Appalachian Mining & Engineering, Inc.

Geolab Materials Testing

April 28, 2022

Mr. Nick Mason, *Mine Engineer*
Allegiance Coal Limited
12250 Hwy 12
Weston, Colorado 81091

Re: Analysis of Surface Subsidence for Development Mining in the Blue Seam at the New Elk Mine

Dear Mr. Mason,

The objective of this study is to examine the potential impact of mining induced surface subsidence as a results of development mining in the Blue Seam at the New Elk underground mining operations located in Las Animas, Colorado. Given the deep cover and multiple seam mining conditions present at the New Elk mine, Mr. Nick Mason (*Mine Engineer*) of **Allegiance Coal Limited** (**AC**) requested that **Appalachian Mining & Engineering, Inc.** (**AME**) evaluate the potential for mining induced surface subsidence as a results of previous longwall mining operations in the Maxwell seam as well as room-and-pillar development mining by New Elk in the Blue seam.

Pillar stability and convergence analyses were conducted with respect to the proposed room-and-pillar development in the Blue seam using the well-accepted Analysis of Coal Pillar Stability (ACPS) program. This information was used in determining the stability of the developed coal pillars and their potential for surface deformation. Using the results of the ACPS analyses, the Surface Deformation Prediction System (SDPS) program was used for the analysis of potential mining induced surface subsidence through the calculation of vertical deformation (subsidence) and maximum horizontal strain. The SDPS results were used to calculate both the total subsidence as a result of underground mining operations as well as differentiating the impact of mining operations and methods used in the recovery of the Maxwell seam from that of the Blue seam.

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The methodology and assumptions used in the ACPS and SDPS analyses are fully described within the enclosed report. The findings, results, and conclusions are presented as a series of pillar safety factor results as well as contours of subsidence and maximum horizontal strain.

Nick, if you have any questions, comments, or concerns as you and others review this report, please contact me at (859)263-8899 or by email at cnewman@ame-geolab.com.

Sincerely,

Appalachian Mining & Engineering, Inc.

Christopher Newman

Digitally signed by Christopher Newman
DN: cn=Christopher Newman, o=Appalachian Mining and Engineering, Inc., ou, email=cnewman@ame-geolab.com, c=US
Date: 2022.05.02 11:53:21 -04'00'

Christopher Newman, Ph.D.
Geomechanical Engineer

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Appendices

I. Introduction and Background

The **New Elk Coal Company, LLC** (**New Elk**), a subsidiary of **Allegiance Coal Limited** (**AC**), operates the New Elk underground mine in the Blue seam. The New Elk mine is a room-and-pillar, development only mining operation with fifteen (15) entry room-and-pillar panels proposed for the development of the Blue coal seam. Given the deep cover (depth > 1,000-feet) and multiple seam stress conditions present at the New Elk mine, Mr. Nick Mason (*Mine Engineer*) of **AC** requested that **Appalachian Mining & Engineering, Inc.** (**AME**) evaluate the proposed room-and-pillar panel layout in regard to pillar stability and potential for surface subsidence.

Proposed mining in the Blue seam will result in overmining of previous mine works in the Maxwell seam approximately 200-feet below the Blue seam. The Analysis of Coal Pillar Stability (ACPS) program was used for the analysis of multiple seam stress distribution and pillar stability of the proposed pillar layout for the Blue seam in relation to gob-solid boundaries located in the underlying Maxwell seam. Multiple seam stress distribution and pillar stability analyses were conducted across twenty (20) unique stress conditions present at the New Elk mining using ACPS. Input parameter for ACPS were derived through a review of geologic and geologist logs, seam structure and orientation, varying surface topography, as well as mine mapping as provided by **AC** Engineering.

Based on a review of 37 drill holes in the area of proposed mining at the New Elk mine, the Blue seam has an average coal height of 4.35-feet with a maximum coal height of 6.87 with a dip of 1.80% across the area. Given the limited coal seam thickness, it is not likely that a 2.5 clean ton per linear foot of mining advance assuming an equivalent 6 raw tons per linear foot of mining advance based on current mining conditions and plant throughput as provided by **AC** Engineering. Therefore, all analyses have been conducted based on a 6-foot mining height at the New Elk mine. The limiting design factor of a 6-foot mining height was provided by **AC**. Additionally, based on a review of core hole data, the excavation height for the Maxwell seam was defined as 5-feet.

II. Approach and Methodology

2.1 Stress Distribution and Pillar Stability Analysis

The evaluation of multiple seam stress distribution and pillar stability for the development of the Blue seam was conducted using ACPS (Analysis of Coal Pillar Stability), a coal pillar analysis program developed by Dr. Christopher Mark and Dr. Zach Agioutantis. The ACPS program integrates ARMPS (Analysis of Retreat Mining Pillar Stability), ALPS (Analysis of Longwall Pillar Stability), and AMSS (Analysis of Multiple Seam Pillar Stability) of the National Institute of Occupational Health and Safety (NIOSH) Ground Control Toolbar into a single and centralized application. Twenty (20) ACPS analyses were conducted for the proposed room-and-pillar panels to cover the variety of multiple and single seam stress scenarios present. It should be noted that the ACPS program allows for a maximum of 11 entry panels. Therefore, to obtain a representative pillar layout for the proposed New Elk pillar layout, ACPS parameters were modified based on the “One active section & two side gob” loading condition with extent of active gob set to zero (0). The barrier pillar between the first and second “side gob” was defined with a width of 35-feet and 35-foot wide “leave pillars” for Row A and Row B. The results of the ACPS analyses are presented in Appendix I. Where the proposed 55-foot by 55-foot pillar layout did not meet the 2.0 recommendation for long term pillar stability, an alternative pillar layout was evaluated and has been designated with the letter “A” in Appendix I.

The analysis of multiple seam stress distribution and pillar stability for the New Elk mine was developed based on the following information;

- Surface contours (**AC**),
- Core logs (**AC**),
- Location and layout of old mine works (**AC**),
- Proposed mine projections (**AC**),
- Mine survey data (**AC**), and
- In situ coal strength of 900-psi.

2.2 Surface Subsidence Analysis

The well-accepted SDPS program was used to determine the ground movement and strain associated with mining the longwall panels. SDPS makes use of the mine geometry, overburden depth, % of hard rock in the overburden, extraction thickness, tangent angle of influence, and strain coefficient to determine the ground surface movement and strain associated with longwall or room-and-pillar mining. Where subsidence survey information is available, site specific values for the empirical parameters can be determined by calibration of the SPDS model to the actual survey data. Given that surface subsidence survey data was not provided for the analysis, empirical parameters were defined based on in-program coal field (Appalachian, Illinois, West) and state specific input parameters. For the analysis of potential mining induced surface subsidence, empirical input parameters were defined with respect to the "West" coal fields and the state of "Colorado" in SDPS. Through a review of geologic core logs, the percent hard rock present at the New Elk underground mine is approximately 50%. This is likely a conservative value for the percent of hard rock within the overburden given the geologic structures present in the Western coal fields. Due to the lack of a surface subsidence survey, the offset distance could not be calibrated. Therefore, "No Edge Effect" was conservatively applied to the model.

III. Stress Distribution and Pillar Stability Results

3.1 ACPS Pillar Stability Results

The fifteen (15) entry production panel layout with 55-foot by 55-foot pillars on center, 18-foot entry width, and 6-foot mining height were evaluated through a series of ACPS single and multiple seam stability analyses. A total of twenty (20) unique analyses were conducted with twelve (12) multiple seam stress conditions evaluated in areas where proposed development in the Blue seam resulted in overmining of previous mine works in the Maxwell seam and eight (8) single seam development only mining conditions. Overburden depth and the interburden thickness for the Blue and Maxwell seams were defined based on seam grid calculations derived from drill holes and core logs provided by **AC**. The in situ coal strength was defined as the default 900-lbs/in^2

with the pressure arch factor as defined by the ACPS program. ACPS multiple seam pillar stability results are available in Appendix I. For loading scenarios in which the proposed pillar dimensions of 55-foot by 55-foot did not meet the required 2.0 for long term pillar stability, the minimum pillar length to achieve the recommended pillar safety factor has been provided.

Based on a review of the ACPS pillar stability results for both multiple seam and single seam stress conditions, it is recommended that the length of production pillars be increased to 110-feet (center-to-center spacing). Operationally, this would involve dropping a single crosscut between the currently proposed 55-foot by 55-foot (center-to-center spacing) pillars. Pillars with safety factors greater than or equal to 2.0 are considered to have long-term stability and are highly unlikely to yield or fail given the mining induced loading conditions modeled within ACPS

3.2 <u>SDPS Surface Subsidence Results</u>

From discussions with Mr. Mason, mining operations at New Elk would like to maintain pillar stability factors of 2.0 for proposed development only mining in the Blue seam. Therefore, for the analysis of the potential for mining induced surface subsidence, mine works within the Blue seam were assumed to be stable with no pillar convergence or yielding. As previously stated, those pillars which maintain an overall safety factor greater than or equal to 2.0 are considered to have long-term stability with negligible pillar convergence or yielding. Therefore, it can be assumed that development pillars (55-feet by 110-feet pillar centers) within the Blue seam will adequately support the overburden load and as a result it is highly unlikely that development mining in the Blue seam will initiate deformations within the surface.

Within the SDPS model, it was assumed that development mining within the Blue seam will not result in pillar convergence or yielding and therefore, the potential for surface deformations was evaluated with respect to longwall mining operations within the underlying Maxwell seam. Based on SDPS results, the maximum mining induced surface subsidence calculated was approximately 2-feet at the center of the subsidence troughs as well as a maximum horizontal strain of 49.53 mm/m at the transition between adjacent subsidence troughs. SDPS result contours are available in Appendix II. Within the SDPS model, all calculated subsidence values are associated with previous longwall mining operations in the Maxwell seam and are not associated with proposed development mining operations in the Blue seam. Therefore, all mining induced damage to the surface is a result of high extraction mining in the Maxwell seam and has occurred prior to the proposed development mining at the New Elk mine.

IV. Summary and Conclusions

The stress distribution and pillar stability analyses presented in this report were developed based on core logs, mine mapping, survey data, and surface contours as provided by **AC**. The in situ coal strength used for both ACPS analyses were defined based on the default 900-psi. Multiple seam stress distribution and pillar stability analyses indicate that the proposed 50-foot by 50-foot production pillars do not meet the 2.0 pillar safety factor recommendation for long term. Therefore, it is recommended that pillar be lengthened for 110-feet to achieve a long term pillar stability factor of 2.0. Following adjustments to the pillar length, ACPS results for both single and multiple seam stress conditions indicate pillar safety factors greater than the recommended 2.0 for long term stability. Given a pillar stability factor of 2.0, it is highly unlikely that development mining within the Blue seam would initiate surface subsidence. As observed within the SDPS results, mining induced surface deformations would be a result of longwall mining operations in the Maxwell seam.

Appendix I

ACPS Input Parameters and Stability Results

Table 1: ACPS Input Parameters and Results for the Proposed Pillar Layout at New Elk

Scenario	High Average Depth of Cover (ft)	Number of Entries	Width Entry (ft)	Height Mining (ft)	Width Pillar (ft)	Length Pillar (ft)	Conditions Stress	CMRR	Interburden Thickness (ft)	Seam Thickness (ft)	Remnant Pillar Width (ft)	Gob Width 1 (ft)	Gob Width 2 (ft)	ACPS SF
1	350	7	18	6	75	100	Development	-	-	-	-	-	-	6.53
2	300	7	18	6	55	75	Development	-	-	-	-	-	-	4.43
3	425	15	18	6	55	55	Gob-Solid	35	255	5	-	620	-	2.09
4	675	15	18	6	55	55	Remnant Pillar	35	255	5	185	620	620	1.76
5	675	15	18	6	55	55	Gob-Solid	35	260	5	-	620	-	1.40
6	325	15	18	6	55	55	Gob-Solid	35	257	5	-	620	-	2.39
7	475	15	18	6	55	55	Remnant Pillar	35	260	5	185	620	620	1.60
8	550	15	18	6	55	55	Gob-Solid	35	265	5	-	620	-	1.57
9	450	15	18	6	55	55	Gob-Solid	35	260	5	-	620	-	1.85
10	540	15	18	6	55	55	Remnant Pillar	35	260	5	185	620	620	1.44
11	600	15	18	6	55	55	Gob-Solid	35	260	5	-	620	-	1.45
12	760	15	18	6	55	55	Development	-	-	-	-	-	-	1.50
13	300	15	18	6	55	55	Gob-Solid	35	260	5	-	620	-	2.55
14	350	15	18	6	55	55	Remnant Pillar	35	265	5	180	620	620	2.00
15	425	15	18	6	55	55	Gob-Solid	35	265	5	-	620	-	1.65
16	650	15	18	6	55	55	Development	-	-	-	-	-	-	1.44
17	475	15	18	6	55	55	Development	-	-	-	-	-	-	1.87
18	625	15	18	6	55	55	Development	-	-	-	-	-	-	1.42
19	725	15	18	6	55	55	Development	-	-	-	-	-	-	1.33
20	780	15	18	6	55	55	Development	-	-	-	-	-	-	1.26

Table 2: ACPS Input Parameters and Results for the Alternative Pillar Layout at New Elk

` Scenario	High Average Depth of Cover (ft)	Number of Entries	Width Entry (ft)	Height Mining (ft)	Width Pillar (ft)	Length Pillar (ft)	Conditions Stress	CMRR	Interburden Thickness (ft)	Seam Thickness (ft)	Remnant Pillar Width (ft)	Gob Width 1 (ft)	Gob Width 2 (ft)	ACPS SF
10A	540	15	18	6	55	120	Remnant Pillar	35	260	5	185	620	620	1.99
11A	600	15	18	6	55	95	Gob-Solid	35	260	5	-	620	-	2.00
12A	760	15	18	6	55	80	Development	-	-	-	-	-	-	1.99
15A	425	15	18	6	55	70	Gob-Solid	35	265	5	-	620	-	1.99
16A	650	15	18	6	55	85	Development	-	-	-	-	-	-	2.03
17A	475	15	18	6	55	60	Development	-	-	-	-	-	-	2.05
18A	625	15	18	6	55	85	Development	-	-	-	-	-	-	2.01
19A	725	15	18	6	55	95	Development	-	-	-	-	-	-	1.99
20A	780	15	18	6	55	110	Development	-	-	-	-	-	-	2.01
4A	675	15	18	6	55	110	Remnant Pillar	35	255	5	185	620	620	1.97
5A	675	15	18	6	55	110	Gob-Solid	35	260	5	-	620	-	2.02
7A	475	15	18	6	55	85	Remnant Pillar	35	260	5	185	620	620	2.01
8A	550	15	18	6	55	80	Gob-Solid	35	265	5	-	620	-	2.01
9A	450	15	18	6	55	60	Gob-Solid	35	260	5	-	620	-	1.99

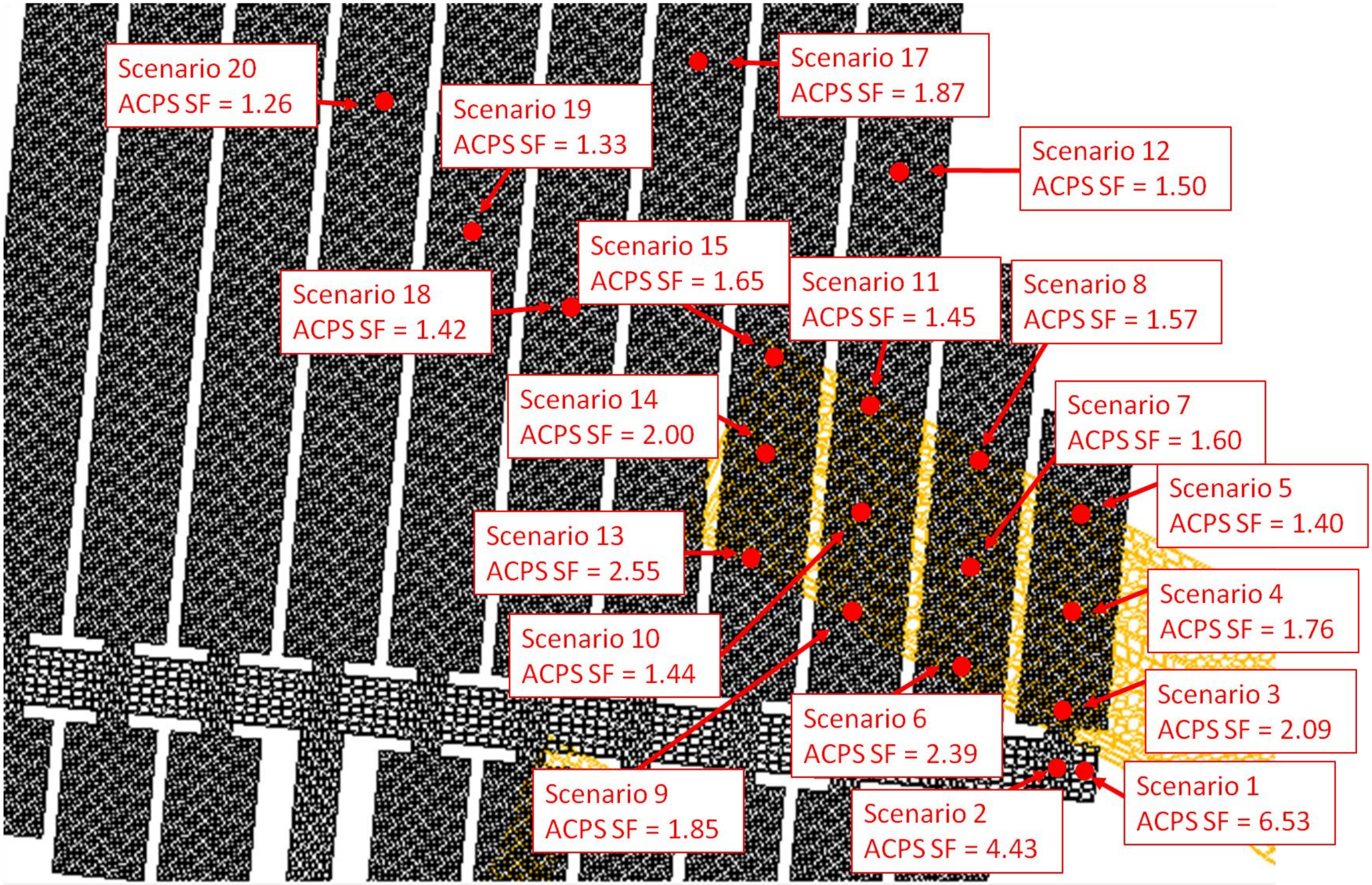


Figure 1: ACPS Safety Factor Results (Scenarios 1-15, 17-20)

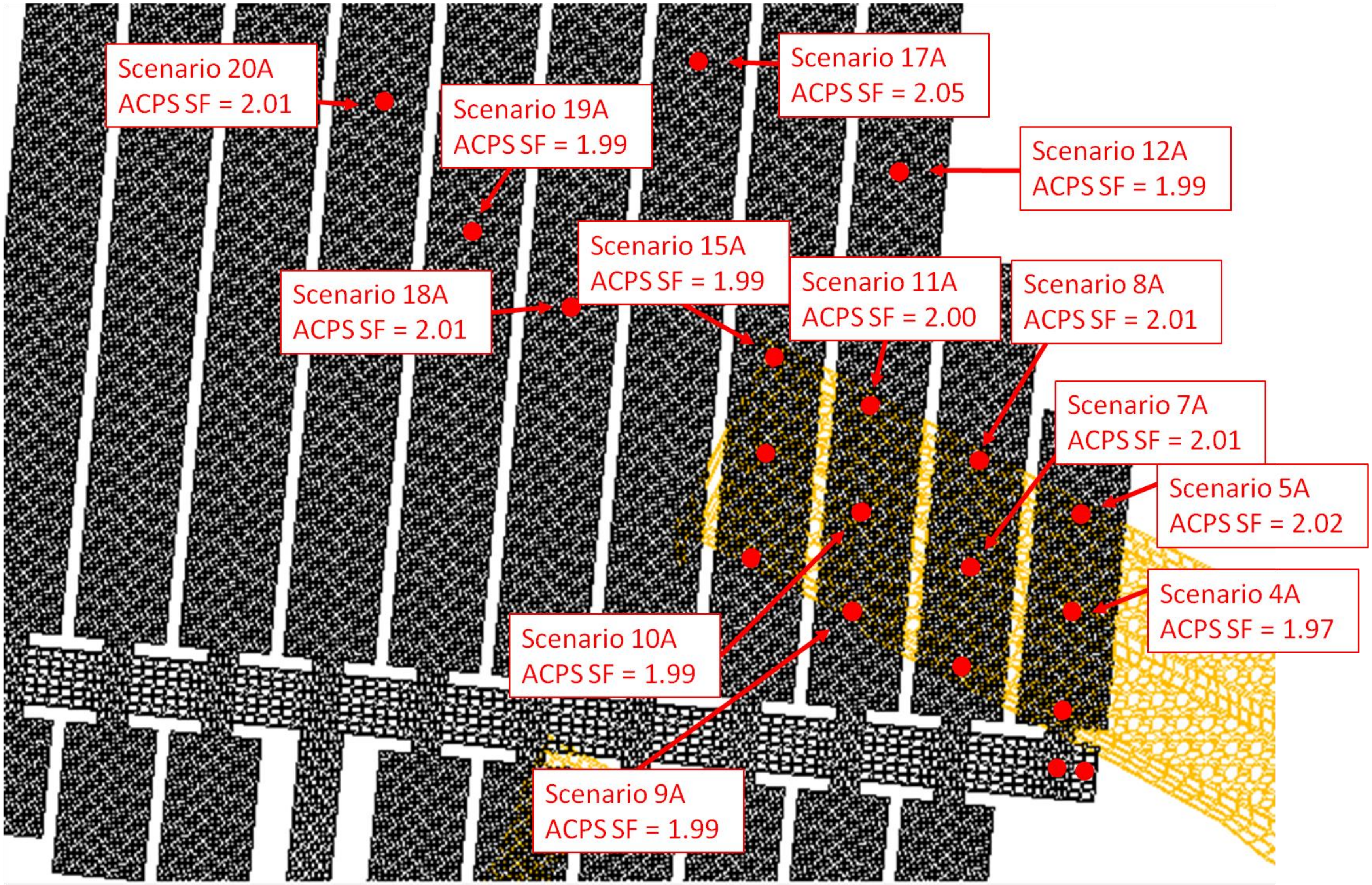


Figure 2: ACPS Safety Factor Results (Scenarios 4A, 5A, 7A-12A, 15A, 17A-20A)

Appendix II

SDPS Input Parameters and Stability Results

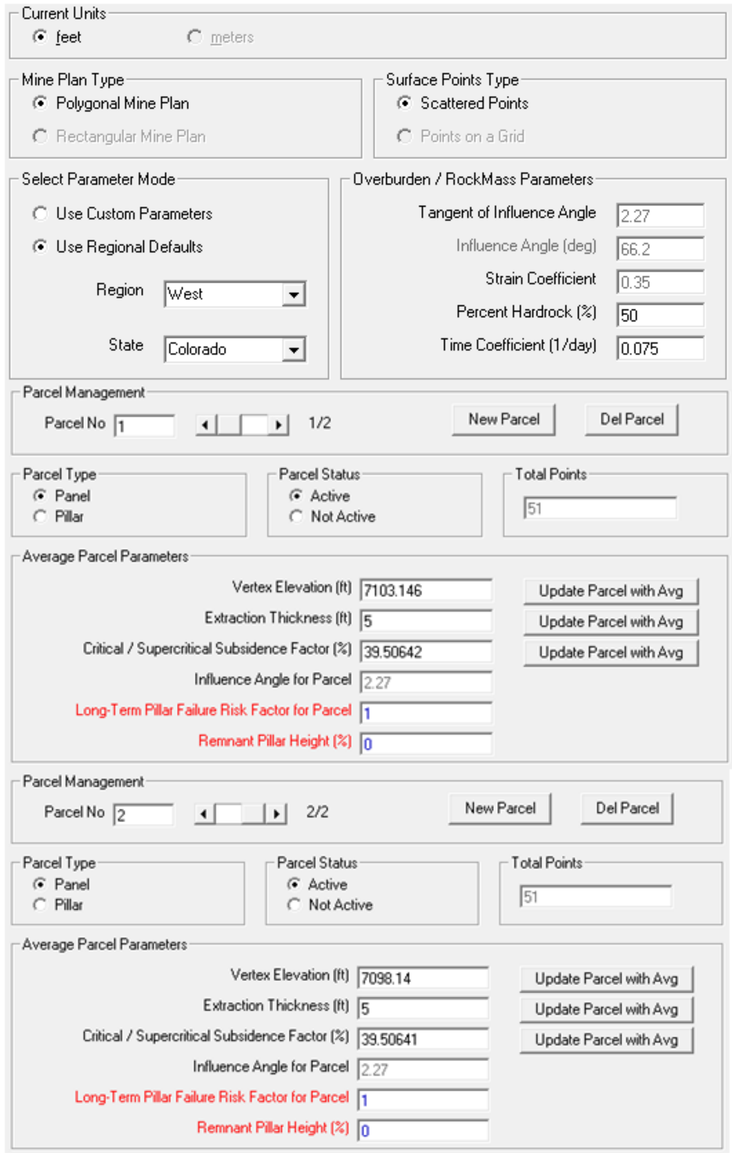
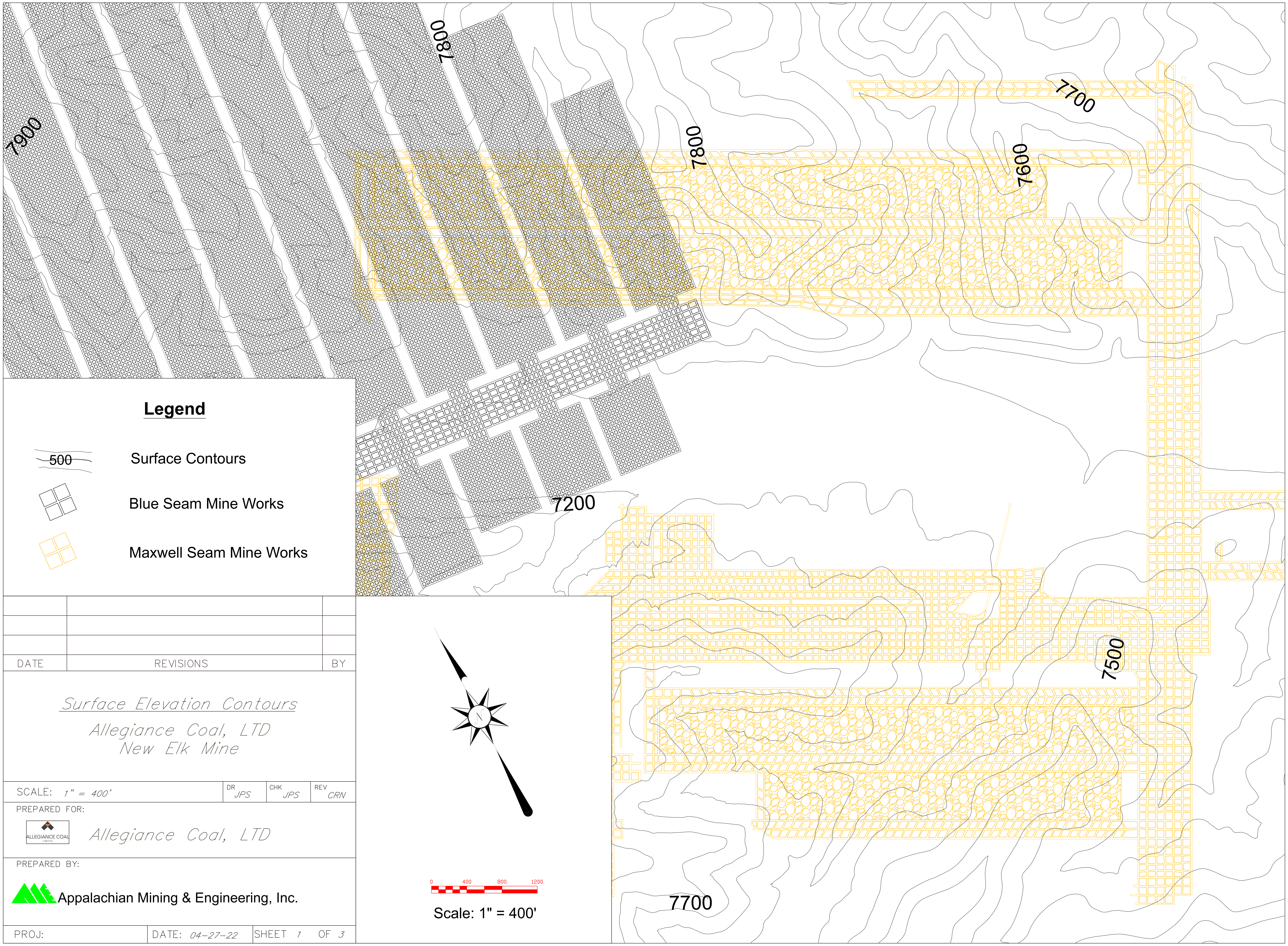
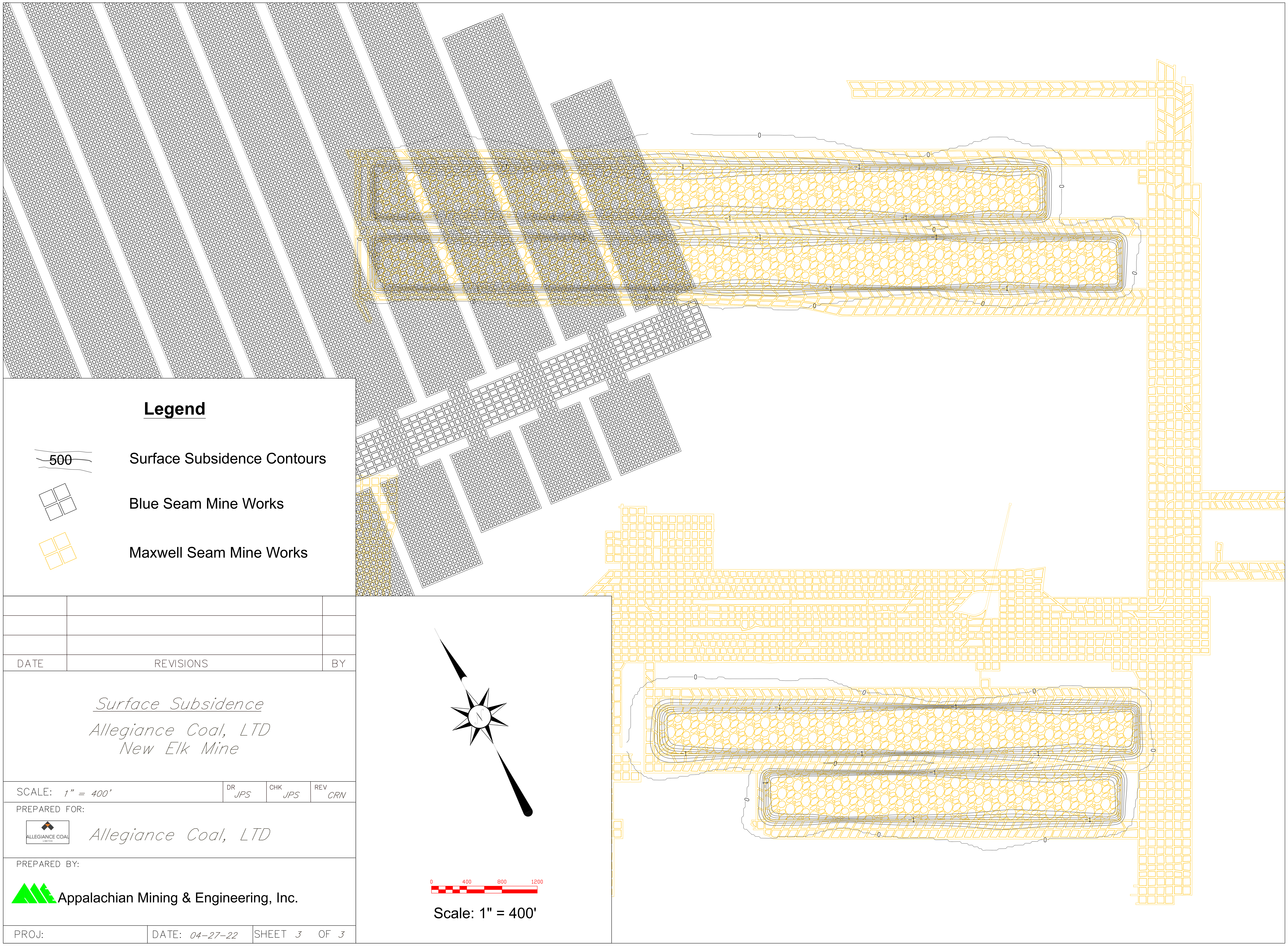


Figure 3: SDPS Input Parameters


7900
7800
7800
7700
7600
7200
7500
7700
Legend
500
Surface Contours
Blue Seam Mine Works
Maxwell Seam Mine Works
DATE
REVISIONS
BY
Surface Elevation Contours
Allegiance Coal, LTD
New Elk Mine
SCALE: 1" = 400'
DR JPS
CHK JPS
REV CRN
PREPARED FOR:
Allegiance Coal, LTD
PREPARED BY:
Appalachian Mining & Engineering, Inc.
PROJ:
DATE: 04-27-22
SHEET 1 OF 3
0
400
800
1200
Scale: 1" = 400'



Legend

500	Surface Subsidence Contours
	Blue Seam Mine Works
	Maxwell Seam Mine Works

DATE	REVISIONS	BY

Surface Subsidence

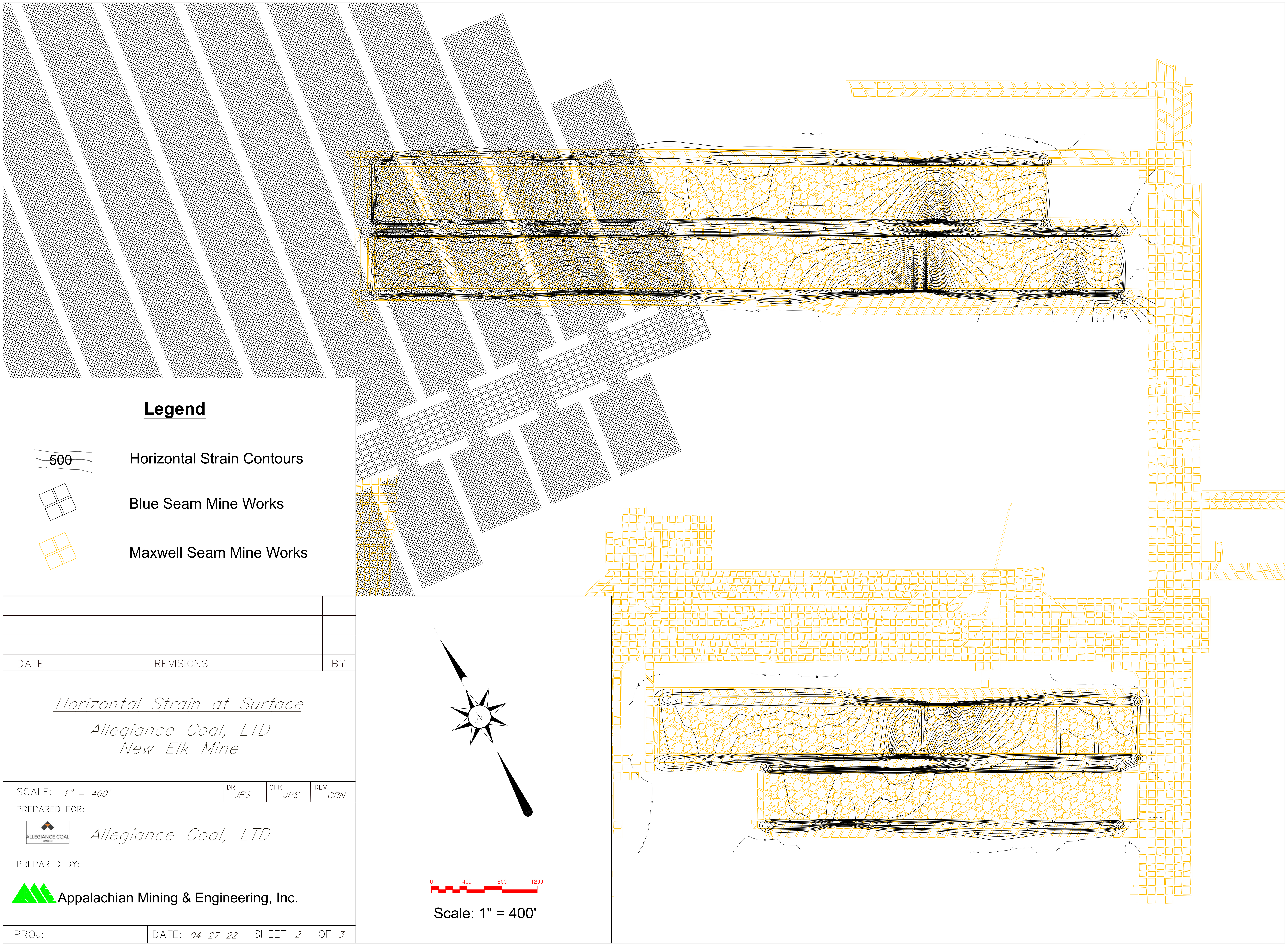
Allegiance Coal, LTD
New Elk Mine

SCALE: 1" = 400' | DR JPS | CHK JPS | REV CRN

PREPARED FOR: Allegiance Coal, LTD

PREPARED BY: Appalachian Mining & Engineering, Inc.

PROJ: | DATE: 04-27-22 | SHEET 3 OF 3



Legend

500	Horizontal Strain Contours
	Blue Seam Mine Works
	Maxwell Seam Mine Works

DATE	REVISIONS	BY

Horizontal Strain at Surface

Allegiance Coal, LTD
New Elk Mine

SCALE: 1" = 400'	DR JPS	CHK JPS	REV CRN

PREPARED FOR:

Allegiance Coal, LTD

PREPARED BY:

Appalachian Mining & Engineering, Inc.

PROJ:	DATE: 04-27-22	SHEET 2 OF 3