Appendix 5-6

Terratek Report

PRELIMINARY STUDY OF POTENTIAL SUBSIDENCE OVER THE GENWAL COAL MINE

Submitted to:

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Huntington, Utah 84528

Attn: Mr. R. Jay Marshal

TR92-47
December 1991

TerraTek

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Contents

1 INTRODUCTION

Genwal Coal Mine is located approximately 18 miles north west of Huntington, Utah. The state lease ML-21569 allows the Genwal Coal Company to mine under all of section 36 of the Rilda Canyon quadrangle in the Utah geological and mineral survey map. The mining is being carried out in the nearly flat-lying, Hiwatha coal seam with an average thickness of 8 ft lying at an average depth of 1600 ft below the surface. The overall mining pattern for the initial stage of mining is shown in Figure 1. At the western end of this lease, mining begins at 100 ft from the lease boundary. The current mining pattern at this end consists of five 20 ft entries separated by four 50 ft wide chains of pillars, running from north-to-south sides of the property (Figure 2a).

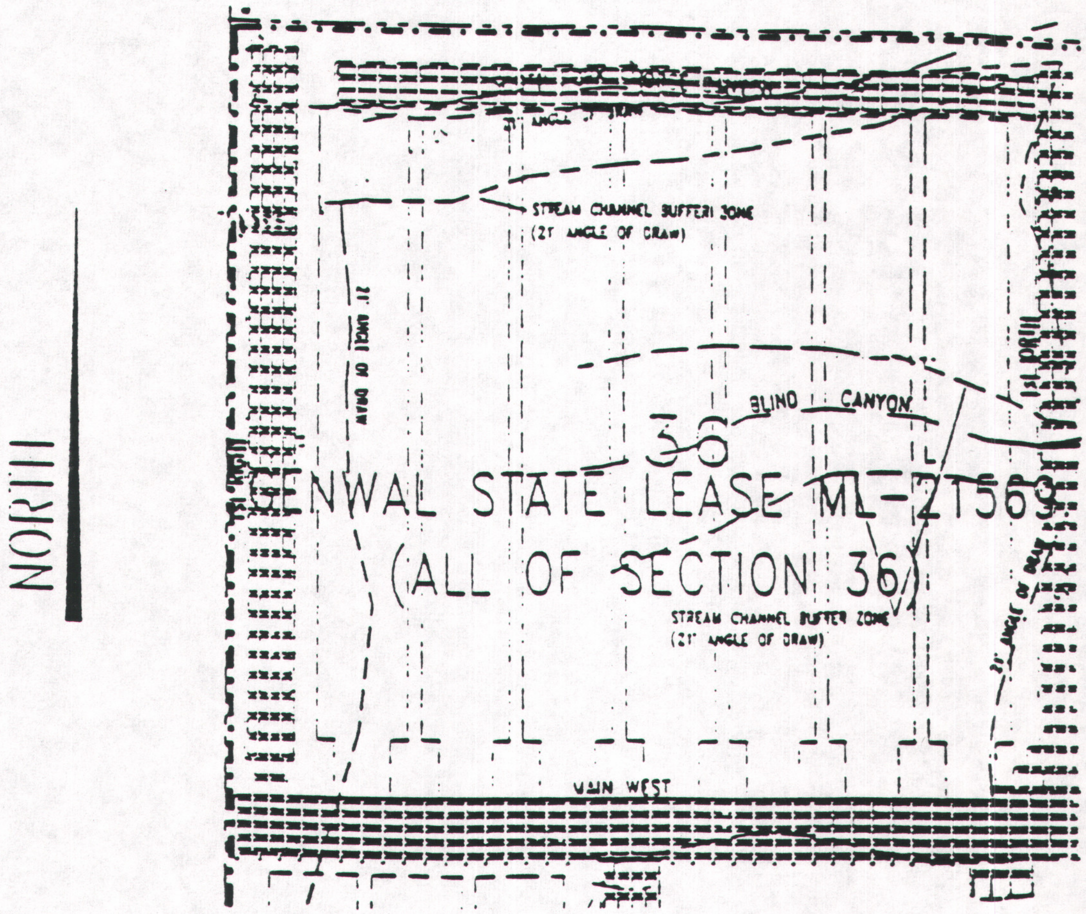
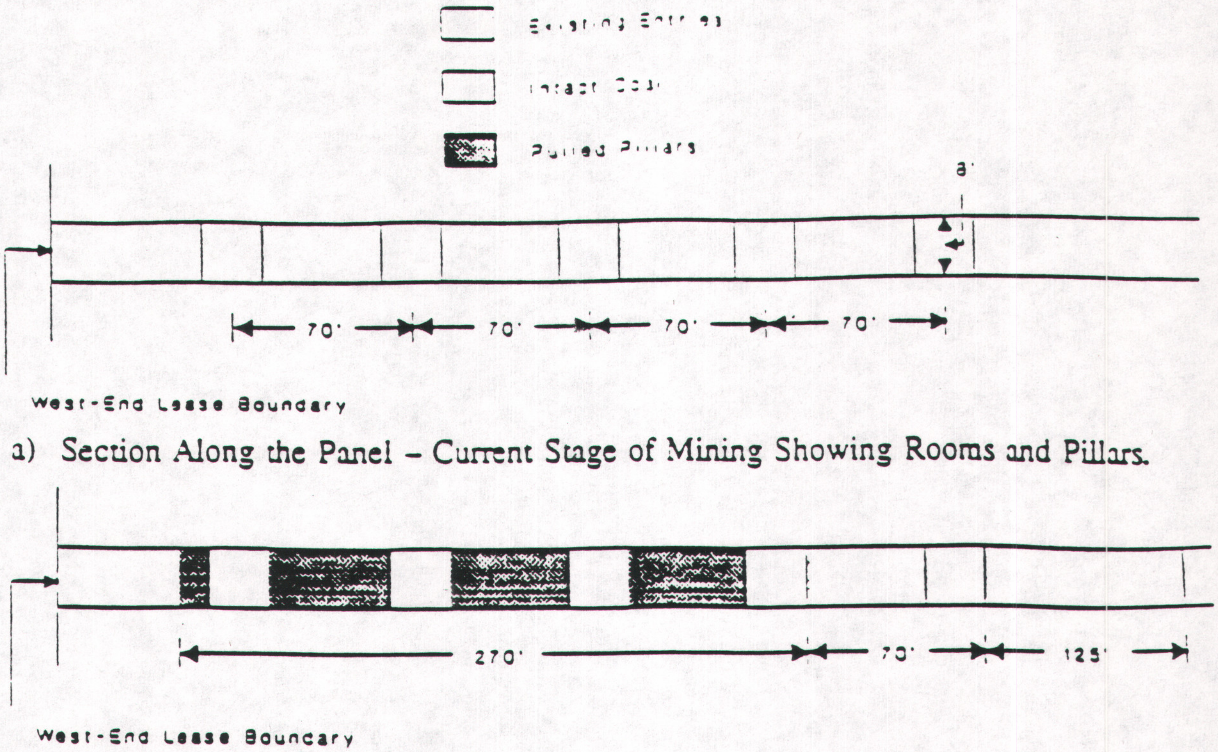


Figure 1: An overall map of Genwal Mine Showing Initial Stage Mining Plan State Lease ML – 21569.

It is planned in the next phase to mine out the three left pillars (Figure 2a), creating approximately 270 ft wide panel flanked by intact coal on the west side and the 50 ft wide fourth pillar followed by 20 ft wide entry on the east side of the panel. As the mining continues further



a) Section Along the Panel – Current Stage of Mining Showing Rooms and Pillars.

b) Section Along the Panel – Proposed Pillar-Pulling Scheme

Figure 2: Current and Proposed Mining Plans for the West-End of the Property

to the east, it is expected to leave a 250 ft wide pillar beyond the last entry (Figure 2b). Thus the proposed secondary mining (pillar-pulling) operation will result in an overall recovery of approximately 50%. **The purpose of this study was to make a preliminary assessment of the nature of any potential subsidence due to the proposed mining (pillar-pulling) operation.**

2 SUBSIDENCE CALCULATION

2.1 National Coal Board Technique

The National Coal Board (NCB) of England has published an empirical set of rules and graphs for computing the maximum subsidence and the subsidence profiles over coal mines NCB, 1975). These empirical rules and graphs are developed from observations over a large number of longwall mining operations in single and multiple seams in England. Nevertheless, the NCB technique of subsidence prediction provides a firsthand guidance for other forms of mining operations in other geographical areas as well. In particular, for the proposed mining at Genwal Mine resulting in the panel length to width ratio of approximately is 1:17, it is very reasonable to assume a longwall situation.

The following calculations are based on the NCB technique:

- Assume: Extracted width, w = 270 ft (82 m)
  Depth of Cover, h = 1,600 ft (488 m)
  Excavated Height, m = 8 ft

- From the NCB curves (p. 9) : $S_{Max}/m = .077$
  where, S_{Max} = Maximum subsidence, at the center of the panel width.

- Therefore, $S_{Max} = .61$ ft

- With a virgin ground reduction factor of .9, $S_{Max} = .55$ ft = 6.6 in.

- A family of curves give the subsidence S at any distance d from the center of the panel as a fraction of the maximum subsidence S_{Max} at the center. These curves are plots of the nondimensionalized ratios w/h vs. d/h for S/Smax values ranging from 0 to 1. In the present case, w/h = 270/1600 = .17. The NCB family of curves are drawn up to a lower limit of w/h = 0.2 only and are not applicable in the present case.

Commonly observed draw angle in the western U.S. region lies between 20° to 35°. For draw angles of ranging between 20° to 40°, the corresponding critical width of an opening as conventionally accepted is given as ranging between .72h to 1.6h ,(h being the seam depth). By these standards the opening in the current case has undoubtedly a subcritical width (270 ft). Unfortunately, for subcritical openings, the empirical techniques based on subsidence factor (S/m) are not very reliable and are likely to overestimate the maximum subsidence as well as the draw angle.

2.2 Deer Creek Mine Subsidence Study

U.S. Bureau of mines has published (Allgaier, 1988) the results of an extensive, long-term subsidence investigation over the Deer Creek Mine (owned and operated by the Utah Power & Light Company), approximately 7 miles south of the Genwal Mine Site. The study consisted of monitoring subsidence over four longwall panels mined in the Blind Canyon coal seam over a period of four years. Blind Canyon coal seam is approximately 70-ft above the Hiwatha coal seam being mined at the Genwal Mine. Since the overall stratigraphy at the Deer Creek Mine Site is generally the same as at the Genwal Mine Site, it is reasonable to assume that the inferences drawn from the USBM study could be applicable to the Genwal Mine as well.

Following general observations can be made:

- It appears that for a single panel of width 480-ft driven to approximately 1,600-ft, the maximum subsidence over the panel was less than 3 inches.

- The draw angles observed at both longitudinal ends of each panel varied from 26° to 38°. The average draw angle for the entire operation has been reported as 30°. It has been mentioned that, this average value of 30° can be used to define the limit of subsidence beyond the limit of mining. This conclusion is based on the excavation of 4 adjacent panels, covering an overall area of approximately 2,400 ft x 2,400 ft, however. A careful investigation of the subsidence contours plotted at various stages of mining shows that for a single panel of 480 ft width, the draw angle on the (virgin ground) rib-side was closer to 25°. Furthermore, the stratigraphy at the Deer Creek Mine seems to lack continuous, competent columns of sandstone as exhibited in the DH-7 column at the Genwal Mine Site. Considering these factors, it is believed that the actual draw angle, in the case of a subcritical opening as proposed at the Genwal Mine should be much lower.

2.3 Elastic Analysis

A simple, two-dimensional, linear-elastic analysis was conducted using the material properties and seam level constraints guided by those reported in the Serrata Geomechanics, Inc., report (SGI, 1991). A boundary element computer program "TABEX-2D" was used for this purpose. The overburden in this analysis is treated as a single layer medium. An equivalent set of elastic properties for this medium is calculated from the SGI data for the component layers given below in Table 1. The component layer stratigraphy was constructed by the SGI based on the geological log obtained from wellbore DH-7.

If H represents the total thickness and E the equivalent Young's Modulus, E can be obtained using an approximate relationship given below:

$$\frac{H}{E} = \frac{H_1}{E_1} + \frac{H_2}{E_2} + \frac{H_3}{E_3} + \frac{H_4}{E_4} + \frac{H_5}{E_5} \quad (1)$$

This gives the equivalent Young's Modulus $E = 3.5 \times 10^6$ psi. The equivalent Poisson's Ratio of .2 was assumed in the analyses. The 5th layer of siltstone lying below the coal layer is included in the equivalent modulus calculation on the premise that any settlement below the coal layer is confined within the immediate floor layers.

The baseline case was analyzed for the mining pattern with a 270 ft wide opening as shown in Figure 2b. No constraints were imposed at the seam level in this case, except that no stresses were transmitted through the mined zones and the unmined coal behaved elastically (Young's and

Table 1: Stratigraphy and Elastic Properties Assumed in the SGI Report.

Layer # (i)	Component Layer	Thickness (ft) (H_i)	Young's Modulus (psi) (E_i)
1	Shale	112	1×10^6
2	Sandstone	1,088	3.375×10^6
3	Siltstone	401	6.86×10^6
4	Coal	10	$.288 \times 10^6$
5	Siltstone	389	6.86×10^6

shear moduli: $E_{coal} = .29 \times 10^6$ psi and $G_{coal} = .12 \times 10^6$ psi). As intuitively expected, very little seam closure (<1 inch) and high pillar stresses (in excess of 5,000 psi) were observed. This is understandable, since no roof break and pillar yielding is allowed in an elastic analysis.

A set of additional runs were made in which a seam closure of 6, 18, and 24 inches, respectively were imposed in the mined out areas, thus relieving the high stresses in the rib area, and in some sense simulating the pillar yielding situation. In order to put these in perspective, it should be mentioned that the maximum room closure for a 100 ft opening calculated in the SGI report (Case 5: all the pillars knocked off) is 2.3 inches, after accounting for realistic manifestations such as pillar yielding, immediate roof break, and the time dependent effects. The subsidence profile for all four cases are shown in Figure 3.

It is clear from Figure 3, that even in the worst case analyzed with a seam closure of 24 inches, the maximum subsidence resulting at the surface is only of the order of 3.5 inches. The profile is fictitiously elongated on either side of the opening due to two reasons:

1. The imposed uniform closures over the entire opening, and

2. Built-in deficiency of the elastic analysis

It is well established that the elastic analysis based on an isotropic rock mass consideration, in general, predicts lower maximum subsidence and higher draw angle as compared to that observed in practice. Transversely isotropic characterization of the rock mass accounts for the presence of stratification and provides more realistic subsidence profiles, if the rock mass is treated as a monolithic structure. Considering these factors, it is reasonable to assume that the actual subsidence profile will have slopes steeper than those exhibited by the curves in Figure 3. It must also be pointed out that the predicted subsidence include any subsidence that might already have taken place.

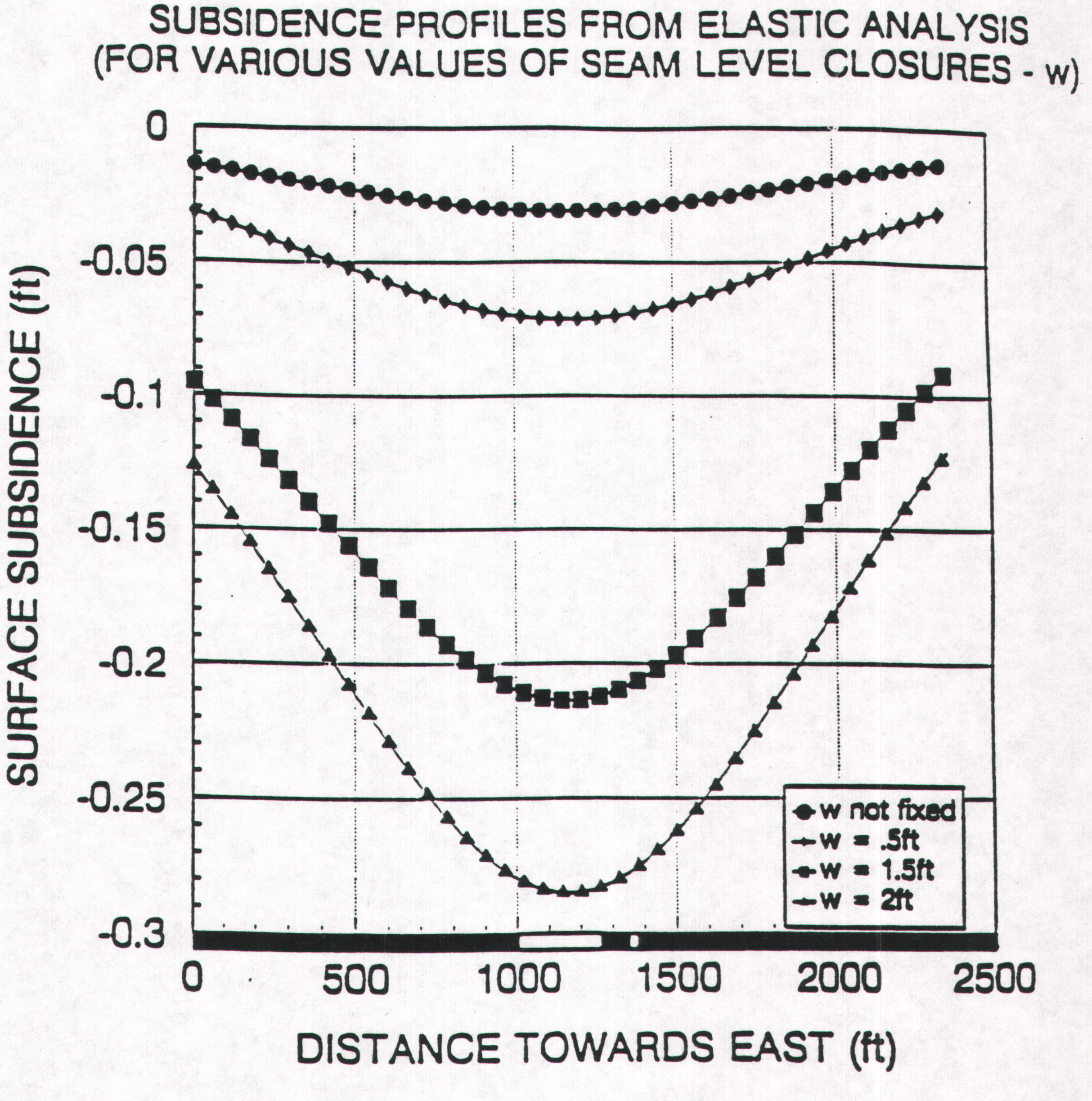


Figure 3: Subsidence Profiles from Elastic Analysis of the Proposed Mining Pattern in the West-End Panel. (Various curves are for different closure values - w, imposed over entire opening)

3 CONCLUSIONS

On the basis of the preliminary analysis reported here. it is estimated that the proposed pillar-pulling scheme will result at the surface a maximum subsidence of not more than 3 to 4 inches at approximately 240 ft inside the lease-boundary at the west-end of the property. The draw angle over the intact coal is expected to be of the order of 20°.

More definitive statements to these effects supported by accurate and more realistic subsidence profiles can only be provided by conducting a detailed analysis in conjunction with laboratory tests to determine the deformational characteristics and failure behavior of the constituent layers of the rock mass.

4 REFERENCES

Allgaier, F.K., 1988, "Surface Subsidence Over Longwall Panels in the western United States-Final Results at the Deer Creek Mine, Utah", USBM Information Circular No. 9194.

NCB, 1975, "Subsidence Engineer's Handbook", National Coal Board- Mining Department, London, England.

SGI, 1991, "Preliminary REM Model for Main Entry System - Determination of Site-Specific Geomechanical Ground Condition for Construction of REM Model", A report submitted to Genwal Coal Company by Serata Geomechanics, Inc.