RESPONSE OF SURFACE SPRINGS TO LONGWALL COAL MINING WASATCH PLATEAU, UTAH[1]

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Abstract: High-extraction longwall coal mining creates zones in the overburden where strata bend, fracture, or cave into the mine void. These physical alterations to the overburden stratigraphy have associated effects on the hydrologic regime. The U.S. Bureau of Mines (USBM) studied impacts to the local hydrologic system caused by longwall mining in the Wasatch Plateau, Utah. Surface springs in the vicinity of two coal mines were evaluated for alterations in flow characteristics as mining progressed. Fourteen springs located above the mines were included in the study. Eight of the springs were located over longwall panels, four were located over barrier pillars and mains, and two were located outside the area disturbed by mining. Flow hydrographs for each spring were compared to climatic data and time of undermining to assess if mining in the vicinity had influenced flow. Heights of fracturing and caving in the overburden resulting from seam extraction were calculated using common subsidence formulas, and used in conjunction with elevations of springs to assess if fracturing influenced the water-bearing zones studied. One spring over a panel exhibited a departure from a normally-shaped hydrograph after being undermined. Springs located over other mine structures, or outside the mine area did not show discernible effects from mining. The limited response of the springs was attributed to site-specific conditions that buffered mining impacts including the elevation of the springs above the mine level, and presence of massive sandstones and swelling clays in the overburden materials.

Additional Key Words: underground coal mining, hydrology

Introduction

Longwall mining involves extracting coal in large blocks called panels using a mechanized shearer. With this method, the mine roof is supported with hydraulic supports that automatically advance as mining progresses. As the supports move, the mine roof is allowed to collapse into the mine void. Strata above the mine level are altered as the mine roof caves behind the shields, creating zones where blocks of rock fill the mine void, or fracture or deform as rock layers warp downward. Recognizing that these alterations in overburden characteristics produce associated changes in the hydrologic system, a study was undertaken to observe and quantify the response of water resources contained in the overburden to mining.

Alterations to the hydrologic system resulting from longwall mining can include (1) increased permeability of the rock mass from fracturing and bed separation, (2) flow loss into mining-induced or dilated fractures or planes of bed separation, and (3) redirection of flow and hydraulic gradients. Studies in the Appalachian and Illinois coal regions indicate that rapid hydrologic response occurs in conjunction with the rapid subsidence induced by longwall mining (Coe and Stowe 1984, Trevits and Matetic 1991). In these studies, dramatic decreases in water levels in wells and flow from springs were observed as the longwall face passed underneath and was followed by subsequent total or partial recovery within months after mining.

Hydrologic response to high-extraction coal mining has become an issue of concern in both Eastern and Western coalfields. Previous studies have examined the effects of longwall mining on aquifers in the Eastern U.S., but few have focused on western U.S. coalfields where the aridity of the region generates concern for the availability of surface and ground water resources. Public sentiment targets coal mining as threat to the available water resources.

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The actual effects and longevity of underground coal mining on water resources in the West are largely unknown at this time. To observe and assess the response of water resources from longwall mining at a western coalfield, 14 springs over 2 mines in the Wasatch Plateau were studied. The springs studied were selected based on proximity to the mines and availability of monitoring records.

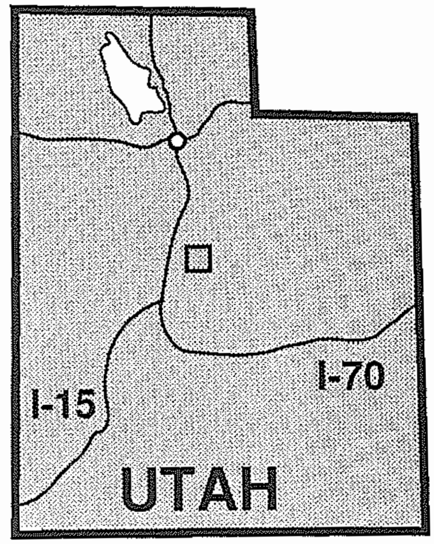

Figure 1. Study site location map.

Site Description

The study site is located in the Wasatch Plateau coalfield of south-central, Utah (fig. 1).

Two mines, Mines A and B, separated by 26 m, operate at the site. Mine B is located above mine A and partially overlaps it. On figure 2, the outlines of both mines and locations of the springs studied are shown. Mine A is at an elevation of 2,265 m, and Mine B is at an elevation of 2,300 m. Both single- and multiple-seam longwall mining occur within the study area. Overburden thickness averages 520 m, and ranges from 260 m to more than 700 m, dependent on local topography. The topography of the area is typified by rugged, mountainous terrain dissected by stream-incised canyons. Local elevation varies from 2,100 m to over 3,000 m.

Exposed strata in the mine area are of sedimentary origin and range from Cretaceous to Quaternary in age. The stratigraphy consists of freshwater limestones, sandstones, and interbedded sandstones, claystones, mudstones, and shales of fluvial and lacustrine origins. Geotechnical testing of mudstone and claystone cores from the area indicate the presence of hydrophilic or swelling clays in the North Horn and Price River Formations. Economic coal deposits occur in the lower portion of the exposed stratigraphic column. The generalized overburden stratigraphy is shown in figure 3 (Lines 1985).

Recharge to the hydrologic system occurs through percolation of precipitation through matrix flow and into joints, fractures, and faults. Ground water occurs in discontinuous, perched water-bearing zones or in saturated fractures. Springs occur where fractures intercept the surface, or where the perched water-bearing zones intercept canyon walls. The presence of the hydrophilic clays largely retards downward migration of water, and therefore the majority of springs in the area occur in the formations containing the clays.

Methodology

The springs studied were designated with a letter identifier of A to N. Locations of the springs occurring over the mines were correlated to mine structures such as panels, barrier pillars, or mains as shown in figure 2. Springs A, B, E, F, I, J, L, and M are located over panels, and springs C, G, K, and N are located over pillars or mains. The two remaining springs, D and H, occur in an area that has not been undermined, and were used as controls to reflect precipitation fluctuations.

Spring flows are collected by mine personnel from July through October due to limited accessibility to the springs during winter months. Based on this availability of data, spring flow was used in the form of seasonal recession curves that show flow trends from runoff to baseflow conditions. Spring occurrence based on issuing formation and mechanism (i.e., perched water table or fracture) was determined by the mining company. This information was incorporated into assessing pre- and post-mining flow characteristics for each spring. Spring flow hydrographs were compared to the time of undermining and precipitation to separate climatic effects spring response for the area and to assess if fracture-issued and perched zone-issued springs exhibited similarly shaped recession curves.

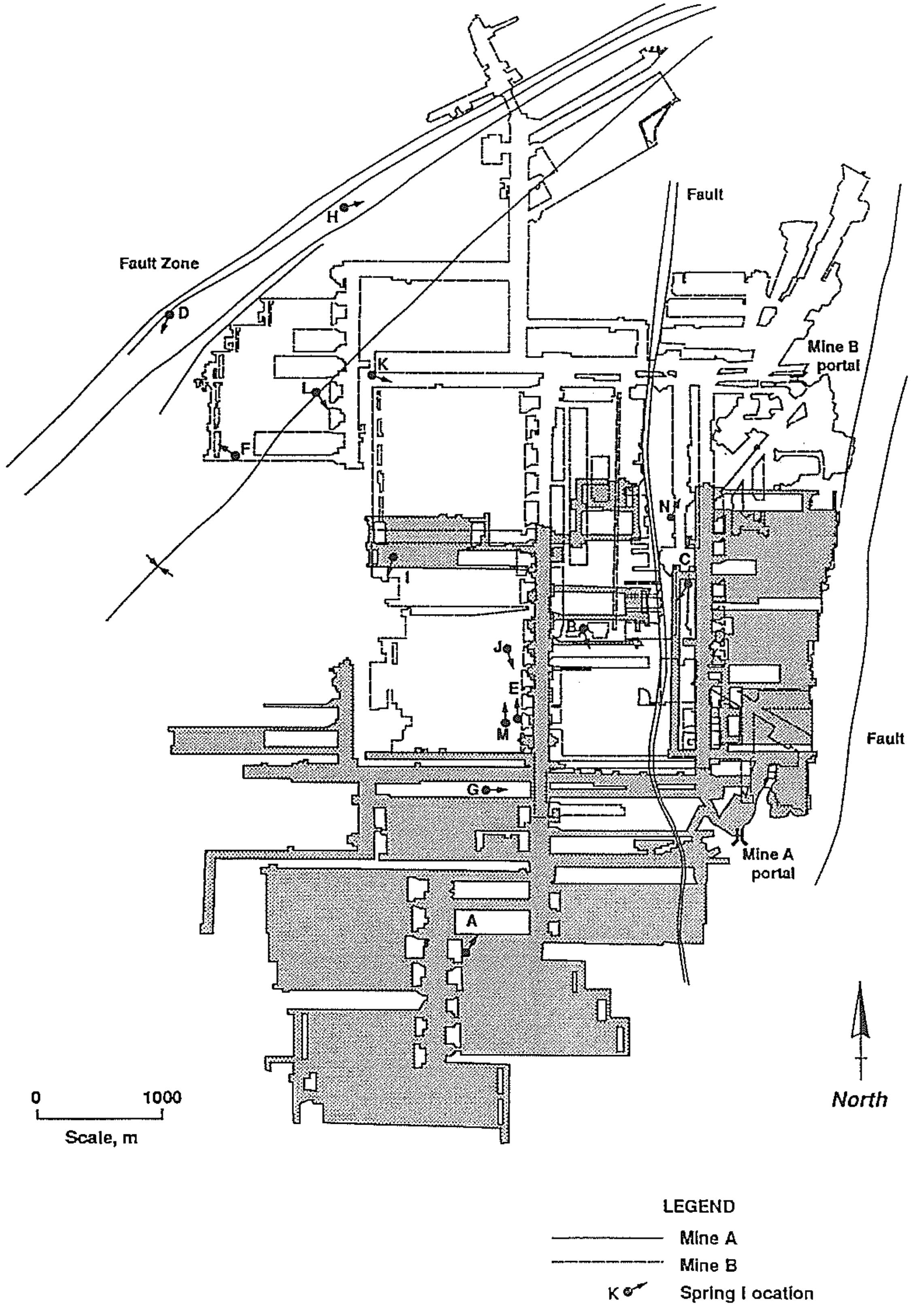

Figure 2. Map showing mine outlines and spring locations.

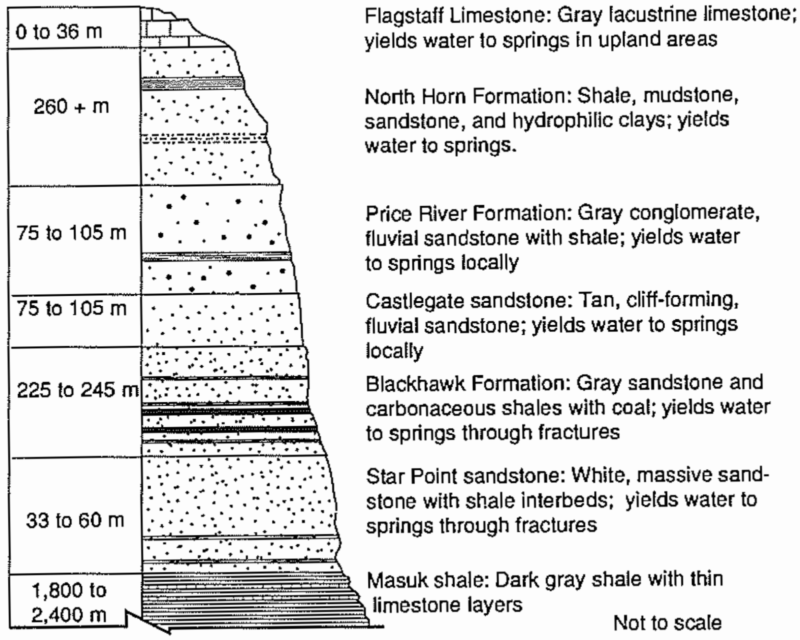

Figure 3. Generalized overburden stratigraphy.

Precipitation trends collected at a weather station at the mine site are illustrated on figure 4. Precipitation and spring flow measurements included data from several years prior to mining and were used to establish a baseline for comparison of spring flow behavior during and after mining. Patterns or trends in the spring flow recession curves were sought to assess if the springs showed similar response to climatic events each year. It is important to note that the region experienced years of decreased precipitation from 1987 to 1992, where precipitation ranged from 70% to 85% of normal.

Spring elevations were compared to anticipated heights of fracturing in the overburden as calculated using widely accepted subsidence engineering formulas (Peng 1992). This comparison allowed for evaluating the overburden fracturing elevation in relation to the elevations where springs were located.

Discussion

Changes in the recession curves, either increases or decreases in flow that could not be attributed to climatic fluctuations, after mining had occurred would indicate a response to undermining. Based on results from other studies (Coe and Stowe 1989, Matetic and Trevits 1991, and Rauch 1989) dramatic decreases in flows would be expected after undermining. Springs located over panels are expected to show a greater response to undermining than those located over mains or barrier pillars since the majority of subsidence occurs over the longwall panels.

Each spring hydrograph was evaluated for normal response to recharge before

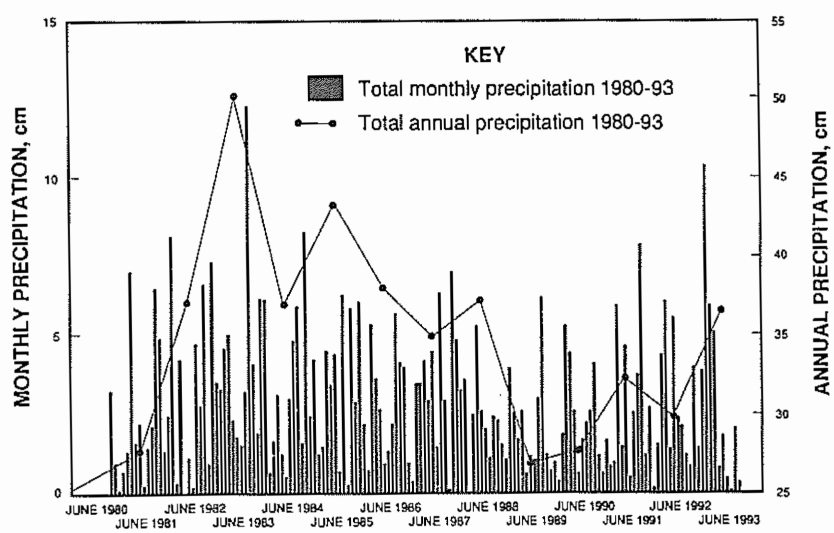

Figure 4. Monthly and annual precipitation, 1980-93.

undermining. The hydrographs of the springs studied all exhibited similar response to precipitation by showing peaks in months of runoff (June or July) grading down to baseflow conditions by September or October. This pattern was repeated each year, but varied dependent upon precipitation. There did not appear to be different climatic response between fracture-issued and perched-zone-issued springs.

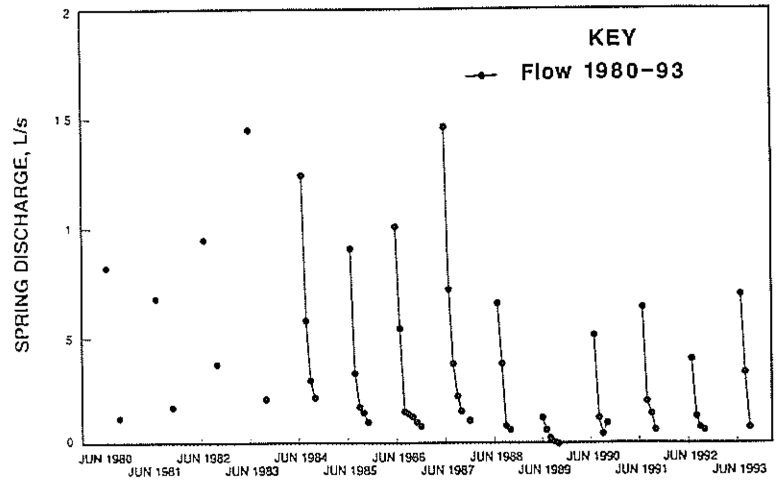

Figure 5. Spring D flow hydrograph.

Springs D and H (which were located outside the area of mining) both exhibited smooth, repeatable recession curves during the course of the study. Since these springs were located in an area that has not been undermined, their responses were used as a baseline for response to precipitation trends in the area. The hydrograph for Spring D is given on figure 5.

Of the springs that were undermined by longwall panels, only spring B showed a departure from the pre-mining hydrograph. Spring B (fig. 6) was undermined by submains in Mine B in August of 1985, and the hydrograph becomes erratic and less repeatable after this time. The spring was then undermined by a panel in Mine A in August 1993. Increased flow was observed after the spring was undermined by the panel, however this was due in part to clearing blockage in a pipe installed at the spring. Spring B occurs at an elevation of 2,822 m, 557 m above Mine A, and 522 m above Mine B. While flow loss was not evident after undermining, the departure of the curves from normal shapes after they had been undermined indicates a response that may be attributable to mining.

Spring elevations were compared to the anticipated elevations of overburden fracturing. To approximate the combined height of fracturing and caving in the overburden, the relationship of fracture height equal to 30 times mining thickness was used (Peng 1992). This relationship was developed for conditions in Eastern U.S. coalfields and may not be wholly applicable to conditions in Western U.S. coalfields. However, no relative value for estimation of caving and fracturing has been developed for western coalfields, thus this estimation was used. The approximated height of fracturing in the overburden correlated to an elevation of 2,600 m for Mine B, and an elevation of 2,500 m for Mine A. To represent both single and multiple-seam mining conditions, it was assumed that fracturing associated with mining the lower seam would be incorporated into the fracturing already present from mining the upper seam (Haycocks 1993). A conceptual subsurface overburden failure schematic is shown on figure 7. The lowest spring studied, Spring E, was at an elevation of 2,737 m, 137 m above the estimated fracturing height.

While Spring B was not the lowest spring in elevation evaluated in the study, it was the only spring to show a response to undermining. The lack of observed response from other springs, especially from those located closer to the mine level, is difficult to ascertain with the data available. The most likely factor limiting response in the other springs is the geologic conditions present, specifically the presence of swelling clays, that buffer the effects of mining on overburden, and hence, hydrologic response. The observed response in Spring B may be

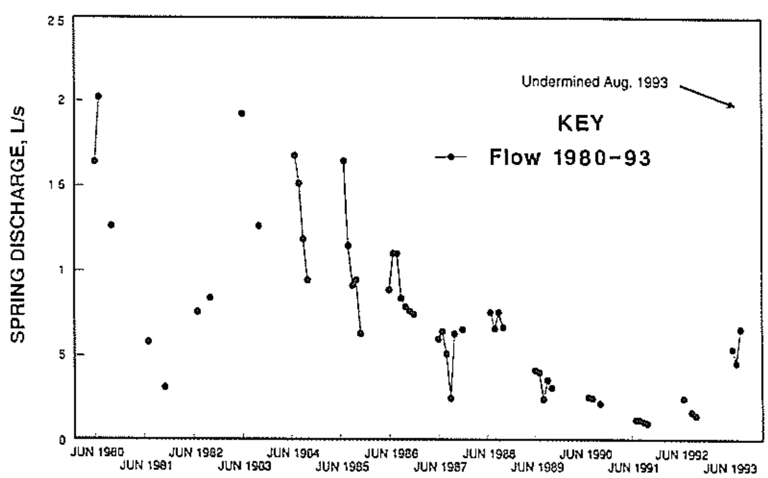

Figure 6. Spring B flow hydrograph.

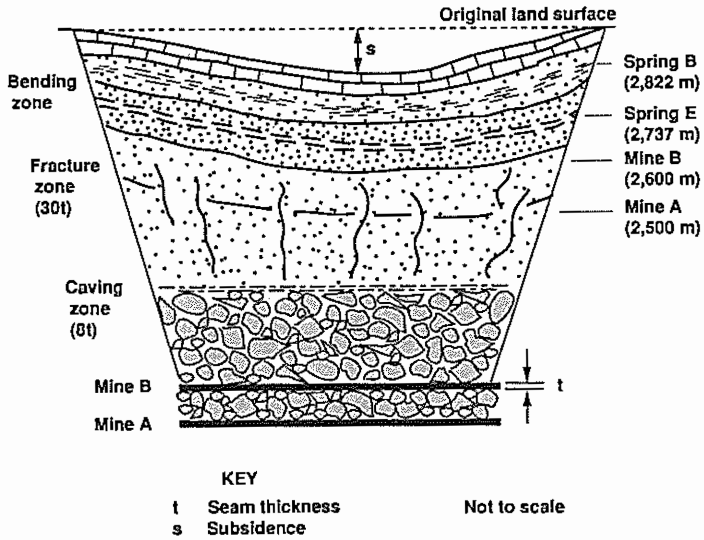

Figure 7. Overburden failure schematic.

attributed to redistribution of stresses in the overburden as subsidence occurred coupled with the fact that surface tension cracks appeared in the vicinity of Spring B.

In contrast to observations made in other studies, the springs studied did not exhibit dramatic effects from undermining. Coe and Stowe (1984) observed rapid and dramatic decreases in spring flow, followed by recovery to pre-mining conditions as the longwall face passed underneath springs 120 m to 145 m above the coal seam. The limited spring response observed at this site may be attributed to several factors; (1) the thickness and composition of overburden present which contained a massive, competent sandstone, which causes bridging in the overburden, limiting subsidence, (2) presence of formations containing swelling clays, and (3) the elevation of the springs above the elevation of estimated heights of fracturing and caving in the overburden.

Conclusions

The U.S. Bureau of Mines performed a study of longwall mining effects on surface springs above two western coal mines using seasonal spring flow, precipitation, and overburden failure mechanics information. These data sets were used to quantify the response of spring flow to underground mining.

Results indicate that of 14 springs studied, 1 located over a longwall panel showed a departure from a normal recession curve after being undermined. The recession curve for Spring B became erratic after undermining but no flow loss was observed. The spring returned to normal response the following year. The departure from a normally-shaped recession curve may be a response attributable to mining. The other springs located over panels, or other mine structures did not exhibit discernible effects from mining.

Incorporation of commonly used subsidence calculations to estimate overburden failure response showed that heights of caving and fracturing in the overburden would not influence the water-bearing zones studied. However, stresses in the overburden could cause opening and closing of pre-existing fractures or bed separation, creating the temporary alteration of flow curves. The data available do not allow for establishing which mechanism would cause the erratic recession curves.

The observed response of springs to undermining at this study site was different than spring responses observed in studies performed in the Appalachian and Illinois coalfields. At these sites, dramatic decreases in spring flow and water levels in wells were noted. The limited response was attributed to site-specific conditions that buffered the effects of mining. These conditions included the thickness of overburden between the mine level and the springs, which ranged from 440 m to over 600 m. Additionally, the presence of hydrophilic clays and mudstones in the overburden likely acted to lessen the vertical extent of strata dewatering, as has also been observed in other studies (Rauch 1989). The location of the springs above the computed elevation of combined fracturing and caving heights also contributed to the lack of discernible effects. The results of this study suggest that effects of mining on the springs studied given the site-specific conditions are minor and temporary. Longer term effects due to residual subsidence are not known and will be the target of future studies.

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