Final Report Fairmont, West Virginia Mine-pool

Prepared for: West Virginia Department of Environmental Protection, Division of Mining and Reclamation, Charleston, WV

Prepared by: US Office of Surface Mining,

Technical Support Division, Pittsburgh, PA

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Report Abstract:

This report describes water level, flow and quality conditions in a flooded complex of closed underground mines near Fairmont, West Virginia, informally referred to as the Fairmont mine-pool. Water levels in the mine-pool have been, and are being, controlled by ground water outflow and withdrawal which offsets subsurface inflow and infiltration. The pool is prevented from overflowing and leaking water into the lower reaches of two streams, Buffalo Creek and Paw Paw Creek. These streams drain directly into the Monongahela River. Mine-pool water contains iron, total dissolved solids and sulfate in elevated concentrations that would be degrade existing surface water quality. Water quality varies spatially within the mine-pool. The combination of outflow and withdrawal has prevented mine-pool impacts to surface waters for about 15 years.

The Office of Surface Mining (OSM) has monitored the mine-pool on behalf of the West Virginia Department of Environmental Protection (WVDEP) since 1997. Water level measurements have been collected from a series of wells located in major mines that are hydrologically connected in varying degree. Several wells were instrumented with automated water level recorders to provide a detailed record. OSM also conducted limited water quality sampling of mine-pool wells and surface water to identify current conditions and assess changes.

The mines constituting the mine-pool are fully flooded, and water levels range between about elevations 815 and 853 feet. This maintains the mine-pool below the local surface water elevation of the Monongahela River. It also remains below a “not to exceed” elevation measured at a mine-pool well designated by WVDEP as an NPDES monitoring point. Ground water flow patterns within the mine-pool are complex and are controlled by the location and thickness of coal barriers, individual in-mine water levels, mine depth, geologic structure, and timing of mine closure and flooding.

Ground water flows from south to north through a series of mines adjacent to the West Fork and Monongahela Rivers. Some of this water is removed from the north end of the mine-pool by a siphon and pump system (Paw Paw Siphon), transferred to the adjacent “Morgantown mine-pool”, and ultimately routed to a treatment facility located further north. Active mining operations located west of the Fairmont mine-pool keep adjacent abandoned mines dewatered by pumping. This protective pumping allows the Fairmont mine-pool to discharge significant amounts of ground water by leakage through coal barriers into dewatered mine works. Another major outflow occurs on the northeast boundary of the Fairmont mine-pool where ground water leaks from the Fairmont mine-pool through a long relatively thin coal barrier to the Morgantown mine-pool. Mine-pool water is also transferred between mines within the Fairmont mine-pool by barrier leakage.

Since individual mines and adjacent mine-pools exchange water, changing conditions, such as stopping, starting or changing pumping schedules, or new mining development, can affect conditions in the Fairmont mine-pool.

The body of this report describes the Fairmont mine-pool in more detail.

Report Cover: Part of the above ground structure of the “Siphon” in the Paw Paw Creek watershed. The siphon removes mine water from the Fairmont mine-pool, routes over a barrier pillar, and discharges into an adjacent mine-pool. April 2012.

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Introduction and Summary

The Fairmont mine-pool consists of a complex of closed, flooded underground coal mines containing poor quality water in Marion County, West Virginia. If water levels were allowed to rise to a discharge elevation, the mine water could enter the Monongahela River and its tributaries and adversely affect surface water quality. *Water levels in the mine-pool are currently being controlled to prevent a surface discharge.* The Office of Surface Mining (OSM) has been monitoring water levels and quality in the Fairmont mine-pool on behalf of the West Virginia Department of Environmental Protection (WVDEP) since 1997. The purpose of this report is to characterize recent water quantity and quality conditions, and identify features that require monitoring and analysis in the future to prevent pollutional discharges.

The mine-pool includes about 52,000 acres of mine works located just west of the Monongahela and West Fork Rivers beneath the town of Fairmont and adjacent areas. The mine-pool extends west toward the town of Mannington, south towards the Marion-Harrison county line and north toward the town of Rivesville and Monongalia County. Figure 1 shows the general location of the mine-pool.

The mine-pool consists of abandoned, fully flooded underground mines in the Pittsburgh coalbed that are hydrologically connected. The mines are located below local base level surface drainage, and only are near ground surface on the eastern edge of the mine-pool, adjacent to the West Fork and Monongahela rivers. The rocks dip to the northwest at a low angle, and coal elevation decreases in this direction. Conversely, coal elevation increases closer to the rivers. This structural orientation and flooding of closed mines creates a potential for mine-pool discharge to the surface near the rivers and some of their tributaries.

Mines closed at various dates ranging from the 1940s to 1980s, and were operated mainly using room and pillar techniques, with some longwall development in more recently mined areas. Active underground operations are located further west of the Fairmont mine-pool under deeper overburden, and there are substantial unmined areas as well. Several companies, including Consol Energy and predecessors, Bethlehem Mines, Eastern Associated, and others operated mines constituting the Fairmont pool.

An internal coal company report (Leavitt, 1993) estimated that flooding of closed mines and discontinuation of dewatering activities would cause the potentiometric head (water levels) in parts of the Fairmont mine-pool to rise to surface discharge elevation by the mid-1990s. Consequently, a mine-pool control and monitoring plan was developed and implemented by Consol Energy to prevent an uncontrolled surface discharge. That plan, with some modifications, has continued in effect to the present under the jurisdiction of the WVDEP.

Water levels in the mine-pool have been controlled since 1997 by withdrawal of mine water at a pump and siphon system located in the Paw Paw Creek watershed (figure 1), in combination with subsurface outflow and leakage to adjacent mines.

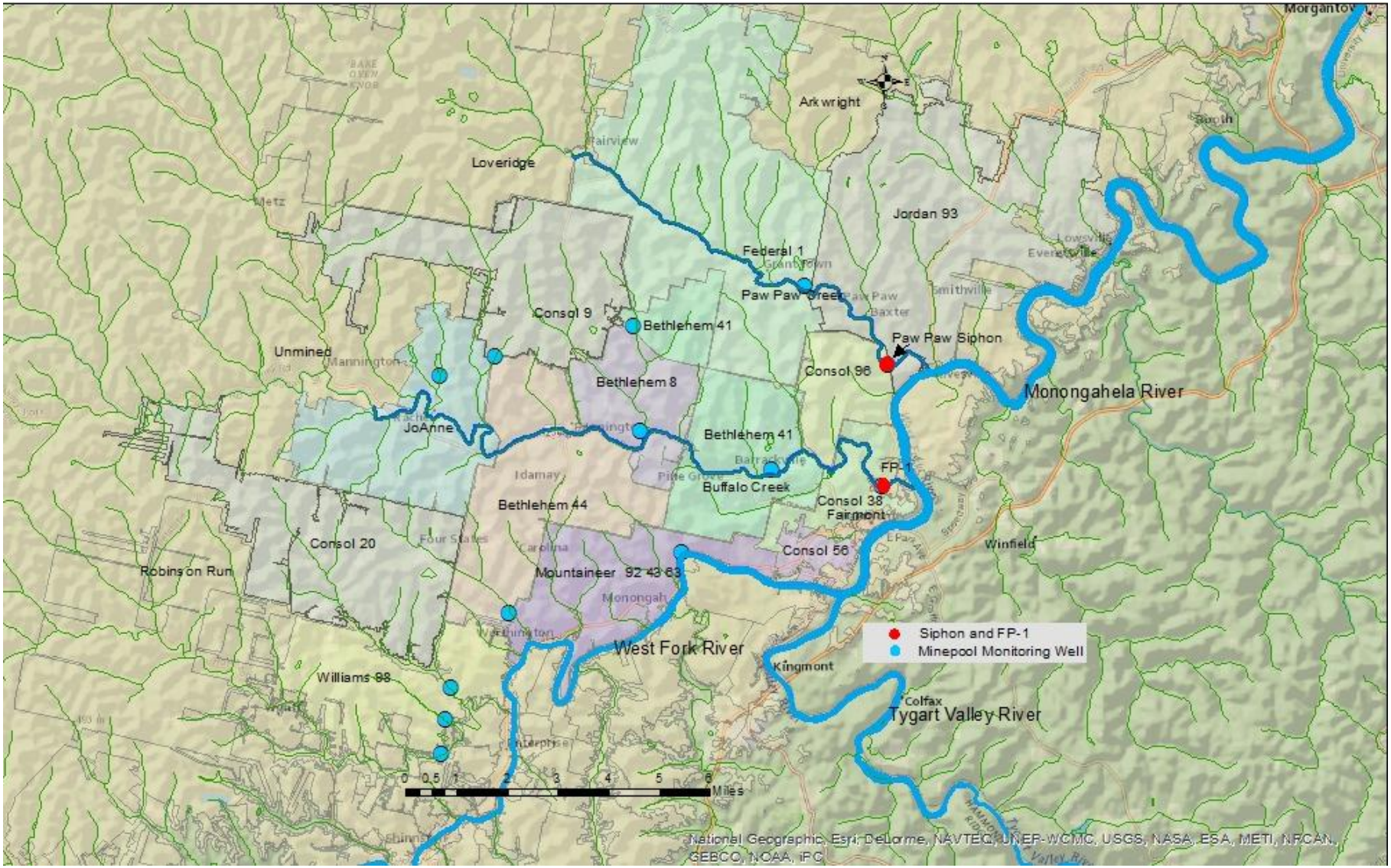

Figure 1. General location and extent of Fairmont Mine-pool, showing proximity to Monongahela River and principal tributaries. Channel segments of Paw Paw Creek and Buffalo Creek that overlie the mine-pool are highlighted in dark blue. Shaded outlines of principal and adjacent mines in the mine-pool are shown as an overlay. Gray shaded mines Consol 20, Consol 9 and Jordan 93 receive mine water outflow from the mine-pool. Paw Paw Siphon and monitoring well FP-1 highlighted in red. Other mine-pool monitoring wells shown in blue.

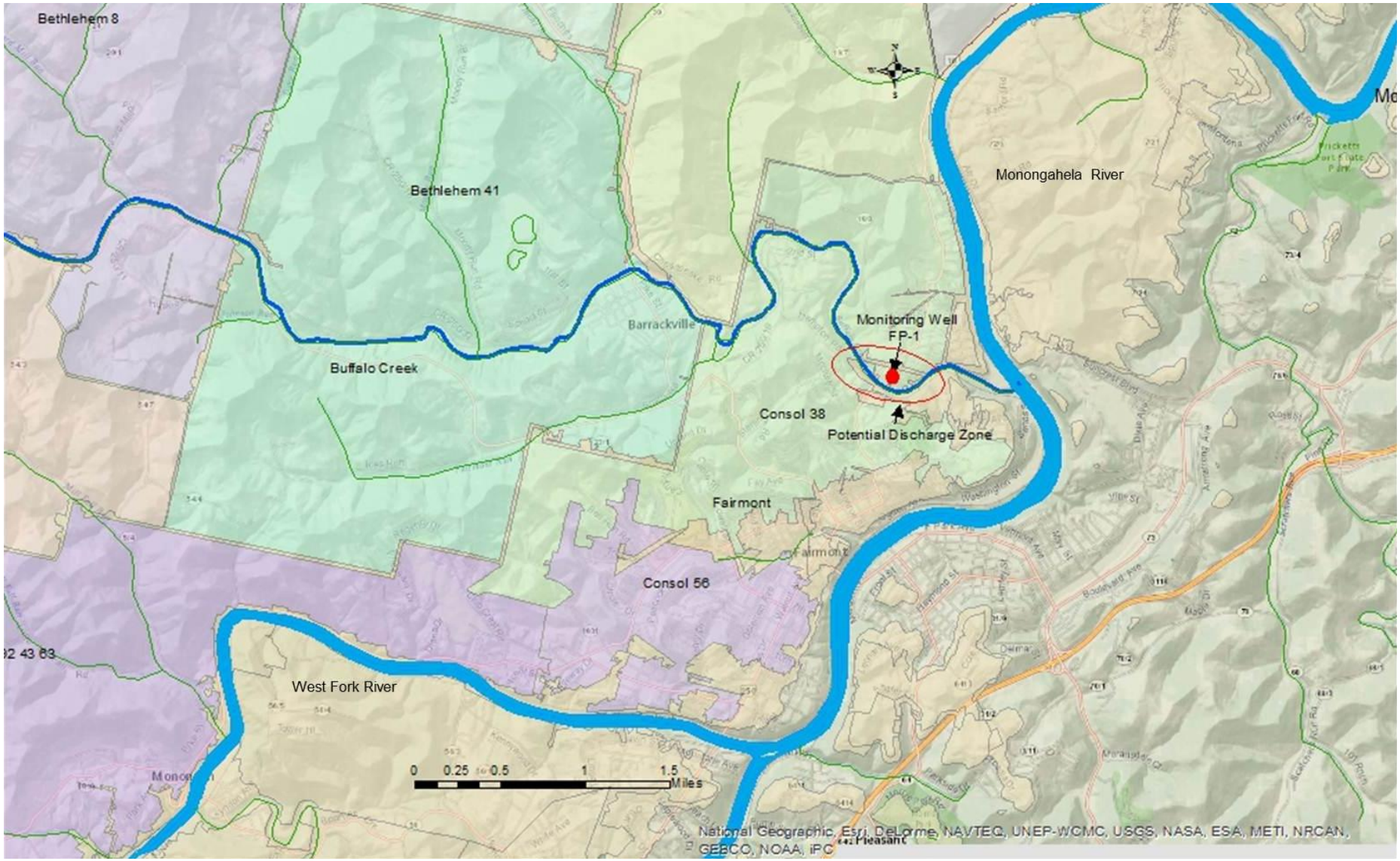

Figure 2. Location of monitoring point FP-1 and potential mine-pool discharge zone in Buffalo Creek. The water level at FP-1 is below the normal pool elevation of 857 m.s.l. for the adjacent segment of the Monongahela River. The red circled segment of Buffalo Creek shows the stream reach where the mine-pool head approaches stream elevation and the Pittsburgh coal is at or near outcrop elevation. If the mine-pool head increased to stream elevation, mine water would leak into Buffalo Creek. Color shaded outlines of mine-works shown as an overlay.

The pump and siphon system is commonly referred to as the "Paw Paw Siphon" or "The Siphon" and that terminology is followed in this report. The five year median Siphon withdrawal for 2008 to 2012 was 850 gallons per minute (gpm). Subsurface outflow and leakage is estimated to remove an additional 1,400 gpm from the mine-pool. *The Siphon withdrawal and subsurface outflow and leakage are the principal mechanisms that prevent the mine-pool from rising to a discharge elevation and overflowing into surface streams.* These water losses and removal from the mine-pool approximately offset the infiltration of precipitation (recharge) into the mine works.

A Clean Water Act order requires the mine-pool to be maintained at an elevation less than the normal pool elevation (857 ft. m.s.l.) of the Monongahela River. The mine-pool elevation is measured at a location designated FP-1 (figures 1 and 2) in NPDES monitoring reports It is also referred to as the Penn Overall monitoring well (Appendix A).

The Paw Paw Siphon moves water from the Fairmont mine-pool, over a narrow coal barrier pillar, and discharges into another closed, underground mine; Jordan 93. This mine, Jordan 93, is part of another complex to the north referred to as the "Morgantown mine-pool". It also consists of Pittsburgh coalbed mines. The mine water is eventually pumped to the surface and managed at a centralized treatment plant. Additional mine water also leaves the mine-pool by leaking through coal barriers along the northeast part of the Fairmont mine-pool and into the Jordan 93 mine in the adjacent Morgantown mine-pool (figures 3 and 4). Mine water also leaves the Fairmont mine-pool on its western perimeter by leaking through coal barriers and into the Consol 9 (Jamison) and Consol 20 (O'Donnell) mines (figures 3 and 4). Water is pumped from these mines to protect active underground mining operations located further to the northwest and southwest.

Figures 3 and 4 both show ground water flow directions in the mine-pool. Figure 3 is a generalized view emphasizing overall movement, while figure 4 provides more detailed information including typical hydraulic head for individual sub-pools.

Siphon withdrawal and subsurface outflow has been an effective strategy for controlling water level in the Fairmont mine-pool since implementation in 1997. The mine-pool water level is being held below potential breakout elevation (approximately 860 ft. m.s.l.), and below the normal pool elevation (857 ft. m.s.l.) of the Monongahela River. The mine-pool was fully flooded by about 2005. Water levels have remained relatively stable from 2005 to date of this report. Significant changes in any of the outflow features should trigger an evaluation of effects on the Fairmont mine-pool and potentially, an adjustment of water level management practices. These changes include:

- the closure and flooding of adjacent active mines, or
- the development of new adjacent underground mines
- changes in pumping rates and water levels in adjacent mines and mine-pools
- periods of prolonged above normal precipitation

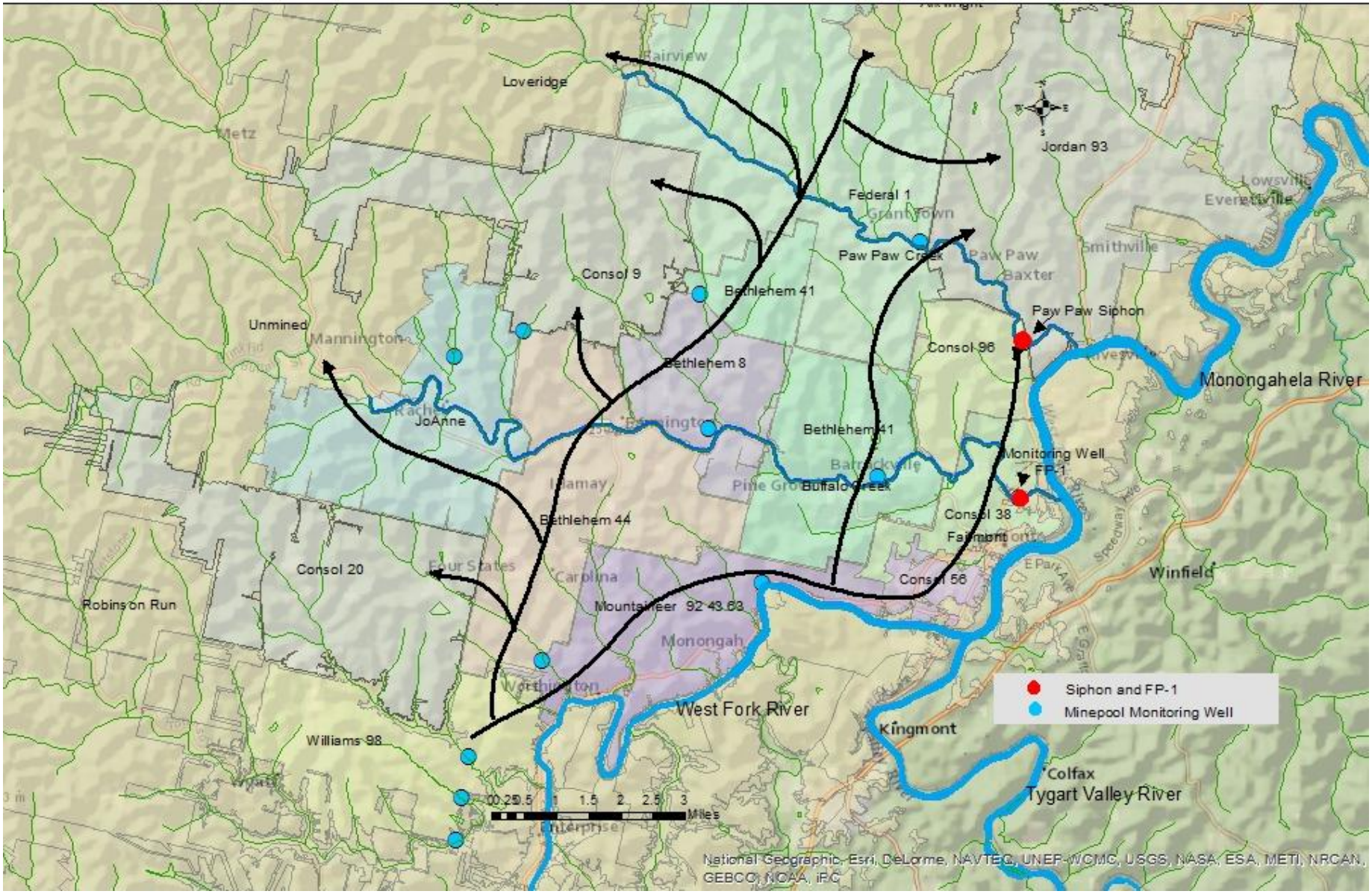

Figure 3. Fairmont Mine-pool showing generalized ground water flow directions for 2011 conditions. Ground water flows from south to north through a series of mines adjacent to the West Fork and Monongahela rivers. Major ground water outflows occur to the Consol 20 and Consol 9 mines to the southwest and northwest and Jordan 93 to the northeast. Additional ground water flow occurs between individual sub-pools. Ground water is also withdrawn at the Paw Paw siphon.

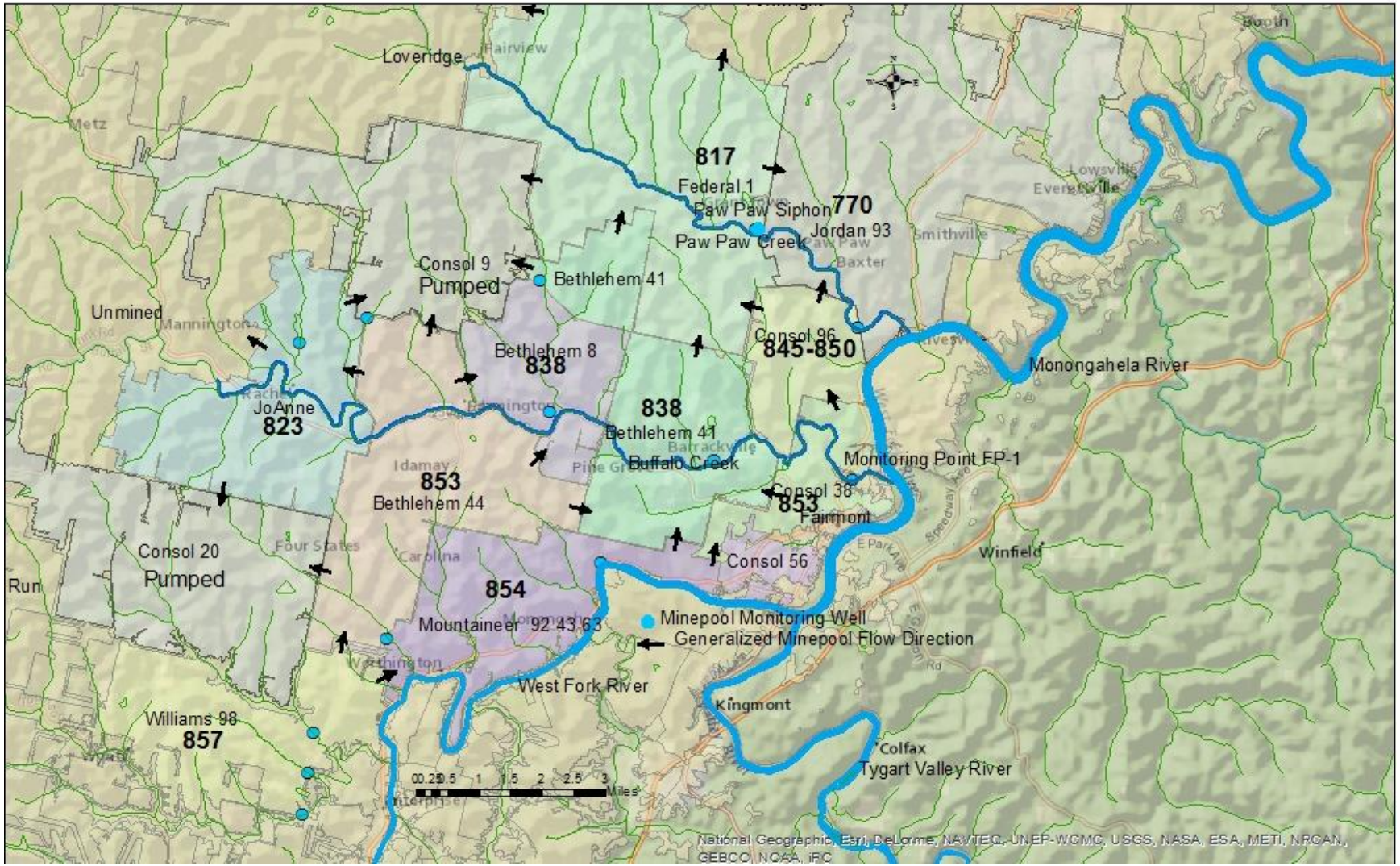

Figure 4. Fairmont Mine-pool showing detailed ground water flow directions (dark arrows) for 2011 conditions, and mine-pool monitoring well locations (Blue Circles). The Paw Paw Creek Siphon is highlighted (large blue circle). Major ground water outflows occur to the Consol 20 and Consol 9 mines to the southwest and northwest, and Jordan 93 to the northeast. Typical hydraulic head values shown in bold numbers for individual sub-pools.

An estimated 1,400 gallons per minute (gpm) leaves the Fairmont mine-pool by subsurface flow and leakage into adjacent mines. These include the Consol 9 and Consol 20 mines on the western perimeter, and the Jordon 93 mine to the northeast. The Consol 9 and Consol 20 mines are mostly dewatered to protect adjacent active mining. A significant reduction in pumping rate in either mine would decrease the rate of outflow from the Fairmont mine-pool. The decreased outflow would eventually have to be offset by increased withdrawal elsewhere in the Fairmont mine-pool, such as at the Siphon. The closure plans for the active mines protected by the current pumping in Consol 9 and Consol 20 should address the effects of reduced or discontinued pumping and flooding on the Fairmont mine-pool.

The Jordan 93 mine is the major recipient of subsurface barrier leakage from the northeast part of the Fairmont mine-pool, and is also the injection point for the Siphon. Its water level is controlled mostly by activities in the Morgantown mine-pool. *Changing conditions in the Morgantown mine-pool that increased water level in Jordan 93 would reduce barrier seepage outflow from the Fairmont mine-pool. The decreased outflow would eventually have to be offset by increased withdrawal elsewhere in the Fairmont mine-pool.* If new or additional underground mine development takes place adjacent to the Fairmont mine-pool, this should have effect of *increasing* outflow from the mine-pool. In that instance the mine-pool could still be managed with a *reduced* discharge rate at the Siphon. Any new adjacent underground mine development should address the expected hydrologic interaction with the Fairmont mine-pool.

Mine-pool water quality is characterized by near neutral pH and large alkalinity concentrations. Variable but generally elevated concentrations of iron, sulfate, and total dissolved solids (TDS) are the principal water quality concerns if the mine-pool discharged to surface waters. In particular, the formation and deposition of iron solids could affect aquatic life and impair stream uses. Limited sampling for twelve trace elements (As, Ba, Be, Cd, Co, Cr, Cu, Ni, Pb, Sb, Se, and Zn) mostly reported analyses less than detection limit. Samples collected over a period of about 10 years show some improvement in water quality in parts of the mine-pool, and little change in others. Therefore, it is unlikely that overall mine-pool quality will attain a composition meeting surface water quality effluent standards in the near term. *Mine-pool water levels will have to be maintained at elevations below surface discharge for an indefinite period to prevent surface water quality impacts.*

A more detailed discussion of mine-pool conditions is presented in the following sections.

Principal and Adjacent Mines in the Fairmont Mine-pool

Ten major underground mines and several smaller mine-works covering about 52,000 acres comprise the Fairmont mine-pool (figure 3). Three adjacent mines, Consol 9, Consol 20 and Jordan 93, interact with and receive leakage from the Fairmont mine-pool. They encompass an additional 29,000 acres. Acreages were determined from digitized polygons of mine boundaries

produced by the West Virginia Geological Survey coal bed mapping project. Summary information for these mines is shown in table 1. The latest identified mining date or date of a final mine map are included to indicate approximate date of mine closure and the presumed beginning of mine flooding. Two large active operations, Loveridge and Robinson Run are present to the west of the mine-pool.

Room and pillar mining was the dominant method of coal extraction in the Fairmont mines with some areas of longwall recovery in Federal 1. A review of mine maps and notations showed typical barrier widths of about 50 feet in the oldest mines such as Consol 38, 56 and 96. More recent mining operations including Joanne, Williams, and Bethlehem 41, 8 and 44 typically have coal barriers about 100 feet thick. Some mine works appear to have been directly connected by cutting through the barrier, especially in the older mines. Some maps also contain notations indicating the breach was sealed, possibly by construction of a block wall. The current condition of any barrier seals is unknown. The relatively thin barriers, possible presence of unplugged or leaky seals in barriers, and hydraulic head or water level measurements discussed in following sections, all suggest that the individual mines are hydrologically connected to varying degrees. Therefore a hydrologic change in one mine, such as a decrease or increase in water level will affect the adjacent mines.

Table 1
Principal and Adjacent Mines in the Fairmont Mine-pool(1)

Principal Mines	Area (acres)	Mining Method	Last Mining or Map Date	Typical Coal Barrier Thickness(feet)
Federal 1	15,401	Longwall, RP	1985	50 to > 100
Consol 96	2,214	RP, Retreat	1935?	50
Consol 38	1,992	RP, Retreat	1946?	50
Consol 56	778	RP, Retreat	1947?	50
Bethlehem 41	6,042	RP, Retreat	1982	50-100
Bethlehem 8	3,199	RP, Retreat	1982	100
Bethlehem 44	7,166	RP, Retreat	1971	100
Joanne	6,280	RP, Retreat	1983	100
Mountaineer 92/43/63	4,674	RP, Retreat	1962	50-100
Williams 98	4,867	RP, Retreat	1979	100
Total	52,613			
Adjacent Mines				
Consol 9 (Jamison)	7,413	RP, Retreat	1978	
Consol 20 (O'Donnell)	8,328	RP, Retreat	1982	
Jordan 93	13,219	RP, Retreat	1973	

(1) RP = Room and Pillar mining

Geologic Setting

The Pittsburgh coal is present in most of northern West Virginia, extending into Pennsylvania, Ohio and Maryland. It is in a large basin like structure, extending in a southwest to northeast direction. The Fairmont mine-pool and adjacent mines are on the eastern edge of the basin (figure 5), and the rocks dip to the northwest at a low angle towards the center of the basin. This structure results in the Pittsburgh coal cropping out at land surface, or being present at shallow depths along the West Fork and Monongahela Rivers near Fairmont. Thus, if water levels in the mine-pool rise sufficiently, the probable discharge zones are along the major rivers, and near the mouths of the tributaries on the west side of these rivers.

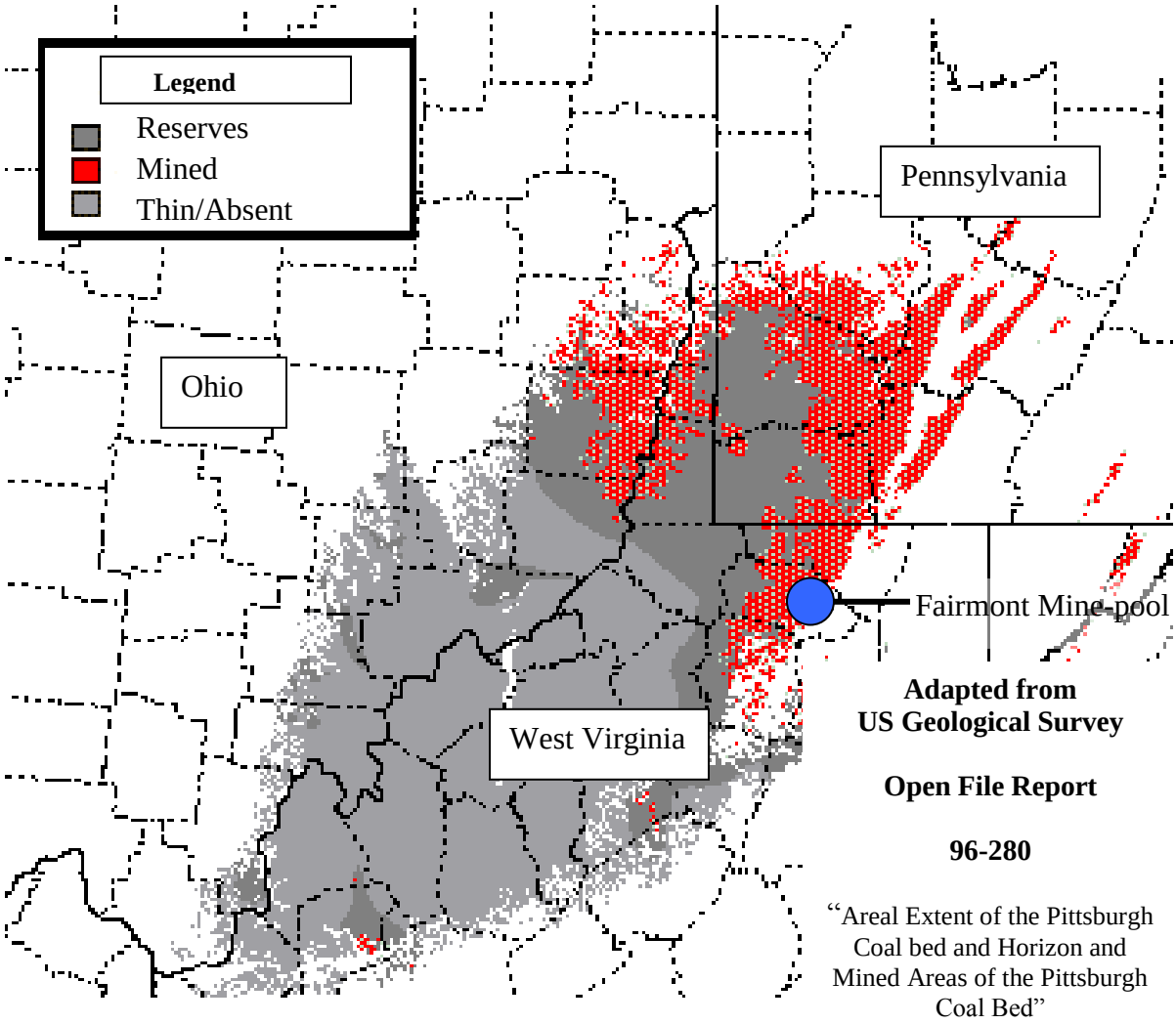

Figure 5. Extent of the Pittsburgh Coalbed. The Fairmont mine-pool is located on the eastern margin of a large basin. Coal elevations are nearest the surface at the margins of the basin.

East of the Monongahela and West Fork rivers, the Pittsburgh coal is above drainage in many locations, and some free draining mine works discharge water into the basin. Older mines near

the Monongahela and West Fork rivers have the thinnest overburden, often less than 200 feet, while mines located to the west and down the structural trend have thicker overburden.

A review of structure contours (elevation) of the base of the Pittsburgh coal and surface topography indicates a likely first overflow or discharge point is near the mouth of Buffalo Creek in Fairmont (figure 2). The Penn Overall monitoring borehole (FP-1) with its established "not to exceed elevation" is located nearby to provide early warning if the water level is approaching breakout elevation. Figure 6 shows the structural trend of the Pittsburgh coal as compiled by the West Virginia Geological Survey Coal Bed Mapping Project with coal elevations greatest near the West Fork and Monongahela rivers.

Water Level Monitoring Network

OSM has monitored water levels since 1997 using as many as thirteen locations in nine mines as shown in figures 3 and 4, and summarized in table 2. The distribution of monitoring points was intended to provide water level data in each major mine, and at different parts of the mine-pool flow system. Water levels were initially measured on a monthly basis, and the frequency was later decreased to bimonthly and then quarterly. The wells include cased mine boreholes formerly used for power supply access or dewatering during active operations that remained unsealed after mine closure, and additional wells installed under the direction of OSM. One monitoring point, in Mine 38, is a well installed by a mining company. Figure 7 shows a typical mine dewatering borehole, now in use as a water level observation point.

Five wells were drilled by OSM in 1999 to provide monitoring in mines where no access existed, including the Joanne mine, and to replace or supplement existing locations. Three additional wells were drilled in 2002 under OSM's direction. Two were replacement wells for sites that had become unusable and one provided access to part of the Mountaineer 92/43/63 complex. The OSM directed wells were installed with slotted well screens of either PVC or stainless steel fabrication, and cased to the surface with a cement grout in the hole annulus. The well design is intended to isolate and monitor the mine-pool separate from ground water in overlying strata. Where feasible, subsurface conditions in wells and boreholes were examined with a down-hole camera and well depths identified via the video log, sounding with a weighted line, and reviewing mine maps.

Water level measurements for each monitoring point in the Fairmont mine-pool for the duration of monitoring are included as Appendix A in spreadsheet and document formats. State plane location coordinates and surface elevation data for each well are also included in Appendix A.

The power and pump dewatering boreholes are completed into open or (now) partially collapsed voids. They are cased to mine level, but do not have well screens since they were originally drilled for other purposes. The monitoring points drilled under OSM supervision are completed

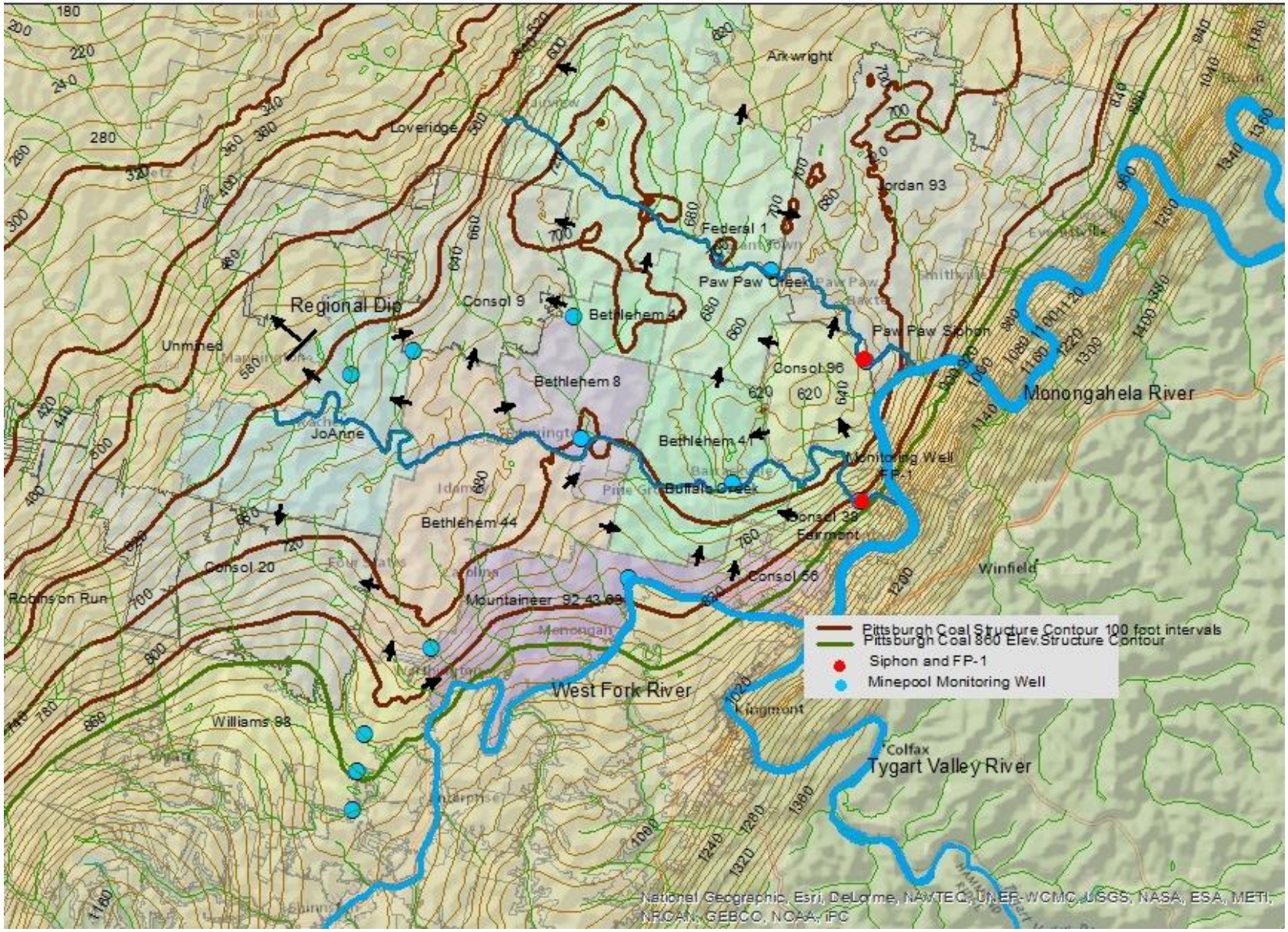

Figure 6. Structure contour map of the Pittsburgh Coalbed (elevation feet m.s.l.). Heavy brown lines denote 100 foot intervals. The 860 foot contour, representing approximate mine-pool breakout elevation is shown as a heavy green line. Mines near the West Fork and Monongahela rivers are at the highest elevation and have the thinnest overburden cover. Regional dip is to the northwest.

Figure 7. Typical abandoned dewatering borehole converted to water level observation. Williams Mine 98, Pump 7.

into open or partially collapsed voids, or in some instances in a pillar. The remarks column in table 2 provides information about individual wells.

Until 2002, water level conditions in the southern end of the pool were inferred mainly from reading one borehole (#7 Pump) in the Williams mine. After a review of mine maps and a field search, two abandoned pump station boreholes were located, examined, and determined to be useable for monitoring. These boreholes are in the Williams and Mountaineer 92/43/63 mines (figure 3).

Data logging pressure transducers were installed in five wells, to record hourly water level measurements in different subpools. Two transducers were removed in 2004 and 2006. Three transducers were located in the Federal 1, Joanne and Bethlehem 41 mines, and recorded hourly water level measurements until they were discontinued in 2013.

Table 2
Fairmont Mine-pool Monitoring Points

Mine	Monitoring Point	2011 Typical Water Elevation[1]	Water level Trend	Well Depth (feet)	Remarks
Consol 96	Paw Paw Siphon	-	-	~100	Withdrawal point for mine-pool. In void.
Consol 38	Penn Overall (FP-1)	853	Stable	~65	Installed 1997. In void
Federal 1	Grantown	817	Stable	~305	Installed 2/99 In void
Bethlehem 41	Barrackville	838	Stable	~175	Existing power borehole In void
Bethlehem 41	Oddfellows	838	Stable	~350	Installed 3/99 In void
Bethlehem 8	Katy	-	-	~480	Installed 2/99, discontinued 2009 In pillar
Bethlehem 44	Carberry	853	Stable	~400	Existing power borehole In void
Joanne	Rachael	823	Rising	~430	Installed 10/02 In Pillar
Mountaineer 92/43/63	#6 Pump	854	Stable	~130	Existing dewatering borehole In void.
Mountaineer 92/43/63	Mine 43	854	Stable	~130	Installed 10/02 In pillar
Williams 98	#7 Pump	857	Stable	~110	Existing dewatering borehole In void
Williams 98	#6 Pump	902	Rising?	~110	Existing dewatering borehole In void
Williams 98	Shinston	-	-	40	Installed 10/02. discontinued 2009 In pillar

Data from the transducers provided information about mine-pool response to precipitation, short term changes in water levels, seasonality and subsurface outflow. These hourly water level data, along with weather information, have been used to analyze mine-pool behavior in more detail. Figure 8 shows a typical arrangement of a monitoring well drilled under OSM supervision with pressure transducer at the Bethlehem 41-Oddfellows site. The well casing is completed flush with ground surface, with locking cap and bolt down lid for security. The transducer is programmed to record and store readings until retrieved with a laptop computer connection.

Figure 8. Typical monitoring well installation with pressure transducer for automated water level recording. Bethlehem 41-Oddfellows Site.

Water level monitoring was discontinued in 2009 at two locations, Bethlehem 8 - Katy and Williams 98 - Shinston as understanding of mine-pool behavior improved. In 2004, the Paw Paw Siphon was modified, which eliminated direct access for water level readings at that location.

Water level measurements have also been collected by personnel from Consol, and by West Virginia University. The university maintains pressure transducers in wells at Consol 38-Penn Overall, Bethlehem 44-Carberry, and Bethlehem 41-Barrackville.

Mine-pool Hydrogeology

Since April 1997, mine-pool water levels have been controlled in part by withdrawing water at the Paw Paw Siphon at the north end of the mine-pool, and by subsurface outflow. The goal is to maintain the pool below elevation 857 ft. m.s.l. at the Consol 38 (FP-1) monitoring location (figures 3 and 4). Figure 9 shows a combined record of water level measurements collected both by OSM, and as reported in NPDES filings for monitoring well FP-1. Measurements are reported in depth below the surface measuring point as specified in the NPDES monitoring requirements for this well. From 2001 to 2012, water level has consistently remained below potential breakout elevation except for one period. Early in 2004, water levels exceeded or were near the 36 foot criterion established for this monitoring point. Increased water levels were measured in all sections of the mine-pool during this time period. *No indication of mine water leakage into Buffalo Creek was found by measurement of indicator water quality parameters and visual inspection during this excursion.* At that time, Consol increased the water withdrawal rate at the Paw Paw Siphon and mine-pool water levels decreased. In the preceding year, 2003, the Fairmont area received about 57 inches of precipitation, which is more than 11 inches (24%) greater than the long term average (NCDC, 2013).

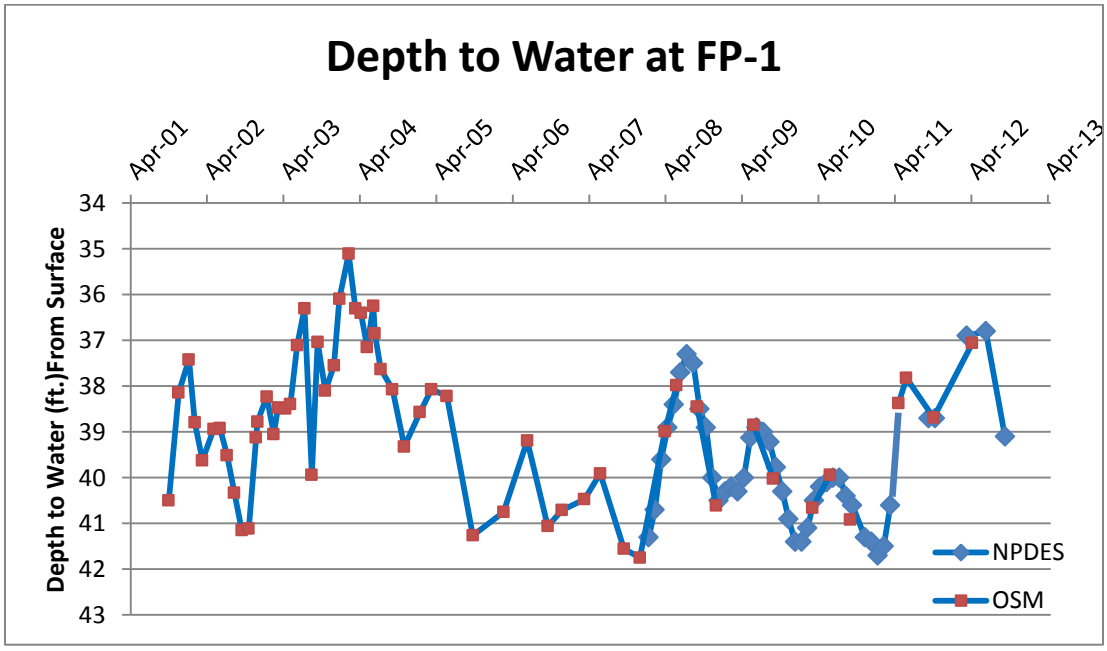

Figure 9. Depth to water at monitoring point FP-1, 2001 to 2012. Combined data from OSM and NPDES readings. Water level is to remain 36 feet or greater below surface.

Figure 10 shows summary annual precipitation from the Fairmont, WV weather station and retrieved from the National Climatic Data Center. The graph highlights the above average precipitation years of 2002, 2003, 2004, and more recently, 2011. In spite of above average precipitation in 2011, the mine-pool was maintained below the 36 foot criterion. The long term

average annual precipitation for the Fairmont weather station (NCDC, 2013) is 45.99 inches per year. A comparison of annual precipitation in figure 10 and depth to water in figure 9 shows a general correspondence between water level and precipitation. Additional recharge to the mine-pool can be expected during wetter than average conditions. Conversely, recharge rate and water levels can be expected to decline during dryer than average periods.

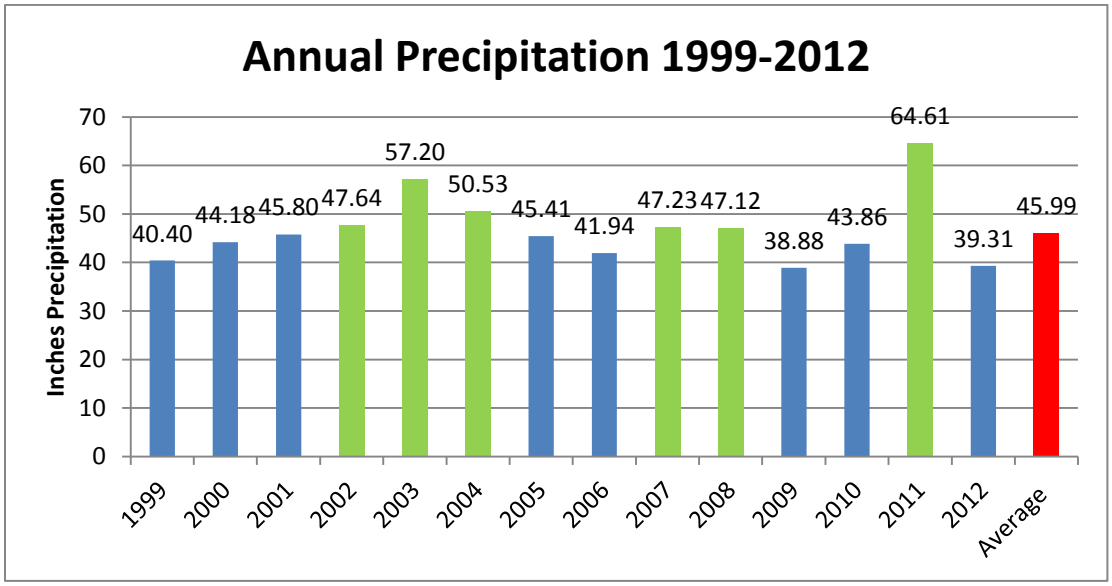

Figure 10. Annual precipitation for the Fairmont weather station. Data from National Climatic Data Center. Long term average annual precipitation is 45.99 inches. The green bars represent years when the total precipitation was above the long term average.

Initially, the Siphon operated for most of the year and was shut down during the fall when precipitation and mine water inflow are at low rates. In recent years, water has been withdrawn more or less continuously. *This pump and siphon system has effectively maintained the mine-pool below a surface discharge elevation.*

Figure 11 shows water level elevations in the Siphon, and monitoring points in Mine 38 (FP-1) and the Williams mine (#7 Pump) for the period of 1997 to 2011. The Siphon began operating in spring 1997 and the plot shows a rapid decline in water levels at the Siphon and the two monitoring points in that time period. Water level trends in the two monitoring points mirror conditions in the Siphon. When the Siphon was running, water levels were lowered (drawn down). When the Siphon was shutoff and began recovering, water levels in the two other monitoring points also increased. The FP-1 monitoring point is about 2.5, and the Williams mine (#7 Pump) about 11 air miles, respectively, from the Siphon.

A complete record of water levels compiled by OSM for all monitored locations is included in Appendix A.

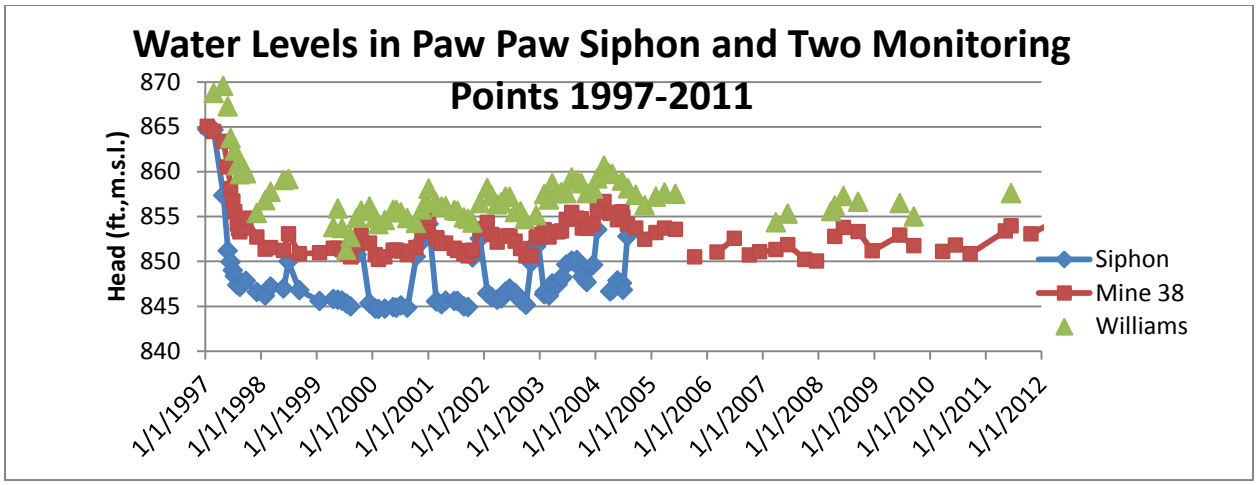

Figure 11. Long term water levels in Paw Paw Siphon, FP-1(Mine 38) and Williams 98 mine. Direct measurement of water level in Paw Paw siphon not available after 2004.

Mine-pool Flow and Water Levels

Flow in the Fairmont mine-pool is controlled by head (water level) differences across barrier pillars, subsurface outflow, leakage and the Siphon withdrawal. Mine water flow directions are shown in figures 3 and 4 as inferred from water level measurements. The overall flow pattern is from south to north toward the Siphon and Jordan 93; and to the west towards the adjacent Consol 9 and Consol 20 mines. Water level conditions shown in figure 4 are typical for 2011 data. The flow patterns are complex due to geologic structure, location of barriers, different dates of mine closure and flooding, and the sub-pools in different mines.

Within the Fairmont pool itself, water level data show that the Siphon receives flow from mines adjacent to the Monongahela and West Fork rivers and Bethlehem 44(figures 3 and 4). *Water levels in Federal 1, Bethlehem 41 and 8, and the Joanne mines are below historical Siphon water levels. These sub-pools do not therefore contribute flow to the Siphon, and water leaves them by outflow to other locations.* Each of the sub-pools is discussed in the following sections.

In all monitoring locations, the mines are fully flooded (roofed) and the water levels in the wells are above the top elevation of the coal. In the Joanne mine, for example, the water level elevation or potentiometric surface of 823 feet is about 200 feet above the coal elevation. Water in the mine-pool is pressurized. This behavior is characteristic of a confined or leaky confined aquifer. The mine-pool takes water into or releases it from storage by expansion or compression of the water and the aquifer rocks. Since water and the rocks have very small coefficients of expansion and compression, the amount of water taken into or released from storage under confined conditions from a unit volume of aquifer is quite small. This has the practical effect of inducing drawdown (decline in water level) in the aquifer at large distances and nearly instantaneously when pumped. *The confined behavior of the mine-pool allows water level to be controlled over large distances and areas from a single pumping or withdrawal point such as the Siphon.*

The coal barriers are thin and conductive enough to transmit or leak water from one sub-pool to another. Yet, they retard flow sufficiently that water level differences have existed between adjacent mines for the entire post flooding monitoring of more than 10 years. Water levels within a single mine complex however, show little difference, indicating that water is readily transmitted within an individual sub-pool. Mines with breached barriers can exhibit the same behavior. Water level measurements at three locations within one mine complex (Bethlehem 41 and 8) consistently have head differences of about one foot or less. The monitoring wells are separated by distances of two to four miles. The hydraulic gradient within that complex is very small. *The overall mine-pool can be visualized as a series of adjacent containers (sub-pools) filled with water that leak across their common boundaries, or "leaky boxes" while water circulates within each box.*

Barrier Seepage Estimates

Quantitative estimates of seepage rates through coal barriers were estimated using Darcy's law for ground water flow in porous media. The calculations are based on horizontal flow through coal barriers as follows:

$$Q = KA\frac{h1 - h2}{L}$$

Where:

Q = seepage rate in cubic ft. per day

K= Hydraulic Conductivity of the intact coal barrier in ft./day

h1 and h2 = water level elevation on each side of the barrier in feet

L = barrier thickness (flowpath length) in feet

A = the cross section area of the barrier through flow is taking place in square feet

Flow over the top of the coal barrier was assumed to be negligible based on the confined behavior of the aquifer.

For this analysis, the mine-pool was assumed to be at steady-state conditions, where head conditions are constant through time. For the current conditions in the Fairmont mine-pool, that approximation is valid. There are small seasonal variations in water levels, but there has been no overall increasing or decreasing head trend in the mine-pool since about 2005. The seasonal variations tend to be of similar magnitude in the sub-pools so that the head differences between mines (h1 − h2) in Darcy's equation do not vary much through the course of the year. Consequently, seasonal variation has limited effect on the estimated seepage quantities between pairs of flooded mines.

Horizontal hydraulic conductivity (K) of the coal barrier was based on values reported by McCoy (2002), and McCoy et al (2006). They estimated K from an analysis of pumping records

from the Consol 9 and Consol 20 mines, barrier dimensions and water levels. Assuming isotropic hydraulic conductivity, a single median value of 0.32 ft./day reported by McCoy et al was used to represent horizontal K of coal barriers in an initial set of calculations.

McCoy et al (2006) note that there may be some differences in K depending on whether horizontal flow is taking place in the direction of face cleat or butt cleat in the coal. A second set of seepage calculations assuming anisotropic horizontal K was conducted, assigning face cleat or butt cleat flow to each barrier segment, depending on its orientation. Following McCoy's approach and based on regional structural data, the angle between face and butt cleat is about N 70ºW in the Fairmont area. Median values of K from McCoy et al (2006) for flow in face and butt cleat directions of 0.55 ft./day and 0.16 ft./day were used.

Coal barrier thickness, L, was estimated from measurement of digitized polygons of mine boundaries (WVGS Coalbed mapping project) and by examining mine maps. Barriers were divided into segments of uniform thickness and L was scaled from the map. An average thickness was used for a few small segments with irregular barrier thickness. The length of each segment was also measured and combined with an average mining height of six feet to generate values for A, cross section area of flow. Heads h1 and h2 are water levels in sub-pools on either side of the barrier. For dewatered sections of Consol 9 and Consol 20, coal elevation, or floor of the mine, represents h2. Flows through individual barrier segments were summed to provide estimates of total inflow and outflow data. Since the value for K is a median value with a range of larger and smaller values, and there are uncertainties in measuring barrier dimensions, the discharge rates reported should be regarded as "best estimates" and not exact values. The calculations do not account for any breached barriers or changes in stratigraphy that may be present.

An example calculation of seepage with Darcy's Law is shown below, where K = 0.32ft/day, water levels for two mines are at elevation 817 and 690 feet, flow occurs through a barrier segment six feet high and 1,122 feet long, and the coal barrier between mines is 139 feet thick.

$$Q = 0.32(6 * 1{,}122)\frac{817 - 690}{139}$$

$$Q = 1{,}968\ \frac{cubic\ ft}{day}\ or\ 10.2\ gpm$$

These calculations were done in spreadsheets after individual barrier segments of uniform thickness had been delineated and measured. The results were summed to estimate flows between pairs of mines and the total mine water flow for the entire mine-pool.

The availability of locally derived hydraulic conductivity values for the coal barrier should provide reasonable estimates of seepage and outflow quantities. Estimated barrier outflows for portions of the Fairmont mine-pool in this report were evaluated against recent pumping records as a check on calculations. Assuming steady state conditions and small recharge rates, the

pumping rate of water removed should equal the estimated seepage rate of water entering the mine.

Five year (2008 to 2012) average pumping rates for Consol 9 and Consol 20 were obtained from the West Virginia DEP and compared to the estimated barrier leakage rates. The estimated seepage outflows were about 16% and 9% greater than the five year pumping average for the Consol 9 and Consol 20 mines, respectively, using isotropic K (single value) calculations. Estimated seepage rates using anisotropic K (separate face and butt values) were about 22% greater, and 10% less than the average pumping rates for the Consol 9 and Consol 20 mines, respectively. The differences between estimated seepage and reported pumping rates may reflect difficulties in identifying values for hydraulic conductivity, measurement of barrier dimensions, unaccounted mine water storage, infiltration entering the mine as recharge, or other factors. The analysis shows overall that the seepage calculations provide reasonable estimates of mine-pool flow with about 10 to 20% uncertainty.

The total estimated outflow and withdrawal from the Fairmont mine-pool using a single isotropic K for all barrier segments is summarized in table 3. The Siphon accounts for about 37% of water removal from the mine-pool; the remainder is barrier leakage. The Siphon withdrawal rate is a median value from reported NPDES monitoring data. It includes the same five year period (2008 to 2012) as the pumping records. Summing outflows and withdrawal from anisotropic analysis with separate face and butt cleat K values yielded a total withdrawal and outflow estimate of 2400 gpm, or about 5% greater than the isotropic analysis. Using an anistropic analysis did change seepage rates in localized areas of the mine-pool, but resulted in only small differences in the overall water budget for the mine-pool.

Table 3
Estimated Outflows and Mine Water Removal From the Fairmont Mine-pool, 2011 Conditions (1)

Source	Estimated Discharge Rate (gpm)	Percentage of Total
Siphon Withdrawal	850	37.2%
Barrier Leakage to Jordan 93	295	12.9%
Barrier Leakage to Consol 9	639	28.0%
Barrier Leakage to Consol 20	395	17.3%
Barrier Leakage to Loveridge	89	3.9%
Barrier Leakage to Arkwright	11	0.5%
Total Withdrawal and Outflow	2279	

(1)Discharge rates derived using a single K value for all barrier segments (isotropic K).

Mine-pool Flow Adjacent to West Fork and Monongahela Rivers

Several flow subsystems exist within the overall mine-pool. One flow path is from the Williams mine at the south end of the pool to the north through a series of shallow mines bordering and adjacent to the West Fork and Monongahela rivers. These mines have the highest water levels of any part of the mine-pool, thus water flows *from* this part of the mine-pool, and *to* other sub-pools. Because of the relatively thin overburden cover, these mines are inferred to contribute a significant portion of the recharge that infiltrates the mine-pool. Leavitt (1997) developed an exponential relationship between overburden thickness and mine infiltration rate showing that infiltration rate is greatest under shallow overburden. Infiltration rate decreases as overburden thickness increases. That relationship of decreasing mine water inflow with increasing cover thickness is often observed anecdotally in operating underground mines.

Based on head measurements, mine water flows from Williams 98(water level 857 ft. m.s.l.) into Mountaineer 92/43/63(water level 854 ft. m.s.l.) then to Mine 38(water level 853 m.s.l.) and finally to the Siphon in the Consol 96 mine as shown in figures 3 and 4. The water levels are typical of 2011 conditions. Water levels cannot now be directly accessed at the Siphon; however, past measurements showed water level to fluctuate within a range of about 845 to 850 ft. m.s.l. Some mine water leaks into the Bethlehem 41 sub-pool (water level 838 m.s.l.) from Mountaineer 92/43/63. The Mountaineer 92/43/63 and Bethlehem 44 have nearly the same water level, which probably indicates that the two sub-pools exchange water. A structural feature in the Williams mine acts as ground water flow divide, so that only about the eastern half of Williams actually contributes flow to the Fairmont mine-pool.

This flow subsystem in shallow mines near the rivers is a significant source of water being withdrawn at the Siphon. The Siphon typically operates at about 850 gpm withdrawal, and that is much greater than would be expected if water transferred from Mine 38 into the Consol 96 mine by barrier leakage only. Examination of mine maps indicated that the barrier between the two mines may have been breached during active operations. A breached barrier could allow a greater leakage rate between mines.

West Virginia University, Hydrogeology Research Center, maintains a pressure transducer for automated water level recordings in the monitoring well (FP-1) in Mine 38. OSM suggests contacting the Hydrogeology Research Center to request access to that data.

The Paw Paw Siphon

The Siphon is located adjacent to Paw Paw creek in the northern end of the mine-pool. It is at the barrier between Consol 96 and Jordan 93 mines (figures 3 and 4). It withdraws water from the Fairmont mine-pool and transfers it the “Morgantown” pool. The required head lift to move water over the barrier from mine to mine is small enough to allow siphoning, as well as pumping. The Siphon withdraws water from the Consol 96 pool, carries it via a near surface pipeline over the barrier, and discharges it into Jordan 93. It has been operating since 1997 with

some refinements and modifications. A pump was installed later to increase system capacity. An in-line flow meter allows instantaneous and total flow measurements in the transfer pipe.

Flow From Bethlehem 44 to Adjacent Mines

The Bethlehem 44 (Idamay) mine has a head value of about 853 ft. m.s.l., which is greater than mines bordering it to the north and west (figures 3 and 4). It is a significant barrier leakage source to the Joanne (water level 823 ft. m.s.l.) and Consol 9 (mostly dewatered) mines, on its west and north boundaries, respectively (figures 3 and 4). Consol 20, on the southwest corner of Bethlehem 44, is also pumped and partially dewatered, and water leaks from Bethlehem 44 to Consol 20. The head in Bethlehem 44 is also about 15 feet greater than Bethlehem 8 and 41(water level 838 ft. m.s.l.) to the east and north, and mine water flows into the Bethlehem 8 and 41 sub-pool through these barriers. The estimated outflows, using a median hydraulic conductivity of 0.32 ft./day, from Bethlehem 44 are summarized in table 4.

Table 4
Estimated Barrier Outflows From Bethlehem 44 to Adjacent Mines

Source	**Estimated Discharge Rate (gpm)**
Barrier Leakage to Consol 20	104
Barrier Leakage to Bethlehem 41 and 8	56
Barrier Leakage to Joanne	52
TOTAL ESTIMATED OUTFLOW	212

Figure 12 is a time series plot of water level measurements for the Bethlehem 44 sub-pool with an overlay of the adjacent Mountaineer 92/43/63 mine. The startup of the Siphon in 1997 is reflected in a drawdown of over 10 feet in Bethlehem 44. Since that time, water levels have remained between about 850 to 855 ft. m.s.l., reaching a maximum 857 ft. m.s.l. in early 2004, at the same time as other sub-pools. Some seasonal variation is also evident with water levels typically changing several feet between spring and fall. Seasonal variation in water levels also occurs in other sub-pools. West Virginia University maintains a pressure transducer for automated water level recordings in the monitoring well for Bethlehem 44. OSM suggests contacting the West Virginia University Hydrogeology Research Center to request access to that data.

Figure 12 shows that water levels in the Bethlehem 44 and Mountaineer 92/43/63 are closely related. The behavior indicates that water is likely exchanged freely between the two sub-pools and they can be considered as members of the same flow system. The small differences in head may be due to differences in surveyed elevations and/or measurement of the projected height of the well casing above ground surface

The head values in Bethlehem 44 are greater than the historical water levels at the Siphon. That condition, and the drawdown observed at the startup of the Siphon indicates that Bethlehem 44 responds to and contributes water to the Siphon by way of Mountaineer 92/43/63. That mine water flows in the system adjacent to the rivers and ultimately reports to the Siphon. As shown in table 4, leakage from Bethlehem 44 to mines located to the west and northwest accounts for an estimated 212 gpm of outflow.

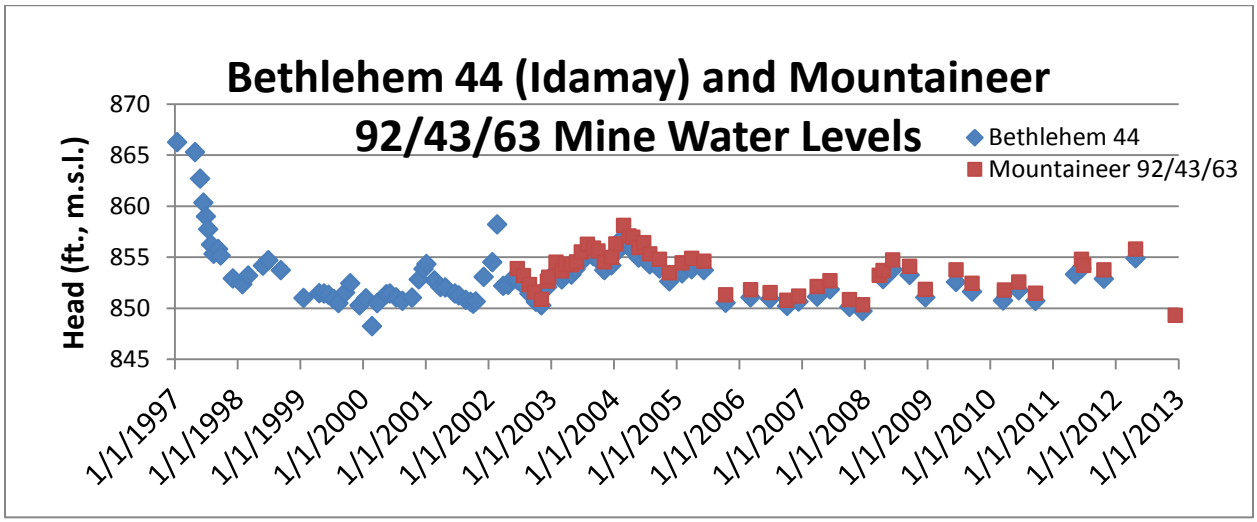

Figure 12. Water levels in Bethlehem 44 (IdaMay) and Mountaineer 92/43/63 Mines, 1997 to 2012.

Flow Into and Out of Bethlehem 41 and 8

The Bethlehem 41 and 8 complex has head elevations less than Bethlehem 44 and Mountaineer 92/43/63 adjoining it on the south and east sides (figures 3 and 4). It therefore receives inflow from these sub-pools and a small inflow from the Consol 96 mine. In turn, water from Bethlehem 41 and 8 flows *into* the Federal #1 mine (water level 817 ft. m.s.l.) located to the north. Water from Bethlehem 41 and 8 also flows *into* the Consol 9 mine to the northwest. Estimated outflows and inflows, using a median hydraulic conductivity of 0.32 ft./day, for the Bethlehem 41 and 8 sub-pool are summarized in table 5.

Under current conditions, water flows into Bethlehem 41 and 8 from surrounding mines on three sides, and it does not contribute flow to the Siphon. That condition has existed through more than 10 years of monitoring as shown in figure 11. In early 2004, the Bethlehem 41 and 8 sub-pool head reached a maximum and was less than two feet below the Siphon water level. Under current conditions, the water level in Bethlehem 41 and 8 would have to increase more than about 10 feet before flow to the Siphon would begin. Such a head increase could occur if flow out of Bethlehem 41 and 8 decreased or head increased in the adjacent Federal 1 mine substantially, or conditions changed in Jamison 9. The time needed for a 10 foot head increase was not estimated

for this report. Increasing head levels in Federal 1 or Consol 9 would reduce the outflow in those directions and cause the head in Bethlehem 41 and 9 to increase.

Table 5
Estimated Barrier Inflow and Outflows To and From Bethlehem 41 and 8

Source	Estimated Inflow or Discharge Rate (gpm)
Barrier Leakage to Federal 1	106
Barrier Leakage to Consol 9	224
TOTAL ESTIMATED OUTFLOW	330
Barrier Inflow from Bethlehem 44	56
Barrier Inflow from Mountaineer 92/63/43	37
Barrier Inflow from Consol 96	3
TOTAL ESTIMATED INFLOW	96

Water level measurements have been collected at three locations in this sub-pool (see figure 3), and they consistently report within about one foot of each other (figure 13). This indicates that the Bethlehem 41 and 8 mines are hydrologically connected and can be considered one sub-pool.

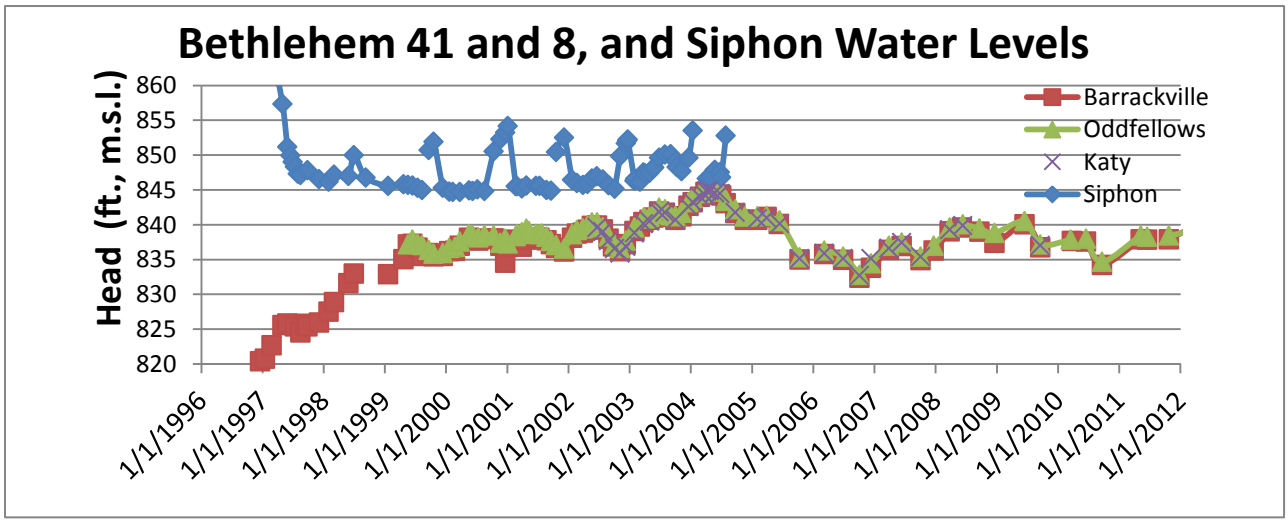

Figure 13. Time series plot of water levels at the Siphon and three monitoring points in the Bethlehem 41 and 8 sub-pool.

The degree of connection or lack thereof between the two mines was unknown when monitoring began. OSM therefore installed two new monitoring points to assess this condition. Monitoring was discontinued in 2009 at the Katy well site, since other locations are now known to provide equivalent information.

OSM has collected hourly transducer recordings of water level data at two locations in the sub-pool; the Oddfellows monitoring site, and the Katy monitoring well from 2000 to 2006. Figure 14 shows the hourly measured water level readings for the Oddfellows site in 2010. It is representative of behavior observed in other years and at other monitoring points. The seasonal variation in water level is about 5 feet. It is highest from March to early June and at a minimum in November. Small short term changes in head of a few hundredths to few tenths of feet are common, and occur in response to significant recharge events and variation in barometric pressure.

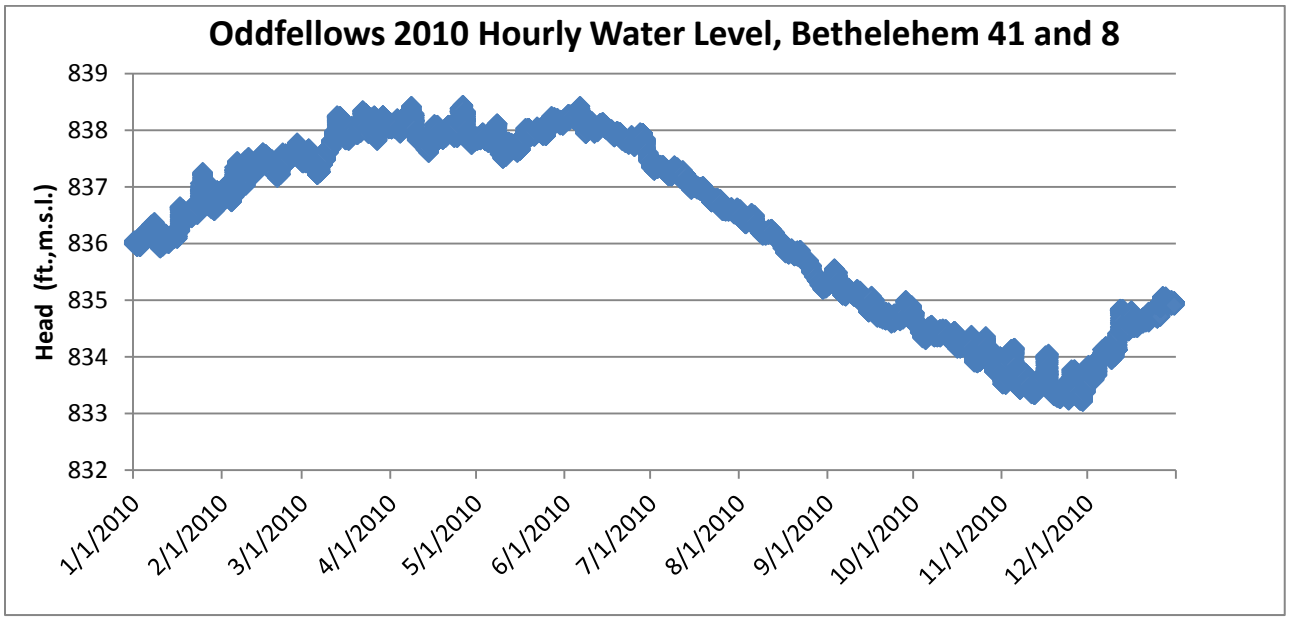

Figure 14. Time series plot of hourly water levels in 2010, Bethlehem 41 and 8 sub-pool, Oddfellows monitoring point.

Flow Into and Out of Federal #1

Federal #1 constitutes the northwest part of the Fairmont mine-pool. Its water level is about twenty to twenty-five feet lower than the adjacent Bethlehem 41 and 8 sub-pool. Therefore, water is flowing into Federal #1 from Bethlehem 41, and it also receives flow from the adjacent Consol 96 mine. Federal #1 also shares barriers on the west with Consol 9 and Loveridge; Arkwright on the north, and Jordan 93 to the east. Loveridge is an active mine, while Arkwright and Jordan 93 are closed and flooded. Consol 9 is closed and mostly dewatered by pumping. *Federal 1 is a major source of outflow on the northern end of the mine-pool. It leaks to Jordan 93, Arkwright, Loveridge and Consol 9.*

Federal #1 shares a long relatively thin coal barrier with Jordan 93. The common barrier is more than 3 miles long, and is on the order of 50 feet thick as measured from mine polygons and maps. As recently as mid-2012, water level measurements show a head difference of 40 to 50

feet between the two mines. *The long thin barrier in combination with the water level difference make leakage from Federal 1 into Jordan 93 a major outflow area for the Fairmont pool.* Table 6 shows an estimated 182 gpm leakage rate. A small amount, approximately 11 gpm, leaks from Federal #1 to Arkwright, and an estimated 89 gpm seeps into Loveridge. Water level data for Jordan 93 and Arkwright were obtained from NPDES monitoring reports to complete barrier leakage estimates. Estimated barrier inflows and outflows are summarized in table 6.

Water level data for the Federal 1 sub-pool are shown in figure 15, and hourly transducer readings have also been compiled for this monitoring point. Water levels are 20 feet or more below the Siphon, and it therefore does not contribute to the Siphon discharge. Unless conditions change markedly in adjacent mines, it is unlikely that the Federal 1 sub-pool will contribute directly to the Siphon discharge. Any increase in head would also increase outflow through barriers to adjacent mine works, in particular to Jordan 93. Like other parts of the Fairmont mine-pool, water levels reached a maximum in 2004, and have declined since then. More detailed analysis of hourly water level data for Federal 1 have shown changes in water level that do not correspond to behavior in other Fairmont sub-pools. The fluctuations are believed to be responses to changes in water level in the adjacent Jordan 93 pool, caused mainly by pumping (withdrawal) to the north. Jordan 93 is in the Morgantown mine-pool.

Table 6
Estimated Inflows and Outflows from the Federal 1 Sub-pool

Source	**Estimated Inflow or Outflow Rate (gpm)**
Barrier Leakage to Consol 9	132
Barrier Leakage to Loveridge	89
Barrier Leakage to Arkwright	11
Barrier Leakage to Jordan 93	182
TOTAL ESTIMATED OUTFLOW	414
Barrier Inflow from Bethlehem 41 and 8	106
Barrier Inflow from Consol 96	15
TOTAL ESTIMATED INFLOW	121

The Jordan 93 and Arkwright mines are not monitored by OSM and are not considered part of the Fairmont pool. However, these adjacent mines do interact with the Fairmont pool. A change in the hydrologic conditions in the adjacent mines will influence the behavior of the Fairmont mine-pool. The Jordan 93 mine receives both barrier leakage and discharge directly from the Siphon. The siphon discharge and barrier leakage mine water is eventually pumped out of the Jordan 93 mine and routed to a central treatment plant. If water levels in the Jordan 93 mine were allowed to rise, barrier leakage from Federal 1 and the Fairmont pool would decrease.

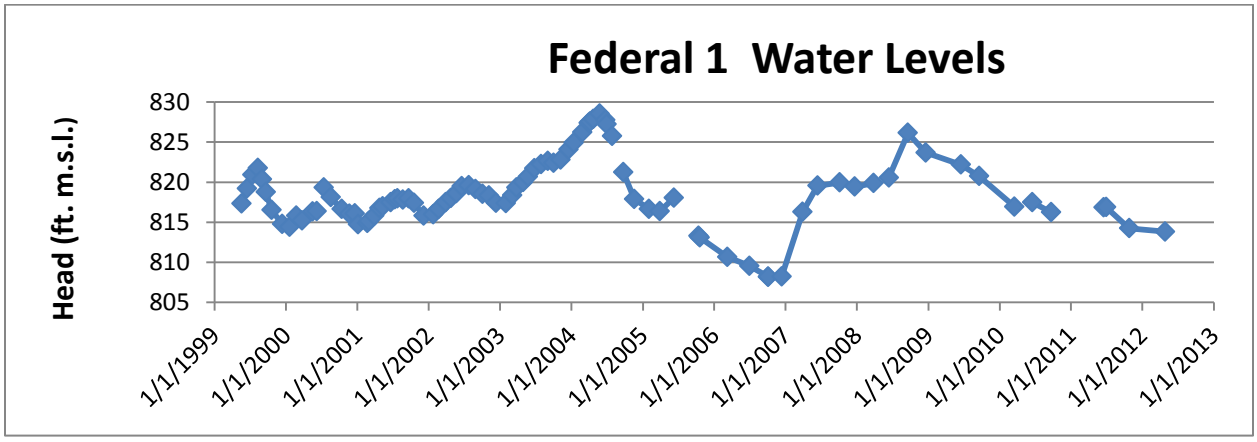

Figure 15. Time series plot of water level in Federal 1 monitoring well. Head in feet, m.s.l.

Historic monitoring data show that the water level in Jordan 93 has been higher in the past compared to recent (2011) conditions, as shown in figure 16. This time series plot shows head measurements in both the Jordan 93 mine-pool and Federal 1 sub-pools compiled from NPDES reporting for the Jordan mine and OSM water level data for the Federal 1 mine. From early 1999 when OSM began consistent monitoring of the Federal 1 sub-pool, head in the Jordan 93 mine was similar to, and at times, exceeded Federal 1. This lasted until mid-2004, and during this time

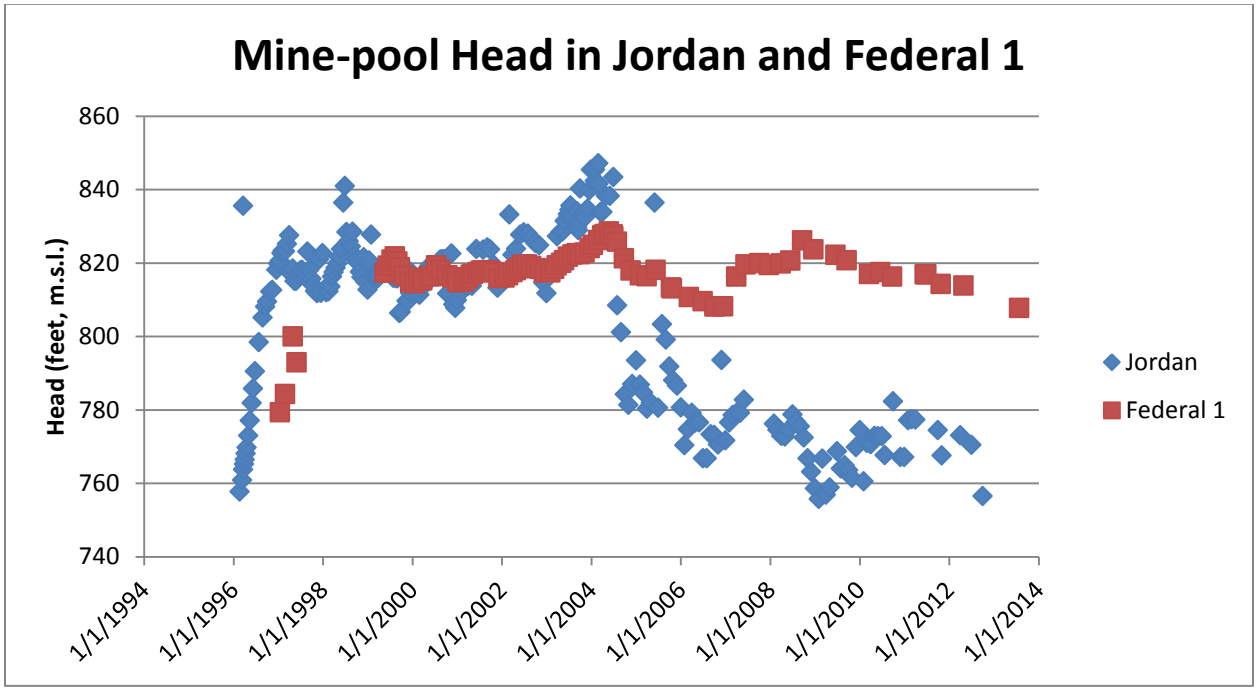

Figure 16. Time series plot of Jordan 93 and Federal 1 water levels.

period, there was little barrier leakage from the Federal 1 mine-pool to Jordan 93. At times, head in Jordan 93 exceeded Federal 1, and mine water leaked from Jordan 93 into the Fairmont mine-pool.

Over about a one year period from mid-2004 to mid-2005, head in the Jordan mine was reduced about 50 feet and has since remained between about 760 and 780 ft. elevation m.s.l. The Federal 1 sub-pool head also decreased about 20 feet from mid-2004 to 2006. Over the five year period of 2008 to 2013, head in Federal 1 has remained between about 815 and 825 ft. m.s.l. Water level data in figure 14 shows that barrier leakage *from* Federal 1 *to* the Jordan mine has been occurring since about mid-2004. The head change response of the two pools in 2004 to 2006 indicates the two interact hydrologically.

Flow Into and Out of the Joanne Mine

The Joanne mine is a principal source of outflow on the western side of the Fairmont mine-pool. Barrier leakage from the Joanne mine enters both the Consol 9 and Consol 20 mines. A large unmined block of coal also borders part of the Joanne mine and some mine-pool water enters the regional flow system. Absent any head measurements in the unmined block, a regional ground water gradient was estimated by using the Ohio River elevation as a reference point. On this basis, the amount of flow into the unmined coal block is minor. Most of the outflow is barrier leakage to the two adjacent pumped mines. The estimated inflows and outflows for the Joanne mine are shown in table 7.

Table 7
Estimated Inflows and Outflows for the Joanne Sub-pool

Source	**Estimated Inflow or Outflow Rate (gpm)**
Barrier Leakage to Consol 20	292
Barrier Leakage to Consol 9	125
Regional Ground Water Flow to Unmined Block	1
TOTAL ESTIMATED OUTFLOW	418
Barrier Inflow From Bethlehem 44	52

A monitoring well with recording transducer was initially installed in this mine in 1999. However the casing was crushed by subsurface movement in 2000 and the well was unusable. At that time, the water level in the Joanne mine was about elevation 760 ft. m.s.l., and was rising at a rate of about 1 foot per month. A replacement well with recording transducer was installed in 2002 and those data are shown in figure 17. The Joanne mine was among the last of the underground workings to close (1983) and flood in the Fairmont mine-pool. It was apparently still in flooding state with head increasing to a maximum of about elevation 839 ft. m.s.l. in 2005. Since 2005 and continuing to 2011, head has remained between elevations 815 to 825 ft. m.s.l. with a slowly increasing trend. If the head continues to increase in the Joanne sub-pool, a corresponding increase in barrier leakage to the adjacent Mine 20 and Jamison mines will occur,

but the effects are small. A 10-foot increase in head in the Joanne mine would increase the estimated seepage rate to Consol 20 from 292 gpm to 310 gpm. Estimated seepage to Consol 9 increases from 125 to 130 gpm if head increases an additional 10 feet in the Joanne mine.

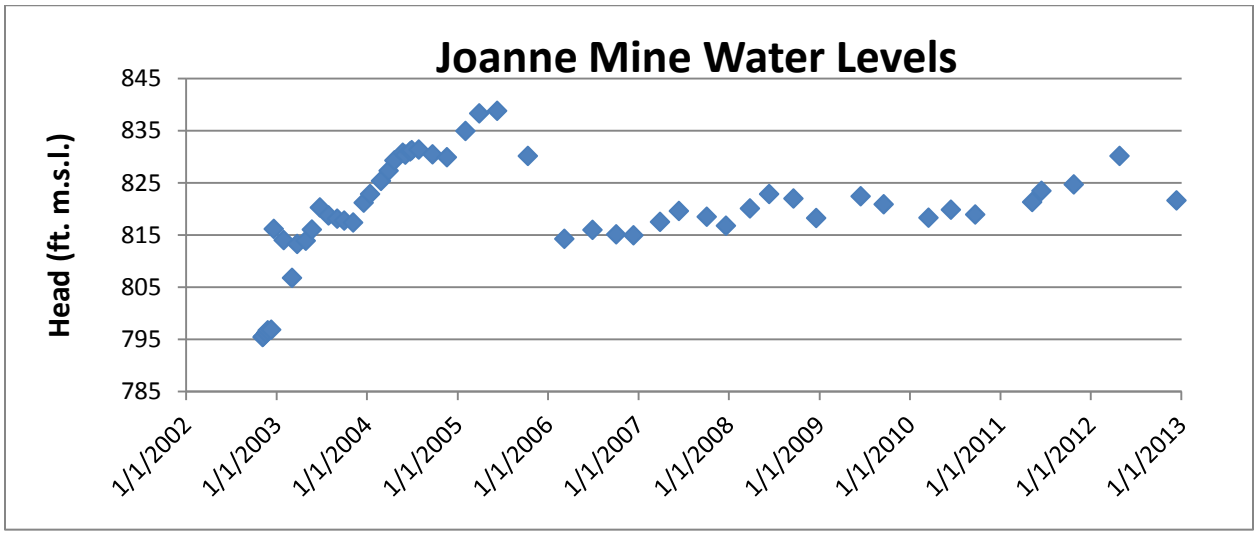

Figure 17. Water level time series in the Joanne monitoring well. Head in ft., m.s.l.

Interaction With Sewickley Seam

The Sewickley coalbed is located stratigraphically about 130 feet above the Pittsburgh coalbed in the Fairmont area. It is of sufficient thickness and quality to be recovered by underground extraction. The head in the underlying Pittsburgh bed mine works is equal or greater than the elevation of the Sewickley coal in most of the Fairmont mine-pool. It would be prudent to assume that the interburden between the two coalbeds leaks and mine water can flow upward from Pittsburgh to Sewickley mine-works. This situation has been encountered in mines located to the north in Greene County, PA, where head is reduced by pumping in the Pittsburgh to allow development and recovery in the overlying Sewickley. Mines in the Sewickley bed are likely to receive ground water inflow from below wherever they are developed over flooded Pittsburgh works with sufficient mine-pool head.

Figure 18 shows the estimated extent of the Sewickley bed that may receive leakage in this manner. The 860 foot elevation contour of the Sewickley coal is highlighted to represent the approximate intersection of the base of the Sewickley with the maximum potentiometric surface in the Pittsburgh mine works. The Sewickley coal structure dips to the northwest. Reserves in this area have the potential to receive leakage from below. As the shaded area in figure 18 shows, most the Fairmont mine-pool could flood overlying Sewickley mine-works. Only the Mountaineer 92/43/63 mine has appreciable areas of Sewickley coal above elevation 860. Federal 1 has the lowest sub-pool water level elevation (about 817 ft. m.s.l.), but the Sewickley lies near or below that elevation over almost all of Federal 1. OSM has on several occasions

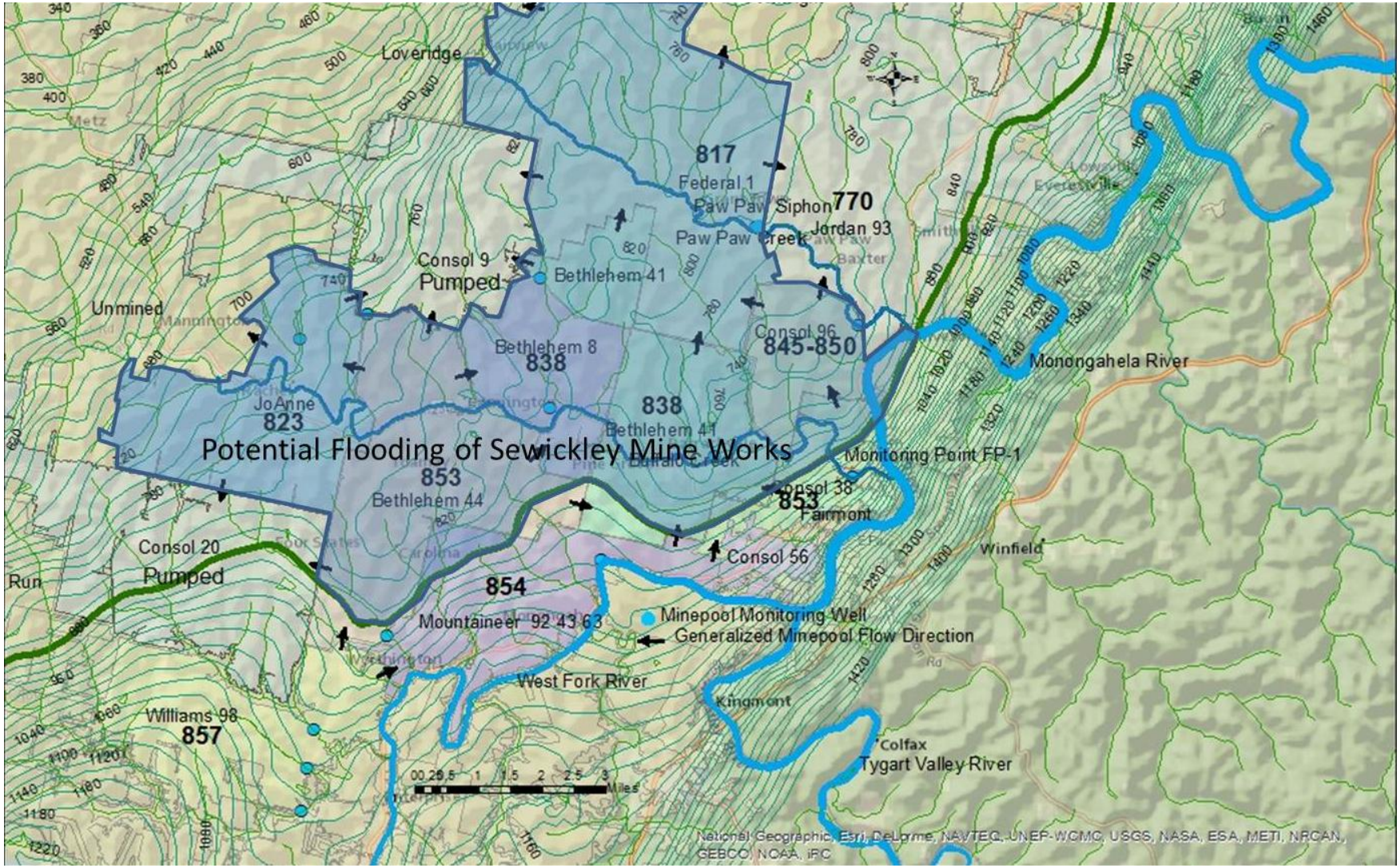

Figure 18. Potential extent of flooding Sewickley mine-works from underlying Pittsburgh Mine-pool. The 860 ft. m.s.l. elevation of the Sewickley coal is highlighted (bold dark green contour) as the maximum extent of potential flooding. Sewickley coal located below elevation 860 ft. m.s.l. shown in blue shading could receive leakage from flooded underlying Pittsburgh mine-works. The structure of both coalbeds dips to the northwest.

during this project provided water level data to consultants working on Sewickley mine development plans in the Fairmont area.

Mine-pool Water Quality

Water quality was measured periodically at five wells to obtain spatial characterization of the mine-pool. These included the Siphon (Consol 96), monitoring point FP-1 (Mine 38), Mountaineer 92/43/63, Williams 98, and Federal 1. On several dates, samples were also collected from additional wells, discharges and small mines adjacent to the main mine-pool. Some wells, such as the Bethlehem 44 monitoring point, were not sampled for quality, because sufficient access to the well for a submersible pump and associated equipment was lacking. Because the principal monitoring goal in this project was water level (head) information, water quality data were collected at extended intervals. A complete compilation of mine-pool water quality data is included as appendices B (Paw Paw Siphon) and C (Mine-pool wells). Location of mine-pool wells with water quality data are shown in figure 19.

Mine-pool water quality is characterized by neutral pH (i.e. not acid), large concentrations of alkalinity, sulfate and dissolved solids, with lesser amounts of dissolved iron. Some sub-pools also have substantial dissolved sodium concentrations. The mine-pool has more acid neutralizing capacity (alkalinity) than acid generating capacity from dissolved metals (i.e. mineral acidity). Therefore discharges from the mine-pool are *not* acidic. Iron, dissolved solids, and sulfate are the principal water quality parameters of concern if the mine-pool discharged into surface waters. Their current concentrations in the mine-pool exceed acceptable water quality criteria for typical surface water uses in West Virginia. Some monitoring points, such as FP-1 (Mine 38) have shown improvement in water quality conditions during monitoring. Chemical conditions in others however, such as Mountaineer 92/43/63, exhibit little change over time.

The Siphon is a principal withdrawal point for the mine-pool and represents combined water quality from various sub-pools. It is also a designated NPDES monitoring point. Figure 20 shows a time series of plot of iron concentration from 1997 to 2012. There is considerable scatter in values. Iron concentrations peaked around 150 mg/L as the mine-pool neared the end of active flooding up to about 2004, and have since declined to about 60 mg/L. These concentrations preclude common uses of the raw water until it is treated by oxidation and settling of solids.

The mine-pool contains large concentrations of measured alkalinity as shown in figure 21. During flooding, alkalinity concentration exceeded 400 mg/L, and gradually increased, reaching a maximum of about 700 mg/L in 2004 as flooding concluded. Eight years of more recent monitoring shows alkalinity concentrations between about 600 to 700 mg/L. The large alkalinity concentrations present in the mine-pool provide ample acid neutralizing capacity.

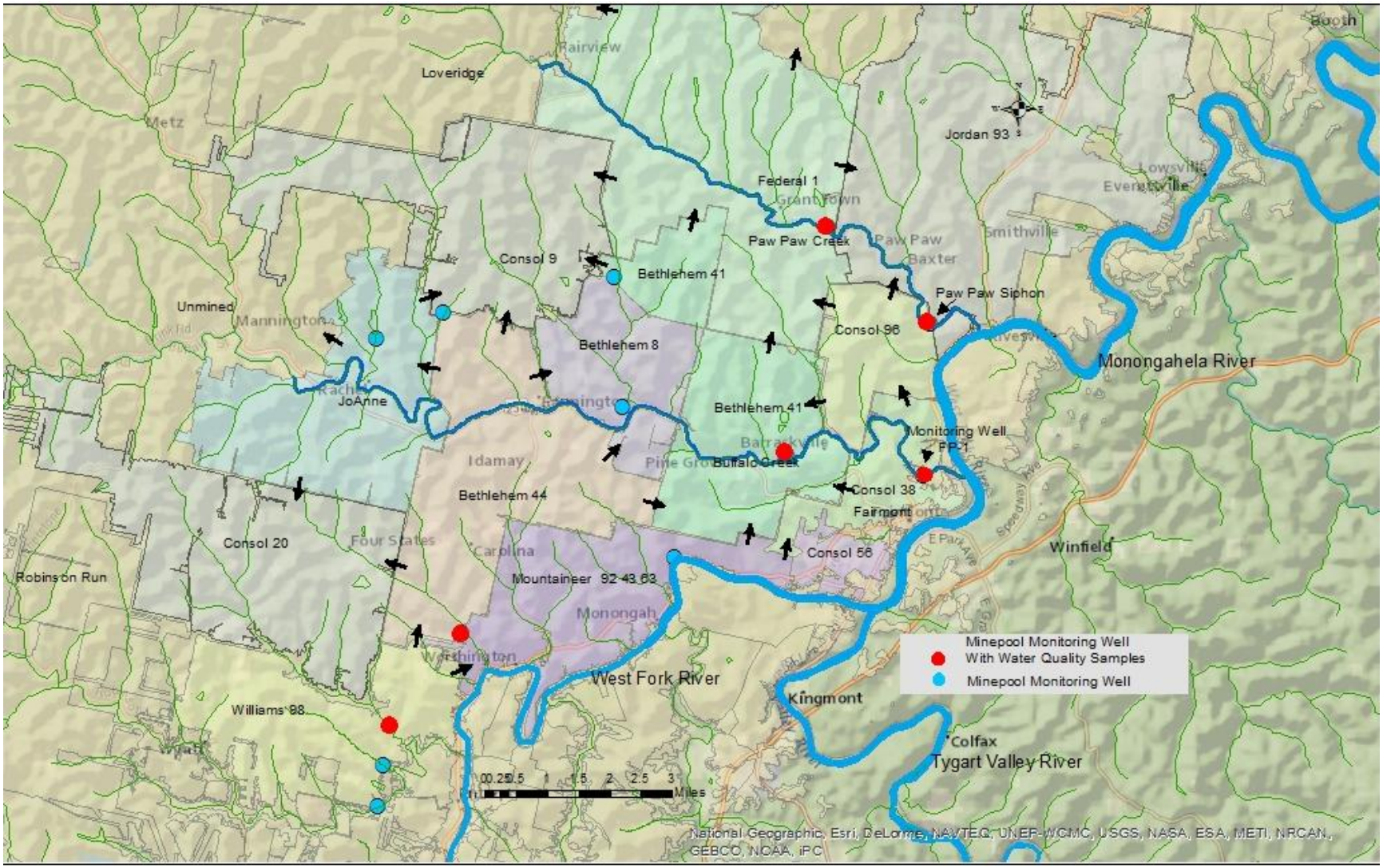

Figure 19. Location of mine-pool wells, with water quality sampling data. Red circles denote wells with chemical data. Analyses presented in tables 8, 9, and 10; figures 20, 21 and 22; and Appendices B (Siphon) and C (Other Mine-pool wells).

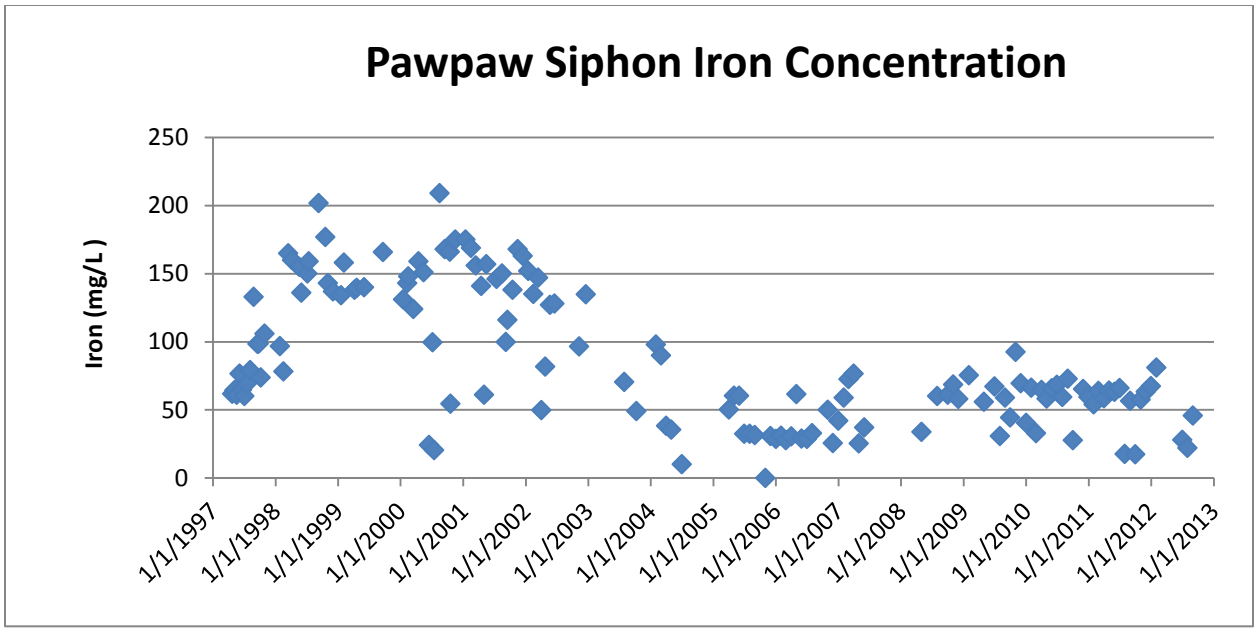

Figure 20. Time series plot of iron concentration at the Siphon (Consol 96). Data compiled from reported NPDES monitoring, and OSM samples up to 2004. NPDES data are listed as average values for the reporting period. See figure 19 for well location.

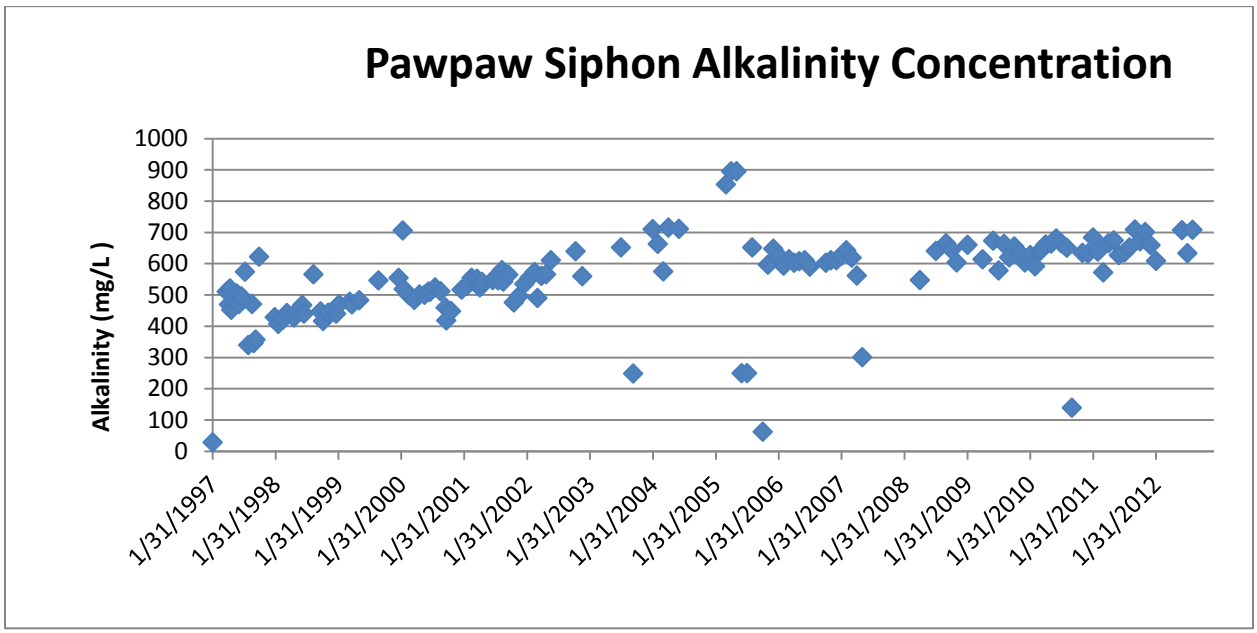

Figure 21. Time series plot of alkalinity concentration (mg/L $CaCO_3$ Eq. at the Siphon (Consol 96). Data compiled from NPDES monitoring and OSM samples up to 2004. NPDES data are listed as average values for the reporting period.

Figure 22 shows TDS concentrations at the Siphon. Initial TDS concentrations were about 6,000 mg/L, and they gradually declined to about 3,500 mg/L by 2008. From 2008 to 2012 water

quality conditions for the Siphon are changing at a slower rate than prior to 2008, as shown by the small slopes on the plots in figures 20 to 22, and data in table 8.

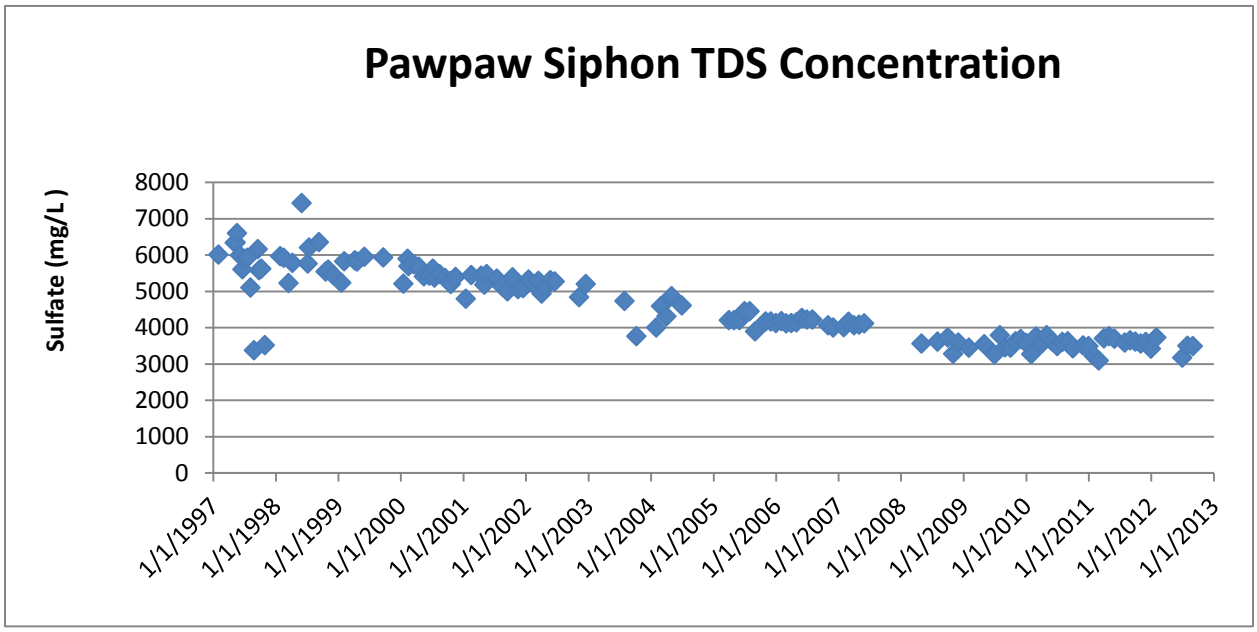

Figure 22. Time series plot of total dissolved solids (TDS) concentration at the Siphon (Consol 96). Data compiled from NPDES monitoring and OSM samples up to 2004. NPDES data are listed as average values for the reporting period.

Annual median chemical concentrations in table 8, summarized from NPDES monitoring data, show small changes in conditions over a five year period. Iron concentration has remained around 60 mg/L; TDS about 3,500 mg/L; and sulfate, a principal constituent of TDS, is about 2,000 mg/L. Alkalinity concentration *increased* over the 5 year period. The Siphon discharge will require management for water quality parameters for an indefinite period.

Table 8
Siphon Median Water Quality Concentrations 2008-2012(1)

Year(2)	Flow	Number of Samples	pH	Alkalinity	Total Dissolved Solids	Iron	Sulfate
2008	800	5	7.13	640	3,582	59	2,033
2009	850	9	7.15	634	3,542	60	2,128
2010	850	11	7.04	641	3,552	59	2,028
2011	850	12	7.11	661	3,600	65	2,006
2012	1,600	4	6.86	670	3,490	61	2,045

(1) Compiled from NPDES reporting data. Flow in gpm, pH in S.U., alkalinity in mg/L $CaCO_3$, TDS, iron and sulfate in mg/L. Entries are median values for the year.

The FP-1 monitoring point is installed in Mine 38, in only about 60 feet of overburden and near the eastern margin of the mine-pool (figures 3, 4 and 19). Water quality has *improved* in this part of the mine-pool. Table 9 summarizes water quality conditions in this sub-pool for the period 1998-2010. Dissolved iron concentrations exceeded 10 mg/L in 1998 but have since decreased. After the mine-pool finished flooding around 2004, iron and other mine water indicator parameter concentrations decreased further. Recent iron concentrations are on the order of 1 mg/L. TDS and sulfate concentrations also decreased about 30 to 50 percent from 1998 conditions. Water composition has gradually shifted from sodium sulfate to calcium sulfate type water. These changes are indicative of the likely water quality evolution as parts of the mine-pool undergo more flushing. Donovan et al. (2003) describe the flooding history and chemical evolution of a mostly flooded underground mine in the Pittsburgh coal bed in southwestern Pennsylvania. They describe three phases of water chemistry including an initial flooding phase of peak concentrations of iron, acidity and other pollutants. Second was a transition phase with decline in iron and other parameter concentrations; then a third phase, where iron declined to less than 10% of initial concentration, and net alkaline conditions developed.

Table 9
Water Quality in Mine 38(FP-1), 1998 to 2010(1)

Date	pH	Sp. Cond	TDS	Alkalinity	Fe	Ca	Mg	Na	Cl	SO_4
9/9/1998	6.63	857	592	155	12.91	65.8	16.7	82.7	18	262
9/20/1999	6.74	1,226	807	197	11.39	100.3	23.0	133.4	46	353
10/18/2000	7.27	919	582	228	6.81	76.9	18.9	94.6	31	186
9/6/2001	7.42	750	555	162	2.30	47.8	11.2	94.6	29	169
12/17/2002	7.32	832	548	179	3.44	60.7	14.1	105.7	34	207
10/18/2003	7.42	635	493	163	4.20	60.6	13.4	60.6	21	140
4/6/2004	6.68	923	442	200	4.31	79.2	17.2	62.4	15	153
5/11/2005	6.95	771	392	157	0.53	75.5	14.6	52.1	24	138
4/17/2008	6.42	637	382	177	0.79	64.5	14.6	46.4	20	127
6/30/2010	6.41	778	440	183	1.48	68.2	13.9	64.7	33	131

(1) pH in S.U., alkalinity in mg/L $CaCO_3$ Eq., Sp. Cond in µS/cm, all others in mg/L. Elemental analyses are dissolved concentrations. See figures 3, 4, and 19 for well location.

Water quality analyses from the Mountaineer 92/43/63 sub-pool are summarized in table 10. It is part of the main flow system carrying water from Bethlehem 44, Williams 98 and other locations from south to north toward the Siphon (Figures 3, 4 and 19). The well is a former pump station borehole (#6 Pump), and is about 130 feet deep. TDS, sulfate, iron, sodium, and other parameter concentrations are greater than at FP-1, and more closely resemble composition of water at the Siphon.

Six samples collected over a nine year period show little variation in mine water composition. With two exceptions, TDS has ranged from about 2,500 to 3,000 mg/L, and iron from 16 to over

30 mg/L. Like the Siphon, alkalinity concentrations are large, characteristically around 600 mg/L. Sodium is the dominant cation, ranging from about 650 to 850 mg/L. None of the parameters listed in table 10 show any obvious trend of decreasing concentration. The water type is sodium sulfate.

Table 10
Water Quality in Mountaineer 92/43/63 (#6 Pump), 2002 to 2011(1)

Date	pH	Sp. Cond	TDS	Alkalinity	Fe	Ca	Mg	Na	Cl	SO_4
6/18/2002	6.96	3,560	2,468	444	24.66	121.6	25.3	649	35	1,345
12/17/2002	7.31	4,100	3,301	589	33.89	158.4	33.1	853	44	1,697
7/31/2003	6.8	4,290	2,972	604	30.9	151	28.8	769	45	1,560
4/5/2005	6.93	3,730	2,358	511	22.4	115.9	22.5	668	5.5	1,233
4/17/2008	6.68	4,760	2,826	660	21.18	135.1	27.1	825	70	1,493
6/29/2011	6.57	3,400	2,460	605	16.0	120	22.8	722	45	1,212

(1) pH in S.U., alkalinity in mg/L $CaCO_3$ Eq., Sp. Cond in µS/cm, all others in mg/L. Elemental analyses are dissolved concentrations. See figures 3, 4, and 19 for well location.

Surface Water Quality

The watersheds of two principal tributaries of the Monongahela River, Buffalo Creek and Paw Paw Creek, overlie much of the mine-pool. The lower reaches of these streams, near the Monongahela, are likely outbreak areas if the pool discharged to the surface. Surface water samples collected both by OSM and the West Virginia DEP were reviewed to establish existing chemical conditions so that mine water would be detectable if it leaked into either stream.

Both streams have an established Cumulative Hydrologic Impact Analysis ("CHIA") trend station with chemistry and flow data collected by WVDEP. The CHIA stations are both located *upstream* of potential mine-pool discharge zones and therefore provide background chemical and flow conditions. They do however reflect the influence of all industrial, municipal, and other discharges upstream of the sampling point. These data cover the period from October, 2002 to January, 2010. Data from71 sampling events were retrieved and summarized as lower quartile (25th percentile), median, and upper quartile (75th percentile) values in tables 11, 12, 13, and 14. Tables 11 and 13 summarize dissolved chemical concentration data for each stream. Tables 12 and 14 contain summary information on chemical loading for each stream. Location of the CHIA trend stations are shown in figure 19.

The CHIA trend station data are subdivided into high and low flow seasons to illustrate seasonality effects. The complete trend station data are included as appendices D and E.

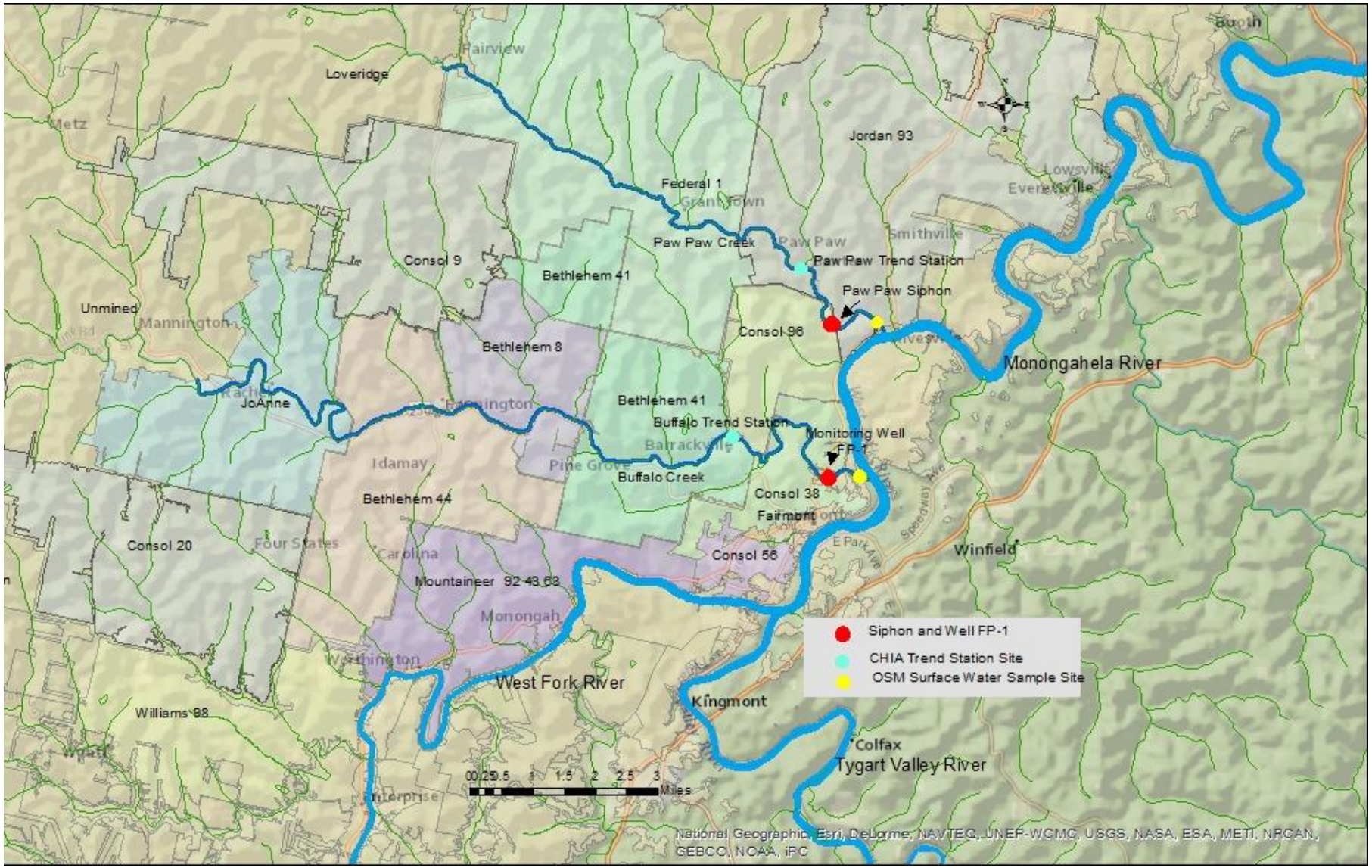

Figure 23. CHIA trend station and OSM surface water sample locations and their proximity to the Siphon and monitoring well FP-1. Trend station measurements collected by WVDEP and summarized in tables 12 to 14. Full data set included in Appendices D and E. OSM surface water data shown in tables 15 and 16.

Table 11[1]
WVDEP CHIA Trend Station Concentration Data, Buffalo Creek
Lower Quartile, Median and Upper Quartile, October 2002 to January 2010

Parameter	Flow (CFS)	pH (Field)	Sp. Cond (Field)	TDS	Alkalinity	Dis Fe	Dis Mn	Dis Al	Sulfate
Low Flow									
Lower Quartile		7.8	362	242	95	0.07	0.04	0.029	80
Median	19.3	8.1	752	468	158	0.11	0.07	0.043	110
Upper Quartile		8.4	1,495	1,002	237	0.12	0.08	0.36	297
High Flow									
Lower Quartile		7.9	277	255	88	0.09	0.05	0.03	72
Median	43.9	8.2	456	318	137	0.14	0.06	0.042	116
Upper Quartile		8.7	812	604	168	0.29	0.09	0.11	193

(1) pH in S.U., alkalinity in mg/L $CaCO_3$ Eq., Sp. Cond in µS/cm, all others in mg/L.
CFS = cubic feet per second.

Table 12[1]
WVDEP CHIA Trend Station Loading Data, lbs/day, Buffalo Creek
Lower Quartile, Median and Upper Quartile, October 2002 to January 2010

Parameter	Flow (CFS)	TDS	Alkalinity	Dis Fe	Dis Mn	Dis Al	Sulfate
Low Flow							
Lower Quartile		51,535	9,321	2.38	1.30	0.92	10,301
Median	19.3	77,822	19,589	5.26	3.60	2.97	22,965
Upper Quartile		160,800	38,639	18.75	6.98	7.34	41,462
High Flow							
Lower Quartile		67,544	21,896	7.45	6.59	2.98	19,196
Median	43.9	121,009	36,505	18.69	8.96	6.56	42,463
Upper Quartile		204,113	72,140	23.14	15.28	13.33	85,367

(1) CFS = cubic feet per second. Chemical loading in lbs/day.

General chemical concentration conditions for the two watersheds are similar (tables 11 and 13). Both streams are moderately buffered with alkalinity usually exceeding 100 mg/L. Specific conductance and dissolved solids values indicate both streams carry appreciable quantities of

dissolved materials. The upper quartile (75% percentile) TDS value for both streams exceeds 1000 mg/L for low flow season. At very low flow conditions, these parameters can increase two to ten fold over median conditions. Figure 24, which shows dissolved solids concentration in Buffalo Creek, exemplifies this behavior. Eleven of the 71 measurements exceed 1000 mg/L TDS, and they occurred, with one exception, at flow conditions of less than ten cubic feet per second (CFS). Sulfate, which is a principal constituent of TDS, behaves in a similar manner. For both stations, the dissolved metals of iron, manganese and aluminum are present in low concentrations; typically 0.2 mg/L or less for iron and usually less 0.1 mg/L for aluminum and manganese, with little seasonal influence. Some samples were reported at less than detection limit for the target metal. Both stream exhibit seasonal effects on other chemical concentrations. Median alkalinity, sulfate and TDS concentrations are larger under low flow compared to high flow conditions by factors of about 5% to more than 50%. If the mine-pool discharged into either stream, the effects on chemical composition would be most pronounced at low flow conditions. Increases in TDS, sulfate and probably iron concentrations and loadings would be the primary water quality impacts.

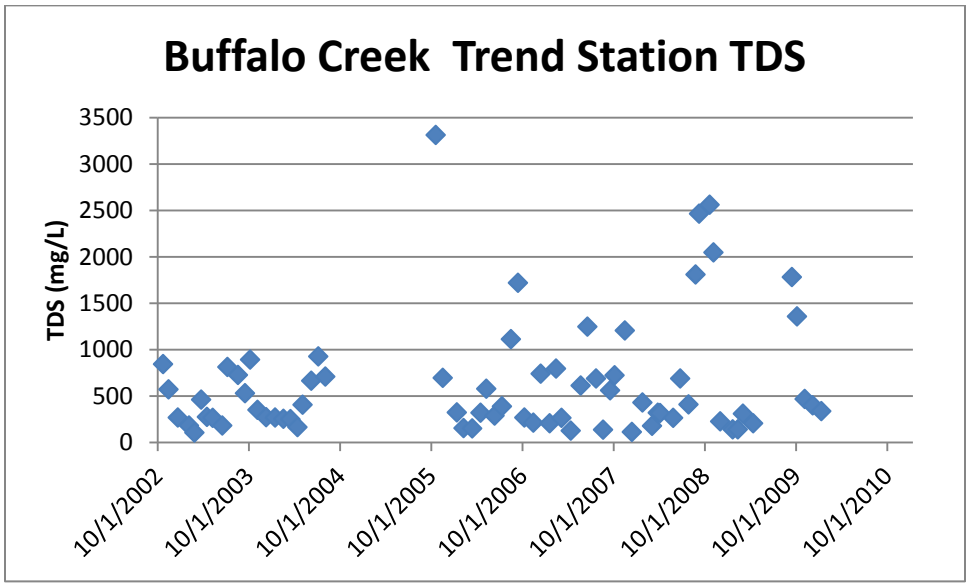

Figure 24. Time Series Plot of TDS at the WVDEP Trend Station, Buffalo Creek.

Chemical loading data, summarized in tables 12 and 14, also show that dissolved solids, sulfate and alkalinity are the most abundant constituents in the two streams. Buffalo Creek has a median dissolved solids load of over 38 tons per day in low flow season and over 60 tons per day in high flow season. About a third of the dissolved solids load is sulfate. Buffalo Creek also carries a median 10 and 18 tons per day of alkalinity in low and high flow seasons. Paw Paw Creek has a smaller discharge rate but exhibits similar trends. Both streams carry small metal loads ranging up to a few pounds per day depending on flow and chemistry conditions. If the mine-pool

discharged into either stream, the largest change in stream water composition is likely to be in metals concentrations and loading.

Table 13[1]
WVDEP CHIA Trend Station Concentration Data, Paw Paw Creek
Lower Quartile, Median and Upper Quartile, October 2002 to January 2010

Parameter	Flow (CFS)	pH (Field)	Sp. Cond (Field)	TDS	Alkalinity	Dis Fe	Dis Mn	Dis Al	Sulfate
Low Flow									
Lower Quartile		8	447	307	99	0.06	0.05	0.024	98
Median	7.8	8.2	917	599	137	0.09	0.08	0.035	176
Upper Quartile		8.4	1,580	1,212	180	0.11	0.11	0.31	413
High Flow									
Lower Quartile		8	435	284	89	0.07	0.04	0.035	90
Median	14.5	8.1	537	372	122	0.09	0.06	0.056	128
Upper Quartile		8.6	798	534	148	0.15	0.07	0.087	251

(1) pH in S.U., alkalinity in mg/L $CaCO_3$ Eq., Sp. Cond in µS/cm, all others in mg/L.
CFS = cubic feet per second.

Table 14
WVDEP CHIA Trend Station Loading Data, lbs/day, Paw Paw Creek
Lower Quartile, Median and Upper Quartile, October 2002 to January 2010

Parameter	Flow (CFS)	TDS	Alkalinity	Dis Fe	Dis Mn	Dis Al	Sulfate
Low Flow							
Lower Quartile		16,504	2,234	0.70	0.24	0.27	4,900
Median	7.8	30,278	6,021	2.22	0.84	1.03	7,010
Upper Quartile		47,707	14,674	8.37	6.84	3.09	15,222
High Flow							
Lower Quartile		26,400	4,761	2.02	1.05	1.25	8,807
Median	14.5	39,116	13,709	6.77	1.83	2.98	15,831
Upper Quartile		62,405	21,363	10.7	7.69	8.25	21,820

(1) CFS = cubic feet per second. Chemical loading in lbs/day.

OSM conducted limited surface water sampling at the mouths of Paw Paw Creek and Buffalo Creek in the early phases of monitoring from 1998 to 2002. These samples were collected *downstream* of the potential mine-pool discharge zones at the locations shown in figure 19. These data are summarized in tables 15 and 16. The OSM and WVDEP CHIA trend station data do not coincide time wise; OSM discontinued its sampling as the trend station sampling was about to start. The complete set of surface water sample analyses collected by OSM is included in appendix F.

Table 15 shows seven OSM sample results over a four and a half year period for Buffalo Creek near its mouth. The location was selected to be in or downstream of the potential discharge zone if the mine-pool reached breakout conditions. Samples include both high and low flow seasons. Composition is somewhat variable with two sampling events reporting elevated chemical concentrations in September 1998 and May 2001. Specific conductance and alkalinity concentrations are with one exception, less than 500 µS/cm and 80 mg/L respectively, and dissolved iron is less 0.2 mg/L in all samples. In general, water quality near the mouth of Buffalo Creek is a somewhat dilute reflection of the upstream chemistry. Between the CHIA trend station and OSM sampling locations, Buffalo Creek flows through parts of the town of Fairmont and receives storm water outfalls. Inflows of storm water runoff would in general have a dilution effect on stream chemical concentrations. None of the OSM samples reflect any obvious mine-pool discharge influence.

Table 15(1)
Surface Water Quality Near Mouth of Buffalo Creek
and Downstream of Potential Mine-pool Discharge Zone

Date	pH	Sp. Cond	TDS	Alkalinity	Fe	Ca	Mg	Na	Cl	SO_4
9/10/1998	7.68	470	359	64	0.02	47.6	11.9	33.6	9.5	171
4/20/1999	7.95	220	280	53	0.12	24.5	6	37.9	14	96
9/20/1999	7.92	220	197	49	0.12	21.7	5.2	12.8	4.8	47
7/6/2000	7.93	360	240	70	0.18	26.9	6.4	35	7.8	81
10/18/2000	7.29	320	197	51	0.15	30.3	7	21.9	9.4	78
5/2/2001	8.05	770	559	133	0.03	43.8	13.1	120	36	241
4/2/2002	7.80	440	260	78	0.09	33.8	8	37.8	12.8	96

(1) pH in S.U., alkalinity in mg/L $CaCO_3$ Eq., Sp. Cond in µS/cm, all others in mg/L. Elemental analyses are dissolved concentrations.

Table 16 shows seven OSM sample results over a four and a half year period for Paw Paw Creek near its mouth, and downstream of the Siphon. Samples include both high and low flow seasons. Two events of elevated specific conductance, dissolved solids, and sulfate concentration were measured in low flow conditions of 1998 and 2000. Cation concentrations including sodium, and the anion chloride, were also measured at increased concentrations in those two samples. The stream composition was similar to what might be expected if the mine-pool was leaking into the

stream. However, measured mine-pool water levels on both dates were *below* potential breakout elevations, i.e. below elevation of the stream. The Paw Paw Creek watershed has other discharge sources upstream of the OSM sampling location, and these may influence stream composition. Dissolved iron, another potential mine water pollutant, was present at concentrations usually less than 0.10 mg/L.

Table 16(1)
Surface Water Quality Near Mouth of Paw Paw Creek and Downstream of Siphon

Date	pH	Sp. Cond	TDS	Alkalinity	Fe	Ca	Mg	Na	Cl	SO_4
9/10/1998	7.98	1,400	1,271	180	0.03	107.2	30.7	238.8	75.9	622
4/20/1999	8.06	270	324	69	0.08	35	8.2	35.4	15.6	106
9/20/1999	8.19	400	303	87	0.06	38.9	10.1	35.5	11.9	110
7/6/2000	8.03	470	333	120	0.08	56.2	12.1	31.4	10.4	111
10/18/2000	7.59	1,000	925	158	0.30	98.8	21.8	159.5	50.8	418
5/2/2001	8.05	580	429	140	0.01	54.4	15.1	56.5	16.9	162
4/2/2002	8.47	430	253	91	0.01	40.1	10.3	25.1	9.8	86

(1) pH in S.U., alkalinity in mg/L $CaCO_3$ Eq., Sp. Cond in µS/cm, all others in mg/L. Elemental analyses are dissolved concentrations.

Both Buffalo Creek and Paw Paw Creek are highly susceptible to water quality degradation if the mine-pool discharged into them. The limited surface water monitoring conducted by OSM, combined with water level measurements indicates that the mine-pool was not having an identifiable effect on surface water quality.

Conclusions and Recommendations

Analyses of water level and quality monitoring data, geologic and mining information, maps, and weather data encompassing about 15 years provides the following summary observations, conclusions and recommendations:

- The siphon and pumping system located in the Paw Paw creek watershed has maintained the Fairmont mine-pool head below "breakout" elevation up to the present. Water level in monitoring well FP-1, with one exception, has remained below the "not to exceed" elevation over the 15 year period. No indication of mine-pool leakage has been found in the likely initial discharge zones in the lower reaches of Buffalo and Paw Paw creeks, based on periodic water quality sampling and visual observations. Confined conditions in the mine-pool (fully flooded with head greater than top of the aquifer) make it possible to control the head in a large mine-pool by withdrawal at one location.

- The mine-pool finished flooding about 2005 and is now at approximate steady state conditions. Recharge and inflow is approximately balanced by withdrawal and subsurface mine water outflow.

- About 2,300 gallons per minute is estimated to discharge from the Fairmont mine-pool. The major discharge mechanisms include the Paw Paw siphon, accounting for about 850 gpm (37.2%); and subsurface outflow by barrier leakage to Consol 9 (639 gpm, 28%) and Consol 20 (395 gpm, 17.3%) and Jordan 93 (295 gpm,12.9%). An estimated 100 gpm of mine water discharges into Arkwright, Loveridge and unmined areas to the north and west.

- Mine water flow within the pool is mainly from south to north, adjacent to the West Fork and Monongahela Rivers, and to the west.

- The Fairmont mine-pool has hydrologic interaction with adjacent mines to the west and north. The Fairmont mine-pool would respond to a change in head or pumping rate in the adjacent mines. The Consol 9 and Consol 20 mines located to the west are currently pumped to protect active mining in the Robinson Run and Loveridge mines. A reduction in pumping rate and increase in head in either Consol 9 or Consol 20 would reduce the current outflow rate from the Fairmont mine-pool. An increase in head in the Jordan mine to the northeast would also decrease the outflow rate from the Fairmont mine-pool. If these types of changes occur, increased withdrawal elsewhere, such as at the siphon, would be needed to maintain mine-pool head below breakout elevation.

- The Fairmont mine-pool consists of several fully flooded sub-pools with different hydraulic heads. Barriers between mines are conductive enough that substantial mine water flow occurs from one sub-pool to another. The head differences result in part from different closure dates and flooding histories.

- The mine-pool contains near neutral pH water with large concentrations of alkalinity, and any discharge of mine-pool water will not be acidic. Water quality composition varies by location in the mine-pool.

- Treatment of mine-pool water is still needed. Concentrations of iron, sulfate and total dissolved solids at the Paw Paw siphon have decreased since monitoring began. However, these three parameter concentrations remain greater than applicable or suggested water quality standards and criteria. The Paw Paw siphon water chemistry is changing, but slowly. Considering the current discharge rate and available mine-pool storage, it may take 30 to 40 years to flush the equivalent of one pool volume.

- Receiving streams water quality would be adversely affected by a discharge of mine-pool water, in particular, at low flow conditions. Iron, sulfate and dissolved solids are the principal risks to surface water quality and stream biota.

- Closure plans for the active mines protected by the current pumping in Consol 9 and Consol 20 should address the effects of reduced or discontinued pumping and flooding on the Fairmont mine-pool.

- Development of new underground mining adjacent to the Fairmont mine-pool or in the overlying Sewickley bed should consider potential mine water flow from the existing mine-pool into active mine works. New mining in the Pittsburgh coalbed would likely act as a ground water sink and decrease hydraulic head in the Fairmont mine-pool.

The Fairmont mine-pool should still be monitored periodically, since an overflow or breakout of mine water would adversely affect surface water quality in Buffalo or Paw Paw creeks or the Monongahela River. Four monitoring points should now provide the information needed to manage the mine-pool in the future. These points are:

1. The Paw Paw siphon
2. Monitoring well FP-1 in the Consol 38 mine
3. Monitoring well in the Federal 1 mine
4. Monitoring well in the Joanne mine

The siphon is the largest single outflow source in the mine-pool and is equipped with a flow meter to record discharge rate. The discharge rate can be adjusted as needed to maintain mine-pool head at an acceptable elevation. West Virginia DEP currently requires quarterly reporting of the average discharge rate and water quality. OSM recommends that those reporting requirements remain in place to monitor withdrawal and changes in water chemistry.

Monitoring well FP-1 has a “not to exceed elevation,” assigned by West Virginia DEP, and requirements for quarterly reporting. It serves as an early warning system. Water level data from this well will indicate if mine-pool head is increasing to a potential breakout to receiving streams. OSM recommends that water level monitoring continue in this well.

Barrier leakage from the Federal 1 mine and Consolidation 96 mines to Jordan 93 are now a major outflow mechanism on the northeast side of the Fairmont mine-pool. A monitoring well was installed in the Federal 1 mine as part of OSM’s technical assistance efforts and provides head data to estimate the leakage rate across that barrier into Jordan 93. Federal 1 also has common barriers with Arkwright, Loveridge, Consol 9, Bethlehem 8, Bethlehem 41 and Dakota

96. The exchange of mine water with these mines is also influenced by the hydraulic head in Federal 1. OSM believes continued monitoring in Federal 1would help assess future mine pool outflow and water movement within the Fairmont mine-pool. This information would be useful if head conditions change significantly in any of these mines.

The Joanne mine monitoring well provides head information to estimate the barrier leakage rates from the Fairmont mine-pool to the Consol 9 and Consol 20 mines, currently a major discharge zone to the west. OSM believes continued monitoring of this well is beneficial. That information can be used to reassess leakage rates if head conditions change significantly in any of these mines.

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Appendix A
Measured Water Level Data for Wells in the Fairmont Mine-pool

Measured Water Level Data for Wells in the Fairmont Mine-pool(see report figures 1, 3, and 19 for locations)												
Location	Paw Paw Siphon	FP-1 (Penn Overall)	Grantown	Barrack-ville	Oddfellows	Katy	Carberry	Rachael	#7 Pump	#6Pump	Shinnston	Pump Station 6
Mine Name	Dakota	Consol 38	Federal 1	Beth 41	Beth 41	Beth 8	Beth 44	Joanne	Williams 98	Williams 98	Williams 98	Mountaineer 92 63 43
Well Reference Elevation	875.18	891.77	977.89	975.41	1029.96	1182.94	1049.21	1040.37	931.1	965.8	1049.21	909.28
Ground Surface Elev	875.18		977.89	973.41	1029.96	1182.94	1047.21	1040.37	929.1	964.6	1047.21	907.98
Northing State Plane	376004	363312	384366	365195	380408	369437	377443	375595	342941	339647	339647	350705
Easting State Plane	1789216	1788493	1780743	1776929	1762698	1763249	1748077	1742505	1743105	1742498	1742498	1749306
Water Level Data in Feet M.S.L.												
12/12/1996	863.1			818.02			862.34					
12/16/1996	864.16			820.41			863.89					
1/14/1997	864.73	865.07	779.3	820.77			866.24		870.25			
2/24/1997	864.66	864.48	784.3	822.67					868.78			
4/29/1997	857.34	863.37	800	825.59			865.27		869.55			
5/29/1997	851.16	860.52	792.9	825.79			862.67		867.27			
6/16/1997	849.94	858.09					860.32		863.72			
6/30/1997	849.01	856.69					858.97					
7/14/1997	848.34	855.52		825.39			857.72		862.35			
7/31/1997	847.34	854.17					856.22		860.7			
8/7/1997		853.62										
8/15/1997	847.14	853.27		824.54			855.32		859.7			
9/10/1997		853.72		825.76			855.79		860.38			
9/25/1997	847.81	854.81		825.38			855.14		859.8			
12/4/1997	846.56	852.71		825.97			852.89		855.4			
1/29/1998	846.18	851.37		827.51			852.34		856.8			

Measured Water Level Data for Wells in the Fairmont Mine-pool(continued, see report figures 1, 3, and 19 for locations)												
Location	Paw Paw Siphon	FP-1 (Penn Overall)	Grantown	Barrack-ville	Oddfellows	Katy	Carberry	Rachael	#7 Pump	#6Pump	Shinnston	Pump Station 6
Mine Name	Dakota	Consol 38	Federal 1	Beth 41	Beth 41	Beth 8	Beth 44	Joanne	Williams 98	Williams 98	Williams 98	Mountaineer 92 63 43
3/4/1998	847.18	851.52		828.91			853.19		857.75			
5/28/1998	846.98	851.22		831.61			854.16		859.05			
6/30/1998	849.98	853.07		832.97			854.69		859.17			
9/9/1998	846.78	850.87					853.71					
1/20/1999	845.56	850.95		832.89			850.99					
4/21/1999	845.78	851.46		835.07			851.44		853.8			
5/19/1999	845.7	851.46	817.32	837.17	837.16	858.84	851.41	757.3	855.89		899.79	
6/15/1999	845.61	851.28	819.22	837.258	837.85	857.76	851.29	758.14	853.7		899.99	
7/14/1999	845.3	850.92	820.9	836.71	837.26	855.92	850.88	758.69	851.27		900.13	
8/11/1999	844.98	850.51	821.75	835.51	837.09	854.17	850.49	759.58	852.71		900.23	
8/31/1999			820.37					759.25				
9/20/1999	850.73	851.92	818.77	835.91	836.39	852.14	851.53	759.87	854.84		896.09	
10/19/1999	851.9	852.89	816.52	835.44	835.85	851.13	852.44	760.16	855.63		896.35	
12/13/1999	845.31	852.04	814.75	835.49	835.93	846.19	850.25	761.96	856.08		896.73	
1/19/2000	844.73	850.73	814.4	836.21	836.68	845.37	850.94	763.16	854.86		897.06	
2/9/2000	844.68	850.21							854.12			
2/23/2000			815.8	836.25	836.8	851.72	848.24	769.57			897.22	
3/23/2000	844.72	850.51	815.21	836.99	837.56	850.66	850.49	766.84	854.6		897.84	
5/17/2000	844.91	851.26	816.33	838.14	838.65	850.58	851.37		855.75		898.43	
6/7/2000	844.83	851.26	816.35	838	838.46	851.14	851.41		855.69			
7/6/2000	845.08	851.13							855.47			
7/12/2000			819.32	837.71	838.19	852.89	851.06					
8/15/2000						854.06						
8/17/2000	844.84	850.76	818.12	837.95	838.51		850.69		854.81			
10/12/2000	850.52	851.53	816.63	838.04	838.45	853.48	851		854.29		899.56	
11/20/2000	852.26	853.35	816.03	837	837.41	853.31	852.79		855.78		909.04	
12/19/2000	853.23	854.31	816.1	834.54	837.98	852.84	853.82		856.7			
1/4/2001	854.18	854.79	814.71	836.8	837.29	852.73	854.31		858.08			

Measured Water Level Data for Wells in the Fairmont Mine-pool(continued, see report figures 1, 3, and 19 for locations)												
Location	Paw Paw Siphon	FP-1 (Penn Overall)	Grantown	Barrack-ville	Oddfellows	Katy	Carberry	Rachael	#7 Pump	#6Pump	Shinnston	Pump Station 6
Mine Name	Dakota	Consol 38	Federal 1	Beth 41	Beth 41	Beth 8	Beth 44	Joanne	Williams 98	Williams 98	Williams 98	Mountaineer 92 63 43
2/21/2001	845.55	852.65	814.89	837.85	838.38	853.22	852.71		856.52			
2/28/2001	845.53	852.55	815.13		838.64	853.52						
3/28/2001	845.22	851.99	815.79	836.85	838.9	854.34	852.04		856.08			
4/24/2001	845.6	852.02	816.75	837.84	839.41	856.29	852.01		856.13			
5/10/2001			816.96		839.08	856.38						
6/20/2001	845.57	851.47	817.49	838.18	838.68	854.87	851.41		855.69			
7/12/2001	845.58	851.22	817.85	838.13	838.65	854.67	851.22		855.65			
7/25/2001			817.95		838.73	854.69						
8/22/2001	844.97	850.81	817.82	837.74	838.26	854.53	850.78		854.89			
9/19/2001	844.9	850.6	817.98	837.22	837.65	854.13	850.61		854.74			
10/3/2001						853.9	850.42					
10/18/2001	850.43	851.26	817.39	836.65	837.06	853.7	850.64		854.3			
12/5/2001	852.53	853.62	815.79	836.15	836.58	853.79	853.05		856.49			
1/23/2002	846.43	854.35	815.98	838.14	838.65	855.64	854.5		858.17			
2/20/2002	846	852.98	816.63	838.74	839.24	855.83	858.18		857.29			
3/28/2002	845.73	852.15	817.47	838.88	839.45	856.62	852.18		856.33			
4/2/2002											910.38	
4/18/2002										895.72		
4/24/2002	845.86		817.99	839.27	839.82	858.33	852.26		856.55	896.05	910.41	
5/21/2002	846.62	852.83	818.61	839.83	840.35	860	852.82		857.2	897.23	910.47	
6/18/2002	846.96		819.48						857.19	896.51	910.54	853.87
6/20/2002		852.85		839.86	840.35	839.62	852.75					
7/24/2002	846.47	852.26	819.61	839.3	839.66	838.99	852.23		855.48	895.3	910.56	853.17
8/28/2002	845.67	851.44	819.14	837.97	838.32	837.73	851.43		855.55	894.98	910.61	852.31
9/24/2002				836.87					854.7	893.7		851.58
10/3/2002	845.16	850.62	818.54		837.17	836.56	850.61					
11/5/2002	849.86	850.66	818.32	836.2	836.68	835.91	850.26		<854.23	893.15	912.04	850.85

Measured Water Level Data for Wells in the Fairmont Mine-pool(continued, see report figures 1, 3, and 19 for locations)												
Location	Paw Paw Siphon	FP-1 (Penn Overall)	Grantown	Barrack-ville	Oddfellows	Katy	Carberry	Rachael	#7 Pump	#6Pump	Shinnston	Pump Station 6
Mine Name	Dakota	Consol 38	Federal 1	Beth 41	Beth 41	Beth 8	Beth 44	Joanne	Williams 98	Williams 98	Williams 98	Mountaineer 92 63 43
12/10/2002	851.69	852.65	817.4	837.19	837.71	836.9	852.07		855.15	892.85	911.97	852.63
12/17/2002	852.04	852.99									912.44	853.01
12/20/2002	852.25							816.12				
1/30/2003	846.33	853.54	817.36	839.1	839.58	838.84	853.57	814.00	857.49	894.54		854.48
2/3/2003	846.57										912.19	
3/4/2003	846.18	852.72	818.38	839.75			852.8	806.74	856.89	895.9		853.66
3/25/2003	847.52	853.30	819.32	840.39	840.99	840.17	853.34	813.25	858.71	897.75	912.22	854.32
4/2/2003	847.35				840.89							
4/10/2003												
4/29/2003	847.44	853.28	820.02	840.69	841.12	840.53	853.26	813.9	857.59	897.75	912.04	854.23
5/23/2003	848.08	853.38	820.68	841.01	841.53		853.8	816.02	857.69	898.77	912.5	
5/29/2003	848.26											854.54
6/25/2003	849.63	854.66	821.7	841.89	842.45	841.84	854.51	820.26	857.6	900.9	912.16	855.5
7/30/2003	850.08	855.47	822.25	841.73	842.21	841.77	855.4	818.72	859.35	901.65	912.21	856.26
9/2/2003	850.13	854.83	822.62		841.36		855.09	818.12				
9/4/2003				841.1					859.01	898.82	912.18	855.88
10/1/2003	849.15	854.73	822.4	840.72	841.23	840.71	854.73	817.72	858.7	897.87	912.07	855.59
10/8/2003	848.29	853.69										
11/6/2003	847.68	853.67	822.8	841.2	841.71		853.72	817.37	857.61	896.59	912.64	854.51
12/18/2003	849.6	854.22	824.06	842.71	843.25	842.59	854.17	821.16	858.08	897.02	912.67	854.96
1/13/2004	853.52	855.68	824.9	843.25	843.82	843.22	855.4	822.85	859.25	898.38		856.28
2/26/2004		856.66	826.24	843.99	844.51	844.03	856.96	825.37	860.65	899.42	912.24	858.11
3/29/2004		855.47	827.39	844.7	845.21	844.19	856	827.32	859.84	899.82	912.28	857.07
4/6/2004	846.64	855.35	827.55			844.83						
4/21/2004	846.83	855.37	827.89	845.09	845.65	844.95	855.81	829.3	859.74	900.15		856.93
5/10/2004												
5/24/2004	847.86	854.62	828.55	844.6	845.07	844.54	854.93	830.76		900.39	912.45	855.93
6/4/2004								830.37				
6/23/2004	847.56	855.52	827.74	844.31	844.98	844.45	855.53	830.99	858.97	900.13	911.89	856.39
6/30/2004	846.82	854.92	827.24	844.21	844.74			831.24				
7/28/2004	852.78	854.14	825.77	843.1	843.51		854.26	831.35		900.71	912.11	855.3
8/2/2004					843.41				858.13			

Measured Water Level Data for Wells in the Fairmont Mine-pool(continued, see report figures 1, 3, and 19 for locations)												
Location	Paw Paw Siphon	FP-1 (Penn Overall)	Grantown	Barrack-ville	Oddfellows	Katy	Carberry	Rachael	#7 Pump	#6Pump	Shinnston	Pump Station 6
Mine Name	Dakota	Consol 38	Federal 1	Beth 41	Beth 41	Beth 8	Beth 44	Joanne	Williams 98	Williams 98	Williams 98	Mountaineer 92 63 43
9/22/2004		853.70	821.25	841.67	842.22	841.77	853.86	830.42	857.42	897.95	912.09	854.78
11/18/2004		852.45	817.88	840.69	841.18		852.61	829.87	856.25	897.02	911.82	853.47
2/1/2005		853.20	816.65	840.7	841.21	840.86	853.4	834.93	857.19	899.14	912.22	854.42
3/29/2005		853.70	816.37	841.1	841.26	840.99	853.8	838.32	857.65	900.68	913.76	854.88
6/9/2005		853.55	818.05	840.09	840.51		853.7	838.78	857.51	902.45	911.92	854.6
6/15/2005					840.62	840.17						
10/12/2005		850.51	813.29	834.99	835.31	835.16	850.51	830.17	<854.3		912.24	851.3
10/19/2005			813.07									
3/8/2006		851.02	810.66	835.77	836.3	835.89	851.05	814.27	<853.6	894.18	911.99	851.81
6/29/2006		852.58	809.54	834.94	835.42	835.12	850.88	815.94	<854.3	893.89	911.94	851.51
10/3/2006			808.18	832.38	832.81	832.72		815.12	<854.3		911.99	850.76
10/5/2006		850.71	808.17				850.19					
12/12/2006		851.06	808.2	833.81	834.45	835.12	850.63	814.94	<854.3	892.51	911.95	851.17
3/29/2007		851.30	816.3	836.36	836.98	836.63	851.12	817.49	854.36	896.17	912.28	852.1
6/13/2007		851.86	819.56	836.92	837.43	837.42	851.84	819.61	855.3	896.7	911.73	852.68
10/4/2007		850.22	819.95	834.93	835.42	835.42	850.09	818.46	<854.3	892.48	911.77	850.83
12/20/2007		850.02	819.44	836.31	837		849.71	816.79	<854.3	892.15		850.32
3/26/2008			819.87	839.04	839.61	839.27		820.07	855.59	897.13	912.15	853.22
4/17/2008		852.78					852.82		856.19			853.67
6/5/2008				839.6								
6/12/2008		853.79	820.58		840.08	839.89	853.77	822.85	857.29	898.21		854.72
9/18/2008		853.32	826.14	839.02	839.46		853.24	821.97	856.63	898.15	911.91	854.1
12/18/2008		851.16	823.68	837.38	838.81		851.06	818.25	<854.3	896.48	911.94	851.82
6/16/2009		852.92	822.19	840.06	840.5		852.56	822.42	856.49	899.69		853.74
9/17/2009		851.75	820.74	836.76	837.15	837.01	851.62	820.87	855	895.98		852.43
3/17/2010			816.93		837.85		850.73	818.27				
3/24/2010		851.11		837.65					<854.3	898.05		851.77
6/16/2010		851.83	817.50	837.56	838.00		851.74	819.85	<854.3	899.55		852.54
9/21/2010		850.85	816.24	834.21	834.66		850.69	818.92	<854.3	896.85		851.46
5/10/2011		853.40		837.91	838.45		853.29	821.32				
6/16/2011		853.95	816.84	837.86	838.25		853.88	823.46	857.58	903.85		854.77

Measured Water Level Data for Wells in the Fairmont Mine-pool (continued, see report figures 1, 3, and 19 for locations)												
Location	Paw Paw Siphon	FP-1 (Penn Overall)	Grantown	Barrack-ville	Oddfellows	Katy	Carberry	Rachael	#7 Pump	#6Pump	Shinnston	Pump Station 6
Mine Name	Dakota	Consol 38	Federal 1	Beth 41	Beth 41	Beth 8	Beth 44	Joanne	Williams 98	Williams 98	Williams 98	Mountaineer 92 63 43
6/29/2011			816.87									854.18
10/25/2011		853.08	814.23	837.91	838.44		852.85	824.67	<856.4	900.82		853.75
4/26/2012		854.71	813.81	838.89	839.28		854.86	830.15	858.69	903.88		855.79
12/12/2012				831.35				821.59	<856.4	898.87		849.3
7/25/2013		850.97	807.76	833.87			850.71	826.54				
8/15/2013									<856.4	901.03		851.52
11/20/2013					831.84			826.29				

Appendix B

Water Quality in the Paw Paw Siphon

Water Quality in the Paw Paw Siphon(see report figures 1,3 and 19 for location)													
Date	pH	Alkalinity (mg/L $CaCO_3$ Eq)	Calculated Acidity (mg/L CaCO3 Eq)	Total Dissolved Solids (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Data Source
1/31/1997	5.06	28	773.9	6010	405	18	2.79	3940	347	129	984	85	CONSOL
4/23/1997	6.62	510	115.1		61.6	1.97	0.21	3830	364	122	1520	195	WVU
5/6/1997	6.84	469	119.1	6330	64.3	2.01	0.05	3860	390	123	1470	185	WVU
5/12/1997	6.75	520	119.5	6340	64.6	1.91	0.05	3950	368	121	1410	178	WVU
5/19/1997	6.36	452	115.9	6600	61.1	2.07	0.48	4030	395	128	1500	175	WVU
6/5/1997	7.0	496	142.1	5988	76.6	2.36	0.1	3810					WVU
6/20/1997	6.8	504	120.4	5604	64.7	2.13	0.1	3920					WVU
7/3/1997	6.5	470	111.7	5885	60.0	1.98	0.1	2000					WVU
7/18/1997	7.0	495	128.8	5918	69.3	2.25	0.1	3690					WVU
8/6/1997	6.8	573	145.4	5104	79.0	1.8	0.1	2920					WVU
8/26/1997	8.0	339	242.2	3370	133.0	1.85	0.1	1210					WVU
9/17/1997	6.8	470	181.8	6159	98.3	2.5	0.2	2261					WVU
9/25/1997	6.6	345	183.1	5579	98.7	3.14	0.1	3680					WVU
10/7/1997	7.5	356	137.2	5620	73.8	2.42	0.1	3600					WVU
10/28/1997	6.6	621	196.2	3513	106.0	3.15	0.1	3470					WVU
1/27/1998	6.5	428	178.9	5967	96.7	2.81	0.1	4220	330	112	1330	143	WVU
2/16/1998	6.7	407	145.4	5916	78.2	2.62	0.1	3640					WVU
3/16/1998	7.0	421	300.1	5228	165.0	2.14	0.1	3520					WVU
4/7/1998	7.3	441	291.6	5778	160.0	2.42	0.1	3810					WVU
5/18/1998	7.0	427	281.9		155.0	1.98	0.1	3870					WVU
6/1/1998	7.8	444	246.9	7430	136.0	1.77		3680					WVU
7/6/1998	7.4	467	273.2	5760	150.0	1.75	0.23	3730					WVU
7/14/1998	7.4	439	289.6	6198	159.0	2.27	0.1	5210					WVU
9/9/1998	7.15	565	367.1	6350	201.87	2.79	0.06	3654	344.6	114.6	1388	106.6	OSM
10/19/1998	7.4	446	321.2	5542	177.0	1.96	0.1	2842					WVU
11/3/1998	8.4	416	260.4	5598	143.0	2.02	0.1	3680					WVU
12/3/1998	7.5	442	249.3	5448	137.0	1.79	0.1	3460					WVU
1/19/1999	7.2	439	244.2	5232	134.0	1.96	0.1	2910					WVU
2/4/1999	7.1	469	287.4	5824	158.0	2.05	0.1	3560					WVU
4/6/1999	7.8	477	250.9	5854	138.0	1.68	0.1	3160					WVU
4/20/1999	7.01	469	254.3	5810	139.6	2.14	0.06	3289	309.7	103.7	1357	138.7	OSM
6/1/1999	7.1	482	254.2	5944	140.0	1.72	0.05	3320					WVU
9/20/1999	7.38	546	302.0	5932	165.73	2.65	0.05	3185	320.8	108.4	1310	97.8	OSM

Water Quality in the Paw Paw Siphon (continued, see report figures 1,3 and 19 for location)													
Date	pH	Alkalinity (mg/L $CaCO_3$ Eq)	Calculated Acidity (mg/L CaCO3 Eq)	Total Dissolved Solids (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Data Source
1/15/2000	7.3	554	240.4	5208	131.0	1.58	0.5	3310					NPDES
2/9/2000	7.35	705	260.4	5890	143.1	2.076	0.04	3132	305.7	102.5	1347	123	NPDES
2/15/2000	7.2	518	268.9	5690	148.0	1.66	0.12	3750					NPDES
3/15/2000	7.4	499	226.2	5747	124.0	1.87	0.12	3800					NPDES
4/15/2000	7.3	483	287.8	5677	159.0	1.27	0.12	3600					NPDES
5/15/2000	7.3	501	274.3	5405	151.0	1.69	0.12	3450					NPDES
6/15/2000	7.3	500	46.8	5426	24.15	1.59	0.11	3600					NPDES
7/6/2000	7.27	509	182.0	5620	99.58	1.862	0.04	3112	249.7	100.8	1330	132.3	OSM
7/15/2000	7.3	509	40.7	5370	20.27	1.46	0.31	3800					NPDES
8/15/2000	7.4	523	378.0	5470	209.0	1.64	0.1	3150					NPDES
9/15/2000	7.0	511	304.6	5363	168.0	1.54	0.15	3650					NPDES
10/15/2000	7.4	459	301.7	5278	166.0	1.86	0.16	3650					NPDES
10/18/2000	7.43	417	100.2	5198	54.49	1.286	0.04	2961	170.3	100.1	1275	117.4	OSM
11/15/2000	7.0	447	318.1	5394	175.0	1.93	0.19	3400					NPDES
1/15/2001	7.3	516	317.0	4789	175.0	1.48	0.13	3750					NPDES
2/15/2001	7.0	528	306.5	5441	169.0	1.54	0.17	3683					NPDES
3/15/2001	6.6	554	283.4		156.0	1.53	0.21	3741					NPDES
4/15/2001	7.0	551	255.5	5426	141.0	1.39	0.06	2883					NPDES
5/2/2001	7.68	523	111.9	5182	60.92	1.4	0.04	3237	185.7	91.88	1053	141.3	OSM
5/15/2001	6.9	541	284.7	5468	157.0	1.82	0.01						NPDES
7/15/2001	7.0	547	265.6	5346	146.0	1.77	0.15	2940					NPDES
8/15/2001	7.0	546	272.9	5125	150.0	1.66	0.21	2640					NPDES
9/6/2001	7.76	578	181.8		99.74	1.66	0.02	2961	245.7	95.61	1292		OSM
9/15/2001	7.1	542	211.8	4991	116.0	1.8	0.12	2533					NPDES
10/15/2001	7.2	564	250.9	5382	138.0	1.73	0.09	2726					NPDES
11/15/2001	7.3	475	304.7	5058	168.0	1.78	0.09	2651					NPDES
12/15/2001	7.3	496	296.9	5081	163.0	2.0	0.22	3365					NPDES
1/15/2002	7.2	534	276.4	5319	152.0	1.54	0.23	3047					NPDES
2/15/2002	7.3	555	244.9	5194	135.0	1.56	0.04	2404					NPDES
3/15/2002	7.2	572	267.2	5287	147.0	1.54	0.18	3018					NPDES
4/2/2002	7.63	489	91.2	4932	49.65	1.153	0.02	2760	147.9	92.3	1260	128.9	OSM
4/24/2002	7.55	560	149.3	5115	81.78	1.481	0.02	2887	224.6	101.7	1273	121.1	OSM
5/22/2002	7.25	564	230.9	5306	127.0	1.802	0.02	2922	266.6	93.0	1261	129	OSM

Water Quality in the Paw Paw Siphon (continued, see report figures 1,3 and 19 for location)													
Date	pH	Alkalinity (mg/L $CaCO_3$ Eq)	Calculated Acidity (mg/L CaCO3 Eq)	Total Dissolved Solids (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Data Source
6/18/2002	7.12	610	232.4	5266	128.03	1.589	0.02	2998	268.5	94.4	1282	128.3	OSM
11/8/2002	7.02	639	175.5	4839	96.45	1.441	0.02	2800	238.9	89.1	1194	124.7	OSM
12/17/2002	7.2	558	244.5	5194	134.75	1.632	0.02	2812	250.6	89.6	1254	119.9	OSM
7/30/2003	7.9	651	128.9	4730	70.40	1.39	0.05	2850	208	81	1060	123	OSM
10/8/2003	8.4	248	92.4	3764	49.0	2.4	0.05	2600	197	57.6	984	112	OSM
1/31/2004	7.11	710	177.8	4000	97.8	1.29	0.05	2360					NPDES
2/29/2004	6.85	662	163.7	4590	90	1.22	0.05	4420					NPDES
3/31/2004	6.60	574	70.5	4308	38.1	1.07	0.05	2500					NPDES
4/30/2004	7.10	715	65.4	4865	35.3	1.04	0.05	2440					NPDES
6/30/2004	6.70	711	19.8	4604	10	0.88	0.05	1920					NPDES
3/31/2005	6.70	853	92.2	4203	50.2	0.86	0.13	2230					NPDES
4/30/2005	7.00	895	110.2	4203	60.2	1.03	0.08	2230					NPDES
5/31/2005	7.00	895	110.2	4203	60.2	1.03	0.08	2230					NPDES
6/30/2005	6.50	249	60.0	4449	32.4	0.94	0.05	2320					NPDES
7/31/2005	6.50	249	60.0	4449	32.4	0.94	0.05	2320					NPDES
8/31/2005	6.60	651	57.9	3894	31.3	0.86	0.05	2240					NPDES
10/31/2005	7.30	62	5.2	4170		0.94	0.62	2400					NPDES
11/30/2005	6.80	596	56.8	4170	30.7	0.81	0.06	2400					NPDES
12/31/2005	7.20	647	53.0	4122	28.6	0.76	0.06	2432					NPDES
1/31/2006	6.30	625	57.0	4174	30.8	0.8	0.06	2277					NPDES
2/28/2006	6.30	593	51.1	4116	27.6	0.74	0.06	2416					NPDES
3/31/2006	6.40	613	56.4	4124	30.5	0.8	0.06	2268					NPDES
4/30/2006	7.30	602	111.5	4136	61.5	0.56	0.06	2152					NPDES
5/31/2006	6.80	607	53.3	4260	28.8	0.75	0.06	2215					NPDES
6/30/2006	7.20	610	52.7	4222	28.5	0.74	0.06	2338					NPDES
7/31/2006	6.50	590	60.5	4222	32.7	0.84	0.06	2338					NPDES
10/31/2006	7.00	602	92.3	4060	49.9	0.93	0.22	2130					NPDES
11/30/2006	7.00	610	47.2	3998	25.43	0.69	0.06	2431					NPDES
5/22/2002	7.25	564	230.9	5306	127.0	1.802	0.02	2922	266.6	93.0	1261	129	OSM
12/31/2006	6.90	610	77.4		41.93	0.83	0.13	2355					NPDES

Water Quality in the Paw Paw Siphon (continued, see report figures 1,3 and 19 for location)													
Date	pH	Alkalinity (mg/L $CaCO_3$ Eq)	Calculated Acidity (mg/L CaCO3 Eq)	Total Dissolved Solids (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Data Source
1/31/2007	7.40	625	107.6	4008	59	0.84	0.06	2336					NPDES
2/28/2007	7.40	642	131.8	4156	72.5	0.85	0.06	2696					NPDES
3/31/2007	6.70	618	140.7	4060	76.5	0.92	0.36	2320					NPDES
4/30/2007	7.00	561	47.4	4080	25.3	0.76	0.13	2349					NPDES
5/31/2007	7.40	300	68.8	4112	37.1	0.8	0.16	2261					NPDES
4/30/2008	7.09	547	65.1	3554	33.74	0.85	0.56	2068					NPDES
7/31/2008	6.98	640	109.6	3612	60.00	0.95	0.07	2161					NPDES
9/30/2008	7.15	664	111.3	3726	61.10	0.88	0.05	2032					NPDES
10/31/2008	7.18	644	124.8	3276	68.60	0.83	0.06	2147					NPDES
11/30/2008	7.13	603	105.9	3582	57.90	0.8	0.12	2128					NPDES
1/31/2009	7.15	659	136.8	3440	75.30	0.88	0.05	2177					NPDES
4/30/2009	6.87	613	103.7	3542	55.76	0.85	0.41						NPDES
6/30/2009	7.25	673	122.1	3262	67.20	0.85	0.02	2034					NPDES
7/31/2009	7.13	577	56.5	3790	30.60	0.71	0.06	2225					NPDES
8/31/2009	7.39	662	107.6	3450	58.93	0.94	0.06	2006					NPDES
9/30/2009	7.89	619	83.3	3442	44.30	0.83	0.44	2090					NPDES
10/31/2009	7.18	654	167.5	3622	92.40	0.82	0.08	1909					NPDES
11/30/2009	7.15	634	126.4	3678	69.50	0.86	0.06	2022					NPDES
12/31/2009	7.13	603	74.0	3572	40.30	0.76	0.08	1978					NPDES
1/31/2010	7.55	627	120.0	3266	66.10	0.78	0.03	2114					NPDES
2/28/2010	7.29	591	60.4	3754	32.82	0.76	0.04	1654					NPDES
3/31/2010	7.09	641	117.1	3552	64.50	0.77	0.03	1896					NPDES
4/30/2010	7.02	660	105.9	3786	58.20	0.8	0.03	2240					NPDES
5/31/2010	6.86	663	119.0	3616	65.60	0.76	0.02	2006					NPDES
6/30/2010	6.94	680	124.0	3488	68.30	0.73	0.06	2076					NPDES
7/31/2010	7.11	664	107.9	3598	59.30	0.69	0.07	2027					NPDES
8/31/2010	7.04	650	132.1	3620	72.80	0.79	0.04	1890					NPDES
9/30/2010	7.35	138	50.9	3426	27.60	0.72	0.03	2003					NPDES
11/30/2010	6.86	634	118.4	3508	65.30	0.7	0.02	1996					NPDES

Water Quality in the Paw Paw Siphon (continued, see report figures 1,3 and 19 for location)													
Date	pH	Alkalinity (mg/L $CaCO_3$ Eq)	Calculated Acidity (mg/L CaCO3 Eq)	Total Dissolved Solids (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Data Source
12/31/2010	6.86	632	107.6	3486	59.30	0.71	0.02	2019					NPDES
1/31/2011	7.03	683	98.1	3214	53.92	0.62	0.06	1867					NPDES
2/28/2011	7.12	638	115.8	3092	63.87	0.67	0.03	2090					NPDES
3/31/2011	6.91	571	106.2	3700	58.51	0.68	0.02	2000					NPDES
4/30/2011	7.02	664	116.4	3760	64.14	0.71	0.03	1999					NPDES
5/31/2011	7.28	674	114.7	3694	63.20	0.71	0.03	1984					NPDES
6/30/2011	7.13	627	119.7		65.98	0.69	0.05	1899					NPDES
7/31/2011	7.21	635	32.8	3586	17.48	0.75	0.02	2257					NPDES
8/31/2011	7.01	651	102.6	3650	56.44	0.66	0.05	2167					NPDES
9/30/2011	6.72	709	32.3	3614	17.26	0.65	0.03	2148					NPDES
10/31/2011	7.1	671	104.3	3556	57.51	0.64	0.02	1993					NPDES
11/30/2011	7.35	700	115.1	3600	63.43	0.69	0.03	2136					NPDES
12/31/2011	7.29	658	122.1	3418	67.33	0.7	0.03	2144					NPDES
1/31/2012	6.6	608	146.2	3730	81.00	0.54	0.02	2057					NPDES
6/30/2012	6.91	706	51.5	3171	27.94	0.54	0.09	2094					NPDES
7/31/2012	6.81	633	40.6	3496	22.05	0.55	0.02	2123					NPDES
8/31/2012	7.5	708	83.3	3484	45.68	0.64	0.05	1922					NPDES

Calculated Acidity computed from concentrations of iron, manganese, aluminum and pH.

Appendix C

Water Quality In Mine-pool Wells

Mine-pool Water Quality, Federal 1 Mine, Grantown well(see report figure 19 for location)												
Date	pH	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance	Total Dissolved Solids mg/L	Sulfate mg/L	Dis. Iron	Dis. Aluminum mg/L	Dis Manganese mg/L	Calcium mg/L	Magnesium mg/L	Sodium mg/L	Chloride mg/L
4/8/1999	7.02	366	3670	3353	1846	6.25	0.04	3.895	357	139	409	76
9/20/1999	6.95	352	3150	3469	1976	4.9	0.06	3.859	387	161	409	61
2/23/2000	7.00	359	3030	3240	1740	2.52	0.04	4.872	400	156	281	62
4/24/2002	7.07	249	3030	3654	2096	7.64	0.13	5.202	460	195	269	50
7/30/2003	6.72	310	3570	3265	1710	4.29	0.06	4.94	468	189	287	53
6/12/2008	6.84	266	3900	3144	2033	5.75	0.14	4.83	465	177	254	15
6/29/2011	6.57	210	2540	2126	1406	2.49	0.19	3.3	327	117	177	36
Mine-pool Water Quality , Williams 98 Mine, #7 Pump well(see report figure 19 for location)												
Date	pH	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance	Total Dissolved Solids mg/L	Sulfate mg/L	Dis. Iron	Dis. Aluminum mg/L	Dis Manganese mg/L	Calcium mg/L	Magnesium mg/L	Sodium mg/L	Chloride mg/L
4/5/2005	6.98	554	2680	1908	841.9	17.50	0.05	0.21	124	21	519	3
4/17/2008	6.63	550	2980	1674	817	5.93	0.03	0.24	115	19	478	3
Mine-pool Water Quality, Beth 41Mine, Barrackville well(see report figure 19 for location)												
Date	pH	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance	Total Dissolved Solids mg/L	Sulfate mg/L	Dis. Iron	Dis. Aluminum mg/L	Dis Manganese mg/L	Calcium mg/L	Magnesium mg/L	Sodium mg/L	Chloride mg/L
9/9/1998	6.90	583	2360	1851	795	60.87	0.03	0.924	268	37	246	46
4/21/1999	7.85	454	1458	979	295	12.53	0.13	0.479	123	21	188	29
9/20/1999	7.27	444	1499	990	291	12.37	0.12	0.487	140	21	179	36
2/23/2000	7.39	672	1700	1078	239	7.24	0.05	0.575	184	27	239	24
8/7/2001	7.10	671	2010	1248	323	12.49	0.05	0.51	192	28	323	48
5/22/2002	7.82	598	1820	946	154	2.18	0.02	0.275	105	17	219	40
7/30/2003	7.28	609	1630	870	112	1.44	0.2	0.26	85	14	243	43
6/5/2008	7.32	716	1009	898	63	0.19	0.06	0.08	28	6	346	6

Water Quality in Mine-pool Wells (continued)												
Mine-pool Water Quality Consol 38 Mine, FP-1 Well(see report figure 19 for location)												
Date	pH	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance	Total Dissolved Solids mg/L	Sulfate mg/L	Dis. Iron	Dis. Aluminum mg/L	Dis Manganese mg/L	Calcium mg/L	Magnesium mg/L	Sodium mg/L	Chloride mg/L
9/9/1998	6.63	155	857	592	262	12.91	0.04	1.43	65.8	16.7	82.7	18
9/20/1999	6.74	197	1226	807	353	11.39	0.04	1.52	100.3	23	133.4	46
10/18/2000	7.27	228	919	582	186	6.81	0.04	0.36	76.9	18.9	94.6	31
9/6/2001	7.42	162	750	555	169	2.3	0.04	0.42	47.8	11.2	94.6	29
12/17/2002	7.32	179	832	548	207	3.44	0.02	0.54	60.7	14.1	105.7	34
10/18/2003	7.42	163	635	493	140	4.2	0.05	0.64	60.6	13.4	60.6	21
4/6/2004	6.68	200	923	442	153	4.31	0.33	0.66	79.2	17.2	62.4	15
5/11/2005	6.95	157	771	392	138	0.53	<.05	0.44	75.5	14.6	52.1	24
4/17/2008	6.42	177	637	382	127	0.79	0.03	0.46	64.5	14.6	46.4	20
6/30/2010	6.41	183	778	440	131	1.48	0.13	0.32	68.2	13.9	64.7	33
Mine-pool Water Quality in Mountaineer 92/43/63 Mine, Pump Station 6 well(see report figure 19 for location)												
Date	pH	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance	Total Dissolved Solids mg/L	Sulfate mg/L	Dis. Iron	Dis. Aluminum mg/L	Dis Manganese mg/L	Calcium mg/L	Magnesium mg/L	Sodium mg/L	Chloride mg/L
6/18/2002	6.96	444	3560	2468	1345	24.66	0.02	0.45	121.6	25.3	649	35
12/17/2002	7.31	589	4100	3301	1697	33.89	0.02	0.64	158.4	33.1	853	44
7/31/2003	6.8	604	4290	2972	1560	30.9	0.06	0.59	151	28.8	769	45
4/5/2005	6.93	511	3730	2358	1233	22.4	0.05	0.38	115.9	22.5	668	5.5
4/17/2008	6.68	660	4760	2826	1493	21.18	0.02	0.41	135.1	27.1	825	70
6/29/2011	6.57	605	3400	2460	1212	16	0.02	0.32	120	22.8	722	45

Appendix D

WVDEP CHIA Trend Station Water Quality in Buffalo Creek

Buffalo Creek CHIA Trend Station at Barrackville (see report figure 23 for location)										
Date	Flow (CFS)	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids (mg/L)	Sulfate (mg/L)	T. Iron (mg/L)	T. Aluminum (mg/L)	T. Manganese (mg/L)	Data Source
10/23/2002	16.8	8.26	260	1408	844	136	0.12	0.5	ND	WVDEP
11/14/2002	55.6	7.98	52	990	572	24	0.11	0.8	ND	WVDEP
12/21/2002	NA	8	56	467	268	106	0.48	0.216	0.07	WVDEP
2/4/2003	NA	7.49	40	344	184	98	15	5.4	0.9	WVDEP
2/25/2003	NA	8.03	154	215	108	55	0.71	0.6	0.09	WVDEP
3/24/2003	86.1	7.21	114	782	460	187	0.18	0.068	0.04	WVDEP
4/16/2003	141	8.28	140	505	276	149	0.13	0.088	ND	WVDEP
5/9/2003	NA	7.63	84	381	264	99	6.19	4.3	0.67	WVDEP
6/17/2003	NA	7.86	174	360	184	95	1.43	1.4	0.07	WVDEP
7/8/2003	NA	7.81	204	1030	812	196	0.79	0.385	0.12	WVDEP
8/19/2003	68	8.35	140	1231	728	314	0.14	0.087	0.03	WVDEP
9/16/2003	19.1	8.08	202	825	532	223	0.14	0.024	0.03	WVDEP
10/7/2003	45	8.33	162	1370	892	272	0.1	0.052	0.03	WVDEP
11/5/2003	87	7.89	200	542	352	95	0.21	0.067	0.05	WVDEP
12/9/2003	102	8.02	196	510	272	87	0.12	0.147	ND	WVDEP
1/14/2004	NA	8.05	158	433	268	110	0.25	0.132	0.06	WVDEP
2/17/2004	NA	7.56	102	462	256	79	0.21	0.096	0.1	WVDEP
3/16/2004	NA	7.65	144	503	252	124	0.28	0.176	0.03	WVDEP
4/13/2004	NA	7.09	94	261	164	66	6.04	3.4	0.72	WVDEP
5/4/2004	86	8.04	200	714	408	242	0.1	0.089	ND	WVDEP
6/7/2004	76	7.97	200	958	664	599	0.08	0.026	0.05	WVDEP
7/5/2004	27	8.44	276	1434	928	563	ND	ND	0.04	WVDEP
8/3/2004	36	8.41	184	1146	708	80	0.15	0.104	0.05	WVDEP
10/19/2005	3.16	8.46	406	3850	3312	227	0.06	0.044	0.08	WVDEP
11/16/2005	NA'	7.69	136	959	696	65	0.23	0.262	0.05	WVDEP
1/11/2006	72.7	7.66	276	510	324	45	0.19	0.153	0.04	WVDEP
2/7/2006	NA'	7.22	70	264	156	83	0.2	0.09	0.04	WVDEP
3/14/2006	NA'	6.92	54	167	152	53	1.08	0.59	0.17	WVDEP

Buffalo Creek CHIA Trend Station at Barrackville(continued, see report figure 23 for location)										
Date	Flow (CFS)	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids (mg/L)	Sulfate (mg/L)	T. Iron (mg/L)	T. Aluminum (mg/L)	T. Manganese (mg/L)	Data Source
4/17/2006	174	7.51	84	591	320	72	0.28	0.227	0.17	WVDEP
5/10/2006	34.4	8.1	138	1087	580	156	0.22	0.031	0.08	WVDEP
6/12/2006	47.5	6.87	120	549	288	68	0.33	0.277	0.09	WVDEP
7/11/2006	82.6	7.19	110	630	388	143	0.25	0.208	0.09	WVDEP
8/16/2006	12.6	8.6	280	1770	1112	480	0.22	0.213	0.12	WVDEP
9/13/2006	18.1	8.71	266	2730	1720	641	0.39	0.36	0.04	WVDEP
10/9/2006	43.5	7.71	158	508	268	117	0.26	0.117	ND	WVDEP
11/14/2006	NA'	7.62	54	357	212	84	0.12	0.113	0.07	WVDEP
12/13/2006	54.8	8.01	210	1275	740	281	0.27	0.045	0.08	WVDEP
1/18/2007	NA'	7.51	78	324	208	80	0.31	0.197	0.05	WVDEP
2/13/2007	FROZEN	7.89	106	1284	796	206	0.2	0.041	0.1	WVDEP
3/7/2007	NA'	7.2	138	473	264	109	0.07	0.05	ND	WVDEP
4/13/2007	NA'	7.01	78	255	128	67	0.32	0.188	0.05	WVDEP
5/22/2007	23.2	7.85	138	926	612	211	0.1	0.065	0.06	WVDEP
6/19/2007	2.98	7.71	254	1850	1248	487	0.06	0.094	0.18	WVDEP
7/23/2007	8.74	7.95	204	1186	688	176	0.21	0.247	0.16	WVDEP
8/21/2007	NA'	6.93	62	185	136	45	3.67	2.4	0.44	WVDEP
9/18/2007	8.21	7.5	204	991	560	165	0.35	0.098	0.07	WVDEP
10/5/2007	7.76	7.71	208	1239	724	220	0.23	0.105	0.04	WVDEP
11/15/2007	NA'	7.91	258	1830	1204	427	2.32	1.2	0.13	WVDEP
12/14/2007	NA'	6.95	36	149	112	40	0.83	0.396	ND	WVDEP
1/25/2008	FROZEN	7.39	122	770	432	133	0.18	0.166	0.11	WVDEP
3/4/2008	NA'	7.11	58	320	180	62	0.82	0.231	0.06	WVDEP
3/27/2008	NA'	7.08	86	546	320	68	0.41	0.175	0.07	WVDEP
4/4/2008	35	7.63	118	564	316	75	0.29	0.15	0.05	WVDEP
5/27/2008	NA'	7.21	118	503	264	85	0.46	0.107	0.08	WVDEP
6/24/2008	40.3	8.22	152	1131	688	254	0.14	0.078	0.05	WVDEP
7/28/2008	29.8	7.8	136	730	409	154	0.1	0.094	0.06	WVDEP

Buffalo Creek CHIA Trend Station at Barrackville(continued, see report figure 23 for location)										
Date	Flow (CFS)	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids (mg/L)	Sulfate (mg/L)	T. Iron (mg/L)	T. Aluminum (mg/L)	T. Manganese (mg/L)	Data Source
8/25/2008	8.26	8.26	334	2461	1808	591	0.25	0.053	0.1	WVDEP
9/8/2008	3.81	8.1	352	3210	2465	871	0.13	0.069	0.11	WVDEP
10/20/2008	2.03	8.3	436	3740	2560	555	ND	ND	0.09	WVDEP
11/4/2008	7.57	8.26	382	3071	2048	661	ND	ND	0.05	WVDEP
12/2/2008	NA'	7.34	116	432	228	69	0.41	0.146	ND	WVDEP
1/20/2009	NA'	7.39	88	263	141	104	0.22	0.198	0.09	WVDEP
2/10/2009	NA'	7.28	64	277	141	55	0.51	0.883	0.06	WVDEP
3/3/2009	58.5	8	146	520	311	95	0.21	0.127	0.06	WVDEP
4/13/2009	NA'	7.92	74	376	208	72	0.16	0.061	0.11	WVDEP
9/15/2009	2.68	8.24	288	2670	1781	541	0.14	0.101	0.07	WVDEP
10/5/2009	8.84	8.1	216	2670	1357	558	0.08	0.046	ND	WVDEP
11/5/2009	19.4	7.96	144	714	468	131	ND	ND	ND	WVDEP
12/7/2009	40.4	7.99	140	636	400	106	0.15	0.057	0.08	WVDEP
1/11/2010	33.9	8.33	152	654	338	95	0.16	0.029	ND	WVDEP

Appendix E

WVDEP CHIA Trend Station Water Quality in Paw Paw Creek

Paw Paw Creek Trend Station at Baxter Upstream of Siphon(see report figure 23 for location)										
Date	Flow (CFS)	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids (mg/L)	Sulfate (mg/L)	T. Iron (mg/L)	T. Aluminum (mg/L)	T. Manganese (mg/L)	Data Source
10/23/2002	3.9	8.26	218	1926	1286	248	0.25	*0.5	ND	WVDEP
11/15/2002	9.49	7.95	88	1129	760	235	0.24	0.075	ND	WVDEP
12/21/2002	59.9	8.15	96	579	292	139	0.53	0.234	0.09	WVDEP
2/4/2003	NA	7.28	28	265	144	72	0.28	0.133	0.1	WVDEP
2/25/2003	NA	8.19	138	314	200	82	0.47	0.5	0.09	WVDEP
3/25/2003	24.2	7.8	88	541	284	130	0.24	0.058	0.08	WVDEP
4/21/2003	30.4	7.52	112	549	348	139	0.17	0.081	0.03	WVDEP
5/9/2003	NA	7.22	60	246	196	66	23.4	12.7	2.89	WVDEP
6/17/2003	70.4	8.15	116	428	216	136	0.33	0.098	0.03	WVDEP
7/8/2003	15	8.15	178	729	504	191	0.13	0.131	0.05	WVDEP
8/19/2003	NA	8.4	132	1589	1205	650	0.09	0.039	ND	WVDEP
9/16/2003	6	8.12	156	1519	1084	402	0.13	ND	0.03	WVDEP
10/7/2003	7	8.21	170	800	600	137	0.12	0.036	0.03	WVDEP
11/5/2003	11	7.8	142	660	492	50	0.18	0.024	0.03	WVDEP
12/9/2003	22.4	7.73	118	598	376	155	0.23	0.039	0.08	WVDEP
1/14/2004	31	8.15	106	707	388	138	0.54	0.129	0.09	WVDEP
2/17/2004	29.3	7.68	102	494	312	92	0.44	0.07	0.17	WVDEP
3/16/2004	50	7.57	124	509	256	232	0.36	0.154	0.05	WVDEP
4/13/2004	NA	6.97	64	266	184	62	5.37	2.5	0.52	WVDEP
5/6/2004	17	7.66	150	729	428	254	0.13	0.049	0.03	WVDEP
6/9/2004	14	7.58	208	767	404	278	0.16	0.065	ND	WVDEP
7/7/2004	8	7.78	156	1118	636	348	0.11	0.06	ND	WVDEP
8/3/2004	7	8.45	150	1231	836	178	0.06	0.051	ND	WVDEP
10/19/2005	0.82	8.1	196	2150	2000	228	ND	0.06	ND	WVDEP
11/16/2005	NA	7.73	116	1014	760	101	0.38	0.44	0.17	WVDEP
1/11/2006	19	7.86	92	512	332	45	0.23	0.078	0.07	WVDEP
2/7/2006	40.1	7.43	90	480	288	159	0.16	0.098	0.03	WVDEP
3/14/2006	NA'	7.28	88	465	252	55	0.53	0.412	0.14	WVDEP

Paw Paw Creek Trend Station at Baxter Upstream of Siphon (continued, see report figure 23 for location)										
Date	Flow (CFS)	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids (mg/L)	Sulfate (mg/L)	T. Iron (mg/L)	T. Aluminum (mg/L)	T. Manganese (mg/L)	Data Source
4/17/2006	41.4	7.75	96	561	304	80	0.18	0.15	0.04	WVDEP
5/10/2006	12.4	8.06	72	887	544	127	0.14	0.026	0.04	WVDEP
6/12/2006	14.3	7.72	154	758	504	89	0.11	0.062	0.03	WVDEP
7/11/2006	6.58	7.63	126	766	436	167	0.13	0.07	0.03	WVDEP
8/16/2006	1.55	8.85	242	1963	1280	448	0.06	0.091	ND	WVDEP
9/13/2006	3.27	8.48	136	1891	1072	295	0.05	ND	ND	WVDEP
10/9/2006	9.66	8	216	1002	632	141	0.27	0.135	ND	WVDEP
11/14/2006	35.4	7.87	62	478	280	130	0.07	0.055	0.06	WVDEP
12/13/2006	15.8	8.26	312	935	556	205	0.25	0.073	0.08	WVDEP
1/18/2007	80.2	7.61	94	393	272	1	0.25	0.133	0.08	WVDEP
2/13/2007	FROZEN	7.57	86	1053	624	174	0.23	0.061	0.12	WVDEP
3/7/2007	47.3	7.02	84	612	340	93	0.21	0.042	0.08	WVDEP
4/24/2007	30.2	7.52	132	575	352	124	0.17	0.118	0.05	WVDEP
5/22/2007	6.1	8.1	144	1220	776	411	0.14	0.086	ND	WVDEP
6/19/2007	0.873	8.05	144	1580	1044	438	ND	0.096	0.07	WVDEP
7/23/2007	NA'	8.09	134	1999	1808	581	0.14	0.168	ND	WVDEP
8/21/2007	NA'	7.15	100	359	196	86	0.65	0.21	0.15	WVDEP
9/18/2007	2.31	8	210	1792	1012	455	0.12	ND	ND	WVDEP
10/5/2007	2.08	7.88	178	1970	1368	577	0.12	0.045	ND	WVDEP
11/15/2007	NA'	7.51	90	676	496	111	0.72	0.677	ND	WVDEP
12/14/2007	NA'	7.35	64	255	156	61	0.47	0.284	ND	WVDEP
1/25/2008	FROZEN	7.42	122	870	468	216	0.26	0.195	0.12	WVDEP
3/7/2008	NA'	7.57	80	473	284	93	0.33	0.188	0.04	WVDEP
3/27/2008	29.4	7.02	106	640	352	104	0.42	0.155	0.07	WVDEP
4/4/2008	7	7.8	120	711	392	115	0.35	0.135	0.06	WVDEP
5/27/2008	40.9	7.2	114	569	324	72	0.35	0.171	0.09	WVDEP
6/24/2008	11.5	8.45	128	1252	804	242	0.13	0.092	ND	WVDEP
7/28/2008	4.11	8.05	156	1240	863	414	0.09	0.069	ND	WVDEP

Paw Paw Creek Trend Station at Baxter Upstream of Siphon (continued, see report figure 23 for location)										
Date	Flow (CFS)	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids (mg/L)	Sulfate (mg/L)	T. Iron (mg/L)	T. Aluminum (mg/L)	T. Manganese (mg/L)	Data Source
8/25/2008	1.54	8.08	154	2320	1632	621	ND	0.026	ND	WVDEP
9/8/2008	2.1	7.6	188	2230	1753	661	0.06	ND	ND	WVDEP
10/20/2008	1.54	8.11	154	2320	1565	596	0.07	0.024	ND	WVDEP
11/4/2008	1.14	8.01	240	2109	1556	488	ND	ND	ND	WVDEP
12/2/2008	12.8	7.55	156	857	494	208	0.31	0.188	ND	WVDEP
1/20/2009	NA'	7.54	106	315	291	81	0.24	0.404	0.11	WVDEP
2/10/2009	88.1	7.37	106	465	236	90	1.12	0.603	0.09	WVDEP
3/3/2009	NA'	8.06	150	861	449	87	0.32	0.119	0.07	WVDEP
4/13/2009	NA'	7.34	94	465	259	97	0.13	0.047	ND	WVDEP
9/15/2009	NA'	8.43	192	3160	2172	731	0.16	0.052	0.08	WVDEP
10/5/2009	2.65	8.19	240	2370	1236	587	0.16	0.093	0.09	WVDEP
11/5/2009	5.25	7.95	152	1024	599	170	0.08	ND	0.06	WVDEP
12/7/2009	8.58	8.08	156	957	508	218	0.11	0.022	0.06	WVDEP
1/11/2010	NA'	8.28	132	1124	647	264	0.26	0.035	0.08	WVDEP

Appendix F

OSM Water Quality Data in Buffalo Creek and Paw Paw Creek

Paw Paw Creek at Siphon - OSM Samples(see report figure 23 for location)												
Date	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids	Sulfate (mg/L)	Dis. Iron (mg/L)	Dis. Aluminum (mg/L)	Dis Manganese. (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)
9/9/1998	8.40	176	1700	1641	824	0.18	0.02	0.012	124	35	330	97
1/20/1999	8.15	66	240	319	111	0.11	0.06	0.053	33	8	37	13
4/20/1999	8.28	79	440	300	121	0.14	0.05	0.026	38	9	40	12
9/20/1999	8.08	145	1000	929	449	0.04	0.06	0.009	103	30	157	42
2/9/2000	8.44	134	640	415	175	0.47	0.04	0.031	63	15	60	26
7/6/2000	8.36	124	530	347	134	0.25	0.04	0.01	59	12	39	10
10/18/2000	7.97	154	1200	1121	526	0.11	0.08	0.016	110	24	205	66
5/2/2001	8.70	135	590	437	148	0.01	0.01	0.06	54	14	55	17
9/6/2001	8.12	155	920		356	0.08	0.02	0.03	77	20	365	
4/2/2002	8.38	84	420	246	86	0.01	0.04	0.028	37	9	25	9
10/8/2003	8.20	137	630	450	147	0.06	0.05	0.02	70	15	56	24
Paw Paw Creek at Mouth - OSM Samples(see report figure 23 for location)												
Date	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids	Sulfate (mg/L)	Dis. Iron (mg/L)	Dis. Aluminum (mg/L)	Dis Manganese. (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)
9/10/1998	7.98	179.96	1400	1271	622	0.03	0.03	0.057	107	30	238	75
1/20/1999	8.06	69.1	270	324	106	0.08	0.05	0.101	34	8	35	15
4/20/1999	8.19	86.7	400	303	110	0.06	0.04	0.039	38	10	35	11
9/20/1999	7.76	103.3	740	662	314	0.02	0.05	0.026	71	19	108	26
2/23/1999	7.89	82.3	350	230	80	0.07	0.05	0.048	39	9	15	6
7/6/2000	8.03	119.7	470	333	111	0.08	0.04	0.052	56	12	31	10
10/18/2000	7.59	157.7	1000	925	417	0.3	0.08	0.125	98	21	159	50
5/2/2001	8.05	140.2	580	429	162	0.01	0.04	0.05	54	15	56	16
4/2/2002	8.47	91.2	430	253	85	0.01	0.04	0.061	40	10	25	9

Buffalo Creek Near Mouth, OSM Samples(see report figure 23 for location)												
Date	pH (lab)	Alkalinity mg/L $CaCO_3$ Eq	Specific Conductance (lab, µS/cm)	Total Dissolved Solids	Sulfate (mg/L)	Dis. Iron (mg/L)	Dis. Aluminum (mg/L)	Dis Manganese. (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)
9/10/1998	7.68	63	470	359	171	0.02	0.03	0.077	47	11	33	9
1/20/1999	7.97	52	220	280	96	0.12	0.08	0.04	24	5	37	14
4/20/1999	7.95	49	220	197	47	0.12	0.07	0.026	21	5	12	4
9/20/1999	7.92	35	350	223	118	0.03	0.05	0.072	30	7	32	10
2/9/2000	7.21	46	460	277	124	0.19	0.04	0.186	38	9	34	20
7/6/2000	7.93	70	360	240	80	0.18	0.16	0.027	26	6	34	7
10/18/2000	7.29	51	320	197	77	0.15	0.11	0.139	30	7	21	9
5/2/2001	8.05	133	770	559	241	0.03	0.04	0.04	43	13	119	36
4/2/2002	7.8	78	440	260	95	0.09	0.1	0.097	33	7	37	12