Hydrogeologic Evaluation
Big Mountain Mine Complex
Shamokin Creek Watershed
Coal Township, Northumberland County, Pennsylvania

Prepared for
Northumberland County Conservation District
And
Shamokin Creek Restoration Alliance

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INTRODUCTION

Dr. Carl Kirby, associate professor of geology at Bucknell University and board member of the Shamokin Creek Restoration Alliance (SCRA), contacted me on January 19, 2006 to determine if Meiser & Earl, Inc. (M&E) would be interested in performing a hydrogeologic evaluation of the Big Mountain mine complex located south of Shamokin, Pennsylvania. The SCRA has a grant through the Northumberland County Conservation District (NCCD) to evaluate the feasibility of constructing a passive treatment system to treat mine drainage in the Shamokin Creek Watershed, with the Big Mountain Mine complex and its discharge as one area being evaluated.

The only company actively mining coal in the Big Mountain mine complex is Blaschak Coal Corporation. Because M&E has worked for Blaschak Coal Corp. (Blaschak) in the anthracite coal region previously and actively works for Fisher Coal Co., a related family coal company, I said I needed to make sure Blaschak did not believe our involvement in this project was a conflict of interest. Fred Wolf and Robin Koeberle, both of Blaschak Coal Corp., stated that they had no problem with M&E working with Dr. Kirby and SCRA.

Dr. Kirby requested that M&E assess the mine hydrology of the Big Mountain mine complex. In addition, we were to assess the source of the pH spike that occurred in the Big Mountain discharge in 1998 and whether the conditions that created this spike could be used to help treat this discharge. On May 8, 2006 Dr. Kirby gave me the verbal approval to begin the evaluation.

INVESTIGATION

Background

As I discussed with Dr. Kirby, this report serves as an overview of some of the general hydrogeologic issues associated with the Big Mountain Mine complex and, as discussed below, further work is required to assess the detailed hydrogeologic conditions at the site. The discharge for the Big Mountain Mine complex is referred to as Site 23 (SR23), because this was the number used in the 1972 Operation Scarlift report prepared by Gannett, Fleming, Corddry, and Carpenter (and Cravotta and Kirby, 2004) for the Shamokin Creek Watershed. Figure 1 is a copy of the Shamokin Creek 7.5 Minute USGS provided to me by Dr. Kirby, showing the limits of nearly the entire Big Mountain mine complex, with Mine Barriers LXX and LXXI defining the western and northern limits, respectively. The eastern limit of the mine complex is just east of the map limit. The southern limit of the mine complex is at the southernmost outcrop of the lowest coal (Lykens Valley 4) that was deep mined and strip mined, which lies just north of the crest of Mahanoy Mountain. Figure 2 is an enlarged view of the same map showing the discharge area and the location of the existing weir (Weir #4) at the mouth of Buck Run before it enters Shamokin Creek to the north. For a description of the SCRA and the projects they have completed, particularly at Site 23, see their website at www.shamokincreek.org.

Deep Mining

David Williams, mining engineer with the Pennsylvania Department of Environmental Protection at Pottsville Office, provided me a 1 inch equals 100-foot scale map of the Big Mountain Improvement Company's Big Mountain Colliery (Big Mountain Mine). The cross sections of the coal veins in the1962 USGS Coal Investigations, Map C-46, show that deep mining occurred in at least 15 different coal veins. In ascending order, they are Lykens Valley 4 (LV4), A, C, D, Buck Mountain (5), Buck Mountain Top Split (5T), Seven-foot (6), Seven-foot Local (6L), Skidmore (7), Bottom Split of Mammoth (8), Top Split of Mammoth (9), Four-foot (9½), Holmes (10), Rough (10½), and Primrose (11). The lowest level of mining is at an elevation of approximately 350 feet above sea level, which exists near the northern edge of the Big Mountain Mine, which is generally limited to the north by the Big Mountain Anticline, as shown on Figure 3. Deep mining occurred 800 feet or more below ground level at some locations. Figure 3, Geologic Map, is a copy of a portion of the map entitled "Geology of Anthracite in the Eastern Part of the Shamokin Quadrangle, Northumberland County, Pennsylvania" (Map C-46). According to the mine map, deep mining was performed from as early as the 1870's to the 1910's in the Big Mountain Mine.

As shown on Figure 3, the bedrock has a regional strike of just north of due east, with four primary structural features producing locally a large range in the amount and direction of bedrock dip. From north to south the structural features are: Big Mountain Anticline, Big Mountain Basin (synclinorium), Enterprise Anticline, and Enterprise Basin (syncline). The deep mining in the Big Mountain Mine is connected across strike by several rock tunnels, which now provide a drainageway for ground water from south to north where it eventually outlets in the former Buck Run stream valley.

Figure 4 is a scanned version of the northernmost portion of the Big Mountain Deep Mine map that lies within the Buck Run Valley, overlaid onto the 7½ minute Shamokin USGS Quadrangle map by Dr. Kirby. As the map shows, surface features on the deep mine map, such as the house and road, were used to overlay the two maps. Discharge A (also called Discharge 1) is west of the pond on Figure 1. This discharge issues from a deep-mine entry, which is at an elevation of 868.7 feet on the deep mine map. Based on geologic and deep-mine mapping, this surface entry should be on the outcrop of the Top Split of the Mammoth (9 vein), with the No. 1 slope on the Bottom Split (8 Vein), which is up hill and northwest of the drift entry next to the pond.

<u>Mine Barriers</u>

As discussed above, there are three mine barrier pillars around the Big Mountain Mine. The southern portion of the Mine is not adjacent to another deep mine complex and, thus, a barrier pillar is not necessary. The Lykens Valley 4 vein, the lowest vein deep mined, outcrops just north of the surface divide defined by the ridge crest of Mahanoy Mountain. The barrier pillars are shown on Figure 3, Geologic Map of Big Mountain Mine Area. In addition, the eastern portion of Figure 7 from Ash (1953) is included as Figure 5 to show the mine barriers and flow of mine pool water.

The Barrier Pillar LXX is on the west side of the complex and separates the Big Mountain Mine from the Burnside Mine to the west. According to Ash (1953), the Big Mountain pool is at altitude 869 feet, where water overflows to the surface through Big

Mountain shaft. I believe this shaft discharge is actually the "drift" entry (Discharge 1) shown on the deep mine map at an elevation of 868.7 feet. The Burnside pool is at altitude 770 feet and flows through a submerged gangway into the Henry Clay-Sterling pool at elevation 770 feet. The workings of the Big Mountain Mine are connected to the Burnside Mine by a barrier-pillar tunnel from the Lykens Valley bed at elevation 342 feet to the Bottom Split of the Mammoth Vein at elevation 345 feet, with the tunnel effectively sealed with two dams. The water level of 869 feet, however, is considered to be the effective elevation of Barrier Pillar LXX. In Gannett's 1972 Operation Scarlift report it shows a portion of the Enterprise Basin (see Figure 3) west of the Barrier Pillar LXX to be in the Big Mountain Mine pool. Presumably, this portion of the Burnside Mine that drains into the Big Mountain Mine Pool is the area defined by the outcrop of the Bottom Split of the Mammoth (8) Vein and lies well above the Big Mountain Mine pool level of 869 feet.

Barrier Pillar LXXI separates the flooded portion of the Henry Clay-Sterling Mines (elevation 770 feet) and the Big Mountain Mine (elevation 869 feet) only at the very northwest portion of the Big Mountain Mine along a distance that is on the order of 1500 feet long. This mine barrier also lies just north of the Big Mountain Anticline, with the structural nature of the bedding contributing to the isolation of the Big Mountain Mine from the Buck Ridge No. 1 mine pool to north at elevation 789 feet.

The third Barrier Pillar LXV separates the flooded portion of the Corbin Mine to the east along a length of a few hundred feet with the Big Mountain Mine. The mine pool in the Big Mountain Mine apparently is not flooded against this barrier pillar as shown on Figure 5. The Corbin Mine Pool is at an elevation of 873 feet where the water flows to the surface through a water-level drift. Thus, the Corbin Mine Pool is only four feet higher than the Big Mountain Mine Pool.

The Corbin Mine Pool is the only mine pool adjacent to the Big Mountain Mine that is at a higher elevation than the Big Mountain Mine Pool. There should be little flow from the Corbin Mine into the Big Mountain Mine, because there is only four feet of head difference between the two mines along a barrier length of a few hundred feet. There could be some significant flow from the Big Mountain Mine Pool (elevation 869 feet) into the Burnside and Henry Clay-Sterling Mine Pools (elevation 770 feet), because there is 99 feet of difference in elevation along a barrier length of several thousand feet. Several mine pools are controlled by the surface overflow at the Central pump slope, which is at elevation 770 feet. In summary, it is more likely that there is a significant net water loss from the Big Mountain Mine Pool into the surrounding mines than a water gain from the adjacent mine pools.

Mine Watershed Area

The mine pool areas discussed in Ash (1953) are based on the portion of the deep mines that are flooded, with the outer limits of these flooded areas shown in gray on Figure 5. The watershed area for each mine pool would extend beyond the flooded area to either a mine barrier pillar or a surface-water divide, whichever is closer. I have calculated a watershed area for the Big Mountain Mine by assuming that: (1) the ridge crest of Mahanoy Mountain defines the southern limit of the watershed, (2) the anticlinal axis of the Big Mountain Anticline east of Buck Run, which is also coincident to a surface-water divide, defines the northern limit, and (3) the mine barriers define the rest of the watershed. The watershed limit for the Big Mountain Mine south of Barrier Pillar LXV was taken from the Operation Scarlift report. The area of the Big Mountain Mine Watershed is on the order of 1090 acres.

Mine Discharge Rates

The exact location of Discharge Point 23 is unknown, but it is described in the Operation Scarlift report as "Continuous discharge from the mine water pool in Big Mountain deep mine workings through seepage in strata. Contributes to flow and pollution to Buck Run." The average flow for Discharge Point 23 is 1.11 million gallons per day, which is equivalent to 770 gallons per minute (gpm). This average flow is based on 11 measurements collected from September 1969 to December 1970, during which the yearly precipitation (41.74 inches) in the watershed was approximately 5% below the average yearly precipitation over the period of record (43.83 inches average from 1904 to 1969). Presumably, the 770-gpm flow should represent a somewhat below average flow for the Big Mountain Mine area.

In Reed (1987), the Big Mountain Mine is described as discharging directly to the surface at elevation 869 feet and is listed as Discharge 98. The flow from Big Mountain Mine, Slope No. 1, was measured on April 16, 1975 at 2.0 cubic feet per second (ft3/sec), which is equivalent to approximately 900 gpm. Obviously, there is some confusion between Slope No. 1 and the drift entry, because they are two different locations. Presumably, this Slope No. 1 flow is the same flow as the drift entry flow (Discharge 1 or A) because Slope No. 1 is at a higher elevation and appears to be connected to the drift entry on the deep mine map. Therefore, Discharge 98, Slope No. 1, Drift Entry (Discharge 1 or A), Site 23, and Site SR23S are all presumably the same discharge.

Cravotta and Kirby (2004) list flow measurements both from the Mouth of Buck Run (BM9) and from Big Mountain Mine Slope No. 1 discharge (SR23), which is approximately 2100 feet upstream from BM9. The measured flows at BM9 in August 1999 and March 2000 were 0.93 and 4.1 ft3/sec, which is equivalent to 417 and 1837 gpm, respectively. The flows at SR23 (presumably measured on the same dates as the measurements at BM9) were 0.51 and 3.6 ft3/sec, which is equivalent to 228 and 1613 gpm, respectively. The mine discharge accounts for 55 and 88 percent, respectively, of the flow at the Mouth of Buck Run, based on these two flows. On page 34 of this report, it reports that Leanne Bjorklund of the SCRA states that SR23 has an intermittent flow. In addition, the SCRA reported that SR23 stopped flowing in 2001 while the same quality water began to flow from a nearby capped shaft, presumably SR23N or Discharge B on Figure 2, discussed later in this report. In the fall of 1998, PADEP data showed a distinct increase in pH, with aluminum concentrations near zero, according to this report.

Figure 6 is a plot of the continuous flow data from Weir #4, which is located at the mouth of Buck Run, as shown on Figure 2. The flow data is from January 2005 through the end of April 2006. The flow ranges from 143 gpm on November 24, 2005 to nearly 8700 gpm on April 3, 2005.

pH Increase

On July 6, 2006 I reviewed the Blaschak Burnside permit file at the Pottsville PADEP office to determine the source of the increase in pH in the fall of 1998. Based on the data provided by Dr. Kirby (collected by a Bucknell student from paper files at the Pottsville PADEP office), the pH increase appears to have occurred in August 1998. In addition, I spoke with PADEP technical personnel Mike Menghini, Keith Laslow, and Nat Houts about the history of the Burnside permit on July 6, 2006. In 1998 Blaschak was backfilling the Mammoth pit within the Enterprise Basin on the west side of Route 125, southeast of the village of Burnside. Although a portion of this strip mine is over the Burnside Deep Mine, as stated above, ground water from this portion of the Enterprise Basin contributes flow to the Big Mountain Mine discharge. Biosolids (sewage sludge) were approved to be used in the reclamation plan and were being stockpiled on site in the spring of 1998 next to the pit that was being backfilled. According to the July 22, 1998 inspection report, the reclamation with biosolids was hampered by extremely dry soil. According to Mike Menghini, the Department requested that Blaschak apply lime to the biosolids to control odor. The NOAA Climatological data for the Bear Gap Station, located approximately 4 miles northeast of the site, recorded a rainfall deficit of 1.54 inches for the month of July 1998. On the other hand, August had 0.91 inches above-normal rainfall. In my discussions with Blaschak personnel prior to my file review, they were not aware of any obvious source of alkalinity into the Big Mountain Mine.

Site Inspection

In the afternoon of July 6, 2006, I inspected the mine discharge locations in the Buck Run Valley with Dr. Kirby. Based on my pacing measurements, the distance from the south side of the large house that exists on the east side of Buck Run to the drift outfall (SR23S) that is the southernmost mine discharge is nearly 400 feet. This is similar to the distance shown on the deep mine map. There was flow in Buck Run up the valley from this discharge point that appeared clear and not obviously mine impacted. I estimated the up-valley flow to be less than 100 gpm. This flow appeared to go into fill material that, according to Dr. Kirby, was placed by the property owner into a portion of the pond that is shown on the 7½-minute Shamokin

Quadrangle map. Apparently this up-valley flow combines with the drift flow at some unknown point. This combined flow crosses the road through a culvert pipe that exits approximately 165 feet south of the south side of the house, as paced along the road. Dr. Kirby said that in recent years the property owner built steps at the down-stream side of this culvert to enable PADEP inspectors to sample the discharge easily. A second mine discharge (SR23N) is located approximately 175 feet north of the south side of the house. This discharge flows south where it flows through a culvert pipe that outlets on the east side of the road and joins with the drift entry flow.

According to Dr. Kirby, SCRA president Jim Koharski checked the depth of the northernmost discharge and found it to be at least 200 feet deep as he angled his plumb tool to the north through the emerging water. Following our field inspection, Dr. Kirby collected water samples from the northernmost mine discharge (SR23N) and the southernmost mine discharge (SR23S). The results from the field measurements and analytical results provided by Dr. Kirby are in Table 1.

<u>Recharge Rate</u>

The website for USGS Water Resources of PA lists for the Shamokin Creek stream gauge a "mean-annual recharge estimates for period of record" of 18.8 and 21.0 inches, depending on the hydrograph analysis method used. This stream gage (USGS No. 01554500) is located north of Shamokin in the gap of Little Mountain. According to the Operation Scarlift report, the Bear Valley Colliery extends into the Mahanoy Creek Watershed and now directs ground water and surface water from 330 acres, which were in the Mahanoy Creek Watershed before mining, into the Shamokin Creek Watershed. On the other hand, the Locust Gap, Locust Spring, Logan, and Centralia Collieries now drain ground water and surface, which were in the Shamokin Creek Watershed before mining, into the Mahanoy Creek Watershed. There is a net loss of 3332 acres or 5.2 squares miles of Shamokin Creek Watershed that was not considered in the 54.2 squares miles of watershed listed by the USGS. Thus, the watershed is 10.6 percent (5.2/49) too large, and the recharge rates should be proportionally increased to 20.8 and 23.2 inches per year. These recharge rates are equivalent to 1.05 and 1.20 gpm/acre.

INTERPRETATIONS

1. The estimated area of the Big Mountain Watershed is 1090 acres. Using the average recharge rates of 1.05 and 1.20 gpm/acre suggests the average discharge rate from the Big Mountain Mine is 1100 to 1300 gpm. Because most of the mine pool levels adjacent to the mine barriers defining the Big Mountain Mine area are 99 feet lower than the Big Mountain Mine pool, some ground water will leak from the Big Mountain Mine pool into the adjacent mine pools. Thus, the acreage that lies over the Big Mountain Mine may over estimate the flow that emerges directly from the Big Mountain Mine discharge at Site 23.
2. Based on the surface elevation of 868.7 feet and the position of the surface features on the mine map, the southern mine discharge (SR23S) is from the former drift entry on the Top Split of the Mammoth Vein in the Big Mountain Mine complex. Due to the position of the northern mine discharge, it is north of any deep-mine mapping shown on the Big Mountain Deep Mine map.
3. According to the National Oceanic and Atmospheric Administration (NOAA) Climatological Data for Pennsylvania, 2001 was one of the five driest years since 1930. The dry conditions in 2001 may have created conditions which resulted in flow out of a previously dry shaft (SR23N).
4. The water quality of the samples collected by Dr. Kirby on July 13, 2006, shown in Table 1, strongly suggests that the northern and southern mine discharges, SR23N and SR23S, respectively, are from the same source area. The north discharge, however, appears to be north of Big Mountain Anticline and an associated reverse fault, but still within the Big Mountain Mine watershed and south of mine Barrier LXXI. Even though we were unable to locate additional mine mapping in the area of the northern mine discharge, the cross section in the Map C-46 publication shows mining north of the Big Mountain Anticline.
5. The flows measured at Weir #4 at the mouth of Buck Run, shown in Figure 6, indicate that at high flows there is a large surface-water runoff component, as shown by the steep increase and decrease in flows. In addition, NOAA recorded 1.97 inches of precipitation on January 14, 2005, the same day the flow peaked at 6400 gpm. Based on the two flows

measured in August 1999 and March 2000 and recorded in Cravotta and Kirby (2004), the deep-mine flow accounts for 55 and 88 percent of the flow at the mouth of Buck Run at these two time periods. Therefore, Weir #4 overestimates the flow from the Big Mountain Mine discharges.

6. Even though deep mining occurred to a depth of more than 500 feet below the ground surface, the mine discharge exhibits ranges in flow more like a shallow ground-water system rather than a deep regional system due to the extensive deep mining that is interconnected by tunnels to the surface. In addition, fracturing due to collapse of the deep mine enhances infiltration and flow into the mine network. Therefore, unless flow monitoring with weirs on the individual discharges suggests otherwise, a treatment system may have to operate over a wide range of flows, even if the mine discharge is separated from the surface water in Buck Run.
7. The most likely source of the pH increase and resulting reduction in aluminum and acidity in 1998 is the lime used by Blaschak Coal Corp. to reduce the odors from the biosolids used during reclamation. This pH spike was observed over only two sampling periods in August, and the analytical results before and after this spike were consistent with previous results. The dramatic and short-term nature of this event suggests that lime rather than limestone or some other alkaline material was the source. In addition, the location and sequencing of the reclamation also supports this interpretation. Unfortunately, the cause of this pH spike is not something that can be easily and cost effectively implemented to treat the Big Mountain Mine discharge.

RECOMMENDATIONS

1. Weirs should be installed with continuous recording devices (transducers) at the outlets of the northern and southern mine discharges to determine the actual mine discharge from the Big Mountain Mine.
2. A third weir with a continuous recording device should be installed in Buck Run just down valley from the northern mine discharge point. The flow from this weir can be compared to the flow from the weir at the mouth of Buck Run to determine the flow contribution from the Buck Ridge Mine.

3. The flow data should be compared to precipitation data to determine the response time to precipitation. It seems that the Big Mountain Mine discharge could respond quickly to precipitation and the lack of precipitation, thereby acting more like a shallow ground-water system than a deep regional ground-water system.
4. Water-quality samples should be collected at high, moderate, and low-flow conditions to determine the acidity and metal loading at each of the locations.
5. The elevations of each of the mine discharge points should be measured and compared with topography down the valley to determine if these discharges could be collected in a separate channel from Buck Run and if there is enough area for passive treatment west of Buck Run and south of Shamokin Creek.
6. Perform a reconnaissance of the Big Mountain Mine area to determine if there are locations of large surface-water inflows to the underlying deep mine. If this condition exists, consideration should be given to constructing surface channels to keep these flows out of the Big Mountain Mine to reduce the amount of water impacted by acid-mine drainage.

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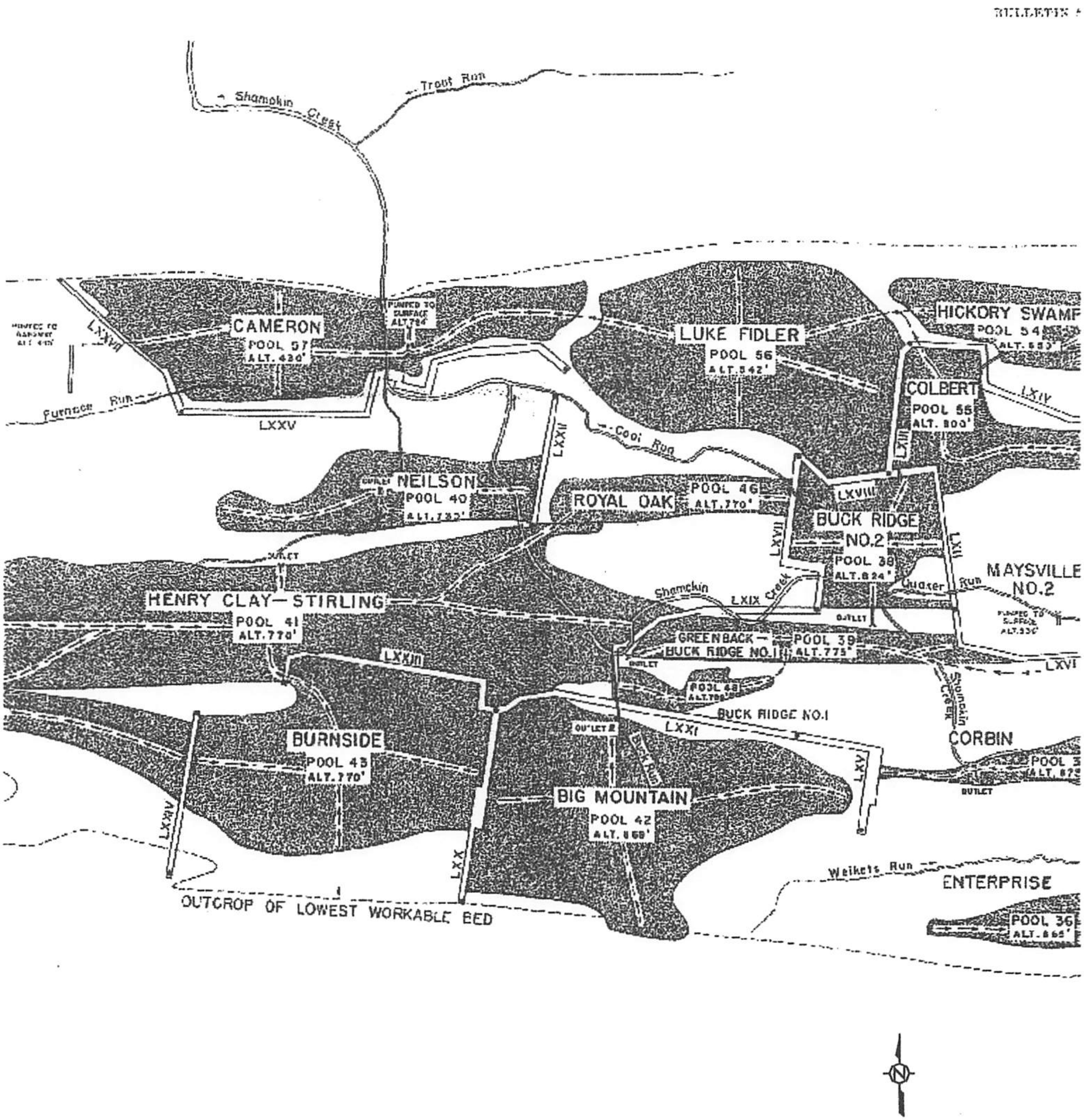
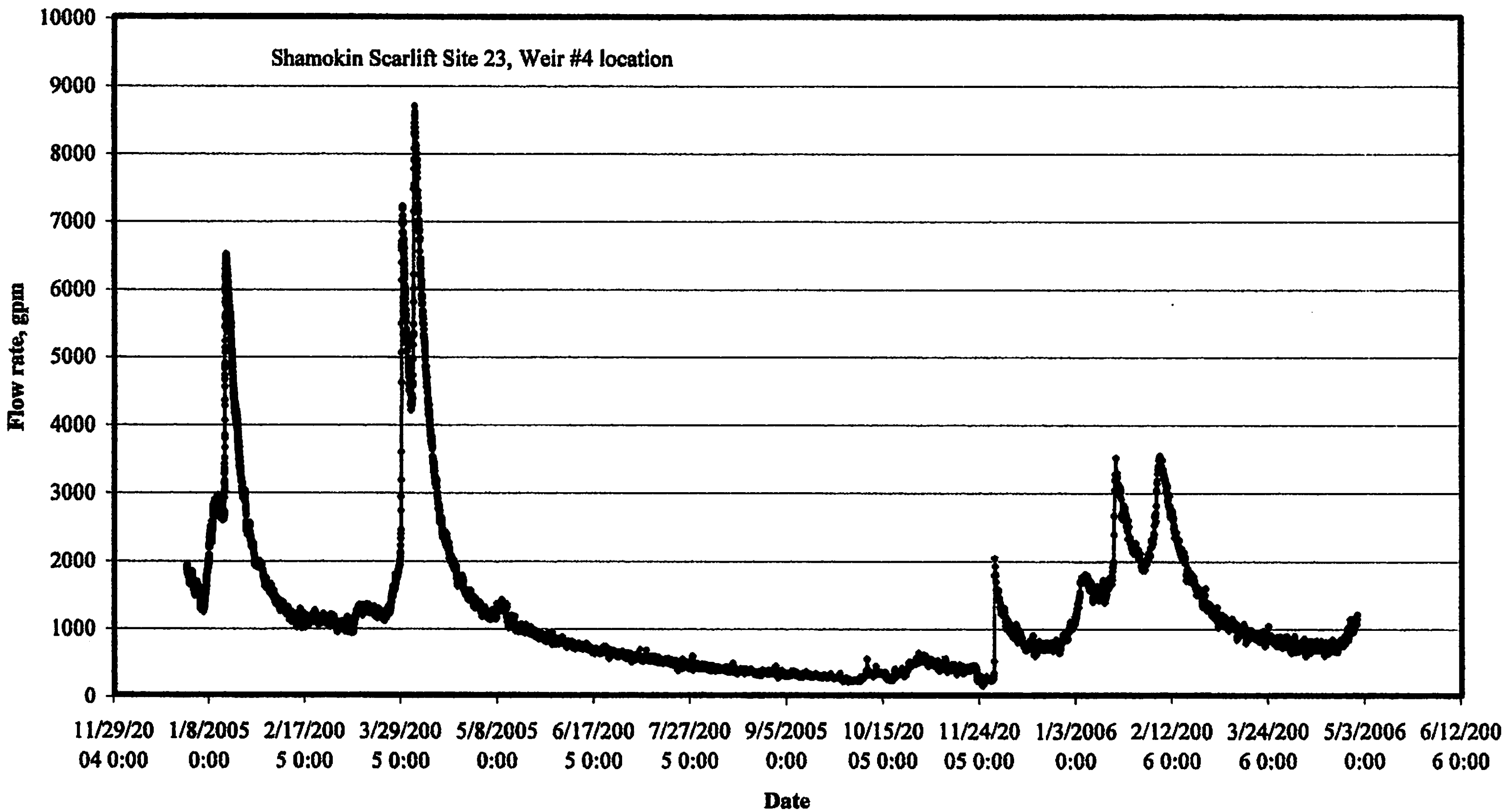
FIGURE 5
Shamokin Creek Restoration Alliance
Flow of Mine Pool Water
Westerly Portion of Western Middle Field



FROM: Ash, S.H., Kennedy, D.O., and Link, H.B., 1953, Barrier Pillars in the Middle Field Anthracite Region of Pennsylvania: US Bureau of Mines Bulletin 521, 92 p. (Figure 7)

SCALE: 1" = 3000'

FIGURE 6
Shamokin Creek Restoration Alliance
Stream Flow Hydrograph
Mouth of Buck Run



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9/14/2006

TABLE 1
Shamokin Creek Restoration Alliance
Water Analyses from SR23N and SR23S
July 13, 2006

Site	DateTime M/D/Y	Temp C	SpCond mS/cm	DOsat %	DO Conc mg/L	pH	ORP mV
SR23N	7/13/2006 12:08	11.16	0.858	14.4	1.58	3.07	468
SR23S	7/13/2006 12:23	11.13	0.837	13.9	1.53	3.14	502

Site	Al, mg/L	Mg, mg/L	Ca, mg/L	Fe, mg/L	Mn, mg/L	H. Acidity	Alk	SO4
SR23N	7	59.6	32.3	6.7	5.4	90.3	<1.0	283
SR23S	6.3	53.1	29.8	7.2	4.8	76	<1.0	259