SECTION I: Introduction

I.A – Overview

This section provides a description of the need for this study and a list of its aims and objectives. It also contains background explanations of certain topics that are relevant to the report and that provide context for subsequent sections.

I.A.1 – Need for this Study

Section 18.1 of the Bituminous Mine Subsidence and Land Conservation Act (BMSLCA) requires the Pennsylvania Department of Environmental Protection (PADEP) to compile, on an ongoing basis, information from mine permit applications, monitoring reports, and enforcement actions. It also requires PADEP to report its findings regarding the effects of underground mining on overlying land, structures, and water resources to the Governor, General Assembly and Citizens Advisory Council at five year intervals.

The Act further stipulates that PADEP is to engage the services of recognized professionals or institutions for purposes of assessing the effects of underground mining and preparing these reports. PADEP initiated a contract with the University of Pittsburgh (hereafter: The University) on 1 September 2012 to fulfill the assessment and reporting requirements for the period from 21 August 2008 to 20 August 2013 (hereafter: 4^{th} assessment period).

I.A.2 – Underground Bituminous Coal Mining's Historical Role in Pennsylvania

Pennsylvania's coal production began with the capture of the sun's energy by ancient plants and the subsequent deposition of layers of undecayed or partially decayed plant matter approximately 300 million years ago. Over the millennia, these layers of plant matter were subjected to low oxygen availability and high pressure and temperature as additional layers of sediment were deposited above the plant layers. The result is the sedimentary (bituminous) or metamorphic (anthracite) rock layers known as coal, which consists mainly of carbon, though it can contain substantial amounts of other elements including hydrogen, sulfur, oxygen and nitrogen. The energy of the sun, stored in the chemical bonds among the materials making coal, represents a substantial treasure that can fuel economic development and prosperity. Coal is the major source of electricity generation worldwide, accounting for 41% of electrical energy production (International Energy Agency 2013). Electricity use scales closely with general metrics of human well-being, measured either by economists as gross domestic productivity or by United Nations as the Human Development Index (Pasternak 2000).

In the Commonwealth of Pennsylvania, the extraction of bituminous coal has a 200 year history and has played a significant role in the state's economic development for over 125 years. Today, coal extraction remains an important industry. In 2012, the U.S. Energy Information Administration reported that Pennsylvania's bituminous underground coal mines directly employed 5,992 workers (U.S. Energy Information Administration 2013a) and produced 44,922,000 tons (short tons) of coal (U.S. Energy Information Administration 2013b), the fourth-largest volume of coal production among the 50 states.

From a national perspective, Pennsylvania's mines represent (U.S. Energy Information Administration 2013b):

- 9.6% of the total number of underground coal mines,
- 10.7% of the total production from underground coal mines,
- 10.6% of the total employment for underground coal mines

While much coal has been mined, there remain approximately 423 million tons of recoverable reserves of bituminous coal in Pennsylvania (U.S. Energy Information Administration 2013c). The coal industry in Pennsylvania directly and indirectly employs approximately 41,577 workers, generates $3.2 billion in economic output and provides tax revenues of approximately $750 million (Pennsylvania Coal Alliance 2012). These data demonstrate the prominent role coal plays in the lives of Commonwealth citizens.

I.A.3 – Environmental Consequences of Mining

The extraction and use of coal in driving the local economy and fueling global development nevertheless has costs. At the global scale, coal contributes disproportionately to global warming relative to other energy sources. Coal has relatively low carbon-use efficiency for the generation of power: In the U.S., coal combustion supplies 39% of total electricity generation but contributes to 75% of the carbon dioxide emissions from the electricity sector (U.S. Environmental Protection Agency 2014). On a local scale, the abundance of coal-related jobs also comes at a cost to both the natural and built environment. Extraction of coal can impact stream ecological health, water and sewer supply systems, roadways and built structures. It is our difficult task as citizens of the Commonwealth to elect lawmakers that will determine the mix of laws and policies that provide energy, jobs, and economic well-being while taking into account the need to maintain healthy lives and a healthy environment for our children and the generations to come. The increasing ability to measure and understand economics, engineering, geology, atmospheric and ecosystem science results from the Industrial Revolution, which has been largely driven by the energy derived from coal. This increased knowledge has resulted in recognition that extraction and use of energy can be accomplished with more sustainable and less harmful techniques. At both state and federal levels, laws and regulations have been adopted and refined toward that end. Today, society demands that the coal mining industry extract this mineral in an environmentally acceptable manner. The outcome of those demands, both in the activities of PADEP as the key regulatory agency concerned with underground mining, and the responses of mine operators, are the subject of this report.

I.B – Environmental Laws and Coal Mining

In the 1940s the Commonwealth began to legislatively recognize the necessity of environmental stewardship to prevent permanent and widespread destruction of its land and water. The Clean Streams Law was amended in 1945 to include acid mine drainage as a pollution source that required regulation. In that same year, the Commonwealth passed the Surface Mining Conservation and Reclamation Act (Act 418), representing its first comprehensive attempt to prevent pollution from surface coal mining. From this point forward, the Commonwealth passed a number of laws that directly addressed environmental issues associated with the deep mining of bituminous coal beds.

I.B.1 – Bituminous Mine Subsidence and Land Conservation Act of 1966 (BMSLCA)

The most significant of these laws was the BMSLCA of 1966. For the first time, certain structures built before April 1966 had to be protected from subsidence regardless of coal ownership rights beneath the structure. This law suggested that coal extraction ratios of less than 50% be used to protect surface properties, but also indicated that specific guidelines could be set by the state.

Gray and Meyers (1970) suggested that the area required underground to minimize subsidence damage on the surface was dependent on the selection of an adequate angle of support (Figure I-1). The angle of support was most dependent on the geologic character of the rocks and, in their report, varied from 15 to 25-degrees. The net result required the support base at the mining level to increase between 53 to 93-ft along its horizontal axis with every 100-ft of overburden. The outcome was a support area for 500-ft of overburden that was equivalent to 3.4 times the support area required at 100-ft of overburden. This method remains the basic support area design for structures requiring damage prevention.

The BMSLCA also established various requirements such as permitting, mapping, protection of certain structures from subsidence damage, repair of subsidence damage to certain structures, and the right of surface owners to purchase support for their structures. Section 4 prohibited subsidence damage to certain structures, homes, public buildings, noncommercial structures, and cemeteries in place on 27 April 1966. Section 6 required operators of underground mines to 1) repair damage within six months and 2) secure a surety bond to cover possible future property damage. Section 15 provided certain owners the right to purchase the coal located beneath their property. This law did not contain any provisions addressing water supplies.

I.B.2 – 1980 amendments to BMSLCA

The BMSLCA was first amended in 1980 to help bring it into compliance with the minimum requirements of the recently passed federal Surface Mining Control and Reclamation Act of 1977 (SMCRA). Section 4, which provided protection to certain structures, was amended to allow the current owner of the structure to consent to subsidence damage, but the damage had to be repaired or the owner compensated. Section 5 was amended to require an operator of an underground mine to adopt measures to prevent subsidence causing material damage to the extent technologically and economically feasible, as well as to maximize mine stability and to maintain the value and reasonably foreseeable use of the surface. These measures were to be described in the permit application. The new language also specifically provided that the new subsection was not to be construed to prohibit planned subsidence or standard room-and-pillar mining.

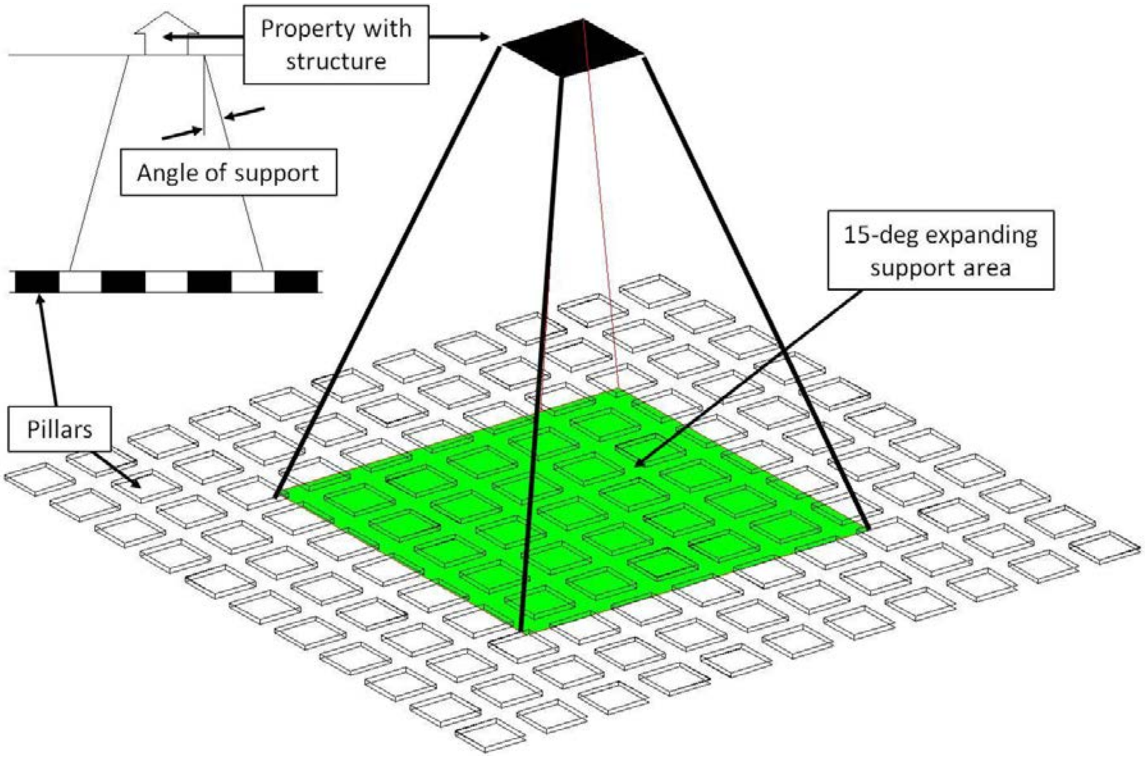

Figure I-1. An interpretation of pillar support required by the BMSLCA (1966) to protect structures from subsidence damage (from Iannacchione et al. 2011).

I.B.3 – Act 54 Amendments

By the mid-1980's, new environmental concerns were being raised about the BMSLCA. In 1986, Arthur Davis, a Professor at the Pennsylvania State University, organized the Deep Mine Mediation Project to bring together the underground bituminous coal industry, agricultural, and non-governmental organizations for the purpose of attaining a consensus position on the BMSLCA.

Ultimately, the state legislature prepared a number of statutory amendments to BMSLCA in 1992. The governor signed the legislation on 22 June 1994 and it became effective on 21 August 1994. This legislation is commonly referred to as Act 54. For the first time the law extended the obligation of coal companies to pay for damage caused to homes and businesses, regardless of when they were constructed. The Act 54 amendments also provided for the replacement of impaired water supplies and provided additional remedies for structural damage:

<u>BMSLCA – revised water supply replacement provisions</u>

- Established a rebuttable presumption zone (RPZ). The RPZ consists of an area above the mine that is determined by projecting a 35-degree line (from vertical) from the edge of mining to the surface. Within this zone, the mine operator is assumed liable for any contamination, diminution or interruption to water supplies.
- Entitled landowners with affected water supplies in the RPZ to a temporary water supply and restoration or replacement of a permanent supply by the mine operator.

- Entitled landowners with affected water supplies outside of the RPZ to permanent water supply restoration or replacement. However, if the operator contests liability in this zone, the burden of proof falls to the landowner or PADEP.
- Established that the RPZ does not apply if a landowner does not allow pre-mining surveys by the mine operator.
- Allowed for voluntary agreements between landowners and mine operators that stipulate the manner in which the water supply is to be restored or an alternate supply provided or that provide fair compensation for the impacts.

BMSLCA – revised structural damage repair provisions

- Mine operators were required to repair or compensate for subsidence damage to any building accessible to the public, non-commercial buildings customarily used by the public, dwellings used for human habitation, permanently affixed appurtenant structures and improvements, and certain agricultural structures.
- Entitled the structure owner or occupant to payments for temporary relocation and other incidental costs.
- Allowed the mine operator to conduct a pre-mining survey of the structure prior to the beginning of mining.
- Voluntary agreements were authorized between mining operators and landowners.
- Allowed underground mining beneath any structure, except a certain limited class of structures and features, as long as the consequential damages are not irreparable and are repaired.
- Stipulated that irreparable damage can only occur with the consent of the owner.

Act 54 imposed certain restrictions and responsibilities on mine operators and on PADEP. Coal operators were responsible for the restoration and/or replacement of a range of features located above, and adjacent to, active underground coal mines. It made PADEP responsible for ensuring the regulations and official mining permits were followed. PADEP was designated to conduct field investigations, examine and approve permits, and report to the general public and industry representatives with their findings.

I.B.4 –Act 54 Reporting Requirements

Act 54 contained a special provision requiring PADEP to produce an assessment of the surface impacts of underground bituminous coal mining every five years. To date three reports have been issued:

- 1st assessment: Submitted by the PADEP in 1999 (PADEP 1999; later amended, PADEP 2001). Covered the period 21 August 1993 to 20 August 1998.
- 2nd assessment: Submitted by California University of Pennsylvania in 2005 (Conte and Moses 2005). Covered the period 21 August 1998 to 20 August 2003.
- 3rd assessment: Submitted by the University of Pittsburgh in 2011 (Iannacchione et al. 2011). Covered the period 21 August 2003 to 20 August 2008.

The University of Pittsburgh was contracted by PADEP again in 2012 to conduct the 4th assessment.

Each report has generated productive discussions between the citizens of the Commonwealth and PADEP regarding desired enhancements to the content of the reports. This in turn has led to modifications of PADEP's reporting requirements associated with mining permits. The University's contract for production of the 4th report (Appendix A) also reflects those discussions. In particular, while mining companies are generally either able to repair, replace, or financially compensate for damages to structures, the ability to repair damage to streams remains largely unknown, as documented in the 3rd assessment. PADEP is therefore seeking a greater scientific understanding of the integrated hydrologic systems that link groundwater and surface water properties. The long-term goal is to better understand the effects of subsidence on the hydrology of undermined areas and thereby improve PADEP's ability to predict sustained damage to streams. To that end, PADEP requested that the University include an analysis of the hydrological impacts of subsidence. In addition, PADEP's task list associated with the contract reflects increased emphasis on comparisons of pre- and post-mining data for streams, both in terms of flow and macroinvertebrate community structure. Prior assessments struggled to make objective determinations of the extent of perturbation and recovery from mining-induced subsidence, highlighting the necessity for the pre-mining data. Also, due to the continuing concern about the length of time necessary for recovery of streams undermined in previous assessment periods, PADEP requested that the University re-visit specific streams from the last assessment that exhibit persistent flow loss problems. Finally, concerns were raised regarding the effects of underground mining on wetlands in response to the previous Act 54 reports. PADEP requested that the University assess pre- and post-mining data on wetland size and type to address these concerns.

I.C – Underground Bituminous Coal Mining Methods in Use in Pennsylvania

The three general methods to extract underground bituminous coal are described below.

I.C.1 – Room-and-Pillar Mining Method

All underground mines use the room-and-pillar mining methods in a similar fashion. Rooms or entries are typically driven 16 to 20-ft wide with continuous mining machines. These rooms outline pillars that are designed to support the overburden weight above the mine and prevent failure of the overlying strata. As long as the pillars are sufficiently sized to support the overburden and the floor rock is strong enough to prevent the pillars from punching or pushing into the bottom, subsidence should not occur with this mining method. Heights of mining range from 3 to 7-ft with some localized areas extending above and below these values. In general, the room-and-pillar mining method relies on two primary components – the main entries and the panels (Figure I-2). Main entries serve as long-standing points of access and egress from the underground and provide the primary means of supplying the underground workings with air, materials and transportation of coal from the working faces. The panels are less permanent and extract the coal in ways that comply with federal and state mining standards and regulations. A production panel begins from the main entries, extending in a series of parallel faces several hundred to several thousand feet into un-mined blocks of coal.

I.C.2 – Pillar Recovery Mining Method

Room-and-pillar mines can use pillar recovery to more fully extract the coal in select production panels (Figure I-2). The areas of pillar recovery mining are of variable shapes and sizes. Figure I-3 shows an example of a partially mined pillar. During pillar recovery, the majority of the pillar is removed, causing the roof strata to collapse into the void created by mining. While commonly employed in past mining operations, this method has seen infrequent use in recent years. When employed, pillar recovery occurs over a relatively small area. Impacts associated with the localized development of a subsidence basin do occur but represent a small fraction of the impacts recorded in PADEP's files (Appendix B).

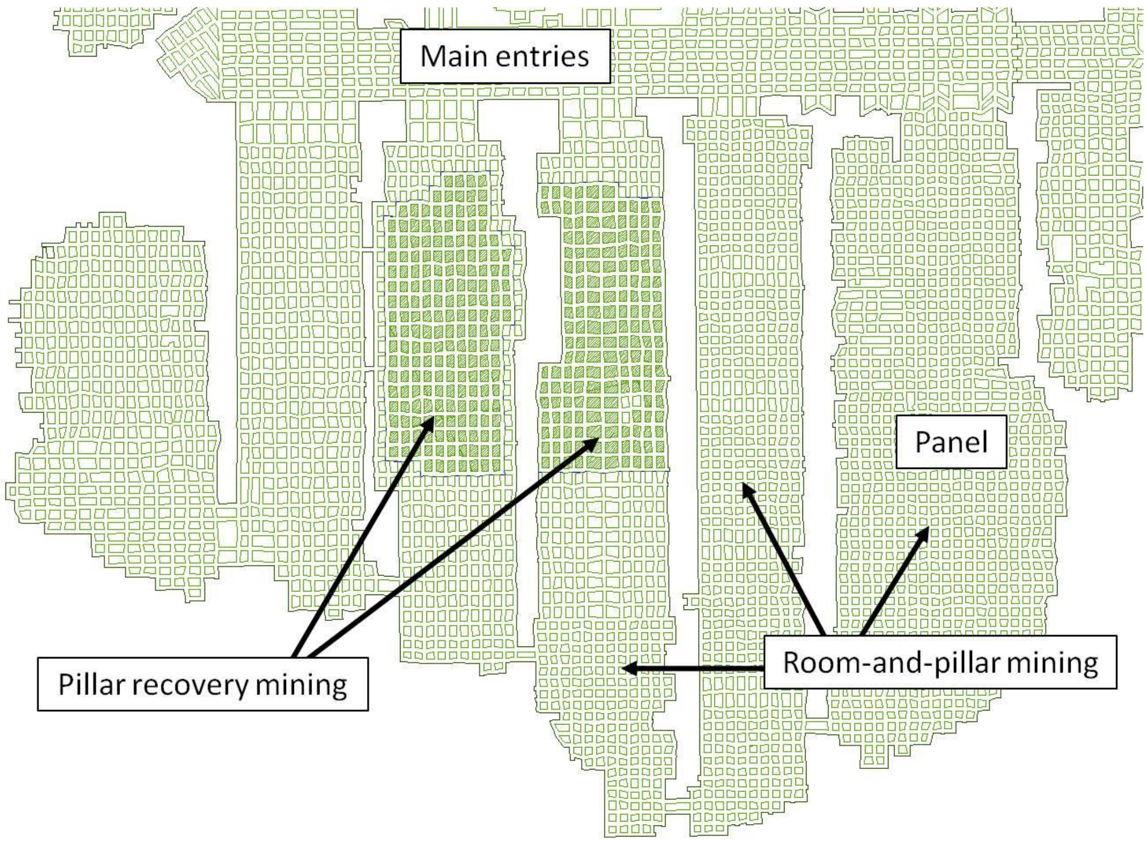

Figure I-2. Example of a room-and-pillar mine where main entries provide long-term access to production panels (from Iannacchione et al. 2011).Green shaded pillars indicate areas where pillar recovery occurred.

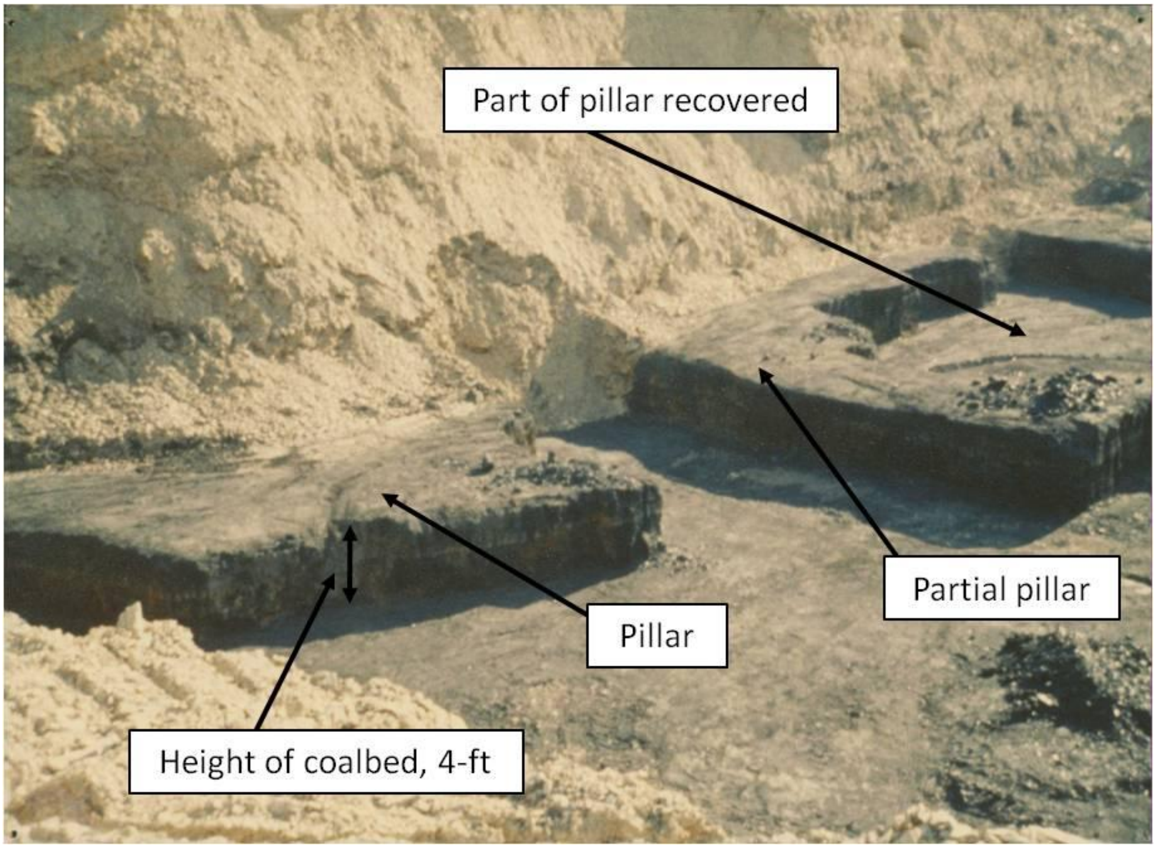

Figure I-3. In this photograph an abandoned mine was uncovered by surface mining revealing a partially mined pillar (from Iannacchione et al. 2011).

I.C.3 – Longwall Mining Method

In the longwall method a high-powered double drum shearer mines the face of the longwall panel. The shearer cuts, on average, 36-in of coal from its short dimension (the width) known as the longwall face (Figure I-4). Longwall operations use room-and-pillar mining methods to develop the main entries and the gate road entries that outline the rectangular panels. At some of the larger longwall mines, one pass of the shearer along a 1,200 to 1,500-ft long face supplies enough coal to fill a unit train. It can take several thousand cuts or slices along the longwall face to completely mine a panel. When a cut is taken, the longwall shield supports move behind the advancing face and allow the strata above the previous position to fall into the void. The entire void area is called the "gob". These longwall gobs are the primary mechanism for subsidence and are a central focus of this study. Six mines employed the longwall method during the 4th assessment period.

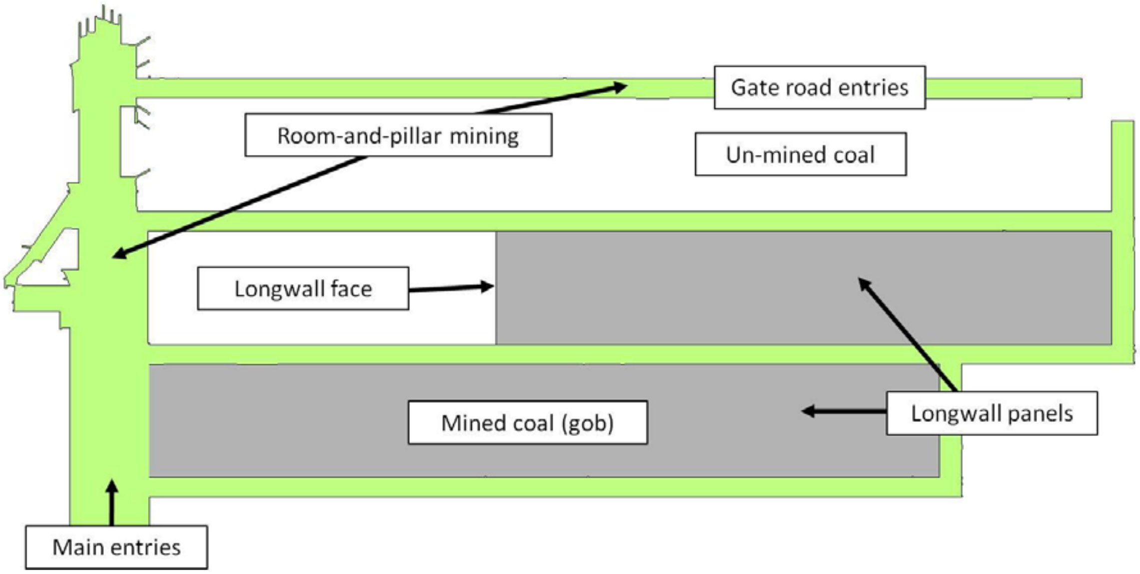

Figure I-4. Example of longwall mining method where longwall panels are developed off main entries and accessed by gate road entries both developed via room-and-pillar mining methods (from Iannacchione et al. 2011).

I.D – Geological Effects of Underground Bituminous Coal Mining

I.D.1 – Geological Effects of Room-and-Pillar Mining

Whenever coal is mined by the underground room-and-pillar mining method, an opening in the rock is created. Groundwater moving through overlying strata can find its way into these openings. Also, under-designed pillars can punch into a softer floor rock and potentially produce subsidence on the surface.

I.D.2 – Geological Effects of Pillar Recovery and Longwall Mining

Both pillar recovery and longwall mining allow the overlying strata to collapse into the mine void, resulting in the formation of a subsidence basin (Figure I-5; Peng 2006). The subsidence immediately above the caved, un-stratified rock layers, creates a zone of extensive fracturing, as much as 20 times the extraction zone height in thickness. In the Pittsburgh Coalbed, where all of Pennsylvania's longwall mining currently occurs, the zone of extensive fracturing can extend over 100-ft above mining. Less extensive, but more persistent fractures can extend over much greater distances and even intercept the surface. Above this zone, the stratum gently bends into the subsidence basin. This bending promotes separations along bedding as the strata moves inward toward the center of the subsidence basin. These fractures and bedding plane separations can affect the water-bearing strata by altering the groundwater flow path and velocity. In addition, the bending stratum introduces complex three-dimensional strain patterns that can stress structures and introduce damage.

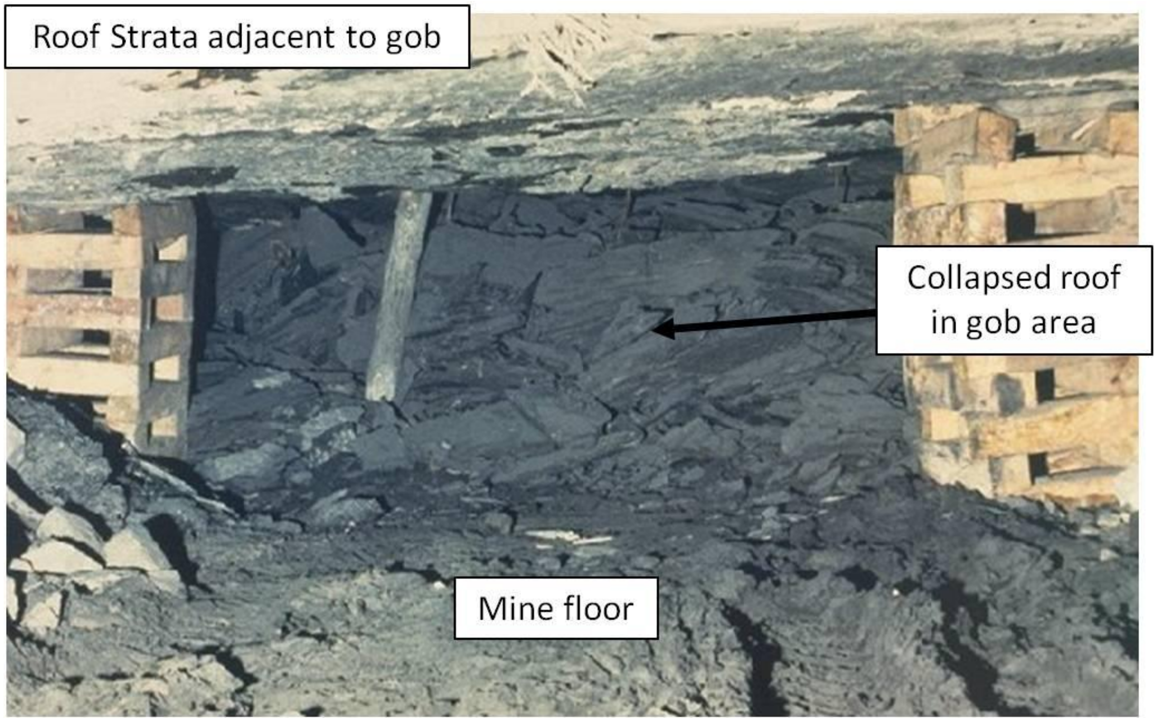

Figure I-5. Example of full extraction mining at the VP No.3 Mine in Virginia. At this mine the roof rock collapses into the void created by the extraction of the longwall panel (from Iannacchione et al. 2011).

I.D.2.1 – Formation of Subsidence Basins

A subsidence basin can be initiated when the extraction zone width-to-overburden ratio exceeds 0.25 (Peng 1992). In longwall mining, the extraction zone width during the 4th assessment period ranged from 1,061 to 1,564-ft (see Table III-8 in Section III). For the average longwall overburden condition of 783-ft (see Table III-11 in Section III), longwall panels have an extraction zone width-to-overburden ratio of 1.3 to 2.0. In pillar recovery mines, full extraction panels are typically 400 to 800-ft wide with overburdens averaging 538-ft (see Table III-11 in Section III), yielding ratios of 0.7 to 1.5. Therefore, a subsidence basin, with significant vertical deformations (> 1-ft), will develop with every longwall and pillar recovery panel mined in Pennsylvania. Furthermore, the maximum vertical subsidence is achieved when the extraction zone width-to-overburden ratio exceeds 1.0. The maximum vertical subsidence is dependent on the thickness of the extraction zone and a subsidence factor that is dependent on overburden, overlying strata properties, and the amount of coal removed.

As the working face of the coal mine advances, the extraction zone increases in size. The composition and thickness of the overlying rock helps determine the subsidence basin that propagates on the surface in advance of the working face underground. The angle between the vertical line at the extraction zone edge and the line connecting the extraction zone edge and point of critical deformation on the surface is called the angle of deformation (Peng and Geng 1982; Figure I-6).

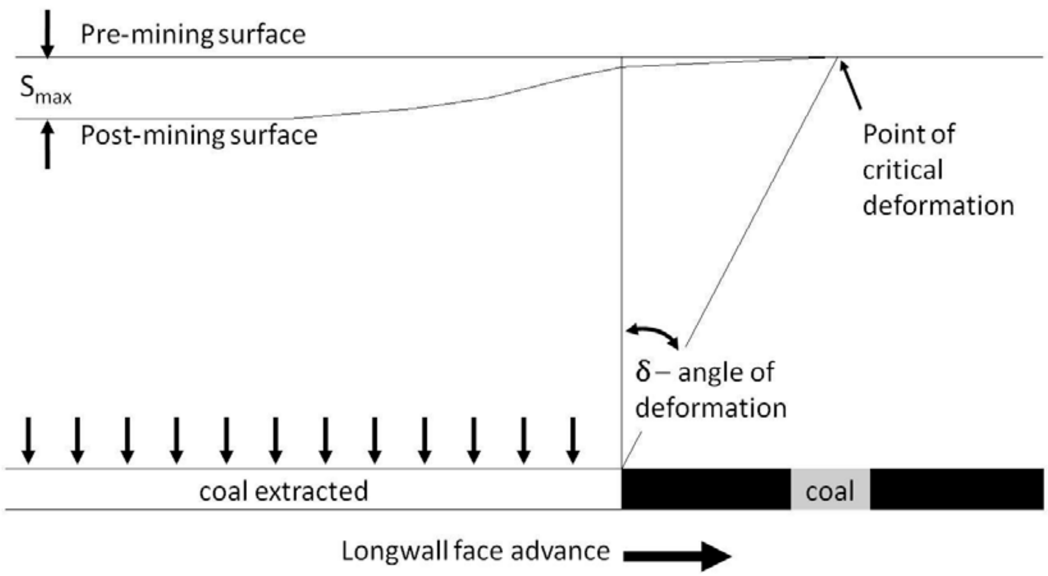

Figure I-6. Generalized model showing how a subsidence basin forms in association with longwall mining (from Iannacchione et al. 2011).

From the point of critical deformation back to the point above the working face, the surface begins to subside even though it is over solid unmined coal. In this zone, the ground surface is extended causing tensional ground strains. Once mining passes under a point on the surface, vertical subsidence accelerates and compression ground strains occur. Tension (extension) in the ground surface can initiate tensile fracturing in structures. Compression (buckling) in the ground surface can initiate shear ruptures and lateral offsets in structures. Finally, as mining moves away, vertical subsidence gradually reduces and movement stops. At this point in time, the maximum subsidence (S_{max}) is achieved and is generally 0.4 to 0.6 times the thickness of the underground extraction zone. In Pennsylvania, the extraction zone generally ranges from 5 to 7-ft, so S_{max} typically ranges between 2 and 5-ft.

I.D.2.2 – The Final Shape and Impact of the Subsidence Basin

Longwall mining subsidence basins are elliptically shaped, three-dimensional surfaces (Figure I-7). The edges of the subsidence basin extend beyond the boundaries of the longwall panel. S_{max} occurs in the center of the basin and subsidence rapidly lessens above the edges of the rectangular longwall panels. The area of the elliptical subsidence basin is significantly larger than the rectangular longwall panel that produces it.

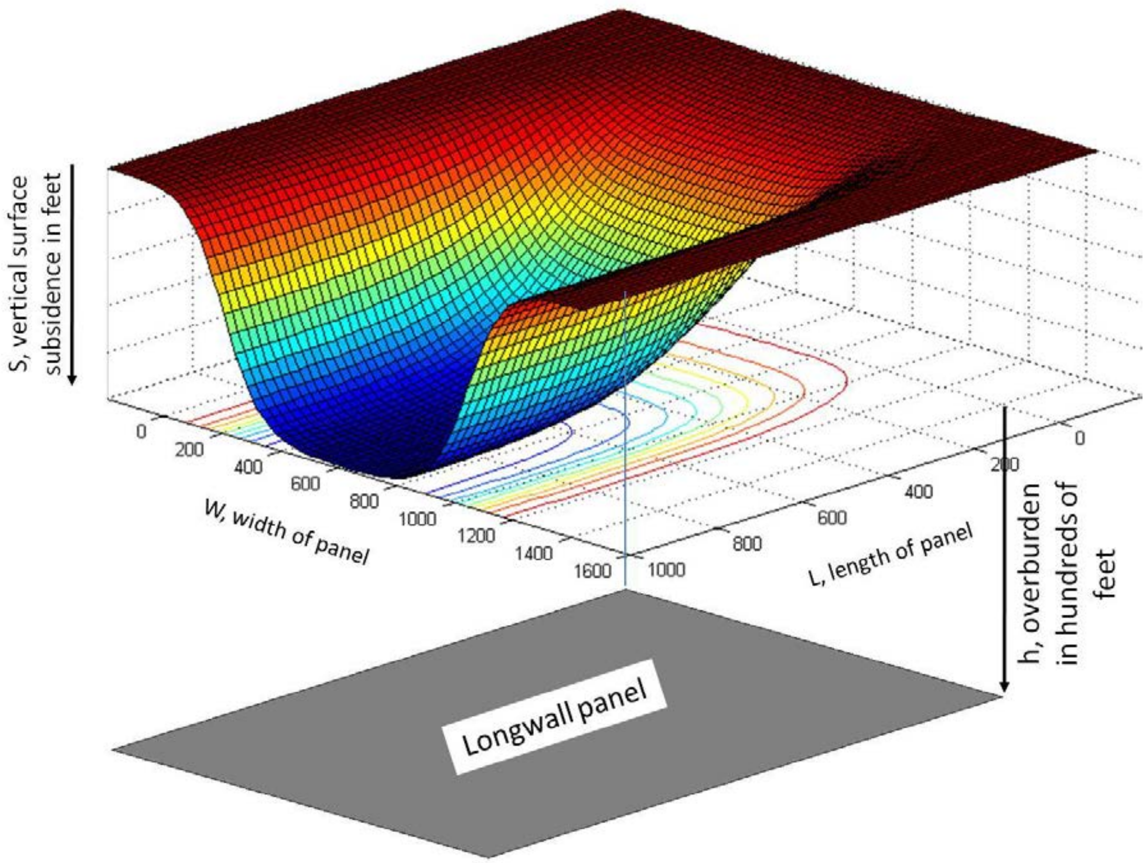

Figure I-7. 3-D view of an idealized subsidence basin overlying a portion of a typical longwall panel in Pennsylvania (from Iannacchione et al. 2011).

I.E. Impacts of Underground Mining on Surface Features and Structures

The majority of possible impacts related to underground mining are associated with mining induced surface subsidence.

I.E.1 – Structures: Impacts of Underground Mining

Any structure that falls within the subsidence basin has the potential to be impacted. The reasons for this are many, including rapidly changing surface slope, curvature, and horizontal strain conditions. Impacts to buildings and structures include shifting of foundations, extensional cracks in walls and floors, and buckling of walls and floors.

I.E.2 – Water supplies: Impacts of Underground Mining

Subsidence-related impacts to water sources can diminish water flow or alter hydrologic flow paths changing water chemistry and sometimes reduce its residential, agricultural and commercial value and use. Impacts to water sources have been occasionally known to extend beyond the subsidence basin (Witkowski 2011).

It should also be noted that room-and-pillar mining may also affect water supplies. The altered groundwater flow paths that can occur under specific conditions may impact the quantity and quality of water produced by wells and springs.

I.E.3 - Hydrology: Impacts of Underground Longwall Mining

Subsidence associated with underground mining has the potential to alter the hydrologic cycle in overlying areas. Changes to surface water flows, either through impedance (i.e. pooling) or routing of surface waters through sub-surface flowpaths (i.e. flow loss), are described below. However, the hydrological impacts to non-stream portions of the landscape are less well characterized. The hydrology of western, and particularly southwestern, Pennsylvania is dominated by interactions between the bedrock, which is composed of extensive strata of sedimentary rock, and the relatively rugged topography, which results from the incision of the surface water drainage network (Figure I-8). This geologic template results in substantial groundwater aquifers that sustain surface water flow during periods without precipitation and provide drinking water for many residents of Pennsylvania living beyond public water distribution networks. Further, these aquifers interact with the surface system in complicated hillslopes with numerous springs that are important for wildlife habitat and livestock watering. The surface disturbances associated with longwall mining have significant implications for these water resources, including the potential “loss” of wells accessing these aquifers (i.e. diminished water yields or water quality from these wells) and the potential loss of flow from springs along the hillslope.

There is a strong emphasis in the standing legislation and technical guidance toward repairing of hydrological impacts to existing water sources. The existence of water sources, by definition, relies heavily on the economic use of the water. However, the simple cycling of water through ground and soil water flow paths provides a wide range of services including provisioning of habitat for trees and various biota and the associated benefits ranging from atmospheric plant respiration inputs to hunting. The widespread diminishment of these processes affects citizens of the Commonwealth beyond individual property owners.

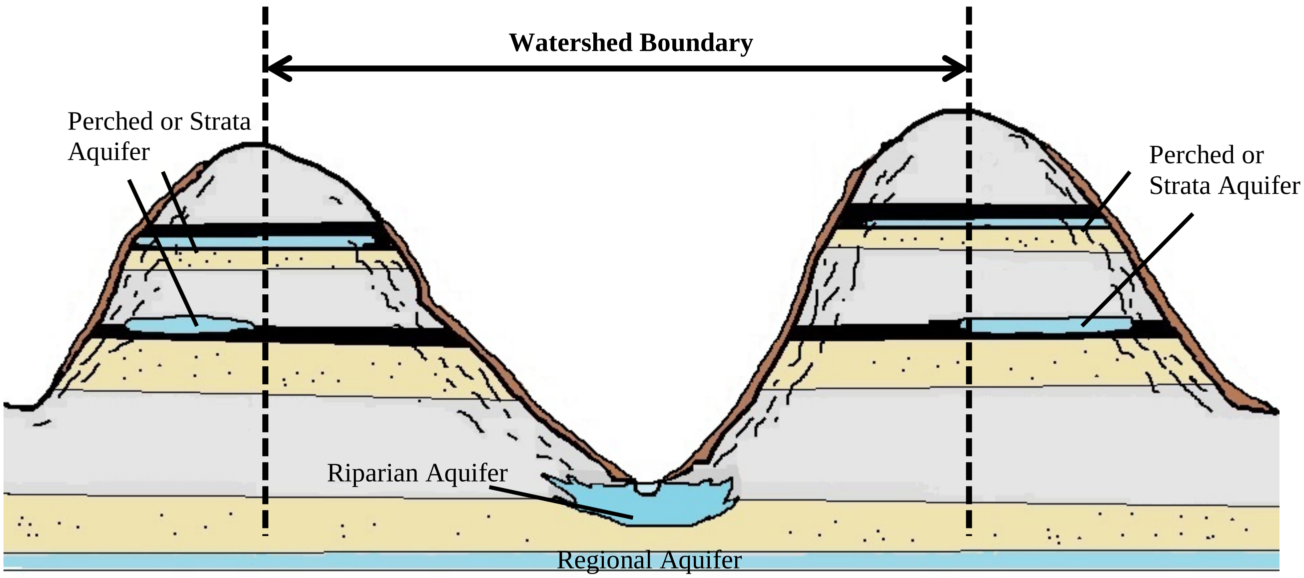

Figure I-8. Conceptual model showing watershed boundaries and ground water aquifer. Source waters and discharge points for ground water drainage patterns are challenging to characterize due to independence from surface topography.

I.E.4. Streams: Ecology and the Impacts of Underground Mining

With over 83,000 miles of streams (U.S. EPA 1998), Pennsylvania is rich in aquatic resources. Pennsylvania has the greatest miles of stream per square mile of land surface of any state in the continental U.S., with three-fold more than Ohio and 1.5-fold that of West Virginia. The total economic benefits derived from rivers and streams are substantial (U.S. National Park Service 2001). For example, angler use and harvest from trout-stocked streams in Pennsylvania generated over $65.7 million across the first eight weeks of the 2005 trout season (Greene et al. 2006). Thus, understanding the impact of underground coal mining on streams and rivers is an especially important issue in the Commonwealth.

In general, subsidence has two geological effects that can impact streams. First, the formation of the subsidence basins above the longwall panels in combination with the un-subsided gate road entries can act as barriers to stream flow. As a result of the uneven subsidence between panels and gate road entries, stream water can pool within the subsidence basin. Second, compressive and tensile forces generated in the bedrock between the mine and the surface can cause bedrock fracturing within and beneath the streambed. The fractures can lead to draining of surface water to deeper strata and loss of stream flow. The fractures can also redirect groundwater to deeper layers, resulting in the loss or reduction of groundwater input to the stream in the immediate area around the fractures.

Disturbances in stream flow and chemistry are widely regarded as the most critical factors influencing stream ecosystems (Resh 1988, Lake 2000, Bunn & Arthington 2002). The effects of pooling disturbances are likely similar to those associated with dams and weirs. Reduction in flow variability and lowered flow rates have been shown elsewhere to result, in some instances, in a number of adverse effects (reviewed in Bunn & Arthington 2002), including excessive stream vegetation growth (Walker et al. 1994), increases in undesirable insect species such as blackflies (De Moor 1986), reduced aquatic insect diversity (Williams and Winget 1979) and ultimately reductions in fish populations (Converse et al. 1998). The effects of subsidence-induced flow loss disturbances are analogous to those of a drought disturbance. During drought, flow loss creates a reduction in habitat space (Lake 2000). As a result, biota can become concentrated into small pools where predation and competition may be intense. Within these small pools, abiotic stressors such as high temperatures and low oxygen can also occur. The continuity of the stream system is broken, as resources that are introduced upstream are no longer carried downstream. Overall, pooling and flow loss result in physiochemical changes that can impact the aquatic life of a stream.

Under the authority of the Pennsylvania Clean Streams Law (35 P.S. §691.1 et seq.) and regulations in PA Code Title 25, including Chapters 86, 89, 93, 96 and 105, the PADEP "will ensure that underground mining activities are designed to protect and maintain the existing and designated uses of perennial and intermittent streams" (PADEP 2005a). In Pennsylvania, four designated uses for streams are identified and required by law (PA Code, Title 25, Chapter 93.3) to be maintained and propagated:

- <u>Cold water fishes</u> – waters containing or suitable for fishes, flora, and fauna that prefer cold water habitats, including fish species of the family Salmonidae (e.g. trout)
- <u>Warm water fishes</u> – waters containing or suitable for fishes, flora, and fauna that prefer warm water habitats
- <u>Migratory fishes</u> – water periodically containing or suitable for fishes that must move through flowing habitats to their breeding ground to complete their life cycle
- <u>Trout stocking</u> – waters stocked with trout and fishes, and the flora and fauna that are indigenous to warm water habitats

In addition, Technical Guidance Document 391-0300-002 (PADEP 2003) specifies criteria for classification as High Quality or Exceptional Value Waters. The ultimate criteria for establishment as Exceptional Value waters, and an important general criterion for establishing designated use category and its attainment, is based on the aquatic macroinvertebrate community the waters contain. Macroinvertebrate community composition generally predicts a stream's fish community (e.g. Lammert & Allan 1999). In addition, macroinvertebrate taxa span a wide range of trophic levels and pollution tolerance, so macroinvertebrate community composition can reflect the physical and chemical characteristics of the stream (Barbour et al. 1999). Measures of the macroinvertebrate community are therefore appropriate for assessing the influence of mining on local stream stretches.

I.E.5 – Wetlands: Ecology and Impacts of Mine Subsidence

In Pennsylvania, wetlands are defined as "areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs and similar areas" (PA Code, Title 25, Chapter 105.1; adopted from U.S. Army Corps of Engineers). Wetlands can provide a number of critical ecosystem services for humans, including flood mitigation, storm abatement, groundwater recharge, pollution prevention, and recreation (Mitsch and Gosselink 2007). Wetlands also provide critical habitat for animal and plant species, many of which are threatened or endangered. Indeed, 28% of plants and 68% of birds listed under the U.S. Endangered Species Act occupy wetland habitats (Mitsch and Gosselink 2007). As a result of their importance to both humans and wildlife, wetlands are protected under federal law. The primary regulation guiding wetland protection is Section 404 of the Federal Water Pollution Control Act (commonly known as the Clean Water Act). The U.S. Army Corps of Engineers is responsible for administering Section 404, with assistance from the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, and state agencies such as PADEP.

Wetlands are generally characterized by three features – wetland hydrology, hydric soils, and vegetation (Environmental Laboratory 1987). Ultimately, the ecological characteristics of wetlands are dictated by surface and groundwater inputs (Keddy 2000). Changes in water level can simultaneously create and destroy microhabitats within wetlands and affect the size and overall function of the wetland.

Mining-related subsidence can affect water levels in wetlands through three major routes. First, subsidence-induced pooling along streams can result in flooding of riparian wetlands. The excess surface water can increase the duration and extent of wetland saturation, resulting in the conversion of upland habitat to wetland habitat. Generally, these impacts are predicted to result in a net gain of wetland acreage. In contrast, subsidence-induced flow loss in streams can diminish surface water and groundwater inputs to riparian wetlands. Surface and sub-surface cracks in the bedrock can divert water away from wetlands, decreasing the zones of inundation and/or saturation. These impacts are predicted to result in a net loss of wetland acreage. Lastly, migration of springs and seeps down slope following mine subsidence could result in the re-location of slope-side wetlands. The migration of a spring or seep and loss of the groundwater discharge at that location is expected to result in the loss of wetland habitat. If the spring re-appears downslope, then a new wetland may be created at that location. Overall, impacts from underground mining can either increase or decrease wetland acreage. To comply with federal regulations, mine operators much show that no net loss of wetlands occurs.

I.F – Selection of Focal Watersheds for Detailed Case Studies of Mining Impacts

The impacts of subsidence are expected to vary with the geologic and hydrologic characteristics of the watersheds in which they occur. To explore how watershed characteristics influence surface impacts, seven focal watersheds were selected from four active longwall mines for detailed analysis (Figure I-10). The watersheds vary in size, land use, depth to mining (Table I-2) and other hydrogeological characteristics. Several chapters of this report will address the nature of surface feature impacts and mitigation/recovery within these focal watersheds.

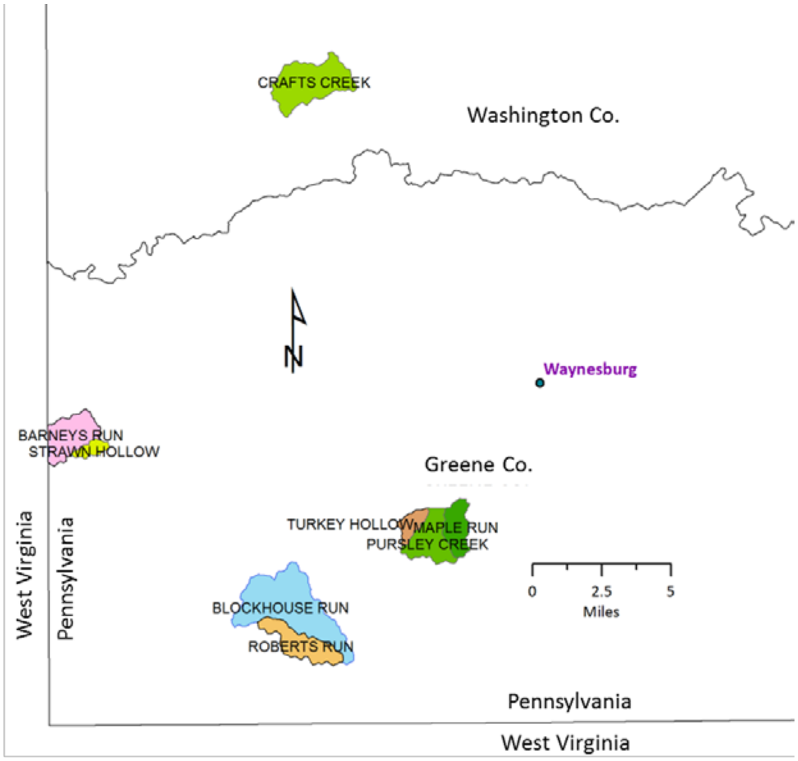

Figure I-10. Location of seven focal watersheds in Greene and Washington Counties.

Table I-2. List of focal watersheds for detailed case studies of mining impacts.

Mine	Focal Watersheds	Watershed Area, Acres	% Forest in Watershed	Average Depth to Mining (ft)	Stream Designated Use
Bailey	Barneys Run	1,506*	77%*	683.3	Trout-stocking fishery
Bailey	Strawn Hollow	349	76%	724.2	Trout-stocking fishery
Blacksville 2	Roberts Run	1,413	91%	955.6	Warm water fishes
Blacksville 2	Blockhouse Run	3,996	77%	964.9	Warm water fishes
Cumberland	Turkey Hollow	472	66%	932.6	High Quality – Warm water fishes
Cumberland	Maple Run	961	91%	852.5	High Quality – Warm water fishes
Cumberland	Pursley Creek	1,692**	80%**	886.7	High Quality – Warm water fishes
Enlow Fork	Crafts Creek	2,388	64%	669.2	Trout-stocking fishery

* - West Virginia portion of Barneys Run watershed not included

** - Includes only portion of Pursley Creek watershed upstream of confluence with Turkey Hollow

I.G. – Current Contract Tasks and Report Structure

The contract that funded this project identified 10 data-related tasks for the University (Appendix A). Listed below are the PADEP's tasks and the sections of this report which address each task.

- Task 1: Review of Information – Section II: Methods: Constructing the Act 54 Geodatabase
- Task 2: Statistical Data – Section III: Underground Bituminous Coal Mining During the 4^{th} Assessment Period
- Task 3: Stream Impacts – Section VII: Effects of Mine Subsidence on Streams During the 4^{th} Act 54 Assessment
- Task 4: Hydrologic Impacts – Section VI: Impacts of Longwall Mining on Groundwater
- Task 5: Stream Impacts - Flow Loss – Section VII: Effects of Mine Subsidence on Streams during the 4^{th} Act 54 Assessment *and* Section VIII: A Follow-Up on the Effects of Mine Subsidence on Streams during the 3^{rd} Act 54 Assessment
- Task 6: Stream Impacts – Pooling – Section VII: Effects of Mine Subsidence on Streams During the 4^{th} Act 54 Assessment
- Task 7: Wetland Impacts – Section IX: Effects of Mine Subsidence on Wetlands
- Task 8: Water Supply Impacts – Section V: Effects of Mining on Water Supplies
- Task 9: Structure Impacts – Section IV: Effects of Mining on Structures
- Task 10: Recommendations/Conclusions – Section X: Recommendations *and* Section XI: Summary and Conclusions

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