WEST VIRGINIA MINE POOL PUMP STORAGE

FINAL PROJECT REPORT FOR THE PERIOD
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WVGES GEOLOGY UNDERLIES IT ALL
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Executive Summary

The West Virginia Geological and Economic Survey (WVGES) examined all underground mines in the state to access their potential as mine pairs for a Mine Pool Pump Storage facility. A mine pair is defined as a lower target mine and an upper storage reservoir mine or surface reservoir. The project expanded on previous work done by McColloch, et al, 2008 which examined 19 seams for potential water supplies to encompass all coal mines in the state. A workflow plan was created utilizing various ArcGIS tools to examine the WVGE's extensive Coal Bed Mapping Project (CBMP) database and Mine Information Database System (MIDS) to identify mine pool pairs from approximately 9,600 mapped underground mine polygons.

The West Virginia Office of Energy (WVOE) specified criteria of at least 100 feet of vertical separation between mine pairs. Using CBMP feature classes including mine polygons, structural contours, coal elevation raster data, coal bed isopachs, coal bed thickness raster data, surface elevation rasters and standard ArcGIS tools the WVGES created a work flow model that assessed the various mines potential for a Mine Pool Storage Facility.

After research the WVGES determined that a storage capacity of at least 100,000,000 gallons (approximately 300 acre/feet) was necessary to construct a small to medium scale pump storage facility large enough to be commercially viable yet small enough to not eliminate every mine. In addition, several limitations were placed in the workflow document to assess the various mines including:

- Potential environmental hazards.
- Very old mining or had no mine maps.
- Presence of poor floor or roof lithologies.
- Mines with down-dip portals.
- Potential barrier failures due to mine interconnectivity.
- Proximity to outcrop and potential for barrier failure.
- Examined inter and intra mine water leakage both vertically and horizontally.
- Eliminated longwall mines and most drift mines.
- Mines currently used for businesses.
- Proximity to electric power transmission lines.

The WVGES identified thirteen possible mine pairs which met all criteria. All options are located in the southern portion of the state. The selections are a mixture of drift, slope and shaft 'target' mines paired with a mixture of upper reservoir mines or surface reservoir(s).

Each option is graphically represented showing the lower target mine in blue, the upper reservoir mine in red and any possible stream valleys to be utilized for a surface reservoir in blue lettering.

The WVGES recommends a more viable use of West Virginia water-filled underground mines: utility scale geothermal energy. The extensive amount of mining spread across the state possesses significant potential for geothermal heating and cooling systems to be utilized by industrial, government and private properties. The large thermal mass of mine waters can serve as an excellent source of utility scale geothermal energy. This is a large scale project requiring a developer or a utility company to design and build the infrastructure. A United States Department of Energy study states that residential homeowners can save 25 to 50 percent in electric heating costs and up to 72 percent on cooling costs over residences using standard air conditioning equipment. Scaling a geothermal project up to a utility scale plant could realize similar savings for businesses, especially industries with high cooling requirements like server farms. A study by Watzlaf and Ackman (2006) states that a properly designed geothermal heat pump system could theoretically heat 20,000 homes.

A geodatabase of all incorporated town polygons in the state and industrial sites was buffered to 0.25 and .50 miles and overlain on the CBMP mine map database. The industrial site shapefile contained only 2 locations with greatly under-represents the total number, but the process demonstrates the ability to determine possible site locations.

Spreadsheets of the resultant data were formatted alphabetically by municipality paired with 2010 census population data and all underlying mining.

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Introduction

The West Virginia Geological and Economic Survey (WVGES) was contracted by the West Virginia Office of Energy (WVOE) through a grant from the United States Department of Energy SEP Program for a six-month study to examine the State's water-filled underground mines to identify possible candidates for pump storage opportunities. A fundamental shift in energy production away from carbon-based fuels and toward renewables appears to be the direction that the US market will take in the next several years. Pump storage facilities have the potential to provide opportunities to enhance the capabilities of the national electric grid while being environmentally responsible in lowering the nation's overall carbon footprint by utilizing a virtually free, previously overlooked, untapped energy source.

Traditionally, electric generation is powered by carbon-based resources including coal, natural gas, and petroleum or non-carbon based nuclear, along with renewable sources including hydroelectric, wind and solar. West Virginia is a primary producer and supplier of fossil carbon-based coal and natural gas as well as a large emitter of carbon dioxide (CO_2) through power generation. The loss of the ability to market and use fossil fuels coupled with resource depletion of the state's natural resources, especially coal, is having a detrimental impact on West Virginia's economy. Diversifying West Virginia's contribution of electric power generation to the rest of the nation, especially through renewable energy, will ensure the state's status as a net electricity exporter.

Power demand on the national grid varies on daily, weekly and seasonally. In order to meet this variability, power plants are cycled on and off to optimize demand requirements. For example, power needs are lower at night than during the day, with peak demand during late afternoon and evening hours. Coal- and nuclear-powered plants are designed to supply a steady base load power generation but are poorly suited to quickly ramp-up for peak demand periods. Thermal stresses created during startup and shutdown phases of operation damages units especially if the plants have not been designed for cycling operations. Analysis of older coal-fired power plants has found them able to withstand these cycles better than newer combined cycle plants, but damage including fatigue and corrosion of boilers and boiler tubes caused by high temperature and pressure rates of change result in increased maintenance and overhaul expenditures (Lefton and Besuner, 2006).

The operating characteristics allowing immediate start-up of on-demand electric sources is limited to pump storage hydroelectric plants and natural gas plants. Coal and nuclear plants require substantial start-up and ramp-up time and therefore cannot meet immediate on-demand power consumption needs (Antal, 2014).

Pump storage power generation is accomplished via a two-reservoir configuration with the reservoirs sited at different elevations. Electricity is generated via a turbine driven by water released from the upper reservoir into a lower reservoir. Water is pumped into the upper reservoir during low-demand, low cost times using surplus electricity in the grid and released to generate power during peak demand higher rate times. Additionally, on-site solar or wind generated power could be used to power the pumps, easing the burden on the existing grid.

West Virginia has a long history of coal mining whose effects honeycomb the hills and subsurface of the State. Many of these abandoned mines are water filled as noted in McColloch, et al, 2012. In many areas, these water-filled mines are overlain by one or more dry mines. These vertically stacked mine sets may possess the potential to act as a pump storage facility with an upper storage reservoir and a lower catch reservoir. Analysis of West Virginia mining shows one remarkable area with seven levels of underground mining. While this area is exceptional, many areas have underground mining at two or more levels. The purpose of this study is to locate potential mine pump storage candidates with storage capacities of at least 100,000,000 gallons.

According to Homer Energy (homerenergy.com) a web based company that provides training and consulting services for information, micro-grid economic and engineering optimization, the actual amount of reservoir capacity will depend on the proposed generating capacity, the duration of daily production time, the difference in elevation between the reservoir and lower target mine, and proposed flow rate. These criteria will need to be determined by qualified consultants.

Purpose

The West Virginia Geological and Economic Survey (WVGES) was tasked with examining all underground mines contained in its comprehensive Coal Bed Mapping Database and report on any target mine-reservoir mine pairs that meet our criteria for a pump storage facility. A mine storage pair is defined as a lower target mine and an upper storage mine or surface reservoir of similar storage capacity and potential (Figure 1). In addition the WVGES will update, expand and enhance the Mine Pool Atlas (McColloch, et al., 2012) and will further examine mines for geothermal potential to act as feedstock from small to large scale industrial, municipal and government facilities in a ½ mile radius of towns.

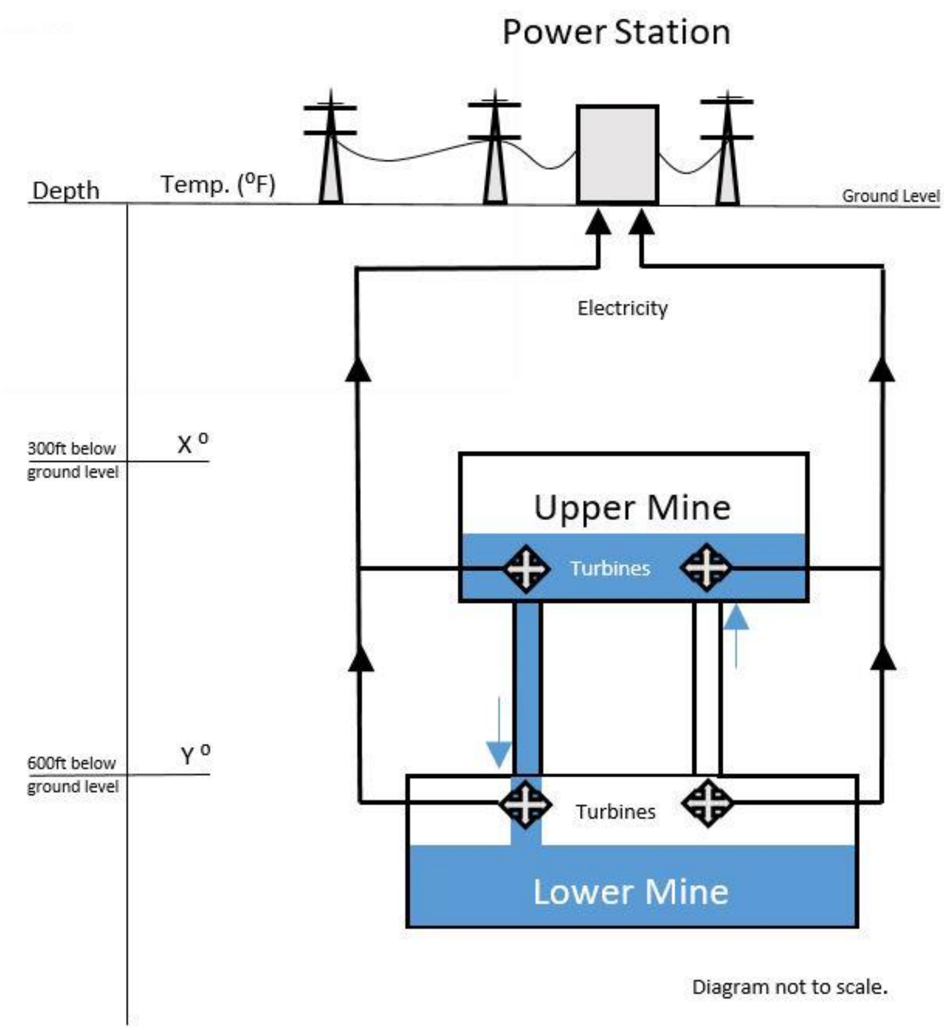


Figure 1: Simple schematic diagram of a mine pump storage system utilizing 2 mines separated vertically by at least 100 feet. Mines do not necessarily need to be stacked directly above one another. A lateral offset is also acceptable.

Geothermal Potential

Extensive water-filled underground mines throughout the coalfields of West Virginia provide significant potential to serve as input sources for medium to large scale geothermal heating and cooling systems designed for industrial, government and private projects. Groundwater stays at the average ambient air temperature for a given region. As a result, large underground bodies of water with stable temperatures can easily provide continuous, uninterrupted supplies of geothermal heat transfer either from or into the mine waters. A geothermal heat pump uses moderate steady temperatures in mine waters (in this case) to boost efficiency and reduce operational costs for heating and cooling systems.

As an addition to this study the WVGES will examine several prospects for geothermal potential associated with towns, cities and industrial facilities throughout the state.

Previous Works

This study expands on many previous studies conducted on flooded coal mines, commonly referred to as mine pools, in West Virginia. The West Virginia Department of Environmental Protection (WVDEP, 2008) created a map delineating estimated mine pools in the Pocahontas No. 3 and No. 4 seams in southern West Virginia. Several reports (Ziemkiewicz and Vandivort, 2004, Ziemkiewicz, et al., 2004, Donovan 2004a, 2004b, and Donovan and Light, 2008) have studied the extent of the Monongahela Basin mine pool flooding based on water level measurements within specific mines of the Pittsburgh coal bed in northern WV and southern PA. The hydrogeology of flooded and unflooded coal mines in the Upper Freeport seam in northern WV and western MD was documented in a reconnaissance mapping study by Morris, et al., 2008. The more comprehensive West Virginia Mine Pool Atlas (McColloch, et al., 2012) addressed the potential for large volumes of groundwater storage in mine voids to serve as water sources for domestic, municipal and industrial water uses. The scope of this study was limited to underground mines at or below drainage with areal extent of 500 acres or greater and only examined 19 coal beds, as specified by WVDEP. The Mine Pool Atlas identified 532 mines exceeding 500 acres which were partially or completely flooded. Finally a document titled Final Report Fairmont, West Virginia Mine Pool (United States Office of Surface Mining, 2014) examined the Pittsburgh mine pool in Marion County, West Virginia.

For the West Virginia Mine Pool Atlas (McColloch, et al, 2012), mine polygons, coal outcrops, structure contours of coal seam elevation, and scanned mine maps were examined to identify areas with adequate data to allow placement of the mines relative to topography (drainage) and to permit development of a tool to predict which mines were dry, partially flooded or totally flooded. The extent of potential mine flooding was dependent on various factors including mine orientation, mine entry location, proximity to other underground mines, structural contour configuration, and direction of ground water flow. Groundwater flooding potential for mines in a particular coal seam may be affected by underground mines in stratigraphically lower coal beds and by pumping of adjacent and subjacent mines during production phases. After pumping ceases mines immediately begin to flood.

The original West Virginia Mine Pool Atlas (McColloch, et al, 2012) study focused on 19 of West Virginia's mined coal seams. This study expands the criteria to incorporate all mined coal seams, regardless of extent, applying new search criteria defined later in this document.

Methodology

A workflow schema was designed to guide geologists in determining likely pump storage mine pairs, whether mine over mine or surface reservoir over mine. Several iterations of the workflow were created resulting from the evolution of criteria as the project progressed.

The only criteria provided to WVGES was to identify mine pairs with at least 100 feet of vertical separation. This left survey geologists with latitude to create rules to eliminate unsuitable mines, mines with too little storage capacity and mines that could pose environmental issues.

It became quickly apparent after initial examination of existing pump storage facilities throughout the United States and the world that a large storage reservoir is required to provide sufficient energy production to be economic. Medium scale pump storage facilities exceed 1500 acre-feet of water capacity. One acre-foot of water equals 326,000 gallons so these reservoirs contain approximately 500,000,000 gallons of storage capacity. It was therefore determined to limit selected mines to at least 100,000,000 gallons of storage capacity or just over 300 acre feet. We believe this to be a reasonable estimate in order to make the program cost effective and able to provide sufficient power to make the project viable while making the desired water volumes small enough to provide some viable options.

Considerations

This study would be impossible without a detailed understanding of the State's mining history as documented by extant mine maps. Mine maps are obtained from various sources including West Virginia Office of Miners Health Safety and Training, West Virginia Department of Environmental Projection, the United States Office of Surface Mining and various public and private sources. Many mine map footprints examined in previous reports (e.g. McColloch et al., 2012) have changed significantly for various reasons and the mine map database is constantly being updated. WVGES remains committed to updating and improving the mine map database as additional data become available.
Several factors were considered with this study.

- The actual extent of mining may be inaccurate because final closure mine maps are not always available. It is possible additional mining has occurred since the most recent map acquisition.
- Mine map quality varies considerably in information presented and cartographic accuracy.
- Many newer mine maps are digitally available. Many older maps have been photographically reproduced and reduced from dimensionally unstable paper copies resulting in distortion from lens geometry and/or poor paper placement (causing wrinkles or creases) during reproduction.
- Some instances of old paper maps stored in damp basements have been encountered where mold and moisture has deteriorated the maps causing inks to fade and the maps to crumble making digital reproductions difficult or impossible.

In some cases mine extents have been gleaned from poorly drafted maps of adjacent mines where portions of the mine can be pieced together from several individual documents but no single map has been identified that shows a complete polygon.

Many paper mine maps are recorded on paper sizes much larger than can be accepted by available wide format scanners. In order to scan these maps, it was necessary to either cut the map into smaller pieces or, if map conditions permit, fold the map in order to scan it. Either process causes distortion. Also very large format maps originally sent to the United States Office of Surface Mining (OSM) were photographically reproduced onto as many as 19 individual microfiche aperture cards, each of which introduces distortion that must be manually rectified using a best fit methodology when reassembling the entire mine polygon.

Municipal and private water supply usage is a factor that must be considered in this project. Several southern West Virginia municipalities obtain water from abandoned underground mines and any disruption of this service would likely be unacceptable (Lessing and Hobba, 1981).

There are a few areas of the state where the historic mining is so old that no mine maps exist in the WVGES database. WVGES knows these areas are mined based on historical documents and Work Projects Administration (WPA) maps created in the 1930s. The WPA maps are 15 minute topographic quadrangles recording workers' visits to known underground mine sites assumed to have been mined prior to the 1930s and records mine name, company name (if known), a general location, the number of mine openings and if the opening is draining water. In many cases no actual mine map is known to exist for these mines with only general assumptions of mining extent.

A partnership with West Virginia Miners Health Safety and Training has allowed workers access to engineering companies, mining companies and private collections of historic mine maps in an effort to collect and record previously undocumented mined areas. Recently several thousand mine maps not previously contained in the WVGES library were collected, scanned and identifying information added to the WVGES Mine Information Database System (MIDS) and are available to the public for review. This effort has discovered dozens of previously unknown mine locations, added mined extent to numerous mines and has added thousands of new thickness and elevation points to improve the WVGES mine model. Typically the new mine map additions are only of smaller mines but occasionally a portion of a large mine is added based on the newer information.

Coal bed elevation and thickness data density varies across the wide spectrum of mine maps evaluated by the WVGES. Modern mine maps typically contain abundant thickness and elevation data. Many older mine maps have limited, illegible or no data. This disparate data density can locally limit the effectiveness and reliability of structural contour lines and thickness isopach maps. Some areas of the state have been heavily mined, drilled, surveyed and geologically examined while many historic parts of the coal fields have little to no available data. In these areas geologists must extrapolate thicknesses and elevations up to three miles from a data point.

Elevation and surface grids were created for water storage potential, capacity and groundwater flow direction.

The final portion of this report includes links to an updated version of the Mine Pool Atlas with expanded coverage to include every mined seam regardless of aerial extent.

Criteria

The only criteria provided to WVGES by the Office of Energy was to identify mine pairs with a minimum of 100 feet of vertical separation. Using this figure, WVGES researchers created work flow guidelines that eliminated unlikely candidates.

Problems and Potential Issues

In the course of selecting candidate mine pairs, several issues relating to safe and successful candidate mines were discussed.

The presence of large volumes of water in the lower, flooded mine is considered essential for the successful development of a pump storage facility. The rapid movement of large volumes of water within the mines may cause serious intra-mine erosional issues. Coal is a brittle material and generally contains closely spaced cleats (fracture) that decrease strength. Unlike in hard-rock mines driven through competent material, coal tends to degrade over time. The turbulent flow associated with the rapid movement of water as it is pumped into a storage mine or returned to generate power would have considerable erosive power. Over many wet-dry cycles erosion of the supporting pillar walls would likely lead to pillar failure and roof falls. The erosive effects of the moving water would be exacerbated by the presence of debris, such as pieces of coal eroded from the mine walls. This mobilized debris would have the potential to damage intrastructural elements as well as possibly clog the system and create blockages in filtration systems or impeding free flow of water.

There is additional danger of substantial roof and floor incision in both the upper and lower mines in this study. Any selected mine will require a detailed and comprehensive assessment of lithological stability which may result in additional mine reinforcement and strengthening (Figure 2).

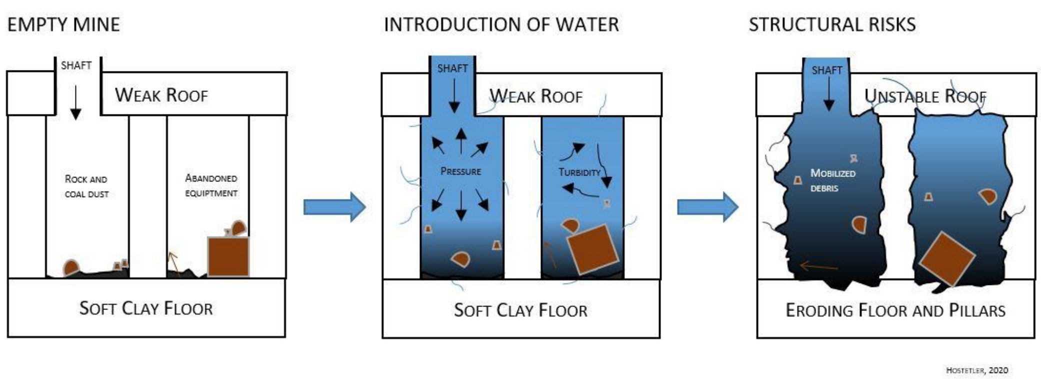


Figure 2. Rapid infilling of mine voids during daily pumping cycles will cause tremendous amounts of erosion within the lower mine. Displaced debris could hinder water flow through the mine or clog pumps.

Second, down dip portals (mine openings at a lower elevation than the mine) on either the lower target mine or the upper storage reservoir mine would be weak points in a closed system that could allow barrier fatigue or failure between the mine and outcrop, or between adjoining mines again causing potential environmental, industrial and potential human damage and loss of life.

Third, bed load transport of mine debris in turbid mine waters caused by daily pumping episodes would be tremendous. Coal mines are notoriously dirty environments with rock dust, coal dust, cribbing timbers, abandoned equipment and tools, cables, wires, etc. all of which would be extremely mobile and detrimental to a pump storage system. A robust filtration system would need to be designed, installed and frequently serviced to avoid debris entering into the pumps and destroying the valuable equipment. This will require access into both target and upper reservoirs by service personnel.

Fourth, discussions with a contractor in the pump storage industry indicated that a site location should be located within about 1 mile of high power lines. Examination of aerial photography would provide clues as to the proximity to high voltage power lines and/or electric infrastructure. Construction of new power line services can cost up to $250,000 or more per mile depending on variables such as topography, line load, labor costs, right of way costs, etc.

Fifth, a possibility for a pump storage facility may allow construction of a surface reservoir rather than utilizing an upper mine void. The West Virginia landscape provides abundant opportunities for construction of a surface reservoir due to the rugged terrain, locally low population density and geologic setting (see Figure 3).

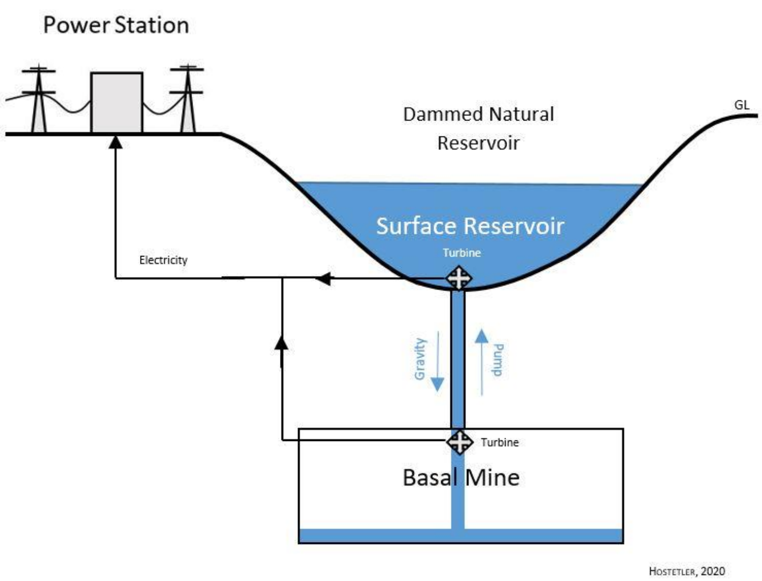


Figure 3: Simple schematic diagram of a mine pump storage System utilizing an upper surface reservoir with a lower mine.

Sixth, too large of a mine or a large number of interconnected mines could present problems. Water infiltration from overlying or interconnected adjacent mines could compromise the viability of a pump storage system by removing or reducing the required storage space needed for waters from the upper reservoir during peak flow conditions (Figure 4). There are county-scale areas in the State totally underlain by water-filled, laterally interconnected mines. If the interconnectivity is extensive, permeability would be essentially infinite. In this situation, water removed from the mine and pumped into the overlying storage would be rapidly replaced by infiltration from adjacent areas, eliminating the void needed to receive the water discharged from storage during power generation.

Additionally leakage of stored water in the upper storage reservoir into down dip adjacent or underlying mines would compromise the system by removing stored water needed to power the system. Adequate seals will need to be confirmed or created and maintained for the system to remain useable. Vertical fractures and joints can extend many feet vertically and act as conduits for water movement between strata. Mining, especially in multiple stacked seams, can exacerbate this phenomena.

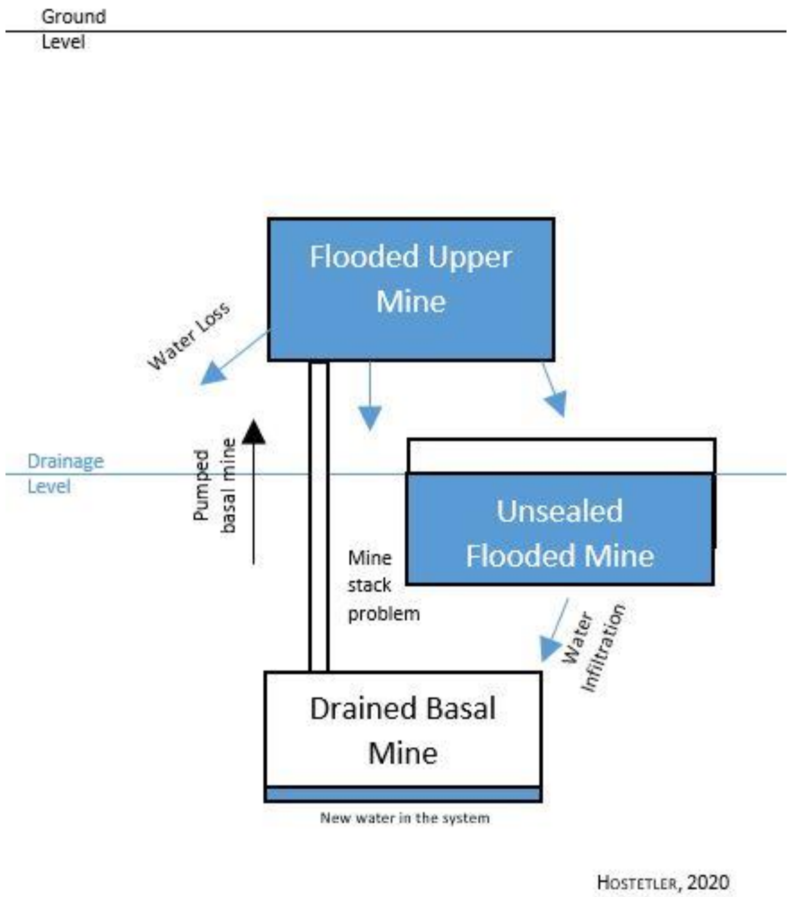


Figure 4: Multiple stacked water-filled mines depicting reservoir water loss either into or out of adjacent or lower mines. Reservoir water leakage can be a detrimental factor either causing loss of water needed to power the mine pump system or filling the lower mine with leaking water.

Seventh, longwall mining causing vertical fracturing and rubblization of the mine void due to roof collapse will jeopardize mine roof stability and mine seals making proper storage difficult if not impossible to create (Figure 5). Longwall mines are designed to allow mined areas to collapse behind active mining creating rubblized zones with tortuous flow conditions.

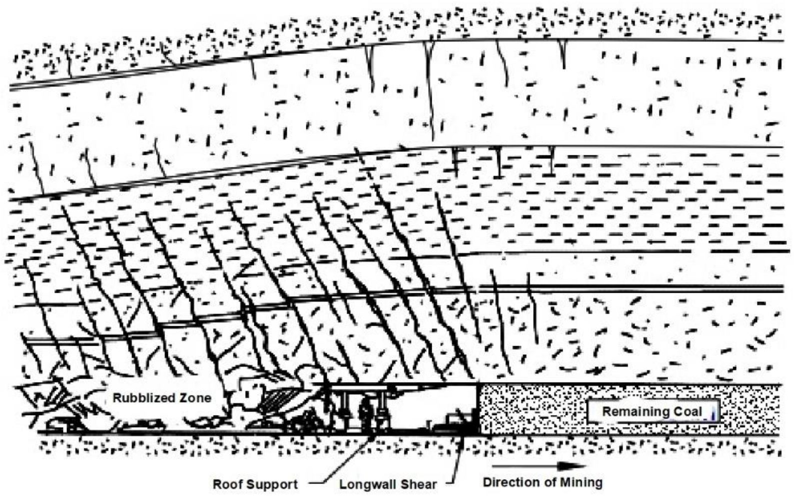


Figure 5: Cross section of typical longwall face with resultant rubblization of overlying strata after mining, adapted from Mine Subsidence Consultants (2007). Note the rubblization of overlying strata behind the roof supports.

Eighth, several municipalities in southern West Virginia utilize mine waters for their public water supply while other mines use the void spaces for various industries such as fish farms, mushroom farms, storage, etc. It will be extremely important to not interfere with an existing industry or water supply.

Finally several coal seams are known acid producers. A pyrite rich coal seam or a seam surrounded by pyritic lithologies produces low pH waters which are environmentally harmful and can adversely affect power generation equipment, quickly corroding parts.

Mine Pool Source Data

Data from the WVGES's Coal Bed Mapping Project (CBMP) used in this study include: mine polygons of approximately 9,600 underground mines, coal bed outcrop polygons, structure contours showing basal elevation of each coal bed, coal bed elevation raster data, coal bed isopachs and coal bed thickness raster data. The individual data layers are dynamic and are subject to intermittent updating as new data warrant. All results presented in this report are preliminary and subject to change. Data layers are robust and mature and future changes are likely to be minor.

The CBMP is comprised of digitized footprints of mine maps from a variety of sources including paper maps, digital scanned maps and CAD images into seam specific mine polygons. These mine polygons were compiled to document the extent of underground mine works. Although efforts are made to use the best available data and locate mines as accurately as possible, because of the following issues:

- Mine polygon locations should be considered approximate. The actual extent of mining may be unknown as final mine maps from the time of mine closure are not always available and not all underground mining has been documented by mine maps.
- The quality of mine maps is highly variable in the amount of detail and information presented. Many modern mine maps are available in digital form. Many older mine maps have been photographically reduced from damaged dimensionally unstable paper copies with folds or creases present in the map. Photographic reduction also introduced distortion due to lens geometry.
- Paper mine maps arrive in varying degrees of preservation ranging from pristine prints to moth eaten, water stained and moldy, damaged fragments. Attempts are made to scan and preserve any mine map presumably with new or better data but limitations of scanner width and the map itself can make digital preservation nearly impossible.
- Coal bed correlations assigned to a mine map by the company and printed on the map may be different from the correlations assigned by WVGES. Coal seam names are frequently regional and incorrect according to WVGES standardized nomenclature.
- Active mines were not differentiated from recently closed mines in the CBMP database. Unless a final closure map of a modern mine has been sent to the WVGES a mine is considered open.

GIS Models

Mine Void Position Relative to Drainage

The Mining Above/Below Drainage Model (MABD) developed for this project is a geoprocessing model comprised of a series of standard ArcGIS™ tools executed in a certain order. The MABD determines the position of mines with respect to drainage based on perennial stream elevations. The Perennial Drainage Elevation Model (PDEM), was generated by assigning CBMP digital elevation model (DEM) surface elevations which were originally derived from USGS 7.5-minute quadrangle elevations to points generated from the National Hydrography Dataset (NHD). The feature nodes of all line segments from the NHD flowline feature class classified as perennial were converted to a point feature class and assigned elevations from the CBMP DEM. The resolution of the DEMs were generated at 10 meters using the Natural Neighbors interpolation method to match the CBMP seam elevation raster data.

The seam elevation DEM, which is interpolated from point locations of bottom of coal measurements, was subtracted from the PDEM to indicate regions of the coal bed above and below surface drainage. The resulting raster layer from the subtraction process was reclassified in three regions: -1000' to -20', -20' to 20' and 20' to 5000', which translates to Below Drainage / At or Near Drainage /

Above Drainage. These results were individually overlaid with the mine footprints to obtain the final GIS layer of potentially flooded mine areas for each mine in every seam.

Mine Pool Volumetric Calculation Method

The CBMP Total Bed Thickness raster layer (totbed) is a 10 meter GRID layer that was the basis for vertical void measure estimates. This layer is produced using an inverse distance weighted algorithm that interpolates grid values between actual coal bed thicknesses. CBMP's mine footprint layer overlaid with the position to drainage resulting areas were the base used to determine areas within each mine void which could be considered flooded, potentially/partially flooded or not flooded. ArcMap™'s spatial analyst extension zonal statistics tool was employed to sum each 10-meter cell within a given mine polygon to calculate the total volume of the mine void. These data were output into a .dbf table (zonalstat). The following mathematical formulas were used:

• Conversion of the zonal statistic result from inches/meters to cubic feet: ((SUM / 12) * 32.808399) * 32.808399
• Conversion of cubic feet to acre feet: cubic_ft / 43560
• Conversion of cubic feet to gallons: cubic_ft * 7.48051948
• Storage gallons were calculated as half of the estimated void gallons: (cubic_ft* 7.48051948)*0.5
• The average thickness of the cells intersected by the mine footprint polygon were calculated by taking the sum of the cell values divided by the count of cell selected.

Mine Pool Flow Direction Method

The Watershed Model, which was used to determine groundwater flow direction, is a standard Esri©ArcMap™ 10.7 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 rasters. 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.

Mine Pool Evaluation Process

WVGES geologists evaluated every mine in the CBMP database by applying the above processes. The result is a database containing volumetrics for each mine, the amount of storage capacity above and below drainage and groundwater flow vectors. From this point, a group of criteria were developed and a work flow was created to evaluate every mine and entered into a series of Excel spreadsheets referred to here as Worksheets 1 through 5.

Worksheet 1: Portals-Structure-Connectivity

Worksheet 1 evaluated lower target mines. The initial step in evaluating mines was designed to identify lower target mines suitable for the lower portion of a pump storage system. Using the volumetrics report generated in Arc, all mines with less than 100,000,000 gallons of storage capacity and situated above drainage were eliminated from the first round of inspection. The remaining mines were placed into a database for processing.

Each mine was then individually checked for proximity to outcrop. Any mine situated within 250 feet of an outcrop was eliminated from consideration due to concerns of a mine water blowout. Repeated episodes of pumping and releasing 100,000,000 or more gallons of water into a closed system would result in considerable degradation of mine stability, eroding support pillars, undermining support infrastructure and eroding of barrier outcrops. This was accomplished by placing a 250 foot buffer around the outcrop polygon and intersecting the mining polygons. An exception was allowed in cases where outcrop or mine portals were up-dip, meaning the outcrop is at a higher elevation than the mine pool and would not experience unusual over-pressurization from the entry and exit of water during pump cycles.

Down dip portals, mine adits at a lower level than the mine pool, were recorded in the database utilizing structural contour lines. Any mine examined with down dip portals was eliminated. A down dip portal would allow water to escape the mine thereby ruining any reservoir capacity (Figure 6). Portals are often sealed either during mining for ventilation purposes or after mining for environmental and public safety purposes. These seals are not sufficient to properly protect the mine from blowouts resulting from repeated pumping of large volumes of water into and out of the mine. This rule applies to both upper storage reservoir mines and lower target mines.

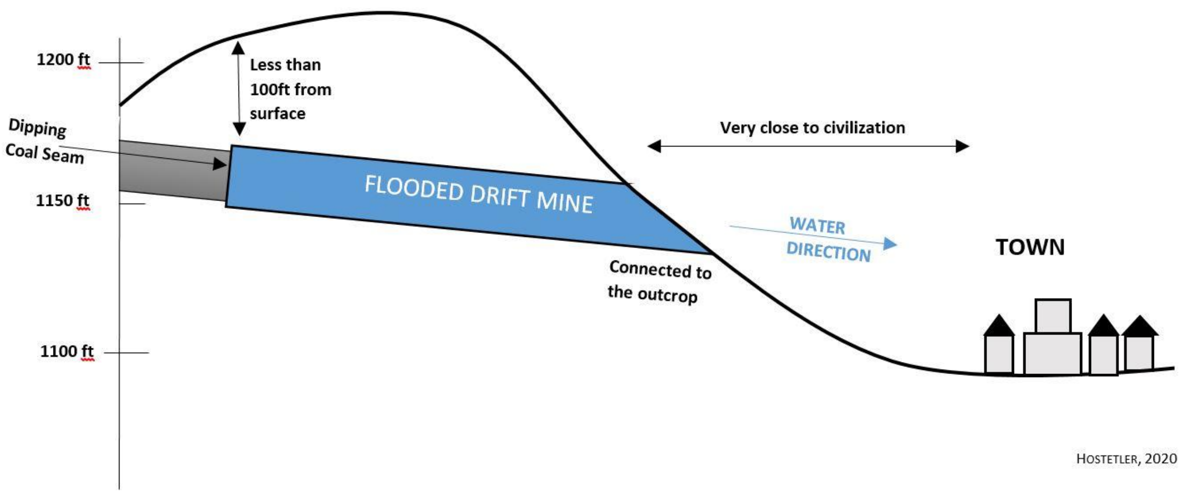


Figure 6: Diagram showing a down dip mine and the difficulty of adequately sealing the mine void.

A mine map document date, if provided, was collected to determine the age of mining. Support, stabilization, construction and infrastructure will be needed in both lower and upper mines to support a mine pump storage facility. Old mines were eliminated from consideration due to deterioration of mine supports, roof stability, rib destabilization, and potential poisonous gasses which are commonly encountered in abandoned mines.

Structural considerations were next considered. Any potential structural features that were deemed problematic were recorded. For example a mine with a rolling structural framework would be less conducive to drainage, as low points would pond potentially allowing large volumes of water to not be pumped. Structural trends away from potential overlying storage mines could be unusable due to pumping distance considerations. Also a mine situated over an anticline could have a storage reservoir capacity effectively cut in half since lower portions of the mine would be separated by a high center (Figure 7).

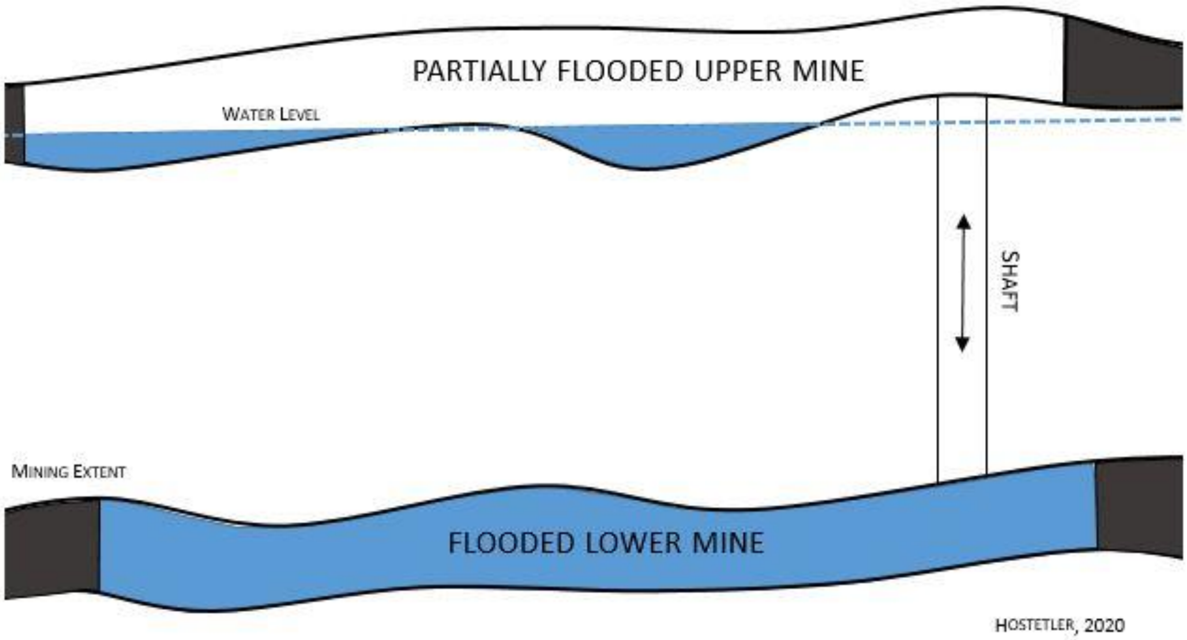


Figure 7. Structural undulations will cause high spots in mines possibly impeding drainage.

Proximity or connectivity between target mines was investigated. Several factors come into play here including reservoir storage integrity. Many mines in West Virginia are situated adjacent to other mines. Therefore WVGES decided to make a minimum 250-foot barrier between adjoining mines a requirement to avoid any inter-mine flow communication. Any zones of weakness between mines could result in leakage from target mine into an adjoining mine (See Figure 4). Similarly the target mine could potentially be fed with water from an adjacent up-dip mine filling the target mine after water was pumped into the upper reservoir. If the target reservoir's seal were compromised and adjacent up dip mine waters infiltrated into the now empty target mine, the water in the upper reservoir would not be able to freely flow into the now full lower reservoir voiding the pump storage process.

The type of mining is an important consideration. There are three ways to access an underground mine: drift, slope or shaft. Drift mines penetrate the earth by adits driven parallel with the coal outcrop extending into the subsurface at or near the mine opening elevation and are above the water table. Many large historic mines in West Virginia are up-dip which allowed water to escape the mine thereby eliminating the need for pumping. Modern mining regulations require pumping. This method of mining was deemed too unlikely to be a sealable unit. WVGES removed mines using this method from consideration.

A slope mine extracts material by driving adits at a downward angle from a higher elevation opening to a lower coal seam. Many slopes access the coal several tens to hundreds of feet below the ground surface which would eliminate, if deep enough, the possibility of mine water blow outs making slope mines viable options for a safe Pump Storage system.

Shaft mining is a method of mining where a vertical shaft is drilled or excavated to the commodity level. Many shafts are hundreds of feet below the surface with no communication with an outcrop. These mines are the ideal candidate for pump storage pairs if other criteria (listed) are met.

Mine method is the final criteria examined. There are, for this study, two methods of mining to consider. Traditional mining, commonly known as room and pillar mining which creates a series of parallel entries connected at intervals by perpendicular to sub-perpendicular crosscuts (depending on mine plan) creating what appears to be a street and alley pattern. The mine roof is supported by the remaining pillars plus crib blocks and roof bolts. Typically between 30 and 50 percent of the coal is removed. A common practice in traditional room and pillar mining happens when corners of support pillars are mined away to extract more coal. Some companies were successful in removing large portions of the pillars which substantially under stabilizes the roof creating similar conditions to longwall mining.

Longwall mining completely removes of the resource by developing access to large blocks or panels of coal. A shearing machine removes slices of the coal block, depositing the mined material on a conveyor belt which runs the length of the longwall panel in conjunction with the shear. Large roof jacks (fields) support the overlaying material until the shear completes removal of the coal at which time the entire system is moved forward while the previously supported roof behind the jacks collapses.

Any longwall mines were immediately eliminated from consideration due to the extreme danger or impossibility of entering the mines and the amount of debris remaining from roof collapse and overburden rubblization which would potentially clog any communication between reservoirs and pump equipment.

All mines were considered using the above criteria and recorded in an Excel spreadsheet. Failure of a mine to meet any criteria resulted in a red designation which removed the mine from consideration.

Remaining mines are saved in Worksheet 1. These mines are the potential lower target mine in a pump storage pair.

Worksheet 2: Overlying Mines

Worksheet 2 deals with the overlying storage mines. All mines that passed the criteria of Worksheet 1 moved on to Worksheet 2. Each mine of this subset is individually selected and intersected with overlying mines. The storage capacity of the lower target mine as well as storage capacities of all overlying mines are recorded in the worksheet.

Upper mines were processed by the ArcGIS tools and were broken up into zones based on their location relative to the water table. *Below the water table* indicates totally flooded, *near* means that the area is approximately the same elevation as the water table (accurate to within +/- 20 feet) *above drainage* means the area is dry. Calculated values were manually entered into the spreadsheet into columns labelled *Near or Above* and *Below* drainage. Total storage capacity for each mine was calculated by adding the values of the two columns. Any mine with a minimum above drainage storage capacity of less than 100,000,000 gallons and any mine completely 'Below' drainage were marked red and removed from the list.

Upper storage mine considerations were further evaluated as follows. Any upper longwall mines were immediately eliminated for the same reason as mentioned in Worksheet 1 above. If the upper mine underlies another flooded mine it will also be immediately eliminated to remove any possibility of unwanted water infiltration from upper to lower reservoirs.

Interburden grids were created to determine thickness between seams. Any interburden less than 100 feet eliminates the upper mine from consideration as defined by Office of Energy criteria. Next, overburden grids were created to determine depth of mine from the surface, and used to determine if a minimum of 100 feet exists between the target mine and the surface.

Data is also collected as to whether the mine pair is mine-over-mine or surface reservoir-over-mine, as the constraints are different depending on the nature of the upper storage reservoir.

Worksheet 3: Surface

Worksheet 3 compared the location of the basal mine to any surficial features. The surface area above the basal mine was examined to determine if a reasonable area, free from human occupation or use where a surface reservoir may be constructed was available. This is only possible where the surface is 100 feet or greater above the target mine. Buffers were created around lower mines of 0.0 , 0.25 and 0.5 miles which identifies any towns or cities directly overlying or in near vicinity of the basal mine.

Lastly state or federally owned land, taken from USGS 7.5 minute quadrangle maps, found to be directly overlying a basal mine was identified and disqualified the target mine from consideration. Following this step, all mines not marked red proceeded to Worksheet 4.

Worksheet 4: Mine Stack-Acid

Worksheet 4 identified any issues between an upper and lower mine, or the surface and an underlying mine that might restrict their use for a pump storage facility. Any mines situated between the basal target mine and the upper storage reservoir mine or surface reservoir may be problematic. For this reason all intervening coal seams were checked for additional mining occurring between the target and reservoir mines. Any mine pairs or mine-surface pairs with intervening mines were marked as potential problems and removed from consideration.

A second criteria examined in this section was assumed acid problem. Some coal seams produce copious amounts of acid due to high concentrations of the mineral pyrite (FeS_2). Pyrite reacts with oxygen in water to produce iron hydroxides and sulfuric acid. Acid producing seams are mainly located in the northern coalfield. Any mine with a history of producing abundant acid mine drainage was eliminated from consideration.

Upper mine connectivity was also considered. Just as lower target mines were eliminated if they were within 250 feet of another mine, upper reservoir mines must meet the same criteria. Upper mines with a down-dip portal or that are within 250 feet of the outcrop were eliminated to prevent the possibility of a mine water blowout caused by multiple pump cycles of very large volumes of mine water.

Worksheet 5: Possibilities

Worksheet 5 contains any mine pairs or mine-surface reservoir combinations which passed all the criteria in Worksheets 1 through 4. This worksheet contains mine name and company name for both the upper and lower mines as well as seam information, dates and designations of whether the pair is mine-over-mine or surface-reservoir over mine.

RESULTS

The WVGES identified thirteen underground target mine pairs which met the WVGES criteria outlined above. All mine pairs are located in southern West Virginia where the negative effects of the coal market decline have been magnified. The possibility of good paying job opportunities should be welcomed in the various communities. The selections are a mix of drift, slope and shaft mines paired with either upper mines or surface reservoirs. Drift mines, although deemed non-optimal prospects due to the reasons laid out in the discussion above, were selected because they were very large and the reservoir was located far enough away from the outcrop that the possibility of barrier failure is minimized.

The WVGES recommends a shaft or slope mine isolated from adjacent mining to be used as the target reservoir in a pump storage system because all of the storage is below drainage and far removed from potential failure with minimal or no chance of barrier failure. It is important that the roof and floor lithologies be sandstone or another resistant lithology to lessen erosional effects during recurring pump storage cycles.

Interburden between lower target mines and upper reservoirs is of low importance since a lined shaft will be constructed between them sealing the interburden from erosional effects.

The upper storage reservoirs are a mixture of six mines and eight surface impoundments (one target mine was viable for either mine or surface reservoir). It is also important that the floor and, to a lesser point, roof lithologies be of resistant lithologies to reduce erosional effects of repeated pump cycles.

Each option is graphically represented showing the lower target mine's polygon footprint in red with aperture card numbers included within the mine. The aperture card scans may be viewed and downloaded on the WVGES MIDS website http://www.wvgs.wvnet.edu/www/mids/main.php

Upper reservoir mines are represented by blue polygons also with aperture card numbers included. Additional adjacent or stacked mines are represented in brownish-yellow but do not have labels of their associated aperture cards.

Surface reservoir stream valley location options are indicated by blue labels on the respective stream valleys.

Each figure is underlain by a portion of its respective 7.5' topographic quadrangle.

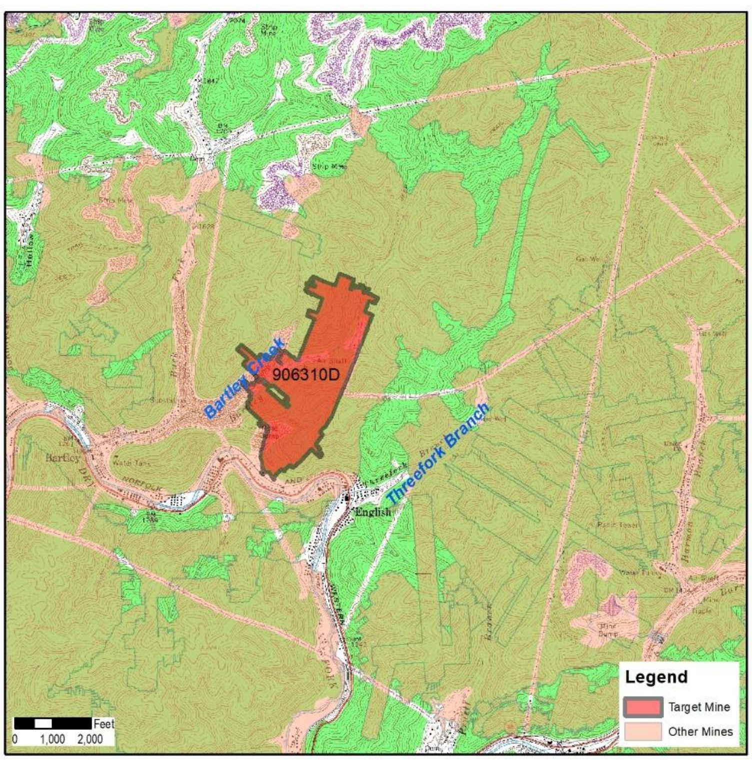
Option 1: McDowell County No. 1 Site, War Quadrangle
Aperture card: 906310D
Mine and Company Name: Mill Creek Mine, Unknown Company
Date: unknown
MSHA number: unknown
Details: Reported as a shaft mine but may be a slope (the only mine map in the WVGES archives is of poor quality) in the Beckley seam utilizing a surface reservoir.

The target mine floor ranges from approximately three feet of fireclay overlying sandy shales and sandstones with shale streaks towards the north to over 100 feet of sandstone to the south. The roof is composed of over 20 feet of shale with interbedded sandstone.

The surface reservoir could be constructed on either Threefork Branch or Bartley Creek tributaries of Dry Fork of Tug Fork.

The target mine and surface reservoirs are situated on War quadrangle, McDowell County. The nearest town is War approximately 3.5 miles to southeast with a population of 862 people according to the 2010 census.

Considerations: Data for the mine and immediate area surrounding the mine are not in WVGES archives, roof and floor conditions can only be inferred from drill holes within about a ½ mile radius. The first few feet of the lower target mine floor is soft erodible fireclay but, after that is removed from multiple pump cycles, the lower lithology is resistant sandstone. The only maps for this mine in the WVGES archives are addendums to other maps, no original map exists in our files. Better more complete maps will need to be located, perhaps from company files or other archives. Both Bartley Creek and Threefork Branch have residents living on the lower portions of the streams near their confluence with Dry Fork.



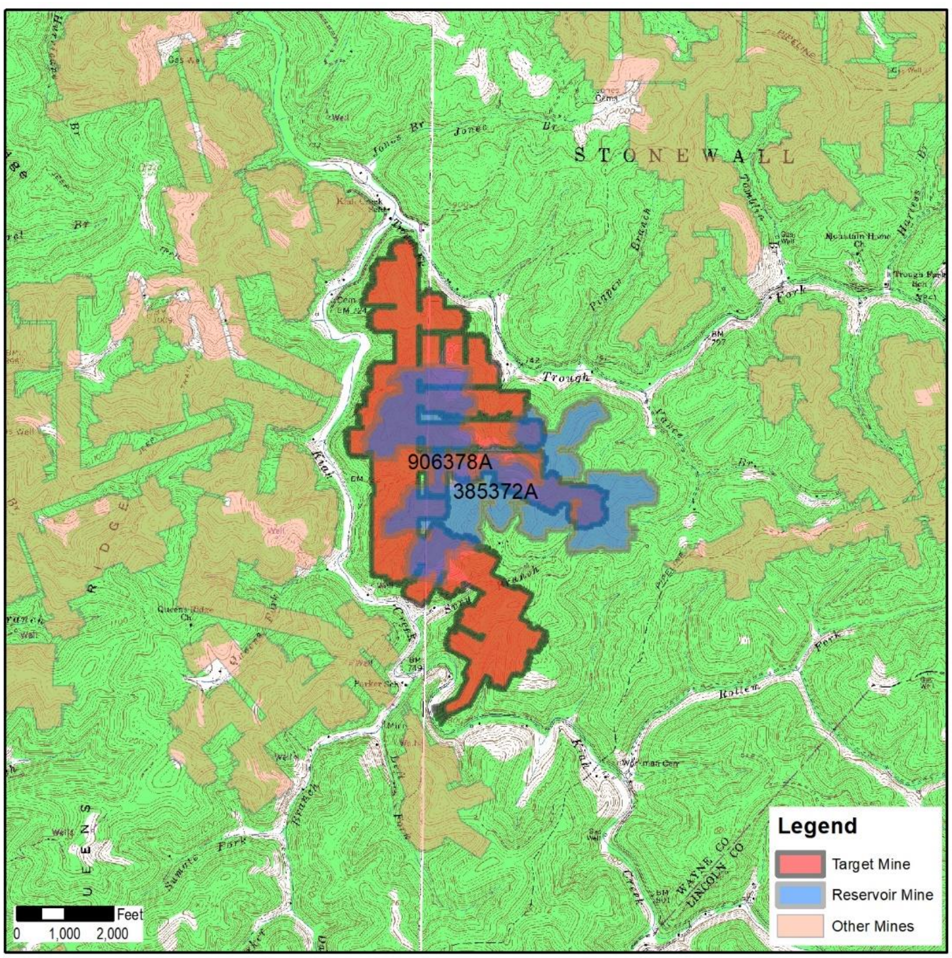
Option 2: Wayne County Site, Kiahville and Ranger Quadrangles
Aperture card: 906378A
Mine and Company Name: Deep Mine No. 6, Argus Energy WV, LLC mine map
Date: 2003
MSHA number: 46-08821
Details: drift mine in the Coalburg seam utilizing an upper mine void aperture card 385372A in No. 5 Block coal seam. Mine name is Pen Coal No. 5, Pen Coal Company, map dated 2000. A second option could be a surface reservoir in one of several unnamed tributaries of Trough Fork of Kiah Creek.

The target mine roof is approximately 25 feet of interbedded sand, shale and coal streaks while the floor is approximately six feet of shale overlying up to 25 feet of sandstone and sandstone with shale streaks.

The upper reservoir mine roof is a mixture of 20 feet of shale and sandstone, while the floor is a mixture of fireclay, shale and some sand.

Both the target mine and upper reservoir are situated on Kiahsville and Ranger quadrangles, Wayne County. Nearest town is Huntington, WV approximately 28 miles north northwest with a population of 46,048 as of 2018.

Considerations: The lower target mine floor is a mixture of soft lithologies overlying more competent lithologies below which will require drilling to determine specifics. The upper reservoir mine is 160 feet above drainage and could be a risk for barrier failure.



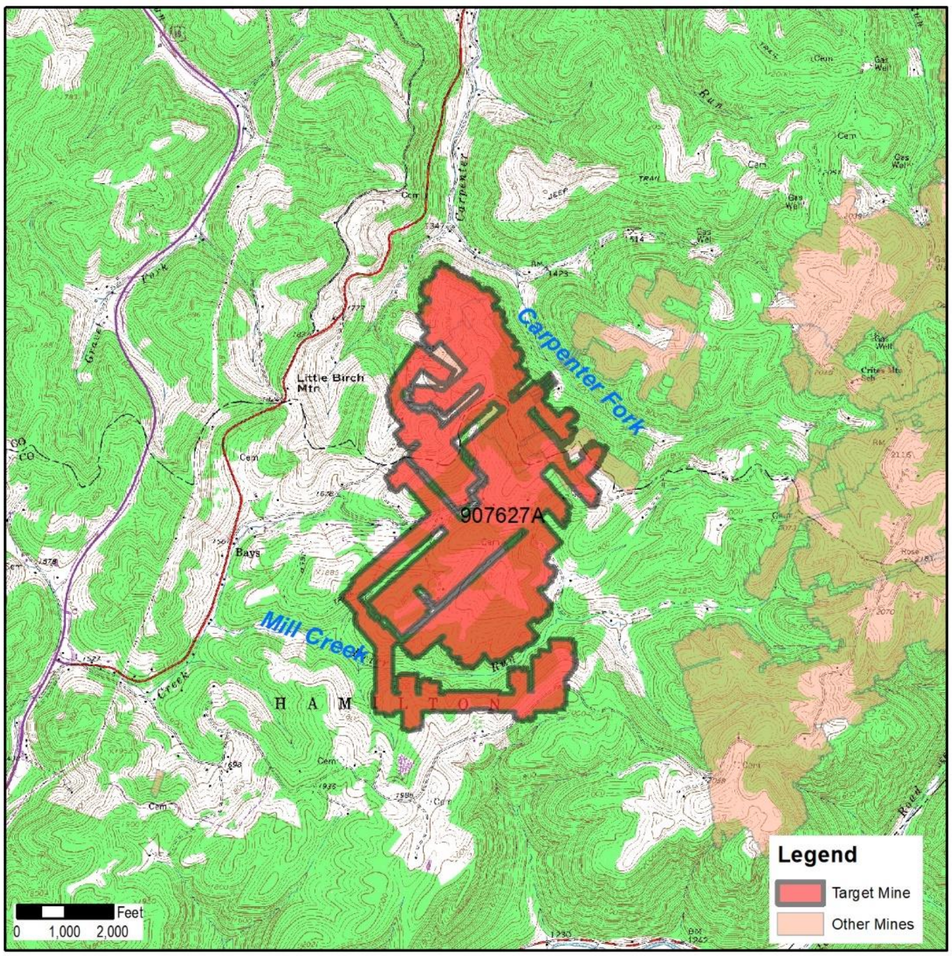
Option 3: Braxton and Nicolas County Site, Little Birch Quadrangle
Aperture card: 907627A
Mine and Company Name: Mine No. 10A, Brooks Run Mining Company
Date: 2007
MSHA number: 46-08852
Details: Drift mine in the Coalburg seam:, utilizing a surface reservoir.

The target mine roof is approximately 30 feet of shale, the floor is 1-2 feet of shale overlying 13 feet of sandstone.

The surface reservoir could be constructed on either of 2 forks of Carpenter Fork of Little Birch River or the upper portion of Mill Creek of Birch River near the community of Bays.

Situated on Little Birch quadrangle, Braxton and Nicholas counties. Nearest town is Summersville, WV approximately 20 miles south southwest with a population of 3,322 as of 2018.

Considerations: A few residents would need to be relocated for a large surface reservoir.



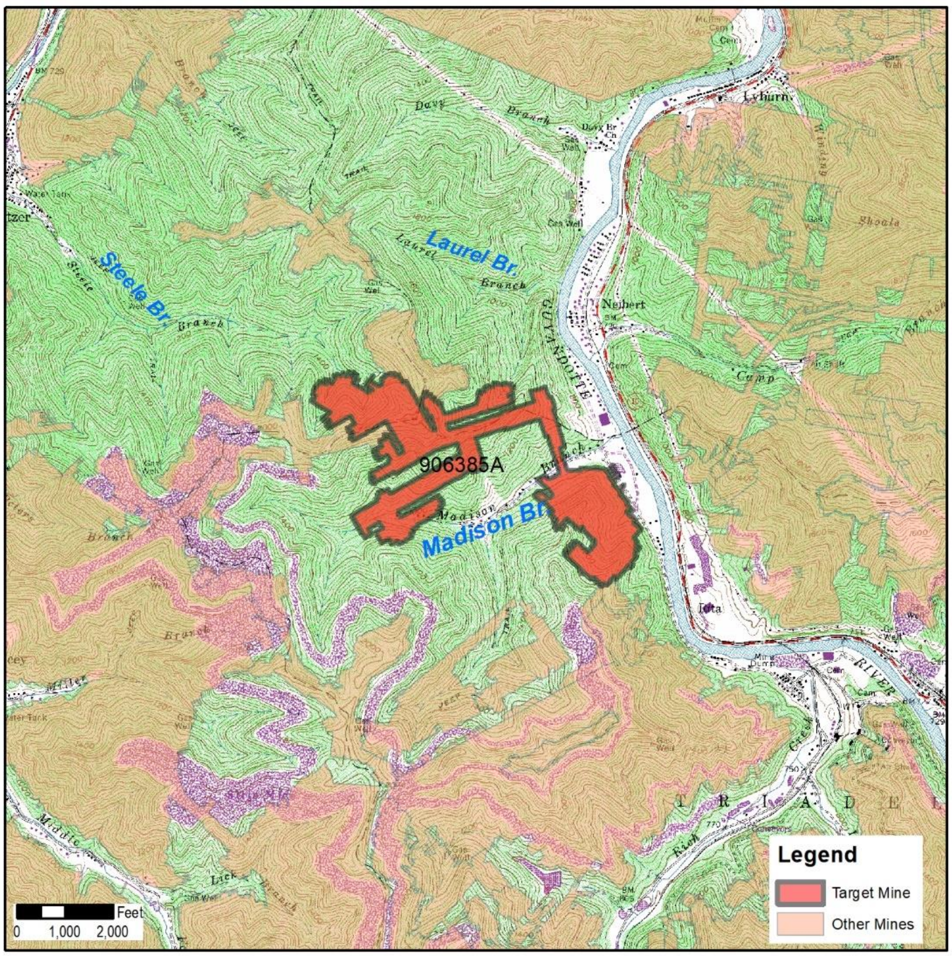
Option 4: Logan County Site, Logan Quadrangle
Aperture card: 906385A
Mine and Company Name: No. 8-C Mine, White's Mining, LLC.
Date: 2005
MSHA number: 46-06500
Details: Drift mine in the Eagle seam utilizing a surface reservoir.

The target mine roof is sandy shale approximately 20 feet thick, the floor is one foot of shale overlying eight feet of sandstone or sandy shale.

The surface reservoir could be constructed on either Madison Branch or Laurel Branch of the Guyandotte River or one of several forks of Steele Branch of Island Creek above the community of Switzer.

Situated on Logan quadrangle, Logan County. Nearest town is Logan, WV approximately five miles north. Several smaller towns including Switzer and Neibert are nearer, both less than one mile away.

Considerations: The surface reservoir would require moving several residents.



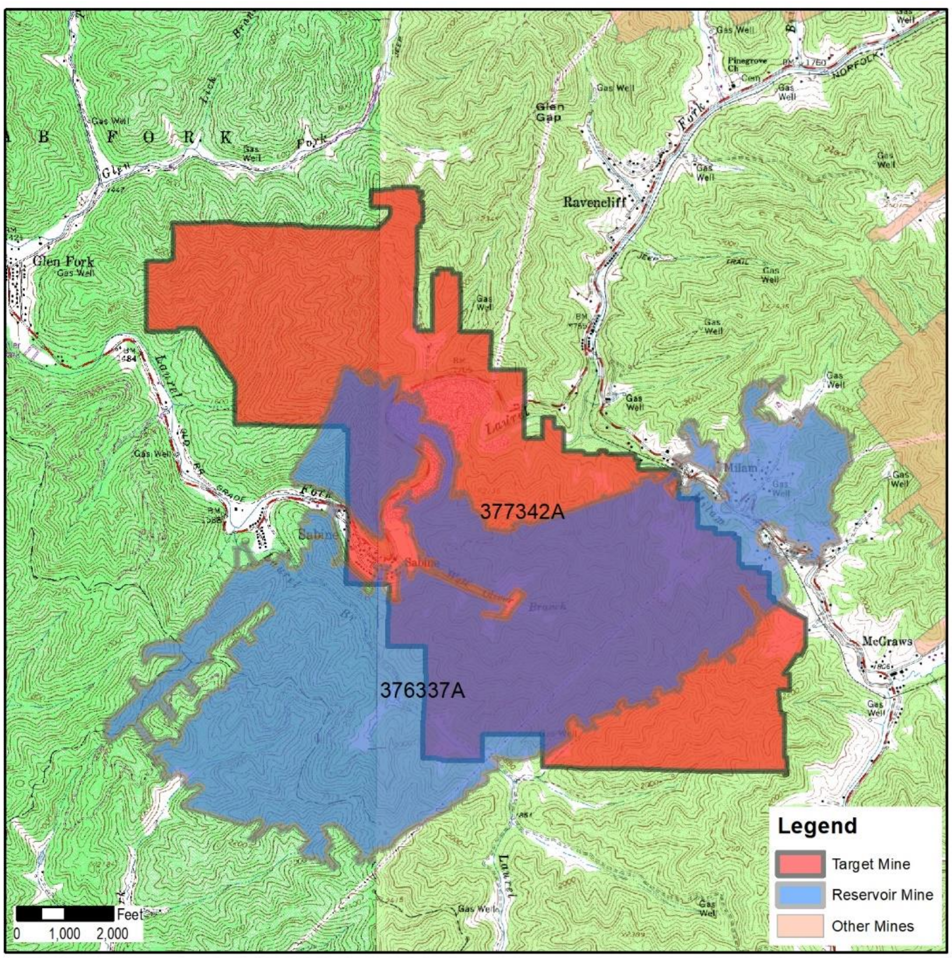
Option 5: Wyoming County No. 1 Site, McGraws and Matheny Quadrangles
Aperture card: 377342A
Mine and Company Name: Beckley No. 2 Mine, Ranger Fuel Corporation
Date: 1988
MSHA number: 46-04581
Details: Shaft mine in the Firecreek seam utilizing an upper mine reservoir aperture card 376337A, No. 1 Mine, J & J Motors, Inc., map dated 1978, in the Sewell seam.

The target mine floor is approximately 20 feet of shale while the roof is 30+ feet of shale with sandstone.

The upper reservoir floor is approximately 40+/- feet of shale with sandstone streaks while the roof is sandstone.

Situated on McGraws and Matheny quads, Wyoming County. Nearest towns are Ravencliff 0.75 miles to north, McGraws 0.30 miles east or Glen Fork 0.5 miles to the west.

Considerations: Target mine floor is 20 feet of soft erodible lithology. Upper reservoir mine floor has 40+ feet of soft lithology. Drilling will need to be conducted in order to better ascertain floor qualities of each mine.



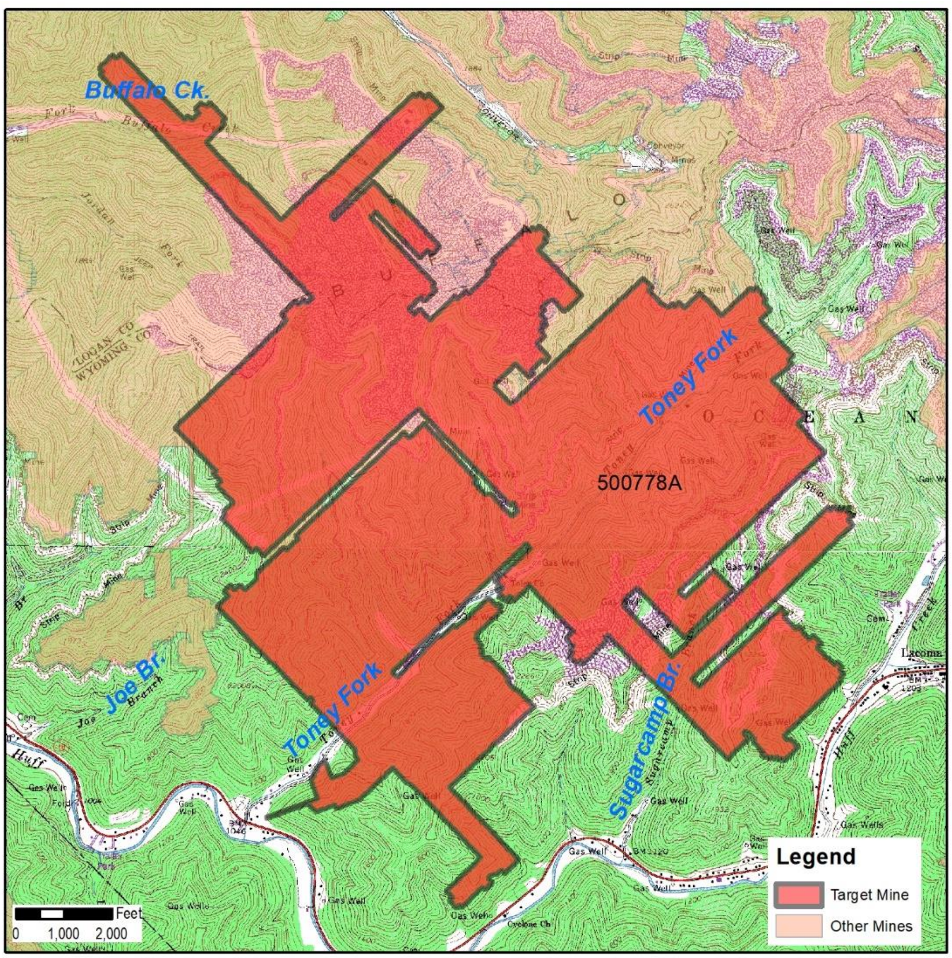
Option 6: Wyoming and Logan Counties Site, Lorado and Oceana Quadrangles
Aperture card: 500778A
Mine and Company Name: Lower War Eagle Mine, Cliffs Logan County Coal/Greenbrier Minerals
Date: 2020
MSHA number: U-4002-99A
Details: Shaft mine in the Glen Alum Tunnel seam, utilizing a surface reservoir.

Target mine floor is 20 +/- feet of shale with coal streaks, roof is approximately 20 +/- feet of shale with coal streaks.

Upper reservoir can be constructed on Toney Fork, Sugarcamp Branch, Joe Branch or one of their unnamed tributaries all of Huff Creek of the Guyandotte River. Other options are Right Fork of Buffalo Creek, or Dingess Branch of Buffalo Creek.

Situated on Loredo and Oceana quadrangles, Wyoming and Logan counties. Nearest town is Amherstdale population 350 (2010 census) approximately four miles northwest. Other smaller communities in the vicinity include Becco, Crites, Landale, Lorado, Lacoma, Cyclone and Campus.

Considerations: WVGS's records show the lower storage mine may still be active. The mine floor is soft and erodible.



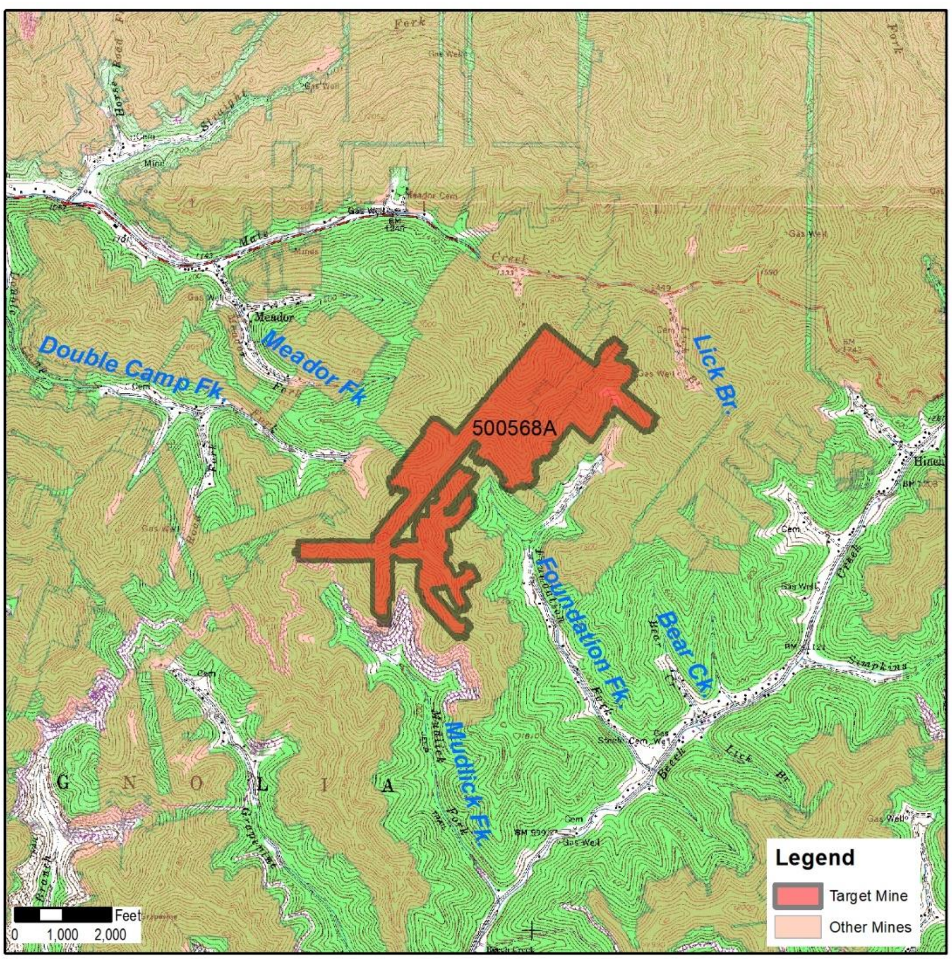
Option 7: Mingo County Site, Majestic Quadrangle
Aperture card: 907816A
Mine and Company Name: Marshall Mining No. 21 Mine, Marshall Mining
Date: 2007
MSHA number: 46-08812
Details: Drift mine in the Number 2 Gas seam, utilizing a surface reservoir

The target mine roof is approximately 20 +/- feet of shale, the floor is interbedded shale and thin coaly seams extending over 20 feet. There is limited drillhole coverage in this area.

The surface reservoir could be situated on Mudlick Fork, Foundation Fork, or Bear Creek of Beech Creek of the Tug Fork River or on Lick Branch, Meador Fork, or Double Camp Fork of Mate Creek of the Tug Fork.

Situated on Majestic quad, Mingo County. Nearest town is Matewan, population 435 (2018) approximately 6 miles west or Red Jacket, population 581 (2018) 5 miles northwest. Surrounding smaller communities include Hinch, Meador, Newtown, and Thacker Mines.

Considerations: Target mine floor is composed of approximately 20 feet of soft shaley lithology but limited drill logs in the WVGES archives limit the amount of information available. More drilling will need to be conducted to better ascertain floor conditions. All stream valleys available for reservoir construction have several residences which will need to be moved.



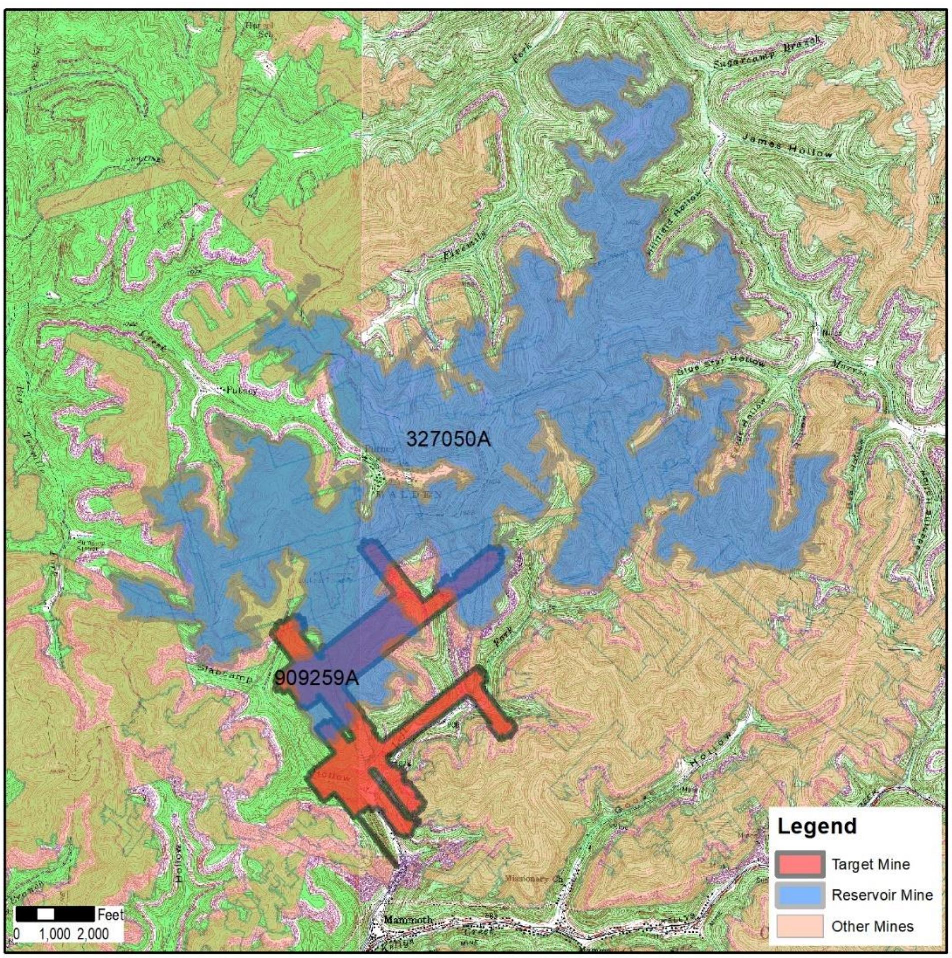
Option 8: Kanawha County Site, Quick and Mammoth Quadrangles
Aperture card: 909259A
Mine and Company Name: Mammoth No 2 Gas Slope Mine, Spartan Mining
Date: 2014
MSHA number: 46-09108
Details: shaft mine in the No. 2 Gas seam, utilizing an upper mine reservoir in the Campbell Creek Mine, Campbell Creek Coal Co., map dated 1961(?), no permit listed, aperture card 327050A in the Number 5 Block seam.

Target mine floor is approximately 20 +/- feet of interbedded shales, fireclays and coals, the roof is approximately 15 feet of interbedded shale, coal, and sandy shales.

Upper Reservoir floor is approximately 12 feet of shale, fireclay and sandy shale overlying 60 to 80 feet of sandstone, the roof is approximately 50 feet of sandstone.

Situated on Quick and Mammoth quads, Kanawha County. Nearest towns are Mammoth population 500 +/-, 0.5 miles south, East Bank population 887 (2018) and Cedar Grove population 997 (2010 census) approximately 4.5 miles southwest.

Considerations: Lower target mine floor is composed of soft lithologies as is the upper reservoir mine floor. Upper mine is almost 60 years old and will have experienced deterioration which would need reviewed. It is suspected the upper mine has been pillared which compromises roof conditions. Also the upper mine is slightly above drainage increasing the possibility of barrier failure.



Option 9: Boone County No. 1 Site, Sylvester Quadrangle

Aperture card: 909274A

Mine and Company Name: Peerless Rachel Mine, Emerald Processing /Kanawha Eagle, LLC

Date: 2015

MSHA number: 46-09258

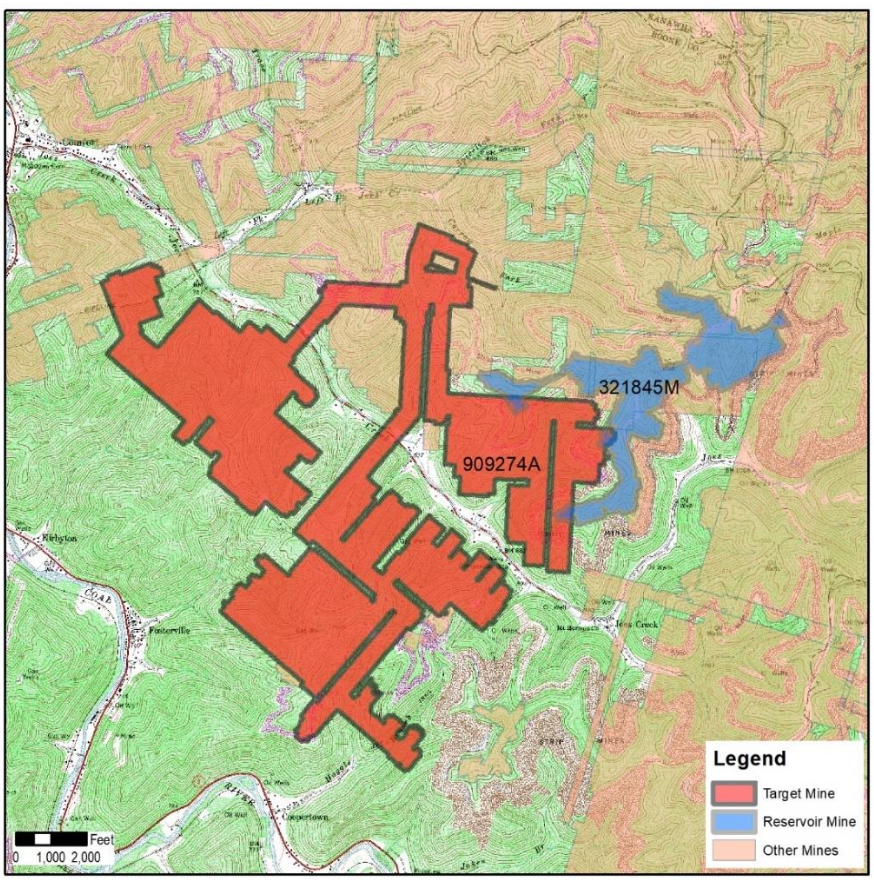
Details: in the Number 2 Gas seam, utilizing an upper mine void reservoir in the No 20 Drift Mine, Carbon Fuel Co., aperture card number 321845M, dated 1973, in the Number 5 Block seam, permit unknown.

Target mine floor is approximately eight feet of shale overlying 20-plus feet of sandstone, the roof is eight feet of shale underlying 26 feet of sandstone or shale.

Upper reservoir mine's floor is approximately 10 feet of shale and sandy shale, the roof is interbedded shale and coal.

Situated on Sylvester quadrangle, Boone County. Nearest towns are Winifrede population 768 and Chelyan population 778 respectively approximately 5 and 6.5 miles to the north. Smaller surrounding communities include Mount Hope, Joes Creek and Comfort.

Considerations: Lower target mine floor is composed of soft lithologies overlying sandstone. Upper mine reservoir is 400 feet above drainage make a substantial possibility of barrier failure. Another option could be a surface reservoir on unnamed creeks off of Joes Creek. There are a few residences in the area that will need to be addressed.



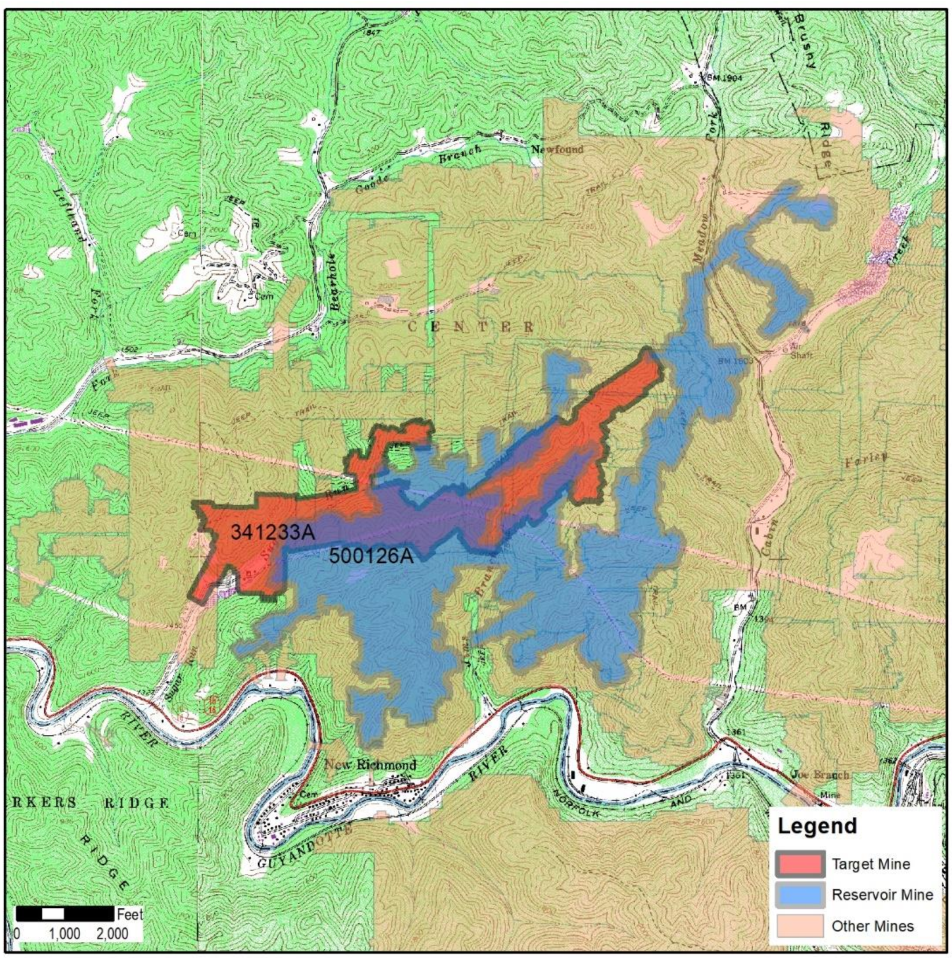
Option 10: Wyoming County No. 2 Site, Pineville and Mullens Quadrangles
Aperture card: 341233A
Mine and Company Name: Itmann Number 4 mine, Itmann Coal Co.
Date: 1975
MSHA number: 46-01577
Details: Shaft mine in the Pocahontas Number 4 seam, utilizing an upper surface mine reservoir in the Firecreek seam, Jims Branch Number 1 mine, Baylor Mining Co., dated 2002, MSHA NO: 46-08537, aperture card number 385837A.

Target mine floor is approximately eight feet of fireclay and sandy shale, the roof is approximately 30 feet of shale and sandy shale.

Upper reservoir floor is approximately one foot of shale underlain by approximately 20 feet of sandstone, the roof is 20+ feet of shale and sandy shale.

Situated on Pineville and Mullens quadrangles, Wyoming County. Nearest towns are Pineville, population 587 (2018) approximately two miles to the west and New Richmond, population 238 (2010), 1.0 miles south.

Considerations: Itman Number 4 is at least 45 years old. Substantial deterioration could be discovered in the mine. The floor is very soft fireclay and shales.



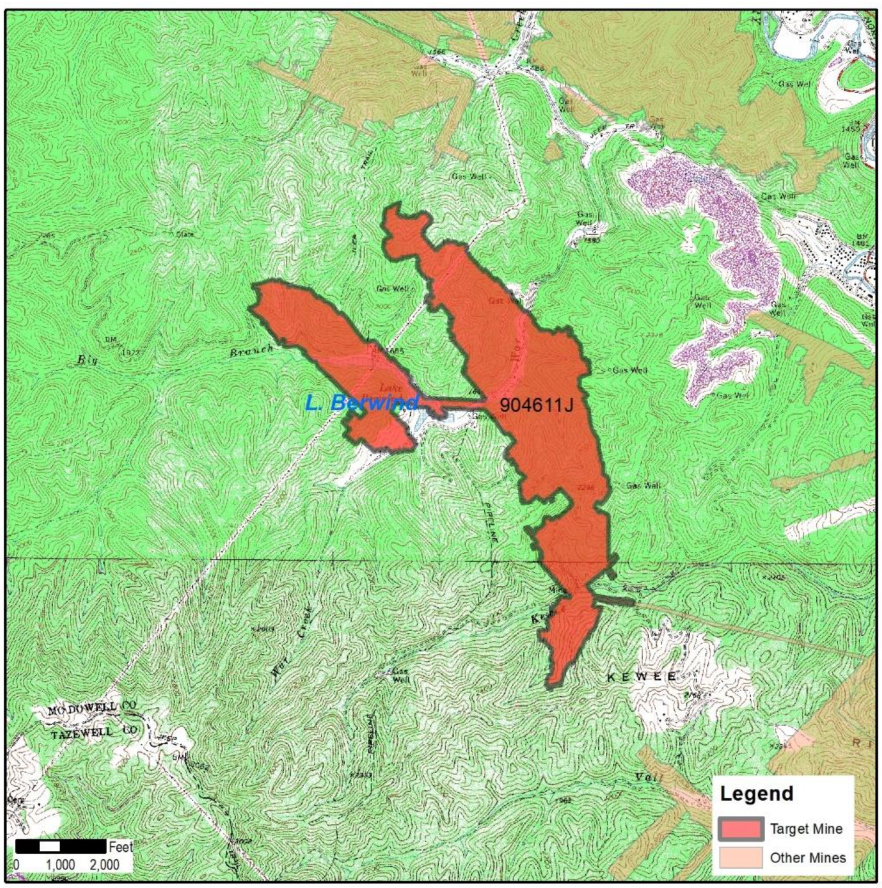
Option 11: McDowell County No. 2 Site, War and Amonate Quadrangles
Aperture card: 904611J
Mine and Company Name: Unknown mine, unknown company
Date: none listed on document
MSHA number: none listed on document
Details: Unclear mining method due to poor document quality, in the Pocahontas Number 4 seam, utilizing a surface reservoir.

Target mine floor is three feet of claystone overlying 50 feet of shale, roof is 3 feet of hard sandstone underlying interbedded sands and shales.

Upper reservoir is potentially Berwind Lake.

Situated on War and Amonate quads, McDowell County. Nearest towns are War, population 705 (2018) approximately 2.25 miles to the north and Berwind, population 278 (2010) approximately 1 mile to the east. Smaller surrounding communities include Canebrake, Cucumber and Rift.

Considerations: A ramp exists between the target mine and a lower Pocahontas No. 3 mine (aperture card number 385844a and 904611J) to the east. The ramp is in the up-dip portion of the mine but could be a source of overflow leakage of reservoir waters. Fortunately the ramp begins in the up-dip portion of the mine so the target mine could be filled with water, as long as it is not overfilled. Secondly the mine map referencing the target mine only shows the mine as an addition to a different mine. Much better mine maps will need to be located in order to proceed. Finally Berwind Lake is probably not suitable for the upper reservoir, however Big Branch or War Creek upstream from the lake could be utilized for a separate surface reservoir. There are very few residences on these streams.



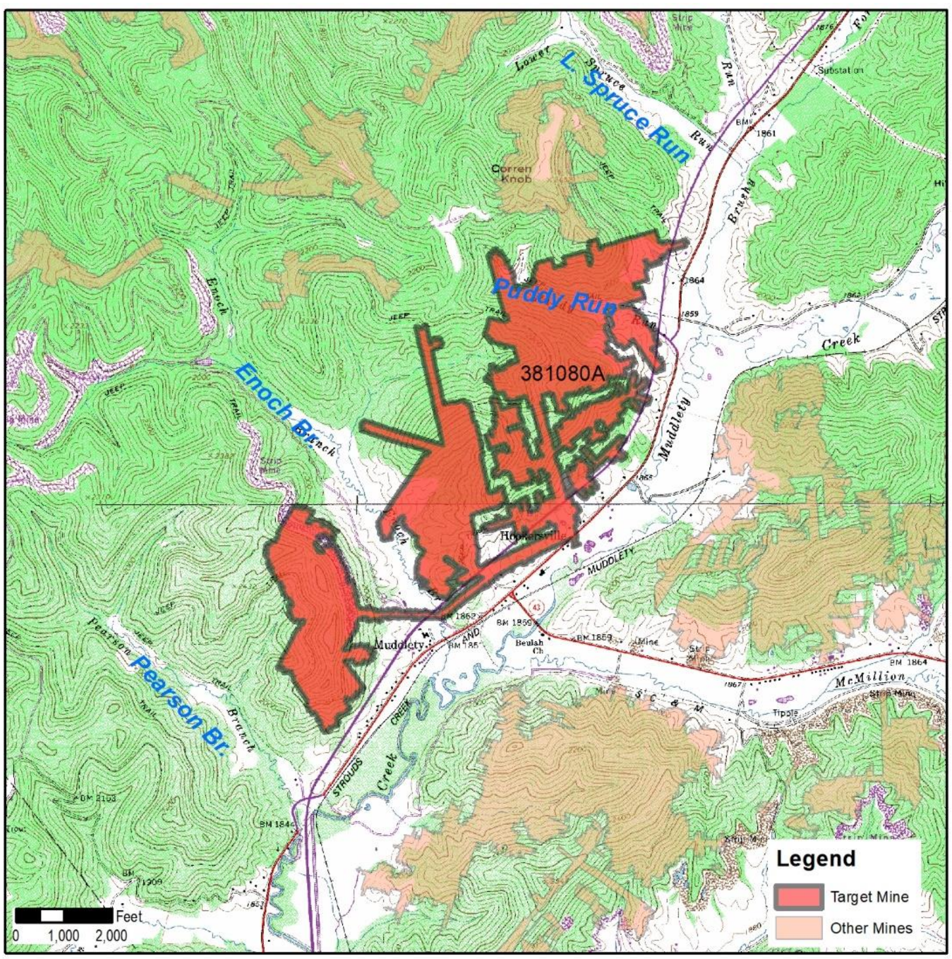
Option 12: Nicholas county Site, Widen and Summersville Quadrangles
Aperture card: 381080A
Mine and Company Name: Day Mine Number 1, Day Mining Inc.
Date: 1994
MSHA number: 46-01735
Details: Unclear mining method due to poor document quality in the Peerless seam, utilizing an upper surface reservoir.

Target mine floor is two to three feet of fireclay overlying 20 +/- feet of shale, sandy shale and sandstone. Mine roof is 15 feet of shale and sandy shale.

Upper reservoir could be constructed on Pearson Branch, Enoch Branch, Puddy Run or Lower Spruce Run all of Muddlety Creek of the Gauley River.

Situated on Widen and Summersville quadrangles, Nicholas County. Nearest town is Summersville, population 3322 (2018) 5.5 miles to the south. Other smaller communities include Muddelty, Hookersville and Kirkwood.

Considerations: Target mine floor lithology is 20+ feet highly erodible soft shale and sandy shale.



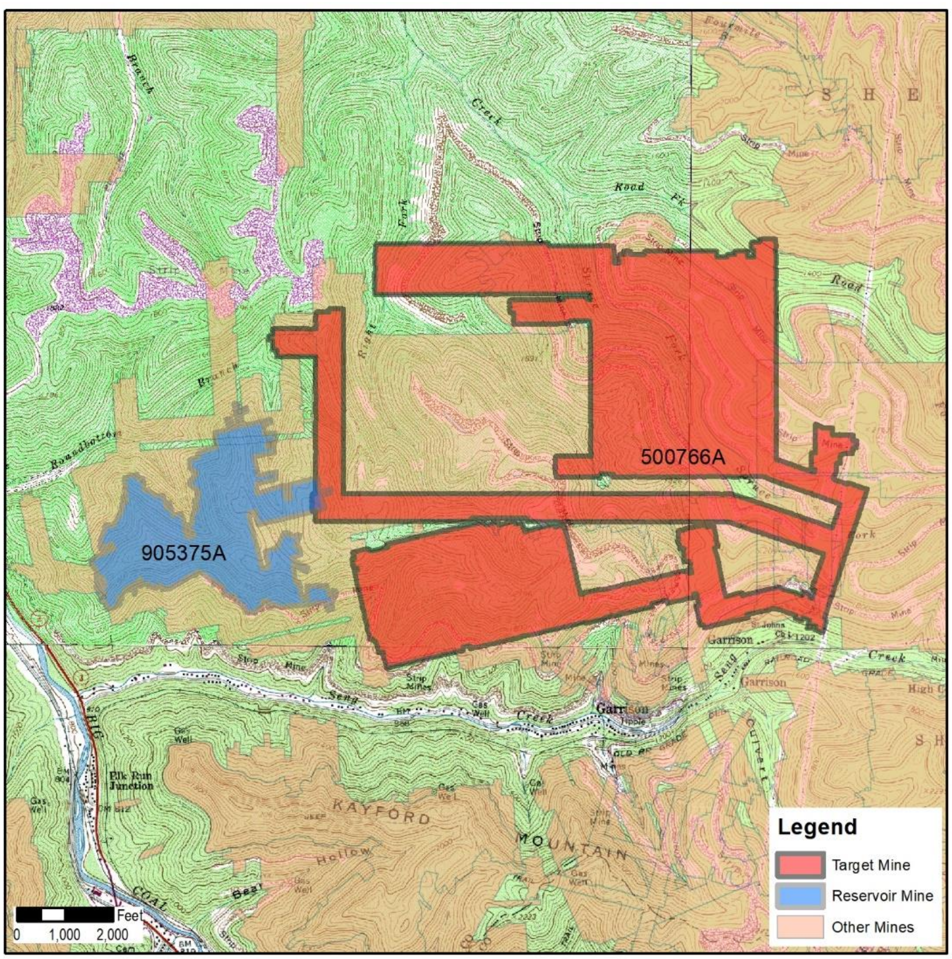
Option 13: Boone County No. 2 Site, Sylvester and Whitesville Quadrangles
Aperture card: 500766A
Mine and Company Name: Hunter Peerless Mine, Elk Run Coal Co.
Date: 2015
MSHA number:
Details: Drift mine currently actively mined in the Williamson seam, utilizing an upper mine aperture card 905375A of unknown name, Webb Coal Co., in the Winifrede seam circa 1948.

Target mine floor is approximately 30 +/- feet of interbedded shales, sandstones with shale streaks, and sandy shales, the roof is 50 + feet of marine shale.

Reservoir mine floor is over 30 feet of sandstone, the roof is 40 + feet of sandstone.

Situated on Sylvester and Whitesville quadrangles, Boone County. Nearest town is Whitesville, population 441 (2018) approximately 2 miles to the south. Smaller surrounding communities include Garrison 0.3 miles south, Kayford, Red Warrior and Sylvester.

Considerations: Target mine floor is questionable with a mix of resistant sandstones and nonresistant shales. Upper reservoir mine is above drainage increasing the possibility of barrier failure, however the mine floor is very good. The possibility of using Spruce Fork or Road Fork of White Oak Creek of Coal River is viable.



Option Summary

Each of the 13 options presented above meet the developed criteria but each has one or more issues that need to be addressed. All locations will require additional core drilling, engineering and geological analysis to more perfectly ascertain their lithologic conditions.

Factoring in roof and floor characteristics and other extenuating circumstances, such as quality mine maps and detailed subsurface data, it is suggested that Option 1, the McDowell County site No. 1 remain in contention but only if considerable data is collected. Although the location, mine type, and lack of adjacent mining are all assets, every cross-referenced mine map in the MIDS database shows no additional data beyond that shown on 906310D. The age of the mining can only be estimated based on the aperture card number and circumstantial evidence from maps at WVGES. If better, more complete mapping could be located, this could be a very viable option.

Option 2, the Wayne County site, Option 3, the Braxton and Nicholas Counties site, Option 4, the Logan County site, Option 5, the Wyoming County No. 1 site, Option 9, the Boone County No. 1 site, Option 11, the McDowell County No. 2 site, Option 12, the Nicholas County site and Option 13, the Boone County site No. 2 are good possibilities based on more resistant roof and floor conditions in the lower target mine. These competent lithologies would be less apt to erode during multiple pumping cycles. Additional mine maps, drillhole data and engineering reports to determine which, if any, are viable.

Option 7, the Mingo County site, Option 8, the Kanawha County site, and Option 10, the Wyoming County No. 2 site should be eliminated from consideration due to soft erodible floor conditions in the lower target mines. Unless the floors were reinforced with grouting, erosion near the pump storage shaft would completely undermine all existing roof support and most likely collapse the mines.

Option 6, the Wyoming and Logan County site will require more study. The lower target mine is reportedly still operating and is a shaft mine but the mine but the floor is an easily erodible shale that would require reinforcement to withstand multiple pumping episodes.

Options 1, the McDowell County No. 1 site, Option 5, the Wyoming County No. 1 site and Option 11, the McDowell County No. 2 site are considered the best possibilities of the options listed above. It is noted that every option has issues that need addressed but these three pairs appear to be the best options available given the available information.

Proximity to power lines is an issue that needs to be addressed. Personal communication with a contractor working in the pump storage field states that a pump storage facility needs to be placed within about 1 mile from power lines. Option 1, the McDowell County No. 1 site has a powerline right of way crossing the mine property east to west. Option 5, the Wyoming County No. 1 site has a major power line right of way transecting the property roughly east to west while Option 11, the McDowell County site has a power line right of way crossing the property northeast to south west.

Regardless of the type of mine selected and meeting all criteria, the reality of the situation is that repeated daily pump cycles of millions of gallons of water could cause massive damage to the existing reservoir mine infrastructure eventually destabilizing the mine to the point of failure. The roof and floor of many mines is generally clay, claystone, shale or some other relatively soft material with interspersed harder sandy units which would be easily eroded. The large amount of loose debris scattered throughout the mines would be a constant source of blockages in any filtration system of the pump system. Reservoir water would become extremely turbid with large fragments of wooden mine support debris.

Other issues would include inter-mine connectivity allowing infiltration of waters into the target or reservoir mines, barrier instability from pressure of stored waters and repeated pumping cycles, compromised mine infrastructure due to deterioration from age.

The pump storage infrastructure within both mines would require workers to be physically in the mines for periods of time. One or more shafts between the two reservoirs would need to be constructed and lined to withstand multiple pumping episodes. It is also likely that the surfaces of the reservoirs would need to be grouted to lessen the damage caused by erosion and to seal the mines.

WVGS does not recommend the construction of a pump storage facility using underground mines. A more likely and cost effective use of mine pool waters is geothermal potential as a heat sink source for geothermal heating and cooling.

GEOTHERMAL POTENTIAL

Geothermal heating systems use a heat pump to transfer heat from the ground to a building and have been in use since the 1940s. A ground source heat pump uses the constant temperature of groundwater as exchange medium. Ground source heat pumps are technically not geothermal like the systems that access hot waters near geysers or other hot spots, but rather utilize groundwater which is near the mean annual temperature of a region.

A typical ground source heat pump for a single home unit uses either vertical loop systems with holes drilled 50 feet or deeper, or, if adequate space is available, a horizontal loop field installed approximately 6 feet below the surface. Circulating waters absorb heat from the ground and return the warmed product to a heat pump which extracts the heat from the fluid. This process can be used for both heating and cooling.

A United States Department of Energy study states that homeowners can save 25 to 50 percent in electric heating costs and up to 72 percent on cooling costs over residences using standard air conditioning equipment.

The thermal mass of large volumes of water can serve as an excellent source of geothermal energy. Generally groundwater would have a temperature near the mean annual temperature for a region, thereby suggesting the mine pool waters should have ambient temperatures in the mid 50s across the state's coalfields. These waters could serve as geothermal feedstock for small to large scale industrial and governmental installations. In appropriate geologic settings, with the correct engineering, geothermal energy can be an economic source of low carbon energy (Preene and Younger, 2014). In conventional geothermal systems the up-front costs to construct the system can be significant. In the case of the mining industry, much of the work required for the geothermal system framework has already been undertaken, possibly reducing costs. Only a handful of mining related geothermal networks have been constructed worldwide, while several proposed projects are in the planning stages.

This is not a new technology and can be economic but there are many engineering challenges and potential ecological risks that must be addressed. Additional detailed geologic and engineering review of each site will need to be conducted.

There are no West Virginia mines with water hot enough to generate electricity (>85 degrees C) therefore heat pumps/exchangers will need to be employed for the system to work.

Three aspects need to be addressed for a geothermal project to be useable.

1 financial savings
2 environmental responsibility
3 gaining benefit from closed and legacy mines

Peele and Younger, (2014) share a few key criteria to assess the feasibility of geothermal systems. The size and parameters of the reservoir, peak temperatures of heat transfer, the quantity And quantity of recoverable energy, determination of the engineering infrastructure of the facility design and potential environmental impacts to determine overall feasibility for a particular project.

Due to the extensive amount of underground mining spread across West Virginia, significant potential exists for geothermal heating and/or cooling systems to be used in industrial, government and private properties. WVGES recommends further examination into this potential energy source.

Several studies in European nations including France and Spain have identified mine pools as potential geothermal sources. Watzlaf and Ackman, 2006 state that mine water could be used in an open loop geothermal heat pump systems. If the mine water is deemed corrosive or scale forming, an additional loop could be used to isolate the mine water from the heat pump

Since 2018, Pennsylvania has been investigating a strategy to boost the use of abandoned mine water in geothermal heating and cooling systems. Korb, 2018 states utilizing geothermal potential for heating and cooling is an established system providing efficient indoor heating and cooling at economical costs with a small carbon footprint. Public buildings such as hospitals, commercial facilities and universities would be ideal settings for such technologies because of their year-round and round-the-clock heating and cooling needs.

An overlying benefit of geothermal heating and cooling requires the circulation of a fraction of the water needed to generate electricity resulting in much less to no erosion of the mine infrastructure thereby preserving the longevity of the mine roof and floor.

Methodology

A geodatabase file for all incorporated towns in West Virginia using data from the United States Census Bureau served as a base file for this query. These spatial data were joined to the same geodatabase of underground mines used in the mine pool study. Each town/city overlying or near underground mining is listed in Appendix 2 along with 2010 census population information, mine ID, mine name, company name, seam designation and storage capacity.

Incorporated towns selected in this study are scattered throughout the coal measures with locations in both the northern and southern coalfields. Water-filled mines underlying or near incorporated towns were identified in seams ranging from the Monongahela Group in the upper portion of the stratigraphic column through Pocahontas-aged coals in the lower portion of the section (Figure 8). Municipalities are listed alphabetically followed by the mine(s) either directly underlying, or within a ¼ or ½ mile buffer of the city limits in separate appendices. Note that some mines will be represented in all three appendices because of their large size.

If a buffer of greater than ½ mile were requested, the amount of generated water-filled mines which could be useable for geothermal heating and cooling would increase dramatically.

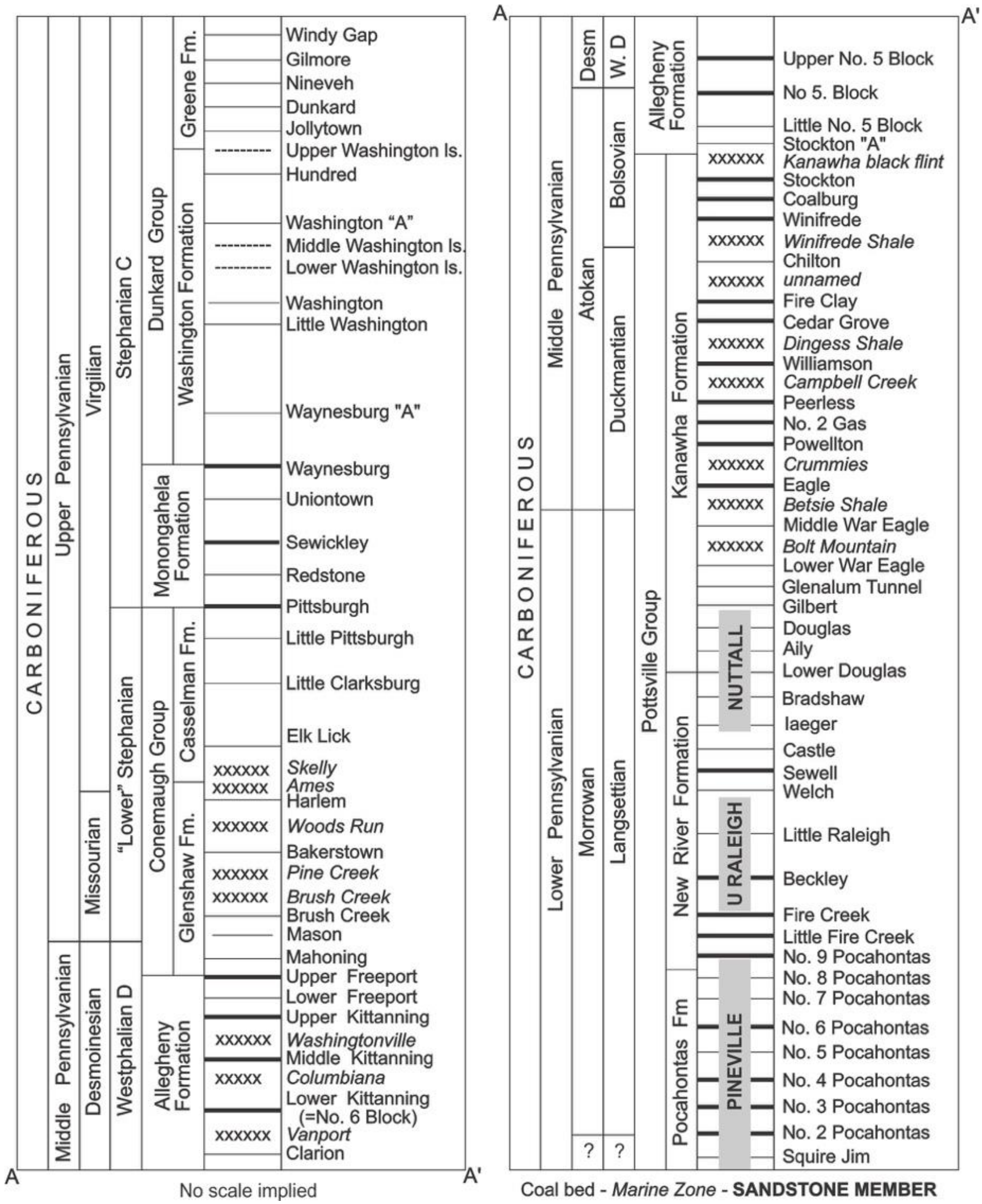


Figure 8: Chronostratigraphic chart of Pennsylvanian stratigraphy of West Virginia coal seams (Blake et al, 2002).

The elevation of the water-filled mine below the surface was not included in the final spreadsheet but is a factor in construction costs and can be generated quickly.

An additional geodatabase from the WVU GIS Tech center includes all industrial parks for the state. The file only contained limited locations which greatly under-represents the total number of sites in West Virginia, but the process demonstrates the ability to determine initial viability of geothermal possibilities at a particular site.

If the WVGES were provided with a more complete shape file of industrial site footprints, the flooded mine location identification process could easily be rerun and more complete results given.

Examination of incorporated towns resulted in 34 water-filled mines directly under the towns, 46 within a quarter mile and 52 water filled mines within one half mile.

The same process was conducted on industrial park locations and produced 11 water-filled mines directly under the sites, 18 water-filled mines within a quarter mile of the sites and 22 water-filled mines within a half mile.

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APPENDIX 1

Worksheet Metadata

Explanation of Worksheet Columns

Worksheet 1 – Portals_Structure-Connectivity

- MINE_ID - number assigned based on the mine map from which the polygon was obtained, letters represent different mine polygons taken from the same map. These data are all available in the WVGS MIDS website.
- SEAM - Coal seam in which the basal mine resides. Uses a WVGS assigned three letter code. Note that several seams may be found on a single document and correlations may change with newer and better data.
- STORAGE_GA - the storage capacity (in gallons) of each basal mine polygon. Potential storage gallons calculated from the Mine Pool Volumetric Calculation.
- Down Dip Portal – describes a basal mine whose outlet to the surface is lower in elevation than the rest of the mine. The ideal mine will have portals that are higher in elevation than the rest of the mine eliminating potential for blowouts.
- Date – date on the map of the basal mine, may be useful to infer conditions within the mines. The date information is gleaned from the mine map, not all mine maps contain accurate dates. Note that dates are also included in the engineers stamp affixed to the map but is not considered to be the date of the map.
- Structure – any structural features listed on the original mine maps that may be of concern. Company added structural contours are usually considered to be accurate based on the amount of data the company has that the survey does not.
- Connected to Other Mines – examines interconnectivity of the basal mine to any other lateral mines in the area. Less than two hundred and fifty feet of separation is used as an indicator. Less than this number will be considered a potential problem since the mines will likely be hydrologically connected thus introducing unpredictable variables. For example fractures or rubblization could compromise the seal of a particular mine allowing water to 'leak' from the mine, down dip into an adjoining mine or for water in an up dip adjoining mine flow into the target mine filling the void which would not allow the water level to be drawn down for the system to work.
- Mine Type – The type of underground mine, options include slope, shaft, drift and longwall. Enter each mine name so they may be searched.
- Within 250' of an outcrop – Any mines that are less than two hundred and fifty feet from an outcrop should be removed to avoid the possibility of a blowout. One exception to this rule: if the portals are up dip from the main body of the mine.
- Comments – note any criteria that may be important for future use to explain why a mine was or wasn't selected for consideration.

Worksheet 2 – Overlying Mines

- MINE_ID - number assigned based on the mine map from which the polygon was obtained, letter represent different mine polygons taken from the same map. All data is available on the WVGS MIDS website.

- SEAM - Coal seam in which the basal mine resides. Uses a WVGS assigned three letter code. Note that several seams may be found on a single document and correlations may change with newer and better data.
- Storage_GA - the storage capacity (in gallons) of each basal mine polygon. Potential storage gallons calculated from the Mine Pool Volumetric Calculation.
- Date - date on the map of the basal mine, may be useful to infer conditions within the mines
- Overlying Map – the Mine ID of any mine that exists over top of the basal mine in the study that passed the original queries from Worksheet 1.
- Seam - Coal seam in which the overlying mine resides. Uses a WVGS assigned three letter code. Note that several seams may be found on a single document and correlations may change with newer and better data.
- Date – date on the map of the overlying mine, may be useful to infer conditions within the mines. The date information is gleaned from the mine map, not all mine maps contain accurate dates. Note that dates are also included in the engineers stamp affixed to the map but is not considered to be the date of the map.
- Storage_GA above/near water table – A value of potential water storage above and near (within 20 feet above or below) the water table.
- Storage_GA below water table - gives a value of potential water storage below the water table.
- Storage_GA - the storage capacity (in gallons) of each overlying mine polygon. These values can be calculated.
- Difference in Storage GA – a measure in the difference of the storage capacity between the Target and Storage mines. Useful to make sure the mines will not over or under fill during the exchange of water. Cannot be computed until the Storage_GA of the overlying mines have been calculated.
- Upper Longwall - Describes if the overlying mine was created using longwall mining techniques. As before, longwall mining will eliminate the mine from consideration due to unstable and rubblized conditions.
- Flooded under Flooded – indicates if another flooded mine overlies the flooded mine in question. If a flooded mine is overlying, the lower mine will be eliminated due to concerns of infiltration of upper mine waters into the lower mine.
- >100' – a measure of whether the basal and overlying mines are separated by at least one hundred feet of thickness. This was a criteria provided by the West Virginia Office of Energy.
- Mine or Surface – tells whether we are looking at a basal and overlying mine or a basal mine and the surface.
- Notes – any notes deemed pertinent by the geologist.

Worksheet 3 – Surface

- MINE_ID - number assigned based on the mine map from which the polygon was obtained, numbers represent different mine polygons taken from the same map. All data is available on the WVGS MIDS website.
- SEAM - Coal seam in which the basal mine resides. Uses a WVGS assigned three letter code. Note that several seams may be found on a single document and correlations may change with newer and better data.
- Date - date on the map of the basal mine, may be useful to infer conditions within the mines. The date information is gleaned from the mine map, not all mine maps contain accurate dates. Note that dates are also included in the engineers stamp affixed to the map but is not considered to be the date of the map.

- Overlying Map - the Mine ID of any mine that exists over top of the basal mine in the study that passed the original queries from Worksheet 1.
- Seam - Coal seam in which the overlying mine resides. Use the three letter code.
- Date - date on the map of the overlying mine, may be useful to infer conditions within the mines. The date information is gleaned from the mine map, not all mine maps contain accurate dates. Note that dates are also included in the engineers stamp affixed to the map but is not considered to be the date of the map.
- Mine or Surface - tells whether we are looking at a basal and overlying mine or a basal mine and the surface.
- Surface Reservoir – tells whether or not the basal mine exists underneath an area suitable for construction of a surface reservoir.
- Overlying Town/Industry – describes and towns or named places that exist directly over top of the basal mine.
- ¼ mile buffer to town/industry - describes and towns or named places that exist directly over top of the basal mine and to a distance of one quarter mile outside of its geographical location.
- ½ mile buffer to town/industry - describes and towns or named places that exist directly over top of the basal mine and to a distance of one half mile outside of its geographical location.
- State/Federal Land – tells whether or not the basal mine resides underneath federal or state owned lands.
- Notes - any notes deemed pertinent by the geologist.

Worksheet 4 – Mine Stack – Acid

- MINE_ID - number assigned based on the mine map from which the polygon was obtained, numbers represent different mine polygons taken from the same map.
- SEAM - Coal seam in which the basal mine resides. Use the three letter code.
- Date - date on the map of the basal mine, may be useful to infer conditions within the mines
- Overlying Map - the Mine ID of any mine that exists over top of the basal mine in the study that passed the original queries from Worksheet 1.
- Seam - Coal seam in which the overlying mine resides. Use the three letter code.
- Date - date on the map of the overlying mine, may be useful to infer conditions within the mines.
- Mine or Surface - tells whether we are looking at a basal and overlying mine or a basal mine and the surface.
- Mine Stack Problem – describes whether there are any other known mines separating the basal and overlying mines (or surface) which could cause a problem for water flow.
- Assumed Acid Problem – Yes or No as to whether either of the mines being considered will likely have a problem with acid production with the reintroduction of oxygen into the subsurface pool. Very low water pH levels are associated with several coal seams, primarily in the northern portion of West Virginia. Low pH would be extremely detrimental to pump storage infrastructure and caustic to equipment.
- Upper Mine Connectivity – Interconnectivity of the overlying mine to any other mines in the area. Less than one hundred feet of separation is used as an indicator.
- Upper Mine Down Dip Portal - describes an overlying mine whose outlet to the surface is lower in elevation than the rest of the mine. The ideal mine will have portals that are higher in elevation than the rest of the mine.
- Notes - any notes deemed pertinent by the geologist.

Worksheet 5 – Possibilities

- MINE_ID - number assigned based on the mine map from which the polygon was obtained, numbers represent different mine polygons taken from the same map.
- Mine Name – the name assigned to the basal mine by the operator.
- SEAM - Coal seam in which the basal mine resides. Use the three letter code.
- Date - date on the map of the basal mine, may be useful to infer conditions within the mines
- Overlying Map - the Mine ID of any mine that exists over top of the basal mine in the study that passed the original queries from Worksheet 1.
- Mine Name – the name assigned to the overlying mine by the operator.
- Seam - Coal seam in which the overlying mine resides. Use the three letter code.
- Date - date on the map of the overlying mine, may be useful to infer conditions within the mines.
- Mine or Surface - tells whether we are looking at a basal and overlying mine or a basal mine and the surface.

APPENDIX 2
Mine Pool Geothermal Spreadsheets

Mine pool geothermal spreadsheets show incorporated towns and industrial parks with underlying mines, mines within a .25 mile buffer of the town boundary and towns within one half mile of the buffered town boundary. No determination of quality or integrity of the mine pool is implied nor has depth below the surface been added. Additional study will need to be conducted to ascertain the viability of a mine pool geothermal project.

Mines Under Incorporated Towns

Town Name	MINE_ID	MINE_NAME	COMPANY_NA	Seam	STORAGE_GA	POP2010
Barrackville	364456A	BETHLEHEM MINES NO 41	BETHLEHEM MINES	SWK	657,228	1302
Beckley	336829AC	CRANBERRY	NEW RIVER CO	SEW	2,494,792,400	17614
Benwood	905091A	Boggs Run Mine	Boggs Run Mining Co.	PGH	35,332,958	1420
Bethlehem	500313A	SHOEMAKER MINE	CONSOL ENERGY	PGH	12,920,450,122	2499
Blacksville	377261A	BLACKSVILLE NO 1	CONSOLIDATION COAL	PGH	430,840,473	171
Fairmont	364456A	BETHLEHEM MINES NO 41	BETHLEHEM MINES	PGH	7,919,234,260	18704
Fairmont	905272A	Home Fuel Company Mine	Unknown	PGH	2,268,606	18704
Fairview	500412A	LOVERIDGE MINE	CONSOL ENERGY	PGH	26,999,259,165	408
Farmington	367093A	BETHLEHEM MINES NO 44	BETHLEHEM MINES	PGH	8,199,607,008	375
Farmington	364456B	BETHLEHEM MINES NO 8	BETHLEHEM MINES	PGH	4,024,710,551	375
Glen Dale	905096A	Glendale Mine	Glendale Gas Coal Co.	PGH	1,038,534,288	1526
Grant Town	366953A	FEDERAL NO 1	EASTERN ASSOCIATED COAL	PGH	18,890,250,174	613
Mannington	365598A	JOANNE	EASTERN ASSOCIATED COAL	PGH	8,157,129,542	2063
McMechen	905094A	Hitchman Mine	Hitchman Coal & Coke Co.	PGH	3,393,345,974	1926
Moundsville	365156A	PARRS RUN	MINERAL STATE COAL	PGH	910,359,096	9318
Moundsville	316947A	PANAMA OR BEN FRANKLIN	MOUNDSVILLE COAL	PGH	807,942,138	9318
Moundsville	302607A	W VA PENITENTIARY	STATE OF W VA BOARD OF CONTROL	PGH	86,574,014	9318
Moundsville	321771A	ALEXANDER	VALLEY CAMP COAL	PGH	5,805,291,714	9318
Mount Hope	324430A	SUN	NEW RIVER COAL	SEW	1,679,985,962	1414
Mount Hope	367319A	SHERWOOD	UNKNOWN	SEW	31,791,386	1414
New Haven	500476B	FLINT HILL MINE	UNKNOWN	RDT	50,916,595	1560
Newburg	953529B	MOUNTAIN BROOK MINE	UNKNOWN	UFP	95,782,140	329
Oak Hill	336829B	LOCHGELLY	UNKNOWN	SEW	2,103,672,266	7730
Oak Hill	334858A	OAKWOOD	NEW RIVER CO	SEW	2,817,881,488	7730
Oak Hill	368088A	WHIPPLE MINE WORKINGS	NEW RIVER	SEW	1,380,026,141	7730
Sophia	362955A	KEYSTONE NO 4	EASTERN ASSOCIATED COAL	PC3	454,662,209	1344
Sophia	322759B	LILLYBROOK COAL	LILLYBROOK COAL	PC6	938,834,867	1344
Welch	355397A	SHANNON BRANCH	VERA MINING	PC3	5,883,523,256	2406
Welch	906309A	POCA NO. 4	SEMET-SOLVAY DIVISION ALLIED CHEMICAL AND DYE CORP	PC4	594,480,541	2406
Welch	314264A	SHANNON BRANCH COLLIERY	ALLIED CHEMICAL	PC4	390,455,847	2406
Welch	500536A	PINNACLE MINE	PINNACLE MINING CO LLC	PC3	15,888,682,582	2406
Welch	904126A	Unknown	Kingston Pocahontas Coal Co.	PC3	1,390,449,408	2406
Wheeling	953151A	VALLEY CAMP NO 3	VALLEY CAMP COAL	PGH	12,113,878,160	28486
Williamson	379413A	JADE ENERGY NO 2	JADE ENERGY	LPW	268,535,891	3191

Mines within .25 miles of Incorporated Towns

Town Name	MINE_ID	MINE_NAME	COMPANY_NA	Seam	STORAGE_GA	POP2010
Barrackville	364456A	BETHLEHEM MINES NO 41	BETHLEHEM MINES	SWK	657228.4917	1302
Beckley	336829AC	CRANBERRY	NEW RIVER CO	SEW	2494792400	17614
Benwood	905091A	Boggs Run Mine	Boggs Run Mining Co.	PGH	35332958.22	1420
Bethlehem	500313A	SHOEMAKER MINE	CONSOL ENERGY	PGH	12920450122	2499
Blacksville	377261A	BLACKSVILLE NO 1	CONSOLIDATION COAL	PGH	430840473.4	171
Fairmont	364456A	BETHLEHEM MINES NO 41	BETHLEHEM MINES	PGH	7919234260	18704
Fairmont	905272A	Home Fuel Company Mine	Unknown	PGH	2268606.016	18704
Fairmont	337064A	LA-MAR	LA-MAR COAL	SWK	7430164.666	18704
Fairview	500412A	LOVERIDGE MINE	CONSOL ENERGY	PGH	26999259165	408
Farmington	367093A	BETHLEHEM MINES NO 44	BETHLEHEM MINES	PGH	8199607008	375
Farmington	364456B	BETHLEHEM MINES NO 8	BETHLEHEM MINES	PGH	4024710551	375
Glen Dale	905096A	Glendale Mine	Glendale Gas Coal Co.	PGH	1038534288	1526
Grant Town	366953A	FEDERAL NO 1	EASTERN ASSOCIATED COAL	PGH	18890250174	613
Lester	906293DU	UNKNOWN	UNKNOWN	SEW	7489836.43	348
Mannington	365598A	JOANNE	EASTERN ASSOCIATED COAL	PGH	8157129542	2063
McMechen	905094A	Hitchman Mine	Hitchman Coal & Coke Co.	PGH	3393345974	1926
McMechen	306841B	MCMILLAN	UNKNOWN	PGH	25212830.26	1926
Moundsville	365156A	PARRS RUN	MINERAL STATE COAL	PGH	910359096.2	9318
Moundsville	316947A	PANAMA OR BEN FRANKLIN	MOUNDSVILLE COAL	PGH	807942137.8	9318
Moundsville	302607A	W VA PENITENTIARY	STATE OF W VA BOARD OF CONTROL	PGH	86574014.31	9318
Moundsville	321771A	ALEXANDER	VALLEY CAMP COAL	PGH	5805291714	9318
Mount Hope	368132A	PRICE HILL	PRICE HILL COLLIERY	SEW	540355238.2	1414
Mount Hope	324430A	SUN	NEW RIVER COAL	SEW	1679985962	1414
Mount Hope	367319A	SHERWOOD	UNKNOWN	SEW	31791385.65	1414
New Haven	500476B	FLINT HILL MINE	UNKNOWN	RDT	50916595.49	1560
Newburg	953529B	MOUNTAIN BROOK MINE	UNKNOWN	UFP	95782139.9	329
Oak Hill	336829B	LOCHGELLY	UNKNOWN	SEW	2103672266	7730
Oak Hill	334858A	OAKWOOD	NEW RIVER CO	SEW	2817881488	7730
Oak Hill	336829A	SUMMERLEE	UNKNOWN	SEW	1928352823	7730
Oak Hill	368088A	WHIPPLE MINE WORKINGS	NEW RIVER	SEW	1380026141	7730
Oak Hill	365845A	SCARBRO	UNKNOWN	SEW	966018298.5	7730
Pax	903870A	Unknown	New River & Pocahontas Consolidated	SEW	72724434.63	167
Phillipi	500408B	SENTINEL MKT	WOLF RUN MINING CO	MKT	3302968044	2966
Rhodell	323266A	HELEN NO 9	EASTERN GAS & FUEL	PC3	1763798858	173
Shinnston	953128A	WILLIAMS NO 3	SCORPIO MINING	PGH	117590884.9	2201
Sophia	362955A	KEYSTONE NO 4	EASTERN ASSOCIATED COAL	PC3	454662209.4	1344
Sophia	500786A	KEYSTONE NO 5	AFFINITY MINING	PC3	710992463.1	1344
Sophia	322759B	LILLYBROOK COAL	LILLYBROOK COAL	PC6	938834867.5	2406
Welch	355397A	SHANNON BRANCH	VERA MINING	PC3	5883523256	2406
Welch	906309A	POCA NO. 4	SEMET-SOLVAY DIVISION ALLIED CHEMICAL AND DYE CORP	PC4	594480541.4	2406
Welch	314264A	SHANNON BRANCH COLLIERY	ALLIED CHEMICAL	PC4	390455847	2406

Mines within .25 miles of Incorporated Towns

Welch	500536A	PINNACLE MINE	PINNACLE MINING CO LLC	PC3	15888682582	2406
Welch	365820A	MAITLAND NO 3 SEAM	CONSOLIDATION COAL	PC3	721894822.6	2406
Welch	904126A	Unknown	Kingston Pocahontas Coal Co.	PC3	1390449408	2406
Wheeling	953151A	VALLEY CAMP NO 3	VALLEY CAMP COAL	PGH	12113878160	28486
Williamson	379413A	JADE ENERGY NO 2	JADE ENERGY	LPW	268535890.7	3191

Mines within .5 miles of Incorporated Towns

NAME10	MINE_ID	MINE_NAME	COMPANY_NA	AM_CC	STORAGE_GA	POP2010
Barrackville	364456A	BETHLEHEM MINES NO 41	BETHLEHEM MINES	SWK	657228.4917	1302
Beckley	336829AC	CRANBERRY	NEW RIVER CO	SEW	2494792400	17614
Beckley	953436A	ECCLES N0 5	WESTMORELAND COAL	BCK	3497337092	17614
Benwood	905091A	Boggs Run Mine	Boggs Run Mining Co.	PGH	35332958.22	1420
Bethlehem	500313A	SHOEMAKER MINE	CONSOL ENERGY	PGH	12920450122	2499
Blacksville	377261A	BLACKSVILLE NO 1	CONSOLIDATION COAL	PGH	430840473.4	171
Fairmont	364456A	BETHLEHEM MINES NO 41	BETHLEHEM MINES	PGH	7919234260	18704
Fairmont	905272A	Home Fuel Company Mine	Unknown	PGH	2268606.016	18704
Fairmont	337064A	LA-MAR	LA-MAR COAL	SWK	7430164.666	18704
Fairview	500412A	LOVERIDGE MINE	CONSOL ENERGY	PGH	26999259165	408
Farmington	367093A	BETHLEHEM MINES NO 44	BETHLEHEM MINES	PGH	8199607008	375
Farmington	364456B	BETHLEHEM MINES NO 8	BETHLEHEM MINES	PGH	4024710551	375
Fayetteville	336829A	SUMMERLEE	UNKNOWN	SEW	1928352823	2892
Glen Dale	905096A	Glendale Mine	Glendale Gas Coal Co.	PGH	1038534288	1526
Grant Town	366953A	FEDERAL NO 1	EASTERN ASSOCIATED COAL	PGH	18890250174	613
Lester	907761A	BAYBECK MINE NO. 1	TEDDY COAL CO., INC.	BCK	1135942925	348
Lester	906293DU	UNKNOWN	UNKNOWN	SEW	7489836.43	348
Mannington	350404A	CONSOL NO 9	MOUNTAINEER COAL	PGH	9463356076	2063
Mannington	365598A	JOANNE	EASTERN ASSOCIATED COAL	PGH	8157129542	2063
McMechen	905094A	Hitchman Mine	Hitchman Coal & Coke Co.	PGH	3393345974	1926
McMechen	306841B	MCMILLAN	UNKNOWN	PGH	25212830.26	1926
Moundsville	365156A	PARRS RUN	MINERAL STATE COAL	PGH	910359096.2	9318
Moundsville	316947A	PANAMA OR BEN FRANKLIN	MOUNDSVILLE COAL	PGH	807942137.8	9318
Moundsville	302607A	W VA PENITENTIARY	STATE OF W VA BOARD OF CONTROL	PGH	86574014.31	9318
Moundsville	321771A	ALEXANDER	VALLEY CAMP COAL	PGH	5805291714	9318
Mount Hope	368132A	PRICE HILL	PRICE HILL COLLIERY	SEW	540355238.2	1414
Mount Hope	324430A	SUN	NEW RIVER COAL	SEW	1679985962	1414
Mount Hope	367319A	SHERWOOD	UNKNOWN	SEW	31791385.65	1414
New Haven	500476B	FLINT HILL MINE	UNKNOWN	RDT	50916595.49	1560
Newburg	953529B	MOUNTAIN BROOK MINE	UNKNOWN	UFP	95782139.9	329
Oak Hill	336829B	LOCHGELLY	UNKNOWN	SEW	2103672266	7730
Oak Hill	334858A	OAKWOOD	NEW RIVER CO	SEW	2817881488	7730
Oak Hill	368088A	WHIPPLE MINE WORKINGS	NEW RIVER	SEW	1380026141	7730
Oak Hill	365845A	SCARBRO	UNKNOWN	SEW	966018298.5	7730
Pax	903870A	Unknown	New River & Pocahontas Consolidated	SEW	72724434.63	167
Phillipi	500408B	SENTINEL MKT	WOLF RUN MINING CO	MKT	3302968044	2966
Rhodell	323266A	HELEN NO 9	EASTERN GAS & FUEL	PC3	1763798858	173
Shinnston	953128A	WILLIAMS NO 3	SCORPIO MINING	PGH	117590884.9	2201
Sophia	362955A	KEYSTONE NO 4	EASTERN ASSOCIATED COAL	PC3	454662209.4	1344
Sophia	500786A	KEYSTONE NO 5	AFFINITY MINING	PC3	710992463.1	1344
Sophia	322759B	LILLYBROOK COAL	LILLYBROOK COAL	PC6	938834867.5	1344

Mines within .5 miles of Incorporated Towns

War	912168A	CUCUMBER MINE	BROOKS RUN MINING CO LLC	PC3	521706889.1	862
Welch	355397A	SHANNON BRANCH	VERA MINING	PC3	5883523256	2406
Welch	906309A	POCA NO. 4	SEMET-SOLVAY DIVISION ALLIED CHEMICAL AND DYE C(	PC4	594480541.4	2406
Welch	314264A	SHANNON BRANCH COLLIERY	ALLIED CHEMICAL	PC4	390455847	2406
Welch	328855A	CARTER MINES - DRILL HOLES	CARTER COAL	PC4	13333193806	2406
Welch	500536A	PINNACLE MINE	PINNACLE MINING CO LLC	PC3	15888682582	2406
Welch	365820A	MAITLAND NO 3 SEAM	CONSOLIDATION COAL	PC3	721894822.6	2406
Welch	904126A	Unknown	Kingston Pocahontas Coal Co.	PC3	1390449408	2406
Wheeling	953151A	VALLEY CAMP NO 3	VALLEY CAMP COAL	PGH	12113878160	28486
Williamson	379413A	JADE ENERGY NO 2	JADE ENERGY	LPW	268535890.7	3191
Worthington	905312A	Vincent Shaft	Moke Cooperative Coal Co.	SWK	11150846.47	158

Mines under Industrial Parks

Name	City	MINE_ID	MINE_NAME	COMPANY_NA	AM_CC	STORAGE_GA
Fayette County Business Park	Glen Jean	324430A	SUN	NEW RIVER COAL	SEW	1,679,985,962
Three-Mile Curve Site	Dabney	906195B	Dehue Mine	Elkay Mining Company	EAG	1,046,868,071
Coal City Road Site	Sophia	385847A	KEYSTONE NO 5	AFFINITY MINING	PC3	710,992,463
Elks Site	Elm Grove	500313A	SHOEMAKER MINE	CONSOL ENERGY	PGH	12,920,450,122
Indian Ridge Industrial Park	Welch	355397A	SHANNON BRANCH	VERA MINING	PC3	5,883,523,256
Millennium Centre Technology Park	Triadelphia	953151A	VALLEY CAMP NO 3	VALLEY CAMP COAL	PGH	12,113,878,160
John D. Rockefeller IV Industrial Park	Wolf Pen	500536A	PINNACLE MINE	PINNACLE MINING CO LLC	PC3	15,888,682,582
Lester Square Site	Crab Orchard	322759B	LILLYBROOK COAL	LILLYBROOK COAL	PC6	938,834,867
Philippi Development Site	Philippi	500408B	SENTINEL MKT	WOLF RUN MINING CO	MKT	3,302,968,044
White Oak No. 10 Site	Beckley	336829AC	CRANBERRY	NEW RIVER CO	SEW	2,494,792,400
Bull Push Site	Montgomery	364989A	KANAWHA MINES NO 8	CANNELTON INDUSTRIES	EAG	898,832,709

Mines within .25 miles of Industrial Parks

Name	City	MINE_ID	MINE_NAME	COMPANY	SEAM	STORAGE_GA
Fayette County Business Park	Glen Jean	324430A	SUN	NEW RIVER COAL	SEW	1,679,985,962
Marshall County Industrail Park	McMechen	905094A	Hitchman Mine	Hitchman Coal & Coke Co.	PGH	3,393,345,974
Three-Mile Curve Site	Dabney	906195B	Dehue Mine	Elkay Mining Company	EAG	1,046,868,071
Fayette County Business Park	Glen Jean	365845A	SCARBRO	UNKNOWN	SEW	966,018,299
Coal City Road Site	Sophia	385847A	KEYSTONE NO 5	AFFINITY MINING	PC3	710,992,463
Elks Site	Elm Grove	500313A	SHOEMAKER MINE	CONSOL ENERGY	PGH	12,920,450,122
Indian Ridge Industrial Park	Welch	355397A	SHANNON BRANCH	VERA MINING	PC3	5,883,523,256
Millennium Centre Technology Park	Triadelphia	953151A	VALLEY CAMP NO 3	VALLEY CAMP COAL	PGH	12,113,878,160
Wolf Creek Business Park	Oak Hill	336829B	LOCHGELLY	UNKNOWN	SEW	2,103,672,266
John D. Rockefeller IV Industrial Park	Wolf Pen	500536A	PINNACLE MINE	PINNACLE MINING CO LLC	PC3	15,888,682,582
Newman Bottom Site	Phillipi	349862A	MIDLAND COAL & COKE NO 1	MIDLAND COAL & COKE	MKT	123,144,996
Lester Square Site	Crab Orchard	322759B	LILLYBROOK COAL	LILLYBROOK COAL	PC6	938,834,867
Philippi Development Site	Philippi	500408B	SENTINEL MKT	WOLF RUN MINING CO	MKT	3,302,968,044
White Oak No. 10 Site	Beckley	336829AC	CRANBERRY	NEW RIVER CO	SEW	2,494,792,400
Three-Mile Curve Site	Dabney	362958C	MELVILLE	HUTCHINSON COAL	EAG	760,189,964
Moundsville North Plant Site	Moundsville	316947A	PANAMA OR BEN FRANKLIN	MOUNDSVILLE COAL	PGH	807,942,138
Bull Push Site	Montgomery	366045B	CANNELTON COAL NO 4	CANNELTON COAL	N2G	26,429,160
Bull Push Site	Montgomery	364989A	KANAWHA MINES NO 8	CANNELTON INDUSTRIES	EAG	898,832,709

Mines within one half mile of Industrial Parks

Name	City	MINE_ID	MINE_NAME	COMPANY_NA	SEAM	STORAGE_GA
Lester Square Site	Crab Orchard	953436A	ECCLES N0 5	WESTMORELAND COAL	BCK	3,497,337,092
Fayette County Business Park	Glen Jean	324430A	SUN	NEW RIVER COAL	SEW	1,679,985,962
Marshall County Industrail Park	McMechen	905094A	Hitchman Mine	Hitchman Coal & Coke Co.	PGH	3,393,345,974
JLW LLC Site	Bradley	368132A	PRICE HILL	PRICE HILL COLLIERY	SEW	540,355,238
Three-Mile Curve Site	Dabney	906195B	Dehue Mine	Elkay Mining Company	EAG	1,046,868,071
Fayette County Business Park	Glen Jean	365845A	SCARBRO	UNKNOWN	SEW	966,018,299
Coal City Road Site	Sophia	385847A	KEYSTONE NO 5	AFFINITY MINING	PC3	710,992,463
Elks Site	Elm Grove	500313A	SHOEMAKER MINE	CONSOL ENERGY	PGH	12,920,450,122
Indian Ridge Industrial Park	Welch	355397A	SHANNON BRANCH	VERA MINING	PC3	5,883,523,256
Millennium Centre Technology Park	Triadelphia	953151A	VALLEY CAMP NO 3	VALLEY CAMP COAL	PGH	12,113,878,160
Wolf Creek Business Park	Oak Hill	336829B	LOCHGELLY	UNKNOWN	SEW	2,103,672,266
John D. Rockefeller IV Industrial Park	Wolf Pen	500536A	PINNACLE MINE	PINNACLE MINING CO LLC	PC3	15,888,682,582
Newman Bottom Site	Phillipi	349862A	MIDLAND COAL & COKE NO 1	MIDLAND COAL & COKE	MKT	123,144,996
Lester Square Site	Crab Orchard	322759B	LILLYBROOK COAL	LILLYBROOK COAL	PC6	938,834,867
Philippi Development Site	Philippi	500408B	SENTINEL MKT	WOLF RUN MINING CO	MKT	3,302,968,044
White Oak No. 10 Site	Beckley	336829AC	CRANBERRY	NEW RIVER CO	SEW	2,494,792,400
Three-Mile Curve Site	Dabney	362958C	MELVILLE	HUTCHINSON COAL	EAG	760,189,964
Moundsville North Plant Site	Moundsville	316947A	PANAMA OR BEN FRANKLIN	MOUNDSVILLE COAL	PGH	807,942,138
Marshall County Industrail Park	Moundsville	302607A	W VA PENITENTIARY	STATE OF W VA BOARD OF CONTROL	PGH	86,574,014
Earl Ray Tomblin Industrial Park	Holden	363123H	Mine No. 8	Island Creek Coal Co.	N2G	1,076,314,104
Bull Push Site	Holden	366045B	CANNELTON COAL NO 4	CANNELTON COAL	N2G	26,429,160
Bull Push Site	Montgomery	364989A	KANAWHA MINES NO 8	CANNELTON INDUSTRIES	EAG	898,832,709