

# USING ESRI'S ARCSCE TO VISUALIZE THE GEOSPATIAL RELATIONSHIP BETWEEN A COAL REFUSE DISPOSAL AREA, AMD SEEPS, AND UNDERGROUND MINING OPERATIONS<sup>1</sup>

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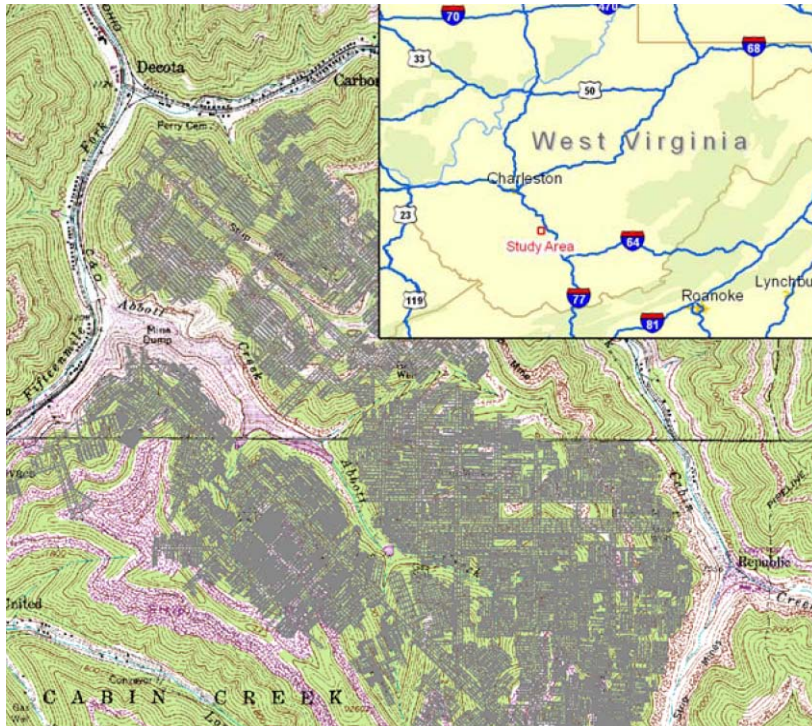
**Abstract.** Downstream of the Abbott Hollow coal refuse disposal site in Kanawha County, West Virginia, Fifteenmile Fork, receives significant metals and acidity runoff from AMD (Acid Mine Drainage) Seeps. The seep water chemistry is characterized as having a pH of 3.2 su, 240 mg/L iron (dissolved), manganese (dissolved) of 13.2 mg/L, and aluminum of 22.1 mg/L (dissolved), which results in the degradation of water quality of downstream Fifteenmile Fork. 3D-GIS models can help visualize the coal refuse disposal area and surrounding underground mines in a new way. One of the 3D GIS software tools available is ESRI's (Environmental Systems Research Institute) is the ArcScene software application. ArcScene models helped visualize the geospatial relationship between the coal refuse disposal area and surrounding underground coal operations that have mined in three different coal seams. Data for this project was gathered from several sources: AutoCad files; ortho-photos; company; and OSM-Mine Map Repository (MMR) scanned mine paper maps. Both pre-and post-SMCRA (Surface Mining Control and Reclamation Act, 1977) placement of AMD-producing refuse materials in the Abbott Hollow refuse area caused and contributes to the generation of AMD seeps from the refuse area. The underground mines contribute to inflows into the refuse pile, which has the geochemical character to produce and contribute to the AMD seeps. The results of this project illustrate how ESRI's ArcScene can be used successfully to visualize the complex geologic spatial relationship between stacked underground mines and adjacent coal refuse disposal areas.

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## INTRODUCTION

A pattern of AMD (acid mine drainage) seeps that occur adjacent to the Abbott Hollow refuse area stain and coat the streambed to downstream reaches of Fifteenmile Fork, Kanawha County, West Virginia. Iron, manganese, and pH levels exceed in-stream water quality limits downstream of the refuse site; however, metals and acidity levels are in compliance upstream of Abbott Hollow. Multi-seam underground mining that surrounds Abbott Hollow contributes to the refuse discharges. The use of ERSR's ArcScene 3D visualization modeling application allows a 3D perspective of the relationship between underground mining, the refuse area, and the AMD seeps. The AMD seeps cause significant loadings of acidity and metals on Fifteenmile Fork but the source of the seeps seemed to be in question. ArcMap and ArcScene were both used for this project and ArcScene specifically was used to visualize the complex 3D relationship between the refuse area valley fill and the role of underground mines to the contribution of the AMD seeps. The location of the study area is shown in Figure 1.



**Figure 1.** Location of study area in Kanawha County, WV

The use of Abbott Hollow as a refuse disposal area started approximately 60 years ago. Even before the effective date of the Surface Mining Control and Reclamation Act (SMCRA), the Fifteenmile Fork watershed had undergone extensive mining in conjunction with the placement of coal refuse in the adjacent Abbott Hollow refuse area. Activities associated with the placement and/or maintenance of pre-and post-SMCRA refuse materials over the years have caused and/or contributed to the degraded water quality of Fifteenmile Fork, downstream of the refuse area. ArcMap and ArcScene were used to visualize the geospatial relationships between the thickness of refuse fill in Abbott Hollow and the surrounding underground mines. Some mines are within the confines of the refuse area that are buried with refuse material, and discharge mine water into the fill.

### **PHYSICAL SETTING**

Figures 2, 3, and 4 show the AMD (acid mine drainage) seeps that flow into the receiving stream, Fifteenmile Fork, which is a tributary of Cabin Creek. The AMD seeps are located immediately adjacent to the Abbott Hollow refuse area. The WVDEP-DMR (West Virginia Department of Environmental Protection-Division of Mining and Reclamation) permit data reflects the AMD seepage runoff that flows into Fifteenmile Fork and degrades downstream water quality for several miles.



**Figure 2.** Runoff from AMD seeps impacting Fifteenmile Fork



Pre-SMCRA mining discharges into upper Fifteenmile Fork produce metals and neutral pH water quality in-stream limits that are met upstream of the Abbott Hollow Refuse disposal site, but not downstream of the refuse facility. The data in Tables 1-2 show the Fifteenmile Fork monitoring in-stream data. Downstream of the Abbott Hollow refuse site, Fifteenmile Fork receives significant metals and acidity runoff from the AMD Seeps.



**Figure 3.** Runoff chemistry pH 3.2 su, Fe-d 240 mg/L, Mn-d 13.2 mg/L, and Al-d 22.1 mg/L



**Figure 4.** AMD seepage pools develop on Fifteenmile Fork bank



## **Characteristics of the Abbott Hollow Refuse Area**

Both coarse and fine coal refuse were deposited in the refuse area. The fine coal refuse was disposed in slurry ponds that were located on coarse refuse materials. The WVDEP permit ABA data demonstrated that the Abbott Hollow refuse materials would produce acidity and/or metals. The ABA (acid base accounting) data for the refuse materials showed a range of negative NAB (net acid base) values that ranged from -0.1 to -58 CaCO<sub>3</sub>/lbs 1000 tons equivalent. Numerous refuse samples also showed negative neutralization potential (NP) values, which clearly indicate the potential for AMD production.

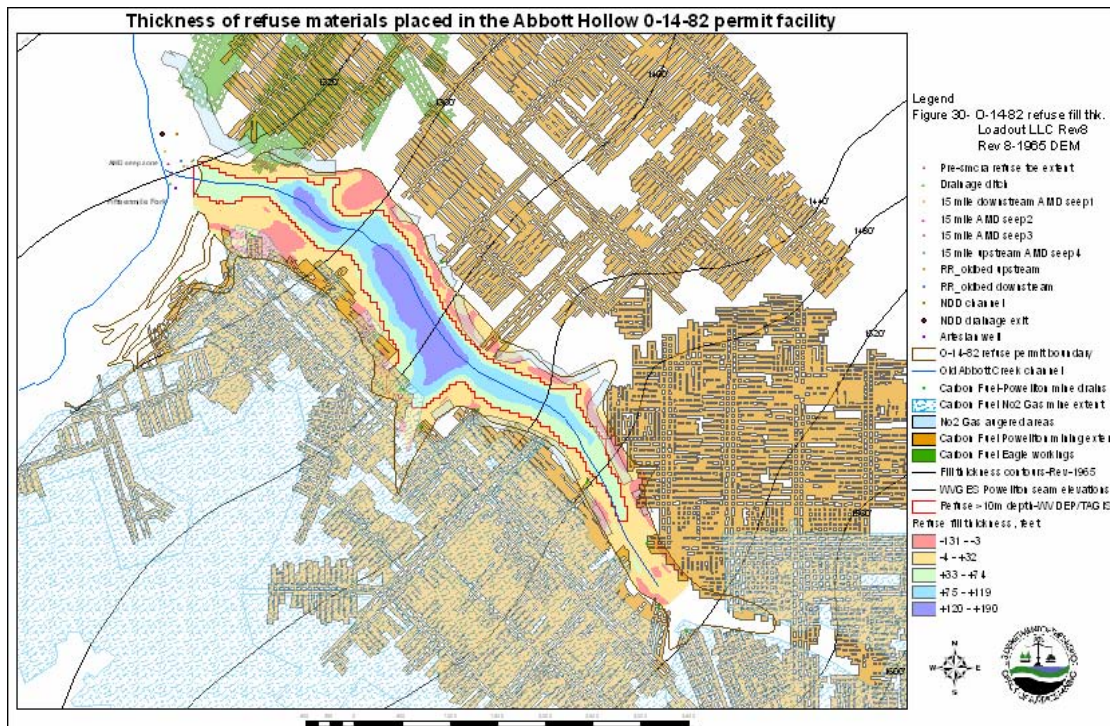
## **GIS Methodology**

### **Abbott Hollow Refuse Area**

Three different surfaces were utilized to depict the Abbott Hollow refuse fill surface for this project. The surfaces that were used consisted of a company map that depicted the 2004 refuse valley floor surface (Loadout, 2003); the Dorothy and Eskdale 1965 quadrangles; and the 2003 SAMB (WV Statewide Addressing and Mapping Board) data. All three surfaces were compared and all three essentially showed the same general trend for the refuse area, even though the time frame for each ranged from 1965 to 2004. 1965 DEM was generated using the USGS Digital Line Graph hypsography from the Eskdale and Dorothy 1:24000 7.5 minute quadrangles. The resolution of the 1965 DEM is 10 feet.

Digital ortho-photography for general alignment of natural and/or cultural features, e.g., roads, railroads, streams, etc that also existed on the company maps were used for georeferencing all maps. The 2003 SAMB ortho-photos became the control base for all subsequent geo-referencing of the company maps (Mastrorocco, 2007), and was used for visualization in ArcScene. Figure 6 shows the thickness of the refuse materials that were placed in the Abbott Hollow refuse area from 1965 to the mid-1980's. The maximum thickness of the refuse material materials that were placed in the refuse fill ranged up to 190 feet thick (refer to map legend in Figure 5).

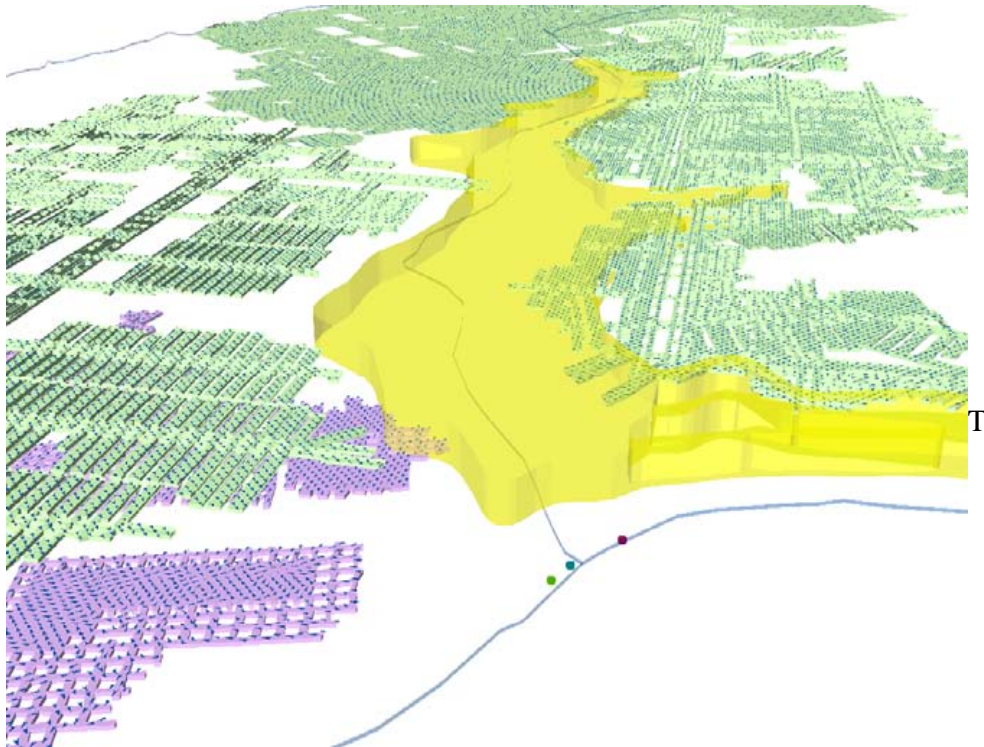




**Figure 5.** Thickness of refuse materials in the Abbott Hollow refuse area (yellow) surrounded by underground mines; the black lines are the Powellton coal seam structure contours.

To determine the thickness of the fill in the refuse area, a raster calculation was conducted by subtracting the 1965 DEM from the 2003 SAMB DEM. The thickness of these materials ranged up to 190 feet thick. The dark blue color in Figure 6 indicates a thickness of 75-119 feet of refuse materials; the purple indicates a thickness of 120-190 feet of refuse materials. The resultant grid depicts areas of gains (refuse placed) as positive values and areas of loss (refuse extracted) or loss of material as negative values; the values represent the depth of gain or loss of material. Figure 6 shows the thickness of the refuse materials that were placed in the Abbott Hollow refuse area from 1965 to 2003; refuse placement stopped during the mid-1980's.

The negative refuse fill thickness values in the figure reflect areas in the valley fill that have been either eroded, or apparently removed by the mine operators. Figure 6 shows the refuse thickness contours demonstrates that the area shown by the refuse fill (>10 meters thick) covers the pre-SMCRA mine dump that was placed from at least 1965 to 1987, which indicates post-SMCRA filling of the valley fill with refuse beyond pre-SMCRA time. Figure 6 displays the 3D occurrence of the Abbott Hollow refuse area, underground mining, and the AMD seeps.



**Figure 6.** Abbott Hollow refuse area (yellow) surrounded by underground mines

In order to use ArcScene and view the 3D aspects of the study area, the thickness of the refuse area was mapped and calculated by ArcMap (Spatial Analyst). The depth of the Abbott Hollow refuse fill a comparison was made using the DEM (digital elevation models) from the 2003 and the 1965 USGS Eskdale and Dorothy quadrangles. The 2003 DEM was obtained from the West Virginia GIS Technical center and was created from statewide Spring 2003 aerial photography in partnership with the U.S.G.S. The DEM that used the 2003 topography was generated at a resolution of 3 meters (1/9 arc second-approx 10 feet) and is compliant with the National Elevation Dataset standards. The 1965 DEM was generated using the USGS Digital Line Graph hypsography from the Eskdale and Dorothy 1:24000 7.5 minute quadrangles. The 1965 DEM's (quadrangles) provide a surface before post-SMCRA (1977) refuse fill placement.

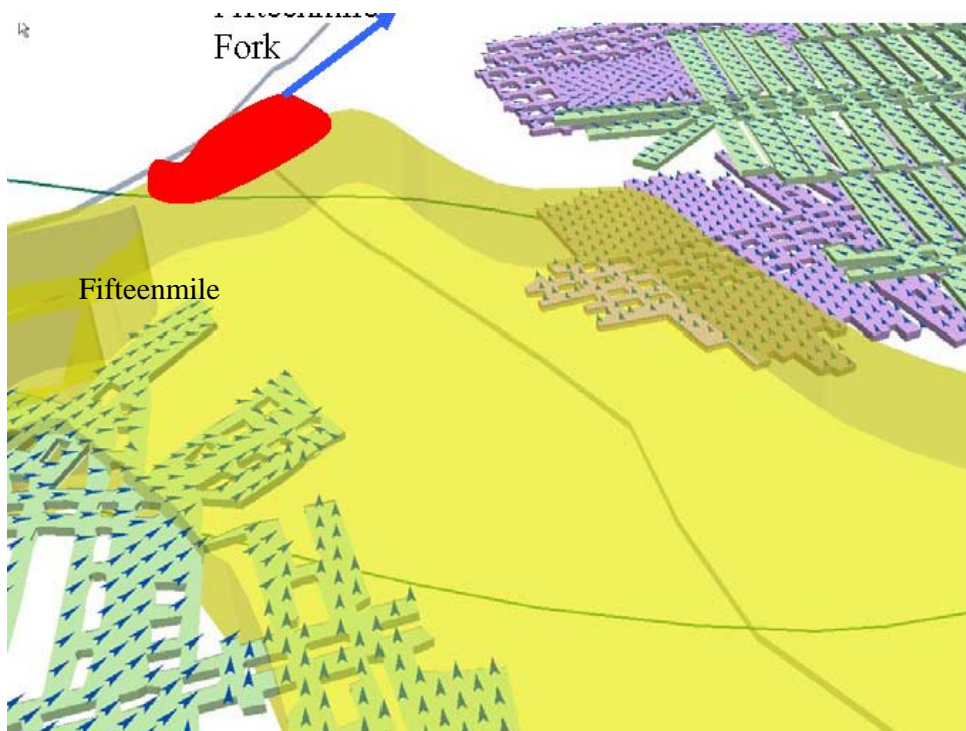
### **Underground mines surrounding Abbott Hollow**

The company provided digital AutoCAD (DWG) files that were referenced to the West Virginia South Zone NAD 1983 State Plane Coordinate System for the No. 2 Gas, Powellton, and Eagle seams (Penn Virginia, 2006). Other digital data that was provided by the Company included three digital non-georeferenced coal reserve maps for each mined seam in the area. In addition, four digital AUTOCAD DWG files georeferenced reserve maps from the company were utilized. Since the Autocad DWG files were already referenced to an established coordinate system and contained well locations that could be identified on the



un-referenced company maps, the DWG files were used as a control base (Mastorocco, 2007).

The study also uncovered localized variation in attitude of the coal seams resulting in a greater likelihood of discharge concentrated around Abbott Hollow. In some cases, the mines developed mine pools that provide mine (seepage) water to the Abbott Hollow refuse pile. Thus, some Powellton and Eagle mines are believed to contribute to inflows into the refuse pile, which has the geochemical character to produce the AMD seeps that have been emanating from the refuse area. Consequently, some pre-SMCRA underground mines contribute to the generation of AMD seepage that emanates from the refuse toe shown in Figure 7.

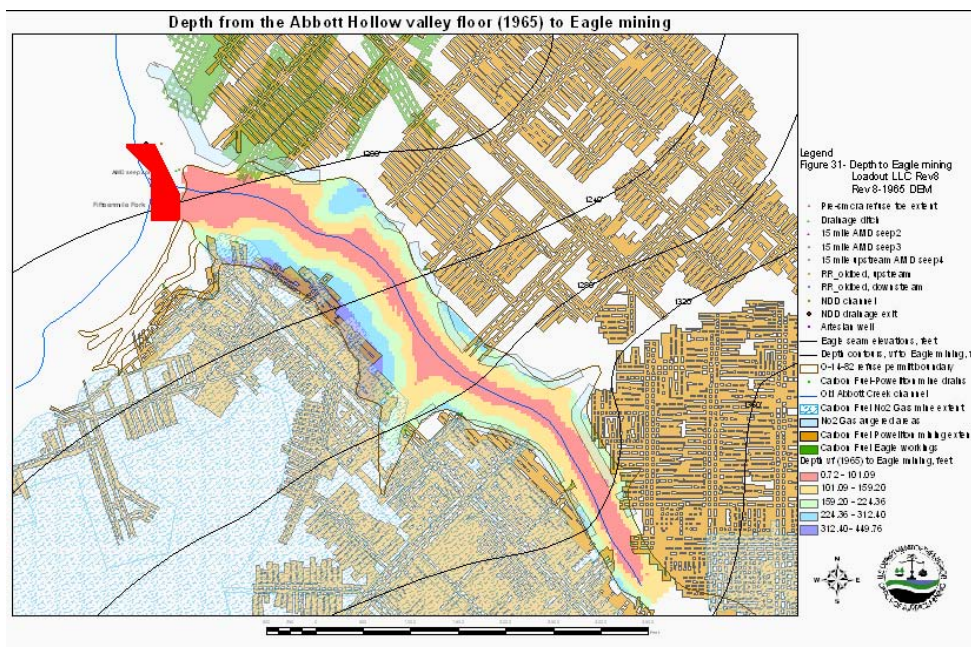


**Figure 7.** South to north view of Powellton (green) and Eagle mining (purple); Powellton seam structure contours; red shows the AMD seep zone.

### The depth from the valley floor to pre-SMCRA underground mining

The depth of Powellton seam mining occurred essentially above the Abbott Hollow valley floor; however, placement of refuse materials in the hollow of up to 191 feet thick covered most of the Powellton seam openings; the locations of draining Powellton portal openings occur along the refuse area. Initially, the depth of the refuse fill to Eagle mining was determined by subtracting the USGS 1965 DEM surface from the 2004 company refuse map

The depth from the Abbott Hollow refuse area down to Eagle seam underground mining was determined using ArcMap, the Eagle structure contour (elevations from the company maps) and the 2003 SAMB surface. The Eagle mined seam structure contour elevations were first subtracted from the SAMB surface elevations. This calculation of the depth to the Eagle seam surface includes the depth of the refuse fill to the 1965 elevation (DEM) surface. The fill depths were subtracted, resulting in an approximate depth below the 1965 valley floor to the Eagle seam. Figure 8 shows the thickness of the refuse material in the fill, relationship between the Powellton (green) and Eagle seams underground mining, and the location of the AMD seeps.

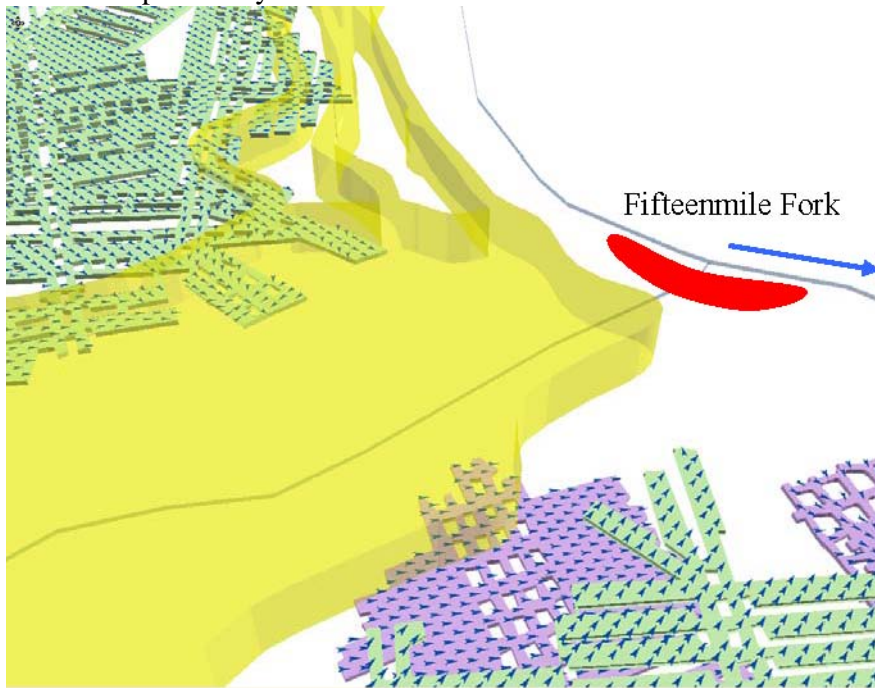


**Figure 8** Depth from the 1965 valley floor to Eagle seam mining (orange); Eagle seam structure shown, Powellton seam mining (green), and red depicts the AMD seeps zone

This calculation reflects the depth from 1965 valley floor (minus any refuse fill thickness to Eagle seam mining. Eagle mining occurs in the area north and near the mouth of Abbott Hollow. ArcMap (Spatial Analyst) depth calculations show the relationship between the Eagle mining elevations to the elevation from the Abbott Hollow valley floor. The ArcMap (Spatial Analyst) calculated the Eagle seam depths that range from 0.72-159 feet around the mouth of Abbott Hollow. The rose colored area (Figure 10) depicts the area of 71 to 130 feet below where Eagle seam mining would occur down from the valley floor to Eagle mining. In fact, in close proximity to the old valley floor, fracturing from mining may provide flowpaths to the refuse area

### USE OF ARCSCENE FOR 3D VISUALIZATION

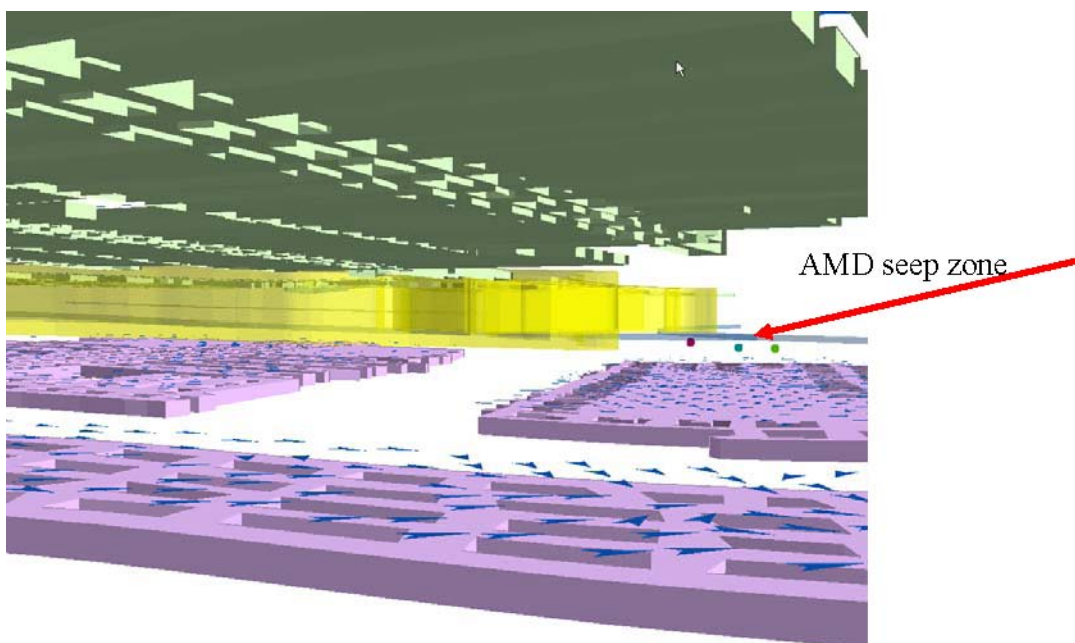
ArcScene was used to visualize the 3D relationship between the refuse area valley fill and the role of underground mines to the contribution of the AMD seeps (Figure 9). Powellton seam mining extends 257-377 feet into the buried area of the Abbott Hollow refuse permit. Along the northern extent of the Abbott Hollow permit boundary, Powellton seam mining extends 162-228 feet into the buried area of the refuse fill. Figure 9 shows a north to south visualization of the Powellton and Eagle seam mining, which is separated by Abbott Hollow.



**Figure 9** North to south visualization of the Abbott Hollow refuse area (yellow) and surrounding Powellton seam (green) mines and structure, and Eagle seam mining (purple)

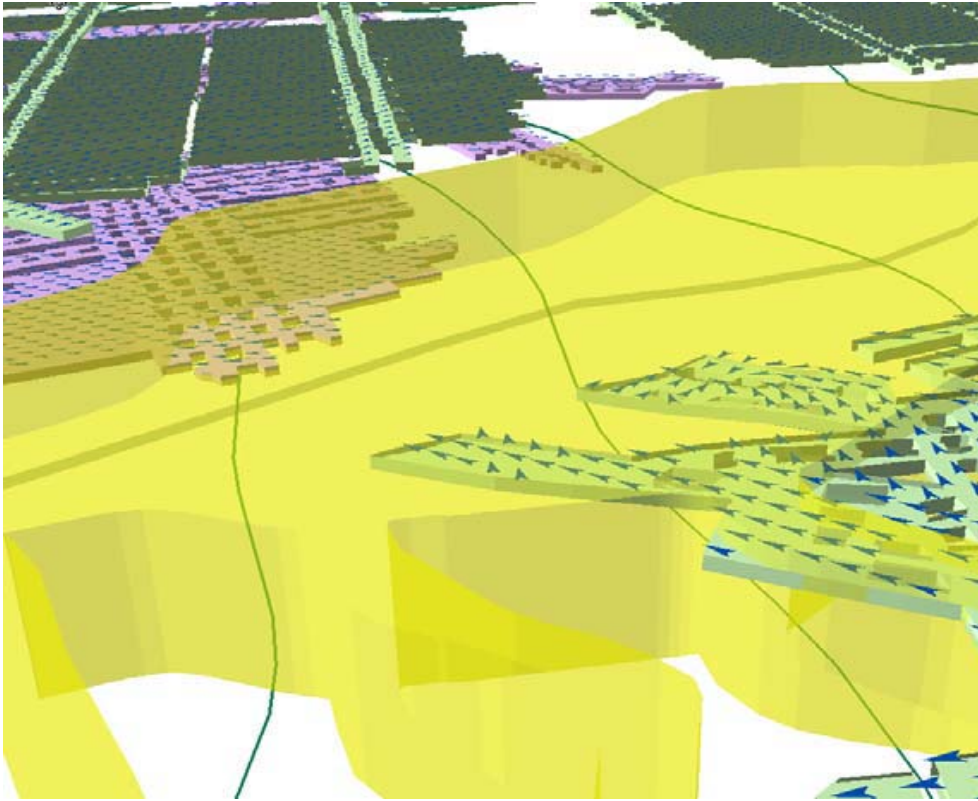


Pre-SMCRA Eagle seam mining extends 257-377 feet into the buried area of the Abbott Hollow refuse permit shown in Figure 10. Flow accumulation arrows reflect the local Eagle seam (purple) structure that is influencing Eagle (and Powellton) mine drainage in the direction of the refuse area and towards old Abbott Creek, and downgradient towards Fifteenmile Fork. The water that is pooled within the Eagle seam mine presumably drains into the refuse fill; in effect, the mine water contributes to the recharge of the refuse pile. Eagle operations adjacent to the refuse were second mined and most probably serve as a ground water sink. Pooled water from the Mine No. 7 may be moving from and either around and/or through the Abbott Hollow refuse pile, and flowing through the pile and exiting at the refuse toe into Fifteenmile Fork. The Eagle seam No. 7 Mine contains at least 40 feet of hydrostatic head (Loadout, 2006).



**Figure 10** North to south visualization of the Abbott Hollow refuse area (yellow) and surrounding Powellton (green) and Eagle seam mining (Purple); Powellton structure (green).

Extracting the elevation measurements from the maps provide a great deal more data to include in the coal surface interpolations rather than relying solely on drill hole data. Site-specific permit data within Abbott Hollow were not used in previous seam structure models, but were included in later generated coal surfaces models. The effects of the extra measurements in the interpolation process altered the local attitude of the structure surface model, and introduce significant hydrologic consequences in the hollow. The flow accumulation arrows shown in Figure 11 shows that any water built up in the mines would drain into the refuse fill.



**Figure 11.** South to north visualization of the Abbott Hollow refuse area (yellow) and surrounding Powellton (green) and Eagle seam mining (purple); WVGES Powellton structure.









## CONCLUSIONS

ArcMap and ArcScene were both used for this project, and ArcScene specifically was used to visualize the 3D relationship between the refuse area valley fill and the role of underground mines that contribute to the generation of the AMD seeps. Pre-SMCRA underground mines that surround Abbott Hollow contribute in part, to the recharge of the refuse area. Some Powellton and Eagle seam abandoned mines developed mine pools, which migrate with time and intercept the Abbott Hollow refuse pile.

Ground water flow still follows the original flow path along the old Abbott Creek stream course downgradient towards Fifteenmile Fork. In effect, the AMD seeps occur in part, as discharge of AMD-enriched ground water, discharging from the old Abbott Creek stream course that flows through the refuse area and discharges AMD from the refuse toe. Local geologic structure depicted by ArcScene is believed to control the contribution of inflows from underground mining into the refuse pile, which has the geochemical character to produce AMD that has been emanating from the refuse area. The use of ERSR's ArcScene 3D visualization modeling application allows a 3D spatial visualization of the relationship between underground mining, the refuse area, and the AMD seeps.

## REFERENCES CITED

Loadout, LLC, 2003, Abbott Hollow Refuse Area, Supplemental Exhibit 1-VI-A

Mastorocco, T., 2007a, the OSM electronic correspondence .

....., 2007b, the OSM personal correspondence .

Penn Virginia, 2006, Carbon Coal Co. reserve maps, O-14-82 WVDEP permit

transactions.....

WVDEP O-14-82, Section I-8, 1982

WVDEP Permit, O-14-82 permits Modification No. 1& 3, September, 1983, 1987