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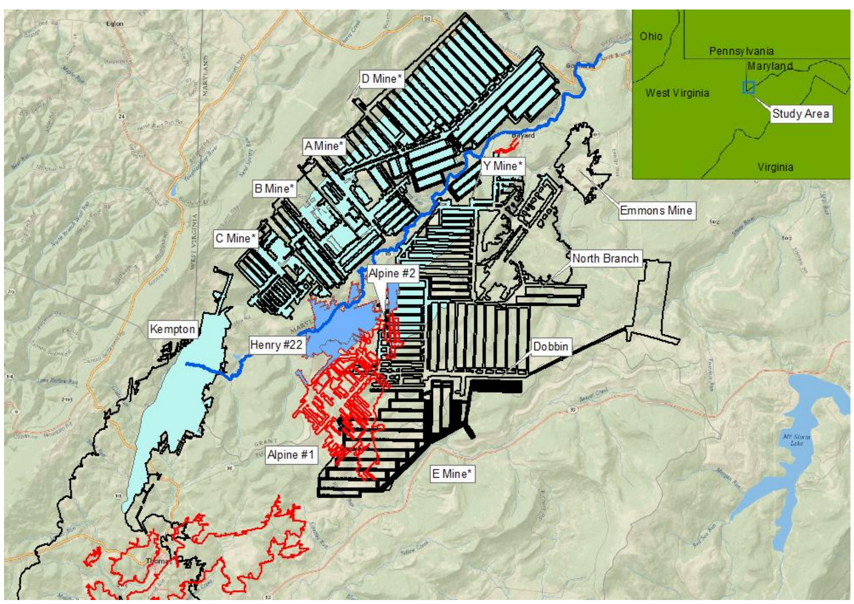
NORTH BRANCH POTOMAC RIVER MINE POOL ASSESSMENT STUDY



APPALACHIAN REGIONAL OFFICE- Nancy Pointon and Jack Felbinger

NOVEMBER 2013

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NORTH BRANCH POTOMAC RIVER MINE POOL ASSESSMENT STUDY

ABSTRACT

There has been and currently are significant underground mining activities within the headwaters of the North Branch Potomac River which spans both the Maryland and West Virginia state line. These activities have a potential for significant current and future hydrologic impacts to the river. This report provides a characterization of the extent and conditions of the current underground mine pools in addition to a prediction for future conditions. The study area includes 12 underground mine sites on 2 coal seams. The mines are a combination of abandoned, active and inactive underground mines. Currently all of the mines have pools being managed by either a coal company or a state agency.

Eleven groundwater sampling sites which includes eight wells, two flowing artesian wells and a deep mine discharge are located within the study area and were sampled as part of the study. Water quality data indicate variability in the mine pools is dependent on the coal seam, saturated conditions of the mine, and timing of the mining activities. Iron, total dissolved solids, and sulfate concentrations are the main water quality concerns for all pools. Currently water from the pools are pumped and/or collected then treated and discharged to the surface or maintained at an elevation below surface drainage.

Predicting future conditions within mine pools and assessing risks posed to surrounding waters is an imprecise endeavor with various methods available. Simple predictive methods are used in this study utilizing water balance equations and groundwater flow principles. These methods are presented to provide a broad based indication of what future hydrologic conditions may exist within the study area and have inherent limitations. The predictions indicate that managing the mine pool elevations at a pool head below the North Branch Potomac River is critical in the protection of the river. Without pool management, most existing mine pools located in both West Virginia and Maryland have the potential to leak and or discharge into the river. Accompanying this leakage is a risk for increased total dissolved solids with accompanying metal concentrations and precipitants to the river.

INTRODUCTION

This report summarizes the results of a study conducted by the Office of Surface Mining Reclamation and Enforcement (OSM), Appalachian Region concerning hydrologic impacts from underground coal mine activities in the headwaters of the North Branch Potomac River watershed. The study area, located upgradient from Gormania, West Virginia (WV) to Kempton, MD, includes 12 underground mines on two coal seams with a total mine acreage in excess of 25,000 acres. Figure 1 shows the location of the study area and salient features.

The Maryland Department of the Environment, Bureau of Mines (MBM) requested OSM's Technical Support Division to undertake this study. Together OSM, MBM and West Virginia Department of Environmental Protection, Division of Mining and Reclamation, in the role of a cooperative partner, developed the study objective and scope of work. The objectives of the study are to: characterize water quantity and quality properties of mine pools within the study area; determine their influence on the flow and chemical composition of the North Branch Potomac River and; estimate potential future hydrologic impacts from the pools individually and collectively.

This study examines the various hydrologic interactions of numerous mines within the study site. The hydrologic evaluations and predictions extend beyond the jurisdiction of one regulatory agency, as the study area encompasses portions of both Maryland and West Virginia. The hydrologic setting of the study area is in a topographic and geologic structural basin where the Potomac River is almost coincident with both the structural and topographic low. The river not only forms the border between the states it is the drain for potential leakage from numerous deep mine pools located in both states. It is for these reasons technical assistance from the Office of Surface Mining was requested.

The study was conducted in three phases. The initial phase focused on characterizing existing hydrologic conditions for each of the deep mines within the study area. Phase two provides predictions for future hydrologic conditions relative to the mine pools and the river. The final phase assesses the potential risks to the North Branch Potomac River posed by the current and potential hydrologic conditions.

A plan for the collection of hydrologic data was developed by MBM and OSM, and initiated in the spring of 2007. A multilevel field investigation was undertaken to gather information on surface and groundwater factors. The plan included the collection of various types of data including the installation of three continuous recording pressure transducers installed in monitoring wells connected to the workings at the Mettiki AB, C, and D Mines in Maryland. These were used to continuously monitor and record the elevation of water, and determine the hydraulic head of the mine pools. The Mettiki mine sites were chosen because mining had ceased, and a mine pool was actively forming. During the active phase of underground mining coal is extracted and groundwater is pumped out of the mine. Once mining is completed, the pumping ceases, groundwater fills the voids and a pool is created. As the mine fills with water and the elevation of the pool is recorded, data on recharge rates and other hydrologic parameters can be calculated and subsequently used to estimate future behavior of the mine pool.

Information on water elevations in each of the mine pools, in addition to other accessible groundwater data was obtained during select field investigations. Water quality sampling of the known mine pools in the study area occurred several times during the period from 2007 to 2010.

There are numerous studies on the Mettiki mine pool authored by federal and state agencies, universities, and the Mettiki Coal LLC. These studies were reviewed and were used in the development of the monitoring plan for this project. A listing of these previous works is found in the Appendix A.

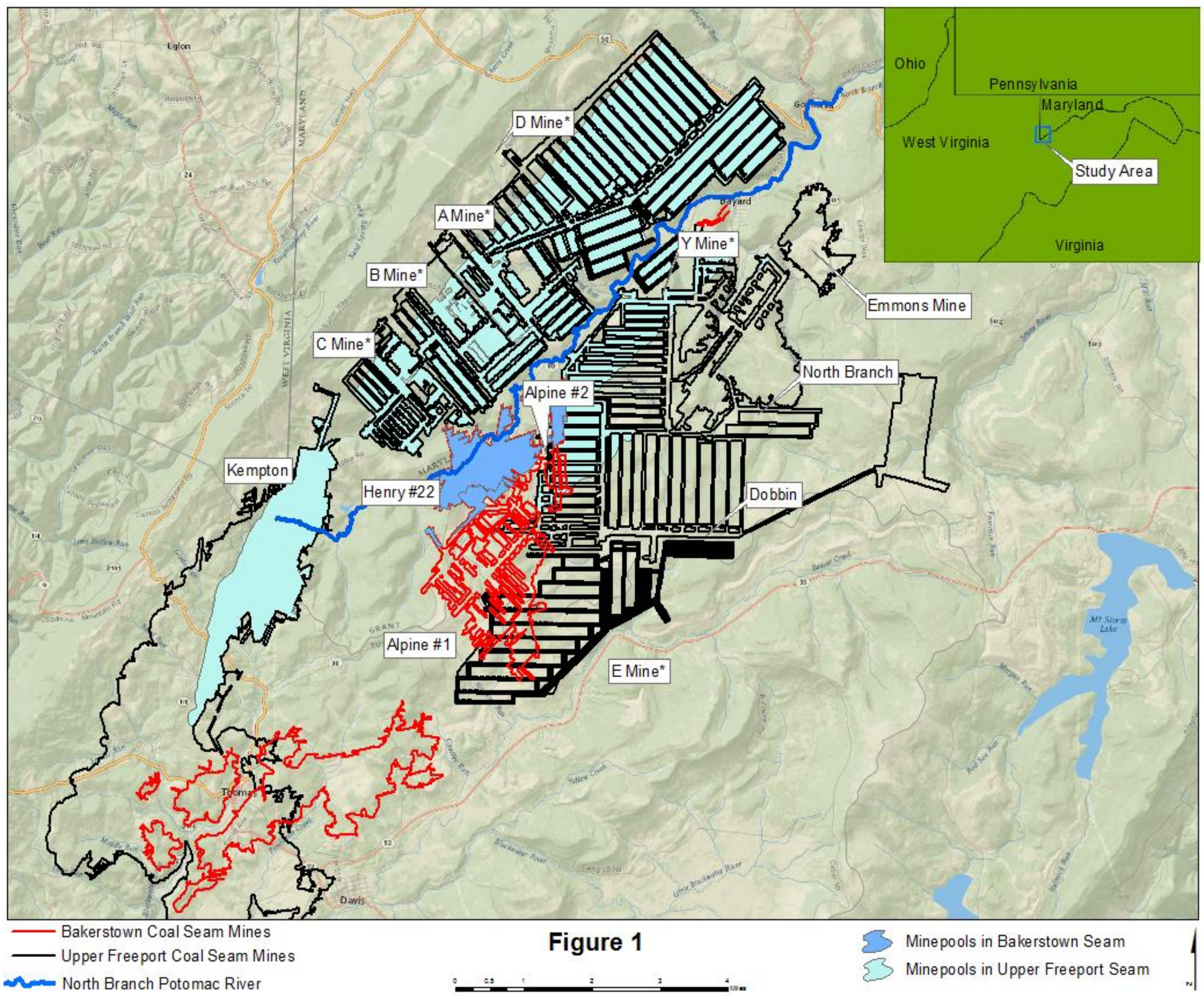


Figure 1

Mining History

The majority of the study area has been impacted by surface and deep mining activities. Underground mining started as early as 1908 on the West Virginia side of the North Branch of the Potomac River. In 1914, the Davis Coke and Coal Company's Kempton Mine in Maryland began extracting the Upper Freeport coal using the room-and pillar mining method at depths ranging from 50 to 700 feet. (Duigon and Smigaj, 1985). Figure 1 shows the location and extent of underground mine works in the Upper Freeport coal bed. Other mines in the Upper Freeport include the Dobbin (also designated Potomac), North Branch and Emmons mines which are abandoned and are currently owned by Consolidated Energy. A number of mining sites operated during the mid-1960s through the mid-1990s. In 2004, Mettiki opened the E Mine, an ongoing longwall operation in the Upper Freeport coal. Early underground mining in the Lower Bakerstown coal, located stratigraphically above the Upper Freeport was conducted in two mines, one by Buffalo Coal Company Mine No. 1 and the other by Davis Coke and Coal Company Mine No. 22. (Duigon and Smigaj, 1985). The extent of the Lower Bakerstown mine works is shown in Figure 1.

Mettiki started underground mining in the area during the summer of 1977 in the Mettiki A Mine which was also known as the Beaver Run Mine. The Mettiki B Mine was known as the Gobblers Knob Mine and mining began in late 1977 or early 1978. The Mettiki C Mine was known as the Big George Mine where mining began in 1978 (Duigon and Smigaj, 1985). The last underground mine Mettiki opened on the Maryland side was the D Mine in 1987. Longwall mining was the predominate method used in the D Mine. The D Mine finished coal production in October 2006 which ended Mettiki's mining in Maryland. Table 1 shows the mining history data such as mines, mining dates, coal production and mine acreage for selected underground mines in the study area.

TABLE 1. Mining History Data for Underground Mines in Study Area.

Mine Name and Location (state)	Mining Dates	Type(s) of Mine	Coal Seam	Mining Method(s)*	Coal Production (tons)	Total Acreage	Permit Number
Kempton – MD/WV	1914 – 4/15/1950	Underground	Upper Freeport	D,R		8,214	
Mettiki A – MD (Beaver Run Mine)	1977 - 1988	Underground	Upper Freeport	D,R,L	5,297,956	1,342	MD 180062101U
Mettiki B – MD (Gobblers Knob Mine)	1978 -	Underground	Upper Freeport	D,R,L		1,353	MD DM-84-104
Mettiki C – MD (Big George Mine)	1978 - 1989	Underground	Upper Freeport	D,R,L	4,920,274	1,044	MD 180065501U
Mettiki D - MD	1987- 2006	Underground	Upper Freeport	D,L	21,565,399	4,193	MD DM-84-101
Mettiki E - WV	2004 –2012 On going	Underground	Upper Freeport	D,L	13,667,133	2,406	WV U-2001-04
Mettiki Y – WV (Part of Mettiki D Mine)		Underground	Upper Freeport	D,L		184	
Dobbin No. 1 – WV	1979 - 1993	Underground	Upper Freeport	D,L	14,943,441	3,641	D00010090
North Branch –WV	1969 - 1993	Underground	Upper Freeport	D,R,L	21,488,707	3,524	D00006466
Henry #22 – WV	1908 - 1928	Underground	Bakerstown	D	1,768,474	704	
Alpine # 1 – WV	1969 - 1980	Underground	Bakerstown	D,R	3,725,469	1,491	D00006465
Alpine # 1 – WV	1964 - 1969	Underground	Bakerstown		4,069,859		
Alpine # 2 – WV	1975 - 1980	Underground	Bakerstown	D,R	621,056	192	D00008855
Emmons- WV	1917 - 1930	Surface/Underground	Upper Freeport	Conventional	1,109,064		
Potomac Mine-WV	1993 - 1997	Underground	Upper Freeport		9,981,567		U00013983

Coal production data from OSM Division of Fee Compliance, and the WV Office of Miners' Health Safety and Training and the US Mine Safety and Health Administration websites

*Mining Methods: D-Developmental; R-Room and Pillar; L-Longwall

REGIONAL GEOLOGY, STRUCTURE AND GEOMORPHOLOGY

The study area is situated within the Physiographic Province of the Allegheny Plateaus of the Central Appalachians. Near its eastern border is the Allegheny Front, a southeast-facing escarpment of the Allegheny Mountains trending northeast-southwest. The western edge of the site is bound by Backbone Mountain. The North Branch Potomac River valley approximates the lowest elevations at 2,300 feet mean sea level (m.s.l.). The highest occurs along the flank of Backbone Mountain at elevations greater than 3,300 feet m.s.l.

Structurally the site is dominated by the North Potomac Syncline, also referred to as the Upper Potomac Syncline. Figure 2 shows the dominant geologic structure of the area with the contours of the Upper Freeport coal seam. Located on the west side of the river, the synclinal axis forms the valley with adjacent anticlines. On the western limb of the syncline the structural contours are very steep, dip of the strata is approximately 18 to 25% to the southeast, while on the eastern flank, the dip is shallower with an average measurement of 5%. Within the study area, the syncline exhibits a northeast plunge and the strike of the strata is N45°E. As stated previously, not only is the North Branch Potomac River the main surface water discharge feature, it is located above the major groundwater sink for the area (the mines).

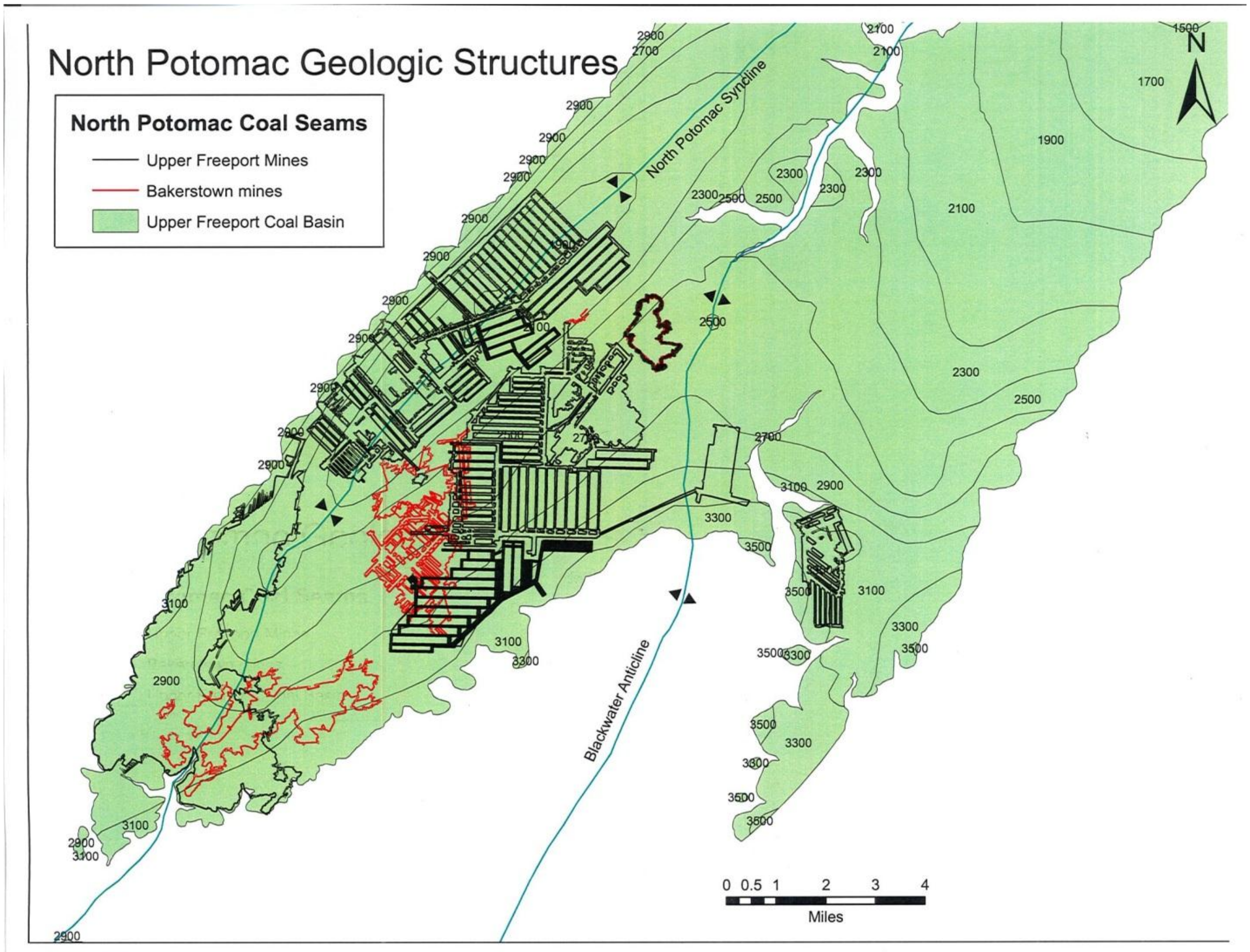


FIGURE 2

Strata within the area are composed entirely of sedimentary rocks consisting of alternating shale, sandstone, clay, and coal. They are of Pennsylvanian age from the Conemaugh and Allegheny Formations. The Conemaugh Formation overlies the Allegheny Formation. The Allegheny Formation extends from the top of the Upper Freeport Coal to the base of the Clarion Coal. A generalized geologic column is shown as Figure 3. The deep mines within the study area are located in the Upper Freeport coal seam and the stratigraphically higher Bakerstown Coal seam, which is part of the Conemaugh Formation. These coals, as other coals in the area, are ranked as medium to low volatile bituminous coals. There is approximately 200 feet of interburden between the two seams and both are underlain by a fire clay unit. Figure 4 provides a geologic cross-section of the study area with names of the formations and the coal seams.

Geologic Column of the Major Coal Seams in Mineral and Grant Counties, West Virginia (adapted from the West Virginia Geological Survey County Reports, 1924)

Coal seam	cum.ft.	int.ft.	thkns ft.	Formation
Sewickley ("Tyson")	50	50	4-8	
Redstone	120	70	2-4	MONONGAHELA FORMATION
Pittsburgh "Rider"	160	40	0-3	
	180	20		
Pittsburgh ("Big Vein")			10-15	
Morantown	200	20	1-5	
Little Pittsburgh	255	55	1-6	
Second Little Pittsburgh	285	30	0-1	
Franklin "Rider"	310	25	0-1	
Little Clarksburg ("Franklin","Dirty Nine-Foot")	330	20	2-7	
Normantown (Upper Hoffman?)	380	50	0-1	
Lower Hoffman	405	25	0-1	
Upper Clarysville	415	10	0-1	
Lower Clarysville	430	15	0-1	
Wellersburg "Rider"	495	65	0-1	CONEMAUGH FORMATION
Wellersburg	505	10	0-1	
Barton "Rider"	510	5	0-1	
Elk Lick ("Barton","Four-Foot")	530	20	2-4	
Federal Hill	580	50	0-1	
Duquesne	590	10	0-1	
Harlem	630	40	1-2	
Upper Bakerstown	730	100	1-5	
Bakerstown ("Thomas")	780	50	3-5	
Brush Creek	855	75	0-1	
Mahoning ("Six-Foot")	935	80	1-6	
Upper Freeport ("Split-Six","Davis")	988	53	4-8	
Lower Freeport	1020	32	0-2	
Upper Kittanning	1070	50	1-3	ALLEGHENY FORMATION
Middle Kittanning	1087	17	0-1	
Lower Kittanning	1120	33	2-3	
Clarion	1150	30	0-1	
Tionesta	1237	87	1-2	
Upper Mercer	1252	15	1-2	
Lower Mercer ("Stockton")	1267	15	0-1	
Quakertown ("Winifrede"?)	1425	158	1-2	POTTSVILLE FORMATION
Sewell ("Sharon"?)	1505	80	1	
Fire Creek	1540	35	0-1	

NOTE: Intervals between coals are calculated from bottom to bottom of seams.

FIGURE 3

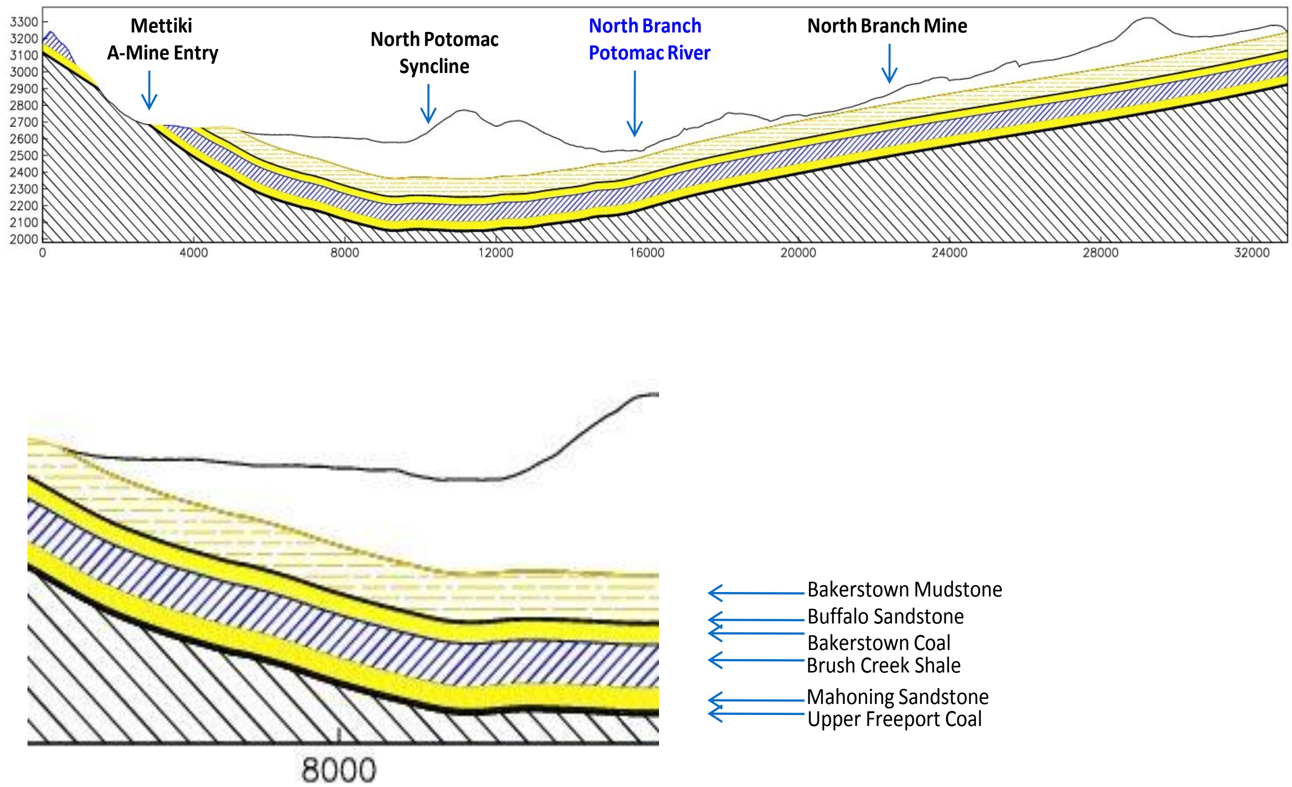

Mettiki
A-Mine Entry
North Potomac
Syncline
North Branch
Potomac River
North Branch Mine
3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
0
4000
8000
12000
16000
20000
24000
28000
32000
8000
Bakerstown Mudstone
Buffalo Sandstone
Bakerstown Coal
Brush Creek Shale
Mahoning Sandstone
Upper Freeport Coal

FIGURE 4

PRECIPITATION AND CLIMATE

The study area's climate is affected by local variations in elevation and topography. The Allegheny Mountains (Backbone Mountain) have the highest elevation in the area and are responsible for significant amounts of precipitation on this portion of the Appalachian Plateaus. Backbone Mountain is located northwest of, and adjacent to, the Mettiki AB, C, and D mines in Maryland (Figure 5). Storms coming from the Ohio Valley to the west ascend Backbone Mountain causing air temperatures to decrease and precipitation to increase. Storms then descend Backbone Mountain (3,360 feet) and enter the valley area surrounding the North Branch Potomac River (2,314 feet). The descending air masses moving further east of the North Branch Potomac River are warmed, clouds dissipate and precipitation decreases from southwest to northeast (U.S. Dept. of Commerce, 1958).

Precipitation fluctuates seasonally in the Backbone Mountain area and in the area surrounding the North Branch Potomac River. Precipitation tends to increase in spring and summer, and decrease in fall and winter (Staubitz and Sobashinski, 1983).

The study area has a nearby U. S. National Oceanic and Atmospheric Administration (NOAA) weather station with long term historical data. Station 8777, Terra Alta #1 is located in Terra Alta, WV and has 51 years of temperature and precipitation data. Figure 5 is a map outlining the study area and shows the location of the Terra Alta weather station. The Terra Alta #1 station is located in Preston County, WV at an elevation of 2,630 feet with a latitude and longitude of 39° 27' N and 79° 33' W (NOAA, 2011). The monthly averages for temperature at the Terra Alta #1 station for the years 1971 to 2000 are shown in Figure 6. The yearly average temperature was 48.4 degrees Fahrenheit (°F) with July (68.6°F) as the warmest month and January (27.2°F) the coldest month. The monthly averages for precipitation at the Terra Alta #1 station for the years 1971 to 2000 are shown in Figure 7. The yearly average precipitation was 55.82 inches with July (5.97 inches) as the wettest month and October (3.49 inches) as the driest month. The spring months typically have the greatest amount of precipitation for the year. However at the Terra Alta #1 station nearby the study area, June and July are the wettest months of the year. This phenomenon is most likely due to the station's location with respect to Backbone Mountain and to the orographic effect.

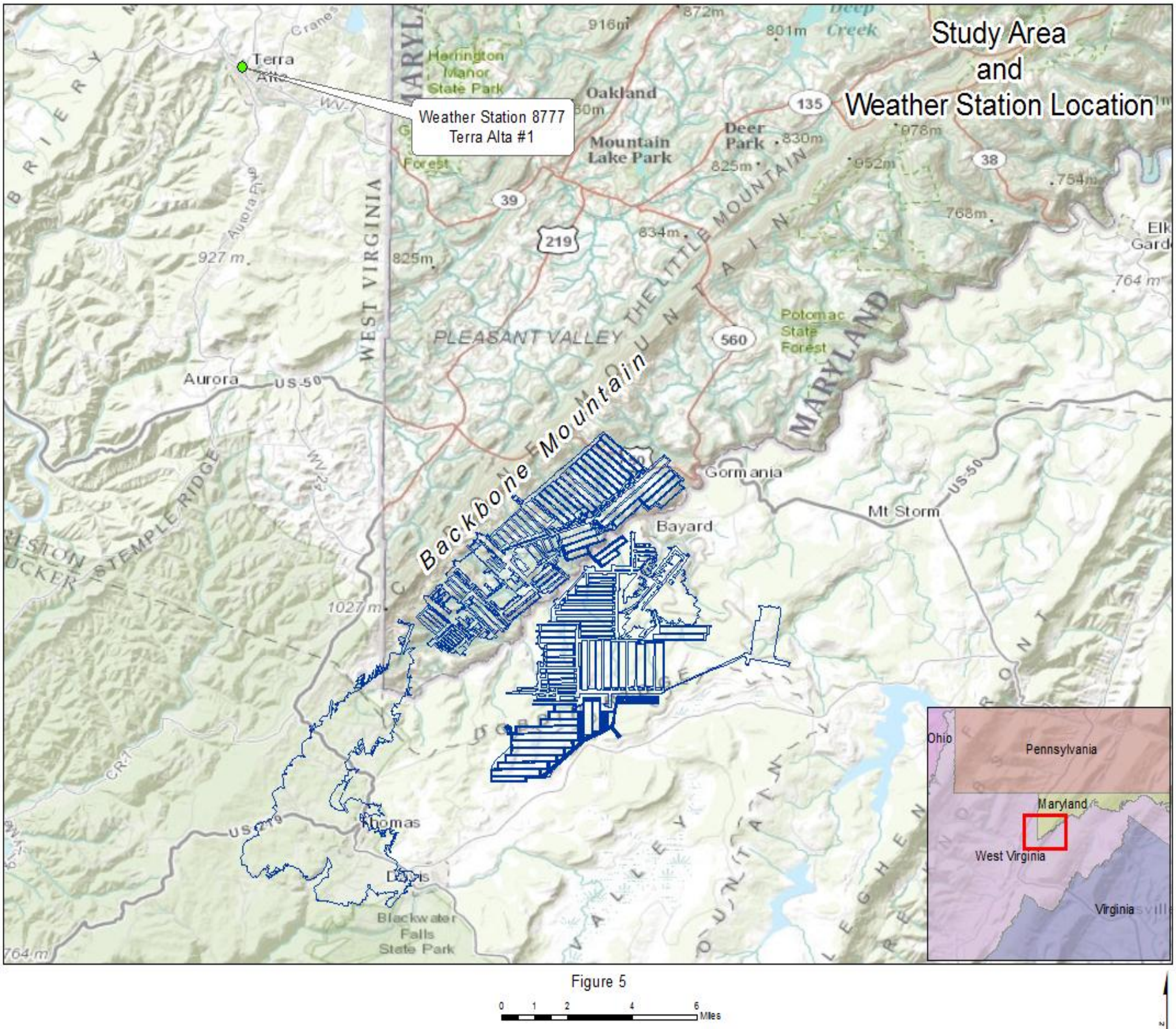

Study Area
and
Weather Station Location
Weather Station 8777
Terra Alta #1
Terra Alta
Oakland
Mountain Lake Park
Deer Park
PLEASANT VALLEY
Backbone Mountain
WEST VIRGINIA
MARYLAND
Aurora
Gormania
Bayard
Mt Storm
Thomas
Davis
Blackwater Falls State Park
Potomac State Forest
Herrington Manor State Park
Ohio
Pennsylvania
Maryland
West Virginia
Virginia

Figure 5

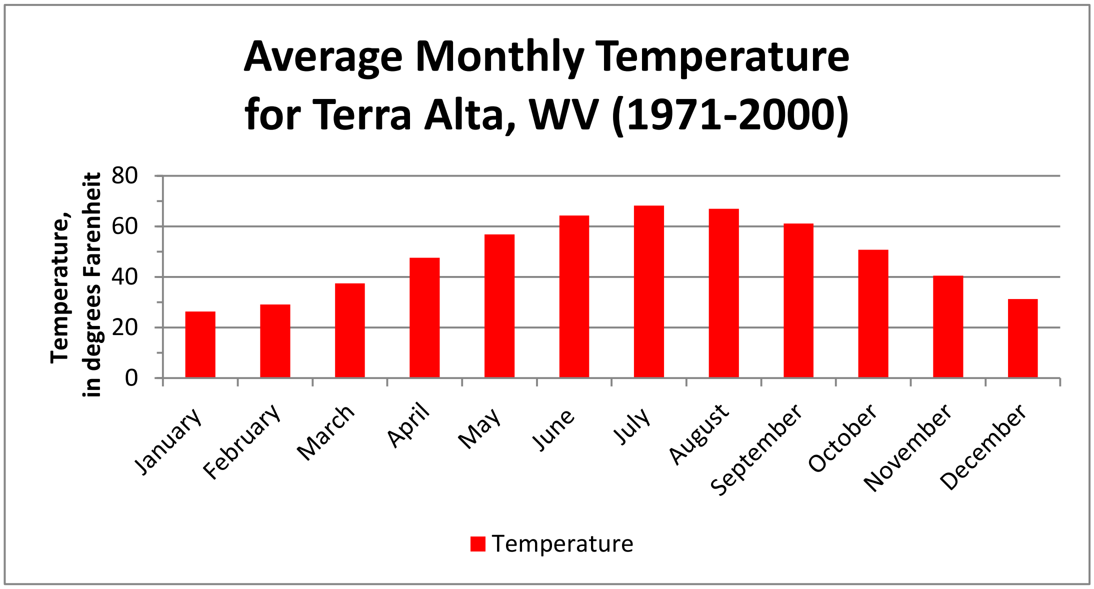


Figure 6. Average Monthly Temperature for Terra Alta, WV for 1971-2000 (Terra Alta #1, No. 8777)

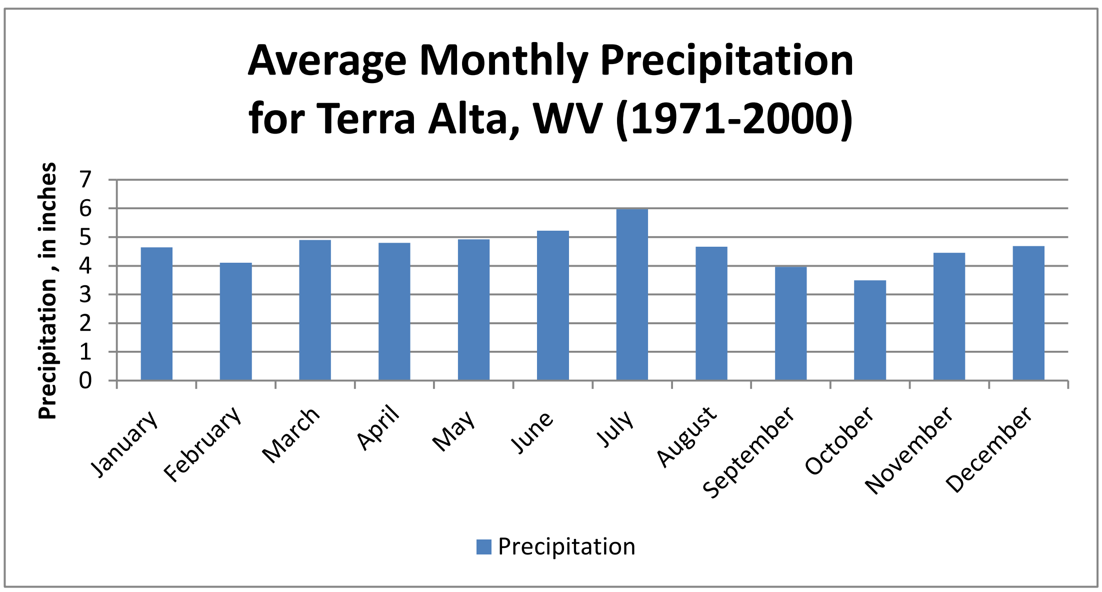


Figure 7. Average Monthly Precipitation for Terra Alta, WV for 1971-2000 (Terra Alta #1, No. 8777)

The yearly precipitation values at Terra Alta #1 station from 1980 to 2011 are shown in Figure 8 with the 30-year average (1971 to 2000) of 55.82 inches shown as a red line. Figure 9 shows the yearly departure values from the average precipitation value of 55.82 inches at Terra Alta #1 from 1980 to 2011. During the study period (2006 to 2011) deficit precipitation occurred during the years 2006, 2007, 2009 and 2010 for a total deficit of 18.85 inches. Excess precipitation occurred in the years 2008 and 2011 for a total of 24.66 inches. The extremely wet year of 2011 had an excess of 16.77 inches of precipitation. The study period had an overall excess precipitation of 5.81 inches which could increase the amount of recharge to the mine pools.

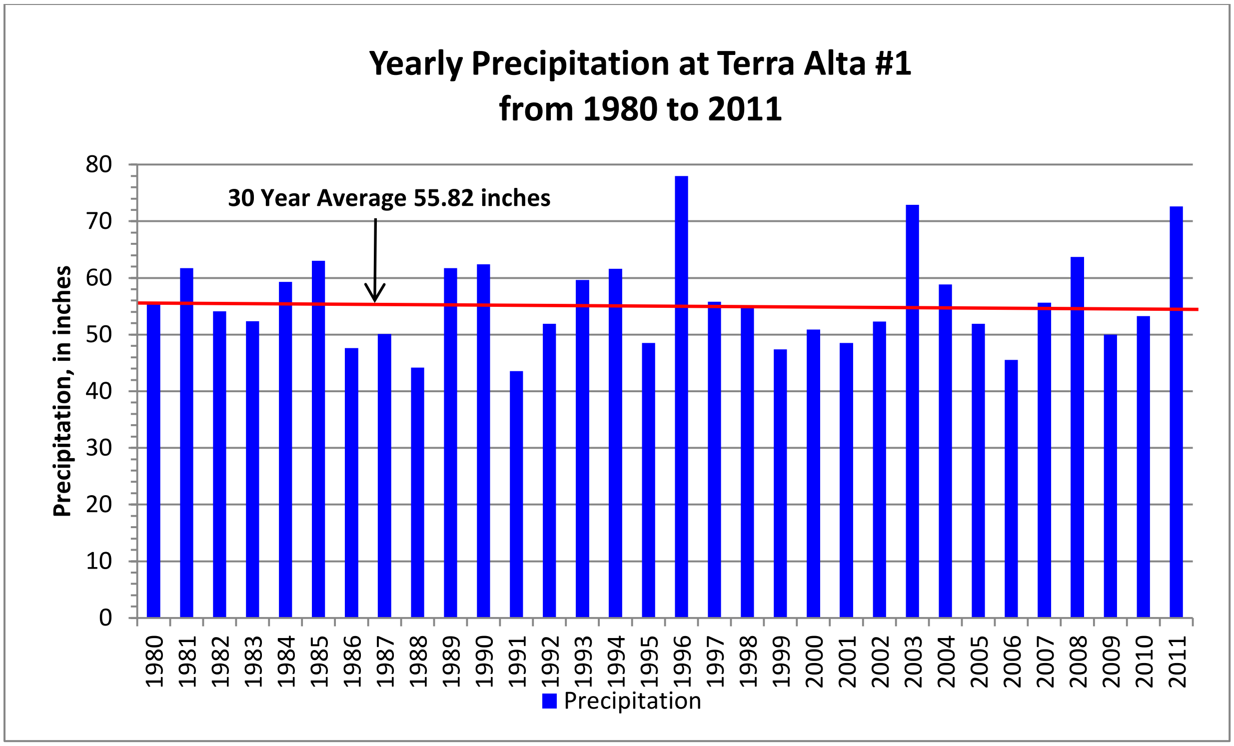


Figure 8. Yearly precipitation for Terra Alta #1 station from 1980 – 2011.

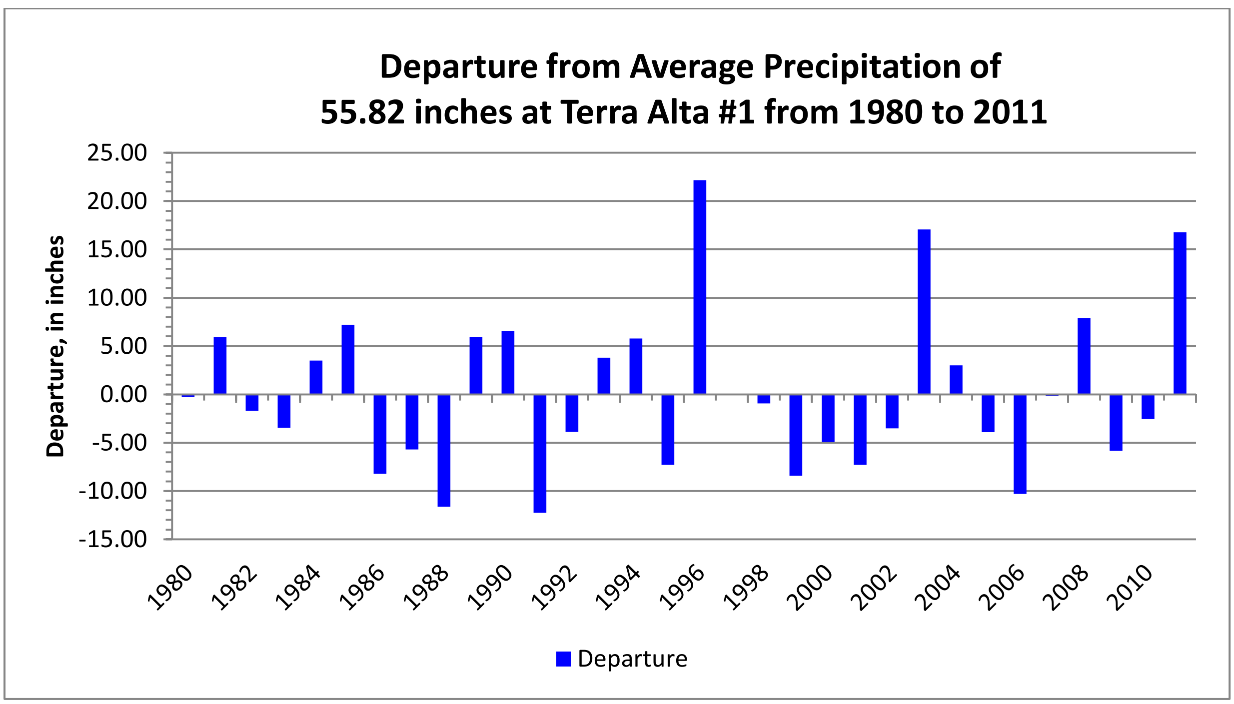


Figure 9. Departure from Average Precipitation of 55.82 inches at Terra Alta #1 from 1980 - 2011.

SURFACE WATERS AND DRAINAGE AREAS

The study site lies within a portion of the North Branch Potomac River which flows from south to north draining a mountain valley. Ultimately the river continues north through Maryland to form the Potomac River and flows into the Chesapeake Bay. The surface area of the study site is dissected with numerous streams. Figure 10 shows the surface streams from the river's source to the town of Gormania, WV, which defines the drainage basin boundaries of the site. Many of the stream valleys are steep sided but will vary depending on the surrounding topography.

The active Mettiki E Mine and the abandoned Kempton Mine underlie both the North Branch of the Potomac River watershed, and the Blackwater River watershed, which flows to the southwest into the Cheat River; part of the Monongahela River Basin. Most of the watersheds within the study area have been impacted by various surface and deep mine activities.

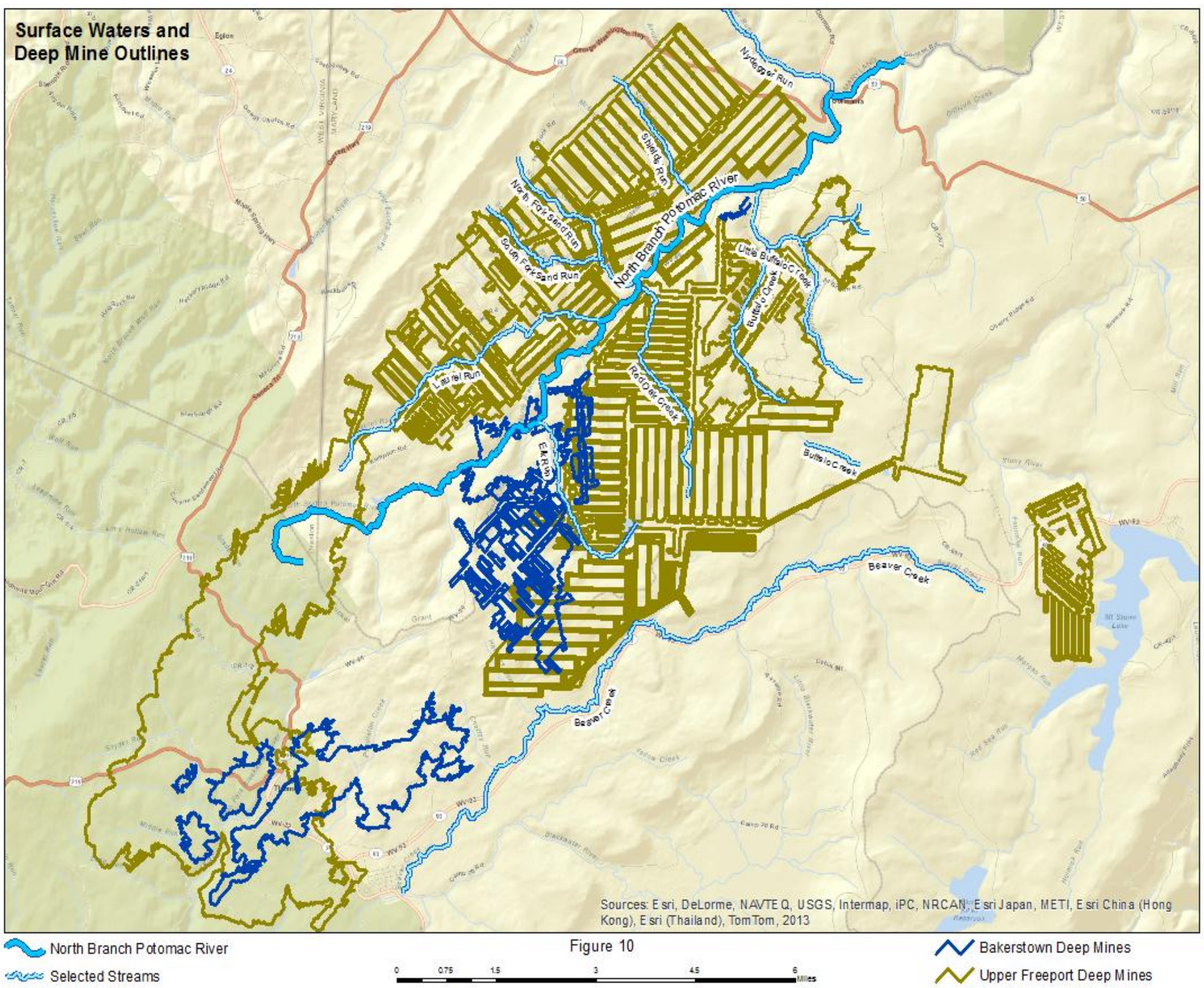


Figure 10

HYDROLOGIC CHARACTERIZATION OF THE MINE POOLS

The following section provides site specific hydrologic information for each individual mine within the study area. The locations of the mines and their current mine pools are shown on Figure 1. The mine workings and their pools are described below with basic hydrologic information. Further explanations on the hydrologic parameters are presented in subsequent sections.

Deep Mine Pools located within the boundaries of Maryland –

Kempton Mine Complex – Northern Pool- Upper Freeport Coal

Although two distinct pools are located within this legacy mine, only the Northern Pool is located within the study area. The Southern pool drains to the southwest into the Blackwater River Basin. The Northern mine pool is at steady state at an elevation of 2,655 feet mean sea level (m.s.l.) maintained by surface discharges at the airshaft and borehole. These discharges are currently being collected and treated by the state of Maryland and discharged to Laurel Run, a tributary to the North Branch Potomac River.

Specific hydrologic data for the pool is highlighted in the table below. The current hydraulic head is calculated from the current water elevation of the pool to the lowest elevation of the mine works and represents the maximum value. The potential hydraulic head is calculated from the highest predicted pool elevation (potentiometric surface) to the lowest elevation of the mine works. In this mine the current head and the potential head are the same as the pool will not increase in the future due to the virtually unrestricted surface discharges at the airshaft and borehole locations. The potential pool elevation is the predicted elevation with no pumping of the pool (The Kempton pool is abandoned and not being pumped.) The critical elevation of the Potomac River refers to the elevation of the river, located close to the mine pool, which if exceeded, could result in mine water being discharged directly into the river. In this case, the critical river elevation is the lowest elevation of the river located above the flooded mine workings. Predicting leakage directly upward into the river would require a minimum pool head elevation greater than the river.

Since the current and potential pool elevations are below the critical elevation of the Potomac River, the Northern Pool will not discharge directly into the Potomac River. [For further discussion on the critical elevation of the Potomac River see section titled Hydrologic Characterization of the Mine Pools-Potential Surface Water Breakout Locations – North Branch Potomac River.]

Current Pool Elevation m.s.l.	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Potential Hydraulic Head near Critical River Location m.s.l.***	***Critical Elevation Potomac River m.s.l.***
2655'	***355' (2655' – 2300')***	***2655'***	***355' (2655'- 2300')***	***305' (2655' – 2350')***	***2685'***

<u>Mettiki Coal LLC – C Mine – Upper Freeport Coal</u>

OSM installed a pressure transducer in January 2007 at a former Mettiki injection well labeled C-Mine well (Figure 11). Water levels were recorded for one year, with erratic results. Figure 12 shows the water level measurements during the OSM monitoring period. Various sludges had been injected into the mine voids in abandoned sections of the mine after closure. The injected sludges included: flue gas desulfurization material from Mt. Storm Power Station, coal slurry from coal preparation plant, and alkaline metal hydroxide sludge from treatment facility. These activities may have changed or obstructed ground water flow patterns within the mine voids. Furthermore, based on a down hole camera survey, the casing of the well is open to an aquifer situated above the deep mine. As a result, the well is not dedicated to monitoring the mine pool alone. For the above stated reasons the well may not provide accurate information on the hydrologic conditions of the pool.

Predicting a scenario without pumping, the pool has the potential to develop to the highest elevation of the mine works which potentially limits and controls the pool's development. *Because this elevation is less than the critical river elevation the pool will not discharge or breakout to the river.*

Current Pool Elevation m.s.l.	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Potential Hydraulic Head near Critical River Location m.s.l.***	***Critical Elevation Potomac River m.s.l.***
2400' (June 2010)	***350' (2400'-2050')***	***2550'***	***500' (2550' –2050')***	***395' (2550'- 2155')***	***2646'***

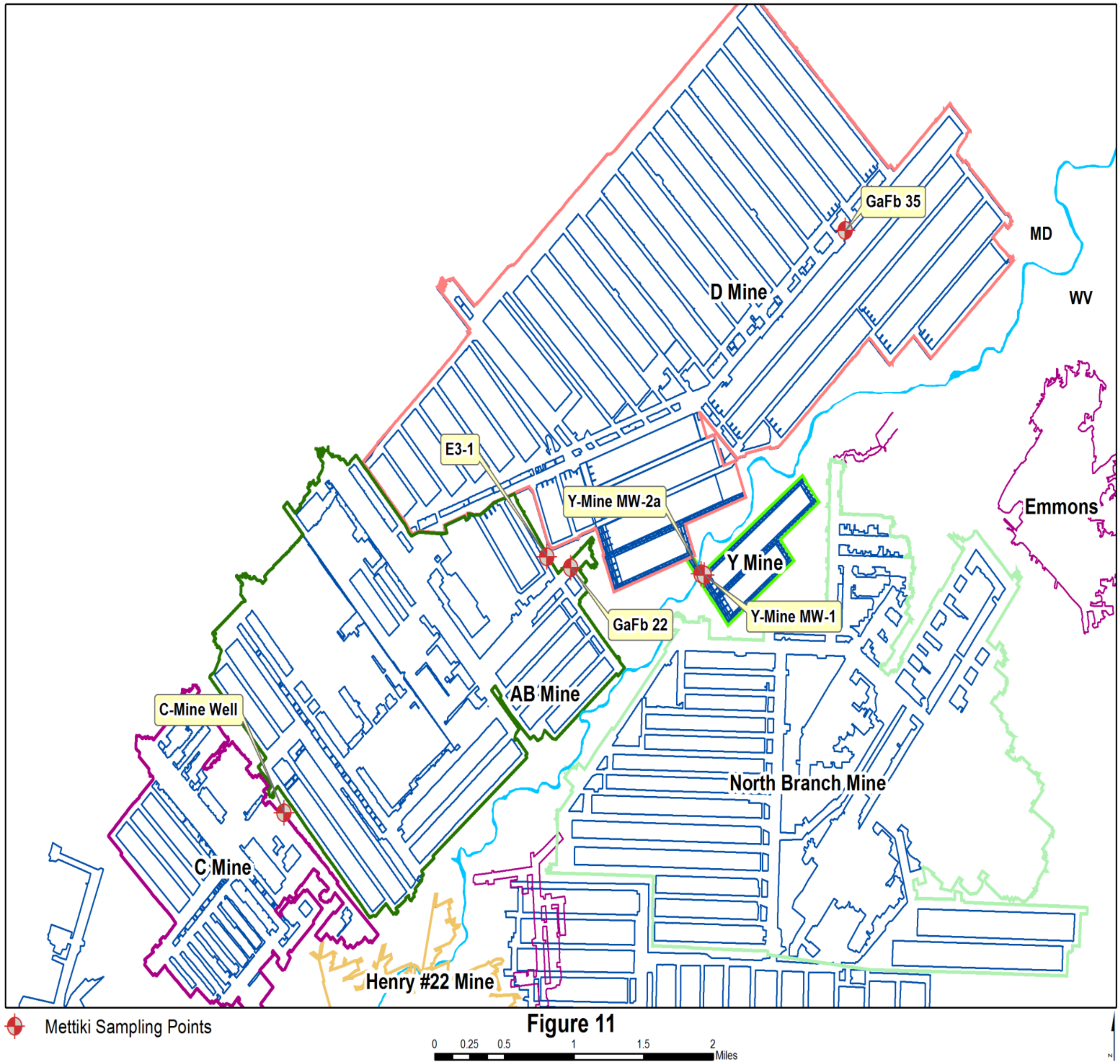
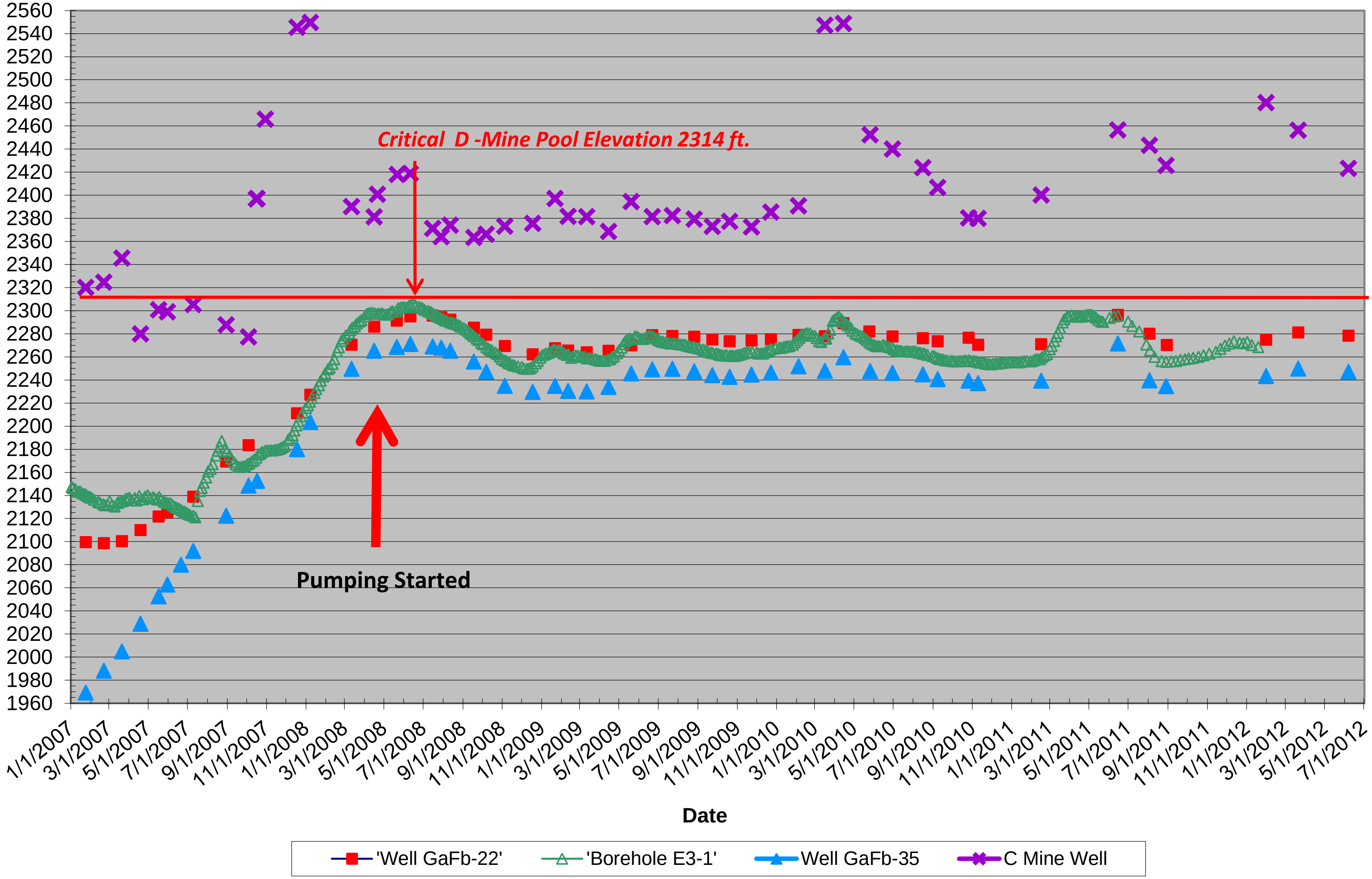

GaFb 35
MD
WV
D Mine
E3-1
Y-Mine MW-2a
Emmons
Y Mine
Y-Mine MW-1
GaFb 22
AB Mine
C-Mine Well
North Branch Mine
C Mine
Henry #22 Mine
Mettiki Sampling Points
0
0.25
0.5
1
1.5
2
Miles

Figure 11

FIGURE 12
Water Level Measurements from Wells GaFb-22, GaFb-35, C Mine and Borehole E3-1



<u>Mettiki Coal LLC – AB Mine – Upper Freeport Coal</u>

A second transducer was installed in January of 2007 at USGS well GaFb-22 (Figure 11). The well is located in the area of the A Mine and was designed to monitor the aquifer below the mine. During the initial phase of mining, Mettiki AB were two separate mines; however, in or around 1985 they were directly connected by longwall panels. Water data collected from well GaFB-22 post mining indicate that the well is connected to the mine pool and has been used as such. During the monitoring period of January 2007 through July 2008 the mine pool increased in elevation from 2080' to 2260' m.s.l.; at a rate of 0.42 feet/day. See Figure 13.

The predicted mine pool could potentially develop to the elevation of the mine works at 2550' m.s.l. which is higher than the critical river elevation, therefore there is a potential for the pool to discharge to the river. The overburden between the river and the mine is 350' and the horizontal distance is less than 100 feet. The horizontal distance is the closest distance between the edge of the mine pool and the river at its critical elevation.

Current Pool Elevation m.s.l.	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Potential Hydraulic Head near Critical River Location m.s.l.***	***Critical Elevation Potomac River m.s.l.***	***Horizontal Distance to River m.s.l.***
2275' June 2010	**225' (2275'- 2050')**	***2550'***	***500' (2550'- 2050')***	***420' (2550' – 2130')***	***2500 (OB – 350')***	***<100'***

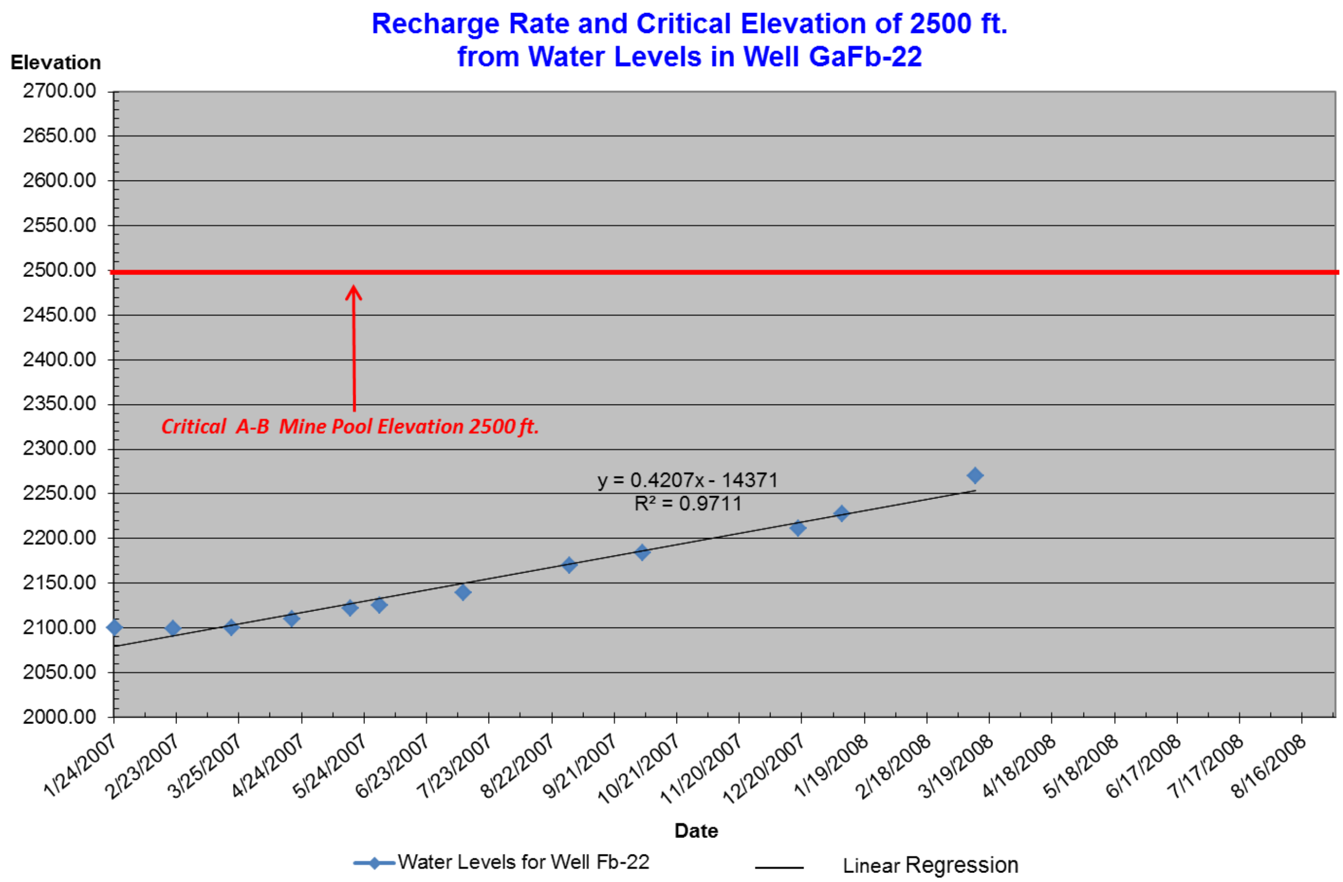


FIGURE 13

Mettiki Coal LLC – D Mine – Upper Freeport Coal

In January 2007, OSM installed a third transducer at existing monitoring well GaFb 35, as shown on Figure 11. The well was originally designed by USGS to monitor the aquifer below the deep mine; however mine workings cut through the well providing a connection to the mine for monitoring purposes. During the monitoring period of January 2007 through April 2008 the mine pool increased in elevation from 1970’ to 2270’; at a rate of 0.66 feet per day as shown on Figure 14. In March of 2008, the company was made aware of the concern for potential mine pool seepage into the river at a breakout elevation of 2314’. With a measured filling rate of 0.66 feet/ day, the mine pool would reach the critical elevation by June 2008. From April of 2008 to the spring of 2012, water levels have been held in a narrow range approximately 60 feet below the critical river elevation. Variations in mine pool levels are due to seasonal fluctuations of recharge and discharge rates and changes in pumping rates. Figure 12 is a graph showing the pool elevations recorded during the monitoring period.

According to MBM, pumping from the mine pool during 2007 was approximately 700 gpm and increased to 7000 gpm by the spring of 2008. Injection of sludges occurred in abandoned sections of this mine for several years. Flue gas desulfurization material from Mt. Storm Power Station, coal slurry from Mettiki's coal preparation plant and alkaline metal hydroxide sludge from the treatment system were injected at various rates.

The pool has the potential to develop to the highest elevation of the mine works which is greater than the critical river elevation therefore, there is a potential for the pool to discharge to the river. There is less than 100 feet of overburden between the river and the mine pool with approximately 500 feet of horizontal distance to the river.

Current Pool Elevation m.s.l.	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Hydraulic Head near Critical River Location m.s.l.***	***Critical Elevation Potomac River m.s.l.***	***Horizontal Distance to River m.s.l.***
2250' (June 2010)	***350' (2250'-1900')***	***2450'***	***550' (2450'–1900')***	***290' (2450' – 2160')***	***2314' (<100' OB)***	***500'***

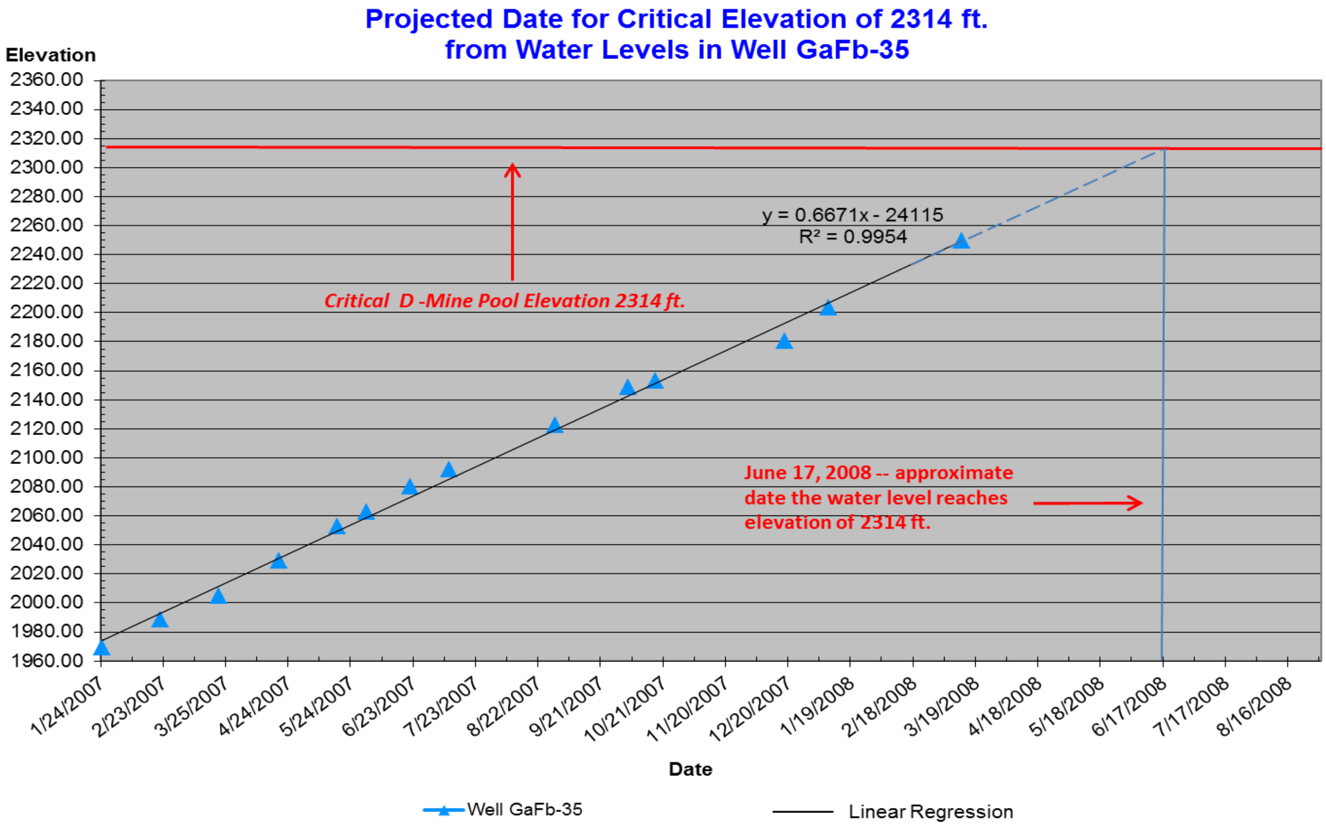


FIGURE 14

Deep Mine Pools located within the boundaries of West Virginia -

<u>Mettiki Coal LLC - Y Mine (Extension of D Mine) – Upper Freeport Coal</u>

The Y Mine is basically an extension of the D Mine and includes a set of entries driven under the river to access 2 longwall panels located east of the river. The existing and potential pool elevations are the same as the D-Mine.

The pool has the potential to develop to the highest elevation of the mine works (D-Mine) which is greater than the critical river elevation (2400' m.s.l.) therefore, there is a potential for the pool to discharge to the river. There is approximately 300 feet of overburden between the river and the mine pool and approximately 200 feet horizontal distance from the edge of the mine workings to the river.

Current Pool Elevation m.s.l.	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Hydraulic Head near Critical River Location m.s.l.***	***Critical Elevation Potomac River m.s.l.***	***Horizontal Distance m.s.l.***
2250' (June 2010)	***175' (2250'-2075')***	***2450'***	***375' (2450'–2075')***	***375' (2450' – 2075')***	***2400' (300' OB)***	***200'***

Consolidation Coal Company Mines

Consolidation Coal Company maintains steady state conditions in the mine pools for the North Branch and Dobbin mines, both located in the Upper Freeport coal seam in addition to the Alpine #1, Alpine #2 and Henry #22 which are located on the Bakerstown coal. The mines located on the Bakerstown seam are physically connected through cross cuts whereas the North Branch and Dobbin mines are physically separated by a coal barrier. Consolidation Coal Company has hydraulically connected all of these mines on both seams to allow transfer of water in a series of pipelines and boreholes. The transfer of ground and surface water from these mines to their treatment facility is described in a later section and shown on a corresponding schematic Figure 15. A map, Figure 16, outlines the numerous Consolidated Coal Company's underground mines and the locations for select boreholes, and the treatment facility.

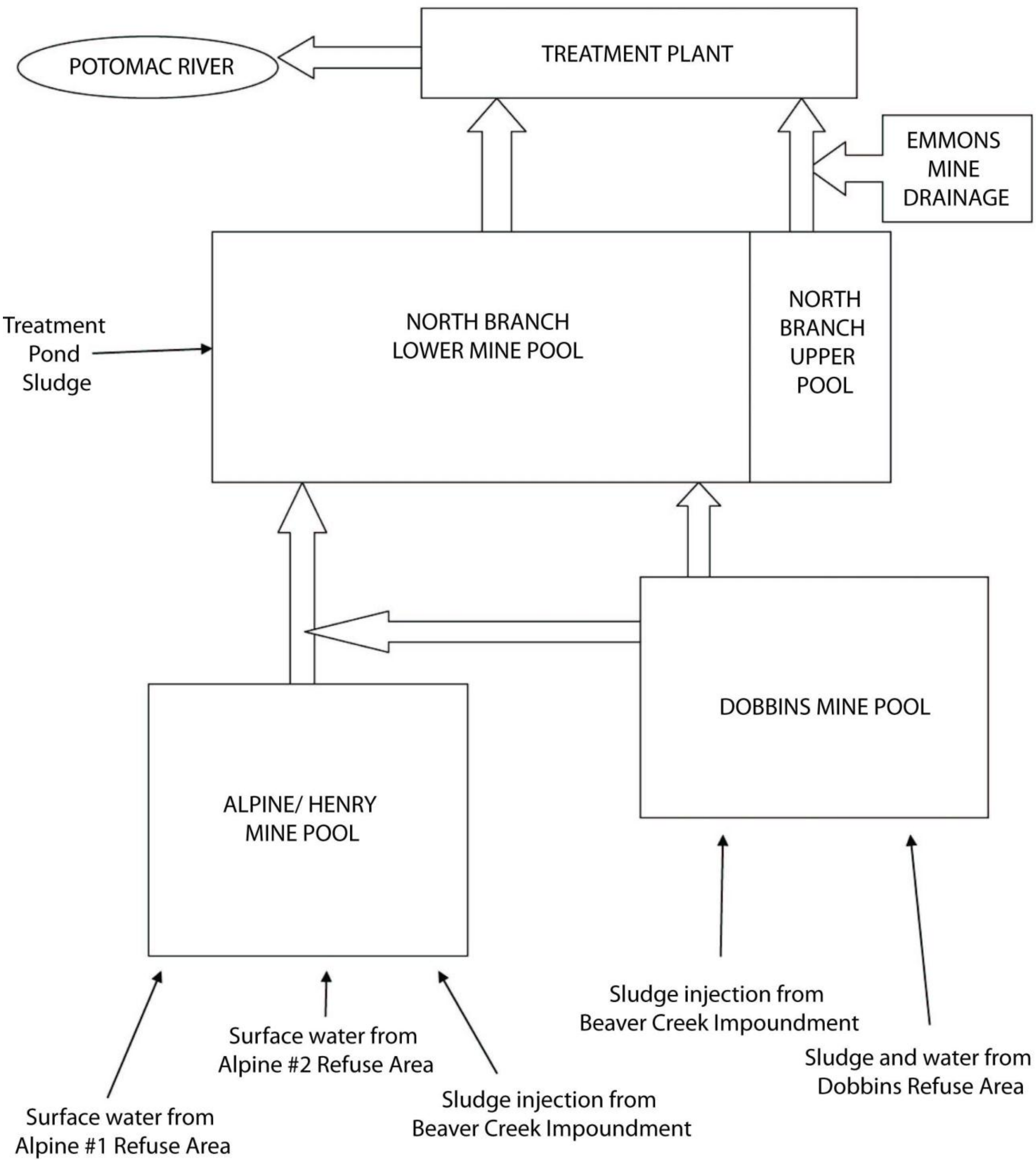
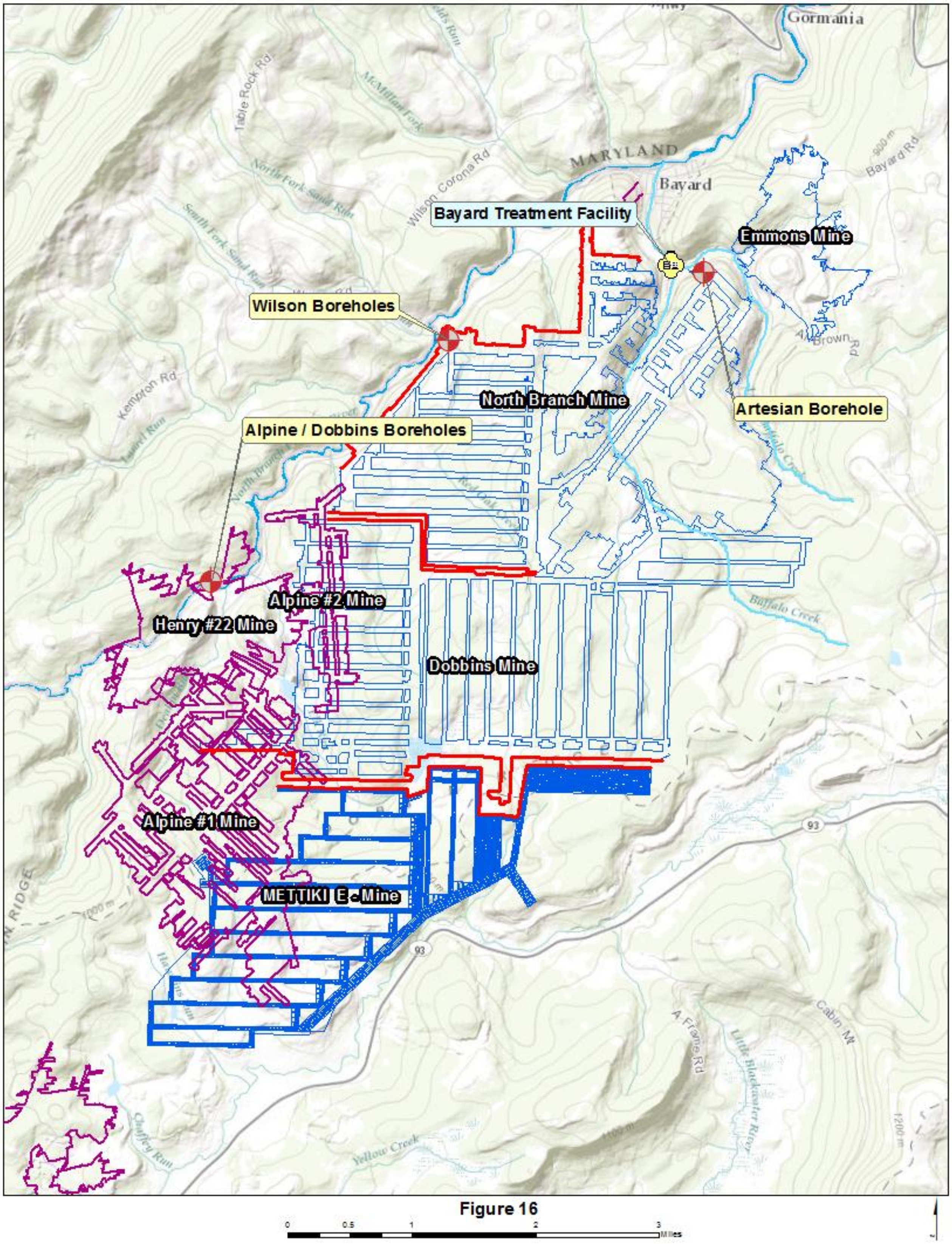

POTOMAC RIVER
TREATMENT PLANT
EMMONS MINE DRAINAGE
Treatment Pond Sludge
NORTH BRANCH LOWER MINE POOL
NORTH BRANCH UPPER POOL
DOBBINS MINE POOL
ALPINE/ HENRY MINE POOL
Sludge injection from Beaver Creek Impoundment
Sludge and water from Dobbins Refuse Area
Surface water from Alpine #2 Refuse Area
Sludge injection from Beaver Creek Impoundment
Surface water from Alpine #1 Refuse Area

FIGURE 15



Gormania
MARYLAND
Bayard
Bayard Treatment Facility
Emmons Mine
Wilson Boreholes
North Branch Mine
Artesian Borehole
Alpine / Dobbins Boreholes
Alpine #2 Mine
Henry #22 Mine
Dobbins Mine
Alpine #1 Mine
METTIKI E - Mine
Table Rock Rd
McMillan Fork
North Fork Sand Run
South Fork Sand Run
Wilson Corona Rd
Kempton Rd
Laurel Run
Red Oak Creek
Buffalo Creek
Brown Rd
Bayard Rd
93
Cabin Mt
A Frame Rd
Little Blackwater River
Yellow Creek
Chaffey Run
0
0.5
1
2
3
Miles

Figure 16

<u>Consolidation Coal Company– North Branch Mine – Upper Freeport Coal</u>

The North Branch Mine has two mine pools, the upper and lower which are separated by the Buffalo Creek valley. The upper pool is maintained at steady state conditions due to the Artesian Borehole discharge; whereas the lower pool is maintained at a maximum elevation of 2350'm.s.l. by pumping. (Note that at the time of the investigation the pool was measured at 2338'm.s.l.) *Future conditions without pumping of the lower pool would cause the two pools to combine and discharge into Buffalo Creek at the Artesian borehole, elevation 2440' m.s.l. and the Wilson Boreholes, located next to the river at an elevation of at 2500'm.s.l.*

Upper Pool m.s.l.	***Current Pool Elevation m.s.l.***	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Hydraulic Head near Critical Location m.s.l.***	***Critical Elevation m.s.l.***	***Horizontal Distance m.s.l.***
	2440' (April – 2009)	***80' (2440' – 2360')***	***2440' and 2500'***	***80' (2440' – 2360')***	***80' (2440' – 2360')***	***2440' (Buffalo Creek)***	***<100'***
Lower Pool	***Current Pool Elevation***	***Current Hydraulic Head***	***Potential Pool Elevation***	***Potential Hydraulic Head***	***Hydraulic Head near Critical River Location***	***Critical Elevation***	***Horizontal Distance to River***
	2338' (April – 2009)	***198' (2338' – 2140')***	***2440' and 2500'***	***360' (2500' – 2140')***	***360' (2500' – 2140')***	***2500' (OB – 355')***	***200'***

<u>Consolidation Coal Company – Dobbin Mine –Upper Freeport Coal</u>

The Dobbin mine pool is currently being maintained by Consolidation Coal Company pumping at a maximum elevation of 2550' m.s.l (note that at the time of the investigation the pool was measured at 2485' m.s.l.). In the absence of pumping, the pool could develop to an elevation (2460' m.s.l) where flooding will occur into the overlying Bakerstown coal seam, Alpine #1 mines; given conditions are suitable and the overlying strata is sufficiently fractured. *The Dobbin pool will then mix with the Alpine/ Henry pool where it will discharge through the Alpine /Dobbin Boreholes at 2680'm.s.l. and potentially leak into the Potomac at 2640'm.s.l., via the Alpine/Henry pool.*

Current Pool Elevation m.s.l.	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Hydraulic Head near Critical River Location m.s.l.***	***Critical Elevation m.s.l.***
2485' (April – 2009)	***225' (2485' – 2260')***	***2680' and 2640'***	***420' (2680' –2260')***	***420' (2680' – 2260')***	***2640' (OB –220')***

<u>Consolidated Coal Company - Emmons Mine – Upper Freeport Coal</u>

Emmons Mine is an abandoned surface and underground mine located on the Upper Freeport coal seam. The mine is at steady state conditions; it is free draining with a gravity discharge near Little Buffalo Creek at an elevation of 2500' m.s.l. Currently the discharge is collected and treated before being routed to the surface. *There is no potential for a direct discharge to the river currently or in the future. The location of the mine is at a significant distance from the river and the mine is free draining.*

<u>Consolidation Coal Company – Alpine #1, Alpine #2 and Henry 22 Mines– Bakerstown Coal</u>

The Alpine #1 and Henry #22 mines have been hydrologically connected via open passages based on information from Consolidation Coal Company personnel and documented in the permit files. The Alpine #2 mine was physically connected to the others to facilitate the control of the pool elevations and water transfer. Consolidation Coal Company currently maintains the mine pool, designated

Alpine/Henry pool, at an approximate elevation of 2620' m.s.l. Water from the pool is pumped out of the mine using Alpine No.5 pumps then piped and injected into the North Branch pool. *The pool has the potential to leak into the Potomac River at an elevation of 2640' m.s.l. and will discharge through Alpine/ Dobbin Boreholes at 2680'm.s.l.*

Current Pool Elevation m.s.l.	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Critical Elevation m.s.l.***	***Horizontal Distance m.s.l.***
2616' (April – 2009)	***296' (2616' – 2320')***	***2680'***	***280' (2680' –2400')***	***2680' (OB –280')***	***0***
2616' (April – 2009)	***296' (2616' – 2320')***	***2640'***	***220' (2640' – 2420')***	***2640 (OB- 220')***	***0***

Current Collection and Transfer of Consolidation Coal Company's Mine Pools to Treatment Facility

A description of the transfer of ground and surface water flow at Consolidation Coal Company's mines within the North Branch Potomac River Study Area is illustrated by the schematic on Figure 15. The mine outlines with significant features are shown on Figure 16.

All surface flow from the Alpine #1 Refuse area is directed by a pipeline into the Alpine /Henry Mine (the mines are connected and located on the Bakerstown Coal). Runoff from Alpine #2 Refuse is also directed into the Alpine/Henry Pool. Alpine/Henry Pool is pumped from Alpine Pump #5, located near the old Alpine Treatment facility (near river elevation of 2650'm.s.l.) into a pipeline then into the Wilson Borehole (North Branch Mine Pool - Freeport Mine). The Alpine/Henry Pool is maintained by pumping at an approximate elevation of 2620' m.s.l.

Dobbin Mine Pool (Upper Freeport Coal) is maintained at a maximum elevation of 2550' m.s.l. through pumping. There are several injection wells into the Dobbin Mine for coal slurry and mine water treatment sludge from the Bayard Mine Water Treatment Facility, Beaver Run Impoundment, and the

Dobbin Refuse Area. There are two pumps from the Dobbin Mine that pump water from the mine into a pipeline that then goes into the North Branch Mine Pool via the Wilson Borehole.

The North Branch mine pool is maintained at a maximum elevation of 2350'm.s.l., which is the lower and larger pool with in the Upper Freeport mine. Water from the pool is pumped out and routed to the Bayard Treatment Facility located in the Buffalo Creek watershed. There is a smaller upper pool in the North Branch Mine controlled by the elevation of the Artesian Borehole at an elevation of 2440'm.s.l. This section of the mine is isolated from the lower section by Little Buffalo Creek and Buffalo Creek valley. Figure 1 shows both pools.

<u>Mettiki – E Mine – Upper Freeport Coal</u>

The Mettiki E-Mine is the only active mining operation within the study area. The mining extent shown on the figures throughout the report is based on the projected mine workings dated October 2009. During the June 2009 investigation of the mine, 2 wells, DW-1 and DW-3 were located in sumps within the mine and used by Mettiki Coal LLC to control the water. Figure 17 shows the extent of the mine and the wells' locations. Water pumped from the mine is piped to the Beaver Creek AMD Treatment Facility located within the Beaver Creek watershed. The potential maximum pool elevation is 2900' m.s.l. at which point it will flow into the overlying Alpine #1 deep mine. *Given the significant distance between the river and the mine workings, there is no predicted leakage directly into the river and no critical elevation determined.*

Current Pool Elevation m.s.l.	***Current Hydraulic Head m.s.l.***	***Potential Pool Elevation m.s.l.***	***Potential Hydraulic Head m.s.l.***	***Hydraulic Head near Critical River Location m.s.l.***	***Critical Elevation at surface m.s.l.***
Actively pumping	***Actively pumping***	***2900'***	***200' (2900' –2700')***	***NA***	***NA***

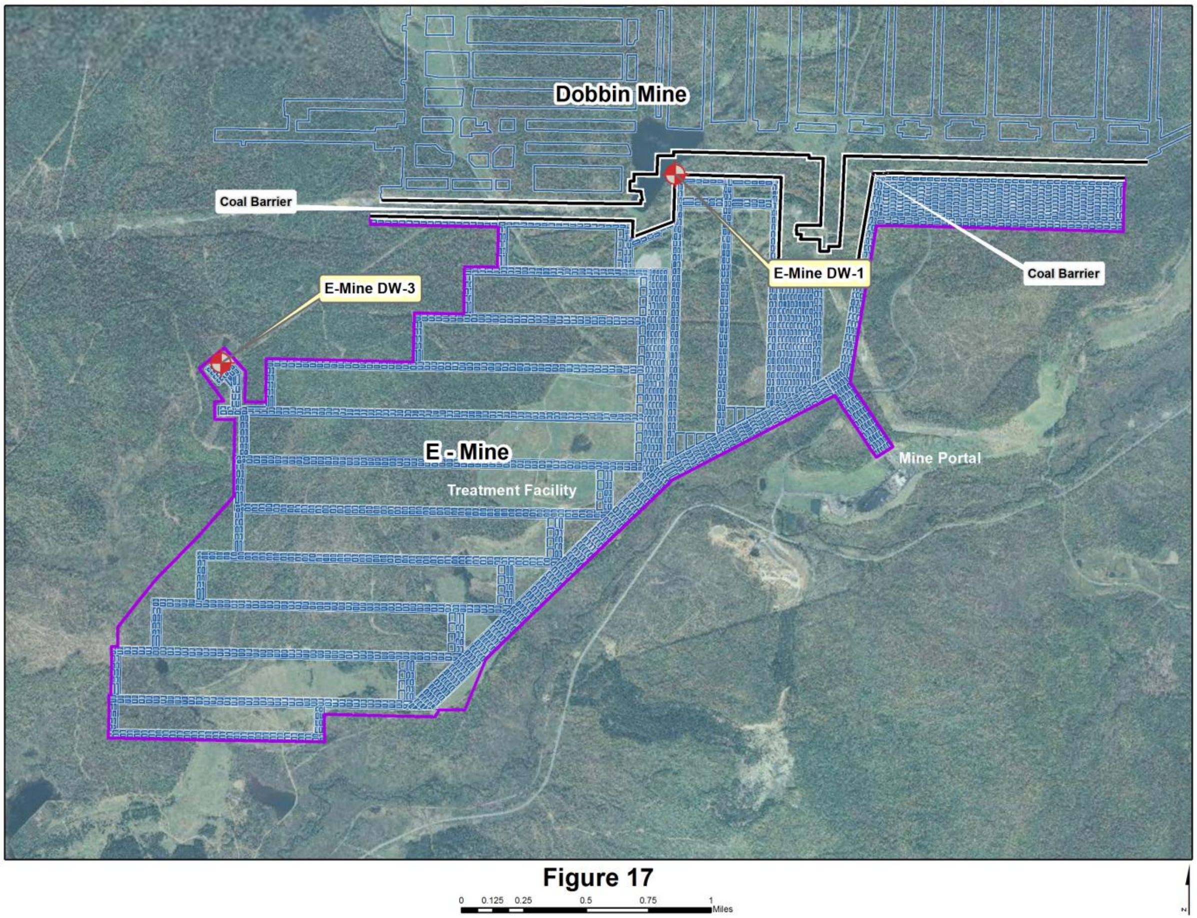


Figure 17

Hydrologic Characterization of the Mine Pools – Water Storage Calculations and Discharge Rates

Water budget characteristics were determined for the following hydrologic parameters for each mine pool under varying conditions: total water storage volume of the mine complex, recharge rates into the mine complex and potential mine pool discharge rates. The varying conditions included current conditions (with active pumping) and potential maximum flooded conditions (without pumping). These data were used to estimate the potential for the mine pools to discharge or leak into the North Branch of the Potomac, and the magnitude of control measures needed to prevent mine pool breakout.

Water storage calculations can be used to help characterize the hydrologic conditions of the mine pool and provide data to determine the potential yield of a mine. Table 2 provides the summary of the current storage volumes. Figure 18 provides an explanation of the calculations. The calculations factor the amount of void space available for saturation based on the type of mining, thickness of the coal and areal extent of the mining. Several methods of deep mining were employed throughout the study area; the most prevalent and efficient is the longwall method which removes approximately 80% to 90% of the coal. In this method, the roof collapses behind the active coal removal which causes factures in the overlying overburden. As the coal is removed subsequent collapsing of the roof rock and fracturing occurs. In the room and pillar method of deep mining, the coal is systematically removed in blocks ranging in size from 30 to 100 feet wide. Intact coal, called pillars are left in place to support the roof. Coal removal using this method is approximately (60%) sixty percent. Retreat mining involves the removal of the pillars and the collapse of the roof rock with subsequent fracturing of the overburden. Acreages used in the calculation for the "total mine" in addition to the individual types of mining were measured using Arc GIS software with digitized mine maps. The current storage volume was calculated using the mean water elevation based on data collected in 2010 and shown on the last column of the table.

The potential total storage volume of the mine complex is the theoretical total storage volume based on calculations that assumes the total mine complex could be saturated throughout. This may never be attained due to site specific topographic or geologic conditions of a mine. An example of this condition is the Emmons Mine, a potential total storage volume has been calculated however, due to the geology and topography of the area, the mine entry comes to the surface. Water from the mine drains freely or the mine is partially saturated with little to no storage of water. Figure 19 (maximum storage) and Figure 20 (minimum storage) show a comparison between the potential storage volumes for all mines versus the current storage volume of the mines. The graphs clearly show the Kempton Mine with the greatest potential storage volume, however, due to the location of an air shaft and borehole which discharge mine water, the mine will not fully flood and this volume is not attained. The charts also show the North Branch, Dobbin and the D-Mine with great potential for water storage. Currently, the Mettiki D Mine has the greatest volume of water stored.

Current Mine Pool Acreages & Storage Volumes FLOODED PORTION OF MINES

Mine name	Current Mine Pool Acreages	1st Mining Acreage (Measured) CURRENT MINE POOL	2nd Mining Acreage (measured) CURRENT MINE POOL	Longwall Mining Acreage (measured) CURRENT MINE POOL	1ST MINING CURRENT POOL VOLUME (MIN/MAX)	2ND MINING CURRENT POOL VOLUME (MIN/MAX)	LONGWALL MINING CURRENT POOL VOLUME (MIN/MAX)	TOTAL CURRENT MINE POOL VOLUME (MIN/MAX)	Mine Pool Elevation (feet MSL)
Kempton mine	1842	1120	723	0	875944904	282726860	0	1158671763	2655
UF					1459908173	565453719	0	2025361892	
Dobbin Mine	793	350	0	443	273732782	0	115489164	389221947	2550
UF					456221304	0	230978329	687199633	
D Mine	3773	1039	0	2734	812595317	0	712748026	1525343343	2250
UF					1354325528	0	1425496052	2779821580	
A Mine	1111	711	82	318	556068595	32065840	82901928	671036364	2275
UF					926780992	64131680	165803857	1156716529	
B Mine	1093	672	94	327	525566942	36758402	85248209	647573554	2275
UF					875944904	73516804	170496419	1119958127	
C Mine	796	494	214	88	386354270	83684022	22941414	492979706	2400
UF					643923783	167368044	45882828	857174656	
E Mine	0				0	0	0	0	
UF					0	0	0	0	
Y Mine	185	38	0	150	30016755	0	39104683	69121438	2250
UF					50027925	0	78209366	128237291	
North Branch Mine (U)	15	15	0	0	11729837	0	0	11729837	2440
UF					19549728	0	0	19549728	
North Branch Mine (L)	868	496	14	358	387918457	5474656	93329844	486722957	2350
UF					646530762	10949311	186659688	844139761	
Henry #22	670	670	0	0	327501722	0	0	327501722	2620
BT					545836203	0	0	545836203	
Alpine #1	114	109	5	0	53280131	1222021	0	54502152	2620
BT					88800218	2444043	0	91244261	
Alpine #2	96	79	17		38615875	4154873	0	42770747	2620
BT					64359791	8309745	0	72669536	
Emmons	0								NA
BT									

TABLE 2

Flooded acreage based on Mine Pool Elevation as of 6-2010

Acreages calculated using ARCMap software - creating shapefiles for each types of mining - **Acreages are Approximate**

FIGURE 18 -Explanation of Values used in Calculations

Acreages used in the calculation for the "total mine" in addition to the individual types of mining were measured using Arc GIS software with digitized mine maps. The types of mining includes; Developmental also known as 1st Mining, Retreat also known as 2nd Mining and Longwall Mining.

The calculations show a coal thickness for the Upper Freeport seam of Eight (8) and Five (5) feet for the Bakerstown coal seam. These values are an average and based on drill hole data from documents related to the mining activities.

The current mine pool storage volumes were calculated by measuring the mine acreage where a pool exist, based on June 2010 or April 2009 measured or known pool elevations.

1. ***Storage Volume in Areas where Developmental Mining (1st Mining) occurred***

   Min: coal thickness x acres of mine x 30% effective porosity x Conversion Factor (CF)

   Dobbin: 8.0 x 1387 ac x 0.3 x 325,872.4 gal/ft ac = 1,084,851,506 gallons

   Max: ***coal thickness x acres of mine x 50% effective porosity x CF***

   Dobbin: 8.0 x 1387 ac x 0.5 x 325,872.4 gal/ft ac = 1,808,085,844 gallons

2. ***Storage Volume in Areas where Retreat Mining (2nd Mining) occurred***

   Min: coal thickness x acres of mine x 15% effective porosity x CF

   Dobbin: 8.0 x 0.0 x 0.15 x 325,872.4 gal/ft ac = 0

   Max: coal thickness x acres of mine x 30% effective porosity x CF

   Dobbin: 8.0 x 0.0 x 0.30 x 325,872.4 gal/ft ac = 0

3. ***Storage Volume in Areas where Longwall Mining occurred***

   Min: coal thickness x acres of mine x 10% effective porosity x CF

   Dobbin: 8.0 x 3,153 x 0.10 x 325,872.4 gal/ft ac = 821,936,904 gallons

   Max: coal thickness x acres of mine x 20% effective porosity x CF

   Dobbin: 8.0 x 3,153 x 0.20 x 325,872.4 gal/ft ac = 1,643,873,809 gallons

4. ***Total Mine Pool Volume (minimum and maximum)***

   Developmental Mining + Retreat Mining + Longwall Mining

5. ***Potential Discharge Rate using various published Recharge Rates***

   Acreage of mine x (0.5)gpm or (0.75)gpm or (1.2) gpm

   CF = Conversion Factor used in some calculations corresponds to 7.481 gallons per cubic foot and 43,560 square feet per acre.

   [7.481 gal/ft^3 x 43560 ft^2/acre = 325,872.4 gal/ft ac]

FIGURE 19
Potential Storage Volume compared to Current Storage Volume (max)

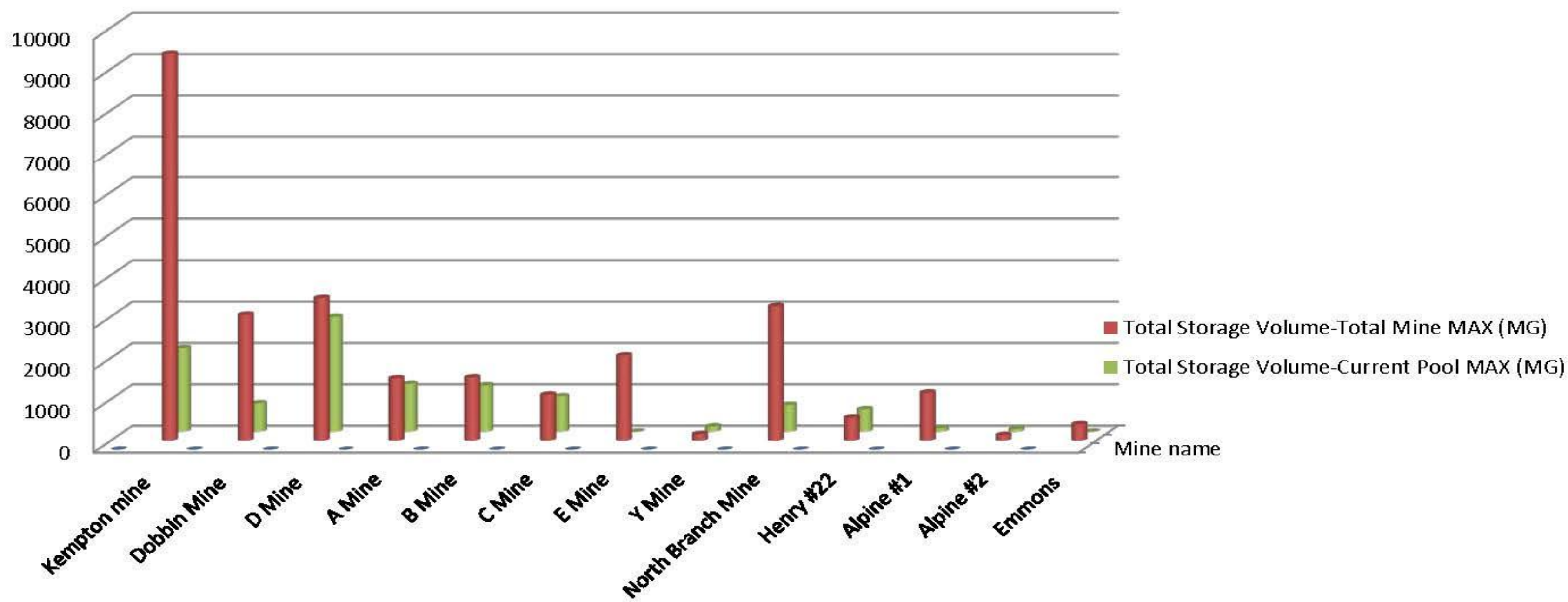
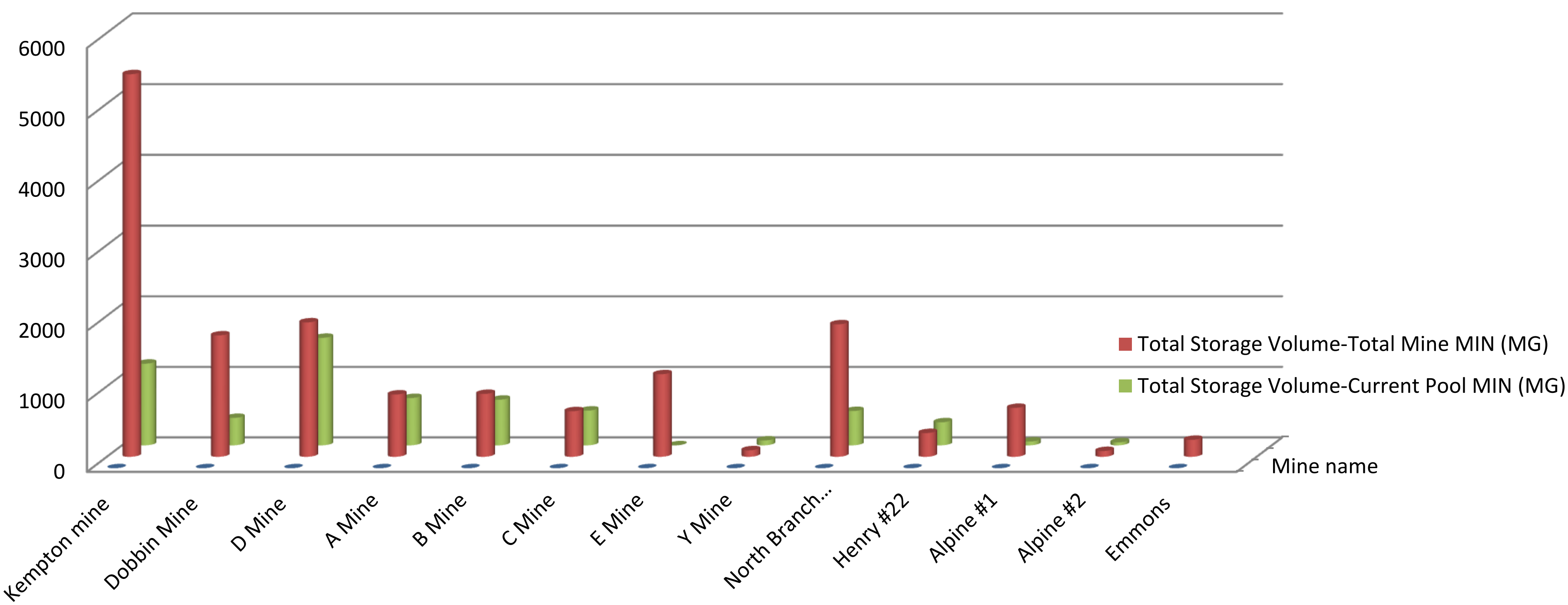


FIGURE 20
Potential Storage Volume compared to Current Storage Volume (min)



Potential discharge rates (PDRs) are the volume of water expected to flow through the mine. PDRs are calculated using a specific recharge rate (i.e.) water flow from precipitation, ground and surface waters then multiplied by the total acreage of the mine. Table 3 provides the potential discharge rates for the individual mines using several recharge rates. Table 4 list a wide range of recharge rates and their applicability and source. A review of the table can be made to determine the most applicable recharge rate for each site. Variables such depth of cover, type of cover rock (shales vs. sandstones), topography, faults and fracture zones and overlying saturated zones can affect the recharge rate and ultimately the potential discharge rate.

The most appropriate rates for this study are those that were generated in or near the study area with similar hydrologic conditions. Rates such as 0.24 gpm/acre and 0.36 gpm/acre were derived from information at the Mettiki E Mine and Mettiki D Mine; however the worst case scenario uses the greatest recharge rate of 1.2 gpm/acre which was also derived from investigations at the Mettiki ABCD Mine. Based on a study conducted at the Kempton Mine from 1998 to 2002, discharges from the Northern Pool were measured and recorded. (US EPA 2002 and Davis and Lyons, 2002). Using this data and the calculated acreage of the mine contributory to the Northern Pool, a calculated flow of 0.5 gpm per acre was calculated. Field derived data such as this is useful in predicting potential discharge values.

Considering this wide range of recharge values in addition to the high precipitation rates of this mountainous location and the significant structure of the mines, a recharge rate of 0.75 was chosen as the most appropriate for this study. A review of Table 3 shows that the areal extent of a mine significantly affects the discharge rates as seen in the rates calculated for the Kempton, Mettiki D and Dobbin Mines.

TABLE 3

POTENTIAL DISCHARGE RATES (PDR) using various POTENTIAL RECHARGE RATES (PRR)

Mine name	PDR with 1.2 PRR (gpm)	PDR with 0.75 PRR (gpm)	PDR with 0.5 PRR (gpm)	PDR with 1.0 PRR (gpm)	PDR with 0.35 PRR (gpm)
Kempton mine	9895	6184	4123	8245	2886
Dobbin Mine	4265	2665	1777	3554	1244
D Mine	5448	3405	2270	4540	1589
A Mine	1598	999	666	1331	466
B Mine	1759	1100	733	1466	513
C Mine	1218	761	507	1015	355
E Mine	2838	1774	1183	2365	828
Y Mine	226	141	94	188	66
North Branch Mine	3747	2342	1561	3122	1093
Henry #22	827	517	345	689	241
Alpine #1	1768	1105	737	1474	516
Alpine #2	233	146	97	194	68
Emmons	591	369	246	493	172

TABLE 4
RECHARGE RATES (with sources)

Recharge Rate	Recharge Rate gpm/Acre	Source	Notes
	0.24	Levitt Method (1997)	E-Mine Permit calculations using 1.117e(-0.0045H)
	0.21	D-mine	USGS Report 1988
	0.36 and 0.31	E-mine permit/calculations for D-mine	Calculations using Pump Records, WV
	0.50	Parizek 1971, 1986 diPretoro Study	OSM Rule of Thumb, US EPA, 1975
12.4"	0.64	Cambria County (McElroy, 1998)	2010 PAGS Water Resource Report 70
20.3"	1.05	Somerset County (2000)	2010 PAGS Water Resource Report 70
	0.76 - 1.2	Hlortdahl, S. N.	Report of Investigation No. 41-A, Garrett Co., MD
	0.26 - 0.75	OSMRE, 2005 Lancaster 15 Mine Complex	Freeport & Kittanning Cambria Co., PA
2"- 6"	0.1 -0.31	Freal @ USGS, 1989	Recharge rate in WV region of E permit

H = Average overburden @ 350'

Hydrologic Characterization of the Mine Pools – Current and Potential Future Mine Pool Elevations

Table 5 is a summary table outlining each mine pool associated with the underground mine and their current and potential future pool elevation. The current pool elevations are based on data collected during the study investigation (2009 and 2010) and the potential future pool elevations were determined using the extent of mining and or spill over points based on coal mine structure and topographic conditions. Generally the future prediction was made using the "highest point of mining" assuming that this will control and limit the pool. These maximum pool elevations may not be reached if significant leakage occurs throughout the mine. The maximum head will be at the level where steady state conditions are reached and the inflow to leakage is balanced.

TABLE 5

CURRENT & PREDICTED MINE POOL ELEVATIONS

MINE POOLS - HYDROLOGIC CHARACTERISTICS

Mine Name	Mine Pool Elevation Current	Comments for Current Pool	Predicted Future Mine Pool Elevation (w/o pumping)	Comments for Predicted Pool
	Feet		Feet	
Mettiki - D Mine	2250	Metikki maintaining pool with pumping (June 2010 measurement)	2450	Highest elevation of mine works
Mettiki -Y Mine	2250	Metikki maintaining pool with pumping (June 2010 measurement)	2450	Mine connected to Metikki D
Metikki - A Mine	2275	Metikki maintaining pool with pumping (June 2010 measurement)	2550	Highest elevation of mine works
Mettiki - B Mine	2275	Metikki maintaining pool with pumping (June 2010 measurement)	2550	Mine connected to Metikki A
Mettiki - C Mine	2400	Metikki maintaining pool with pumping (June 2010 measurement)	2550	Highest elevation mine works
North Branch Mine -Upper	2440	Artesian Borehole (Buffalo Creek)	2500 & 2440	Artesian Boreholes @ Buffalo Creek (2440) & Wilson Boreholes (2500)
North Branch Mine -Lower	2350 (2338*)	Consolidated Coal maintains through pumping system	2500	Wilson Boreholes
Dobbin Mine	2550 (2485*)	Consolidated Coal maintains through pumping system	2680 & 2640	Flow into Alpine/Henry Mine thru Alpine/ Dobbin Borehole (2680) & leakage to River (2640)
Kempton Mine	2655	Airshaft and Borehole Discharges	2655	Airshaft and Borehole Discharges
Metikki - E Mine	2650**	Actively Mining - no pool developed	2900	Leakage into Alpine / Henry Mine (2900)
Henry #22	2620 (2616*)	Consolidated Coal maintains through pumping system	2680 & 2640	Alpine Borehole (2680) & Leakage into River (2640)
Alpine #1	2620	Consolidated Coal maintains through pumping system	2680 & 2640	Mine interconnected with Henry & Alpine
Alpine #2	2620	Consolidated Coal maintains through pumping system	2680 & 2640	Mine interconnected with Henry & Alpine
Emmons	2500	Gravity Drain Discharge	2500	

Current pool elevations for Consolidation Coal Company mines are based on maximum elevation maintained by company

* - Elevations measured with Consolidated Coal on 4-2009

** - Lowest elevation of coal seam in E mine

Hydrologic Characterization of the Mine Pools – Potential Surface Water Breakout Locations – North Branch Potomac River

A determination of potential breakout or leakage points to the surface with particular emphasis on the Potomac River is provided. The areas with greatest potential for a post-mining discharge or leakage from the mine pools are those areas with high hydraulic head in the mine pool that is greater than surface elevation and thin, fractured overburden. These areas are designated as potential breakout areas. Water from the mine pool, due to fluid pressure, flows through the fractures to areas of lower hydraulic pressure, and ultimately releases water from the pool. The difference in the hydraulic head from one point to another, divided by the length of flow path, is the hydraulic gradient. In hydrogeology, it is commonly expressed as dh/dl, and is the driving force for water movement. Using these principles, potential breakout points were plotted on Figure 21. The greatest risk for a mine pool to break-out in or near the river is the location where the hydraulic pressure is the greatest and the overburden thickness is the least. Fractures in valley bottoms are greater in depth and of more frequency than valley sides. This concept has been studied by numerous researchers describing groundwater flow. Ferguson (1967 and 1974); Ferguson and Hamel (1981); Wyrick and Borchers, (1981); Kipp and Dinger (1991) and Minns (1993) have documented the existence and extent of fracture systems within the valleys and ridges of the Appalachian Plateau. These naturally occurring fractures, in addition to mining-induced subsidence and tectonically-formed fractures, must be accounted for in assessing risk for mine pool surface breakouts. In general, the greater the overburden thickness between the mine and the river, the less the risk for mine water to come to the surface. The mine pool hydraulic head must attain the same or greater elevation as the river elevation and there must be an open flow path formed by fracture or group of interconnected fractures or porous media for the mine water to breakout to the surface.

Figure 21 shows five potential breakout locations labeled A through E. Location A is at a river elevation of 2314’ m.s.l. with 90 feet of overburden between the mine and the river. The potential for a breakout is significant when the D-Mine pool reaches an elevation of 2314’ m.s.l. (river elevation) and greater. If the pool continues to increase beyond the predicted maximum elevation, further leakages will develop upstream. The approximate minimum horizontal distance between the edge of the mine works and the river location is 500 feet. Location B is at a river elevation of 2500’ m.s.l. with an overburden of 355 feet. If the North Branch Mine Pool reaches an elevation of 2500’m.s.l. or greater there is a potential for leakage. The minimum horizontal distance is 200 feet which increases the risks of pool leakage. Location

C is the breakout location relative to the Mettiki AB Pool. Location D is the breakout location relative to the Alpine/Henry Mine Pool and Location E the breakout location for the Y Mine (D-Mine Extension). Table 6 below summarizes the factors for all five breakout locations.

TABLE 6

LEGEND	MINE POOL	RIVER ELEVATION	Overburden Thickness	Horizontal Distance (min)
A	D MINE	2314’m.s.l.	90’	500’
B	NORTH BRANCH	2500’m.s.l.	355’	200’
C	AB MINE	2500’m.s.l.	350’	<100’
D	ALPINE/HENRY	2640’m.s.l.	220’	0
E	Y MINE	2400’m.s.l.	300’	200’

The maximum predicted pool elevation is used to define the five breakout locations noted in Table 6 and Figure 21. If the pools exceed their maximum predicted elevations, further leakage will occur in upstream reaches beyond the breakout locations; in particular, the Y-Mine entries located beneath the river at an elevation of 2460’ m.s.l. and the Henry Mine workings located directly beneath the river. These reaches may be at risk for breakouts if the associated mine pools rise beyond their predicted elevations.

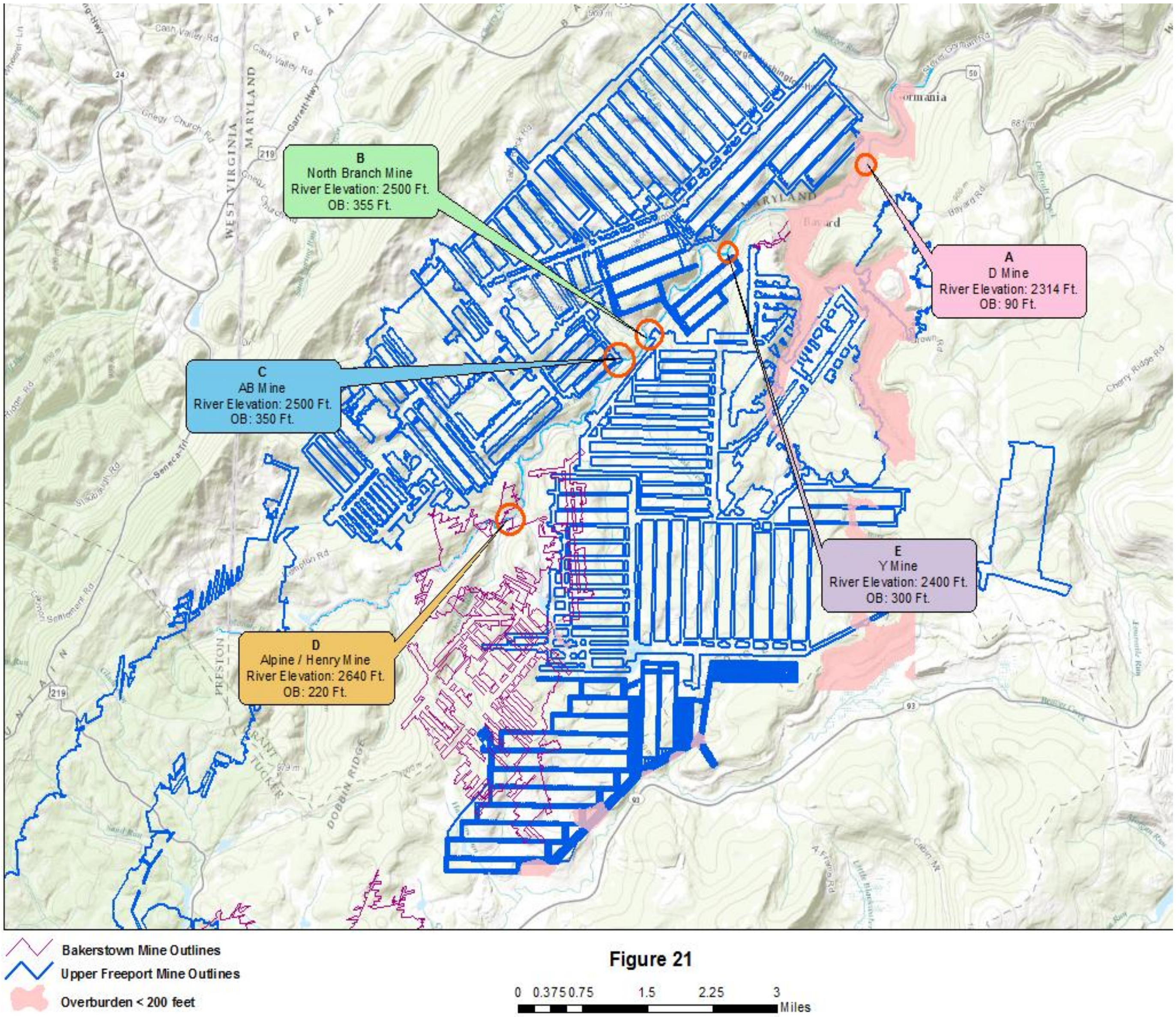


Figure 21

Figure 21 also shows the areas within the study site where the overburden is less than 200 feet thick (pink shaded areas). These locations are susceptible to leakage from mine pools given pathways created by fractures in the shallow overburden and weathered strata. The importance of the weathered zone is that fractures are more frequent and there is a greater connectivity within the first 200 feet of strata. This condition provides a pathway for leakage from the pools to the surface.

Hydrologic Characterization of the Mine Pools – Water Balance Calculations

Using a water balance calculation, mine filling rates at Mettiki AB, and D mines were estimated. Inflow includes recharge (precipitation & surface), vertical leakage, horizontal leakage (through barriers) and water introduced for operational purposes. Outflow includes horizontal seepage (through barriers), pumping from the mine, discharges to the surface, baseflow to streams, and vertical seepage into overlying mines. The results were 0.7 gpm per acre for the AB Mines and 0.5 gpm per acre for the D Mine and D Extension (Y Mine). The timeframe for the measurements were from January 2007 through March 2008.

Water Balance Calculation AB Mine (see Figure 22)

Pool Elevation – 2100' – 2315 acres

[pool elevation and acreage at time 0 days]

Pool Elevation – 2230' – 1532 acres

[pool elevation and acreage at time 288 days]

783 acres of mine flooded in 288 days

8' x 783 acres x 0.30 x 43560 ft2/acres x 7.481 gal/ft3 = 612379339 gal

[thickness of UF coal x void space available x conversion factor]

612379339 gal/288 days x 1 day/1440 min = 1477 gal/min

[Gallons of water produced per 288 days x conversion factor]

*1477 gpm + **203** gpm (pumping from Mine) = 1680 gpm*

[add the amount of water pumped out from company]

1680 /2450 (total area of AB Mine) = 0.69 gpm per acre

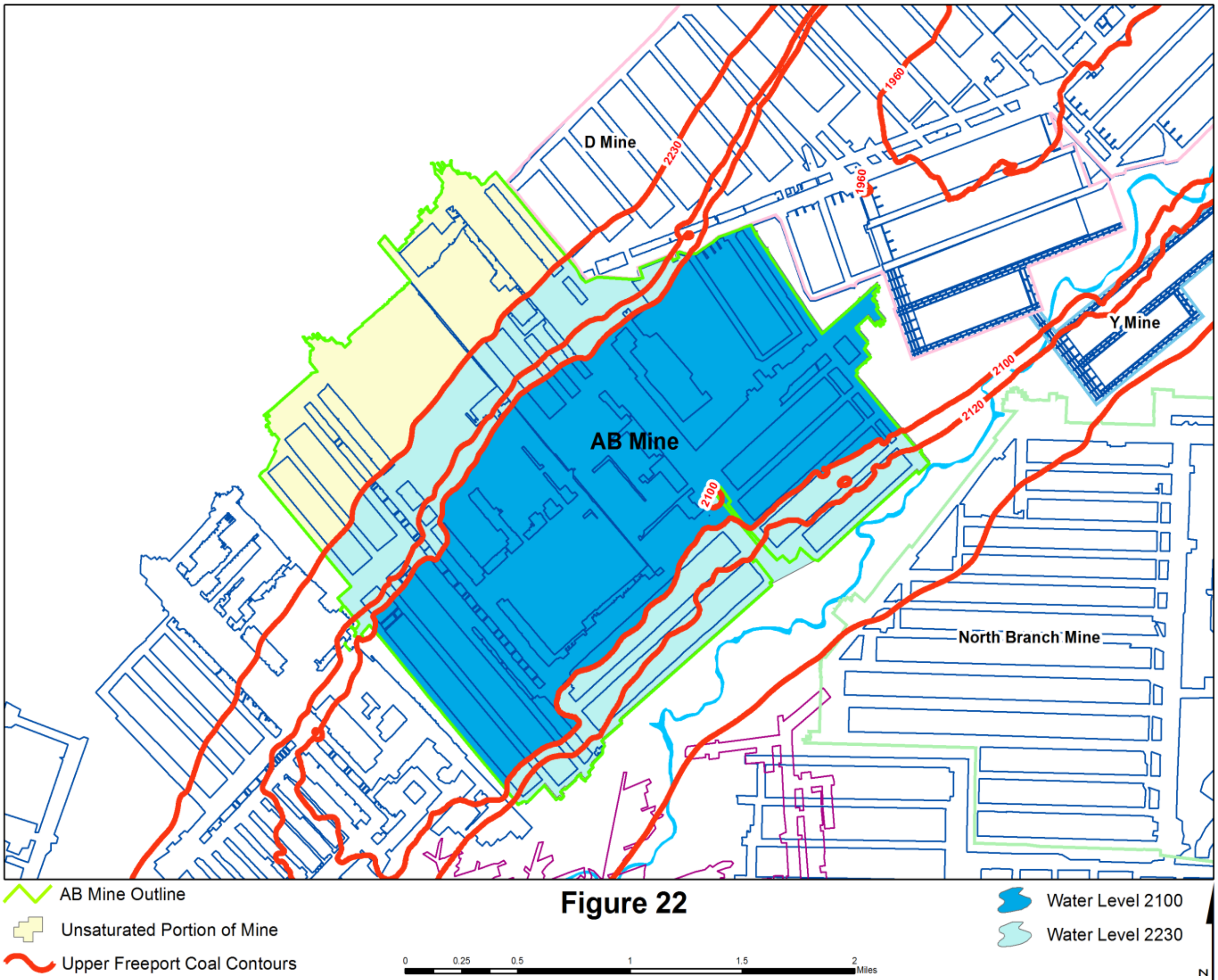


Figure 22

Pumping Calculations from January 2007 to March 2008.

Approximately 700 gpm for all Mettiki Mines, D, Y, AB and C

Mine Name	*Acreage*	*Percent of Total Mine*	*Pumping Rate gpm* *Total 700 gpm*
D/Y Mine	*5,036*	*59*	***413***
AB Mine	*2,450*	*29*	***203***
C Mine	*1,041*	*12*	*84*

Water Balance Calculation for Mettiki D Mine / D Extension (Y Mine)

Pool Elevation – 1960' m.s.l. – 1234 acres

Pool Elevation – 2120' m.s.l. – 3597 acres

2363 acres of mine flooded in 220 days

8' x 2363 acres x 0.10 x 43560 ft2/acre x 7.481 gal/ft3 = 616029109 gal

616029109 gal/220 days x 1 day/1,440 min = 1945 gpm

*1945 gpm + **413** gpm (pumping from mine) = 2358 gpm*

2358/ 5036 (total area of D Mine/Y Mine) = 0.47 gpm per acre

RECHARGE RATES (infiltration rates) USING 2008 PUMP RECORDS

Using the pumping records from January 2008 to December 2008, which are submitted to the MDE, Water Management Administration under a water withdrawal permit, an average recharge rate of 0.7 gpm per acre, is calculated for the Mettiki Mines in Maryland. Based on information received from the MDE, pumping from the mine (AB through Y) significantly increased from the year 2007 to 2008. The pumping rate used in 2008 was for the purpose of maintaining the pool elevation at a level below the North Branch Potomac River, whereas the pumping rate used in 2007 was for operational purposes.

INTERACTIONS BETWEEN MINE POOLS WITHIN THE STUDY AREA

This section discusses both the current interactions, that is, transfer of water, and potential future interaction between the various mine pools within the study area. On the Maryland side, data have been presented individually for each of the Mettiki AB, D, Y, and C Mines. Although these mines have been discussed separately relative to their hydrologic properties, they are physically connected through cross cuts and openings, and somewhat restricted water transfer also takes place as flow through intact coal barriers. However, hydrologically they act as separate leaky pools. Due to the coal structure, leakage is occurring from the C Mine to AB then to D /Y extension.

Figure 12 is a graph showing water levels for 4 wells which represent the different mines as discussed in earlier sections. Borehole E3-1 and Well GaFb-22 are both located in the AB Mines and show similar water levels from August 2007 throughout the monitoring period. Since May of 2008, pumping increased and the pool has been relatively stable with slight fluctuations. Well GaFb-35 is located in the

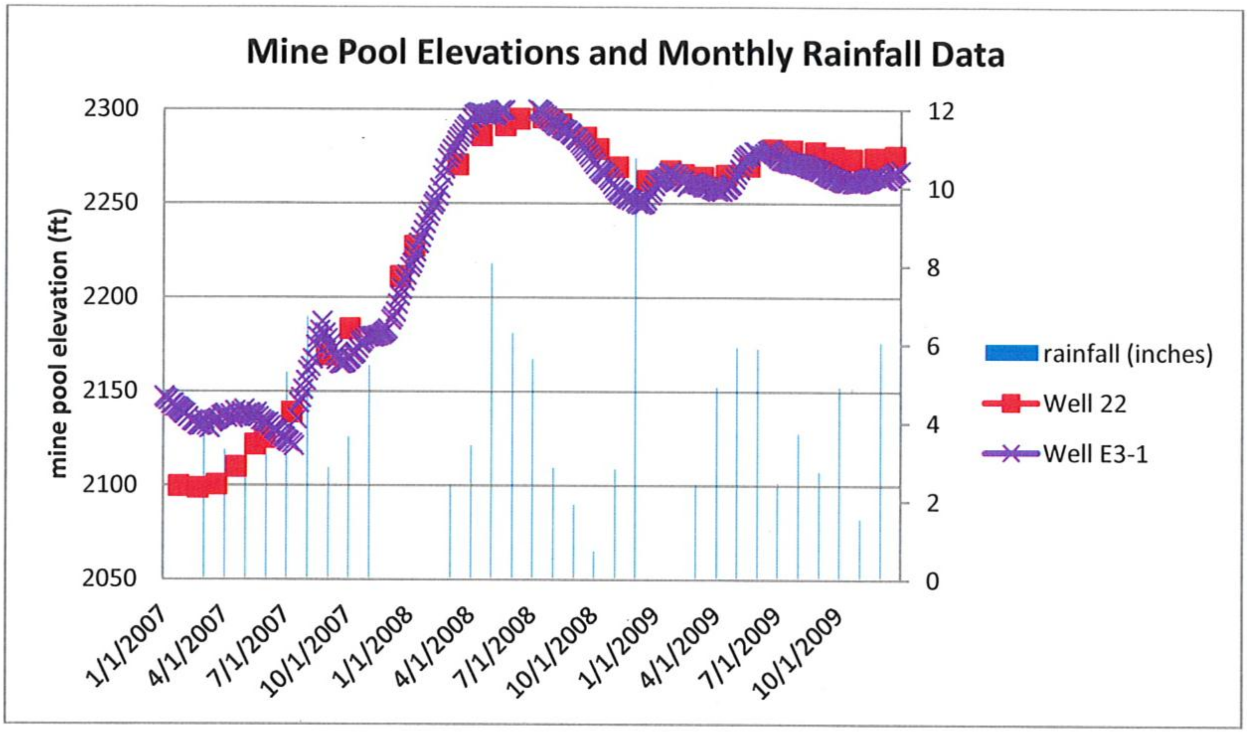
D Mine and shows a similar water level pattern, however, it is between 20 to 30 feet lower in elevation than the AB Mines. The C- Mine well which has been consistently higher than the others is difficult to interpret due to its location in an area where a significant amount of slurry was injected. Additionally, there is evidence that an upper saturated zone leaks into the monitoring well; compounding the interpretation of water elevations. However, based on the coal structure, Mine C is located in the up dip portion of the mine complex, therefore it is expected that the mine pool would have the highest elevation. Based on mine locations and hydraulic head data, the general sequence of water flow and barrier leakage between mines is:

C mine leakage to AB Mine

AB mine leakage to D Mine

Figures 23 through 25 show the precipitation vs. water levels in the Mettiki AB, C, and D pools based on water level measurements from the wells. A review of the graphs shows that the rise and fall of the mine pool levels are not clearly related to the precipitation events; nor does there appear to be the same seasonality in the water levels as seen in the rainfall data. It would then follow that the current pumping and injection activities of Mettiki are the most significant influence on mine pool levels.

FIGURE 23


Mine Pool Elevations and Monthly Rainfall Data
mine pool elevation (ft)
2300
2250
2200
2150
2100
2050
12
10
8
6
4
2
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
rainfall (inches)
Well 22
Well E3-1

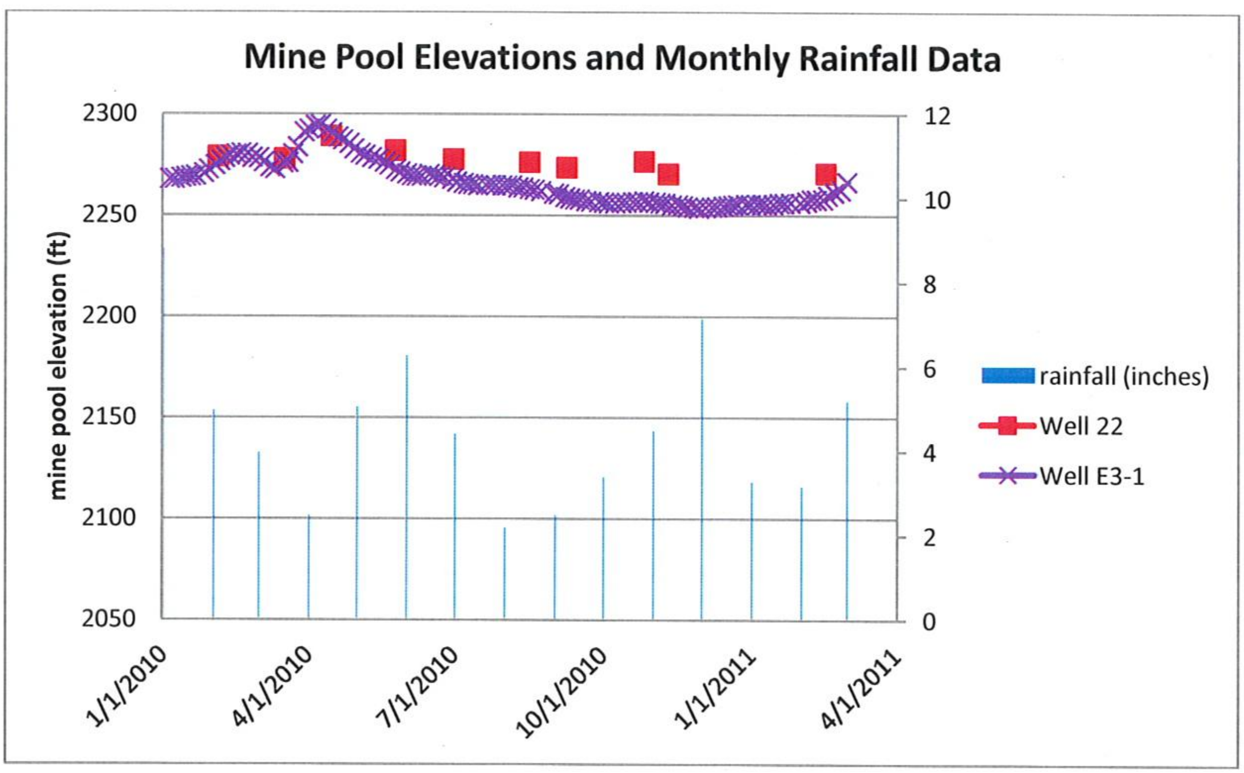
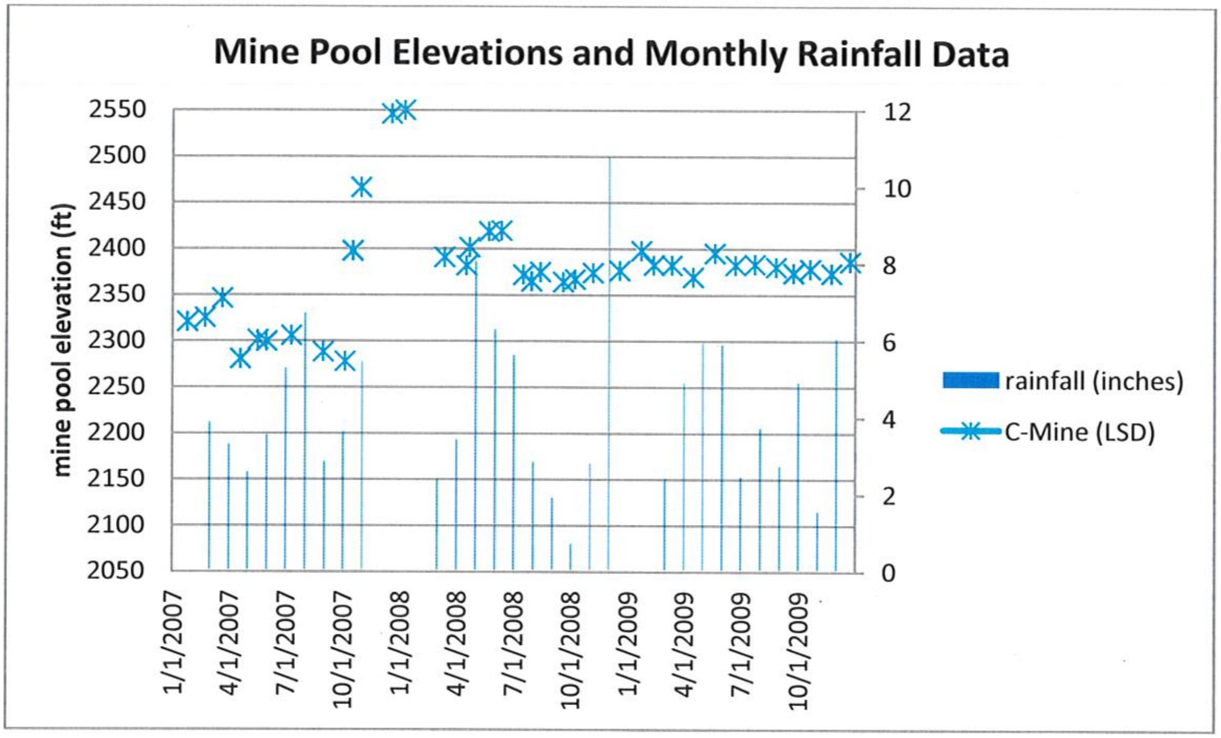

Mine Pool Elevations and Monthly Rainfall Data
mine pool elevation (ft)
2300
2250
2200
2150
2100
2050
12
10
8
6
4
2
0
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
rainfall (inches)
Well 22
Well E3-1

FIGURE 24


Mine Pool Elevations and Monthly Rainfall Data
mine pool elevation (ft)
2550
2500
2450
2400
2350
2300
2250
2200
2150
2100
2050
12
10
8
6
4
2
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
rainfall (inches)
C-Mine (LSD)

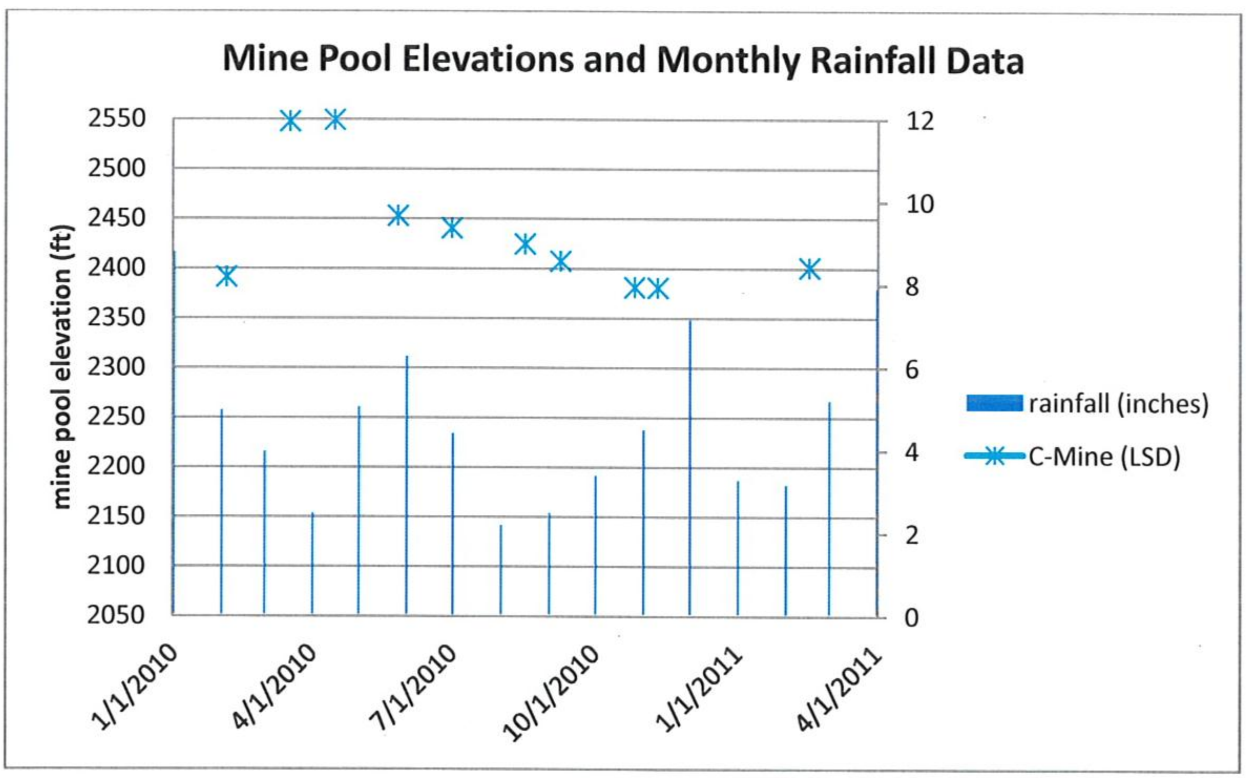
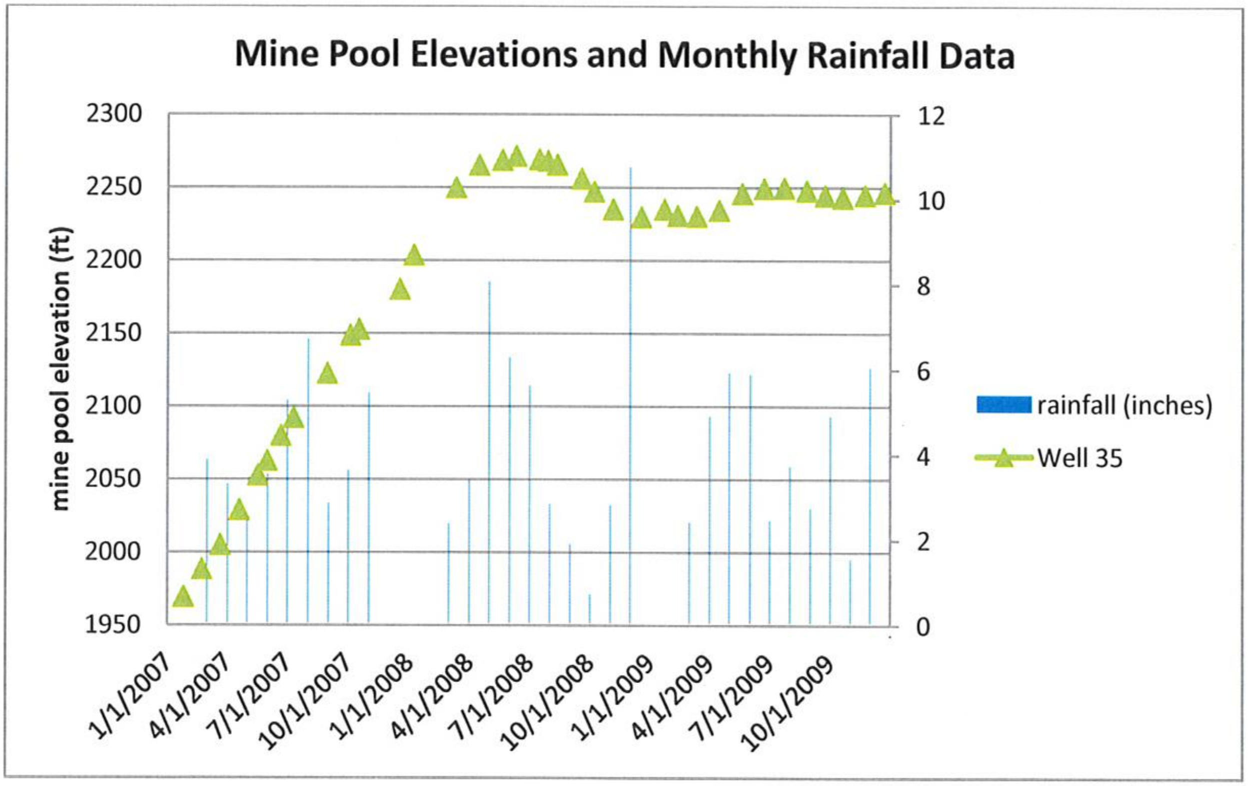

Mine Pool Elevations and Monthly Rainfall Data
mine pool elevation (ft)
2550
2500
2450
2400
2350
2300
2250
2200
2150
2100
2050
12
10
8
6
4
2
0
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
rainfall (inches)
C-Mine (LSD)

FIGURE 25



Mine Pool Elevations and Monthly Rainfall Data
mine pool elevation (ft)
2300
2250
2200
2150
2100
2050
2000
1950
12
10
8
6
4
2
0
rainfall (inches)
Well 35
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
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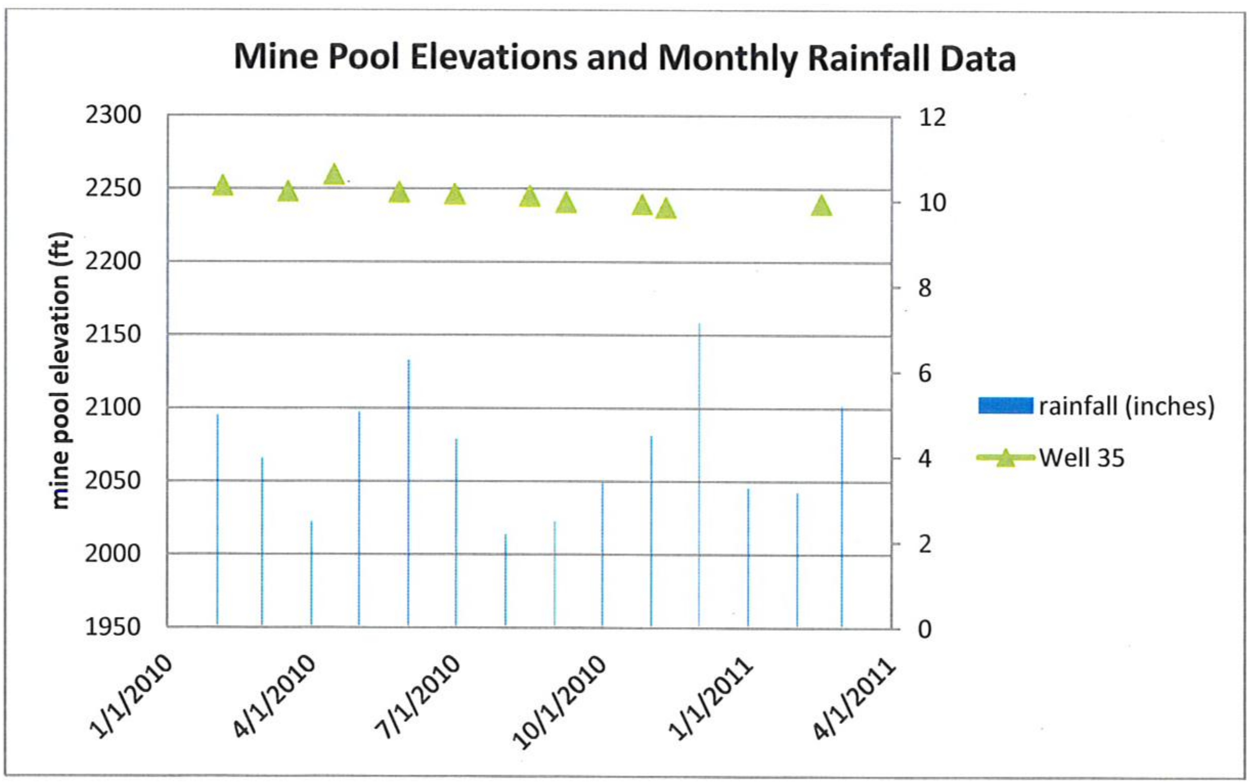
7/1/2009
10/1/2009



Mine Pool Elevations and Monthly Rainfall Data
mine pool elevation (ft)
2300
2250
2200
2150
2100
2050
2000
1950
12
10
8
6
4
2
0
rainfall (inches)
Well 35
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011

On the West Virginia side of the project area, there are physical connections between Consolidation Coal Company's mines located on the Bakerstown Coal Seam (i.e.) the Alpine #1, #2, and Henry #22 Mines. The mines located on the Upper Freeport coal seam are not physically connected, however Consolidation Coal through a system of pipelines and wells, have provided a hydrologic connection for the purpose of water treatment. (Figure 15) The Dobbin Mine has a coal barrier along its northern edge which separates its workings from the North Branch Mine. The barrier dimensions are approximately 11,000' in length and between 200' to 300' wide. Mettiki's active Upper Freeport mine, the E-mine, is located south of Consolidation Coal Company's Dobbin Mine. At the northern border of the mine there is a coal barrier between the Dobbin Mine. Its length is approximately 21,000 'and its width varies from 350' to 500'. The barrier is clearly shown on Figure 17.

MINE POOL LEAKAGE ANALYSES – UPPER FREEPORT MINE POOL - Current Condition

Leakage analyses were performed to estimate quantitatively the potential for leakage to occur to the North Branch Potomac River from the current mine pools. The analyses were performed using the Darcy equation assuming one dimensional (horizontal) leakage through coal barriers. This equation [Q=KIA] is used extensively to describe groundwater flow through a porous medium. The flow [Q] is dependent upon the hydraulic conductivity [K] of the media, the head difference over a specific length [I] and the cross sectional area [A] to the flow. Table 7 is a summary of various K values for coal and overburdens associated with coal mining. K values describe the ease in which water flows through the medium. The table was compiled and consulted to determine the most appropriate values for the leakage calculations.

TABLE 7

HYDRAULIC CONDUCTIVITY VALUES (K) with sources

Hydraulic Conductivity ft/sec	Hydraulic Conductivity ft/day	Source	Material	Notes
1.71E-05	1.47	Jay W. Hawkins	coal	Lancashire #15 Report
2.64E-06	0.23	Jay W. Hawkins	coal	"
1.92E-08	0.00	Jay W. Hawkins	coal	"
8.66E-06	0.75	Jay W. Hawkins	LK coal	median value used in report
	0.12	McCoy, Donovan, Leavitt 2006	coal isotropic	moderate depth
	0.59	McCoy, Donovan, Leavitt	coal isotropic	moderate depth
	0.24	McCoy, Donovan, Leavitt	coal anisotropic	moderate depth
	1.10	McCoy, Donovan, Leavitt	coal anisotropic	moderate depth
	1.00	Miller, J.T. , D.R. Thompson, 1974	UF	shallow cover
	3.21	Miller, J.T. , D.R. Thompson, 1974	UF	shallow cover
	0.75	Miller, J.T. , D.R. Thompson, 1974	UF	LK Coal &OB shallow cover
	4.25	Miller, J.T. , D.R. Thompson, 1974	OB	shallow cover above mine void
	1.98	Miller, J.T. , D.R. Thompson, 1974	Mine Debri	100' cover
	0.065*	Hawkins & Smoyer, 2012	interburden	Middle & Lower Kittanning Coal (Elk County, PA)
* vertical K value all others are horizontal K values				

Current hydraulic head conditions within the Upper Freeport mine pools are such that mine pools developed in WV leak toward the mine pools located in MD. Flow is mainly horizontal and confined to the coal seam. Figure 26 shows the flow path segments where the calculations were made and Table 8 located in the Appendix B provides the calculations with an explanation of the values.

There is no potential for leakage to the Potomac River given the current pool elevations, which are being maintained through pumping. Segments 1A through 1C delineate the potential leakage from the North Branch Mine Pool to the Mettiki AB Mine. Flow occurs from the southeast to the northwest below the river bed. Segments 2A through 2G delineate potential leakage from the North Branch to the D/Y Mine. Maximum and minimum calculations were completed using two different K values for the coal seam. The maximum flow from the WV mine pools to the MD pools was calculated at 30 gpm and the minimum was 23 gpm. The range of flow values calculated is due to the range of K values used. These values were chosen due to their applicability to the site (i.e.) coal is the medium for flow and values were derived from underground mine studies. Table 7 outlines various K values and their sources.

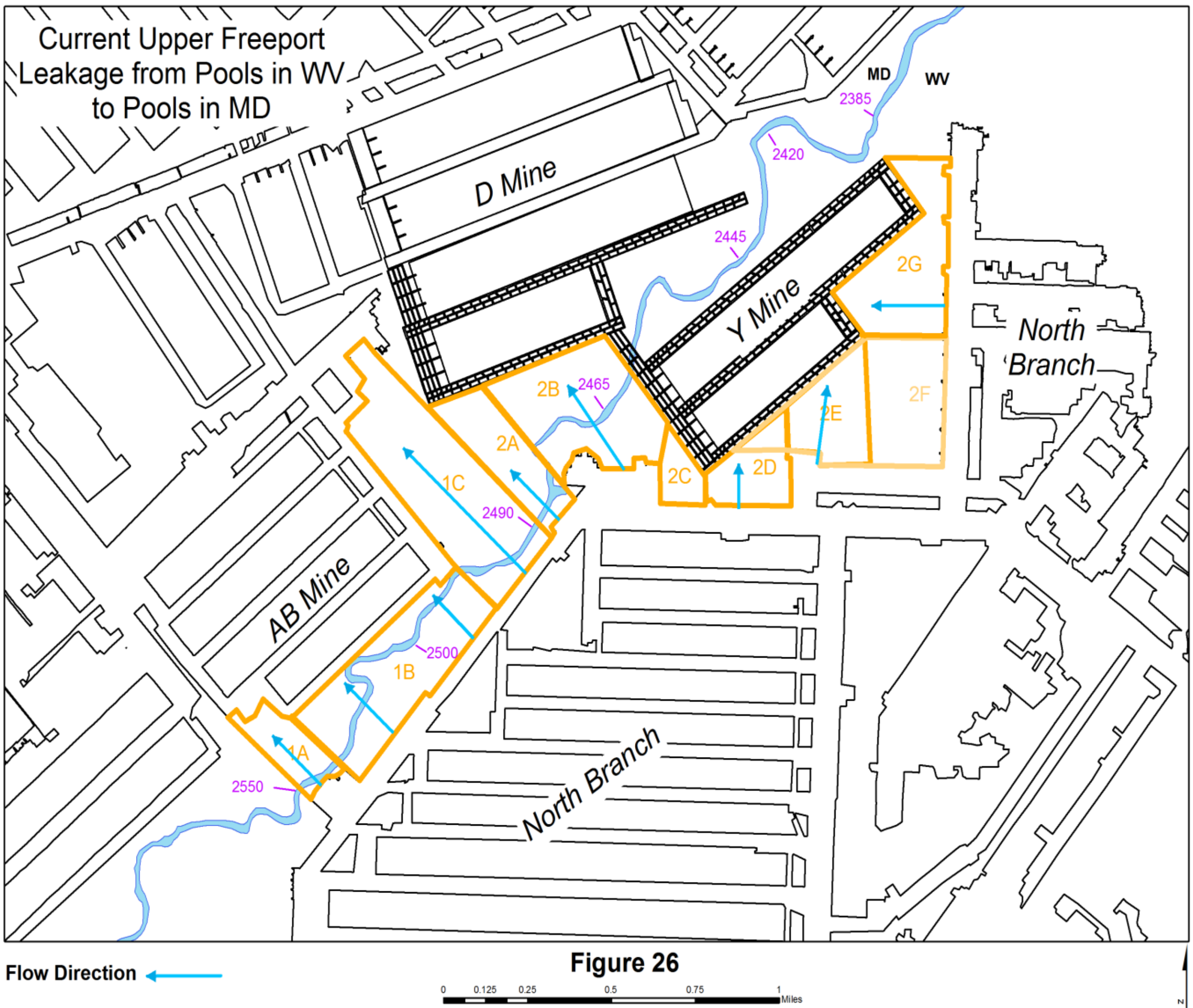


Figure 26

MINE POOL LEAKAGE ANALYSES – UPPER FREEPORT MINE POOL -Predicted Future Conditions

A leakage analyses was performed to determine the potential leakage from the mine pools to the river in the future if pumping of the mines was not occurring. This represents a worst case analysis of no control on the mine pool and maximum hydraulic head. It is unlikely that the pools will be fully flooded given the significant structure of the mines. The pool may reach steady state conditions where recharge and outflow are balanced at something less than maximum head values.

Figure 27 outlines the flow path segments where the calculations were made to determine the potential leakage amount. Flow was assumed to be horizontal and confined to the Upper Freeport coal seam. The figure shows potential leakage from the pool located in MD, specifically the Mettiki AB and D Mines to the river. Table 9 located in the appendix provides the calculations. Flow was calculated from the mine pools to the river in a SE direction however, not all segments have flow from the pool to the river due to lack of head differences. The maximum flow from the MD mine pools to the river was calculated at 67 gpm and the minimum at 28 gpm.

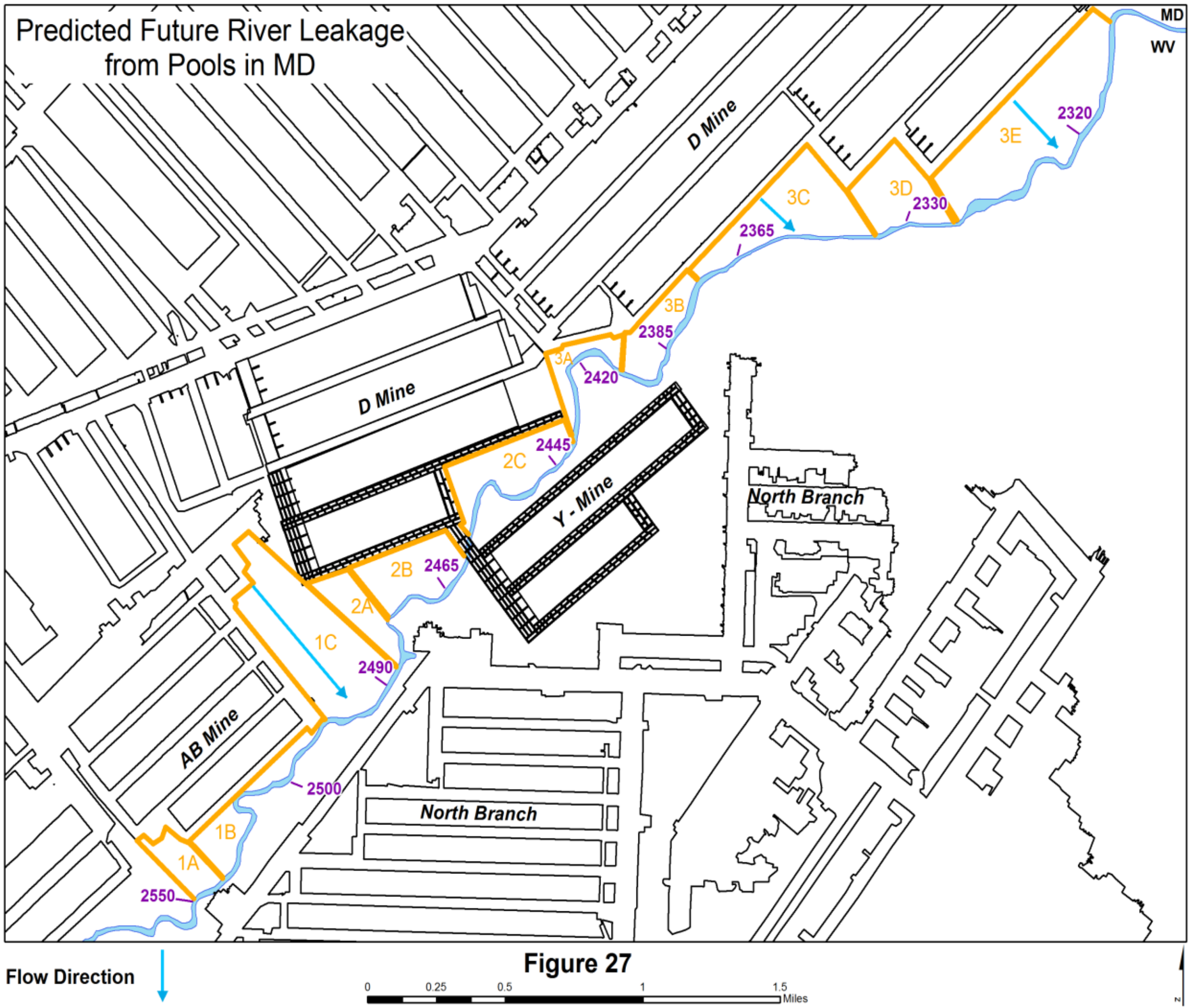


Figure 27

Figure 28 shows potential leakage from the pool located in WV, specifically the North Branch Mine and Mettiki Y Mine to the river. Again, flow is assumed horizontal and through the coal seam to the river. All segments have flow calculated from the mine pools to the river in a northwest direction. The maximum flow from the WV mine pools to the river was calculated at 18 gpm and the minimum at 13 gpm. Calculations are found on Table 10 in the appendix.

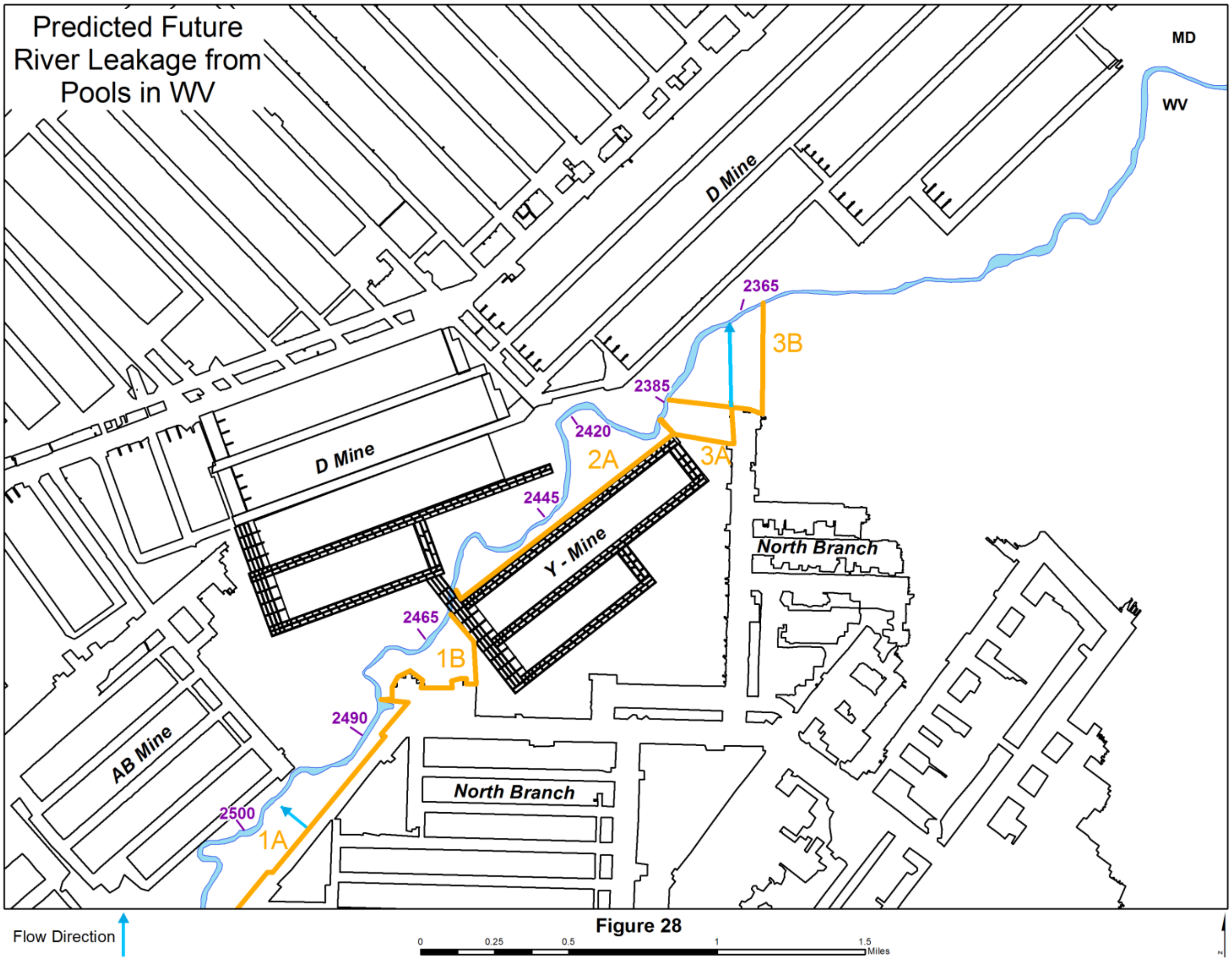


Figure 28

E- Mine Pool has the potential to leak through the coal barrier into the Dobbin Mine in the future if the predicted head exceeds the head of the Dobbin Mine. The barrier prevents the free flow from the E Mine to the Dobbin but it does not prevent significant leakage. A seepage analyses was conducted for that scenario. Figure 29 shows the flow segments used in the calculations and Table 11 (in appendix) provides the calculations. Flow is horizontal and confined to the coal. Maximum leakage from the E-Mine to the Dobbin pool is 270 gpm while the minimum is 200 gpm. Conceptually, this leakage will not increase the pool elevation but increase outflow from the Dobbin mine pool. This increase in outflow could be seen as additional leakage to the river (via the Alpine/Henry pool). It is reasonable to assume that not all the leakage will manifest itself as leakage to the river; outflow may also occur as horizontal and vertical leakage to adjacent pools or surrounding aquifers.

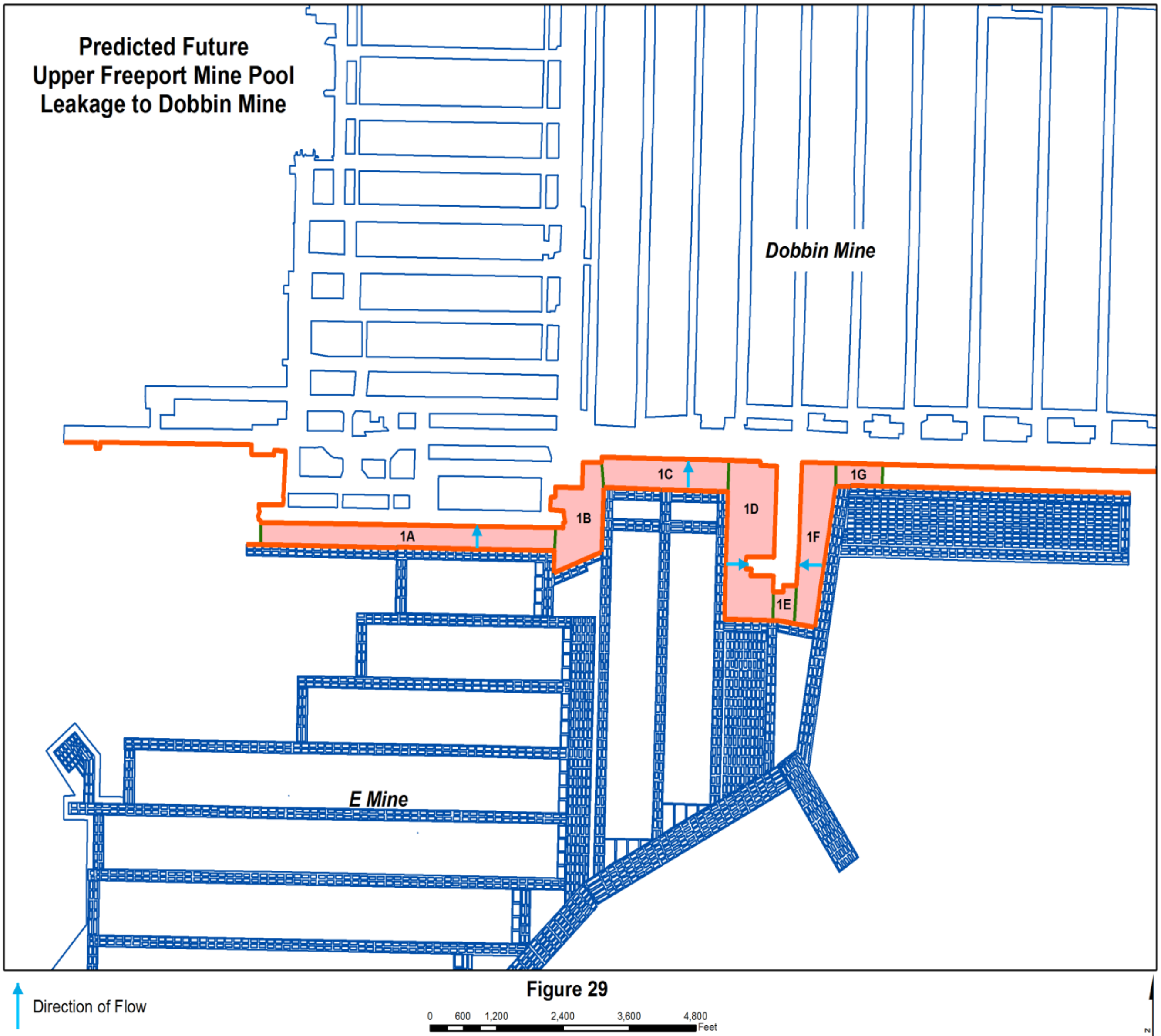


Figure 29

Horizontal barrier leakage calculations were also completed from the Dobbin pool to the North Branch mine. Figure 30 illustrates the segments used to calculate the rates and Table 12 provides the calculations. Note that sections 1D and 1E are upgradient of flooded sections therefore, average mine floor structure contours were used for head values. *Based on the one-dimension calculations, the maximum potential leakage is 304 gpm while the minimum is 225.*

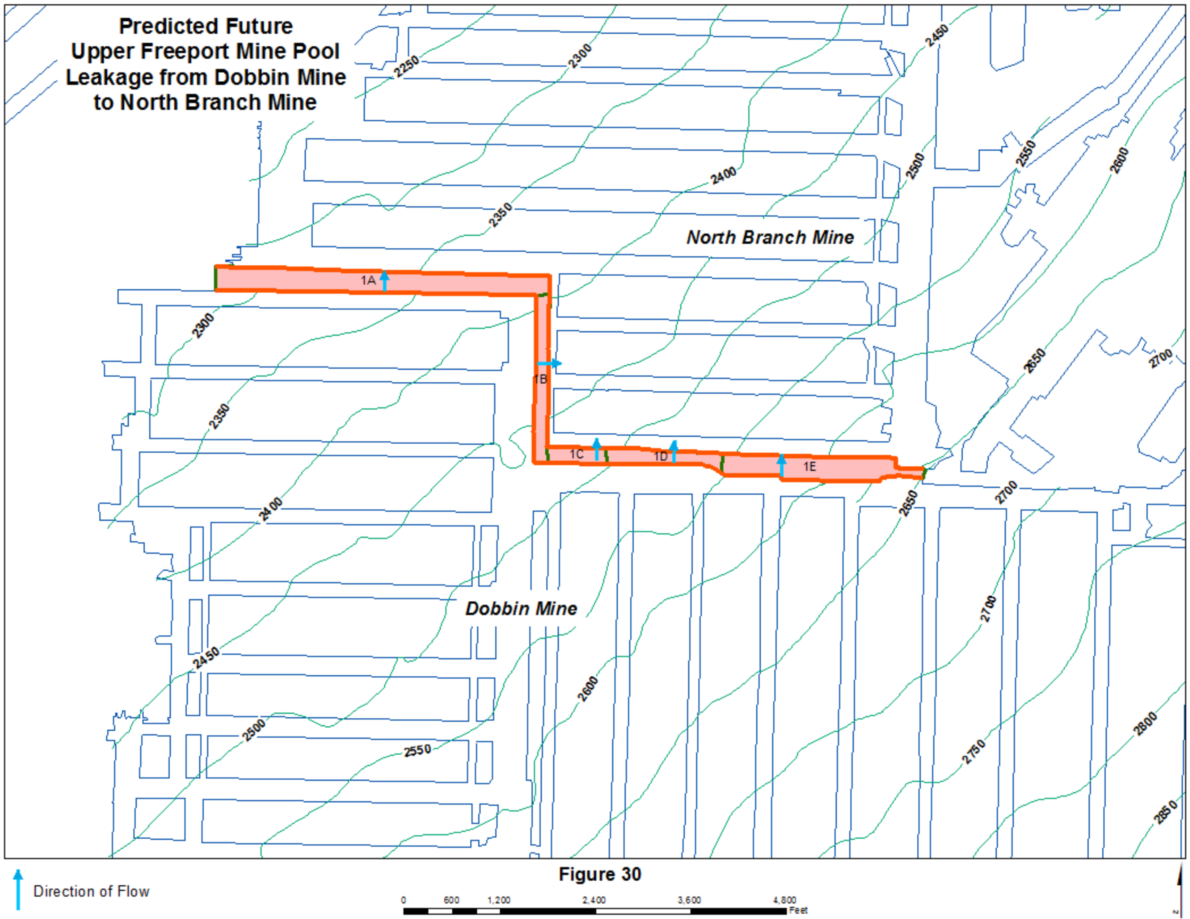


Figure 30

MINE POOL LEAKAGE ANALYSES – BAKERSTOWN MINE POOL – Current Conditions

Currently the Alpine/Henry mine pool in the Henry #22, Alpine #1, and Alpine #2 are maintained at approximately 2620' m.s.l. due to pumping. *This current pool elevation is lower than the Potomac River; therefore there is currently no leakage to the river.* The closest existing mine pools are the Dobbin and North Branch which are hydrologically connected through Consolidation Coal Company 's pumping regime. No leakage from the current pool to adjacent lower Upper Freeport coal mines in Maryland would be expected.

MINE POOL LEAKAGE ANALYSES – BAKERSTOWN MINE POOL – Predicted Future Conditions

Predicting the potential leakage from the Alpine and Henry Mines will assume that the pumping of the pool ceased and that the Alpine/Dobbin pump boreholes controls the pool's elevation at 2680' m.s.l. Discharges to the Potomac River would occur from the boreholes. The maximum leakage rate can be estimated from the total calculated potential discharges for all three mines (as shown on Table 3) plus any additional flow from barrier leakages. The average calculated discharge for all 3 mines (based on a recharge rate of 0.75 gpm/acre) is approximately 1,700 gpm. It is reasonable to assume that a portion of the pool would flow from the borehole while a component of the flow would occur as leakage to the river. Figure 31 shows the flow path segments and Table 13 (located in the appendix) provides the calculations for potential leakage from the underlying pool to the river. In the calculations, a 50 foot horizontal flow segment was established on both sides of the river with vertical flow from the Alpine/Henry mine pool up to the river. The 50 feet horizontal width in combination with the 10 foot river width provided the total width of 110’ to represent the stream valley. Given the location of stress relief fractures in combination with subsidence fractures these segments represent potential flow paths from the pool to the river bed. Since the flow path is vertical, overburden thickness values were used as length of the flow path. Due to the occurrence of both fracture systems in this location, the overburden is expected to be very permeable therefore, relatively large K values should be appropriate. The maximum flow was calculated as 967 gpm applying a K value of 2.0 ft/day with a minimum flow of 358 gpm applying a K value of 0.75 ft/day. These rates are realistic when compared to the potential discharge rates.

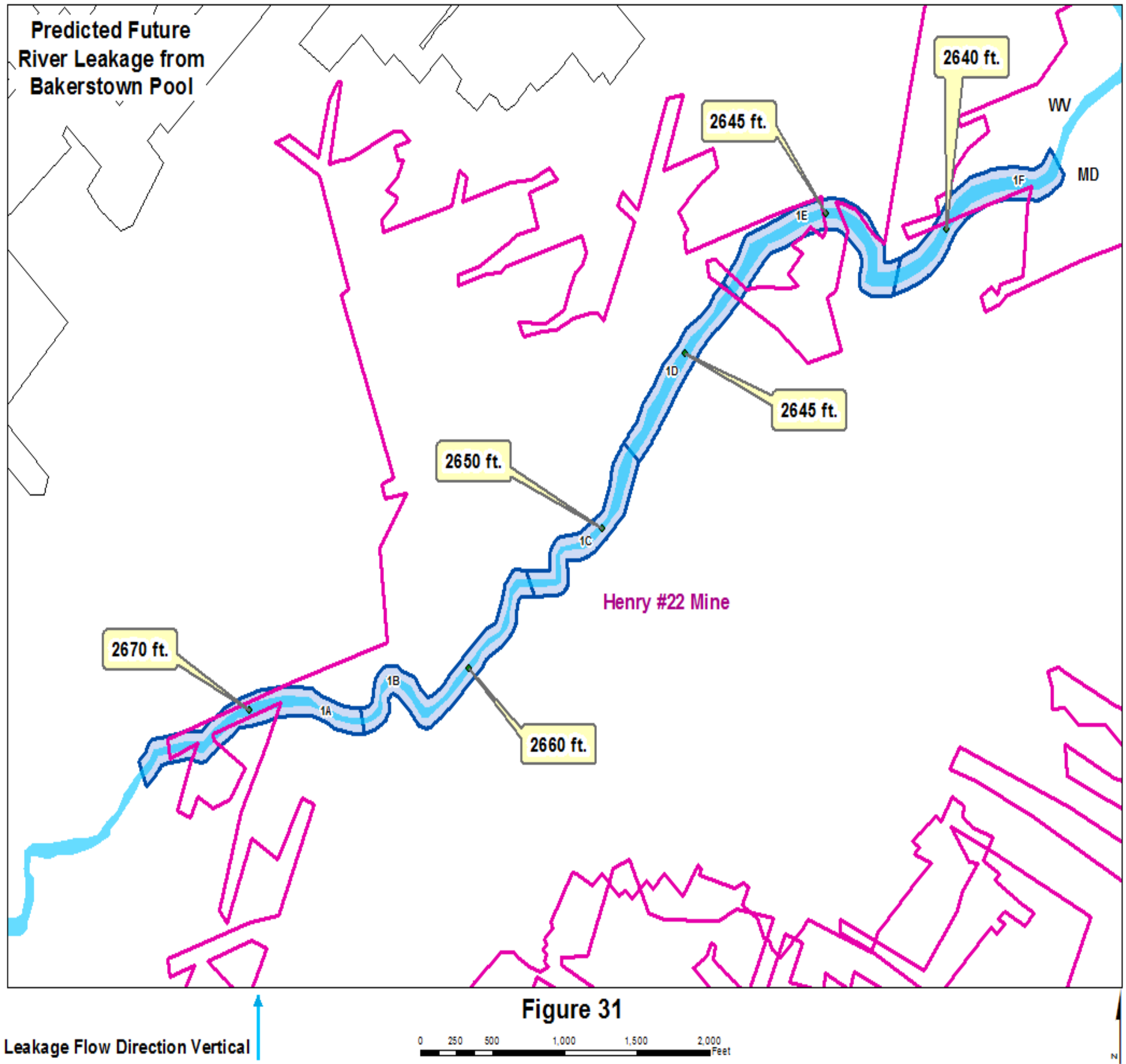


Figure 31

Another future scenario related to the leakage from the Alpine/Henry pool involves the Dobbin Mine. As stated in an earlier section, portions of the Dobbin Mine are located directly below the Alpine#2 and a very small portion of Alpine#1. Figure 16 shows these locations. As the Dobbin pool rises it would hydraulically connect to the Alpine/Henry pool which is controlled by the borehole at 2680' m.s.l. The head in the Dobbin pool must attain a higher head than the Alpine/Henry pool to hydraulically connect however, it will not continue to rise significantly due to the borehole spill point. An estimate of the additional leakage is based on the calculated potential discharge rate from the Dobbin Mine which is 2665 gpm. Calculations for the leakage rate through the vertical strata between the mines are completed using 2 different hydraulic heads for the Dobbin pool; 2690' and 2685' m.s.l. The vertical hydraulic conductivity was 0.007 ft/ day, the length of the flow path was 180' which is the interburden in this location and the cross-sectional area was the estimated area of the overlying Alpine#2 mine. The resultant rate was 17 gpm with a ten foot head and 8 gpm for the five foot head. Table 14 provides the calculations. The vertical K value was based on a value derived from an OSM hydrologic study of overlying mine pools located in Pennsylvania (Hawkins and Smoyer, 2012). The value used is an order of magnitude smaller and has been rounded off from the field derived value of 0.065 ft/day. There is a lack of field derived vertical K values within the Appalachian Region that one can obtain from studies and publications. The modification of the value used was to provide realistic results based on the potential discharge rates and to compensate for the thicker interburden between the mines.

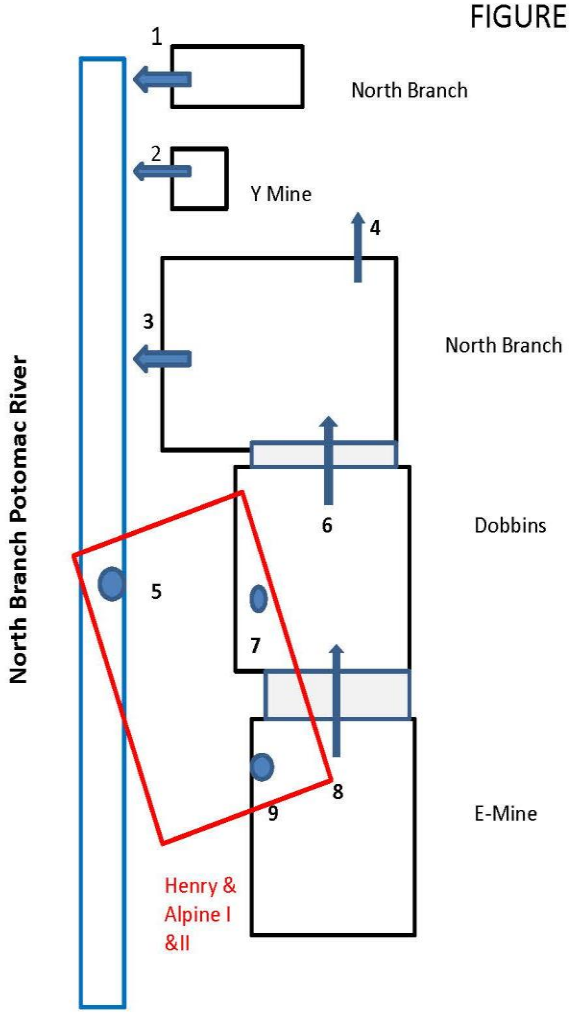
The final predicted leakage scenario calculated for the Alpine/Henry pool involves the E-Mine. The Mettiki E- Mine underlies the Alpine #1 Mine (Figure 16 shows locations). If the pool elevation reaches 2900' m.s.l. the E-Mine pool would drain into Alpine/Henry pool. This would potentially add additional leakage to the river and additional flow to the borehole. Using an average recharge rate of 0.75 gpm/acre; there is an estimated additional flow of 1774 gpm. A predicted vertical leakage rate was calculated applying a vertical K value of 0.007 ft/day (same as previous calculation). Table 15 provides the calculations. The leakage area was estimated using an average cross sectional area while the flow length was the average thickness of the interburden between the Bakerstown coal seam and the Upper Freeport coal. The head difference in this calculation is much greater than the previous leakage calculation regarding the Dobbin mine. The predicted leakage rate for the E-Mine into the Bakerstown pool is 716 gpm.

MINE POOL LEAKAGE ANALYSES - LIMITATIONS AND ASSUMPTIONS

Simple predictive methods are used in this study which applies basic water balance equations and groundwater flow principles. They are presented to provide a broad-based indication of what future hydrologic conditions may exist within the study area and have inherent limitations. A maximum hydraulic head for the mine pools is used in the future leakage calculations. The predicted maximum hydraulic head often represents fully flooded mines. It is unlikely that these heads will be attained given the significant structure of the mines and other leakages unaccounted for such as horizontal and vertical leakage to surrounding aquifers. Several assumptions and simplifications have been made in the leakage calculations; such as assuming the flow is confined to the coal seam and does not extend to the broken overburden or collapsed roof. The use of hydraulic conductivity (K) values in the calculations requires an assumption that the value chosen is the most appropriate for the setting. The leakage calculations also assume that the vertical separation between the river and the mine will have fractures and or weathered strata which allows the mine pool to rise to its potentiometric surface elevation which is greater than the river elevation. This same assumption is made in the flow calculations used to determine vertical flow rates through the overburden into the overlying mine. Field truthing the calculations by analyzing the pumping rates at the mines would provide valuable information on the accuracy of the values and factors used.

The leakage calculations for the mine pools located in West Virginia are more complicated than presented. Figure 32 is a schematic using boxes to represent mine pools and arrows representing potential leakage rates. Assigning a rate to each leakage (arrow) is dependent on the hydrologic condition of the adjacent pools. A hydrologic change in any of the mines (i.e.) increase or decrease in inflow or leakage will affect the hydrologic condition of the adjacent mine pools. In some cases both the overlying mine and the horizontally adjacent mine are hydrologically affected. The calculations presented in the report do not account for all the hydrologic influences. They are simplified to provide a broad understanding of future mine pool flows and leakages.

FIGURE 32



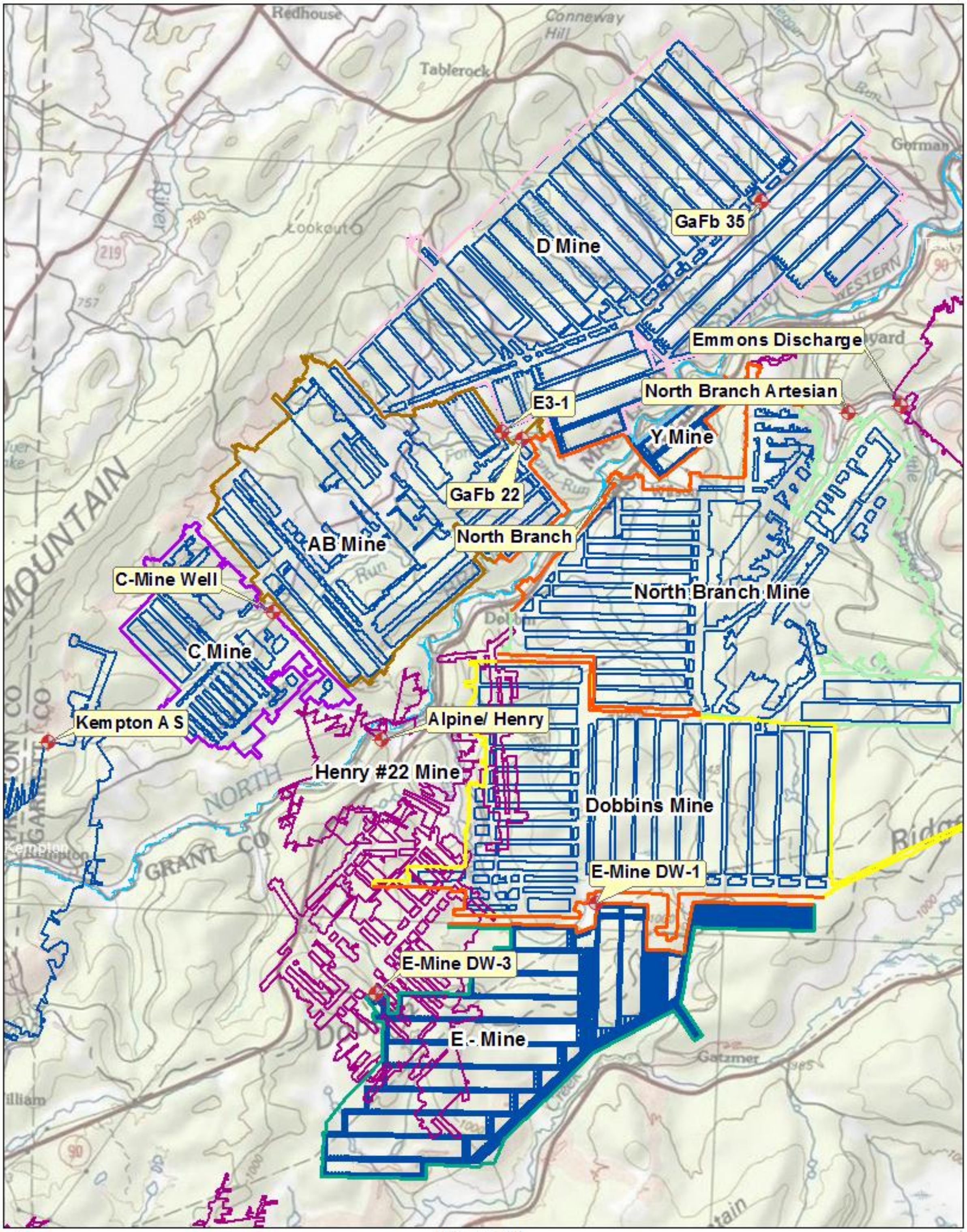
1. Leakage to river from Upper Freeport pool
2. Leakage to river from Upper Freeport pool
3. Leakage to river & discharge to river from Upper Freeport pool
4. Discharge to tributary from Upper Freeport pool
5. Vertical leakage & discharge to river from Bakerstown pool
6. Leakage across coal barrier Upper Freeport pool
7. Vertical leakage to Bakerstown pool
8. Leakage across coal barrier Upper Freeport pool
9. Vertical leakage to Bakerstown pool

QUALITATIVE ANALYSES OF EXISTING MINE POOLS

MINE POOL WATER QUALITY

This section discusses historical and recent mine pool water quality conditions. Some of the historical groundwater quality data for the North Branch Potomac mine pool (MD and WV) can be found in Duigon and Smigij, 1985; the U.S. Geological Survey (USGS) National Water Information System (NWIS) website at http://waterdata.usgs.gov/nwis; OSM Ground Water Information Manual: Coal Mine Permit Applications –Volume 2., Chapter 2 (Richards editor, 1987); and MBM studies of Kempton, Frostburg State University, MDDNR-Paul Petzrick; Western Maryland Resource Conservation and Development Council, Inc.

Recent water quality is represented by samples taken by OSM for the current study during 2007-2010. There were 11 sampling sites that included 8 wells, 2 flowing artesian wells and a deep mine discharge (Figure 33.) Four of the sample locations (Well Fb-22, Well Fb-35, C-Mine well and Kempton Discharge) were in Maryland and seven sites were located in West Virginia (E Mine wells DW-1 and DW-3, Alpine/Henry mine, Dobbin mine, Emmons mine discharge, North Branch mine, and North Branch artesian well). Three sites were sampled twice (Well Fb-22, Well Fb-35 and Kempton Discharge-flowing artesian well) and one site (C Mine Well) was sampled three-times during the study. The results for the general chemical analyses are shown in Table 16 located in Appendix D. The dissolved and total metals (including trace metals) analyses results are found in Table 17 also located in Appendix D.



Study Sampling Points

Figure 33

The pH of the water samples ranged from 2.8 standard units (SU) (Alpine/Henry) to 9.24 SU (Well GaFb-22). There were 5 out of 11 sampling points with a pH less than 6 SU. These were GaFb-35 well (5-26-10), Kempton discharge, Alpine / Henry, Emmons, and N. Branch artesian. There were 3 out of 11 sampling points with a pH between 6 and 7 SU. These were GaFb-35 well (10-17-07), Dobbin, and the N. Branch. The sampling points which were most acidic were the Alpine /Henry pH =2.8 SU (4-14-09), Kempton discharge with a pH = 3.43 SU (10-30-07) and 3.07 SU (5-27-10), and the N. Branch artesian pH = 3.11 SU (4-14-09).

While water quality varies throughout the mine pools and spatially within the pool, overall quality including the more recently abandoned Mettiki sections would potentially degrade the North Branch of the Potomac River if uncontrolled discharges occur. Total dissolved solids, including sulfate, calcium, and iron concentrations would increase river concentrations. Iron and aluminum are expected to form solids that deposit on the streambed substrate and /or contribute to suspended solids and turbidity.

Based on the data collected during the study, discharges and or leakage from the Bakerstown pool will impact the North Branch Potomac River far greater than the pools associated with the Upper Freeport coal (with the exception of the Kempton pool). Furthermore, the quality of the Kempton and the Alpine/Henry discharges which have been abandoned for some time indicate that long term control (decades) is required before improvement to the water quality would occur.

Additional findings of the sampling program are as follows. There is great variability in the water quality of the pools sampled throughout the study area as evidenced by the wide ranges of pH values in addition to iron and sulfate concentrations. There is no consistent quality among those mines located in the Upper Freeport coal seam within the study area. Water samples varied from acidic to alkaline. Specifically, the Kempton and the North Branch upper (artesian) pools were acidic while most of the samples from the Mettiki A, B, C, and D/Y Mine pools were alkaline. The water sample associated with the underground mine in the Bakerstown coal seam did exhibit an acidic quality with associated high metal concentrations.

USGS Water Sampling and Borehole Water Quality Profiling

Recent water samples were taken by USGS for the Maryland Bureau of Mines (MBM) in 2009 -2012 using a passive sampling method with diffusion samplers (Archfield and LeBlanc, 2005). This passive sampling method was used in several of the USGS wells to monitor changes in water quality in the Mettiki mines and shallower aquifers. Diffusion samplers were set at various well depths in the borehole and left for a period of several weeks after which the samplers were retrieved and sent to the lab for analyses. One of the purposes of the sampling was to determine if the water quality in the borehole water column changed with depth or if the water quality was homogeneous throughout the column.

The USGS also conducted a water quality profile of the well bore for wells GaFb-22 and GaFb-35 on May 21, 2008. The profiling used a multi-parameter probe that was lowered down the boreholes and recorded temperature, water level, barometric pressure, turbidity, oxidation-reduction potential (ORP), pH, dissolved oxygen, and conductivity.

MINE POOLS LOCATED IN MARYLAND - UPPER FREEPORT MINE POOLS

Kempton Mine

The Kempton discharge is an acid mine drainage (AMD) that flows under artesian pressure from two shafts that intersect the mine workings: an abandoned airshaft and a power borehole. Acid mine drainage (AMD) from these two sites ranges from a minimum of one million to a maximum of six million gallons a day (mgd) (Davis and Lyons, September 2002). Two water samples were taken from the flowing abandoned airshaft: one on October 30, 2007, and the other on May 27, 2010. The low pH values of 3.43 SU (10/30/07) and 3.07 SU (5/27/2010) are typical of acid mine drainage. Elevated values for specific conductance, total dissolved solids (TDS), iron, manganese, aluminum and sulfate were also present (Tables 16 and 17 in appendix D). The general water chemistry from the two samples exhibited some differences in values that are probably due to normal seasonal variation of flow. However, most of the dissolved and total metal values were fairly consistent between the samples with only a few exceptions. The water for both samples was identified as calcium-sulfate type water.

Mettiki A, B, C, and D Mines

Water samples from well GaFb-22, C-Mine well and well GaFb-35 represent mine water in the Mettiki A, B, C, and D mines respectively. Water samples take in 2007 should be representative of the water quality of the mine pool as it was filling up with water. Water samples taken in 2010 should be representative of the water quality of the mine pool in a quasi-steady state condition. Mettiki started in the spring of 2008 pumping the mine pool at a rate that prevents the level of the mine pool from discharging into the North Branch Potomac River.

Well GaFb-22

Water samples from well GaFb-22 (Table 18) should represent the mine pool water in Mettiki A and B mines. The water sample taken on April 18, 2007 represents alkaline mine drainage. Water characteristics for this sample are as follows: the pH was 7.24 SU; specific conductance value (1,060 µS/cm), and TDS value (896 mg/L); with elevated values for sulfate (1,200 mg/L), calcium (343 mg/L), and elevated metals values for iron (27.8 mg/L) and manganese (1.68 mg/L). Conversely, the water sample taken on May 25, 2010 showed more characteristics of groundwater in unmined strata than mine water. The specific conductance value (307 µS/cm) and TDS value (172 mg/L); with low values for sulfate (48 mg/L) and calcium (3.2 mg/L), and lower metal values for iron (0.39 mg/L) and manganese (0.05 mg/L) are more representative of shallow groundwater and not mine pool water.

Well	GaFb – 22	GaFb-22
Date	April 18, 2007	May 25, 2010
Iron, Dissolved	27.8	0.39
Manganese, Dissolved	1.68	< 0.01
Chloride	21	12
Fluoride	0.4	0.2
Sulfate	584	48
pH-Lab.	7.24	9.24
Specific Conductance	1,060	307
Total Dissolved Solids	896	172
Total Suspended Solids	1,110	5
Total Acidity	-85	-45
Bicarbonate	112	88
Total Alkalinity	112	103
Calcium, Dissolved	343	3.2
Magnesium, Dissolved	72.8	2.5
Sodium, Dissolved	76.8	49.7
Aluminum, Dissolved	<0.1	0.3

Table 18. Selected water quality data from Well GaFB-22. Parameters units are in mg/L except for pH-standard units; specific conductance-µS/cm; bicarbonate, total acidity and alkalinity-mg/L as $CaCO_3$

The pH value of 9.24 SU was higher in the 2010 sample than in the 2007 sample (7.24 SU). The borehole water quality profile of well GaFb-22 conducted by the USGS on May 21, 2008 revealed that the pH value was greater than 10 SU's in the upper 60 feet of the water column (water level between 242 to 302 feet) and then decreased to a pH value of 8.4 SU towards the bottom of the water column (at a depth of 493 feet). Several wells the USGS had sampled at depths of 300 feet and greater had pH values ranging from 9.47 to 9.92 SU's. The cause of the high pH is not known.

The specific conductance in the well profiling increased from the top (208 µS/cm) to the bottom (1,389 µS/cm). The well profiling and water samples indicate the water is stratified in the water column. The water samples taken in 2010 indicate a recent change (improvement) in water quality in well GaFb-22.

Piper and Stiff Diagrams

The Piper diagram is a graphical interpretation method used to determine and/or compare water classifications or water types. The water type for the well GaFb-22 April 18, 2007 sample is calcium-sulfate type located at the top of the diamond in Figure 34. For the well GaFb-22, May 25, 2010 sample, the water type is sodium-bicarbonate type located at about midway between the bottom vertex and the right vertex of the diamond (Figure 34). The calcium-sulfate type water in the 2007 sample is typical of mine waters high sulfate, TDS, and metal values. The sodium-bicarbonate type water indicates a different water source such as shallow groundwater with low sulfate, TDS, and metals values, rather than mine influenced waters.

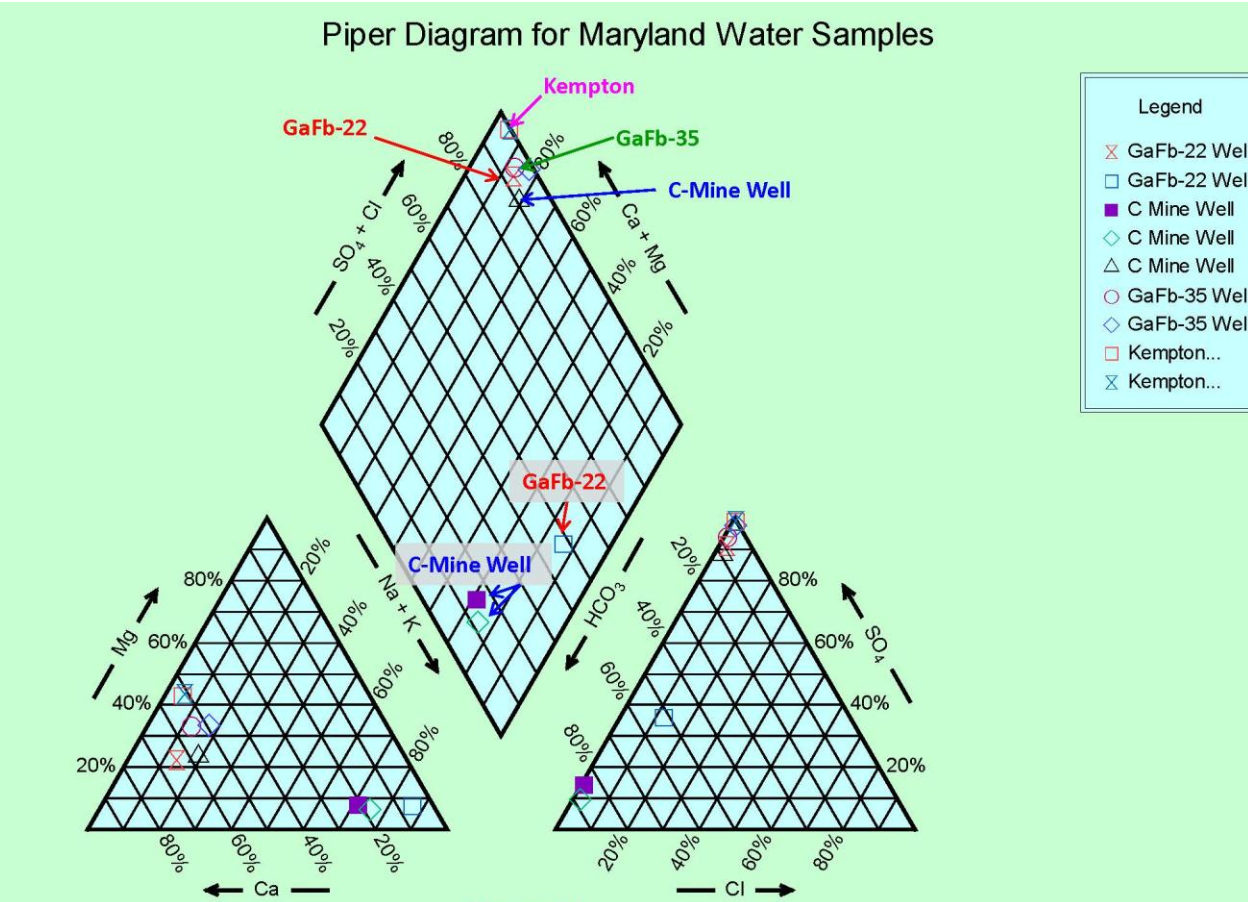


Figure 34.

The Stiff diagram is another type of graphical representation of water data. Figure 35 shows the two water samples taken from well GaFb-22. When interpreting Stiff diagrams, similar shaped patterns indicate similar types of water. The pattern of the top diagram (4-18-2007 sample) is calcium-sulfate type water whereas, the pattern of the bottom diagram (5-25-2010 sample) is sodium-bicarbonate type water although harder to detect because of the large scale needed for the 4-18-2007 sample. Using both graphical methods (Piper and Stiff diagrams) together rather than either one by itself provides a better understanding of water types and water composition. Additional Stiff diagrams of the Mettiki study wells are located in Appendix C.

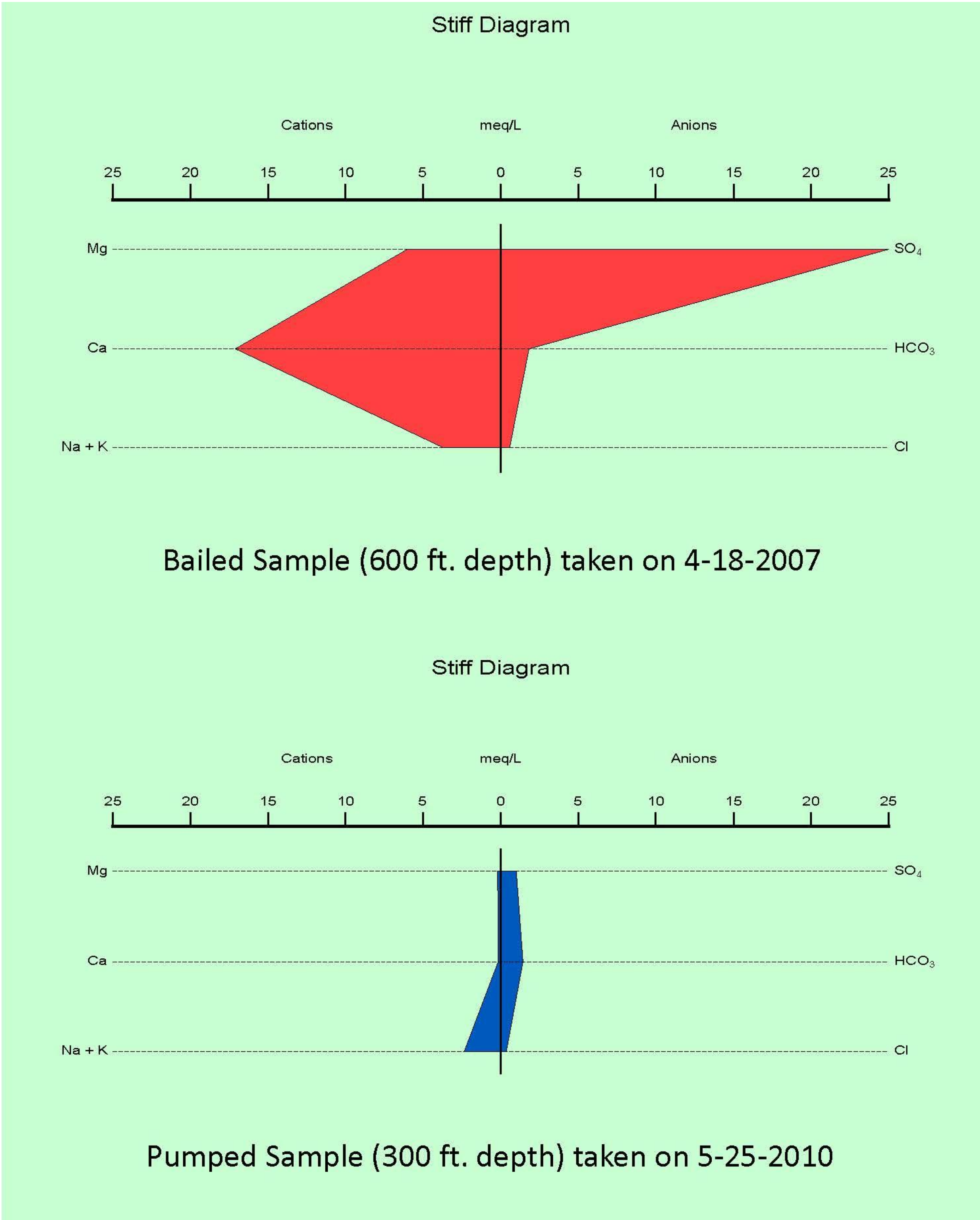


FIGURE 35. Stiff Diagrams of GaFb-22 Well Water Samples

There were significant water quality differences between the water samples taken in 2007 and 2010. TDS is one parameter that is used as an indicator of water quality. The 2007 water sample had a high TDS value of 896 mg/L while the 2010 water sample had a lower TDS value of 172 mg/L. Additional parameters such as pH, specific conductance, TSS and others also showed changes in water quality. These differences in water quality may be due to sampling techniques, timing of mining operations, and the infiltration of shallow groundwater leaking into the well bore. The 2007 sample was a composite sample taken using a bailer whereas the 2010 sample was pumped. The mine pool was starting to fill with highly mineralized water for the sample taken in 2007, while the 2010 sample was taken after over two years of maintaining a stable mine pool which may have resulted with less mineralized water. Shallow groundwater leaking into the well bore could dilute the mine pool water.

C-Mine Well

Water samples were taken from the C-Mine Well on three different occasions: April 18, 2007; October 16, 2007 and; May 26, 2010 (Table 19). The two samples taken in 2007 yielded results indicating the same water type; a sodium-bicarbonate type water as shown in the Piper diagram (Figure 34). The analyses exhibit typical low values for shallow groundwater as follows: sulfate less than and equal to 21 mg/L; specific conductance less than and equal to 265 µS/cm; TDS less than and equal to 244 mg/L and; manganese less than and equal to 0.07 mg/L. Conversely, the water sample taken May 26, 2010 is calcium-sulfate type water that typically represents typical mine pool water. Figure 36 shows the Stiff diagrams for the three samples taken from the C-Mine well and the water types for the samples. High values were identified in the 2010 sample for: sulfate 1,350 mg/L; specific conductance 2,340 µS/cm; TDS 2,170 mg/L; iron 28 mg/L and; manganese 1.60 mg/L.

Well	C- Mine Well	C- Mine Well	C - Mine Well
Date	April 18, 2007	October 16, 2007	May 26, 2010
Iron, Dissolved	10.4	0.11	28
Manganese, Dissolved	0.07	0.02	1.6
Chloride	1	2	28
Fluoride	0.7	0.4	<0.1
Sulfate	21	12	1,350
Lab, pH	7.44	7.99	7.28
Specific Conductance	255	265	2,340
Total Dissolved Solids	160	244	2,170
Total Suspended Solids	213	24	213
Acidity, Total	-84	-110	-143
Bicarbonate	160	138	181
Alkalinity, Total	160	139	181
Calcium, Dissolved	12.8	10.8	343
Magnesium, Dissolved	2.9	2.4	84.7
Sodium, Dissolved	48.5	50.3	124
Aluminum, Dissolved	<0.1	<0.1	<0.1

Table 19. Selected water quality data from C-Mine well. Parameters units are in mg/L except for pH-standard units; specific conductance-µS/cm; bicarbonate, total acidity and alkalinity-mg/L as $CaCO_3$

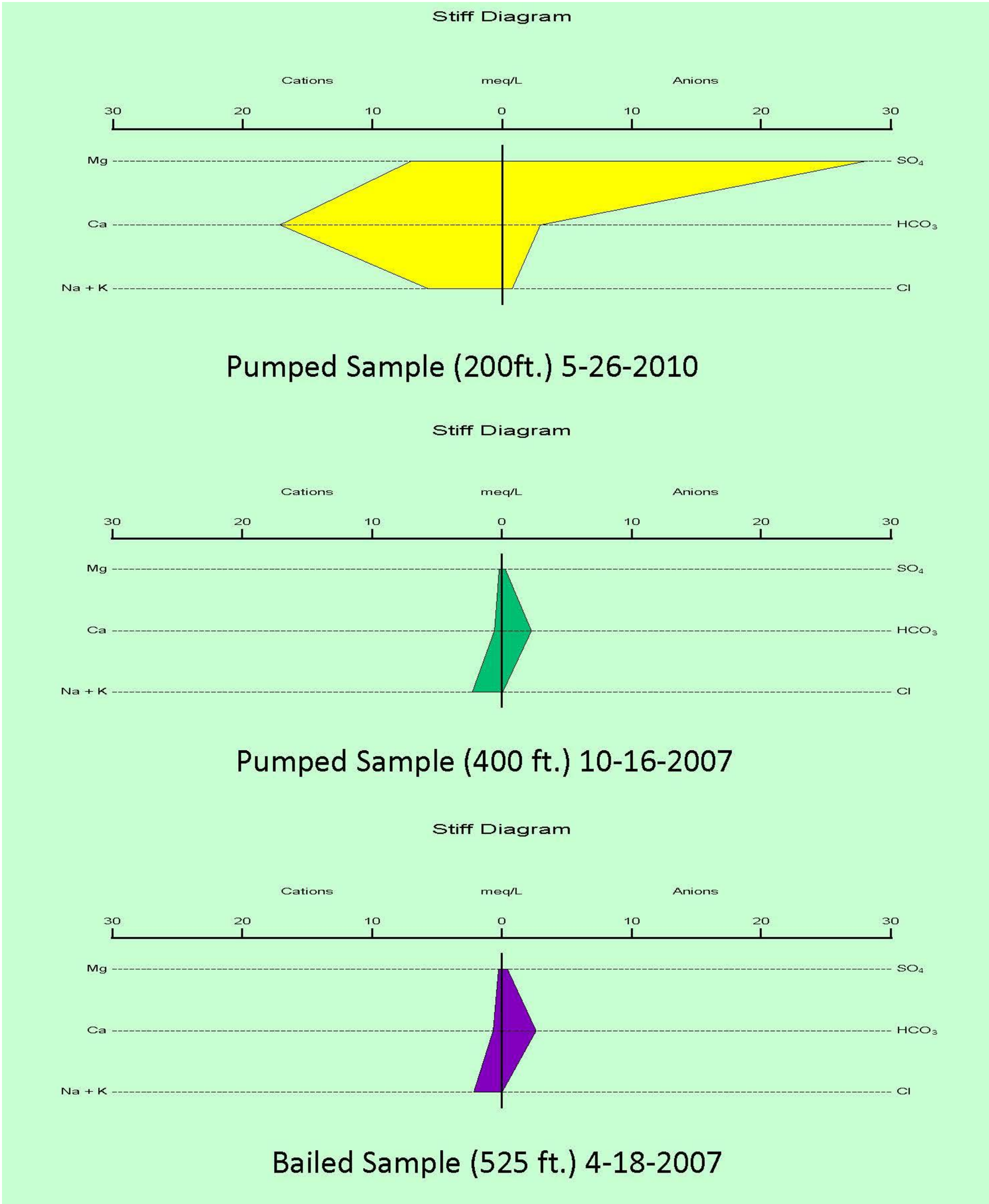


FIGURE 36. Stiff Diagrams of C-Mine Well Water Samples

There were significant differences in the water quality from the 2007 and 2010 water samples. The 2010 water sample was obtained after pumping the well at 15 gallons per minute (gpm) for 1.5 hours, thus drawing water up the borehole from the mine pool below. The April 2007 water sample was taken using a bailer representing sitting or stagnant water in the well bore. The October 2007 sample was pumped at 1.5 gpm for about 1.5 hours. The water in the well for the October 2007 sample was stratified therefore, the sample represented a composite of the shallow groundwater and mine pool water. Also, there is evidence of groundwater leakage into the well through the casing at a depth of 70 to 75 feet.

Well GaFb-35

Water from Well GaFb-35 was sampled twice by OSM during the study, on October 17, 2007 and on May 26, 2010 (Table 20). Samples taken from this well represent water from the mine pool in the D Mine. Both water samples, taken near mine level, were obtained by the bailer method. The water types for the two samples are of the calcium-sulfate type which plot near the top of the diamond on the Piper diagram (Figure 37). Water from Well GaFb-35 is the most mineralized water of all the OSM samples taken in 2007 and 2010. The 2007 water sample yielded analyses as follows: specific conductance greater than 3,000 µS/cm; TDS greater than 3,000 mg/L; sulfate greater than 2,100 mg/L, and high values for calcium, magnesium, sodium, and potassium. The pH value was 6.22 SU for the 2007 sample and 5.90 SU for the 2010 sample. The May 26, 2010 sample showed some improvement in water quality with lower values for specific conductance (2,560 µS/cm), TDS (2,370 mg/L), and sulfate (1,690 mg/L). Iron and manganese values were lower in the May 26, 2010 sample.

Well	GaFb - 35	GaFb - 35
Date	October 17, 2007	May 26, 2010
Iron, Dissolved	313	72
Manganese, Dissolved	11	1.43
Chloride	20	16
Fluoride	0.4	<0.1
Sulfate	2,170	1,690
Lab, pH	6.22	5.90
Specific Conductance	3,040	2,560
Total Dissolved Solids	3,250	2,370
Total Suspended Solids	230	76
Acidity, Total	120	22
Bicarbonate	152	25
Alkalinity, Total	152	25
Calcium, Dissolved	538	360
Magnesium, Dissolved	199	148
Sodium, Dissolved	132	133
Aluminum, Dissolved	<0.1	<0.1

Table 20. Selected water quality data from Well GaFB-35. Parameters units are in mg/L except for pH-standard units; specific conductance-µS/cm; bicarbonate, total acidity and alkalinity-mg/L as $CaCO_3$

The USGS passive diffusion samples from this well have specific conductance values greater than 3,350 µS/cm for the 2009 samples but values decreased to less than 1,200 µS/cm for the 2010 samples. Sulfate concentration values also decreased from greater than or equal to 1,950 mg/L for the 2009 samples to less than 1,470 mg/L the 2010 samples.

The USGS water quality profiling provides evidence of water stratification in the water column. The pH values decrease going down the water column from 7.2 (at 290 feet) to 6.59 SU (at 596 feet). The specific conductance values increase with depth in the well bore from 1,853 µS/cm to 2,966 µS/cm at the bottom. Dissolved oxygen values decrease from 6.62 mg/L at the top to 1.24 mg/L at the bottom of the water column sampled.

The water quality in the Well GaFb-35 appears to show some improvement from 2007 to 2010. Between the two sampling events, hydraulic head increased over 210 feet as mine flooding progressed. The water level currently fluctuates in a narrow range due to pumping of the mine pool by Mettiki. The more or less steady state of water levels in the mine pool and the flushing/turnover of mine pool water could result in an improved water quality of the mine pool due to the reduced amount of oxidation of the remaining pyritic materials in the flooded mine. This results in less acid production and higher pH values in the mine pool water.

MINE POOLS LOCATED IN WEST VIRGINIA

During this study, a total of seven water samples were collected (2008-2009) from mine pools on the West Virginia side of the North Branch Potomac River. On February 25, 2008 water samples were taken from wells DW-1 and DW-3 located in the Mettiki E Mine that taps the Upper Freeport coal. Five water samples were taken on April 14, 2009 from mines located in both the Bakerstown coal seam (one sample from the Alpine/Henry mine) and Upper Freeport coal seam (four samples from the North Branch, North Branch Artesian, Emmons and Dobbin mines). Consolidation Coal Company is responsible for water treatment for all these mines. The complete chemical analyses for the water samples are in Tables 16 and 17 located in Appendix D.

BAKERSTOWN MINE POOL

The water sample (Table 21) from the Alpine/Henry mine represents the water quality in the Bakerstown mine in addition to waters from past mining activities. For water samples taken in mine pools in the West Virginia study area, the Alpine/Henry water sample has one of the highest values for specific conductance (2,000-µS/cm), TDS (1,950 mg/L), and sulfate (1,270 mg/L). The greatest acidity value for the study of 590 mg/L is from the Alpine/Henry water sample.

Mine	Alpine/Henry
Date	April, 14, 2009
Iron, Dissolved	199
Manganese, Dissolved	5.26
Chloride	3
Fluoride	0.4
Sulfate	1,270
Lab, pH	2.8
Specific Conductance	2,000
Total Dissolved Solids	1,950
Total Suspended Solids	33
Acidity, Total	590
Bicarbonate	<5
Alkalinity, Total	<5
Calcium, Dissolved	201
Magnesium, Dissolved	59.8
Sodium, Dissolved	7
Aluminum, Dissolved	20.3

Table 21. Selected water quality data from a Bakerstown mine pool well. Parameters units are in mg/L except for pH-standard units; specific conductance-µS/cm; bicarbonate, total acidity and alkalinity-mg/L as $CaCO_3$

The Alpine/Henry sample had the highest dissolved iron value of 199 mg/L and the lowest pH value of 2.8 SU of all water samples taken. The high iron, acidity, and sulfate concentrations coupled with the low pH may indicate that pyrite oxidation and leaching of acid products is ongoing in the partially flooded mine pool. Iron-oxidizing bacteria and oxygen may be abundant in the Alpine/Henry mine.

UPPER FREEPORT MINE POOLS

Water samples (Table 22) from the North Branch, North Branch Artesian, Dobbin, Emmons and Mettiki E-Mines comprise the water from the Upper Freeport mine pools. Water type is calcium-sulfate for all samples taken from the Upper Freeport mine pools. Figure 37 is a Piper diagram which illustrates the water type. The composition of the North Branch Artesian water is typical of acid mine drainage (AMD) water and is isolated from the North Branch main pool. This water has a low pH and high values for specific conductance, TDS, sulfate, and metals.

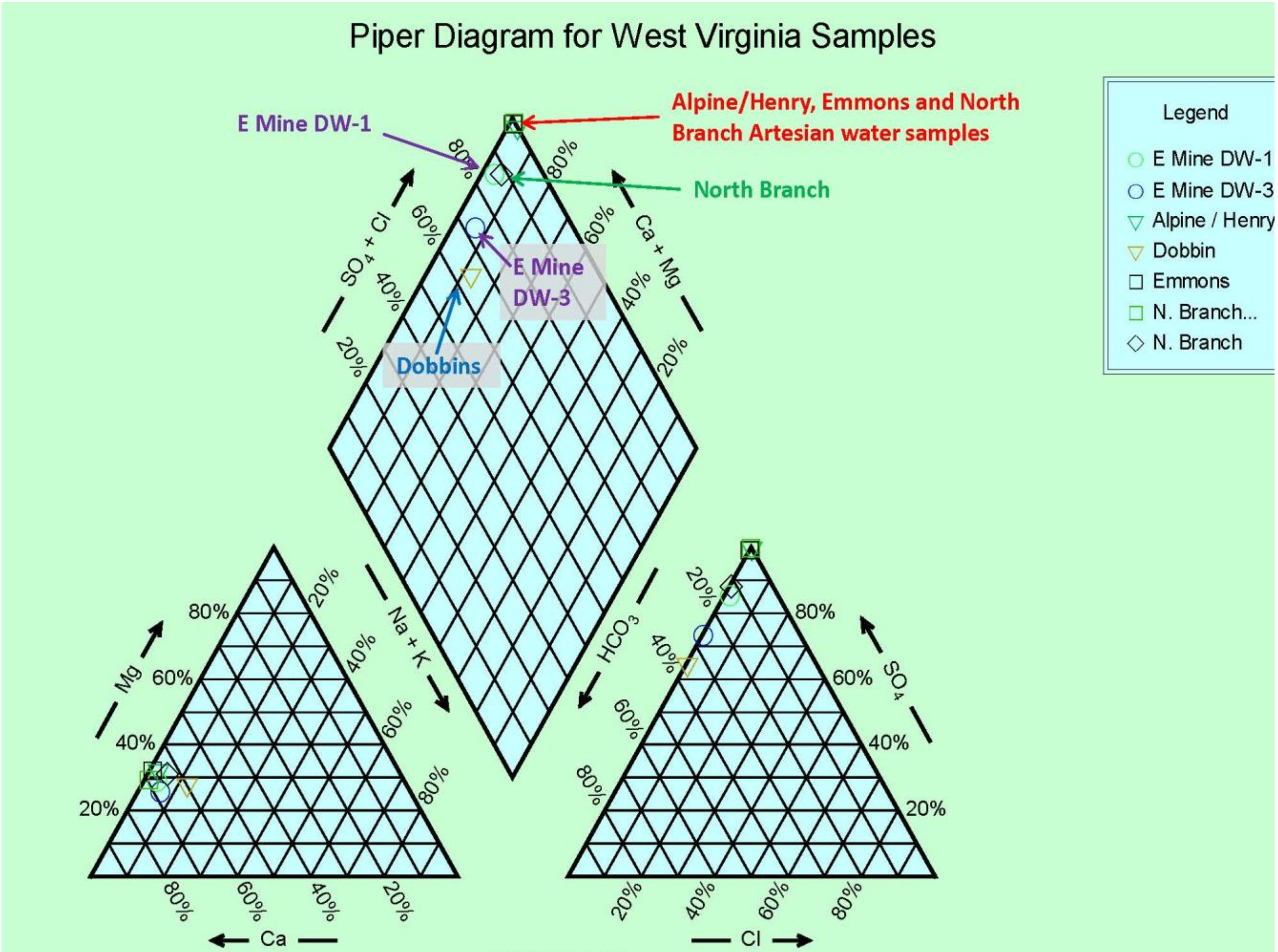


FIGURE 37

Water quality results from water samples taken from the two Mettiki E-Mine wells in the Upper Freeport mine pool showed similar values in about half of the parameters listed below. Sulfate, specific conductance, TDS, and calcium were some of the parameters that showed similar values. Some of the parameters that had significantly different values are dissolved iron and manganese, acidity, bicarbonate, and alkalinity. The E-Mine is currently active and being pumped to facilitate mining activities.

The water analyses indicate that water from the Upper Freeport mine pool would degrade the North Branch Potomac River if allowed to discharge into it. Furthermore, the mine pool water will have to be treated and managed to prevent this from happening.

Mine	Dobbin	North Branch Artesian	North Branch	E Mine Well DW-1	E Mine Well DW-3	Emmons
Date	April 14, 2009	April 14, 2009	April 14, 2009	February 25, 2008	February 25, 2008	April 14, 2009
Iron, Dissolved	6.45	25.4	2.53	0.61	0.37	194
Manganese, Dissolved	1.72	3.42	1.29	0.86	0.19	15.1
Chloride	2	1	3	5	1	4
Fluoride	<0.1	0.3	<0.1	0.2	0.2	<0.1
Sulfate	435	795	590	377	344	1,860
Lab, pH	6.84	3.11	6.32	7.63	8.08	5.5
Specific Conductance	1,170	1,350	1,100	984	967	2,350
Total Dissolved Solids	892	1,070	926	698	666	2,650
Total Suspended Solids	<5	<5	10	42	<5	40
Acidity, Total	-289	180	-75	-46	-125	300
Bicarbonate	302	<5	98	75	159	18
Alkalinity, Total	302	<5	98	75	161	18
Calcium, Dissolved	178	179	175	149	148	428
Magnesium, Dissolved	50.2	46.9	52.2	39	33.7	125
Sodium, Dissolved	36.3	1.5	13	4.2	9.8	3.3
Aluminum, Dissolved	<0.1	11.6	0.3	0.1	<0.1	<0.1

Table 22. Selected water quality data from Upper Freeport mine pool wells in West Virginia. Parameters units are in mg/L except for pH-standard units; specific conductance-µS/cm; bicarbonate, total acidity and alkalinity-mg/L as $CaCO_3$

Piper Diagram

The water type for all water samples from the West Virginia mine pools is calcium-sulfate type water. The North Branch Artesian, Emmons and Alpine/Henry samples represent water that is typical AMD water and is shown on the Piper diagram at the top of the diamond (Figure 37). The Bakerstown seam water has a lower pH and generally is more mineralized than the water in the Upper Freeport seam. The North Branch, Dobbin, and E Mine DW-1 and DW-3 water samples would be considered alkaline mine water based on net alkalinity. The Dobbin water sample (orange triangle) plots about a third of the way down from the top apex of the diamond because of the high bicarbonate value (302 mg/L) and the low sulfate value (435 mg/L).

The details of water quality on individual wells and discharges can be found in Appendix D. Additional Stiff diagrams for water quality information collected by OSM are found in Appendix C.

Trace elements analyses

Trace element analyses were completed for all of the mine pool samples; results are presented in Table 17 located in Appendix D. With few exceptions, almost all of the dissolved trace metal values were below US EPA drinking water standards. The samples in Table 23 have a dissolved trace total metal value above the EPA primary drinking water standard for the listed parameter. US EPA Drinking Water Standards are provided here as a means to compare the parameter concentrations, not as regulatory standards.

Well	Date of Sample	Trace Element	Sample Value	EPA Drinking Water Standard
Kempton	10/30/2007	Beryllium	0.01 mg/L	0.004 mg/L
Kempton	5/27/2010	Beryllium	0.009 mg/L	0.004 mg/L
Alpine-Henry	4/14/2009	Beryllium	0.007 mg/L	0.004 mg/L
N. Branch Artesian	4/14/2009	Beryllium	0.007 mg/L	0.004 mg/L
Kempton	10/30/2007	Lead	0.05 mg/L	0.015 mg/L
Kempton	10/30/2007	Nickel	0.34 mg/L	0.1 mg/L
Kempton	5/27/2010	Nickel	0.36 mg/L	0.1 mg/L
E Mine DW-1	2/25/2008	Nickel	0.14 mg/L	0.1 mg/L
Alpine-Henry	4/14/2009	Nickel	0.26 mg/L	0.1 mg/L
N. Branch Artesian	4/14/2009	Nickel	0.25 mg/L	0.1 mg/L

Table 23. Samples that had dissolved values above EPA Primary Drinking Water Standards

The Alpine-Henry well sample had a cadmium value of 0.005 mg/L which is the EPA primary drinking water standard. All samples had lead values below the detection limit of 0.02 mg/L except for the Kempton sample taken on 10/30/2007 which had a value of 0.05 mg/L.

CURRENT RISKS TO THE NORTH BRANCH POTOMAC RIVER

In summary, all of the mine pools within the study area are currently being controlled or maintained at conditions which do not pose a significant risk to the hydrology of the river, based on the current regulatory framework.

FUTURE POTENTIAL RISKS TO THE NORTH BRANCH POTOMAC RIVER

In summary, the predicted maximum potential hydraulic head for all the mine pools within the study area will either reach an elevation greater than the North Branch Potomac River or contribute to adjacent pools which will reach a head elevation greater than the river. Depending on the area of influence exerted by the mine pool head, leakage from the pool may be directly into the river or within the upper reaches of its valley.

Summary details on the risks associated with the mine pools located in Maryland are as follows:

Kempton – Mine pool elevation is controlled by the borehole and airshaft discharges which are currently collected and treated by the MBM then discharged to Laurel Run, tributary of the North Branch Potomac River. Predicted risk to the river from the pool is moderate given that treatment must continue into the future to protect the headwaters of the river.

Mettiki C-Mine – The predicted pool elevation will not reach the elevation of the critical river location therefore risk to the river and surrounding surface waters is very low to none.

Mettiki AB-Mine – The predicted pool elevation will develop above the critical river elevation. Risk for direct discharges to the river is moderate to high given the less than 100 feet lateral distance from the edge of the mine works to the river. Risk to the river is dependent on the amount of interconnection in the overlying strata (350 feet) which would allow flow in a vertical direction. Maximum horizontal leakage rate from the mine to the river is forecasted at 15 gpm.

Mettiki D-Mine – The predicted pool elevation will develop above the critical river elevation. Risk for direct discharges to the river is moderate to high given that there is less than 100 feet vertical distance from the mine works to the river. The lateral distance from the edge of the mine workings and the river is approximately 500 feet and factors into a risk determination. Maximum horizontal leakage rate from the mine to the river is forecasted at 51 gpm.

Summary details on the risks associated with the mine pools located in West Virginia are as follows:

Consolidation Coal Company Emmons - This surface and underground mine does not have a pool associated with it, however, there is a gravity discharge which is currently being collected and treated. This discharge is predicted to be present in the future and will require treatment so as to protect the Buffalo Creek, a tributary of the river.

Mettiki Y-Mine (Extension of D-Mine) – The predicted pool elevation will develop above the critical river elevation. Risk for direct discharges to the river is moderate given that there is approximately 300 feet vertical distance from the mine to the river while the lateral distance is 200 feet. Maximum horizontal leakage rate from the mine to the river is calculated at 4 gpm.

Consolidation Coal Company – North Branch – Upper Pool - The Upper Pool is currently discharging through the Artesian borehole located in the Buffalo Creek Valley, tributary of the North Branch Potomac River, where it is collected and treated. The future pool will combine with the larger Lower Pool and continue to discharge through the borehole. There is a moderate risk associated with this pool as treatment will be required in the future.

Consolidation Coal Company – North Branch – Lower Pool - The predicted pool elevation will develop above the critical river elevation. Risk for direct discharges to the river is moderate to high given the less than 100 feet lateral distance from the edge of the mine works to the river. Risk to the river is dependent on the amount of interconnection in the overlying strata (350 feet) which would allow flow in a vertical direction. Maximum horizontal leakage rate from the mine to the river is calculated at 13 gpm. Additionally, discharges from the Wilson boreholes are predicted which will flow directly to the river.

Consolidation Coal Company – Dobbin – The predicted future pool is at an elevation that leakage will occur in both the horizontal direction through the internal coal barrier to the North Branch mine and vertically into the Alpine #2 mine (Bakerstown Pool). The calculated horizontal seepage through the barrier is 304 gpm and the maximum seepage through the vertical overburden into the Bakerstown pool is 17 gpm. Although direct leakage to the North Branch Potomac River is not anticipated, increases in flow to the Bakerstown pool which is predicted to discharge and leak into the river will be increased. Additionally, leakage through the internal coal barrier will increase flow into the North Branch pool which potentially increases discharges and leakage to the river. In consideration of these scenarios, the risk to the river from future hydrologic conditions of the Dobbin Mine is substantial.

Mettiki E-Mine – This is the only active mine within the study area with the pumping of water occurring continuously to support the mining operations. The predicted future pool is at an elevation that leakage will occur in both the horizontal direction through the internal coal barrier to the Dobbin Pool and vertically into the Alpine #1 mine (Bakerstown Pool). The calculated horizontal seepage through the barrier is 270 gpm and the maximum seepage through the vertical overburden into the Bakerstown pool is 716 gpm. Direct leakage to the North Branch Potomac River is not anticipated, increases in flow to the Bakerstown pool which is predicted to discharge and leak into the river will be increased. Additionally, leakage through the internal coal barrier will increase flow into the Dobbin pool which potentially increases discharges and leakage to the river. In consideration of these scenarios, the risk to the river from future hydrologic conditions of the E-Mine is substantial.

Consolidation Coal Company- Henry #22, Alpine #1, Alpine #2 (Bakerstown Pool) – All three mine are physically connected and are referred to as the Bakerstown pool. The pool is currently maintained by the company through pumping and treating. The predicted pool elevation will be controlled by the Alpine borehole with discharges from the borehole to the river in addition to potential leakage directly to the river. The maximum calculated leakage to the river is 967 gpm. Additionally, 2 separate underground mines have the potential to increase flow to the Bakerstown pool, increasing leakage and or flow from the discharge. The risk to the river from future hydrologic conditions is very high given the amount of flow potentially leaking and discharging to the river.

Water Quality Considerations from Future Mine Pools –

The water quality data collected from the study indicates variability in the pools dependent on the saturated conditions of the mine and timing of the mining activities. There is a difference in water chemistry based on flooding stages of the mines. Fully flooded sections are anoxic, however, non-flooded portions allow acid formation to occur because of continued pyrite oxidation. Kempton and the North Branch upper pools are partially flooded and have been for decades. These pools are characterized by acidic conditions with accompanying high metal concentrations.

The coal seam and its associated overburden are also factors which affect the quality of the mine pool. The Bakerstown coal seam in this area has produced acidic pools and discharges. Water quality sampling of the Alpine/Henry mine pool shows acidic water with high metal concentrations. However, the pools in the Upper Freeport Coal seam are not consistent in their water quality as they range from acidic to alkaline. Water samples from the Kempton, Emmons and the North Branch upper pools are acid whereas, the samples from the Mettiki AB, C, and D/Y were mostly alkaline. There are substantial water quality influences from injected sludges and waters and groundwater recharge within the Mettiki AB, C, and D/Y pools. Additionally, the pools appear to be stratified and highly variable in their concentrations of total dissolved solids specifically sulfate and iron concentrations.

Water data collected from the Mettiki E-Mine is more representative of the incoming water and current active mining conditions and does not provide significant insight to future water quality determinations. The common risk that all the future pools within the study area possess is the potential to degrade the North Branch Potomac River with increased total dissolved solids and accompanying metal precipitants such as iron.

SUMMARY AND RECOMMENDATIONS

Current hydrologic conditions of the 12 underground mine sites within the study area are being managed by either a coal company or state agency with no known pollutional discharges to the North Branch Potomac River. All of the mine pool elevations are either maintained below the North Branch Potomac River elevation or have a controlled flow which is being collected and treated.

Basic hydrologic information was provided for each underground mine works including water storage and discharge rates. Potential future hydrologic conditions were predicted for each mine with the main objective determining future conditions of the mines and their potential impact to the adjacent river. Water quality data indicate variability in the pools dependent on the coal seam, saturated conditions of the mine and timing of the mining activities. Iron, total dissolved solids and sulfate concentrations are the main water quality concerns for all pools. These concentrations have the potential to degrade the North Branch Potomac River and surrounding surface and groundwaters.

The future predictions indicate that managing the mine pool elevations at a pool head below the Potomac River is critical in the protection of the North Branch Potomac River. Without pool management, all existing mine pools located in both West Virginia and Maryland have the potential to either increase the flow through the transfer of leakage from various mines or directly leak and or discharge to the river. Considering the rate of leakage calculated from the Bakerstown pool (Alpine/Henry pool) and the prediction for mine pool discharges through the Dobbin boreholes in combination with its poor water quality, future hydrologic conditions of this pool pose the greatest risk to the river.

This significant risk to the North Branch Potomac River posed by the mines within the study area should be monitored closely. The most efficient method is to continuously monitor the elevation of the pool heads in each individual mine in addition to periodically monitoring the water quality of the pools.

Due to the significant drainage area of the North Branch Potomac River and its wide river channel, monitoring of the river for changes in water quality may not be useful. Significant degradations may occur before surface water sampling indicates such.

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APPENDIX B - LEAKAGE CALCULATIONS

TABLE 8

CURRENT MINE POOL LEAKAGE - UPPER FREEEPORT POOL CALCULATIONS

Segment	1A				1A		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	*2338*			*h2*	*2338*		
h1	2275			h1	2275		
dl	1510			dl	1510		
Height	8			Height	8		
Length	665			Length	665		
Q	222	ft^3/day		Q	166	ft^3/day	
	1,660	gal/day	1,660		1,245	gal/day	1,245

Segment	1B				1B		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	*2338*			*h2*	*2338*		
h1	2275			h1	2275		
dl	1175			dl	1175		
Height	8			Height	8		
Length	3445			Length	3445		
Q	1,478	ft^3/day		Q	1,108	ft^3/day	
	11,053	gal/day	11,053		8,290	gal/day	8,290

Segment	1C				1C		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	*2338*			*h2*	*2338*		
h1	2275			h1	2275		
dl	3745			dl	3745		
Height	8			Height	8		
Length	1220			Length	1220		
Q	164	ft^3/day		Q	123	ft^3/day	
	1,228	gal/day	1,228		921	gal/day	921

Segment	2A				2A		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	2338			h2	2338		
h1	*2250*			*h1*	*2250*		
dl	2360			dl	2360		
Height	8			Height	8		
Length	530			Length	530		
Q	158.1	ft^3/day		Q	118.6	ft^3/day	
	1183	gal/day	1183		887	gal/day	887

Segment	2B				2B		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	*2338*			*h2*	*2338*		
h1	2250			h1	2250		
dl	1475			dl	1475		
Height	8			Height	8		
Length	2140			Length	2140		
Q	1,021	ft^3/day		Q	766	ft^3/day	
	7,640	gal/day	7640		5,730	gal/day	5730

Segment	2C				2C		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	*2338*			*h2*	*2338*		
h1	2250			h1	2250		
dl	760			dl	760		
Height	8			Height	8		
Length	675			Length	675		
Q	625	ft^3/day		Q	469	ft^3/day	
	4,677	gal/day	4677		3,508	gal/day	3508

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Segment	2D				2D		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	*2338*			*h2*	*2338*		
h1	2250			h1	2250		
dl	1010			dl	1010		
Height	8			Height	8		
Length	1300			Length	1300		
Q	906	ft^3/day		Q	680	ft^3/day	
	6,778	gal/day	6778		5,083	gal/day	5083

Segment	2E				2E		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	2338			h2	2338		
h1	*2250*			*h1*	*2250*		
dl	1470			dl	1470		
Height	8			Height	8		
Length	845			Length	845		
Q	404.7	ft^3/day		Q	303.5	ft^3/day	
	3027	gal/day	3027		2270	gal/day	2270

Segment	2F				2F		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	2338			h2	2338		
h1	*2250*			*h1*	*2250*		
dl	2370			dl	2370		
Height	8			Height	8		
Length	1820			Length	1820		
Q	540.6	ft^3/day		Q	405.5	ft^3/day	
	4044	gal/day	4044		3033	gal/day	3033

Segment	2G				2G		
K	1.00E+00	ft/day		K	7.50E-01	ft/day	
h2	2338			h2	2338		
h1	*2250*			*h1*	*2250*		
dl	2675			dl	2675		
Height	8			Height	8		
Length	1300			Length	1300		
Q	342.1	ft^3/day		Q	256.6	ft^3/day	
	2559	gal/day	2559		1919	gal/day	1919
		TOTAL (GPD)	43,849.02			TOTAL (GPD)	32,885.90
		TOTAL (GPM)	30.45			TOTAL (GPM)	22.84

Flow is confined to the coal seam and flow is from WV mine pool to MD mine pool (general NW direction)

Q = KIA

Q = flow from mine pool

K = hydraulic conductivity

I = Hydraulic Gradient (h1-h2/dl)

A = Cross sectional area perpendicular to flow path (Height X Length)

h2 = elevation of mine pool used in determining change in head (dh)

h1 = elevation of mine pool used in determing change in head (dh)

dl = lenghth used in hyraulic gradient - along flow path

Height - height of cross sectional area perpendicular to the flow path of the mine pool

Table 8, pg 2 — Length - length of cross sectional area perpendicular to the flow path of the mine pool

TABLE 9

FUTURE MINE POOL LEAKAGE TO RIVER CALCULATIONS - UPPER FREEPORT POOL (MD)

Segment	1A				1A		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2550*			*h2*	*2550*		
h1	2550			h1	2550		
dl	1510			dl	1510		
Height	8			Height	8		
Length	650			Length	650		
Q	0	ft^3/day		Q	0	ft^3/day	
	0	gal/day	0		0	gal/day	0

Segment	1B				1B		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2550*			*h2*	*2550*		
h1	2500			h1	2500		
dl	500			dl	500		
Height	8			Height	8		
Length	3445			Length	3445		
Q	2,756	ft^3/day		Q	2,039	ft^3/day	
	20,615	gal/day	20,615		15,255	gal/day	15,255

Segment	1C				1C		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2550*			*h2*	*2550*		
h1	2490			h1	2490		
dl	3460			dl	3460		
Height	8			Height	8		
Length	1220			Length	1220		
Q	169	ft^3/day		Q	125	ft^3/day	
	1,266	gal/day	1,266		937	gal/day	937

Segment	2A				2A		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	2450			h2	2450		
h1	*2490*			*h1*	*2490*		
dl	1820			dl	1820		
Height	8			Height	8		
Length	530			Length	530		
Q		ft^3/day		Q		ft^3/day	
		gal/day	0			gal/day	0

Segment	2B				2B		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2450*			*h2*	*2450*		
h1	2460			h1	2460		
dl	940			dl	940		
Height	8			Height	8		
Length	1800			Length	2140		
Q		ft^3/day		Q		ft^3/day	
		gal/day	0			gal/day	0

Segment	2C				2C		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2450*			*h2*	*2450*		
h1	2445			h1	2445		
dl	720			dl	720		
Height	8			Height	8		
Length	2580			Length	2580		
Q	143	ft^3/day		Q	106	ft^3/day	
	1,072	gal/day	1,072		793	gal/day	793

Table 9, pg 1

Segment	3A				3A		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2450*			*h2*	*2450*		
h1	2420			h1	2420		
dl	150			dl	150		
Height	8			Height	8		
Length	1260			Length	1260		
Q	2,016	ft^3/day		Q	1,492	ft^3/day	
	15,080	gal/day	15,080		11,159	gal/day	11,159

Segment	3B				3B		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	2450			h2	2450		
h1	*2385*			*h1*	*2385*		
dl	575			dl	575		
Height	8			Height	8		
Length	1900			Length	1900		
Q	1718.3	ft^3/day		Q	1271.5	ft^3/day	
	12853	gal/day	12,853		9511	gal/day	9,511

Segment	3C				3C		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	2450			h2	2450		
h1	*2355*			*h1*	*2355*		
dl	1150			dl	1150		
Height	8			Height	8		
Length	3100			Length	3100		
Q	2048.7	ft^3/day		Q	1516.0	ft^3/day	
	15324	gal/day	15,324		11340	gal/day	11340

Segment	3D				3D		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	2450			h2	2450		
h1	*2330*			*h1*	*2330*		
dl	1355			dl	1355		
Height	8			Height	8		
Length	1240			Length	1240		
Q	878.5	ft^3/day		Q	650.1	ft^3/day	
	6571	gal/day	6,571		4863	gal/day	4,863

Segment	3E				3E		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	2450			h2	2450		
h1	*2320*			*h1*	*2320*		
dl	1460			dl	1460		
Height	8			Height	8		
Length	4325			Length	4325		
Q	3080.8	ft^3/day		Q	2279.8	ft^3/day	
	23045	gal/day	23,045		17053	gal/day	17,053
		TOTAL (GPD)	95,825			TOTAL (GPD)	70,911
		TOTAL (GPM)	67			TOTAL (GPM)	28

Flow is horizontal through the coal from MD mine pools to the Potomac River (general SE direction)
dl = vertical distance from mine to the river, Area (height x length), height = Coal height; length = segment length

Q = KIA
Q = flow from mine pool
K = hydraulic conductivity - based on various sources (1)
I = Hydraulic Gradient (h1-h2/dl)
A = Cross sectional area perpendicular to flow path (Height X Length)
h2 = elevation of mine pool used in determining change in head (dh)
h1 = elevation of mine pool used in determing change in head (dh)
dl = lenghth used in hyraulic gradient - along flow path
Height - height of cross sectional area perpendicular to the flow path of the mine pool
Table 9, pg 2 Length - length of cross sectional area perpendicular to the flow path of the mine pool

TABLE 10

FUTURE MINE POOL LEAKAGE TO RIVER - UPPER FREEPORT POOL CALCULTIONS (WV)

Segment	1A				1A		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2500*			*h2*	*2500*		
h1	2495			h1	2495		
dl	500			dl	500		
Height	8			Height	8		
Length	3530			Length	3530		
Q	282	ft^3/day		Q	209	ft^3/day	
	2,112	gal/day	2,112		1,563	gal/day	1,563

Segment	1B				1B		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2500*			*h2*	*2500*		
h1	2465			h1	2465		
dl	750			dl	750		
Height	8			Height	8		
Length	1750			Length	1750		
Q	653	ft^3/day		Q	483	ft^3/day	
	4,887	gal/day	4,887		3,616	gal/day	3,616

Segment	2A				2A		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2450*			*h2*	*2450*		
h1	2435			h1	2435		
dl	700			dl	700		
Height	8			Height	8		
Length	4980			Length	4980		
Q	854	ft^3/day		Q	632	ft^3/day	
	6,386	gal/day	6,386		4,725	gal/day	4,725

Segment	3A				3A		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	2500			h2	2500		
h1	*2385*			*h1*	*2385*		
dl	1150			dl	1150		
Height	8			Height	8		
Length	650			Length	650		
Q	520.0	ft^3/day		Q	384.8	ft^3/day	
	3890	gal/day	3890		2878	gal/day	2878

Segment	3B				3B		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2500*			*h2*	*2500*		
h1	2365			h1	2365		
dl	1250			dl	1250		
27 Height	8			Height	8		
Length	1300			Length	1300		
Q	1,123	ft^3/day		Q	831	ft^3/day	
	8,402	gal/day	8,402		6,217	gal/day	6,217

TOTAL (GPD)	25,676	TOTAL (GPD)	19,000
TOTAL (GPM)	18	TOTAL (GPM)	13

Flow is horizontal through the coal from WV mine pools to the Potomac River (general NW direction)
dl = vertical distance from pool to river, Area (height x length), height = coal height; length = segment length

Q = KIA
Q = flow from mine pool
K = hydraulic conductivity - based on various sources (1)
I = Hydraulic Gradient (h1-h2/dl)
A = Cross sectional area perpendicular to flow path (Height X Length)
h2 = elevation of mine pool used in determining change in head (dh)
h1 = elevation of mine pool used in determing change in head (dh)
dl = lenghth used in hyraulic gradient - along flow path
Height - height of cross sectional area perpendicular to the flow path of the mine pool
Length - length of cross sectional area perpendicular to the flow path of the mine pool

Table 10

TABLE 11

FUTURE LEAKAGE FROM E- MINE TO DOBBIN MINE CALCULATIONS

Segment	1A				1A		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2900*			*h2*	*2900*		
h1	2680			h1	2680		
dl	375			dl	375		
Height	8			Height	8		
Length	5400			Length	5400		
Q	25,344	ft^3/day		Q	18,755	ft^3/day	
	189,573	gal/day	189,573		140,284	gal/day	140,284

Segment	1B				1B		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2900*			*h2*	*2900*		
h1	2680			h1	2680		
dl	1200			dl	1200		
Height	8			Height	8		
Length	875			Length	875		
Q	1,283	ft^3/day		Q	950	ft^3/day	
	9,599	gal/day	9,599		7,104	gal/day	7,104

Segment	1C				1C		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2900*			*h2*	*2900*		
h1	2680			h1	2680		
dl	500			dl	500		
Height	8			Height	8		
Length	2170			Length	2170		
Q	7,638	ft^3/day		Q	5,652	ft^3/day	
	57,135	gal/day	57,135		42,280	gal/day	42,280

Segment	1D				1D		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	2900			h2	2900		
h1	*2680*			*h1*	*2680*		
dl	950			dl	950		
Height	8			Height	8		
Length	2500			Length	2500		
Q	4631.6	ft^3/day		Q	3427.4	ft^3/day	
	34644	gal/day	34,644		25637	gal/day	25,637

Segment	1E				1E		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2900*			*h2*	*2900*		
h1	2680			h1	2680		
dl	600			dl	600		
Height	8			Height	8		
Length	430			Length	430		
Q	1,261	ft^3/day		Q	933	ft^3/day	
	9,435	gal/day	9,435		6,982	gal/day	6,982

Table 11, pg 1

Segment	1F				1F		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2900*			*h2*	*2900*		
h1	2680			h1	2680		
dl	520			dl	520		
Height	8			Height	8		
Length	2500			Length	2500		
Q	8,462	ft^3/day		Q	6,262	ft^3/day	
	63,292	gal/day	63,292		46,836	gal/day	46,836

Segment	1G				1G		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2900*			*h2*	*2900*		
h1	2680			h1	2680		
dl	350			dl	350		
Height	8			Height	8		
Length	675			Length	675		
Q	3,394	ft^3/day		Q	2,512	ft^3/day	
	25,389	gal/day	25,389		18,788	gal/day	18,788

TOTAL (GPD)	389,068	TOTAL (GPD)	287,910
TOTAL (GPM)	270	TOTAL (GPM)	200

Flow is confined to the coal seam and flow is from E-Mine Pool through coal barrier to Dobbins Mine Pool (North direction)

Q = KIA

Q = flow from mine pool
K = hydraulic conductivity - based on various sources (1)
I = Hydraulic Gradient (h1-h2/dl)
A = Cross sectional area perpendicular to flow path (Height X Length)
h2 = elevation of mine pool used in determining change in head (dh)
h1 = elevation of mine pool used in determing change in head (dh)
dl = lenghth used in hyraulic gradient - along flow path
Height - height of cross sectional area perpendicular to the flow path of the mine pool
Length - length of cross sectional area perpendicular to the flow path of the mine pool

Table 11, pg 2

TABLE 12

FUTURE LEAKAGE FROM DOBBIN MINE TO NORTH BRANCH

Segment	1A				1A		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2680*			*h2*	*2680*		
h1	2500			h1	2500		
dl	275			dl	275		
Height	8			Height	8		
Length	4100			Length	4100		
Q	21,469	ft^3/day		Q	15,887	ft^3/day	
	160,589	gal/day	160,589		118,836	gal/day	118,836

Segment	1B				1B		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2680*			*h2*	*2680*		
h1	2500			h1	2500		
dl	175			dl	175		
Height	8			Height	8		
Length	2000			Length	2000		
Q	16,457	ft^3/day		Q	12,178	ft^3/day	
	123,099	gal/day	123,099		91,094	gal/day	91,094

Segment	1C				1C		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2680*			*h2*	*2680*		
h1	2500			h1	2500		
dl	200			dl	200		
Height	8			Height	8		
Length	600			Length	600		
Q	4,320	ft^3/day		Q	3,197	ft^3/day	
	32,314	gal/day	32,314		23,912	gal/day	23,912

Table 12, pg. 1

Segment	1D				1D		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2680*			*h2*	*2680*		
h1	2525			h1	2525		
dl	200			dl	200		
Height	8			Height	8		
Length	1500			Length	1500		
Q	9,300	ft^3/day		Q	6,882	ft^3/day	
	69,564	gal/day	69,564		51,477	gal/day	51,477

Segment	1E				1E		
K	1.00E+00	ft/day		K	7.40E-01	ft/day	
h2	*2680*			*h2*	*2680*		
h1	2575			h1	2575		
dl	300			dl	300		
Height	8			Height	8		
Length	2500			Length	2500		
Q	7,000	ft^3/day		Q	5,180	ft^3/day	
	52,360	gal/day	52,360		38,746	gal/day	38,746

gal/day	437,926	gal/day	324,065
gpm	304	gpm	225

Flow is confined to the coal seam and flow is from Dobbins Mine Pool through coal barrier to North Branch Mine.

Q = KIA

Q = flow from mine pool
K = hydraulic conductivity - based on various sources (1)
I = Hydraulic Gradient (h1-h2/dl)
A = Cross sectional area perpendicular to flow path (Height X Length)
h2 = elevation of mine pool used in determining change in head (dh)
h1 = elevation of mine pool used in determing change in head (dh)
dl = lenghth used in hyraulic gradient - along flow path
Height - height of cross sectional area perpendicular to the flow path of the mine pool
Length - length of cross sectional area perpendicular to the flow path of the mine pool

Table 12, pg.2

TABLE 13

FUTURE MINE POOL LEAKAGE TO RIVER - BAKERSTOWN MINE POOL CALCULATIONS (2680')

1A

K	7.40E-01	ft/day	
h2	*2680*		
h1	2670		
dl	230		
Height	110		
Length	1380		
Q	4,884	ft^3/day	
	36,532	gal/day	36,532

1A

K	2.00E+00	ft/day	
h2	*2680*		
h1	2670		
dl	230		
Height	110		
Length	1380		
Q	13,200	ft^3/day	
	98,736	gal/day	98,736

1B

K	7.40E-01	ft/day	
h2	*2680*		
h1	2660		
dl	230		
Height	110		
Length	1380		
Q	9,768	ft^3/day	
	73,065	gal/day	73,065

1B

K	2.00E+00	ft/day	
h2	*2680*		
h1	2660		
dl	230		
Height	110		
Length	1380		
Q	26,400	ft^3/day	
	197,472	gal/day	197,472

1C

K	7.40E-01	ft/day	
h2	*2680*		
h1	2650		
dl	240		
Height	110		
Length	1000		
Q	10,175	ft^3/day	
	76,109	gal/day	76,109

1C

K	2.00E+00	ft/day	
h2	*2680*		
h1	2650		
dl	240		
Height	110		
Length	1000		
Q	27,500	ft^3/day	
	205,700	gal/day	205,700

1D

K	7.40E-01	ft/day	
h2	2680		
h1	*2645*		
dl	275		
Height	110		
Length	1100		
Q	11,396	ft^3/day	
	85,242	gal/day	85,242

1D

K	2.00E+00	ft/day	
h2	2680		
h1	*2645*		
dl	275		
Height	110		
Length	1100		
Q	30,800	ft^3/day	
	230,384	gal/day	230,384

1E			
K	7.40E-01	ft/day	
h2	*2680*		
h1	2645		
dl	275		
Height	110		
Length	1400		
Q	14,504	ft^3/day	
	108,490	gal/day	108,490

1E			
K	2.00E+00	ft/day	
h2	*2680*		
h1	2645		
dl	275		
Height	110		
Length	1400		
Q	39,200	ft^3/day	
	293,216	gal/day	293,216

1F			
K	7.40E-01	ft/day	
h2	*2680*		
h1	2640		
dl	230		
Height	110		
Length	1280		
Q	18,120	ft^3/day	
	135,540	gal/day	135,540

1F			
K	2.00E+00	ft/day	
h2	*2680*		
h1	2640		
dl	230		
Height	110		
Length	1280		
Q	48,974	ft^3/day	
	366,325	gal/day	366,325

TOTAL (GPD)	514,978
TOTAL (GPM)	358

TOTAL (GPD)	1,391,833
TOTAL (GPM)	967

Flow is vertical from the underlying coal through the overburden to the river bottom.

Q = KIA

Q = flow from mine pool

K = hydraulic conductivity - based on various sources (1)

I = Hydraulic Gradient (h1-h2/dl)

A = Cross sectional area perpendicular to flow path (Height X Length)

h2 = elevation of mine pool used in determining change in head (dh)

h1 = elevation of mine pool used in determing change in head (dh)

dl = lenghth used in hyraulic gradient - along flow path

Height - height of cross sectional area perpendicular to the flow path of the mine pool

Length - length of cross sectional area perpendicular to the flow path of the mine pool

Table 13, pg.2

TABLE 14

FUTURE MINE POOL LEAKAGE FROM DOBBINS TO BAKERSTOWN POOL

Polygon	HEAD 1	HEAD 2	dl (overburden height)	Segment Width	Length
1	2690*- 2685*	2680	180	1000	8200

* - The Dobbins pool must attain a higher head elevation than the Bakerstown pool, therefore the head elevation has been set at 2690' and 2685'. It is unlikely that the head will continue to rise in the Dobbin pool once it is interconnected to the Bakerstown pool due to the borehole discharge.

Polygon	1		
K	7.00E-03	ft/day	
h2	*2690*		
h1	2680		
dl	180		
Height	1000		
Length	8200		
Q	3,189	ft^3/day	
	23,853	gal/day	23,853
		TOTAL (GPD)	23,853
		TOTAL (GPM)	17

Polygon	1		
K	7.00E-03	ft/day	
h2	*2685*		
h1	2680		
dl	180		
Height	1000		
Length	8200		
Q	1,594	ft^3/day	
	11,926	gal/day	11,926
		TOTAL (GPD)	11,926
		TOTAL (GPM)	8

Flow is vertical from the underlying coal through overburden into Alpine Mine

Q = KIA

Q = flow from mine pool

K = hydraulic conductivity - based on various sources (1)

I = Hydraulic Gradient (h1-h2/dl)

A = Cross sectional area perpendicular to flow path (Height X Length)

h2 = elevation of mine pool used in determining change in head (dh)

h1 = elevation of mine pool used in determing change in head (dh)

dl = lenghth used in hyraulic gradient - along flow path

Height - height of cross sectional area perpendicular to the flow path of the mine pool

Length - length of cross sectional area perpendicular to the flow path of the mine pool

Table 14, pg 1

TABLE 15

FUTURE MINE POOL LEAKAGE FROM E- MINE TO BAKERSTOWN POOL

POLYGON 1

K	7.00E-03	ft/day	
h2	*2900*		
h1	2680		
dl	200		
Height	11500000		
Length	1		
Q	88,550	ft^3/day	
	662,354.0000	gal/day	662,354

Potential Leakage Area	HEAD 1 (ft)	HEAD 2 (ft)	dl (interburden height ft)	AREA (ft2)
POLYGON 1	2900	2680	200	11,500,000.00
POLYGON 2	2900	2680	200	6,400,000.00
TOTAL				17,900,000.00

POLYGON 2

K	7.00E-03	ft/day	
h2	*2900*		
h1	2680		
dl	200		
Height	6400000		
Length	1		
Q	49,280	ft^3/day	
	368,614	gal/day	368,614

TOTAL (GPD)	1,030,968
TOTAL (GPM)	716

Flow is vertical from the underlying coal through overburden into Alpine Mine

Q = KIA
Q = flow from mine pool
K = vertical hydraulic conductivity
I = Hydraulic Gradient (h1-h2/dl)
A = Cross sectional area perpendicular to flow path (Height X Length)
h2 = elevation of mine pool used in determining change in head (dh)
h1 = elevation of mine pool used in determing change in head (dh)
dl = lenghth used in hyraulic gradient - along flow path
Height - height of cross sectional area perpendicular to the flow path of the mine pool
Length - length of cross sectional area perpendicular to the flow path of the mine pool

Table 15, pg.1

APPENDIX C– STIFF DIAGRAMS

Stiff Diagrams

Stiff diagrams are used by hydrologist as a forensic tool that provides a fingerprint or signature pattern for water samples. Stiff diagrams with similar patterns indicate similar types of water chemistry or water composition. An example of calcium-sulfate type water for samples taken from three Maryland wells in an Upper Freeport mine using Stiff diagrams is shown in Figure S-1. The anion pattern or shape for all three samples located on the right side of the zero axis has a significant peak to the right for sulfate (SO_4) and then narrows close to the zero axis for the bicarbonate ($HC0_3$) and the chloride (Cl) values. The cation pattern or shape for all three samples located on the left side of the zero axis has a large peak to the left for the calcium (Ca) value. Magnesium (Mg) on top has smaller values than those for calcium but larger than the values for sodium and potassium (Na +K) on the bottom. Although the patterns or shapes differ slightly in the amounts of anions and cations, the overall patterns are similar and identify the major cation and anion as calcium-sulfate type water. Mine water is often calcium-sulfate type water. The water well samples from West Virginia Upper Freeport mines and the Bakerstown mines also exhibit calcium-sulfate type water as shown in Figures S-2 and S-3.

Figure S-1. Stiff Diagrams for Maryland Upper Freeport Wells-Calcium-Sulfate type water.

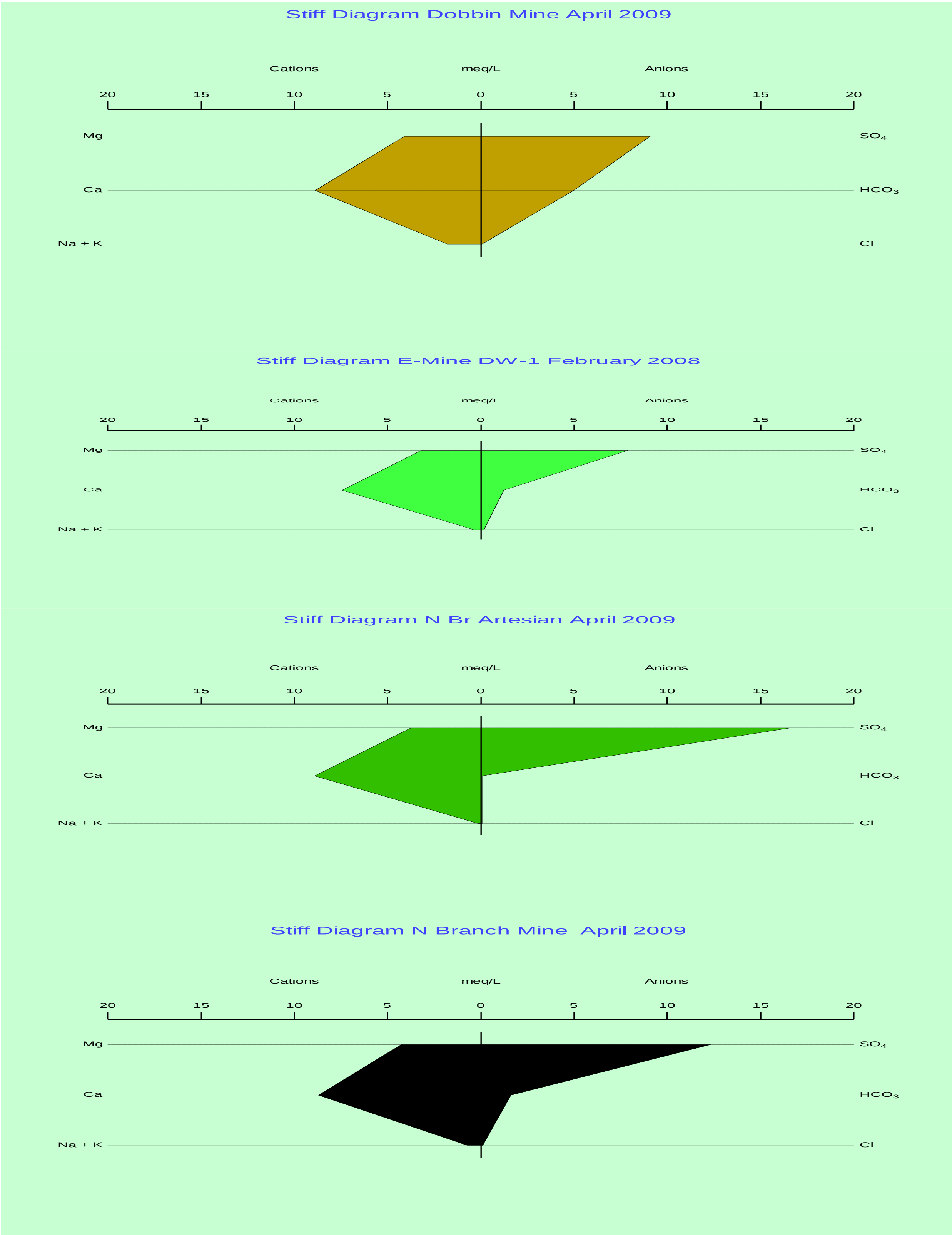

Figure S-2. Stiff Diagrams for WV Upper Freeport Wells -Calcium-Sulfate type water.

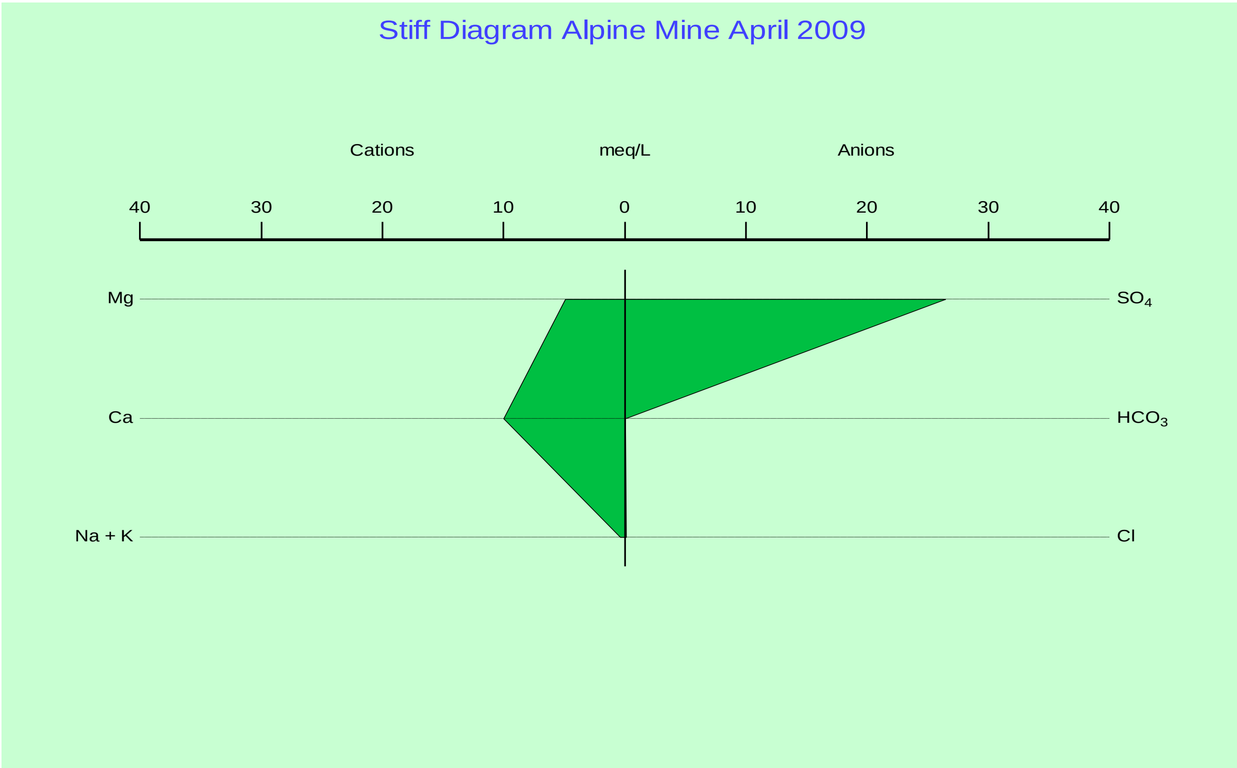

Figure S-3. Stiff Diagrams for WV Bakerstown Wells- Calcium-Sulfate type water.

APPENDIX D - WATER QUALITY TABLES

TABLE 16 - GENERAL CHEMISTRY RESULTS

		GaFb - 22	GaFb-22	C- Mine Well	C- Mine Well	C Mine Well	GaFb - 35	GaFb-35	Kempton Discharge	Kempton Discharge	E Mine DW-1	E Mine DW-3	Alpine/Henry	Dobbin	Emmons	N. Branch Artesian	N. Branch
Date		4-18-2010	5-25-2010	4-18-2007	10-16-2007	5-26-2010	10-17-2007	5-26-2010	10-30-2007	5-27-2010	2-25-2007	2-25-2007	4-14-2009	4-14-2009	4-14-2009	4-14-2009	4-14-2009
Analytes	Unit																
Nitrogen, Nitrate	mg/L as N	<0.05	<0.05	<0.05	0.29	<0.05	<0.05	<0.05	<0.05	<0.05			<0.05	<0.05	<0.05	0.13	0.29
Nitrogen, Nitrite	mg/L as N	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05			<0.05	<0.05	<0.05	<0.05	<0.05
Chloride	mg/L	21	12	1	2	28	20	16	3	2	5	1	3	2	4	1	3
Fluoride	mg/L	0.4	0.2	0.7	0.4	<0.1	0.4	<0.1	0.6	<0.1	0.2	0.2	0.4	<0.1	<0.1	0.3	<0.1
Sulfate	mg/L	584	48	21	12	1350	2170	1690	459	564	377	344	1270	435	1860	795	590
Nitrogen, Ammonia	mg/L as N		2.38		<0.10	2.93	2.13	1.85	0.38	0.4			2.13	1.27	1.76	0.66	0.47
Specific Conductance	umhos/cm	1060	307	255	265	2340	3040	2560	826	1070	984	967	2000	1170	2350	1350	1100
Total Dissolved Solids	mg/L	896	172	160	244	2170	3250	2370	638	862	698	666	1950	892	2650	1070	926
Total Suspended Solids	mg/L	1110	5	213	24	213	230	76	13	<5	42	<5	33	<5	40	<5	10
Acidity, Total	mg/L as CaCO3	-85	-45	-84	-110	-143	120	22	210	260	-46	-125	590	-289	300	180	-75
Bicarbonate	mg/L as CaCO3	112	88	160	138	181	152	25	<5	<5	75	159	<5	302	18	<5	98
Alkalinity, Total	mg/L as CaCO3	112	103	160	139	181	152	25	<5	<5	75	161	<5	302	18	<5	98
Chemical O2 Demand	mg/L				<10		83		14								
Lab, pH	SU	7.24	9.24	7.44	7.99	7.28	6.22	5.90	3.43	3.07	7.63	8.08	2.80	6.84	5.50	3.11	6.32
Total Organic Carbon	mg/L	7.3	10.1	3.3	0.8	0.7	17.7	1.2	1.3	0.8	<0.5	2.5	1.3	0.7	<0.5	0.6	0.5

APPENDIX D - WATER QUALITY TABLES

TABLE 17 - DISSOLVED & TOTAL METAL ANALYSE

Date			GaFb - 22 April 18, 2007		GaFb - 22 May 25, 2010		C- Mine Well April 18, 2007		C- Mine Well October 16, 2007		C- Mine Well May 26, 2010		GaFb - 35 October 17, 2007		GaFb - 35 May 26, 2010	
Analytes	Unit	Detection Limits	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Aluminum	mg/L	0.1	<0.1	1.6	0.3	<0.1	<0.1	1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Antimony	ug/L	1.0	<1.0	1.7	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Arsenic	ug/L	1.0	<1.0	4.7	<1.0	<1.0	<1.0	<5.0	<1.0	<1.0	1.6	1.1	<1.0	<1.0	<1.0	<1.0
Barium	mg/L	0.01	0.07	0.23	0.04	0.04	0.26	4.23	0.14	0.21	0.24	0.21	0.06	0.05	0.02	0.01
Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.05	0.1	0.13	<0.05	<0.05	0.08	0.46	0.07	0.06	0.10	0.09	0.24	0.27	0.11	0.10
Cadmium	mg/L	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	0.002	0.002	<0.002	<0.002
Calcium	mg/L	1.0	343	31.8	3.2	3.1	12.8	24.3	10.8	10.9	343.0	338	538	566	360	317
Chromium	mg/L	0.01	0.028	0.093	<0.01	<0.01	0.012	0.358	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.03	<0.005	<0.005	<0.005	<0.005	0.037	0.052	<0.005	<0.005
Copper	mg/L	0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/L	0.05	27.8	57.7	0.39	1.9	10.4	380	0.11	5.19	28.0	24.5	313	375	72.0	59.2
Lead	mg/L	0.02	<0.02	0.16	<0.02	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Magnesium	mg/L	0.1	72.8	3.5	2.5	2.4	2.9	4	2.4	2.4	84.7	83.1	199	203	148	140
Manganese	mg/L	0.01	1.68	0.56	<0.01	0.02	0.07	3.47	0.02	0.11	1.60	1.60	11	13.3	1.43	1.36
Mercury	ug/L	0.20	<0.20	0.6	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Nickel	mg/L	0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.03	<0.01	<0.01
Potassium	mg/L	0.5	13.8	13	7.8	7.5	2.3	3	2	1.4	11.4	11.1	17.1	17.3	16.6	16.6
Selenium	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Silica	mg/L	Varies	0.96		0.61	0.72	5		2.8	1.7	7.0	9.5	1.4	1.5	0.59	<0.20
Silver	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	0.008	<0.005	<0.005
Sodium	mg/L	0.2	76.8	42	49.7	49.0	48.5	48.4	50.3	54	124	122	132	134	133	141
Thallium	ug/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.02
Zinc	mg/L	0.01	0.08	0.55	0.05	<0.01	0.03	0.09	0.02	<0.01	0.02	<0.01	0.09	0.22	0.03	<0.01

Date	Kempton Discharge October 30, 2007		Kempton Discharge May 27, 2010		E Mine DW-1 February 25, 2008		E Mine DW-3 February 25, 2008		Alpine/Henry April 14, 2009		Dobbin April 14, 2009		Emmons April 14, 2009		N. Branch Artesian April 14, 2009		N. Branch April 14, 2009	
Analytes	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Aluminum	18.7	19.3	25.1	26.6	0.1	1.5	<0.1	<0.1	20.3	20.1	<0.1	<0.1	<0.1	1.6	11.6	11.7	0.3	1.2
Antimony	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.8	1.7	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Arsenic	3.2	3.3	2.6	2.8	1	1.9	1.2	1.4	1.9	2.5	<1.0	<1.0	2.4	2.5	<1.0	<1.0	<1.0	<1.0
Barium	0.01	0.01	0.01	<0.01	0.06	0.06	0.11	0.11	<0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Beryllium	0.01	0.01	0.009	0.011	<0.001	<0.001	<0.001	<0.001	0.007	0.007	<0.001	<0.001	<0.001	<0.001	0.007	0.007	<0.001	<0.001
Boron	0.26	0.28	0.06	0.08	<0.05	<0.05	0.05	0.05	0.05	0.05	0.08	0.08	<0.05	<0.05	<0.05	<0.05	0.08	0.08
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	0.004	<0.002	<0.002	0.004	0.004	<0.002	<0.002	<0.002	<0.002
Calcium	57.9	59	51.9	54.3	149	148	148	146	201	196	178	182	428	432	179	176	175	180
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.01	<0.010	<0.01	<0.010	<0.01	<0.010	<0.01	<0.010	<0.01
Cobalt	0.198	0.202	0.201	0.202	0.094	0.093	0.018	0.018	0.133	0.13	0.018	0.019	0.115	0.115	0.126	0.125	0.023	0.024
Copper	<0.01	<0.01	0.020	0.020	<0.01	<0.01	0.01	0.01	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01
Iron	49.9	51.1	52.2	53.7	0.61	2.71	0.37	0.81	199	198	6.45	6.89	194	196	25.4	24.3	2.53	4.36
Lead	0.05	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Magnesium	29.1	30	26.6	27.8	39	38.6	33.7	33.2	59.8	57.8	50.2	52.0	125	125	46.9	46.0	52.2	54.4
Manganese	3.43	3.51	3.19	3.21	0.86	0.82	0.19	0.18	5.26	5.15	1.72	1.77	15.1	15.1	3.42	3.31	1.29	1.32
Mercury	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Nickel	0.34	0.35	0.36	0.35	0.14	0.14	0.02	0.02	0.26	0.25	0.02	0.02	0.08	0.08	0.25	0.23	0.05	0.05
Potassium	3.2	3.5	3.1	3.1	8.8	6.8	10.5	10.5	4.3	4.2	9.6	10.1	6.2	6.1	3.4	3.2	7.2	7.4
Selenium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Silica	37	37	34	34	4.1	1.4	1.4	<0.20	5.7	6.1	0.68	0.96	1.6	1.8	2.7	2.8	1.3	1.4
Silver	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sodium	4.6	4.7	4.3	4.1	4.2	4	9.8	9.7	7	6.8	36.3	37.3	3.3	3.2	1.5	1.4	13.0	13.4
Thallium	0.4	0.3	0.3	0.3	<0.02	<0.02	<0.02	<0.02	0.3	0.3	<0.2	<0.2	<0.2	<0.2	0.2	0.2	<0.2	<0.2
Zinc	0.94	0.93	0.93	0.94	0.44	0.41	0.1	0.09	0.85	0.82	0.02	0.02	0.15	0.14	0.50	0.48	0.10	0.10