Department of Environmental Protection
Bureau of Mine Safety

DOCUMENT NUMBER: 583-2219-001

TITLE: Guidelines for Submittal of Benching Plans

EFFECTIVE DATE: XXXX

AUTHORITY: Section 1915-A of the Administrative Code of 1929, 71 P.S. § 510-15; 25 Pa. Code §§ 207.313 and 207.104(a)(3)

POLICY: The Bureau of Mine Safety (BMS) promotes benching practices in underground industrial mineral mines that protect all individuals working underground. These practices include evaluating the integrity of the mine pillars, ensuring adequate roof beam and roof control measures, establishing safety standards during and after benching, and maintaining adequate floor beam.

PURPOSE: The purpose of this guidance document is to provide information to reduce the risk of roof and pillar failure during benching and thereafter for the health and safety of those working in underground industrial mineral mines and to prevent surface subsidence.

APPLICABILITY: This guidance is applicable to all underground industrial mineral mine operators and personnel.

DISCLAIMER: The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of the Department to give these rules that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: X pages

LOCATION: Volume X, Tab X

1. BACKGROUND

BMS's mission is to reduce the possibility of accidents in and about the underground mines, to protect the property connected therewith, to provide for the health and safety of the individuals working underground, and to contribute to the public safety in relation to underground mining activities. To accomplish these objectives, BMS conducts inspections, engineering reviews, and plan approvals.

Benching is a process where material from the bottom of the existing mine passage is extracted vertically between the existing pillars of an underground industrial mineral mine. The floor of the developed portion of the mine is removed through blasting. During benching, the pillar height increases as stone is removed but the width of the mine passage remains the same. The extracted stone is typically processed and sold by the operator.

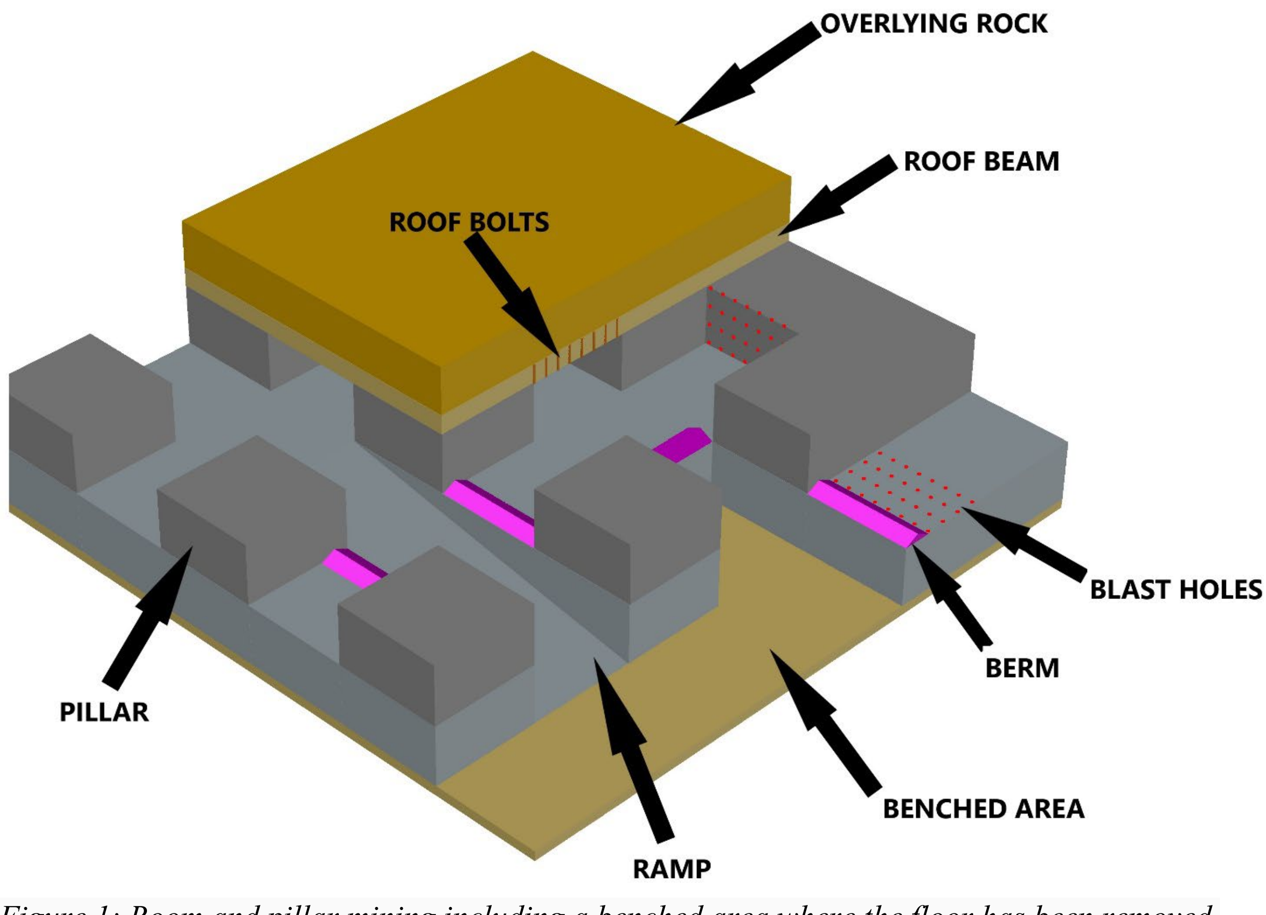


Figure 1: Room and pillar mining including a benched area where the floor has been removed between existing pillars. Shot holes are drilled vertically into the floor of the initial mine heading and a thickness of the initial mine floor is removed after blasting. The area is ramped down for access and haulage. Berms are placed between the initial developed portion of the mine and the benched area. The darker gray colored material represents the upper part of the mined geologic formation with the lighter gray colored material being the lower portion of the mined geologic formation.

For over half a century benching has been practiced successfully in many Pennsylvania underground industrial mineral mines. Until recently, benching operations were left up to the mine operator to ensure the health and safety of those working underground. As catastrophic pillar failures, airblasts, and surface subsidence occurred over the past decade, BMS and the mining operators embarked on an initiative to improve mining techniques to ensure long-term stability of the mines and safeguard the health and safety of miners.

Catastrophic pillar failures in Pennsylvania's industrial mineral mines refer to incidents where an array of structural pillars supporting underground industrial mineral mines fail and may subsequently result in an airblast and surface subsidence. An airblast is an abrupt displacement of often pressurized air, caused by pillar collapse in a constrained area. Surface subsidence is the depression formed on the surface above or adjacent to the underground mine. These terms and consequences are described in detail in the referenced publications in Appendix A.

Pillar failures can occur due to various factors such as poor mining practices, geologic conditions, and the overloading of pillars. From 2015 to 2021, four massive pillar collapses were documented in three Pennsylvania underground industrial mineral mines. All four instances of pillar failure led to airblasts and surface subsidence, with one instance resulting in serious injuries. These instances have been documented by the Mine Safety & Health Administration (MSHA), the National Institute for Occupational Safety and Health (NIOSH), and BMS and are detailed further in the references listed in Appendix A.

To reduce the potential risks to the health and safety of underground workers and to protect the stability of underground industrial mineral mines from potential collapse due to proposed benching activities, BMS requests that the mining operator conduct a risk assessment for pillar failure; analyze the roof beam, pillars, and floor; and model the post structure stresses. This information should be presented to BMS as a benching plan prior to conducting benching activities.

Operators have been submitting benching plans to BMS since 2021.This guidance document can inform the mining operator's process of evaluation of proposed benching areas and the potential risks associated therewith.

A. Assessment Process

The mine risk assessment process consists of first identifying a proposed benching area. Then, the likelihood of a pillar collapse in that area is evaluated per Section 2B of this TGD. This evaluation helps to define the geotechnical and mining geometry data that is necessary to conduct the assessment. The overall likelihood of a collapse can then be assessed based on a qualitative evaluation.

Another step is to evaluate the consequences of a potential collapse. The Pillar Collapse Consequence Matrix guides the evaluation, which considers both the potential hazards that would be present in different locations in the mine, and the exposure of the individuals working underground to those hazards.

Pillar Collapse Consequences Matrix

Location of Miners	Condition/Hazards	Consequence
Working within pillar collapse area, engaged in active benching operations	Massive rock fall, no warning	Death
Working or traveling in travelways or haul roads directly adjacent to pillar collapse area	High air velocities (airblasts), flying debris, small rock falls	Death or severe injury
Working or traveling directly above a pillar collapse area	Sudden development of a surface sinkhole	Death or severe injury
Working or traveling in high velocity air pathways leading from pillar collapse area to portals	Diminishing air velocities depending on the number of pathways and distance from pillar collapse	Injury
Other locations in the mine	Damage to ventilation controls or escapeway routes	Indirect hazards

Finally, for those areas where the combination of likelihood and consequence is great enough, potential steps to mitigate the risk should be considered if benching is desired in those areas.

B. Likelihood of a Pillar Collapse

The likelihood of a pillar collapse is typically evaluated utilizing various rock mechanic models, equations, and software appropriate for the mine conditions. Developed by The National Institute for Occupational Safety and Health (NIOSH), S-Pillar is the most common software tool used by most mining operators in Pennsylvania to evaluate the likelihood of a pillar collapse in areas where the proposed rock unit to be mined. However, at this time, the S-Pillar software is typically applicable to areas of relatively low dip (typically of less than 5 degrees), single level mining, strong strata, lack of clayey bands in pillars, and a strong floor and roof. In areas that do not meet these requirements, an alternate model or a combination of sound engineering alternatives may be utilized to analyze the likelihood of a pillar collapse.

The likelihood of pillar collapse evaluation has two parts:

- The first part is the safety factor calculation. S-Pillar estimates the strength of the pillars based on their width-to-height (w/h) ratio, the uniaxial compressive strength (UCS) of the strata, and most importantly, the presence of discontinuities (typically joints) within the pillars. The impact of the joints on pillar strength depends on their spacing and dip angle. The Factor of Safety (FS) is calculated by comparing the pillar strength to the tributary area load. S-Pillar recommends that the FS for a stone pillar layout should exceed 1.8. Other applicable sound engineering alternatives, where a safety factor is calculated based on area specific conditions may also be used.

- The second part of the evaluation is the w/h ratio. S-Pillar and various technical publications recommend that the w/h should exceed 0.8, regardless of the FS.

In both stages of the assessment, it is important to use the typical as-mined pillar dimensions rather than the planned dimensions. The remaining factors for consideration include:

i. ***Pillar Dimension Variability***: If the pillar array contains some pillars that are significantly smaller than the typical dimensions, these small pillars can fail first and potentially trigger a larger collapse. Additionally, signs of pillar overloading (rib spalling, hourglass shaped, rounded) suggest that the area may not be well supported by the existing pillars.

ii. ***Pressure Arch/Spanning Potential:*** The tributary area loading model assumes that the pillars carry the full weight of the overburden. In reality, with typical overburden geologies and panel widths, only a few pillars in the center of the panel may carry the full tributary area load, while the pillars near the edges of the panel are somewhat shielded. More of the pillars would be expected to see the full tributary area load when the overburden is weak or shallow, or where the panel is very wide. On the other hand, where the panel is narrow, the cover is deep, and/or the overburden is strong, a pressure arch can transfer enough weight that none of the pillars see the full tributary area load, thus decreasing the likelihood of a collapse.

iii. ***Size of Benched Area:*** All things being equal, a larger benched area is more likely to collapse and also have larger consequences if it does.

iv. ***Major Geologic Features:*** Faults come in many forms, and so one fault's effect on any particular benched area needs to be evaluated on a site-specific basis. For example, the fault that was present at a southwestern Pennsylvania Loyalhanna limestone mine collapse may have contributed to weakening the overburden, thereby increasing the pillar load. Karst features, joints, bedding planes, and similar geologic discontinuities might also influence the likelihood of a pillar collapse.

v. ***Weak (Soft)Floor:*** A weak geologic floor of the underground mine, typically consists of rock composed primarily of clay and can reduce pillar strength by squeezing out and causing pillar dilation.

vi. ***Weak Bands in the Pillars:*** Thick bands of weak material, like clay, can cause rib dilation and slabbing, thereby reducing a pillar's strength and load bearing area.

vii. ***Roof Beam Competency and Thickness***: Roof beams consisting of discontinuities, thinly bedded intervals, or areas of groundwater infiltration should be evaluated and potentially avoided by for benching, as these areas are typically already geologically weakened.

viii. ***Nearby Historic or Active Mining***: Historic mining and current mining above and below the mine, multilevel mining, and other mining in close lateral proximity could cause stress fields to redistribute and further impact pillar stability in the mine.

C. Consequences of Pillar Collapse

The assessment assumes that a collapse would create two kinds of hazards: rock falls and airblasts. It also assumes that a potential collapse could occur at any time, without warning.

The consequence matrix begins by defining possible locations of those individuals working underground relative to a potential collapse. The hazards and the potential consequences of a collapse to the individuals working underground in those locations are then described. The assessment consists of estimating the exposure of individuals within each of the areas based on the number of individuals exposed and the frequency of their exposure:

i. ***Working within collapse area:*** This includes individuals that are actively engaged in benching operations. A collapse would entail a massive rock fall and potentially lead to fatalities for individuals in this area.

ii. ***Working or traveling directly adjacent to collapse area:*** Fortunately, most previously benched areas have been bermed off to prevent personnel access as a best management practice to protect the health and safety of those working underground. However, haulroads and other travelways may be located adjacent to or near the potential collapse area. Individuals located in the immediate vicinity of a collapse would likely be exposed to extremely high air velocities and entrained flying debris. There might also be small rock falls from the back or pillar ribs as loose rock is detached by the vibrations. Fatalities or severe injury are possible for individuals in these locations.

iii. ***Working or traveling in high velocity air pathways:*** Research has shown that the real hazard to individuals from an airblast is high velocity air. When a collapse occurs, the air will travel the path of the least resistance to the outside of the mine, and the individuals located in those airways are at risk. Individuals located outside of a direct air pathway are unlikely to be hurt. In general, a larger combined cross-sectional area for air movement occurs where there are more air pathways. Therefore, the further the air travels to reach any given point subsequently lowers the air velocity at that point. Estimating air velocity is very complex, even if characteristics of the initial air pulse are known.

iv. ***Working or travelling in portal area:*** The air would be expected to coalesce as it exits the mine, with the air velocity depending on the number of air pathways, the distance from collapse, and the number of portals.

D. Areas to Avoid

If a proposed benching area falls into one or more of the listed areas, then additional rationale, including supporting engineering calculations, safety precautions, etc., to avoid adverse safety impacts may be requested by BMS. Or BMS may recommend that the area should be avoided for benching. This list is not all-inclusive and is intended to provide guidance on certain areas which BMS may have additional safety concerns.

- Areas not already developed and surveyed.
- Areas that do not comply or will not comply with the Roof Control Plan.
- Areas that do not meet or exceed the minimum FS or w/h ratio.
- Areas defined as safety zones.
- Areas of overburden cover of less than 100 feet.
- Areas within 150 feet of the crop line and mine portals.
- Areas withing a 150-foot radius of any ventilation shafts.

- Areas surrounding an oil and gas well.
- Areas above gas storage fields
- Areas of excessive scaling of the pillars or roof, or where pillar shape may indicate signs of instability.
- Areas of or immediately adjacent to previous roof falls or pillar failures.
- Areas where geologic discontinuities may adversely affect pillar or roof stability.
- Areas with significant groundwater inflows that may affect pillar stability.
- Areas that do not meet permit requirements.
- Any other areas deemed relevant to avoid by BMS or the operator.

Should a pillar be considered questionable due to under-sizing, geologic instability, etc., the operator may submit a specific area plan for benching. For example, the operator may propose one or more of the following actions which will be evaluated by BMS on a case by case basis:

a) Reduce the benching depth around the questionable pillar. A ramp may be constructed from the normal benching depth to a reduced benching depth around the designated questionable pillar. Therefore, the benching area plan should include a discussion and the mapping should depict the ramp location, berms, etc.

b) Improve the pillar conditions through roof control measures. This may include rib bolting, rib mesh, narrowing of the bench width near the questionable pillar, etc.

c) Abandon the area surrounding the questionable pillar.

d) Prior to submittal to BMS, discuss with BMS potential other solutions to improve the conditions around the questionable pillar to allow for benching activities to safely occur.

2. BENCHING PLAN SUBMITTAL PROCEDURES:

Submitting a benching plan involves identifying a portion(s) of the developed and surveyed mine to propose for benching and supplying the following information in Sections A, B, C, and D below. An example benching plan is included as Appendix B. All submittals should include an Industrial Mineral Plan Approval Routing Slip with the appropriate signatures and section of law referenced.

The plan is to be initially submitted to the Underground Mine Inspector and will subsequently be reviewed by the BMS Engineering Group, BMS Mine Safety Engineer Manager, BMS Industrial Minerals Mine Safety Program Manager, and the BMS Director. The information contained within will be verified through field and desktop reviews by BMS. The mine inspector will conduct a visual and situational analysis of the proposed benched area(s). Should any safety or additional information become necessary as a result of the review, BMS will contact the operator to address those concerns. Written approval will be provided by BMS to state that the plan adequately addressees potential safety concerns.

To allow for changing mine conditions, the area(s) chosen for benching should be areas where benching activities are anticipated to be conducted within the next six (6) months. The mining operator can request a written extension from the BMS mine inspector to extend the BMS approval should benching not occur within the six-month time frame.

A. Plan Narrative

At a minimum, the narrative should include the following information:

- Cover letter on company letterhead including the date, contact information, mine name, permit number, company name, and the purpose of the plan.

- Specific location(s) of the proposed benching area(s) within the mine utilizing the location grid system on the annual maps for the mains and crosscuts. For example, 3E-5E/12N-15N.

- Development heights/pillar heights of the area(s) proposed for benching.

- Thickness of stone to be removed during benching and if applicable, state if benching will leave a floor beam of the same mineral being mined or if benching will occur to the geologic formation contact. If benching is to occur to the formation contact, describe the composition of the underlying geologic unit.

- Maximum pillar height after benching is completed for each proposed area.

- The actual dimensions of the smallest pillar within each proposed area to be benched (length and width).

- The maximum depth of cover for each proposed benching area.

- An indication as to whether the escapeways are to be rerouted for each proposed benching area. To protect the health and safety of those working in and about the mine, escapeways shall be bermed from areas being benched and, if applicable, those areas where benching previously occurred.

- An indication that after benching is completed in the designated area(s), berms shall be placed between the pillars on the drift level around the benching area to prevent access.

- If a roof beam is required by the permit, indicate the minimum roof beam thickness for each proposed benching area. Include a statement how the roof bench thickness was determined, such as scoping, scrape tests, etc., and where those records can be obtained.

- If applicable, state if any areas within the proposed benching areas have roof supports installed (i.e., bolted, glued, etc.) and the specifications of such supports, such as being installed in accordance with the roof control plan

- Roof stability monitoring systems are currently utilized or proposed to be utilized within or in the vicinity of the proposed benching area. If none, are existing or proposed, indicate under what conditions may a roof monitoring system may be utilized.

- Presence and identification of the types of geologic features and discontinuities within or adjacent to the proposed benching area. This should include, but is not limited to, the locations of faults, fractures, prominent joints, karst/solution cavities, slickensides, mineralization zones, thin clay seams, groundwater infiltration zones etc. that could impact roof or pillar stability during or after benching. The narrative should note the approximate steepness (dip) of fractures, joints, or faults, if present, and if these features are open, mineralized, or closed.

- Statement regarding the groundwater conditions in the area to be benched, including whether groundwater is currently present or expected to accumulate after benching.

- Uniaxial Compressive Strength (UCS) of the rock being mined and why the UCS is appropriate for modeling.

- If any areas in the proposed benching areas have an area already benched included, discuss the benched height and if further benching is proposed to occur.

- Any other information deemed relevant by the mining operator or BMS.

B. Stability Analysis

A stability analysis is an essential component of the submittal where software should be utilized, such as S-Pillar, or industry accepted methods and models that are also accessible to the BMS. The stability analysis should consider the smallest pillar dimensions and highest depth of cover for the proposed benching area(s). If present, large angular discontinuities within the proposed benching area must be accounted for in the stability analysis. Justification for the UCS utilized in the calculations should be included in the submittal. At a minimum, a safety factor exceeding 1.8 and w/h ratio of greater than 0.8 is adequate. Safety factors and/or ratios may need to be increased to address adverse conditions. The operator should supply to BMS all modeling inputs and results for each proposed benching area.

C. Map(s)

Scaled map(s) should include the following items:

- Include a title, legend, north arrow, and scale/scalebar.

- Entries (Mains) and crosscut designations that matches the mine development-ventilation map.

- Survey spads and elevations within the proposed benching area. The area proposed for benching must be surveyed.

- Include surface/overburden contours, and seam contours. Contour shall be 20 feet maximum or less.

- Identification of the smallest pillar within the proposed benching area(s).
- Locations where roof anchoring system are installed within or adjacent to the proposed benching area(s).
- The primary and/or secondary escapeways in the vicinity of the proposed benching area(s).
- Bermed or backfilled areas adjacent to the proposed benching area(s).
- Previously benched areas near the proposed benching area(s) and the maximum pillar heights in those areas.
- The locations of any currently installed or proposed roof monitoring systems.
- The locations of geologic features or discontinuities in the roof, pillars, and floor within or immediately adjacent to the proposed benching area(s). If poor roof conditions appear to be a result of horizontal stresses, indicate the primary horizontal stress direction.
- The locations of oil and gas wells with the appropriate barrier.
- If applicable, safety zones and/or limited extraction areas.
- If applicable, roadways, structures, or known utilities on the surface and overtop the area(s) proposed for benching.
- Any other relevant features that may improve or adversely impact the stability of the roof beam and pillars.
- Provide a generalized blasting diagram for the benching area. The diagram should include the if the blasting will be vertical and/or horizontal, spacing, hole diameter, and depth of the shot holes.
- Any other information deemed relevant by either the mining operator or BMS.

An updated mine development-ventilation map may be utilized for the submission in lieu of creating a map for the proposed benching.

D. <u>Risk Assessment</u>

The risk assessment is where the mining operator acknowledges that the risks were evaluated and demonstrates the threat of pillar collapse is not likely to occur. The Pillar Collapse Consequences table should be included in the benching plan submittal.

3. POST BENCHING EVALUATION

After benching is completed by the mining operator, a post evaluation is to be conducted by the mining operator, and verified by BMS, to ensure compliance with the plan and to demonstrate that adequate safety measures are in place.

APPENDIX A- Resources

1. *Christopher Mark and Gregory Rumbaugh, (2022). International Experience with Airblasts and Its Relevance to Underground Stone Mines (msha.gov). MSHA, 18 pp.*

2. *Gregory M. Rumbaugh, Christopher Mark, and Todd Kostecki (2022). Massive Pillar Collapses in U.S. Underground Limestone Mines: 2015-2021 (msha.gov). MSHA, 12 pp.*

3. *Gabriel S. Esterhuizen, Paul L. Tyrna, and Michael M. Murphy (2019). A Case Study of the Collapse of Slender Pillars Affected by Through-Going Discontinuities at a Limestone Mine in Pennsylvania (msha.gov). MSHA, 12 pp.*

4. *Gabriel S. Esterhuizen, Anthony T. Iannacchione, John L. Ellenberger, Dennis R. Dolinar (2006), Pillar Stability Issues Based On A Survey Of Pillar Performance In Underground Limestone Mines (cdc.gov), NIOSH, 8pp.*

5. *Gabriel S. Esterhuizen, Dennis R. Dolinar, John L. Ellenberger, and Leonard J. Prosser (2011). Pillar and Roof Span Design Guidelines for Underground Stone Mines (msha.gov). MSHA, 75 pp.*

6. *G. S. Esterhuizen, D.R. Dolinar, and J.L. Ellenberger (2007). Observations and Evaluation of Floor Benching Effects on Pillar Stability in U.S. Limestone Mines (cdc.gov). NIOSH, 7 pp.*

7. *G. S. Esterhuizen, (2021). Stone Mine Pillar Stability and Design. NIOSH, 36 pp.*

8. *Gamal Rashed, Brent Slaker, Michael Murphy (2021), Exploration of Limestone Pillar Stability in Multiple-Level Mining Conditions Using Numerical Models (nih.gov). NIOSH, 27 pp.*

9. *MSHA. Safety Alert Stone Mine Massive Pillar Collapses (msha.gov). 1pp.*

10. *Iannacchione AT and Varley F (2008). The Application of Major Hazard Risk Assessment (MHRA) to Eliminate Multiple Fatality Occurrences in the U.S. Minerals Industry (cdc.gov). NIOSH 1C 9508, 142 pp.*

11. *MSHA (2021). Assessing Pillar Collapse and Airblast Hazards in Underground Stone Mines. 36 pp.*

APPENDIX B-Example Benching Plan

(Company Name)
(Address)
(Phone)

(DATE)
<u>(Company Name), (Mine Name) Benching Plan</u>
<u>Permit Number: (XXXXXXXX)</u>

This benching plan is being submitted to the Bureau of Mine Safety (BMS) for the following area of the developed mine and is depicted on the enclosed map.

N10-N12/E23-E25

Attached are the industrial mineral routing slip, benching safety standards, S-Pillar inputs/outputs, and risk assessment table.

The area proposed for benching has no roof bolts, is dry, and maintains a minimum of a 10-foot roof beam of the "AAA" limestone. Groundwater is not expected to be encountered and benching will be to the underlying formation contact consisting of the thinly bedded "BBB" sandstone or a maximum benched height of 48 feet, whichever occurs first. The minimum roof beam thickness for this benching area was verified by borehole scoping and scrape tests which are documented in the log book at the mine.

The geological discontinuities are shown on the attached mapping and are primarily located in the roof with a few extended to the pillars within the proposed benching area. The discontinuities consist of major closed fractures. The fractures appear to be near vertical. No slickensides, open joints, faults, or other geologic discontinuities were observed. Other numerous near vertical closed joints are present throughout the benching area. No clay seams were observed in the pillars or roof.

Any discontinuities that may present a safety concern will be monitored and addressed prior to benching by either bolting and/or utilization of a miners helper. No roof monitoring systems are currently located within or adjacent to the benching area. All work areas will be inspected prior to each shift.

No fans or escapeways are located in the benching area and benching will not affect the ventilation plan.

<u>Benching Area Summary</u>

Maximum Overburden Thickness (ft):	321
Smallest Pillar Dimensions (ft):	42.8x43.1
Average Development Height (ft):	27

Total Maximum Benched Height (ft):	48
Benching Depth(ft):	21
Uniaxial Compressive Strength (psi):	22,000 (from published resources)
S-Pillar Benched Factor of Safety (FOS):	3.66
Benched Width to Height Ratio:	0.89
Groundwater Present:	No, and none expected
Structures Overlying the Proposed Benching Area:	None
Benching Proposed within or adjacent to a Safety Zone:	No
Benching Occurring within 150 feet of a Gas Well:	No
Adverse Safety Impacts from Previous Benching:	No

Sincerely,
XXXXXXX
XYZ@XYZ.com

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

BUREAU OF MINE SAFETY
INDUSTRIAL MINERAL MINE DIVISION
PLAN APPROVAL ROUTING SLIP

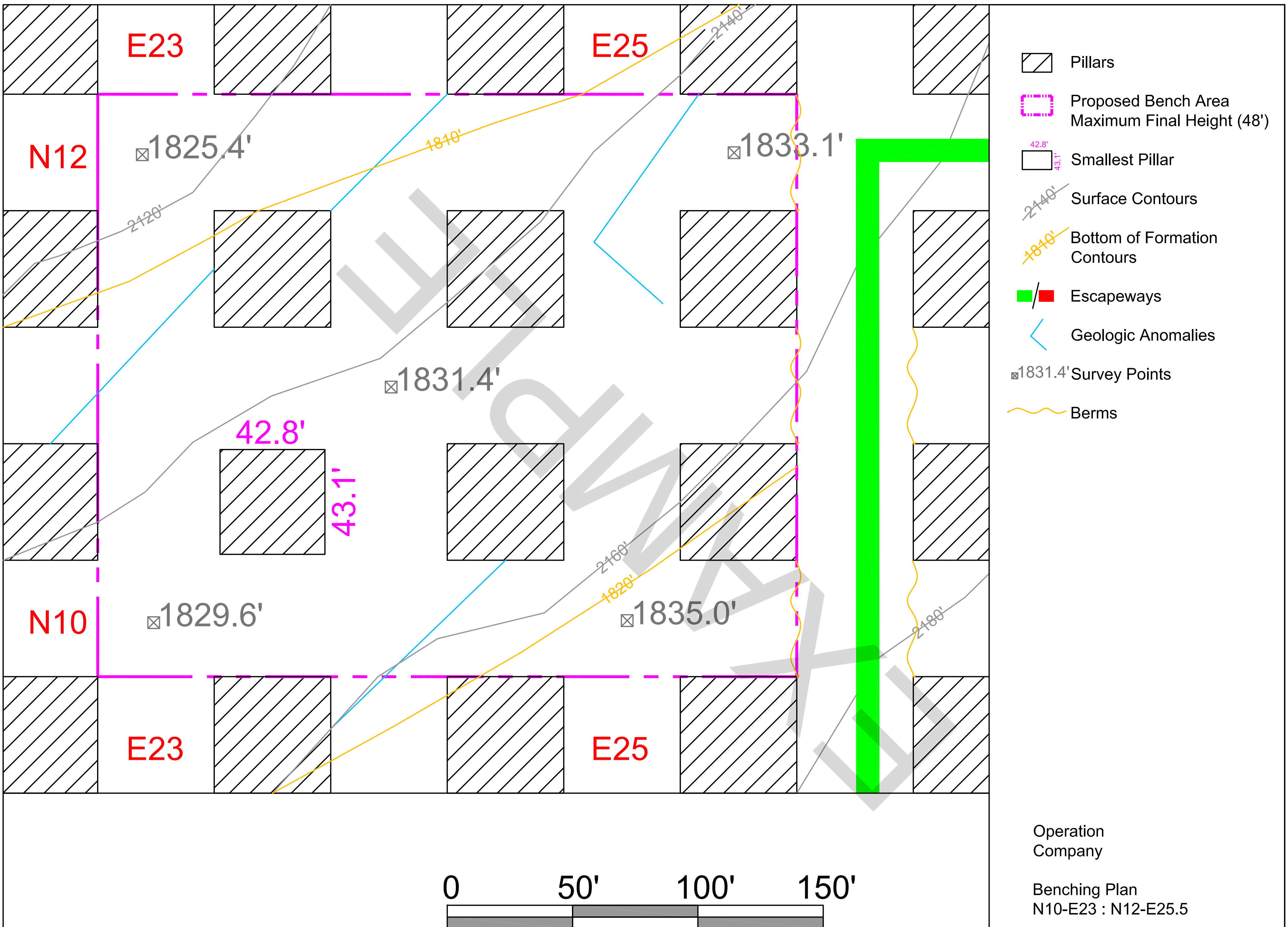
Company	Name of Mine
Benching Plan Subject of Approval	Section 1915-A of the Administrative Code of 1929, 71 P.S. §510-15; 25 Pa. Code §§207.313 and 207.104(a)(3) Section of Law
Registered Engineer Date	Company Representative Date

FOR DEPARTMENT USE ONLY

No. ________

Mine Inspector	Date Received	Date Forwarded
Electrical Inspector	Date Received	Date Forwarded
Electrical Inspector Supervisor	Date Received	Date Forwarded
Mining Engineer	Date Received	Date Forwarded
Mining or Electrical Engineer Manager	Date Received	Date Forwarded
Industrial Mineral Program Manager	Date Received	Date Forwarded

- Submit one (1) paper copy to the mine inspector. If the associated maps are larger than 11" x 17", two copies must be provided with the plan.
- The approval/denial letter and the final plan will be emailed to the original submitter.
- It is the responsibility of the submitter to ensure the mine receives a copy of the approved plan.



Operation
Company

Benching Plan
N10-E23 : N12-E25.5

Benching Standards

1. Operator shall perform a survey of all pillars in the area to be benched. This survey will include the pillars height, width, and length. Geologic disconformities shall be noted on the exhibit including slickensides, faults, mineralization and shaley zones, etc. The smallest pillar located in the benching area will be determined. The operator may use standard survey tools, and/or measuring tapes and laser distance finders to determine the required dimensions.

2. The roof shall be examined and all loose and hanging material scaled and secured. If any questionable roof discontinuities are discovered that present a concern a miner helper should be installed in the closest test hole.

3. Operator will confirm that the 10’ roof beam is in place and the depth to the bottom of the formation to be mined. Total final mining heights shall be limited by permit and S-Pillar (Final SF – 2.00 W/H>0.8) calculations attached. Proposed mining heights shall not be exceeded.

4. The State Mine Inspector shall review the area to be benched and approve of the plan prior to benching.

5. The geological hazard map will be used in assessing pillar and roof stability.

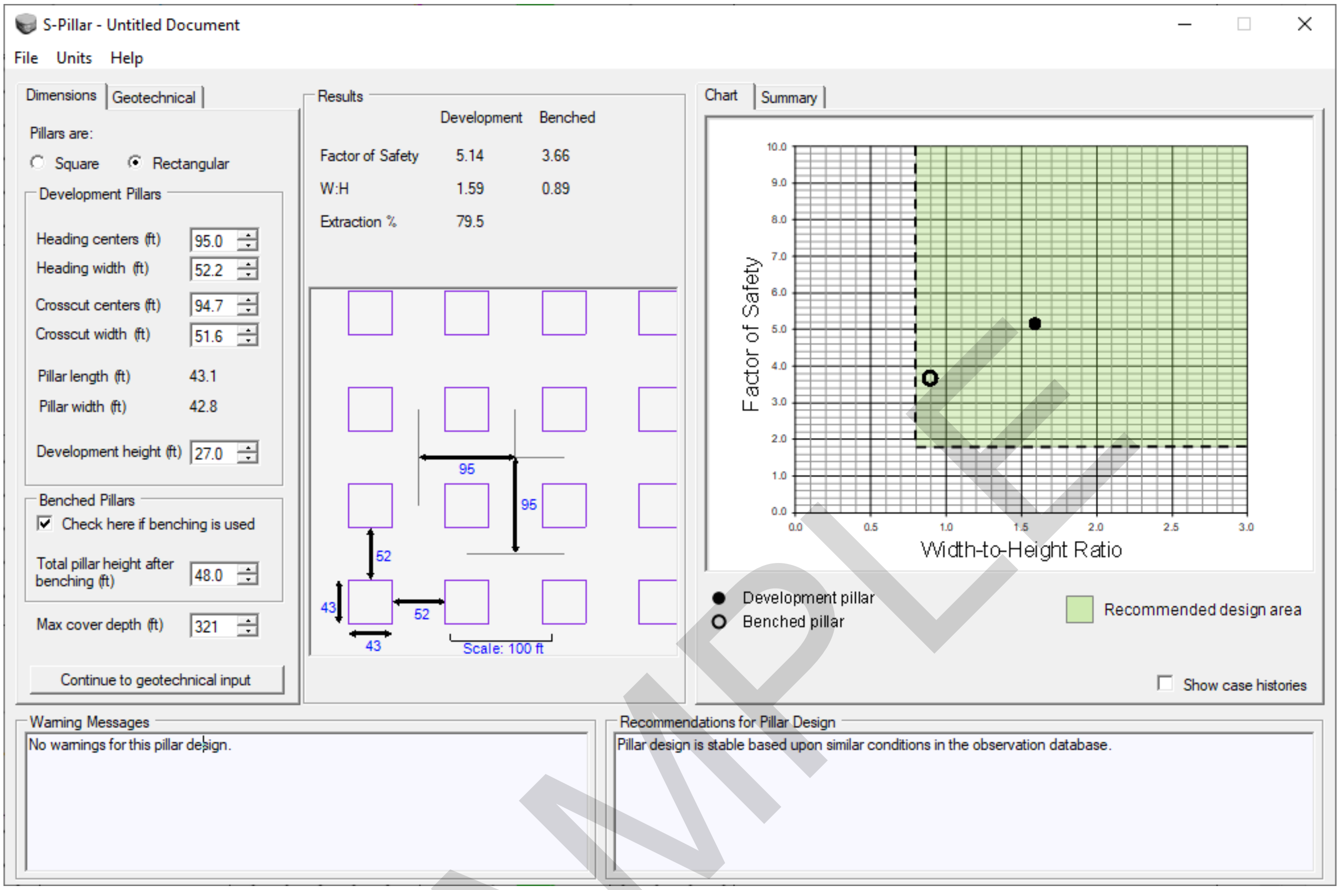
6. Overburden mapping for the proposed benching area will be used.

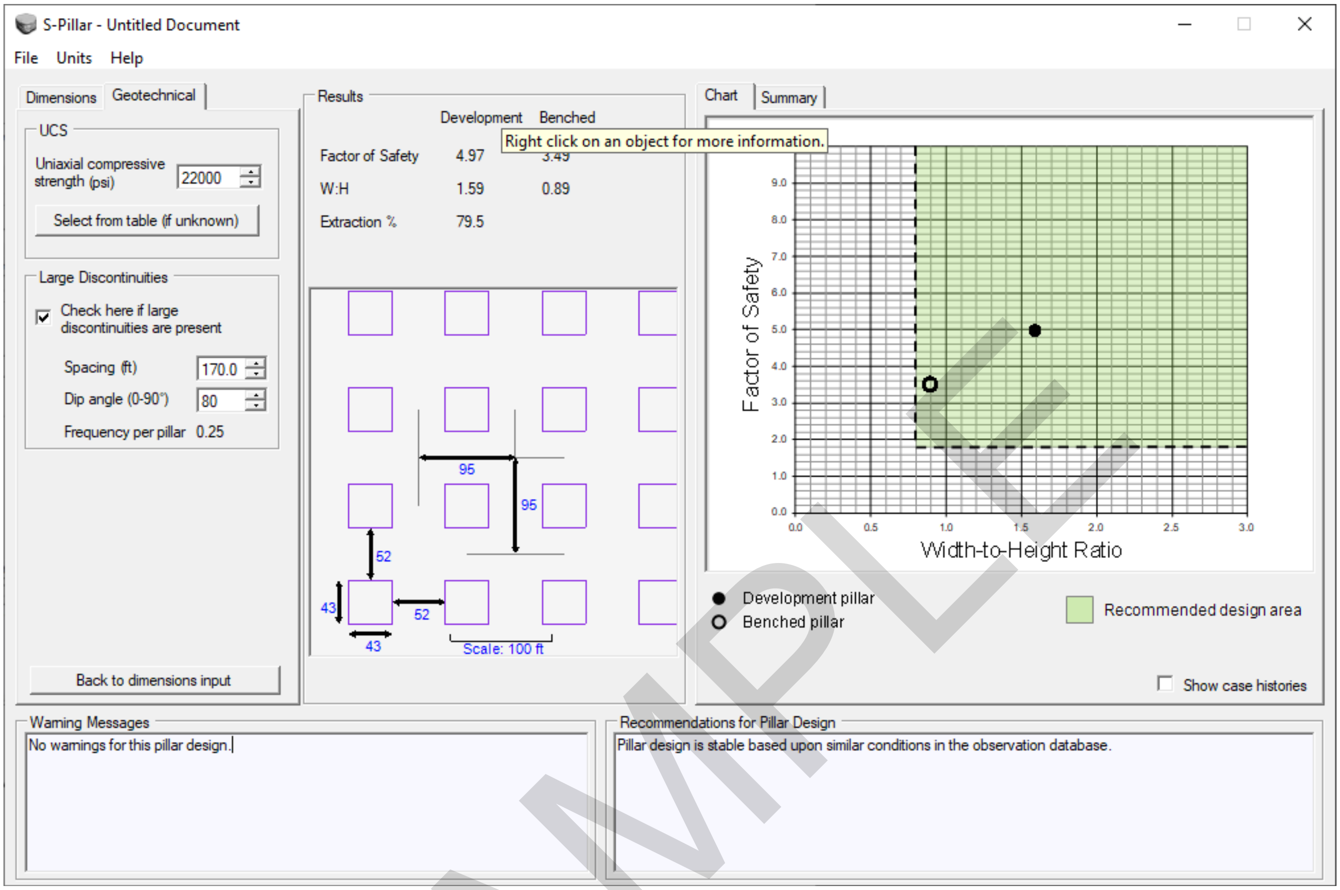
7. Escapeways shall be bermed from areas benched or in the process of being benched.

8. Escapeways shall be rerouted around active benching area to provide open travel in the event of possible collapse.

Risk Assessment for Pillar Collapse

Location of Miners	Conditions/Hazards	Consequence
Working within pillar collapse area, engaged in active benching operations	Massive rock fall, no warning	Death
Working or traveling in travelways or haul roads directly adjacent to pillar collapse area	High air velocities, flying debris, small rock falls	Death or severe injury
Working or traveling directly above a pillar collapse area	Sudden development of a surface sinkhole	Death or severe injury
Working or traveling in high velocity air pathways leading from pillar collapse area to portals	Diminishing air velocities depending on number of pathways and distance from pillar collapse	Injury
Other locations in the mine	Damage to ventilation controls or egress routes	Indirect hazards


S-Pillar - Untitled Document
File Units Help
Dimensions Geotechnical
Pillars are:
Square Rectangular
Development Pillars
Heading centers (ft) 95.0
Heading width (ft) 52.2
Crosscut centers (ft) 94.7
Crosscut width (ft) 51.6
Pillar length (ft) 43.1
Pillar width (ft) 42.8
Development height (ft) 27.0
Benched Pillars
Check here if benching is used
Total pillar height after benching (ft) 48.0
Max cover depth (ft) 321
Continue to geotechnical input
Results
Development Benched
Factor of Safety 5.14 3.66
W:H 1.59 0.89
Extraction % 79.5
95
95
52
52
43
43
Scale: 100 ft
Chart Summary
Factor of Safety
Width-to-Height Ratio
Development pillar
Benched pillar
Recommended design area
Show case histories
Warning Messages
No warnings for this pillar design.
Recommendations for Pillar Design
Pillar design is stable based upon similar conditions in the observation database.



NIOSH S-Pillar V1.2 2018
Pillar Strength Analysis
1
1/4/2024 12:41:47 PM
-----------DEVELOPMENT DATA----------
Pillar width 42.8 ft
Pillar length 43.1 ft
Pillar height 27.0 ft
W:H ratio 1.59
UCS 22000 psi
LDF 0.97
-------RESULTS DEVELOPMENT------------
Pillar strength 8589 psi
FOS Development 4.97
-----------BENCHING DATA-------------
Pillar width 42.8 ft
Pillar length 43.1 ft
Pillar height 48.0 ft
W:H ratio 0.89
UCS 22000 psi
LDF 0.95
----------RESULTS BENCHING--------------
Pillar strength 6042 psi
FOS Benching 3.49