LONGWALL MINING A to Z:
Learning from the Pennsylvania Experience

Prepared for:

CITIZENS COAL COUNCIL

125 West Pike Street, Suite 2
Cannonsburg, PA 15317
(724) 338-4629
www.citizenscoalcouncil.org

Prepared by:

Schmid & Company, Inc.
Consulting Ecologists
1201 Cedar Grove Road
Media, PA 19063-1044
(610) 356-1416
www.schmidco.com

March 2016

TABLE OF CONTENTS

LIST OF FIGURES

LONGWALL MINING A to Z

Coal has been mined underground in the United States for more than 200 years. For most of that time the primary method of extraction was room-and-pillar mining, which continues to be a feasible and profitable mining method. Traditional room-and-pillar methods extract about 40-60% of the coal in an area, but leave enough coal in place (in the pillars) to support the mine roof and prevent surface subsidence. During the 1960s and 1970s, a higher-extraction method known as longwall mining was being introduced to this country. With the longwall method as much as 70-75% of the coal in an area currently can be extracted, but because it provides no surface support (except in the narrow gates between mine panels), roof collapse and surface subsidence are intrinsic to the longwall process. This report provides basic information about longwall mining and its effects in a simple dictionary-type format. It addresses key terms alphabetically for the general reader and provides citations to and links for sources of more detailed information.

Pennsylvania has been a major producer of coal since the late 1700s (PADEP 2014a) and currently is home to two of the largest longwall mines in the United States (Coal Age 2016). In 2014, bituminous coal was mined by underground methods at 48 mines in 9 Pennsylvania counties. Longwall mining was used at only 4 of those mines in 1 county (PADEP 2016). However, during the 2008-2013 period, longwall mining was responsible for 74% of all documented impacts to land, structures, and water supplies from underground bituminous mines in Pennsylvania (University of Pittsburgh 2014).

In 2013, coal produced by underground methods was reported for 17 States, and longwall mining was used in 11 of those States (EIA 2015). Pennsylvania is unique in that it is the only State where data about the effects of underground coal mining have been systematically collected, compiled, and analyzed by its main regulatory agency (the PA Department of Environmental Protection, or PADEP) for more than 20 years in accordance with a 1994 amendment to the State mining law. The focus here is on Pennsylvania, but this information is applicable to, and should be of great use in, other States where longwall mining is practiced but comparable documentation is not available.

Specific regulatory requirements for mining operations vary from State to State, but Pennsylvania is often regarded as one of the most proactive and stringent in terms of environmental protection requirements (personal communication with Ben Owens, OSMRE 2015). Despite having strict legal protections on paper, however, available data suggest that the application and implementation of those requirements has been inadequate in Pennsylvania. Like all of the coal mining States, Pennsylvania regulatory agencies face chronic budgetary and manpower shortages. Those administrative challenges, however, do not excuse allowing unavoidable damages to the land, water, or people.

A

ACT 54

Adopted on 22 June 1994, Pennsylvania Act 54 amended the State's 1966 mining law known as the Bituminous Mine Subsidence and Land Conservation Act (BMSLCA). For nearly 30 years Pennsylvania's 1966 Mining Law specifically prohibited damage by coal mine surface subsidence to most structures, including homes, public and quasi-public buildings (churches, hospitals, schools), and cemeteries. That prohibition was upheld throughout a protracted legal challenge by coal mine operators that went all the way to the US Supreme Court.

Act 54 fundamentally changed that prohibition, such that avoidance and minimization of damage were no longer required. Under Act 54, mine-related damages are allowed, with the expectation that mine operators will be responsible for repairing subsidence damages to structures and water supplies. With no incentive to avoid impacts, longwall mining technology instead has focused on increasing the scale and efficiency of coal extraction. As a result damages attributable to longwall mining have increased steadily in Pennsylvania. Rather than actually repairing damaged homes and water supplies, mine operators often settle claims through private agreements (with non-disclosure clauses) and either purchase a damaged property or provide financial compensation to affected private landowners. Longwall subsidence damages to streams, groundwater, and other natural resources are generally ignored (Schmid & Company, Inc. 2000, 2010b, 2011, 2015).

ACT 54 FIVE-YEAR ASSESSMENT

In accordance with Section 18.1 of Act 54, the PADEP is required to prepare, every five years, an analysis disclosing the effects of underground coal mining on subsidence of surface structures, features, and water resources. The main purposes of the Five-Year Assessments are to identify and analyze the impacts that occurred as a result of underground bituminous coal mining during the study period. The *need* for these assessments is based on the fact that when Act 54 was adopted in 1994, for the first time State law specifically allowed damages to occur at the land surface as a consequence of underground coal mining. The four Act 54 Assessments prepared to date (see box below) demonstrate that damage can occur from either room-and-pillar mines or from longwall mines. With room-and-pillar mining, the limited damage is unanticipated, whereas with longwall mining the substantial damages are an intrinsic, intentional part of the process. The Assessments also demonstrate that damages from longwall mining have become more numerous and

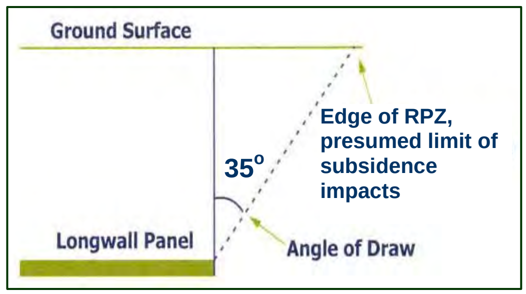
Four Five-Year Assessments have been prepared to date by the Department in accordance with Section 18.1 of Act 54:

Report	Year Released	Prepared by	5-Year Period	Report Cost
1st	1999	PADEP	1993-1998	N/A
1st (supplement)	2001	PADEP	1993-1998	N/A
2nd	2005	California University of Pennsylvania	1998-2003	$200,000
3rd	2011	University of Pittsburgh	2003-2008	$313,000
4th	2014	University of Pittsburgh	2008-2013	$603,000

more severe over time; sometimes they are irreparable. The first Act 54 Assessment was prepared in-house by the PADEP (PADEP 1999b, 2001); the next three were prepared on behalf of the PADEP by outside consultants (California University of Pennsylvania 2005, University of Pittsburgh 2011, 2014).

ANGLE OF DRAW

Angle of draw is a way to estimate the area on the surface that may be affected by longwall mining. It is determined by projecting a line tilted a certain number of degrees from vertical from the roof of the mine to the surface. One such angle of draw is called the Rebuttable Presumption Zone (RPZ). Act 54 established the RPZ as a 35-degree angle within which a mine operator is presumed to be liable for any contamination, diminution, or interruption to water supplies (see graphic).



Several Act 54 Assessments suggest that the 35° angle may not be large enough. The 2nd Assessment (California University of Pennsylvania 2005) questioned the validity of the 35°-angle standard, suggesting that a fixed horizontal distance (they suggested 328 feet) from the edge of longwall panels might be more realistic. That suggestion was not followed-up in the 3rd or 4th Assessments, despite much publicized damage to the dam at Ryerson Station State Park caused by nearby longwall mining at 66°, nearly twice the angle of predicted influence (PADEP 2010).

The 4th Assessment found that 25% of water supply effects occurred outside the RPZ, as much as 85 degrees outward and upward from the edge of mine panels. The validity of the 35°-angle of influence clearly needs to be reevaluated in light of current longwall mine practices and dimensions, which are significantly larger than in the 1990s. The land area encompassed by the angle of draw at the surface is important because the burden of proof shifts to the surface landowner for damages located outside the limit, and the mine operator is not required to perform premining inventories of the condition of features outside the limit as part of a permit application.

For other mine-related purposes a smaller (30°) angle often is required. In accordance with PADEP regulations at 25 *Pa. Code* §89.141 to prepare a

Subsidence Control Plan, a minimum 30° "angle of draw" is used, inside which a mine operator must describe which structures, facilities, or features may be materially damaged by mine subsidence.

In accordance with §89.142a, mine operators must complete a structure survey prior to the time that a structure falls within a 30° angle of draw of an underground mine panel. In addition, the Department could require an operator to install monitors within the 30° angle of draw to detect surface movement resulting from the underground mining, so that if excessive subsidence occurs the mining can be stopped before the protected structures or features are damaged. Neither monitoring data nor impact avoidance have been mentioned in any of the five-year Act 54 reports

In accordance with §89.154, a "general mine map" is to be prepared for each application showing all areas where structures may be damaged and surface lands may suffer material damage as a result of mine subsidence. At a minimum, the map must cover the entire area above the mine defined in the mine permit application, and all areas within a 30° angle of draw of the limits of the mine.

The PADEP also uses a 30^o angle for potentially affected landowner notification purposes. As described in a brochure on Act 54 (PADEP 2014b), a 30^o angle is used to determine properties located within the potential subsidence profile of each longwall mine. The mine operator is responsible for notifying each property owner within this zone of its planned mining operations. In all of these cases, if a 35^o angle currently is inadequate because properties often are impacted at greater distances than it would determine, then a 30^o angle appears to be even less useful.

AVOIDANCE (OF IMPACTS)

Under most State and federal environmental regulatory programs impacts are to be avoided as much as possible. There typically is a sequence whereby the permit applicant first is to avoid impacts, then any impacts that cannot be avoided are to be minimized. Only those impacts which cannot be avoided and have been properly minimized can be allowed, but then those impacts must be mitigated. Impact avoidance rarely happens under the Pennsylvania Mining Program because damages are *allowed* under Act 54, a major change from the 1966 Mining Law (see "Act 54" above and "BMSLCA" below). Allowing damage to structures and wells is understandable in one sense --- manmade things typically can be repaired. Restoring natural features and systems is a different matter altogether. Indeed, surface water and groundwater systems are so complex that it is exceedingly difficult even to fully understand how the various interrelated components work, much less to believe they can be fixed once damaged. Act 54 specifically states that it does not supersede the Pennsylvania Clean Streams Law, which would require avoidance and minimization of impacts to streams and other waters of the Commonwealth (see also "Clean Streams Law" and "Waters of the Commonwealth" below).

B

BACKSTOWING

Backstowing is a process whereby rock and other waste material inevitably extracted along with coal is returned to the void created by its removal prior to withdrawing hydraulic roof supports (National Academy of Sciences 1975). Where practiced, backstowing provides two significant benefits: (1) it reduces the amount of coal waste stored on the surface (coal waste areas not only are unsightly but can leach contaminants into surrounding waters), and (2) it fills up some of the underground void spaces, thereby lessening the opportunity for mine roof collapse and surface subsidence. Backstowing has been used successfully in Germany and Poland, and a related mitigation measure known as "overburden grout injection" has been used successfully in China (NSW Minerals Council 2007, Jianfeng *et al*. 2011). Backstowing virtually never is done in Pennsylvania, however, because the PADEP accepts the industry's unsubstantiated excuse that backstowing is impractical, despite findings that suggest otherwise (Roberts and Masullo 1986). A quarter-century ago a US Bureau of Mines report (Walker 1993) discussed numerous available methods for backfilling mine voids to reduce the probability of subsidence. While those techniques largely were focused on inactive mines, it suggested that "...*with the increased use of high-extraction mining methods, backfilling during the mining operation may be a future option for subsidence control*."

In accordance with PADEP regulations at 25 *Pa. Code* §89.142a(c) "*Backfilling or backstowing of voids*" is specifically cited as one of six available measures that mine operators could employ if there is a possibility that subsidence will cause material damage to, or reduce the reasonably foreseeable use of, certain structures and features. Such paper requirements are generally ignored and do not receive even lip service in longwall mine permit applications (Schmid & Company, Inc. 2000, 2010b). Without strict requirements to avoid and minimize surface impacts there is no incentive for industry to make backstowing technologically and economically feasible.

BALANCE

Balance is what Act 54 supposedly was intended to provide, according to proponents of the mining industry (Pippy 2015). However, it is not clear that anything ever was out of balance prior to Act 54, apart from mine operators' hopes for greater profit.

Prior to the passage of the Act 54 Amendments, even prior to 1966, there actually was a balance in underground coal mining. Coal companies (owners of the mineral estate) were expected to extract their coal in a way that did not harm the surface estate owners. The surface owners were entitled to the enjoyment of their surface lands, provided they did not damage the coal beneath the surface or prevent access to it. This balance worked reasonably well for more than 200 years --- and still works --- as coal companies profitably mine coal by the room-and-pillar method.

In the 1960s, with a rise in the use of the risky retreat mining method to achieve a higher percentage of coal extraction from room-and-pillar mines, damage to Pennsylvania's surface lands also was increasing. It was becoming clear that the former balance was being lost. In 1961 Pennsylvania initiated a Mine Subsidence Insurance program with a $1 million public endowment to help homeowners with subsidence damage from abandoned mines (see "MSI" below). Then in 1966 the Bituminous Mine Subsidence and Land Conservation Act was passed by the General Assembly to specifically prohibit damage to existing structures from underground mining subsidence.

For nearly three decades the 1966 mining law restored the balance, but eventually the longwall mining method was being improved and used as a less dangerous and more profitable high-extraction alternative to retreat mining. The 1966 law's prohibition on subsidence damage to surface structures was problematic for proponents of the longwall method for which subsidence is an intrinsic part. The coal industry objected to the need to leave any coal in place (in pillars) to support the surface, arguing that it amounted to an unjust "taking" of their property. Several large mine operators tried but failed to *overturn* the law in the courts (going as far as the US Supreme Court), so they then sought to *change* the law to allow longwall mining.

The theoretical "balance" mine operators wanted to build into the Act 54 amendment would allow them to use high-extraction mining methods that would intentionally cause damage, with the stipulation that structures and water supplies that subsequently were damaged by underground mining would be repaired or restored promptly. The idea was that if you broke it, you fixed it; damages could be and would be fixed. At least, that was the intent. The data provided in four Act 54 Five-Year Reports to date demonstrate that the intended "balance" is not working. On the one hand, the mine operators have used and improved longwall mining methods to increase production and decrease costs, leading to greater profitability. On the other hand, longwall mining has been associated with ever increasing impacts to surface lands and surface landowners. Only a small proportion of damages actually are being fixed, and landowners who are damaged by mining typically must wait years for some kind of resolution, a resolution for which they often must fight and which all too frequently is inadequate.

BITUMINOUS

One of the two common types (or ranks) of coal found in Pennsylvania (the other is anthracite). Coal forms when dead plant matter is converted into peat, which in turn is first buried and then converted by heat and immense pressure into lignite, then subbituminous coal, then bituminous coal, and lastly anthracite coal. The transformation from one to the next involves physical, biological, and geological processes that take place over thousands to millions of years. Bituminous coal is found principally in the western part of Pennsylvania, and anthracite is found in the northeast (**Figure 1**).

The primary bituminous coal bed mined by longwall methods in Pennsylvania is the Pittsburgh seam. Its thickness (6 to 8 feet), general uniformity, and wide extent make it suitable for the mechanized high-extraction longwall process. Other bituminous seams are mined by room-and-pillar and by surface methods in western Pennsylvania. Anthracite mining in eastern Pennsylvania has declined sharply during the past century.

BITUMINOUS MINE SUBSIDENCE AND LAND CONSERVATION ACT (BMSLCA)

BMSLCA is the original Pennsylvania underground coal mining law that was enacted in 1966. It was in effect for 28 years, until it was amended in 1994 by Act 54. Under BMSLCA, damage to most surface structures built before 1966 was prohibited. In adopting this law Pennsylvania was leading the nation in its early acknowledgment of, and attempts to prevent, environmental damages from coal mining.

Pennsylvania’s leadership in this regard was due in no small part to the fact that it already had had been a major coal-producing State for close to 2 centuries and had suffered the negative effects that distinction carried with it, including thousands of miles of streams impaired by acid mine drainage. SMCRA (Surface Mining Control and Reclamation Act), the comprehensive law regulating coal mining at the federal level, was not passed until 1977, and it drew heavily on the 1966 BMSLCA (McElfish and Beier 1990). The prohibition of surface damage in Pennsylvania ended with the enactment of the Act 54 amendments.

BONDING

Bonds typically are posted to allow restoration or reclamation to be completed in the event that a mine operator goes bankrupt or otherwise becomes unable to successfully complete the work necessary at the cessation of profitable coal removal. Such bonds generally are inadequate (McElfish and Beier 1990, Swanson 2002). At best, bonds are calculated to cover only those impacts which are specifically predicted to occur, such as to uncover a stream that was filled to construct surface facilities. (In fact, whether bonds actually cover all of the costs to fully restore a stream to its premining physical and biological condition is debatable; evidence for successful stream restoration is sparse.) No bonds are posted to restore flow to streams that experience flow loss, because lacking any model or basis for doing so, such impacts are never predicted. Also, according to Technical Guidance Document

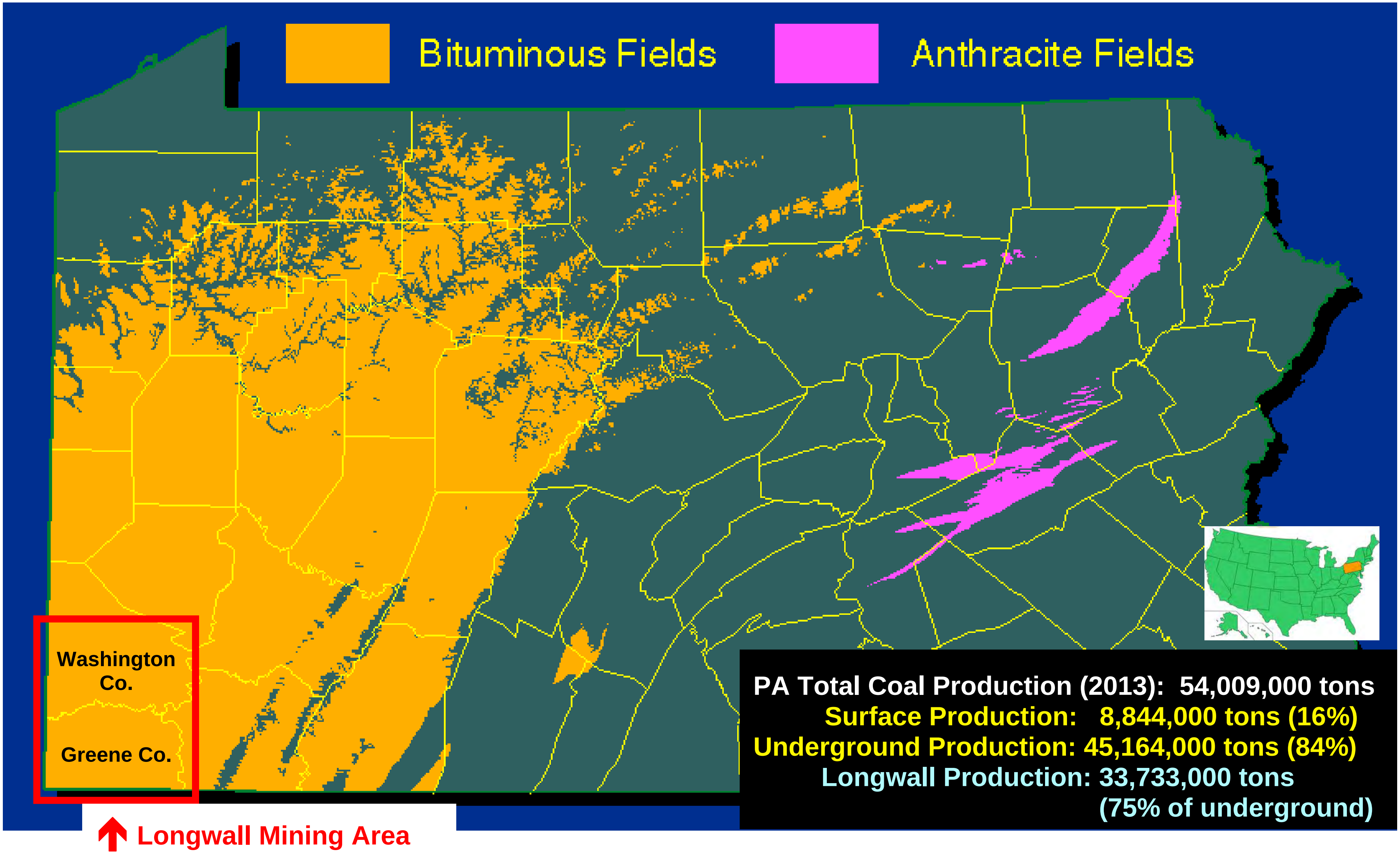


FIGURE 1. Locations of the coalfields of Pennsylvania. All longwall mining has occurred in the Pittsburgh seam of the bituminous coalfield in two counties in the southwestern corner of the State.

(TGD) 563-2504-101 (PADEP 2000), subsidence bonds are only required for predicted damage to perennial (not intermittent or ephemeral headwater) streams.

The recent fall in the price of coal, and its oversupply in the US due to phasing out of old coal-fired electric generating plants and stiff competition from natural gas, has led to consolidations, bankruptcies, and a sharp reduction in the stock price of many coal companies, including some very large ones. These events raise serious concerns about the adequacy of current bond amounts and the financial ability of companies to honor their commitments to reclaim and otherwise restore landscapes and waters damaged by their coal mining activities.

C

CLEAN STREAMS LAW

The Pennsylvania Clean Streams Law[1] (CSL) was adopted in 1937. By that time, more than 100 years of coal mining had polluted many Commonwealth streams by acid mine drainage (AMD). One of the primary objectives of the Clean Streams Law was to address past impacts from coal mining and prevent future mine-related stream pollution:

> "...regulating the operation of mines and regulating the impact of mining upon water quality, supply and quantity..."

The Pennsylvania CSL preceded by 11 years the original federal Clean Water Act, which was adopted in 1948 and at the time was called the Water Pollution Control Act[2]. Although the legacy of acid mine drainage still impairs more than 5,500 miles of streams in Pennsylvania (PADEP 2014c), regulators and mine operators have largely eliminated AMD from today's surface and underground coal mines.

Currently, both the PA Clean Streams Law and the federal Clean Water Act and their underlying regulations seek to protect the uses and functions of waterways. When it was passed in 1994, Act 54 specifically allowed damages to structures and wells. The allowance of damages also was applied by PADEP to streams and other natural features, even though Act 54 specifically stated that it did not supersede the Clean Streams Law. Thus, under Act 54, longwall mines presented a new threat to waterways --- the disruption of flow. The CSL protection for streams addresses more than merely traditional pollution like acid mine drainage --- its objective is to prevent adverse changes to the chemical, physical, or biological properties of waterways.

[1] The Clean Streams Law, Act of June 22, 1937, P.L.1987 as amended, 35 P.S. § 691.1
[2] Water Pollution Control Act of 1948, P.L. 80-845, 62 Stat. 1155

Unfortunately, the Pennsylvania Mining Program has been slow to recognize this and still has not effectively addressed the widespread effects to streams, wetlands, and other waters that are associated almost exclusively with longwall mines (Schmid & Company, Inc. 2011, 2014b, 2015a).

COAL

This is what it's all about. This finite resource was formed millions of years ago from thick deposits of vegetative matter that were subjected to a series of biological and geochemical processes (heat and pressure) that compressed it into coal. The organic carbon in coal was a convenient source of energy and chemical compounds that powered the Industrial Revolution. Coal usually occurs in layers or strata called coal beds or coal seams. The Pittsburgh coal seam in southwestern Pennsylvania is well suited to longwall mining because of its large extent and relatively uniform thickness of 6 to 8 feet. The most accessible coal deposits in Pennsylvania and elsewhere already have been extracted after more than 200 years of mining.

The remaining Pittsburgh seam reserves typically are deeper, and more difficult and more costly to access and extract without incurring serious damages. It is estimated that at current rates of extraction, the remaining coal in the Pittsburgh seam in PA will be mined out in about 3 decades (University of Pittsburgh 2014). In January 2016, the US Energy Information Administration (EIA) reported that 900 million short tons of coal were produced in the United States in 2015, a decline of about 100 million short tons from the previous year, and the lowest level of US coal production in 30 years (Associated Press 2016). Although coal long has been and continues to be the largest single source of electricity in the United States, it has declined from 50% to 38% of total generated power in the last ten years (**Figure 2**).

On a global scale the combustion of coal threatens massive environmental consequences from global warming, climate change, sea-level rise, and ocean acidification, even if its direct impacts on humans and other organisms can be controlled. Locally its extraction by longwall methods threatens structures, water resources, and other surface features.

CORPS (or CORPS OF ENGINEERS)

The US Army Corps of Engineers is the lead federal agency responsible for issuing Section 404 permits under the Clean Water Act. A permit from the Corps is required for any activity that would require fill to be placed in a stream or wetland within federal jurisdiction, such as for construction of a coal preparation plant, a coal refuse disposal area, or other surface facilities. The Pittsburgh District of the Corps has jurisdiction within the Ohio River Basin in western Pennsylvania, where all of Pennsylvania longwall mining is located.

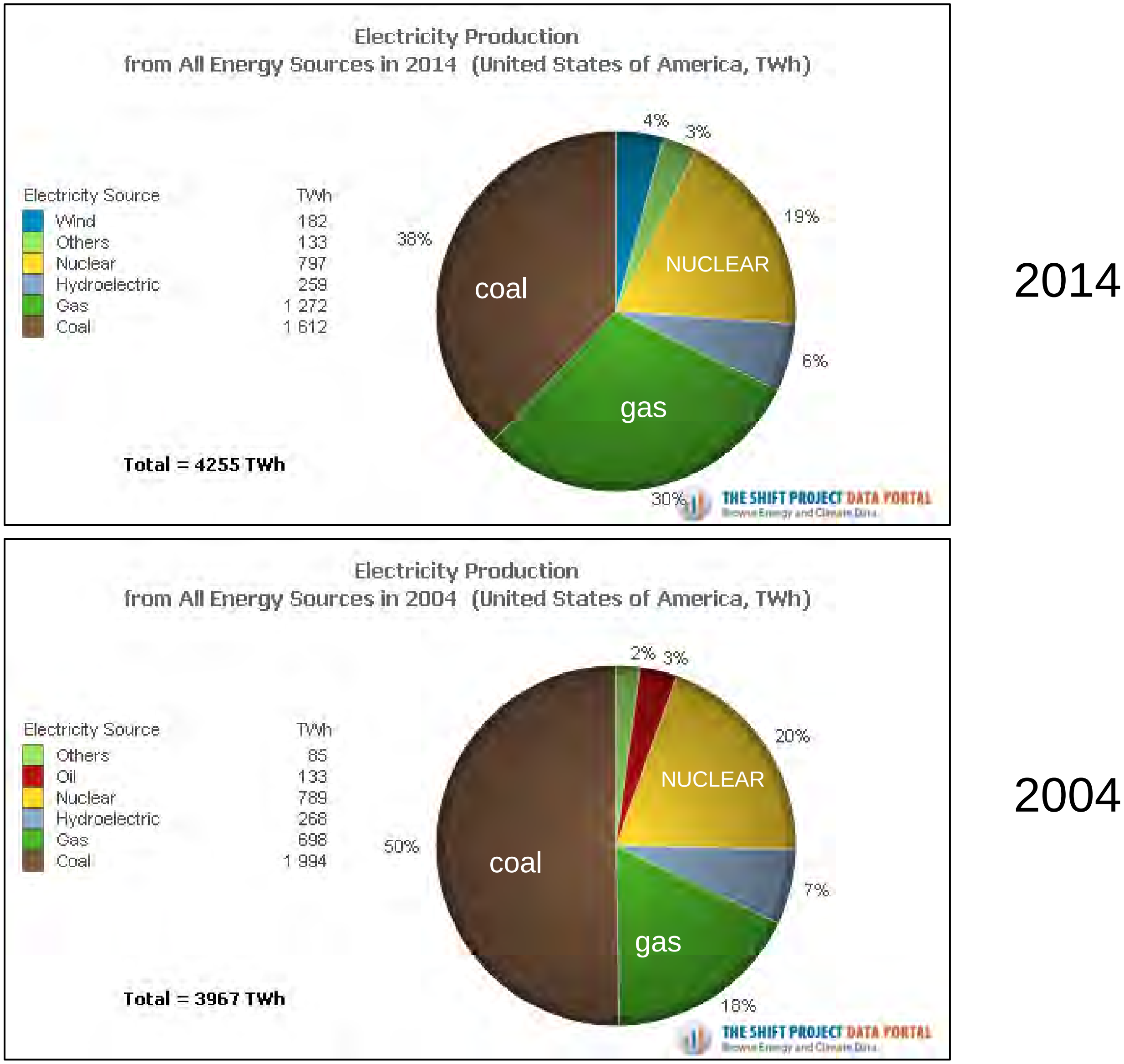


FIGURE 2. Coal as a percentage of all energy sources for generation of electricity in the United States has declined from 50% in 2004 to 38% in 2014.

Source: The Shift Project. 2016. Interactive website accessed on 22 February 2016. [http://www.tsp-data-portal.org/Breakdown-of-Electricity- Generation-by-Energy-Source#tspQvChart](http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart)

D

DEWATERING

Also known as flow loss, this is a common stream impact associated with longwall mining, and almost documented instances of stream dewatering have been associated with longwall mining. During the 2008-2013 Act 54 assessment period, six separate streams that had been dewatered by a longwall mine in Greene County, Pennsylvania were determined by the PADEP to have been irreparably damaged after the mine operator unsuccessfully had worked to restore them for many years (University of Pittsburgh 2014). Dewatering and contamination of private water supply wells in western Pennsylvania also are common effects of longwall subsidence. (See also "Flow Loss" below.)

E

ELEVEN

This is the number of States in the US that reported coal production from longwall methods in 2013, the latest year statistics are available (EIA 2015). From most to least production tonnage, the eleven are: West Virginia, Pennsylvania, Illinois, Colorado, Utah, Ohio, Alabama, Montana, New Mexico, Virginia, and Wyoming (see **Figure 3**). Only Pennsylvania, under Section 18.1 of Act 54, requires its regulators to perform periodic analyses of the effects of underground mining. The important information about the impacts of longwall mining derived from 20 years of Act 54 Assessments prepared by the PADEP is applicable to other States where longwall mining is practiced but no comparable statistics are being compiled.

ENVIRONMENTAL RIGHTS AMENDMENT

On 18 May 1971, after approval by a constitutional convention followed by unanimous adoption by both houses in two successive sessions of the General Assembly, Pennsylvania voters by a four-to-one margin ratified what is now Article I, Section 27 of the State constitution (see box below).

In the 162-page plurality opinion written in conjunction with a 2012 decision of the

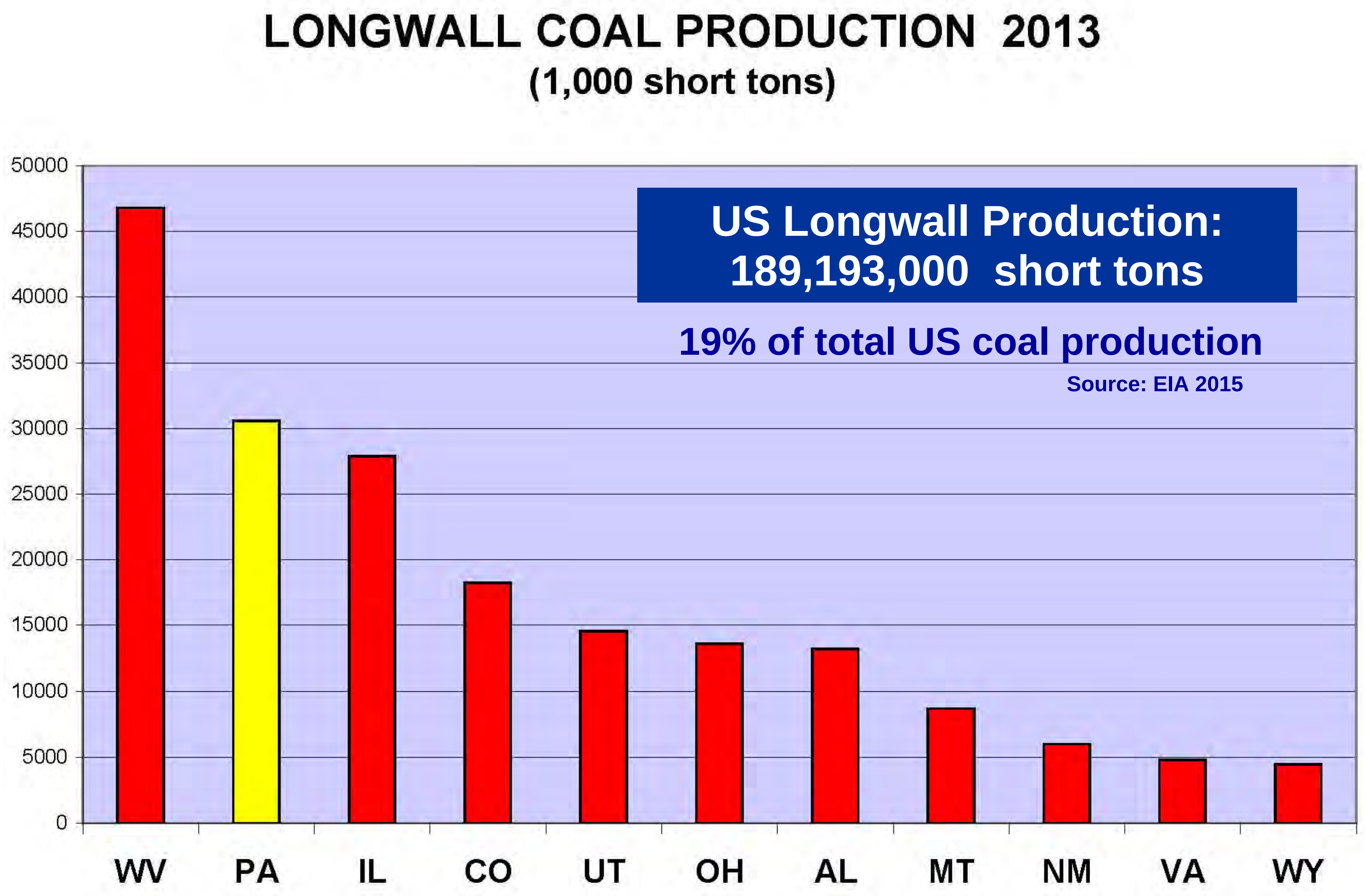
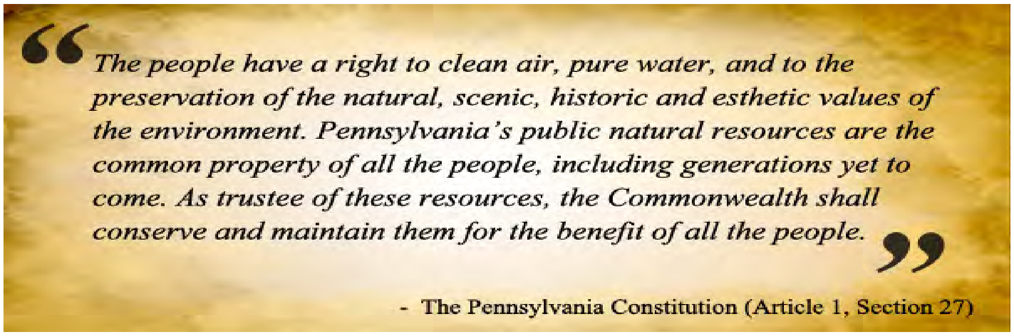


FIGURE 3: Pennsylvania ranked second among the eleven States that produced coal underground by longwall methods in 2013.



Pennsylvania Supreme Court[3], Chief Justice Ronald Castille noted that Article I, Section 27 of the Pennsylvania Constitution was drafted in part to correct abuses inflicted on the environment by past coal mining. When Act 54 was adopted in 1994, it explicitly stated that it does not supersede the Clean Streams Law and similar environmental legislation enacted to protect streams and other water resources.

EXTERNALITIES

These are costs related to the extraction, processing, transport, and use of coal that have not been absorbed by the coal mining companies who seek to make a profit from those activities, but instead are borne by the public and by the environment (NAS 2010). Externalized costs sometimes are difficult to quantify and do not fit easily into a typical accounting spreadsheet. Such costs often are related to public and employee health effects, aesthetic and environmental impacts, and community and social disruption. (See also "Justice" below.)

F

FEASIBLE

One of the words often found in the Pennsylvania mining regulations and/or technical guidance provides a huge loophole for coal operators who simply don't want to comply with a requirement. As an example, according to TGD 653-2000-655 "*Mining operations should be planned to avoid or minimize adverse effects on wetlands to the extent feasible*." A quick reading of that sentence makes it appear to be a strict requirement, but mine operators use any excuse (and PADEP will generally accept

---

[3] *Robinson Township et al. v. Commonwealth et al.*, Nos. 63 MAP 2012, 64 MAP 2012, 72 MAP 2012, 73 MAP 2012, 2013 WL 6687290 (Pa. Dec. 19, 2013). http://www.pacourts.us/assets/opinions/Supreme/out/J-127A-D-2012oajc.pdf

all of them) to suggest that avoiding an impact may not be feasible.   Other loophole phrases include "*to the extent practicable*" and "*as expeditiously as possible*".

FLOW LOSS

One of the main types of documented impacts that occur to streams undermined by longwall methods (the other is pooling). In the PADEP's third Act 54 Review Report (University of Pittsburgh 2011), 52 of the 55 separate instances of mine-related stream damages documented to have occurred between August 2003 and August 2008 were flow losses (only 2 were unpredicted pooling, and one was both pooling and flow loss). All 55 recorded stream damages were associated with longwall mines; none with room-and-pillar mines. The 4th Act 54 Review Report (University of Pittsburgh 2014) reported that six streams dewatered by longwall mining were determined by PADEP to be irreparably damaged after restoration attempts over many years had failed to restore their premining conditions. Many other streams dewatered during the 2008-2013 period were at some stage of attempted restoration, including 95 streams which had artificial flow augmentation installed (74 of which were still active), 57 streams which had received streambed grouting, and 3 streams which had streambed liners installed. As noted above, bonds typically are not posted to restore flow to streams that may experience flow loss because there is no model being used to predict incidents of flow loss.

FULL EXTRACTION MINING

This is another name for longwall mining (**Figure 4**). However, it is not a particularly accurate term, because every longwall mine uses room-and-pillar methods during "development" of the perimeter of the longwall panels with gates and entryways for miners and supplies to access the underground mine. Although longwall mines extract virtually 100% of the coal within a *panel*, the actual net amount of coal extracted from a longwall *mine* is closer to 75%. Because longwall mining provides only a marginal increase in the amount of coal extracted in a given area, the US Supreme Court in 1987 found that it was not a "taking" to require coal to be left in place to provide surface support (which support was determined to serve valid public health and safety purposes). Indeed, surface support would not necessarily have to come from coal (see "Backstowing" above), although that is how it has been provided in the past.

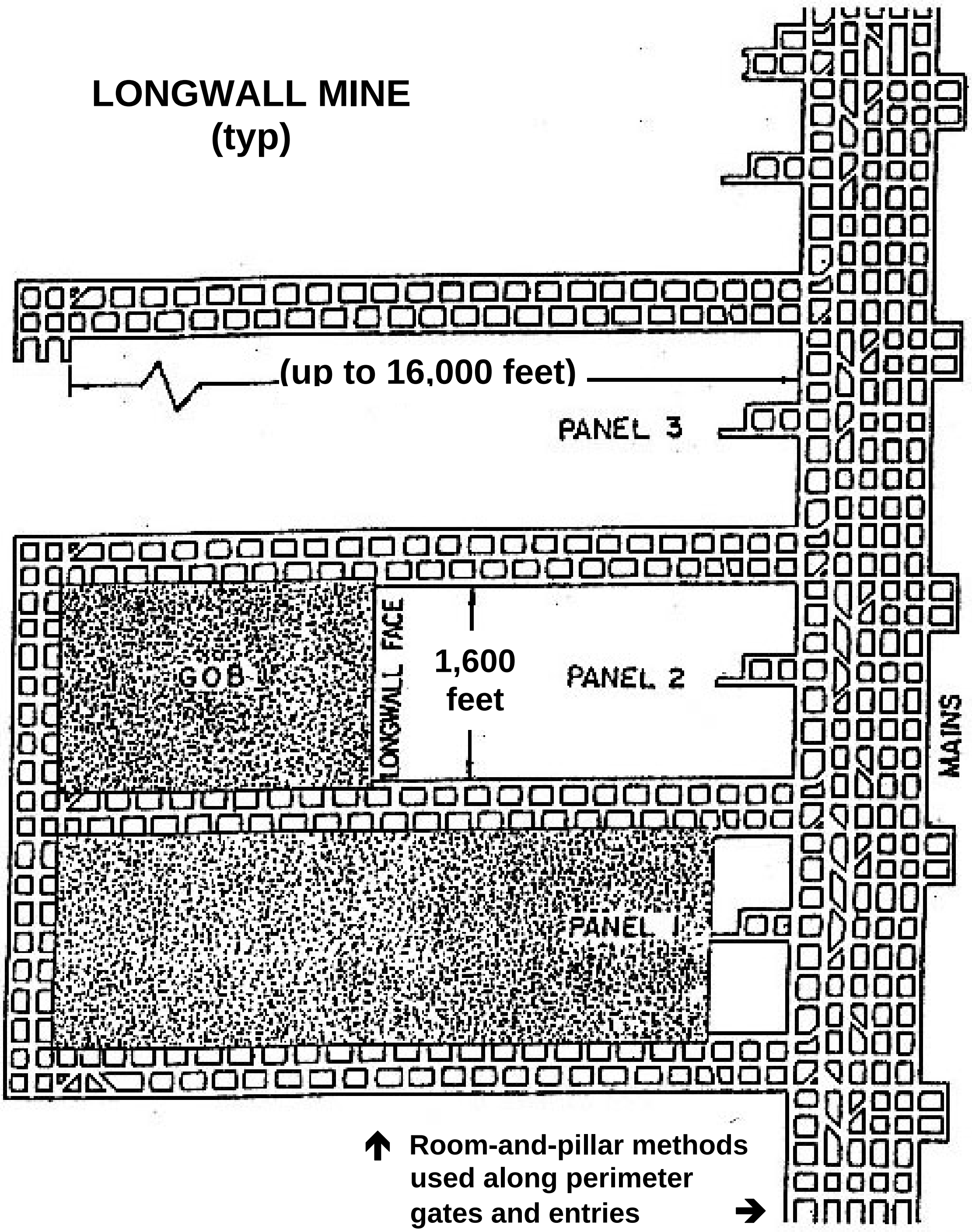


FIGURE 4. In modern longwall mines, a form of "full-extraction" mining, a single panel can be up to 16,000 feet long and 1,600 feet wide. The perimeter of the panels are developed using traditional room-and-pillar methods.

G

GATES/ENTRYWAYS

Gates and entryways are the tunnel areas around the perimeter of a longwall panel which are "developed" by room-and-pillar methods. These areas at present typically are between 200 and 270 feet wide. They provide access between the ground surface and the underground mine for the movement of miners, equipment and supplies, and coal. Because they are created by room-and-pillar mining methods, the land above gates and entryways does not subside as does that above the unsupported longwall panel itself.

GROUNDWATER

Act 54 does not directly address groundwater, and it addresses water supply impacts only in a very narrowly defined way. Groundwater is the actual supply for water for many residents of southwestern PA. However, under the PADEP implementation of Act 54, a well (not the groundwater) is considered the water supply, and if the well can no longer function properly after longwall mining because the groundwater level has been lowered, the “fix” often is (a) to dig a deeper well, (b) to extend public water lines to the property, or (c) to buy the property from the landowner. In none of those cases does the damage to the groundwater get repaired. Loss of water supply can dramatically reduce the value of real estate, impacting both the individual's property and the municipality's tax revenue. This is especially problematic when the common resolution ("c" above) is no fix at all but simply purchase by the mining company of the damaged property.

Groundwater is part of both the "hydrologic balance" and regulated "Waters of the Commonwealth" (see discussions of both terms below).

H

HYDROLOGIC BALANCE

As defined in *25 Pa. Code* Chapter 89 (Underground Coal Mining), the “hydrologic balance” is

> The relationship between the quality and quantity of water inflow to, water outflow from and water storage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake or reservoir. It encompasses the dynamic relationships among precipitation, runoff, evaporation and changes in groundwater and surface water storage.

This definition recognizes the complex and dynamic interrelationship between surface water and ground water, which involves both water quality as well as quantity. Thus, the Pennsylvania regulatory directive to protect the hydrologic balance (box below) by necessity requires a clear understanding of the complex factors involved.

> **§ 89.36. Protection of the hydrologic balance.**
> (a) The operation plan shall describe, with appropriate maps and cross sections, the measures to be taken to ensure the protection of the hydrologic balance and to prevent adverse hydrologic consequences. The measures shall address: (1) The quality and quantity of surface and groundwater within the proposed permit and adjacent areas. (2) The rights of present users to surface and groundwater. ....
> (b) The operation plan shall also describe how the proposed mine development plan will prevent or minimize adverse hydrologic consequences.
> [underlining added for emphasis]

For the hydrologic balance to be protected, one first must identify and understand the interrelationships between each of the surface water and groundwater components at a proposed coal mine. Yet despite decades of experience with longwall mining, no models have been developed to understand the local and regional hydrologic changes that result when cracks are induced in many square miles of aquifer-bearing bedrock, when streambeds experience heaving, and when springs, seeps, and wetlands are dried up. The absence of a clear understanding of the hydrologic balance, however, has not precluded the routine issuance of mine expansion permits in Pennsylvania and other States.

I

INTERMITTENT STREAM

This is a stream that does not have flowing water year-round. As defined in Pennsylvania mining regulations (25 *Pa. Code* Chapter 89.5) it is:

> A body of water flowing in a channel or bed composed primarily of substrates associated with flowing water which, during periods of the year, is

below the local water table and obtains its flow from both surface runoff and groundwater discharges.

Many streams in the headwaters (uppermost sections) of a watershed are intermittent. Small headwater streams often make up most of the stream-miles in the overall watershed, and research demonstrates that they are crucial to the quantity and quality of downstream waters (Alexander *et al.* 2007, Clarke *et al*. 2005, Freeman *et al*. 2007, Kaplan *et al*. 2008, Meyer *et al*. 2003, Meyer *et al.* 2007). Yet prior to about 2005, impacts to intermittent streams were largely ignored in the context of coal mining in Pennsylvania; only those perennial streams never observed to have gone dry received explicit protection in the mining regulations. Under the Clean Streams Law and the associated PADEP regulations, however, both intermittent and perennial streams are afforded regulatory protection. (See also "Waters of the Commonwealth" below.)

Technical Guidance Document 391-2000-014 offers direction regarding the methods and procedures to be used to determine the "point of first stream use", which is the farthest upstream location where Chapter 93 Water Quality Standards must be applied, typically within the intermittent section of smaller streams. The TGD on stream protection (# 563-2000-655) provides guidance for mine applicants on how to identify biologically diverse and biologically variable segments of intermittent and perennial streams. The full extent of Pennsylvania streams warranting legal protection often is not shown on available maps (such as USGS quadrangles and the National Hydrography Database).

IMPACTS

Simply put, an impact is any effect (typically adverse, but not always) that results from an activity. The extraction of coal, particularly by longwall mining methods, can have many obvious direct and less obvious indirect adverse impacts to the biota, land, water, and air in the vicinity of a mine, as well as social and economic impacts to individual people and communities (**Figure 5**). State and federal mining laws and regulations are meant to avoid, lessen, or otherwise control the impacts associated with coal extraction, but their effectiveness has been sorely lacking, as demonstrated by the Pennsylvania experience documented in four Act 54-mandated assessments prepared on behalf of the PADEP. Some significant impacts of longwall mining, such as the flooding of prime farmland are not as severe in Pennsylvania because of its steep topography as in other States such as Illinois.

FIGURE 5. Photos of some typical impacts associated with longwall mine subsidence. Clockwise from top left: a dip in the bed and tracks of a railroad, heaving and cracking of the bed of a stream leading to flow loss, a “water buffalo” serves as a temporary replacement of a home’s lost water supply, cracks in the yard and foundation of a home, and wooden bracing installed to mitigate irregular house settlement.

J

JUSTICE

Many coalfield residents suffer a significant lack of justice. This is because they are made to endure the health, aesthetic, environmental, and social consequences of underground coal mining simply because they happen to live near a coal seam. In a "just" world, the mine operators who benefit from selling coal would be held accountable for all of the costs incurred during coal extraction, processing, and transport. Instead, significant costs are externalized to the general public and are borne disproportionately by landowners, residents, and businesses located in the coalfields and beyond (Muller *et al*. 2011, NAS 2010, Downstream Strategies 2012, McIlmoil and Hansen 2009).

The PADEP has specifically defined Environmental Justice Areas --- those areas having a poverty rate of 20% or greater or a non-white population of 30% or greater, based on the latest US Census data. The PADEP is required to implement enhanced public participation procedures when reviewing permit applications in Environmental Justice communities. Much of the areas where coal mining already has occurred in southwestern Pennsylvania, as well as nearly one-third of the remaining unmined Pittsburgh seam (**Figure 6**), are in Environmental Justice Areas.

K

KILOWATT

A kilowatt is 1,000 watts of energy. Electric power is often described in terms of kilowatts or kilowatts per hour. Most coal today is mined for the purpose of generating electric power. The proportion of electric power that comes from coal (see Figure 2) has been declining in recent years in Pennsylvania and the United States as the cost of competing sources of energy such as natural gas and renewables has dropped.

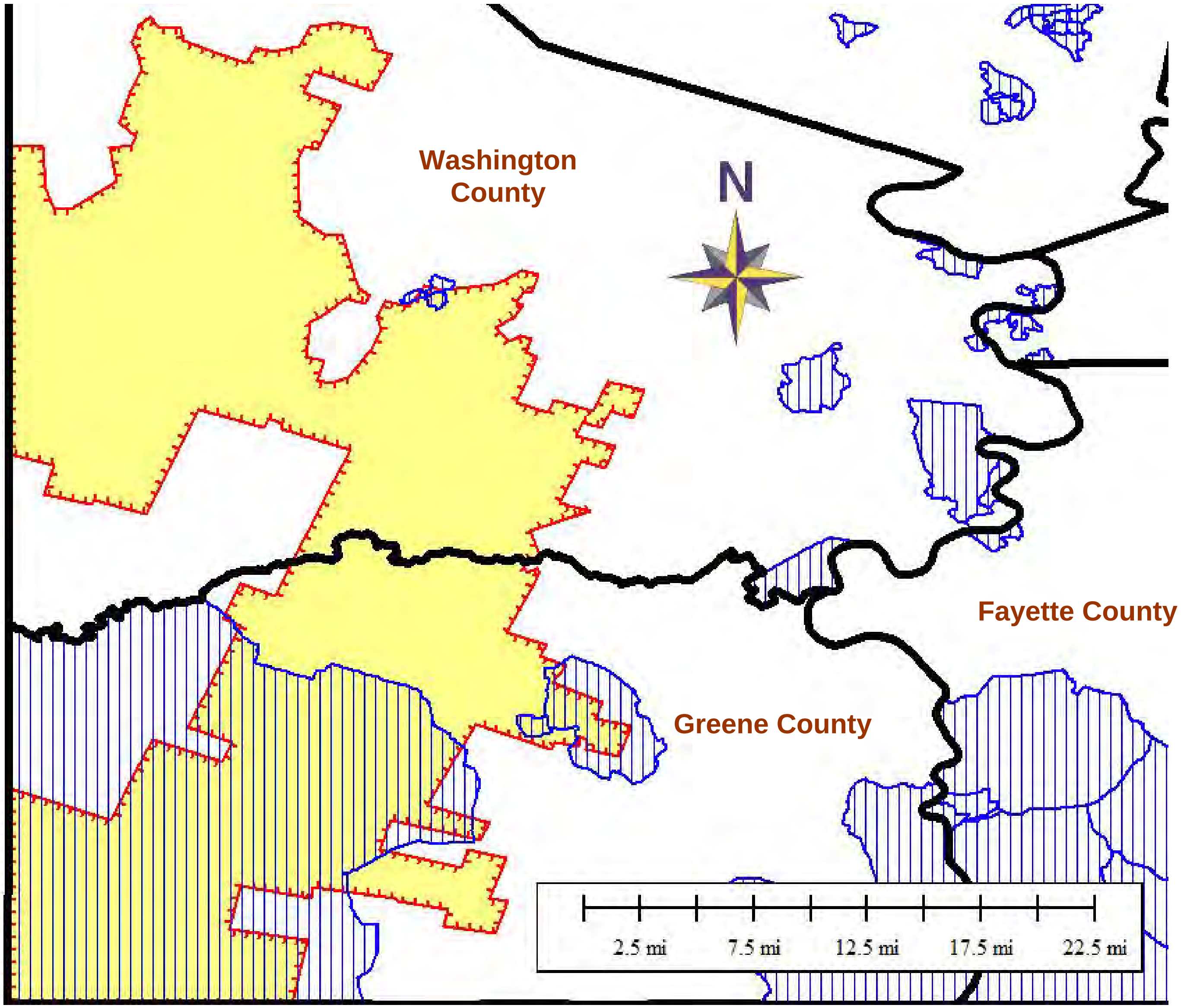


FIGURE 6. Environmental Justice Areas (blue vertical hatching) represent about 98,000 acres, or 32%, of the remaining unmined reserves of the Pittsburgh coal seam (yellow) in Washington and Greene Counties, Pennsylvania.

L

LONGWALL MINING

In the 1970s, a new high-extraction mining method -- longwall mining -- was being introduced into southwestern Pennsylvania as a safer and more predictable method than retreat mining (defined below). Using modern longwall methods up to 75% of the coal in an area can be removed. A longwall mine starts out using traditional room-and-pillar methods to develop access ”gates” and entryways around the perimeter of large rectangular "panels". Shearers then remove all of the coal from the panels themselves while the mine roof is temporarily supported by hydraulic jacks. Surface subsidence is an intrinsic part of longwall mining because no coal remains to provide surface support (except in the narrow gates between the panels). Consequently, longwall mining often results in damage to structures and other features on the subsiding land surface, and thus was incompatible with the 1966 Mining Law's prohibition of intentional surface damage by coal extraction. Longwall mining is preferred by mine operators because of its profitability --- it substitutes capital for labor, with large machines reducing the labor required to produce the coal.

There were 46 underground bituminous coal mines active at some point during the 4th Act 54 Assessment period (2008-2013), including 7 longwall mines, 34 room-and-pillar mines, and 5 retreat mines (**Figure 7**). The number of longwall mines in southwestern Pennsylvania has always been significantly less than the number of room-and-pillar or retreat mines. During the 3rd Assessment period (2003-2008), only 8 of 50 mines were longwall, and during the 2nd Assessment period (1998-2003), only 10 of 68 mines were longwall. Despite their fewer numbers, during the 4th Act 54 Assessment period, longwall mines accounted for about half (54%) of the total acreage of all underground bituminous coal mines, yet were disproportionately responsible for most (about three-quarters) of the documented mine-related impacts.

M

MATERIAL DAMAGE

Federal and State mining regulations on paper define, and seek to prevent (or at least minimize), material damage from mining operations. As defined in Pennsylvania mining regulations (*25 Pa. Code* Chapter 89.5) "material damage" is:

FOURTH ACT 54 PERIOD (2008-2013)

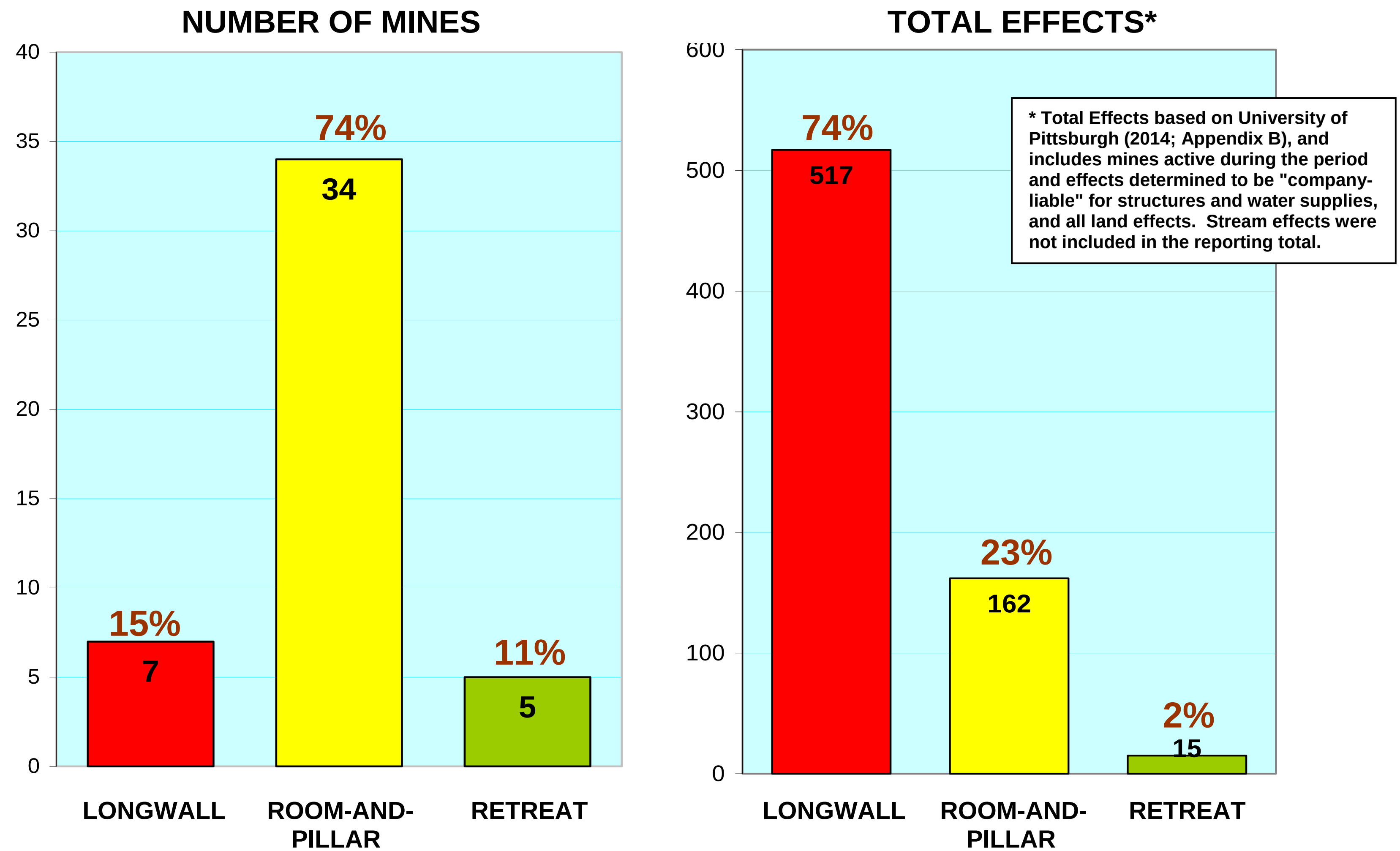


FIGURE 7. Longwall mines have been disproportionately responsible for impacts. Longwall mines (red) accounted for only 15% of all mines active during the latest 5-year Act 54 review period, and they operated beneath only about half (54%) of the total acreage undermined, yet they were responsible for 74% of all reported effects.

Damage that results in one of the following:
(i) Functional impairment of surface lands, structures, features or facilities.
(ii) Physical change that has a significant adverse impact on the affected land's capability to support current or reasonably foreseeable uses or causes significant loss in production or income.
(iii) Significant change in the condition, appearance or utility of a structure or facility from its presubsidence condition.

MINE SUBSIDENCE INSURANCE (MSI)

In 1961 Pennsylvania became the first State to institute a *Mine Subsidence Insurance Program* to address the issue of subsidence damage from abandoned mines. The insurance covers damage caused by mine subsidence or mine water breakouts, which typically are not covered by regular homeowners' insurance.

The MSI Program estimates that about 1 million homeowners statewide are at risk of damage from subsidence from abandoned coal mines. During fiscal year 2014 (which ended June 2015) there were about 58,000 MSI policyholders. The cost of MSI is quite modest – currently, for a home worth $185,000 the annual premium is $100; the average premium paid last year was $85. If the estimate of 1 million households at risk is accurate, then less than 6% of owners perceive the risk as great enough to purchase a low-cost MSI policy.

In FY 2014**,** 218 MSI claims were filed, but only 14 were found to be due to mine subsidence. Payouts on claims that year totaled about $700,000. By contrast, MSI Program administrative expenses that year were more than twice as much ($1.9 million). Premiums collected totaled $5.4 million, and interest on the MSI fund netted almost $2 million more. The balance in the MSI fund has grown from an initial endowment in 1961 of $1 million to more than $100 million currently.

When Act 54 passed in 1994, proponents argued that damage from abandoned mines was a serious problem, and that "planned" longwall mine subsidence would be preferable. Yet experience with the MSI Program suggests otherwise. Only a very small percentage of property owners deemed to be "at risk" are concerned enough to have MSI, subsidence from abandoned mines damages only a very small number of homes each year, and the MSI Fund balance, which has been increasing by $3 to $5 million each year, is more than adequate to deal with the handful of legitimate claims.

MITIGATION/RESTORATION

Restoration commonly refers to activities taken to return a damaged feature to its previous condition, for example, "stream restoration". Mitigation is a slightly broader term that refers to actions or activities that can be done either before an impact occurs (to minimize its severity) or afterwards, when it can involve restoration of the damaged feature or creation of a new feature to replace the damaged feature, either in the same or a different location; for example, "wetland mitigation". Reclamation is another term commonly used in the context of mining, which is similar to restoration, except that reclamation does not necessarily return a disturbed area to its previous condition, but rather to a condition deemed adequate by regulators (for example, to "approximate original contour"). With respect to streams, research suggests that it is exceedingly difficult to fully restore biological functions and conditions to streams after they have been damaged (Carr *et al*. 2005, Doyle and Shields 2012, Palmer *et al.* 2010, Pond *et al*. 2008, Stout 2004). One study of 434 stream mitigation projects associated with 117 coal mine permits in Appalachia found that 97% reported suboptimal or marginal habitat even after 5 years of monitoring (Palmer and Hondula 2014).

MODULES

There currently are 32 Modules associated with a Pennsylvania application for a permit to establish or expand an underground bituminous coal mine. Each Module covers a different mine-related activity or issue of concern. Not every Module necessarily is relevant to every mine application. The arrangement of the Modules appears to be random and haphazard. The Modules do not track well with nor do they consistently make reference to the mining regulations they seek to implement (Schmid & Company, Inc. 2015, 2014b, 2012b, 2010b).

N

NON-DISCLOSURE AGREEMENT

These are used by coal operators to limit or avoid the need to provide full repair or compensation of damages that may result from longwall mining subsidence. Commonly, the mine operator will approach landowners before a mine permit has been issued, and sometimes even before a permit application has been submitted, to strongly encourage them to sign a non-disclosure agreement. Also called a "confidentiality agreement", it would prohibit the landowners from disclosing to others information about damage to their house or other property, in exchange for a cash payment up front or later. Anecdotal information suggests that landowners frequently are pressured or intimidated (Lombardi 2009a), but by law the mine operator cannot force anyone to sign a non-disclosure agreement. As the 5-year Act 54 Reports demonstrate, an accurate accounting of the number and extent of impacts that have actually been repaired in Pennsylvania is not possible because of non-disclosure agreements.

O

OPERATION MAPS AND PLAN

Pennsylvania Underground Bituminous Coal Mine Modules 9 and 10 deal with Operation Maps and Operation Plans, respectively. The maps identify a significant amount of information in great detail about the proposed mining operation. The Plan provides a similar amount of detailed information in narrative form.

OSMRE

The Office of Surface Mining Reclamation and Enforcement (OSMRE) is a federal agency within the US Department of the Interior, established under the Surface Mining Control and Reclamation Act (SMCRA) of 1977. OSMRE is responsible for federal regulation of coal mining operations (including the surface impacts of underground coal mines), for cleaning up abandoned mine lands, and for oversight of State-level coal mining programs. Its regulations (30 CFR Chapter VII) were in part patterned after the Pennsylvania regulations and suffer from some of the same deficiencies (Schmid & Company, Inc. 2015b). During 2015 the OSMRE received more than 94,000 public comments on its proposal to revise and update its stream protection requirements (Schmid & Company, Inc. 2015b --- see "Stream Buffer Zone" below).

OVERBURDEN

Overburden is the rock material that lies above a coal seam. It includes the rock, soil, and sometimes other seams of coal that lie between the coal seam being mined and the ground surface. In room-and-pillar mines, the pillars are designed to prevent collapse of the mine roof and preserve the overburden intact. In longwall mines, the overburden in panels is temporarily held in place by huge hydraulic shields while the face of the coal seam is being removed, but then is allowed to drop into the void as the entire operation advances forward. Subsidence cracks and fissures in the overburden often extend all the way to the surface.

P

PANEL

In longwall mining, the panel is the area, typically rectangular in shape, from which 100% of the coal is removed (see "Longwall Mining" above). A longwall mine starts out using traditional room-and-pillar methods to develop access ”gates” and entryways around the perimeter of the panel, where miners and materials can move between the underground mine and the surface. As much as 25% of a longwall mine’s land area may be devoted to the gates and entries, so a longwall mine *per se* does not remove 100% of the coal seam although it often is labeled "full-extraction" mining (see "Full Extraction Mining" above). Mining advances back and forth across the face (width) of the panel, slicing off about 3 feet of coal at each pass. As the operation moves forward into the mined-out area, the overburden which had been held up temporarily by huge hydraulic supports is allowed to fall into the void behind. Surface subsidence (in the absence of backstowing or other provision of roof support) is an intrinsic part of longwall mining because no permanent surface support is provided (except in the narrow gates between its panels). Consequently, the ridge-and-depression topography resulting from longwall mining subsidence often results in damage to structures and other features on the surface comparable to that from slow-moving earthquakes.

A single longwall panel today can be 1,600 feet or more in width and up to 3 miles in length. These dimensions are significantly larger than they were when longwall mining was first taking hold in Pennsylvania around 1970. Since subsidence deformation increases significantly as longwall panel width increases in proportion to coal seam depth, such increases in panel size raise concerns about increases in surface damage (RTC 2002).

PERENNIAL STREAM

This is a stream that has flowing water year-round during most years. As defined in Pennsylvania mining regulations (*25 Pa. Code* Chapter 89.5) it is:

> A body of water flowing in a channel or bed composed primarily of substrates associated with flowing waters and is capable, in the absence of pollution or other manmade stream disturbances, of supporting a benthic macroinvertebrate community which is composed of two or more recognizable taxonomic groups of organisms which are large enough to be seen by the unaided eye and can be retained by a United States Standard No. 30 sieve (28 meshs per inch, 0.595 millimeter openings) and live at least part of their life cycles within or upon available substrates in a body of water or water transport system.

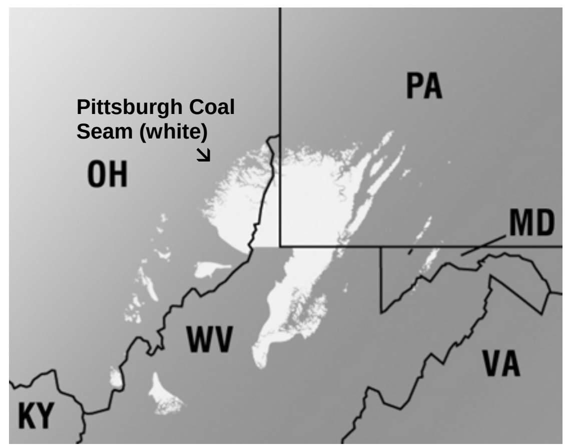
Currently, perennial streams which go dry occasionally are regulated and protected by Pennsylvania regulations, but historically they were not.

PIECEMEALING

This is how the PADEP Mining Program deals with different aspects of a longwall mine, rather than insisting that all aspects of the planned mine, and thus all potential impacts, be identified together upfront so that a proper evaluation and comparison of costs vs. benefits can be performed. A longwall mine typically receives hundreds of permit modifications to increase the extent of land to be mined over dozens of years.

PITTSBURGH COAL SEAM

The Pittsburgh No. 8 coal bed extends over 5,000 square miles in Ohio, Pennsylvania, West Virginia, and western Maryland (see illustration at right). All longwall mines in Ohio and Pennsylvania operate in the Pittsburgh seam, where it varies in thickness from 56 to 84 inches. In West Virginia, the Pittsburgh seam varies from 54 to 98 inches in thickness. In over 220 years, the Pittsburgh seam has yielded more coal than any other US coal bed. Other coal beds mined by longwall methods in western States are even thicker, ranging up to 240 inches at the Bowie No. 2 Mine in Colorado (Coal Age 2016).



PLANNED SUBSIDENCE

This is a phrase with no meaning, yet it was a major selling point of Pennsylvania's Act 54. In theory, "planned" subsidence at longwall mines is supposed to be better than “unplanned” subsidence at legacy room-and-pillar mines because (A) the longwall operator can take steps before and during undermining to minimize the predicted damage, and (B) the coal mine operator will still be around and able to fix any damage that results. But this is not the way things currently work. Less than 10% of the damages from premeditated longwall mining subsidence are actually being repaired (University of Pittsburgh 2011, 2014). By contrast, any Pennsylvania homeowner who lives above an abandoned room-and-pillar mine can be compensated for damages from unplanned subsidence if they have purchased relatively inexpensive insurance from the Mine Subsidence Insurance Fund. Such insurance is not available for longwall mine damages, all of which are supposed to be covered by the provisions of Act 54.

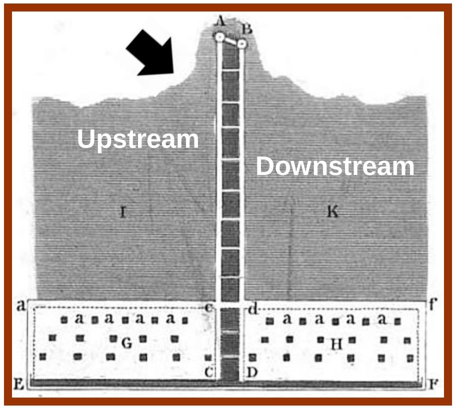
None of the Act 54 Five-Year Assessments has made any attempt to quantify the number of predicted (versus unpredicted) stream impacts or to evaluate whether any or all predicted stream impacts occurred to the same extent as predicted. Collection of the data that would enable an analysis of such impacts has never been a priority for the PADEP Mining Program.

POOLING

One of the two main types of documented impacts that occur to streams undermined by longwall methods is pooling (the other is flow loss). Pooling occurs because the land surface above a longwall panel subsides (drops) as much as several feet vertically, but the gates and entries along the perimeter of the panel do not; so when a stream overlying the mined area extends across several panels, its flow becomes blocked by the unsubsided gates which then act like dams (**Figure 8**). When a section of a formerly free-flowing stream becomes pooled in this way, it collects sediment, loses oxygen, becomes warmer, and prevents the movement of fish and the transport of organic matter. All of these changes have a negative effect on the biological and chemical properties of the stream. The typical "fix" for pooling is to cut through the unsubsided gate so it matches the lowered elevation of the streambed on either side. The 4th Act 54 Report noted, however, that it takes on average 682 days (1.9 years) for mine operators just to *begin* efforts to restore streams impacted by pooling (University of Pittsburgh 2014). The time required for actual biological recovery of pooled streams has not been documented.

PREMINING/POSTMINING INVENTORIES

In theory, the inventories included in permit applications (premining inventories) should identify all resources at risk from each underground mine operation, and, when compared with a postmining inventory, allow analysis of impacts that have occurred. In reality, many premining inventories are deficient; for example, the quantity (capacity) of private water wells does not have to be tested until after a permit has been approved and mining already is underway and close to a home, by which time the water supply may already have been adversely affected. Even where premining inventory requirements have improved (as for streams and wetlands under TGD 653-2000-655), postmining inventories rarely are done and comparisons are thus precluded.



Gate (center) between two panels, typ.

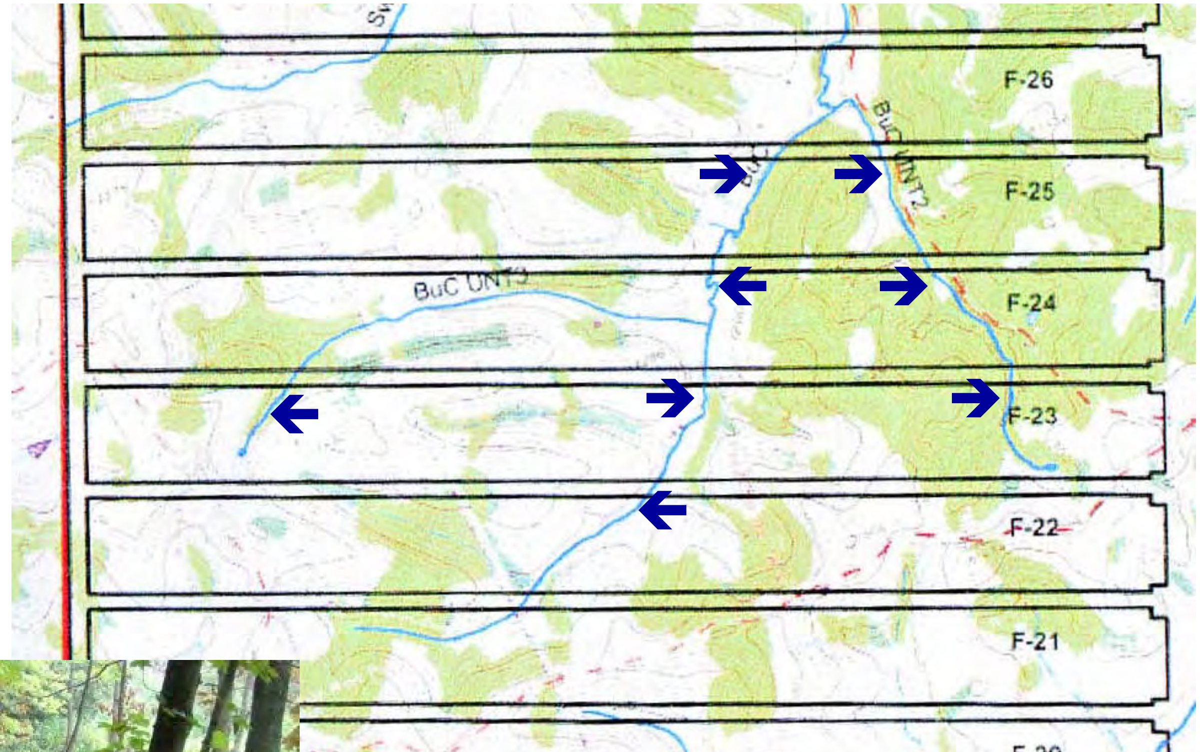


FIGURE 8. Stream pooling typically occurs above a longwall panel on the upstream side of the unsubsided gates (at arrows).

Q

QUALITY AND QUANTITY OF WATERS

Environmental laws and regulations exist to protect water, air, and land from adversely being impacted by mining activities. The unfortunate historic legacy of more than 200 years of coal mining in Pennsylvania is that more than 5,500 miles of streams currently are degraded by acid mine drainage (PADEP 2014c). As a result of technological changes now being implemented in response to environmental regulations, AMD is no longer a major concern with modern underground coal mining. The biggest concerns at present are the subsidence-induced changes caused by longwall mines to the *quantity* of stream flow (either by pooling or by flow loss). The Pennsylvania Environmental Hearing Board[4] has found that hydrologic changes such as pooling and flow loss fit within the definition of “pollution” under the Clean Streams Law. This is because a loss of flow in a stream can be as detrimental to its biological conditions as the discharge of a pollutant. The effect of longwall subsidence on streams is adverse even if the hydrologic changes are “planned and controlled”.

In Pennsylvania, as in most States, streams have a "designated use" (one assigned to them on the basis of the best available information, which may or may not include actual in-stream assessment) which is used for water quality regulation purposes. Many streams also have an "existing use", which can be determined on the basis of actual in-stream assessment typically done in accordance with scientifically-accepted protocols and methods (*e.g.*, PADEP 2003, 2009). When a stream's existing use is found to be better than its designated use, the stream is to be protected at the higher use. PADEP regulations require that for all surface waters of the Commonwealth “*existing instream water uses and the level of water quality necessary to protect the existing uses*” be “*maintained and protected*” (*25 Pa. Code* §93.4a). Although both the mine application form and the PADEP regulations require that a permit applicant identify the designated <u>and</u> the existing uses of all streams within a proposed mine area, permits commonly are issued without any determination of the actual existing use of the streams. In Pennsylvania this is a particularly noteworthy shortcoming on the part of the PADEP Mining Program, because it requires (and routinely gets from mine applicants) detailed physical and bioassessment studies of all streams prior to mining (in accordance with Technical Guidance Document 563-2000-655), and so an existing use determination could be made with little additional effort. In 2009, prompted by a conservationist petition, the existing uses of several streams in the coalfields of Greene County, Pennsylvania were formally upgraded beyond their designated use (Schmid & Company, Inc. 2009).

[4] *Oley Township v. DEP*, 1996 EHB 1098

R

REBUTTABLE PRESUMPTION ZONE

An area within which a mine operator is presumed to be liable for any contamination, diminution, or interruption to water supplies, as specified in Act 54 and incorporated into the Pennsylvania mining regulations. (See "Angle of Draw" above.)

REFUSE

Refuse is the waste material that is left over at the end of coal mining and preparation processes. After being extracted from the mine, coal often needs to be processed, refined, and “cleaned” before it is ready to be shipped to coal-fired power plants or steel mills. Coal cleaning typically occurs at an onsite preparation plant where impurities such as sulfur, ash, pyrite, and rock are removed using physical and/or chemical methods. Chemicals used in the processing may be toxic or carcinogenic. Coal refuse material varies from coarse to very fine. Coal itself contains a number of inorganic and organic materials, including at least 28 different metals such as arsenic, chromium, copper, lead, mercury, and uranium (USEPA 2008).   After processing, coal refuse is dumped into containment impoundments, but such impoundments have been known to leak or breach, which can introduce harmful substances into the nearby land, groundwater, or surface water. Chronic exposure to metals found in coal refuse can cause human health problems.

RETREAT MINING

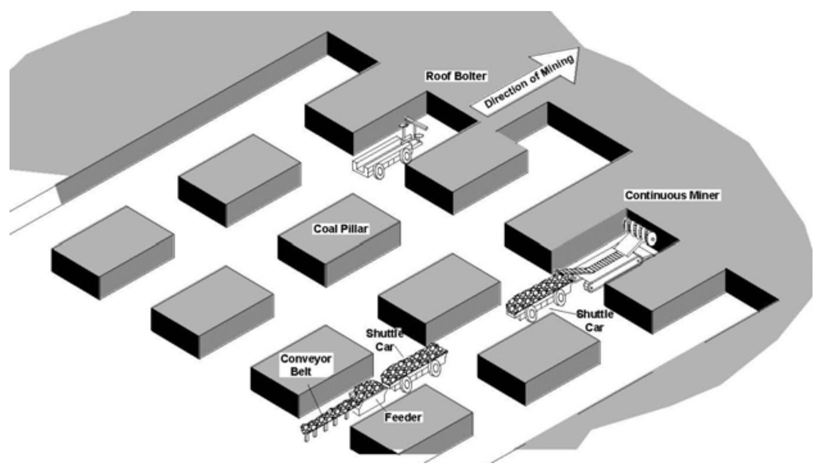
In addition to longwall and room-and-pillar, retreat mining is a third method of underground mining and is a sort of hybrid of the two. Prior to the widespread use of longwall mining, retreat mining was used as a "high-extraction" method to recover a higher percentage of coal. Retreat mining (also known as "second mining" or "pillar extraction") is used after the coal seam has been developed using standard room-and-pillar mining. In retreat mining, the coal pillars that initially were left in place for support are selectively removed, or "pulled", retreating back towards the mine entrance. After the pillars are removed, the roof (or back) is allowed to collapse behind the mining area.

Numerous methods of retreat mining, and variations of those methods, were used over time and under different geologic conditions, often on a trial and error basis, in attempts to develop the most efficient and least hazardous design under a variety of complex conditions. According to the U.S. Bureau of Mines, in the early 1980s about 70 percent of all mines in western Pennsylvania had some form of pillar extraction plan on file (Kauffman *et al*. 1981).

The removal of the support pillars often resulted in the collapse of the overburden (rock above the mine) and in the weakening of adjacent pillars, causing surface subsidence to occur, often at unpredictable times. Retreat mining therefore was a particularly dangerous and destructive form of mining. Between 1978 and 1998, this type of mining was responsible for 25% of US coal mining deaths caused by failures of the roof or walls, even though it represented only 10% of the coal produced (Chase *et al*. 2002).

In Pennsylvania, retreat mining has declined in popularity in favor of the more efficient longwall mining. During the latest Act 54 review period (2008-2013), of the 46 active mines only 5 used retreat mining methods.

ROOM-AND-PILLAR MINING



Room-and-pillar is a method of underground mining that has been practiced in Pennsylvania since the late 1700s (PADEP 2014a), and it continues to be used profitably today. Using a continuous miner, this method extracts about 40% to 60% of the coal in an area, but leaves enough coal in place (in the pillars) to support the mine roof (see illustration). Room-and-pillar mining does not cause surface subsidence, at least not intentionally and not if the mine is properly designed and operated to preserve roof support. Today, as historically, more underground coal mines in Pennsylvania exclusively use the traditional room-and-pillar mining method rather than any other underground mining method.

S

SMCRA

The primary federal law relating to coal mining was passed in 1977 and is known as the Surface Mining Control and Reclamation Act (SMCRA). It was enacted 11 years after the Pennsylvania mining law (see "BMSLCA" above) and in part was based on it. Under SMCRA, the OSMRE has federal jurisdiction over coal mining activities, but States which adopt a mining program that conforms with the basic requirements of SMCRA can assume "primacy" for coal regulation (as is the case in Pennsylvania).

SPECIAL PROTECTION WATERS

In Pennsylvania, the very best waters are those identified as Exceptional Value (EV) and High Quality (HQ), collectively known as “Special Protection” waters. The Pennsylvania antidegradation program ostensibly provides more stringent levels of protection for such waters in accordance with 25 *Pa. Code* §93.4a. Throughout the Commonwealth, only 4% of all streams have been recognized as qualifying as Exceptional Value, and an additional 27% are recognized as High Quality (DRN 2011). The mining application form and the PADEP review of longwall mines make no distinction whether the water to be undermined is designated as “Special Protection” or not. Although direct discharges to Special Protection waters require more detailed review and an NPDES (National Pollutant Discharge and Elimination System) permit, potential subsidence impacts to Special Protection waters are treated no differently than to other waters in Pennsylvania (Schmid & Company, Inc. 2010a).

STREAM BUFFER ZONE

A federal SMCRA requirement known as the Stream Buffer Zone Rule prohibits mining activities in or within 100 feet of any stream if those activities will adversely affect the stream. During 2015 the OSMRE received more than 94,000 public comments on its proposal to revise and update its stream protection requirements (Schmid & Company, Inc. 2015b).

The Pennsylvania version of the Stream Buffer Zone Rule is especially stringent, at least on paper. As detailed in its regulations at 25 *Pa. Code* §86.102, the State may grant a variance for activities within 100 feet of any intermittent or perennial stream, but only

> “… *if the operator demonstrates beyond a reasonable doubt that there will be no adverse hydrologic impacts, water quality impacts or other environmental resources impacts as a result of the variance*.”

In a recent longwall mine application the operator conceded that “*The majority of streams proposed for impact will be filled, eliminating their contribution to watershed hydrology and potential as aquatic habitat*” (Schmid & Company, Inc. 2014b). Requested Stream Buffer variances are almost always granted by PADEP, usually with little actual demonstration of a lack of impact, but merely a statement that the surface activity is needed to operate the mine.

SUBSIDENCE

In simplified terms, subsidence is what happens when you dig a tunnel underground large enough to cause the rocks and earth above and around that tunnel to collapse into the tunnel. If the tunnel is large enough or close enough to the surface, it can cause the ground (and things on the surface) to shift (see "X-Section" below).

Intentional subsidence occurs when underground coal mining is done by the longwall mining method. The removal of a long rectangular block of coal results in the development of a trough-shaped depression of the surface above the extracted area (Jeran and Adamek 1991). Subsidence virtually never happens when coal is mined by the room-and-pillar method, because --- when properly designed --- enough coal is left in place in the pillars to support the roof of the mine. Preventing subsidence through proper mine engineering design historically was a primary focus of mine operators and PADEP mine regulators prior to the advent of longwall mining.

Subsidence can be minimized by any of several known methods which can be incorporated into either room-and-pillar operations or longwall operations. Two techniques which have been used successfully are backfilling (or backstowing) and grout injection. The main reasons to prevent or minimize subsidence are to protect homes and other structures on the surface, to protect wells and other water supplies, and to protect streams, wetlands, and other sensitive natural resources. The main reasons not to incorporate backstowing or another subsidence-minimization measure into a mine operation are that it increases the cost of extraction, it may slow down the extraction process, and it reduces corporate profits. (See "Backstowing" above.)

T

TECHNICAL GUIDANCE DOCUMENTS

Technical Guidance Documents (TGDs) are issued by the PADEP and are meant to provide practical and specialized technical direction, for the benefit of both regulatory agency staff and the regulated public, with regard to a specific issue or regulation. TGDs are used to explain acceptable technical or administrative procedures and requirements, to provide assistance in compliance with statutes or regulations, and to establish policies or procedures. TGDs are not meant to be a substitute for regulations.

TGD #563-2000-655, entitled "Surface Water Protection - Underground Bituminous Coal Mining Operations", was last revised 8 October 2005. It establishes procedures and provides guidance on how to identity and protect regulated surface waterways and wetlands from underground mining activities. The 2005 TGD was possibly the most significant policy change to address stream protection that the PADEP Mining Program adopted since the enactment of Act 54 in 1994. The 4th Act 54 Report noted that this TGD had begun to be implemented at some mines during the reporting period, but its implementation was inconsistently applied by both the mine operators and the PADEP.

U

UNDERGROUND MINING

Underground mining is one of two general types of coal extraction; the other is surface mining. Longwall mining is one method of conducting underground mining. Mountaintop removal is one method of surface mining. The two methods share certain similarities in that they both are highly mechanized, their use reduces the manpower needs of the operation, they are efficient at extracting coal, and they are associated with numerous externalized costs (to the environment and to public health and welfare). The immediate consequences of mountaintop removal are much more disturbing visually than longwall mining, and consequently the problems associated with its use are more widely known to the general public.

V

VICTIM

A victim is someone harmed by the actions of another. Victims of longwall mining include individual homeowners, residents, and businesses that are located above the mines and do not own the mineral rights to the coal, as well as other residents and visitors who did in the past, or might want in the future, to enjoy hiking, hunting on, or otherwise recreating in or near clean free-flowing streams in southwestern Pennsylvania. Entire communities near longwall mine sites also have become victims of the activity.   (See "Externalities" and "Justice" above.)

VIOLATION

If a mine operator conducts an activity or allows a discharge to a stream that is not in conformance with the terms and conditions of the mine permit, that may be considered a violation. A violation could be discovered during a routine PADEP inspection, during random testing or inspections, or in response to a report or complaint from a member of the public. Some violations may be documented in a formal Notice of Violation, a Compliance Order, or a Consent Order and Agreement, which detail what law or regulation was violated and what actions must be taken, by when, to correct the violation. Module 3 of the Pennsylvania underground mine permit application requires an applicant to identify the status of all mine-related violations that it was responsible for in the prior three-year period. No permit revision or new permit is to be issued if an operator has an outstanding violation that is not in the process of being resolved, has demonstrated a pattern of willful violations resulting in irreparable damage to the environment, or has demonstrated a lack of ability or intention to comply with the mining laws or regulations. This apparently is a low standard: the mine operator who was found to have irreparably dewatered six separate streams, and to have damaged the dam on the only recreational lake in Greene County (causing the State Park lake to be permanently drained more than 10 years ago), has subsequently been issued numerous permits to expand its mining operations.

VOID

The empty space underground created when coal is extracted. In room-and-pillar mining, the void is a "room" that is supported and protected by the pillars of coal intentionally left in place for that purpose. In longwall mining, the void within each panel is only very temporary: huge movable pneumatic roof supports hold up the mine roof while the longwall shearer carves coal from the working face, protecting both the machinery and the nearby miners until the operation pushes forward and allows the overburden to collapse behind into the void. The process has been described as comparable to a slow-moving earthquake in its effects at the land surface.

W

WATERS OF THE COMMONWEALTH

The Pennsylvania Clean Streams Law defines a large class of water resources as "Waters of the Commonwealth[5]". These include both surface waters and groundwater, and both their quantity and quality are intended to be protected. As noted above, Act 54 specifically states that it does not supersede the Clean Streams Law. Mine-related impacts to Waters of the Commonwealth, however, often are underreported for a number of reasons including inadequate premining inventories, inadequate postmining inventories, and inadequate database tracking by the PADEP, among others. (See also "Avoidance [of Impacts]", "Clean Streams Law", "Groundwater", and "Hydrologic Balance" above.)

WETLANDS

Wetlands are recognized as a special subset of regulated "Waters of the Commonwealth". According to 25 *Pa. Code* Chapter 105 (§105.17): "*Wetlands are a valuable public natural resource. This chapter will be construed broadly to protect this valuable resource.*" However, if the limits of wetlands are not delineated accurately in the field, then the wetlands cannot be protected during a mining operation, or restored afterwards if affected by it. Inadequate identification of wetlands in Pennsylvania is a significant problem that is not fully appreciated by the PADEP or other regulatory agencies (Schmid & Company, Inc. 2000, 2010b, 2011, 2014a, 2015a; University of Pittsburgh 2011, 2014).

Wetlands typically occupy the transitional areas between dry land and permanently standing or flowing water. Wetlands play a crucial role in protecting and improving water quality by removing excess nutrients, sediments, and pollutants from the water flowing through them. In light of their ability to filter a variety of pollutants, artificial wetlands have even been used to neutralize acid mine drainage and to treat municipal sewage. Wetlands also can decrease flooding, recharge groundwater, protect shorelines, provide habitat for fish and wildlife, and provide recreational, research, and educational opportunities. Although they occupy only about 2% of the

[5] "Waters of the Commonwealth" shall be construed to include any and all rivers, streams, creeks, rivulets, impoundments, ditches, water courses, storm sewers, lakes, dammed water, ponds, springs and all other bodies or channels of conveyance of surface and underground water, or parts thereof, whether natural or artificial, within or on the boundaries of this Commonwealth. [From Section 1. Definitions in The Act of Jun. 22, 1937, P.L. 1987, No. 394 Cl. 32]

land area in Pennsylvania, the value of the services performed by natural wetlands greatly exceeds their scarcity in the landscape.

Wetlands comprising Waters of the United States also are protected pursuant to Section 404 of the Clean Water Act. There are no detailed maps of regulated wetlands in Pennsylvania or elsewhere. The US Fish & Wildlife Service in the 1980s initiated a program (known as the National Wetlands Inventory, or NWI) to identify from high-altitude aerial photography areas of obvious wetlands for wildlife habitat protection purposes. The NWI mapping is not, and never was intended to be, accurate for regulatory purposes (Schmid & Company, Inc. 2010b, 2011, and 2014b).

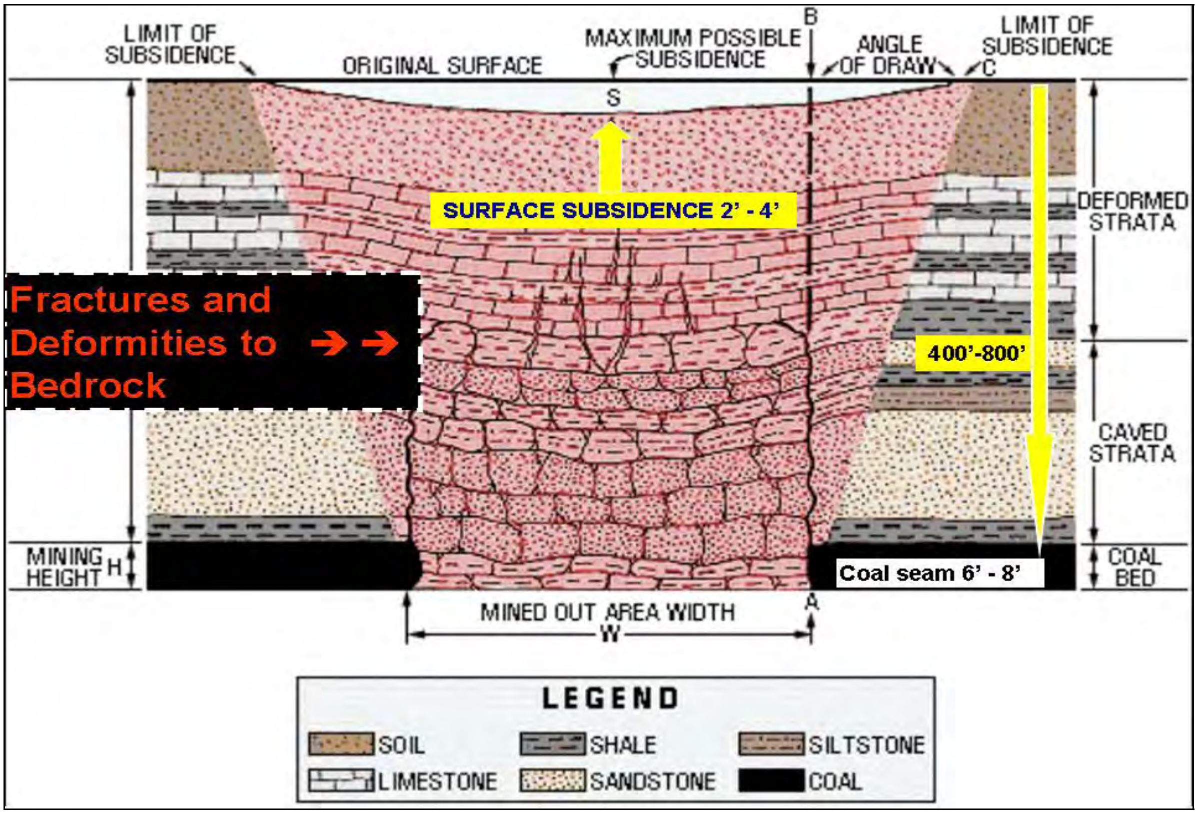
Wetland limits typically are field-identified (delineated) on a site for a project-specific purpose. The PADEP uses the same technical methodology to identify the limits of wetlands based on three criteria (plants, soils, and water) as is used by the Army Corps of Engineers. PADEP has adopted the current federal methodology for wetland delineation (25 *Pa. Code* 105.451), but the Mining Program personnel lack the time and expertise to undertake formal review of wetland delineations. Fortunately, the Corps of Engineers has established a straightforward, no-fee process for checking the accuracy of wetland delineations for federal and State purposes. That process (known as a "Jurisdictional Determination", or JD) is widely used in conjunction with other types of development projects throughout Pennsylvania and other States. To date, the PADEP has failed to take advantage of the Corps JD process for confirming wetland delineations in conjunction with coal mining projects.

X

EXPANSION

Historically, after a longwall mine receives its initial State permit, the operator applies for multiple permit revisions and mine expansions. A longwall mine may start out with a relatively small footprint, but with subsequent expansions, it may become many times larger. Enlow Fork Mine was first approved in 1986 with a mining footprint of less than 5 square miles, but by October 2013 this single longwall mine encompassed about 55 square miles, more land surface than the City of Pittsburgh. From the beginning an operator knows the extent of its coal reserves and holdings in an area, so the ultimate extent of the mine operation could be disclosed to allow a review and evaluation of the likely cumulative impacts --- but that is never done.

X-SECTION of a LONGWALL MINE



As shown above in cross-section, when a longwall mine extracts a 7-foot thick seam of coal from a panel** about 800 feet below the surface, it can cause the rock layers above it to crack, bend, and twist as the overburden falls into the void created. This can result in irregular subsidence of the surface, up to 3 or 4 feet or more near the center of the panel, and lesser amounts near the gates and entries at the edges of the panel. For structures, streams, and other features on the surface, this movement can be devastating, and it has aptly been compared to a slow-moving earthquake.

** A modern longwall panel from which all of the coal is removed can be as much as 1,600 feet wide and 16,000 feet long, encompassing an area of more than 500 acres.

Y

YARDS

Although the 1966 Mining Law only explicitly prohibited damage to homes built before 1966 and certain other structures, in effect it protected their yards, wells, springs, streams, and other resources and features situated *near* the protected structures. Although protected only indirectly, the yards and other ancillary features were protected nevertheless. In trying to justify how Act 54 would make matters better (Beauduy 1990), the mine operators argued that the 1966 Mining Law only protected structures built prior to 1966, not newer structures (and not water supplies --- conveniently ignoring the provisions in the Pennsylvania Clean Streams Law in effect since 1937). The mine operators argued that all structures (and water supplies) should be afforded the same protection. That made sense, except for the fact that the "protection" they intended to provide was to change the law so that all homes, other structures, and water supplies could be intentionally damaged (with the expectation that all damages would or could be fixed.)

YEARS

This is the amount of time that it takes to resolve many of the damages resulting from longwall mining, if they can be resolved at all. In the case of streams, there are effectively two types of impacts that can occur: pooling or dewatering. In theory it should be easier to correct pooling impacts (where the water still is present, but is trapped behind an unsubsided gate) than it is to correct flow loss impacts (where the hydrology of not only the stream but also its surface and groundwater inputs have been disrupted). The 4th Act 54 Report noted that it takes on average 682 days (1.9 years) for mine operators to begin any restoration of streams impacted by pooling. It did not calculate the average length of time to conduct the pooling restoration work itself or assess its effectiveness in restoring flow volume or biological conditions afterwards. For a formerly free-flowing stream, and particularly a "Special Protection" water, to experience pooling for even two years is detrimental to its uses and values. It is not uncommon for restoration efforts undertaken to attempt to correct flow loss/dewatering impacts to last 4 or 5 years or longer, and the PADEP has formally determined that at least 6 different streams had been irreparably damaged after they could not be restored after many years of trying.

Z

ZERO-SUM

A situation, game, or relationship in which a gain for one side equates to a loss for the other, and the sum of all gains and losses is zero. One of the more common myths about environmental protection is the belief that protecting the environment and promoting economic prosperity is a zero-sum game. For decades, both the business community and environmental interests have often acted as if economic prosperity and environmental protection are mutually exclusive goals.

Producers (such as coal mine operators) often argue that attempts to regulate their activities, by minimizing adverse environmental impacts for example, will result in their inability to operate and will cause them to shut down their operations, thereby leading to a local loss of employment and revenue. The environmental community often views strict regulations as a way to more equitably allocate the costs of production so that those who stand to gain the most (in this case, mine operators) also shoulder more of the costs (such as pollution and health impacts) that would otherwise be externalized to individual landowners or the general public.

Strict standards for protecting features on the surface are not incompatible with underground coal mining. Mines operated quite productively and profitably during the 28 years that there was a prohibition on damage to surface structures under the 1966 Pennsylvania mining law. Even today, with stricter environmental standards in place, room-and-pillar mines can maintain profitability, and in fact are more numerous than longwall mines, while at the same time extracting coal with significantly fewer impacts.

When regulatory requirements are viewed as fair and are applied evenly and consistently, industry usually complies eventually (after initial cries of doom) and incorporates them into their routine business model. As with most other things, regulation has changed and evolved over time. The old-school mode of regulation was more heavy-handed: command and control; these days regulation is often more effective when a standard is set but the regulated community is given greater latitude to devise innovative ways to meet that standard on their own. Thus, it would not be appropriate to ban or prohibit any specific mining method (such as longwall mining). Rather, a reasonable standard should be set (such as no stream damage) and individual mine operators then are free to extract their coal using any method they can devise so long as the standard is met.

USEFUL WEBSITES for Further Information

Citizens Coal Council (CCC):
http://www.citizenscoalcouncil.org/

Pennsylvania Department of Environmental Protection

Mining, general:
http://www.dep.pa.gov/Business/Land/Mining/Pages/default.aspx#.VsR-0CArKM9

Act 54 Reports:
http://www.dep.pa.gov/Business/Land/Mining/BureauofDistrictMining/Act54/Pages/default.aspx#.VsR_PyArKM8

Bituminous coal reports:
http://www.dep.pa.gov/Business/Land/Mining/BureauofMiningPrograms/Reports/BituminousCoal/Pages/default.aspx#.VsSayyArKM8

Mine Subsidence Insurance Program:
http://www.dep.state.pa.us/MSIHomeowners/CCMSIB/CCMSIB.htm
http://www.dep.state.pa.us/MSIHomeowners/msi_info.htm

Office of Surface Mining Reclamation and Enforcement (OSMRE)
http://www.osmre.gov/about.shtm

US Energy Information Administration (EIA)

Coal data: http://www.eia.gov/coal/

Schmid & Company, Inc.

Mining-related reports, Act 54 reviews, etc.: www.schmidco.com

REFERENCES CITED OR CONSULTED

Alexander, R.B., E.W. Boyer, R.A. Smith, et al. 2007. The role of headwater streams in downstream water quality. Journal of the American Water Resources Association 43(1):43-59.

Associated Press. 2016. Coal output hits 30-year low. 8 January 2016.

Audubon Society of Western Pennsylvania. 1998. An investigation of high extraction mining and related valley fill practices in southwestern Pennsylvania. Two volumes: Background Papers and Executive Summaries. Sponsored by Audubon at Beechwood. Managed by Dames & Moore. Pittsburgh PA. Variously paged.

Beauduy, Thomas W., Esq. 1990. Deep mine mediation project, consensus proposal, March 18, 1990. 22 p.

California University of Pennsylvania (CUP). 2005. The effects of subsidence resulting from underground bituminous coal mining on surface structures and features and on water resources: Second Act 54 five-year report. Department of Earth Sciences. California PA. 338 p. http://www.portal.state.pa.us/portal/server.pt/community/act_54/20876

Carr, Jamie, David Hart, and Jim McNair. 2005. Compilation and evaluation of stream restoration projects: learning from past projects to improve future success. Academy of Natural Sciences of Drexel University.

Clarke, A., R. MacNally, N. Bond, et al. 2008. Macroinvertebrate diversity in headwater streams: a review. Freshwater Biology 53:1707-1721.

Coal Age. 2016. 2016 US longwall census: US longwall operators scale back production. Volume 121, No. 2. (February). Mining Media, Inc. Englewood CO. 5 p. http://coal.epubxp.com/i/640014-feb-2016

Delaware Riverkeeper Network (DRN). 2011. Protecting Pennsylvania's Cleanest Streams: A Review of Pennsylvania's Antidegradation Policies and Program with Recommendations for Improvements. Bristol PA. 78 p.

Downstream Strategies. 2012. The impact of coal on the Pennsylvania state budget. Morgantown WV. 78 p. http://downstreamstrategies.com/documents/reports_publication/ds_penncoal_budget_final.pdf

Doyle, Martin W., and F. Douglas Shields. 2012. Compensatory mitigation for streams under the Clean Water Act: reassessing science and redirecting policy. Journal of the American Water Resources Association. 48(3):494-509. June 2012. 16 p.

Energy Information Administration (EIA). 1995. Longwall mining. US Department of Energy. Washington DC. 63 p. DOE/EIA-TR-0588 http://webapp1.dlib.indiana.edu/virtual_disk_library/index.cgi/4265704/FID1578/pdf/coal_nuc/tr0588.pdf

EIA. 2015. Annual coal report 2013. US Department of Energy. Washington DC. 59 p. https://www.eia.gov/coal/annual/pdf/acr.pdf

Freeman, Mary C., Catherine M. Pringle, and C. Rhett Jackson. 2007. Hydrologic connectivity and the contribution of stream headwaters to ecological integrity at regional scales. Journal of the American Water Resources Association. 43(1):5-14.

Hobba, W.A. 1981. Effects of underground mining and mine collapse on the hydrology of selected basins in West Virginia. USGS and OSM. West Virginia Geological and Economic Survey. Report of Investigation RI-33. 77 p.

Jeran, Paul W., and Vladimir Adamek. 1991. Subsidence over the end of a longwall panel. US Department of the Interior, Bureau of Mines. Report of Investigations 9338. 7 p.

Jianfeng, Zha, G. Guangli, F. Wenkai, and W. Qiang. 2011. Mining subsidence control by solid backfilling under buildings. Transactions of the Nonferrous Metals Society of China. 21(2011) 670−674.

Kaplan, Louis A., T. L. Bott, J. K. Jackson, J. D. Newbold, and B. W. Sweeney. 2008. Protecting headwaters: The scientific basis for safeguarding stream and river ecosystems. Stroud Water Research Center. Avondale PA. 18 p.

Kauffman, Peter W., Steven A. Hawkins, and Robert R. Thompson. 1981. Room and pillar retreat mining: a manual for the coal industry. US Department of the Interior, Bureau of Mines. Information Circular 8849. Reston VA. 228 p.

Kunz, Stephen P. 2002. Comments on Draft Technical Guidance 563-2000-655. Letter to Harold Miller, PADEP – Bureau of Mining and Reclamation; dated 1 May 2002. Schmid & Company, Inc. Media PA. 17 p.

Kunz, S. P. 2005a. Comments on draft Technical Guidance Document 563-2000-655 surface water protection - underground bituminous coal mining. Letter to Harold Miller, PADEP – Bureau of Mining and Reclamation; dated 23 March 2005. Media PA. 8 p. http://www.schmidco.com/TGD%20-655%20Comments%2023%20March%202005.pdf

Kunz, S. P. 2005b. Comments on the second Act 54 five-year report. Letter to Susan Wilson, PADEP Citizens Advisory Council, dated 21 April 2005. Media PA. 20 p.

Kunz, S. P. 2012. Comments on the fourth Act 54 five-year review report University of Pittsburgh master agreement (Contract No. 4400004037). Letter to Thomas Callaghan, Director, PADEP Bureau of Mining Programs, dated 25 September 2012. Media PA. 11 p.

Lombardi, Kristen. 2009a. Undermined. The Center for Public Integrity. Washington DC. 21 p. http://www.publicintegrity.org/investigations/longwall/assets/pdf/CPILongwall1lr.pdf

Lombardi, K. 2009b. The big seep. The Center for Public Integrity. Washington DC. 18 p. http://www.publicintegrity.org/investigations/longwall/assets/pdf/CPILongwall2lr.Pdf

Lombardi, K. 2013. New scrutiny of 'longwall' mining finds damage in Pennsylvania streams. The Center for Public Integrity. Washington DC. http://www.publicintegrity.org/2013/06/21/12877/new-scrutiny-longwall-mining-finds-damage-pennsylvania-streams

McElfish, James M., Jr., and Ann E. Beier. 1990. Environmental regulation of coal mining: SMCRA's second decade. Environmental Law Institute. Washington DC. 282 p.

McIlmoil, Rory and Evan Hansen. 2009. The decline of central Appalachian coal and the need for economic diversification. Downstream Strategies, Inc. Morgantown WV. 38 p.

Meyer, Judy L., Louis A. Kaplan, Denis Newbold, David L. Strayer, Christopher J. Woltemade, Joy B. Zedler, Richard Beilfuss, Quentin Carpenter, Ray Semlitsch, Mary C. Watzin, and Paul H. Zedler. 2003. Where rivers are born: The scientific imperative for defending small streams and wetlands. American Rivers and Sierra Club, sponsors. Washington DC. 24 p.

Meyer, Judy L., David L. Strayer, J. Bruce Wallace, Sue L. Eggert, Gene S. Helfman, and Norman E. Leonard. 2007. The contribution of headwater streams to biodiversity in river networks. Journal of the American Water Resources Association 43(1):86-103

Muller, Nicholas Z., Robert Mendelsohn, and William Nordhaus. 2011. Environmental accounting for pollution in the United States economy. *American Economic Review 101 (August 2011):1649–1675. 27 p.* http://www.aeaweb.org/articles.php?doi=10.1257/aer.101.5.1649

National Academy of Sciences (NAS). 1975. Underground disposal of coal mine wastes. A report to the National Science Foundation. Washington DC. 172 p.

NAS. 2010. Hidden costs of energy: unpriced consequences of energy production and use. Washington DC. 506 p. http://nap.edu/12794

NSW Minerals Council. 2007. Submission to the independent expert panel into underground mining in the southern coalfield. Sydney NSW. Variously paged (220 p.)

O'Connor, Kevin. 2001. Effects of undermining Interstate Route 70, South Strabane Township, Washington County, Pennsylvania, November 1999 to October 2000. Prepared by GeoTDR, Inc. for PADEP Bureau of Mining and Reclamation. Westerville OH. 22 p (plus 11 appendices).

Palmer, M. A., E. S. Bernhardt, W. H. Schlesinger, K. N. Eshleman, E. Foufoula-Georgiou, M. S. Hendryx, A. D. Lemly, G. E. Likens, O. L. Loucks, M. E. Power, P. S. White, P. R. Wilcock. 2010. Mountaintop mining consequences. In Science, Vol. 327. 8 January 2010. 2 p.

Palmer, Margaret A., and Kelly L. Hondula. 2014. Restoration as mitigation: analysis of stream mitigation for coal mining impacts in southern Appalachia. In Environmental Science & Technology (2014) 48:10552-10560.

Peng, Syd S. 1992. Surface subsidence engineering. Society of Mining, Metallurgy and Exploration. Littleton CO. 161 p.

Peng, S.S., and H.S. Chiang. 1984. Longwall mining. John Wiley & Sons, Inc. New York NY. 708 p.

Peng, S.S., and Y. Luo. 1994. Comprehensive and integrated subsidence prediction model - CISPM version 2.01. User's manual. Dept of Mining Engineering, West Virginia University. Morgantown WV. 62 p.

Pennsylvania Department of Environmental Protection (PADEP). 1997. Design criteria - wetlands replacement/monitoring. Technical Guidance Document (TGD) Number 363-0300-001. Bureau of Water Quality Protection. Harrisburg PA. 11 p. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-48803/363-0300-001.pdf

PADEP. 1998. Water supply replacement and permitting. Technical Guidance Document (TGD) Number 563-2112-605. Bureau of Mining and Reclamation. Harrisburg PA. 31 p. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-101334/563-2112-605.pdf

PADEP. 1999a. Water supply replacement and compliance. Technical Guidance Document (TGD) Number 562-4000-101. Bureau of Mining and Reclamation. Harrisburg PA. 43 p.

PADEP. 1999b. The effects of subsidence resulting from underground bituminous coal mining on surface structures and features and water resources. Harrisburg PA. Variously paged (170+ p.)

PADEP. 2000. Procedures for calculating mine subsidence bonds. Technical Guidance Document 563-2504-101. Bureau of Mining Programs. Harrisburg PA. 18 p. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-101477/563-2504-101.pdf

PADEP. 2001. The effects of subsidence resulting from underground bituminous coal mining on surface structures and features and water resources - supplement to the June 1999 report. Harrisburg PA. 45 p.

PADEP. 2003. Water quality antidegradation implementation guidance. Technical Guidance Document (TGD) Number 391-0300-002. Bureau of Water Supply and Wastewater Management. Harrisburg PA. 137 p.

PADEP. 2005. Surface water protection - underground bituminous coal mining operations. Technical Guidance Document (TGD) Number 563-2000-655 Bureau of Mining and Reclamation. Harrisburg PA. 43 p. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-100633/563-2000-655.pdf

PADEP. 2008a. Brief explanation of the stream redesignation process. Bureau of Water Standards and Facility Regulation. Harrisburg PA. 1 p. http://www.depweb.state.pa.us/portal/server.pt/community/water_quality_standards/10556/stream_redesignations/553982

PADEP. 2008b. Policy and procedure for evaluating wastewater discharges to intermittent and ephemeral streams, drainage channels and swales, and storm sewers. Technical Guidance Document (TGD) Number 391-2000-014. Bureau of Water Standards and Facility Regulation. Harrisburg PA. 13 p.

PADEP. 2009. Instream comprehensive evaluation surveys. Bureau of Water Standards and Facility Regulation. Harrisburg PA. Technical Guidance Document 391-3200-001. 46 p. http://files.dep.state.pa.us/Water/Drinking%20Water%20and%20Facility%20Regulation/WaterQualityPortalFiles/Methodology/ice_2009am.pdf

PADEP. 2010. Ryerson Station State Park, Ryerson Station Dam, Damage Claim Number SA 1736, interim report. California District Mining Office. 173 p. http://www.dep.state.pa.us/dep/deputate/minres/bmr/Ryerson_report/RYERSON%20STATION%20DAM%20DAMAGE%20CLAIM%20REPORT_revised_2-12.pdf

PADEP. 2014a. Pennsylvania mining history. PADEP Bureau of Mining Programs, Mine Subsidence Insurance website. http://www.dep.state.pa.us/msi/mininghistory.html

PADEP. 2014b. A guide to water supply replacement and subsidence damage repair. Document # 5600-BK-DEP4054. 10/2014. Coal Center PA. 16 p. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-103061/5600-BK-DEP4054.pdf

PADEP. 2014c. Pennsylvania integrated water quality monitoring and assessment report. Bureau of Clean water. Harrisburg PA. 74 p. http://www.dep.pa.gov/Business/Water/PointNonPointMgmt/WaterQuality/Pages/Integrated-Water-Quality-Report-2014.aspx#.VstfuSArKM8

PADEP. 2016. Reports on bituminous and anthracite mining. PADEP Bureau of Mining Programs. http://www.dep.pa.gov/Business/Land/Mining/BureauofMiningPrograms/Reports/Pages/default.aspx#.VscsoiArKM8

Pippy, John. 2015. Testimony of John Pippy, CEO, Pennsylvania Coal Alliance, to PADEP Citizens Advisory Council regarding Act 54. Harrisburg PA. 12 p.

Pond, G. J., and S. E. McMurray. 2002. A macroinvertebrate bioassessment index for headwater streams in the eastern coalfield region, Kentucky. Kentucky Department of Environmental Protection, Division of Water. Frankfort KY. www.water.ky.gov/NR/rdonlyres/8C6EDA04-98204D60-9EBC-A66A31C4C29F/0/EKyMBI2.pdf

Pond, G. J. 2004. Effects of surface mining and residential land use on headwater stream biotic integrity in the eastern Kentucky coalfield region. Kentucky Department of Environmental Protection, Division of Water. Frankfort KY. www.water.ky.gov/NR/rdonlyres/5EE3130F-88374B9F-8638-42BD0E015925/ 0/coal_mining2.pdf

Pond, G. J., Margaret E. Passmore, Frank A. Borsuk, Lou Reynolds, and Carole J. Rose. 2008. Downstream effects of mountaintop coal mining: comparing biological conditions using family- and genus-level macroinvertebrate bioassessment tools. Journal of The North American Benthological Society, 27(3):717–737.

Resource Technologies Corporation. 2002. Effects of longwall mining on real property value and the tax base of Greene and Washington Counties, Pennsylvania. Prepared for PADEP Bureau of Mining and Reclamation. State College PA. 105 p.

Roberts, James M., and Angelo L. Masullo, Jr. 1986. *Pneumatic stowage becomes affordable.* In Coal Age, 21:52-56. SRW Associates, Inc. Pittsburgh, PA.

Sanzotti, Michael J., Susan B. Bealko, and Christopher J. Bise. 1994. The potential and the prospects for alleviating longwall-mining concerns through the use of backstowing. Paper presented at the International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage, Pittsburgh, PA, April 24-29,1994. 8 p.

Schmid and Company, Inc. 2000. Wetlands and longwall mining: regulatory failure in southwestern Pennsylvania. Prepared for the Raymond Proffitt Foundation. Media PA. 83 p. http://www.schmidco.com/Wetlands%20and%20Longwall%20Mining%202000.pdf

Schmid and Company, Inc. 2009. Review of a petition to redesignate tributaries to South Fork Tenmile Creek from HQ-WWF to WWF. Prepared for Citizens for Pennsylvania's Future, Center for Coalfield Justice, and Mountain Watershed Association. Media PA. 37 p. http://www.schmidco.com/SchmidCo_Report.pdf

Schmid and Company, Inc. 2010a. A need to identify "Special Protection" status and apply existing use protections to certain waterways in Greene and Washington Counties, Pennsylvania. Prepared for Citizens Coal Council, with support from Buffalo Creek Watershed Association and The Foundation for Pennsylvania Watersheds. Media PA. 15 p. (plus 80 p. appendices) http://www.schmidco.com/Schmid_Co_SpecialProtectionStatus_26_April_2010.pdf

Schmid and Company, Inc. 2010b. Protection of water resources from longwall mining is needed in southwestern Pennsylvania. Prepared for Citizens Coal Council. Media PA. 195 p. http://www.schmidco.com/Final%20Report%2026%20July%202010.pdf

Schmid and Company, Inc. 2011. The increasing damage from underground coal mining in Pennsylvania: A review and analysis of the PADEP's third Act 54 report. Prepared for Citizens Coal Council. Media PA. 50 p. http://www.schmidco.com/17April2011SchmidAct54Analysis.pdf

Schmid & Company, Inc. 2012a. Independent technical review of proposed Donegal Mine, Butler County, Pennsylvania. Prepared for California District Mining Office and Office of Active and Abandoned Mine Operations on behalf of Rosebud Mining Company. Media PA. 74 p.

Schmid & Company, Inc. 2012b. Recommendations to expedite the Department's underground bituminous coal mine permit application reviews. Letter to John J. Stefanko, Deputy Secretary, PADEP Office of Active and Abandoned Mine Operations. Media PA. 17 p.

Schmid & Company, Inc. 2014a. The effects of converting forest or scrub wetlands into herbaceous wetlands in Pennsylvania. Prepared for Delaware Riverkeeper Network. Media PA. 49 p. http://www.schmidco.com/Leidy_Conversion_Final_Report.pdf

Schmid & Company, Inc. 2014b. The illusion of environmental protection: permitting longwall coal mines in Pennsylvania. Prepared for Citizens Coal Council, Bridgeville, PA. Media PA. 138 p. http://www.schmidco.com/IllusionReport_July2014.pdf

Schmid and Company, Inc. 2015a. Undermining the public trust: a review and analysis of PADEP's fourth Act 54 five-year assessment report. (Prepared for Citizens Coal Council.) Media PA. 65 p. http://schmidco.com/Mar_2015_Undermining_the_Public_Trust.pdf

Schmid and Company, Inc. 2015b. Comments to OSMRE on Docket ID: OSM–2010–0018 [proposed stream protection rule]. Prepared for the Foundation for Pennsylvania Watersheds (Alexandria PA). Media PA. 36 p.

Stout, Benjamin M., III. 2002. Impact of longwall mining on headwater streams in northern West Virginia. West Virginia Water Research Institute. Morgantown WV. 35 p.

Stout, B. M., III. 2004. Do headwater streams recover from longwall mining impacts in northern West Virginia? West Virginia Water Research Institute. Morgantown WV. 33 p.

Stout, B. M., III. 2009. Stream conditions in South Fork Tenmile Creek watershed, Greene County, Pennsylvania. Wheeling Jesuit University. Wheeling WV. 17 p.

Stout, B. M., III. 2010. Physical, chemical, and biological condition of nine headwater streams in the Buffalo Creek and Dunkard Fork watersheds of southwestern Pennsylvania. Prepared for the Buffalo Creek Watershed Association. Wheeling Jesuit University. Wheeling WV. 22 p.

Stout, B. M., III, and Schmid & Company, Inc. 2013. Biological assessment of Stony Run, Springfield Township, Fayette County, Pennsylvania. Prepared for University of Pittsburgh Environmental Law Clinic. 17 p.

Swanson, Timothy M. 2002. An introduction to the law and economics of environmental policy: issues in institutional design. Emerald Group Publishing Limited. 540 p.

Takacs, David. 2008. The public trust doctrine, environmental human rights, and the future of private property. 16 New York University Environmental Law Journal 711, 732-33. http://www.ielrc.org/content/a0804.pdf

The Monaco Group, Inc. 1999. Evaluation of implementation of Pennsylvania's longwall mining regulations. Prepared for the Pennsylvania Environmental Council. Pittsburgh PA.

University of Pittsburgh. [2011]. The effects of subsidence resulting from underground bituminous coal mining on surface structures and features and on water resources, 2003 to 2008. Prepared for the Pennsylvania Department of Environmental Protection. Pittsburgh PA. 513 p. http://www.dep.pa.gov/Business/Land/Mining/BureauofDistrictMining/Act54/Pages/default.aspx#.VsY1FyArKM8

University of Pittsburgh. [2014]. The effects of subsidence resulting from underground bituminous coal mining, 2003 to 2008. [Released 30 December 2014] Prepared for the Pennsylvania Department of Environmental Protection. Pittsburgh PA. 470 p. http://www.dep.pa.gov/Business/Land/Mining/BureauofDistrictMining/Act54/Pages/default.aspx#.VsY1FyArKM8

US Army Corps of Engineers and US Environmental protection Agency. 2008. Compensatory mitigation for losses of aquatic resources. 73 *Federal Register* 70:19594-19705 (10 April 2008). 112 p. http://water.epa.gov/lawsregs/guidance/wetlands/upload/2008_04_10_wetlands_wetlands_mitigation_final_rule_4_10_08.pdf

US Department of the Army, Environmental Laboratory (USA-EL). 1987. Corps of Engineers wetlands delineation manual. Final Report. Technical Report Y-87-1. US Army Engineers Waterways Experiment Station. Vicksburg MS. 189 p.

US Environmental Protection Agency (USEPA). 2000. Letter to US Fish and Wildlife Service summarizing the results of field work on Enlow Fork and Dunkard Fork. 11 September 2000. Wheeling WV. 8 p.

USEPA. 2008. Coal mining detailed study. Publication EPA-821-R-08-012. Washington DC. 153 p.

USEPA. 2010. A field-based aquatic life benchmark for conductivity in central Appalachian streams. Office of Research and Development, National Center for Environmental Assessment. Washington DC. EPA/600/R-10/023A. 193 p.

USEPA. 2015. Connectivity of streams and wetlands to downstream waters: a review and synthesis of the scientific evidence. Office of Research and Development. Washington DC. EPA/600/R-14/475F. 408 p. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=296414#Download

US Fish & Wildlife Service (USFWS). 2004. A survey of fish and aquatic habitat in three streams affected by longwall mining in southwestern Pennsylvania. State College PA. 71 p.

US Geological Survey (USGS). 2014. Characterizing natural streamflow in small ungaged watersheds. Proposed scope of work for a 3-year study to be conducted jointly between USGS and PADEP. Pittsburgh PA. 8 p.

Volz, Conrad D. 2007. Issues: Southwestern Pennsylvania's water quality problems and how to address them regionally. University of Pittsburgh, Institute of Politics. Pittsburgh PA. 62 p. http://www.chec.pitt.edu/Issue%20Brief%20Water%20Quality.pdf

Walker, Jeffrey S. 1993. State-of-the-art techniques for backfilling abandoned mine voids. US Department of the Interior, Bureau of Mines. Information Circular 9359. Pittsburgh PA. 17 p.

AUTHORSHIP AND ACKNOWLEDGMENTS

This report was prepared on behalf of the Citizens Coal Council by Stephen P. Kunz with the assistance of James A. Schmid. Both are senior ecologists with Schmid & Company, Inc. Mr. Kunz has been a consulting ecologist since receiving a degree in human ecology from Rutgers University in 1977. Dr. Schmid is a biogeographer with more than 40 years of experience in ecological consulting. Both Mr. Kunz and Dr. Schmid are certified as *Senior Ecologists* by the Ecological Society of America and as *Professional Wetland Scientists* by the Society of Wetland Scientists.

Mr. Kunz and Dr. Schmid offer outstanding credentials as experts in ecology, wetlands, environmental regulation, and impact assessment. They have analyzed the environmental impacts of many kinds of proposed development activities in many states, including coal mining facilities, industrial facilities, transportation facilities, and commercial and residential developments. They have prepared environmental inventories and written Environmental Impact Statements under contract to various federal, State, and local government agencies, and a diverse array of private sector entities. Regarding the regulation of underground coal mining, they have reviewed and provided public comments on proposed new regulations, revisions to existing regulations, technical guidance documents, and permit application forms and procedures, both at the State and federal levels. They also have reviewed and assessed specific coal mine permit applications. Regarding Pennsylvania Act 54, they have reviewed and provided formal comments on all four of the Five-Year Assessments and associated documents. They have been engaged with the PADEP Citizens Advisory Council on Act 54 issues for more than a decade.

CITIZENS COAL COUNCIL

Since its formation in 1989, the Citizens Coal Council (CCC) has been working to protect people, land, and water from the harm caused by coal mining throughout the United States. Its mission is *"To inform, empower, and work for and with communities affected by the mining, processing, and use of coal."* CCC seeks to address the core problem in the coalfields: the unequal distribution of power between the coal industry and citizens. It serves as a watchdog of the coal industry and the government agencies that oversee mining. It provides a forum for the exchange of ideas and the development of strategic alliances among coalfield leaders and citizens. CCC monitors national regulations, policies, and legal decisions, and serves as a vehicle for bringing coal-related issues before national policymakers. Aimee Erickson is the *Executive Director* of CCC, and she can be reached at aimee@citizenscoalcouncil.org .