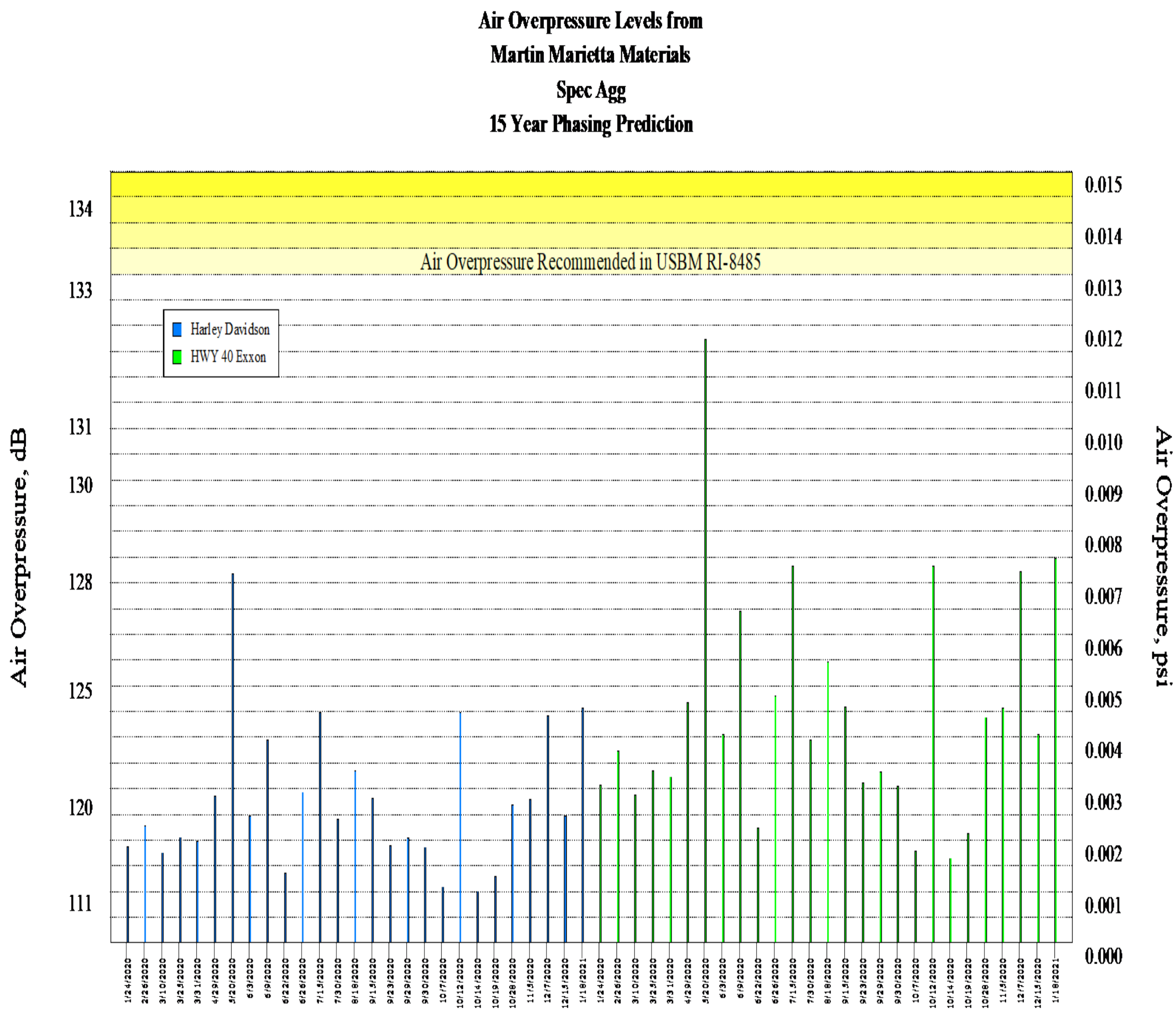
Description: The green and blue bars represent the 2020 predicted air overpressure values from the ten-year phasing boundary to the off-site receptors of concern. The yellow area represents the USBM RI-8485 air overpressure exceedance limit beginning at 133dB.

FIGURE B-6



Description: The green and blue dots represent the 2020 predicted peak particle velocity values from the fifteen-year phasing boundary to the off-site receptors of concern. The red line represents the USBM RI-8507 ground vibration criteria curve.

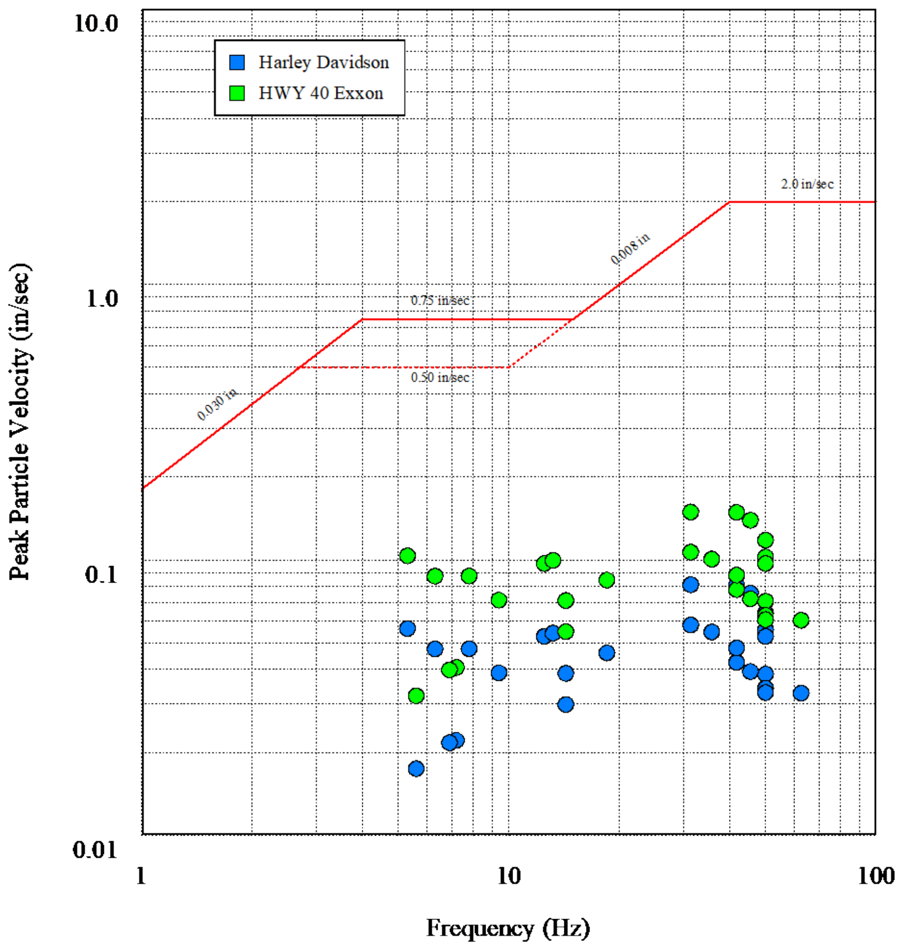
FIGURE B-7



Description: The green and blue bars represent the 2020 predicted air overpressure values from the fifteen-year phasing boundary to the off-site receptors of concern. The yellow area represents the USBM RI-8485 air overpressure exceedance limit beginning at 133dB.

FIGURE B-8

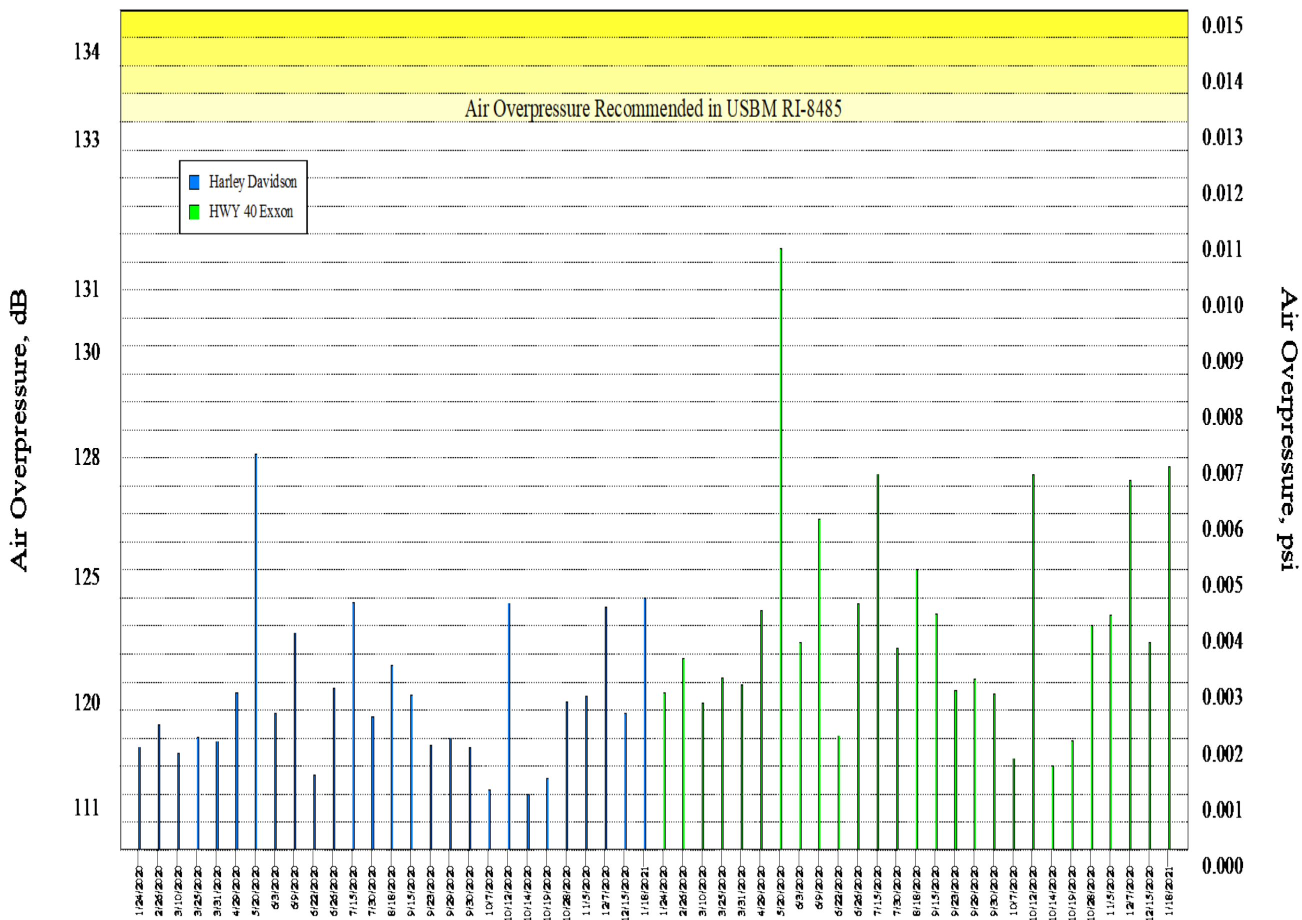
Comparison of Measured Blast Vibrations
to Current U.S. Bureau of Mines Recommendations
Martin Marietta Materials
Spec Agg
20 Year Phasing Prediction



Description: The green and blue dots represent the 2020 predicted peak particle velocity values from the twenty-year phasing boundary to the off-site receptors of concern. The red line represents the USBM RI-8507 ground vibration criteria curve.

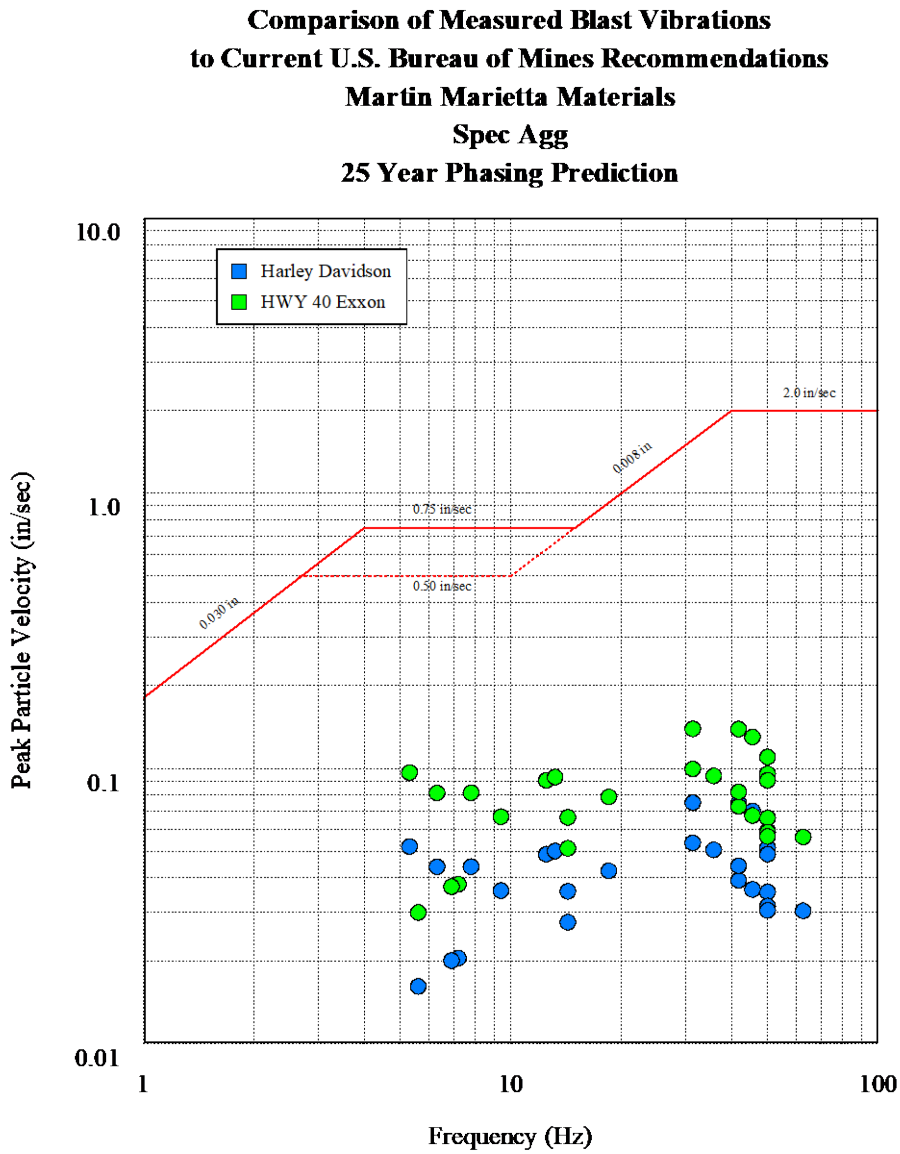
FIGURE B-9

Air Overpressure Levels from
Martin Marietta Materials
Spec Agg
20 Year Phasing Prediction



Description: The green and blue bars represent the 2020 predicted air overpressure values from the twenty-year phasing boundary to the off-site receptors of concern. The yellow area represents the USBM RI-8485 air overpressure exceedance limit beginning at 133dB.

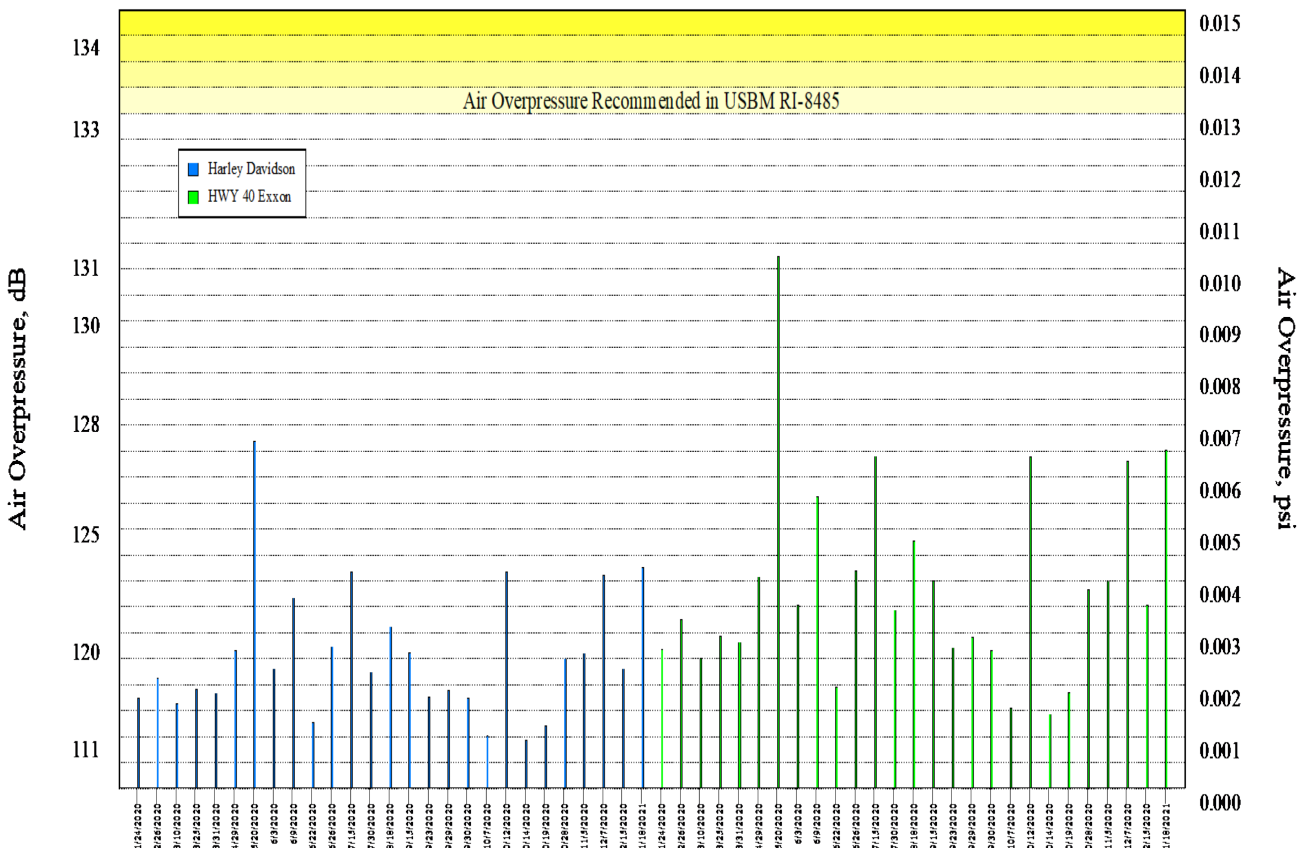
FIGURE B-10



Description: The green and blue dots represent the 2020 predicted peak particle velocity values from the twenty-five-year phasing boundary to the off-site receptors of concern. The red line represents the USBM RI-8507 ground vibration criteria curve.

FIGURE B-11

Air Overpressure Levels from
Martin Marietta Materials
Spec Agg
25 Year Phasing Prediction



Description: The green and blue bars represent the 2020 predicted air overpressure values from the twenty-five-year phasing boundary to the off-site receptors of concern. The yellow area represents the USBM RI-8485 air overpressure exceedance limit beginning at 133dB.

FIGURE B-12

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