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West Virginia Mine Pool Atlas Project—A Work in Progress

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Introduction

The Mine Pool Atlas project is a two-year study funded by the West Virginia Department of Environmental Protection (WVDEP) to evaluate abandoned coal mines as potential groundwater sources. Although West Virginia receives an average of 44.31 inches of precipitation each year (SERCC, 2011) and is considered to have an abundant supply of water, much of West Virginia's precipitation exits the State by way of its many streams. The remainder infiltrates the ground surface, but only a small amount of this water provides recharge to groundwater aquifers. One currently underutilized and often overlooked source of stored groundwater is abandoned coal mines (fig. 1). In order to develop an understanding of the potential of this water source for development, the West Virginia Geologic Survey (WVGES) is in the process of building a dynamic, interactive geographic information system (GIS) to portray the location of mine pools that could provide large volumes of water for various private, public, and industrial uses. The GIS will provide tools to estimate mine pool volumes in West Virginia.

Coal bed and mining information available from the West Virginia Geological and Economic Survey (WVGES) Coal Bed Mapping Program (CBMP) during the study was used to estimate the potential extent of mine flooding and the volume of water contained in each mine pool. Figure 2 shows the status of work being conducted by CBMP (B.M. Blake, West Virginia Geological and Economic Survey, unpub. data, 2011). (Note: After this presentation was given, the West Virginia Mine Pool Atlas was completed, in 2012, and is available for download at *http://www.wvgs.wvnet.edu/www/coop_rpts/coop_research.htm*.) The results of the study are presented in a PDF-format report that includes a series of maps showing information and statistics about each mine pool.

Figure 1. Water discharging from a power hole in the down dip end of the Summerlee mine in the Sewell coal bed emerges from a pipe at Dempsey, WV, where the water is treated. The mine is approximately 340 feet below the surface at this location (photograph by G.H. McColloch).

Project Overview

CBMP data are being used to determine which coal beds have mine pools capable of supplying large quantities of groundwater. Underground mining has taken place in 69 of 73 of the West Virginia's mineable coals, and information about underground mining in these coal beds is being incorporated in the CBMP GIS. Mine polygons of approximately 9,500 underground mines have been digitized from mine maps (fig. 3). In addition, a cropline, a structure contour of the elevation of the base of the coal bed, coal bed elevation raster data, and an isopach have been created for each coal bed.

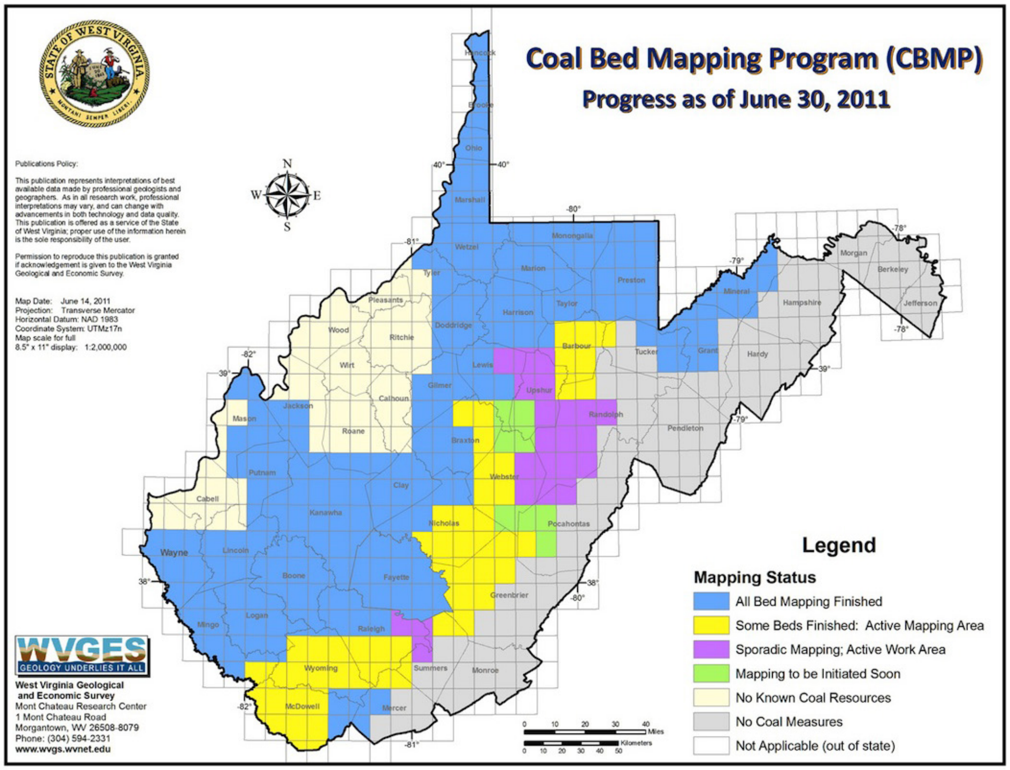

Figure 2. Status of coal bed mapping in West Virginia by the WVGES Coal Bed Mapping Program, projected to June 30, 2011 (B.M. Blake, West Virginia Geological and Economic Survey, unpub. data, 2011).

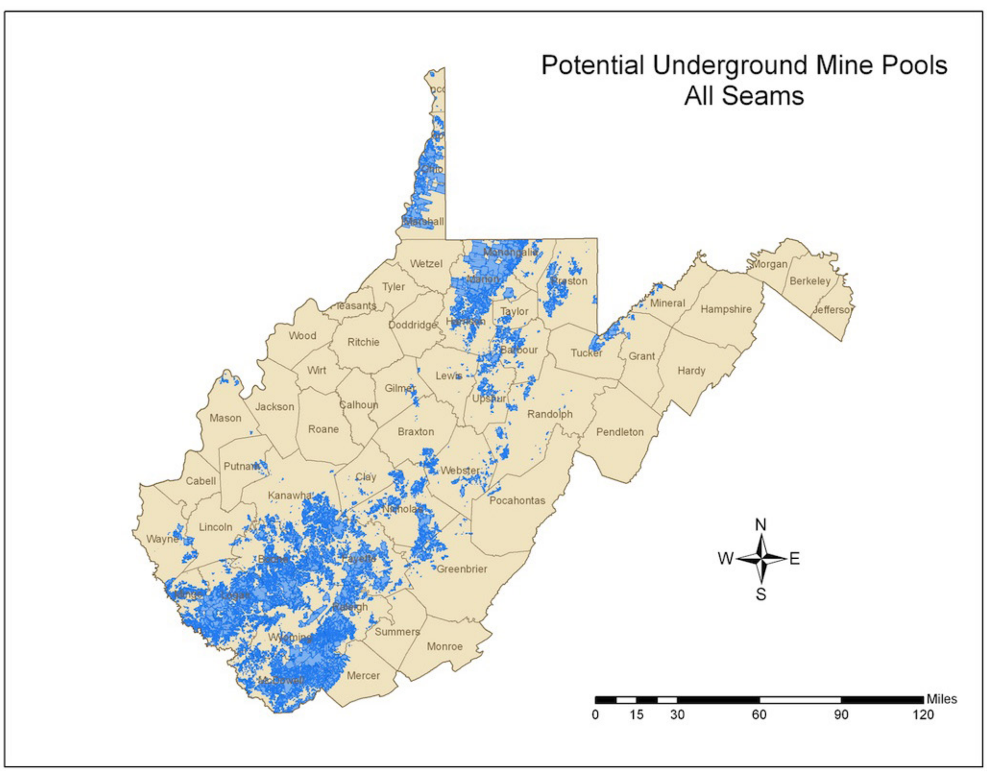

Figure 3. The footprints of all documented underground mines in West Virginia coal beds delineate the areas of potential mine pools in the State (WVGES, 2010a).

GIS analytical tools have been developed for this study to assist in determining the position of each mine with respect to drainage (above, near, or below), the relative amount of potential groundwater flooding (not flooded, partially flooded, or flooded), and direction of groundwater flow. Much of the underground mining in the State occurs above drainage, and the extent of potential mine flooding is more dependent on the orientation of the mine than on the volume of the mined void. Maps and statistics about each mine pool derived from coal bed and mining information available from the WVGES CBMP during the period the mine pool study is conducted are presented in a series of five maps per mine pool in the final report to WVDEP.

The project consists of the following tasks:

- Conducting a regional evaluation of each coal bed to determine which parts of the bed are above major drainage, near major drainage, and below major drainage.
- Calculating the estimated mine pool volume of each coal bed, assuming an average thickness based on WVGES CBMP GIS data and an extraction rate determined by the mining patterns for mines located near and below drainage.
- Developing map templates for the report.
- Preparing maps of each mine pool for the report.

Regional Evaluation

Because this study was ongoing in 2011, the focus of this presentation is the regional evaluation of each coal bed using WVGES CBMP GIS data layers and models. The GIS data layers for each coal bed include underground mine polygons, coal boundaries (croplines), and a structure contour of the elevation of the base of the coal bed (fig. 4). In addition to visual analysis of GIS data layers, models were developed to aid in determining the position of each mine with respect to drainage, the amount of potential groundwater flooding, and direction of groundwater flow.

The Watershed Model, which was used to determine groundwater flow direction, is a standard Environmental Systems Research Institute (Esri) ArcMap™ 10.0 geoprocessing model that uses the Spatial Analyst™ Hydrology toolset to convert the CBMP coal bed elevation raster data into predictive hydrologic flow direction and flow accumulation raster data. From these generated datasets, the model outputs generalized "stream" features that can be used to predict the direction of groundwater movement through mine voids relative to the coal outcrop. This model was run for all coal beds to aid in determining the extent of potential flooding in underground mines. An example of model output for the Sewell coal bed is shown in figure 5.

The Mining Above/Below Drainage Model (MABD), which is a geoprocessing model (a series of standard ArcGIS

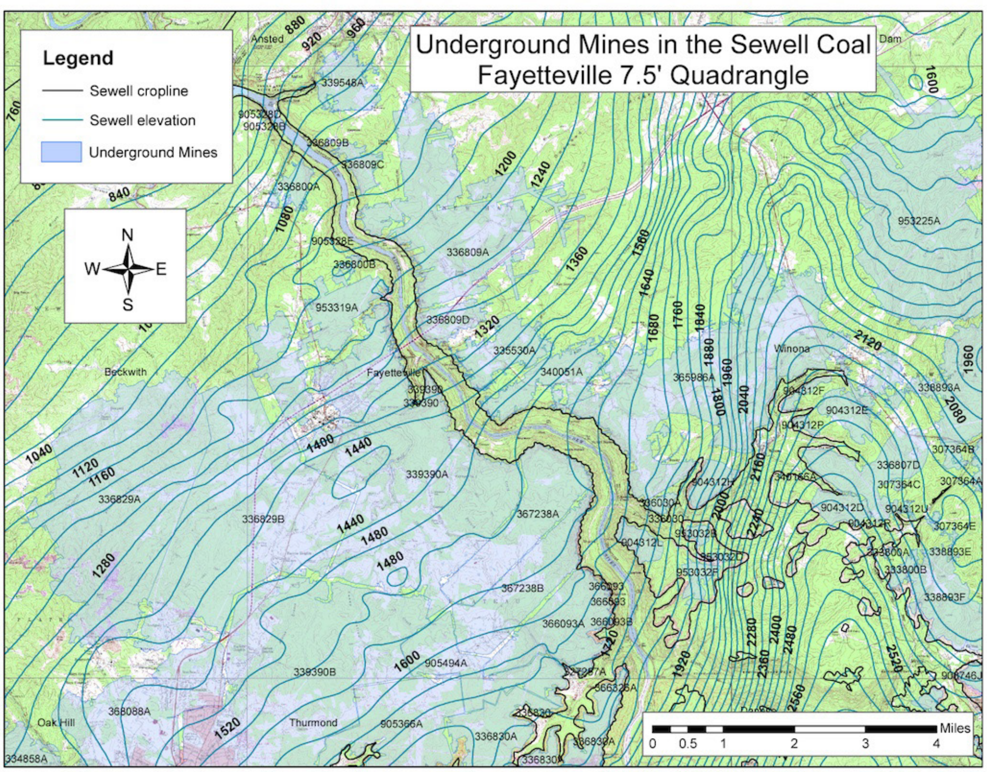

Figure 4. Extent of underground mines in the Sewell coal bed, in the Fayetteville 7.5-minute topographic quadrangle and surrounding area.

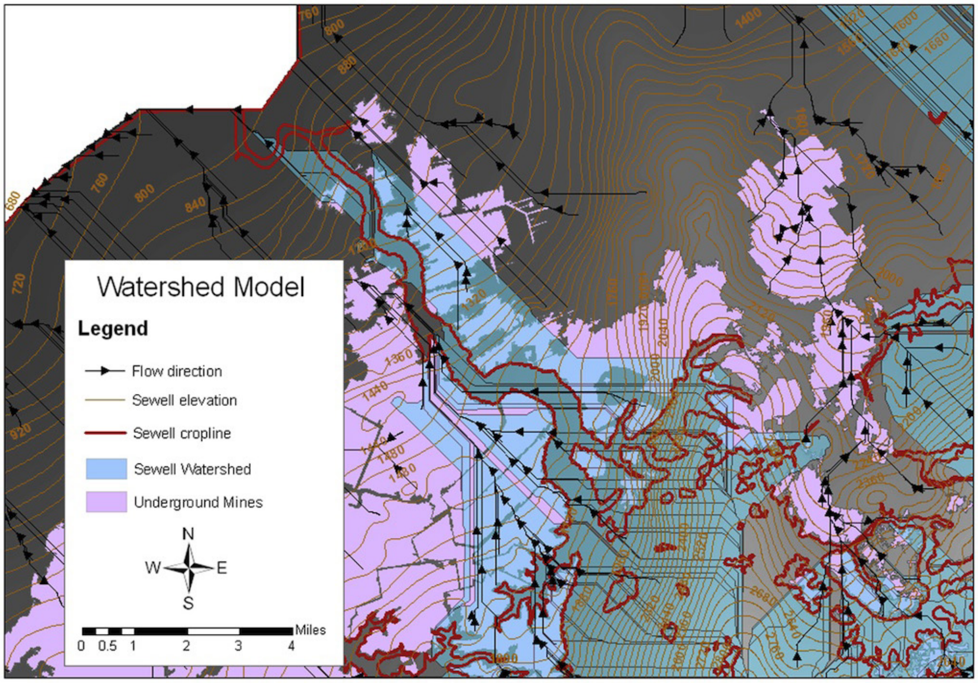

Figure 5. Watershed model output shows predicted direction of groundwater flow through mine voids in the Sewell coal bed. Black arrows show flow direction. The blue watershed zone represents areas contributing to surface-water flow. This model was run for all coal beds having available input data to aid in determining extent of potential flooding in underground mines.

tools executed in a certain order), was developed for this study to determine the position of mines with respect to drainage based on perennial stream elevations. Two versions of the MABD Model, the Major Drainage Elevation Model (MDEM) and the Perennial Drainage Elevation Model (PDEM), were generated by assigning elevations to points selected from the National Hydrography Dataset (NHD) shown on USGS 7.5-minute quadrangle maps and located within hydrologic features. The MDEM selected points located within digitized perennial stream polygons; the PDEM selected points located along digitized perennial stream lines. The resolutions of these digital elevation models (DEMs) were generated to 10 meters to match the CBMP coal bed elevation raster data. The coal elevation DEM was subtracted from the MDEM and the PDEM to indicate regions of the coal bed that lie above and below major drainage; these results were individually overlaid with the mine footprint to obtain the two versions of the final GIS layer of potentially flooded mine areas shown in figures 6 and 7.

The effectiveness of the MDEM and PDEM models was tested by comparing the model output for 472 mines in the Sewell coal bed located in southern West Virginia with the results of the visual structure contour/cropline examination of the same underground mines. The results are shown in table 1. The visual structure contour/cropline examination is the most effective method of identifying drainage position and potential extent of flooding in mines. The MDEM proved ineffective in predicting mine position with respect to drainage and potential extent of mine flooding. The PDEM is a fair predictive tool, but it is most effective in identifying potential flooding below drainage.

The Sewell coal bed was selected to assess the MABD GIS models because it has been extensively mined by underground methods in southern West Virginia (fig. 8). Coal and mining information for the Sewell coal bed, including mine extent polygons, coal cropline, structure contour of the base of this coal, and scanned images of mine maps (WVGES, 2011), were visually examined to establish which areas have adequate data available to determine the position of each mine relative to major drainage (above, near, or below) and to determine the potential for each mine to be partially or completely filled with groundwater. In addition, locations of discharges from a few underground mines in the Sewell coal bed within the New River Gorge near Fayetteville, WV, were verified by fieldwork being conducted for geologic mapping of the Fayetteville 7.5-minute topographic quadrangle map (figs. 9, 10, 11, 12, and 13).

Of the 884 documented mines in this coal bed, 472 are located in areas in which cropline, structure contour, and coal bed elevation raster data are available to provide input to the models. Visual structure contour/cropline examination of underground mines indicates 431 mines are above drainage, 24 are near drainage, and 17 are below drainage. Nineteen of the mines that are near drainage and 250 of the mines above

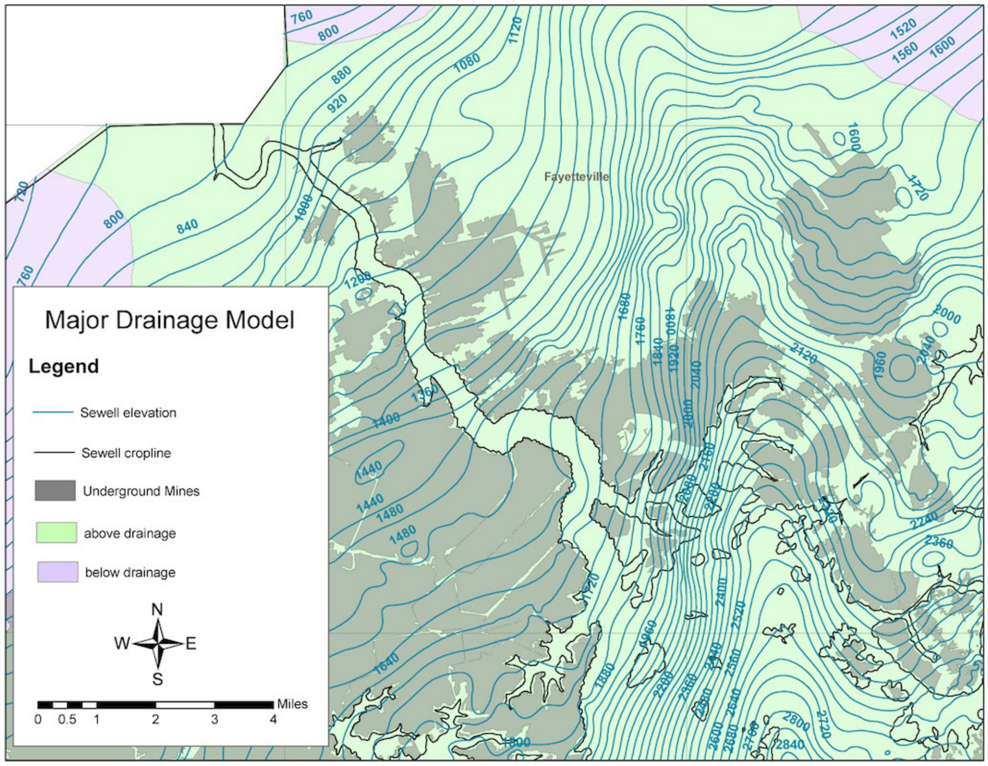

Figure 6. Major Drainage–Mining Above/Below Drainage (MABD) model output shows areas of the Sewell coal bed that lie above and below major drainage. This model, which was developed to determine mine position with respect to drainage based on perennial stream elevations, generated a Major Drainage Elevation Model (MDEM) by assigning elevations to points selected from the National Hydrography Dataset (NHD) shown on the USGS Fayetteville 7.5-minute quadrangle map and are located within digitized perennial stream polygons.

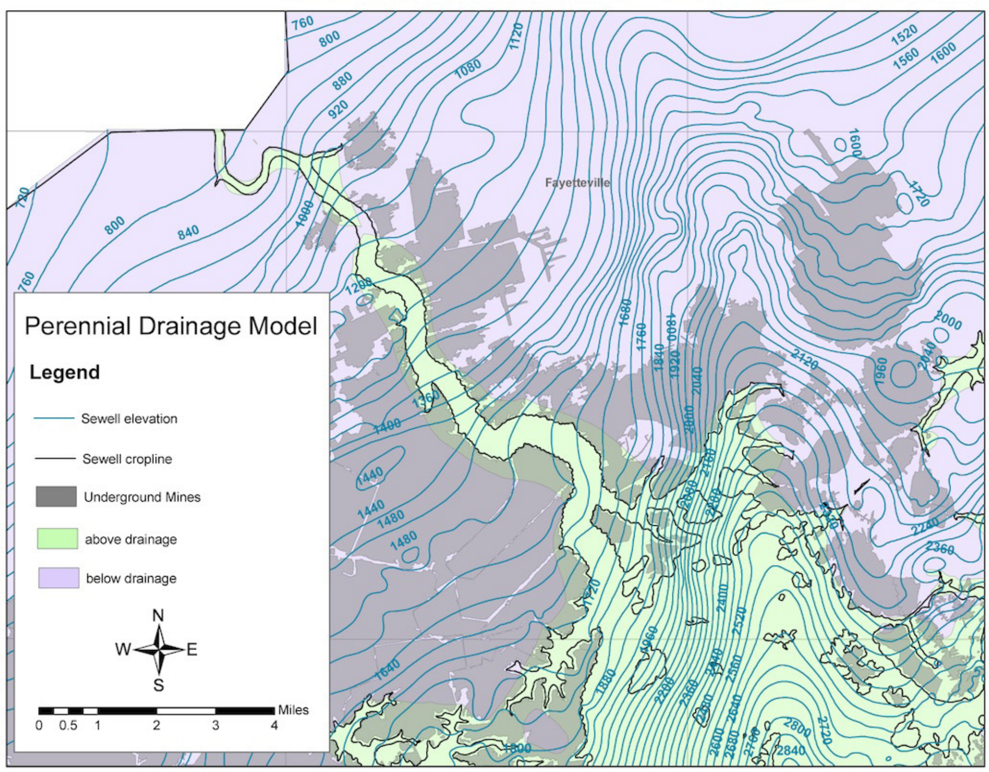

Figure 7. Perennial Drainage–Mining Above/Below Drainage model output shows areas of the Sewell coal bed that lie above and below perennial drainage. This model, which was developed to determine mine position with respect to drainage based on perennial stream elevations, generated a Perennial Drainage Elevation Model (PDEM) by assigning elevations to points selected from the National Hydrography Dataset (NHD) shown on the USGS Fayetteville 7.5-minute quadrangle and located along digitized perennial stream lines

Table 1. Comparison of structure contour/cropline examination to the major and perennial Mining Above/Below Drainage GIS models for determining mine position with respect to drainage and extent of probable groundwater flooding for underground mines in the Sewell coal bed.

Mine position relative to drainage/extent of probable groundwater flooding		**METHOD**		
		Structure Contour/ Cropline examination	**Perennial drainage model**	**Major drainage model**
Mines above drainage	not flooded	181	265	428
	partially flooded	250	118	2
	flooded	0	48	1
Mines near drainage	not flooded	2	0	23
	partially flooded	19	15	1
	flooded	3	9	0
Mines below drainage	not flooded	0	0	12
	partially flooded	0	0	4
	flooded	17	17	1
Total Mines		**472**	**472**	**472**

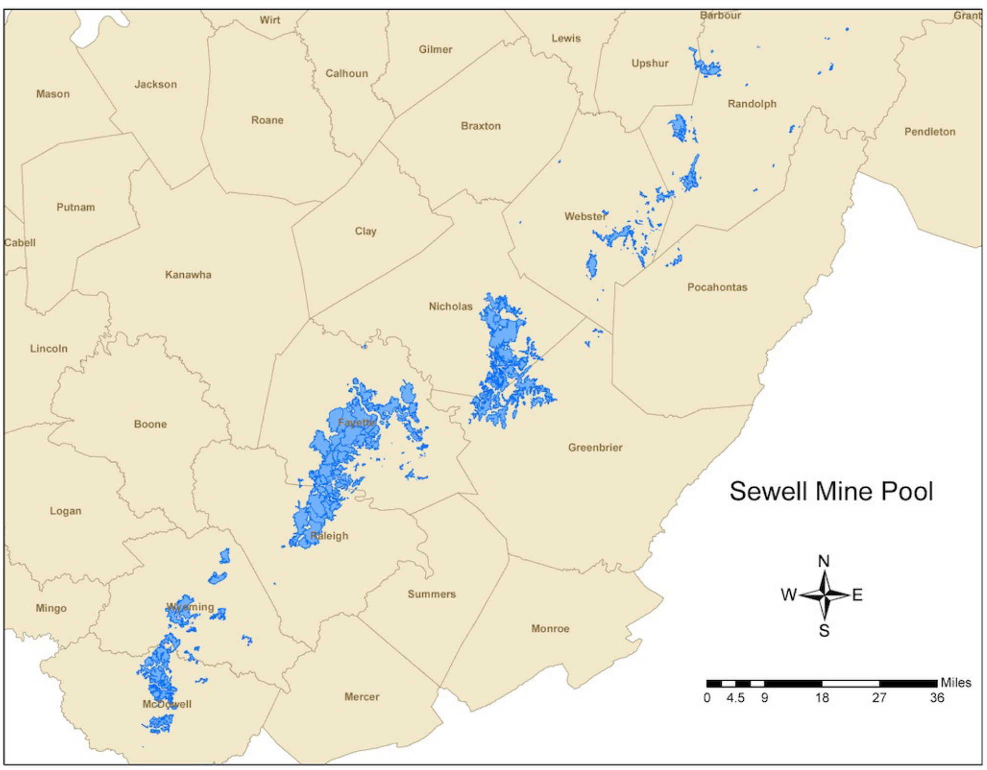

Figure 8. The footprints of all documented underground mines in the Sewell coal bed of the Pennsylvanian New River Formation (WVGES, 2010b).

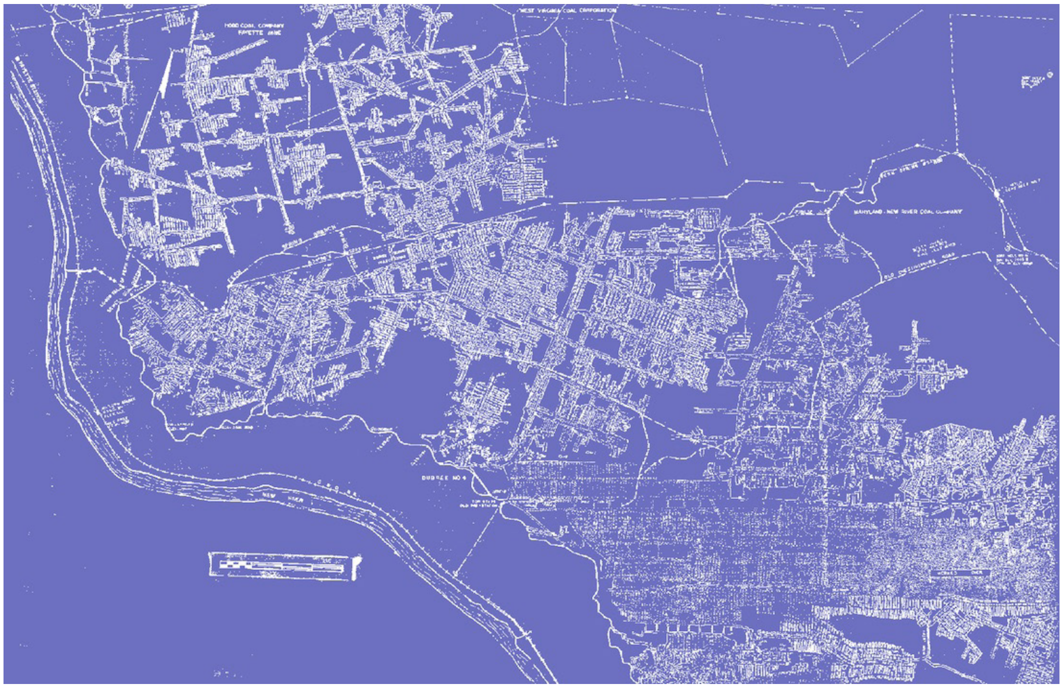

Figure 9. A mine map, Document #340051, shows the locations of Sewell coal mines in the New River Gorge area east of Fayetteville, WV (WVGES, 2011).

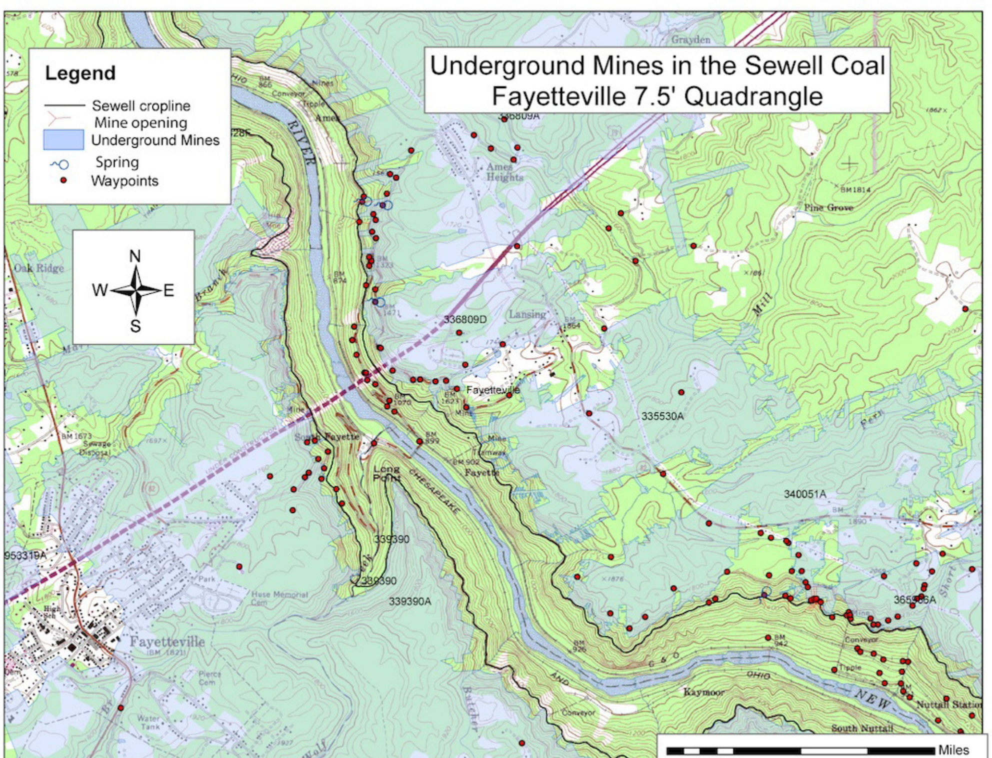

Figure 10. The locations of mine openings and mine water discharges were among waypoints recorded during the process of geologic field mapping.

Figure 11. Mine water discharges from a trough built into an opening in the Ames Mine in the New River Gorge east of Fayetteville, WV (photograph by G.H. McColloch).

Figure 12. Mine water discharges through an earthen seal of an undocumented mine opening in the Sewell coal bed west of the Dubree No. 4 mine near the site of Nuttallburg in the New River Gorge. The location of this photograph is approximately 415 yards west of the location of the photograph in figure 13 (photograph by G.H. McColloch).

Figure 13. At this opening in the Dubree No. 4 mine in the Sewell coal bed near the site of Nuttallburg in the New River Gorge near Fayetteville, WV, no water is detected. The grate over the mine opening provides sufficient access for bats (photograph by G.H. McColloch).

drainage are potentially, partially flooded. Three of the mines near drainage and all 17 mines below drainage are potentially, totally flooded. The potentially completely flooded mines have footprints that range in area from 1.7 to 4,587.4 acres and jointly occupy approximately 33,361 acres. The underground mines located below or near drainage have the greatest potential to provide large quantities of water. The down dip areas of some of the large mines located above drainage may also be potential sources of groundwater.

Acknowledgments

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