# AN INVESTIGATION OF HIGH EXTRACTION MINING AND RELATED VALLEY FILL PRACTICES IN SOUTHWESTERN PENNSYLVANIA

Sponsored by:
The Audubon Society of Western Pennsylvania

## Background Reports

## Background Reports (continued)

# SECTION A

# INTRODUCTION

# CHAPTER 1

# PROJECT INTRODUCTION

The Audubon Society of Western Pennsylvania
Project Sponsors

Fifteen to twenty years ago a new and highly automated system of coal mining called longwall mining was introduced to Western Pennsylvania. The process removes all of the coal within a longwall panel leaving no support for the surface and guaranteeing that subsidence will occur. The degree of subsidence that quickly occurs at the surface depends on a number of factors. Although this high extraction mining technique is very efficient and provides many benefits to the mining industry, it is creating potential problems for our environment and our society.

Stemming from the Energy Policy Act of 1992, changes in federal regulations for underground mining were adopted in order to address the utilization of newer high extraction mining techniques, including longwall mining, that were being employed nationwide. Pennsylvania also amended its deep mine regulations accordingly through the Deep Mine Mediation Program which produced Act 54. Act 54 is a Pennsylvania law which paralleled the federal regulations to permit the use of high extraction mining techniques and attempt to maintain property values and protect the environment.

Pennsylvania regulations now permit the undermining of homes, perennial streams with certain provisions, and private water supplies as long as the coal operator agrees to "repair" the structural damage and "replace" water supplies. This is a simple solution to a not so simple problem. Many of the problems may go unnoticed and/or unremediated.

Originally longwall mining was used in rural areas where many of the impacts were less noticeable. In recent years mining has moved into rural residential areas and even within the city limits of Washington, PA. As more structural and environmental damage became apparent, more people starting asking questions for which there were few answers. These questions centered around legal issues concerning property rights and mining rights, long-term environmental impacts and social issues where people expressed helplessness to protect their homes from subsidence damage.

In 1995 a group of people including the Executive Director of the Audubon Society of Western Pennsylvania felt that there was insufficient information concerning these issues related to longwall mining in the area. With these issues in mind and the Audubon Society of Western Pennsylvania as the administrative agent, a steering committee was formed to coordinate research into these matters. This report is the result of efforts to identify what is known and not known about high extraction mining and its regulation in Southwestern Pennsylvania.

The mission of the Audubon Society of Western Pennsylvania is to inspire and educate the people of Southwestern Pennsylvania to be respectful and responsible stewards of the natural world. With that in mind it was determined that an unbiased scientific approach would be utilized to research the different legal, environmental, and socioeconomic issues that have been impacted by high extraction mining. The research was intended to be preliminary in nature. More in-depth study may be appropriate for those agencies with oversight authority. The Audubon Society is hopeful that the research will provide insight and background information to the public and decision-makers.

The international consulting firm of Dames and Moore was retained to manage the project. Authors with experience and knowledge in their respective fields were contracted with the Audubon Society and all work was to be peer reviewed so that it could be presented as sound and credible science.

Various issues were researched in the areas of: social, economic, legal, environmental, hydrogeologic consequences, valley fills, and subsidence phenomena. The results are presented in a bound series of background papers. A separate binder contains a series of executive summaries highlighting the work of each individual author. This report may raise as many questions as it answers. The work represents one of the first objective and scientific views of many of these issues. It is presented so the reader can evaluate the implementation of this technology for himself. It will hopefully enable individuals to better recognize the long-term socioeconomic and environmental implications of the continued use of this technology under current regulations. It was not an objective of the project to make recommendations or propose alternatives that could eliminate or minimize the impacts. The objective was merely to identify what is known and not known about a variety of issues and provide commentary thereon.

High extraction mining and its impacts present very complex issues. A good deal of background information needs to be presented so that one can understand the issues that include:

- What environmental problems are associated with this mining technique? What are the long-term impacts of subsidence on wood lots, agricultural lands, perennial streams and wetlands? Are coalbed methane releases a significant problem?
- What are the effects (short-term and long-term) on the supply and quality of groundwater and surface water? Are pre-mining surveys of water supplies providing sufficient data

to evaluate the impacts on groundwater supplies and has there been sufficient research to determine hydrologic consequences?

- How accurately can the industry model subsidence and can mitigation measures be implemented to minimize the damage to peoples' homes?
- What is the true impact of the mining industry on the local economy and how is the tax base impacted?
- What is the impact on property values and real estate markets?
- Do Pennsylvania laws and regulations covering longwall mining and the disposal of coal refuse in valley fills conflict with any existing state or federal environmental regulations?

The authors contracted by the Audubon Society researched these complex issues and found a general lack of information related to the topic of high extraction mining as it pertains to the areas investigated. This in itself is a powerful conclusion for those concerned with extraction mining and its management and regulation.

Many people have been supportive of this project and it would be impossible to thank everyone who has provided information and support at one point in time. Especially helpful have been the members of the steering committee: Jeff Au, Bruce Bickel, Court Gould, Brian Hill, Bill Hopwood, William McClure, Andrew McElwaine and Davitt Woodwell. Their input and direction was invaluable in producing this final report. Also, the consulting firm of Dames & Moore provided valuable insight and resources to complete this project. Their professional approach to the project and maintaining an unbiased structure should be commended.

Additional copies of the executive summaries and background papers can be obtained from the Audubon Society of Western Pennsylvania by calling 412.963.6100. A charge for shipping and handling will be applied.

# CHAPTER 2

# MINING METHODS AND VALLEY FILL OPERATIONS AND THEIR IMPACTS ON THE SURFACE

Derek J. Steele
Dames & Moore
Cincinnati, Ohio

## 1.0 PURPOSE

The purpose of this report is to provide an explanation of the technical mining operations which are the subject of various supplementary reports that comprise this study, and to define related technical mining terms. Specifically, this report describes the longwall and room-and-pillar mining methods, and the surface method of disposing of mined waste into valley fills, such that the reader can obtain a basic understanding of theses types of mining activities prior to reviewing the contents of nine supplementary issues reports. Each issues report addresses the impacts of these mining activities on specific surface matters that are identified in a later section of this report. Longwall mining is the principal coal extraction method used in Southwestern Pennsylvania and it is described, therefore, in greater detail.

In order to assist the reader further in understanding the contents of the reports, a glossary of mining terms is included in Appendix A.

## 2.0 BACKGROUND

The traditional method of extracting coal in North American mines is known as room-and-pillar mining. Longwall mining, which was introduced into the United States in the 1950s, has been used increasingly since that date as the mine operator realizes higher productivity, enhanced safety, and lower mining costs. In 1997, the nation had 65 longwall faces, of which ten were operated in the Pittsburgh Seam in Southwestern Pennsylvania and which produced more than 40 percent of the bituminous coal mined in the Commonwealth.

The term valley fill is used to describe hollows between hillsides into which reject mined material is deposited. Since the term does not describe a mining method, this process of disposing of waste mined materials is discussed in a separate section of this introductory report.

## 3.0 LONGWALL MINING

In longwall mining, coal is extracted from a rectangular panel, which may be up to 12,000 feet long and 1,000 feet wide, that has been blocked out by entries driven around its perimeter. Entries are passageways up to 20 feet wide that are supported along each side by coal pillars. Coal is mined by a machine which passes across the width of the panel (or the length of the face) removing up to 3.5 feet of coal during each pass leaving the entry support pillars in place. Generally, mining commences at the furthest extremity of the panel and the face retreats toward the main mine entries. The entries surrounding the panel, that range from 2 to 5 in number, are used to ventilate the face with fresh air, and to provide access for miners, materials, and coal transportation (Figure 1). As depicted in Figure 1, the main mine entries comprise a series of five to nine passageways established in a manner similar to that in which the main mine entries for room-and-pillar mining are developed.

The mining height at the coal face of the longwall panel is dependent on the seam thickness together with any thickness of roof or floor stratum that is removed. The roof is continuously supported by hydraulic shields that are moved forward to support the roof newly exposed by coal extraction, thus allowing the previously supported roof in the panel to collapse into the mined-out void which is known as the gob. The collapse of the overlying strata in this manner causes it to fragment, and occupy a larger volume, thus filling the void such that it supports the higher beds of strata which move downwards to compress the fragmented material. Dependent on geological conditions, and the dimensions of the longwall extraction, this downward movement of strata ultimately causes surface subsidence. Longwall mining is applicable at any depth below the surface, and increased depth results in less downward movement of the surface for any given mining height and longwall panel width.

Since the operations of coal extraction, coal transportation, and roof support are highly mechanized, the mining process is essentially continuous. As a result, longwall faces progress at retreat rates of, say, 200 feet per week, during which coal will be removed over an area of approximately 4 acres, yielding high rates of production and yielding productivity. Although longwall mining results in complete, 100 percent, coal extraction over very long and very wide panel areas, it does not allow full extraction of the seam since coal remains in place in the pillars left to support the main and panel entries. As depicted in Figure 1, the percentage of coal removed will typically range from 60 to 70 percent. Hence, longwall mining may be described as high extraction mining since a greater percentage of coal is removed compared with room-and-pillar mining in which pillars are not extracted.

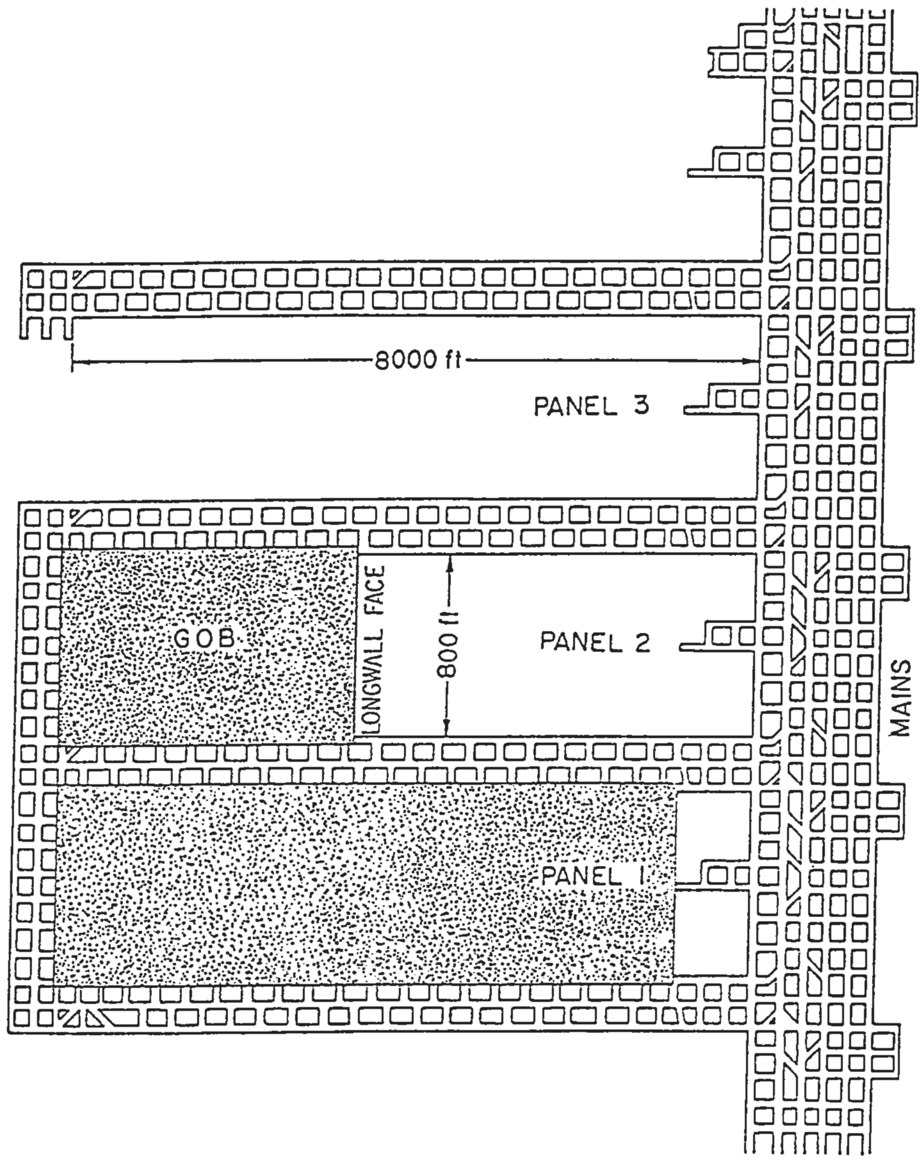



**Figure 1: Longwall Mining Method**

Source: Stefanko, 1983 (modified)

## 4.0 ROOM-AND-PILLAR MINING

In room-and-pillar mining, coal is extracted from entries or rooms driven in a checkerboard pattern while the intervening coal pillars are left to support the roof. The proposed mining area is developed by main entries ranging between 5 and 9 in number that are advanced parallel to each other at spacings between 60 and 100 feet. Entries are typically 18 to 20 feet wide and are interconnected by crosscut entries. Additional entries are driven in a direction perpendicular to the mains to divide the area into panels in which rooms are developed to provide the major source of production as shown in Figure 2. Coal pillars, particularly in the production panels, may be partly removed to increase the percentage of coal recovery above that which is normally obtained that ranges between 50 and 65 percent. Room-and-pillar mining generally is limited to depths of about 1,000 feet below the surface, since larger support pillars are required as depth increases, resulting in decreased coal recovery percentage.

## 5.0 SURFACE MOVEMENTS RESULTING FROM MINING

The strata composing the earth's crust are, generally speaking, subject to two main natural forces, namely, vertical and lateral compressive forces. Normally, these forces are in a state of balance. The general effect of mining is to create a space into which the overlying strata tend to subside and break down. Disturbance of the equilibrium causes vertical and lateral movements in the strata, which may ultimately be transmitted to the surface giving rise to either pit or sag subsidence. The movements continue until equilibrium has been restored.

Pit subsidence occurs in discrete areas resulting in a vertical drop of the surface to a depth of a few feet over an area ranging from 2 to 40 feet in diameter. Specific pit dimensions are dependent on the local geologic conditions and the type and extent of mining. This type of subsidence is normally associated with coal extraction at depths of less than 150 feet below the surface, that is significantly less than the normal depth of 500 to 1,200 feet at which longwall mining takes place in the Pittsburgh Seam in Southwestern Pennsylvania.

Sag or trough subsidence results in a general surface depression over a broad area. The sag may affect extensive areas of surface dependent on geological conditions and the method of coal extraction. Since the amount of downwards sag varies throughout the trough, the surface is unevenly affected.

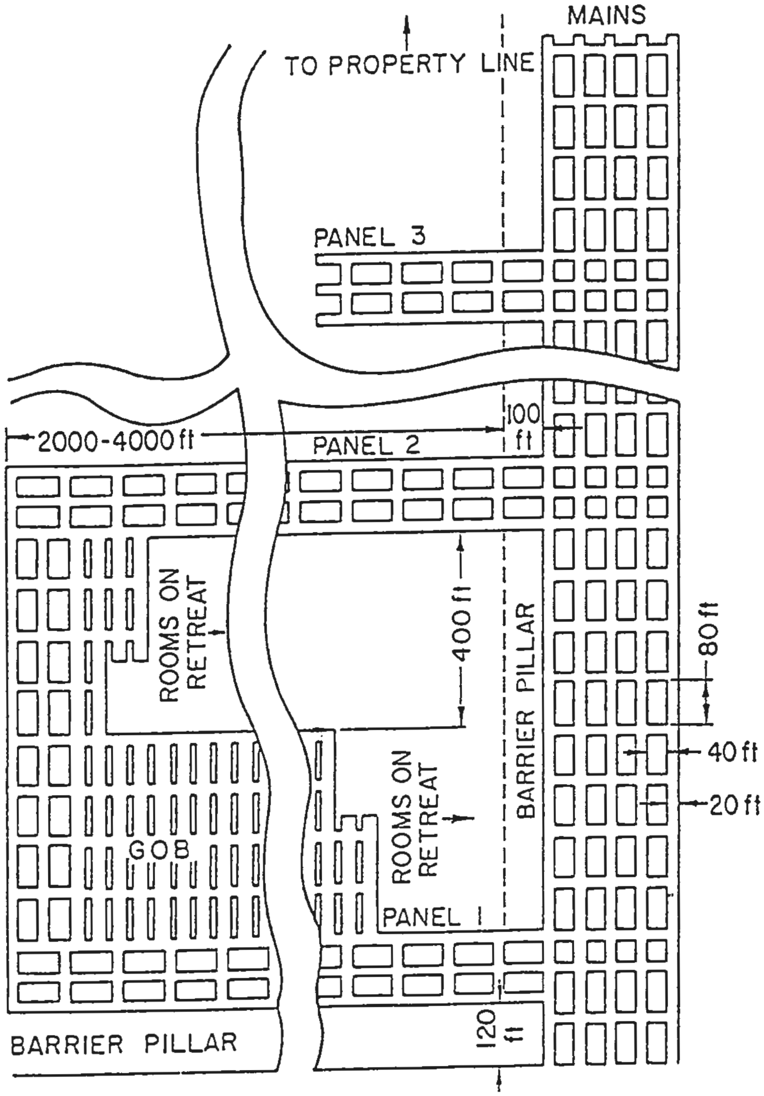



**Figure 2 Room-and-Pillar Mining Method**

Source: Stefanko, 1983 (modified)

## 5.1 LONGWALL MINING SUBSIDENCE

Sag-type subsidence caused by longwall coal extraction gives rise to both vertical and horizontal movements in the surface. Vertical lowering of the surface is termed subsidence, while horizontal movement is defined by the extent to which the distance between two surface points increases, or decreases, giving rise to tensile strain, or compressive strain, respectively. The combined effects of subsidence and lateral movement cause tilt and curvature in the ground surface and changed gradients. The magnitude of these various parameters will determine whether surface structures or facilities are impacted by coal extraction.

Figure 3, which is a generalized cross-section drawn along the width of a longwall panel, shows that the surface extent of subsidence is greater than the extent of extraction. The amount by which the subsided surface extends over the solid coal is known as the draw, and the angle between a vertical line drawn from the limit of mining, and a line drawn from this position to the limit of subsidence, is known as the angle of draw. Sag causes the area above the solid coal to be subjected to tensile strain while the area above the gob undergoes compressive strain. Since longwall panels are extracted parallel to each other (Figure 1), the surface impacts resulting from adjacent panels overlap and increase the downwards and lateral movement.

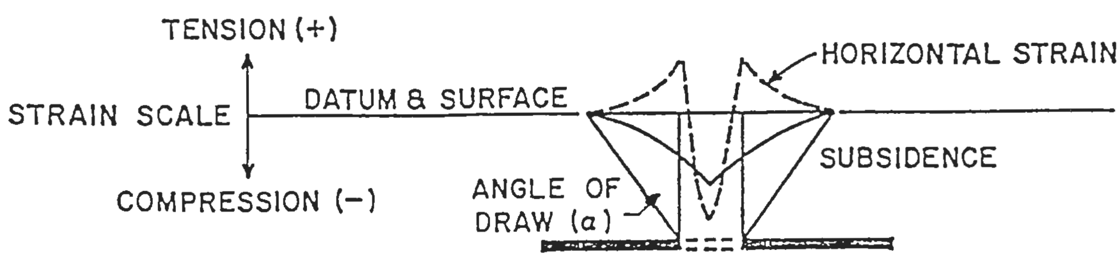



**Figure 3: Cross-Section Through a Longwall Panel**

Source: Stefanko, 1983 (modified)

It should be noted that the simple concept depicted in Figure 3 must also be applied in a direction perpendicular to panel width, that is in the direction in which the face is moving, thus giving rise to traveling strain zones.

The magnitude and extent of the various surface movements caused by longwall mining are dependent on geological conditions and mining dimensions. In the conditions prevailing in Southwestern Pennsylvania, the maximum vertical lowering of the surface is, typically, equal to 60 percent of the mining height, equivalent to 3 to 4 feet of surface lowering in a mining height of 5 to 6.5 feet. Thus, the amount of vertical lowering in a subsidence trough ranges from a few inches to 3 to 4 feet. However, the effects of subsidence from longwall mining follow a regular form and are anticipated. State-of-art subsidence engineering techniques that are described in supplemental documents to this report, enable surface movements to be predicted thus allowing planned subsidence to take place.

## 5.2 ROOM-AND-PILLAR MINING SUBSIDENCE

Room-and-pillar mining in which coal is not extracted from pillars does not generally cause surface subsidence. However, at shallow depths below the surface, pit subsidence may occur by collapse into entries or rooms, particularly if the overlying strata are weak. This is not normally a consideration in Southwestern Pennsylvania since the depth of mining is too great.

In circumstances where pillar extraction is practiced, it is generally not possible to extract the whole pillar. Since partial roof support remains, the amount of surface movement can be highly variable and difficult or impossible to predict. Further, since subsequent loss of pillar strength may result from deterioration due to age or the presence of water, surface movements may occur up to 50 years or more after mining has taken place.

# 6.0 VALLEY FILLS

## 6.1 DESCRIPTION

The term valley fill is used to describe surface hollows or low-lying tracts of land between hills or mountains into which reject mined material or waste is deposited. In many areas of Appalachia, where the topography is rugged and surface mining is the principal extraction method, the excess material that results from the removal of the strata above the seam may be disposed of in a valley fill. On the other hand, underground mining also produces waste materials which may be present within the seam itself or may be removed from the roof or floor of the seam during mining. Coal preparation facilities are used at the surface to separate out these waste products, which comprise rock, clay, and silt, and that may be deposited in a valley fill. Materials from the latter source are likely to comprise the majority content of valley fills to be constructed in Western Pennsylvania.

Valley fills are constructed to regulated engineering standards to ensure stability and to control impacts that may result from their existence.

## 6.2 SURFACE CONSIDERATIONS

Valley fill areas are often traversed by streams or creeks which receive the natural drainage from the surrounding high ground. The placement of mined waste in a valley fill may result in the loss of the headwater stream(s) and the loss of possibly significant upstream areas. Land use, geology, and soil characteristics in small and large catchment areas affect the water quality and quantity in the lower reaches of any drainage system. Hence, valley fill disposal areas may affect downstream flows and riparian habitat since critical functions of tributaries are removed from the drainage system. Further, negative upstream effects may have commercial, economic, and recreational significance in downstream areas.

## 7.0 SURFACE IMPACTS OF UNDERGROUND MINING AND VALLEY FILLS

The surface and related impacts of high extraction longwall coal mining and valley fills are described in detail in various research papers that support this introductory document as follows:

- Mining Methods and Valley Fill Operations and Their Impacts on the Surface
- Regulation of Longwall Mining and Valley Fill Practices in Pennsylvania
- Hydrologic Consequences of High Extraction Mining in Southwestern Pennsylvania
- Surface Subsidence and Structural Damage
- Subsidence Prediction Techniques
- Potential Effects of Longwall Mining and Associated Activities on the Ecology of Southwestern Pennsylvania
- Environmental Concerns Related to the Practice of Valley Filling in Pennsylvania

- Importance of Coal Mining, with Emphasis on Greene and Washington Counties
- Longwall Mining in Southwestern Pennsylvania: Perceptions of Near-by Residents
- Property Value, Tax Revenue, and Underground Coal Mining Practice in Southwestern Pennsylvania

A Glossary of Mining Terms is included as Appendix A to assist the reader in interpretation of the foregoing documents.

# APPENDIX A

## GLOSSARY OF MINING TERMS

| | |
|---|---|
| **Angle of Draw** | The angle between a line drawn vertically upwards from the limit of mining and a line drawn from the same point to the limit of subsidence. |
| **Barrier Pillar** | Pillars or strips of coal left unmined for the purpose of dividing the working areas of the mine. |
| **Bed Separation** | The moving apart of stratified beds caused by undermining. |
| **Breaks** | Fractures that develop in the strata surrounding an excavation due to deformation. |
| **Caving** | The action of withdrawing support from beneath the mine roof and allowing the overlying strata to collapse. |
| **Coal Measure Strata** | Strata containing coal seams between layers of shale, sandstone, and limestone. |
| **Coal Pillar** | An area of coal left to support the overlying strata. |
| **Coal Seam** | A bed or stratum of coal. |
| **Compressive Strain** | Change in length per unit length produced by compression. |
| **Critical Area of Extraction** | That area of extraction which causes the full subsidence of one point on the surface. |
| **Critical Width** | The width of a critical area. |
| **Crosscut** | A short interconnecting entry between mains or submains entries. |
| **Draw** | The distance by which the surface affected by subsidence extends over solid coal beyond the limit of mining. |
| **Entry** | An underground passageway, usually rectangular in cross-section, used for transportation and/or ventilation. |

| | |
|---|---|
| **Floor** | The stratum immediately below a coal seam. |
| **Full Subsidence** | The maximum possible amount of surface lowering that can be caused in a specified mining height. |
| **Gates** | The entries located at each end of the longwall face. |
| **Geological Fault** | A naturally occurring discontinuity which may displace stratum vertically or laterally. |
| **Gob** | The inaccessible area of the mine from which coal has been extracted. |
| **Hydraulic Flushing** | The placement of material into the gob or abandoned mine areas through a pipeline using water. |
| **Hydraulic Shield** | A 2-leg or 4-leg hydraulic unit that supports the roof and is sequentially released, advanced, and reset as the coal face advances. |
| **Longwall Face** | A length of exposed coal seam ranging between 600 to 1,000 feet from which coal is mechanically extracted in narrow slices. |
| **Longwall Panel** | An area of coal surrounded by development entries that is to be extracted by a longwall face. |
| **Longwall Panel Length** | The distance over which the face is to be advanced. |
| **Longwall Panel Width** | The distance between the entries at the end of the face being equal to the face length. |
| **Mains (Entries)** | A series of parallel entries driven into large areas of coal to secure long-term access. |
| **Mining Height** | The thickness of coal and overlying/underlying stratum extracted measured in a direction perpendicular to the floor. |
| **Overburden** | The strata lying between the seam and the surface. |
| **Retreat Mining** | Mining which commences at, or near to, the limits of a mining property and progresses towards the main access entries or surface outlets of the mine. |

**Roof** — The stratum immediately above a coal seam.

**Roof Bolt** — A tensioned rod or rope anchored in a hole drilled into the strata to increase the inherent strength of the roof.

**Room-and-Pillar Mining** — A method of coal extraction in which passageways are driven in checkerboard pattern such that intervening coal pillars, which may later be wholly or partly extracted, provide the main roof support.

**Seam Depth** — The distance measured from the surface to the bottom of the seam.

**Seam Thickness** — The perpendicular distance measured between the top and bottom of the coal seam.

**Stowing** — The placement of material into the gob to provide support.

**Strain** — A dimensionless physical quantity expressed as change in length per unit length.

**Sub-Critical Area of Extraction** — An area of extraction smaller than the critical area such that no point on the surface experiences full subsidence.

**Submains** — Parallel entries driven perpendicularly to main entries to subdivide and gain access to mining areas.

**Subsidence** — Vertical lowering of the surface that results from coal extraction; in informal usage, the term may be used to include laterally-induced movement of the surface.

**Subsidence Trough** — The depression formed by strata subsiding into an excavation.

**Super-Critical Area of Extraction** — An area of extraction greater than the critical area such that an area on the surface experiences full subsidence.

**Tensile Strain** — Change in length per unit length produced by extension.

# CHAPTER 3

# REGULATION OF LONGWALL MINING AND VALLEY FILL PRACTICES IN PENNSYLVANIA

James M. McElfish, Jr.[1]
Environmental Law Institute
Washington, D.C.

1. Senior Attorney and Director, ELI Mining Center, B.A. 1976, Dickinson College, J.D. 1979, Yale Law School. The author also wishes to thank Sheela Sathyanarayana for her helpful assistance and research for this study.

This study describes the federal and Pennsylvania laws applicable to underground longwall coal mining and the disposal of coal refuse in stream valleys in the Commonwealth. After an introduction to the legal framework, it examines the legal requirements in four areas: (1) the subsidence effects of longwall mining, (2) the water supply effects of longwall mining, (3) permitting and enforcement issues related to subsidence and water supply, and (4) the disposal of coal refuse in valley fills. The study is intended to assist citizens, legislators, policy makers, and others in understanding the coverage of existing laws, regulations, and policies, including areas of uncertainty.

The laws and regulations governing these areas are lengthy and complex. Nevertheless, coal operators' obligations and surface owners' rights are explained in detail. Differences between the federal and Pennsylvania laws and regulations are also described and placed into context. Perhaps most important, the timing and nature of opportunities for citizen involvement in the regulatory processes are set out so that citizens can take advantage of these opportunities where they now exist, and can seek the creation of additional opportunities where they do not.

# 1.0 INTRODUCTION

## 1.1 FRAMEWORK OF FEDERAL AND STATE LAWS

Environmental effects of underground coal mining operations have been regulated in Pennsylvania for decades. Pennsylvania was one of the leaders in such regulation prior to enactment of the federal Surface Mining Control and Reclamation Act of 1977 (SMCRA).[2]

SMCRA is the primary federal law that addresses the environmental effects of coal mining operations. It is complemented by the federal Clean Water Act, which regulates discharges of pollution into the waters of the United States. Despite its name, SMCRA is not limited to the regulation of surface mining methods, but also regulates the surface effects of underground mining. These include subsidence (the caving and settling of the land surface overlying the underground mine); disturbance of the hydrology (including diminution or contamination of wells, springs, and

2. 30 U.S.C. § 1201 et seq.

other waters); surface disturbances associated with mine openings; and the disposal of coal refuse (unwanted materials excavated from the mine but separated from marketable coal).[3]

In 1992, SMCRA was amended by the Energy Policy Act (EPAct), which added a new section requiring underground coal operators to repair, or compensate owners for, material damage to occupied residential dwellings and noncommercial buildings resulting from subsidence; and to replace drinking, domestic, or residential water supplies from any well or spring affected by contamination, diminution, or interruption caused by underground coal mining operations.[4]

SMCRA created a federal regulatory program that operates directly to regulate coal mining activities in the states unless a state elects to develop and implement its own program. SMCRA provides that any state may assume "exclusive jurisdiction" over the regulation of coal mining operations -- subject to continuing federal oversight and back-up federal enforcement -- if it enacts laws and adopts regulations that are consistent with SMCRA permitting and performance standards, and has enforcement provisions that are no less stringent than the federal requirements.[5] Provisions of state law that are more stringent than SMCRA are not deemed inconsistent with the federal law.[6]

The Office of Surface Mining (OSM), an agency within the U.S. Department of the Interior, is the federal agency responsible for review and approval of state programs. It also conducts oversight of state implementation, and provides back-up federal enforcement against coal operators in instances where a state fails to carry out its approved program. Federal approval of a state program as sufficient under SMCRA is commonly termed "primacy," referring to the state's primary role in regulation. Pennsylvania received primacy on July 31, 1982, upon OSM's conditional approval of its regulatory program. Pennsylvania's coal mining regulatory program is administered by the Department of Environmental Protection (DEP).

Pennsylvania enacted its Bituminous Mine Subsidence and Land Conservation Act (BMSLCA) in 1966, and its Coal Refuse Disposal Control Act in 1968. Both laws were amended

3. 30 U.S.C. § 1291(28). Also see 30 U.S.C. § 1266 (setting the performance standards applicable to underground mining).
4. 30 U.S.C. § 1309a(a).
5. 30 U.S.C. §§ 1253, 1271(d). See generally, James M. McElfish, Jr. and Ann E. Beier, Environmental Regulation of Coal Mining: SMCRA's Second Decade, esp. Chapter 3 "Federal-State Relations: The Core Issue," (Environmental Law Institute, 1990).
6. 30 U.S.C. § 1255(b).

in 1980 in order to bring them into consistency with SMCRA, supporting the grant of "primacy" to the Commonwealth by OSM in 1982. In 1994, Pennsylvania's legislature amended these laws again.

If federal requirements change, states that wish to maintain primacy must submit amendments to their approved programs in order to keep them consistent with the federal regulatory program. Similarly, if a primacy state adopts laws and regulations on its own initiative, these must be submitted to OSM for review and approval to assure that the state program remains consistent with federal requirements.

Pennsylvania amended the BMSLCA in 1994 to provide for repair or compensation for damage to structures, and for replacement of water supplies damaged by underground mining.[7] The amendment, commonly known as Act 54, was intended both to implement the 1992 EPAct requirements, and to carry out the result of a (controversial) multi-year mediation effort among Pennsylvania underground coal mine operators and some conservation groups. Act 54 also removed some of the substantial impediments to longwall mining in Pennsylvania that had been a feature of state law since 1966. The BMSLCA, as originally enacted, had prohibited subsidence of dwellings, public buildings and certain other structures in existence in 1966,[8] and so posed an obstacle to the use of longwall mining in populated areas. Act 54 repealed these prohibitions while adopting water replacement and subsidence repair and compensation obligations. The DEP began implementing Act 54 immediately after its enactment. In 1998, Pennsylvania's Environmental Quality Board adopted final regulations to implement Act 54.[9] These regulations will be reviewed by OSM for consistency with SMCRA/EPAct in order to determine whether they can be approved as part of Pennsylvania's primacy program.

Pennsylvania also amended its Coal Refuse Disposal Control Act in 1994. These amendments, commonly known as Act 114, allow disposal of coal refuse in stream valleys and encourage the siting of coal refuse disposal areas in places adversely affected by prior coal mining

7. As amended, the law is found at 52 P.S. § 1406.1 et seq.

8. See Keystone Bituminous Coal Assn. v. DeBenedictus, 480 U.S. 470 (1987) (upholding the Act against a constitutional challenge).

9. "Mine Subsidence Control, Subsidence Damage Repair, and Water Supply Replacement," (amendments to 25 Pa. Code, Chapter 89), adopted March 17, 1998, Environmental Quality Board; to be published in Pa. Bulletin. (Amended regulations cited hereafter as 25 Pa. Code 89. (1998)).

activities that remain unreclaimed.[10] These amendments were conditionally approved by OSM in 1998.[11] As with Act 54, Pennsylvania began implementing Act 114 immediately after its enactment.

## 1.2 WHAT LAW APPLIES?

State-enacted laws and state-adopted regulations are fully operative and enforceable as a matter of state law, even before they have been reviewed and approved by OSM under SMCRA, and operators must comply with them.[12] However, they are not regarded by OSM as part of the state's approved primacy program prior to approval by OSM; and they may be preempted by federal law if they are inconsistent with SMCRA.[13] If state provisions are subsequently disapproved by OSM, the state must adopt new laws and regulations in order to maintain primacy jurisdiction.

When inconsistencies between state and federal regulations arise because of newly adopted federal requirements, the federal government generally must await their incorporation into state law before the new requirements can be applied directly to particular operators. However, OSM determined that the 1992 EPAct provisions protecting structures and water supplies are directly enforceable by OSM in instances where the corresponding state provisions are incomplete.[14] OSM took this position because the law speaks directly to the obligations of operators and the protection of surface owners as of a specific date (October 24, 1992) rather than strictly in terms of performance standards for state programs to incorporate into permits. In Pennsylvania, there is, consequently, "joint enforcement" with respect to subsidence damage and water replacement; DEP enforces Act 54, while OSM enforces any federal regulatory provisions that are beyond the scope of DEP's authority pending achievement of consistency between the programs.[15]

Because of the complex interplay between state and federal regulation, coal mining operations often are permitted by DEP under state laws and regulations (1) that have been federally approved as part of the primacy program, (2) that are awaiting federal approval, or (3) that have not

10. 52 P.S. § 30.51 et seq. (Act 114). The CRDCA was originally enacted in 1968, and had been amended in 1980 to bring it into consistency with SMCRA.
11. 63 Fed. Reg. 19802-19821 (April 22, 1998).
12. 30 U.S.C. § 1255.
13. See 30 U.S.C. § 1255.
14. See 60 Fed. Reg. 38685-38689 (July 25, 1995)(OSM announces that it will enforce subsidence damage and water replacement provisions directly to the extent to which they are not enforceable by Pennsylvania).

yet been brought into conformance to federal requirements (viz. where state law is either silent or appears to conflict with federal law).

Of course, Pennsylvania statutes and regulations that have been approved as part of the primacy program clearly apply. Pennsylvania statutes and regulations awaiting approval must be complied with as a matter of state law, but are subject to disapproval by OSM (which will require them to be changed if Pennsylvania is to maintain its primacy status). There is also a credible legal position, not shared by all legal scholars, that statutes and regulations awaiting approval but that are inconsistent with SMCRA are also automatically preempted by federal law even before OSM acts. Statutes and regulations disapproved by OSM as inconsistent with SMCRA are preempted by federal law;[16] however, OSM has frequently allowed states a period of time to bring them into consistency through the device of "conditional" approval.

This array of circumstances may subject the operator to at least theoretically conflicting mandates, and can leave citizens and regulators alike uncertain of applicable remedies. Because the coal mining operation is governed in the first instance by its permit (which is issued under state law for a five-year term, subject to renewal),[17] the state provisions are frequently implemented during the course of any disagreement between the DEP and OSM. However, the possibility of federal or citizen suit enforcement of federal provisions exists where the state law or regulations are inconsistent with SMCRA and the federal regulations.

The issue of applicable standards is also inevitably complicated by litigation. The coal industry and environmental groups have filed suit over virtually every federal regulation adopted during SMCRA's 21-year history. One federal appeals court has observed: "As night follows day, litigation follows rulemaking under the statute."[18] The federal regulations implementing EPAct were adopted in 1995,[19] and Pennsylvania's 1998 regulations implementing Act 54 must be consistent with these federal regulations. But the National Mining Association (NMA) filed a federal lawsuit in the

15. Id.
16. 30 U.S.C. § 1255.
17. The normal term is five years, although a longer term is allowed under some circumstances, 25 Pa. Code § 86.40; but the permit must be "reviewed" at least every five years. 25 Pa. Code § 86.51.
18. National Wildlife Fedn. v. Lujan, 950 F. 2d 765, 767 (D.C. Cir. 1991).
19. 60 Fed. Reg. 16722-51 (March 31, 1995). This was approximately one and one-half years after they were required to have been promulgated. The delay was due, in part, to the contentious nature of the new requirements, which imposed new obligations on underground coal mine operations.

District of Columbia in 1995 challenging the validity of the federal regulations. Although the district court upheld these regulations, rejecting NMA's legal challenge in 1998, an industry appeal maintains at least the possibility that the federal regulations may need to be changed in the future, making them a potentially moving target for state consistency.[20]

## 2.0 REGULATION OF THE SUBSIDENCE EFFECTS OF LONGWALL MINING

Regulatory standards for subsidence impacts of longwall mining fall into two general categories: (1) requirements for preventive measures, and (2) repair, replacement, and compensation requirements.

### 2.1 PREVENTION REQUIREMENTS

#### 2.1.1 Federal Requirements

SMCRA provides that each permit issued to the operator of underground coal mining operations must require the operator to:

> adopt measures consistent with known technology in order to prevent subsidence causing material damage to the extent technologically and economically feasible, maximize mine stability, and maintain the value and reasonably foreseeable use of such surface lands, *except*

20. National Mining Association v. Babbitt, Civ. No. 95-CV-0938(WBB) (D.D.C. May 29, 1998). Industry had argued unsuccessfully that: 1) the regulations unlawfully conflict with EPAct and SMCRA by prohibiting or interrupting underground coal mining operations; 2) the regulations unlawfully conflict with states' "exclusive" authority to regulate, and OSM allegedly failed to provide notice and comment on its intention to conduct federal enforcement of the requirements; 3) the regulations are arbitrary, capricious, and otherwise inconsistent with law in that:

(a) OSM failed to explain its requirement of a presubsidence survey of the condition of protected surface structures,

(b) requiring planned subsidence operators to engage in any damage minimization conflicts with § 516(b)(1) of SMCRA,

(c) the regulations' performance standards for water replacement and subsidence repairs unlawfully abrogate rights under state law such as state statutes of limitations, water rights, and waivers,

(d) replacement of water supply requirements exceed OSM's authority under EPAct which is limited to replacement of water and not replacement of damaged water delivery systems,

(e) repair and replacement requirements conflict with an OSM rule that terminates jurisdiction over mining sites upon bond release,

(f) requiring bonding for subsidence damage is ultra vires and arbitrary and capricious, and

(g) the "material damage" definition is arbitrary and capricious and exceeds the plain language of EPact; and (4) the regulations are arbitrary, capricious, and illegal because they prescribe an angle of draw of 30 degrees to identify the buildings presumptively entitled to repair even though the scientific and technical literature will not support such an angle (Plaintiff's Motion for Summary Judgment, Feb. 16, 1996).

*in those instances where the mining technology used requires planned subsidence in a predictable and controlled manner.*[21]

Despite the "except" clause, longwall operators are not excused from the obligation to "maintain the value and reasonably foreseeable use" of the land. The federal district court that reviewed the regulations based on this section ruled that planned subsidence operators must still file subsidence control plans that demonstrate that they "will protect the values" reflected in this section.[22] In other words, "subsidence in a predictable and controlled manner" means more than mere use of the longwall mining method.

Damage prevention is, moreover, in no way inconsistent with longwall mining. Both structural reinforcement and subsidence engineering can prevent material damage and help maintain the value and foreseeable use of surface lands.[23] Material damage is broadly defined as "any functional impairment of surface lands, features, structures or facilities; any physical change that has a significant adverse impact on the affected land's capability to support any current or reasonably foreseeable uses or causes significant loss in production or income; or any significant change in the condition, appearance or utility of any structure or facility from its pre-subsidence condition."[24]

In addition to these requirements, the new federal regulations adopted in 1995 to implement EPAct (but based in part on the above provision) require a longwall mining operator to:

> take necessary and prudent measures, *consistent with the mining method employed*, to minimize material damage to the extent technologically feasible to non-commercial buildings and occupied residential dwellings and structures related thereto.[25]

However, the longwall operator need not minimize material damage to these structures if the operator has obtained the written consent of the building owners, or if the costs of the measures would exceed the costs of repair (unless the anticipated damage is a threat to health or safety).[26]

21. 30 U.S.C. § 1266(b)(1).
22. In re: Permanent Surface Mining Regulation Litigation, 10 Envt. L. Rep. (Envtl. L. Inst.) 20208, 20217, 14 Env't. Rep. Cas. (BNA) 1083, 1098 (D.D.C. Feb. 26, 1980)
23. James M. McElfish, Jr. and Ann E. Beier, Environmental Regulation of Coal Mining: SMCRA's Second Decade (Environmental Law Institute, 1990), at pp. 193-94.
24. 30 CFR 701.5.
25. 30 CFR 817.121(a)(2) (emphasis supplied).
26. 30 CFR 817.121(a)(2).

Several other provisions of SMCRA require prevention of subsidence damage to specific lands and structures. The law requires a regulatory agency "in order to protect the stability of the land" to "suspend coal underground mining under urbanized areas, cities, towns, and communities and adjacent to industrial or commercial buildings, major impoundments, or permanent streams" *if* it finds "imminent danger to inhabitants of the urbanized areas, cities, towns, and communities."[27] The regulations implementing this provision prohibit any underground operations (including longwall operations) beneath or adjacent to:

(1) public buildings and facilities,
(2) churches, schools, and hospitals, and
(3) impoundments or bodies of water with volume of 20 acre-feet or more,

"unless the subsidence control plan demonstrates that subsidence will *not* cause material damage to, or reduce the reasonably foreseeable use of" these structures or features.[28]

Federal regulations also require that all underground mining operations be "conducted in a manner which minimizes damage, destruction, or disruption of services provided by oil, gas, and water wells; oil, gas, and coal-slurry pipelines[;] railroads; electric and telephone lines; and water and sewage lines" that pass through the permit area, unless the owner of the facilities gives permission for the damage and the state regulatory agency approves.[29]

SMCRA prohibits surface coal mining operations in certain areas (subject to valid existing rights); these include areas within the National Park System, the National Wildlife Refuge System, the National System of Trails, the National Wilderness Preservation System, the Wild and Scenic Rivers System (including study rivers), and National Recreation Areas designated by Congress. They also include Federal lands within the boundaries of any National Forest except where the Department of Interior finds that there are no significant recreational, timber, economic, or other values that may be incompatible with such operations; and parks or places on the National Register of Historic Sites unless approved jointly by the state and any federal, state, or local agency with jurisdiction over the site. Such operations are also not permitted within one hundred feet of any

27. 30 U.S.C. § 1266(c); 30 CFR 817.121(f).
28. 30 CFR 817.121(d).
29. 30 CFR 817.180.

public road except where mine access roads or haulage roads join the outside right of way line (subject to relocation); nor within three hundred feet of any occupied dwelling (unless waived by the owner) nor within three hundred feet of any public park, public building, school, church, community, or institutional building, nor within one hundred feet of a cemetery.[30] There is a continuing controversy over whether these prohibitions apply to the subsidence effects of underground mining. OSM is still attempting to resolve this issue by regulation after 21 years of controversy.[31] In the meantime, most states do not apply the prohibition except to underground mine openings, facilities and similar surface disturbances. Nevertheless, these prohibitions may become an issue with respect to future operations.

Federal law also provides that primacy states must have processes for the designation of other areas as "unsuitable" for surface coal mining based on a petition process. Such designations may be made if mining operations will be incompatible with state or local land use plans or programs; will affect fragile or historic lands by producing significant damage; will affect renewable resource lands so that a substantial loss or reduction of long range productivity of water supply or of food or fiber products could result; or will affect natural hazard lands in which such operations could substantially endanger life and property.[32]

### 2.1.2 Pennsylvania Requirements

At common law, the land surface and structures thereon are entitled to support, unless the coal owner or its predecessors in interest acquired either the support estate or a waiver or release of liability for subsidence-related damage. Much of the coal in Pennsylvania was conveyed many decades ago in mineral deeds which conveyed or waived the right of support and which released the coal owner from damages for subsidence.[33] However, where the right was not waived nor damages released, the operator must prevent subsidence damage, as a matter of tort law and property law apart from any regulatory requirements.

30. 30 U.S.C. § 1272(e).
31. See 62 Fed. Reg. 4836-72 (Jan. 31, 1997) (proposed rule); 62 Fed. Reg. 20138 (April 25, 1997) (public hearings).
32. 30 U.S.C. § 1272(a).
33. See generally, Henry Ingram, "Regulations of Mine Subsidence -- Legal Issues Raised by Government Intervention

Enactment of the BMSLCA in 1966 provided much broader protection to structures in existence on the date of that Act. It prohibited operators from causing subsidence damage to "any public building or noncommercial structure customarily used by the public, including but not being limited to churches, schools, hospitals, and municipal utilities or municipal public service operations," to "any dwelling used for human habitation," and to "any cemetery," if the protected structure was in place on April 27, 1966.[34] The 1966 law also allowed owners of post-1966 structures an opportunity to purchase the support coal under their homes to prevent subsidence damage.[35] Although these regulatory provisions were repealed by Act 54, Pennsylvania law retains some prevention obligations, as to both lands and structures. The BMSLCA continues to provide that the operator:

> shall adopt measures and shall describe to the department in his permit application measures that he will adopt to prevent subsidence causing material damage to the extent technologically and economically feasible, to maximize mine stability, and to maintain the value and reasonable foreseeable use of such surface land: Provided, however, that nothing in this subsection shall be construed to prohibit planned subsidence in a predictable and controlled manner or the standard method of room and pillar mining.[36]

Although this provision is similar to the federal SMCRA provision quoted above, it appears on its face to be more protective of surface lands and structures. Instead of saying "*except* in those instances where the mining technology used requires planned subsidence in a predictable and controlled manner," the BMSLCA imposes the damage prevention obligation generally upon all underground mining operations, and then states that the obligation cannot be construed to "prohibit" planned subsidence mining in a predictable and controlled manner. The statutory duty in Pennsylvania to prevent material damage, maximize mine stability, and maintain the value and reasonable foreseeable use of land plainly applies to both planned subsidence and conventional underground operations -- subject only to the proviso that planned subsidence, like other forms of underground mining, is not prohibited. However, the DEP does not appear to interpret this law to require more prevention than that provided by the federal SMCRA.

in Historically Private Arrangements," 5 E. Min. L. Inst. ch.6 (1984).
34. former 52 P.S. § 1406.4.
35. former 52 P.S. § 1406.15.
36. 52 P.S. § 1406.5(e).

The BMSLCA also continues to require an applicant for a permit to submit a "detailed description of the manner, if any, by which the applicant proposes to support the surface structures overlying the bituminous mine or mining operation. Upon receipt of such application in proper form the department shall cause a permit to be issued or reissued if, in its opinion, the application discloses that sufficient support will be provided for the protected structures and that the operation will comply with the provisions of this act and the rules and regulation issued thereunder."[37] Although the reference to "protected structures" was understood in the past to refer to pre-1966 structures, the legislature's retention of this provision despite its enactment of Act 54 must be read as purposeful. It may be read as a requirement to provide support where necessary to prevent damages to the structures identified below.

The Commonwealth does not interpret Act 54 and the new regulations to require longwall operators to "minimize" material damage to dwellings and miscellaneous noncommercial buildings to the same extent as under the federal regulations.[38] Act 54 requires operators to undertake minimization measures only where "irreparable injury" is likely to occur to dwellings and farm buildings. Specifically, Act 54 provides that if the DEP determines that a "proposed mining technique or extraction ratio will cause subsidence which will result in irreparable injury" to dwellings and permanently affixed appurtenant structures or farm buildings (barns, silos, permanently affixed structures of 500 square feet or greater), use of the technique or ratio "shall not be permitted unless the building owner, prior to mining, consents to such mining or the mine operator, prior to mining, agrees to take measures approved by the department to minimize or reduce impacts resulting from subsidence to such buildings."[39]

The effect of this protection may be quite limited in practice. DEP's Program Guidance Manual notes that the Department's "experience has been that most structures damaged by

37. 52 P.S. § 1406.5(a)(emphasis supplied).
38. See Comment and Response Document, March 17, 1998 rulemaking (Comment and Response #74, p. 35): "Section 9.1 of BMSLCA does not provide for measures to minimize material damage to dwellings and noncommercial buildings. It limits damage minimization measures to situations where dwellings and agricultural structures are likely to experience irreparable damage."
39. 52 P.S. § 1406.9a(b). This resembles the federal regulatory requirement that planned subsidence operators take "necessary and prudent measures" to minimize material damage to dwellings and noncommercial buildings except where the cost of the measures exceeds the cost of repairs. 30 CFR 817.121(a)(2).

subsidence can be repaired."[40] However, the Manual also notes that structures "actually listed on the National Register of Historic Places" may have their "intrinsic value...destroyed by extensive repairs" and so may need to have preventive measures applied under this section.[41]

As under federal law, Act 54 provides for prevention of subsidence damage where a "proposed mining technique or extraction ratio will result in subsidence which creates an imminent hazard to human safety."[42] The law provides that use of the technique or ratio shall not be permitted unless the operator takes measures "approved by the department to eliminate the imminent hazard to human safety."[43] Also, as under federal law, underground mining activities are prohibited beneath or adjacent to:

(1) public buildings and facilities,
(2) churches, schools, hospitals, and
(3) impoundments or bodies of water with a capacity of 20 acre-feet or more

> "unless the subsidence control plan demonstrates that subsidence will not cause material damage to or reduce the reasonably foreseeable use of such features or facilities."[44] The department may limit the percentage of coal extracted under or adjacent to such features and facilities, or under or adjacent to any aquifer or body of water that serves as a significant water source for any public water supply system.[45] The DEP ordinarily requires the operator to leave 50 percent of the coal beneath these protected features and facilities, but "an operator will be allowed to use a higher extraction rate if he can demonstrate that the resulting subsidence will not result in material damage to the structure."[46]

40. DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Interim Implementation of Act 54," Document No. 563-3900-404 (effective November 7, 1997). The same language appeared in the previous DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Water Supply Replacement and Subsidence Damage Repair Under Act 54 Amendments to the Bituminous Mine Subsidence and Land Conservation Act." I.04.04 (Sept. 19, 1994).
41. DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Interim Implementation of Act 54," Document No. 563-3900-404 (effective November 7, 1997). The same language appeared in the previous DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Water Supply Replacement and Subsidence Damage Repair Under Act 54 Amendments to the Bituminous Mine Subsidence and Land Conservation Act." I.04.04 (Sept. 19, 1994).
42. 52 P.S. § 1406.9a(a).
43. 52 P.S. § 1406.9a(a).
44. 52 P.S. § 1406.9a(c). Compare 30 CFR 817.121(d).
45. 52 P.S. § 1406.9a(c). Compare 30 CFR 817.121(d).
46. DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Interim Implementation of Act 54," Document No. 563-3900-404 (effective November 7, 1997). The same language appeared in the previous DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Water Supply Replacement and Subsidence Damage Repair Under Act 54 Amendments to the Bituminous Mine Subsidence and Land Conservation Act." I.04.04 (Sept. 19, 1994).

Until 1998, Pennsylvania's regulations contained an identical prohibition for mining beneath or adjacent to "coal refuse disposal areas" unless the prevention standards were met.[47] However, in 1998, the Environmental Quality Board deleted this provision.[48] Pennsylvania regulations also formerly prohibited underground mining beneath structures where the depth of overburden was less than 100 feet.[49] However, the 1998 rules allow such mining if the subsidence control plan demonstrates to DEP's satisfaction that the mine workings will be stable and that the overlying structures will not suffer "irreparable" damage.[50]

The BMSLCA, as amended by Act 54, does not prescribe a special duty to minimize damage to utilities. However, in order to maintain consistency with federal regulatory requirements, such a duty does exist in the regulations:

> Underground mining shall be planned and conducted in a manner which minimizes damage, destruction or disruption in services provided by oil, gas and water wells; oil, gas and coal slurry pipelines; rail lines; electric and telephone lines; and water and sewerage lines which pass under, over, or through the permit area unless otherwise approved by the owner of the facilities and the Department.[51]

Prior to 1998, the regulations specified that measures to minimize damage would include not only measures taken in the mine itself, but also measures on the surface of the land to minimize damage, destruction, or disruption, as well as a program for detecting subsidence damage and avoiding disruption in services.[52] According to Pennsylvania's Environmental Hearing Board, the prevention obligation imposed by the prior regulations could not be satisfied merely by requiring the operator to provide the utility owner advance notice of subsidence.[53] But the 1998 regulations adopted by the Environmental Quality Board allow as sufficient "a notification to the owner of the facility which specifies when underground mining beneath or adjacent to the utility will occur."[54] This notice is intended to allow the investor-owned utility to take measures to prevent damage or

47. 25 Pa. Code § 89.143(b)(1)(v)(1997).
48. 25 Pa. Code § 89.142a(c)(1998).
49. 25 Pa. Code § 89.143(a)(4)(1997).
50. 25 Pa. Code § 89.142a(a)(3).
51. 25 Pa. Code § 89.142a(g)(1)(1998); see former 25 Pa. Code § 89.143(c)(1)(1997).
52. former 25 Pa. Code § 89.143(c)(2)(1997).
53. People United to Save Homes v. Commonwealth, EHB Docket No. 95-232-R, 95-233-R (Nov. 27, 1996); on reconsideration (Dec. 23, 1996).
54. 25 Pa. Code § 89.142a(g)(2)(ii)(1998).

disruption in service, with the costs being borne by whichever party does not own the support right; in many settings this will be the utility.[55]

However, an operator is required to take measures to "minimize" damage to customer-owned gas and water service connections "unless the customer does not consent to such measures.[56] In addition, the Environmental Quality Board interprets the term "public buildings and facilities" in Act 54 to include government-owned utilities "such as a water or sewer authority."[57] Thus, the operator is required to prevent material damage to, or reduction of the reasonably foreseeable use of, a government-owned utility line.[58]

The BMSCLA provides, in a provision unchanged by Act 54, that the grantor of any surface land in a county where bituminous coal is found shall certify in the deed whether or not any structure then or thereafter erected on the land is entitled to support. Absent such certification, the grantee of the land must sign a notice printed in the deed indicating that the grantee knows that it may not be obtaining protection against subsidence.[59] Because the regulatory duty of support for pre-1966 buildings is no longer in effect, this provision suggests that some deeds will need to be changed in connection with the next transfer of title; this may reduce the value and marketability of these lands.

Finally, with respect to prevention obligations, Pennsylvania does have provisions in its laws to declare an area unsuitable for surface mining; this process is applicable to the surface activities connected with underground mining rather than to the underground mining itself.[60]

55. Preamble, March 17, 1998 final rulemaking, to be published in Pennsylvania Bulletin: "The Board agrees that the matter of who should bear the costs for taking precautionary measures should be primarily based on which party owns the right of support. In cases where the mine operator owns the right of support, his responsibilities may be limited to providing timely notice to the investor owned utility operator of imminent mining beneath the utility line...In cases where the investor owned utility possesses the right to support, a mine operator must provide support and bear the costs associated with providing support."
56. 35 Pa. Code § 89.142a(g)(3)(1998).
57. Preamble, March 17, 1998 final rulemaking, to be published in Pennsylvania Bulletin.

58 25 Pa. Code § 89.141(d)(3)(1998).
59. 52 P.S. § 1406.14. Act 54 eliminated statutory support rights (thus leaving support rights only to those who never conveyed such rights, or who purchased them from mineral owners). The law also requires grantors to give notice of the ability of grantees to protect property by private contract with the coal owners; while the right to purchase support coal was eliminated in 1994, this notice is still valid as coal owners are free to enter into such agreements voluntarily.
60. 52 P.S. § 1396.4e; see § 1396.3.

## 2.2 REPAIR AND COMPENSATION REQUIREMENTS

### 2.2.1 Federal Requirements

Repair of material damage to surface *lands* is required, "to the extent technologically and economically feasible, by restoring the land to a condition capable of maintaining the value and reasonably foreseeable uses that it was capable of supporting before subsidence damage."[61] This provision applies to all underground operations, including longwall mines.[62]

Repair or compensation requirements for damage to *structures* are limited. In 1979, OSM adopted a regulation requiring operators to repair or compensate owners for subsidence damage to structures, but it eliminated the requirement in 1983, instead allowing individual state laws to determine whether repair or compensation would be required. The courts eventually ruled in 1991 that while SMCRA could support a federal regulation requiring repair or compensation, the law did not require OSM to adopt such a regulation.[63] In response, in 1992, Congress enacted EPAct, adding a new section to SMCRA explicitly requiring that underground coal mine operations conducted after October 24, 1992:

> promptly repair, or compensate for, material damage resulting from subsidence caused to any occupied residential dwelling and structures related thereto, or non-commercial building.[64]

The law further provides that "[r]epair of damage shall include rehabilitation, restoration, or replacement...[while c]ompensation....shall be in the full amount of the diminution in value resulting from the subsidence."[65]

The federal regulations implementing these provisions make the underground coal mine operator presumptively responsible for repairing or compensating for material damages to these buildings whenever the damage "occurs as the result of earth movement within...a specified angle of draw," defined as a 30-degree angle unless the state shows in writing that a different angle has a

61. 30 CFR 817.121(c)(1).
62. NWF v. Hodel, 839 F.2d 694, 741 (D.C. Cir. 1988).
63. NWF v. Lujan, 928 F. 2d 453, at 458-459 (D.C. Cir. 1991).
64. 30 U.S.C. § 1309a(a)(1).
65. 30 U.S.C. § 1309a(a)(1). See 30 CFR 817.121(c)(2).

more reasonable basis based on geotechnical analysis in the state.[66] Operators may also obtain state approval of a site-specific angle of draw if authorized by the state.[67]

The presumption of liability based on the angle-of-draw does not apply if the permittee was denied access to the land to conduct a pre-subsidence survey.[68] Also, the operator may rebut the presumption by showing a different cause for the damage, that the damage predated mining, or that the damage occurred outside the subsidence area.[69] However, whether or not the presumption applies, in any determination whether damage to protected structures was caused by subsidence, "all relevant and reasonably available information will be considered by the regulatory authority."[70]

When subsidence damage occurs to lands, to noncommercial buildings or occupied dwellings, or to other structures that may be protected by state law, federal regulations provide that the operator must post an additional performance bond. The bond must be posted unless the repair, compensation, or replacement is completed within 90 days (a period that may be extended if damage is ongoing).[71]

Repair or compensation with respect to structures other than dwellings and noncommercial buildings is not required by federal regulations, unless otherwise "required under applicable provisions of State law."[72]

### 2.2.2 Pennsylvania Requirements

The BMSLCA requires the operator to "prevent subsidence causing material damage to the extent technologically and economically feasible, to maximize mine stability, and to maintain the value and reasonable foreseeable use of such surface land."[73] As under federal law, the operator's

66. 30 CFR 817.121(c)(4)(i).
67. 30 CFR 817(c)(4)(ii).
68. A survey is required under 30 CFR 784.20(a).
69. 30 CFR 817.121(c)(4)(iii),(iv).
70. 30 CFR 817.121(c)(4)(v).
71. 30 CFR 817.121(c)(5).
72. 30 CFR 817.121(c)(3). This regulatory provision, which predates the 1992 EPAct, was upheld in court. National Wildlife Federation v. Lujan, 928 F.2d 453 (D.C. Cir. 1991).
73. 52 P.S. § 1406.5(e)

duty to maintain the value and reasonable use of land includes the duty to *correct* material damage to such land to the extent technologically and economically feasible.[74]

However, the 1998 Pennsylvania regulations lack the qualifying language "by restoring the land to a condition capable of supporting the value and reasonably foreseeable uses that it was capable of supporting before subsidence damage," a proviso found in the former Pennsylvania regulations and in the federal regulations.[75] In addition, while prior Pennsylvania regulations required the operator to correct material damage caused by subsidence to perennial streams,[76] the 1998 regulations only require the operator to "mitigate the effects to the extent technologically and economically feasible."[77]

Act 54 requires underground coal mine operators to repair or provide compensation with respect to a broader array of structures than those covered by federal law:[78]

> (1) "any building which is accessible to the public, including, but not limited to, commercial, industrial and recreational buildings and all permanently affixed structures appurtenant thereto,"
>
> (2) "any noncommercial buildings customarily used by the public, including, but not limited to, schools, churches and hospitals,"
>
> (3) "dwellings used for human habitation and permanently affixed appurtenant structures or improvements in place on [August 21, 1994] or on the date of first publication" of the mine's permit application or a five-year renewal thereof, and
>
> (4) "the following agricultural structures: all barns and silos, and all permanently affixed structures of 500 or more square feet in area that are used for raising livestock, poultry or agricultural products, for storage of animal waste or processing or retail marketing of agricultural products produced on the farm." However, if an irreparably damaged agricultural structure is being used for a different purpose than that for which it was constructed, the operator may provide for the reasonable cost to replace the structure with one satisfying the current use.[79]

A few structures covered by federal law fall outside the scope of Act 54. These are (1) dwellings constructed after April 27, 1966 and damaged prior to August 21, 1994, (2) dwellings

74. 25 Pa. Code § 89.142a(e)(1998).
75. 25 Pa. Code § 89.145(a)(1997), 30 CFR 817.121(c)(1).
76. former 25 Pa. Code § 89.145(a)(1997).
77. 25 Pa. Code § 89.142a(h)(2)(1998).
78. 52 P.S. § 1406.5d(a).

where the operator was denied access for premining or postmining surveys (discussed below), and (3) noncommercial buildings not used by or accessible to the public.[80] Initially it was believed that Act 54 also did not cover dwellings constructed after August 21, 1994 but damaged prior to the operator's next permit renewal.[81] However, in 1998, the Environmental Quality Board determined that this timing limitation applied only to "improvements" constructed after Act 54's effective date, not to dwellings and appurtenant structures.[82] Thus, even dwellings constructed during the course of an operator's mining are deemed to qualify for repair or compensation.

The Act 54 duty to repair or compensate for subsidence damage to the listed structures is termed the "sole and exclusive remedy for such damage" and is not diminished by prior leases, agreements, or deeds relieving operators from such a duty (except for valid waivers of pre-1966 building protections entered into for consideration between 1966 and the 1994 Act).[83]

The owner of any structure covered by Act 54 who believes that a structure has been damaged by subsidence must first notify the mine operator. If the operator accepts responsibility, the operator must repair the damage or provide compensation.[84] If the parties are unable within six months of the date of the notice to agree on the cause of the damage or the reasonable cost of repair or compensation, the owner "may" file a claim with the DEP. (The DEP will not act until after the operator "has had six months to address the complaint.")[85] The claim must be filed within two years

79. 52 P.S. § 1406.5d(b).
80. 60 Fed. Reg. 18046, 18048 (April 10, 1995).
81. 60 Fed. Reg. 18046, 18048 (April 10, 1995).
82. Preamble to Final Rulemaking, 25 Pa. Code, Ch. 89 (March 17, 1998), to be published in Pa. Bulletin: The statute and regulations "are now being interpreted to require the operator to repair all dwellings in place at the time of underground mining and all permanently affixed appurtenant structures in place at the time of underground mining. This interpretation is based on the rule of statutory construction known as 'the rule of the last antecedent'....This rule provides that unless plainly meant otherwise a modifying clause operates only upon the phrase preceding it. This interpretation differs from the Department's previous interpretation in that the requirement to be in place on August 21, 1994, the date of first publication of the permit application, or date of first publication of a permit renewal application is no longer viewed as applicable to dwellings or permanently affixed appurtenant structures. Under the rule of the last antecedent, the requirement for being in place on one of the specified dates applies only to 'improvements'." Preamble at pp. 7-8; 29-30.
83. 52 P.S. § 1406.5f(c).
84. 52 P.S. § 1406.5e.
85. DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Interim Implementation of Act 54," Document No. 563-3900-404 (effective November 7, 1997). The same language appeared in the previous DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Water Supply Replacement and Subsidence Damage Repair Under Act 54 Amendments to the Bituminous Mine Subsidence and Land Conservation Act." I.04.04 (Sept. 19, 1994).

of the date damage occurred.[86] The DEP must investigate the claim within 30 days, and within 60 days following the investigation must issue a determination as to causation and reasonable costs of repair or replacement. If the DEP finds that the mining caused the damage, it must order the operator to compensate the owner or make repairs within 6 months (or a longer period if further subsidence damage is expected).[87] The occupants of a subsidence-damaged structure are also entitled to payment of reasonable expenses for temporary relocation, and for other incidental costs if approved by the DEP.[88]

Neither Act 54 nor the Pennsylvania regulations establish any angle of draw presumption of liability -- rebuttable or otherwise. The absence of such a presumption and the assignment of the determination of liability to DEP means that the agency will require substantial expertise in subsidence mechanics, structural engineering, building appraisal, and damage estimation in order to carry out its obligations. The 1998 regulations require the subsidence control plan filed with the operator's permit application to address all areas within a 30-degree angle of draw; although not a presumption, this may serve as a general guide to DEP in determining causation.[89] This is an increase from the smaller 25-degree angle of draw area formerly specified in Pennsylvania regulations for subsidence planning purposes.[90]

If the operator is aggrieved by the DEP's order, it may appeal to the Environmental Hearing Board, but must deposit the compensation amount ordered by the DEP in escrow. If the operator loses the appeal and still fails to comply, the DEP must pay the escrow amount with accumulated interest to the landowner. Likewise, if the landowner is aggrieved by the DEP's "order," the landowner may appeal to the Environmental Hearing Board.[91]

If the operator does not comply with the DEP order, and does not appeal, or has exhausted its appeal rights without compliance, the DEP must take further necessary action, including issuance of cessation orders and commencement of permit revocation.[92]

86. 52 P.S. § 1406.5e(b).
87. 52 P.S. § 1406.5e(c).
88. 52 P.S. § 1406.5e(d).
89. 25 Pa. Code §§ 89.141(d)(1998); see also 25 Pa. Code § 89.142a(c)(2)(vi)(1998).
90. former 25 Pa. Code § 89.141(d)(1997).
91. 52 P.S. § 1406.5e(e).
92. 52 P.S. § 1406.5e(f).

The operator is not liable for subsidence damage under Act 54 if it was denied access for premining and postmining surveys, thereafter served notice by personal service or certified mail upon the landowner, and the landowner failed to grant access within ten days after receipt of the notice.[93]

Claims for damages to structures must be filed with the DEP within two years after the damage to the structure occurred in order to invoke the procedures under Act 54.[94] Failure to file a subsidence damage claim with DEP within two years after damage to a structure is not, however, a defense to liability. The Environmental Quality Board found that the two-year limit in Act 54 "only pertains to a structure owner's right to a Department investigation of his subsidence claim. It does not relieve an operator of the responsibility to repair or compensate for subsidence damage."[95] The Board rejected the interpretation of the statute taken in proposed regulations that would have made the failure to file a claim within two years an absolute defense to liability for repair or compensation.[96]

Bonding for subsidence damage is required in a "reasonable amount as determined by the Department."[97] Bonding may be phased, with an initial deposit of $10,000 and annual increments added, or the DEP may require subsidence insurance in lieu of the subsidence bond. The DEP also has discretion to accept a self-bond from the permittee. However, as a matter of custom and practice, the DEP requires $10,000 as the entire subsidence bond.[98] Act 54 does not provide for the posting

93. 52 P.S. § 1406.5d(c).
94. 52 P.S. § 1406.5e.
95. Preamble, March 17, 1998 final rulemaking, to be published in Pennsylvania Bulletin. The DEP program guidance manual also simply provides that the DEP will terminate investigation of a claim if it has been filed after the passage of two years. DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Interim Implementation of Act 54," Document No. 563-3900-404 (effective November 7, 1997). The same language appeared in the previous DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Water Supply Replacement and Subsidence Damage Repair Under Act 54 Amendments to the Bituminous Mine Subsidence and Land Conservation Act." I.04.04 (Sept. 19, 1994).
96. Act 54 § 1406.5e says that the owner "may" file a claim with DEP, and that "all claims under this subsection shall be filed within two years of the date damage to the building occurred." Because the owner's right to repair or payment is actually created by the preceding section (§ 1406.5d), what the statute cuts off after two years is only recourse to the DEP for investigation and determination (along with associated rights of appeal, escrow, orders, and permit revocations), not the liability of the operator. This interpretation is supported by the fact that in drafting the two-year provision, the Pennsylvania legislature did not use the same language as it did in § 1406.5a(b), which clearly does cut off liability for water replacement for failure to file a claim within two years.

97. 52 P.S. § 1206.6
98. See PUSH and Penn American Water Co. v. Commonwealth, EHB No. 95-232-R (Nov. 27, 1996), on reconsideration (Dec. 23, 1996).

of an additional bond after the occurrence of subsidence damage, relying instead on its enforcement mechanisms and escrow provisions.

Under Act 54, a mine operator and landowner may enter into an agreement at any time to establish the "manner and means" for repair or compensation for subsidence damage. The release of liability must clearly state what rights are established by the law, and the landowner must expressly acknowledge the release for consideration -- provided that the consideration (payment or other valuable undertaking) is not less than that necessary to compensate an owner for reasonable costs of repair or replacement. The release is of no effect if no mining occurs for a period of 35 years within the "coal field" of which the coal underlying the surface property is a part.[99] The landowner must include the agreement and release in any deed for the conveyance of property covered by the agreement in order to notify future surface owners that the statutory rights have been modified by agreement.[100]

## 2.3 DISCUSSION

Neither the federal government nor Pennsylvania has clearly defined the operator's duties of prevention of subsidence damage with respect to the land surface itself. Maintaining value and reasonably foreseeable use of lands and waters has not been meaningfully translated into clear preventive obligations. With respect to minimizing longwall subsidence damage to structures, federal regulations and Pennsylvania law are generally comparable, although Act 54's qualification of prevention obligations with respect to dwellings with the term "irreparable damage" has no counterpart in the federal regulations. Pennsylvania's explicit duty of damage minimization with respect to irreparable damage to farm buildings is not present in the federal regulations.

In general, Pennsylvania's repair and compensation obligations apply to a much broader array of buildings than do federal obligations, which apply only to dwellings and noncommercial buildings. But there is a gap in coverage in Pennsylvania for post-1966 dwellings and noncommercial structures that were damaged by subsidence between October 1992 and August 1994. As time passes, this gap in coverage will become less important, and indeed most claims from

99. 52 P.S. § 1406.5f(a).

this period should already have been identified and addressed by the federal Office of Surface Mining.

In determining responsibility for repair, replacement, or compensation for dwellings and noncommercial buildings, federal regulations make the operator presumptively liable for damages occurring within a 30-degree angle of draw (or another angle adopted by a state). Act 54 and its implementing regulations lack such a presumption. This creates an issue of whether Act 54 is consistent with federal requirements and whether Pennsylvania's program will be approved by OSM. The absence of a presumption means that surface owners and the DEP will carry the burden of proving an operator's liability for subsidence damage in all cases.

Pennsylvania law also bars claims for repairs, replacement or compensation if the surface owner did not grant the operator access for premining and postmining structural surveys. This provision, which has no counterpart in the federal law, may be particularly problematic for surface owners since Act 54 requires provision of such access within a fairly narrow window of time (within 10 days of notice). The Pennsylvania regulations provide no opportunity to cure the denial even if there was good cause for missing the original ten-day notice period, and even if the operator would not be prejudiced thereby -- for example, if a surface owner (or owner's successor in interest) could grant access to the operator for a premining or postmining survey outside that time period. The absence of such a provision raises the spectre of unknowing, unintended, or needless waivers of rights by surface owners.

Act 54 provides that DEP is to wait six months after the filing of a subsidence damage claim before taking action. Thereafter it is to investigate within thirty days, and within sixty days following the investigation to order the responsible operator to repair the structure or compensate the surface owner "within six months or a longer period."[101] Whether this period of longer than one year for resolution of damage claims is consistent with the federal requirement that the operator is "promptly" to repair or compensate for subsidence damage is uncertain. It may be that these periods will be deemed too long.

100. 52 P.S. § 1406.5f(b),(d).
101. 52 P.S. § 1406.5e.

Surface owners may also have some difficulty in appealing adverse DEP decisions on repair or compensation. Although Act 54 provides for DEP determinations and orders, the law only refers to appeals of "orders." If DEP determines that an operator did not cause the subsidence damage, there may be no order, and hence a potential problem for the surface owner. However, the Environmental Quality Board has concluded that the negative determination is appealable.[102]

Bonding amounts for subsidence damage are not well-supported by experience in Pennsylvania. The customary practice is to impose the minimum statutory bond of $10,000. This is substantially less than amounts generally needed to deal with subsidence damages to lands and structures. Indeed, even the voluntary agreements executed between coal operators and surface owners in Southwestern Pennsylvania generally provide (in the aggregate) for more than this amount if more than one dwelling is involved. Calculation of "full-cost" bonding, or greater support for establishment of a standard or customary bond amount may be appropriate. Act 54 contains a provision that requires the Department to compile data on deep mining effects "on subsidence of surface structures and features and on water resources, including sources of public and private water supplies" and to file a written report with the Governor, the General Assembly, and the Citizens Advisory Council at 5 year intervals.[103] The first report is due in 1998. It should be directed at bonding issues of this sort, as well as at issues of damage prevention and minimization.

Given the frankly remedial character of the law, the DEP could also seek to clarify issues in ways that protect surface owners to the greatest extent possible. Section 1406.19 provides that the BMSLCA is remedial legislation "and each and every provision hereof is intended to receive a liberal construction such as will best effectuate that purpose, and no provision is intended to receive a strict or limited construction."[104] This supports, for example, the Environmental Quality Board's decision to interpret the time limitation on protection of structures constructed after August 21, 1994 as applicable only to "improvements." It could also support interpretations of the statute by the Environmental Hearing Board and the courts in ways that resolve ambiguities in favor of surface owners.

102. Preamble, March 17, 1998 final rulemaking, to be published in Pennsylvania Bulletin.
103. 52 P.S. § 1406.18a.
104. 52 P.S. § 1406.19.

Other provisions of the BMSLCA make it clear that the DEP has authority to go beyond the prescriptive statutory requirements:

> The department shall have the authority to adopt such rules, regulations, standards, and procedures as shall be necessary to protect the air, water, and land resources of the Commonwealth and the public health and safety from subsidence, prevent public nuisances, and to enable it to carry out the purposes and provisions of this act, including additional requirements for providing maps, plans, and public hearings.[105]

This language could enable the DEP to go much farther than mere repair of damaged structures and replacement of water "supplies." These legislative directions run counter to the effort in Executive Order 1996-1 and DEP's Reg Basics Initiative to drop Pennsylvania's protection to the minimum levels required by federal laws except where Pennsylvania law specifies otherwise. It is possible that that the BMSLCA falls within the exceptions to Exec. Order 1996-1, which allow Pennsylvania regulations to exceed federal standards if "justified by a compelling and articulable Pennsylvania interest *or required by state law.*"[106]

The compelling and articulable Pennsylvania interest may also be provided by the Commonwealth's constitution: "The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic, and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people."[107] Although Pennsylvania courts have not overturned state actions for violation of this provision, Commonwealth Court has established a three-part test for applying it to decisions by state agencies. The decision maker must determine: "(1) Was there compliance with all applicable statutes and regulations relevant to the protection of the Commonwealth's public natural resources? (2) Does the record demonstrate a reasonable effort to reduce environmental incursion to a minimum? (3) Does the environmental harm which will result from the challenged decision or action so clearly outweigh the benefit to be derived therefrom that to proceed further would be an abuse of discretion?"[108]

105. 52 P.S. § 1406.7(b).
106. Exec. Order 1996-1 (Feb. 6, 1996), 1.e. (emphasis supplied).
107. Pa. Const. art I, § 27.
108. Payne v. Kassab, 11 Pa. Commw. 14, 29-30, 312 A.2d 86 (1973), aff'd, 468 Pa. 226, 361 A.2d 263 (1976).

The legislative findings under the BMSLCA echo these concerns, suggesting a link between the Constitution and the legislation that could support further regulatory action. The findings include, among others: "(2) Damage from mine subsidence has seriously impeded land development of the Commonwealth. (3) Damage from mine subsidence has caused a very clear and present danger to the health, safety and welfare of the people of Pennsylvania. (4) Damage by subsidence erodes the tax base of the affected municipalities..."[109] All of these factors suggest a basis for adopting more preventive measures to supplement the repair and compensation measures that are embodied in Act 54.

## 3.0 REGULATION OF HYDROLOGIC EFFECTS OF LONGWALL MINING

## 3.1 PREVENTION OF DAMAGE TO WATER SUPPLIES

### 3.1.1 Federal Requirements

Federal law does not clearly spell out detailed prevention duties with respect to developed water supplies. Although SMCRA does require the operator to describe the measures to be taken to protect water supplies, these duties are expressed in broad terms.[110] Most of the focus of performance standards is on duties to minimize damage to groundwater and surface water systems. Operators must "minimize the disturbances of the prevailing hydrologic balance at the minesite and in associated offsite areas, and to the quantity of water in surface groundwater systems."[111] Operators must "avoid" acid or toxic mine drainage, and "prevent, to the extent possible using the best technology currently available, additional contributions of suspended solids to streamflow or runoff outside the permit area."[112] Operators must also "prevent material damage to [the] hydrologic balance outside [the] permit area."[113]

The most specific prevention obligations applicable to water supplies are subsidence-related. Federal regulations provide that a state regulatory authority may limit the percentage of coal

109. 52 P.S. § 1406.3
110. 30 U.S.C. § 1258(a)(13)
111. 30 U.S.C. § 1266(b)(9); see also 30 CFR 817.41(a).
112. 30 U.S.C. §§ 1266(b)(9)(A),(B).
113. 30 U.S.C. § 1260(b)(3); see also 30 CFR 817.41(a).

extracted under or adjacent to any "aquifer or body of water that serves as a significant water source for any public water supply system" if necessary to minimize material damage.[114] Also, underground mining activities may not be conducted under impoundments or bodies of water with a capacity or volume of 20 acre-feet or greater unless the subsidence control plan first demonstrates that there will be no material damage to, or reduction in the reasonable use of, the water body.[115]

### 3.1.2 Pennsylvania Requirements

Except for sources of water for public water systems, the BMSLCA does not specifically require prevention of damage to developed water supplies, focusing instead upon replacement or provision of alternative water supplies if damage should occur.

However, as under the federal regulations, operators must "minimize changes to the prevailing hydrologic balance in both the permit and adjacent areas."[116] In addition to complying with effluent limits, operators must "avoid" drainage into groundwater and surface water from pollution-forming underground development waste and spoil.[117] Regulations provide that underground mining must be conducted in a manner that maintains the value and reasonably foreseeable uses of perennial streams, such as aquatic life, recreation, and water supply, as they existed prior to mining beneath the stream.[118] Pennsylvania's Clean Streams Law also requires that discharges from underground mines not pollute the waters of the Commonwealth.

The DEP may limit the percentage of coal extracted under or adjacent to any "aquifer or body of water that serves as a significant water source for any *public* water supply system" if necessary to minimize material damage.[119] Also, underground mining activities may not be conducted under impoundments or bodies of water with a capacity or volume of 20 acre-feet or

114. 30 CFR 817.121(d).
115. 30 CFR 817.121(d).
116. 25 Pa. Code § 89.52(a)(1998).
117. 25 Pa. Code § 89.58(1998).
118. 25 Pa. Code § 89.142a(h)(1)(1998). Compare former 25 Pa. Code § 89.143(d)(1)(1997).
119. 52 P.S. § 1406.9a(c) (emphasis supplied).

greater unless the subsidence control plan first demonstrates that there will be no material damage to, or reduction in the reasonable use of, the water body.[120]

## 3.2 REPLACEMENT OF DAMAGED WATER SUPPLY

### 3.2.1 Federal Requirements

Although the issue of whether SMCRA required underground coal mine operators to replace damaged water supplies was disputed for many years, in 1988, a federal appeals court ruled that OSM was not obliged to require states to compel operators to replace damaged water supplies.[121] Congress responded by enacting a mandatory water replacement requirement limited to certain water supply uses. The 1992 EPAct provides that "underground coal mining operations conducted after October 24, 1992" must "promptly replace any drinking, domestic, or residential water supply from a well or spring in existence prior to the [permit] application . . . which has been affected by contamination, diminution, or interruption resulting from underground coal mining operations."[122] The federal regulations define "drinking, domestic or residential water supply" as "water received from a well or spring and any appurtenant delivery system that provides water for direct human consumption or household use." Wells and springs that serve only agricultural, commercial or industrial enterprises are excluded, except to the extent that they support direct human consumption, sanitation, or domestic use.[123] The regulations provide that the water loss will be determined using the hydrologic and geologic baseline information required as part of the permit application.[124] The federal regulations do not create presumptions, nor do they establish time limits on claims by water users.

"Replacement of water supply" is defined as "provision of water supply on both a temporary and permanent basis equivalent to premining quantity and quality...includ[ing] provision of an equivalent water delivery system and payment of operation and maintenance costs in excess of

120. 52 P.S. § 1406.9a(c).
121. National Wildlife Fedn. v. Hodel, 839 F. 2d 694 (D.C.Cir. 1988).
122. 30 U.S.C. § 1309a.
123. 30 CFR 701.5.
124. 30 CFR 817.41(j), cross-referencing 30 CFR 780.21 and 784.22.

customary and reasonable delivery costs for premining water supplies."[125] The water supply owner may, however, accept a one-time payment for operating and maintenance costs. If the affected water supply is not needed at the time of loss nor for the postmining land use, the owner may accept the operator's demonstration that a suitable alternative supply is available and could be feasibly developed, without actually requiring replacement.[126]

If a water supply is damaged, the regulatory authority must require the operator to provide additional bonding unless the replacement is completed within 90 days (which may be extended if damage is ongoing).[127]

### 3.2.2 Pennsylvania Requirements

Act 54 provides that any operator who, after August 21, 1994, "as a result of underground mining operations, affects a public or private water supply by contamination, diminution or interruption" must "restore or replace" the supply with an alternate source which "adequately services in quantity and quality the premining uses of the supply or any reasonable uses of the supply."[128] The quality of the replacement supply is deemed adequate if it meets drinking water standards, or is comparable to the premining supply if that supply did not meet such standards.[129]

While federal law is limited to replacement of drinking, domestic, or residential water supplies from a well or spring, in Pennsylvania the law requires replacement of a water supply "used for domestic, commercial, industrial or recreational purposes, or for agricultural uses...or which serves any public building or any noncommercial structure customarily used by the public, including, but not limited to, churches, schools and hospitals."[130] Agricultural uses include water supplies to be used in constructed irrigation systems that were in place on August 21, 1994.[131]

However, Pennsylvania law does not require replacement of the following water supplies that are protected by federal law: (1) drinking, domestic, or residential water supplies affected between

125. 30 CFR 701.5.
126. 30 CFR 701.5.
127. 30 CFR 817.121(c)(5).
128. 52 P.S. § 1406.5a(a)(1).
129. 52 P.S. § 1406.5a(a)(2).
130. 52 P.S. § 1406.5a(a)(3).

Oct. 24, 1992 and August 21, 1994, (2) cases where landowners waived water supply replacement (not waivable under federal law) or accepted compensation, and (3) cases where the mine operator was denied access to conduct pre- or postmining surveys and no pre-mining data was available.[132]

Under Act 54, a landowner or water user must notify the mine operator of a claim of contamination, diminution or interruption, and the operator must investigate "with reasonable diligence."[133] The operator must notify the DEP of any claim and its disposition.[134] Within 24 hours of notice from the landowner or water user, the operator must provide a "temporary water supply" if the affected water supply is within a 35 degree angle of draw from the outside of any coal removal area and the user is "without a readily available alternate source."[135] If a temporary supply is not provided within 24 hours, the department must order the operator to provide one within 24 hours.[136]

If the water supply is not replaced or if the operator ceases to provide an alternate source, the landowner or water user may request a DEP investigation. The DEP must investigate any claim of water loss within ten days of such request and determine within 45 days whether the mining activity caused the damage to the water supply, notifying all parties of its finding. If it finds causation, the DEP must order the operator to comply with its obligations, including temporary water supplies and permanent replacement.[137] The law's further explanation of DEP's authorities says that the DEP may order the operator to provide "a permanent alternate source where the contamination, diminution or interruption does not abate within three years of the date on which the supply was adversely affected."[138]

Any landowner, water user, or operator aggrieved by an "order or determination" by DEP has the right to appeal "such order" to the Environmental Hearing Board within 30 days of its receipt.[139]

131. Id.
132. 60 Fed. Reg. 18046, 18048 (April 10, 1995). Nor does it cover replacement of water supplies damaged by anthracite mining. Id. The Commonwealth also noted that Act 54 does not cover cases where a post-1992 drinking, domestic, or residential water supply is used to support an irrigation system constructed after Aug. 21, 1994.
133. 52 P.S. § 1406.5b(a)(1).
134. 52 P.S. § 1406.5b(a)(3).
135. 52 P.S. § 1406.5b(a(2).
136. 52 P.S. § 1406.5b(a)(3).
137. 52 P.S. § 1406.5b(b)(2).
138. 52 P.S. § 1406.5b(b)(2).
139. 52 P.S. § 1406.5b(k).

The operator is presumptively responsible for water replacement if the affected supply is within a 35-degree angle of draw from the outside of any coal removal area. However, the operator may rebut this presumption if it affirmatively proves that it was denied access "to conduct premining and postmining surveys of the quality and quantity of the supply" and that it had thereafter served notice upon the landowner by certified mail and the landowner failed to provide access within ten days after receipt of the notice.[140] Under the statute, this denial of access *does not bar recovery by the landowner*, but simply shifts the burden of proof from the operator to the claimant or the DEP.

If the presumption does not apply, the landowner, user, or DEP must prove that the operator caused the contamination, diminution, or disruption. Moreover, if the operator was denied access to conduct a premining survey despite serving the required notice, the landowner or Department *must* produce "premining baseline data...relative to the water supply" as part of the proof.[141] Thus, where the operator was not allowed to collect premining baseline data, more than mere assertions of damage to the water supply must be shown.

A mine operator can entirely avoid liability for water replacement by affirmatively proving that the contamination, diminution or interruption:

(1) existed prior to the mining activity as determined by a premining survey,

(2) occurred more than three years after the mining activity, or

(3) was caused by something other than the mining activity.[142]

An operator is also "not liable" for water replacement under Act 54 if the claim was made more than two years after the water supply was adversely affected.[143]

The Environmental Quality Board has now interpreted the water replacement obligation as extending to contamination, diminution or interruption "from the time of underground mining to the period ending three years after reclamation has been completed."[144] This interpretation of the three-year limitation is broader than that in the DEP's Program Guidance Manual, which formerly

140. 52 P.S. § 1406.5b(c).
141. 52 P.S. § 1406.5b(d).
142. 52 P.S. § 1406.5b(e).
143. 52 P.S. § 1406.5a(b).
144. Preamble, March 17, 1998 final rules, to be published in Pennsylvania Bulletin. See description of 25 Pa. Code §§ 89.145a and 89.152 (linking water supply impacts to "underground mining activities" rather than "underground

interpreted the provision to bar claims for water supply impacts occurring "more than 3 years after the most recent mining in the vicinity of the supply."[145]

On the issue of permanent remedies, if a water supply is "not restored or reestablished or a permanent alternate source" is not provided within three years, the landowner may either negotiate for and accept agreed compensation from the mine operator, or "at the option of the landowner" may require the mine operator to purchase the property for its fair market value as of the time immediately prior to the damage to the water supply, or may require the mine operator to make a one-time payment reflecting the diminution in fair market value brought about by the damage to the water supply.[146] The landowner may request from DEP an advisory opinion on whether a permanent water supply cannot "reasonably be restored or that a permanent alternate source...cannot reasonably be provided" in order to assist the landowner in exercising these rights to compensation.[147]

Notwithstanding the specific replacement and compensation requirements of Pennsylvania law, a mine operator and landowner may enter into a voluntary agreement at any time to establish the "manner and means" for water replacement or for compensation. In order to be valid, the release of liability must clearly state what rights are established by the law, the landowner must expressly acknowledge the release for value received, and the term of the release must not exceed 35 years.[148] The landowner must incorporate the agreement and release in any deed for the conveyance of the property covered by the agreement.[149] If a voluntary agreement calls for restoration or replacement, but the water supply "cannot be reasonably restored" or an alternate source "cannot reasonably be provided" within three years after the damage, the landowner may elect to invoke his or her statutory right to sell the land to the operator or receive compensation for the diminution in fair market value (minus any payment already received under the agreement).[150]

mining.").
145. DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Interim Implementation of Act 54," Document No. 563-3900-404 (effective November 7, 1997). The same language appeared in the previous DEP Bureau of Mining and Reclamation, Program Guidance Manual, "Water Supply Replacement and Subsidence Damage Repair Under Act 54 Amendments to the Bituminous Mine Subsidence and Land Conservation Act." I.04.04 (Sept. 19, 1994).
146. 52 P.S. § 1406.5b(g).
147. 52 P.S. § 1406.5b(h).
148. 52 P.S. § 1406.5c(a).
149. 52 P.S. § 1406.5c(b).
150. 52 P.S. § 1406.5c(a).

Act 54 does not specifically address the provision of an additional bond to cover water supply replacement as under the federal regulations.[151] The Environmental Quality Board has concluded that the law "does not authorize" DEP to require additional bonding to ensure the resolution of water supply complaints.[152]

Act 54 provides that the rights to water replacement or compensation set forth in the Act are non-exclusive, and landowners and water users not proceeding under this law may pursue any other remedies available at law or equity, subject to any defenses that may be available in mineral deeds, leases, or otherwise.[153]

## 3.3 DISCUSSION

The array of water supply uses for which replacement is required under Pennsylvania law is far broader than the "drinking, domestic, or residential" supplies covered by the federal requirements. However, the Pennsylvania law does not require replacement of water supplies damaged between the date of the federal law (October 24, 1992) and the state law (August 21, 1994).

Act 54 establishes a rebuttable presumption of operator liability if a water supply is within a 35-degree angle of draw of the coal removal area. This is broader than the federal law, which contains no such presumption. However, Pennsylvania denies use of the presumption if the surface owner fails to grant access for premining and postmining surveys of the water supply. If the presumption does not apply (either because the water supply is outside the angle of draw or because of denial of access), the surface owner and DEP must use "premining baseline data" concerning the water supply. It is unclear what level of data would be deemed sufficient for this purpose: Testimony that water once came out of the faucet and doesn't? Or that the owner could fill a stock trough in ten minutes and now it takes 3 hours? The regulations and DEP guidance manual do not provide guidance on this point.

As with provisions regarding surface owner denial of access for premining and postmining subsidence surveys (discussed above), the regulations do not provide a means to cure such denials

151. 52 P.S. § 1406.6.
152. Preamble, March 17, 1998 final rules, to be published in Pennsylvania Bulletin (discussing §89.145a(b)).
153. 52 P.S. § 1406.5c(c).

in cases where there would be no prejudice to the operator but the information could still be obtained in time to assist the finder of fact.

Act 54 cuts off all rights to replacement or compensation under the Act for failure to make a claim for water loss within 2 years of the loss, or if mining occurred more than 3 years before the loss. The 3-year post-mining cutoff, in particular, appears unduly strict and potentially inconsistent with federal regulations. Although most water losses (particularly in quantity) from longwall mining occur rapidly, it is not at all clear that water losses from contamination will all occur within three years of the nearest mining. This may be particularly true where the mine is flooded after mining. Similarly, where the hydrologic regime is altered by another part of the mine but the effect is experienced in a previously mined area, the three-year cutoff may be inappropriate. The Environmental Quality Board's interpretation of the three-year cutoff provision as being triggered by the completion of reclamation at the mine, rather than simply completion of coal extraction in the particular longwall panel nearest the water supply is apparently intended to address this concern. The two-year limit for filing of claims provided by Act 54 may also raise concerns, but procedural provisions like state statutes of limitation are more apt to receive federal deference than are cut-offs of liability based on state substantive provisions.

Act 54 provides that if a water supply is not restored or replaced within three years, the operator may be relieved of further responsibility by entering into a compensation agreement, or (at the election of the surface owner) purchasing the property for its premining value or paying the amount of the diminution in value of the property caused by the water loss. This buyout option is usable where the supply "cannot reasonably be restored" or a permanent alternate source "cannot reasonably be provided"; but these terms are not defined. The "reasonably" language is particularly troublesome, as it may suggest an economic test or balancing test for restoring or replacing water supplies. If this is the case, then Act 54 would create a virtual "eminent domain" right over properties with water supplies in the vicinity of longwall mines. It should be noted that the federal law and regulations do not provide for a buyout, but require replacement in all instances.

As noted in the preceding section, the BMSLCA provides ample authority to adopt additional protective requirements. These are not simply limited to elaborations on obligations to replace water supplies, but may also support additional preventive obligations if the Environmental

Quality Board and the DEP sought to adopt them. Of particular note in this regard is the "Purpose" section of the BMSLCA, as amended: "This act shall be deemed to be an exercise of the police powers of the Commonwealth for the protection of the health, safety and general welfare of the people of the Commonwealth, by providing for the conservation of surface land areas which may be affected in the mining of bituminous coal by methods other than "open pit" or "strip" mining, to aid in the protection of the safety of the public, to enhance the value of such lands for taxation, *to aid in the preservation of surface water drainage and public and private water supplies*, to provide for the restoration or replacement of water supplies affected by underground mining, to provide for the restoration or replacement of or compensation for surface structures damaged by underground mining and generally to improve the use and enjoyment of such lands and to maintain primary jurisdiction over surface coal mining in Pennsylvania."[154] The italicized language provides a further basis for requiring prevention, as well as replacement.

## 4.0 SUBSIDENCE AND WATER LOSS ISSUES IN THE PERMITTING AND ENFORCEMENT PROCESS

### 4.1 PERMITTING ISSUES

Before an underground coal mining operation may begin surface-disturbing activities it must obtain a permit under the BMSLCA. Operators are also required to conduct surveys of structures and water supplies and to give notice to surface landowners prior to the undermining of properties. Surface owners and others have opportunities for involvement in the permitting and premining survey processes. This section describes the Pennsylvania process, with cross-references to federal requirements where appropriate.

The permit is the heart of the regulatory process. The operator is required to file a copy of the permit application with the recorder of deeds of each county where the operation is located, and to give notice of the application within 5 days to each affected political subdivision.[155] Notice of the permit application must be published in local newspapers once a week for four consecutive weeks.[156]

154. 52 P.S. § 1406.2 (emphasis supplied).
155. 52 P.S. § 1406.5(c).
156. 52 P.S. § 1406.5(g).

The DEP publishes notice of the application in the Pennsylvania Bulletin. The public has an opportunity to comment on the application for a period extending 30 days after the appearance of the last newspaper notice.[157] In addition, any person may request an informal conference with the DEP concerning the application.[158]

Pennsylvania's permit application regulations require preparation and submittal of detailed geologic data, watershed data, hydrologic data, substantial technical information, and a mining map.[159] Under Pennsylvania regulations, operators must submit subsidence control plans with the permit application.[160] The subsidence control plan must address, at a minimum, the area within a 30-degree angle of draw.[161] The plan must describe whether subsidence "could cause material damage to or diminish the value or reasonably foreseeable use of any structures or could contaminate, diminish, or interrupt water supplies."[162] The plan must also describe measures to maintain the value and reasonably foreseeable use of the surface land and perennial streams; these requirements are believed by the Environmental Quality Board to address a corresponding federal requirement to project subsidence impacts to "renewable resource lands."[163]

Pennsylvania operators must also conduct pre-subsidence surveys of structures prior to "the time that a structure falls within a 30 degree angle of draw of underground mining, or such larger area as required by the Department."[164] The regulations excuse the operator from surveying a structure constructed less than 15 days before the structure falls within the angle of draw.[165] The results of the survey must be provided to the land owner within 30 days of completion, and to the DEP upon request.[166] The operator must not provide the results of the premining survey of structures to anyone other than the structure owner and the DEP.[167]

157. 25 Pa. Code § 86.32.
158. 25 Pa. Code § 86.34.
159. 52 P.S. § 1406.5; 25 Pa. Code §§ 89.33, 89.34, 89.35, 89.36, 89.141, 89.154 (1998). Compare 30 U.S.C. § 1257; 30 CFR Parts 777, 778, 783, 784.
160. 25 Pa. Code § 89.141(d)(1998).
161. 25 Pa. Code § 89.141(d)(1998).
162. 25 Pa. Code § 89.141a(d)(2)(1998).
163. 25 Pa. Code §§ 89.141(d)(8)-(10)(1998). See Preamble, March 17, 1998 final rule, to be published in Pennsylvania Bulletin. Federal requirements are at 30 CFR 784.20(a)(2); and see definition of "renewable resource lands" at 30 CFR 701.5.
164. 25 Pa. Code § 89.142a(b)(1)(ii)(1998).
165. 25 Pa. Code § 89.142a(b)(1).
166. 25 Pa. Code § 89.142a(b)(1)(iii)(1998). Federal regulations also require provision of the results to the owner and

Federal regulations require both the subsidence control plan and the pre-subsidence survey to be submitted with the permit application.[168] However, under Pennsylvania regulations, the operator is not required to conduct the pre-subsidence survey until "prior to the time that a structure falls within a 30 degree angle of draw of underground mining."[169] The timing of the structure survey under the 1998 Pennsylvania regulations may be inconsistent with federal law and problematic in practice.[170] Although it is desirable to know the pre-mining condition of structures close to the time of mining both in order to establish the baseline for repair and compensation and to protect such structures as they then exist, it may also be quite difficult at that time to redesign the overall mining approach or include appropriate preventive measures in the subsidence control plan if the structures are not assessed until after the permit has been issued.

Federal regulations require planned subsidence operators to describe measures to "minimize" material damage to dwellings and noncommercial buildings unless the owner has consented in writing to such damage or the cost of minimization measure exceeds the anticipated cost of repair (except where health and safety is involved).[171] The operator must also describe measures to "mitigate or remedy" material damage to the land and such structures.[172] The Pennsylvania regulations only require the subsidence control plan submitted with the application to include a description of measures to be used to correct any subsidence-related material damage to surface lands;[173] and to describe measures to ensure that subsidence will not cause material damage to, or reduce the reasonably foreseeable uses of, public buildings and water bodies greater than 20 acre-feet.[174] But with respect to dwellings and other structures, the regulations do not address such minimization at the permit application stage. The Environmental Quality Board has concluded that

the regulatory agency. 30 CFR 784.20(a)(3).
167. 25 Pa. Code § 89.142a(b)(1)(iv).
168. 30 CFR 784.20.
169.25 Pa. Code § 89.142a(b)(1)(ii)(1998).
170. Indeed, OSM's comments on the proposed regulations noted this inconsistency. Comment and Response Document, March 17, 1998 final regulations.
171. 30 CFR 784.20(b)(7).
172. 30 CFR 784.20(b)(8).
173. 25 Pa. Code § 89.141(d)(5).
174. 25 Pa. Code § 89.141(d)(3)(1998).

"the specific plans to minimize damage to a particular structure are best determined near the time of mining rather than at the time of permit application."[175]

It is important that surface owners be aware of the significance of the pre-subsidence survey. The Pennsylvania statute and regulations provide that if the surface owner fails to provide access within 10 days of the operator's notice of intent to conduct a survey, and the operator's notice advised the surface owner that failure to provide access would bar the owner altogether from maintaining a claim for subsidence repair or compensation, the surface owner cannot maintain a claim for repair or compensation.[176] The federal regulations provide only that if a surface owner denies the operator access, upon notice by the operator, the denial of access will prevent the owner from taking advantage of the federal regulations' rebuttable presumption of liability within the 30-degree (or other approved) angle of draw, which is not found in Act 54.[177]

Premining requirements also apply to potential effects on water supplies. Pennsylvania regulations require the subsidence control plan submitted with the permit application to describe whether subsidence "could contaminate, diminish, or interrupt water supplies."[178] A similar prediction is required in the operation plan, submitted with the permit application.[179] Pennsylvania's Act 54 provides that operators must describe how they intend to replace water supplies contaminated, diminished, or interrupted by underground coal mining activities.[180] The regulations require that the information on plans for water replacement must be provided with the operation plan filed with the permit application.[181]

The federal regulations provide that the operator must record the quantity and quality of all drinking, domestic, and residential water supplies within the permit area and adjacent area that could be adversely affected by subsidence, and must submit this information with the permit application.[182] Pennsylvania's regulations require the operator to conduct a premining survey of the quantity and

175. Preamble, March 17, 1998 final regulations, to be published in Pennsylvania Bulletin.
176. 52 P.S. § 1406.5d(c); 25 Pa. Code § 89.142a(b)(2)(1998).
177. 30 CFR 784.20(a)(3); see discussion of rebuttable presumption, infra.
178. 25 Pa. Code § 89.141(d)(2).
179. 25 Pa. Code § 89.35(1998).
180. 52 P.S. § 1406.5b(j).
181. 25 Pa. Code § 89.36(c)(1998); see § 89.31 for timing.
182. 30 CFR 784.20(a)(3).

quality of all water supplies within the permit and adjacent areas.[183] However, in Pennsylvania the premining survey need not be conducted prior to the permit application, but only "prior to mining within 1000 feet of a water supply unless otherwise authorized or required by the Department based on site specific conditions."[184] The results of the analysis must be provided to the landowner and the DEP within 30 days of their receipt by the operator.[185] The premining survey need not be conducted if the owner will not allow access to the site; the operator must, in that case, submit evidence that the owner failed to provide access within 10 days of the operator's notice of intent to conduct a survey; the notice must advise the owner that failure to provide access will bar the owner from relying on the presumption for water replacement where the affected supply lay within a 35-degree angle of draw.[186] The timing of the premining survey may not be consistent with the federal requirements because it places the water supply survey too late in the permitting process (indeed, allowing it after the permit has been issued), thus making planning for the protection or restoration of water supplies more difficult. However, Pennsylvania's requirements (applicable at the time of permit application) that operators predict whether there will be impacts on water supplies,[187] inventory the quantity and quality of water and usage of wells and springs,[188] and provide a description of measures to replace such supplies,[189] may provide a similar level of protection if they are interpreted strictly by the DEP.

Underground coal mining operators must give notice by registered or certified mail to political subdivisions and to surface landowners at least six months prior to mining under the property.[190] The notices must advise landowners of the availability of mining maps, which must be filed both with the county recorder of deeds and with the offices of whatever political subdivisions request them.[191] Mining maps must be updated every six months.[192]

183. 25 Pa. Code § 89.145a(a)(1)(1998).
184. 25 Pa. Code § 89.145a(a)(1)(1998).
185. 25 Pa. Code § 89.145a(a)(2)(1998).
186. 25 Pa. Code § 89.145a(a)(3)(1998).
187. 25 Pa. Code § 89.35; § 89.141(d)(2)(1998).
188. 25 Pa. Code § 89.34(a)(1)(i)(1998).
189. 25 Pa. Code § 89.36(c)(1998).
190. 52 P.S. § 1406.10. Compare 30 CFR 817.122.
191. 52 P.S. §§ 1406.10, 1406.8.
192. 25 Pa. Code § 89.154(1998).

## 4.2 ENFORCEMENT ISSUES

Commonwealth Court and the courts of common pleas each have jurisdiction to issue injunctions to prevent violations of the BMSLCA and otherwise to enforce the law upon suit by the DEP, the county commissioners, any political subdivision, or any affected property owner.[193] Officials of political subdivisions, including counties, within which underground mining is conducted, and their agents, are legally entitled to access to inspect the mining operations to determine whether the provisions of the law are being complied with.[194]

Citizen suits for compliance may be brought after 60 days' notice to the DEP and any alleged violator, or immediately upon notice to the DEP where the violation or order complained of presents an imminent threat to the health or safety of the plaintiff or would immediately affect a legal interest of the plaintiff.[195]

County commissioners have independent authority to prevent underground coal mining in violation of the law, and to prevent the miners from entering the mine until such time as the law is complied with.[196]

Civil penalties may be assessed by DEP for up to $5,000 per day for each violation; and not less than $750 per day for failure to correct a violation within the period prescribed by order or notice of violation. Criminal penalties are also prescribed.[197] The existence of unresolved subsidence claims may not be used by DEP to withhold permits or delay the processing of permits, however, unless the operator has violated a DEP order to make repairs or pay compensation.[198]

SMCRA provides for back-up enforcement by OSM in the event that a state is not adequately enforcing its approved program. If OSM becomes aware of a violation, it must give the DEP ten days' notice before taking enforcement action itself, unless the violation is causing an imminent danger to the public health and safety or significant imminent environmental harm, in

193. 52 P.S. § 1406.13.
194. 52 P.S. § 1406.11.
195. 52 P.S. § 1406.13(b),(d),(e).
196. 52 P.S. § 1406.12.
197. 52 P.S. § 1406.17.
198. 52 P.S. § 1406.5e(f),(g).

which case OSM may act immediately.[199] Where the violation involves a water replacement or subsidence damage provision of EPAct that is not covered by Pennsylvania law, OSM will take enforcement action itself under the federal law after notice to DEP.

## 5.0 REGULATION OF VALLEY FILLS

Disposal of materials in stream valleys has arisen as an issue in recent years in Pennsylvania as underground coal mining operations seek to locate disposal areas for the wastes associated with coal preparation and processing. In Pennsylvania this is commonly referred to as the "valley fill" issue.

In much of the eastern United States the term "valley fill" is used broadly to refer to the controlled disposal of any surface or underground mining-associated material (such as overburden, waste rock, spoil, or coal refuse) in a steep stream valley.[200] Pennsylvania's bituminous coal mining operations generally have disposed of such materials elsewhere (either at the mine site in order to restore the site to its approximate original contour, or in permitted coal refuse disposal areas not located in stream valleys). Thus, there is sometimes a misunderstanding when the term "valley fill" is being discussed in a federal or regional context. As used in Pennsylvania, the term "valley fill" is generally understood to refer to the siting of permitted coal refuse disposal areas in stream valleys under the Commonwealth's Coal Refuse Disposal Control Act (CRDCA).[201]

### 5.1 COAL REFUSE DISPOSAL CONTROL ACT

Prior to 1994, Pennsylvania law did not allow coal refuse disposal within one hundred feet of a stream bank.[202] In 1994, Pennsylvania amended its Coal Refuse Disposal Control Act in order to give the DEP authority to grant variances to this provision. The amendments allow coal companies to apply for a variance to "dispose of coal refuse and to relocate or divert streams in the

199. 30 U.S.C. § 1271(a).
200. Federal regulations define a valley fill as "a fill structure consisting of any material, other than organic material, that is placed in a valley where the side slopes of the existing valley, measured at the steepest point, are greater than 20 degrees, or where the average slope of the profile of the valley from the toe of the fill to the top of the fill is greater than 10 degrees." 30 CFR 701.5.
201. 52 P.S. § 30.51 et seq.

stream buffer zone if the operator demonstrates to the satisfaction of the department that there will be no significant adverse hydrologic or water quality impacts as a result of the variance."[203] The 1994 amendments (referred to as Act 114) also established new requirements for the siting of coal refuse disposal areas and new design and performance standards. In addition, Act 114 provided for a special authorization process and modified effluent limits for coal refuse disposal areas sited on lands with a pre-existing pollution discharge. The Act 114 provisions apply to new coal refuse disposal sites permitted on or after January 6, 1995, including lateral expansions of existing sites.

Act 114 was conditionally approved in 1998 by the federal Office of Surface Mining as part of Pennsylvania's primacy program under SMCRA.[204] The Pennsylvania regulations for coal refuse disposal operations (Chap. 90) have not been amended since the enactment of Act 114, except in connection with broad amendments to all of Pennsylvania's mining regulations (Chaps. 86-90) intended to reduce requirements to federal minimum standards whenever possible in accordance with the Governor's Executive Order 1996-1 and the DEP's "Reg Basics Initiative."[205] Act 114 does require the Environmental Quality Board to develop regulations to implement a portion of the Act dealing with coal refuse disposal on previously affected areas in order to assure consistency with federal and state water quality provisions for remining of surface coal mined areas.[206] These regulations have not yet been developed. In 1997, the DEP circulated a draft technical guidance document on site selection for coal refuse disposal sites. The DEP issued final guidance on site selection in 1998.[207]

### 5.2 PERMITTING PROCESS

As administered by the DEP, the CRDCA provides for a two step process for coal companies to dispose of coal refuse in a valley fill. First, a suitable site must be selected; and second, the company must obtain a permit for coal refuse disposal from the DEP. A number of state and federal

202. 52 P.S. §30.56a(h)(5)(1993).
203. 52 P.S. §30.56a (h)(5)
204. 63 Fed. Reg. 19802-10821 (April 22, 1998).
205. The Environmental Quality Board voted to propose these changes at its Feb. 18, 1997 meeting, and they were subsequently published in the Pennsylvania Bulletin (May 3, 1997) for public comment; the final changes were adopted by the Board at its January 20, 1998 meeting and they were published in the Pa. Bulletin on May 9, 1998.
206. 52 P.S. § 30.53b(b).

agencies play a role, or can become involved, in the site selection and permitting processes. These include the DEP, the Pennsylvania Fish and Boat Commission, the Pennsylvania Game Commission, the U.S. Army Corps of Engineers, the federal Office of Surface Mining, U.S. EPA Region III, and the U.S. Fish and Wildlife Service.[208]

### 5.2.1 Site Selection

Subject to valid existing rights (usually defined as possessing a valid permit prior to 1977) certain lands are designated by both federal and state law as off-limits for coal refuse disposal.[209] These include lands within the National Park System, the National Wildlife Refuge System, the National System of Trails, the National Wilderness Preservation System, the Wild and Scenic Rivers System (including study rivers), and National Recreation Areas designated by Congress. Coal refuse disposal is also not permitted on any Federal lands within the boundaries of any National Forest except where the Department of Interior and the DEP find that there are no significant recreational, timber, economic, or other values that may be incompatible with disposal operations. Disposal in parks or places on the National Register of Historic Sites is also prohibited unless approved jointly by the DEP and any federal, state, or local agency with jurisdiction over the site.[210]

Coal refuse disposal is also not permitted within one hundred feet of any public road except where mine access roads or haulage roads join the outside right of way line. DEP may permit roads to be relocated or the area affected to lie within one hundred feet of a right of way line if after public notice and opportunity for public hearing, a written finding is made that the interests of the public land and the landowners affected will be protected. Disposal operations are not permitted within three hundred feet of any occupied dwelling (unless waived by the owner) nor within three hundred feet of any public park, public building, school, church, community, or institutional building, nor within one hundred feet of a cemetery.[211] As noted above, disposal was also not permitted within one hundred feet of any stream bank; but because state law had created the stream bank prohibition, the legislature was free to amend this provision to allow a variance like that provided for in federal

207. Coal Refuse Disposal - Site Selection, 563-2113-660, Feb. 23, 1998, BMR/PGM Section II, Part 6, Supart 60.
208. Personal communication, Joel Koricich, Pennsylvania Department of Environmental Protection.
209. See 30 U.S.C. §1272(e); 52 P.S. §30.56a(h).
210. 30 U.S.C. § 1272(e); 52 P.S. §30.56a(h)

regulations.[212] In 1994, the legislature in Act 114 authorized DEP to grant variances to dispose of coal refuse within one hundred feet of a stream bank and to relocate and divert streams if the operator demonstrates that there will be "no significant adverse hydrologic or water quality impacts as a result of the variance."[213]

The federal Office of Surface Mining granted conditional approval to this variance provision, noting that it lacked several provisions found in the corresponding federal variance. The federal regulations allow a variance from the stream buffer requirement only where the authorized activity will not "cause or contribute to the violation of applicable State or Federal water quality standards *and* will not adversely affect the water quantity and quality or other environmental resources of the stream."[214] The Act 114 variance language does not expressly address conformance to water quality standards, although this may be implied from its language. But Act 114's use of the word "significant" to modify "adverse hydrologic or water quality impacts," introduced a qualifying word not present in the federal standard which OSM believed would make Pennsylvania's variance less protective of streams. It also was not clear whether Act 114's variance provision protected "other environmental resources of the stream." Thus, the Office of Surface Mining conditioned its approval of the Pennsylvania program upon modification of the Act's variance provision to reflect the federal standards. On May 30, 1998, the DEP "suspended implementation" of the word "significant," using its authority under Act 114 to suspend implementation of any portion of the Act found to be inconsistent with SMCRA in order to maintain primacy. DEP explained that, in any event, it interprets Act 114 consistently with the federal regulations. The DEP further advised OSM that it would implement the variance so as to require conformity to water quality standards and protection of water quantity and the other environmental resources of the stream, and would promulgate regulations to clarify this issue.[215]

Act 114 also provides that, except for preferred sites (see below), coal refuse disposal operations shall not be sited in prime farmlands, in sites known to contain threatened or endangered

211. 30 U.S.C. § 1272(e); 52 P.S. §30.56a(h)
212. 30 CFR 816.57(a), 817.57(a).
213. 52 P.S. §30.56a (h)
214. 30 CFR 816.57(a), 817.57(a) (emphasis supplied).
215. 28 Pa. Bull. 2544-2545 (May 30, 1998); also see DEP submittal to OSM (on file with author).

species, in watersheds designated as "exceptional value" under the regulations implementing Pennsylvania's Clean Streams Law, in areas hydrologically connected to certain exceptional value wetlands, and in watersheds of less than 4 square miles located upstream of public water supplies or public recreational impoundments.[216]

The site selection process begins with an applicant identifying a search area for potential coal refuse disposal sites. Act 114 states that:

> For new refuse disposal areas to support an existing coal mining activity, the applicant shall identify the alternative sites considered within a one mile radius and the basis for their consideration....For other new coal refuse disposal activities, the applicant shall identify the alternative sites considered within a twenty-five square mile area and the basis for their consideration.[217]

The DEP's technical guidance document provides that the DEP district mining office should "encourage meetings involving the applicant, the Pa. Fish and Boat Commission, the Pa. Game Commission and the U.S. Fish and Wildlife Service at key points in the [site selection] review process including: prior to the site selection process to discuss the procedures to be used; before defining the search area; before selecting the final site; and before developing a mitigation plan."[218] There are, however, no procedures for involving the public in any of these stages. Nor is there any notice to the public that an operator is engaged in site selection discussions, studies, and negotiations.

#### 5.2.1.1 Preferred Sites

Identifying a "preferred site" within the designated search area is the next step for the applicant. A "preferred site" is defined by Act 114 as:

(1) A watershed polluted by acid mine drainage.

(2) A watershed containing an unreclaimed surface mine but which has no mining discharge.

216. 52 P.S. § 54a(b).
217. 52 P.S. §30.54a(c),(d).
218. Coal Refuse Disposal - Site Selection, 563-2113-660, Department of Environmental Protection Bureau of Mining and Reclamation

(3) A watershed containing an unreclaimed surface mine with discharges that could be improved by the proposed coal refuse disposal operation.

(4) Unreclaimed coal refuse disposal piles that could be improved by the proposed coal refused disposal operation.[or]

(5) Other unreclaimed areas previously affected by mining activities.[219]

The DEP's technical guidance document states that ordinarily about 25 percent of the first-order watershed where the coal refuse disposal area is to be sited should consist of unreclaimed mine lands in order to invoke (2) or (3).[220]

By designating these areas as preferred disposal sites, the law creates an incentive for operators to redisturb areas previously affected by coal mining activities rather than to disturb new areas.

A site otherwise meeting one of the five criteria is not "preferred" under the statute if the "adverse impacts" of its use for coal refuse disposal "clearly outweigh the public benefits."[221] If a preferred site is considered for coal refuse disposal, the applicant must identify any adverse environmental impacts and any public benefits that might occur as a result of coal refuse disposal, including any environmental impacts that might result from a variance to the stream buffer requirement. The applicant must submit this information to the DEP for evaluation.[222] If the DEP finds that adverse environmental impacts outweigh public benefit, site approval is denied, and the DEP issues a report documenting the reasoning behind the its decision. If the DEP finds that adverse environmental impacts do not outweigh public benefit, site approval is granted, and the permitting process begins.[223]

The first valley fill site selection completed entirely under Act 114 illustrates this process. The operator chose a "preferred site" after searching a 1-mile radius. The operator, DEP, the Fish and Boat Commission, the Game Commission, and the Army Corps of Engineers engaged in

219. 52 P.S. § 30.54a(a)(1)-(5).
220. Coal Refuse Disposal - Site Selection, 563-2113-660, Department of Environmental Protection Bureau of Mining and Reclamation.
221. 52 P.S. § 30.54a(a).
222. Coal Refuse Disposal - Site Selection, 563-2113-660, Department of Environmental Protection Bureau of Mining and Reclamation, p.4; implementing 52 P.S. § 30.54a(a),(c),(d).
223. Coal Refuse Disposal - Site Selection, 563-2113-660, Department of Environmental Protection Bureau of Mining and Reclamation

discussions concerning the adverse environmental impacts of the chosen disposal site, and determined that the adverse impacts would not (with mitigation) outweigh the public benefit. Mitigation was needed for loss of a length of stream and approximately 2-3 acres of wetlands; the parties identified a mitigation site not near the proposed disposal site because there was little nearby disturbed area suitable for restoration activities. The mitigation site selected was an unreclaimed refuse pile adjacent to a stream. The preferred site and mitigation plans were decided upon among the agencies and the company during the site selection phase.[224]

#### 5.2.1.2 Non-preferred sites

If there are no preferred sites within the search area, or if an applicant identifies a preferred site within the search area but does not intend to use it based on the greater suitability of another site, the applicant must conduct an alternatives analysis comparing all potential sites. The analysis must demonstrate the basis for exclusion of other sites, and must demonstrate that the proposed site is "the most suitable on the basis of environmental, economic, technical, transportation, and social factors."[225]

The Pennsylvania DEP uses this analysis, along with a study of adverse environmental impacts conducted by the Pennsylvania Fish and Boat Commission, to determine whether the adverse environmental impacts outweigh public benefit for coal refuse disposal in a non-preferred site. If the DEP finds that adverse environmental impacts outweigh public benefit, site approval is denied, and DEP issues a report documenting the reasoning behind its decision. If DEP finds that adverse environmental impacts do not outweigh public benefit, site approval is accepted, and the permitting process begins.[226]

224. Interview, Pennsylvania Department of Environmental Protection.
225. 52 P.S. § 30.54a(c),(d).
226. Coal Refuse Disposal - Site Selection, 563-2113-660, Department of Environmental Protection Bureau of Mining and Reclamation.

### 5.2.2 Permitting

The permit is the public process wherein the operation is evaluated. The DEP's technical guidance document contemplates this process as commencing *after* the operator and state agencies have agreed on the selected site:

> After site selection has been approved by the Department, the operator may submit an application to obtain a permit to dispose of coal refuse on the selected site.[227]

Statutory permit procedures require the applicant to publish notice of the filing of the application in local newspapers once a week for four consecutive weeks, and public notice and comment procedures are governed by the same regulations that govern the permitting of underground coal mines described previously in this report.[228] Written comments or objections may be submitted to the DEP within 30 days after the last publication of the newspaper notice; and any person may request an informal conference on the application during the same period. The conference must be held publicly within 60 days of the close of the public comment period.[229]

The permit application must contain detailed geological, hydrological, engineering, and other information prescribed by the CRDCA and regulations.[230] Permit application information is available for public review and inspection.[231] The DEP conducts a technical review of the entire application. The plan must "include a system to prevent adverse impacts to surface and groundwater and to prevent precipitation from contacting the coal refuse."[232] In addition, the system must, when final reclamation of the disposal area is achieved, minimize infiltration to the extent practicable and be graded to promote surface runoff in a manner that does not promote erosion. The reclaimed area, including the infiltration control system, must allow for revegetation.[233]

The decision on the permit must be made within 60 days after the informal hearing.[234] If the permit is approved, the operator must post the required bond. Prior to commencing disposal

227. Coal Refuse Disposal - Site Selection, 563-2113-660, Department of Environmental Protection Bureau of Mining and Reclamation.
228. 52 P.S. § 30.55.
229. 25 Pa. Code §§ 86.32, 86.34.
230. 52 P.S.§ 30.55; See 25 Pa. Code Chap. 86, Chap. 90.
231. 25 Pa. Code § 86.35.
232. 52 P.S. § 30.56a(i).
233. 52 P.S. §§ 30.56a(i), 30.55(3); 25 Pa. Code Chap. 90.
234. 25 Pa. Code § 86.34(f).

operations "the operator shall file with the department a bond for the land to be affected by the coal refuse disposal area . . . payable to the Commonwealth . . . . The amount of the bond required shall be in an amount determined by the secretary based upon the total estimated cost to the Commonwealth of completing the approved reclamation plan."[235] In accordance with DEP's bonding guidelines, an applicant posts a bond equal to $1,000 per each disturbed acre of land. Under the statute no bond may be less than $10,000.[236] In the Vesta Mining application, which was the first approved under Act 114, the DEP required a bond of $3,000 per acre, covering both the coal preparation plant and the associated coal refuse disposal area ($3,000 per acre is the usual amount required for preparation plants).[237]

Liability under the bond extends for the duration of the operation plus five years after completion of reclamation.[238] Bonds may be released on a phased basis, but no part of the bond is to be released so long as "the lands to which the release would be applicable are contributing suspended solids to streamflow or runoff outside the permit area in excess of the requirement of law."[239] DEP releases the entire bond when "the operator has completed successfully all coal refuse disposal and reclamation activities" after the period of responsibility has been completed.[240] Bond releases are subject to public notice and comment procedures.[241]

#### 5.2.2.1 Stream Buffer Variance

For valley fill disposal, an applicant must submit an additional request for variance to the prohibition against coal refuse disposal within 100 feet of a stream bank. The application must include a list of all adverse hydrologic and water quality impacts resulting from coal refuse disposal activities within 100 feet of the stream bank, a mitigation plan to prevent or reduce adverse environmental impacts, proof of public notification in two newspapers of general circulation, and a complete scientific characterization of streams to be impacted by the coal refuse disposal. The

235. 52 P.S. §30.56(a).
236. 52 P.S. §30.56(a).
237. Interview, DEP Bureau of Mining and Reclamation.
238. 52 P.S. § 56(a).
239. 52 P.S. § 30.56(c).
240. 52 P.S. §30.56(c)
241. 52 P.S. § 30.55(i).

Pennsylvania DEP provides copies of the application to the Army Corps of Engineers, US EPA, US Fish and Wildlife Service, Pennsylvania Fish and Boat Commission, and the Pennsylvania Game Commission. These agencies have 30 days in which to respond to the application.[242] The US EPA has stated that it intends to review individually all applications for instream coal refuse disposal projects in the Commonwealth.[243]

Pennsylvania law requires an applicant to "give public notice of his application for the variance in two newspapers of general circulation in the area once a week for two successive weeks. Should any person file an exception to the proposed variance within twenty days of the last publication of the notice, the department shall conduct a public hearing with respect to the application within thirty days of receipt of the exception." It is at this time that any person may comment upon the application for variance, and a hearing may be held to address public concerns. The Department must also "consider any information or comments submitted by the Pennsylvania Fish and Boat Commission prior to taking action" upon the request.[244] The variance process will typically be combined with, and handled concurrently with, the coal refuse disposal permit process.

#### 5.2.2.2 Special Authorization for Site With Pre-Existing Discharge

If an operator proposes to engage in coal refuse disposal activities in an area with pre-existing pollution discharges resulting from mining operations, DEP must issue special authorization to proceed with coal refuse disposal activities.[245] Such a special authorization may be necessary where the operator has selected (or been required to select) a "preferred site," since some such sites, by definition, have discharges that do not meet state water quality standards.

The operator must provide a characterization of all preexisting discharges with its application. In order to obtain special authorization, the operator must demonstrate that "the proposed pollution abatement plan will result in a significant reduction of the baseline pollution load

242. Coal Refuse Disposal - Site Selection, 563-2113-660, Department of Environmental Protection Bureau of Mining and Reclamation; see also 52 P.S. § 30.56a(h)(5) for the statutory variance requirements.
243. 63 Fed. Reg. at 19813 (April 22, 1998).
244. 52 P.S. §30.56a(h)(5).
245. 52 P.S. § 30.56b.

and represents best technology."[246] Pre-existing discharges that are encountered by the coal refuse disposal facility must be treated in accordance with effluent standards during the life of the operation.[247] The operator must also demonstrate that the area can be reclaimed and that the coal refuse disposal activities will not cause any additional surface water pollution or groundwater degradation.[248]

An operator granted special authorization is relieved of the requirements of the Clean Streams Law with respect to non-encountered preexisting discharges "to the extent of the baseline load" if the operator complies with the terms and conditions of the pollution abatement plan approved as part of the application and the baseline load has not been exceeded at the time of final bond release.[249] An operator may be required to treat non-encountered preexisting discharges under some circumstances if the operator causes the baseline pollution load to be exceeded.[250]

In establishing the bond amount for special authorization areas, the DEP is to credit toward the amount of the bond any funds collected from a prior bond forfeiture on the area.[251] The federal Office of Surface Mining has conditioned its approval of this provision on a showing that this credit would not result in a lesser standard of reclamation than would have been achieved under the original bond forfeiture.[252]

## 5.3 OTHER PERMITS

In addition to the coal refuse disposal permit, an operator wishing to construct a coal refuse valley fill must obtain two permits under the federal Clean Water Act in connection with the placement of material into streams and operation of the coal refuse disposal facility. The U.S. Army Corps of Engineers must issue a Section 404 permit which regulates the placement of materials into waterways.[253] And the DEP must issue a discharge permit under the Commonwealth's Clean Streams

246. 52 P.S. § 30.56b(c)(2).
247. 52 P.S. § 30.56b(g)(1)(I); see 63 Fed. Reg. at 19809-19810 (April 22, 1998).
248. 52 P.S. § 30.56b(c)(3),(4).
249. 52 P.S. §30.56b(m)
250. 52 P.S. § 30.56b(g).
251. 52 P.S. §30.56b(l)
252. 63 Fed. Reg. at 19811, 19820-21 (April 22, 1998).
253. 33 U.S.C. § 1344.

Law satisfying the requirement under Section 402 of the federal Clean Water Act for permitting of pollution discharges.[254]

The § 404 permit may be issued by the Corps on an individual permit application, subject to notice and comment procedures. The permit process requires that the applicant demonstrate that there are not "practicable alternatives" to the discharge of the material in the selected location that would have less adverse effects on the aquatic ecosystem.[255] The Corps also applies a sequence of steps to determine that the applicant has minimized adverse effects on the aquatic ecosystem.[256] An applicant must first avoid filling where possible; if impacts cannot be avoided, they must be minimized to the extent practicable by the project's design; any remaining impacts must be compensated for by providing other resources (such as rehabilitation of other stream or wetlands resources).[257] Individual Corps permits may be vetoed by the U.S. EPA if the project will have "unacceptable adverse effects."[258]

The Corps has provided for the approval of certain similar activities with minimal impacts under so-called "nationwide" general permits under the law. The nationwide permits do not require a separate, individualized permit application and public review process, but simply require notice to the Corps, and set standard conditions. Nationwide Permit 21 (NWP21) covers activities associated with coal mining activities regulated under SMCRA, allowing them provided they are authorized by a state permit.[259] However, the practice of the Pittsburgh District of the Corps is to require operators to obtain individual § 404 permits for coal refuse valley fills because of the potential extent of the impacts.[260]

The Clean Streams permit is issued to set the pollution discharge limits from the coal refuse disposal area. The limits are the technology-based standards (based on best available technology), as modified by water quality standards (where the technology-based standards are not sufficient to

254. 33 U.S.C. § 1342.
255. 40 CFR 230.10.
256. 40 CFR 230.10.
257. Memorandum of Agreement between the U.S. Environmental Protection Agency and U.S. Department of the Army, Determination of Mitigation Under the Clean Water Act § 404(b)(1) Guidelines (eff. Feb. 7, 1990).
258. 33 U.S.C. § 1344(c).
259. See 61 Fed. Reg. 65874 (1996).

meet stream quality designations). As noted under the discussion of areas with pre-existing discharges above, coal refuse disposal operations with "special authorizations" are subject to more limited (modified) effluent requirements reflecting baseline conditions. The US EPA also has the power to review the Clean Streams permit, and has stated that it will exercise this authority for each such permit issued by the DEP.[261] Environmental organizations have argued that disposal of coal refuse and other coal-mining related materials in valley fills is unlawful under Section 402 of the Clean Water Act, Section 401 of the Clean Water Act (dealing with water quality standards), and federal antidegradation regulations intended to protect water quality and existing uses, because such fills can result in the burial of long sections of stream.[262] No final decisions have been rendered on this issue in federal court. EPA Region III has also begun to examine valley fill permitting throughout the region to determine whether there are ways in which the process can be made more protective of riparian habitat and wetlands.

## 5.4 ENFORCEMENT

It is unlawful to establish, operate or maintain a coal refuse disposal area in a manner that fails to comply with any rule, regulation, order or permit of the department, or in violation of the Coal Refuse Disposal Control Act.[263] It is also unlawful to "cause air or water pollution in connection with coal refuse disposal operations and not otherwise proscribed by" the Act.[264] DEP may issue orders to enforce any provision of the Coal Refuse Disposal Control Act.[265] The DEP has the authority to issue cessation orders if the operator does not have a permit or where the public safety and welfare is immediately threatened. A cessation order stays in effect until the operator takes

260. Moreover, NWP 21 now requires the discharger's notification to the Corps to contain a state-approved mitigation plan, in any event, so that even if it applied, mitigation would be required. Nationwide Permit Conditions, 13(c)(5) (1996).
261. 63 Fed. Reg. at 19811, 19820-21 (April 22, 1998).
262. E.g., Raymond T. Proffitt Foundation v. Pennsylvania Dept. of Environmental Protection, (W.D. Pa., filed Feb. 11, 1998).
263. 52 P.S. §30.57
264. 52 P.S. §30.57
265. 52 P.S. § 30.59.

corrective steps to the satisfaction of the department.[266] DEP may also obtain injunctive relief to restrain violations.[267]

DEP may assess civil penalties of up to $5,000 per day for each violation, and must assess a civil penalty of not less than $750 per day for each day of violation beyond the period described for abatement.[268] Criminal penalties may be assessed as well.[269] All fines, civil penalties, bond forfeitures and fees collected under the CRDCA are paid into the state treasury "Coal Refuse Disposal Control Fund." All moneys in this fund are to be used by the DEP to carry out the purposes provided in the Coal Refuse Disposal Control Act such as the elimination of pollution and the abatement of health and safety hazards and nuisances.[270]

The law provides that "Any person having an interest which is or may be adversely affected may commence a civil action on his own behalf to compel compliance with this act or any rule, regulation, order or permit issued pursuant to this act against the department where there is alleged a failure of the department to perform any act which is not discretionary with the department or against any person who is alleged to be in violation of any provision of this act or any rule, regulation, order or permit issued pursuant to this act."[271] An action may not be filed prior to 60 days written notice to the DEP and any alleged violator, unless the violation constitutes an imminent threat to the health or safety of the plaintiff or a threat to the legal interests of the plaintiff.[272]

Any person may present information which gives the department reason to believe that a person is in violation of a requirement of the CRDCA or any condition of a permit; DEP will immediately order an inspection of the operation. The person filing the information may be present at the time of inspection.[273]

266. 52 P.S. §30.58
267. 52 P.S. § 30.60.
268. 52 P.S. §30.62
269. 52 P.S. § 30.62.
270. 52 P.S. §30.64
271. 52 P.S. §30.63(a)
272. 52 P.S. §30.63(c),(d).
273. 52 P.S. § 30.63(b).

The law has a savings clause that preserves the right of the Commonwealth or any district attorney to proceed in court to "abate pollutions forbidden under this act, or abate nuisances under existing law."[274]

The § 404 permit is enforceable by the Corps of Engineers or the U.S. Environmental Protection Agency through orders, injunctions, civil penalties, and criminal penalties.[275] Clean Streams enforcement actions may be brought by the DEP. And citizen suits, subject to the 60-day notice requirement under the Clean Water Act, are also available.[276]

## 5.5 PETITIONS TO DESIGNATE AREAS AS UNSUITABLE FOR COAL REFUSE DISPOSAL

Pennsylvania law allows the public and local governments to petition the DEP to designate an area as unsuitable for coal refuse disposal operations.[277] An area must be designated, upon petition, if the DEP finds that reclamation is not technologically and economically feasible.[278] An area may be designated if its use for disposal will be incompatible with state or local land use plans or programs, will affect fragile or historic lands in which such operations could result in significant damage, will affect renewable resource lands in which such operations could result in substantial loss of long-range productivity of water supply or food or fiber (including aquifers and aquifer recharge areas) or will affect natural hazard lands on which such operations could substantially endanger life or property.[279]

## 5.6 DISCUSSION

It is important to note that there is currently no role for the public in the site selection process for coal refuse disposal areas. Indeed, while the DEP has bifurcated the process in order to simplify its permitting obligations and to meet permit grant or denial timetables expeditiously by deferring

274. 52 P.S. § 30.65.
275. 33 U.S.C. §§ 1344(s), 1319.
276. 33 U.S.C. § 1365.
277. 52 P.S. § 30.56a(a)-(g).
278. 52 P.S. § 30.56a(a).
279. 52 P.S. § 30.56a(b).

the actual application until most of the agreements have already been reached, the division of coal refuse disposal permitting into a 2-step process does not appear to be required by Act 114. Section 30.54a simply requires the applicant to identify alternatives considered within the applicable area, and to demonstrate suitability of the selected site. It then provides standards for the DEP to disapprove a site. But the statute itself does not provide that either the demonstration or the approval/disapproval must take place in advance of the permit application and before the opportunity for public scrutiny. The DEP's practice and its technical guidance document, however, clearly segregate these two processes. The DEP provides for submittal of the coal refuse disposal application, with attendant public processes only "[a]fter site selection has been approved by the Department." The lack of meaningful public review is further demonstrated by the fact that even the mitigation sites are selected, designed, and approved by all of the relevant agencies before the permit application is submitted. Opening up the site selection process and the alternatives analysis to real public involvement may result in improving the site selection, alternatives analysis, and the mitigation decisions.

The DEP expects perhaps a half dozen valley fill permit applications over the next ten years, so such permits will not be a frequent occurrence. Exposing them to an earlier and more substantial level of public scrutiny should not, therefore, be unduly burdensome for the agency. Regulations to implement Act 114 have not been developed, but could improve the process by providing for reasonable levels of public involvement.

In addition, the relationship between protection of water quality, stream health, and the use of the stream buffer variance is likely to attract substantial regulatory and research attention over the next several years.

# SECTION B

# PHYSICAL AND BIOLOGICAL ISSUES

# CHAPTER 4

# HYDROLOGIC CONSEQUENCES OF HIGH EXTRACTION MINING AND VALLEY FILL PRACTICES, WITH EMPHASIS ON SOUTHWESTERN PENNSYLVANIA

Milena F. Bucek, Ph.D.
Bucek & Associates, Inc.
Philipsburg, Pennsylvania

and

Richard S. diPretoro
Private Practice
Pittsburgh, Pennsylvania

# 1.0 INTRODUCTION

This paper addresses hydrogeologic issues related to high extraction underground mining of bituminous coal as well as valley fill practices, with emphasis on Southwestern Pennsylvania.

While 29 counties in Pennsylvania have underground mining reserves, this paper focuses on the five Pennsylvania counties which currently have high extraction underground bituminous coal mining (Armstrong, Greene, Indiana, Somerset, and Washington). Among those five, the emphasis is on Greene and Washington counties as these two host by far the densest concentration of high extraction operations in the state. The term "high extraction" is preferred to "full extraction" as all mining methods leave some coal in the ground, inside and outside the mining plan area.

This paper is based on literature review and interviews with scientists, regulators, and citizens, and the personal experience of the authors. Sections 3, 4, and 6 were written by Milena F. Bucek, Sections 2, and 5 were written by Richard S. diPretoro.

# 2.0 TOPOGRAPHY, CLIMATE AND GEOLOGY

## 2.1 TOPOGRAPHY

The major underground coal-producing areas of the counties of this study (See Figure 2.1) lie in Southwestern Pennsylvania in the Pittsburgh Low Plateau and Allegheny Mountain physiographic provinces of PA. Neither province is glaciated.

### 2.1.1 Pittsburgh Low Plateau Section

The Pennsylvania Department of Conservation and Natural Resources provides as follows:

> The Pittsburgh Low Plateau Section consists of a smooth undulating upland surface cut by numerous, narrow, relatively shallow valleys. The uplands are developed on rocks containing the bulk of the significant bituminous coal in Pennsylvania. The landscape reflects this by the presence of some operating surface mines, many old

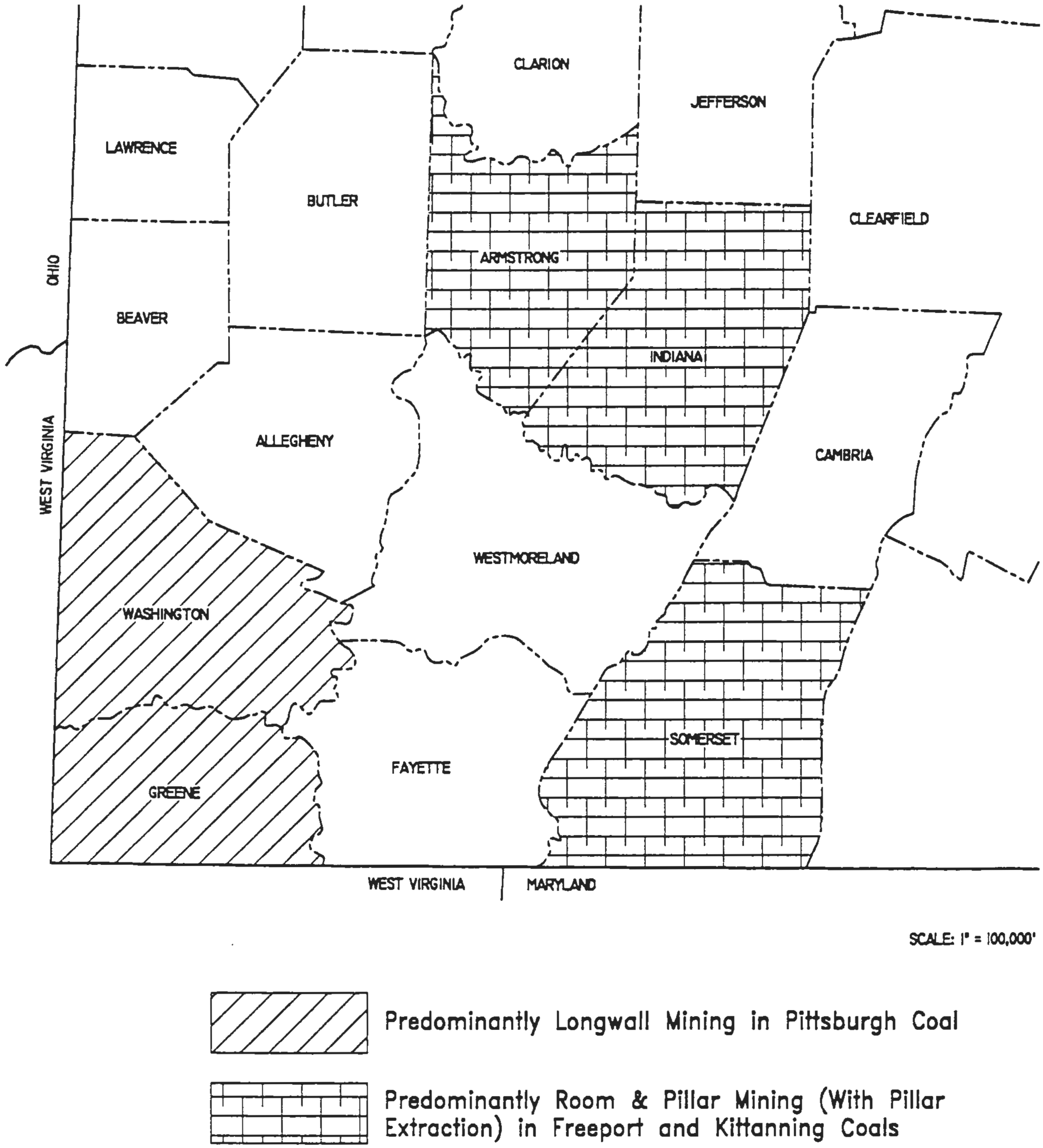



**Figure 2.1 Major Underground Coal-Producing Counties of Pennsylvania**

stripping areas, and many reclaimed stripping areas. The local relief on the uplands is generally less than 200 feet. Local relief between valley bottoms and upland surfaces may be as much as 600 feet. Valley sides are usually moderately steep except in the upper reaches of streams where the side slopes are fairly gentle. Elevations range from 660 to 1,700 feet. Some of the land surface in the southwestern part of the Section is very susceptible to landslides.

> The Section covers much of western and Southwestern Pennsylvania. It includes all of Greene, Washington, Allegheny and Armstrong Counties, most of Beaver, Butler, Clarion, Jefferson, Clearfield, Westmoreland, and Indiana Counties, and parts of Lawrence, Venango, Elk, Cambria, and Fayette Counties.

### 2.1.2 Allegheny Mountain Section

The Pennsylvania Department of Conservation and Natural Resources provides as follows:

> The Allegheny Mountain Section consists of broad, rounded ridges separated by broad valleys. The ridges decrease in elevation from south to north and the ridges have no topographic expression at the north end of the section. The ridges occur on the crests of anticlines that have been eroded enough to expose the very resistant rocks that form the crests of the ridges. However, not enough erosion has occurred to breach the anticlines and create parallel ridges such as occur in the Appalachian Mountain Section. The southern parts of these ridges form the highest mountains in Pennsylvania. The valleys are broad, undulating surfaces with shallow to deep stream incision. Relief between the ridge crests and the adjacent valley lowland can be greater than 1,000 feet. Local relief on the broad, valley lowland is generally less than 500 feet. Elevations in the Section range from 775 to 3,210 feet, the highest elevation in Pennsylvania at Mt. Davis.
>
> The Section occurs in Southwestern Pennsylvania and includes all of Somerset County, about half of Fayette and Cambria Counties, and parts of Westmoreland, Indiana, Blair, and Bedford Counties.

## 2.2 CLIMATE

Climate is humid continental with rainfall ranging from 36 inches at Pittsburgh to nearly 50 inches on Laurel Hill on the border of Fayette and Somerset Counties. Precipitation is fairly evenly distributed covers the ground an average of 33 days per year. Yearly temperatures average 50-55 degrees F, with extremes of -25 to 105.

## 2.3 GEOLOGY

### 2.3.1 Stratigraphy

The coals of Southwestern Pennsylvania formed 300 million years ago. The coal beds form part of a semi-repetitive system of sediments along with sandstone, siltstone, shale, clay, claystone, mudstone, and limestone, see Figure 2.2. The relationship , as the Mississippi River threatens to leave its current channel above New Orleans and take a different route to the Gulf). Sometimes they dumped mud, sometimes sand directly on top of the peat. This marked the end of the development of the peat and formed the roof rock of the coal seam today. The length of time that the swamp survived before being covered with sediment determines the thickness of the coal. Its original area was determined by the size of the swamp. The Pittsburgh coal, for example, is remarkably consistent and uniform compared to other coals and covers an unusually large area. It apparently developed when mud and sand deposition stayed away from a large peat swamp for a long time.

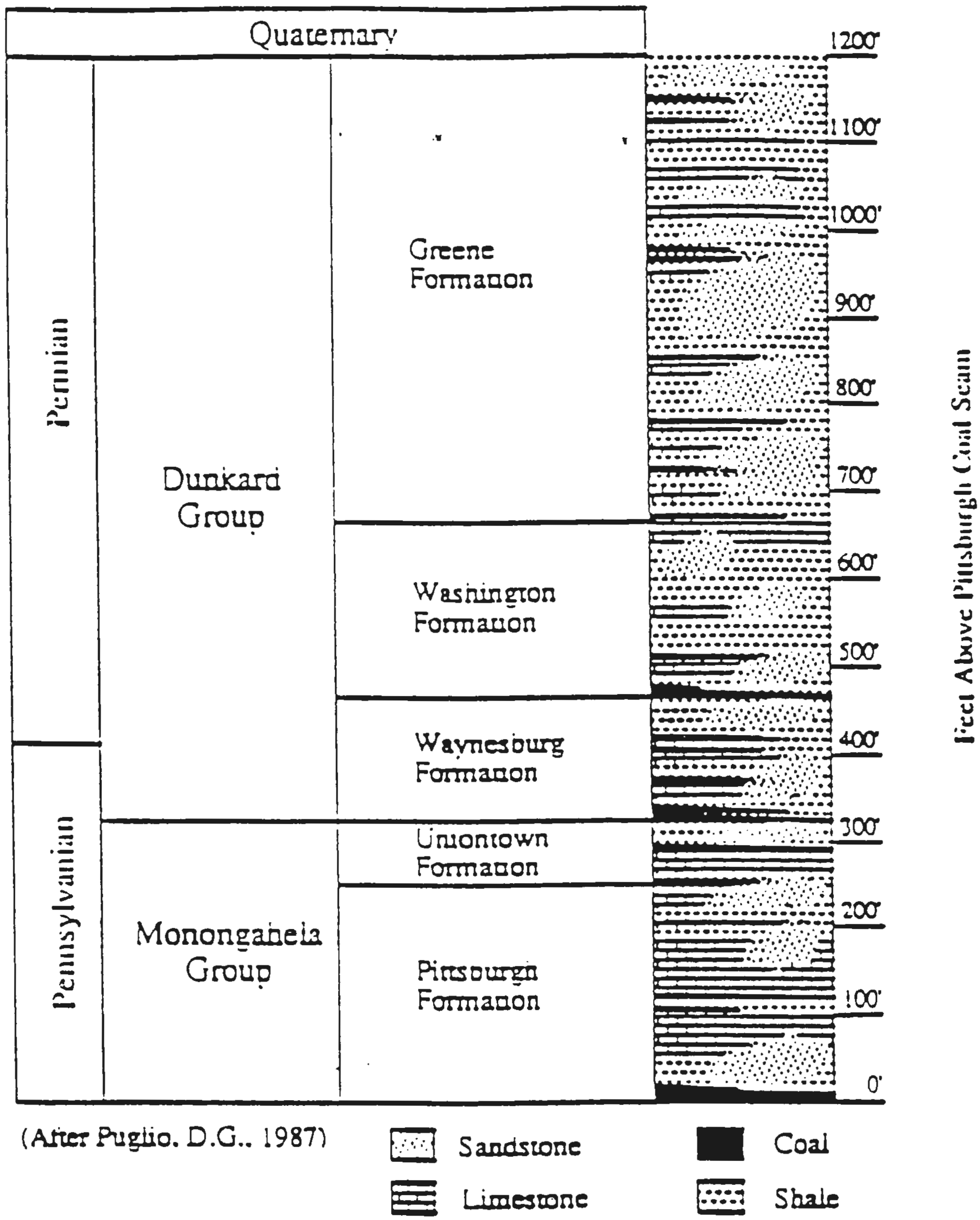



**Figure 2.2 Stratigraphic column (taken from Parizek and Ramani, 1996).**

The weight of the accumulating sediments actually depressed the crust of the earth, causing a type of slow, natural subsidence. Continuous subsidence of the delta throughout the coal-forming period allowed most of deposition to take place at or near sea level, and yet over 2,000 feet vertical thickness of rocks resulted.

The shifting of the rivers back and forth, over and over, resulted in semi-regular repetitions of sediment types. Sand, mud, lime mud, soil, and peat produced sandstone, shale, limestone, underclay and coal respectively. Each of these types of rocks can grade laterally and vertically, sometimes abruptly, into other types of rocks. This has significance, discussed later, for the movement of groundwater today.

The result of delta-switching has been likened to a semi-randomly stacked packet of tissue-thin tree leaves. The veins of the leaves represent sandstone channels and the material between the veins represents shales, coals and other rocks. Over a period of millions of years, the packet of sediments sank deeper below sea level until the pressure of the overlying rocks and heat from the earth changed them from loose materials into hardened rocks.

The thickness of commercially minable coals ranges from about 3 to 10 feet but they can cover many hundreds and even thousands of square miles. To give an idea of scale, the ratio of thickness to width and length for the Pittsburgh Coal is about one tenth that of a double newspaper page. This means that operators must range over and disturb a large area to recover a relatively tiny fraction of the crust of the earth.

### 2.3.2 Structure

The sedimentary rocks of the Appalachian Basin which contain the coals of interest were uplifted, folded and fractured by a mountain-building episode between 280 and 230 million years ago. The land has remained above sea level, subject to erosion, and without recent glaciation ever since. The uplift imparted folds and fractures which play a significant role in the natural and mining-influenced hydrogeology of Southwest Pennsylvania.

#### 2.3.2.1 Folds

Mountain-building compressed the coal-bearing rocks from the southeast and raised them up above sea level. The folding and uplift created open folds with trends roughly parallel to mountains like Chestnut Ridge and Laurel Hill, about north 30 degrees east. The amplitude, or height, of the folds is low and generally decreases from east to west. Even when low however, the folds impart measurable slope to the rocks, called dip, which has importance in controlling groundwater flow. Structural dip, typically less than 5 percent, also controls the depth of the coal below the surface. For example, coal deep enough to mine by underground methods in one area may rise too close to the surface for underground mining a few miles away. Its horizon may even rise above the surface and it will therefore be missing due to erosion. The coal's horizon intersects the surface along a line called the cropline. The Pittsburgh Coal cropline reaches elevations exceeding 1,000 feet above seal level in southeast Greene County and northwest Washington County. The lowest downfold of the entire Appalachian basin, its axis called the Nineveh Syncline, runs about N30E through western Greene and central Washington Counties. There, the Pittsburgh Coal reaches down to less than 100 feet above sea level. East of that axis, the rocks generally dip (down) to the northwest. West of the axis, the rocks generally dip to the southeast. In investigating the fate of a domestic water source in relation to mining, it is important to determine the dip of the rocks. The long-term flooding behavior of the mine after abandonment also is determined to a large extent by its structural position in relation to the cropline and to other mines.

#### 2.3.2.2 Fractures

Fractures occur ubiquitously naturally in rocks and exert significant control over groundwater flow. Naturally existing fractures tend to open as a result of the stresses created by high extraction mining.

Fractures are called joints in rock and cleat in coal. They are semi-random but, especially in coal, tend to develop parallel to and perpendicular to the same trend as the folds discussed just above, about north 30 degrees east and north 60 degrees west. In coal, the better-developed set of fractures is oriented perpendicular to the trend of the mountains and is called the face cleat. The less well-developed set is oriented parallel to the mountains and is called the butt cleat. Mining engineers usually plan mines to take advantage of coal cleat to aid the removal of coal because the coal falls out of the face more easily when the long axis of the panel is parallel to the face cleat.

Another important type of fracture lies roughly parallel to the dip and is called bedding plane fracture. These can form along planes of weakness where rock-type changes, as a result of the relief of pressure by erosive removal of overlying rock.

The spacing of fractures is roughly proportional to the grain size of the rock. Rocks with larger grain sizes have larger spacing of their fractures. For example, there may be several fractures per foot in coal with several feet between fractures in sandstone. Zones of concentrated fractures, called fracture zones or lineaments, can significantly control groundwater flow, both to domestic supplies and to the mines. They can often be seen on various maps and photos and therefore they can be located in advance of mining.

Very little in the way of true geologic faulting exists in Southwestern Pennsylvania. A fault, as defined by geologists, is a fracture along which movement has occurred. Miners sometimes use the term fault to designate an area where coal is missing, typically due to scouring and replacement by sandstone channel as a result of channel switching discussed above.

Joints, bedding plane fractures, and lineaments play a significant role in the movement of groundwater and will be discussed in later chapters.

## 3.0 HYDROLOGIC CYCLE AND HYDROLOGIC BALANCE

The basic premise of environmental protection that considers impacts of high extraction mining on ground and surface water resources entails several fundamental hydrologic concepts, namely the principles of hydrologic cycle and its balance, and the prediction of hydrologic consequences of mining.

This chapter reviews these basic concepts and provides definitions of the hydrologic terms necessary for an understanding not only of those concepts, but also for the understanding of the Pennsylvania statutes and regulations as they pertain to underground mining and its potential environmental impacts.

## 3.1 HYDROLOGIC CYCLE

Figure 3.1 is a three-dimensional schematic representation of a hydrologic cycle, namely the interaction of its four basic elements which are: precipitation (P), runoff (R), evaporation and transpiration, or evapotranspiration (ET), and change in surface and groundwater storage ( S). The relationship of these elements (assuming no water transfer across basin boundaries) can be described as

$$P = R + ET + \Delta S$$

The term basin refers to a basic hydrologic entity, e.g. ground or surface water watershed. The elements of the hydrologic cycle are dynamic entities that are, at a given time, balanced within a basin, i.e. there is an equilibrium of water input, output, and change in groundwater storage. Some of the elements may be directly impacted by a mining operation with the resulting change in the hydrological balance. The descriptions of the elements are given below.

> Precipitation (P), in the form of rain or snow melt, represents the water input to the hydrologic system (see Section 2.2 for information on climate of Southwestern Pennsylvania).

The term runoff describes the portion of the precipitation that travels over the land surface, to be ultimately collected by surface water drainage channels (channel flow). Stoner et al., 1987, calculated that on average, 39% of the annual precipitation becomes runoff; the calculations were based on the calendar year records of 1941 to 1980 for part of South Fork Tenmile Creek watershed that lies in Greene County in Southwestern Pennsylvania.

In addition to overland flow that contributes to the stream flow, groundwater discharge to streams in the form of a base flow maintains the stream flow during dry periods. Streams with continual flow that is maintained by the base flow recharge are the perennial streams while the streams where the flow is not always maintained by the base flow recharge are the intermittent streams.

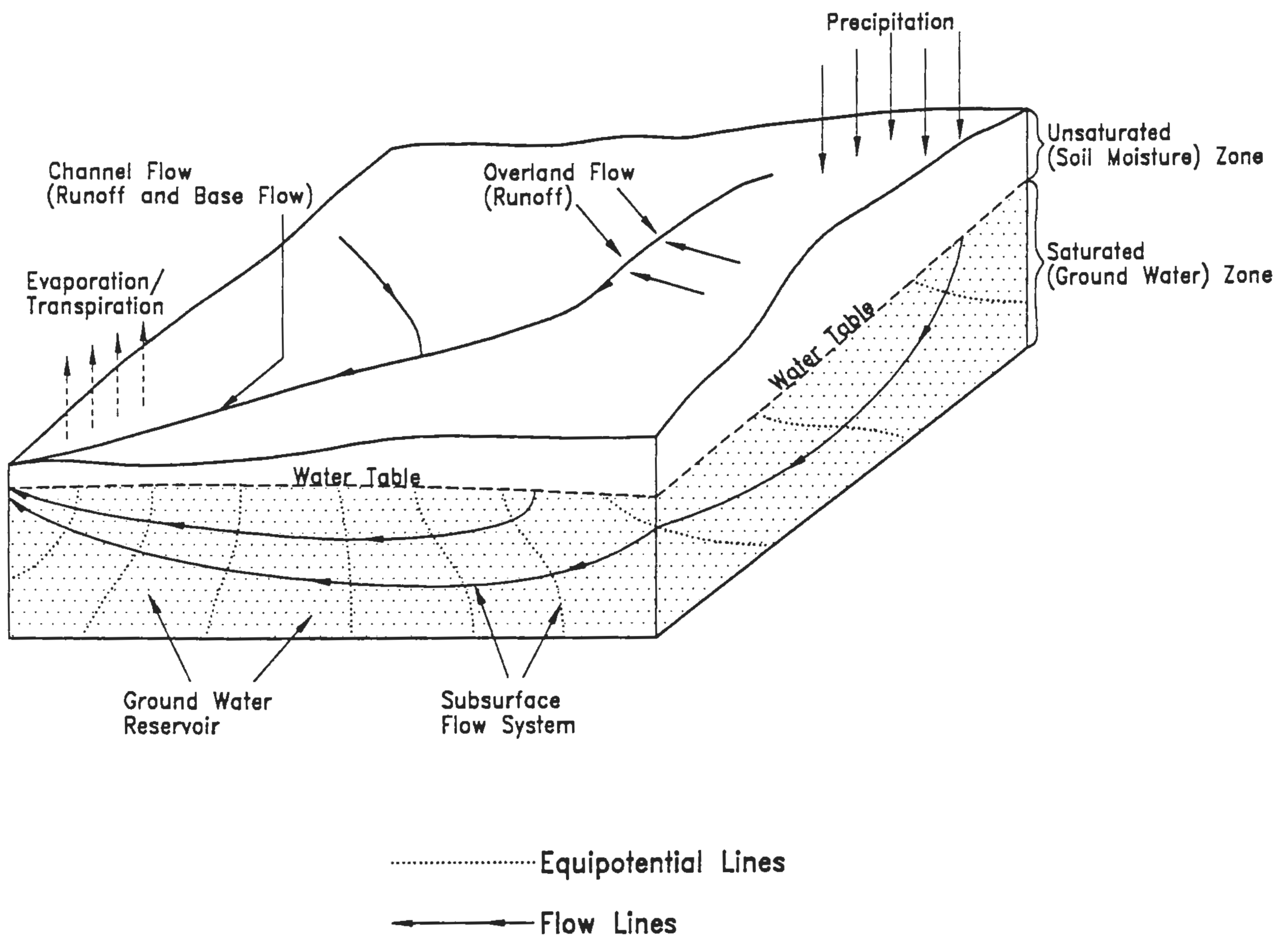



**Figure 3.1.** **Schematic representation of a hydrologic system (modified from Freeze and Cherry, 1979).**

25 Pa. Code §89.5 defines perennial stream as a body of water flowing in a channel or bed composed primarily of substrates associated with flowing water 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 cycles within or upon available substrate in a body of water or water transport system.

25 Pa. Code §89.5 defines intermittent stream as 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 the surface runoff and groundwater discharge.

High extraction mining may impact the runoff element of the hydrologic cycle, namely the flow characteristics of streams, by producing changes in the ground surface configuration, including local modifications of stream gradients, and by impacting the groundwater reservoir and subsequently its role in recharging the streams, thus potentially changing the stream status from perennial to intermittent.

The term evapotranspiration (ET) refers to the process by which the precipitation is returned to the atmosphere directly by evaporation and by transpiration by plants. Average ET losses for two water years (1980 and 1981) reported for the Southwestern Pennsylvania, i.e. parts of watersheds of South Fork Tenmile Creek and Enlow Fork in Greene County by Stoner et al.,1987, represent 52% and 56% of the annual precipitation, respectively. ET losses for the period of record from 1941 to 1980, also for part of the South Fork Tenmile Creek watershed, were reported by Stoner et al., 1987, to be 61%.

The term groundwater storage (S) (or change in groundwater storage, S) refers to the groundwater element of the hydrologic cycle. The flow in the saturated zone is governed by the nature of the subsurface materials that controls the amount of water storage in the groundwater reservoir.

High extraction mining may impact the groundwater storage and associated hydraulic properties via rock fracturing that propagates from the area of collapsed mine roof through underground mine overburden, extending to the ground surface.

The quantity of water available for use within each hydrologic entity (watershed) is affected by each element of the cycle. The development of water resources and their use depend on and are limited by the amounts of water in each element; the man-induced water withdrawal, e.g. dewatering due to pumping may profoundly impact the hydrological balance and water use in the area as is discussed in the following sections.

## 3.2 HYDROLOGIC BALANCE

The hydrologic balance as used in the context of the regulatory statutes pertaining to underground coal mining in Pennsylvania is defined by 25 Pa. Code §89.5 as a relationship between the quality and quantity of water inflow to, water outflow from, and water storage in hydrologic units 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.

The protection of hydrologic balance vis-a-vis impacts of high extraction mining deals mainly with induced changes in runoff, specifically channel flow and groundwater storage. As discussed above, the groundwater system provides base flow to streams, and the designation of a stream as intermittent or perennial is determined in large part by the contribution of base flow to the stream. During dry periods, when there is little or no surface runoff, the base flow to streams from the groundwater reservoir maintains the stream flow. If a segment of the stream is located above the saturated groundwater reservoir, the stream will be dry during periods when runoff is not present, and is classified as intermittent in this segment. However, the stream segments that are below the top of saturated strata (regional groundwater reservoir) are always supplied by groundwater recharge (base flow) and are therefore perennial. Furthermore, the location of the point where a stream becomes perennial is based on the elevation of the water table of the regional aquifer, gradients within that aquifer, and the relative position and configuration of the stream bed.

In addition to the relationship between the ground and surface water flow systems, the hydrological balance, as defined in the regulations, includes maintenance of the flow into and from, water storage in an aquifer. This addresses the concept of use, as an aquifer is defined in the regulations in terms of use. As the aquifers are used as private water supply sources as well as sources for base flow to the streams, maintaining the hydrologic balance includes providing for continued use of the aquifers for private water supplies as well as maintaining the base flow recharge to the streams.

## 4.0 GROUNDWATER FLOW REGIMES OF SOUTHWESTERN PENNSYLVANIA

This chapter introduces general concepts of groundwater occurrence and movement in coal-bearing rocks and their effect on surface drainage, necessary for understanding and evaluation of severity of the impact of high extraction mining in Southwestern Pennsylvania.

### 4.1 GENERAL GROUNDWATER HYDROLOGY

The term groundwater refers to subsurface water contained in openings in soils or rocks that are fully saturated; groundwater reservoir lies beneath the upper boundary of the saturation, i.e. water table or potentiometric surface. The flow in a zone of saturation is from an area of groundwater recharge to an area of groundwater discharge. Idealized local and regional groundwater flow conditions are shown in Figure 4.1.

The position of the water table changes in response to the amount of recharge by precipitation, and to a lesser degree due to changes in barometric pressure. The water level fluctuations are most prominent in shallow groundwater flow systems and less pronounced in water table or confined aquifers where the influence of precipitation is delayed. Furthermore, seasonal water level fluctuations are usually greatest in wells located in uplands and lesser in wells closer to valley bottoms. To illustrate this point for conditions that prevail in Greene County, graphs of water level fluctuations from selected wells located in various topographic positions and developed in shallow and deep aquifers are given in Figures 4.2 and 4.3.

Decline of water level is often associated with high extraction mining and water withdrawal from underground mine workings. In order to differentiate the natural water level fluctuations from those caused by man-induced changes, a baseline record is necessary. The correct evaluation of mining impacts thus requires that background or pre-mining water levels be measured for at least a hydrological year to include periods of high recharge as well as periods of drought. The same is true

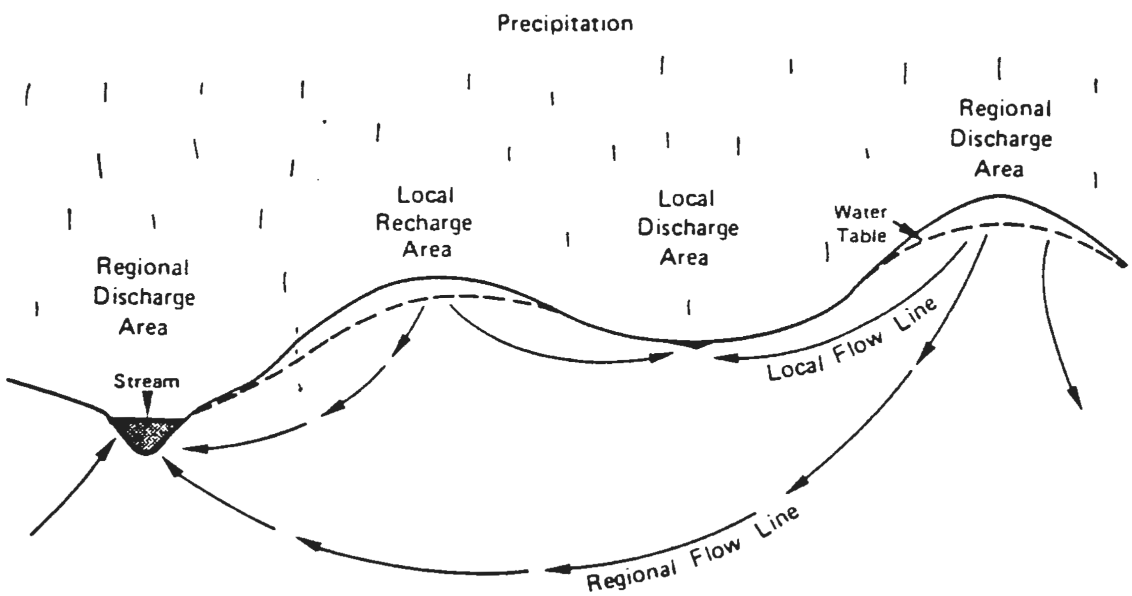



**Figure 4.1** **Idealized local and regional groundwater flow system (from D. B. Richards, 1985).**

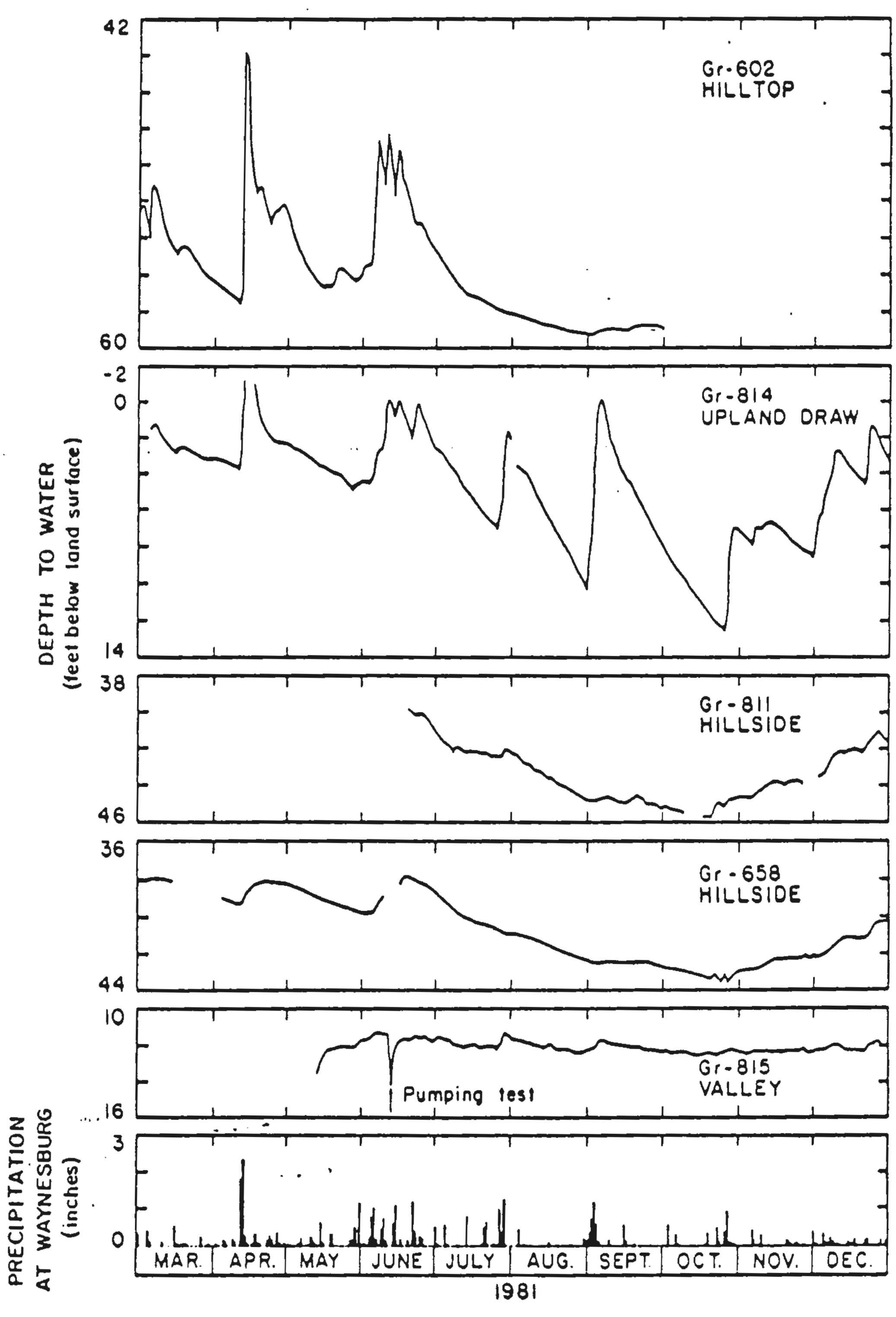



**Figure 4.2** **Relationship of water level fluctuations in wells to daily rainfall and topographic position (from Stoner et. al, 1987).**

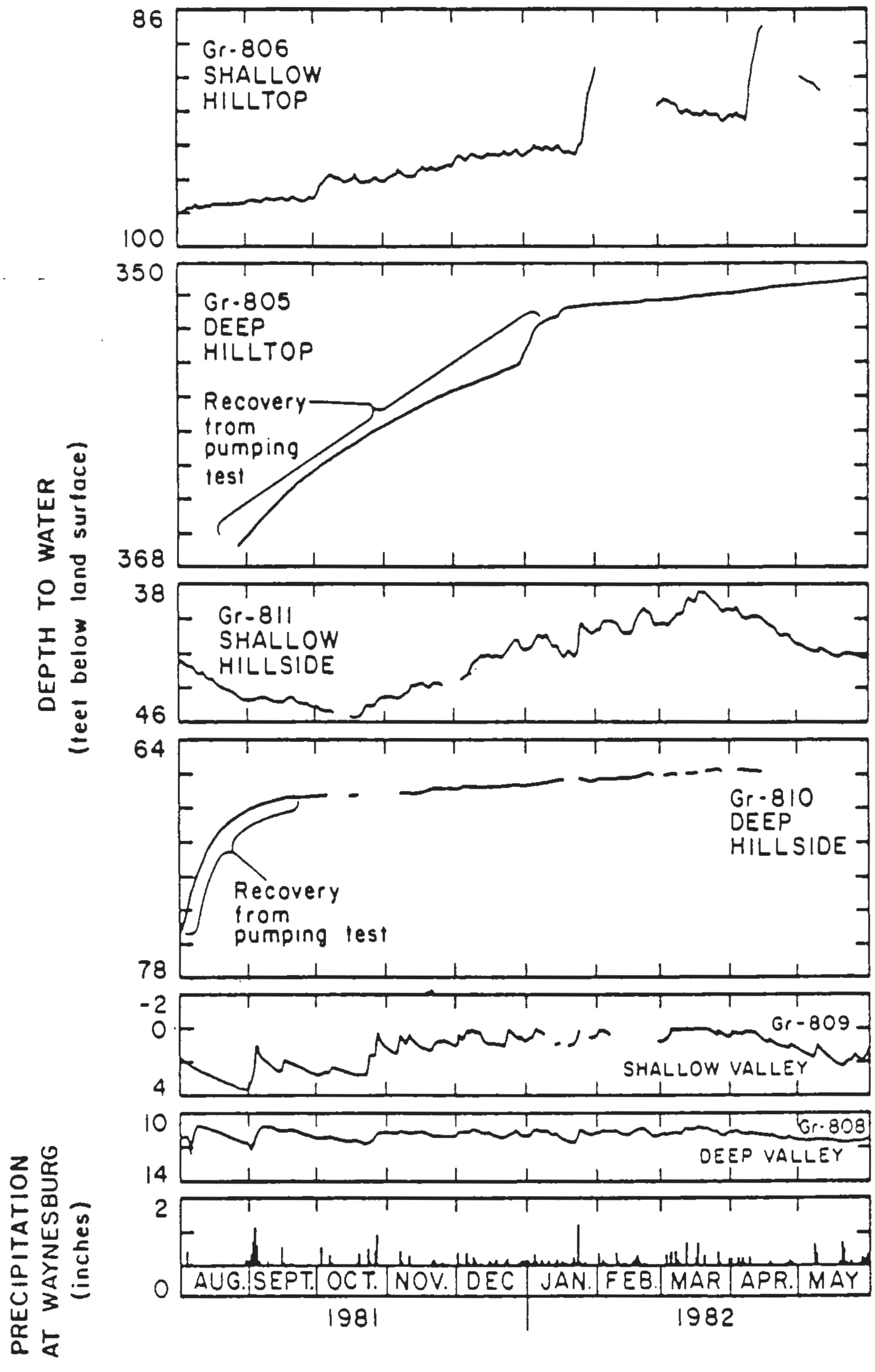



**Figure 4.3** **Relationship of water level fluctuations in tightly cased wells to depth of aquifer and daily rainfall (from Stoner et. al, 1987).**

of the baseline records for streams in the areas of high extraction mining as the ecological balance of streams is often adversely affected by flow diminution or dewatering.

The groundwater reservoir contributes water to streams in the form of a base flow that maintains stream flow during periods of no surface runoff. The decline in water levels and hydraulic gradients in a groundwater reservoir adjacent to the streams diminishes the amount of base flow delivered to the stream and may impact the stream's perennial status.

The term aquifer describes a water-bearing zone that yields usable quantities of potable water to wells and springs. Aquifers are usually composed of several water-bearing units within a geologic formation or formations - as an example see the data from water well driller's records as reported for Greene County by Stoner et al., 1987. Many wells developed in the coal-bearing rocks of Southwestern Pennsylvania are naturally low yielding and the evaluation of well yields may be difficult. A specific capacity test is used in determining the yield of a well in gallons per minute per foot of drawdown that is induced by pumping from the well at a constant rate for a given period of time.

As yields of wells may be impacted by the high extraction mining, pre-mining testing of well's specific capacity is needed for supply replacement strategy as the replacement should be not only of the same quality but also of the same quantity, i.e. yield.

Permeability of rocks is a measure of their ability to transmit water. The groundwater movement in the coal-bearing strata in Southwestern Pennsylvania is predominantly controlled by secondary permeability, i.e. the permeability related to fractures. The hydraulic properties of the strata thus change with degree of fracturing, its density, fracture aperture and interconnection of the fracture network. The secondary permeability usually decreases as the aperture and density of fractures decreases with depth.

It has been shown and documented by various research efforts (see Section 6) that subsidence induced by high extraction mining has produced increased hydraulic permeabilities in the strata overlying the underground mines where the increased hydraulic conductivity is caused by the augmented or new fracturing and bed separation.

The hydraulic properties of an overburden unit are governed primarily by joints and fractures. Because these discontinuities often cross rock boundaries, the hydraulic properties of shale and claystone units - rock types commonly assumed to be impervious - may not be distinctly different, locally, from those of the sandstones, which are commonly assumed to be "pervious" (Bruhn, 1985). Fracturing due to jointing and faulting can locally reduce the confining effect of relatively impermeable beds and create much greater hydraulic conductivities in shales and siltstones. If the fractures form a network of interconnected conduits and a large volume of material is considered, the principles of Darcian flow allow the use of standard drawdown and recovery tests for permeability evaluations (Lewis and Burgy, 1963).

An evaluation of hydraulic properties of water-bearing strata is needed to quantify changes in groundwater storage and flow rates that occur naturally or are affected by high extraction mining. These properties are: hydraulic conductivity (K) - rate of flow through a unit cross section of rock under a unit hydraulic head (length/time); transmissivity (T) - rate at which water flows through a unit width of aquifer of saturated thickness b and under a unit hydraulic head (transmissivity is related to hydraulic conductivity by T=Kb, ($length^2/time$); storage coefficient (storativity) (S) - the volume of water that an aquifer of saturated thickness b releases from or takes into storage per unit surface area of aquifer per unit change in head (dimensionless); Specific storativity (Ss) - the volume of water that a unit volume of aquifer releases from storage per unit decline in head ($length^{-1}$).

Determinations of transmissivity and storage coefficients of several aquifers in Greene and Washington Counties were made using standard aquifer testing procedures (Stoner, et.al., 1987; and Williams, Felbinger, and Squillace, 1989). Summary of these aquifer tests for both counties is given in Tables 4.1 and 4.2.

## 4.2 GROUNDWATER FLOW SYSTEMS

### 4.2.1 General Concepts

The topographic and geologic conditions of Southwestern Pennsylvania produce a very complex groundwater flow regime that reflects the topographic configuration of the Appalachian Plateau, the variable presence and depth of fractures and joints, and the coal-bearing strata

**Table 4.1**

**Summary of aquifer tests for wells located in Washington County (modified from Williams et al., 1989)**

| Principal Water-bearing Unit | Test Date | Transmissivity $ft^2/d$ | Average hydraulic conductivity $ft^2/d$ | Storage coefficient |
|---|---|---|---|---|
| Washington | 7/1/71 | 1.0<br>15 | 0.01<br>0.15 | -- |
| Washington | 8/23/83 | 18 | 0.18 | -- |
| Waynesburg | 8/19/83 | 65 | 1.2 | -- |
| Waynesburg | 8/26/83 | 35<br>31 | 0.7<br>0.6 | -- |
| Waynesburg | 8/24/83 | 19<br>24 | 0.25<br>0.32 | -- |
| Uniontown | 7/12/83 | 3<br>4 | 0.04<br>0.05 | -- |
| Washington | 12/5/84 | 18 | 0.14 | -- |
| Pittsburgh | 7/13/83 | 1 | 0.02 | -- |
| Pittsburgh | 8/19/83 | 2 | 0.04 | -- |
| Washington | 5/3/84 | 0.7<br>0.4 | 0.007<br>0.003 | -- |
| Alluvium | 9/29/80 | 160<br>159 | 18<br>18 | -- |
| Waynesburg | 9/30/80 | 84 | 0.6 | -- |
| Waynesburg | 7/29/81 | 130<br>57<br>81 | 1.0<br>0.4<br>0.6 | -- |
| Waynesburg | 9/30/80 | 120<br>81 | 1.0<br>0.6 | $1.7 \times 10^{-4}$<br>-- |
| Waynesburg | 7/29/81 | 330<br>68 | 2.6<br>1.9 | $9.0 \times 10^{-5}$<br>-- |

Table 4.2

**Summary of aquifer tests for wells located in Greene County (modified from Stoner et. al., 1987)**

| Principal Water-bearing Unit | Test Date | Transmissivity $ft^2/d$ | Average hydraulic conductivity $ft^2/d$ | Storage coefficient |
|---|---|---|---|---|
| Waynesburg | 7/29/81 | 130 | 1.0 | -- |
| | | 330 | 2.6 | $0.9x10^{-6}$ |
| | 6/17/81 | 3.0 | 0.48 | -- |
| | | 6.6 | 0.11 | $8x10^{-4}$ |
| | 6/25/81 | 9.4 | 0.12 | -- |
| | | 5.4 | 0.067 | $0.6X10^{-4}$ |
| | 8/3/81 | -- | -- | -- |
| | | 500 | 4.3 | $3x10^{-6}$ |
| Alluvium | 9/29/80 | 160.0 | 18.0 | -- |
| | 5/13/81 | 28 | 3.5 | -- |
| Greene | 11/14/79 | 0.04 | 0.001 | -- |
| | 8/24/81 | 4.0 | 0.20 | -- |
| | 3/5/80 | 0.3 | 0.002 | -- |
| | 5/15/80 | 30 | 0.51 | -- |
| | 8/26/81 | <0.4 | <0.01 | -- |
| | 2/11/81 | <0.004 | <0.00007 | -- |
| Washington | 5/28/80 | 0.9 | 0.01 | -- |
| | 5/14/80 | 3.3 | 0.066 | -- |
| | 4/16/80 | 11 | 0.10 | -- |
| | 12/10/80 | 0.00038 | 0.0000024 | -- |
| | 5/13/81 | 0.12 | 0.0012 | -- |
| | 6/11/81 | 59 | 1.1 | -- |
| Waynesburg | 6/11/74 | 420 | 5.9 | -- |
| | 10/17/79 | 2.1 | 0.027 | -- |
| | 6/4/80 | 1,100 | 50 | -- |
| | 6/10/81 | 0.94 | 0.19 | -- |
| | 10/7/80 | 0.42 | 0.0046 | -- |
| | 7/16/81 | 0.20 | 0.0014 | -- |
| | 8/5/81 | 98 | 0.72 | -- |
| | 7/31/81 | 690 | 13 | -- |
| Uniontown and Pittsburgh | 4/22/81 | 0.04 | 0.0005 | -- |
| Casselman | 9/6/79 | 11 | 0.12 | -- |
| | 9/30/79 | 1.7 | 0.012 | -- |

characterized by cyclothemic repetitions of various lithologic types. The complexity of the system is further enhanced by subsidence following high extraction mining, and related deformation and fracturing of overburden strata.

Predominantly dendritic drainage pattern developed in the area is often deeply incised, creating topographic highs where the flat-lying or gently dipping sedimentary strata are daylighted with coal croplines surrounding the highs. The local topographic relief may range from 200 to 400 feet. Contact springs usually cluster at given elevations following the outcropping contacts between more and less permeable strata, e.g. coal and underclay.

The uplands are dissected by perennial streams that collect drainage from tributary valleys, carrying first and second order streams. The flow in these tributary streams is mostly intermittent depending on the topographic position of the tributary valley bottoms relative to the top of the regional aquifer.

The groundwater occurrence and movement in the coal-bearing strata of the Appalachian Plateau Province that is applicable to the Southwestern Pennsylvania was described by Wyrick and Borchers, 1981 as controlled by stress-relief fracturing caused by differential stress associated with erosion of stream valleys. The stress-relief concept indicates that the most permeable fracture systems are located beneath the stream valleys where the bedding planes are open as a result of a post-erosional upward stress relief. The erosional landscape development also creates a weathered zone that envelopes the valley walls and hillsides and is characterized by significant natural fracturing. The cores of the hills where the rocks are in a state of compression exhibit low permeability. Figure 4.4 presents a model of the stress-relief fracturing occurrence in a typical Appalachian valley.

This model was further refined, especially as it applies to the shallow groundwater flow and aquifer properties in upland settings, by Hawkins et al., 1996, as shown in Figure 4.5. The conceptual shallow flow model is based on detailed groundwater study performed in the coal-bearing strata of the southcentral Pennsylvania in Clearfield County. The presented conceptual groundwater flow model is based on fracture frequency analysis, testing of aquifer properties, measurements of water level fluctuations and distribution of hydraulic heads from series of piezometers, all combined with a detailed water quality assessments. As the study conclusions are generally applicable to the shallow groundwater conditions of the Southwestern Pennsylvania, they are listed below as presented in the study:

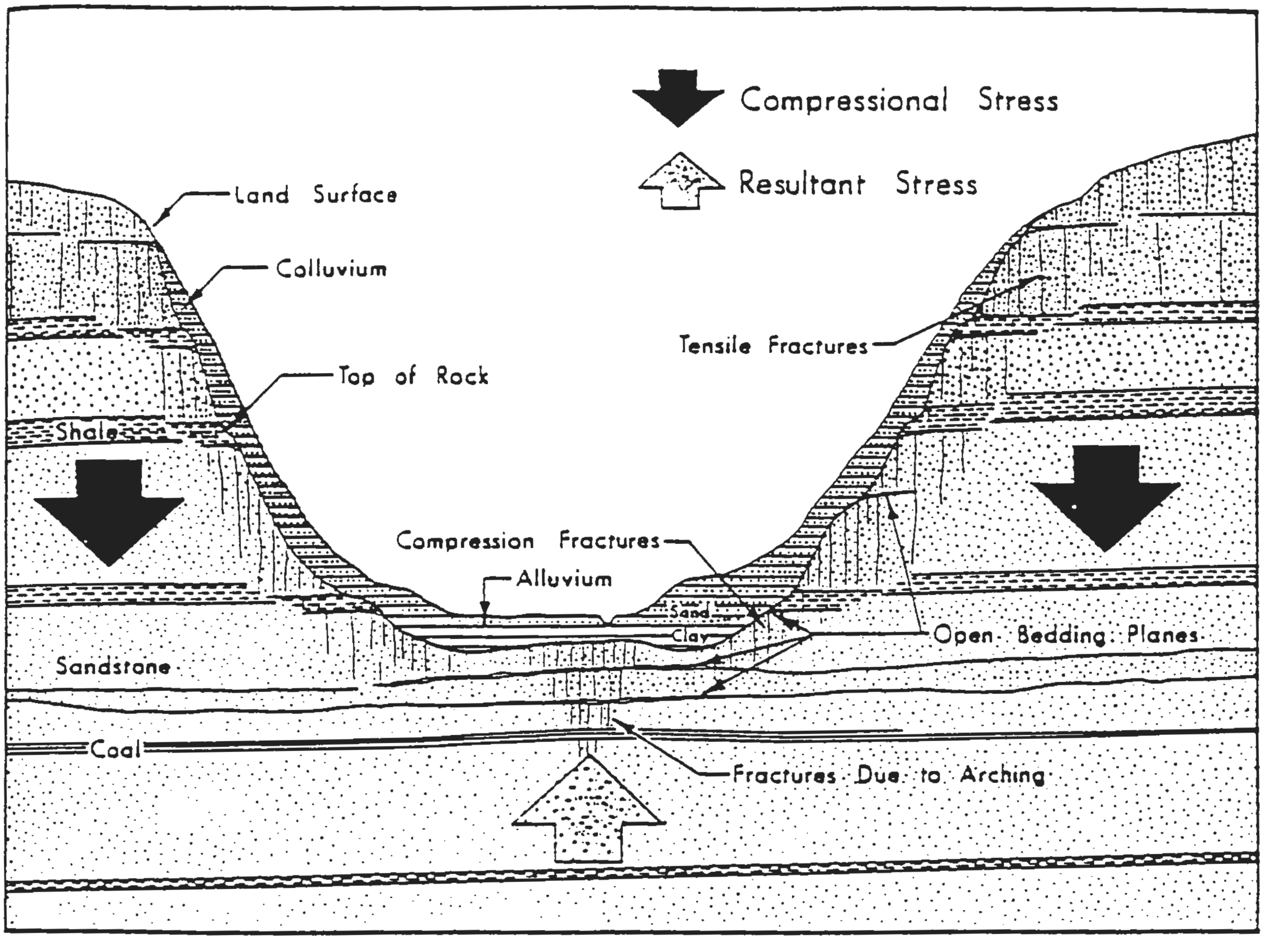



**Figure 4.4** **Generalized geologic section showing features of stress-relief fracturing (taken from Wyrick and Borchers, 1981)**

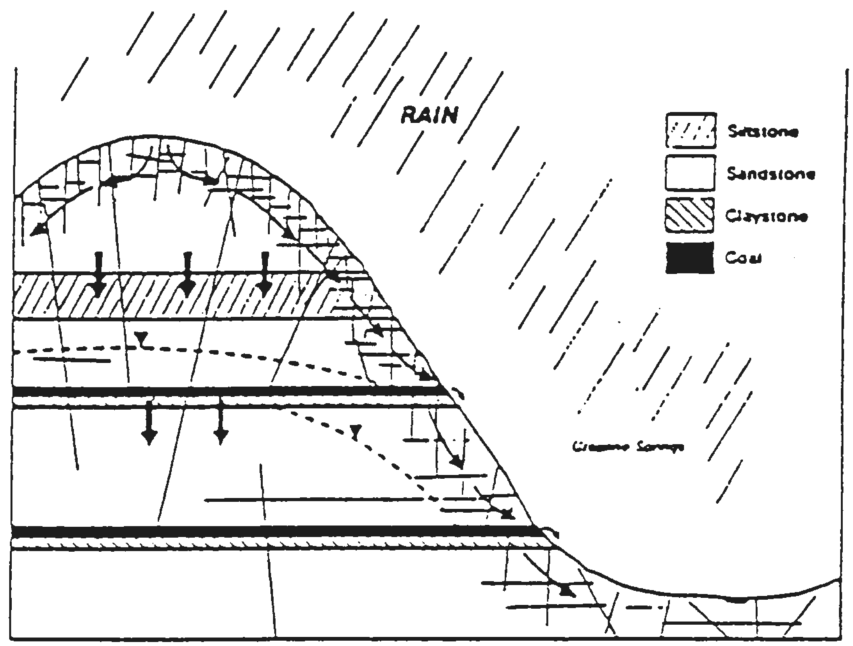



**Figure 4.5** **Schematic cross-section with conceptual groundwater flow paths (taken from Hawkins, 1996)**

A highly fractured and weathered zone up to 20 meters thick blankets the hilltops and hillsides in the Appalachian Plateau. This zone is highly transmissive and is underlain by progressively less transmissive fractured units. This less transmissive zone facilitates a temporary perched system from rainfall events. Rainwater quickly infiltrates into near surface fractures flowing vertically for several meters and then flows laterally toward the hillsides. This water has a short residence time in this shallow highly transmissive zone.

Much of the laterally flowing near-surface groundwater emanates at cropline springs. These springs occur at the level of the coal seams. Fractures in the coal underclay tend to be poorly transmissive. Some shallow flowing water passes through the underclay and continues down slope in the weathered/highly fractured zone. Some of this shallow-flowing groundwater recharges underlying aquifers via deeper fractures and emanates from coal seams at lower elevations.

Data collected from the piezometers indicates that a series of confined or semiconfined aquifers exist beneath the water-table aquifer underlying a coal underclay. Decreasing head levels with depth indicate that there is a downward ground-water flow component. Aquifer tests performed on piezometers in the deeper confined aquifers illustrate that they have low transmissive properties and moderate head pressure; therefore, groundwater movement into them and through them is slow. Decreases in the fracture frequency with depth account for the reduction in hydraulic conductivity with depth in the unconfined aquifer and the low hydraulic conductivity of the underlying confined units.

Determination of ground-water flow in the Appalachian Plateau is complex. Changes in transmissive properties caused by decreasing fracture development with increasing depth must be considered when designing a monitoring and water quality characterization plan. Water quality at cropline springs is representative of groundwater flowing though a near-surface, highly fractured and weathered zone.

### 4.2.2 Shallow Groundwater Flow Systems

The shallow groundwater flow systems that occur in Southwestern Pennsylvania originate in the upland portions of the terrain above the regional base level. The character of these shallow systems depends on the local geologic conditions ranging from water-bearing zone developed in a weathered regolith formed on the underlying bedrock, colluvial or alluvial unconsolidated deposits, or in the shallow coal-bearing bedrock where differences in the permeability cause local perching.

Groundwater perching requires the presence of strata characterized by low permeability (e.g. shale or clay) that are overlain by a more permeable bed (e.g. coal or sandstone). In cases where the aquitard/aquiclude bed is laterally consistent, a saturated zone developed by vertical flow retardation may provide a water yield sufficient to support an abundantly yielding well; contact springs usually develop around the periphery of the aquiclude/aquitard contact outcrop where the lateral flow is discharged. In instances where the perching bed does not fully control the vertical leakage, portion of the perched aquifer recharge is lost to the underlying perched or a regional aquifer.

The distribution of hydrostatic heads in the perched or semi-perched groundwater flow systems is controlled by the elevation of the coal/underclay outcrops and the points of groundwater discharge (cropline or contact springs).

The shallow groundwater systems in the unconsolidated deposits or the regolith are recharged by precipitation; the shallow bedrock water-bearing zones may also be recharged by leakage through the discontinuities in the perching beds. The perched or semi-perched shallow water-bearing zones are underlain by unsaturated strata and are characterized by predominant lateral flow component, the underlying groundwater basins are fully saturated with flow patterns determined by the recharge/discharge relationships determining the distribution of hydrostatic heads.

Shallow groundwater systems are especially vulnerable to impacts of subsidence following high extraction mining when the integrity of perching bed is compromised by fractures. Resulting leakage of water robs the shallow water-bearing zone of part or all of its water (see Section 6 for further discussion).

### 4.2.3 Regional Groundwater Flow System

The regional groundwater system is in hydraulic connection with the perennial streams that serve as major discharge zones for the system. It underlies the shallow flow systems and is partially or fully recharged by leakage from the overlying aquifers or from streams in upland valleys. In the valley setting, the groundwater reservoir is characterized by open water table condition; the deeper flow regime, especially in areas away from the main valleys and under the topographic highs, may be confined or semi-confined depending on the occurrence of low permeability strata.

Groundwater movement in deeper systems is controlled by distribution of hydrostatic heads with flow direction determined by the recharge /discharge configuration. The flow in the areas underlying the main valleys, where the stress relief fracturing enhanced the fracture controlled permeability, is usually with an upward flow component that facilitates the groundwater discharge from the system (see Figures 4.6 and 4.7).

Hydraulic conductivity in the regional system is also fracture controlled with flow through a network of fractures. The hydrostatic heads in regional systems are mostly sufficient to induce flow through fractures in strata of the lithologic types less conducive to fracturing, such as shale or claystone. The density of the fracture network decreases with the depth and with the increasing distance from the valley areas. The development of the drainage network usually coincides with the occurrence of fracture zones and increased permeabilities (see Figure 4.8). Underground mine workings often experience increased water inflows at the active face when it reaches a fracture zone that underlies a valley (Schmidt, 1992). Fracture zones are zones of intense fracturing, usually 20 to 50 feet wide and more than 300 feet deep; a surface expression of a fracture zone is a fracture trace (fracture trace mapping has been used as an important tool in locating zones of increased permeability). In multiple water-bearing zones aquifer settings, fracture zones act as vertical hydraulic connectors between separate water-bearing strata facilitating leakage that otherwise would not be possible. Fracture zones also expedite infiltration of surface water into the underground mine workings.

The majority of underground coal mining in Southwestern Pennsylvania takes place in the regional groundwater system, i.e. where strata are fully saturated and pumpage from the mine workings is required to keep them dry. The underground mine water handling methods, and especially the groundwater removal from the underground mine changes the groundwater conditions in the mine vicinity by inducing the groundwater flow toward the mine. The dewatering impacts on the groundwater may carry significant hydrological consequences (to be discussed in Section 6.)

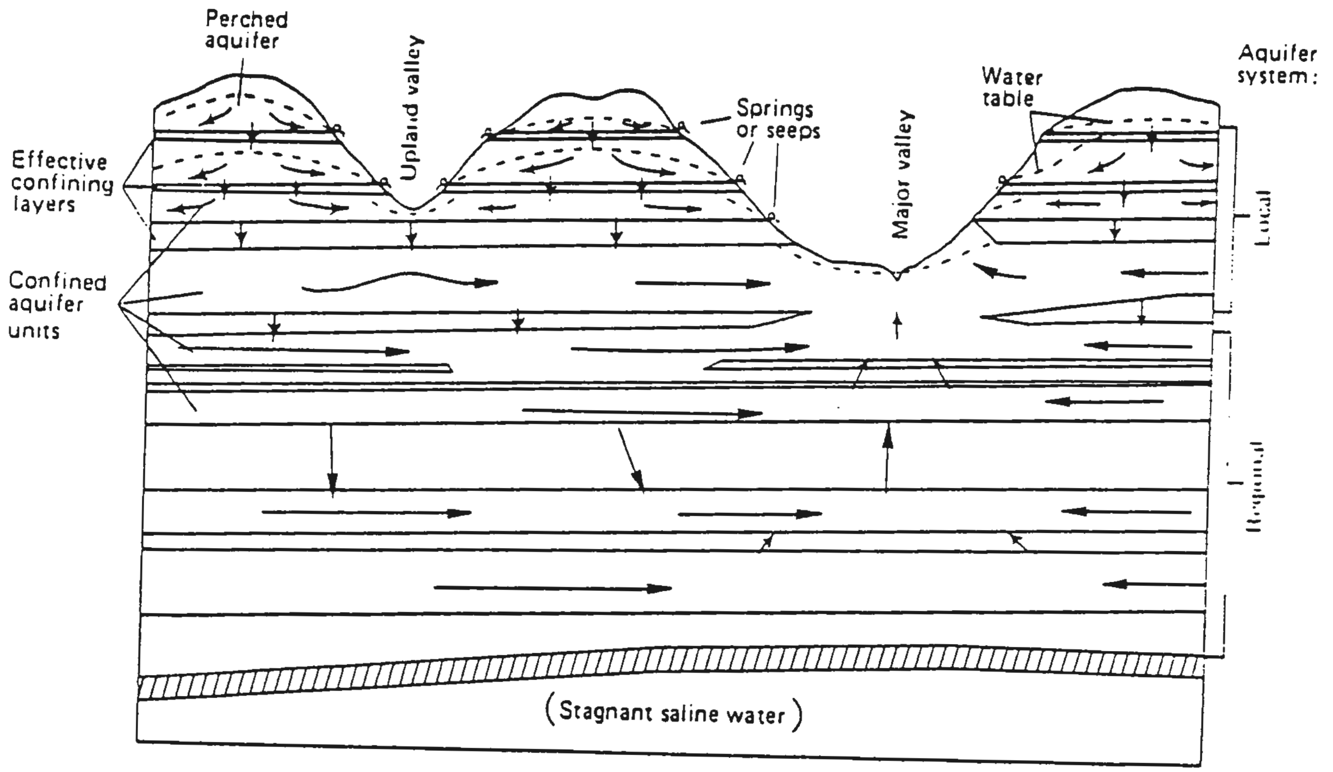



**Figure 4.6** **Schematic cross-section of local and regional groundwater movement (taken from Stoner et al., 1987)**

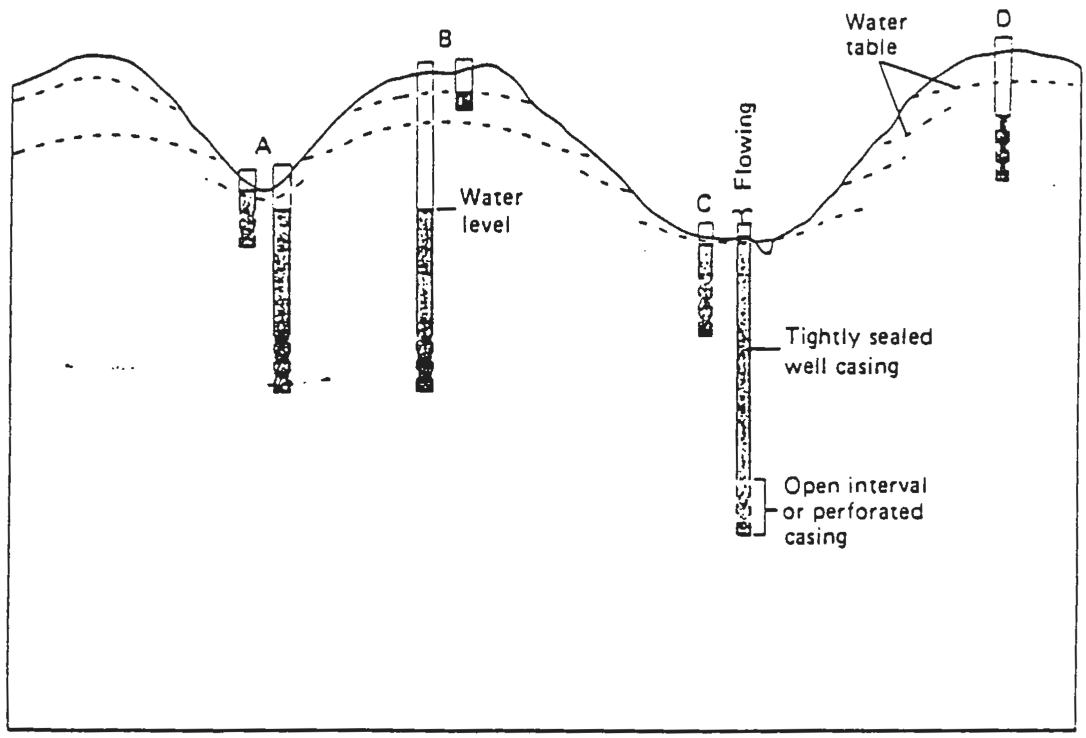



**Figure 4.7** **Relationship of water levels in wells of various depths and topographic positions within the regional groundwater movement framework (modified from Stoner et al., 1987)**

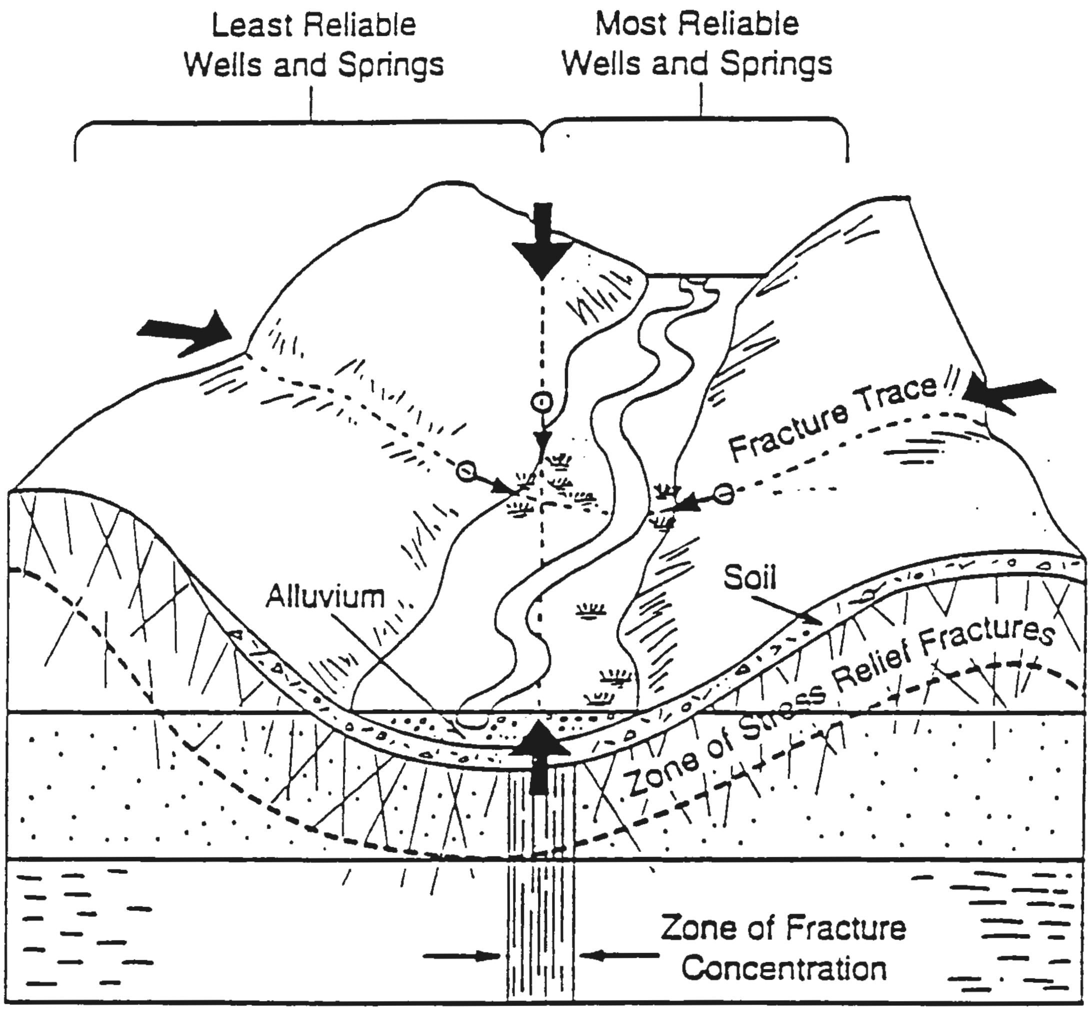



**Figure 4.8** **Stress relief fracture network associated with valleys (taken from Parizek and Ramani, 1996)**

Where numerous oil and gas wells have been drilled, the vertical hydraulic connection in the groundwater flow reservoir may be enhanced. Thompson, 1972 suggests that a combination of oil wells, underground mines and surface mines in Butler County, Pennsylvania, provides a mechanism for upward movement of contaminated mine water. The contaminated water may move to the surface from areas where the head is sufficient, through the abandoned oil and gas wells and ultimately discharge to local streams.

Oil and gas drilling records from Southwestern Pennsylvania also indicate that brines were encountered below the regional aquifer, at depths ranging from 1,770 to 2,000 feet below the land surface (Stoner et al., 1987.)

## 4.3 WATER USE IN SOUTHWESTERN PENNSYLVANIA

There are two major publications that provide information on groundwater availability in Southwestern Pennsylvania. Water resources of Washington County are described Williams, Felbinger, and Squillace in an unpublished report (1989) prepared by U.S. Geological Survey in cooperation with The Pennsylvania Geologic Survey, The Washington County Planning Commission and The Washington County Conservation District. The water resources of Greene County are described by Stoner et al., 1987 in a report published by the Bureau of Geologic and Topographic Survey, prepared in cooperation with The U. S. Geological Survey. The materials presented in this chapter are taken from these two documents.

The five principal water-bearing units that are used as a source for water supplies in Washington County are in the Greene, Washington, Waynsburg, Uniontown, and Pittsburgh Formations. The mean values of reported yields for the five formations range from 8.8 to 15 gal/min. A summary of well depths, yields, water levels, and specific capacities by aquifer for Washington County are given in Table 4.3, for Greene County in Table 4.4.

**Table 4.3**

**Summary of well depths, reported yields, water levels, and specific capacities of aquifers, Washington County (modified from Williams, Felbinger, and Squillace, 1989)**

| Aquifer Formation | Well Depth (ft) | | | Reported yield (gpm) | | | Water Level[1] (feet below land surface) | | | Specific capacity[2] [(gal./min.)/ft.] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Wells | Median | Range | Number of Wells | Median | Range | Number of Wells | Median | Range | Number of Wells | Median | Range |
| Alluvium | 4 | 40 | 7-63 | 4 | 194 | 100-350 | 4 | 8 | 3-14 | 2 | -- | 1.6-5.1 |
| Greene | 66 | 81 | 15-204 | 13 | 11 | 2-35 | 38 | 33 | 5-90 | -- | -- | -- |
| Washington | 114 | 107 | 19-310 | 39 | 9.6 | 0.5-50 | 62 | 52 | 8-38 | 6 | 1.2 | 0.03-3.3 |
| Waynesburg | 148 | 99 | 15-310 | 30 | 10 | 0.5-60 | 93 | 43 | 3-170 | 4 | 1.6 | 0.18-2.8 |
| Uniontown | 137 | 101 | 15-285 | 26 | 15 | 1-75 | 73 | 38 | F-170 | 2 | -- | 0.08-0.24 |
| Pittsburgh | 140 | 114 | 18-250 | 49 | 8.8 | 0.33-50 | 79 | 47 | F-170 | 1 | -- | 0.04 |
| Casselman | 25 | 139 | 44-438 | 15 | 46 | 2-160 | 13 | 57 | F-150 | 2 | -- | 9.7-22 |
| Glenshaw | 6 | 112 | 60-165 | 4 | 33 | 1-110 | 2 | -- | 33-55 | 1 | -- | 0.52 |

**Table 4.4**

**Summary of well depths, reported yields, water levels, and specific capacities of aquifers, Green County (modified from Stoner et al., 1987)**

| Aquifer | Well Depth (ft) | | | Reported yield (gal./min.) | | | Water Level[1] (feet below land surface) | | | Specific capacity[2] [(gal./min.)/ft.] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Wells | Median | Range | Number of Wells | Median | Range | Number of Wells | Median | Range | Number of Wells | Median | Range |
| Alluvium | 7 | 16 | 12-20 | -- | -- | -- | 6 | 4 | 0.5-8 | 2 | -- | 0.18-1.6 |
| Carmichaels Formation | 12 | 23 | 10-32 | 2 | -- | 35-42 | 10 | 10 | 2-19 | -- | -- | -- |
| Greene Formation | 105 | 65 | 8-400 | 55 | 2 | 0.03-20 | 69 | 18 | 0.3-110 | 6 | 0.06 | 0.02-1.2 |
| Washington Formation | 98 | 70 | 4-652 | 39 | 3 | 0.08-26 | 69 | 15 | 0.5-357 | 4 | .36 | 0.02-0.86 |
| Waynesburg Formation | 80 | 84 | 8-393 | 35 | 3.8 | 0.2-40 | 52 | 22 | F-140 | 11 | .40 | 0.01-4.4 |
| Uniontown Formation | 20 | 113 | 13-374 | 8 | 6 | 1-30 | 12 | 43 | F-80 | 1 | -- | 0.05 |
| Pittsburgh Formation | 13 | 97 | 21-600 | 2 | -- | 0.1-1 | 7 | 27 | F-85 | 1 | -- | 0.01 |
| Casselman Formation | 3 | -- | 25-168 | -- | -- | -- | 3 | -- | 3-28 | 1 | -- | 0.34 |

1 F, Flowing
2 Data derived from 1-hour test by U.S. Geological Survey

Water-bearing strata tapped by the supply wells are generally no deeper than 150 feet. Water levels in wells are generally shallow in valleys and become deeper with increasing elevation at hilltops. The mean of measured water levels and mean depth of wells located in upland draws, valleys, and hilltops are given in Table 4.5 for the Washington County and in Table 4.6 for the Greene County.

Developed springs are commonly used in the area as water supplies, including their use for livestock watering. Stoner et al., 1987 reports that although spring discharges were usually yielding less than 1 gpm, 75% of springs were reported by their owners as perennial. Over 95% of all springs in bedrock formations were reported to be on hillsides and were believed to be perched contact springs. Few springs near valley bottoms were perennial and most likely recharged from the regional system.

**Table 4.5 Summary of mean depth to water and mean well depth in various topographic positions in Washington County (modified from Williams, Felbinger, and Squillace, 1989).**

| | Mean depth to water level (feet below land surface) | Number of wells | Mean well depth (feet below land surface) | Number of wells |
|---|---|---|---|---|
| Upland draw | 21 | 11 | 104 | 13 |
| Valley | 22 | 58 | 88 | 97 |
| Hillside | 42 | 201 | 102 | 345 |
| Hilltop | 62 | 94 | 114 | 185 |

**Table 4.6 Summary of mean depth to water and mean well depth in various topographic positions in Greene County (modified from Stoner et al., 1987).**

| Topographic setting | Median depth to water level (feet below land surface) | Median well depth (feet below land surface) | Number of wells |
|---|---|---|---|
| Valley | 6 | 64 | 42 |
| Upland Draw | 9 | 35 | 37 |
| Hillside | 18 | 42 | 45 |
| Hilltop | 38 | 96 | 19 |

## 5.0 HIGH EXTRACTION MINING LOCATION AND RESERVES

### 5.1 LOCATION OF HIGH EXTRACTION MINING

Of the approximately 45 active underground mines in Pennsylvania, about 16 practice high extraction methods. See Table 5.1 for the seams and counties. Table 5.1 shows that the high extraction mining in Pennsylvania can be broken down into two groups.

#### 5.1.1 Greene and Washington Counties

First and by far more significant is the mining in the Pittsburgh seam in Greene and Washington Counties (see also Figure 5.1). Those two counties account for 45 million of the 58 million tons of underground mined coal production in Pennsylvania in 1996. (The figure of 58 million tons includes 6.7 million tons produced from Greene county but reported as WV production.) With the exception of the Mathies and Humphrey mines which used room and pillar with pillar extraction, all of this production was mined by longwall.

#### 5.1.2 Indiana, Armstrong, and Somerset

Under 40 percent of the 10.5 million tons of underground production from these three counties came from room-and-pillar mining with pillar extraction.

The only significant future of coal mining in PA lies in the remaining underground reserves of the Pittsburgh seam in Washington and Greene counties. Some interest has been expressed in mining the Upper Freeport coal from under the Pittsburgh reserves in Washington, Greene, and Allegheny counties, but that appears to be on hold for the time being.

**Table 5.1**

**Underground Bituminous Coal Production in Pennsylvania in 1996**

| County | Mine Name | Mining Type | Seam | Mining Height (inches) | 1997 Production (Ktons) |
|---|---|---|---|---|---|
| Armstrong | DiAnne | RP | LK | 50 | 1,416 |
| | Tripple K No. 1 | RP | M | 56 | 272 |
| | Roaring Run | RP | UF | 36 | 240 |
| | Emilie 1&2 | RP/w | UF | 42 | 1,004 |
| | Rosebud 2 | RP | LK | 45 | 60 |
| | Rosebud 3 | RP | C | 34 | 259 |
| | TJS 1 | RP | UF | 36 | 235 |
| | Darmac | RP | UF | 34 | 197 |

## Table 5.1 (Continued)

| County | Mine Name | Mining Type | Seam | Mining Height (inches) | 1997 Production (Ktons) |
|---|---|---|---|---|---|
| | Darmac | RP | UF | 36 | 283 |
| Cambria | Pelesmitco No. 3 | RP | UK | 41 | 25 |
| | Rice 2 | RP | LF | 40 | 35 |
| Clearfield | Laurel Ridge | RP | LK | 30 | 73 |
| | Manor 44 | RP | LK | 36 | 101 |
| Greene | Bailey | LW | P | 67 | 7,462 |
| | Blacksville No. 2 | LW | P | 74 | 3,407 |
| | Cumberland | LW | P | 75 | 6,217 |
| | Dilworth | LW | P | 78 | 4,842 |
| | Emerald | LW | P | 72 | 3,230 |
| | Enlow Fork | LW | P | 67 | 8,724 |
| | Humphrey | LW & RP/w | P | 84 | 3,297 |
| | B&M 2 | RP | S | 52 | 58 |
| | Titus | RP | S | 48 | 12 |
| | Warwick* | LW | S | 62 | 1,880 |
| | Target | RP | S | 57 | 240 |
| Indiana | Plumcreek | RP | UF | 36 | 441 |
| | Urling | RP/w | UK | 60 | 865 |
| | Penn Run | RP | UF | 32 | 98 |
| | Tanoma | RP/w | LK | 38 | 559 |
| | Lucerne 6 | RP/w | UF | 48 | 999 |
| | Marshall Run | RP | UK | 45 | 820 |
| | Rayne No. 1 | RP | LF | 39 | 170 |
| | Leonard Run | RP | LK | 45 | 237 |
| Jefferson | Dora 6 | RP | LK | 29 | 498 |
| | Dora 7 | RP | LK | 28 | 42 |
| | Ramsaytown | RP | LK | 30 | 17 |
| Somerset | Solar 7 | RP | UK | 48 | 309 |
| | Grove 1 | RP | UK | 52 | 466 |
| | Solar 10 | RP | UK | 38 | 40 |
| | Diamond T-B | RP/w | LK | 72 | 644 |
| | Diamond T-c | RP/w | MK | 45 | 265 |
| | Longview | RP | LK | 72 | 663 |
| Washington | Eighty-Four | LW | P | 68 | 3,027 |
| | Maple Creek | LW | P | 64 | 3,402 |
| | Mathies | RP/w | P | 66 | 1,077 |
| | Hillsboro** | LW | P | ** | ** |

Seams:
C = Clarion
LK = Lower Kittanning
MK = Middle Kittanning
UK = Upper Kittanning
UF = Upper Freeport
LF = Lower Freeport
M = Mahoning
P = Pittsburgh
S = Sewickley

Mine Types:
L = longwall
RP = room and pillar
RP/w = room and pillar with pillar extraction

* Warwick Mine now shut down
** Hillsboro Mine not yet open

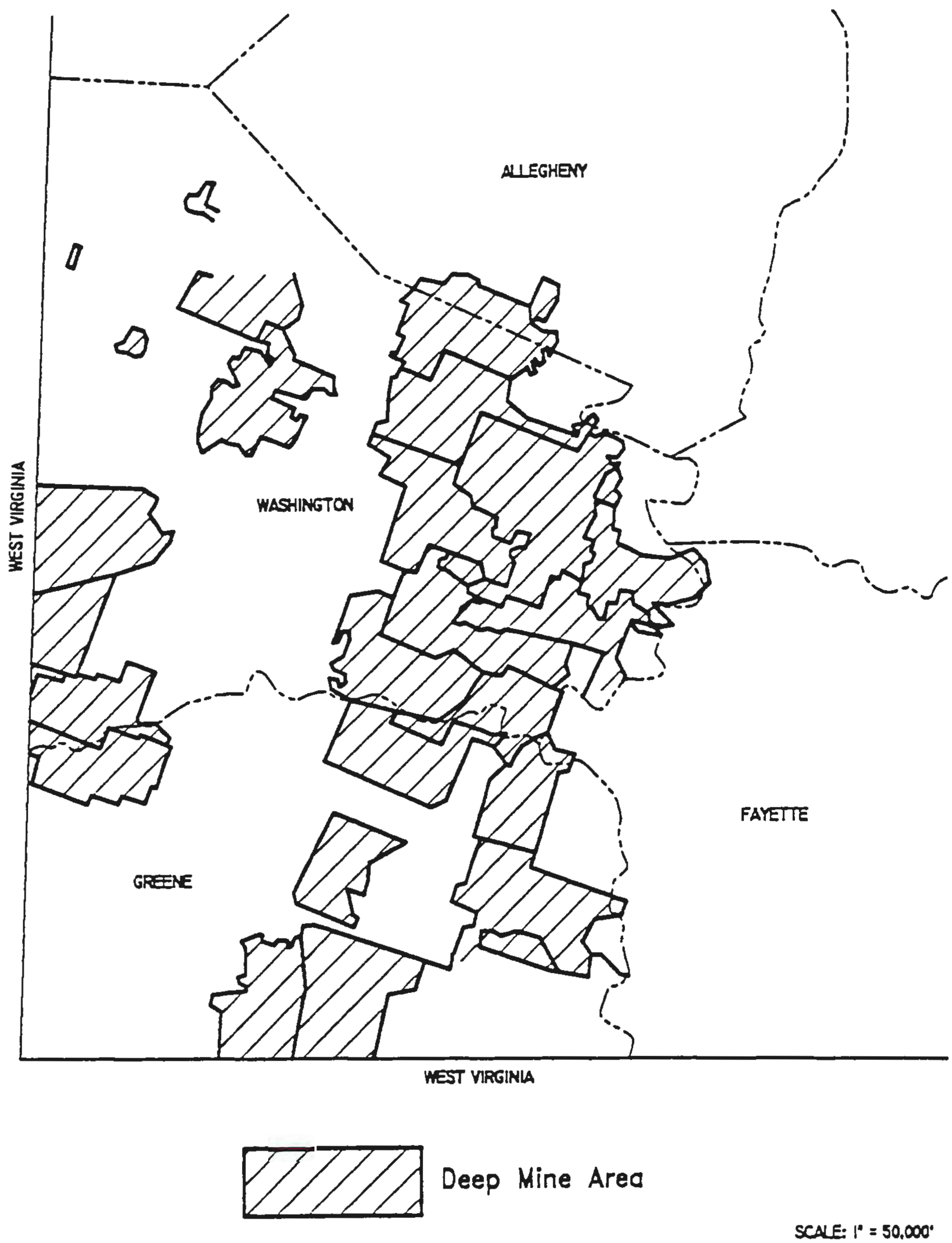



**Figure 5.1 High extraction coal mining areas of Green and Washington Counties.**

## 5.2 RESERVES

Greene County coal assessor, John Frazier, reports that Greene County has 218,000 acres of Pittsburgh coal remaining containing 1.8 billion tons of raw coal.

In Washington County, coal assessor Gary Riley reports 201,413 acres of Pittsburgh Coal remaining unpermitted. Washington County does not calculate the tonnage. However, the thickness of the Pittsburgh exceeds 98 inches in southeast Greene County and drops steadily to less than 42 inches in northwest Washington County. Therefore, it is safe to assume that Washington County has fewer tons per acre than Greene County.

A fair estimate of the remaining minable reserves in the two-county area would be 3 billion tons. According to the data presented in Table 2.1, the two-county area produced 45 million tons in 1996. Pennsylvania Department of Environmental Protection Inspector Mark Frederick reports that Consolidation Coal Company plans to boost production at its Bailey and Enlow Fork mines to 10 million tons each from the current total of 16 million. It therefore reasonable to use the figure of 50 million tons per year for the two counties for the purpose of calculating the length of time coal will be mined there. Dividing 3 billion tons by 50 million tons per year yields a figure of 60 years. If production increases above the 50 million ton figure and/or if some of the coal remains permanently unmined, the time period will decrease. If production decreases, the time period could increase.

Consolidation Coal Company spokesman, Tom Hoffman stated at a public forum in Pittsburgh in early 1998 his company will be mining well into the next century. He specifically mentioned the figure of 50 years.

The Pennsylvania Coal Association has indicated that the state as a whole has an underground reserve base sufficient to last 500 years at current production.

# 6.0 HYDROLOGIC CONSEQUENCES OF HIGH EXTRACTION MINING

## 6.1 REVIEW OF PREVIOUS RESEARCH

A number of studies of mining impacts on hydrological balance have been conducted in the Northern Appalachian Coal Basin, namely in northern West Virginia, Southwestern Pennsylvania and southeastern Ohio. Some of the studies deal with the impacts of underground mining on the ground and surface water flow systems, while other are focused on observations of the impacts of high extraction on water supplies.

One of the first detailed hydrogeologic investigations of coal mining impacts was conducted in Clearfield County, Pennsylvania, by Brown and Parizek, 1971 where the groundwater flow systems in the study were approximated by flow net representation. The study used piezometer wells to determine the distribution of hydrostatic heads in the local strata needed for the flow net construction. The authors suggest that flow nets, even though interpretative, are useful in describing groundwater movement and should be beneficial in designing projects to prevent, treat, or isolate mine drainage.

Subitzky, 1976, in a study of Painters Run and McLaughlin Run basins in Allegheny County, Pennsylvania indicate that the combination of natural jointing and subsidence induced fissures influences groundwater flow pattern above the underground mine workings in the Pittsburgh seam; the flow lines are deflected toward the mined-out coal seam. He implies that during mine subsidence the rock units above the underground mine undergo deformations, varying from bending to vertical displacement within the rock units and fracturing that extends across lithologic boundaries.

The importance of fractures in controlling flow patterns into and above a coal mine in Cambria County, Pennsylvania was investigated during a pumping test above an underground coal mine as reported by Wahler and Associates, 1979. The groundwater drawdown pattern during the pumping test was asymmetrical, indicating the preferred path of subsurface flow. Despite the depth of the underground mine (500 to 525 feet), a rapid response to significant rainfall was observed in the underground mine outflow indicating a hydraulic connection of the underground mine workings with the ground surface; high inflows were reported to follow fracture zones beneath stream channels. Wells and springs overlying the mine may be affected or drained completely, especially when subsided.

Sgambat et al., 1980 suggest that subsidence can alter the hydrologic system by increased secondary permeability at the surface that will result in increased infiltration of precipitation and decreased overland runoff, decreased travel time of groundwater flow from surface to points of its discharge, large fluctuations of water levels, increased groundwater base flow to nearby streams as a result of the relatively free subsurface circulation created by fractures over mined-out seams, and decreased surface water flow where subsidence fracturing extends under a stream bed.

He further points out that the alteration of natural groundwater patterns by underground mining is indirectly indicated by changes in water levels in aquifers, in the amount of groundwater seepage to the streams, and by groundwater quality. Active mines as well as abandoned mines serve as hydraulic sinks or discharge zones that function like large horizontal wells. Consequently, water levels in aquifers above and adjacent to the mines decline in response to water loss due to mine dewatering.

Effects of underground mining and mine collapse on the hydrology of selected basins in West Virginia was studied by U.S. Geological Survey in cooperation with the West Virginia Geological and Economic Survey. The study focused on mining and subsidence impacts on surface and groundwaters in areas where the main coal bed was mined above and below a major stream. The overall effect of coal mining on hydrologic budget was determined by measuring stream flows, mine pumpage, ground-water levels, and precipitation, and by mapping mine-collapse features. The impacts observed during the study included lowered ground-water levels, causing some wells or streams to become dry, deterioration of water quality, and structural damage to buildings, roads, pipelines, and reservoirs while on the other hand, some abandoned flooded underground mines were used as groundwater reservoirs providing water to wells for public supply (Hobba, 1993).

The author also indicates that the hydrological effects of underground mine subsidence are manifested in an increased transmissivity of near-surface strata, resulting in accelerated infiltration rates and decreased evapotranspiration rates, occurrence of both losing and gaining streams (base flow recharge may be increased as a result of increased infiltration rates), and large fluctuations of static water levels in wells. He also observed that subsidence cracks generally parallel the predominant joint sets in the bedrock. The study presents two block diagrams that describe general concepts of groundwater flow conditions in unmined, mined, and mined-subsided areas where the mined bed is above (Figure 6.1) and below (Figure 6.2) a major stream. The general effect of underground mining and subsidence on surface water and groundwater in zones shown in Figures 6.1 and 6.2 are listed in Table 6.1.

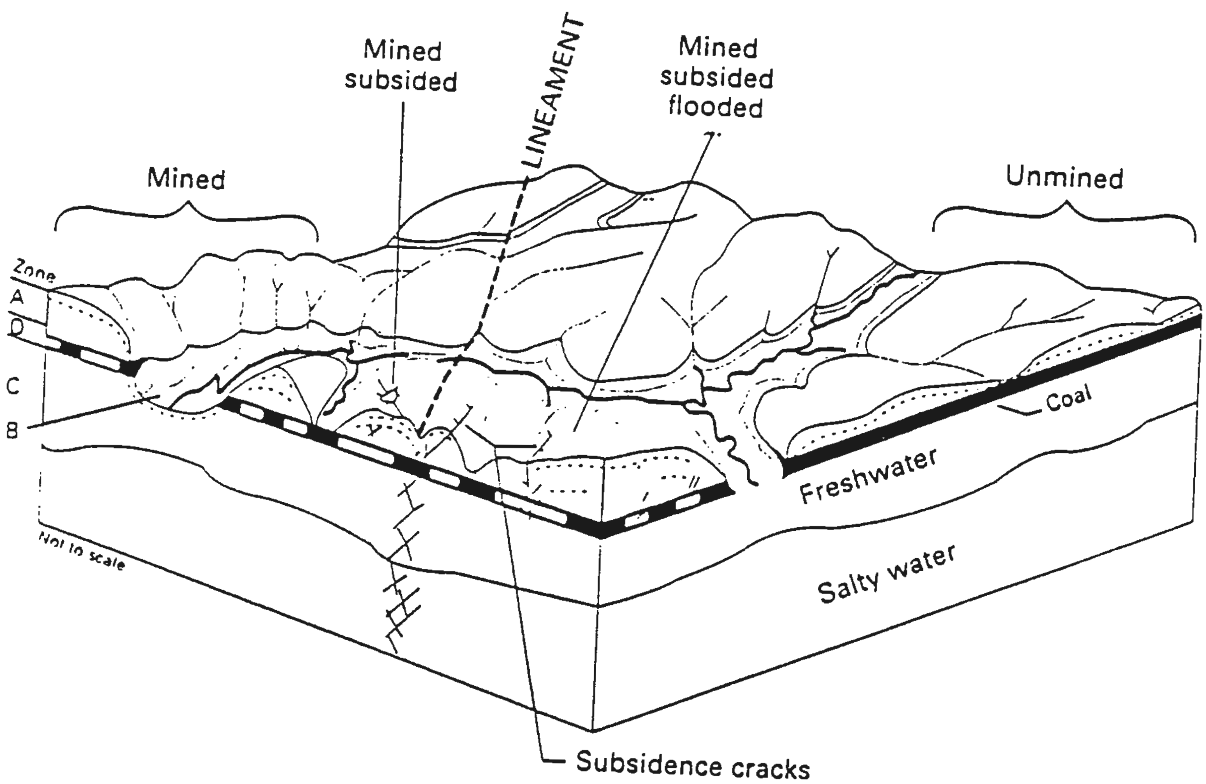



**Figure 6.1.** **General concept of groundwater conditions in unmined, mined and mined-subsided areas where the mined bed is above major streams (taken from Hobba, 1993)**

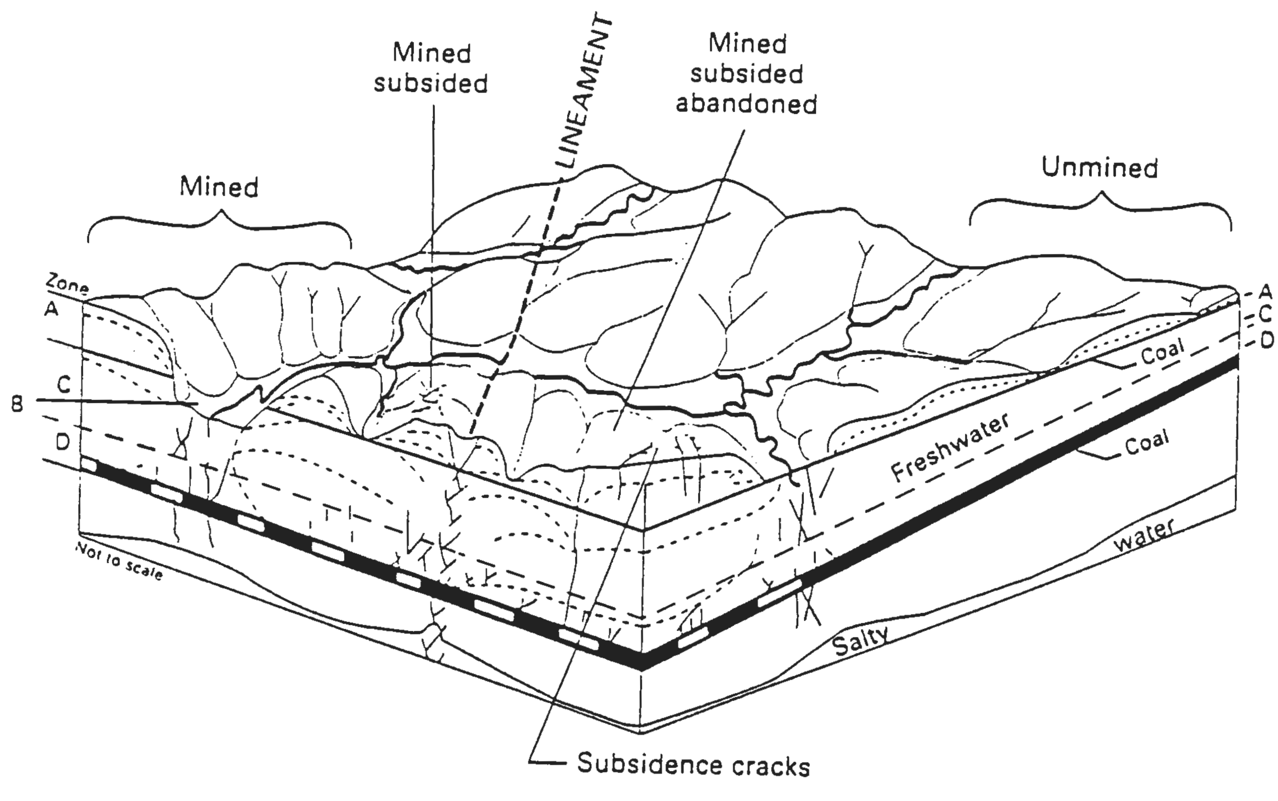



**Figure 6.2. General concept of groundwater conditions in unmined, mined and mined-subsided areas where the mined bed is below major streams (taken from Hobba, 1993)**

**Table 6.1**

**General effect of underground mining and subsidence on surface water and groundwater in zones shown in figures 6.1 and 6.2 (taken from Hobba, 1993)**

| Zone | Surface water Flow and Pond Retention | Ground-Water Yields and Levels |
|---|---|---|
| A. Rock strata from land surface to top of zone D (fig 6.1), or to the bottom of the upper coal bed (fig. 6.2). | Below normal near mine shafts, lineaments, and subsidence features. Otherwise near normal. | Below normal near mine shafts, normal fractures, and subsidence features; otherwise near normal. Some water may be perched on clay or shale layers. |
| B. Land surface area below upper bed of coal. | Fig. 6.1 Above normal where coal beds dip toward valley and below normal where coal bed dip away from valley. | Fig. 6.1 Above normal spring flow and mine discharge where coal beds dip toward valley; below normal where coal beds dip away from valley. Normal at most wells. |
| | Fig. 6.2 Base flow generally above normal where mines are inactive or subsided. Generally below normal where mines are active. | Fig. 6.2 Spring discharge and seepage generally above normal near streams in subsided areas. |
| C. Rock strata below mined coal bed (fig. 6.1) or between upper coal bed and top of zone D (fig. 6.2). | Fig. 6.1 Not applicable. | Fig. 6.1 Below normal yields under hills, normal or above normal yields under valleys (but below normal water levels.) |
| | Fig. 6.2 Not applicable. | Fig. 6.2 Below normal near mine shafts, lineaments, and subsidence features; nor normal otherwise. Deeper wells most often below normal. May be above normal if mine abandoned and flooded. |
| D. Rock strata 100 to 150 ft. above the mined coal bed. | Fig. 6.1 Below normal near lineaments, subsidence features, and where mined coal bed is at shallow depth. | Fig. 6.1 Below normal most places; some perched water or unfractured rocks may occur above coal bed. |
| | Fig. 6.2 Not applicable. | Fig. 6.2 Below normal near mine shafts, lineaments, subsidence features, and active mine pumps. Above normal if mine is abandoned and flooded. |

Impacts of coal extraction by longwall mining on an overlying aquifer was studied by Hill and Price, 1983 in western Pennsylvania. The mining was done in the Lower Kittanning seam, 52 to 56 inches thick, at an average depth of 550 feet. Monitoring wells were constructed above the panel to monitor the changes in static water levels as the longwall face passed below the wells. The most significant drop in water levels occurred coincidentally with the surface subsidence, with subsequent partial water level rebound. The presented explanation of the water level drop and rebound suggests that during the maximum subsidence, new fractures are created and/or existing fractures are enlarged; the substantial drop in the piezometric head is caused by the physical loss of water from the overlying strata through the newly created flow paths into the mine and by additional pore space caused by rock fracturing, thereby increasing groundwater storage in the aquifer and the subsequent loss in head. In summary, the authors list the following conclusions of the study:

> The impact of mining on the overlying hydrogeologic system was localized with regard to the passage of the mining front,
>
> the shallower aquifer system (within 75 feet of the surface) was isolated from major impacts caused by mining,
>
> the most significant hydrogeological impacts associated with mining occurred during the period of maximum subsidence, and
>
> the groundwater depletion probably was enhanced by enlargement of existing fractures above the zone of caving during maximum subsidence. As subsidence slowed and the strata settled, groundwater levels rebounded as flow paths to the mine became less direct.

Information on the groundwater system and results of an analysis of present and future hydrologic effects of coal mining in Southwestern Pennsylvania is presented by Stoner, 1983. The presented work and case history used in the analysis was based on an on-going hydrogeologic investigations in Greene County by U. S. Geological Survey, Water Resources Division in cooperation with the Pennsylvania Geological Survey; it was completed and published by Stoner et al., 1987.

Probable hydrologic effects of underground mining were simulated in a two-dimensional flow model with the following conclusions:

> Water levels could decline as much as 4.6 m (15 ft) in 45 m (150 ft) deep wells located along undermined valleys. The maximum noticeable effects of water-level decline would occur within one year of mining,
>
> Springs and shallow wells above drainage probably would not be affected,
>
> Stream flow may be reduced by 6.6 $l/sec/km^2$ (0.6 $ft^3/sec/mi^2$) one year after undermining completion. Larger reductions could occur with higher permeability vertical fracture zones; and the presence of vertical fracture zones could magnify and accelerate the drawdown effects and mine inflow.

Furthermore, water level measurements and their correlation with the mining progress suggest that the water level changes, namely the magnitude of the water level decline due to undermining, are expected to be inversely proportional to the thickness of the bedrock between the mine and the well bottom.

Impacts of longwall mining on water levels in shallow perched aquifers at 2 sites (Case I and Case II), located in southeastern Ohio were reported by Coe and Stowe, 1984. Case histories are given for the two sites, including hydrographs of measured water levels and flows at selected well and springs. The overburden thickness above the mined seam varies between 400-800 feet in Case I and 200-400 feet in Case II. According to the authors, nearly every spring or well located above or adjacent to an active mine panel (Case I) was affected during the longwalling at the site. The very local groundwater flow systems with minimal storage resulting from the rugged topography were sensitive to land subsidence. Fracturing of the upper sandstone aquifer led to increased downward leakage of water and depletion of the shallow perched system thereby changing the local hydrologic balance.

The authors state further that in Case II, the majority of water sources monitored were not affected by land subsidence. Impacts were observed in the case of stream T-1 that appeared to have been affected as a result of extension fracturing along the sides of the panels. The stream was reported to flow sporadically over short reaches of the channel. In all, the authors state that though the average overburden thickness was approximately only one-half that of Case I, a higher percentage of clays, shales and claystones resulted in a lesser degree of interconnected fracturing. This, combined with a less rugged topography apparently resulted in a less localized groundwater flow system and less disturbance to the hydrologic balance.

In conclusion, the authors emphasize that because of the varied stratigraphy and hydrogeologic conditions, the mining impacts cannot be properly evaluated without developing an accurate conceptual model of pre-mining conditions which require surveying and monitoring of springs, streams, wells and ponds and relating their changes to climatological and hydrogeologic influences.

U.S. Department of Energy and U. S. Bureau of Mines sponsored a study of high extraction mining impacts on groundwater levels above underground mine workings at Kitt Energy Corporation mine in Barbour County, West Virginia, as described by Bruhn, 1986. Maximum subsidence of 1.75 feet, corresponding to 32% of the mined coal thickness, was observed. Seven piezometers in two clusters were installed above the mine panel with screens in four sandstone bodies that occur in the 600 feet thick mine overburden. In addition to the piezometers, various other instruments were installed to measure the ground response to mining.

The author reported that no structural changes in the overburden strata were observed during the developmental stages of mining. However, during the retreat stages of mining, the individual lithological units composing the overburden strata appeared to behave as a sequence of weakly bonded plates of various thicknesses and mechanical properties that during the pillar extraction sagged downward into the mined area with accompanying lateral slippage and fissuring. Slippage zones were abundant throughout the overburden and developed at vertical intervals of 5 to 50 feet, commonly along bedding surfaces.

The changes in the water pressure distribution with depth before, during and after mining (water pressure defined as a product of unit weight of water and the pressure head measured in piezometers) as given in the paper are shown in Figure 6.3. Prior to mining, the piezometric profile was linear from near the surface to the mine level. After the development of the mine, the levels immediately above the mine workings decreased. As the mine retreat progressed, the piezometric levels in the mine roof began to decrease. The maximum thickness of overburden strata above the mine workings where the decrease in pressure head was decreased was approximately 400 feet. The

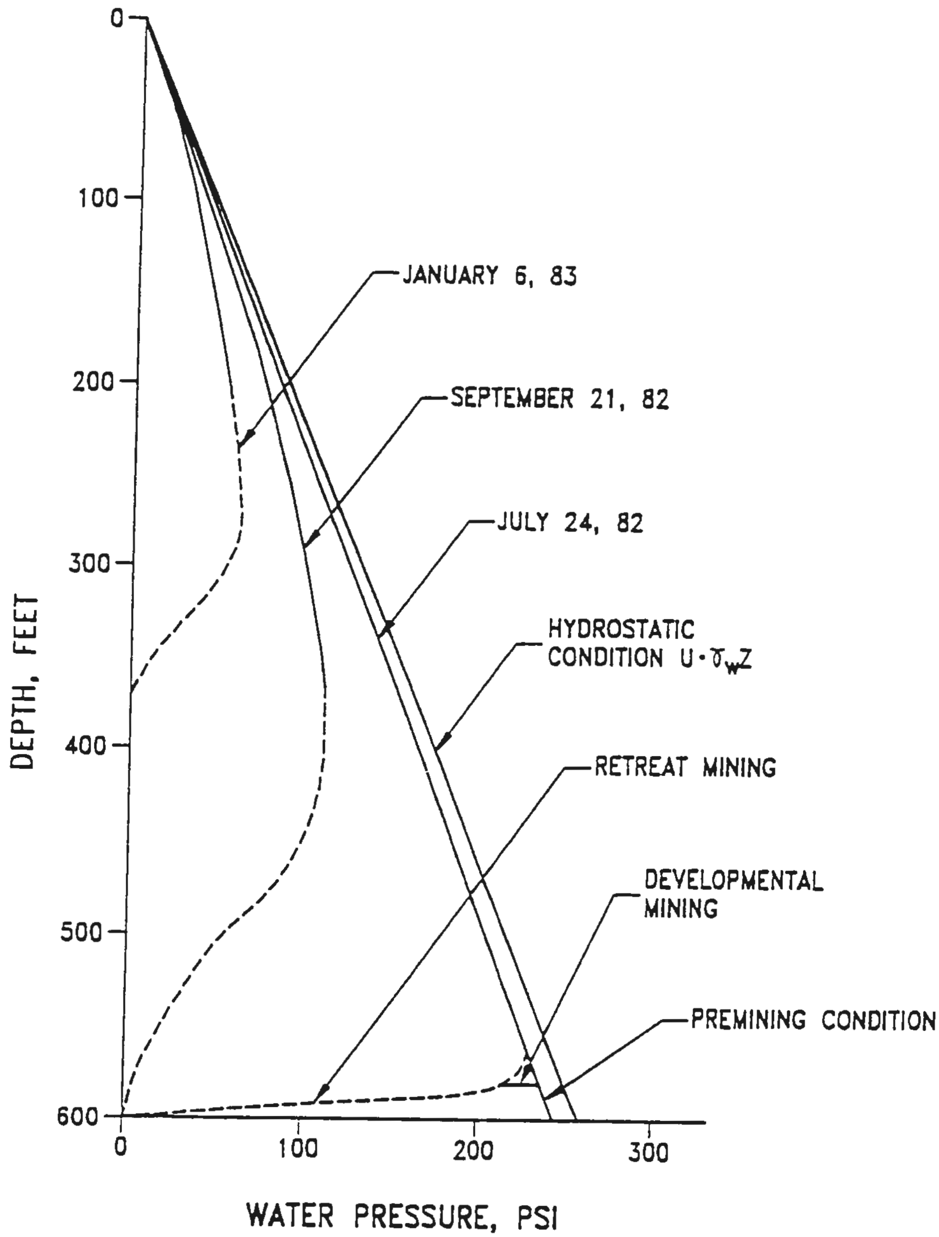



Figure 6.3 **Profile of water pressure in the overburden at various stages of mining. Note that the dashed segments of the September 21, 1982 and January 6, 1983 profiles reflect the progressive dewatering of the deeper lying strata during mining (taken from Bruhn, 1986).**

author states that it may be expected that after an indefinitely long period of time and after the entire mine has been abandoned , the piezometric levels may approach the premining condition. However, the degree to which this is realized depends upon the mine closure, as well as on the cumulative effect on the groundwater regime of other mining in the region. In summary, the findings of the paper indicate that the high extraction mining produced significant water declines in deep-lying strata but had little effect on water levels at shallower depths.

A considerable research effort of underground mining and its impacts on groundwater resources was conducted at the West Virginia State University in Morgantown, West Virginia, under the direction of Henry W. Rauch, Ph.D., Professor of Geology. A summary of the findings was presented in the Proceedings of Coal Mine Subsidence Special Institute in Pittsburgh, 1989 by Rauch. Some of the previous papers prepared as part of this research effort include the following: Carver and Rauch (1994), Cifelli and Rauch (1986), Dixon and Rauch (1988), O'Steen and Rauch (1983), Rauch, O'Steen, Ahnel, and Giannatos (1984) and Tieman and Rauch (1987).

The research conclusions presented by Rauch (1989) that address impacts of high extraction mining on groundwater are listed below:

> Initial aquifer dewatering is more extensive over underground mines where rock overburden subsidence is intentionally practiced, such as in longwall mines and pillar retreat mines. With respect to mine subsidence theory, initial aquifer dewatering should be complete in the caved (gob) zone, and partial to complete in the deep rock fracturing zone which extends upward to 30 to 60 times the mined coal seam height above the ceiling of a subsided mine. Aquifer dewatering (partial or total) has been measured to extend typically up to 120 to 400 feet above subsided deep mines, depending upon subsided mine section (panel) width and geologic factors like mine overburden stratigraphy and lithology. Subsided water supplies having a mined panel width to mine overburden thickness ratio of greater than about 2.0 are typically in the dewatered aquifer zones described above. In such settings the recovery of dewatered supplies (wells and springs) is typically slight within a few months to years of undermining.
>
> Usually just a temporary lowering of groundwater levels occurs in the shallow rock strata of the "aquiclude" and surface layer subsidence zones, which occur vertically above the 120 to 400 foot elevation mark over the subsided mine. Groundwater supply wells there typically are not extensively dewatered and recover within a few days of initial mining impacts; such supplies usually have mined panel width to mine overburden thickness ratios of less than 2.0. A major exception to the slight dewatering trend for the shallow mine subsidence zone is a major and long term

dewatering pattern for steep hill side aquifers and shallow water supplies. Raised water tables and new springs often form near the base of hill slopes as a result, raising the danger of landslides in some unstable ground areas.

Aquifer and water supply dewatering tends to be most severe and takes longer to recover from over longwall panel centers, and is least severe and takes less time to recover from adjacent to longwall panels. Dewatering is common adjacent to panels within a 30° ± 10° angle of dewatering influence, similar to the angle of draw concept. Dewatering of supplies is especially common where over 50% of their maximum recharge areas have been impacted by mine subsidence.

Streams and lineaments are usually beneficial in helping to minimize the extent of dewatering for nearby supplies over subsided mines. This occurs despite the loss of streamflow that commonly happens over mines.

Structural damage to water wells is common following mine subsidence, especially below the surface layer subsidence zone. The closer the wells penetrate to the mine, the more extensive is the damage. Many such wells require their replacement by new ones after subsidence.

Where structural damage occurs or where dewatering of supplies extends to several weeks after mine subsidence happens, replacement of such supplies is called for by the company involved. Companies in these situations typically either drill a deeper water well or else set up a central water distribution system tapping a surface or municipal water source.

Long term trends call for water level and yield recoveries of most impacted water supplies following subsided mine abandonment and flooding, if the mine is situated below the regional drainage level. The recovery time period is uncertain, but may be a few years after mine pumping ceases. The possible exception to this generalization is a continued dewatered (lower water table) state for the upper portions of steep hills within tensional fractured areas.

Aquifer property changes above subsiding longwall mine panels were tested over and near two active longwall panels in Herrin (No.6) coal in southern Illinois (Booth and Spande, 1992), where the overburden of about 750 feet consisted mainly of interbedded shales and siltstones, with thin limestones, coals and sandstone interbeds, and a 60-85 feet thick sandstone body (Mt. Carmel Sandstone) in the upper portion of the sequence. The changes in hydraulic properties were evaluated by pumping tests in a well in Mt. Carmel Sandstone, and packer tests in a 700 foot deep bore hole (pre-mining), and a 520 foot deep bore hole (post-mining). An increase of about an order of magnitude (from $3\times10^{-6}$ cm/sec before, to $4\times10^{-5}$ cm/sec after subsidence) in hydraulic conductivity in the sandstone was indicated from four hour pump tests; permeabilities of the underlying shale-limestone sequence was observed to increase significantly at local horizons, e.g. at shale-limestone intervals. The study established that the combination of tests produced a consistent picture of increased hydraulic conductivities in the bedrock due to fracturing and bed separation, even though the different testing methods indicated a varying degree of change.

A status report on ongoing research of longwall mining and its impacts on local groundwater systems performed in the Bureau of Mines Pittsburgh Research Center, was summarized in a paper by R. J. Matetic and presented at the FOCUS Conference on Eastern Regional Groundwater Issues in September of 1993. According to the paper, the Bureau had been conducting a comprehensive research program that includes basic hydrological field studies integrated with fundamental subsidence information.

The paper provides a synopsis of three research studies performed by the Bureau in the Greene and Cambria Counties, Pennsylvania, and the Vinton County, Ohio. Even though the Bureau had installed many monitoring wells, collected data from all wells to monitor well yields, transmissivity, specific capacity and water level fluctuations before, during, and after mining activity, very little specific data is presented in the paper, and only a set of generalized observations offered:

> The changes in groundwater chemistry at producing wells which occur after mining do not affect the potability of the water.
>
> Short-term, significant water-level fluctuations occur at the approximate time of the longwall panel is undermined or is adjacent to the observation well. In the case of observation wells located directly above the mining activity, the mining-induced water level fluctuation which occur in the lower monitoring zone are significantly more dramatic than fluctuation examined in the upper mining zone.
>
> The mining-induced decline in water level begins upon undermining(or when the longwall face passes by the well line) and water level recovery begins when the FP/OB ratio is about 0.4 or when the longwall face has progressed beyond a well about 40 % of the thickness of the overburden.
>
> Water level recovery begins before the process of subsidence is complete and may be related to the readjustment (closing of open fractures) of the affected rock mass.

> A relationship exists between the ground strain developed by the approaching longwall face and the timing and magnitude and fluid level fluctuations in observation wells positioned above the centerline of the longwall panels. The onset of fluid level change coincides with the dynamic development of the tension mechanism regarding the subsidence process. Fluid level decline ceases prior to or at the point of maximum tension.
>
> Observed increases in hydraulic conductivity are monitored at observation wells located directly above the mining activity. The increases in hydraulic activity are directly related to the mining of longwall panels. Fracturing of the overburden strata above the excavation may have created new passages or avenues for groundwater to flow thereby, increasing the ability of the subsurface strata to transmit groundwater.

While the majority of the studies addressed various impacts of longwall mining on surface and groundwater resources, some were devoted solely to the impacts on water supplies.

Effects of longwall coal mining on rural water supplies and stress relief fracture flow systems were described by Leavitt and Gibbens, both of Consol, Inc., Pennsylvania in 1992 at the Third Workshop on Subsidence due to Underground Mining in Morgantown, Virginia. The response of 174 domestic water supplies to longwall mining of the Pittsburgh coal seam was compared to various physical parameters. The responses of water sources to mining classification was based on the supply usability and its adequacy for use. For instance, the unaffected supplies, where mining had no effect on well or spring usability; temporarily affected , where the supply was less than adequate for a period of time, but later returned to an adequate supply, etc.

The authors conclude the following:

> Of the 174 sources studied, 112 (64%) of the original premining sources ultimately returned to service for the landowner, while 62 (36%) were replaced either by a new well or deepened well (38 sources), or by connection to municipal water supplies (24 sources). These 24 municipal connections do not provide any data on post mining groundwater availability. Of the 150 remaining water supplies for which there is groundwater data both before and after mining, 149 continue to rely on groundwater sources after mining. This represents in excess of 99 % groundwater availability after longwall mining.
>
> The topographic setting of domestic water supplies seems to be the dominant factor governing the response of the supply to longwall mining. Pre-mining sources located in valley settings are more often available after mining that those sources in hillside or hilltop areas. It should be noted that almost without exception ground-water sources are available after mining.

The location of a source over a longwall panel has some influence on its long term-response to mining , although the topographic setting still appears to be the primary controlling factor in the response of the source to mining.

Within the study area, overburden thickness in itself is apparently not a factor in source response, where the overburden thickness is greater than 300 feet. The bottom of the well-to-mine relationship is believed to be an expression of the topographic influence. Only sources located within valleys benefit from an increased well-to-mine distance.

The relationship between the bottom of the well and local base level may also be described as a topographic effect, as those wells that reach total depth below base level are nearly always located in valleys areas.

Since both the pre-mining and post-mining flow patterns are fracture controlled, it is very difficult to predict, with absolute certainty, the behavior of an individual well or spring to longwall mining. However, the probability of water supply survival in the Northern Appalachian Coal Basin can be predicted based on the results of the study. Regardless of the response of any individual source to longwall mining, groundwater remains available in usable quantities and qualities for domestic and agricultural uses throughout the study area.

Donohue, Parizek, and Ramani, 1993 prepared a report that deals with the impacts of longwall mining on domestic and farm groundwater supplies. The research was sponsored by federal funds from the U. S. Bureau of Mines, the Pittsburgh Research Center and was performed at The National Mined Land Reclamation Center, Eastern Region, The Pennsylvania State University. The goal of the study was to assess longwall mining impacts on water supplies in the Washington and Greene Counties where the mining conditions are characterized by thick overburden cover.

Nine wells and eighteen springs comprised the data set used in the study. The data were made available by three coal companies (sites A, B, and C) that included pre-mining and post-mining records of static water levels and spring flows. Water level fluctuations continuously measured in two U.S.G.S monitoring wells were compared to the monitoring records of the wells and springs and were used to separate the static water level and spring flow changes due to undermining or precipitation impacts. It was established that six out of nine studied wells and six out of eighteen springs were affected by the longwall mining.

The authors also provide an assessment and correlation between the observed impacts and selected mining factors such as supply's topographic position, its location above panel workings and overburden thickness. A linear relationship between the source's position above drainage, the overburden thickness, and the impact potential was indicated on a plotted scatter graph; deterministic probability fields for mining impacts on water supplies were determined on the basis of the scatter graphical analysis as shown in Figure 6.4.

Even though the data base used in the analysis was limited, the overall conclusions of the investigation are in agreement with the results of some of the other studies:

> Hilltop and hillside topographic settings tended to lose water supplies when undermined while valley settings gained new ones in the form of springs and increased water well levels. Deeper wells located in higher topographic settings remained reasonably unaffected. Topographic setting, well depth, and overburden thickness, are the most important aspect for whether a water supply will be affected by longwall mining under these overburden conditions. The authors also add that coal companies exhibited good success in finding replacement water supplies by drilling new, deeper wells nearby for those affected property owners.

The most recent summary of findings on longwall mining and its impacts on water supplies is given in a report by R. R. Parizek and R. V. Ramani, 1996, on Longwall Coal Mines: Pre-Mine Monitoring and Water Supply Replacement Alternatives; it was prepared as part of a grant to the Pennsylvania State University under Legislative Grant No. 10085196. The report contains a matrix that summarizes the impacts of longwall mining on surface and groundwater resources that have been observed by the authors and/or described in the literature; the summary is given in Table 6.2.

Disturbance of surface stream due to longwall mining manifested in formation of migratory or stationary ponds over the longwall panels was studied at undisclosed location; the study was sponsored by the West Virginia University National Research Center for Coal and Energy, Morgantown, West Virginia (Peng, Sun and Peng, 1994). Field investigation of stream subsidence was observed and monitored at three longwall panels over a mine with overburden thickness of 230 to 350 feet; the extracted seam was 6.5 feet thick. The following conclusions were reached:

> The presence of stream ponds may create water problems for surface environment and underground mining operation, especially when a large stationary pond is formed in the tension zone by the head entry.

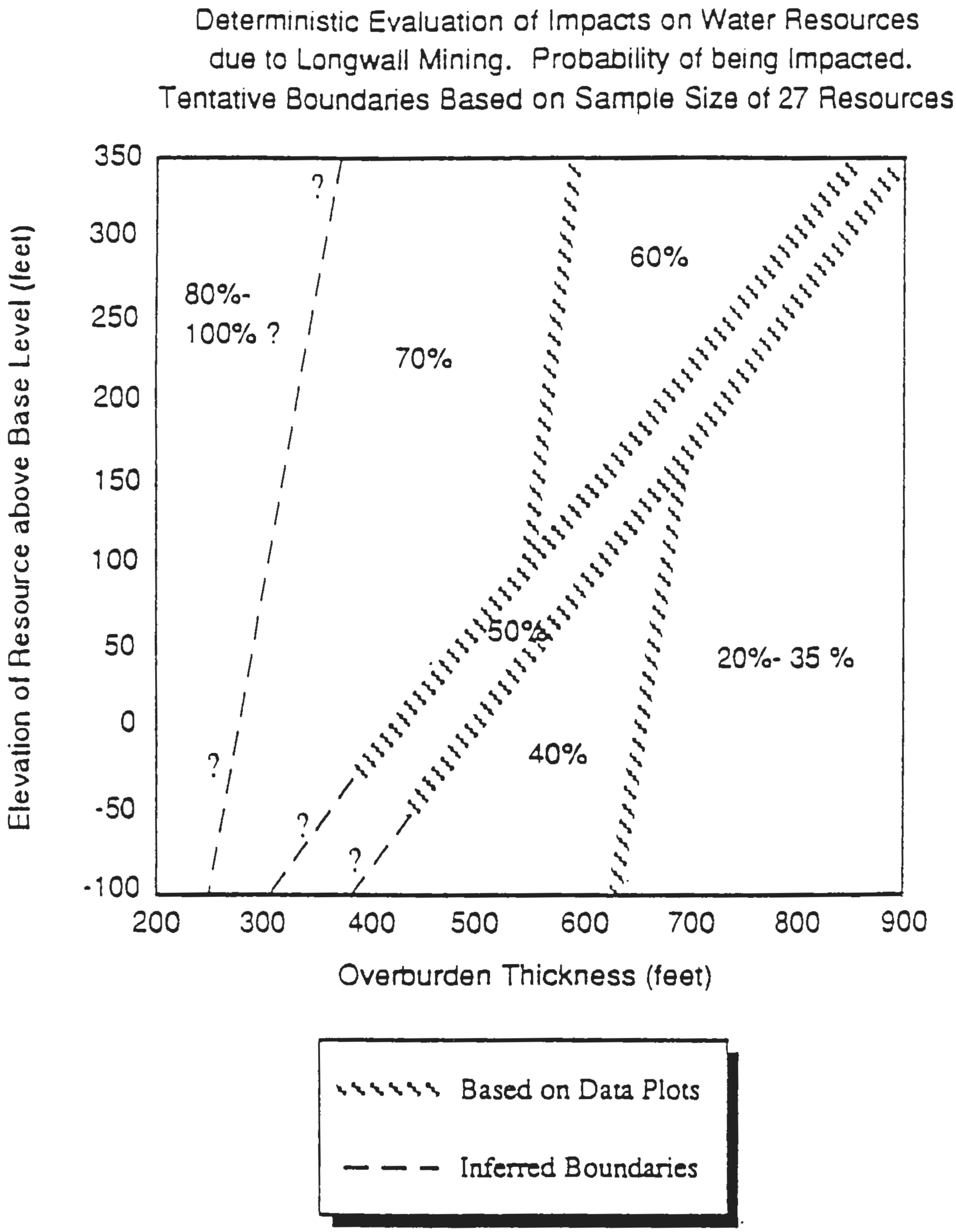



**Figure 6.4. Deterministic probability fields for prediction of potential mining impacts on water resources resulting from longwall mining (modified from Donohue, Parizek and Ramani, 1993)**

The formation process of the stream ponds may be affected by many factors, including precipitation, soil properties, vegetation, variation of water source, etc. However, the topographic change resulting form surface subsidence plays a major role in governing the distribution of the stream ponds.

The migratory pond is created by a dynamic surface subsidence process. If the dynamic strain exceeds the limiting value, water loss to dynamic cracks may occur in the migratory pond when it travels across the longwall panel.

A stationary pond is formed as the migratory pond reaches a sable stage, when the local subsidence reaches about 80 to 90 % of the final subsidence. The location and size of the stationary pond depend mainly on the topography and magnitude of the final subsidence basin.

The defined angle of stream flow can be used to guide the longwall panel design to minimize water problems caused by a disturbed surface stream. The optimum angle of stream flow is 90 and 270 , based on the configuration of the adjacent new longwall panel. The mitigative measures , pumping the water, digging trenches, sealing the bottom of the stream bed, etc. can also be designed based on the study.

Formation of ponds that follows subsidence over longwall panels may create various environmental problems. The authors also point out that the creation of ponded water above the underground mine workings, especially those with shallow overburden, may present a hazard to the underground operation. The water from the ponds may infiltrate through cracks created by the coal extraction.

## 6.2 STATUS OF TO-DATE RESEARCH EFFORTS

Prediction of hydrologic consequences of mining operations as well as predictions of their cumulative hydrologic impacts is required by Title 25 Pa. Code § 90.35 and § 86.37 of the regulations dealing with underground mine permitting. The to-date research of high extraction mining and its hydrologic consequences, as reviewed in the previous section, failed to provide a concise and reliable model for the prediction of the hydrologic consequences. Ultimately, the present knowledge of the impacts and its combined causes is lagging behind the complexity of the problem. The often presented oversimplified research conclusions do not provide the industry or the regulatory personnel with adequate tools to be responsive to this regulation.

**Table 6.2**

**Summary matrix table indicating possible influences of longwall mining. (modified from Parizek and Ramani, 1996)**

| tential Issues of Concern | During Undermining | Following Undermining | Following Closure of Mine |
|---|---|---|---|
| Stream Baseflow | Partial or complete loss of base flow | Partial or complete loss of base flow | (a) Partial or complete loss of base |
| | | | (b) Breakout of mine water, seeps springs or diffuse seeps |
| | | | (c) Change in stream water quality |
| Springs | (a) Partial or complete loss in spring flow | (a) Partial or complete loss in spring flow within uplands and hill slopes | (a) Partial or complete loss in spri flow in uplands and along hill slop |
| | (b) Change in spring location to lower elevations | (b) Change in spring location to lower elevations | (b) Change in spring location to lo elevations, enhanced flows possib |
| | (c) Enhanced spring flows at lower elevation | (c) Enhanced spring flows at lower elevation | (c) Breakout of mine water, increa in spring discharge |
| | | | (d) Change in stream water quality |
| Shallow wells | (a) Partial of complete dewatering in uplands side hills and valleys | (a) Partial or complete dewatering | (a) Partial or complete dewatering |
| | (b) Enhanced yields and higher water levels in valley bottom wells | (b) Partial water level recovery | (b) Partial water level recovery |
| | (c) Damage to well casings, grout seals, pumps | (c) Change in water quality possible | (c) Change in water quality |
| | (d) Possible release of methane | (d) Damage to well casings, grout seals, pumps | (d) Damage to well casings, groun seals, pumps |
| Shallow wells (continued) | (e) Subsidence fractures connected to land surface may increase chances for shallow groundwater affects derived from septic tanks, feed lots, farming, etc. | (e) Increase in or decrease in well setting | (e) Increase or decrease in well yi depending upon pool level followi mine closure |
| | | (f) Possible release of methane gas | (f) Possible release of methane ga |
| | | (g) Subsidence fractures connected to land surface may increase effects on shallow groundwater | (g) Subsidence fractures connecte land surface may increase effects shallow groundwater |

**Table 6.2 (Continued)**

| tential Issues of Concern | During Undermining | Following Undermining | Following Closure of Mine |
|---|---|---|---|
| Intermediate and deep ls | (a) Partial or complete well dewatering | (a) Partial or complete well dewatering | (a) Partial or complete well dewatering |
| | (b) Aquifer dewatering within mine roof strata if not sealed by casing and grout | (b) Partial water level recovery | (b) Partial water well recovery |
| | © Commingling of mine water within overlying and underlying aquifers if wells are improperly constructed. Grout columns or similar supports required | © Change in water quality likely<br>(d) Damage to well casing, grout seals, pumps | © Change in water quality<br>(d) Damage to well casings, grout seals, pumps |
| Well completed below the e after mining | | (e) Increase in or decrease in well yield | (e) Increase or decrease in well yi depending upon final mine pool le |
| | (b) Damage to well casings, grout seals, pumps | (f) Change in water quality induced by lateral flow of groundwater | (f) Change in water quality induce lateral flow of groundwater |
| | © Minor to abrupt loss in stream baseflow | (g) Release of methane gas possible | (g) Difficult to control artesian flo of mine water |
| | (d) Possible release of methane gas | (d) Possible release of methane gas | (h) Release of methane gas possi |
| | (a) Drop in water levels | (a) Drop in water levels | (a) Rise in water levels |
| | (b) Aquifer dewatering within mine roof strata if not sealed by casing and grout | (b) Migration of groundwater | (b) Migration of groundwater |
| Wells completed near the es of long wall panels. uifers near the edge of long l panels | © Commingling of mine water within overlying and underlying aquifers if wells are improperly constructed. Grout columns or similar supports required | © Same as (b) and (c) to the left | © Change in water quality if piezometric level is maintained be mine pool level |
| | (b) Increase in upland infiltration and recharge | (b) Decrease or permanent increase in upland infiltration and recharge | (d) Same as © to the left<br>(a) Drop or rise in water levels ca by mine pool casings, grout seals, pumps |
| | (a) Drop or rise in water levels | (a) Drop or rise in water levels | |
| | (b) Damage to well casings, grout seals, pumps | (b) Damage to well casings, grout seals, pumps | (b) Minor to abrupt loss in stream baseflow |
| 7) Surface pipelines, tanks, dams, etc.<br>Infiltration and undwater recharge | © Minor to abrupt loss in stream baseflow | © Minor to abrupt loss in stream baseflow | © Diffuse seeps and large breakou topographically low lying areas located below the final mine pool level |
| | (d) Possible release of methane gas | (d) Possible release of methane gas | (d) Inadequate hydraulic barrier to contain mine water |

**Table 6.2 (Continued)**

| tential Issues of Concern | During Undermining | Following Undermining | Following Closure of Mine |
|---|---|---|---|
| | (e) Where subsidence fractures extend to surface, enhanced potential for change in groundwater quality from surface sources (a) Structural damage due to extensional/compressional subsidence wave (a) Formation of local subsidence depressions possible (b) Increase in upland infiltration and recharge | (e) Where subsidence fractures extend to surface, enhanced potential for change in groundwater quality from surface sources | © Increased mine groundwater ba area |
| | | (a) Structural damage due to extensional/compressional subsidence wave | ----- |
| | | (a) Formation of local subsidence depressions possible | (a) Net increase or decrease in upl recharge |
| | | (b) Decrease or permanent increase in upland infiltration and recharge | (b) Long term change in water production and quality, possibly b out; treatment and mine pool leve control may be required |
| ) Enhance permeability to air circulation ) Change in groundwater ides | © Increase in mine water pumpage and treatment | © Increase in mine water pumpage and treatment | |
| | (a) Enhanced air circulation, possible alternation in shallow groundwater quantity and quality | (a) Enhanced air circulation, possible alteration in shallow groundwater quantity and quality | (a) Enhanced air circulation, possi long term change in shallow groundwater quantity and quality |
| | (a) Shift of groundwater divides away from the active face of mining | (a) Permanent shift of groundwater divides away from longwall panels | (a) Permanent shift of groundwate divides away from long wall pane |
| | (b) Increased minewater basin area | (b) Reduced local groundwater discharge | (b) Reduced local groundwater discharge |
| | © Increased pumpage and treatment | © Increased mine groundwater basin area | © Increased mine groundwater ba area |
| | | (d) Increased pumpage and treatment | (d) Increased baseflow of streams receiving minewater discharge |
| | (b) Valley water supplies may be enhanced | (e) Increased streamflow where mine water discharged to surface | (e) Long term mine pool level cor may be required treatment |
| | | © Mine aquifer being dewatered | (f) Regional interconnections of m induced aquifers |

**Table 6.2 (Continued)**

| tential Issues of Concern | During Undermining | Following Undermining | Following Closure of Mine |
|---|---|---|---|
| ) Aquifer Properties | (a) Enhanced or reduced hydraulic conductivity of fractured bedrock aquifers depending upon stress<br>(b) Increased storage properties of bedrock<br>© Decreased or increased groundwater availability depending upon the setting | (a) Enhanced or reduced conductivity of bedrock aquifers depending upon final stress distribution | (a) Enhanced or reduced hydraulic conductivity of bedrock aquifers depending upon final stress distribution |
| | | (b) Increased storage properties of bedrock<br>© Decreased or increased groundwater availability depending upon the setting | (b) Increased storage properties of bedrock<br>© Increased groundwater availabi within mine subsided strata |
| (12) Stream Channels<br>) Topographic Irregularities<br>) Sole source aquifers | (a) Increased streambed infiltration properties; may need channel liners, seals, etc.<br>(a) Subsidence depressions, wetlands, ponds, on flood plains and uplands<br>(a) Partial or complete loss of shallow groundwater; more likely within uplands and hill sides<br>(b) Valley water supplies may be enhanced | (a) Increased streambed infiltration properties; may need channel liners, seals, etc.<br>(a) Subsidence depressions, wetlands, ponds, on flood plains and uplands<br>(a) Partial or complete loss of shallow aquifers; more likely in uplands hill sides<br>(b) Partial resaturation of shallow aquifers<br>© Mine aquifer being dewatered | (a) Increased streambed infiltratio properties; may need channel line seals, etc.<br>(a) Subsidence depressions, wetla ponds, on flood plains and upland<br>(a) Partial or complete loss of sha aquifers; more likely in uplands a hill sides<br>(b) Partial and complete resaturati of shallow aquifers<br>© Mine aquifer partially or totally flooded |
| 4) Sole source aquifers ntinued) | | (d) Access to deep aquifers costly, requires drilling through subsided strata, construction of grout columns and similar other water control structures | (d) Water quality problems |
| | (b) Upflow through mine floor | (e) Deep aquifers may be lacking or contain highly mineralized water | (e) Access to deep aquifers costly requires drilling and grouting thro subsided strata, and possible mine pools |
| | | (c) Some lateral flow through coal and roof strata | (f) Deep aquifers may be lacking contain highly mineralized water |

Γ ˙

**Table 6.2 (Continued)**

| tential Issues of Concern | During Undermining | Following Undermining | Following Closure of Mine |
|---|---|---|---|
| ) Final mine pool level | (a) No mine pool; mine being dewatered; local water sumps likely | (a) No mine pool; mine being dewatered, or mine water allowed to accumulate in sumps | (a) Final mine pool level uncertai |
| | (b) Slow to long term near airways, haulage ways & near the margins of panels | (b) Slow to long term near airways, haulage ways & near the margins of panels | (b) Possible breakout of mine wat low lying areas, within seeps, spri or floods, to creeks, rivers, wells, foundations, etc. |
| | | | (c) May require pumping to contr pool levels and breakouts |
| | | | (d) Long term water quality treatn required |
| | | | (e) Regional interconnections or partial interconnections between c among adjacent mine pools withir district |
| ) Groundwater gradient ersals | (a) Flow downward toward the mine in groundwater recharge areas. Some lateral flow in coal seam and roof strata | (a) Flow toward the mine and downward if mine is a groundwater recharge area | (a) Flow toward or away from the mine |
| | (b) Upflow through mine floor | (b) Upflow through the mine floor | (b) Upward or downward flow in mine roof depending upon topographic setting |
| | | (c) Some lateral flow through coal and roof strata | (c) Flow upward or downward through mine-floor strata dependi upon pool level, bedrock structure regional topography |
| ) time of subsidence | (a) Rapid to immediate during longwall mining | (a) Nearly complete above longwall panels | (a) Nearly complete above longwa panels |
| | (b) Slow to long term near airways, haulage ways & near the margins of panels | (b) Slow to long term near airways, haulage ways & near the margins of panels | (b) Slow to long term near airway haulage ways & near the margins panels |
| ) Coal recovery | (a) Maximum possible recovery of coal | (a) Maximum possible recovery of coal | (a) Maximum possible recovery o coal |

Furthermore, the scope of research performed in the eighties and early nineties by independent parties has been reduced to a minimum or is nonexistent. The communications of Richard DiPretoro with researchers at universities and at government research and regulatory agencies have revealed that research of the hydrologic effects of high extraction mining has come to a complete halt. Leading authors of previously published research indicated that they knew of not a single research project underway in the eastern United States. Contacts that can attest to the status of the research effort is given below:

Clifford H. Dodge, Bureau of Topographic and Geologic Survey
Thomas H. A. McKnight, Deep Mine Safety, Uniontown
Harry Payne, OH DNR, Columbus
Paul Ziemkiewicz, National Mine Land Reclamation Center, Morgantown
Henry Rauch, WVU, Morgantown
Clim Booth, Northern Illinois University, DeKalb
Rudy Matetic, US DOE, Bruceton
Chris Mark, US DOE, Bruceton
Eberhard Werner, Geologist, Morgantown

The need for more comprehensive research of high extraction mining was further expressed by some of the scientist involved with the research of the mining and subsidence impacts. For instance, R. J. Matetic, states in the introduction to his paper from 1993, the following:

> Detailed research studies involving longwall mining and its impact upon local domestic water supplies are very restricted. Due to the limited body of available information, it is difficult for mine operators and regulatory officials to make informed decision about the potential effects of high- extraction mining techniques on the groundwater system. Furthermore, it is unclear if hydrological/mining results collected in one area can be universally applies to other mining areas within the same region or between coal mining regions.

Parizek and Ramani, 1996, also emphasize the need for further research and demonstration studies to provide additional data on alternate methods of water supply replacement, using the methods identified in this report that, according to the authors, by so far have not been attempted or adopted by the coal industry. Furthermore, the authors state that there is a need to address the long term longwall mining impacts on domestic, farm and municipal groundwater supplies and under what mining and hydrogeologic circumstances these water supplies can be protected or replaced.

In fact, the research of the high extraction mining and the resulting subsidence impacts on water supplies indicates that there is not one single factor or a known combination of factors that characterize the physical background of a mined site that would provide guarantees of no impacts or that would allow a reasonable prediction of impacts and their degree.

Many studies have been searching for common factors that control the impacts and would thus allow to develop a model for prediction of potential impacts on aquifers supporting local water supplies. Many researches agree that it is the aquifer topographic position relative to local base level, the vertical distance and separation between the underground mine and aquifer that play an important role that determine the final impact.

Several factors which were shown to have a causative relationship with the impacts include topographic factors, for instance the position of a water supply near a ridge top, above the regional base level and in a valley, at the regional base level; geologic factors, for instance the secondary permeability of various lithologies and their ability to fracture; and the position of a supply relative to the geometry of a longwall panel.

Furthermore, there are other individual factors and their combinations that determine the severity of the effects that were rarely considered in the research efforts, namely evaluating the impacts in view of the prevailing groundwater conditions, including sufficiently long pre-mining or post-mining baseline records, for instance of stream flows, changes in hydrostatic heads and gradients in the groundwater system, mode and density of the fractures and the presence of significant fracture zones, the character of the groundwater system (local or regional), local and regional water levels and their natural fluctuations, stream gradients, composition of stream beds, the amount of stream incision into the regional water system, etc.

Many of the studies considered the impacts in terms of water use; very few research projects addressed the hydrological consequences in the framework of the hydrological balance and cumulative impacts, including the question of interbasin water transfer after the large undermined areas are abandoned and flooded.

The conclusions of the published research on the effects of longwall mining show inconsistencies in describing impacts on groundwater systems as manifested in impacts on water supplies, wells and springs. The research has focused on timing of the observed impacts relative to the mining cycle, and the severity and the duration of these impacts. Frequently, the changes in the hydrologic conditions of the site are not compared to the pre-mining condition and the baseline monitoring record is either lacking or insufficient. Some papers report quick or a complete recovery to pre-mining conditions whereas others report permanent well dewatering.

The position of the researchers that are associated with the coal mining industry is that to date, the replacement for impacted supplies were always provided and that is in compliance with the regulatory requirements.

## 6.3 HYDROLOGICAL CONSEQUENCES

This section of the report provides a summary of the present knowledge of the hydrological consequences of high extraction mining as they relate to changes in groundwater regime, namely in the shallow and perched water-bearing zones and the regional groundwater system. Flow charts (Figures 6.5 and 6.6) are presented to show the relationships of each hydrologic change to its cause and consequences.

### 6.3.1 Shallow Groundwater Flow System

The shallow groundwater flow systems that prevail in Greene and Washington Counties are described in section 4.2.2 of the report. Figure 6.5 provides a flow chart of hydrology consequences of high extraction mining applicable to the shallow perched water-bearing zones.

The shallow water-bearing zones lie above the regional base level and are recharged mostly by precipitation. They are separated from the regional groundwater system by unsaturated zone. The water-bearing properties of shallow systems depend mostly on secondary permeability, although some unconsolidated deposits, such as alluvium or colluvium, may have relatively high primary porosity. The water storage capability of these shallow systems depends on a permeability differential between the water-bearing fractured or porous media and the underlying strata, that retard downward water percolation and create perching.

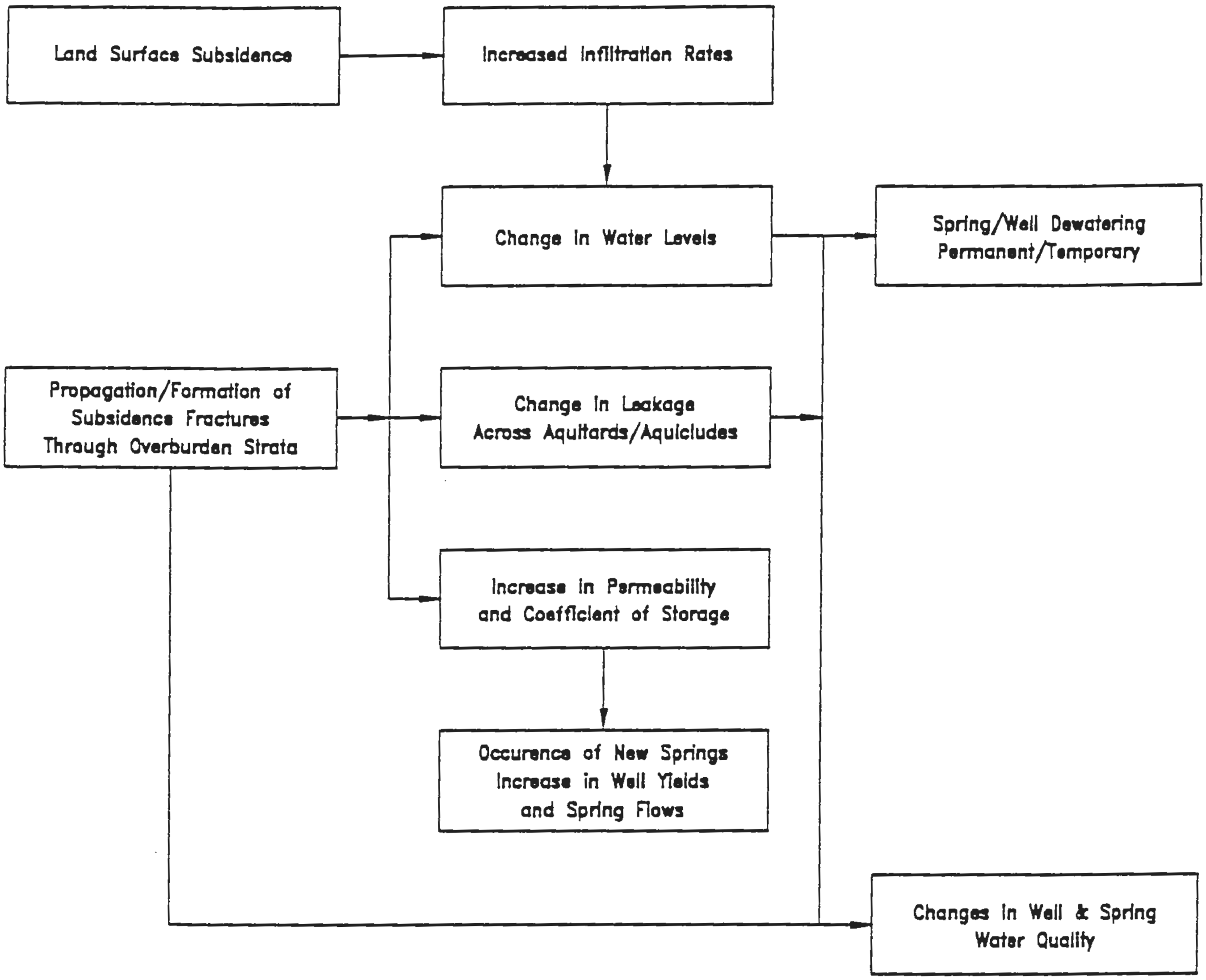



Figure 6.5. Hydrologic consequences of high extraction mining/subsidence on shallow/perched water bearing systems.

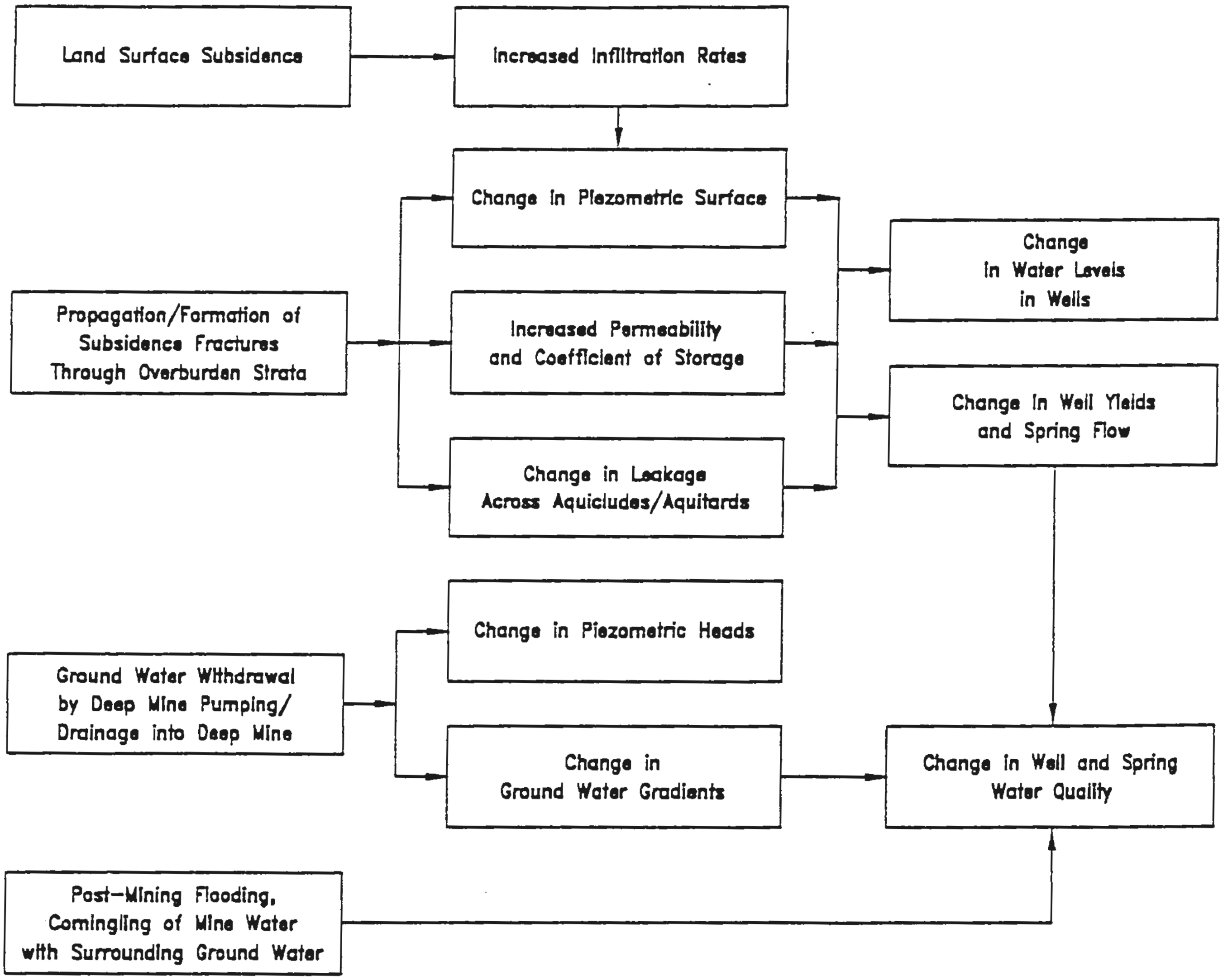



**Figure 6.6.** Hydrologic consequences of high extraction mining/subsidence on regional groundwater systems.

High extraction mining subsidence changes the surface configuration, often creating depressions, thus decreasing the rate of surface runoff and enhancing infiltration. This in addition to near surface rock fracturing provides for accelerated water recharge to the shallow system reflected in the rise of water levels. In instances, where the perching layer is not disturbed by fracturing, the water-bearing properties of the shallow aquifer may be improved, subsequently providing higher water yields.

Groundwater perching in the coal-bearing strata is a common occurrence as the bedrock contains beds of changing lithologic make-up and hydraulic properties. Water-bearing zones (aquifers) are underlain by aquicludes or aquitards. The lateral flow component predominates and the amount of perching depends on the integrity of the perching bed and its lateral extent. Majority of the residents that live in the upland and hillside sections of such an area depend on these perched shallow system as a source of water to wells or springs.

The subsidence induced fracturing impacts the integrity of the perching bed and creates leakage through fractures that convey water from the water-bearing zone to the underlying strata. Fractures across the perching bed may totally dewater a water-bearing zone or deplete significantly its water storage, resulting in water level drop. It is the proportion of the newly created leakage to the recharge and existing water storage that determine the severity of the impacts on a water supply. In instances where the leakage through the perching bed exceeds the recharge, the aquifer is totally dewatered. The severity of the impacts also depends on the areal extent of the water-bearing zone and its water storage capacity. If the perched system is of a small areal extent, it is more easily dewatered.

The permanence of dewatering depends on whether the newly created fractures will continue to maintain their capability to transmit water to the underlying strata. Examples of permanently dewatered wells or springs suggest that this, in some instances, is the case.

On the other hand, leakage of water to underlying strata that were previously water deprived may create a new water bearing zone with usable water yields, providing that the integrity of its perching bed is not compromised. In instances, where the lithologic strata are all prone to fracturing, the entire shallow system may be dewatered or depleted by leakage into the underlying regional system. This shift in productive water-bearing zones to topographically lower sections has been described and documented by occurrence of new springs and higher yielding wells. The higher yield is also attributable to changed hydraulic properties of the newly fractured rocks characterized by increased permeability and storage.

In summary, the effects of high extraction induced subsidence on shallow systems depends on the local geologic conditions and their response to fracturing. Presence of fractures, their density, aperture, and distribution are the critical factors in judging the potential impacts. Other factors, such as the vertical separation of the shallow systems from the underground mine, their position relative to the regional groundwater reservoir, position relative to the mined longwall panel are some of the other factors that influence the propagation of the fractures through the overburden and thus indirectly impact the hydrological consequence.

### 6.3.2 Regional Groundwater Flow System

The regional groundwater system that prevails in Greene and Washington Counties is described in section 4.2.3 of this report. Figure 6.6 provides a flow chart of hydrological consequences of high extraction mining on the regional groundwater system.

The high extraction mining in Southwestern Pennsylvania is done solely within the regional groundwater reservoir below the local base level, i.e. below the major streams that drain the overlying surface area. The underground mining process requires water pumping to keep the mine workings dry. The volume of water pumped depends on the position of the mine within the groundwater reservoir and the degree of permeability of the surrounding strata.

The water drains into the underground voids through the mine roof but may also be entering the workings through the mine floor, depending on the hydraulic gradients that surround the mine. The mine workings create a hydrologic sink within the regional groundwater system and change the hydraulic gradients above and immediately below the mine opening with flow lines deflected toward the underground mine.

The overburden dewatering initially effects the immediate mine roof overburden and progresses upward depending on the rate of water inflow and the pumping rate, determined by the permeability of the overlying strata. The role of the secondary permeability in the underground mine overburden and its effect on groundwater flow system was discussed in previous sections of the report. However, additional fracturing due to subsidence changes the hydraulic properties of the mine overburden by propagation of fractures through the overlying strata. While during the pre-retreat mining stages the underground mine acts as an underground sink, the post-retreat flow into the underground mine workings is enhanced by mine roof collapse and propagation of fracture into the overlying strata. The subsequent reduction of water storage in the overlying aquifer is manifested by declining potentiometric heads and reductions in flow from discharge points draining the overlying aquifer.

The changes in hydraulic heads within the regional aquifer are often accompanied by a decline in potentiometric surface (water table) that defines the top of the saturated system. The decline during the retreat stages of the mining is attributable to changes in storage properties of the overburden strata and enhanced hydraulic conductivity due to the subsidence induced fracturing. The intense overburden fracturing also affects beds of low permeability that previously acted as aquitards/aquicludes, thus modifying the groundwater flow patterns. The stratified attribute of the regional system is thus modified to produce a more homogenous groundwater system characterized by a network of fractures that weakens the flow pattern characterized by stratification.

The enhanced hydraulic conductivity and storage capacity of the fractured strata improve the potential of the system for higher yields beneficial for public or private water supplies. In general, the long term negative impacts of the high extraction mining on wells located in the regional system should thus be in most cases absent. However, it is the site specific condition that determines the final verdict. As the increased permeability of the system promotes the groundwater movement from the watershed, the initial drop in water levels that follows the subsidence may become permanent. Therefore, the shallow wells in the upper portions of the regional system will experience water level declines and may be, in some cases, dewatered. Furthermore, the subsidence induced shifting in the overburden that creates new fractures may close others. If a well's original yield depended on the hydraulic conductivity of the fracture that closed, the well yield will drop.

A drop in the water surface elevation of the regional system and a decline in the hydraulic gradients, namely in the upper portions of the system may have a negative impact not only on the shallow wells but also on the rate of base flow recharge to the local streams.

The changes in groundwater quality accompany the increased permeability of the strata, and the reduced contact time of groundwater with the host strata will be reflected in an overall reduction of total dissolved solids. On the other hand, underground mining in the Southwestern Pennsylvania, especially in the Pittsburgh seam, has created acid mine drainage discharges and subsequent movement of polluted water from the mine workings into the adjacent groundwater system. Any well that penetrates acid mine drainage plume generated in the underground mine workings will get polluted.

The amount of water removed from the groundwater storage during the active stages of the mining is reflected in the amount of water pumping from the underground mine workings, unless some of the mine water is transferred to an adjacent mine. The role of the hydraulic conditions of the adjacent mines and their interconnection is especially significant in the post-mining stages when all mine water pumping has stopped and underground mine workings are flooded. The assessment of the cumulative impacts of the proposed coal mining extends thus beyond the individual mines and the assessment needs to consider the entire watershed where the mining complex occurs.

## 7.0 BIBLIOGRAPHY

Abate, C., 1993. *A Numerical Modeling Approach to Estimation of Parameters Describing Groundwater Flow in Coal-Bearing Rocks of the Allegheny Plateau*, M.S. thesis, Department of Geosciences, Pennsylvania State University, University Park, Pennsylvania.

Ackman, T. E., and J. R. Jones, 1988. "Stream Sealing to Reduce Surface Water Infiltration into Underground Mines," *Proceedings of the Mine Drainage and Surface Mine Reclamation Conference, 1988*, The American Society for Surface Mining and Reclamation and the US Department of Agriculture, Vol. I, Mine Water and Waste, Pittsburgh, Pennsylvania, pp. 232-239.

Ackman, T. E., and J. R. Jones, 1991. "Methods to Identify and Reduce Potential Surface Stream Water Losses into Abandoned Underground Mines," *Environmental Geology Water Science*, Vol. 17, No. 3, pp. 227-232.

Ahmad, M.Y., 1988. *Hydrologic Impacts of the Underground Mining of Powhatan No. 6 Mine at Dysart Woods*, Report of Dept. of Geological Sciences, Ohio University, Athens, Ohio, 14 pp.

Ahnell, G., and H. W. Rauch, 1978. "The Effect of Underground Coal Mining on Water Wells in Monongalia County, West Virginia," *Groundwater* Vol. 16, No. 5.

Aston, T. R. C., and R. N. Singh, 1983. "A Reappraisal of Investigations into Strata Permeability Changes Associated with Longwall Mining," *International Journal of Mine Water,* Vol. 2, No. 1, pp. 1-14.

Bai, M. and D. Elsworth, 1991. "Modeling Subsidence and Groundwater Flow Due to Underground Mining," *Proceedings of 34th Annual Meeting of The Association of Engineering Geologists, Environmental And Geological Challenges for the Decade*, Association of Engineering Geologists, pp. 981-989.

Booth, C. J., 1984. "The Hydrogeological Impact of Deep Longwall Mining, Appalachian Plateau, Pennsylvania," *Proceedings of Conference on the Impact of Mining on Groundwater*, National Water Well Association, Worthington, Ohio, pp. 360-379.

Booth, C. J., 1986a. *A Numerical Model of Groundwater Flow Associated with an Underground Coal Mine in the Appalachian Plateau, Pennsylvania*, Ph.D. dissertation, Pennsylvania State University, University Park, Pennsylvania.

Booth C. J., 1986b. "Strata-Movement Concepts and the Hydrogeological Impact of Underground Coal Mining," *Groundwater*, Vol. 24, No. 4, pp. 507-515.

Booth, C. J., 1988. "Interpretation of Well and Field Data in Heterogeneous Layered Aquifer Setting, Appalachian Plateau," *Groundwater*, Vol. 26, No. 5, pp. 596-606.

Booth C. J. and E. D. Spande, 1992. "Potentiometric and Aquifer Property Changes Above Subsiding Longwall Panels, Illinois Basin Coalfield", *Groundwater*, May-June, 1992, 8 pp.

Borch, M., and J. R. Runkle, 1990. *Possible Impacts of Longwall Mining on the Hydrology near Dysart Woods and Possible Impacts of Longwall Mining in the Vegetation near Dysart Woods*, Report for the National Water Well Association, Ohio, 69 pp.

Borchers, J. W., and G. W. Granville, 1981. "Application of Stress-relief Fracturing Concepts for Monitoring the Effects of Surface Mining on Groundwater in Appalachian Plateau Valleys," *Symposium on Surface Mine Hydrology, Sedimentology and Reclamation*, University of Kentucky, Lexington, Kentucky, pp. 443-449.

Brady K. et al, 1996. "Shallow Groundwater Flow in Unmined Regions of the Northern Appalachian Plateau: Part 2: Geochemical Characteristics," *Proceedings of the Thirteenth*

*Annual Meeting, American Society for Surface Mining and Reclamation*, Knoxville, Tennessee, pp. 52-62.

Brown, R. F. and R. R. Parizek, 1971. *Shallow Groundwater Flow System Beneath Strip and Deep Coal Mines at Two Sites, Clearfield County, PA, Coal Res. Section,* The Pennsylvania State University Res. Report. SR-84, pp 216.

Bruhn, R. W., 1985. "A Note on Ground Movements and Associated Groundwater Response at Underground Appalachian Mine," *Preprint for February 1985 Annual Meeting of SME-AIME.*

Bruhn, R. W., 1986. "Influence of Deep Mining on the Groundwater Regime at a Mine in Northern Appalachia," *Proceedings of the 2nd Workshop on Surface Subsidence Due to Underground Mining*, S. S. Peng (ed.), West Virginia University, Morgantown, West Virginia, pp. 234-238.

Bruhn, Robert W., M. O. Magnuson, and R. E. Gray, 1978. "Subsidence Over the Mined-out Pittsburgh Coal," *American Society of Civil Engineers Spring Convention*, Pittsburgh, Pennsylvania (ASCS Preprint 3292), pp. 26-55 (Cited by Gray and Bruhn, 1984).

Carver, L., and H. W. Rauch, 1994. "Hydrogeologic Effects of Subsidence at a Longwall Mine in the Pittsburgh Coal Seam," *Proceedings of the 13th Conference on Ground Control in Mining*, West Virginia University, Morgantown, West Virginia, pp. 298-307.

Cifelli, R. C., and Henry W. Rauch, 1986. "Dewatering Effects from Selected Underground Coal Mines in North-central West Virginia," *Proceedings of the 2nd Workshop on Surface Subsidence Due to Underground Mining*, S. S. Peng (ed.), West Virginia University, Morgantown, West Virginia, pp. 249-263.

Coe, C. J., and Samuel M. Stowe, 1984. "Evaluation of the Impact of Longwall Coal Mining on the Hydrologic Balance," *Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation*, University of Kentucky, Lexington, Kentucky, pp. 395-403.

Coe, C. J., and S. M. Stowe, 1984. "Evaluating the Impact of Longwall Mining on the Hydrologic Balance," *Proceedings of the National Water Well Association Conference on the Impact of Mining on Groundwater*, National Water Well Association, Denver, Colorado, pp. 348-359.

Coen, A. W., 1992. *Streamflow, Water Quality, and Biological Data on Streams in an Area of Longwall Coal Mining, Southern Ohio, Water Years 1987-89*, U.S, Geological Survey, Open File Report 92-120. Ohio Dept. Of Natural Resources, Division of Reclamation, Columbus, Ohio, 75 pp.

Dixon, D. Y., and H. W. Rauch, 1988. "Study of Quantitative Impacts to Groundwater Associated with Longwall Coal Mining at Three Mine Sites in Northern West Virginia Area," *Proceedings 7th International Conference on Ground Control in Mining,* West Virginia University, Morgantown, West Virginia, pp. 321-335.

Dixon, D. Y., and H. W. Rauch, 1990. "The Impact of Three Longwall Coal Mines on Streamflow in the Appalachian Coalfield," *Proceedings of Ninth International Conference on Ground Control in Mining*, West Virginia University, Morgantown, West Virginia, pp. 169-182.

Donohue, T. D. A., R. R. Parizek, and R. A. Ramani, 1993. *Evaluation of the Long Term Impact on Domestic and Farm Groundwater Supplies Under Pennsylvania's Deep Long Wall Mining Conditions, 1993*, Final Report Project PSU-10, MLR9205, Penn State Environmental Resources Institute, University Park, Pennsylvania.

Duigon, M. T. and M. J. Smigaj, 1985. *First Report on the Hydrologic Effects of Underground Mining in Garret County, Maryland*, Maryland Geological Survey RI NO. 41, 99 pp.

Evans, G. A., H. M. Weagraff, J. W. Warner, and G. S. Lowry, 1983. *Impact of Longwall Mining on the Hydrologic Balance: Premining Data Collection,* Bureau of Mines Report, BUMINES-OFR-187-83, 142 pp.

Earle, J., and M. Dimatteo, 1989. *An Aquatic and Hydrologic Investigation of Roaring Run, Cambria County, Pennsylvania*, Pennsylvania Department of Environmental Resources, Bureau of Mining and Reclamation, Division of Environmental Analysis and Support, Environmental Studies Section.

Elsworth D. and J. Liu, 1995. "Topographic Influence of Longwall Mining on Ground-water Supplies," *Groundwater*, Vol. 33, No. 5, pp. 786-793.

Evans, G. S., J. Warner, and T. Hailu, 1984. "The Impact of Longwall Mining on the Hydrologic Balance: Premining Data Collection," *Proceedings of the National Water Well Association Conference on the Impact of Mining on Groundwater*, National Water Well Association, Denver, Colorado, pp. 324-347.

Freeze, R. A., and J. A. Cherry, 1979. *Groundwater*, Prentice Hall, Inc.

Gburek, W. J. and J. B. Urban, 1990. "The Shallow Weathered Fracture Layer in the Near-Stream Zone," *Groundwater*, Vol. 28, No. 6, pp. 875-883.

Gerhart, J. M., 1984. "A Model of Regional Ground-Water Flow in Secondary-Permeability Terrain," *Groundwater*, Vol. 22, No. 2, pp. 168-175.

Girrens, S. P., et al., 1981. "Numerical Prediction of Subsidence with Coupled Geomechanical-hydrological Modeling," *Proceedings, Workshop on Surface Subsidence Due to Underground Mining*, West Virginia University, U.S. Department Of Energy and U. S. Bureau of Mines, pp. 63-72.

Green, J. B., M. A. Trevits, and J. S. Walker, 1986. "Case Study of the Effects of Subsidence on a Local Groundwater System," *Proceedings, 1986 Symposium of Surface Mining, Hydrology, Sedimentology, and Reclamation*, University of Kentucky, Lexington, Kentucky, pp. 223-231.

Hasenfus, G. J., K. L. Johnson, and D. W. H. Su, 1988. "A Hydrogeochemical Study of Overburden Aquifer Response to Longwall Mining," *Proceedings: 7th International Conference on Ground Control in Mining*, Morgantown, West Virginia, pp. 149-162.

Harlow, G. E., Jr., and G. D. Lecain, 1991. *Hydraulic Characteristics Of, and Groundwater Flow In, Coal-Bearing Rocks of Southwestern Virginia*, USGS Open File Report 91-250.

Hawkins, J., et al., 1996. "Shallow Groundwater Flow in Unmined Regions of the Northern Appalachian Plateau: Part 1: Physical Characteristics," *Proceedings of the Thirteenth Annual Meeting, American Society for Surface Mining and Reclamation*, Knoxville, Tennessee, pp. 42-51.

Hill, J. G., and D. R. Price, 1983. "The Impact of Deep Mining on an Overlying Aquifer in Western Pennsylvania," *Groundwater Monitoring Review*, Vol. 3, No. 1, pp. 138-143.

Hill, J. G., G. J. Burgdorf, and D. R. Price, 1984. *Effects of Coal Mine Subsidence on Groundwater Aquifers in Northern Appalachia,* U.S. Bureau of Mines Contract No. J0199063, SMC Martin, Inc., U.S. Bureau of Mines OFR No. 142-84, NTIS PB 84-236710, 149 pp.

Hiortdahl, S. N., 1987. *Hydrologic and Mining Data from an Area of Underground Coal Mining Basins in Garret County, Maryland*, Maryland Geologic Survey RI NO. 41-A, 114 pp.

Hobba, William A., Jr., 1993. *Effects of Underground Mining and Mine Collapse on the Hydrology of Selected Basins in West Virginia*, West Virginia Geological and Economic Survey RI33, 77 pp.

Ingrams, D. N. and J. K. Prentice, 1982. "Theory for Aquifer Test Analysis in Fractured Rocks under Linear (Nonradial) Flow Conditions," *Groundwater*, Vol. 20, No. 1, pp. 12-21.

Jinkain, Kenneth L., 1991. "Effects of Longwall Coal Mining on the Hydrology of Two Appalachian Stream Valleys," *Proceedings, Fifth National Outdoor Action Conference on Aquifer Restoration, Groundwater Monitoring, and Geophysical Methods,* Groundwater Management 5:1111-1125.

Johnson, K. L., 1984. *Hydrologic Impacts of Longwall Mining: Project Site Description and Initial Data Analysis, Shoemaker Mine, West Virginia*, Report prepared by Conoco, Inc. Research and Development Department, Coal Research Division, Ponca City, Oklahoma, 36 pp.

Johnson, K. L., 1991. "Effects of Longwall Coal Mining on the Hydrology of Two Appalachian Stream Valleys," *Proceedings of 6th National Outdoor Action Conference on Aquifer Restoration, Groundwater Monitoring and Geophysical Methods, Las Vegas, Nevada, 1991*, pp.2.01 - 2.31.

Johnson, K. L., 1992. "Influence of Topography on the Effects of Longwall Mining on Shallow Aquifers in the Appalachian Coal Field," *Proceedings of the Third Workshop on Surface Subsidence Due to Underground Mining*, Morgantown, West Virginia, pp. 197-203.

Johnson, K. L., 1983. "The Use of Monitoring Wells to Determine Mine Inflows," *Groundwater Monitoring Review*, Vol. 3, No. 1, pp. 92-94.

Kendorski, F. S., 1993. "Effect of High extraction Coal Mining on Surface and Groundwater," *Proceedings of the 12th Conference on Ground Control in Mining, Morgantown, West Virginia*, pp. 412-425.

Khair, J. A., and J. S. Dinger, 1987. "Stress-relief Fracture Control of Ground-water Movement in the Appalachian Plateaus," *Proceedings of the Focus on Eastern Regional Groundwater Issues: a Conference*, Burlington, Vermont, pp. 423-438.

Leavitt, B. R. and J. F. Gibbens, 1992. "Effects of Longwall Coal Mining on Rural Water Supplies and Stress Relief Fracture Flow Systems," *Proceedings of the Third Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia*, pp. 237-243.

Lewis, D. C., and R. H. Burgy, 1963. "Hydraulic Characteristics of Fractured and Jointed Rock," Presented at the National Water Well Exposition, *Groundwater* Vol. 2, No. 3, pp. 4-9.

Matetic, R. J., 1993. "An Assessment of Longwall Mining - Induced Changes in the Local Groundwater System", *FOCUS Conference on Eastern Regional Groundwater Issues, Bureau of Mines, Pittsburgh Research Center*, Pittsburgh, Pennsylvanaia.

Matetic, R. J., and M. A. Trevits, 1990. "Case Study of Longwall Mining Effects on Water Wells," *Preprint No. 90-141, SME Annual Meeting*, Salt Lake City, Utah.

Matetic, R. J. and M. A. Trevits, 1990. "Longwall Mining Impact on Near-Surface Water," *Proceedings, Mine Subsidence - Prediction and Control*, C. Dale Elifrits (ed.), Association of Engineering Geologists Symposium Series, pp. 131-139.

Matetic, R. J., and M. A. Trevits, 1991. "Does Longwall Mining Have a Detrimental Effect on Shallow Groundwater Resources?" *Proceedings, Fifth National Outdoor Action Conference on Aquifer Restoration, Groundwater Monitoring and Geophysical Methods*, Association of Groundwater Scientists and Engineers, Division of NWWA, May 13-26, 1991, Las Vegas, Nevada.

Matetic, R. J. and M. A. Trevits, 1992. "Hydrologic Variations Due to Longwall Mining," *Third Workshop On Surface Subsidence Due to Underground Mining,* Morgantown, West Virginia, pp. 203-213.

Mather, J. D., D. A. Gray, and D. G. Jenkins, 1969. "The Use of Tracers to Investigate the Relationship Between Mining, Subsidence, and Groundwater Occurrence," *Hydrology*, Vol. 9, No. 2, Aberfan, South Wales, pp. 136-154.

Moebs N. N., and T. M. Barton, 1985. *Short-term Effects of Longwall Mining on Shallow Water Sources*, U.S. Department of Interior, Bureau of Mines, Information Circular 9042:13-24.

Moebs, C. E., and J. V. Tracy, 1981. "Flow Through Fractures" *Water Resources Research*, Vol. 17, No. 1, pp. 191-199.

Moebs, N. N., and G. P. Sames, 1988. "Lineaments a Predictive Tool for a Bad Roof?, *Coal,* March, 1988, pp. 94-96.

Moore, R. C., and M. A. Nawrocki, 1980. *Effects of Subsidence from Thick Seam Coal Mining on Hydrology*, U. S. Bureau of Mines (BUMINES OFR 93-80), Washington, D.C., March 7, 1980, 245 pp.

Neate, C. J., and B. N. Whittaker, 1979. "Influence of Proximity of Longwall Mining on Strata Permeability and Groundwater," *Proceedings of the 20th U. S. Symposium on Rock Mechanics, Austin, Texas, June 4-6, 1979*, New York Society of Mining Engineers of AIME, pp. 217-224.

Novakowski, K. S., 1990. Analysis of Aquifer Tests Conducted in Fractured Rock: a Review of the Physical Background and the Design of a Computer Program for Generating Type Curves," *Groundwater*, Vol. 28, No. 1, pp. 99-107.

O'steen, W. N., and H. W. Rauch, 1983. "Effects of Coal Mining on Ground-Water Quality in West Virginia," *Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation,* University of Kentucky, Lexington, Kentucky, pp. 355-363.

Owili-Eger, A. S. C., and L. M. Clay, 1982. *Sustained Geohydrologic and Hydrogeochemical Effects of Longwall Mining on Local Groundwater Systems at Shoemaker Mine, Marshall County, West Virginia*, Continental Oil Company, Research and Development Department, Mining and Minerals Division, Mining Research Section, Report No. 1334-8-1-82, 82 pp.

Owili-Eger, A. S. C., 1983. *Geohydrologic and Hydrogeochemical Impacts of Longwall Coal Mining on Local Aquifers,* Society of Mining Engineering, AIME Preprint 83-376, pp. 1-16.

Owili-Eger, A. S. C., 1987. "Response of Overlying Aquifers to Full Extraction Mining," *Proceedings of the Society of Mining Engineers Eastern Regional Meeting*, Pittsburgh, Pennsylvania, Preprints, 12 pp.

Parizek, R. R., and R. V. Ramani, 1996. *Longwall Coal Mines: Pre-mine Monitoring and Water Supply Replacement Alternatives*, Final Report on Legislative Initiative Program 181-90-2658 (Mlr9602), Pennsylvania State University, Environmental Resources Research Institute, University Park, Pennsylvania, 194 pp.

Peffer, Jeffrey R. 1991. "Complex Aquifer-Aquitard Relationships at an Appalachian Plateau Site," *Groundwater*, Vol. 29, No.2, pp. 209-217.

Peng, F. F., Z. Sun, and S. S. Peng, 1994. "Disturbance of Surface Water Stream Due to Longwall Mining, *International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage*, Pittsburgh, PA, April 24-29, 1994.

Peng, S. S., A.W. Khair, and Y. Luo, 1987. "Topographical Effects of Surface Subsidence - A Case Study," *National Symposium on Mining, Hydrology, Sedimentology, and Reclamation*, 1987 National Symposium on Mining, Hydrology, Sedimentology, and Reclamation, University of Kentucky, Lexington, KY; pp. 223-228.

Peng, S. S., 1992. *Surface Subsidence Engineering*, Society for Mining, Metallurgy, and Exploration, Inc., 161 pp.

Pennington, D., J. G. Hill, G. J. Burdorf, and D. R. Price, 1984. *Effects of Longwall Mine Subsidence on Overlying Aquifers in Western Pennsylvania*, U.S. Bureau of Mines Research Contract Report Number J0199063 by SMC Martin, Inc., 129 pp.

Rauch, H. W., W. N. O'steen, G. Ahnell, and D. F. Giannatos, 1984. "Predictions for Aquifer Dewatering over Underground Mines in the Pittsburgh, Sewickley, and Upper Freeport Coals of Northern West Virginia," *Proceedings of Fifth Annual West Virginia Surface Mine Drainage Task Force Symposium,* West Virginia Surface Mining and Reclamation Association, Morgantown, West Virginia.

Rauch, H. W., 1989a. "A Summary of the Groundwater Impacts from Underground Mine Subsidence in the North-central Appalachians," *Proceedings of Coal Mine Subsidence Special Institute, Eastern Mineral Law Foundation Institute on Coal Subsidence,* Pittsburgh, Pennsylvania, pp. 2.01-2.31.

Rauch, H. W., 1989b. "Groundwater Impacts from Surface and Underground Mining," *Proceedings of a Conference on West Virginia Groundwater 1987 - Status and Future Directions: Morgantown, West Virginia University, Water Research Institute*, 21 pp.

Richards, D. B., 1985. *Groundwater Manual: Coal Mine Permit Applications, Volume I*, U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, prepared in cooperation with U.S. Geological Survey, pp. 275.

Schmidt, R. D., 1992. "Factors Affecting Residential Water Well Yields in the Vicinity of Room and Pillar Mines," *Proceedings of the Third Workshop on Surface Subsidence Due to Underground Mining,* Morgantown, West Virginia, pp. 244-252.

Schmidt, R. D., and G. Ahnel, 1985. *A Fracture Zone Dewatering to Control Groundwater Infiltration to Underground coal Mines*, U.S. Bureau of Mines R.I. 8981, pp84.

Schubert, J. P., 1980. "Fracture Flow of Groundwater in Coal-Bearing Strata," *Proceedings of the Symposium on Surface Mining Hydrology, Sedimentology, and Reclamation,* University of Kentucky, Lexington, Kentucky, pp. 61-73.

Schultz, R. A., 1998. *Groundwater Hydrology of Marshal County, West Virginia, with Emphasis on the Effects of Longwall Coal Mining*, U.S. Geological Survey Water Resources Investigations Report 88-4006, 147 pp.

Sendlein, L. V. A, J. S. Giner, and T. D. Fickel, 1992. "Impact of Underground Coal Mining on the Anvil Rock Aquifer," *Proceedings of the 4th Conference on Ground Control for Midwestern U.S. Coal Mines, Mt. Vernon, Illinois*, pp. 15-50.

Sgambat, J. P., E. A. Labella, and S. Roebuck, 1980. *Effects of Underground Coal Mining on Groundwater in the Eastern United States*, EPA Interagency Energy/Environment Research and Development Program Report, EPA-600/7-80-120, 182 pp.

Shimmin, M. D., and P. J. Zillis, 1984. "The Impact of Groundwater Law on Mining: a Survey of Rules Governing Dewatering of Mines and Utilization of Groundwater," *Proceedings of the NWWA Conference on the Impact of Mining on Groundwater,* Denver, Colorado, pp. 1-23.

Singh, M. M., and Francis S. Kendorski, 1981. "Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments," *Proceedings, 1st Conference on Ground Control in Mining, Syd S. Peng (ed.), Department of Mining Engineering, West Virginia University, Morgantown, West Virginia*, pp. 76-88.

Singh, R. N., S. Hibber, and R. J. Fawcett, 1985. "Numerical Calculation of Groundwater Inflow to Longwall Coal Faces," *Proceedings of the Second International Congress, Convened by International Mine Water Association, Granada, Spain*, pp. 541-552.

Sloan, P. G., and R. C. Warner, 1984. "A Case Study of Groundwater Impact Caused by Underground Mining," *Proceedings, 1984 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, University of Kentucky, Lexington*, December 2-7, 1984, pp. 113-120.

Sloan, P. G., 1986. *Factors Determining Extent of Groundwater Disturbance from Underground Mining*, U.S. Bureau of Mines Research Contract Report Number J0199063 by SMC Martin, Inc., 129 pp.

Stoner, J. D., 1983. "Probable Hydrologic Effects of Subsurface Mining," *Groundwater Monitoring Review*, Vol. 3, No. 1, pp. 128-137.

Stoner, J. D., D. R. Williams, T. F. Buckwalter, et al., 1987. *Water Resources and the Effects of Coal Mining: Green County Pennsylvania*, Water Resources Report 63, Pennsylvania Geological Survey, Harrisburg, Pennsylvania, 166 pp.

Subitzky, S., 1976. *Greater Pittsburgh Region, Land and Water Studies for Environmental Analysis, Hydrogeologic Studies, Allegheny County, Pennsylvania*, Misc. Field Studies Maps MF-642A Through MF-641 E USGS, Washington, D.C.

Thompson, D. R., 1972. "Complex Ground-water and Mine Drainage Problems from a Bituminous Coal Mine in Western Pennsylvania," *Bulletin of Engineering Geologists*, New York, NY., Vol. 9, No.4.

Tieman, G. E., and H. W. Rauch, 1987. *Study of Dewatering Effects from Two Underground Longwall Mines in the Pittsburgh Coal of the Northern Appalachian Coal Field*, U.S. Bureau of Mines Information Circular 9137, pp. 72-89.

Tieman, G. E., H. W. Rauch, and L. S. Carver, 1992. " Study of Dewatering Effects at a Longwall Mine in Northern West Virginia," *Proceedings of the Third Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia*, pp. 214-221.

Tomic, V. and N. Kresic, 1985. "The Significance of Structural Investigations in Defining of Possible Directions of Inflow of Groundwater into Underground Mineworks," *Proceedings of the Second International Congress, Convened by the International Mine Water Association*, Granada, Spain, pp. 53-58.

Toran, L., and K. R. Bradbury, 1988. "Ground-water Flow Model of Drawdown and Recovery near an Underground Mine," *Groundwater*, Vol.26, No. 6, pp. 724-733.

Trevits, M. A., and R. J. Matetic, 1991. "A Study of the Relationship Between Saturated Zone Response and Longwall Mining Induced Ground Strain," *Proceedings of Fifth National Outdoor Action Conference, Las Vegas, Nevada*, National Water Well Association, pp. 1101-1109.

Van Roosendaal, D. J., D. F. Brutcher, B. B. Mehnert, et al., 1990. "Overburden Deformation and Hydrologic Changes Due to Longwall Subsidence in Illinois," *Proceedings Third Conference on Ground Control Problems in the Illinois Coal Basin, Y. P. Chugh (ed.),* Southern Illinois University, Carbondale, Illinois, pp. 73-82.

Wahler, W. A., and Associates, 1979. *Dewatering Active Underground Mines, EPA-600/7-79-124*, Interagency Energy/Environmental R&D Program Report, Cincinnati, Ohio, 124 pp.

Walker, J. S., 1988. *Case Study of the Effects of Longwall Mining Induced Subsidence on Shallow Groundwater Sources in the Northern Appalachian Coalfield*, U.S. Bureau of Mines, Report of Investigation 9198.

Walker, J. S., J. B. Green, and M. A. Trevits, 1986. "A Case Study of Water Level Fluctuations over a Series of Longwall Panels in the Northern Appalachian Coal Region," *Proceedings of 2nd Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia*, pp. 264-269.

Werner, E., and J. C. Hempel, 1987. *Effects of Coal Mine Subsidence on Shallow Ridge-top Aquifers in Northern West Virginia (Abstract)*, Geological Society of America Abstracts with Programs 19(1):65.

Werner, E., and J. C. Hempel, 1992. "Effects of Coal Mine Subsidence on Shallow Ridge-top Aquifers in Northern West Virginia," *Proceedings, Third Workshop on Surface Subsidence Due to Underground Mining, Syd S. Peng (ed.)*, Department of Mining Engineering, West Virginia University, Morgantown, West Virginia, pp. 237-243.

Whittaker, B. N., R. D. Singh, and C. J. Neate, 1979. "Effect of Longwall Mining on Ground Permeability and Subsurface Drainage," *Mine Drainage, Proceedings First International Mine Drainage Symposium, G. O. Argal and C. O. Brawner (eds.), Denver, Colorado*, pp. 161-183.

Williams, D. R., J. K. Felbinger, and P. J. Squillace, 1989. *Water Resources and the Hydrologic Effects of Coalmining in Washington County, Pennsylvania*, Unpublished report, prepared by U.S. Geological Survey.

Wright, W. G., 1987. "Hydrogeologic Factors Affecting Flow in the Ground-water Systems of the Coalfields of Southwestern Virginia," *Proceedings of the 1987 National Symposium on Mining, Hydrology, Sedimentology, and Reclamation*, pp. 419-422.

Wyrick, G. G., and J. W. Borchers, 1981. *Hydrologic Effects of Stress-Relief Fracturing in an Appalachian Valley*," U. S. Geological Survey Water-Supply Paper 2117, Washington D. C., U. S. Government Printing Office, 51 pp.

## 8.0 CONTACTS

Andrew N. Schaer, WV DEP, Logan
Jo Ann Erwiin, WV DEP, Philippi
Harold Parsons, WV DEP, Philippi
Jay W. Hawkins, OSM, Pittsburgh
Robert Biggi, OSM, Harrisburg
Rick Buckley, OSM, Charleston
Clifford H. Dodge, Bur. of Topographic and Geologic Survey, Harrisburg
Nick Fedorko, WV Economic and Geological Survey, Morgantown

Scott McCullough, WV Economic and Geological Survey, Morgantown
Thomas H. A. McKnight, Deep Mine Safety, Uniontown
Jack Paciga, Deep Mine Safety, Uniontown
Harry Payne, OH DNR, Columbus
Dan Ramsey, US Fish and Wildlife Service, Elkins
Roger Anderson, WV DNR, Elkins
Paul Ziemkiewicz, National Mine Land Reclamation Center, Morgantown
Joel Koricich, PA DEP, McMurray
Amy Stanley, PA DEP, McMurray
Laura Kirwan, PA DEP, McMurray
Joe Szunyog, PA DEP, McMurray
Mark Frederick, PA DEP, McMurray
Tony Tornowske, PA DEP, McMurray
Bob Sporcic, PA DEP, McMurray
Jeff Sowers, PA DEP, McMurray
Mike Dimatteo, PA DEP, Harrisburg
Mike Dimatteo, PA DEP, Harrisburg
Henry Rauch, WVU, Morgantown
James Kotcon, WVU, Morgantown
Colin Booth, Northern Illinois University, DeKalb
John Frazier, Greene County Coal Assessor, Waynesburg
Gary Riley, Washington County Coal Assessor, Washington
Bruce Leavitt, Consolidation Coal Company, Washington
Leslie Ruppert, USGS, Washington, D.C.
Jim Eychaner, USGS, Charleston
Rick Lorson, PA Fish and Boat Commission
Steve Kepler, PA Fish and Boat Commission
Gary Bryant, US EPA, Wheeling
Rudy Matetic, US DOE, Bruceton
Robert Kleinmann, US DOE, Bruceton
Paul Jeran, US DOE, Bruceton
Chris Mark, US DOE, Bruceton
Sue A. Perry, South Florida Natural Resource Center, Homestead
Eberhard Werner, Geologist, Morgantown

## 9.0 GLOSSARY OF HYDROLOGIC/HYDROGEOLOGIC TERMS
**(From Robert Bowen, Groundwater, 1980)**

| | |
|---|---|
| **Aeration, Zone of** | Subsurface between the surface and the water table divisible into a belt of soil water, an intermediate region and a lowermost capillary fringe. |
| **Apparent Velocity of Groundwater** | The apparent rate of movement of groundwater in the zone of saturation is expressible thus: $V = Q/A$, where $Q$ is the volume of water passing through a cross section of area $A$ in unit time. |
| **Aquiclude** | A stratum of low porosity absorbing water slowly and not transmitting it freely enough to comprise useful supplies for a well. |
| **Aquifer** | A permeable deposit which can yield useful quantities of water when tapped by a well. |
| **Artesian Aquifer, Confined Aquifer** | An aquifer in which the water is under pressure and confined beneath an impermeable deposit. |
| **Artesian Head, Negative** | Used in regard to a well in which the hydrostatic pressure is negative and the free water level is below the existing water table. |
| **Artesian Head, Positive** | Used in regard to a well in which the hydrostatic pressure is positive and the free water level is above the existing water table. |
| **Average Velocity of Groundwater** | The mean distance covered by mass of groundwater per unit of time (equal to total volume of groundwater passing through unit cross sectional area per unit of time divided by the porosity of the medium. |
| **Basin** | This is topographically either a river-drained area or low lying land encircled by hills. The geological meaning is different and given to an area in which stratified rock strata dip towards a central point, these strata possessing a centroclinal dip. |

| | |
|---|---|
| **Basin Recharge** | The difference between precipitation and runoff plus other losses, i.e. that part of the former which resides as groundwater, surface storage, and soil moisture. |
| **Capillary Fringe** | The belt of ground immediately above the water table, i.e. at the bottom of the zone of aeration and containing capillary water. |
| **Coefficient of Permeability** | The rate of flow of water through unit cross section of a medium under a hydraulic gradient of unity and at a specified temperature. Also known as coefficient of conductivity and coefficient of transmission. |
| **Cone of Depression** | This is the inverted conical depression in the water table round a well or borehole in which pumping is going on. Also known as cone of exhaustion and cone of influence. |
| **Darcy's Law** | This is used to determine the velocity of percolation of water through natural materials of granular type. |
| **Effective Porosity** | The ratio of the volume of water in a pervious mass previously saturated with water which can be drained by the force of gravity to the total volume of the mass. |
| **Effective Velocity of Groundwater** | The volume of groundwater passing through unit cross sectional area divided by effective porosity of the material. Also known as field, true, or actual velocity. |
| **Flowing Well** | A well in which the hydrostatic pressure of the water is sufficient to cause it to rise and flow out at the surface. |
| **Flow Net** | A net of equipotential lines and flow lines intersecting at right angles. |
| **Fluctuation of Water Table** | The alternate upward and downward movements of the water table due to period of intake and discharge of water in the zone of saturation. |

**Groundwater** Water in the zone of saturation.

**Groundwater Basin** A basin-shaped group of rocks containing groundwater and with geologic/hydraulic boundaries suitable for investigation and description. A basin of this type normally includes both the recharge and the discharge areas.

**Groundwater Budget** An estimate of water resources usually applied to a groundwater basin or province. Recharge, storage and discharge are important factors in it. Also known as groundwater balance.

**Groundwater Flow** Part of stream flow derived from the zone of saturation through seepage or springs. Also the movement of groundwater in the aquifer.

**Groundwater Storage** Estimate of the amount of water in the zone of saturation. The stage of the hydrologic cycle when water is leaving and entering groundwater storage.

**Head** The potential energy of water arising from its height above a given datum.

**Hydraulic Conductivity** A term occasionally used for coefficient of permeability.

**Hydraulic Gradient** In a closed conduit, this is an imaginary line connecting the points to which water will rise in vertical open pipes extending upwards from the conduit. In an open channel, it is the free surface of flowing water.

**Hydraulic Profile, Aquifer** A vertical section of the piezometric surface from any given aquifer.

**Hydrologic Cycle** The series of transformations occurring in the circulation of surface waters to atmosphere, to ground as precipitation and back to surface and subsurface waters.

**Hydrostatic Pressure** The pressure at any given point in a liquid at rest; equals its density multiplied by the depth.

| | |
|---|---|
| **Impermeable, Impervious** | Word used to describe a soil, rock, or other substance permitting the passage of water at an extremely slow rate. |
| **Infiltration** | Slow movement of water through or into the interstices of a soil. |
| **Infiltration Coefficient** | The ratio of infiltration to precipitation for a soil under specified conditions. |
| **Main Water Table** | The surface of the zone of saturation, *q.v.* Also termed the phreatic surface. |
| **Perched Water Table** | The upper surface of a small water body above a main water table and retained in its elevated position by an impervious stratum. |
| **Permeability** | Capacity of a rock or soil or other substance to transmit water. |
| **Phreatic** | A word applied to groundwater and its concomitants. Thus, groundwater may be referred to as phreatic water. |
| **Piezometer** | An instrument for measuring pressure head; normally a small pipe tapped into the side of a closed or open conduit and connected to a gauge. |
| **Piezometric surface, Potentiometric surface** | The imaginary surface to which water will rise under its full head from any given groundwater aquifer. |
| **Plane of Saturation** | The water table. |
| **Pore Pressure** | The pressure of water and air in the interstices between the grains of a rock or soil mass. |
| **Porosity** | The percentage ratio of the volume of voids to the total volume of a rock or soil sample. Thus where $P$ is the percent porosity, $W$ is the saturated weight, $D$ is the dry weight, $S$ is the weight of saturated sample when suspended in water. |

| | |
|---|---|
| **Potential Gradient, Groundwater** | The rate of change in potential in a mass of groundwater. Where no direction is specified, that of maximum gradient is taken. |
| **Potential Yield** | The maximum rate at which water may be extracted from an aquifer throughout the foreseeable future, ignoring recovery cost. |
| **Precipitation** | Total quantity of water falling as rain, hail, snow, and expressed as millimeters or inches of rainfall over a specified period. Moisture deposited as dew. |
| **Pressure Head** | Describes the water pressure in a system, expressible a $N/mm^2$ or psi or as meters or feet head. |
| **Pumping Test** | (1) Water yield: quantities and water levels are recorded during the test period. The test pumping rate is usually greater than that at which water will be needed and covers a period long enough to show whether the yield can be maintained. (2) Water quality: taking samples of water during the test to determine by chemical analysis the major constituent and organic purity. Such tests may extend over 2 weeks. |
| **Runoff** | That part of precipitation flowing from a catchment area and finding its way into streams, lakes, etc. Includes direct runoff and groundwater runoff. |
| **Specific Capacity (of a well)** | This is the rate at which water can be pumped from a well per unit of drawdown, *q.v.* |
| **Specific Yield** | The quantity of water which a unit volume of soil or rock will yield after being saturated and allowed to drain under specified conditions. Expressed as a percentage of volume. |
| **Storage Coefficient, Aquifer** | The ratio of (a) the volume of water taken into or released from storage in a prism of aquifer of unit surface area and the total thickness of the aquifer to (b) the volume of the prism of aquifer per unit change in the component of pressure head normal to that surface. |

| | |
|---|---|
| **Storage of Aquifer** | The amount of water released from storage in an aquifer with a given lowering of head. |
| **Total Porosity** | This term includes capillary porosity, i.e. the small voids holding water by capillarity, and non-capillary porosity, i.e. the large voids which will not hold water by capillarity. |
| **Unconfined Groundwater** | Groundwater which is not restrained in its movement by an impervious or confining bed above or below. |
| **Vadose Water** | Water held in the zone of aeration. |
| **Water Table** | The surface of the zone of saturation. Subject to fluctuation, it follows in a flatter form the profile of the land surface. |
| **Water Table Gradient** | The inclination of the water table. |
| **Water Table Level** | That level at which the water table is encountered in borehole or well. |
| **Well** | An excavation from the surface to obtain water ranging from shallow level to about 400 ft. |
| **Yield** | Usually the economic yield of a well. Probable yield can be estimated if the permeability of the strata is known and a short pumping test is effected in order to give the different values of drawdown for successive increases in rate of pumping. |
| **Zone of Aeration** | The ground above the main water table and extending to the surface. Comprising in ascending order the capillary fringe, *q.v.*, an intermediate belt, *q.v.* and the belt of soil water, *q.v.* Obviously variable in thickness. |
| **Zone of Saturation** | The mass of water-bearing ground below the main water table and comprising solid rocks and incoherent materials. |

# CHAPTER 5

# SURFACE SUBSIDENCE AND STRUCTURAL DAMAGE

David A. Newman, Ph.D.
Appalachian Mining and Engineering, Inc.
Lexington, Kentucky

# 1.0 SURFACE SUBSIDENCE AND STRUCTURAL DAMAGE

The objective of this section is to describe the mechanics of surface subsidence for both longwall and room-and-pillar mining methods. A discussion of both methods is essential to the understanding of the extraction sequence, the onset and development of subsidence, and to introduce basic subsidence and mining terminology.

## 1.1 SUBSIDENCE ATTRIBUTABLE TO FULL EXTRACTION MINING

### 1.1.1 Historical Background on the Pittsburgh Coal Seam

The Pittsburgh coal seam known as the No. 8 seam in Ohio and the Big Vein in Maryland is perhaps the most historically and economically significant coal deposit in the United States. It covers approximately 6,000 square miles over portions of Western Pennsylvania, Northern and Central West Virginia, Eastern Ohio, and Western Maryland. The Pittsburgh seam is the lowest coalbed of the Monongahela Series, Pennsylvanian Era and dates to between 310 and 325 million years (Seyfert and Sirkin, 1973).

Studies of Pittsburgh seam date to 1759 (Kenny, 1913) where reference was made to a coal seam being mined from the hills surrounding Pittsburgh. The economic importance, geology, and geographic extent of the seam were studied in detail during the late 1800's as described by Rogers (1884). This effort intensified during the early 1900's when stratigraphic correlations were established across Western Pennsylvania, Northern West Virginia, Maryland, and Southeastern Ohio. Although the Pittsburgh seam has been heavily mined for over one hundred years, a substantial reserve base still remains in Western Pennsylvania and Northern West Virginia. Because of the seam height, re-mining activities including pillar recovery from abandoned underground mines using surface and underground methods is economically viable.

The combination of the excellent coking characteristics of the Pittsburgh seam in Western Pennsylvania, the local availability of limestone, and the low cost of shipping iron ore culminated in the establishment of Pittsburgh as a Northern center of steel production. Many of the first large underground mines were owned and operated as captive mines by major steel producers. However, beginning in the late 1970's the steel companies divested their captive mines, opting to purchase metallurgical coal or coke in lieu of mining. Western Pennsylvania, Maryland, and Northern West Virginia hold the best reserves in terms of quality and thickness. Outside of this region, the Pittsburgh seam thins and the coal quality diminishes from metallurgical (coking) coal to a steam coal used for power generation. Presently, the vast majority of the Pittsburgh seam is used for steam coal.

### 1.1.2 Background and Units Operations for Longwall and Room-and-Pillar Mining

Longwall and room-and-pillar are the predominate underground mining methods used to extract the Pittsburgh coal seam. All underground mining was initially done by room-and-pillar methods until the 1950's to 1960's when mechanized longwall mining was first introduced in the Northern Appalachian coalfield. For typical Pittsburgh seam mining conditions, longwall mining is more productive, less labor intensive, safer, lower cost, compared to room-and-pillar mining. Consequently, it is the predominate underground mining method in the Pittsburgh seam. Presently, all the underground longwall mines in the Pittsburgh seam operate double drum shearers as opposed to plows. Room-and-pillar mining is relegated to longwall development including mains, submains, and gate roads.

Prior to discussing the onset of surface subsidence above areas of full extraction mining, a brief discussion of the unit operations of each method and mining terminology is helpful. Room-and-pillar mining involves driving between five (5) and nine (9) parallel entries or "tunnels" into the solid coal. The entries are typically eighteen (18') feet to twenty (20') feet wide. Connections between adjacent entries, known as crosscuts or breaks are driven at standard intervals. The spacing between adjacent entries and crosscuts varies dependent upon the overburden thickness, required pillar safety factor for a specific area of the mine, statutory, and operational considerations. Overburden is the rock between the ground surface and the top of the coal seam. The main operational consideration is the Mine Safety and Health Administration (MSHA) approved depth to which the continuous miner can cut prior to withdrawing to permit the installation of roof support. The entry and crosscut centers (distance between the mid point of one entry/crosscut to the adjacent entry or crosscut) are typically spaced on integer multiples of the cut depth for efficient and economic mining. Entry and crosscut spacing commonly ranges between sixty (60') feet and one hundred (100') feet. However, the spacing of specialized longwall pillars called abutment pillars may exceed two hundred (200') feet dependent upon the overburden and longwall panel width. These pillars are used in conjunction with smaller yielding pillars, spaced fifty (50') feet to sixty (60') feet apart to provide improve roof conditions and safety on the longwall panels.

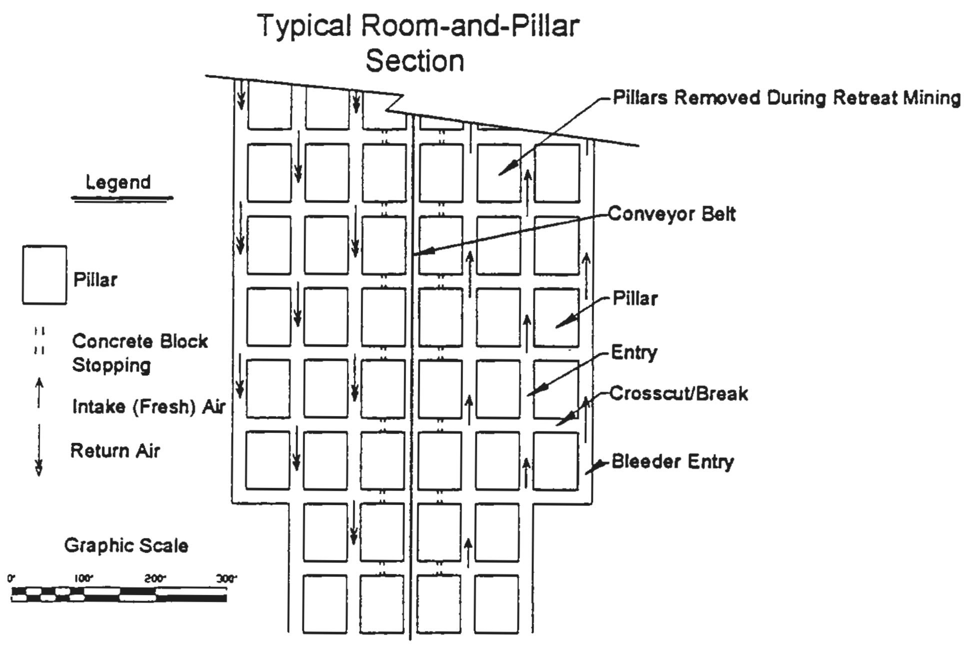



**Figure 1. Typical Room-and-Pillar Panel With Full Pillar Extraction.**

A typical room-and-pillar production panel is illustrated in Figure 1. Here the seven (7) entries have been driven with intervening crosscuts. During secondary pillar mining all the pillars will be removed except those at the entrance or neck of the panel. The pillars are pulled across a given row and the immediate roof rock falls into the void created by pillar removal. Wood timbers, cribs, or posts are set in the entries and crosscuts to protect the equipment operators from the failed roof rock called "gob." These supplementary supports crush out over time and are not intended to support the mine roof. One to two pillar rows, known as a "bleeder" are left standing at the back end of the panel for the purpose of routing dust and gas laden air out of the mine using one or more large ventilation fans. Typically the pillars in the first panel of a series of panels are left standing to serve as the main bleeder. Subsequent panels are connected to this first panel at the upper end to form a continuous or "wrap around" bleeder system. For subsequent panels, all the pillars are recovered because the gas and dust laden return air is pulled through the gob into the "wrap around" bleeder.

In longwall mining, a rectangular block of coal ranging between seven hundred (700') feet and twelve hundred (1,200') feet in width by two thousand (2,000') feet to fifteen thousand (15,000') feet long is isolated from the reserve by a headgate, tailgate, bleeder, and submains. As shown in Figure. 2, the headgate and tailgate are comprised of a set three (3) to five (5) parallel entries driven on either side of the longwall block. A bleeder consisting of two to three parallel entries connects the headgate and tailgate at the back end of the longwall block. The headgate is used to transport coal from the longwall face using a conveyor belt located in the entry adjacent to the longwall block. Miners and supplies reach the longwall face by rail on the track entry located next to the belt entry. Intake or fresh air travels up the headgate entries, passes across the longwall face diluting dust and gas, and travels down the tailgate as return or dirty air on its way out of the mine. The location of the gateroads (headgate and tailgate), abutment pillars, bleeders, and submains are illustrated in Figure 2, a three dimensional view of a longwall panel.

Coal is extracted from the longwall block using a track mounted shearer or a plow mounted on wire rope that travels back and forth across the width of the longwall block. The shearer has two rotating drums and is mounted on a conveyor which traverses back and forth across the longwall face. Figure 2 illustrates a typical longwall shearer. A plow has multiple pick-like teeth and is pulled across the face with wire rope. The plow is limited to soft, weak coals whereas the shearer can be used under any conditions. Hydraulic shields support the roof once the coal has been removed and protect miners and face equipment from the caved rock or gob as it falls in behind the shields.

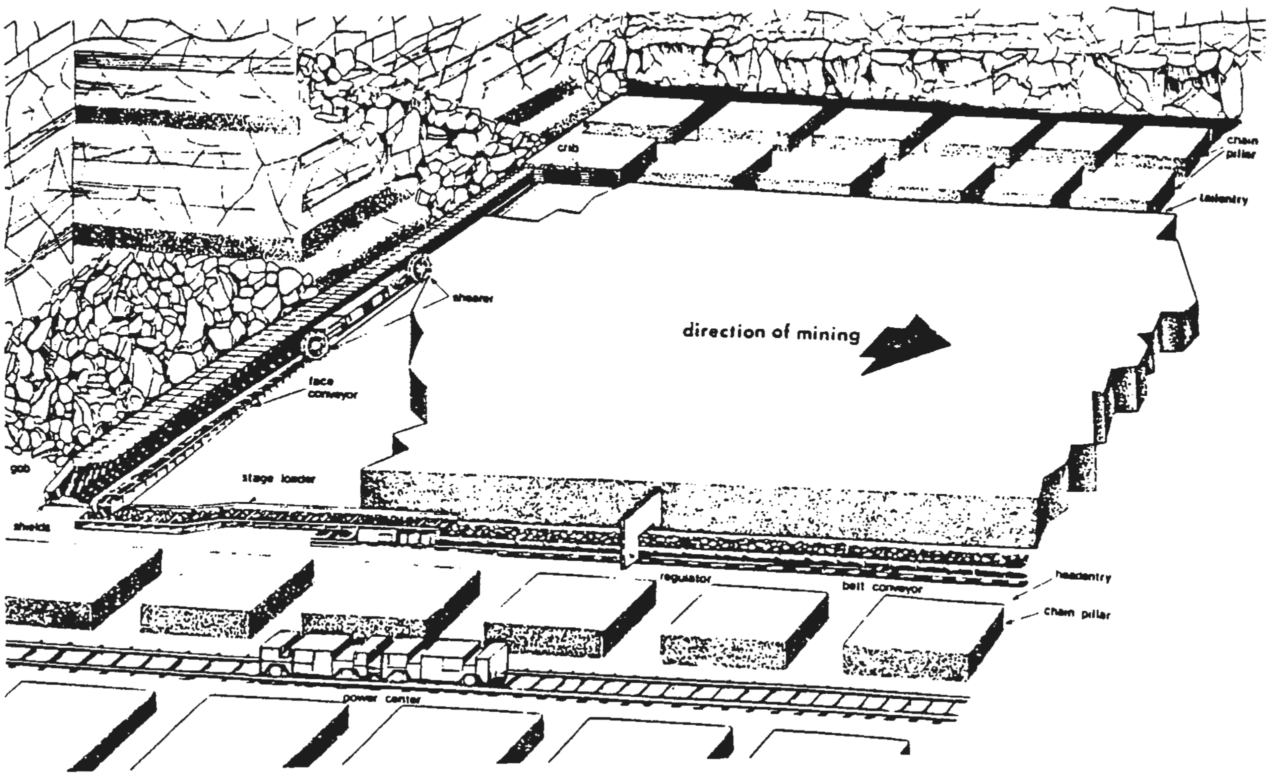



**Figure 2. Typical Longwall Retreat Panel Layout (Peng, 1984).**

### 1.1.3 Mechanics of Subsidence in the Pittsburgh Coal Seam

When full extraction mining occurs four distinct zones are created in the rock strata above the coal seam; caved zone, fractured zone, zone of bed separation or sagging, and surface cracks. These zones are shown in Figure 3, an idealized cross section taken through the mined out area.

The sequence of events through which these zones develop and culminate in surface subsidence follows. The sequential collapse of the roof rock propagates upwards until the increased volume of broken rock completely fills the void space, preventing further roof falls. This forms the upper boundary of the caved zone that is comprised of broken rock. Because the broken rock in the caved zone cannot support the weight of the overlying rock in the same manner as it did when it was intact, the overlying rock bends or sags into the caved zone. The height of the caved zone is empirically established as 3t to 10t where t is the mining height. For a six (6') foot mining height, typical of the Pittsburgh seam this is between eighteen (18') feet and sixty (60') feet above the top of the coal seam.

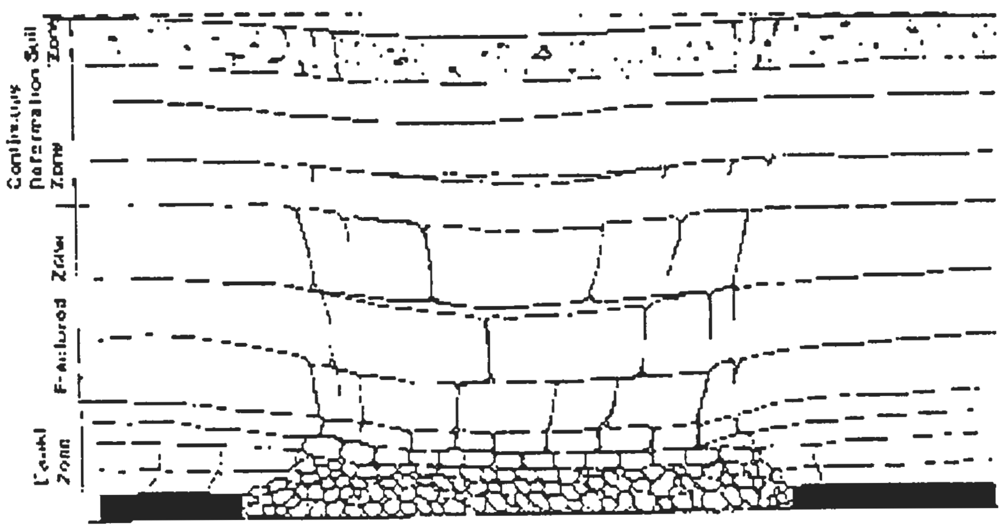



**Figure 3. Idealized Cross Section Through Subsided Ground (Singh and Kendorski, 1981).**

Rock is a competent, rigid, and brittle material that fails at displacements in the hundredths of inches. Consider, the weakest coal measure rocks including fireclays, mudstones, siltstones are typically stronger than concrete (3,000 lb/in$^2$). Sandstone, sandy shale, and limestone can have compressive strengths in the range of 10,000 lb/in$^2$ to 20,000 lb/in$^2$. Consequently, fractures develop in the strata above the caved zone as the beds bend and deform. The weight of the rock within the fractured zone compacts and consolidates failed rock within the caved zone to the point where the fractured zone is supported by the caved zone and no further movement occurs. The extent of the fracture zone ranges between 6t to 10t and 24t to 30t (Kendorski, 1993).

The downward movement in the fractured zone is propagated upwards to the zone of bed separation or sagging/dilated zone. Here, the void created by the fractured zone is not sufficient to induce failure but rather the beds delaminate and separate from each other. This dilated zone occurs over a range of 24t to 30t and 60t above the mined out area (Kendorski, 1993). The sagging and bed separation is translated into a series of surface fractures resulting from tensile movement on the ground. Above 60t a constrained zone is present where fractures may be partially closed or self healed due to compression within the overburden.

The surface cracks are generally shallow extending to fifty (50') feet below the surface. As shown in the cross section, under sufficient overburden *there are no continuous fractures that connect the ground surface with the mine void.* If water does drain from the surface into the mine void it is generally over a long period and through a complex series of stair step cracks. The preceding statements are not true under shallow overburden where the fractured zone may intersect the surface. Under these conditions, a direct conduit is established between the mine void and any surface water.

The magnitude and direction of the surface and overburden movement varies with location over the mine void. As would be anticipated, the greatest subsidence occurs in the center of a longwall panel or room-and-pillar panel as shown in Figures 3 and 4. Movement in the center of a full extraction panel is completely vertical. In all other areas, the movement is a combination of horizontal and vertical displacement as the strata and ground surface is stretched and pulled toward the center of the mine void. The movement extends past the area of full extraction to adjacent areas above solid coal. As the areal extent of the mined out area increases, a trough or bowl forms on the surface as the ground moves to the center of the full extraction area.

The basic subsidence terminology is listed in Figure 4. The angle of draw ( ) is the angle between a vertical line from the coal seam to the surface and the extent of ground movement. Although simple in concept, the field definition is subjective since there is a "gray" area separating no movement from minimal movement that is partially composed of the inherent error in surveying, heave due to the warming and cooling of the ground. Typically, a low threshold of ground movement is established as "zero movement." The angle of draw varies , dependent upon the rock type or lithology. Sandstones, sandy shales, and limestones referred to as "hard" rocks have a smaller angle of draw compared with weaker shales, siltstones, claystones, fireclays, coals, and other "soft" rocks. An approximate range for the angle of draw is between fifteen (15°) degrees and thirty-five (35°) degrees.

The maximum subsidence, $S_{max}$ equals the mining height times a constant "a" that depends upon the percentage of hard, resistant rock in the overburden and the ratio of extracted width to overburden thickness. The constant "a" varies between 0.20 and 0.65 (Karmis, et.,al, 1984). A full extraction area is described as subcritical, critical, or supercritical dependent upon whether the maximum amount of subsidence has occurred. The subsidence trough develops both laterally and vertically as the width of extraction increases. At the critical width, the maximum subsidence ($S_{max}$) develops at a single point in the trough. Once the extracted area exceeds the critical width (supercritical), the maximum subsidence is achieved over the flat portion of the subsidence trough.

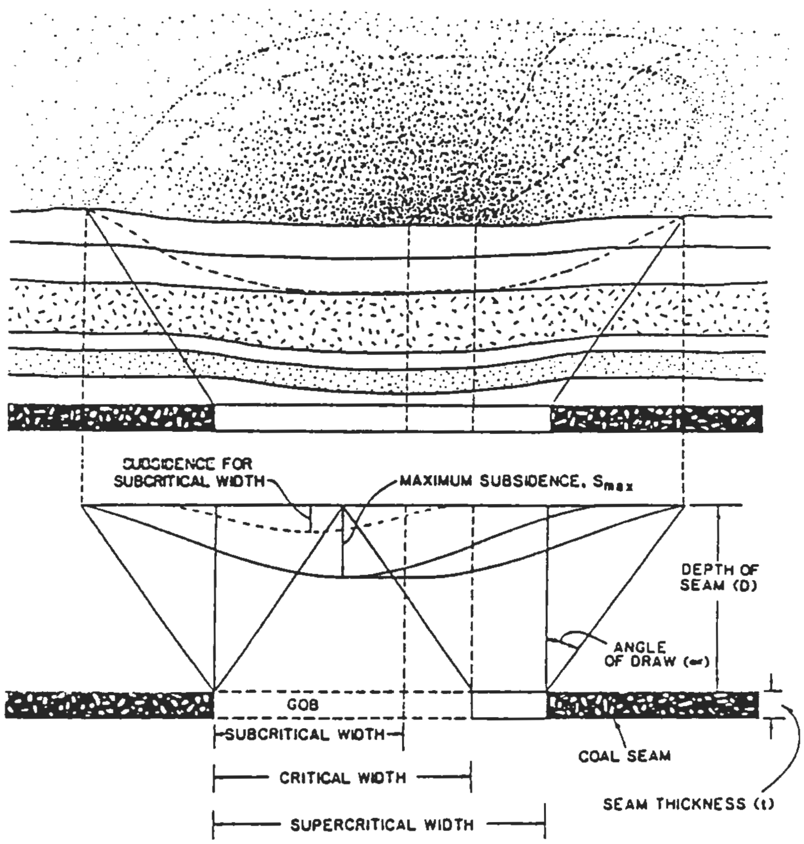



**Figure 4. Influence of Mine Subsidence on the Overburden and Surface (Mining Engineers Handbook, 1992).**

The maximum vertical movement (subsidence) occurs over the center of the panel while the maximum horizontal movement (surface cracking) occurs at the edge of the panel. Horizontal strain is a dimensionless quantity, defined as the horizontal movement per original unit length (inches/inch). The horizontal strain reaches a maximum (see Figure 5) on either side of the panel edge. Outside the panel, the strain is tensile as the surface deforms toward the subsidence trough. Within the trough the strain is compressive. Tensile and compressive strains have distinctly different effects on surface structures.

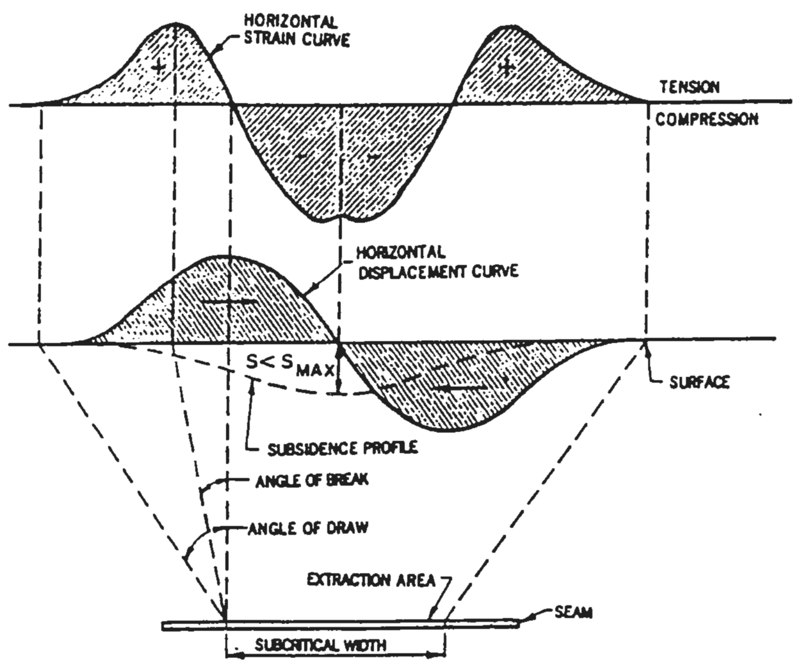



**Figure 5. Horizontal Strain and Horizontal Displacement Curves Above a Longwall Panel. (Mining Engineers Handbook, 1992).**

Although both full extraction room-and-pillar mining and longwall mining create void areas beneath the surface, the subsidence behavior in response to each method can be significantly different. Longwall mining by nature is constrained to the complete recovery of large, rectangular blocks of coal. The geometry of the extraction areas is uniform and consistent. Once the longwall panels have been designed and the gateroads driven, no changes can be economically made to the panel dimensions or the extent of coal recovery. Consequently, the resulting subsidence is similarly uniform, predictable, and may modeled by either analytical or numerical methods.

A room-and-pillar mine plan is composed of a series of smaller rectangular panels. Each panel is composed of a series of individual rectangular or square pillars. In comparison to longwall mining, room-and-pillar mining is very flexible. A panel can be lengthened or shortened based upon changes in geological, market, mining conditions or operational constraints. These decisions to alter panel geometry and extraction are made quickly, often by mine foremen or the superintendent and have minimal affect on the continuity of the mining operation. Mine economics are predicated on the complete recovery of the entire panel once a panel is developed to its limit. However, during pillar recovery the decision can be made to not to recover portions of individual pillars or several rows of pillars, or the remainder of the panel due to mining conditions or economics. Because of a potentially irregular extraction geometry, room-and-pillar subsidence can be highly variable and difficult to predict. There are instances where subsidence will not occur even though pillars have been extracted. If the areal extent of pillar recovery and mine void is insufficient to initiate caving of the main roof, no further movement will occur in the overburden or on the surface. If a massive sandstone, limestone, or sandy shale bed is present in the overburden,"bridging" can occur between the areas of solid coal or barrier pillars that separate areas of complete pillar extraction.

There are many factors that affect the magnitude and rate at which the subsidence occurs for both room-and-pillar and longwall mines. Factors that increase the magnitude of subsidence include;

- greater mining height (sum of the coal seam thickness, in-seam rock partings, and out-of-seam rock taken during mining),
- weak and/or thinly bedded overburden,
- presence of faults or regional discontinuities,
- weak or water sensitive immediate floor strata,
- abandoned, overlying mine(s) where full pillar recovery was not practiced,
- areas of steep slopes where surface movement may initiate landslides,
- critical to supercritical panel widths,

- unconsolidated material, thick soil layer, or glacial till on the surface, and
- thin overburden (<200 feet).

Subsidence is proportional to mining height so the thicker the seam, the greater the magnitude of surface subsidence. Similarly, subsidence is proportional to the extracted width to the critical width where the maximum subsidence is achieved. Where the overburden strata are weak, easily fractured, and have a lower "swell" factor, a greater percentage of the mine void is manifested as surface subsidence. Under areas of low overburden the fractured zone and possibly the caved zone may intersect the surface creating a circular cavity, known as chimney subsidence. In areas where the rock surface is blanketed by a thick layer of unconsolidated material or soil, this material tends to enter into fractures and develop a larger, deeper subsidence trough. Many of the empirical subsidence prediction techniques rely upon the ratio of mining width to overburden depth to predict subsidence.

Subsidence is a time dependent process. Where full extraction mining is practiced, subsidence at a given point on the surface begins in advance of direct undermining. As illustrated in the cross sectional view of Figure 4, the adjacent ground moves toward the extraction zone as described by the angle of draw. The same concept is applicable to the ground surface in advance of mining. For a given point on the ground surface, subsidence is analogous to an ocean wave passing by a buoy. At first the buoy is drawn toward the wave, it then moves vertically as the wave crest passes over the buoy, and finally moves in the direction of the wave as it passes. The entire range of movement is frequently not appreciated when viewing a final subsidence cross section as shown in Figure 4.

Subsidence is measurable when the active face is within 1.00H (H = the overburden depth) (Peng, 1992) of a given point on the surface. When the face is directly below a point approximately seven (7%) percent of maximum subsidence occurs. As shown in Figure 6, the remaining subsidence occurs rapidly once the face has passed the given point. Approximately ninety (90%) percent of the subsidence event is completed when the face passes 1.20H. This is the primary subsidence phase which occurs in response to the mining. In longwall mining the primary subsidence is typically completed within two (2) to four (4) weeks after undermining. This range can vary based on the rate at which the face is retreated, the percentage of hard rock within the overburden, and the overburden thickness.

A secondary or residual phase follows as the broken gob within the caved zone consolidates and compacts under the gravity loading of the overburden. The time required for this phase can vary between one (1) month and several years (Gray et al., 1977) depending upon the overburden thickness. For longwall mining, both the primary and secondary subsidence events are concluded within one (1) to two (2) months after mining. At this point, no further ground movement should be anticipated. A distinct benefit of longwall mining is that the subsidence event is both predictable in terms of magnitude, direction, timing, and duration. Subsidence can be easily monitored through routine surveying techniques. In fact surface surveyed has provided the data upon which empirical subsidence prediction methods are based. It is used to verify numerical and analytical models. Consequently, protective modifications can be made to surface structures in advance of undermining and remedial measures taken after the subsidence event with the knowledge that surface deformation has ended.

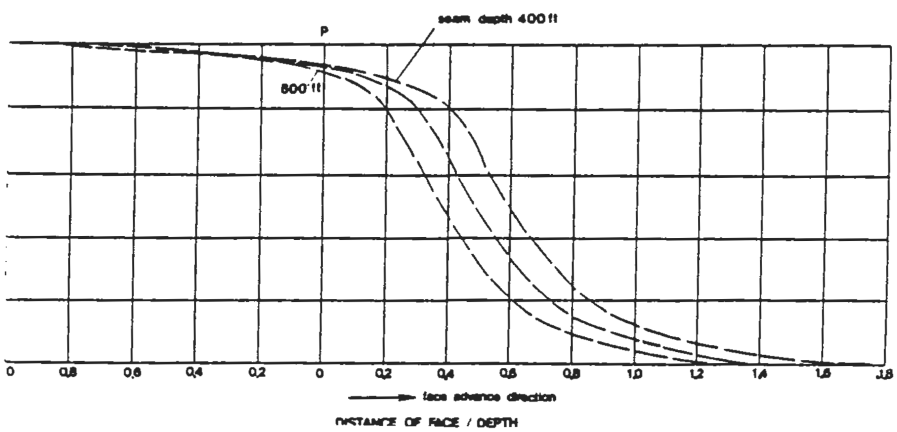



**Figure 6. Subsidence Development Curve as a Function of Face Advance and Overburden Depth. (Peng, 1992).**

For room-and-pillar mining, the subsidence process is slower. As pillar extraction or retreat mining progresses, the first falls are generally to the height of the roof bolts. Once the immediate roof has failed, the main roof strata bend into the void space created by the collapse of the immediate roof. The roof fall continues to propagate into the overburden until the extent of the caved zone is reached. However, the initial panel width may not be sufficient to break thicker or stronger rock beds within the overburden. Good mining practice and the Federal Code of Regulations Part 75.388 states that a minimum barrier, fifty (50') feet wide shall separate active and abandoned or pillared areas of an underground mine unless a program of test drilling is carried out. Consequently, room-and-pillar panels are commonly separated by a fifty (50') foot barrier of solid coal. This has the effect of providing an abutment between caved panels and permitting competent strata in the overburden to "bridge" across mined out panels. Consequently, subsidence may not be manifested on the surface if bridging occurs and the seam is sufficiently thin that roof and floor converge without roof failure or it may be delayed until multiple panels are extracted.

Subsidence prediction is further complicated for room-and-pillar mining because individual pillars or multiple rows of pillars may not be extracted because of geologic or mining conditions. Furthermore, partial pillar extraction is frequently practiced where one (1) to five (5) cuts are taken from a pillar and full roof caving does not occur. In this instance, subsidence may never occur or its onset is delayed for several years to decades. Under partial extraction, pillar failure may occur through weathering and deterioration. Pillar punching may occur as the immediate floor is weakened over years of saturation as the mine is inundated. Examples of delayed subsidence events are commonly limited to older room-and-pillar operations, under shallow overburden where full pillar recovery was not practiced. Here extraction ratios between sixty (60%) percent and eighty (80%) percent were achieved through driving long, narrow pillars or splitting pillars on retreat. In comparison to longwall mining, the magnitude, direction, and timing of room-and-pillar subsidence is not as uniform and more difficult to predict. Consequently, protective and remedial measures for surface structures cannot be implemented as easily above room-and-pillar mines practicing full pillar in comparison to longwall mines.

Since the Surface Mining Control and Reclamation Act (SMCRA) of 1977 that requires all mine operators to have a subsidence control plan, subsidence has played an integral part in mine planning and permitting. Since implementation of the Act, underground mine planning is a dichotomy between full extraction or limited extraction. Under the latter category, panel extraction is commonly limited to fifty (50%) percent or less. In practice, regulatory approval to mine is easier and quicker for a limited extraction plan under which full recovery is not practiced. However, limited extraction mining is a tremendous waste of natural resources because once the mine operator pulls back from an active panel it is uneconomic to go back and recover pillars. When a panel is abandoned or the mine is closed, the coal remaining in the pillars is lost forever. Considering barrier pillars left to protect main entries, under a limited extraction plan the total recovery of a coal reserve ranges between thirty (30%) to forty (40%) percent. Since coal is a non renewable resource, limited extraction plans waste or sterilize the finite amount of available resource. Furthermore, implementation of a limited extraction plan may serve only to delay the onset of subsidence for decades as discussed. European counties have historically sought to maximize resource recovery through full extraction mining, carefully synchronized with protective measures for surface structures. These measures, addressed later in this chapter, enable the undermining of cities and smaller towns, minimizing surface damage and disruption to human activity.

The surface manifestation of subsidence varies according to surface topography. On flat, cleared ground subsidence trough development is relatively easy to see through either a change in the topography or by the creation of localized depressions or ponded water. In hilly terrain subsidence is obscured by vegetation and changes in surface elevation that may be one to three orders of magnitude greater than the subsidence trough. For hilly topography subsidence is commonly evident as fractures colloquially referred to as "mountain breaks." These features are located in hard, competent, erosion resistant strata (sandstone, sandy shale, limestone) on ridge flanks, immediately below the ridge line.

Dependent upon the soil strength and physical properties (shear strength, cohesion, and friction angle) subsidence may cause localized slope failure or landslides. The combination of hilly topography, soil strength and physical properties, presence of groundwater seeps or springs has rendered certain areas historically slide prone. Subsidence induced ground movement may be sufficient to destabilize marginally stable slopes and initiate failure within the soil horizon and through any unconsolidated material. Slope failure may also develop as surface water and/or storm runoff enters into upslope tension cracks. The prediction of subsidence induced slope failure requires a considerable amount of soil information and thorough knowledge of the existing slope stability.

## 2.0 EFFECT OF SUBSIDENCE ON SURFACE STRUCTURES

The sequence and magnitude of ground movements associated with mine subsidence are dependent upon a multitude of mining and geological factors. The magnitude, direction, and timing of these movements range between uniform, predictable (longwall mining) and erratic, difficult to calculate (partial extraction room-and-pillar mining). Similarly, the effect of mine subsidence on surface structures varies with the type of structure, construction (wood frame, masonry, stone) type and quality, condition/maintenance, and foundation. Surface structures where the effect of mine subsidence should be analyzed include commercial and public buildings, churches, cemeteries, private residences, utility (electric, telephone, cable) transmission towers/poles, pipelines (oil, natural gas, water, sanitary and storm sewer), railroads, bridges, and roads.

The expression of subsidence on the ground has been divided into four (4) categories (Peng, 1992, Brauner, 1973, Mahar and Marino, 1981):

- surface cracks and fissures,
- steps,
- pits or cave-ins, and
- compression zones.

Surface cracks, fissures, and "mountain breaks" range from nearly imperceptible soil cracks to deep openings, multiple feet wide and long. The most severe cracks occur under shallow overburden where the overburden depth is less than fifty (50) times the mining height (Peng, 1992) and within resistant rock strata along ridge flanks. For the typical six (6') foot Pittsburgh seam mining height, this translates to overburden depths less than three hundred (300') feet.

The cracks open in response to tensile strains in advance of and on the sides of the moving panel. Those cracks occurring in advance of mining, for example in center of a longwall panel, dilate as the face approaches a given point and close once the face has passed this point. In woodland and agricultural areas smaller cracks are "self healing" because they are filled by soil and leaf debris. The more severe cracks that remain dilated at the conclusion of mining frequently must be backfilled and regraded.

A step or sharp drop-off in topography most commonly occurs under shallow overburden, at the boundaries of retreat mining, along a fault plane or other geologic discontinuity, or when the continuous movement of the retreat mining face has stopped. Steps have a vertical component of movement where the elevation of opposite sides of a surface crack differ by several inches to several feet.

Pits, cave-ins, or chimney subsidence occurs under very shallow overburden (100 feet or less) where the fracture of caved zone reaches the surface or unconsolidated material. Here the ground collapses directly into the mine void and forms a circular depression around the area. This phenomenon is most common above old, abandoned room-and-pillar mines. The subsidence event can be triggered by a roof collapse, pillar failure, or pillar punching in a localized area. This type of subsidence is extremely difficult to predict and frequently occurs many years after mining has been completed.

Compression zones form in valleys and topographic lows or near the center of extraction panels where the ground has moved from the surrounding areas of tension. Buckling and heaving of the ground on the order of one (1) foot to several feet (Peng, 1992) are the most common features associated with compression zones.

The ground movement above an extraction zone is non-uniform as illustrated in Figures 4, 5 , and 6. Consequently, a surface structure may be subjected to compressive and tensile strains, curvature and bending, torsional (rotational) deformation, tilt, and twisting, and shear movement dependent upon its location and orientation relative to the extraction panel. For longwall mining these ground movements can be predicted and quantified to within several tenths of a foot. As previously mentioned, the complexity, non-uniform geometry, and wide variation in panel dimensions of room-and-pillar extraction diminishes the predictability of subsidence.

In Figure 8 examples of common foundation and superstructure types in residential home construction are illustrated. Prime concerns in evaluating the stability of an existing foundation include;

- soil bearing capacity and strength properties,
- degree of compaction prior to footer installation,

- elevation and fluctuation of the groundwater table,
- drainage provisions at the footer horizon,
- prior settlement,
- adherence to local building codes, and
- location of pre-existing cracks in the foundation or superstructure, foundation failures.

Minimum structural damage occurs when the surface structure is in the center of the extraction panel with the long axis of the structure parallel with the direction of retreat and the rate of extraction is both rapid and continuous. In areas of tensile strain (see Figure 5) vertical and stepwise diagonal cracks develop and are most obvious in the masonry exterior. The cracks may initiate at the top or bottom of the structure respectively dependent upon whether the ground curvature is concave or convex. The typical crack geometry indicative of specific ground movement is illustrated in Figure 9. Cracks propagate in a stair step fashion along the mortar joints within brickwork, beginning at a corner, door frame, window or other structurally weak area. The cracks are generally dilated wider at the location of greater tension (top for convex, bottom for concave curvature). When a structure is orientated at angle to the direction of retreat mining, twisting or angular movement causes differential settlement of the foundation. The greatest damage occurs in the pair of walls connecting those that most closely parallel the mining orientation. Here the twisting results in the binding of exterior entry doors, garage doors, and windows. Vertical displacement cracks also appear in continuous floor slabs.

Damage in the zone of compressive strain is manifested by a buckling, bowing, tilting, or outward movement of masonry walls. Buckling or upward movement of the floor may occur in materials other than concrete slabs. Horizontal cracks commonly form in the lower portion of a structure along mortar joints between windows and doors. The difficulty with separating these individual movements is that a structure may be subject to more than one form of ground movement as the undermining progresses.

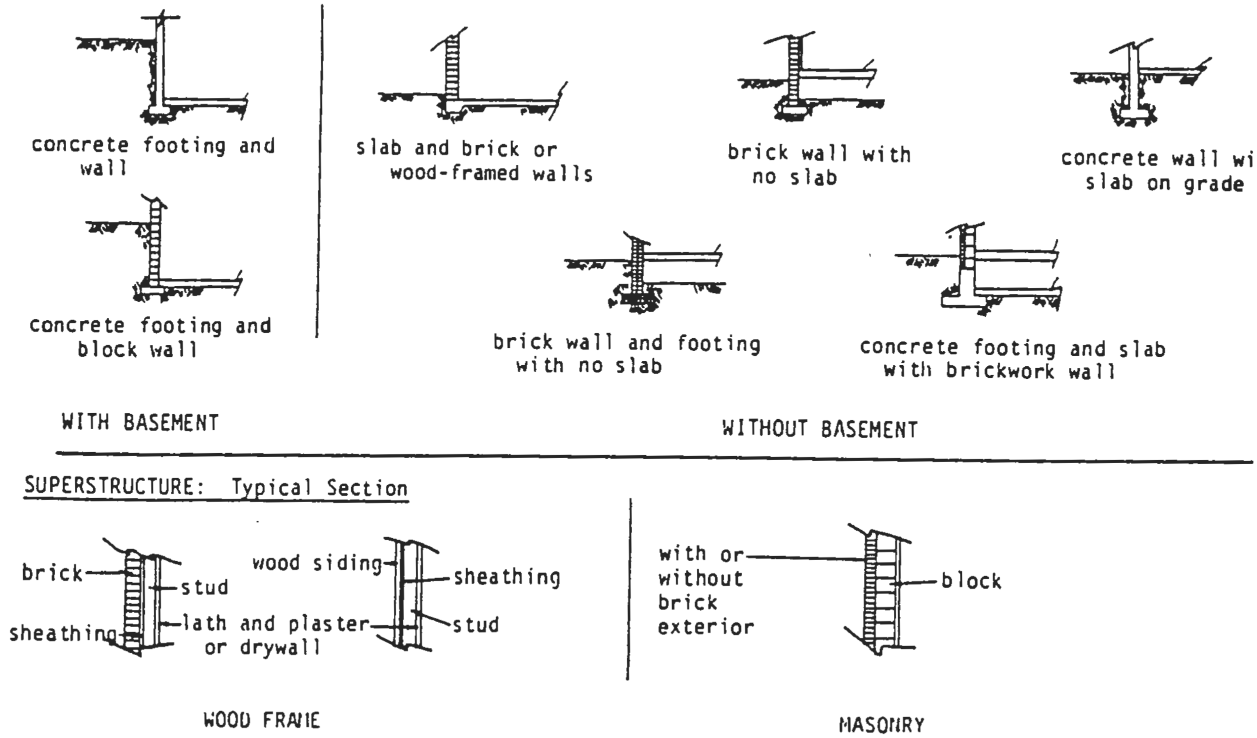



**Figure 8. Common Foundations and Superstructures for Residential Structures (Mahar and Merino, 1981.)**

Damage indices and classifications have been developed in Europe and the United States. Bruhn et, al., 1982 proposed a damage classification and basement repair severity classification for the Northern Appalachian coalfield that is shown in Table 1. Kratzsch (1983) developed a table (TABLE 2, modified by Peng, 1992) ranking the sensitivity of various surface structures and land to the effect of subsidence, changes in slope, curvature, displacement, tension, and compression. Both Tables 1 and 2 are qualitative in terms of description and subsidence prediction. A more extensive and quantitative set of damage criteria are summarized in Table 3 by Singh, 1992.

It should be noted that although the magnitude and orientation of ground movement, strain, and curvature can be readily determined through analytical and numerical methods, these are not the quantities transmitted to a given structure. The contact between the foundation and the surrounding soil is not rigid. Consequently, slippage develops between the soil and foundation effectively dampening the soil movement and strain as they are transferred to the foundation. The amount of dampening varies depending upon the quantity (subsidence, strain, displacement) and the plane in which the movement occurs.

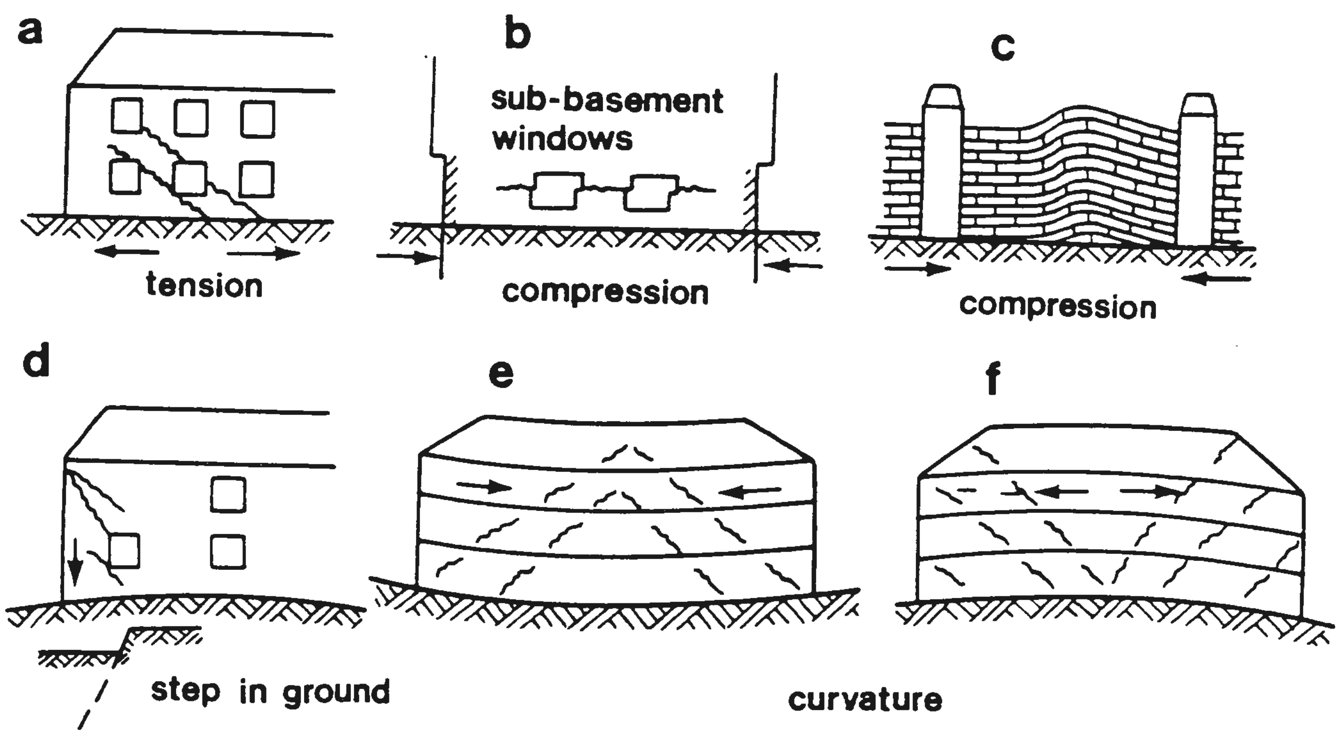



**Figure 9. Crack Orientations Resulting From Subsidence Ground Movements (Kratzsch, 1983).**

**Table 1**

**Subsidence Classification for Northern Appalachian Coalfield (Bruhn et, al., 1983).**

| Class | Characteristic Basement Damage | Severity Index |
|---|---|---|
| I Slight | • Hairline cracks in one or more basement walls and possibly floor slab.<br>• Some cracks in perimeter walls causing loss of water tightness.<br>• Repointing required in some or all walls. | 0<br><br>1 |
| II Moderate | • Cracks in one or more basement walls and floor slab.<br>• Some wall/footing reconstruction and floor slab replacement required, as well as local repointing. | 1<br><br>2 |
| III Severe | • Cracks in one or more basement walls and floor slab.<br>• Possible wall instability and loss of superstructure support, requiring shoring and bracing.<br>• Extensive repair work involving wall/footing reconstruction and floor slab replacement. | 2<br><br>4 |
| IV Very Severe | • Cracks typically in all basement walls, as well as floor slab.<br>• Possible instability of several walls and loss of superstructure support, requiring extensive shoring and bracing.<br>• Possible significant tilt to home.<br>• General reconstruction of basement walls, footings and floor slab required. | 4<br><br>5 |

## Table 2

## Sensitivity of Various Surface Structures to Subsidence Initiated Ground Movement (Kratzsch (1983) as modified by Peng, 1992).

| Structure | Subsidence | Slope | Curvature | Displacement | Tension | Compression |
|---|---|---|---|---|---|---|
| House | | x | x | | x | x |
| Commercial building | | (x) | x | | x | x |
| Row of houses | | x | x | | x | xx |
| Machine shop | | | (x) | | (x) | (x) |
| Blast furnace | | xx | | | | |
| Machinery | | xx | | | | |
| Conveyor belt | | | | x | x | x |
| Chimney | | xx | | | | |
| Pipeline crossing | | | | x | | |
| Reservoirs, water tank | | x | xx | | x | |
| Water treatment plant | | xx | | | x | x |
| Railway | x | | | | x | x |
| Railway station | x | (x) | | | x | x |
| Road | (x) | | | | x | x |
| Canal | xx | | | | | |
| Lock | xx | x | x | | x | (x) |
| Bridge | x | (x) | | x | | |
| Pipeline | | | | | x | x |
| Water mains | | | | (x) | x | x |
| Sewer | xx | | | (x) | x | x |
| Gas mains | (x) | | | branch off | x | x |
| Underground cable | | | | | (x) | x |
| Field meadows | x | | | | | |
| Woods | x | | | | | |
| Drainage trench | x | xx | | | | |
| Natural water flow | xx | xx | | | | |

Note: Sensitivity level, xx high, x medium, (x) slight.

In general stiff foundation systems have the least susceptibility to subsidence movement (Mahar and Merino, 1981). These foundation systems including reinforced concrete slabs and reinforced concrete wall footings are capable of spanning any changes in the ground surface. Structures with more than one foundation system, for example, a house on a concrete block footer with an addition on concrete block piers are more susceptible to subsidence damage. Superstructures connected tightly to their foundation also received heavier damage than those which could move relative to the foundation.

In terms of construction materials brick and masonry superstructures are weak in tension and poor in resistance to bending and twisting movement. Wood has greater flexibility and consequently is subject to less damage. As will be described in the following section on mitigation techniques, one of the keys to minimizing subsidence damage to is decouple the foundation from the ground enabling the ground to move independently of the foundation and the rest of the surface structure. This is accomplished through trenching around the perimeter. A second key is to increase the structural stiffness so the foundation and superstructure can bridge over localized curvatures within the ground surface.

**Table 3. Damage Criteria for a Variety of Buildings (after Singh, 1992).**

| Building Category | Damage Severity Level | Movement: Type | Movement: Limits | Country | Reference | Suggested Value |
|---|---|---|---|---|---|---|
| Brick and masonry/ brick bearing walls/ low-rise structures | Architectural | Angular distortion | 1.0–2.0 $\times 10^{-3}$ | Germany | Niemczyk (1949) | 1.0 $\times 10^{-3}$ |
| | | | 0.5–1.0 $\times 10^{-3}$ | | Meyerhoff (1953) | |
| | | | 1.0–2.0 $\times 10^{-3}$ | | Skempton and McDonald (1956) | |
| | | | 1.0 $\times 10^{-3}$ | USSR | Polshin and Tokar (1957) | |
| | | | 1.0–2.0 $\times 10^{-3}$ | US | Sowers (1962) | |
| | | | 1.0 $\times 10^{-3}$ | US | O'Rourke (1976) | |
| | | | 1.0 $\times 10^{-3}$ | UK | Attewell (1977) | |
| | | | 1.2 $\times 10^{-3}$ | US | Boscardin (1980) | |
| Brick and masonry/ brick bearing walls/ low-rise structures | Architectural | Horizontal strain | 0.6 $\times 10^{-3}$ | Germany | Niemcyzk (1949) | 0.5 $\times 10^{-3}$ |
| | | | 0.4 $\times 10^{-3}$ | UK | Beevers and Wardell (1954) | |
| | | | 0.5 $\times 10^{-3}$ | USSR | Polshin and Tokar (1957) | |
| | | | 0.8 $\times 10^{-3}$ | UK | Priest and Orchard (1957) | |
| | | | 0.5 $\times 10^{-3}$ | Japan | Goto (1968) | |
| | | | 0.4–0.5 $\times 10^{-3}$ | India | Singh and Gupta (1968) | |
| | | | 0.25 $\times 10^{-3}$ | UK | Littlejohn (1975) | |
| | | | 0.5–1.0 $\times 10^{-3}$ | UK | National Coal Board (Anon., 1975a) | |
| | | | <0.75 $\times 10^{-3}$ | US | O'Rourke (1976) | |
| | | | 0.5–1.0 $\times 10^{-3}$ | UK | Attewell (1977) | |
| | | | 1.0–1.5 $\times 10^{-3}$ | US | Cording et al. (1976) | |
| | | | 0.5 $\times 10^{-3}$ | US | Yokel (1978) | |
| | | | 0.5 $\times 10^{-3}$ | US | Boscardin (1980) | |
| Brick and masonry/ brick bearing walls/ low-rise structures | Architectural | Deflection ratio | 0.3–0.7 $\times 10^{-3}$ | USSR | Polshin and Tokar (1957) | 0.3 $\times 10^{-3}$ |
| | | | 1.0 $\times 10^{-3}$ | US | Grant (1974) | |
| | | | 0.4 $\times 10^{-3}$ | UK | Burland and Wroth (1975) | |
| Brick and masonry/ brick bearing walls/ low-rise structures | Functional | Angular distortion | 3.5 $\times 10^{-3}$ | US | Meyerhoff/Terzaghi (1953) | 2.5–3.0 $\times 10^{-3}$ |
| | | | 3.3 $\times 10^{-3}$ | US | Skempton and McDonald (1956) | |
| | | | 4.0–6.0 $\times 10^{-3}$ | USSR | VNIMI (Anon., 1958) | |
| | | | 2.0 $\times 10^{-3}$ | US | Bjerrum (1963) | |
| | | | 3.3 $\times 10^{-3}$ | US | Grant (1974) | |
| | | | 3.3–5.0 $\times 10^{-3}$ | Poland | Starzewski (1974) | |
| | | | 3.0 $\times 10^{-3}$ | | Ulrich (1974) | |
| | | | 2.0–3.3 $\times 10^{-3}$ | Sweden | Broms and Fredrikson (1976) | |
| | | | 2.7 $\times 10^{-3}$ | UK | Thorburn and Reid (1977) | |
| | | | 2.5 $\times 10^{-3}$ | Poland | Adamek and Jeran (1981) | |
| | | | 3.0–6.0 $\times 10^{-3}$ | Japan | Nishida et al. (1982) | |
| Brick and masonry/ brick bearing walls/ low-rise structures | Functional | Horizontal strain | 2.0–4.0 $\times 10^{-3}$ | USSR | VNIMI (Anon., 1958) | 1.5–2.0 $\times 10^{-3}$ |
| | | | 1.0 $\times 10^{-3}$ | | Ulrich (1974) | |
| | | | 2.5–3.5 $\times 10^{-3}$ | US | Cording et al. (1976) | |
| | | | 1.5 $\times 10^{-3}$ | Poland | Adamek and Jeran (1982) | |
| Brick and masonry/ brick bearing walls/ low-rise structures | Functional | Deflection ratio | 0.14–0.22 $\times 10^{-3}$ | | Rigby and Dekoma (1952) | 0.5 $\times 10^{-3}$ |
| | | | 0.25 $\times 10^{-3}$ | | Wood (1952) | |
| | | | 0.6 $\times 10^{-3}$ | US | Horne and Lambe (1964) | |
| Brick and masonry/ brick bearing walls/ low-rise structures | Functional | Radius of curvature | 1.9–12.4 mi (3–20 km) | USSR | VNIMI (Anon., 1958) | 12 mi (20 km) |
| | | | 12.4 mi (20 km) | | Ulrich (1974) | |
| | | | 12.4 mi (20 km) | Poland | Adamek and Jeran (1982) | |
| | | | 8.0 mi (13 km) | Japan | Nishida et al. (1982) | |

**Table 3 (Continued)**

| Building Category | Damage Severity Level | Movement Type | Movement Limits | | Country | Reference | Suggested Value | |
|---|---|---|---|---|---|---|---|---|
| Brick and masonry/ brick bearing walls/ low-rise structures | Structural | Angular distortion | 7.0–8.0 | $\times 10^{-3}$ | US | O'Rourke et al. (1977) | 7.0 | $\times 10^{-3}$ |
| Brick and masonry/ brick bearing walls/ low-rise structures | Structural | Horizontal strain | 3.5<br>2.75 | $\times 10^{-3}$<br>$\times 10^{-3}$ | UK<br>US | National Coal Board (Anon., 1975a)<br>Boscardin (1980) | 3.0 | $\times 10^{-3}$ |
| Steel and reinforced concrete | Architectural | Angular distortion | 1.0–2.0<br>2.0<br>2.0–2.5<br>2.2<br>1.3<br>2.0 | $\times 10^{-3}$<br>$\times 10^{-3}$<br>$\times 10^{-3}$<br>$\times 10^{-3}$<br>$\times 10^{-3}$<br>$\times 10^{-3}$ | US<br>USSR<br>US<br><br>US<br>UK | Skempton and McDonald (1956)<br>Polshin and Tokar (1957)<br>Sowers (1962)<br>Breth and Chambrosse (1975)<br>O'Rourke (1976)<br>Attewell (1977) | 1.3 | $\times 10^{-3}$ |
| Steel and reinforced concrete | Functional | Angular distortion | 2.5–3.3<br>3.3–6.6<br>3.3–5.0 | $\times 10^{-3}$<br>$\times 10^{-3}$<br>$\times 10^{-3}$ | <br>US<br>Poland | Thomas (1953)<br>Skempton and McDonald (1956)<br>Starzewski (1974) | 3.3 | $\times 10^{-3}$ |
| Timber frame | Architectural | Angular distortion | 2.0 | $\times 10^{-3}$ | US | Mahar and Manno (1981) | 1.5 | $\times 10^{-3}$ |
| Timber frame | Architectural | Horizontal strain | 1.0 | $\times 10^{-3}$ | Japan | Goto (1968) | 1.0 | $\times 10^{-3}$ |
| Timber frame | Functional | Angular distortion | 5.0–10.0<br>3.3–5.0 | $\times 10^{-3}$<br>$\times 10^{-3}$ | Poland<br>Sweden | Starzewski (1974)<br>Broms and Fredriksson (1976) | 3.3–5.0 | $\times 10^{-3}$ |

*Legend:*
Architectural: Small scale cracking of plaster and sticking of doors and windows.
Functional: Instability of some structural elements, jammed doors and windows, broken window panes, building services restricted.
Structural: Impairment of primary structural members, possibility of collapse of members, complete or large-scale rebuilding necessary, may be unsafe for habitation.

No data available on rigid, massive structures/central core design.

Buried pipelines and underground cables are subject to the soil strains and deformations to a greater degree than foundations. Although some slippage occurs along the soil-pipeline interface, a higher proportion of the subsidence induced movement and strain is transferred to the pipeline or cable. This is attributable in part to the cohesion and friction angle of the soil and to the friction coefficient between the pipe or its exterior coating and the soil. Similar to foundations, the material type (steel, ductile iron, plastic, pre-stressed concrete) and the joint connections (bell & spigot, welded, etc.) are critical to determining a given pipelines ability to withstand subsidence related ground movement. Pre-stressed concrete is among the most susceptible pipe material to subsidence movement and rubber gasket bell and spigot connections have a low resistance to deflection and tensile strain. Pipelines are most severely affected by tensile strain and curvature with the joint connections typically being the weakest link. If the strains and deformation associated with either longwall or room-and-pillar retreat mining can be predicted, an estimate of the susceptibility of a particular pipeline and its joint connections can be made based upon the known tensile strength of the pipe and joints.

A distinction should be made between the pressurized gas and water pipelines and gravity flow pipelines such as sanitary and storm sewers. For sanitary sewer lines grades of 0.50% to 1.00% are common while the grades on storm sewer lines are typically higher. Therefore, in addition to the potential impact on the pipe and joint connections, these lines are adversely affected by any permanent changes in the ground slope.

Multi-leg towers including high voltage electric lines and microwave are most susceptible to changes in the ground slope resulting from differential movement of one or more legs. Toppling can occur when the tower's center of gravity lies outside the tower base. As would be anticipated the higher the tower, the more susceptible the structure to tilting or differential movement of one or more legs to the remaining legs since the height to base ratio increases. Another concern is the potential for the footers beneath each leg to slide down a subsidence induced slope or change in topography. However, these structures can be safely undermined by the longwall method without damage and disruption to service. An example, occurred in Ohio where a large water tower was undermined and the legs raised or lowered in response to the predicted and subsequently measured ground movement.

The effect of subsidence on surface structures is a function of the soil properties, thickness of the soil layer, type, condition, and construction of the foundation and superstructure, footer, or pipeline. Generalities or "rules-of-thumb" regarding the effect of mine subsidence on residential construction are difficult because of major differences in the materials used and the quality of construction. A foundation sufficiently rigid to bridge dynamic, short term changes in the surface topography is able to withstand subsidence initiated ground movement. Unfortunately, most residential construction is not sufficiently rigid to resist subsidence movement or is comprised of more than one foundation system. Local building codes, foundation designs, and construction practices are intended to support the structural load and match the load to the bearing capacity of the soil. This problem is best addressed in new construction codes. In coalfield areas where the future undermining of a new structure is likely, building codes should require foundations designed to resist ground deformations in addition to dispersing the building load across the soil. Similarly, in previously mined out areas, the same requirements should be stipulated for new construction.

## 3.0 SUBSIDENCE MITIGATION TECHNIQUES

The initial step in planning for subsidence mitigation is to examine the location of surface structures relative to the orientation and areal extent of the proposed mining. Longwall mining is the least flexible mining method in terms of the ability to make changes once a panel has been driven and the longwall block isolated by a headgate and tailgate. However, because of the uniformity of mining and complete recovery of a large rectangular block of coal, it is the easiest mining method to predict subsidence. Therefore, remedial and mitigation efforts focus on:

- decoupling of the structure from the surrounding soil,
- reacting to the ground movement associated with subsidence, and
- increasing the stiffness and rigidity of the foundation and superstructure.

Room-and-pillar mining is very flexible in terms of variations in panel length and width. It affords the ability to selectively retreat mine specific areas or to leave a support pillar beneath a surface structure. As a result, subsidence for room-and-pillar mining can be extremely complex and never approaches the level of predictability of longwall mining. However, the available remedial and mitigation methods equally involve both the surface structure and alterations of the mining plan.

The first approach to minimize subsidence damage for both longwall and room-and-pillar mining is, if possible and economically feasible, to avoid locating panels where structures will be subjected to the maximum ground movement. Therefore, where possible panels should be located so that structures are outside of the extraction panel where no subsidence will occur, above the headgate or tailgate chain pillars, over barrier pillars, or in the center of the extraction panel. The foregoing alternatives are qualitatively ranked from most to least favorable. The panel edges, particularly those that are permanent where the tensile strains and ground curvature are highest should be placed away from subsidence sensitive structures. The long axis of the structure should parallel the retreat direction unless the structure is located in the center of the extraction panel. In this instance the short axis should be parallel to the direction of mining to minimize the exposure of the building to dynamic subsidence or the subsidence wave that travels with the active face. Where possible the panel width should be maximized so a flat bottom is located within the subsidence trough.

While retreat mining, the active face should move as quickly as possible. Where possible a three shift (two production shifts, one maintenance), seven day operation should be run to avoid stopping the face over a weekend. The face should not be stopped within the subsidence influence zone of a surface structure. Where possible longwall mining under shallow overburden should be avoided, particularly where the depth to mining height ratio could permit the fractured zone to contact the surface.

The recommendations for longwall mining are also applicable to room-and-pillar mines. Additionally, in room-and-pillar mines, second mining can be selectively stopped and started to insure that stable pillars are left within the subsidence influence zone beneath a structure. This zone is commonly taken as the fifteen (15') foot offset plus fifteen (15°) degrees from the vertical plane. Fifty (50%) percent extraction or a pillar safety factor in excess of 2.00 is recommended for long term stability. The bearing capacity of the immediate floor strata should be determined under saturated conditions to insure that "pillar punching" will not occur if the mine is abandoned and subsequently becomes inundated over time.

For residential structures there are two basic approaches to subsidence mitigation. The first is isolate the house foundation from the ground movement and strains while the second is to maintain the existing level of the house while the ground movement occurs. If the foundation is effectively decoupled from the surrounding soil the horizontal and vertical strains cannot be transferred. A third approach is to stiffen the foundation and superstructure in anticipation of mine subsidence.

For small wood frame homes, the simplest alternative may be to remove the house from its foundation during mining. After mining any necessary repairs are made to the foundation prior to reseating the house. Decoupling the foundation from the surrounding soil is accomplished by digging trenches around the house to absorb compressive strains. The longitudinal axis of the trench should be oriented perpendicular to the direction of maximum compression. The trench should be excavated (Peng, 1992) to a depth four (4") inches to eight (8") inches below the bottom of the footer and at a horizontal distance of three (3') feet to six (6') feet from the foundation. Loose, unconsolidated material should be placed in the trench to prevent collapse and the trench capped.

Leveling is achieved through a variety of methods. The favored approach is to place hydraulic or screw jacks beneath the home and adjust each jack as necessary. Since most Appalachian homes are constructed with a concrete block wall basement to which wood floor joists are bolted, the jacks are placed along the load bearing floor beams or joists. In this manner the foundation is free to move independently from the superstructure. Numerical modeling of the anticipated subsidence enables an accurate estimate of the magnitude of the subsidence movement. The knowledge of subsidence activity combined with close coordination to the face position enables the individual jacks to be raised or lowered to maintain the pre-mining level of the house. A steel or reinforced concrete bearing plate can be placed between the jacks and the floor joists so the house can be moved as a unit. An alternative is to install stiff springs between the foundation and floor joists. The philosophy is that the springs will expand or compress as required to maintain the house level. In practice, if the elastic limit of the springs is exceeded, a combination of springs and jacks is used.

The rigidity and stiffness of a house is increased through the use of cables or rods placed in tension around the exterior or through the interior. Tensioned steel rods may be placed at each corner, around the exterior of the home. A preset tension is placed on the rods or cable prior to subsidence activity. During the course of the subsidence event the cables or rods are adjusted to maintain the preset tension. The effect of this technique is to place the area between the bolts in compression. This strengthens the concrete block, masonry, or wood structure which is weak in tensions and counters the tensile strains associated with subsidence.

External and internal wall bracing is used to counteract the tendency of long unsupported walls to bow or buckle outward in response to compressive strains. Where long, unsupported runs exist, pilasters or columns are used to shorten the length and strengthen the wall. Expansion joints in new construction are used to provide a flexible structure that can deform in response to subsidence before permanent damage occurs.

In mined out areas back stowing material into the mine void can be used to reinforce abandoned mine workings. Dependent upon the proximity of the groundwater table to the coal seam, mine preparation plant refuse (slurry) can be pumped back into the mine void. As the slurry dewaters, the remaining fine coal and rock particles consolidate and provide resistance to roof collapse. Before remedial actions are taken a thorough analysis of the potential for subsidence is the first step. In many areas of the country, prior mining was done using long, narrow production pillars under shallow overburden. It is common for the extraction ratios in these old room-and-pillar mines to range between sixty (60%) percent to eighty (80%) percent. Certain areas of the United States are historically subsidence prone because of a combination of mining practices, overburden depth, weak overburden strata, and a thick layer of unconsolidated material on the ground surface. In addition to portions of Western Pennsylvania, these areas include Madisonville, Kentucky, Colorado Springs, Colorado, Rock Springs, Wyoming, Southern Illinois, and Petersburg, Indiana.

Protection from subsidence initiated from abandoned room-and-pillar mines involves some form of pressurized grouting, slurry injection, or back stowing. Okonkwo et al., 1987 divide these measures into two categories;

i) selective support for structures and

ii) filling of voids

Selective support is used to supplement the resistance provided by the remaining coal pillars. Driving piles, drilling piers, and construction of grout columns, are examples of deep foundation support techniques used for selective support. Selective support is focused on the protection of a single surface structure or several structures in a very limited area. Accurate mine maps are essential for selective support since these methods involve drilling to the mine void and placing support between existing pillars. Small errors in the mine surveying or inaccurate maps may result in drilling into a pillar instead of the void space. A summary of selective support methods is presented in Table 4 (after Gray et al., 1974).

**Table 4**

**Summary of Selective Support Methods (after Gray et al., 1974).**

| Method | Conditions for Use | Approximate Cost* |
|---|---|---|
| Grout Columns | Overburden >30 feet, <150 feet, mining height < 6 feet, no extensive caving of gob, surface accessible | $1,500 average to $4,500 maximum Per support |
| Groutcase | Overburden >30 feet, <150 feet, mining height < 6 feet, no extensive caving of gob, surface accessible | $700 per support |
| Piers Constructed in Mine Void | Accessible, dry mine voids, ventilated, safe to enter and work | Costs vary widely dependent upon mine conditions |
| Deep Foundations | Mine depth less than 1,000 feet, structure not constructed, surface accessible | $75 (drilled piers) $50 (piles) per linear foot |

* Cost Data Based Upon 1987 Prices

Grout columns are initially constructed by drilling into the mine void and placing a grout pipe into the hole. Gravel is poured into the mine void until it reaches the roof level. The pipe is retracted in the borehole and grout is injected under pressure into the gravel pile to form a cemented gravel structure. The pressure should be adequate to penetrate the gravel. Grout tubes are also used to create grout columns within the mine void. The tubes are engineered fabric, closed at end and placed at the bottom of the mine void. A flyash/Portland cement grout is pumped into the tube, expanding it until the tube is in firm contact with the roof and floor.

Grout injection methods involve pumping a particulate or chemical grout under pressure into the mine void, gob, and fractured rock. Particulate grouts are composed of flyash and Portland cement. Chemical grouts are organic compounds that may expand and harden over a short period so that the grout-rock bond and the combined strength of the grout-broken rock aggregate is capable of overburden support. These grouts are typically pumped at less than the overburden pressure which is approximately 1.10 lb/in$^2$ per foot of overburden depth. This insures grout can penetrate pre-existing cracks and fissures in the rock mass without dilating them.

**Table 5**
**Summary of Void Filling Methods (after Gray et al., 1974).**

| Method | Conditions for Use | Approximate Cost/yd$^3$ * |
|---|---|---|
| Hydraulic Flushing | Accessible, dry, uncaved, mine voids, safe to enter | \$2.85 or greater |
| Remote Filling | Overburden not extensively caved, surface accessible | \$4.80 to \$8.00 or greater |
| Dowell Process | Overburden not extensively caved | \$4.50 to \$12.00 or greater |
| Pneumatic Controlled Filling | Accessible, dry, mine voids | \$5.00 to \$10.00 or greater |
| Fly Ash Injection | Surface accessible | \$30.00 to \$90.00 or greater |
| Grouting | Surface accessible | \$60.00 to \$150.00 or greater |
| Excavation and Backfilling | Mine voids at shallow depth, no surface restrictions, dry or drainable mine void | \$3.50 to \$40.00 per yd$^3$ |

* Cost Data Based Upon 1987 Prices

The objective of the filling of voids is as the name implies, to prevent subsidence by eliminating the existing void space so no further ground movement is possible. This approach is used where the potential for subsidence exists and the areal extent of either the the structures to be protected or the mine workings is too large to economically justify selective support methods. Dependent upon the surrounding land use, certain of these methods can be combined with re-mining operations where coal extraction and reclamation occur simultaneously. In Table 5, a summary of void filling methods is presented. These methods depend upon access to large quantities of low cost materials or waste products including power plant fly ash or preparation plant refuse slurry. Initially, the topography of the mine floor is determined from the bottom-of-seam elevations recorded as part of routine mine surveying. Once the topographic high area(s) have been located, the direction and potential extent of travel is determined. If the mine is active, water tight bulkheads can be constructed underground to isolate the flyash or refuse slurry in specific area of the mine. If the mine is not accessible, the location of mine seals will indicate where the slurry is likely to be impounded underground. Care must be exercised since unless the method of seal construction is known and verified, slurry can pass through or around the seals and enter other areas of the mine. For the Dowell or slurry injection processes, a borehole is drilled from the surface to a topographically high point in the mine. Slurry injection commonly occurs under the natural pressure (0.43 $lb/in^2$ per foot) difference between the surface and the mine level. Pumping should continue until the slurry returns up the borehole. The standing level of the grout within the borehole is used to determine the final pressure under which the slurry remains in the mine. Once a borehole has achieved return, additional boreholes can be drilled on the mine property and slurry pumped into the mine void following the same methodology.

Where room-and-pillar mine workings are within one hundred (100') feet of the surface and if the stripping ratio ($yd^3$ of overburden moved/ton of coal recovered) is economic, re-mining the remnant pillars within old mine workings is one of the best solutions to subsidence mitigation. It promotes resource recovery, removes the possibility of subsidence, and provides for the reclamation of abandoned mine lands. The latter point is important since many of the re-mining sites are not reclaimed having been abandoned prior to the SMCRA law of 1977 which mandates reclamation of all surface disturbance associated either underground or surface mining. Potential constraints and problems include;

- current land use and density of residential and commercial development,
- whether mine workings are flooded and any potential water quality and/or treatment problems prior to releasing the impounded water, and
- pillar stability within the mine to insure that re-mining will not initiate subsidence activity.

In summary, selective support methods are only useful for development only or partial retreat room-and-pillar mines where subsidence is either active or pending. Subsidence associated with longwall mines occurs as part of the mining process and cannot be halted using any type of grouting or back stowing process. It may be useful in those areas where partial pillar recovery was practiced and subsidence has not progressed to the surface. However, selective support is prohibitively expensive for most Appalachian residential structures. Slurry injection is more economically viable and will improve a larger area compared to selective support methods. Similar to re-mining, the injection of preparation refuse slurry into mine voids has environmental benefits to both surface and underground. If not used for injection, the refuse slurry or power plant fly ash would be placed respectively in a large impoundment dam or in a fill on the surface. Through underground injection the waste materials can consolidate and compact within the mine void providing both permanent storage and subsidence mitigation.

## 4.0 BIBLIOGRAPHY


Adamek, V., P.W. Jeran, and M.A. Trevits, 1987. *"Prediction of Surface Deformations Over Longwall panels in the Northern Appalachian Coalfield,"* U. S. Bureau of Mines Report of Investigations No. 9142, 19 p.

Adamek, V., and P.W. Jeran, 1986,"Precalculation of Subsidence Over Longwall Panels In the Northern Appalachian Coal Region," *Proceedings From the Eastern Coal Mines Geomechanics; Bureau of Mines Technology Transfer Seminar, Pittsburgh, Pennsylvania,* U. S. Bureau of Mines Information Circular 9137, pp. 34-56.

Adamek, V., and P.W. Jeran, 1982. "Evaluation of Existing Predictive Methods for Mine Subsidence in the U. S.," *Proceedings from the Workshop on Surface Subsidence Due to Underground Mining,* Morgantown, West Virginia, West Virginia University, pp. 88-98.

Adamek, V., and P. W. Jeran, 1982. "Evaluation of Surface Deformation Characteristics Over Longwall Panels in the Northern Appalachian Coalfield," *State-of-the-Art of Ground Control in Longwall Mining and Mining Subsidence,* Y.P. Chugh and M. Karmis (eds.), SME-AIME, pp. 183-197.

Andromalos, K. B., and C.R., Ryan, 1988. "Subsidence Control by High Volume Grouting," *Proceedings of the Symposium Sponsored by the Geotechnical Engineering Division of the American Society of Civil Engineers in Conjunction with the ASCE National Convention,* Nashville, Tennessee, May 11, 1988, ASCE, pp. 53-68.

Bennett, R. M., E. C. Drumm, G. Lin, T. Triplett, and L. Powell, 1996. "Effects of Ground Subsidence on a House," *Journal of Performance of Constructed Facilities*, American Society of Civil Engineers, Vol. 10, No. 4, pp. 152-158.

Brauner, G., 1973. *Subsidence Due to Underground Mining,* United States Bureau of Mines Information Circular No. 8572.

Chen, C. Y., and S. S. Peng, 1986. "Underground Coal Mining and Attendant Subsidence Control: Some History, Technology, and Research," *Mining Engineering,* February 1986, pp. 95-98.

Daemen, J. K., and M. Hood, 1982. "Subsidence Profile Functions Derived From Mechanistic Rock Mass Models," *Proceedings from the Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia,* West Virginia University, pp. 124-140.

Fernando, D. A., 1988. "Review of Subsidence and Its Stabilization Techniques," *Proceedings of the Symposium Sponsored by the Geotechnical Engineering Division of the American Society of Civil Engineers in Conjunction with the ASCE National Convention, Nashville, Tennessee, May 11, 1988,* ASCE, pp. 189-206.

Gray, R.E., R.W. Bruhn, and R.J., Turka, (1977), "Study and Analysis of Surface Subsidence Over Mined Pittsburgh Coalbed," *Final Report for U.S. Bureau of Mines Contract No. J0366047*, July, 145 p.

Hazen, G. A, and S. M. Sargand, 1988. "Methods for assessing effects on Longwall Mining on Surface Subsidence," *Mining Engineering*, June 1988, pp. 451-454.

Hood, M., R.T. Ewy, and L.R. Riddle, 1982, "Empirical Methods of Subsidence Prediction - a case study," *Proceedings from the Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia,* West Virginia University, pp. 100-122.

Hucka, V. J., C. K. Blair, and E. P. Kimball, 1986. "Mine Subsidence effects on a Pressurized Natural gas pipeline," *Mining Engineering*, October 1986, pp. 980-984.

Jeran, P. W., and V. Adamek, 1986. "Subsidence Over Chain Pillars," *Proceedings From the Easter Coal Mines Geomechanics; Bureau of Mines Technology Transfer Seminar, Pittsburgh, Pennsylvania,* U. S. Bureau of Mines Information Circular 9137, pp. 65-71.

Jeran, P.W., and T.M. Barton, 1986, "Comparison of the Subsidence Over Two Different Longwall Panels," *Proceedings From the Eastern Coal Mines Geomechanics*; *Bureau of Mines Technology Transfer Seminar, Pittsburgh, Pennsylvania, 1986,* U. S. Bureau of Mines Information Circular 9137, pp. 25-33.

Jeran, P.W., and T.M. Barton, 1986 "Comparison of the Subsidence Over Two Different Longwall Panels," *Proceedings From the Eastern Coal Mines Geomechanics*; *Bureau of Mines Technology Transfer Seminar, Pittsburgh, Pennsylvania,* U. S. Bureau of Mines Information Circular 9137, pp. 25-33.

Jones, T. Z., and K. Kohli, 1985. "Subsidence Over a Room and Pillar Mine in the Appalachian Coal Province and the use of Subsidence Predictive Methods--A Comparative Analysis," *Proceedings of the 26th U. S. Symposium on Rock Mechanics,* Rapid City, South Dakota, 1985, South Dakota School of Mines & Technology, pp. 179-187.

Karmis, M., P. Schilizzi, A. Jarosz, 1985. "The Development of Ground Subsidence Above Underground Coal Mines in the Appalachian Coalfield and its Prediction Using Empirical Techniques," *Proceedings of the 2nd Conference on Ground Control Problems in the Illinois Coal Basin,* Southern Illinois University at Carbondale, pp. 127-137.

Karmis, M., Goodman, G., Hasenfus, G., 1984. "Subsidence Prediction Techniques for Longwall and Room and Pillar Panels In Appalachia, *Stability in Underground Mining II,* pp. 541-553.

Karmis, M, and T. Triplett, and P. Schilizzi, 1984. "Recent Developments in Subsidence Prediction and Control for the Eastern U. S. Coalfields," *Rock Mechanics in Productivity and Protection, Proceedings of the 25th U. S. Symposium on Rock Mechanics,* Northwestern University, SME-AIME, pp. 713-721.

Karmis, M., C. Haycocks, B. Webb, and T. Triplett, 1982. "The Potential of the Zone Area Method for Mining Subsidence Prediction in the Appalachian Coalfield," *Proceedings from the Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, 1981,* West Virginia University, pp.48-59.

Kendorski, F.S., 1993. "Effect of High Extraction Coal Mining on surface and Groundwaters," *Proc. 12th Conference on Ground Control in Mining,* West Virginia University, pp. 412-425.

Kenny, J., 1913."Journal to Ye Westward," *Pennsylvania Magazine of History and Biography,* Vol. 37, 1913 p. 418.

Khair, A. W., M. K. Quinn, and R. D. Chaffins, 1988. "Effect of Topography on Ground Movement due to Longwall Mining," *Mining Engineering*, August 1988, pp. 820-822.

Kohli, K. K., and S.S. Peng, 1982, "Subsidence Experiences in the Room-and-Pillar Mines of the Northern Appalachian Coalfield," *Proceedings from the Conference on Ground Control in Room-and-Pillar Mining, Southern Illinois University-Carbondale, August 6-8, 1980,* SME-AIME, pp. 133-138.

Kohli, K. K., S. S. Peng, and R. E. Thill, 1980. "Surface Subsidence Due to Longwall Mining in the Northern Appalachian Coal Field," *Preprint No. 80-53, SME-AIME Annual Meeting, Las Vegas, NV, February 24-28, 1980,* SME-AIME, pp. 1-8.

Kolesar, J.E., E.C. Palmer, and V.A. Scovazzo , 1982. "Subsidence Monitoring Plan of Longwall Panels - a case study," *Proceedings from the Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, 1981,* West Virginia University, pp. 225-230.

Korber, E.J., F.A. Burns, and D.E. Raab, 1981. "Fifteen Years of Consistent Longwall Production at Bethlehem's Cambria Division, Ebensburg, Pennsylvania," *Proceedings from the SME-AIME annual meeting, Chicago, Illinois, 1981,* SME-AIME, pp. 169-177.

Kratzsch, H., (1983), *Mining Subsidence Engineering,* Trans. from original German by R. F.S. Fleming, Springer-Verlag, Berlin Germany, 543 p.

Mack, E.C., 1981. "Movement of Longwalls at Shoemaker Mine," *Proceedings from the SME-AIME annual meeting, Chicago, Illinois, 1981,* SME-AIME, pp. 149-154.

Mahar, J.W. and Marino, G., 1981. "Building Response and Mitigation Measures for Building Damages in Illinois, *Proc. Workshop on Surface Subsidence Due to Underground Mining,* S.S. Peng ed., West Virginia University, Morgantown, W.Va. pp. 34-47.

Marino, G. G., J. W. Mahar, and E. W. Murphy, 1988. "Advance Reconstruction for Subsidence - Damaged Homes," *Proceedings of the Symposium Sponsored by the Geotechnical Engineering Division of the American Society of Civil Engineers in Conjunction with the ASCE National Convention, Nashville, Tennessee, May 11, 1988,* ASCE, pp. 87-106.

Moebs, N. N., and T. M. Barton, 1985. "Short-Term Effects of Longwall Mining on Shallow Water Sources," *Mine Subsidence Control, Proceedings of the Bureau of Mines Technology Transfer Seminar, Pittsburgh, Pennsylvania, September 19, 1985,* U. S. Bureau of Mines Information Circular 9042, pp.13-24.

Moebs, N. N., 1982. *Subsidence Over Four Room-and-Pillar Sections in Southwestern Pennsylvania,* Report of Investigations No. 8645, prepared by the United States Bureau of Mines, 1982.

Moebs, N. N., and J.L. Ellenberger, 1982. "Hazardous Roof Structures in Appalachian Coal Mines," *Proceedings from the Conference on Ground Control in Room-and-Pillar Mining, Southern Illinois University-Carbondale, August 6-8, 1980,* SME-AIME, pp.9-16.

Munson, D. E., and H. J. Sutherland, 1982, "Empirical and Analytic Approaches to Subsidence Prediction," *Proceedings from the Conference on Ground Control in Room-and-Pillar Mining, Southern Illinois University-Carbondale, August 6-8, 1908,* SME-AIME, pp. 139-149.

National Coal Board, (1975), *Subsidence Engineers Handbook* NCB Mining Dept., London, 111 p.

Okonkwo, I. O., W. R. Judd, and A. G. Altschaeffl, 1988. "A Review of Some Aspects of Grouting for Mine Subsidence Control," *Proceedings of the Symposium Sponsored by the Geotechnical Engineering Division of the American Society of Civil Engineers in Conjunction with the ASCE National Convention, Nashville, Tennessee, May 11, 1988,* ASCE, pp. 127-146.

Peng, S. S., 1992. *Surface Subsidence Engineering*, Society for Mining, Metallurgy, and Exploration, Littleton, Colo.

Peng, S.S., Chiang, H.S., 1984. *Longwall Mining* John Wiley & Sons, 708 p.

Peng, S. S., and C. T. Chyan, 1982. "Surface Subsidences, Surface Structural Damages and Subsidence Predictions and Modeling in the Northern Appalachian Coalfield," *Proceedings from the Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, 1981,* West Virginia University, pp. 73-84.

Peng, S. S., and D. Y. Geng, 1982. "Methods of Predicting the Subsidence Factor, Angle of Draw and Angle of Critical Deformation," *Proceedings from the International Symposium on "Ground Control in Longwall Coal Mining and Mining Subsidence-State of the Art", SME-AIME fall meeting, 1982,* SME-AIME, pp. 211-221.

Rogers, W.B., 1884. *Geology of the Virginias,* Appleton and Company.

Roscoe, M. S., 1981. "Longwall Subsidence Over the Pittsburgh No. 8 Coal on North American Coal Corporation's Eastern Ohio Properties," *Longwall-Shortwall Mining State-of-the-Art,* R. V. Ramani (ed.), SME-AIME, pp. 87-98.

Seyfert, C.K. and Sirkin, L.L., 1973. *Earth History and Plate Tectonics,* Harper and Row. 504 p.

Singh, M.M. 1992, "Mine Subsidence", Chapter 10.6 in *Mining Engineers Handbook*, AIME-SME, Littleton, Colo. pp. 938-971.

Singh, M.M. and Kendorski, F.S. 1981. "Strata disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments," *Proceedings 1st Conference on Ground Control in Mining*, West Virginia University, pp. 76-89.

Speck, R.C., R.W. Bruhn, and R.E. Gray, 1982. "Instrumentation Plan for Monitoring Ground Movements Associated with Pillar Extraction Mining at the Kitt No. 1 Mine in Northern West Virginia," *Proceedings from the Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, 1981,* West Virginia University, pp.231-236.

Tandanand, S., and L. Powell, 1982. "Consideration of Overburden Lithology for Subsidence Prediction," *Proceedings from the Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, 1981,* West Virginia University, pp.17-29.

Tieman, G.E., and H.W. Rauch, 1986. "Study of Dewatering Effects at an Underground Longwall Mine Site in the Pittsburgh Seam of the Northern Appalachian Coalfield," *Proceedings From the Eastern Coal Mines Geomechanics: Bureau of Mines Technology Transfer Seminar, Pittsburgh, Pennsylvania, 1986,* U. S. Bureau of Mines Information Circular 9137, pp.72-89.

Trent, B.C., 1982, "Empirical, Continuum & Block Cabinet Computer Models for Surface Subsidence," *Proceedings form the Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, 1981,* West Virginia University, pp.142-146.

Trevits, M.A., L. Roger, and B.V. Johnson, 1986. "Bureau of Mines Subsidence Research Program," *Proceedings From the Eastern Coal Mines Geomechanics: Bureau of Mines Technology Transfer Seminar, Pittsburgh, Pennsylvania, 1986,* U. S. Bureau of Mines Information Circular 9137, pp. 57-64.

Walker, J.S., and J.C. LaScola, 1989. *Foundation response to subsidence-induced ground movements: A case study,* Report of Investigations No. 9224, Walker, J.S., 1993, "State-of-the-Art Techniques for Backfilling Abandoned Mine Voids," *U.S. Bureau of Mines IC 9353,* 17 p.

Webster, S., C. Haycocks, and M. Karmis, 1984. "Subsidence Interaction Effects in Multi-Seam Mining," *Proceedings from the 2nd International Symposium on Stability in Coal Mining,* 1984, SME-AIME, pp. 589-604.

# CHAPTER 6

# SUBSIDENCE PREDICTION TECHNIQUES

David A. Newman, Ph.D.
Appalachian Mining and Engineering, Inc.
Lexington, Kentucky

# 1.0 SUBSIDENCE PREDICTION TECHNIQUES

## 1.1 BACKGROUND

The impetus to develop and continually refine mine subsidence prediction techniques is directly proportional to the proximity of population centers and surface structures to underground mining operations. The earliest subsidence prediction efforts were in Europe where underground metal mining dates to the Middle Ages. In Europe, mining operations were historically near or directly beneath population centers. This is attributable to the fact that towns commonly developed around mining and metallurgical operations and the population density is high in comparison with less developed areas of the world. One of the earliest references to mine subsidence in Argicola's classic text *De Re Metallica* originally published in 1556.

Subsidence prediction techniques can be subdivided into two broad categories, empirical and numerical methods. Empirical techniques developed primarily in Europe and the United States are the most common methods for subsidence prediction and have been used successfully worldwide for many years. These methods rely upon the compilation of many case histories, each based upon detailed field measurements and observations of subsidence in a specific geographic location. Numerical modeling including finite element, boundary element, and displacement-discontinuity has been used to simulate the behavior of the coal seam, immediate roof, and overburden in response to extraction. These models are based upon continuum mechanics and were originally developed to model the stresses and strains in metals, wood, and concrete for spacecraft, airplanes, bridges, high rise buildings, and other man-made structures. The material properties are well defined since the alloy, tree species, or concrete mix is specified for a particular application. The materials are assumed to conform to either idealized elastic, viscoelastic, elastic-plastic, plastic, or elastic-elastoplastic material behavior. Numerical modeling has not achieved the success of the empirical techniques because of the variability of the rock and coal properties and the presence of fractures, cracks, and discontinuities within the overburden. Unlike man-made materials, geologic materials are heterogeneous, anisotropic, and do not readily conform to idealized behaviors. For example, the strength and physical properties of shale are dependent upon the bedding plane thickness, clay content, presence/absence of siderite nodules or sandstone streaks, and percentage of carbonaceous material (black shale versus gray shale). In contrast, aluminum 2024-T4 alloy has consistent strength and physical properties irrespective of shape (bar or rod) or dimensions. Numerical models require a strong technical background and have a substantial leaning curve for a user to become proficient.

## 1.2. EMPIRICAL SUBSIDENCE PREDICTION MODELS

Empirical methods are based upon many case histories, typically drawn from a specific geographic region. The information collected as part of the case history begins with measurements of horizontal and vertical surface movement over time as a particular area of the mine or panel is being extracted. Surface movement is determined from closed loop surveying of subsidence monuments set before longwall mining or pillar extraction to insure accuracy. Mining and geologic information including; panel width and length, overburden depth, percentage of hard or resistant rock in the overburden, percent extraction, and mining height are recorded as part of the case history.

Once a sufficient number of case histories are collected, a mathematical function is derived to express vertical subsidence, horizontal strain, ground curvature, and horizontal displacement at any point along a cross section or longitudinal section of the mining panel. From these data, important subsidence parameters including the angle of draw, tangent angle of influence, and subsidence factor (surface subsidence expressed as a function of mining height) are obtained. Empirical methods are subdivided into three categories:

i) graphical,

ii) profile functions, and

iii) influence functions.

Once the accuracy of a particular approach has been verified by level surveying at a mine, the future panels do not need to be surveyed. Since empirical methods rely upon site specific constants, the purpose of the initial surveying is to calibrate the particular model to given site through the adjustment of these constants.

### 1.2.1 Graphical Approach

The British National Coal Board (NCB) developed the best known and widely accepted graphical approach as part of their subsidence engineer's handbook published in 1975. This method is intended for longwall mining under the geological conditions of the British coalfields. Initially, the maximum subsidence is determined based upon the ratio of the extracted length ($L_1$) or the gob to the overburden thickness (h). If $L_1 \geq 1.4h$ then the nomograph shown in Figure 1 is used to determine the subsidence factor (a) from the intersection of the extracted panel width and overburden depth. The maximum subsidence that occurs at the center of the panel is;

$$S_{max} = aH. \tag{Eq. 1}$$

Where:

$S_{max}$ = the maximum vertical subsidence, (meters)
a = subsidence factor the nomograph in Figure 1, and
H = mining height (meters).

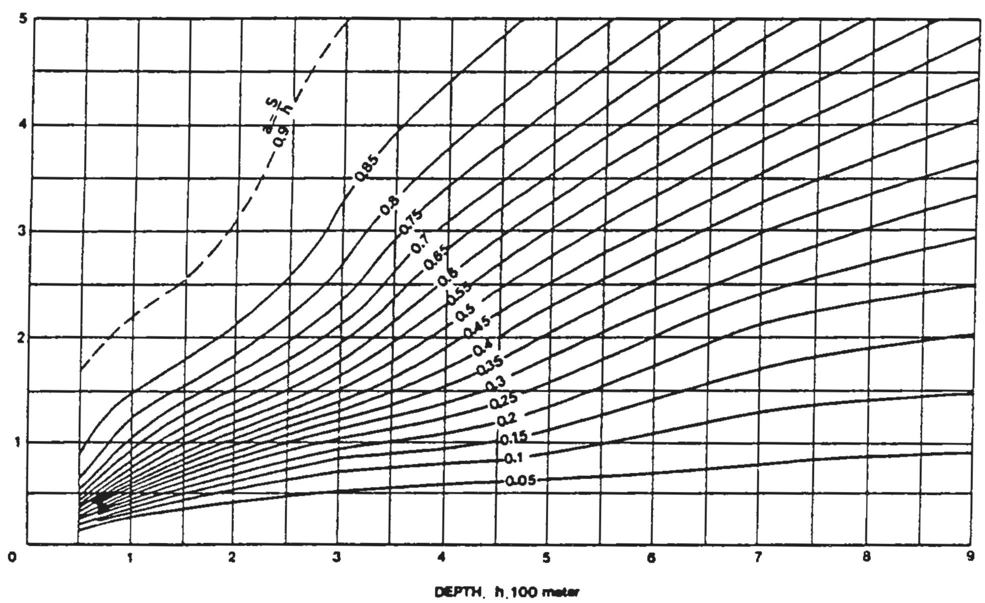



**Figure 1. Subsidence Factor Nomograph (Peng, 1984).**

If the extracted panel length $L_l \leq 1.4h$ then the critical extraction length has not been achieved and the maximum subsidence (S) calculated in equation 1 must be adjusted to reflect the actual subsidence (s') according to the nomograph in Figure 2.

Once the maximum subsidence has been calculated, the subsidence profile perpendicular to the direction of panel retreat is determined using the nomograph in Figure 3 to calculate the percentage of $S_{max}$ at specific distances from the panel center. The ratio of extracted width (w) to overburden depth (h) is on the y axis while the distance from the center of the panel in terms of x/h is on the x axis. A subsidence profile is established by constructing a table and plotting the results. The horizontal strain profile is determined in a similar manner using nomographs to obtain a constant that is multiplied times the ratio of subsidence to overburden depth. The shape of the subsidence profile is a trough with the greatest subsidence at the center point of the panel for the critical panel width. In excess of the critical width $S_{max}$ at the panel center flattens to a trough.

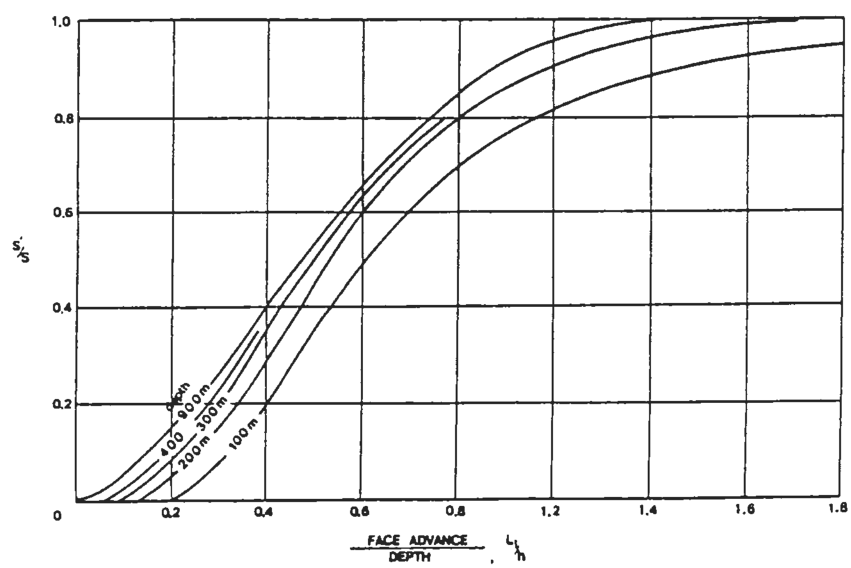



**Figure 2. Nomograph for Determining Subsidence Factor for Subcritical Panels (Peng, 1984).**

The NCB method typically over estimates subsidence in the Illinois and Appalachian coalfields primarily because the United States has stronger overburden strata capable of spanning wider distances above the mine void. The sandstones, sandy shales, shales, and limestones common in U.S. overburden do not fracture as readily and fill the void space created by coal extraction in comparison with the softer shales and mudstones typical of British overburden. Consequently, the amount of surface subsidence is less where the overburden consists of stronger, more resistant strata. The difference in overburden lithology also influences the angle of draw for Northern Appalachian conditions (15° to 30°, typical 19° to 23°) in comparison with English conditions (25° to 35°, typical 30° to 35°). The stronger overburden moves the point of inflection in Northern Appalachia toward the center of the panel. The point of inflection is where the tensile strains present over the panel edge become compressive strains toward the panel center. The surface curvature is zero at the point of inflection.

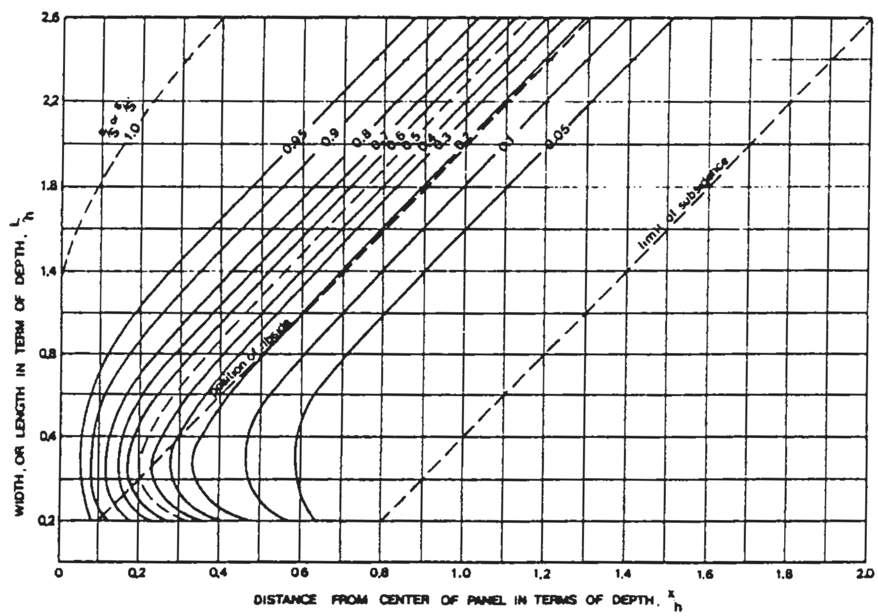



**Figure 3. Nomograph to Develop Subsidence Profile (Peng, 1984).**

### 1.2.2 Profile Functions

Profile functions are derived from field data and are, in some respects, similar to the NCB graphical method. This approach is derived from fitting empirically collected subsidence data to a mathematical formula. Trigonometric functions are the most amenable to quantifying the shape of the subsidence trough. A summary of the most widely accepted profile functions is presented In Table 1. The majority of the profile functions are a form of sine or hyperbolic tangent expressions with constants used to express relationships between panel geometry and the overburden depth. The main benefit of the profile function is that the shape of the subsidence trough, horizontal strain, horizontal displacement, and curvature can be readily determined for points at specific distance from the panel center or edge.

Several profile functions have been developed specifically for Appalachian longwall mining conditions. Karmis et. al, 1982 use a form of the hyperbolic tangent function shown in equation 1.

$$S(x) = 0.5\ S_{max}\ [1 - \tanh(cx)/B] \qquad \text{Eq. 1}$$

Where:

- $S(x)$ = subsidence at a point along the profile,
- $S_{max}$ = maximum subsidence = am,
- a = subsidence factor or percentage of subsidence as a function of m the mining height,
- c = a constant; 1.4 for subcritical panels, 1.8 for critical and super critical panels,
- x = distance from the inflection point to the point in question,
- B = distance from the inflection point to $S_{max}$ = D tan $\gamma$,
- D = overburden depth, and
- $\gamma$ = angle of draw.

The constant "a" is determined from a set of curves based upon the percentage of hard or resistant rock (sandstone, sandy shale, limestone) in the overburden and the ratio of panel width to overburden depth. The value of "a" varies between 0.62 at 0% hard rock to 0.20 for 80% hard rock. The point of inflection is the point on the subsidence curve where the shape of the curve changes from concave to convex. It is also the point at which the surface strain changes from tension (toward the panel edge) to compression (toward center of trough). Subcritical panels are those where the panel width is insufficient to generate $S_{max}$. For critical panels, $S_{max}$ occurs at one point in the center of the panel. In supercritical panels this point flattens into a tough at a common vertical displacement of $S_{max}$.

Adamek and Jeran (1985) developed a profile function specifically for use in Pittsburgh seam longwall mines. The approach that relies upon equations 2 (critical and super critical panels) and 3 (subcritical panels).

$$S_{max} = ma \qquad \text{Eq. 2}$$

$$S_{max} = mae \qquad \text{Eq. 3}$$

Where:

$S_{max}$ = maximum subsidence,
m = the mining height,
a = subsidence factor,
= -3.587 x $10^{-8}$ $X^3$ + 1.628 x $10^{-5}$ $X^2$ - 9.105 x 10 X + 0.1359,
X = distance (feet) from panel edge to panel centerline, and
e = efficiency coefficient for partial area of influence.

**Table 1.**
**Common Profile Functions for Subsidence Prediction (SME, 1992).**

| Name | Function | Country/Area | Reference |
|---|---|---|---|
| *Critical Extraction:* | | | |
| Hyperbolic | $S(x) = \frac{1}{2} S_{max}\left[1 - \tanh\left(\frac{cx}{B}\right)\right]$ | UK | King and Whetton (1957)<br>Wardell (1965)<br>Cherny (1966) |
| Error | $S(x) = \frac{1}{2} S_{max}\left\{1 - \left[\frac{2}{(\pi)^{1/2}}\int_{o}^{(\pi x/B)} exp(-u^2)du\right]\right\}$ | Poland/<br>Upper Silesia | Knothe (1953) |
| Exponential | $S(x) = S_{max}\, exp\left[-\left(\frac{1}{2}\right)\frac{(x + B)^2}{B^2}\right]$ | Hungary | Martos (1958)<br>Marr (1958–59) |
| | $S(x) = S_{max}\, exp\left[-\left(\frac{cx}{B}\right)^{a}\right]$ | US/Appalachia | Peng and Cheng (1981) |
| Trignometric | $S(x) = \frac{1}{2} S_{max}\left[1 - \left(\frac{x}{B}\right) - \left(\frac{1}{\pi}\right)\sin\left(\frac{\pi x}{B}\right)\right]$ | USSR/Donets | General Institute of Mine Surveying<br>(Anon., 1958) |
| | $S(x) = S_{max}\sin^2\left[\left(\frac{\pi}{4}\right)\left(\frac{x}{B} - 1\right)\right]$ | | Hoffman (1964) |
| *Subcritical Extraction:* | | | |
| Trignometric | $S(x) = S_{max}\,(n_1, n_2)^{1/2}\left[n^2\left(1 - x + \frac{\sin 2\pi x}{2\pi}\right) + \frac{1 - n^2}{4}(1 + \cos \pi x)^2\right]$ | USSR/Donets | General Institute of Mine Surveying<br>(Anon., 1958) |
| Hyperbolic | $S(x) = \frac{1}{2} S_{max}\left[\tanh\frac{2(x + w)}{B} - \tanh\frac{2x}{B}\right]$ | Poland/<br>Upper Silesia | Knothe (1957)<br>Wardell and Webster (1957) |
| | | US/Appalachia | Peng (1978) |

$x$ = horizontal distance
$c$ = arbitrary constant
$B$ = radius of critical area of excavation
$u$ = integration variable
$w$ = panel width

$S(x)$ = profile function
$S_{max}$ = maximum possible subsidence
$n_1, n_2$ = coefficients related to width/depth
$n$ = $n_1$ or $n_2$ depending on side of panel

*Source:* Updated from Brauner (1973) and Hood et al. (1981).

The constant "e" is determined from a table based upon the angle of draw, ratio of panel width to overburden depth and ratio of X to panel width.

The limitations of the profile methods are similar to those of the graphical approach. Since each profile function is derived from case history data from a given coalfield, set of geologic conditions, heavily weighted to a specific coal seam such as the Pittsburgh seam, the ability to extrapolate to other areas may be limited. However, when profile functions are used with site specific empirical constants, the accuracy of prediction is typically within tenths of a foot. Accuracy in the prediction of surface strains and curvature is commonly less than for subsidence because the increment of measurement is smaller and subject to variation in soils or weathered surface rock. In many instances the strains and curvature are over estimated, resulting in a conservative analysis.

Profile functions are most applicable to the regular mining geometry associated with longwall panels where complete coal extraction occurs within a rectangular area. The profile function is used to examine subsidence along cross sections taken parallel with either the panel length or width. This method is not useful for room-and-pillar mining where the extraction geometry is neither square or rectangular. Irregular extraction, where isolated pillars are not recovered due to ground control problems (pillar crushing, poor roof or floor conditions), is prevalent in room-and-pillar mining.

### 1.2.3 Influence Functions

The influence function approach is based upon superimposing the influence of infinitesimally small extraction areas on the ground surface. In Figure 4, a representation of the influence function approach is shown. Because the areas being evaluated can be of any dimension, this method is useful in terms of evaluating subsidence for irregular geometries and mining methods.

The amount of subsidence at point P shown in Figure 4 is the sum of the subsidence that occurs at each small extraction area. The area of influence is an important concept for influence functions. The point P is most effected by the mining directly beneath it. The effect on surface subsidence at P diminishes with increasing horizontal distance from the point directly beneath P. Table 2 contains a summary of the more significant influence functions.

The concept of superposition and influence area is illustrated in Bals theory (Bals, 1931/1932), a commonly used influence function. In Figure 5, the subsidence at a surface point P is dependent upon the location and percent extraction with the base of the cone. The cone in the figure is positioned over the edge of a panel where a portion of the cone lies on an extracted zone and the other portion is on solid coal. The radius of the cone is equal to the angle of draw. The angle of draw is subdivided into five equal angles from which five radii are established. Four diameters are drawn to divide the base of the cone into forty areas, each with a specific influence on the subsidence at point P. The percent extraction is shown for each of the areas that have coal extraction within them. The total subsidence at point P is the sum of the individual subsidence occurring at each of the forty areas weighted by the influence of each area.

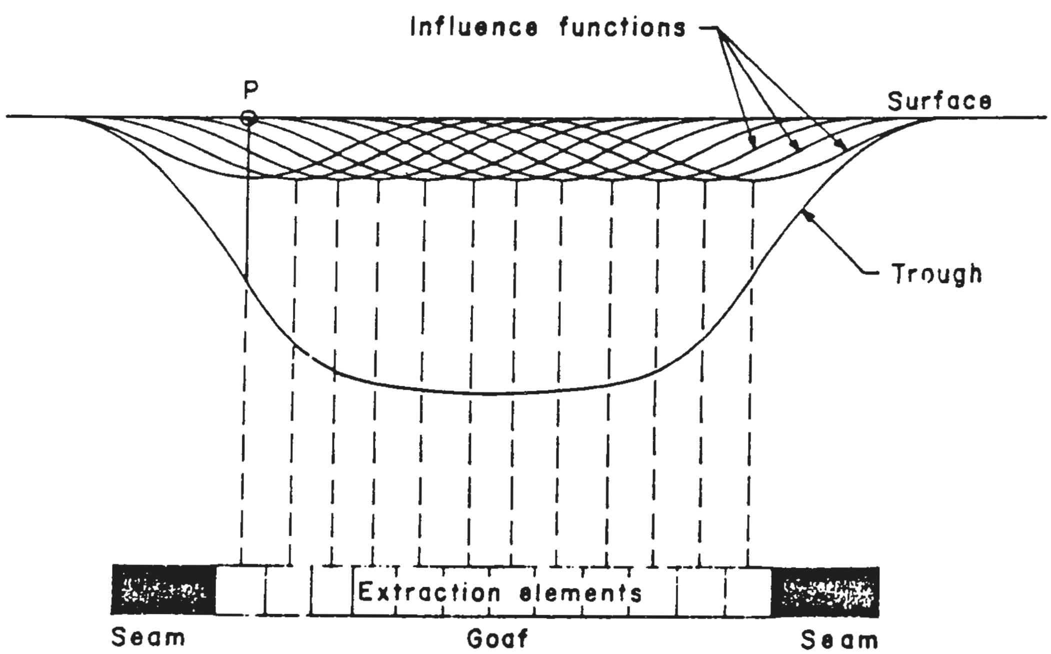



**Figure 4. Influence Function - Superposition of Infinitesimally Small Extraction Areas. (Brauner, 1973).**

From the figures it is clear that the influence method can incorporate any mining geometry, seam dip, remnant pillars, irregularly shaped pillars or extraction areas into the calculation of surface subsidence. Influence area methods are powerful in terms of the absence of geometric restrictions and the accuracy of calculation. Similar to profile methods, the accuracy is dependent upon the calibration of empirical constants to site conditions. The actual calculations are both numerous and tedious for large areas. Because of the amount of calculation, influence functions are very amenable to computerization.

**Table 2.**
**Common Influence Functions for Subsidence Prediction (SME, 1992).**

| Function | Reference |
|---|---|
| $\phi(r) = \dfrac{S_{max}}{\pi\{\sin\gamma\cos\gamma + [(\pi/2) - \gamma]\}}$ $\dfrac{B^3 \tan^3\gamma}{r(r^2 + B^2\tan^2\gamma)^2}$ | Bals (1932–33) |
| $\phi(r) = \dfrac{3\,S_{max}}{\pi\,B^2}\left[1 - \left(\dfrac{r}{B}\right)^2\right]^2$ | Beyer (1945) |
| $\phi(r) = \dfrac{n\,(2)^{\frac{1}{n}}\,S_{max}}{\pi B \Gamma\,(1/2n)\,r}\,exp\left[-4\left(\dfrac{r}{B}\right)^{2n}\right]$ | Sann (1949) |
| $\phi(r) = \dfrac{2\,S_{max}}{(\pi)^{3/2}\,Br}\,exp\left[-4\left(\dfrac{r}{B}\right)^2\right]$ when $n = 1$ | |
| $\phi(r) = 0.216\,\dfrac{S_{max}}{Br}\,exp\left[-4\left(\dfrac{r}{B}\right)^6\right]$ when $n = 3$ | |
| $\phi(r) = \dfrac{n\,S_{max}}{B^2}\,exp\left[-n\,\pi\left(\dfrac{r}{B}\right)^2\right]$ | Litwiniszyn (1957) |
| $\phi(r) = \dfrac{S_{max}}{B^2}\,exp\left[-\pi\left(\dfrac{r}{B}\right)^2\right]$ when $n = 1$ | |
| $\phi(r) = \dfrac{2\,S_{max}}{B^2}\,exp\left[-2\,\pi\left(\dfrac{r}{B}\right)^2\right]$ when $n = 2$ | |
| $\phi(r) = \dfrac{4.6\,S_{max}}{\pi\,B^2}\,exp\left[-4.6\left(\dfrac{r}{B}\right)^2\right]$ | Ehrhardt and Sauer (1961) |
| $\phi(r) = \dfrac{n\,S_{max}}{2\pi\,r_o^2\,\Gamma(2/n)}\,exp\left(-\dfrac{r}{r_o}\right)^n$ | Kochmanski (1959) |
| $\phi(r) = \dfrac{7\,S_{max}}{B^2}\,exp\left(-6.65\,\dfrac{r}{B}\right)$ when $n = 1$ and $B = 6.65\,r_o$ | |

$r$ = radial distance from reference point
$B$ = radius of critical area of excavation
$\gamma$ = angle of draw
$n$ = parameter for characterizing strata conditions
$\phi(r)$ = influence function
$S_{max}$ = maximum possible subsidence
$\Gamma$ = gamma function
$r_o$ = independent parameter

*Source:* Brauner (1973); Hood et al. (1981).

Similar to the profile functions, the effect of percent rock hard in the overburden and "edge" effect at the panel edges can be incorporated into the subsidence calculations. Profile and influence functions are routinely incorporated within computer codes and are the most common methods of subsidence prediction and evaluation of the potential for surface effects from full or partial extraction mining.

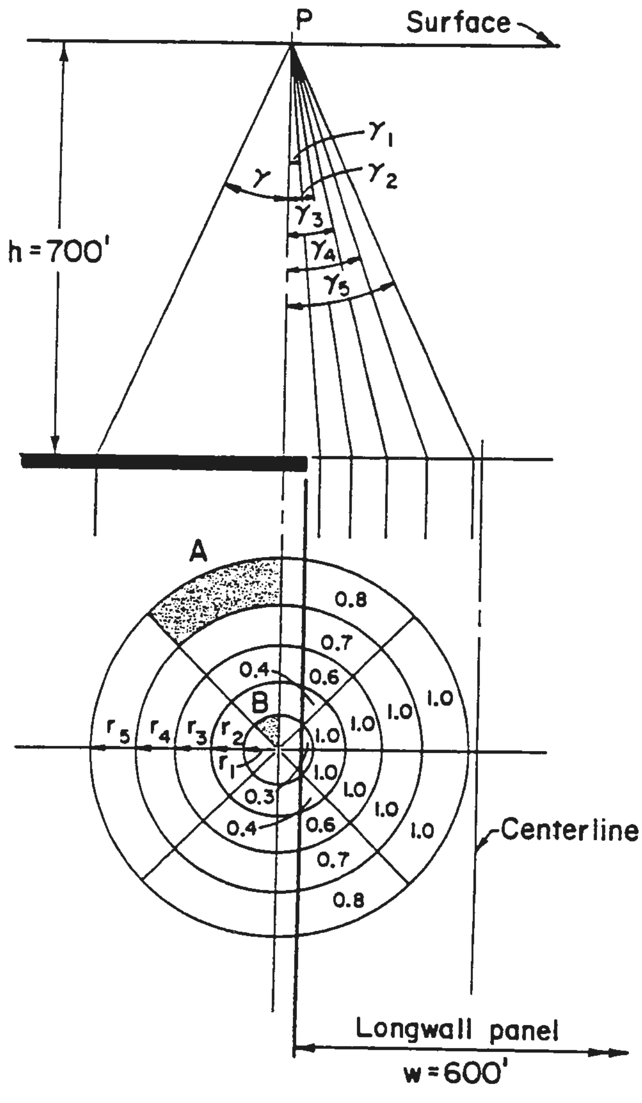



**Figure 5. Graphic Depiction of Bals Influence Theory. (Adamek and Jeran, 1985).**

The mining geometry, location of the calculation points, and overburden thickness at each calculation point are typically input with a CADD drawing. This increases the amount and spacing input data and consequently the accuracy of the output data. Dialog boxes are used to input parameters including angle of draw, tangent angle of influence, edge effect, mining height, and other parameters complete the input data. Output is terms of subsidence, horizontal strain, horizontal displacement, curvature, and slope. The output parameters are easily contoured on the CADD drawing used for model input. Currently, the state-of-the-art in subsidence prediction is the use of influence functions embedded in a computer code with CADD based input of surface topography, mine geometry (pillar, gob, and panel dimensions). This approach provides the most accurate prediction, ease of data input, rapid computation, and can be directly integrated into future mine planning.

## 1.3 NUMERICAL METHODS

Numerical methods including finite element, boundary element, and displacement-discontinuity are based upon the principles of continuum mechanics. As discussed in the background portion of this chapter, numerical models are most amenable to evaluating the stability of structures of man-made materials. The quantity and detail of the required input data make numerical models difficult to use without simplifying assumptions. Because the numerical model is constructed to depict the thickness, strength, and physical properties of the immediate floor, coal, roof, and overburden, a thorough and extensive knowledge of the pre-existing stress state and each geological material is required to accurately characterize the mine, overburden, and resulting subsidence behavior. This level of information is typically not available from coal company exploration programs and would be prohibitively expensive to collect on a routine basis.

Discontinuities in the overburden including regional linears, local joints, fractures, and bedding planes are typically unknown even with extensive core drilling. Numerical methods are also dependent upon square or rectangular elements that somewhat limits the range of geometries that can be modeled. The numerical models must be calibrated to known case histories before confidence is established in the subsidence predictions. Finally, the creation of a numerical model is very time consuming and requires a high level of engineering expertise. Although numerical models are used extensively to examine roof, pillar, and floor behavior within the mine, the time and data requirements make this approach less appealing than the empirical (graphical, profile, and influence) techniques discussed earlier in this chapter for subsidence prediction.

## 1.4 REFERENCES


Adamek, V. and Jeran, P.W., 1985. "Precalculation of Subsidence Over Longwall Panels in the Northern Appalachian Coal Region," *Mine Subsidence Control, U.S. Bureau of Mines IC 9042*, pp. 34-56.

Agricola, G., 1950. *De Re Metallica*, translated L. and H. Hoover, Dover Publications, New York.

Anon. 1975. *Subsidence Engineer's Handbook*, National Coal Board, Mining Department London, 166 p.

Bals, R., 1931/1932. "A Contribution to the Problem of Precalculating Mining Subsidences," *Mitteilungen aus dem Markscheidewesen*, Vols. 42/43, pp. 98-111.

Brauner, G., 1973. "Subsidence Due to Underground Mining, Part 1. Theory and Practices in Predicting Surface Deformation," *U.S. Bureau of Mines IC 8571,* 56p.

Hood, M., Ewy, E.T., and Riddle, L.R., 1981. "Empirical Methods of Subsidence Prediction - A Case Study," *Proc. Workshop on surface subsidence Due to Underground Mining,* S.S. Peng ed., West Virginia University, Morgantown, W.Va., pp. 1--123.

Karmis, M., G. Goodman, and G. Hasenfus, 1982. "Subsidence Prediction Techniques for Longwall and Room and Pillar Panels in Appalachia," *Stability in Underground Mining II,* Lexington, Kentucky, AIME-SME, pp 542-553.

Karmis, M., C. Haycocks, B. Webb, and T. Triplett, 1982 "The Potential of the Zone Area Method for Mining Subsidence Prediction in the Appalachian Coalfield," pp. 48-59.

Peng, S.S. and Chiang, H.S., 1984. *Longwall Mining*, John Wiley & Sons, N.Y.

Society for Mining, Metallurgy, and Exploration, 1992. *SME Mining Engineering Handbook, Chapter 10.6 Mine Subsidence*, Hartman ed., Society for Mining, Metallurgy, and Exploration, pp. 938-971.

# CHAPTER 7

# POTENTIAL EFFECTS OF LONGWALL MINING AND ASSOCIATED ACTIVITIES ON THE ECOLOGY OF SOUTHWESTERN PENNSYLVANIA

Jan W. Briedé, Ph.D. and David A. Dixon
Dames & Moore
Cincinnati, Ohio

# 1.0 INTRODUCTION

This document details the results of an investigation on the potential effects of longwall mining and associated activities, on the ecology of Southwestern Pennsylvania (Washington and Greene Counties). The objective of this study was to develop a set of independent papers (chapters in this document) that discuss potential ecological effects. This study was required to be impartial. Because of these requirements, it is based on a literature review; two visits to areas in Southwestern Pennsylvania that were previously undermined; and personal/professional experience of the two main authors. Some data on tree growth after subsidence were collected in the field; however sample size was too small to reach a definitive conclusion.

## 1.1 OBJECTIVES

This section concentrates on the effect of subsidence on the prevailing ecosystems in Southwestern Pennsylvania, because subsidence appeared to be the major impact of longwall mining on the ecological landscape of the area. The initial plan was to conduct a detailed literature study; however, little scientific information was available on the effect of subsidence on a region's ecology. Library and database searches were conducted at the University of Kentucky, the University of Cincinnati, and the University of Pittsburgh. Databases consulted included Biological Abstracts, Environmental Abstracts and the local library catalogues. Very little information was found on the effects of both longwall mining and subsidence on the ecology of a region. After the library search it became increasingly clear that the authors needed to rely on field observations, their own experience and discussion with experts. These discussions and field observations were used to develop a number of scenarios about what happens to the ecology of a region after subsidence. These scenarios are based on speculations, since no "hard" data were available. Field investigations conducted for this report, showed that subsidence may cause some localized heavy ecological stress. These field visits also show that the Southwestern Pennsylvania ecosystems appear to be very resilient, as the ecosystems showed few visual changes as the result of recent subsidence. Long-term impacts of subsidence may be very ecosystem or even site dependent; and would require detailed research. However, it seems that many ecosystems are tolerant to some environmental changes without much long-term harm. In other words, ecosystems are very dynamic and constantly evolving. Some will argue that ecosystems have never evolved with pressures such as subsidence and that this subsidence occurs over large areas. Both statements are correct, and it is this uncertainty that was the reason for this project. It could also be argued that any change to the present state of an ecosystem is undesirable, and should be avoided at all cost. This is not necessarily correct, as many ecosystems are maintained and renewed by disturbance (and changes), while others have been stable for centuries. In a sense, all ecosystems in Southwestern Pennsylvania are disturbance dependent. While forest ecosystems depend on fire, tree fall and gap creation for renewal, pastures and wetlands depend on grazing and fire for renewal.

This document discusses the potential effect of longwall mining and associated subsidence on the four major ecosystems encountered in Southwestern Pennsylvania in the following sections.

ECOSYSTEMS

Field investigations encountered four major ecosystems in Southwestern Pennsylvania. For this document they are classified as: streams, riparian areas, wetlands and uplands. Ecosystems are defined as the sum of plant communities, animal communities and the environment in a particular region, or:

Ecosystem = Plant Community + Animal Community + Environment

Most ecosystems are fairly specialized to prevailing conditions in a region, and changes in one of these three components are likely to change the ecosystem (sum). However, there are also strong interactions between the three ecosystem components. For example, an environmental change, such as increased soil moisture, may increase the growth of plants, which in turn may increase the number of animals that eat these plants. An increase of these animals may increase the number of predators at a site. The final result may be the development of a different ecosystem.

These four ecosystems include: streams, riparian ecosystems, wetlands and uplands (Figure 1). Uplands include forests, agricultural lands and pastures. A final section discusses some important related terms and issues, including methane releases, endangered species and weedy species (underlined words in the main body of the text are defined elsewhere). Each of the major chapters contain a brief definition and discussion of the subject, a discussion of relevant regulatory issues, and a discussion on the effect of longwall mining on the subject. Whenever possible, a list of references, additional reading materials and experts are also added.

# 2.0 STREAMS AND LONGWALL MINING/VALLEY FILLS

## 2.1 DEFINITION

A stream can be generally defined as a mass of usually surface water with its load moving in a more or less defined pattern with channels and banks following the course of least resistance toward a lower elevation. Streams are typically fed by groundwater sources, such as seeps and springs, and by direct surface runoff as a result of precipitation. On the basis of continuity of flow, there are three basic stream types; perennial, intermittent, and interrupted streams. Perennial streams receive their waters mostly through seepage and springs from subsurface water and from the confluence of intermittent streams, and the water table in the immediate drainage area usually stands at a higher level than the floor of the stream. Intermittent streams receive their waters primarily from surface runoff, such as precipitation and snow melt, with stream flow occurring during the wet periods. Naturally occurring interrupted streams flow alternately on and below the surface, with subsurface flow through coarse gravel or limestone caverns.

## 2.2 REGULATORY ISSUES

Perennial streams are protected by several federal and state statutes, including the Clean Water Act (33 U.S.C. 1344), the Surface Mining Control and Reclamation Act (SMCRA) of 1977 (30 U.S.C. 1201), the Energy Policy Act (Pub. L. 102-486, 106 Stat. 2776), the 25 Pennsylvania Code 89, Act 54 of the Bituminous Mine Subsidence and Land Conservation Act (BMSLCA) of 1966 (52 P.S.1406), and the Coal Refuse Disposal Control Act (CRDCA) of 1968 (52 P.S.30.51).

According to the Bureau of Mining and Reclamation's Program Guidance Manual for Perennial Stream Protection (1994), longwall mining operations within 400 feet horizontally or 200 feet vertically of a perennial stream are regulated (with specialized restrictions and requirements based on site specific mine plans). Included in the requirements are the determination of adverse effects and associated corrective action for documented impacts to perennial streams. It should be noted that many streams may directly or indirectly support federally endangered species, and impacts to these species is regulated by the U.S. Endangered Species Act (although this is not the case in Southwestern Pennsylvania).

Chapter 105 of Pennsylvania's Dam Safety and Waterway Management regulations protect "Waters of the Commonwealth." It defines encroachment as "a structure or activity which changes, expands or diminishes the course, current or cross section of a watercourse, floodway or body of water." Watercourses include channels of surface water with defined bed and banks, including streams, creeks, brooks, and rivers (Department of Environmental Resources [DER] Permit Guide to Water Obstruction and Encroachment Permits). Floodways are determined by one of two methods: 1) by the Federal Emergency Agency (FEMA); and in absence of a FEMA flood study, the floodway limits are established as 50 feet landward from the top of each stream bank. Bodies of water include natural and artificial lakes, ponds, reservoirs, swamps, marshes and wetlands. Subsidence has been shown to affect the course, current and cross sections of streams, and it is unclear how longwall mining and the resulting subsidence are regulated the above mentioned regulations.

## 2.3 DISCUSSION

### 2.3.1 Background

Streams morphology includes a stream bed, stream bank, flood prone area (flood plain) and a riparian area (Fig 3). Stream beds generally consist of pools and riffles. These morphological characteristics are the result of the influence of physical laws on the function and process of the stream channels. In their natural state, streams are in a dynamic equilibrium, and are well balanced by equal rates of erosion and deposition. Sediments and water are supplied by the watershed, and a stream carries the water efficiently as a result of its morphology. This organized nature of streams allows researchers to consistently classify streams using measurable variable. One such method was published by Rosgen (1994), and is widely accepted as the most state-of-the-art classification method. It is presently used by the U.S. Forest Service throughout the US. Rosgen examined over 450 rivers in the US, Canada and New Zealand during the development of this method, and was able to identify 42 major stream types. These stream types were classified by entrenchment ration, width/depth ratio, sinuosity, slope range, and channel material particle size.

Stream beds generally have two distinct habitats; namely, riffles and pools, that form an alternating aquatic complex. Riffles and pools are considered of equal importance to a stream.

Riffles are characterized by shallow water where the velocity of the current is great enough to keep the bottom clear of silt and other loose material, thus providing a firm substrate, being the material making up the bottom of the stream. Riffles occupy the majority of the upper and middle sections of the stream. These sections exhibit steep to moderate gradients, with less extensive flood plains than the lower courses. Definite banks, standing higher than the stream, are present and are typically vegetated with riparian plant species. Current-created turbulence tends to maintain a relatively uniform set of physiochemical conditions, with high oxygen levels and constant nutrient reintroduction. Because of this, the productivity of primary producers in riffles is up to 30 times that of those in standing water (Nelson and Scott, 1962). In addition, an assortment of substrates for colonization and the development of communities are present. This aquatic habitat consists of a variety of boulders, cobble, gravel, and silt and is usually occupied largely by specialized benthic (bottom-living) organisms which become firmly attached or cling to a firm substrate (aufwuchs), and by strong swimmers, such as darters, trout, and daces (types of fish). Insects are the predominant occupant of riffle areas, as well as aufwuchs organisms such as diatoms, blue-green and green filamentous algae, and water moss. Characteristic of riffle insects are the nymphs of mayflies, caddisflies, true flies, stoneflies, and alderflies. Thus, riffle habitats are the prime source of energy in the lower levels of the food chain.

Pools, on the other hand, are typically areas of deeper water where the velocity of current is reduced and silt and other loose materials tend to settle to the bottom. The stream in this instance may be operating in a broad flood plain of low relief, with the shores generally poorly defined and sometimes bordered by marshes or swamps, with emergent vegetation present. While riffles are productive habitats that introduce oxygen to the water, pools are also productive and are major sites for carbon dioxide production during the summer and fall (Neel, 1951). A balance between oxygen and carbon dioxide production is important in streams, and any changes in this balance will upset the ecosystem. Pools are also the catch basins of organic material, for here the velocity of the current is reduced enough to allow a part of the load to settle out, and decomposition is abundant. As the result of decreased flow, the faunal organisms are able to move about to obtain their food, and a plankton population of a sort is developed in pools. Typical pool inhabitants include minnows, carp, suckers, catfish, bass, turtles, and amphibians. The loose mud, silt, and organic detritus provide a soft substrate favorable for burrowing forms of organisms. Mollusks, pulmonate snails, crustaceans, tube-dwelling worms, and burrowing insects such as mayflies. Plankton and protozoan are common in pools. Pools contain large quantities of first-order consumers in the food chain, due to the abundance of detritus. Pools are also the spawning site of a wide variety of aquatic life.

Aquatic settings such as stream riffles and pools are the habitat for a wide variety of flora and fauna during the course of their life cycles. Perennial streams provide year-round habitats, while intermittent streams are dry during much of the year, and typical aquatic communities do not become established. They also offer unique and critical habitats to many protected species as regulated by the Endangered Species Act, including fish, amphibians, and birds.

### 2.3.2 Longwall Mining and Streams

Longwall mining activities have the potential to severely diminish stream flow, destroy aquatic habitats, or impact an existing water use when existing regulations are not adequately regulated and enforced. The process of longwall mining includes planned subsidence of the strata overlying the coal. When longwall mining occurs in the vicinity of streams, increased fracturing in the strata overlying the underground workings creates avenues for infiltration of stream water (Figures 1 and 4), and natural perennial or intermittent streams can become interrupted streams as a result of subsidence. The potential for acid mine drainage may increase when this water infiltrates the seam that is being mined.

Fracturing of the substrate has been responsible for partial or complete loss of stream flow, and has been recorded for streams up to 350 feet from a panel and 500 feet beneath the mine (Walliser, 1995). The 1997 field visit to Southwestern Pennsylvania showed two streams of which sections were completely dewatered. Land owners insisted that these streams were perennial; however, the mining companies successfully claimed that these streams were ephemeral were not affected by the regulations. Upstream flow disappeared into cracks in the soil and reappeared down stream in the creek bed. Measurements in one stream showed that up to 1200 feet of stream habitat was impacted. Loss of water in these streams will likely coincide with habitat loss in the stream and along the stream (riparian area), although this may depend on the depth of the water. When a particular segment of a stream has reduced stream flow, many of the aquatic organisms will die.

Others, more adapted to periodic dry periods, may survive for a short time. Eventually, the entire stream habitat will no longer support aquatic life.

In addition to the de-watering of streams, subsidence causes changes to the make-up of a stream, such as the creation of pool habitats in lower reaches of fast-moving streams, or the deepening of existing pool habitats (Photographs 1 and 2). Riffle habitats disappeared or became less pronounced and pool habitat appeared in its place. In these scenarios, subsidence lowers the bottom of the stream without de-watering the channel, creating a deeper pool capable of sustaining more pool-oriented species. The section of riparian ecosystems discusses subsidence induced habitat changes of streams in more detail. Subsided stream beds may loose some of the benefits associated with riffles such as oxygenation and nutrient reduction. As a results, riffle oriented species may eventually disappear from a stream section that was subsided.

As mentioned above, Rosgen (1994) used the organized nature of streams to classify them by determining entrenchment ration, width/depth ratio, sinuosity, slope range, and channel material particle size. This technical classification can be used to predict short- and long-term impacts of subsidence on stream encroachment. Further, this method can be used to develop management and stream repair projects, using bioengineering or engineering practices, by making sure that the restoration is balanced with stream morphology.

Lining of a perennial stream with a concrete liner after subsidence is presently a measure to manage and mitigate subsidence induced stream impacts. This would require the temporary diversion or collection of stream flow, accompanied by the complete removal of existing substrate in the stream bed. Upon placement of the liner, the substrate, or artificial media, would be returned to recreate the original stream channel. This procedure, however, would involve drastic disturbance of stream life, because it requires the periodic displacement of most of the aquatic organisms that occupy the stream. Mortality of these displaced species can be expected to be high. However, although extremely slow and uncertain, successful re-establishment of the flora and fauna may be possible over time. The reestablished species will likely not evolve into the original ecosystem encountered at the site, before subsidence.

It is not certain how to manage and repair a disappeared stream in a biologically sound way. Cracks and pores in the bedrock may eventually fill up with debris that is carried by the stream, and stream may eventually reappear when the infiltration of water through these cracks becomes too slow. This reappearing of streams was reported by the mining industry; however, no time frame was given, and long-term ecological effects of the water disappearance on the local flora and fauna could not be evaluated. It seems possible that grouting with a cement like material could be used to infiltrate the cracks and pores, thus blocking the undergroundwater flow, forcing the creek to resume its original flow. Re-establishment of a fully functioning ecosystem in areas where streamflow has disappeared is then possible, but may be slow and uncertain, and the original ecosystem will likely not be restored.

As discussed previously, longwall mines in Southwestern Pennsylvania may require the construction of valley fills, in which coal refuse and reject materials are deposited. These valley fills will disrupt the habitats that contain streams. Existing streams and most offsite runoff would have to be diverted around the fill with onsite runoff from the fill itself channeled into underdrain systems. During construction of a valley fill, the riffle or pool habitat formerly occupying the stream would be lost, and the organisms would die. However, CRDCA regulates the placement of valley fills, with primary selection sites being previously disturbed mined areas, with avoidance of environmentally sensitive areas such as wetlands and high quality watersheds.

## 2.4 REFERENCES

Neel, J.K. 1951. Interrelations of certain physical and chemical features in headwater limestone streams, Ecology, 32:368-391.

Nelson, J.K. and D.C. Scott. 1962. Role of detritus in the productivity of an outcrop community in a Piedmont stream. Limnol. Oceanog. 3:396-413.

Rosgen, D.L. 1994. A classification of natural rivers. Catena, 22:169-199.

Walliser, J.J. 1995. Longwall Mining's Impacts on Perennial Streams: The Regulatory Framework in Pennsylvania.

## 2.5 ADDITIONAL INFORMATION

*Additional recommended reading:*

Allen, J.D. 1995. Stream ecology: structure and function of running water. Chapman & Hall, NY.

Dunn, T., and L.B. Leopold. 1978. Water in environmental planning. Freeman and Comp., San Francisco, 818 pp.

Harper, D.M., and A.J.D. Ferguson (Eds.). 1995. The ecological basis for river management. J. Wiley, NY, 614 pp.

Whitten, B.A. (Ed). 1975. River ecology. University of California Press, Berkeley, 715 pp.

*Experts:*

Many consulting companies have experts who specialize in stream classification, problem identification and restoration.

Also try your local University and Agriculture Extension Agent

**Pennsylvania Department of Environmental Protection**
Bureau of Dams, Waterways and Wetlands
P.O. Box 8554
Harrisburg, PA 17105-8554
tel: 717-783-1384

**U.S. Fish and Wildlife Service**
315 South Allen Street
State College, PA 16801
tel: 814-234-4090

**Pennsylvania Fish and Boat Commission**
P.O. Box 67000
Harrisburg, PA 17106-7000
http://www.state.pa.us/PA_Exec/Fish_Boat/pfbchom2.html

**U.S. Army Corps of Engineers**
(Pennsylvania is serviced by at least four different offices, Southwestern Pennsylvania falls under the Ohio River Basin)
http://www.usace.army.mil/ (for general information)
http://wetland.usace.mil/ (the regulatory homepage)

1. **Ohio River Basin**
   Pittsburgh District Corps of Engineers
   Room 1834 Federal Building
   100 Liberty Ave.
   Pittsburgh, PA 15222
   tel: 412-644-6872

2. **Great Lakes**
   Buffalo District Corps of Engineers

3. **Delaware River Basin**
Philadelphia District Corps of Engineers

4. **Susquehanna River Basin**
Baltimore District Corps of Engineers

**U.S. Forest Service**
Rocky Mountain Experiment Station
Fort Collins, Colorado

# 3.0 RIPARIAN ECOSYSTEMS

## 3.1 DEFINITION

Riparian ecosystems are located in zones along rivers, streams, and creeks, and form the interface between land and water. Riparian areas are very dynamic and undergo processes such as flooding, scouring of the soil and silt deposition. Riparian areas are paramount to maintaining stream bank stability and stream integrity, and are very rich in species. These ecosystems contain plant and animal species that depend on the water for their reproduction, distribution and survival. Typical riparian plant species include sycamore, cottonwood, ash, elm, willow, ferns, and jewelweed. Riparian animal species include salamanders, turtles, otters, beavers, and belted kingfishers. Additional information on riparian systems can also be found in the sections on streams and wetlands.

## 3.2 REGULATORY ISSUES

Many of the regulations that apply to perennial streams may also apply to riparian areas (habitat immediately adjacent to these streams). State encroachment regulations, in particular, deal with impacts on riparian habitats. Chapter 105 of Pennsylvania's Dam Safety and Waterway Management regulations protect "Waters of the Commonwealth." It defines encroachment as "a structure or activity which changes, expands or diminishes the course, current or cross section of a watercourse, floodway or body of water." Watercourses include channels of surface water with defined bed and banks, including streams, creeks, brooks, and rivers (DEP Permit Guide to Water Obstruction and Encroachment Permits). Riparian areas can often be found on the banks of stream.

As discussed later in this section, and in other sections of this document, subsidence has been shown to affect the course, current and cross sections of streams evaluated in Southwestern Pennsylvania, and it will be likely that it will also affect riparian habitats.

## 3.3 DISCUSSION

### 3.3.1 Background

Riparian areas are paramount to the health of stream. They provide valuable habitat for a wide variety of plant and animals species and have a large biodiversity. Riparian ecosystems are adapted to periodic, short-term, often annual, flooding and moist soil conditions that often reshapes the landscape. This flooding creates very fertile areas because nutrient-laden silt washed from surrounding areas is deposited during floods. Because of the frequent flooding (disturbance), riparian plant species are able to grow rapidly and colonize newly created silt bars, providing bank stability. In addition to bank stability, riparian vegetation provides shade which is essential in maintaining lower ambient water temperatures and light regime that are required by many stream inhabiting species for optimal growth and reproduction (see discussion below). Further overhanging plant species provide fish with hiding places from predators. Riparian vegetation provides cover or edge habitat for terrestrial species, where they can forage and get easy access to drinking water. The nearby water body also provides cover for animals, such as amphibians, retreating from predators, and offers a great source of food in the form of aquatic plants and animals.

### 3.3.2 Longwall Mining and Riparian Areas

As mentioned in the previous section, examination of streams in subsided areas in southwestern PA showed three possible outcomes after an area is under mined by longwall mining. These outcomes include (1) the formation of riffles; (2) the sudden appearance of pools; and (3) the complete disappearance of a creek or stream. Observations in Southwestern Pennsylvania showed that generally more pool habitat than riffle habitat is formed as a result of subsidence.

The formation of riffles in a pool section of a stream seems to have little effect on a riparian ecosystem. Water will still flow through the stream and streams will supply the surrounding vegetation with water. However, pool formation will have a dramatic effect on riparian areas. The sudden creation of pools and deepening of existing pools as a result of subsidence was observed at various locations in SW PA. In some cases, the vegetation and trees that were located on the banks of these stream became permanently flooded. This sudden inundation killed even the most adapted species, and dead trees were seen standing in water of more than one foot deep (Photographs 1 and 2). These dead trees may become valuable habitats for a different class of species, such as bats (including the endangered Indiana bat), insects, birds and many other species. Eventually the trees may fall over into the stream, and they could become valuable hatching areas and hiding places for young fish. Further, the rotting trees will attract large numbers of microscopic aquatic life and aquatic insects, which are a valuable food source for a variety of animals, including fish and birds. In summary killing of trees is not necessarily detrimental to an ecosystem, although dead trees are considered an eye sore by some, and are symptomatic of biological changes taking place in a river.

The killing of the trees and shrubs may have a potential negative effect on areas that have a narrow riparian band. These riparian buffers could be eliminated entirely when these bands are narrow. Further, the next layer of species (vegetation) may not include any species that are adapted to riparian (frequently wet soils) conditions, and growth of these non-adapted species may slow down. Some species may actually die. In these cases, the positive effects that a riparian ecosystem has on a stream may be lost. Dying of riparian trees will allow more light to reach the streams, which may result in a rise of water temperature in the pools. Some species of fish are extremely water temperature dependent for their survival and reproduction. Many river and stream species are also not adapted to high light intensities. High light intensities may also increase the plants and algae that grow in steams. Algae and plant growth in the pools have been shown to have a positive and negative effect on stream organisms. The increased plant growth in a stream may increase the diversity in streams and oxygenate the water, but on the long-term may alter the biological balance of a stream. Further, dying water plants and algae have been shown to decrease oxygen levels of water, and increase toxin levels in a stream. Rising water temperatures will also lower the oxygen holding capacity of the water. Combined with the loss of riffles in these subsided stretches of the stream which oxygenate the water, subsidence and the potential loss of riparian habitats could have devastating effects on a stream. It is not sure if the subsidence created riffles off-set the loss of riffles in the subsided areas.

As mentioned in the section on streams, the disappearance of streams as a result of longwall mining is likely caused by stress fractures in a stream bed. The water will flow into these cracks to the next aquifer and likely follow this aquifer, until it again surfaces in the stream (Figure 4). This was observed in two creeks during a visit to Southwestern Pennsylvania in the summer of 1997. In one stream, an approximately 1,200 foot section of a stream had dried up; water disappeared at one spot and appeared further down stream, in the same stream bed. No distance measurements were taken in the second stream; however, a similar phenomenon was observed. It can be expected that during large rainfall events, not the entire stream will disappear under ground, but that a portion of the stream will flow above ground.

The long-term effect stream disappearance may be devastating to the aquatic and riparian communities. Mortality of fish, aquatic plants, aquatic insects and aquatic microorganisms will be complete. Riparian communities typically depend on high soil moisture supplied by the stream for their survival, and the disappearance of streams may devastate this community, in particular when the new course of the creek water is below the root zone (Figure 4). During the 1997 visit, no changes in the riparian ecosystems were observed near the two streams that disappeared as the result of subsidence. Ecosystem changes are usually a subtle and long-term process, and effect may not be noticeable in the short time span since the creeks disappeared. However, plant growth may decrease as a result of the lack of moisture and the species may be under increasing stress. This would make them susceptible to disease, insect attacks, droughts and the competition of more adapted species. Shallow-rooted riparian plants that depend on a steady water supply can be expected to have the highest morality and may disappear from an area. Further, mortality of germinating and establishing of seedlings of riparian species will be high.

In conclusion, the increased stress on the riparian ecosystems resulting from subsidence, described in this section and in the section on streams, is likely to cause vegetational changes. Plants will die when they become submerged, or when the soil becomes either too dry or too wet. Eventually these plants will be replaced by new, more adapted species. Eventually a new, stable ecosystem will become established. At this point, assigning values to the old and new ecosystem for comparison purpose is subjective. A detailed, long-term ecological studies should allow decision makers to develop a value system on which to base such comparisons. However, in the mean time, this lack of data should not lead to the lack of action. A subsided area should be monitored for the invasion of exotic or weedy species. The authors therefore recommend that once changes to a stream are documented, the area is monitored for vegetation changes. A vegetation management plan may be required when these studies show that weedy species are invading. As mentioned in the section on streams, mitigation of water loss is possible through the lining of stream beds. This should be used as last resort, because lining may reduce the water available to the riparian species, and thus harm the riparian vegetation. Further, the process of lining may also require massive disturbance of riparian areas.

## 3.4 ADDITIONAL INFORMATION

*Additional recommended reading:*

Harper, D.M., and A.J.D. Ferguson (Eds.). 1995. The ecological basis for river management. J. Wiley, NY, 614 pp.

Malanson, G.P. 1993. Riparian landscapes. Cambridge University Press, NY 296 pp.

Platt, W.S. 1987. Methods for evaluating riparian habitats with application to management. USDA Forest Service, Intermountain Research Station, General Technical Report 221, 177 pp.

Whitten, B.A. (Ed). 1975. River ecology. University of California Press, Berkeley, 715 pp.

*Experts:*

Many consultant companies have experts who specialize in riparian areas, ecological monitoring and ecosystem restoration.

Also try your local University and Agriculture Extension Agent

~ state and federal sources of expertise ~

**Pennsylvania Department of Environmental Protection**
Bureau of Dams, Waterways and Wetlands
P.O. Box 8554
Harrisburg, PA 17105-8554
tel: 717-783-1384

**U.S. Fish and Wildlife Service**
315 South Allen Street
State College, PA 16801
tel: 814-234-4090

**Pennsylvania Fish and Boat Commission**
P.O. Box 67000
Harrisburg, PA 17106-7000
http://www.state.pa.us/PA_Exec/Fish_Boat/pfbchom2.html

**U.S. Army Corps of Engineers**
(Pennsylvania is serviced by at least four different offices,
Southwestern Pennsylvania falls under the Ohio River Basin)
http://www.usace.army.mil/ (for general information)
http://wetland.usace.mil/ (the regulatory homepage)

1. **Ohio River Basin**
   Pittsburgh District Corps of Engineers
   Room 1834 Federal Building
   100 Liberty Ave.
   Pittsburgh, PA 15222
   tel: 412-644-6872

2. **Great Lakes**
   Buffalo District Corps of Engineers

3. **Delaware River Basin**
   Philadelphia District Corps of Engineers

4. **Susquehanna River Basin**
   Baltimore District Corps of Engineers

# 4.0 WETLAND ISSUES AND LONGWALL MINING

## 4.1 DEFINITION

The definition of wetlands varies among authors (TABLE 1). The U.S. Fish and Wildlife Service defines wetlands as areas that are transitional between terrestrial (land) and aquatic (water) based systems (Cowardin et al. 1979). Because of its position between these two systems, the water table is near the surface or, in some cases, the land is covered by water (less than six feet deep). The U.S. Army Corps of Engineers (Federal Register 1982) and the U.S. Environmental Protection Agency

(Federal Register 1980) define wetlands as "areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas" (Braddock 1995). Typically wetlands have either a high water table or saturated soils; they also occur in areas where the land is covered by shallow water that may be up to six feet deep. Saturation or flooding should be at least for 12 days during the growing season (typically between mid-April and September).

## 4.2 REGULATORY ISSUES

Wetlands are protected by Section 404 of the Clean Water Act (33 U.S.C. 1344). This Act includes wetlands in its definition of waters of the U.S., and regulates the discharge of fill materials in wetlands. In other words, filling of wetlands is strictly regulated by the Clean Water Act. Any such activity requires an extensive delineation and permitting process. Under the present circumstances, draining of a wetland is allowed, when no soil is moved. In a recent publication, Braddock (1995) gives a good overview of ecological, law, permitting and enforcement issues as they relate to wetlands.

Wetlands are protected by Chapter 105 of Pennsylvania's Dam Safety and Waterway Management. Wetland impacts are defined as encroachments of the Waters of the Commonwealth. Chapter 105 defines encroachment as "a structure or activity which changes, expands or diminishes the course, current or cross section of a watercourse, floodway or body of water." Watercourses include channels of surface water with defined bed and banks, including streams, creeks, brooks, and rivers (DEP Permit Guide to Water Obstruction and Encroachment Permits). Floodways are determined by one of two methods: 1) by the FEMA; and in absence of a FEMA flood study, the floodway limits are established as 50 feet landward from the top of each stream bank. Bodies of water include natural and artificial lakes, ponds, reservoirs, swamps, marshes and wetlands. It is unclear how these regulations interact with longwall mining and the resulting subsidence; however, as discussed later in this section, subsidence has been shown to affect wetlands in Southwestern Pennsylvania.

**TABLE 1**
**Wetland Definitions by Various Authors and Organizations**
**(adapted from Post 1996).**

| Purpose and Scope | Wetland Definition | Author |
|---|---|---|
| Regulatory (United States) | " ... those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." | Mitsch and Gosselink (1993) |
| Classification | "... wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year." | Cowardin et al. (1979) |
| Science | "... an ecosystem that depends on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate ... and biological features reflective of the recurrent, sustained inundation or saturation. Common diagnostic features of wetlands are hydric soils and hydrophytic vegetation." | National Research Council (1995) |
| Classification (Canada) | "Land that has the water table at, near, or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment." | Tarnocai (1980) in Zoltai (1988) |

## 4.3 DISCUSSION

### 4.3.1 Background

In the past, wetlands were maligned and considered worthless. People referred to wetlands as marshes, swamps and bogs that were insect-ridden, unattractive and dangerous, with some names such as the "Great Dismal Swamp." Wetlands were routinely drained for use in agriculture and development. During the past 20 years, the public opinion about wetlands has changed dramatically, and wetlands are now considered to be very valuable. Humans increasingly depend on wetlands for clean water, clean air, recreation and wildlife. Niering (1985) details some of the benefits of wetlands in the Audubon Society Nature Guide to Wetlands. Benefits of wetlands include the maintenance of biodiversity, as many plant and animal species rely completely on wetlands. Wetlands are resting areas for migratory birds, including waterfowl and game birds. Research has shown that they are crucial to the survival of many species. In the U.S., it is estimated that at least 150 bird species and 200 fish species directly depend on wetlands for their survival (Niering 1985). Further, wetlands are among the most productive ecosystems in the world, that tie up large amounts of CO2 and marsh gasses such as methane. These gasses are responsible for greenhouse warming and the disappearance of the ozone layer. Other benefits of wetlands to society include flood control, groundwater discharge, and pollution filtration. As a result, wetlands are presently closely protected as a valuable resource.

The definition of wetlands is very broad, and in the strictest interpretation of the definition, wetlands can occur almost anywhere. The U.S. Army Corps of Engineers (COE) published a delineation manual which can be used by professionals to determine whether a site is a wetland (Environmental Laboratory 1987). For a site to be classified as a wetland, it is tested for three mandatory parameters. These parameters include the presence of (1) hydric soils, (2) hydrophytic vegetation, and (3) wetland hydrology at the site.

Hydric soils are saturated, flooded or ponded long enough to develop certain characteristics. These conditions are caused by the lack of oxygen in the soil and are manifested by a general gray color and bright mottles in the soil. A list of hydric soils has been prepared by the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). Further, county offices of the NRCS usually have a list of the hydric soils that occur in the county.

Hydrophytic vegetation includes plants that require regular saturation, flooding, or ponding conditions. Certain species are better adapted to saturated conditions and can only survive in saturated soils. These plants are called obligate wetland plants. Other plants can not survive any saturation and are called upland plants. Naturally other plants will survive at various degrees of flooding, and a scale was developed to indicate the wetland status of many of the naturally occurring plant species (Upland, Facultative Upland, Facultative, Facultative Wetland, and Obligate Wetland). This list is available in various US Fish and Wildlife Service (FWS) Publications and on the web page of the FWS.

Wetland hydrology is a condition that facilitates saturation, flooding or ponding. Areas near seeps and springs or areas in depressions may have suitable hydrology. Ecologists typically look for signs of flooding such as drift lines, stained leaves and stems.

Wetlands can be found throughout the landscape, even on hill slopes and on top of some hills. On the other hand, floodplains may not be classified as wetland, when they only flood in the winter and do not have the proper soil and plant indicators.

The Clean Water Act requires that prior to development, land owners or developers have to conduct a wetland survey to determine the presence of wetlands on their property, and to determine if development will affect these wetlands. Typically, ecologists conduct a routine wetland delineation using the Corps of Engineers Manual (Environmental Laboratory 1987). The property owner has to go through a permitting process, once it has been determined that wetlands will be affected by the planned development. The State of Pennsylvania and the COE have developed a joint approach to deal with stream and wetland impacts (DEP undated a, and DEP undated b). A developer has to prepare a joined permit application and submit three copies to the Pennsylvania DEP. DEP will then forward one copy to the COE for the federal permit. In their permit request, land owners and developers must prove that impacts were avoided or minimized. Only then are they allowed to propose to mitigate for impacts on wetlands, and a mitigation plan should be part of the permit. The Pennsylvania rules are specific about which type of permit is needed (DEP undated a, and DEP undated b). As a rule of thumb, wetlands over 0.3 acre can not be impacted without some form of permitting and mitigation. Mitigation generally consists of creating new wetlands in the area at a ratio of at least 1.5 to 1 (1.5 acres created for 1 acre affected). In some areas the mitigation ratio may be as high as 4 to 1 or even 10 to 1.

### 4.3.2 Longwall Mining and Wetlands

As discussed in different sections of this document, the major impact of longwall mining on an area's ecology is through subsidence. Some of the impacts caused by subsidence include (1) a general slumping of the land; (2) changes in groundwater flow; (3) the drying up of springs; and (4) the sudden appearance of springs, elsewhere. These changes will likely affect wetlands. For example, wetlands that are fed by springs that suddenly dry up after subsidence will disappear. Further, stress fractures can also drain wetlands. Lastly, a wetland can also subside and become a pond. This will result in the loss of the wetland functions of the area; however, ponds are valuable habitats for other species. Robertson and Slack (1995) report on the effect of subsidence from groundwater, oil and gas extraction on lesser snow goose habitat in Texas. Subsidence causes the changes from marsh to pond, which was considered a negative impact on the geese, who needed the marshes for food supply. It is not clear whether subsidence induced wetland impacts are regulated, as Section 404 of the Clean Water Act does not regulate the draining of wetlands unless the soil is actually (mechanically) moved.

Once a wetland is drained and has dried up, it is expected that plants and animal species will either die or move away from the area. The area will subsequently be invaded by species that are adapted to these new conditions, and a new stable ecosystem will eventually develop. This is also the case with the creation of wetlands. The original plant and animal species will disappear, after which a wetland community will become established through a process called natural succession. Succession will take time; light seeded plant species and species that are eaten by animals will invade (colonize) an area first, followed by other species with larger seeds. This opening of an ecosystem caused by the sudden disappearance of plant and animal species makes an area extremely susceptible to the invasion of weedy species. Once weedy species take a hold of a site, it may be difficult for the appropriate native vegetation to become established. As a result such a site may loose its value as natural area and the area may become a source of weeds that may threaten the ecology and agriculture of the entire region. It is therefore paramount that the vegetation that is created by subsidence caused drainage or creation of wetlands is monitored extensively to ensure that a native vegetation is developing and the area is not taken over by weeds.

As mentioned above, subsidence may also be responsible for wetland creation. During a field visit to Southwestern Pennsylvania it was seen that wetlands appeared in depressions (Photograph 3) and in mined areas that have new springs. However, such a sudden creation of wetlands is not necessarily a good thing, in particular when the area is left unmanaged and weeds are allowed to invade the area. The definition of wetlands that was discussed above mentions the need for hydric soils, hydrophytic vegetation and hydrology. While a spring or depression creates a favorable hydrology, it may not have any value as a wetland, in particular when the soils and vegetation are lacking. Typically, soils and vegetation will develop hydric characteristics and gain value over time; however, this may take up to 100 years for the soils and at least five years for the vegetation. The wetland in Photograph 3 became established on a soil that was already hydric (had wetland characteristics), but appeared to have been drained for agriculture. This area may rapidly develop wetland characteristics because it has the hydrology and the soil. Seeds of wetland species were either still in the soil, blew in with the help of the wind, or were brought to the area in the mud on the feet of water fowl. This area will likely develop as a fully functioning wetland over time. However, the site should be monitored to ensure proper development into a native wetland and minimize the invasion of weedy species. Care should also be taken that wetlands are not the result of breached septic system leech fields, as has occurred in the region. Water in these wetlands are most likely contaminated with fecal coliform bacteria and other organisms.

In addition to subsidence, longwall mining may require valley fills, handling and processing facilities. The CRCDA specifies that valley fills will be put in areas previously affected by mining and may not be placed in wetlands. Although these restrictions seem to be sufficiently restrictive in their protection of wetlands, valley fill may have a long-term, lasting impact on wetlands down stream. Valley fills may impact downstream wetlands that are being recharged (receive their soil moisture from) by streams that originally passed through the area. Streams will be diverted, but will not pass through their natural substrate and not be recharged by the area occupied by the valley fill. As a result, total water flowing through these streams is likely to be less, and as a result of the decreased flow, the stream may carry more pollutants. Such changes may cause an irreparable harm to the wetlands, or cause changes that are undesirable or even harmful to the ecosystem. Further, there are some reports of leaking valley fills. These leakages may cause a direct effect on the water quality of nearby wetlands, or contaminate the groundwater that feeds wetlands some distance away from the valley fill.

## 4.4 REFERENCES

Braddock, T. 1995. Wetlands. An introduction to ecology, the law and permitting. Government Institutes, Inc., Rockville, MD.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. USFWS, USFWS/OBS 79/31.

DEP. Undated a. DEP permit guide to water obstruction and encroachment permits. Commonwealth of Pennsylvania, Department of Environmental Resources.

DEP. Undated b. Joint permit application. Instruction booklet for Commonwealth of Pennsylvania/U.S. Army Corps of Engineers.

Environmental Laboratory. 1987. Corps of Engineers Wetland Delineation Manual. United States Army Engineer Waterway Experiment Station, Technical Report Y-87-1, Vicksburg, MS.

Mitsch, W.J., and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York. 539 pp.

National Research Council. 1995. Wetlands: characteristics and boundaries. National Academy of Sciences, Washington, DC 307 pp.

Niering, W.A. 1985. The Audubon Society nature guides. Wetlands. A.E. Knopf, Inc. New York.

Robertson, D.G., and R.D. Slack. 1995. Landscape changes and its effects on the wintering range of a lesser snow goose (Chen caerulescens cearulescens) population: a review. Biol. Conserv., 71(2):179-186.

Zoltai, S.C. 1988. Wetland environments and classification. pp: 1-26. In: National Wetlands Working Group. Wetlands of Canada. Ecological Land Classification Series, No. 24. Sustainable Development Branch, Environment Canada, Ottawa and Polyscience Publications, Inc., Montreal.

## 4.5 ADDITIONAL INFORMATION

*Experts:*

Many consultant companies have experts who specialize in wetland issues, delineations, permitting, mitigation, and ecosystem restoration.

*~ state and federal sources of expertise ~*

**Pennsylvania Department of Environmental Protection**
Bureau of Dams, Waterways and Wetlands
P.O. Box 8554
Harrisburg, PA 17105-8554
tel: 717-783-1384

**Pennsylvania Department of Environmental Resources**
Southwest Office
400 Waterfront Drive
Pittsburgh, PA 15222-4745

**U.S. Fish and Wildlife Service**
315 South Allen Street
State College, PA 16801
tel: 814-234-4090

**Pennsylvania Fish and Boat Commission**
P.O. Box 67000
Harrisburg, PA 17106-7000
http://www.state.pa.us/PA_Exec/Fish_Boat/pfbchom2.html

**U.S. Army Corps of Engineers**
(Pennsylvania is serviced by at least four different offices,
Southwestern Pennsylvania falls under the Ohio River Basin)
http://www.usace.army.mil/ (for general information)
http://wetland.usace.mil/ (the regulatory homepage)

1. **Ohio River Basin**
   Pittsburgh District Corps of Engineers
   Room 1834 Federal Building
   100 Liberty Ave.
   Pittsburgh, PA 15222
   tel: 412-644-6872

2. **Great Lakes**
   Buffalo District Corps of Engineers

3. **Delaware River Basin**
   Philadelphia District Corps of Engineers

4. **Susquehanna River Basin**
   Baltimore District Corps of Engineers

# 5.0 UPLANDS

## 5.1 DEFINITION

Uplands are areas that cannot be classified as wetlands or aquatic habitat (Figure 2). They include pastures, croplands, scrub lands and forests that do not depend on saturation at regular intervals. Upland areas may be located on slopes and top of hills, but may also include valley bottoms that have a dry moisture regime. Upland forests in Southwestern Pennsylvania consist of oaks, cherries, tulip trees, elm, hickories and beech. The climax vegetation for the region seems to be forest, and a forest will eventually become established at a site, once the area is not farmed. It will quickly revert to shrub land that eventually develops into a mature forest (this process is also known as natural succession). An ecosystem is valuable at all successional stages, although the value may be different at each stage. Once mature, forests are valuable habitat to animals and as producers of timber and firewood.

## 5.2 REGULATORY ISSUES

No specific regulations exist concerning uplands. Relevant regulation found are the Endangered Species Act. These regulations are discussed in a subsequent section of this document.

## 5.3 LONGWALL MINING AND UPLANDS

As mentioned before, little data are available on the effect of longwall mining on an ecosystem, and limited data are available on the effect on agriculture. The majority of the conclusions in this chapter are thus based on conjecture, with the exception of the remarks on agriculture. Darmody et al. (1992) and Hetzler and Darmody (1992) describe their research on the effect of subsidence on crop yield in southern Illinois. These authors showed that crop yields were depressed by 95% in some cases, after subsidence. The extent of crop failure was not mentioned by the authors, but it seems that crop failure was isolated. Crop failure was not caused by a direct impact of subsidence on plants, but by changes in surface and sub-surface hydrology of an area. Areas that subsided became saturated and crop failure followed as a result of the saturation. Their research also showed that the mitigation of area with crop failure was possible by constructing drainage ways, and crop production reached pre-subsidence levels. Crop growth remained depressed during excessively wet years.

Slumping and cracking of soils caused by undermining was encountered during a field visit to Southwestern Pennsylvania in the summer of 1997. In addition to the sudden appearance of wetlands throughout the area land that once was smooth and used for crops and pasture suddenly appeared very rough. This sudden appearing of surface roughness and popping up of streams in a hay land appeared to be the cause of two tractor accidents on pastures near Nebo, Pennsylvania. A local farmer told the investigators that the soils in this pasture had become very unstable and a tractor turned over while mowing tall grass (name of the farmer is with-held at his request).

As mentioned above, little information could be found concerning the effect of subsidence on terrestrial vegetation. It can be expected these areas will also be subjected to the massive soil movement and the stresses seen on agricultural and pasture land. Most crops are annual, meaning that they will need to be replanted every year. Further, these plants tend to have a small root system. It is therefore difficult to study the direct effect of subsidence on an agriculture species such as corn or wheat. Indirect effect of subsidence on crops can be tied to hydrologic changes in the landscape. Pasture plants have a small, shallow root system, and cracking of the soil will not affect individual plants to such an extent as it would plants with a larger root system. However, pasture plants will be subjected to indirect effects such as drying out of the soil due to cracking, or flooding.

Forest and shrub ecosystems can also be subjected to indirect effects such as flooding, in particular in flat areas in valley bottoms. In addition, trees and shrubs may also be impacted by direct effects such as the severing and crushing of their extensive root system during subsidence. No information can be obtained on this subject, and most of the following discussion is based on professional judgment and some speculation. Trees and shrubs have an extensive and deep root system, and it can be expected that the root systems of trees and shrubs are subjected to all the stresses that the soils are subject to, more so than crop and pasture species. As a result, fracturing of the soil at the tensile zones is likely to damage the roots of these plants. Some of the cracks observed in the field were one foot wide and more than five feet deep. Roots growing across these and smaller cracks will be severed. Further, these roots will suddenly be exposed to air in the soil. This will result in a decreased ability of these trees to take up water and nutrients, thus slowing down their growth rates. Severed roots may also become the site for pathogens to enter the tree.

In order to determine if trees are under increased stress, a small pilot study was initiated. Dames & Moore conducted a study that compares trees in a three subsided areas and one non-subsided area in Southwestern Pennsylvania. Trees selected for the study appeared to be healthy and in good condition at the time of the study. Preliminary results indicate a growth depression at the period of subsidence (unpublished data). Tree rings appear to be close together following a subsidence event. This indicates that the trees were under stress which slowed down their growth. Growth seems to resume at a regular rate, approximately three years after the subsidence, with the exception of two ash trees that were examined. Growth in these two trees remained depressed. These results indicate that the vegetation is subjected to considerable stress during subsidence, and that the vegetative response may be species specific. From a recent similar study it could be concluded that tree species reaction to subsidence is very species specific (Runkle 1992). For example it was seen that both ash and maple exhibited a significant growth depression, while elm and oak were not affected by subsidence. Eventually older or weaker trees may die when the subsidence or species reaction is severe.

The above research seems to indicates that some species are very resilient. For example the author's limited data indicates that normal tree growth seemed to resume after approximately three years. Soil cracks had probably filled in by that time and root growth had resumed. The effect of subsidence on already weak trees was not studied; however, it can be assumed that a subsidence event could be the final blow to a weak tree, and kill that plant. Further, a forest may not be able to recover, when such a subsidence event coincides with a serious disease or pest outbreak such as gypsy moth.

Cracking and slumping of areas may also adversely affect the animal population in uplands by altering their habitat or the cracking of burrows and tunnels. Ahola (1990) and Dyni and Ahola (1991) report on the effect of subsidence on raptor nesting sites in Utah. They found that subsidence could alter the structure of an escarpment, thus affecting the safety of raptor nests in the area. Raptors in Pennsylvania mostly nest in trees and this research may not be applicable to the region. Further, animals are inventive and should be able to adapt to the new situation relatively quickly and the effect on the nests, burrows and tunnels should be for a short duration. Nests can be rebuilt in other areas during the next breeding season. In Southwestern Pennsylvania it was seen that a one year old crack was already being used by a wood chuck as a burrow.

Subsidence may have a positive effect on an ecosystem. Depressions and stress fractures will slow down run-off of rain water forcing it to infiltrate. Pohl et al. (1996) showed increased groundwater recharge in a nuclear subsidence crater at the Nevada test site. Increased infiltration and soil moisture is particularly important in arid climates, and this effect might not be significant in Pennsylvania. However, increased soil moisture may actually help in the survival of trees and shrubs with severed and crushed root systems the first three years after subsidence takes place. Trees would have more water available for growth and could survive the drastic decrease in root biomass.

The above examples from the literature are sparse. Data are from Texas, Utah and Nevada and may not be applicable to the situation in Southwestern Pennsylvania. They illustrate the lack of information that is available.

## 5.4 REFERENCES


Ahola, M.P. 1990. Geomechanical evaluation of escarpments subjected to mining induced subsidence. pp:129-136. In: W.A. Hustrulid and G.A. Johnson (Eds), Rock Mechanics Contributions and Challenges: Proceedings of the 31st Symposium. Balkema, Rotterdam.

Darmody, R.G., R.T. Hetzler, and F.W. Simmons. 1992. Coal mine subsidence: the effect of mitigation on crop yields. Proceedings, third workshop on surface subsidence due to underground mining, West Virginia University, Morgantown, WV., pp:183-188.

Dyni, R.C., and M.P. Ahola. 1991. The effect of underground mining on raptor nesting sites in the western United States - A geomechanical evaluation. Thorne Ecol. Inst. Proc. V: Issues and Technology in the Management of Impacted Wildlife. Snowmass Resort, CO.

Hetzler, R.T., and R.G. Darmody. 1992. Coal mine subsidence mitigation: effects on soil and crop yields. Proceedings, National Symposium on Prime Farmland Reclamation, Dept. of Agronomy, Univer. of Illinois, Urbana, IL, pp: 129-135.

Pohl, G.M., J.W. Warwick, and S.W. Tyler. 1996. Coupled surface-subsurface hydrologic model of a nuclear subsidence crater at the Nevada Test Site. Journal of Hydrology. 186:43-62.

Runkle, J.R. 1992. Effect of Longwall Mining on Surface Soil Moisture and Tree Growth. Proceedings: Third Workshop on Surface Subsidence Due to Underground Mining. West Virginaia University, Morgantown, WV.

Van Roosendaal, D.J., P.J. Carpenter, B.B. Mehnert, M.A. Johnston, and J.T. Kelleher. 1992. Longwall mine subsidence of farmland in southern Illinois: near-surface fracturing and associated hydrogeological effects. Proceedings, National Symposium on Prime Farmland Reclamation, Dept. of Agronomy, Univer. of Illinois, Urbana, IL, pp: 147-158.


## 5.5 ADDITIONAL INFORMATION

*Additional recommended reading:*

Note: Any good ecology text book should help the reader understand some of the principles discussed in this section. Examples of these texts are:

Audubon Society's nature guide to Eastern Forests

Avery. Natural Resources Management. McGraw-Hill., NY. (publishing date not available).

Allen and Sharpe. An Introduction to American Forestry. McGraw-Hill., NY. (publishing date not available).

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology. The Benjamin/Cummings Publishing Company, Menlo Park.

Dunn, T., and L.B. Leopold. 1978. Water in environmental planning. Freeman and Comp., San Francisco, 818 pp.

*Experts:*

Many consultant companies have experts who specialize in these issues.

also try your local University and Agriculture Extension Agent

*~ state and federal sources of expertise ~*

**Pennsylvania Department of Environmental Protection**
Bureau of Dams, Waterways and Wetlands
P.O. Box 8554
Harrisburg, PA 17105-8554
tel: 717-783-1384

**Pennsylvania Department of Environmental Resources**
Southwest Office
400 Waterfront Drive
Pittsburgh, PA 15222-4745

**U.S. Fish and Wildlife Service**
315 South Allen Street
State College, PA 16801
tel: 814-234-4090

# 6.0 RELATED ISSUES

## 6.1 METHANE

Methane is a major by-product of coal mining. The majority of the methane is released during the mining process, and depends on geological elements such as permeability of the coal (Gas Research

Institute 1992). Methane is flammable, and mines need to vent this gas to enhance mine safety. Methane vents are boreholes that are connected with mine workings and allow methane to escape into the atmosphere, and numerous methane vents were seen during visits to Southwestern Pennsylvania. Methane is valuable and is also known as natural gas, which is used for commercial purposes. Kruger (1994) estimates that coal mines in the Appalachian release between 120 and 200 billion cubic feet (Bcf) of methane in the atmosphere each year. They estimate that 50 to 90 Bcf can be recovered by the year 2000, creating 2,000 to 3,000 jobs throughout the Appalachian region. The U.S. Environmental Protection Agency (USEPA) (1995) estimates that mines in Washington and Greene Counties produce more than 10.3 Bcf per year and recovery of this methane is considered of great economic and environmental importance. However, during the mining process methane is diluted by the air that is used to ventilate the mine. Once diluted, it is nearly economically impossible to re-concentrate the gas into a usable concentration (Gas Research Institute 1992).

In addition to the economic benefits, methane recovery is also desirable for environmental reasons (Kruger 1994). Methane is a potent greenhouse gas, that is approximately 20 times more effective at trapping heat in the atmosphere than carbon dioxide over a 100 year time period (USEPA 1993). Coal mines are estimated to account for 15 to 20 percent of the total global methane emissions in 1990 (USEPA 1993).

Methane is a greenhouse gas, which is rapidly increasing in the atmosphere. Greenhouse gasses are implicated in global warming and it can be expected that ecological changes will take place as the result of global warming. While this report is not a forum to discuss global warming, its ecological effect, or Southwestern Pennsylvania's contribution to the atmospheric methane, it seems paramount for both economic and environmental reasons that methane is recovered as much as possible. Major limiting factor for coalbed methane development in Southwestern Pennsylvania appears to be ownership, permeability and gas content of the coal. It seems that no Pennsylvania state regulations exist that safeguard coalbed methane ownership. This needs to be resolved before this valuable resource can be exploited effectively (Fernandez 1997).

## 6.2 WEEDS AND NOXIOUS WEEDS

Weeds are plants or animals that are growing where they are undesired or unappreciated. In other words, a tomato plant that grows in a pea patch is a weed. In most cases weed populations in mature ecosystems are low, and weeds will increase as result of disturbance.

A specific class of weeds, also referred to as noxious weeds, may over take an entire community once they have gained a foot-hold in an ecosystem. Most of these noxious weeds are not native to the area and have no natural enemies. Some of the most common noxious weeds include: kudzu which is taking over the Southeast; purple loose strife which has invaded may wetlands and is killing the native vegetation; garlic mustard, amur and tartarian honeysuckle that are taking over the forests in the midwest; glossy buck thorn which is invading forests and shrub lands near the great lakes; and tamarisk which now dominates the wetlands in the southwest. These plants are not native to the U.S. and invaded entire ecosystems, displacing native plants, many endangered species, and driving away animals that depended for their survival on native plants. These species typically gain a place in anecosystem through disturbance (the dying of other species). Once they are in, they do not need disturbance to continue their destructive path of complete domination of the entire ecosystem. However, the time needed for complete domination is shorter when the disturbance continues.

Previously it was detailed how subsidence may affect riparian vegetation, suddenly creates wetlands, or may (temporarily) weaken native plants. All these impacts are likely to open an ecosystem up and makes it susceptible to the invasion of (noxious) weeds. Long-term impacts of this invasion may be devastating to an areas ecosystems. Invasion of species can be documented by developing a plan that monitors impacts on the ecosystem. Monitoring plans should include permanent vegetation monitoring plots in the various ecosystems. The value of the information increases when monitoring plots are also established on non-subsided sites that have a similar ecosystem as a control. Such controls will allow researchers to determine if the observed vegetative trends are caused by subsidence or by other influences. No animal sampling will be needed unless it can be documented that vegetation changes are taking place. To be able to document vegetational changes or the lack there off, monitoring should start one year (season) before subsidence takes place and continue for a number of years post subsidence (i.e., 5 years).

## 6.2 BIODIVERSITY

The best-known champion of the biodiversity concept is E.O. Wilson, who defines it as "the variety of organisms considered at all levels, from genetic variants belonging to the same species through species to arrays of genera, families, and still higher taxonomic levels" (Wilson 1992).

Taxonomic Classification

Taxonomists have divided the natural environment into five distinct groups, which are also know as kingdoms: Monera (Bacteria), Protoctista (Protozoa and Algae), Plantae (Plants), Fungi (Molds and Mushrooms), and Animalia (Animals including Insects, Mammals, Fish, Mollusks, and Birds). These kingdoms can be further divided as follows:

Kingdom
|
Phylum
|
Class
|
Order
|
Family
|
Genus
|
Species
|
Sub-species or variety

(adapted from Campbell 1987)

Since the purpose of this document is the study of the potential impact of longwall mining on the ecology of an area, we are mostly concerned with the plant and animal kingdoms. A collection of plants in an area are also known as the area's flora, while animals are known as the fauna.

Wilson continues by stating that biodiversity also includes "the variety of ecosystems, which comprise both the community of organisms within particular habitats and physical conditions under which they live." As these two statements detail biodiversity can be approached from an ecosystem side and from a species (taxonomic) side. It is presently unclear to what extent longwall mining impacts an area's (ecosystem) biodiversity. Previously this report detailed that the sudden subsidence of an area may impact streams, wetlands, riparian areas and uplands, and shifts in ratios will occur (i.e., more pools, less riparian areas. It can thus be expected that short-term changes in this form of biodiversity can be observed in an area that is subsided.

Subsidence will also impact the taxonomic biodiversity. Streams may be altered in such a way that changes in habitat can be detected. The creation of more pools in streams and disappearance of riffle habitat may affect the biodiversity of a stream. Some species may disappear by moving to non-subsided areas, or through mortality. Increases in pool habitat will may increase the biodiversity of an area. Changes in the other vegetation types such as upland forests may be more subtle and may manifest itself by the invasion of weedy species. Once weeds invade an area, biodiversity generally declines.

## 6.3 ENDANGERED SPECIES ISSUES AND LONGWALL MINING

The threat of extinction is at the heart of all concerns when a species receives the classification as an endangered or threatened species. Wilson (1992) describes extinction as "the termination of any lineage of organisms, from subspecies to species and higher taxonomic categories from genera to phyla." Extinction can be local, where a species disappears from a specific area, or total, where all populations die out. For example, approximately 6,723 plant taxa (species, subspecies and varieties) native to the U.S. were considered to be under some kind of threat of extinction in 1990; 253 of these species were critically endangered (Falk 1991).

The Endangered Species Act of 1973 (ESA) contains a variety of protections designed to save from extinction those plant and animal species that the Secretary of Interior designates as threatened or endangered and to conserve the habitats upon which these species depend. The ESA is located in the 16 United States Code (USC) Sections 1531-1544. These numbers are not frequently used; however the parts of the ESA are frequently referred to as Sections. The ESA was amended in 1976, 1978, 1979, 1982, 1986 and 1988. More changes are expected. The ESA only deals with federally endangered species, and states have published their own lists of state endangered species.

It is presently unclear if there are any direct effects of longwall mining on endangered species, or whether the area has endangered species. The area of concern has not been sufficiently studied for the presence of endangered species. However as discussed in previous sections, indirect effect cannot be ruled out if endangered species are present. An endangered species that uses stream riffles as primary habitat may be threatened with extinction when subsidence causes riffles to disappear. A similar effect can be expected when springs or wetlands dry up, or suddenly appear at sites where endangered species can be found. More subtle effects could include the invasion of weedy and/or competitive species and the subsequent extinction of a species from an area.

The U.S. Fish and Wildlife Service and State agencies such as the Pennsylvania Department of Conservation and Natural Resources, and the Pennsylvania Fish and Boat Commission, and the Pennsylvania Game Commission maintain databases that detail the location of endangered species in an area. Post-subsidence monitoring should increase the knowledge on the effect of subsidence on these species.

## 6.4 KEYSTONE SPECIES

Some species, including endangered species, may be classified as keystone species. Keystone species are species whose removal from the ecosystem has a much larger impact than may be expected from its abundance (Stone 1995). Examples include the removal of predators from an area, after which their prey proliferates and seriously impacts the ecosystems. The disappearance of a keystone species may have an important ripple effect throughout the ecosystem. Presently it is not known if any of the species that are located in the areas impacted by longwall mining can be classified as keystone species. Ecological monitoring of areas after subsidence should assist in determining if such species are present or affected by mining. Recently, Pimm (1991) showed that ecosystem (risk assessment) models can be developed to determine the effect of species removal on an ecosystem, in particular on endangered species.

## 6.5 THE FOOD CHAIN

Food chains are defined as the transfer of food from trophic (feeding) level to trophic level. Southwestern Pennsylvania has two major food chains: a terrestrial (land based) and an aquatic (water based) food chain:

| Trophic (feeding) level | Terrestrial food chain | Aquatic food chain |
|---|---|---|
| Quartenary Consumers | Carnivores (Meat eaters) - eagles | Carnivores (Meat eaters) - human/eagle |
| Tertiary Consumers | Carnivores (Meat eaters) - snakes | Carnivores (Meat eaters) - trout |
| Secondary Consumers | Carnivores (Meat eaters) - moles/humans | Carnivores (Meat eaters) - fish |
| Primary Consumers | Herbivores (Plant eaters) - insects/cows | Zooplankton |
| Producers | Plants | Phytoplankton |

(adapted from Campbell 1987)

With every step up the food chain energy is lost. For example, herbivores may only be able to use 10% of all the energy that was available to the plants. The secondary consumers in turn may only be able to use 10% of the energy that was available to the herbivores. It is easy to see that the energy available to the higher order consumers (tertiary and quartenary) becomes critical. Changes in the productivity of the producers may have grave consequences up the food chain. As discussed above, subsidence induced changes to streams, may change the productivity of phytoplankton, which in turn will influence the number of fish, eagles or sports fishermen that the area can support. The same would be the case for land-based food chains.

## 6.6 SUCCESSION

Succession is a change in species composition of an area over time (Barbour et al. 1987). Changes in species composition are usually the result of disturbance. Examples include the regrowth of an area after a wildfire, or the reestablishment of a forest ecosystem in an abandoned agriculture field. The first species that invade an area are called early successional or early seral species. These species usually have light, wind-blown seeds that are easily transported into the area. Some seeds may be easily transported by animals by either clinging to their fur, or by having indigestible seeds. Cherries are an example of the indigestible seeds. Birds eat the fruit and deposit the undigested seeds in their droppings. Over time more and more species will come in to the area, until the area resembles a mature natural state. At that time, natural processes such as death, decomposition and germination should be at the pre-disturbance level. This process of vegetational change is called succession.

The concern with longwall mining is that the natural process of succession may be short-cut by the invasion of weedy species. It can be expected that early successional species will invade an area when the vegetation is affected by subsidence. Most weeds have light, or easily transported seeds and are also early successional species. As a result weeds may be the first to invade an area. The problem with these weeds is that some do not allow the next group of seral species to invade and succession stops. Some of these weeds are so aggressive that, once they have a foot-hold in the vegetation of an area, they may continue pushing out species in non-disturbed areas or invade agricultural areas.

## 6.7 REFERENCES


Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology. The Benjamin/Cummings Publishing Company, Menlo Park.

Campbell, N.A. 1987. Biology. The Benjamin/Cummings Publishing Company, Menlo Park.

Falk, D.A. 1991. Joining biological and economic models for conserving plant genetic diversity. pp. 209-223, In: D.A. Falk and K.E. Holsinger (eds.), Genetics and Conservation of Rare Plants. Oxford University Press, NY.

Fernandez, R.L. 1997. Personal Communications. USEPA Coalbed Methane Program, Washington, DC.

Gas Research Institute. 1992. Coalbed methane technology development in the Appalachian basin. Final Report. Gas Research Institute, Chicago, IL., GRI - 92/0138, 168 pp.

Kruger, D.W. 1994. The environmental and economic benefits of coalbed methane development in the Appalachian region. Coalbed Methane Outreach Program, Office of Air and Radiation (6202J). Washington, D.C. EPA/430/R-94/007.

Stone, R. 1995. Taking a new look at life through a functional lens. Science, 269:316-317.

USEPA. 1993. Anthropogenic methane emissions in the United States: estimates for 1990. Report to Congress. Office of Air and Radiation (6202J). Washington, D.C. EPA 430-R-93-003.

USEPA. 1995. Finance opportunities for coal mine methane projects: A guide for Southwestern Pennsylvania. Public Draft. Office of Air and Radiation (6202J). Washington, D.C. EPA/430-R-95-008.

Wilson, E.O. 1972. The Diversity of Life. W.W. Norton and Co. New York, NY.

## 7.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

In this document Dames & Moore attempts to identify the state of knowledge concerning the effect of longwall mining and the related impacts, such as subsidence and valley fill, on the ecology of Southwestern Pennsylvania. This was done through literature and database searches, interviews of experts, and field visits. Early on it was established that potentially none of the ecosystem components found in the area were exempt from the mining impacts (Figure 4). Ecosystems include streams, wetlands, riparian areas and uplands. The term "uplands" encompasses agriculture lands, pastures, shrub land, and forested areas.

Literature searches discovered a litany of information on the hydrologic effects of longwall mining; however, information on the ecological effects is scant. One paper was found on the effect of subsidence on wetlands in Texas (Robertson and Slack 1995); two publications were discovered on the mitigation of subsidence affected crop land in Illinois (Darmody et al. 1992, and Hetzler and Darmody 1992); and one study was found on the impact of subsidence on raptor nesting in Utah (Dyni and Ahola 1991). Both Darmody papers could also be applied as evidence of wetland creation as a result of subsidence. Further, some of the hydrologic reports mentioned hydrologic changes, including the loss of water from streams, but did not discuss the ecological effects of these impacts. Discussion with experts acknowledged this gap in scientific information. It was therefore decided to use the physical evidence of subsidence that was seen in the field to develop and report on potential theoretical impacts of longwall mining on the ecology of a region.

During a field visit, the following impacts were evident: streams were observed that clearly disappeared at one point, and re-appeared down grade in the same stream bed; the morphology (make-up) of streams were drastically altered; wetlands had spontaneously appeared in a landscape; springs had dried up and spontaneously turned up elsewhere; once smooth pastures had become rough; and the soil had fractured extensively, with some cracks as wide as one foot and deeper than five foot. These field observed phenomena were used to develop potential ecological scenarios that detail the ecological consequences of longwall mining on a region.

As mentioned above, this review indicates that a number of ecological changes are likely to occur as a result of longwall mining. Some changes will be temporary, while others may have long-term consequences. Changes include alterations in the riffle and pool habitats in streams. Riffle habitat seem to decline, while pool habitat will likely increase. Some streams and creeks may disappear in fractures in the substrate and flow underground for some time. This will impact the aquatic habitat and biota in that section of the stream that disappears, and will likely impact the riparian habitat. Riparian habitat may also be impacted by the expansion of pools. Trees may die and become habitat for a large number of species. However, riparian habitat disappearance may have a negative effect on pool habitat through increases in radiation and water temperature. Subsidence seems to be a creator of wetlands. In most cases this is favorable, except for the land owner. Created wetlands may initially not be as valuable as natural wetlands, but even new wetland habitats can contribute valuable resources for a large number of animals and is important for the human population. Some wetlands may become too deep and revert to a pond. Ponds are also valuable as habitat, albeit for different species of wildlife. Drying out of springs and a sudden appearance of these springs elsewhere seems to be a negative side effect of subsidence. Spring (wetland) habitat may be lost, while new spring habitat may not develop in sufficient time to keep weedy species at bay. Upland habitats are affected by subsidence as well. Soil fractures are likely to tear roots of the larger trees. Preliminary review of some tree growth data collected by Dames & Moore showed that these impacts on trees may be temporary.

Most impacts described in this report seem to be long-term, with the exception of the root damage in the trees and shrubs. Nature is generally resilient and should be able to adapt to the environmental and pursuing ecological changes that are predicted in this report. This adaptation may involve species mortality and invasion. These processes should be monitored for the possible invasion of weedy and exotic species. Once weedy species invade, it seems unlikely that the natural vegetation can become established. Subsequently, the area may become a source of weeds that could impact the vegetation and agriculture of the surroundings. We therefore recommend that areas, where such a dramatic shift in vegetation is expected or observed, are monitored and managed in such a way that a native and natural vegetation becomes established at the site.

A review of the some present laws and regulations shows that mining legislation regulates the effect of longwall mining on stream and rivers. Interpretation, enforcement and use of these regulations in the field seems to be a limiting factor. During the field visits and discussions with experts there appeared to be a persistent disagreement between mining companies on one side and the regulatory community and citizens on the other side, whether a stream could be classified as perennial or intermittent. Reason for this disagreement seems to be that laws regulate impacts on perennial stream, but are less restrictive about impacts on intermittent streams. Regulations also do not seem to address the habitat altering effect that subsidence has on streams.

While wetlands and endangered species are protected by law, the review was unclear on how a potential effect on wetlands and endangered species is regulated and monitored. Weed invasion and the ecological impacts in uplands do not seem to be regulated unless endangered species are involved.

Concluding, longwall mining has regional ecological impacts, but these impacts are not well documented, and there seems to be a large data gap. While impacts such as altered groundwater flow, or altered stream morphology may cause long-term changes in the ecology of a region, it is expected that eventually plant and animal species will become established that are more adapted to the changed environment. These new species may not be native or weedy, and the resulting vegetation may not be as stable as before mining. However, partially based on the lack of data, it is difficult at this time to compare the pre-mining and post-mining vegetation types on aesthetic, biological or ecological value. The majority of the discussions in this document are based on field observations and personal/professional experience. Some degree of speculation was applied to this study, which is a good reason to conduct long-term ecological research in areas affected by subsidence.

## 8.0 REFERENCES

Ahola, M.P. 1990. Geomechanical evaluation of escarpments subjected to mining induced subsidence. pp:129-136. In: W.A. Hustrulid and G.A. Johnson (Eds), Rock Mechanics Contributions and Challenges: Proceedings of the 31st symposium. Balkema, Rotterdam.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology. The Benjamin/Cummings Publishing Company, Menlo Park.

Braddock, T. 1995. Wetlands. An introduction to ecology, the law and permitting. Government Institutes, Inc., Rockville, MD.

Campbell, N.A. 1987. Biology. The Benjamin/Cummings Publishing Company, Menlo Park.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. USFWS, USFWS/OBS 79/31.

Darmody, R.G., R.T. Hetzler, and F.W. Simmons. 1992. Coal mine subsidence: the effect of mitigation on crop yields. Proceedings, third workshop on surface subsidence due to underground mining, West Virginia University, Morgantown, WV., pp:183-188.

DEP. Undated a. DEP permit guide to water obstruction and encroachment permits. Commonwealth of Pennsylvania, Department of Environmental Resources.

DEP. Undated b. Joint permit application. Instruction booklet for Commonwealth of Pennsylvania/U.S. Army Corps of Engineers.

Dyni, R.C., and M.P. Ahola. 1991. The effect of underground mining on raptor nesting sites in the western United States - A geomechanical evaluation. Thorne Ecol. Inst. Proc. V: Issues and Technology in the Management of Impacted Wildlife. Snowmass Resort, CO.

Environmental Laboratory. 1987. Corps of Engineers Wetland Delineation Manual. United States Army Engineer Waterway Experiment Station, Technical Report Y-87-1, Vicksburg, MS.

Falk, D.A. 1991. Joining biological and economic models for conserving plant genetic diversity. pp. 209-223, In: D.A. Falk and K.E. Holsinger (eds.), Genetics and Conservation of Rare Plants. Oxford University Press, NY.

Fernandez, R.L. 1997. Personal Communications. USEPA Coalbed Methane Program, Washington, DC.

Gas Research Institute. 1992. Coalbed methane technology development in the Appalachian basin. Final Report. Gas Research Institute, Chicago, IL., GRI - 92/0138, 168 pp.

Hetzler, R.T., and R.G. Darmody. 1992. Coal mine subsidence mitigation: effects on soil and crop yields. Proceedings, National Symposium on Prime Farmland Reclamation, Dept. of Agronomy, Univer. of Illinois, Urbana, IL, pp: 129-135.

Kruger, D.W. 1994. The environmental and economic benefits of coalbed methane development in the Appalachian region. Coalbed Methane Outreach Program, Office of Air and Radiation (6202J). Washington, D.C. EPA/430/R-94/007.

Mitsch, W.J., and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York. 539 pp.

National Research Council. 1995. Wetlands: characteristics and boundaries. National Academy of Sciences, Washington, DC 307 pp.

Neel, J.K. 1951. Interrelations of certain physical and chemical features in headwater limestone streams, Ecology, 32:368-391.

Nelson, J.K. and D.C. Scott. 1962. Role of detritus in the productivity of an outcrop community in a Piedmont stream. Limnol. Oceanog. 3:396-413.

Niering, W.A. 1985. The Audubon Society nature guides. Wetlands. A.E. Knopf, Inc. New York.

Pennsylvania Department of Environmental Protection. Bureau of Mining and Reclamation. 1994. Program Guidance Manual - Perennial Stream Protection - Act 54.

Pimm, S.L. 1991. The balance of nature. University of Chicago Press, Chicago, IL.

Pohll, G.M., J.W. Warwick, and S.W. Tyler. 1996. Coupled surface-subsurface hydrologic model of a nuclear subsidence crater at the Nevada Test Site. Journal of Hydrology. 186:43-62.

Post, R.A. 1996. Functional profile of Black Spruce wetlands in Alaska. Alaska Department of Fish and Game and U.S. EPA. EPA 910/R-96-006.

Robertson, D.G., and R.D. Slack. 1995. Landscape changes and its effects on the wintering range of a lesser snow goose (Chen caerulescens cearulescens) population: a review. Biol. Conserv., 71(2):179-186.

Runkle, J.R. 1992. Effect of Longwall Mining on Surface Soil Moisture and Tree Growth. Proceedings: Third Workshop on Surface Subsidence Due to Underground Mining. West Virginaia University, Morgantown, WV.

Stone, R. 1995. Taking a new look at life through a functional lens. Science, 269:316-317.

USEPA. 1993. Anthropogenic methane emissions in the United States: estimates for 1990. Report to Congress. Office of Air and Radiation (6202J). Washington, D.C. EPA 430-R-93-003.

USEPA. 1995. Finance opportunities for coal mine methane projects: A guide for Southwestern Pennsylvania. Public Draft. Office of Air and Radiation (6202J). Washington, D.C. EPA/430-R-95-008.

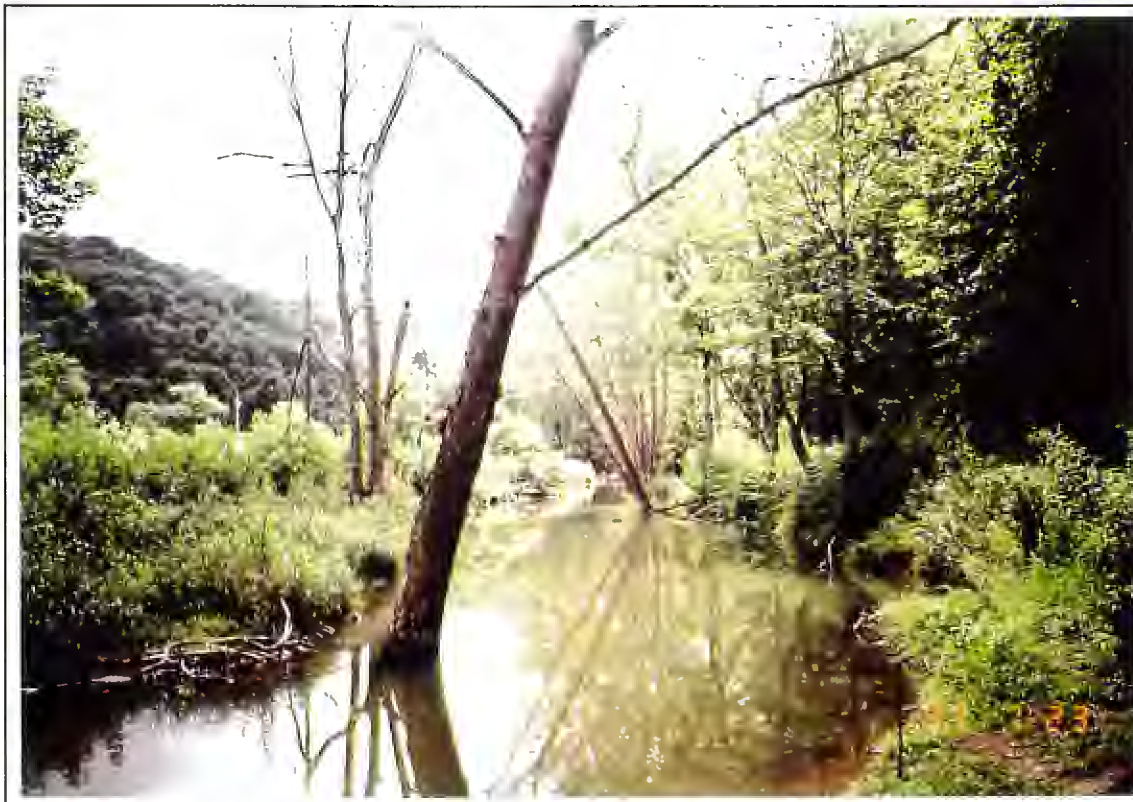
Van Roosendaal, D.J., P.J. Carpenter, B.B. Mehnert, M.A. Johnston, and J.T. Kelleher. 1992. Longwall mine subsidence of farmland in southern Illinois: near-surface fracturing and associated hydrogeological effects. Proceedings, National Symposium on Prime Farmland Reclamation, Dept. of Agronomy, Univer. of Illinois, Urbana, IL, pp: 147-158.

Walliser, J.J. 1995. Longwall Mining's Impacts on Perennial Streams: The Regulatory Framework in Pennsylvania.

Wilson, E.O. 1972. The Diversity of Life. W.W. Norton and Co. New York, NY.

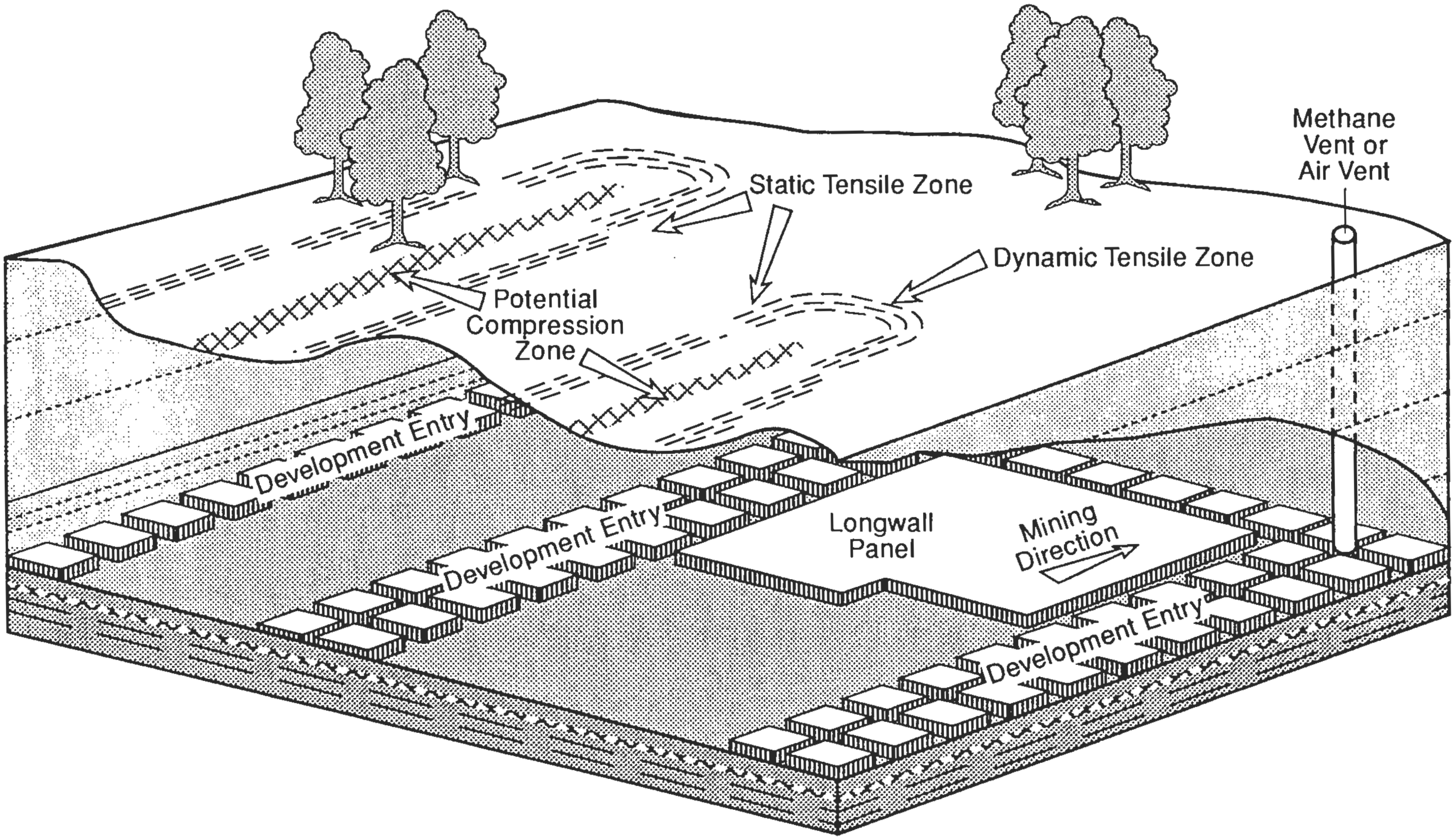
Zoltai, S.C. 1988. Wetland environments and classification. pp: 1-26. In: National Wetlands Working Group. Wetlands of Canada. Ecological Land Classification Series, No. 24. Sustainable Development Branch, Environment Canada, Ottawa and Polyscience Publications, Inc., Montreal.


PHOTOGRAPH 1: Looking at a subsidence-induced riffle within a pool segment of a stream. This riffle is only three years old and will erode over time.



PHOTOGRAPH 2: Looking at a pool area deepened by subsidence. Note the presence of dead trees. Trees were killed by the rising water after the subsidence.

PHOTOGRAPH 3: Looking at a subsidence-induced wetland within an agricultural field.

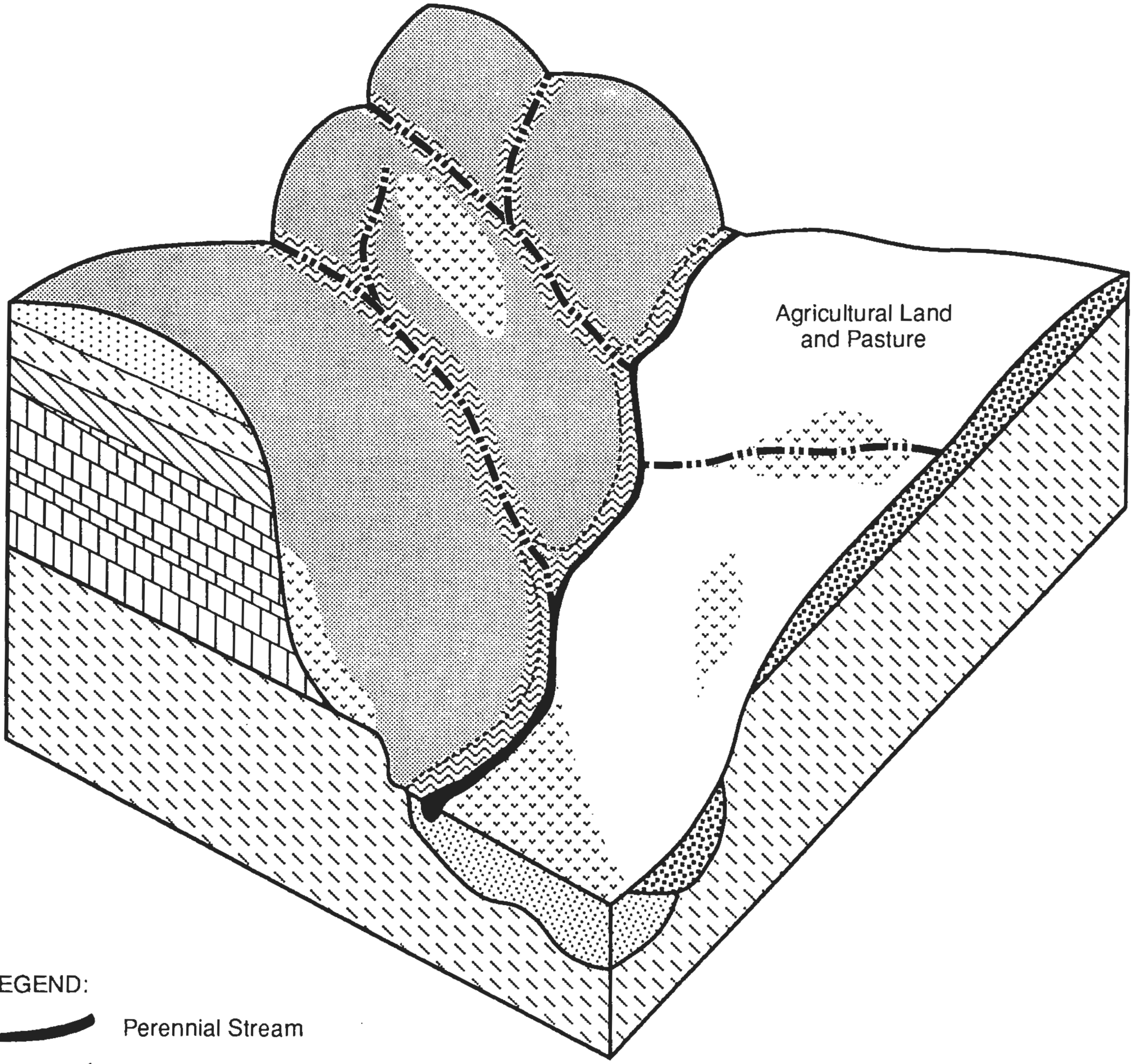



Adapted from Van Roosendaal et al., 1992.

**Audubon So**
**OF WESTERN PENNSYL**

FIGURE 1
SCHEMATIC BLOCK DIAGRA
LONGWALL PANELS SHOWING DE
OF TYPICAL STRESS FRACT

JOB NO. 34480-001-122 D




LEGEND:

- Perennial Stream
- Intermittent Stream
- Riparian Vegetation
- Upland Vegetation
- Wetland
- Sandstone
- Shale
- Red Clay Shale
- Interbedded Shale, Siltstone and Limestone
- Alluvium
- Colluvium

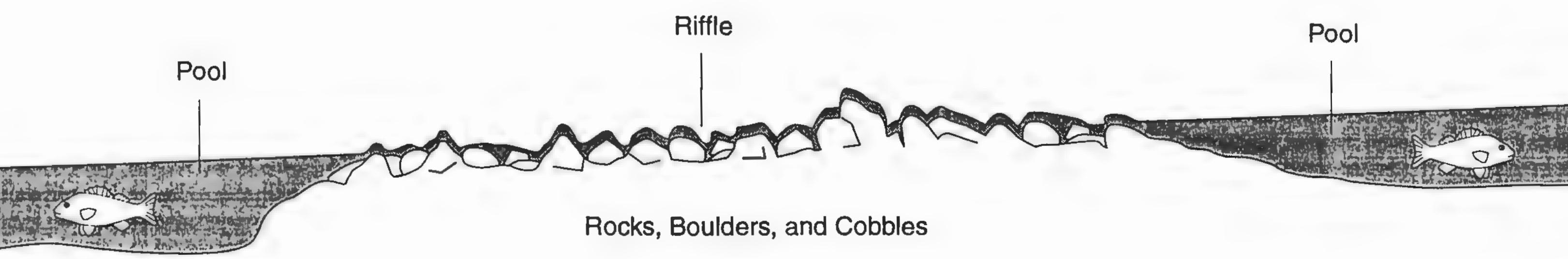
SOURCE: Adapted from Green and Washington County Soil Survey, 1983.

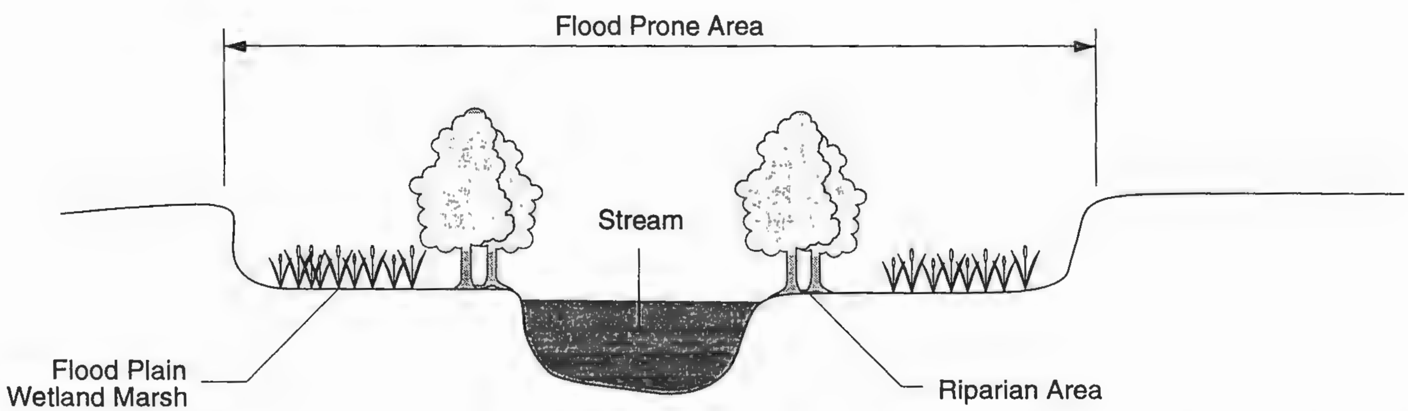
**Audubon Society**
**OF WESTERN PENNSYLVANIA**

**FIGURE 2**
**SCHEMATIC OVERVIEW OF THE DIFFERENT ECOSYSTEMS IN SOUTHWESTERN PENNSYLVANIA**

JOB NO. 34480-001-122 **Dames & Moore**

AUDUBON SOCIET 80-001-5056-122

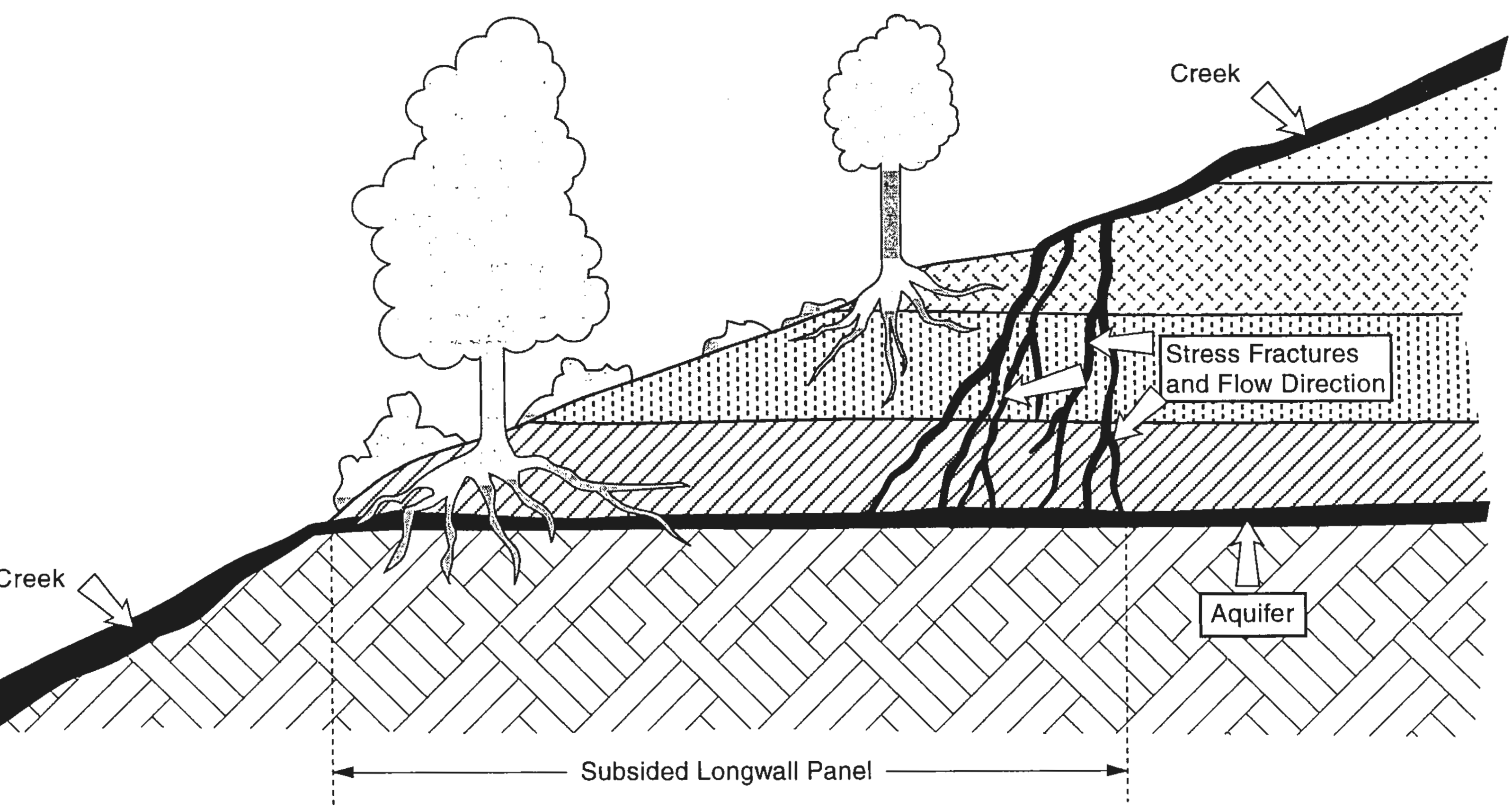



**Audubon Soc**
**OF WESTERN PENNSYLV**

**FIGURE 3**
**THE ANATOMY OF A STREAM OF**

JOB NO. 34480-001-122 Da




**Audubon So**

**OF WESTERN PENNSYL**

**FIGURE 4**
**SCHEMATIC OVERVIEW OF THE SU**
**INDUCED DISAPPEARANCE OF A CR**
**THAT IN PARTICULAR THE VEGETATIO**
**MAY BE AFFECTED BY THE WAT**

JOB NO. 34480-001-122 D

| ACTIVITY | | POTENTIAL ENVIRONMENTAL IMPACTS |
|---|---|---|
| EXPLORATION | Drilling | Run-off<br>Silt |
| SIS | | |
| PERMITTING | | |
| W | | |
| CONSTRUCTION | Construction of:<br>•Mining Facilities<br>•Access Roads<br>•Handling Facilities<br>•Valley Fills<br>•Mitigation<br>•Methane Vents<br>•Airshafts<br>•Room and Pillar Access Tunnels | Clearing of Areas and Impact on Streams |
| TION | | |
| MINING | Extraction of Coal and Related Activities | Subsidence<br>Valley Fill<br>Methane<br>Acid Mine Drainage |
| TION | | |
| CLOSURE (Abandonment) | Reclamation<br>Mitigation | |

Subsidence:

| ECOSYSTEM | EFFECT | ECOSYSTEM | EFFECT | ECOSYSTEM |
|---|---|---|---|---|
| Streams | Loss of streams, loss of riffles, increase of pools, changes in habitat make-up | Uplands: | | Endangered and Keystone Species |
| Springs | Loss of springs, appearance of springs | Agriculture Lands | Loss of crops, creation of wetlands, increased surface roughness | Weedy Species |
| Wetlands | Conversion of wetlands to ponds, loss of wetlands, creation of wetlands | Pasture | Creation of wetlands, increased surface roughness | Succession |
| Riparian Areas | Loss of riparian areas | Forest and Shrub Lands | Increased stress on woody species, slow down of growth, increased infiltration, creation of wetlands | Foodchain |

Valley Fill:

| ECOSYSTEM | EFFECT | ECOSYSTEM | EFFECT | ECOSYSTEM | EFFECT |
|---|---|---|---|---|---|
| Streams | Loss of streams habitat | Uplands | Loss of habitat | Succession | Increase c |
| Riparian Areas | Loss of riparian areas | | | Foodchain | Interruptio |

NOTE: It is assumed that placement of valley fills require that no springs, wetlands or endangered sp impacted.

Methane:

NOTE: All of the impacts caused by methane occur on a global scale and are not directly caused by are a side effect of greenhouse gas emissions. Methane is a greenhouse gas. However, it is not a u product or result of longwall mining, but mines contribute to the total global methane emissions.

# CHAPTER 8

# ENVIRONMENTAL CONCERNS RELATED TO THE PRACTICE OF VALLEY FILLING IN PENNSYLVANIA

Cindy L. Tibbott
U.S. Fish and Wildlife Service
State College, Pennsylvania

# 1.0 INTRODUCTION

A "valley fill" is a method of coal waste disposal used by the coal industry to dispose of overburden, coarse refuse (rock and soil), and/or slurry (a mixture of coal fines and water remaining after the coal is washed in processing). The pragmatic definition of a valley fill in federal mining regulations ("a fill structure consisting of any material, other than organic material, that is placed in a valley where side slopes of the existing valley, measured at the steepest point, are greater than 20 degrees, or where the average slope of the profile of the valley from the toe of the fill to the top of the fill is greater than 10 degrees" (30 CFR 701.10) fails to convey the real impacts of a practice that literally fills entire valleys with waste, from ridgetop to ridgetop, burying streams, wetlands, and hundreds of acres of wildlife habitat under hundreds of feet of material.

The practice of valley filling related to coal waste disposal has become more controversial in the past several years in Pennsylvania due to the 1994 enactment of amendments to the State's Coal Refuse Disposal Control Act (CRDCA), which removed a prohibition on the disposal of coal refuse "within 100 feet of the bank of any stream." The change facilitates the permitting of valley fills, at a time when longwall mining is expanding in southwestern Pennsylvania and needs more disposal areas. The amendments led to adverse publicity against the practice and threats of lawsuits by environmental organizations. Concerns have been raised about the environmental impacts of individual projects, and the cumulative effects of many valley fills on aquatic ecosystems.

Pennsylvania is not alone in confronting the valley fill issue. The practice of valley filling is used throughout the Appalachian coal region, and has been the focus of growing controversy over the last several years:

- In Virginia, the failure of a coal slurry impoundment valley fill in October 1996 released 6 million gallons of coal slurry into the upper Tennessee River basin, smothering all aquatic life in 10 miles of streams and damaging an additional 55 miles. The damage affected federally listed threatened and endangered mussels and fish and their designated critical habitats.

- In West Virginia, a *U.S. News and World Report* article (August 11, 1997) described the impacts of "mountaintop removal" operations (a type of valley fill where overburden is dumped into valleys as massive drag lines literally take the tops off mountains to access coal seams) on communities and the landscape. *Business Week* magazine followed with a similar article on November 17, 1997, the television show

> *ABC Nightline* aired an entire 30-minute show on the subject on April 21, 1998, and the *New York Times* newspaper explored the issue in its May 7, 1998 edition. Controversy over this practice was heightened in April 1998, when West Virginia passed legislation which allows coal companies to bury streams with watersheds up to 480 acres in size without providing compensatory mitigation. Adding fuel to the fire, Arch Coal announced its plans for the largest surface mine in West Virginia history: a massive mountaintop removal and valley filling project that will affect 5 square miles.

In response to the growing number and sizes of valley fills, and the increased negative publicity questioning the potential environmental and social impacts of the practice, the three federal agencies with primary responsibility for regulating valley fills—the U.S. Environmental Protection Agency (EPA), the U.S. Office of Surface Mining Reclamation and Enforcement (OSM), and the U.S. Army Corps of Engineers (COE) -- assisted by the U.S. Fish and Wildlife Service (FWS), have initiated an intensive study of valley filling. The study will focus on a number of environmental, legal, and safety issues.

Initial scoping meetings among these agencies have revealed that the long-term effects of valley filling on a local ecosystem are unknown. Likewise, cumulative impacts (the effects of more than one valley fill in a given watershed) have not been evaluated. These data gaps are significant, because they mean that decisions are being made on permit issuance for more and bigger projects in the Appalachian coal fields without full understanding of the environmental impacts of those decisions. Nor are the data easy to obtain. A twelve-month effort by FWS offices in four coal mining states (Pennsylvania, West Virginia, Virginia, and Kentucky) to quantify the number of stream miles, acres of wetlands, and acres of terrestrial wildlife habitat lost to the practice of valley filling discovered that permit information for these projects is tracked differently in each state (sometimes differently between different regions of the same state); that no state is tracking cumulative losses to aquatic or terrestrial resources; and that it may be necessary in some states to comb through hundreds of individual permit files to derive the loss totals. The valley fills documented by FWS so far account for the destruction of between 300 and 500 miles of perennial, intermittent, and ephemeral streams in West Virginia since the mid-1980's, and 12 miles of streams and 54 acres of wetlands in Pennsylvania since 1977.

## 2.0 ECOLOGICAL CONCERNS

A tally of lost stream miles and wetland acres is a worthwhile exercise, but the significance of those losses to functioning ecosystems in Appalachia is more important. While quantifying the losses is difficult, interpreting the ecological meaning of the numbers is even harder, and will only be accomplished through research.

Valley filling in Pennsylvania, which is primarily related to coal waste disposal, is not expected to occur at the rate and scale of valley filling for mountaintop removal operations in West Virginia. Nevertheless, with the expansion of longwall mining in Pennsylvania, particularly in Greene and Washington Counties, it is important to understand the potential environmental impacts of the industry's waste disposal techniques. Assuming that 3 billion tons of coal are available for removal by longwall mines in those two counties (Richard DiPretoro, pers. com.), and assuming a 20 to 35 percent refuse content, between 21 and 36 additional valley fills may be needed.[280]

### 2.1 DIRECT AND INDIRECT IMPACTS TO FISH AND WILDLIFE RESOURCES

To our knowledge, no before-and-after biological studies have been conducted on valley fills in Pennsylvania. While the direct impacts (the natural resources destroyed under the footprint of the fill) can be quantified in advance for each new valley fill, the indirect impacts (on downstream and surrounding ecosystems) will be site-specific, depending on the geology of the area, the acid mine drainage-producing potential of the particular waste being disposed, the disposal methods being used, etc.

The FWS has been involved in the field review of at least seven valley fill projects in Pennsylvania since 1989. In all cases, wildlife habitat in the affected valleys was good to excellent, with a high potential for use by scores of migratory bird species, as well as game birds such as ruffed grouse and wild turkey. Wetlands were present in all cases, ranging from small spring-seep areas to several-acre cattail wetlands. Upland and wetland wildlife habitat loss was an important factor

280. This calculation assumes that one ton of refuse occupies one cubic yard (Don Stump, OSM, Pittsburgh, PA, pers. com.), and uses an average of 28.8 million cubic yards per valley fill, based on an average of recent valley fill projects in Pennsylvania.

in the FWS recommendations to regulatory agencies that permits for these projects be denied. While it is a common misconception that wildlife will simply "go somewhere else" when their habitats are destroyed, in reality the only "somewhere else" they can go is probably already occupied by as many individuals of the same species as that habitat can support. In the long term, reclamation practices have the potential to provide wildlife habitat; however, in two of the most recently permitted projects (Vesta Mining Company in Washington County and Cyprus Emerald Resources in Greene County), the final revegetation plan calls for a grass-dominated seed mix that will not replace pre-project valley forests.

One to two miles of perennial streams of varying length were present in every case. Most of these streams were highly productive in terms of aquatic insects, and in some cases minnows were present. Game fish are lacking in these small, headwater streams. Nevertheless, the importance of these headwater areas to the aquatic ecosystem as a whole should not be underestimated. Each headwater stream is an important source of clean water, nutrients, and food production (aquatic invertebrates) to larger waterbodies downstream. In their literature review to evaluate "The Importance of Headwater Streams to Downstream Areas and a Comparison of Stream and Pond Productivity," Perry and Golden (1997) wrote:

> ...headwater streams serve as a crucial part of the watershed network. The functions that headwater catchments play in forming the energy and nutrient base, as well as the flow regime for downstream areas is where their true irreplaceable value lies. Transported organic matter processed in upstream areas forms the bulk of downstream energy supplies. Land use, geology, and soil characteristics in small catchments effect the water quality and quantity in the lower reaches of the drainage system. ...in areas that are completely filled all of the critical functions of that tributary are removed from the drainage system. Since water moves unidirectionally downstream, any negative impacts upstream inherently influence downstream areas that may have more commercial, economic and recreational significance than the small headwater areas that are being degraded and lost. Therefore, the value of a stream, small or large, intermittent or perennial, cannot be ascertained solely from measures of biological production. Some measure of the streams [*sic*] impact and importance to downstream areas must be taken into account.

Downstream areas can be adversely affected when refuse disposal facilities develop acid mine drainage (AMD) or other water-quality related discharges. In such cases, such as the situation at the Doverspike Brothers' Coal Company slurry impoundment/coarse refuse valley fill in Jefferson County, the original stream in Weisner Hollow was enclosed in a pipe before refuse/slurry disposal began, and was supposed to emerge at the toe of the valley fill. However, some time after disposal began, the flow from this pipe became acid, and the flow is now intercepted and sent to a treatment facility (Steve Kepler, Pennsylvania Fish and Boat Commission, pers. com.). Therefore, areas downstream of this project no longer receive fresh water flow, let alone the nutrients and organic matter originally produced by this valley. On the other hand, refuse disposal activities at the Cyprus Emerald facility in Greene County and the 84 Mining Company facility in Washington County apparently have discharges that meet required permit standards for all monitored chemical parameters, due to more alkaline refuse. In these cases, however, nutrient and organic matter production originally provided by the filled stream system is no longer being supplied to downstream areas.

The FWS is also concerned that stream flows below valley fills cannot be maintained. There is some risk that eventually no water will discharge from the stream pipe under a valley fill, because the stream's watershed (recharge area) has been lined with an impermeable liner and filled with waste. The Pennsylvania Department of Environmental Protection (DEP), however, asserts that water quantity can be preserved. Objective studies are needed at a number of existing valley fills to determine the effects of these projects on the enclosed stream systems. Because National Pollutant Discharge Effluent System (NPDES) permits issued for discharges from refuse disposal areas require that flows be monitored, it should be relatively easy to determine flow trends at existing valley fill sites. The FWS has recommended that this be included as a component of the upcoming federal valley fill study.

Aside from the issue of downstream impacts, the direct impacts of filling a stream are problematic from the standpoint of the federal Clean Water Act. U.S. EPA's Antidegradation Policy (40 C.F.R. 131.12(a)(1)) requires that "existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." U.S. EPA Region III has stated (Maslany, 1998) that valley fills violate the Antidegradation Policy, but in consideration of the apparent lack of alternatives, has declined to object to permits where adequate compensatory mitigation is provided. This situation is problematic because, for any permit issued under the authority of Clean Water Act Sections 402 or 404, the State must certify that the discharge will not violate State water quality standards (which contain the Antidegradation Policy).

## 2.2 MITIGATING "UNAVOIDABLE" VALLEY FILL IMPACTS TO FISH AND WILDLIFE RESOURCES

"Mitigation," in the context of federal regulations, encompasses a sequential process whereby environmental impacts are first avoided; remaining impacts are minimized as much as possible; and any unavoidable impacts still anticipated at the end of this process are then "compensated" by replacing the functions and values of the resources being lost. The process is most commonly used in the permitting of fills in wetlands, where "compensatory mitigation" for unavoidable impacts translates into the applicant having to create an equal or greater acreage of wetlands to compensate for the acreage to be filled.

The determination that environmental impacts are "unavoidable" is critical in mitigation sequencing, and in federal authorization of valley fill projects through Clean Water Act Section 404. The 404(b)(1) Guidelines (40 CFR Part 230) require that an alternatives analysis be prepared to document that the selected alternative, involving the placement of fill material into waters of the United States, is in fact the least environmentally damaging practicable alternative. The FWS and EPA normally request that applicants prepare alternatives analyses for valley fill proposals in Pennsylvania. In most cases, the resulting analyses focus on the environmental impacts of filling alternative valleys, and give only superficial consideration to non-valley fill alternatives. Alternative disposal methods, such as back-stowing into mines, are dismissed as "not practicable" because they are technically infeasible, unsafe, and/or too expensive. Natural resource agency staff charged with reviewing these reports are biologists with few qualifications to evaluate engineering, economic, and safety data, and are therefore less capable of responding to industry claims. While OSM and DEP may have staff with such expertise, nothing in federal or State mining regulations empowers these regulators to require such an alternatives analysis. Meanwhile, the CRDCA amendments allow an applicant to limit the search area for alternative disposal sites to a one-mile radius for existing facilities, and a three-mile radius for new facilities. In Southwestern Pennsylvania, this generally means that no previously-degraded (i.e., "preferred") sites will be found, and a pristine watershed will be destroyed due to "unavoidable"

impacts.

Pennsylvania DEP's Coal Refuse Disposal Program Guidance, intended to implement the 1994 amendments to the CRDCA, requires that an application for a variance to the 100-foot stream buffer requirement include "a plan to mitigate any adverse [hydrologic and water quality] impacts that cannot be avoided." DEP currently requires that a mitigation plan be approved by the Pennsylvania Fish and Boat Commission prior to permit issuance. In addition, permit conditions specify that implementation of the mitigation plan must begin concurrently with initiation of construction of the refuse disposal area. The issue of mitigation for terrestrial wildlife habitat is currently being debated between the Pennsylvania Game Commission and DEP.

It is intuitively obvious that a stream buried by a valley fill can never really be "recreated" somewhere else. If topography, geology, precipitation, and all of the other ingredients necessary to form a stream are present in a given area, a stream will already exist there. Most of the factors essential to stream formation are not conducive to creation by human intervention. Therefore, mitigation of stream impacts generally involves improvement of water quality and aquatic habitats in existing streams outside of the valley fill project area. Current proposals to mitigate stream impacts related to valley fills in Pennsylvania involve two basic types of project: 1) eliminating mine-related stream pollution in another area; and, 2) enhancing stream habitat and water quality by constructing in-stream habitat structures and working with private farmers to restrict livestock access to streams and restore riparian vegetation.

## 3.0 SUMMARY AND CONCLUSION

A 1994 change to Pennsylvania's Coal Refuse Disposal Control Act which removed a previous ban on disposing of coal refuse in streams has raised concern among natural resource agencies and the public that losses of streams and valuable wildlife habitat due to valley filling will increase. Simultaneously, controversy over valley filling in other states has focused the attention of federal regulatory agencies on the practice.

Valley filling for coal refuse and/or coal slurry disposal in Pennsylvania usually involves the destruction of streams, wetlands, and valuable upland wildlife habitat. Field studies to document the direct and indirect environmental impacts of these projects have not been conducted, but are needed. Although the streams in these valleys are small, they are critical to the aquatic ecosystem as a whole by providing clean water, nutrients, and food production to larger waterbodies downstream. While "mitigation" for the destruction of these areas is supposed to encompass a process where environmental impacts are first avoided, remaining impacts are minimized, and any unavoidable impacts are then "compensated" by replacing the functions and values of the lost natural resources, the avoidance component of the process is seldom used in these cases.

The pending federal valley fill study will evaluate existing projects in terms of water quantity and quality effects, changes in aquatic and terrestrial habitats, effects on downstream flooding, effectiveness of reclamation and mitigation practices, and the effectiveness of current federal and state regulatory programs. The information is needed to ensure that the existing environmental protection provisions of the Clean Water Act and the Surface Mining Control and Reclamation Act are being fully implemented, and that the environmental impacts of valley fills are understood and factored into informed, environmentally sound, and consistent decisions in the permitting of new valley fill projects.

## REFERENCES

Maslany, Thomas J. 1998. Letter to Honorable Rick Staton, Chairman, House Judiciary Committee, West Virginia House of Delegates, from Director, Water Protection Division, Region III, U.S. Environmental Protection Agency.

Perry, Sue A., and Michael Golden. 1997. *The Importance of Headwater Streams to Downstream Areas and a Comparison of Stream and Pond Productivity.* West Virginia Cooperative Fish and Wildlife Research Unit, Division of Forestry, West Virginia University, Morgantown.

# SECTION C

# SOCIAL AND ECONOMIC ISSUES

# CHAPTER 9

# IMPORTANCE OF COAL MINING, WITH EMPHASIS ON GREENE AND WASHINGTON COUNTIES

H. Wade VanLandingham
VanLandingham Consulting
Warriors Mark, Pennsylvania

# 1.0 GREENE COUNTY PROFILE

Section 1.0 deals with demographic, economic, and socio-economic conditions in Greene County, Pennsylvania. Special attention is paid to the role of coal mining in the County.

## 1.1 INTRODUCTION: IMPORTANCE OF COAL MINING TO GREENE COUNTY

There were about 18,125 jobs in the coal mining industry in Pennsylvania in 1990 (Department of Labor & Industry, 1990). Of these, 2,510 or almost 14 percent were located in Greene County. This was the largest concentration of coal mining employment in the Commonwealth. The 1990 Census of Population and Housing indicates that 1,480 residents of the County were employed in coal mining (Bureau of the Census, STF 3, 1990). Hence, there was a net inflow of just over 1,000 employees – about 40 percent of the total – to work in the coal mines of Greene County. Despite the commuting of coal miners into Greene from other counties, Greene had the highest percentage of its resident workforce employed in this activity of all Pennsylvania Counties.

The County had only 39,550 residents in 1990 (TABLE 1) and only 13,506 residents in the employed labor force (TABLE 8), therefore, both the total number of mining jobs and the total number of Greene County residents employed in mining were very significant. Since coal mining has been a major employer in the County for at least the past 100 years, the demographic and socio-economic impacts of this economic activity, if any, should be visible in the population of this County if they are discernible in any County in the Commonwealth.

Washington County, Greene's larger and more metropolitan neighbor, also had a high percentage of the state's total coal mining employment. Presumably, if certain differences exist between Greene and the remainder of the Commonwealth, and if those differences are attributable to coal mining, there should be a similar, if less obvious, correspondence in Washington County. Hence, Washington County is also profiled and used as a check on the comparative findings.

This section of the analysis is a straight-forward Profile of the characteristics of the population and economy of Greene County and of the changes in some of those variables in the past two decades. Most data reported in this section are shown in the Tables. Each Table indicates the data source. Only data which are not from a Table found in this section are referenced separately.

## 1.2 BASIC POPULATION PARAMETERS

### 1.2.1 Recent Changes in Total Population

In 1990, Greene County had 39,550 residents (TABLE 1). This was a decrease in total population of 926 persons from 40,476 in 1980 (2.29 percent). On the other hand, in 1970 the County had 36,090 residents; hence from 1970 to 1980 population increased by 4,386 or 12.1 percent. Even with the decline from 1980 to 1990, Greene County had 9.59 percent more residents in 1990 than in 1970 (TABLE 1). Although this is not a rapid rate of increase in comparison to many counties in southeastern Pennsylvania, it is substantially greater than that for the Commonwealth as a whole or for the southwestern corner of the state where Greene is located.

### 1.2.2 Population Estimates and Projections

The Pennsylvania State Data Center estimates that the population of Greene County has increased since 1990 to a total of 41,114 in 1995. If this estimate is accurate it would be 3.9 percent increase in five years, a reversal of the trend of the 1980's. Strong support for the contention that Greene County is now growing in population may be found in the County's employment statistics. Between 1990 and 1996 Greene County added about eleven percent more jobs (Department of Labor & Industry, 1996).

### 1.2.3 Population Density

Greene is a rural County. The population density of the County in 1990 was only 68.5 persons per square mile which was only 26.0 percent of the Pennsylvania average of 263.9 persons per square mile (TABLE 1). Further, the largest population center in the County at the last Census was Waynesburg Borough with 4,270 residents (Bureau of the Census, STF 3, 1990).

### 1.2.4 Generalized Age Structure

The age structure of the population of Greene County shows a slight "barbell effect" compared to the Commonwealth. In 1990, 25.6 percent of residents were below the age of 18 and 16.4 percent were over the age of 65. For the state as a whole, the percentages were 23.5 and 15.4 respectively. The County had slightly more people, as a percentage, at each end of the distribution (TABLE 1). In consequence, the dependency ratio (i.e. the sum of the population at both ends of the age structure divided by the total population) for the County was 42 percent compared to 38.9 percent for the state.

### 1.2.5 Minorities and Ethnic Groups

Blacks and Hispanics are very small minorities in the County. In 1990, less than one percent of the population was African-American and only 0.5 percent were Hispanic (TABLE 1). This is low even for rural counties in the Commonwealth.

### 1.2.6 Household Change

Although population declined, households increased by 3.3 percent from 14,157 to 14,624 between 1980 and 1990; and household size decreased from 2.86 persons per household to 2.54 (TABLE 1). This was in keeping with both national and statewide trends.

### 1.2.7 Family Households

Families as a percentage of households fell from 76.9 to 73.1 percent. In both 1980 and 1990, families as a percent of all households was higher in Greene County than in the state; this is typical for rural counties because there are usually fewer single person households than in the urban centers.

## 1.3 DETAILED ANALYSIS OF POPULATION AND HOUSEHOLD CHARACTERISTICS

This section provides some in-depth analysis of the basic population parameters and deals with further aspects of population structure and characteristics.

### 1.3.1 Age Structure of the Population

The age structure of the population is important for several reasons:

- It indicates the percentage of the resident population who are of working age versus those who are too young or too old to work (the dependent population).
- It shows the percentage of persons of child bearing age and, hence, gives an indication of how fast the population is likely to grow through natural increase.
- It indicates the kind and amount of services which are likely to be needed by the residents: whether schools, senior centers, or unemployment compensation.

TABLES 2.1-2.4 show the age structure of the population by five year cohorts, i.e. age groups, for Pennsylvania, Greene, and Washington Counties in 1990.

The population of Greene County under 20 years of age totaled 11,532 in 1990. The population over 70 totaled 4,546. These were 29.2 and 11.5 percent of the population respectively. In contrast, the Commonwealth had 26.6 and 10.3 percent in each of these age cohorts. Thus, there are fewer persons in the working age population and more in the dependent populations in the County than in the state as a percent of total population.

Between 1980 and 1990, the increase in persons age 35 to 49 was exceedingly high in Greene County compared to either the Commonwealth or Washington County. Most of this change was caused by aging of the cohort, i.e. by those who were 25 in 1980 becoming 35 in 1990 (TABLES 2.1-2.4). The increase was not caused by in-migration since the overall population declined between 1980 and 1990. On the other hand, persons 20 to 34 showed a large decline and are now a much smaller percentage than they are in the state, 20.5 compared to 23.4 percent. The implication is that there are fewer young adults in the County than would be expected and that this will show up in future decades as a lower rate of natural increase.

### 1.3.2 Mobility and Migration

TABLE 3 shows both Mobility and Migration Statistics. Over 80 percent of persons living in Pennsylvania in 1990 were born in Pennsylvania. This was the highest percentage of residents born in the state of all the United States. Perhaps because it is located in the corner of the Commonwealth, adjacent to West Virginia, Greene County has a lower percentage of born-in-Pennsylvania residents, 75.6 percent. Over 16 percent of Greene County's residents are from the South (including West Virginia); which is far above the 5.6 percent of southern in-migrants in Pennsylvania as a whole.

Most of the migrants from out-of-state who located in Greene County did so before 1985. This is shown by the fact that 94.2 percent of all 1990 residents of the County lived in Pennsylvania in 1985. Economic conditions in the state, in general, in the 1980's were not conducive to in-migration; 92.9 percent of all 1990 residents of the Commonwealth lived here in 1985. Greene County was, perhaps, slightly less attractive than Pennsylvania, on average, to new in-migrants.

### 1.3.5 Education

In 1990 there were 25,473 persons over the age of 25 in the County; 15.6 percent had less than a ninth grade education compared to 9.4 percent in Pennsylvania (TABLE 5). High school graduates in the County were 68 percent of those over 25; in the state they were 74.7 percent. Further, in the state 17.9 percent had at least a college degree and in Greene County only 11.4 percent were college graduates. These statistics are important not only because education and income are highly correlated in our society but also because a less educated workforce tends to indicate relatively fewer employment options and economic development opportunities.

### 1.3.6 Mortality

The average annual age-adjusted death rate for Greene County for the period 1991 through 1995 was 5.4 (per thousand residents); this was slightly higher than the state rate of 5.0 and above most counties in Southwestern Pennsylvania ( Pennsylvania Department of Health, 1997). Among the causes of death, heart disease, chronic obstructive pulmonary disease (lung diseases including black lung), pneumonia, and unintentional injuries were all significantly above the state norm.

### 1.3.7 Household and Family Incomes

Incomes in Greene County are low. In 1989 the median household income for the Commonwealth was $29,069 (TABLE 9); for Greene County it was $19,903. This was only 68.5 percent of the state median and was among the lowest of the 67 Pennsylvania Counties. Not only did over fifty percent of all households in the County have incomes under $20,000, but 24 percent had incomes under $10,000. At the other end of the income spectrum, only 5.4 percent of households in the County had incomes over $60,000 compared to 14.4 percent in the state. As seen in a later section, the low income of Greene County residents is something of a surprise: wages paid in the County are among the highest in the Commonwealth due largely to the coal mining industry. This dichotomy must a reflection of one or more of the following:

- the very low labor force participation rate,
- the high dependency ratio,
- persistently high unemployment, and/or
- the high percentage of coal miners who commute in from other counties.

Families (defined as households with at least two related members) had a median income in 1989 of $25,284, while non-family households (which includes all single person households) had a median income of only $10,503. In Pennsylvania the comparable incomes were $34,856 and $15,099 respectively (TABLE 9). Hence, families in the County were relatively better off than the average of all households but the County's median family income was still only 72.5 percent of the state median.

### 1.3.8 Per Capita Income and Poverty

Overall per capita income in Greene County in 1989 was just 71.1 percent of the state average. In Greene, each person had an average income of $10,005 compared to $14,068 for

Pennsylvania. Blacks, Hispanics, American Indians all had incomes below even the low County average, while Asians and Pacific Islanders were higher (TABLE 10).

As might be expected, the poverty rate in Greene County in 1989 was almost twice that of the state as a whole. Just over 11 percent of the Commonwealth's citizens had incomes below the poverty level in 1989. About 21.3 percent of all persons in Greene County were in poverty (TABLE 10). The age distribution of poverty followed that of the state closely in 1989; i.e. neither children or elderly were significantly more likely to be in poverty than would be expected.

Of great concern, however, is the fact that of those in poverty, almost one-half have incomes of less than 50 percent of the poverty level. Nine percent of the total population had incomes of less than 50 percent of the poverty level in 1990 compared to about 5.1 percent statewide.

### 1.3.9 Housing Values

The median value of an owner occupied home in Greene County in 1990 was $38,400. This was only 55 percent of the median value of such housing in the Commonwealth. This was the fourth lowest in Pennsylvania. The overall distribution of housing values shows that, not only were most values low, only 17 units were valued above $200,000 and only 66 were valued at more than $125,000 (TABLE 11). This suggests that there is not a sizeable minority of well-to-do hidden by the mass of less fortunate households in the County. Low housing values and low incomes offset each other to a degree because housing is a major component of the household budget.

## 1.4 LABOR FORCE CHARACTERISTICS

### 1.4.1 Place of Work

Greene County is not merely physically close to West Virginia, there are economic ties as well as shown in TABLE 4. Just over 14 percent of the County's residents worked out of state in 1990 and, presumably, most of those who worked out of Pennsylvania were employed in West Virginia, since that state surrounds Greene County on two sides and has several population centers within easy commuting distance. In Pennsylvania only 4.3 percent of all residents work out of state.

In 1990, 64.4 percent of the employed residents of Greene County worked in the County, compared to the 74.9 percent average in all Pennsylvania Counties; 21.5 percent worked out of the County but in the Commonwealth. The latter figure is slightly above the state average of 20.8 percent (TABLE 4). The lack of major population centers and fewer local economic opportunities leads to employment of over 35 percent of all Greene County workers out of the County. It is also significant to note that, although Greene County is a net labor exporter, in some important industries – notably coal mining – a high percentage of the County's employees are commuters from other counties in Pennsylvania and from West Virginia.

### 1.4.2 Transportation to Work, Travel Time, and Working Hours

The rural nature of Greene County assures that the automobile will be the most important means of transportation to work. TABLE 4 shows that fewer than 40 people (less than 1.0 percent) were able to take any kind of mass transit to work. Almost 90 percent either drove alone or car-pooled.

Because so many residents of the County work elsewhere average commutes are fairly long. Forty-two percent of all employees had commutes of over 25 minutes in 1990 compared to less than 37 percent of all Pennsylvania workers.

There is a considerable amount of shift work in the County; almost 19 percent of all workers left for work between noon and midnight in 1990, compared to less than 15 percent statewide. In the state 52.6 percent of all workers left home for their job between 6:30 a.m. and 8:30 a.m. In Greene County less than 49 percent kept these "regular" hours.

### 1.4.3 Employment and Labor Force Participation

There were 14,348 males over the age of 16 in Greene County in 1990 (TABLE 5a). Of these, 8,013 were employed and 1,261 were unemployed and seeking work. Thus, the labor force participation rate for males in the County was 64.6 percent. The male labor force participation rate in Pennsylvania in that year was 71.4 percent. This statistic is more meaningful when those over 65, who are usually considered of retirement age, are removed from the data. Using the male population between 16 and 64 as the denominator, the adjusted Labor Force Participation Ratio (LFPR) in the County was 77.4 percent; in the state it was 83.8 percent.

Of the 15,400 females over the age of 16 in the County, 6,110 were employed or seeking work. This yields a total LFPR of 39.7 percent, substantially lower than the state average of 45.3 percent (TABLE 5). Age structure is a not a factor contributing to this low rate, since, when the over 65 cohort is removed, the adjusted LFPR for the County was 48.7 percent compared to the state's adjusted rate of 66.1 percent.

The overall Labor Force Participation Rate, using all persons over 16 — as it is usually calculated -- was 50.1 percent in Greene County in 1990. This was far below the 61.5 percent found in the state in that year. The low rate of labor force participation was reflected in by the fact that only 67 percent of males, and 42.6 percent of females, over 16 in the County were employed at all during 1989. By contrast, 76.5 percent of males, and 57.8 percent of females, over 16 in the Commonwealth held some employment in 1989. Coupled with the out-migration statistics for the previous decade, it is safe to assume that the low LFPR is a direct reflection of a long time dearth of good job opportunities. Many people left the County, many others simply quit looking for work.

### 1.4.4 Unemployment

There were a total of 1,878 persons unemployed and seeking work in the County in April of 1990. This was an unemployment rate of 12.2 percent, more than twice the Pennsylvania average in that year. Unemployment in the County has remained relatively high throughout the 1990's. In December of 1996 the Greene County had the 6$^{th}$ highest unemployment rate in the state at 7.9 percent; the Pennsylvania rate for that period was 4.4 percent (Department of Labor & Industry,1996).

### 1.4.5 Disability and Employment

Greene County has a high rate of disability, especially among males. Of males 16 to 64, as shown in TABLE 6, 12.1 percent reported a work disability in the 1990 Census. Of these, 7.8 percent were prevented from working by their disability. In the Commonwealth, 8.7 percent claimed some disability but only 4.3 percent were prevented from working. More than 44 percent of males over 65 in Greene County indicated that they suffered from some disability. Of these 37.2 percent were prevented from working. Only 31.4 percent of the Commonwealth's males over 65 claimed a disability and, of those, only 24.2 percent were prevented from working.

The disability statistics for females were similar but not as extreme. Almost 10 percent of females 16 to 64 had some work disability but only 6.9 percent were prevented from working. In the Commonwealth 8.8 percent of women 16 to 64 reported a disability but only 4.5 percent were prevented from working. Females over 65 in the County had a total disability rate of 36.1 and 33 percent were not able to work. In Pennsylvania the comparable rates were 30.5 and 26.5 respectively (TABLE 6).

### 1.4.6 Industry of Employment, by Place of Residence

The Census of Population and Housing reports employment statistics according to where a person lives. This differs from the practice of most other agencies which report employment statistics by place of work. Both kinds of data are valuable but it is important to know which is being used for a particular study. TABLE 8 reports the Census data for 1990.

Greene County in 1990 had 13,506 employed residents. As noted earlier many of these persons were employed out of county and even out of state. Of obvious import is the percentage of Greene County employment in mining; of the total, 11.0 percent or 1,480 persons were employed by this sector in 1990. In the Commonwealth only 0.6 percent of all employment is in the mining sector. As will be seen later, almost all of this employment is attributable to coal mining.

While mining employment is high, manufacturing employment is extremely low. In 1990, only 8.5 percent of the Greene County workforce was employed in the manufacturing industries; by comparison, 20.0 percent of the state's employment was in this sector (TABLE 8). Agricultural employment in the County was relatively high at 2.4 percent, about 33 percent higher than the state rate but not as high as most of the counties on the southern tier of Pennsylvania. In other regards the distribution of employment was similar to other rural counties in the Commonwealth: finance, insurance, and real estate employment was under-represented, as was employment in business services; construction, and public utilities employment was higher than the state average.

### 1.4.7 Occupation

It will probably be no surprise, given the mix of employment by industry and the educational statistics, that employment in blue collar occupations significantly exceeds that in the white and pink collar occupations in Greene County. In 1990, the Census reported that 56.1 percent of all employed residents in the County held jobs in traditional blue collar occupations as is shown in TABLE 8. For the state as a whole, only 43.3 percent of all employment is in these same job categories.

The largest single classification of employment was in the "precision production" group which had 18.1 percent of total employment compared to the state average of 11.6 percent. This group includes most miners. Also substantially over-represented were the lesser skilled laborer type positions such as transport workers and material movers, and handlers, equipment cleaners, and general laborers. Under-represented occupations include: executives and managers, sales, and administrative support.

### 1.4.8 Private and Public Sector Employment

TABLE 8 also shows that private for-profit wage and salary employment is a substantially lower percentage of total employment in Greene County than in the state (67.6 and 72.1 percent respectively). Not-for-profit employment is also lower than the Commonwealth average (8.3 percent compared to 9.6 percent). Both state and local government employment are higher than the Pennsylvania average. In 1990, local government employed 8.0 percent of all workers; state government employed 6.1 percent. In Pennsylvania, local government employed 5.8 percent and state government employed 3.1 percent.

## 1.5 TAXES AND MUNICIPAL FINANCE

In 1990, the government of Greene County had total revenues of $9,633,820 and total expenditures of $8,383,057. The County was solvent. Greene had a positive difference per capita between revenues and expenses in 1990 while the state was slightly negative. In that year revenues collected amounted to $243.58 per person and expenditures were $211.97. This contrasts with the $238.57 collected and $255.05 expended on a per capita basis statewide (Department of Community

Affairs, 1990). None of the surrounding Pennsylvania counties were in such an enviable position; most spent more than they took in. County taxes per capita were fairly high at $162.15, and were 67 percent of total County revenues. Only two other counties in the Commonwealth (Philadelphia and Allegheny) had higher County taxes in 1990 but about one-half had higher total revenues. This indicates that taxes as a percent of total revenues in the County were quite high. It should be noted, however, that County levied taxes are a small part of the total tax bill.

Between 1990 and 1995 revenues for County Government increased to $10,395,256, about 8.0 percent. County levied taxes were reduced by about $21.86 per capita or 13.5 percent. Since expenditures fell to $10,050,528, the County remained solvent (Department of Community Affairs, 1996).

On average the County's 26 municipalities received more than they spent. Average revenues per capita for the County's 26 municipalities were $195.72; average expenditures were $172.16. Total municipal taxes per capita were $88.14. The overall average for all municipalities in the Commonwealth was $108.38. Given the low level of income in the County, the actual municipal tax burden as a percentage of income is slightly higher in the County than in the state.

The County's municipalities also remained solvent on balance in 1995; average revenues per capita were $290.23 and expenditures were $273.98. Taxes increased over the period to $114.99, about 5.7 percent.

## 1.6 ECONOMIC STRUCTURE AND CHANGE

The previous section of this profile dealt with characteristics of the resident population of Greene County, described, in large part, by data in the Census of Population and Housing. The data in this section are derived from the Unemployment Compensation files of the Pennsylvania Department of Labor and Industry. The section presents Greene County employment, wage, and establishment data collected by place of work and, hence, deals with the structure of the economy rather than the well-being of County residents.

### 1.6.1 Comparisons of 1990 Employment in Greene County to Census Statistics

Using 1990 figures from both the Census and Labor and Industry, in order to provide an accurate comparison, we see that Greene County is a net exporter of labor. Whereas 13,506 residents of the County were employed in 1990 (TABLE 8), establishments located in Greene County employed only 9,587 (TABLE 12). (The latter number does not include self-employed persons and certain others not covered by Unemployment Compensation and, therefore, understates total employment slightly, but not by almost 4,000 workers). The remainder of the employed residents of the County must have worked in surrounding Counties and/or in West Virginia.

### 1.6.2 Coal Mining Employment

The same data sets also indicate that almost 26 percent of all employment in Greene County in 1990 was in coal mining. This is an extraordinarily high percentage. Overall in Pennsylvania, only 0.5 percent of the workforce was employed in mining in that year. Even Pennsylvania counties such as Washington, Indiana, and Clearfield which had extremely high concentrations of mining employment compared to the state had less than 10.0 percent of their total employment in this sector (TABLE 12).

Since 40 percent of all coal miners who work in Greene County live elsewhere, it is clear that roughly 15 percent of all employed residents of the County are employed in coal mining.

### 1.6.3 The Impact of Coal Mining on Average Wages Paid in Greene County

The impact of high coal mining employment on total wages paid is readily seen. In Greene County, in 1990, the coal mining industry paid average wages of just over $44,000 per year. The 26 percent of the workforce who earned this high wage accounted for 46 percent of total wage income paid in Greene County in 1990. This boosted the overall average wage to $24,259, seventh highest among Pennsylvania Counties (TABLE 13). Without the coal mining employment Greene would have been one of the lowest wage counties in the Commonwealth. The average wage for all other employees was $17,532.

It must be remembered, as well, that over 40 percent of the wages paid by coal mine operators in Greene County accrued to residents of other counties. This helps to explain how Greene County can apparently pay high wages yet have very low household incomes. Almost one-half of the highest wages paid in the County were not paid to County residents and were not spent in Greene County.

### 1.6.4 Structure of the Economy in 1996 and Changes Since 1990

Mining is clearly the dominant industry in Greene County but employment in this sector declined in total employment, from 2,510 jobs to 2,369, a reduction of 5.6 percent between 1990 and 1996. Most other sectors of economic activity saw a rather large increase in employment between 1990 and 1996 in Greene County. Employment figures for Construction and Agriculture were not published in 1996; and Transportation and Public Utilities saw no change. Service sector employment grew by 14.9 percent and Government by 27.8 percent. Wholesale Trade was up by 7.2 percent and Retail by 2.1 percent.

Between 1990 and 1996 manufacturing sector employment increased by 60.4 percent. In 1990 there were only 369 manufacturing jobs in the County; this was only 3.8 percent of total employment. In 1996, there were 592 manufacturing jobs in Greene County; this was still only 5.6 percent of total employment compared to the Commonwealth average of 18.0 percent. (TABLE 12).

Despite the increases in employment between 1990 and 1996, most sectors of economic activity were under-represented in Greene County in 1996. Transportation, Communications, and Public Utilities and the Government sector had a higher percentage of the total workforce in Greene County than they did in the state. These sectors had 8.3 and 20.9 percent of the County's employment respectively, compared to 4.9 and 13.4 percent in the state (TABLE 12). They were also the highest paying sectors of the economy other than mining. The under-represented sectors included Agriculture and Agricultural Services, Construction, Manufacturing, Wholesale Trade, Finance, Insurance and Real Estate, and Services. All of which paid substantially less than their Commonwealth counterparts. In fact, no sector of economic activity in Greene County — other than the mining sector — paid as much as the Pennsylvania average wage for that sector (TABLE 13).

Normally in Pennsylvania manufacturing is a large sector which pays a high wage but in Greene County in 1990 the few manufacturing jobs which existed were concentrated in lower wage industries such as Lumber and Wood Products (SIC 24) and Printing and Publishing (SIC 27). The average manufacturing wage paid in Greene County in 1990 was $16,083, which was only 56 percent of the average state wage in manufacturing (Pennsylvania Department of Labor and Industry, 1996). By 1996 average manufacturing wages had risen to $22,123, an increase of almost 38 percent. By 1996, the manufacturing wage in the County was approximately 61 percent of the state average (TABLE 12).

The low level of wages outside of coal mining in the County may be attributed to the structure of the economy. Even in 1996 there was relatively little manufacturing in the County and what there was low wage compared to the Commonwealth. Most of the other sectors paid wages which were well below the manufacturing wage. The services sector, for example, employed 1,850 persons and paid an average annual wage of $19,003. Retail trade, which employed 1,650 persons paid only $12,130. Hence, most of the employment which exists outside of coal mining is in low paying positions.

The rapid increase in Manufacturing employment and wages probably helped to pave the way for the overall wage increase to $29,511 in the County in 1996 (TABLE 12). Coal mining wages increased by 26 percent compared to 38 percent for manufacturing. The average wage increased by 22 percent across all sectors.

### 1.6.5 Specific Industries of Importance to Greene County

Major employers in Greene County in 1992 are shown in TABLE 14a. Note that of the top 20 employers, only the two Coal Mining industries (SIC 1221 and SIC 1222), SIC 2321: Men's and Boys' Shirts, SIC 4922: Natural Gas Transmission, and SIC 3463: Nonferrous Forgings are basic (i.e. export) industries which sell significant portions of their output beyond the borders of the County. Between them the Coal Mining Industries account for over 80 percent of all export dollars earned by the County. These two industries have been declining in employment in County and in the state in the recent past, losing 5.6 percent of their employment in the County between 1990 and 1996.

# 2.0 WASHINGTON COUNTY PROFILE

Section 2.0 deals with demographic, economic, and socio-economic conditions in Washington County, Pennsylvania. Special attention is paid to the role of coal mining in the County.

## 2.1 INTRODUCTION: IMPORTANCE OF COAL MINING IN WASHINGTON COUNTY

Washington County, Pennsylvania is an integral part of the Pittsburgh metropolitan area. As such it is a fairly dense County with a high degree of urbanization. Coal mining is important to Washington County; in fact, the County has the third highest level of coal mining employment in the Commonwealth, after Greene and Indiana. In 1990, there were 1,878 persons employed in coal mining in establishments located in the County (Labor and Industry, 1990). The Census of Population and Housing indicated that in 1990, an equal number (1,873) of residents of the County were employed in mining (TABLE 8). Some cross commuting probably did occur but, on balance, County employers provided just as many jobs in the industry as residents found in the County and elsewhere. This is in distinct contrast to the situation in Greene County where almost 40 percent of the employees in coal mining commute in from other counties or from West Virginia.

Because Washington is a large County with a population of over 200,000, the impacts of coal mining cannot be expected to show up as major elements in the overall profile of the County. The profile is generated as a baseline for future changes which may occur due to changes in coal mining practice.

## 2.2 BASIC POPULATION PARAMETERS

### 2.2.1 Recent Changes in Total Population

In 1990 there were 204,584 residents of Washington County. Population decreased by 5.8 percent between 1980 and 1990. Between 1970 and 1980 population increased slightly in the

County so that the 1990 population represented a decrease of only 3.0 percent from 1970 to 1990 (TABLE 1).

### 2.2.2 Population Estimates and Projections

The Pennsylvania State Data Center estimates the 1995 population of Washington County to be approximately 208,017, an increase of 1,963 persons or less than 1.0 percent since 1990. Some increase in population seems likely because employment rose in the County by almost 4,000 between 1990 and 1996 (Labor and Industry, 1996). Increased job opportunities usually lead to increased in-migration.

### 2.2.3 Population Density

The overall population density of the County in 1990 was 238.8 persons per square mile which was comparable to the population density of the state. The largest Minor Civil Divisions (MCD's) in the County in 1990 were suburban Peters Township which borders Allegheny County with 14,467 residents and Washington City with 15,864 (Census of Population and Housing, STF 3, 1990).

### 2.2.4 Generalized Age Structure

The population of Washington County is significantly older than that of the Commonwealth. In 1990, only 22.5 percent of the population was under the age of 18 and 17.5 percent was over the age of 65 (TABLE 1). The state's percentages were 23.5 percent under 18 and 15.4 percent over 65. Hence, the overall dependency ratio (those over 65 and under 18 as a percentage of total population) for the County is not much higher than the state's ratio but the type of services demanded will likely be those needed by seniors rather than children.

### 2.2.5 Minorities and Ethnic Groups

Persons of African-American descent were 3.1 percent of the population in 1990, down from 3.5 percent in 1980, compared to 9.2 percent of the population of the state as a whole. Hispanics were only 0.5 percent, approximately the same as the Pennsylvania average (TABLE 1).

### 2.2.6 Household Change

Despite the decrease in population, households increased by 2.0 percent. Household size fell from 2.82 persons to 2.54, a somewhat sharper decrease than for the state (TABLE 1). This is typical for an area with an aging population.

### 2.2.7 Family Households

The number of family households in Washington County decreased between 1980 and 1990, from 60,098 to 57,237. This was a decrease of almost 4.8 percent. By contrast, family households increased in absolute number in the state, though the gain was less than 1.0 percent.

## 2.3 DETAILED ANALYSIS OF POPULATION AND HOUSEHOLD CHARACTERISTICS

This section provides some in-depth analysis of the basic population parameters and deals with further aspects of population structure and characteristics.

### 2.3.1 Age Structure of the Population

TABLES 2.1-2.4 show the age structure of the population by five year cohorts, i.e. age groups, for Pennsylvania, Greene, and Washington Counties in 1990.

As noted above, Washington County has an older population than Pennsylvania as a whole. All five-year age cohorts above the 35 to 39 age group were larger as a percentage of total population in the County than their equivalent groups in the state at large (TABLES 2.1-2.4). In other words, it is not merely the groups over 65 which cause Washington to show an older age profile, but rather all groups over the age of "household formation" and "nest building." Of particular concern is the fact the 20 to 34 year old group is significantly smaller (as a percentage) than its Pennsylvania counterpart.

From 1980 to 1990, all cohorts 0 to 29 years of age decreased in absolute numbers in the County (TABLES 2.1-2.4). The group which would have been 20 to 24 in 1990 declined in number by 29 percent and the group which would have been 25 to 29 decreased by 19 percent (TABLES 2.1-2.4). There are fewer people in the age group starting families than would be expected in the usual age distribution. This means that it will be difficult for the County to grow through natural increase. If population decline is to be arrested in the next few decades, in-migration will be required.

### 2.3.2 Mobility and Migration

Over 86 percent of the residents of Washington County were born in the state of Pennsylvania (TABLE 3). This is quite high, even for Pennsylvania which has an exceptionally high rate of native born persons. In the Commonwealth just over 80 percent were born in state. Of those few residents of the County who were not born in Pennsylvania most (5.8 percent of total population) were born in the South.

As might be expected from such a stable population group, most Washington County residents lived in the same house in 1990 that they lived in 1985 (TABLE 3). This is a good measure of in-migration, and therefore of economic opportunity. When economic opportunity in an area is high there tends to be substantial in-migration and, therefore, a relatively low percentage of persons living in the same house as five years previously. In Washington County over 69 percent of all residents over the age of five lived in the same house in 1990 that they lived in 1985. In the state as a whole only 63.4 percent lived in the same house. Further, of the 30.8 percent who had moved, over one-half (18.9 percent of all persons over age five) moved within the County and another 7.6 percent moved within the state. Only 4.4 percent of persons over five who lived in Washington County in 1990 had lived in another state or outside the U.S. in 1985 (TABLE 3).

### 2.3.3 Education

Almost 27 percent of all persons over 25 in Washington County do not hold a high school diploma. This is about three percentage points higher than the Commonwealth average. Likewise only 13.6 percent have at least a college degree and only 4.7 percent have a graduate degree. The comparable numbers for the Commonwealth are 17.9 percent and 6.6 percent (TABLE 5). Educational attainment is low for a suburban county and suggests that the workforce is predominantly blue collar.

### 2.3.4 Mortality

Average annual age-adjusted death rates for Washington County for the period from 1991 to 1995 were the same as those for the Commonwealth at 5.0 per one-thousand. Among the listed causes of death, heart disease, pneumonia and influenza, and unintentional injuries were above the state average, while cerebrovascular and chronic lung disease were below average in the County. Heart disease was particularly common as a cause of death in the 1991 to 1995 period in the County. While the state had 359.9 deaths per 100,000 population, the County had 415.1 per 100,000, placing it in the top third of Pennsylvania Counties on this measure (Department of Health, 1997).

### 2.3.5 Household and Family Incomes

Household incomes are slightly below the state levels but significantly above those in Greene County. In 1989 the median household income in Washington County was $25,284 compared to the state median of $29,069 (TABLE 9). This contrasts sharply with the median household income in Greene County. In 1989, the Greene County median was under $20,000.

The age structure difference between the state and the County shows up in the fact that median family incomes are somewhat closer to the median for the state. In 1989, the County had a median family income of $31,239 compared to $34,856 in Pennsylvania. Hence, the median family income was 89.6 percent of the state median and the median household income was 87.6 percent of the state level. This difference is attributable to the fact that there are more elderly single people in the County as a percentage of the total population; these single person households as a group always have a lower income than family households. In fact, the median non-family household in the County was $11,589 in 1989 (TABLE 9).

### 2.3.6 Per Capita Income and Poverty

Overall, the per capita income in Washington County in 1989 was 90.6 percent of the state average. Whites and American Indians had below average per capita incomes compared to the Commonwealth and Blacks, Asians, and Hispanics had higher incomes (TABLE 10).

Although the poverty rate of 12.8 percent was above the state level of 11.1 percent, it was not especially high by western Pennsylvania standards. By contrast, over 21 percent of persons in Greene County were in poverty in 1990. Poverty was just slightly below average for children and above average for the elderly (TABLE 10).

### 2.3.7 Housing Values

Compared to the income level, housing values in Washington County are quite low. The median owner occupied house was valued at $53,600 in 1990 (TABLE 11). This was just 77 percent of the state median while household incomes were about 87.6 percent of the state level. Of the 59,368 owner occupied housing units in the County, only 5.8 percent were valued at over $125,000 compared to 15.8 percent statewide.

## 2.4 LABOR FORCE CHARACTERISTICS

### 2.4.1 Place of Work

The suburban nature of Washington County can clearly be seen in the fact that only 63.5 percent of the employed residents of the County work in the County. By comparison, 74.9 percent of all Pennsylvania's work in their County of residence (TABLE 4). Most of the residents who work out of County are probably employed in the urbanized area of Pittsburgh; this is indicated by the fact that only 3.1 percent work out of state. This is true despite the fact that Washington County borders West Virginia very near the City of Wheeling.

On balance, there approximately as many residents of the County employed in coal mining as there are jobs in the coal mining industry in the County. Hence, there is no net commuting in this industry.

It is also characteristic of suburban counties that relatively few of the employed workers of the County work in their own municipality. In the state 30 percent work in their own place of residence but in Washington County only 16.8 are able to work so close to their own residence (TABLE 4).

### 2.4.2 Transportation to Work, Travel Time, and Working Hours

Because a very high percentage, about a third, of the employed residents of Washington County work outside the County, most are dependent on the automobile for their transportation to work. Over 78 percent drive alone and over 12 percent car-pool. Mass transit is not an important means of transportation in the County (TABLE 4).

About one-third of all workers have commutes of over one-half hour; but the proximity of employment centers in the greater Pittsburgh area assures that most of those commutes are less than one hour (TABLE 4). Over 20 percent have work days which start between noon and 6:00 a.m. which suggests a fairly high degree of shift work (TABLE 4).

### 2.4.3 Employment and Labor Force Participation

In 1990, the Labor Force Participation Rate for Washington County was slightly lower than the Commonwealth average but significantly above the rate for many counties in western Pennsylvania, including Greene. Employed males were 61.0 percent of all males over 16 and employed females were 42.1 percent of females over that age. Comparable statewide numbers were 66.9 percent and 49.9 percent respectively (TABLE 5). The overall LFPR in the County was 55.1 percent compared to the state's 61.5 percent and Greene County's 50.1 percent. It should be noted that one reason that the LFPR in the County is low is that all persons over 16 are included and the County has a high percentage of persons over the usual retirement age of 65.

### 2.4.4 Unemployment

Unemployment was higher than the state average at 8.2 percent for males and 6.7 percent for females. In 1990 the unemployment rate for the County was 7.6 percent compared to 5.9 percent in the Commonwealth (TABLE 5). By 1996 the unemployment rate in the County had fallen to be roughly the same as that in the state as a whole — 4.5 percent compared to 4.4 percent (Labor and Industry, February, 1997). In general the County's rate tends to be close to that of the state because of the job opportunities provided in the Pittsburgh metropolitan area.

### 2.4.5 Disability and Employment

Persons with a work disability in Washington County are a slightly higher percentage of the total population than in the Commonwealth at large. Of males age 16 to 64 in the County, 5.9 percent had a disability which kept them from working compared to 4.3 percent in Pennsylvania. In the same age group 5.5 percent of females had a disability which kept them out of the labor force compared to 4.5 percent statewide. Among those over 65 disabilities kept just over 25 percent of the men and just over 26 percent of the women from being employed. These statistics roughly mirrored those of the state (TABLE 6).

### 2.4.6 Industry of Employment, by Place of Residence

The employment of Washington County residents is also not very different than that of the state as a whole. Only 18.2 percent work in manufacturing industries compared to 20 percent statewide and retail trade employment is higher at 19.6 percent versus 17.1 percent.. Business services, finance, other professional services, and public administration are also lower. Construction, transportation, and health employment is higher. About 2.2 percent are employed in mining which is almost four times the state average but well below the percentage in Greene County (TABLE 8). With the exception of mining, the employment pattern is not exceptional.

### 2.4.7 Occupation

All of the white collar occupations, except sales, are slightly under-represented in the County. Total blue collar employment is about 47.4 percent of the total which just four percentage points above the state average. Of the blue collar trades, precision production workers — skilled laborers — are largest group with 13.9 percent of total employment (TABLE 8). This is slightly above the state average but not remarkably so. Since manufacturing employment is below the state norm and mining is above, it is probable that many of the skilled workers are miners.

### 2.4.8 Private and Public Sector Employment

Washington County is not highly dependent on government employment. In 1990, only 11.1 percent of all workers were employed in the public sector. In Pennsylvania about 11.7 percent of all employees were in government. Private sector for-profit employment was 74.1 percent of the total compared to the Commonwealth average of 72.1 percent (TABLE 8).

## 2.5 TAXES AND MUNICIPAL FINANCE

Washington County government had revenues of $42,721,912 in 1990. In the same year expenditures were $44,401,835. Hence, revenues lagged behind expenditures by a small percentage. Both revenues and expenditures per capita were below the state norm for counties. In 1990, the average county in Pennsylvania had revenues of $238.57 per capita and expenditures of $255.05 per capita: Washington had revenues of $208.82 and expenditures of $217.03. Total county level taxes were $67.04 or 32 percent of total revenues. County taxes per capita were only 78 percent of the state average (Department of Community Affairs, 1992).

Between 1990 and 1996 total County revenues increased to $54,077,838 and total expenditures increased to $52,606,569. Hence, revenues increased by 26.6 percent and expenditures by 18.5 percent and the gap between funds collected and expended increased slightly (Department of Community Affairs, 1996).

On average the municipalities of Washington County were also quite sound fiscally. The average municipality collected $184.46 per capita and expended $179.64. Taxes per capita were low at $97.27. The average municipal tax per capita in the Commonwealth in 1992 was $108.38. When taxes are compared to incomes the actual burden in the County's municipalities is about the same as the average for the state (Department of Community Affairs, 1992).

On average, revenues continued to exceed expenditures at the municipal level as well. In 1995, average per capita revenues collected by all municipalities was $223.92 and expenditures were $210.31. Taxes per capita were $109.66 which was 49.0 percent of total revenues collected by municipal units (Department of Community Affairs, 1996). This represented a significant increase across the period.

## 2.6 ECONOMIC STRUCTURE AND CHANGE

The previous section of the Washington County profile dealt with the characteristics of the resident population of the County, described, in large part, by data from the Census of Population and Housing. The data in this section are derived from the Unemployment Compensation files of the Pennsylvania Department of Labor and Industry. The section presents employment, wage, and establishment data collected by place of work and, hence, deals with the structure of the economy rather than the well-being of County residents.

### 2.6.1 Comparisons of 1990 Employment to Census Statistics

In 1990 there were 63,037 persons employed in Washington County (TABLE 12); however, 83,675 residents of the County were employed (TABLE 8). (It should be remembered that these two datasets are calculated differently: the Census includes all workers but the Labor and Industry data include only those covered by Unemployment Compensation and, therefore, understates the total employment in the County considerably...but not by more than 25 percent). This fairly major difference is explained by the proximity of Washington to the major employment centers of the Pittsburgh metropolitan area. As is true for most suburban counties, many of Washington's municipalities serve as bedroom communities for the urban core. On balance, Washington County exports some labor to surrounding counties and West Virginia.

### 2.6.2 Coal Mining Employment

Of the 63,037 employees in Washington County about 1,800 were employed in the mining of coal. The County had the third highest coal mining employment of all Pennsylvania counties but the impact of that employment -- roughly 3.0 percent of total -- was less significant compared to total employment than it was in Greene County. Still, it is important to note that Greene County "imported" 40 percent of its coal miners while, on balance, Washington County residents provided all coal mining labor from its resident population.

### 2.6.3 The Impact of Coal Mining on Average Wages Paid in Washington County

In 1990, the average wage paid by mining in the County was $43,632. This was more than $10,000 higher than the next highest paying sector, construction. The average wage paid by all sectors in Washington County in 1990 was fairly high for western Pennsylvania. In that year the state average was $23,262 and the County average was $22,016 (TABLE 13). But, since the 1,800 workers in the mining sector were only 3.0 percent of total employment in the County, the impact of the very high wages paid in this sector was fairly small at about 5.0 percent of the total wage bill.

Most sectors in the County had wages near the state mean; only the Finance, Insurance, and Real Estate Sector paid less than 75 percent of the state average for the sector. The relatively high wage level helps explain why Washington County incomes were also close to the state average.

### 2.6.4 Structure of the Economy in 1996 and Changes Since 1990

Employment in the Mining and Construction sectors of the economy was quite high in the County in 1996 but appeared to be in long term decline. Employment in the Finance, Insurance, and Real Estate sector was quite low. In most other respects Washington County mirrored the Commonwealth. Total jobs increased from 63,037 to 66,904 or 6.1 percent (TABLE 12).

Although Mining and Construction jobs both declined by from 17 to 18 percent from 1990 to 1996 they were still major export earnings generators for the County. The only other sector to decline during the period was Transportation, Communications, and Public Utilities. All of these employment declines were between 17 and 18 percent.

Four sectors saw double digit percentage growth: Agriculture and Agricultural Services, Wholesale Trade, Finance, Insurance, and Real Estate, and Services. Even after growth of more 250 jobs between 1990 and 1996 Finance, Insurance, and Real Estate is still under-represented, while Mining -- even after declining by 326 jobs or 17.4 percent -- still has nearly six times the concentration found in the Commonwealth (TABLE 12).

### 2.6.5 Specific Industries of Importance to Washington County

The ten largest employers in Washington County in 1992 at the specific industry level were: SIC 9003: Local Government, SIC 5812: Eating Places, SIC 8062: General Medical and Surgical Hospitals, SIC 5411: Grocery Stores, SIC 9002: State Government, SIC 3312: Blast Furnaces and Steel Mills, SIC 5311: Department Stores, SIC 8051: Skilled Nursing Facilities, SIC 1222: Bituminous Coal Mining, Underground, and SIC 8011: Offices and Clinics of Medical Doctors (TABLE 14b). Note that of these only coal mining and steel mills are usually considered basic (or export oriented) industries. Again, this pattern is fairly close to that seen in the Commonwealth. Most large employers are (or tend to be) local serving industries. These ten industries make up almost one-third of all employment in the County.

Like coal mining and steel mills most of the other basic industries of the County are declining older style "foundry industries": SIC 3612: Transformers, except Electronic, SIC 3229: Pressed and Blown Glass, SIC 3316: Cold Finishing of Steel Shapes, Sic 2653: Corrugated and Solid Fiber Boxes. Of the large basic industries, only SIC 3089: Plastic Products and SIC 3678: Electronic Connectors are among the newer growth industries in the Commonwealth (TABLE 14b).

## 3.0 REFERENCES

Pennsylvania Department of Labor and Industry, 1990. *Employment by County and Industry, 1990.*

Pennsylvania Department of Community Affairs, 1992. *Local Government Financial Statistics, 1990.*

U.S. Department of Commerce, 1992. *Census of Population and Housing, 1990.* Summary Tape File 3.

Pennsylvania State Data Center, 1996. *County Population Estimates, 1995.*

Pennsylvania Department of Community and Economic Development, 1997. *Local Government Financial Statistics, 1995.*

Pennsylvania Department of Health, 1997. *Pennsylvania Vital Statistics, 1995.*

Pennsylvania Department of Labor and Industry, 1996. *Employment by County and Industry, 1996.*

Pennsylvania Department of Labor and Industry, 1997. *Pennsylvania Labor Force, December, 1996.*

Farber, S., 1998. "Undesirble Facilities and Property Values: A Summary of Empirical Studies," *Ecological Economics,* 24(1): 1-14..

## TABLE 1: DEMOGRAPHIC CHANGE

| | Pennsylvania | Greene County | Washington County |
|---|---|---|---|
| AREA IN SQUARE MILES | 45019.6 | 577.7 | 856.8 |
| POPULATION 1970 | 11,766,310 | 36,090 | 210,877 |
| POPULATION 1980 | 11,864,720 | 40,476 | 217,074 |
| POPULATION 1990 | 11,881,643 | 39,550 | 204,584 |
| DENSITY 1990 | 263.9 | 68.5 | 238.8 |
| POPULATION CHANGE 1980 TO 1990 | 16923 | -926 | -12490 |
| % CHANGE IN POPULATION, 80 to 90 | 0.14 | -2.29 | -5.75 |
| % CHANGE IN POPULATION, 70 to 90 | 0.98 | 9.59 | -2.98 |
| FEMALES AS A % OF TOTAL 1990 | 52.1 | 52.5 | 52.1 |
| FEMALES AS A % OF TOTAL 1980 | 52.1 | 51.3 | 51.7 |
| LESS THAN 18 AS A % OF TOTAL, 1990 | 23.5 | 25.6 | 22.5 |
| LESS THAN 18 AS A % OF TOTAL, 1980 | 26.3 | 29.1 | 25.8 |
| OVER 65 AS A % OF TOTAL, 1990 | 15.4 | 16.4 | 17.5 |
| OVER 65 AS A % OF TOTAL, 1980 | 12.9 | 13.8 | 13.2 |
| BLACKS AS A % OF TOTAL, 1990 | 9.2 | 0.9 | 3.1 |
| BLACKS AS A % OF TOTAL, 1980 | 8.8 | 0.8 | 3.5 |
| HISPANICS AS A % OF TOTAL, 1990 | 1.0 | 0.5 | 0.5 |
| HISPANICS AS A % OF TOTAL, 1980 | 1.3 | 0.6 | 0.6 |
| TOTAL HOUSEHOLDS, 1990 | 4495966 | 14624 | 78533 |
| TOTAL HOUSEHOLDS, 1980 | 4219606 | 14157 | 77033 |
| PERSONS PER HOUSEHOLD, 1990 | 2.57 | 2.62 | 2.54 |
| PERSONS PER HOUSEHOLD, 1980 | 2.81 | 2.86 | 2.82 |
| TOTAL FAMILIES, 1990 | 3155989 | 10691 | 57237 |
| TOTAL FAMILIES, 1980 | 3134322 | 10886 | 60098 |

# TABLE 2.1: POPULATION BY FIVE-YEAR COHORT: 1970 TO 1990

| | 1990 | | | 1980 | | | 1970 | | |
|---|---|---|---|---|---|---|---|---|---|
| hort | Pennsylvania | Greene | Washington | Pennsylvania | Greene | Washington | Pennsylvania | Greene | Washingto |
| --4 | 797058 | 2515 | 11876 | 747458 | 2977 | 13400 | 926187 | 2690 | 152 |
| --9 | 788301 | 2737 | 12811 | 805151 | 3254 | 14943 | 1082755 | 3087 | 183 |
| --14 | 755161 | 3026 | 13158 | 931891 | 3395 | 16695 | 1168554 | 3560 | 213 |
| --19 | 818058 | 3254 | 14521 | 1080610 | 3610 | 18636 | 1075430 | 3765 | 199 |
| -24 | 863007 | 2567 | 12806 | 1059815 | 3241 | 18121 | 852425 | 2452 | 143 |
| 5-29 | 920217 | 2511 | 13088 | 945051 | 3203 | 16204 | 705823 | 1733 | 111 |
| --34 | 992239 | 3049 | 16145 | 847847 | 2955 | 15251 | 609374 | 1525 | 107 |
| --39 | 923018 | 3199 | 15934 | 682283 | 2208 | 12371 | 626266 | 1631 | 110 |
| --44 | 821849 | 2829 | 14658 | 591789 | 1738 | 11133 | 741521 | 2045 | 136 |
| --49 | 656083 | 2117 | 11607 | 600257 | 1762 | 11041 | 776574 | 2298 | 148 |
| --54 | 557762 | 1669 | 10363 | 695755 | 2070 | 13321 | 738751 | 2308 | 146 |
| --59 | 552378 | 1679 | 10085 | 712074 | 2276 | 14229 | 658686 | 2200 | 128 |
| --64 | 607406 | 1897 | 11762 | 632981 | 2189 | 12987 | 559437 | 1983 | 106 |
| --69 | 590557 | 1955 | 11818 | 537045 | 1981 | 10879 | 441329 | 1564 | 74 |
| --74 | 479464 | 1719 | 9787 | 407020 | 1468 | 7450 | 348786 | 1286 | 60 |
| --79 | 361306 | 1364 | 7152 | 282000 | 1042 | 4839 | 246383 | 945 | 43 |
| --84 | 225943 | 820 | 4142 | 174908 | 620 | 3095 | 144044 | 580 | 28 |
| 35+ | 171836 | 643 | 2871 | 129960 | 487 | 2479 | 91584 | 438 | 16 |
| TAL | 11881643 | 39550 | 204584 | 11863895 | 40476 | 217074 | 11793909 | 36090 | 210 |

rce: Census of Population and Housing, 1990

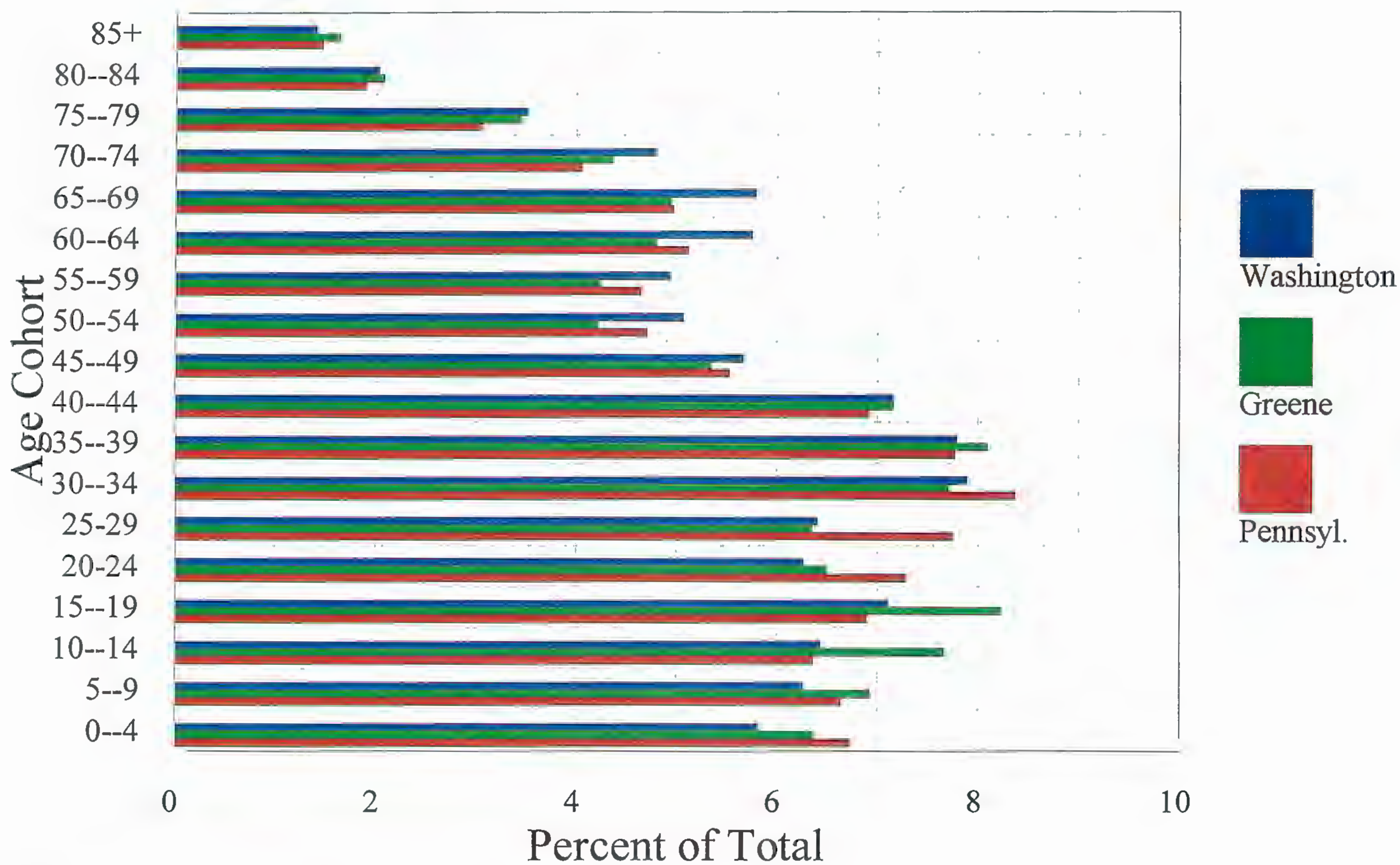
## TABLE 2.2:PERCENTAGE OF TOTAL POPULATION BY FIVE-YEAR COHORT: 1970 TO 1990

| | 1990 | | | 1980 | | | 1970 | | |
|---|---|---|---|---|---|---|---|---|---|
| ort | Pennsylvania | Greene | Washington | Pennsylvania | Greene | Washington | Pennsylvania | Greene | Washingto |
| )--4 | 6.7 | 6.4 | 5.8 | 6.3 | 7.4 | 6.2 | 7.9 | 7.5 | |
| --9 | 6.6 | 6.9 | 6.3 | 6.8 | 8.0 | 6.9 | 9.2 | 8.6 | |
| )--14 | 6.4 | 7.7 | 6.4 | 7.9 | 8.4 | 7.7 | 9.9 | 9.9 | 1 |
| --19 | 6.9 | 8.2 | 7.1 | 9.1 | 8.9 | 8.6 | 9.1 | 10.4 | |
| )-24 | 7.3 | 6.5 | 6.3 | 8.9 | 8.0 | 8.3 | 7.2 | 6.8 | |
| 5-29 | 7.7 | 6.3 | 6.4 | 8.0 | 7.9 | 7.5 | 6.0 | 4.8 | |
| )--34 | 8.4 | 7.7 | 7.9 | 7.1 | 7.3 | 7.0 | 5.2 | 4.2 | |
| --39 | 7.8 | 8.1 | 7.8 | 5.8 | 5.5 | 5.7 | 5.3 | 4.5 | |
| )--44 | 6.9 | 7.2 | 7.2 | 5.0 | 4.3 | 5.1 | 6.3 | 5.7 | |
| --49 | 5.5 | 5.4 | 5.7 | 5.1 | 4.4 | 5.1 | 6.6 | 6.4 | |
| )--54 | 4.7 | 4.2 | 5.1 | 5.9 | 5.1 | 6.1 | 6.3 | 6.4 | |
| --59 | 4.6 | 4.2 | 4.9 | 6.0 | 5.6 | 6.6 | 5.6 | 6.1 | |
| )--64 | 5.1 | 4.8 | 5.7 | 5.3 | 5.4 | 6.0 | 4.7 | 5.5 | |
| --69 | 5.0 | 4.9 | 5.8 | 4.5 | 4.9 | 5.0 | 3.7 | 4.3 | |
| )--74 | 4.0 | 4.3 | 4.8 | 3.4 | 3.6 | 3.4 | 3.0 | 3.6 | |
| --79 | 3.0 | 3.4 | 3.5 | 2.4 | 2.6 | 2.2 | 2.1 | 2.6 | |
| )--84 | 1.9 | 2.1 | 2.0 | 1.5 | 1.5 | 1.4 | 1.2 | 1.6 | |
| 35+ | 1.4 | 1.6 | 1.4 | 1.1 | 1.2 | 1.1 | 0.8 | 1.2 | |
| TAL | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 10 |

Census of Population and Housing, 1990

# AGE STRUCTURE OF THE POPULATION, 1990

## Pennsyl., Greene and Washington Co.'s




urce: Census of Population and Housing, 1990

# TABLE 2.3: CHANGE IN POPULATION BY COHORT, 1970 TO 1990

| | Change 1970-1980 | | | Change 1980-1990 | | | Change 1970-1990 | | |
|---|---|---|---|---|---|---|---|---|---|
| hort | Pennsylvania | Greene | Washington | Pennsylvania | Greene | Washington | Pennsylvania | Greene | Washingto |
| --4 | -178729 | 287 | -1899 | 49600 | -462 | -1524 | -129129 | -175 | -34 |
| --9 | -277604 | 167 | -3410 | -16850 | -517 | -2132 | -294454 | -350 | -55 |
| --14 | -236663 | -165 | -4627 | -176730 | -369 | -3537 | -413393 | -534 | -81 |
| --19 | 5180 | -155 | -1347 | -262552 | -356 | -4115 | -257372 | -511 | -54 |
| )-24 | 207390 | 789 | 3768 | -196808 | -674 | -5315 | 10582 | 115 | -15 |
| 5-29 | 239228 | 1470 | 5020 | -24834 | -692 | -3116 | 214394 | 778 | 19 |
| --34 | 238473 | 1430 | 4540 | 144392 | 94 | 894 | 382865 | 1524 | 54 |
| --39 | 56017 | 577 | 1349 | 240735 | 991 | 3563 | 296752 | 1568 | 49 |
| --44 | -149732 | -307 | -2537 | 230060 | 1091 | 3525 | 80328 | 784 | 9 |
| --49 | -176317 | -536 | -3826 | 55826 | 355 | 566 | -120491 | -181 | -32 |
| --54 | -42996 | -238 | -1346 | -137993 | -401 | -2958 | -180989 | -639 | -43 |
| --59 | 53388 | 76 | 1349 | -159696 | -597 | -4144 | -106308 | -521 | -27 |
| --64 | 73544 | 206 | 2978 | -25575 | -292 | -1225 | 47969 | -86 | 17 |
| --69 | 95716 | 417 | 3397 | 53512 | -26 | 939 | 149228 | 391 | 43 |
| --74 | 58234 | 182 | 1398 | 72444 | 251 | 2337 | 130678 | 433 | 37 |
| --79 | 35617 | 97 | 324 | 79306 | 322 | 2313 | 114923 | 419 | 26 |
| --84 | 30864 | 40 | 249 | 51035 | 200 | 1047 | 81899 | 240 | 12 |
| 5+ | 38376 | 49 | 818 | 41876 | 156 | 392 | 80252 | 205 | 12 |
| TAL | 69986 | 4386 | 6198 | 17748 | -926 | -12490 | 87734 | 3460 | -62 |

ce: Census of Population and Housing, 1990

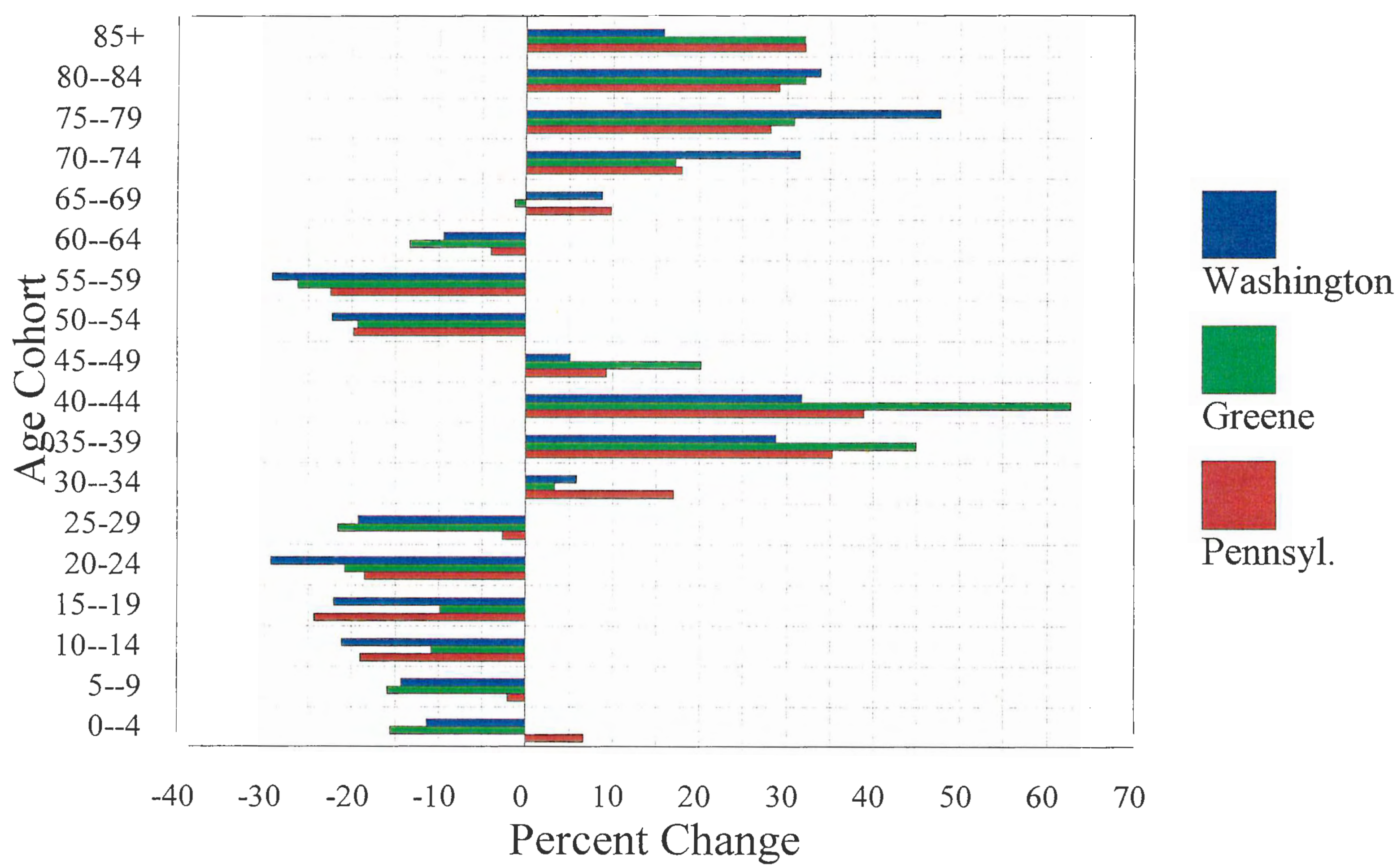
**TABLE 2.4: PERCENTAGE CHANGE IN POPULATION BY COHORT, 1970 TO 1990**

| | % Change 1970-1980 | | | % Change 1980-1990 | | | % Change 1970-1990 | | |
|---|---|---|---|---|---|---|---|---|---|
| hort | Pennsylvania | Greene | Washington | Pennsylvania | Greene | Washington | Pennsylvania | Greene | Washingto |
| --4 | -19.3 | 10.7 | -12.4 | 6.6 | -15.5 | -11.4 | -13.9 | -6.5 | -2 |
| --9 | -25.6 | 5.4 | -18.6 | -2.1 | -15.9 | -14.3 | -27.2 | -11.3 | -3 |
| --14 | -20.3 | -4.6 | -21.7 | -19.0 | -10.9 | -21.2 | -35.4 | -15.0 | -3 |
| --19 | 0.5 | -4.1 | -6.7 | -24.3 | -9.9 | -22.1 | -23.9 | -13.6 | -2 |
| )-24 | 24.3 | 32.2 | 26.3 | -18.6 | -20.8 | -29.3 | 1.2 | 4.7 | -1 |
| 5-29 | 33.9 | 84.8 | 44.9 | -2.6 | -21.6 | -19.2 | 30.4 | 44.9 | 1 |
| --34 | 39.1 | 93.8 | 42.4 | 17.0 | 3.2 | 5.9 | 62.8 | 99.9 | 5 |
| --39 | 8.9 | 35.4 | 12.2 | 35.3 | 44.9 | 28.8 | 47.4 | 96.1 | 4 |
| )--44 | -20.2 | -15.0 | -18.6 | 38.9 | 62.8 | 31.7 | 10.8 | 38.3 | |
| --49 | -22.7 | -23.3 | -25.7 | 9.3 | 20.1 | 5.1 | -15.5 | -7.9 | -2 |
| )--54 | -5.8 | -10.3 | -9.2 | -19.8 | -19.4 | -22.2 | -24.5 | -27.7 | -2 |
| --59 | 8.1 | 3.5 | 10.5 | -22.4 | -26.2 | -29.1 | -16.1 | -23.7 | -2 |
| )--64 | 13.1 | 10.4 | 29.8 | -4.0 | -13.3 | -9.4 | 8.6 | -4.3 | 1 |
| --69 | 21.7 | 26.7 | 45.4 | 10.0 | -1.3 | 8.6 | 33.8 | 25.0 | 5 |
| )--74 | 16.7 | 14.2 | 23.1 | 17.8 | 17.1 | 31.4 | 37.5 | 33.7 | 6 |
| --79 | 14.5 | 10.3 | 7.2 | 28.1 | 30.9 | 47.8 | 46.6 | 44.3 | 5 |
| )--84 | 21.4 | 6.9 | 8.7 | 29.2 | 32.3 | 33.8 | 56.9 | 41.4 | 4 |
| 35+ | 41.9 | 11.2 | 49.2 | 32.2 | 32.0 | 15.8 | 87.6 | 46.8 | 7 |
| TAL | 0.6 | 12.2 | 2.9 | 0.1 | -2.3 | -5.8 | 0.7 | 9.6 | - |

'Census of Population and Housing, 1990

# CHANGE IN AGE STRUCTURE, 1980 -- 1990

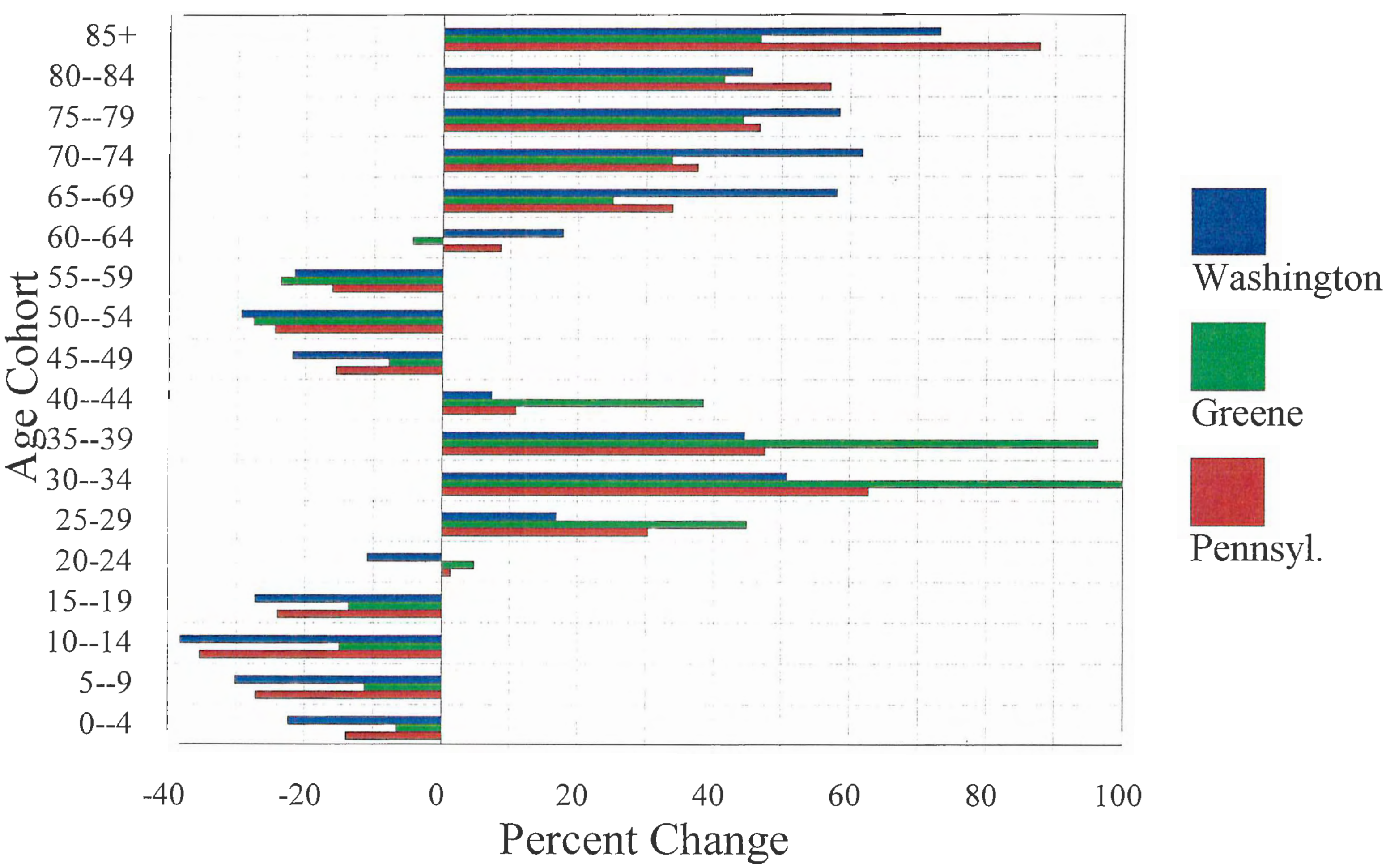
## Pennsyl., Greene and Washington Co.'s




urce: Census of Population and Housing, 1990

# CHANGE IN AGE STRUCTURE, 1970 -- 1990

## Pennsyl., Greene and Washington Co.'s



## TABLE 3: ANCESTRY AND MOBILITY

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| ANCESTRY (MOST RESPONSES) | | | | | | |
| Universe: Persons | | | | | | |
| English (015, 022) | 749786 | 3816 | 18493 | 6.3 | 9.6 | 9.0 |
| German (032-045) | 3485436 | 9955 | 45629 | 29.3 | 25.2 | 22.3 |
| Irish (050, 081, 099) | 1270330 | 4833 | 18989 | 10.7 | 12.2 | 9.3 |
| Italian (030-031, 051-074) | 1047893 | 1956 | 25539 | 8.8 | 4.9 | 12.5 |
| Polish (142-143) | 632518 | 1986 | 14730 | 5.3 | 5.0 | 7.2 |
| Scotch-Irish (087) | 195220 | 1813 | 10306 | 1.6 | 4.6 | 5.0 |
| Slovak (153) | 295843 | 1622 | 12057 | 2.5 | 4.1 | 5.9 |
| United States or American (939-994) | 309814 | 2820 | 5164 | 2.6 | 7.1 | 2.5 |
| Race or Hispanic origin groups (200-299, 900-92ℓ | 1161853 | 1493 | 8467 | 9.8 | 3.8 | 4.1 |
| Unclassified or not reported (863-899, 995-997, 9 | 911105 | 4089 | 12699 | 7.7 | 10.3 | 6.2 |
| TOTAL PERSONS | 11881643 | 39550 | 204584 | 100.0 | 100.0 | 100.0 |
| | | | | | | |
| PLACE OF BIRTH | | | | | | |
| Universe: Persons | | | | | | |
| Born in State of residence | 9527402 | 29902 | 176133 | 80.2 | 75.6 | 86.1 |
| Born in other State in the United States (001-059): | | | | | | |
| Northeast (009, 023, 025, 033-034, 036, 042-04 | 742755 | 640 | 3584 | 6.3 | 1.6 | 1.8 |
| Midwest (017-020, 026-027, 029, 031, 038-039. | 348917 | 1774 | 7818 | 2.9 | 4.5 | 3.8 |
| South (001, 005, 010-014, 021-022, 024, 028, 0 | 666122 | 6429 | 11809 | 5.6 | 16.3 | 5.8 |
| West (002-004, 006-008, 015-016, 030, 032, 03 | 104730 | 353 | 1636 | 0.9 | 0.9 | 0.8 |
| Born outside the United States (060-099): | | | | | | |
| Puerto Rico (072-075) | 67413 | 23 | 24 | 0.6 | 0.1 | 0.0 |
| U.S. outlying area (060-071, 076-099) | 4463 | 14 | 16 | 0.0 | 0.0 | 0.0 |
| Born abroad of American parent(s) | 50525 | 81 | 525 | 0.4 | 0.2 | 0.3 |
| Foreign born (100-999) | 369316 | 334 | 3039 | 3.1 | 0.8 | 1.5 |
| TOTAL PERSONS | 11881643 | 39550 | 204584 | 100.0 | 100.0 | 100.0 |
| | | | | | | |
| RESIDENCE IN 1985—STATE AND COUNTY LEVEL | | | | | | |
| Universe: Persons 5 years and over | | | | | | |
| Same house in 1985 | 7026054 | 24436 | 133407 | 63.4 | 66.0 | 69.2 |
| Different house in United States in 1985: | | | | | | |
| Same county | 2451510 | 7906 | 36437 | 22.1 | 21.3 | 18.9 |
| Same State | 815011 | 2552 | 14592 | 7.4 | 6.9 | 7.6 |
| Northeast | 284847 | 240 | 1181 | 2.6 | 0.6 | 0.6 |
| Midwest | 103682 | 449 | 1736 | 0.9 | 1.2 | 0.9 |
| South | 233010 | 1160 | 3544 | 2.1 | 3.1 | 1.8 |
| West | 72481 | 235 | 1304 | 0.7 | 0.6 | 0.7 |
| Abroad in 1985: | | | | | | |
| Puerto Rico | 13960 | 0 | 13 | 0.1 | 0.0 | 0.0 |
| U.S. outlying area | 2118 | 0 | 18 | 0.0 | 0.0 | 0.0 |
| Foreign country | 82497 | 62 | 470 | 0.7 | 0.2 | 0.2 |
| PERSONS OVER FIVE YEARS OLD | 11085170 | 37040 | 192702 | 100.0 | 100.0 | 100.0 |

SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

## TABLE 4: PLACE OF WORK AND TRAVEL TO WORK

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| PLACE OF WORK—STATE AND COUNTY LEVEL | | | | | | |
| Universe: Workers 16 years and over | | | | | | |
| Worked in county of residence | 4006525 | 8553 | 52002 | 74.9 | 64.4 | 63.5 |
| Worked outside county of residence | 1110200 | 2849 | 27329 | 20.8 | 21.5 | 33.4 |
| Worked outside State of residence | 231407 | 1875 | 2531 | 4.3 | 14.1 | 3.1 |
| TOTAL WORKERS | 5348132 | 13277 | 81862 | 100.0 | 100.0 | 100.0 |
| PLACE OF WORK—MINOR CIVIL DIVISION LEVEL | | | | | | |
| Universe: Workers 16 years and over | | | | | | |
| Worked in the minor civil division of residence | 1609919 | 2680 | 13735 | 30.1 | 20.2 | 16.8 |
| Worked outside minor civil division of residence | 3738213 | 10597 | 68127 | 69.9 | 79.8 | 83.2 |
| MEANS OF TRANSPORTATION TO WORK | | | | | | |
| Universe: Workers 16 years and over | | | | | | |
| Drove alone | 3818385 | 10157 | 64127 | 71.4 | 76.5 | 78.3 |
| Carpooled | 689656 | 1778 | 10152 | 12.9 | 13.4 | 12.4 |
| Bus or trolley bus | 229544 | 30 | 852 | 4.3 | 0.2 | 1.0 |
| Streetcar or trolley car | 14016 | 0 | 315 | 0.3 | 0.0 | 0.4 |
| Subway or elevated | 54832 | 1 | 93 | 1.0 | 0.0 | 0.1 |
| Railroad | 41128 | 0 | 7 | 0.8 | 0.0 | 0.0 |
| Ferryboat | 125 | 3 | 0 | 0.0 | 0.0 | 0.0 |
| Taxicab | 4079 | 5 | 88 | 0.1 | 0.0 | 0.1 |
| Motorcycle | 5000 | 16 | 60 | 0.1 | 0.1 | 0.1 |
| Bicycle | 12556 | 7 | 88 | 0.2 | 0.1 | 0.1 |
| Walked | 304589 | 764 | 3754 | 5.7 | 5.8 | 4.6 |
| Other means | 29671 | 108 | 433 | 0.6 | 0.8 | 0.5 |
| Worked at home | 144551 | 408 | 1893 | 2.7 | 3.1 | 2.3 |
| TRAVEL TIME TO WORK | | | | | | |
| Universe: Workers 16 years and over | | | | | | |
| Less than 5 minutes | 209293 | 808 | 3549 | 3.9 | 6.1 | 4.3 |
| 5 to 9 minutes | 663562 | 1761 | 10708 | 12.4 | 13.3 | 13.1 |
| 10 to 14 minutes | 873894 | 1810 | 13711 | 16.3 | 13.6 | 16.7 |
| 15 to 19 minutes | 874134 | 1805 | 12201 | 16.3 | 13.6 | 14.9 |
| 20 to 24 minutes | 762843 | 1519 | 10485 | 14.3 | 11.4 | 12.8 |
| 25 to 29 minutes | 306291 | 807 | 4784 | 5.7 | 6.1 | 5.8 |
| 30 to 34 minutes | 620439 | 1563 | 8986 | 11.6 | 11.8 | 11.0 |
| 35 to 39 minutes | 131044 | 400 | 2407 | 2.5 | 3.0 | 2.9 |
| 40 to 44 minutes | 158154 | 481 | 2517 | 3.0 | 3.6 | 3.1 |
| 45 to 59 minutes | 350019 | 1133 | 6060 | 6.5 | 8.5 | 7.4 |
| 60 to 89 minutes | 212848 | 587 | 3856 | 4.0 | 4.4 | 4.7 |
| 90 or more minutes | 41060 | 195 | 705 | 0.8 | 1.5 | 0.9 |
| Worked at home | 144551 | 408 | 1893 | 2.7 | 3.1 | 2.3 |
| TIME LEAVING HOME TO GO TO WORK | | | | | | |
| Universe: Workers 16 years and over | | | | | | |
| 12:00 a.m. to 4:59 a.m. | 113266 | 350 | 1684 | 2.1 | 2.6 | 2.1 |
| 5:00 a.m. to 5:29 a.m. | 106697 | 325 | 1570 | 2.0 | 2.4 | 1.9 |
| 5:30 a.m. to 5:59 a.m. | 191096 | 411 | 3163 | 3.6 | 3.1 | 3.9 |
| 6:00 a.m. to 6:29 a.m. | 455724 | 1260 | 7334 | 8.5 | 9.5 | 9.0 |
| 6:30 a.m. to 6:59 a.m. | 634759 | 1455 | 9438 | 11.9 | 11.0 | 11.5 |
| 7:00 a.m. to 7:29 a.m. | 782625 | 1820 | 12189 | 14.6 | 13.7 | 14.9 |
| 7:30 a.m. to 7:59 a.m. | 788256 | 1870 | 11601 | 14.7 | 14.1 | 14.2 |
| 8:00 a.m. to 8:29 a.m. | 609274 | 1335 | 8289 | 11.4 | 10.1 | 10.1 |
| 8:30 a.m. to 8:59 a.m. | 308621 | 544 | 4653 | 5.8 | 4.1 | 5.7 |
| 9:00 a.m. to 9:59 a.m. | 270164 | 632 | 4081 | 5.1 | 4.8 | 5.0 |
| 10:00 a.m. to 10:59 a.m. | 101122 | 265 | 1674 | 1.9 | 2.0 | 2.0 |
| 11:00 a.m. to 11:59 a.m. | 53950 | 131 | 974 | 1.0 | 1.0 | 1.2 |
| 12:00 p.m. to 3:59 p.m. | 393286 | 1181 | 6590 | 7.4 | 8.9 | 8.1 |
| 4:00 p.m. to 11:59 p.m. | 394741 | 1290 | 6729 | 7.4 | 9.7 | 8.2 |
| Worked at home | 144551 | 408 | 1893 | 2.7 | 3.1 | 2.3 |

SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

## TABLE 5: EDUCATION AND EMPLOYMENT

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| EDUCATIONAL ATTAINMENT | | | | | | |
| Universe: Persons 25 years and over | | | | | | |
| Less than 9th grade | 741167 | 3984 | 15647 | 9.4 | 15.6 | 11.2 |
| 9th to 12th grade, no diploma | 1253111 | 4167 | 21765 | 15.9 | 16.4 | 15.6 |
| High school graduate (includes equivalency) | 3035080 | 11061 | 59055 | 38.6 | 43.4 | 42.3 |
| Some college, no degree | 1017897 | 2482 | 16919 | 12.9 | 9.7 | 12.1 |
| Associate degree | 412931 | 893 | 7288 | 5.2 | 3.5 | 5.2 |
| Bachelor's degree | 890660 | 1827 | 12431 | 11.3 | 7.2 | 8.9 |
| Graduate or professional degree | 522086 | 1059 | 6610 | 6.6 | 4.2 | 4.7 |
| PERSONS OVER 25 | 7872932 | 25473 | 139715 | 100.0 | 100.0 | 100.0 |
| SEX BY EMPLOYMENT STATUS | | | | | | |
| Universe: Persons 16 years and over | | | | | | |
| Male: | | | | | | |
| In Armed Forces | 16659 | 16 | 154 | 0.4 | 0.1 | 0.2 |
| Employed | 2952871 | 8013 | 46938 | 66.9 | 55.8 | 61.0 |
| Unemployed | 198697 | 1261 | 4213 | 6.3 | 13.6 | 8.2 |
| Not in labor force | 1248442 | 5058 | 25696 | 28.3 | 35.3 | 33.4 |
| MALES 16 AND OLDER | 4416669 | 14348 | 77001 | 100.0 | 100.0 | 100.0 |
| Female: | | | | | | |
| In Armed Forces | 1951 | 0 | 16 | 0.0 | 0.0 | 0.0 |
| Employed | 2481661 | 5493 | 36737 | 49.9 | 33.6 | 42.1 |
| Unemployed | 146098 | 617 | 2636 | 5.6 | 10.1 | 6.7 |
| Not in labor force | 2346437 | 10256 | 47855 | 47.2 | 62.7 | 54.9 |
| FEMALES 16 AND OLDER | 4976147 | 16366 | 87244 | 100.0 | 100.0 | 100.0 |
| PERSONS 16 AND OLDER | 5797937 | 15400 | 90694 | 5.9 | 12.2 | 7.6 |
| SEX BY WORK STATUS IN 1989 | | | | | | |
| Universe: Persons 16 years and over | | | | | | |
| Male: | | | | | | |
| Worked in 1989 | 3376682 | 9617 | 54696 | 76.5 | 67.0 | 71.0 |
| Did not work in 1989 | 1039987 | 4731 | 22305 | | | |
| Female: | | | | | | |
| Worked in 1989 | 2878602 | 6965 | 43555 | 57.8 | 42.6 | 49.9 |
| Did not work in 1989 | 2097545 | 9401 | 43689 | | | |

SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

## TABLE 5a: LABOR FORCE AND EMPLOYMENT

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| SEX BY EMPLOYMENT STATUS | | | | | | |
| Universe: Persons 16 years and over | | | | | | |
| Male: | | | | | | |
| In Armed Forces | 16659 | 16 | 154 | 0.4 | 0.1 | 0.2 |
| Employed | 2952871 | 8013 | 46938 | 66.9 | 55.8 | 61.0 |
| Unemployed | 198697 | 1261 | 4213 | 6.3 | 13.6 | 8.2 |
| Not in labor force | 1248442 | 5058 | 25696 | 28.3 | 35.3 | 33.4 |
| MALES 16 AND OLDER | 4416669 | 14348 | 77001 | 100.0 | 100.0 | 100.0 |
| Female: | | | | | | |
| In Armed Forces | 1951 | 0 | 16 | 0.0 | 0.0 | 0.0 |
| Employed | 2481661 | 5493 | 36737 | 49.9 | 33.6 | 42.1 |
| Unemployed | 146098 | 617 | 2636 | 5.6 | 10.1 | 6.7 |
| Not in labor force | 2346437 | 10256 | 47855 | 47.2 | 62.7 | 54.9 |
| FEMALES 16 AND OLDER | 4976147 | 16366 | 87244 | 100.0 | 100.0 | 100.0 |
| PERSONS 16 AND OLDER | 9392816 | 30714 | 164245 | 3.7 | 6.1 | 4.2 |
| | | | | | | |
| SEX BY WORK STATUS IN 1989 | | | | | | |
| Universe: Persons 16 years and over | | | | | | |
| Male: | | | | | | |
| Worked in 1989 | 3376682 | 9617 | 54696 | 76.5 | 67.0 | 71.0 |
| Did not work in 1989 | 1039987 | 4731 | 22305 | | | |
| Female: | | | | | | |
| Worked in 1989 | 2878602 | 6965 | 43555 | 57.8 | 42.6 | 49.9 |
| Did not work in 1989 | 2097545 | 9401 | 43689 | | | |

SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

## TABLE 6: DISABILITY AND EMPLOYMENT

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| SEX BY AGE BY WORK DISABILITY STATUS AND EMPLOYMENT STATUS | | | | | | |
| Universe: Civilian noninstitutionalized persons 16 years and over | | | | | | |
| Male:16 to 64 | | | | | | |
| With a work disability:but in LF | | | | | | |
| Employed | 119302 | 358 | 1869 | 3.3 | 3.1 | 3.0 |
| Unemployed | 18713 | 144 | 315 | 0.5 | 1.2 | 0.5 |
| Not in labor force: | | | | 0.0 | 0.0 | 0.0 |
| Prevented from working | 157563 | 906 | 3673 | 4.3 | 7.8 | 5.9 |
| Not prevented from working | 22804 | 97 | 412 | 0.6 | 0.8 | 0.7 |
| No work disability:and in LF | | | | 0.0 | 0.0 | 0.0 |
| Employed | 2724702 | 7383 | 43549 | 75.2 | 63.5 | 70.3 |
| Unemployed | 175617 | 1114 | 3831 | 4.8 | 9.6 | 6.2 |
| Not in labor force | 406352 | 1620 | 8310 | 11.2 | 13.9 | 13.4 |
| MALES 16 TO 64 | 3625053 | 11622 | 61959 | 100.0 | 100.0 | 100.0 |
| 65 years and over: | | | | | | |
| With a work disability:and in LF | | | | | | |
| Employed | 14121 | 56 | 179 | 2.0 | 2.2 | 1.3 |
| Unemployed | 1165 | 0 | 6 | 0.2 | 0.0 | 0.0 |
| Not in labor force: | | | | 0.0 | 0.0 | 0.0 |
| Prevented from working | 167426 | 951 | 3556 | 24.2 | 37.2 | 25.4 |
| Not prevented from working | 34824 | 125 | 635 | 5.0 | 4.9 | 4.5 |
| No work disability:and in LF | | | | 0.0 | 0.0 | 0.0 |
| Employed | 94746 | 216 | 1341 | 13.7 | 8.4 | 9.6 |
| Unemployed | 3202 | 3 | 61 | 0.5 | 0.1 | 0.4 |
| Not in labor force | 377047 | 1208 | 8203 | 54.4 | 47.2 | 58.7 |
| MALES 65 AND OLDER | 692531 | 2559 | 13981 | 100.0 | 100.0 | 100.0 |
| Female:16 to 64 | | | | | | |
| With a work disability:but in LF | | | | | | |
| Employed | 75939 | 149 | 968 | 2.0 | 1.2 | 1.5 |
| Unemployed | 11531 | 26 | 233 | 0.3 | 0.2 | 0.4 |
| Not in labor force: | | | | 0.0 | 0.0 | 0.0 |
| Prevented from working | 174353 | 837 | 3626 | 4.5 | 6.9 | 5.5 |
| Not prevented from working | 36960 | 196 | 839 | 1.0 | 1.6 | 1.3 |
| No work disability:and in LF | | | | 0.0 | 0.0 | 0.0 |
| Employed | 2328749 | 5174 | 34685 | 60.5 | 42.5 | 53.0 |
| Unemployed | 130186 | 584 | 2363 | 3.4 | 4.8 | 3.6 |
| Not in labor force | 1091636 | 5210 | 22767 | 28.4 | 42.8 | 34.8 |
| FEMALES 16 TO 64 | 3849354 | 12176 | 65481 | 100.0 | 100.0 | 100.0 |
| 65 years and over: | | | | | | |
| With a work disability:but in LF | | | | | | |
| Employed | 6763 | 5 | 50 | 0.7 | 0.1 | 0.2 |
| Unemployed | 992 | 0 | 6 | 0.1 | 0.0 | 0.0 |
| Not in labor force: | | | | 0.0 | 0.0 | 0.0 |
| Prevented from working | 274923 | 1188 | 5330 | 26.5 | 33.0 | 26.4 |
| Not prevented from working | 34023 | 109 | 682 | 3.3 | 3.0 | 3.4 |
| No work disability:and in LF | | | | 0.0 | 0.0 | 0.0 |
| Employed | 70210 | 165 | 1034 | 6.8 | 4.6 | 5.1 |
| Unemployed | 3389 | 7 | 34 | 0.3 | 0.2 | 0.2 |
| Not in labor force | 646309 | 2123 | 13051 | 62.3 | 59.0 | 64.7 |
| FEMALES 65 AND OLDER | 1036609 | 3597 | 20187 | 100.0 | 100.0 | 100.0 |

SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

# TABLE 7: MOBILITY AND SELF-CARE LIMITATIONS

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| SEX BY AGE BY MOBILITY AND SELF-CARE LIMITATION STATUS | | | | | | |
| Universe: Civilian noninstitutionalized persons 16 years and over | | | | | | |
| Male:16 to 64 | | | | | | |
| With a mobility or self-care limitation: | | | | | | |
| Mobility limitation only | 37327 | 227 | 857 | 1.0 | 2.0 | 1.4 |
| Self-care limitation only | 79301 | 256 | 1310 | 2.2 | 2.2 | 2.1 |
| Mobility and self-care limitation | 35080 | 192 | 661 | 1.0 | 1.7 | 1.1 |
| No mobility or self-care limitation | 3473345 | 10947 | 59131 | 95.8 | 94.2 | 95.4 |
| MALES 16 TO 64 | 3625053 | 11622 | 61959 | 100.0 | 100.0 | 100.0 |
| 65 to 74 years: | | | | | | |
| With a mobility or self-care limitation: | | | | | | |
| Mobility limitation only | 16013 | 97 | 324 | 3.5 | 2.8 | 3.4 |
| Self-care limitation only | 21658 | 29 | 558 | 4.7 | 2.7 | 5.3 |
| Mobility and self-care limitation | 16830 | 86 | 301 | 3.7 | 4.5 | 3.7 |
| No mobility or self-care limitation | 402087 | 1372 | 8151 | 88.1 | 89.9 | 87.5 |
| MALES 65 TO 74 | 456588 | 1584 | 9334 | 100.0 | 100.0 | 100.0 |
| 75 years and over: | | | | | | |
| With a mobility or self-care limitation: | | | | | | |
| Mobility limitation only | 19964 | 120 | 457 | 8.5 | 9.1 | 8.8 |
| Self-care limitation only | 14003 | 58 | 407 | 5.9 | 4.6 | 6.9 |
| Mobility and self-care limitation | 22559 | 123 | 456 | 9.6 | 8.8 | 9.7 |
| No mobility or self-care limitation | 179417 | 674 | 3327 | 76.0 | 77.5 | 74.6 |
| MALES 75 AND OLDER | 235943 | 975 | 4647 | 100.0 | 100.0 | 100.0 |
| Female:16 to 64 | | | | | | |
| With a mobility or self-care limitation: | | | | | | |
| Mobility limitation only | 52034 | 178 | 1002 | 1.4 | 0.9 | 1.5 |
| Self-care limitation only | 82482 | 277 | 1527 | 2.1 | 1.5 | 2.2 |
| Mobility and self-care limitation | 39279 | 200 | 733 | 1.0 | 0.5 | 1.0 |
| No mobility or self-care limitation | 3675559 | 11521 | 62219 | 95.5 | 97.1 | 95.4 |
| FEMALES 16 TO 64 | 3849354 | 12176 | 65481 | 100.0 | 100.0 | 100.0 |
| 65 to 74 years: | | | | | | |
| With a mobility or self-care limitation: | | | | | | |
| Mobility limitation only | 36112 | 209 | 695 | 6.0 | 4.5 | 6.7 |
| Self-care limitation only | 28268 | 114 | 748 | 4.7 | 2.1 | 4.9 |
| Mobility and self-care limitation | 24926 | 126 | 453 | 4.1 | 2.5 | 4.4 |
| No mobility or self-care limitation | 513227 | 1606 | 10124 | 85.2 | 90.9 | 83.9 |
| FEMALES 65 TO 74 | 602533 | 2055 | 12020 | 100.0 | 100.0 | 100.0 |
| 75 years and over: | | | | | | |
| With a mobility or self-care limitation: | | | | | | |
| Mobility limitation only | 71378 | 258 | 1326 | 16.4 | 16.1 | 17.5 |
| Self-care limitation only | 20947 | 76 | 505 | 4.8 | 3.5 | 5.4 |
| Mobility and self-care limitation | 56391 | 209 | 1102 | 13.0 | 10.7 | 13.5 |
| No mobility or self-care limitation | 285360 | 999 | 5234 | 65.7 | 69.7 | 63.6 |
| FEMALES 75 AND OLDER | 434076 | 1542 | 8167 | 100.0 | 100.0 | 100.0 |

SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

## TABLE 8: INDUSTRY, OCCUPATION, AND TYPE OF EMPLOYMENT

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| INDUSTRY | | | | | | |
| Universe: Employed persons 16 years and over | | | | | | |
| Agriculture, forestry, and fisheries (000-039) | 97811 | 327 | 1488 | 1.8 | 2.4 | 1.8 |
| Mining (040-059) | 31396 | 1480 | 1873 | 0.6 | 11.0 | 2.2 |
| Construction (060-099) | 331161 | 1084 | 6190 | 6.1 | 8.0 | 7.4 |
| Manufacturing, nondurable goods (100-229) | 445349 | 377 | 4040 | 8.2 | 2.8 | 4.8 |
| Manufacturing, durable goods (230-399) | 641871 | 776 | 11181 | 11.8 | 5.7 | 13.4 |
| Transportation (400-439) | 241749 | 681 | 4214 | 4.4 | 5.0 | 5.0 |
| Communications and other public utilities (440-49 | 134992 | 622 | 2107 | 2.5 | 4.6 | 2.5 |
| Wholesale trade (500-579) | 234880 | 463 | 3831 | 4.3 | 3.4 | 4.6 |
| Retail trade (580-699) | 931987 | 2185 | 16440 | 17.1 | 16.2 | 19.6 |
| Finance, insurance, and real estate (700-720) | 351519 | 448 | 3952 | 6.5 | 3.3 | 4.7 |
| Business and repair services (721-760) | 236825 | 383 | 2940 | 4.4 | 2.8 | 3.5 |
| Personal services (761-799) | 138027 | 281 | 2108 | 2.5 | 2.1 | 2.5 |
| Entertainment and recreation services (800-811) | 56928 | 109 | 1059 | 1.0 | 0.8 | 1.3 |
| Health services (812-840) | 539555 | 1522 | 9018 | 9.9 | 11.3 | 10.8 |
| Educational services (842-860) | 448888 | 1465 | 6698 | 8.3 | 10.8 | 8.0 |
| Other professional and related services (841, 861- | 352988 | 605 | 4242 | 6.5 | 4.5 | 5.1 |
| Public administration (900-939) | 218606 | 698 | 2294 | 4.0 | 5.2 | 2.7 |
| | 5434532 | 13506 | 83675 | 100.0 | 100.0 | 100.0 |
| OCCUPATION | | | | | | |
| Universe: Employed persons 16 years and over | | | | | | |
| Executive, administrative, and managerial occupat | 610637 | 1107 | 8181 | 11.2 | 8.2 | 9.8 |
| Professional specialty occupations (043-202) | 756447 | 1618 | 10328 | 13.9 | 12.0 | 12.3 |
| Technicians and related support occupations (203- | 205051 | 485 | 2928 | 3.8 | 3.6 | 3.5 |
| Sales occupations (243-302) | 605915 | 1119 | 10180 | 11.1 | 8.3 | 12.2 |
| Administrative support occupations, including cler | 912845 | 1585 | 12415 | 16.8 | 11.7 | 14.8 |
| Private household occupations (403-412) | 15050 | 69 | 194 | 0.3 | 0.5 | 0.2 |
| Protective service occupations (413-432) | 85556 | 286 | 951 | 1.6 | 2.1 | 1.1 |
| Service occupations, except protective and househ | 607914 | 1716 | 11116 | 11.2 | 12.7 | 13.3 |
| Farming, forestry, and fishing occupations (473-50 | 90255 | 329 | 1424 | 1.7 | 2.4 | 1.7 |
| Precision production, craft, and repair occupations ( | 628076 | 2445 | 11644 | 11.6 | 18.1 | 13.9 |
| Machine operators, assemblers, and inspectors (70 | 419553 | 801 | 5161 | 7.7 | 5.9 | 6.2 |
| Transportation and material moving occupations ( | 237902 | 989 | 4318 | 4.4 | 7.3 | 5.2 |
| Handlers, equipment cleaners, helpers, and labore | 259331 | 957 | 4835 | 4.8 | 7.1 | 5.8 |
| CLASS OF WORKER | | | | | | |
| Universe: Employed persons 16 years and over | | | | | | |
| Private for profit wage and salary workers | 3916675 | 9135 | 61991 | 72.1 | 67.6 | 74.1 |
| Private not-for-profit wage and salary workers | 520922 | 1121 | 6883 | 9.6 | 8.3 | 8.2 |
| Local government workers | 314364 | 1079 | 4204 | 5.8 | 8.0 | 5.0 |
| State government workers | 166843 | 819 | 3654 | 3.1 | 6.1 | 4.4 |
| Federal government workers | 153652 | 332 | 1439 | 2.8 | 2.5 | 1.7 |
| Self-employed workers | 337297 | 933 | 5071 | 6.2 | 6.9 | 6.1 |
| Unpaid family workers | 24779 | 87 | 433 | 0.5 | 0.6 | 0.5 |

SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

## TABLE 9: HOUSEHOLD AND FAMILY INCOME, 1989

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| HOUSEHOLD INCOME IN 1989 | | | | | | |
| Universe: Households | | | | | | |
| Less than $5,000 | 244825 | 1369 | 5104 | 5.4 | 9.4 | 6.5 |
| $5,000 to $9,999 | 452700 | 2126 | 9390 | 10.1 | 14.6 | 11.9 |
| $10,000 to $12,499 | 221502 | 1023 | 4466 | 4.9 | 7.0 | 5.7 |
| $12,500 to $14,999 | 193801 | 932 | 4310 | 4.3 | 6.4 | 5.5 |
| $15,000 to $17,499 | 215433 | 988 | 4359 | 4.8 | 6.8 | 5.5 |
| $17,500 to $19,999 | 196882 | 889 | 3627 | 4.4 | 6.1 | 4.6 |
| $20,000 to $22,499 | 220556 | 683 | 4153 | 4.9 | 4.7 | 5.3 |
| $22,500 to $24,999 | 186047 | 517 | 3266 | 4.1 | 3.5 | 4.1 |
| $25,000 to $27,499 | 206417 | 743 | 3613 | 4.6 | 5.1 | 4.6 |
| $27,500 to $29,999 | 172621 | 500 | 2988 | 3.8 | 3.4 | 3.8 |
| $30,000 to $32,499 | 207578 | 628 | 3562 | 4.6 | 4.3 | 4.5 |
| $32,500 to $34,999 | 158078 | 428 | 2817 | 3.5 | 2.9 | 3.6 |
| $35,000 to $37,499 | 176887 | 460 | 2955 | 3.9 | 3.2 | 3.8 |
| $37,500 to $39,999 | 140281 | 370 | 2287 | 3.1 | 2.5 | 2.9 |
| $40,000 to $42,499 | 162316 | 440 | 2537 | 3.6 | 3.0 | 3.2 |
| $42,500 to $44,999 | 120365 | 294 | 1942 | 2.7 | 2.0 | 2.5 |
| $45,000 to $47,499 | 126527 | 305 | 2001 | 2.8 | 2.1 | 2.5 |
| $47,500 to $49,999 | 101820 | 255 | 1532 | 2.3 | 1.7 | 1.9 |
| $50,000 to $54,999 | 192430 | 481 | 2819 | 4.3 | 3.3 | 3.6 |
| $55,000 to $59,999 | 148154 | 343 | 2073 | 3.3 | 2.4 | 2.6 |
| $60,000 to $74,999 | 292049 | 441 | 4262 | 6.5 | 3.0 | 5.4 |
| $75,000 to $99,999 | 193936 | 211 | 2725 | 4.3 | 1.4 | 3.5 |
| $100,000 to $124,999 | 71686 | 79 | 858 | 1.6 | 0.5 | 1.1 |
| $125,000 to $149,999 | 29870 | 35 | 273 | 0.7 | 0.2 | 0.3 |
| $150,000 or more | 60197 | 45 | 786 | 1.3 | 0.3 | 1.0 |
| | 4492958 | 14585 | 78705 | 100.0 | 100.0 | 100.0 |
| MEDIAN HOUSEHOLD INCOME IN 1989 | | | | | | |
| Universe: Households | | | | | | |
| Median household income in 1989 | 29069 | 19903 | 25469 | 100.0 | 68.5 | 87.6 |
| MEDIAN FAMILY INCOME IN 1989 | | | | | | |
| Universe: Families | | | | | | |
| Median family income in 1989 | 34856 | 25284 | 31239 | 100.0 | 72.5 | 89.6 |
| MEDIAN NONFAMILY HOUSEHOLD INCOME IN 1989 | | | | | | |
| Universe: Nonfamily households | | | | | | |
| Median nonfamily household income in 1989 | 15099 | 10503 | 11589 | 100.0 | 69.6 | 76.8 |

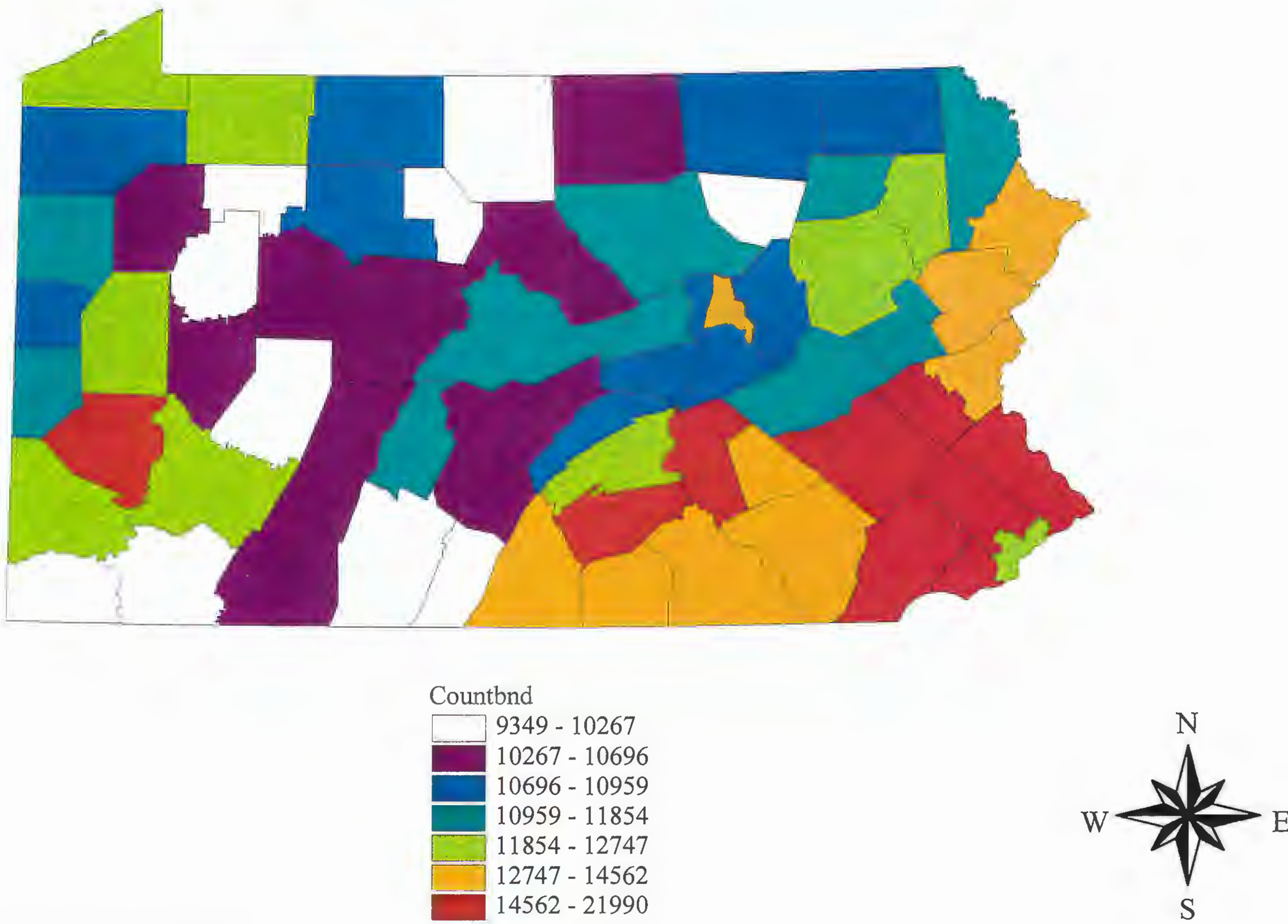
SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

## TABLE 10: PER CAPITA INCOME AND POVERTY, 1989

| | Pennsylvania Number | Greene Number | Washington Number | Pennsylvania Percent | Greene Percent | Washington Percent |
|---|---|---|---|---|---|---|
| PER CAPITA INCOME IN 1989 | | | | | | |
| Universe: Persons | | | | | | |
| Per capita income in 1989 | 14068 | 10005 | 12744 | 100.0 | 71.1 | 90.6 |
| PER CAPITA INCOME IN 1989 BY RACE | | | | | | |
| Universe: Persons | | | | | | |
| White | 14688 | 9987 | 12878 | 100.0 | 68.0 | 87.7 |
| Black | 9140 | 5974 | 8416 | 100.0 | 65.4 | 92.1 |
| American Indian, Eskimo, or Aleut | 10546 | 3455 | 4648 | 100.0 | 32.8 | 44.1 |
| Asian or Pacific Islander | 13210 | 27194 | 21570 | 100.0 | 205.9 | 163.3 |
| Other race | 5772 | 1607 | 6462 | 100.0 | 27.8 | 112.0 |
| PER CAPITA INCOME IN 1989 | | | | | | |
| Universe: Persons of Hispanic origin | | | | | | |
| Per capita income in 1989 | 7489 | 4980 | 8306 | 100.0 | 66.5 | 110.9 |
| POVERTY STATUS IN 1989 BY AGE | | | | | | |
| Universe: Persons for whom poverty status is determined | | | | | | |
| Income in 1989 below poverty level: | | | | | | |
| Under 5 years | 137831 | 887 | 2355 | 10.7 | 10.9 | 9.3 |
| 5 years | 26063 | 155 | 498 | 2.0 | 1.9 | 2.0 |
| 6 to 11 years | 145372 | 955 | 2851 | 11.3 | 11.7 | 11.2 |
| 12 to 17 years | 122961 | 895 | 2589 | 9.6 | 11.0 | 10.2 |
| 18 to 24 years | 180271 | 1019 | 3284 | 14.0 | 12.5 | 12.9 |
| 25 to 34 years | 185812 | 1236 | 3514 | 14.5 | 15.2 | 13.8 |
| 35 to 44 years | 128066 | 990 | 2858 | 10.0 | 12.1 | 11.2 |
| 45 to 54 years | 82123 | 527 | 1704 | 6.4 | 6.5 | 6.7 |
| 55 to 59 years | 40496 | 253 | 981 | 3.2 | 3.1 | 3.9 |
| 60 to 64 years | 51539 | 258 | 1054 | 4.0 | 3.2 | 4.1 |
| 65 to 74 years | 92516 | 501 | 1965 | 7.2 | 6.1 | 7.7 |
| 75 years and over | 90579 | 477 | 1759 | 7.1 | 5.9 | 6.9 |
| | 1283629 | 8153 | 25412 | 100.0 | 100.0 | 100.0 |
| RATIO OF INCOME IN 1989 TO POVERTY LEVEL | | | | | | |
| Universe: Persons for whom poverty status is determined | | | | | | |
| Under .50 | 589241 | 3442 | 11225 | 5.1 | 9.0 | 5.6 |
| .50 to .74 | 308342 | 2102 | 5911 | 2.7 | 5.5 | 3.0 |
| .75 to .99 | 386046 | 2609 | 8276 | 3.3 | 6.8 | 4.2 |
| 1.00 to 1.24 | 432161 | 1772 | 8307 | 3.7 | 4.6 | 4.2 |
| 1.25 to 1.49 | 455189 | 2621 | 8141 | 3.9 | 6.9 | 4.1 |
| 1.50 to 1.74 | 534370 | 2088 | 10604 | 4.6 | 5.5 | 5.3 |
| 1.75 to 1.84 | 210944 | 1048 | 4459 | 1.8 | 2.7 | 2.2 |
| 1.85 to 1.99 | 335983 | 1224 | 6642 | 2.9 | 3.2 | 3.3 |
| 2.00 and over | 8283773 | 21274 | 135645 | 71.8 | 55.7 | 68.1 |
| | 11536049 | 38180 | 199210 | 100.0 | 100.0 | 100.0 |

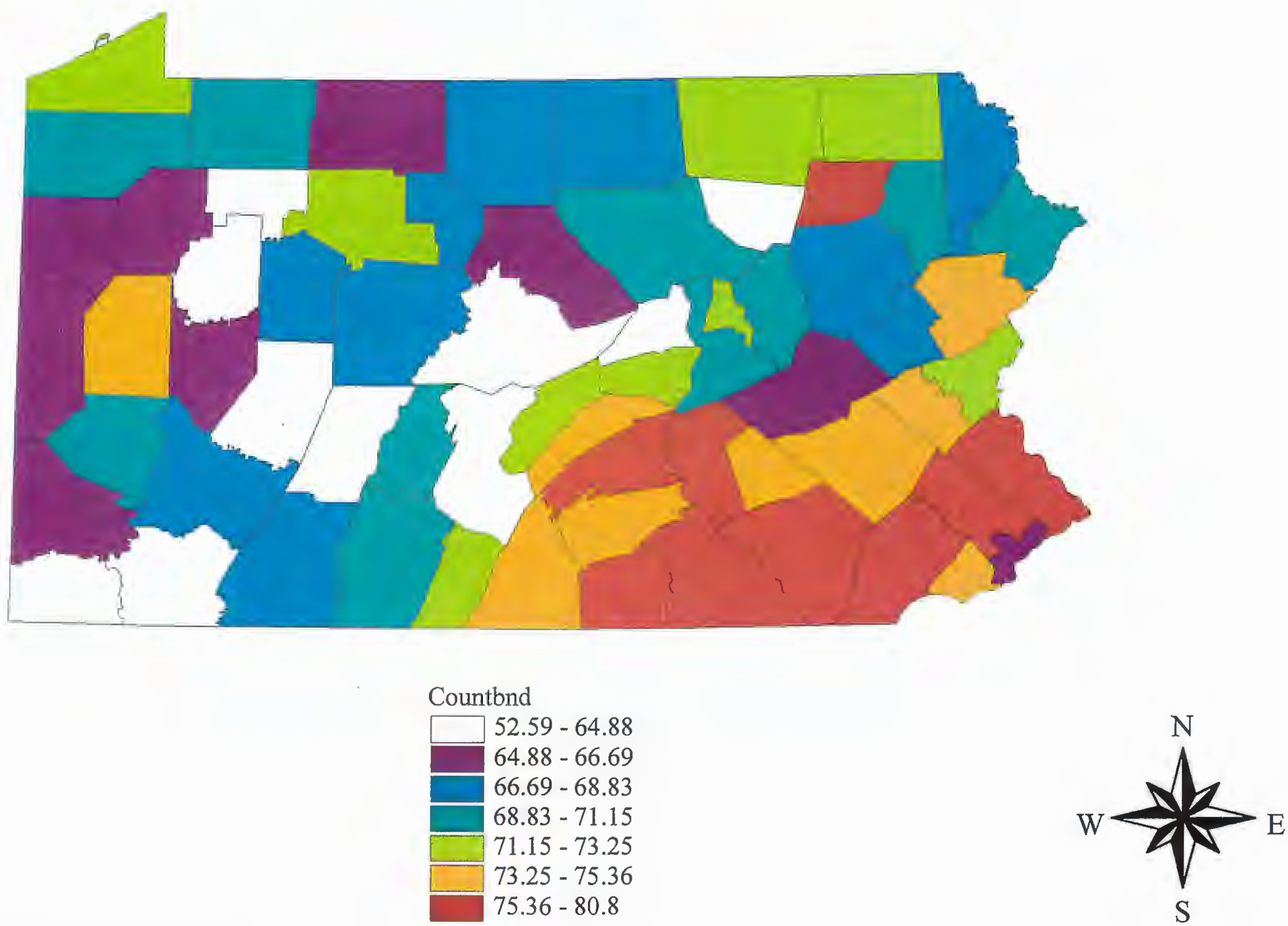
SOURCE: CENSUS OF POPULATION AND HOUSING, 1990

# Income Per Capita, 1989



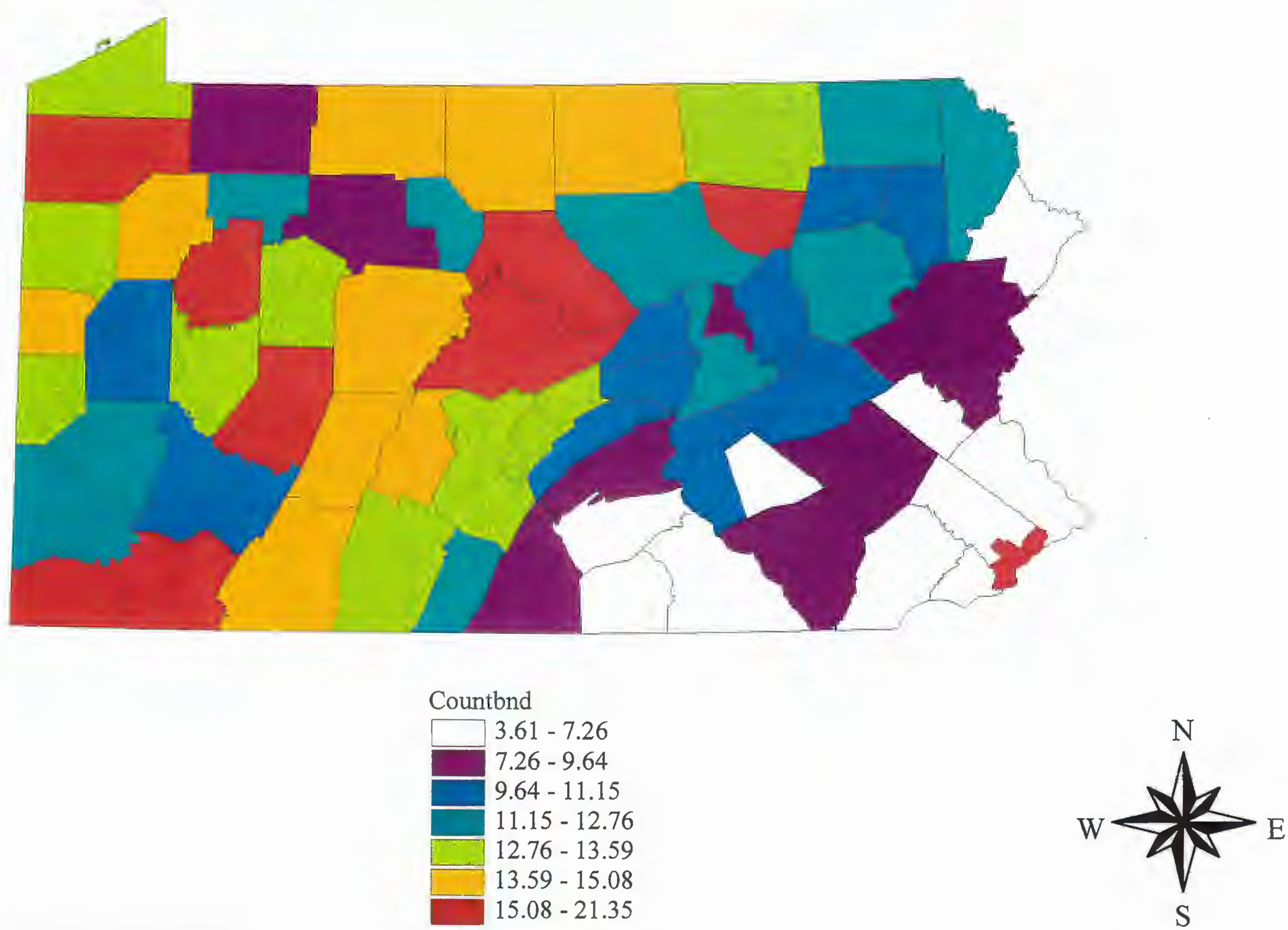

s of Population and Housing, 1990

# Labor Force Participation Rate: Males, 1990



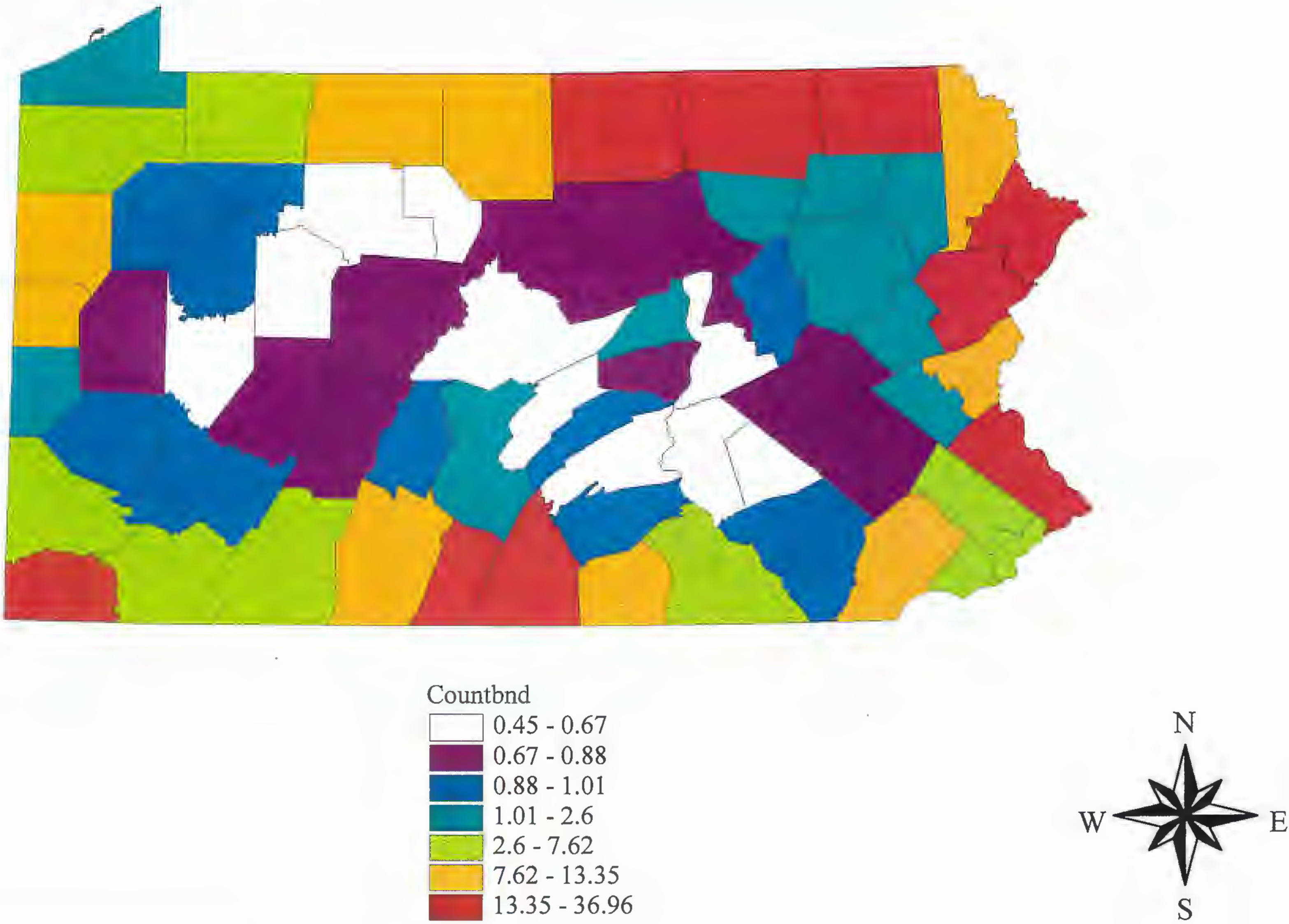

of Population and Housing, 1990

## Persons in Poverty as a Percent of Total, 1990



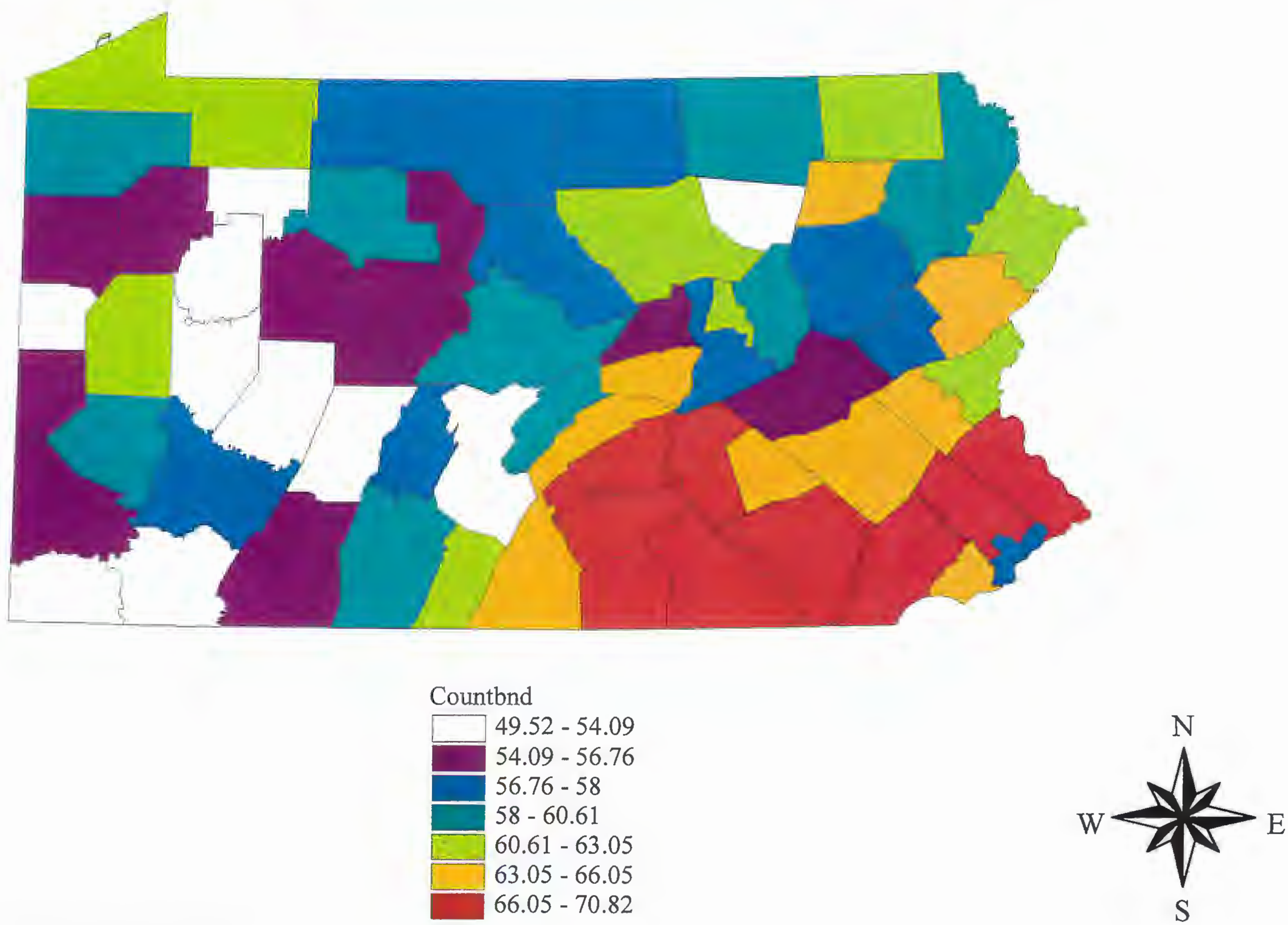

of Population and Housing, 1990

# Percent of Employed Persons Working Out of Pennsylvania



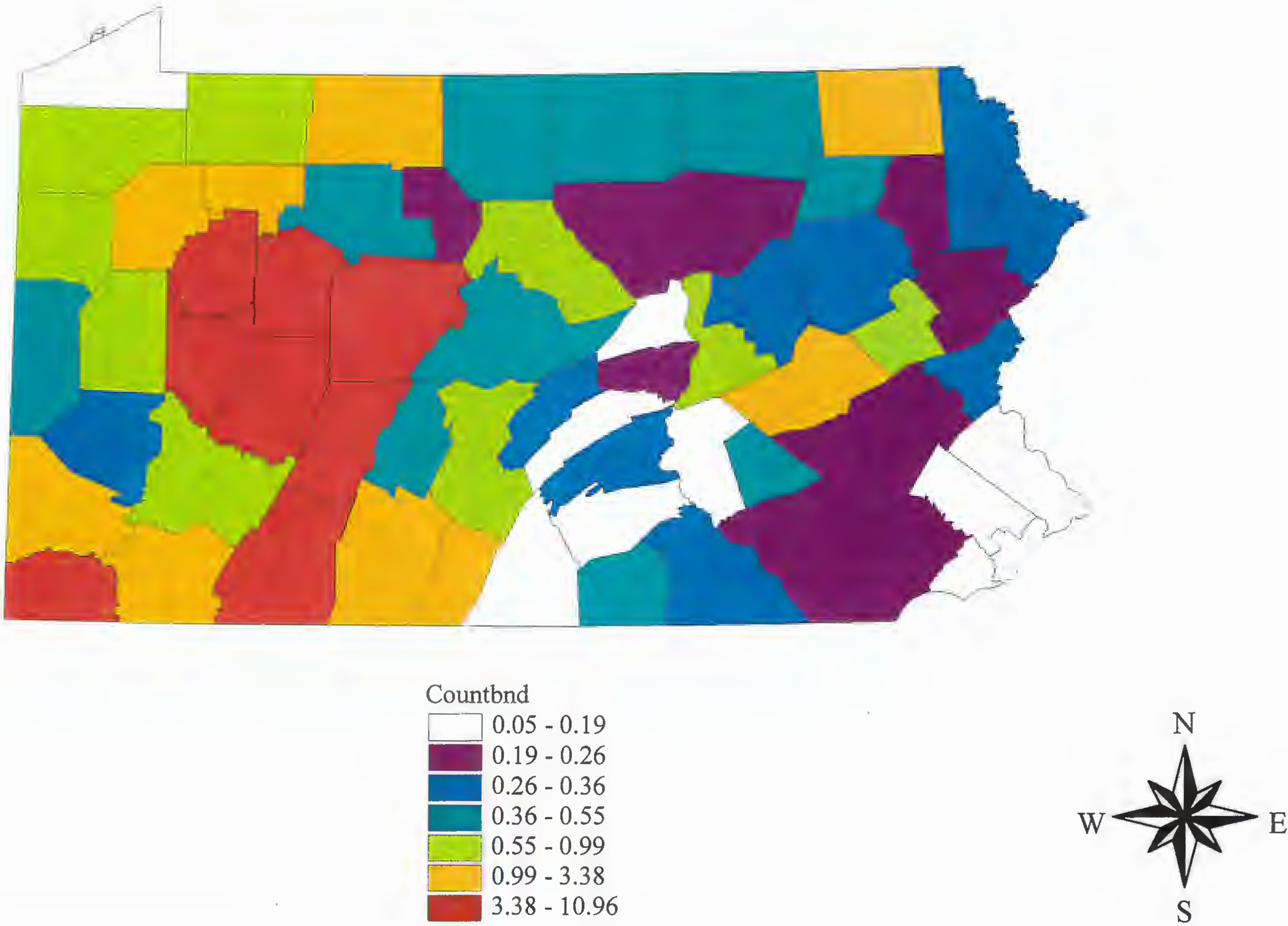

of Population and Housing, 1990

# Overall Labor Force Participation Rate, 1990



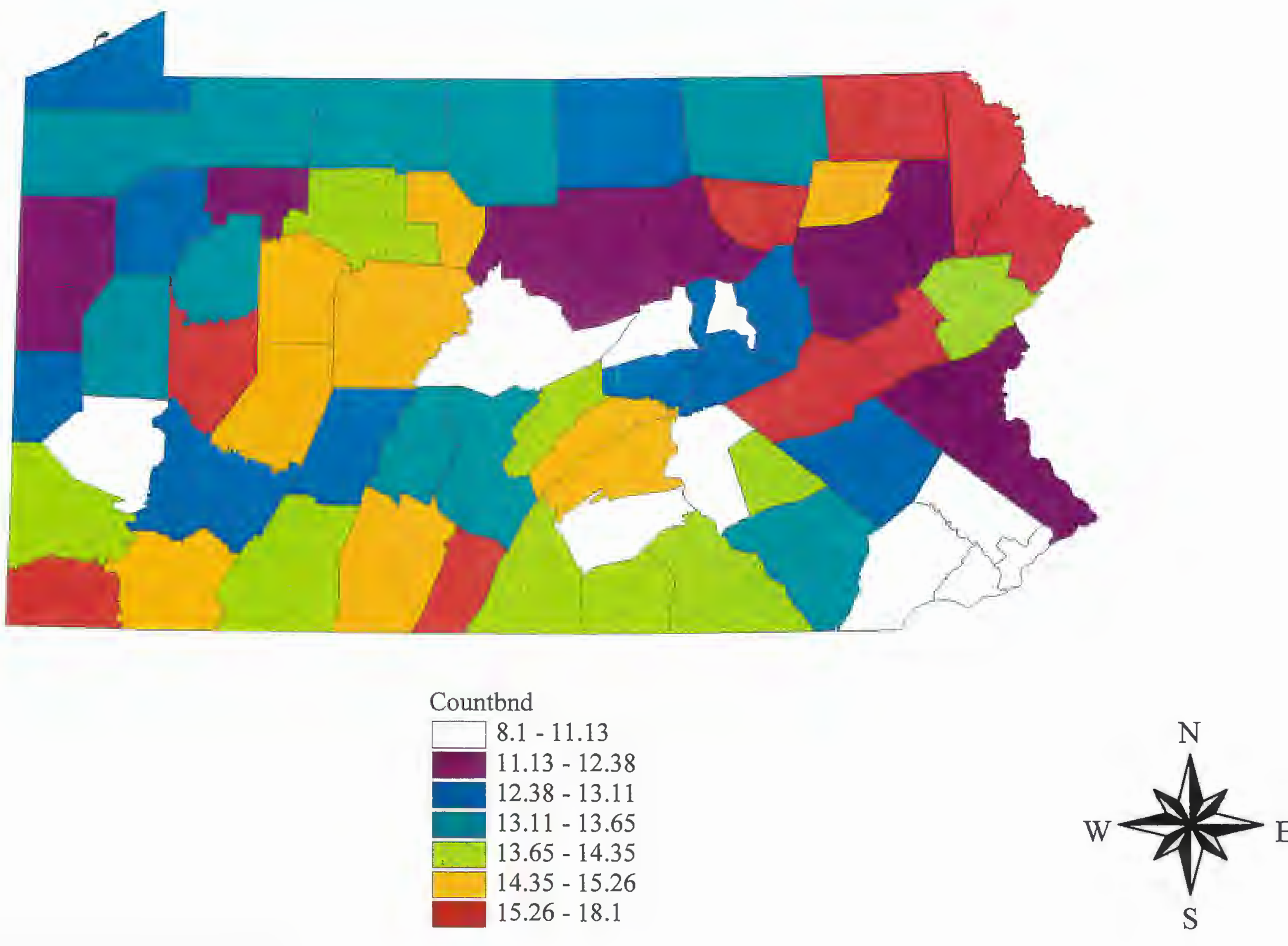

of Population and Housing, 1990

# Percent of Workers Employed in Mining, 1990



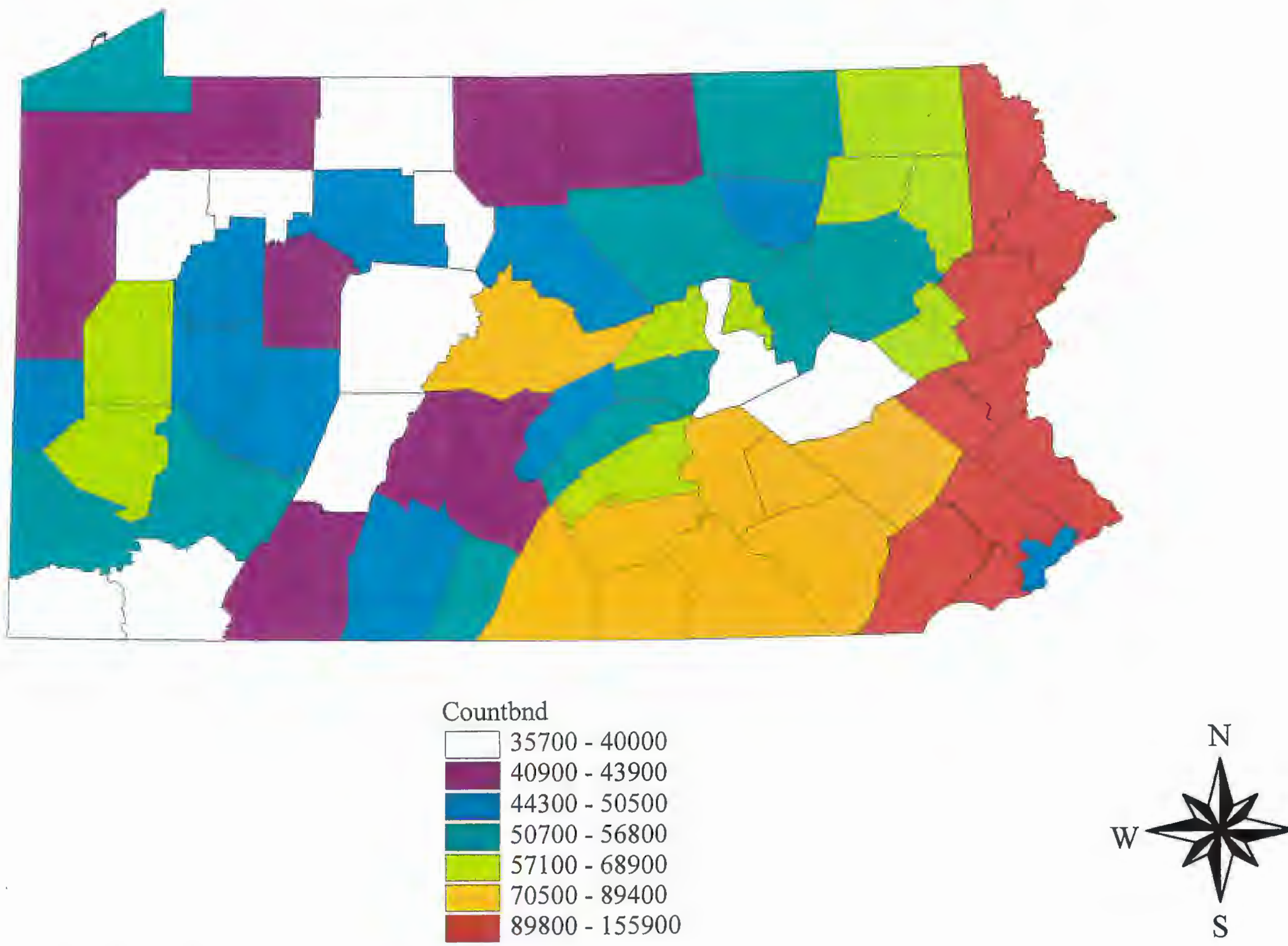

of Population and Housing, 1990

## sion Production Workers -- Skilled Labor -- as a Percentage of Tota



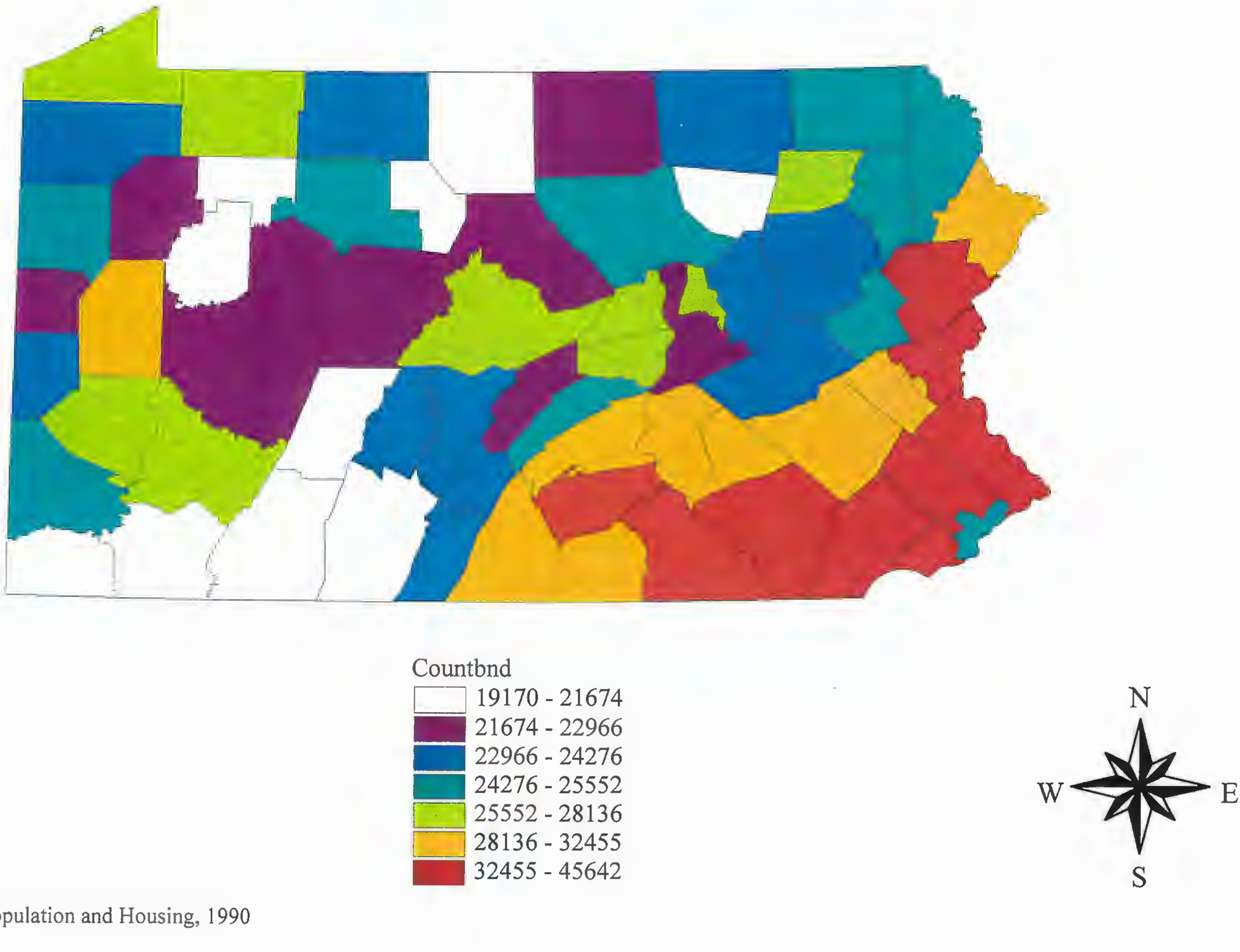

s of Population and Housing, 1990

# Median Value of Housing, 1990




nsus of Population and Housing, 1990

# Median Household Income, 1989



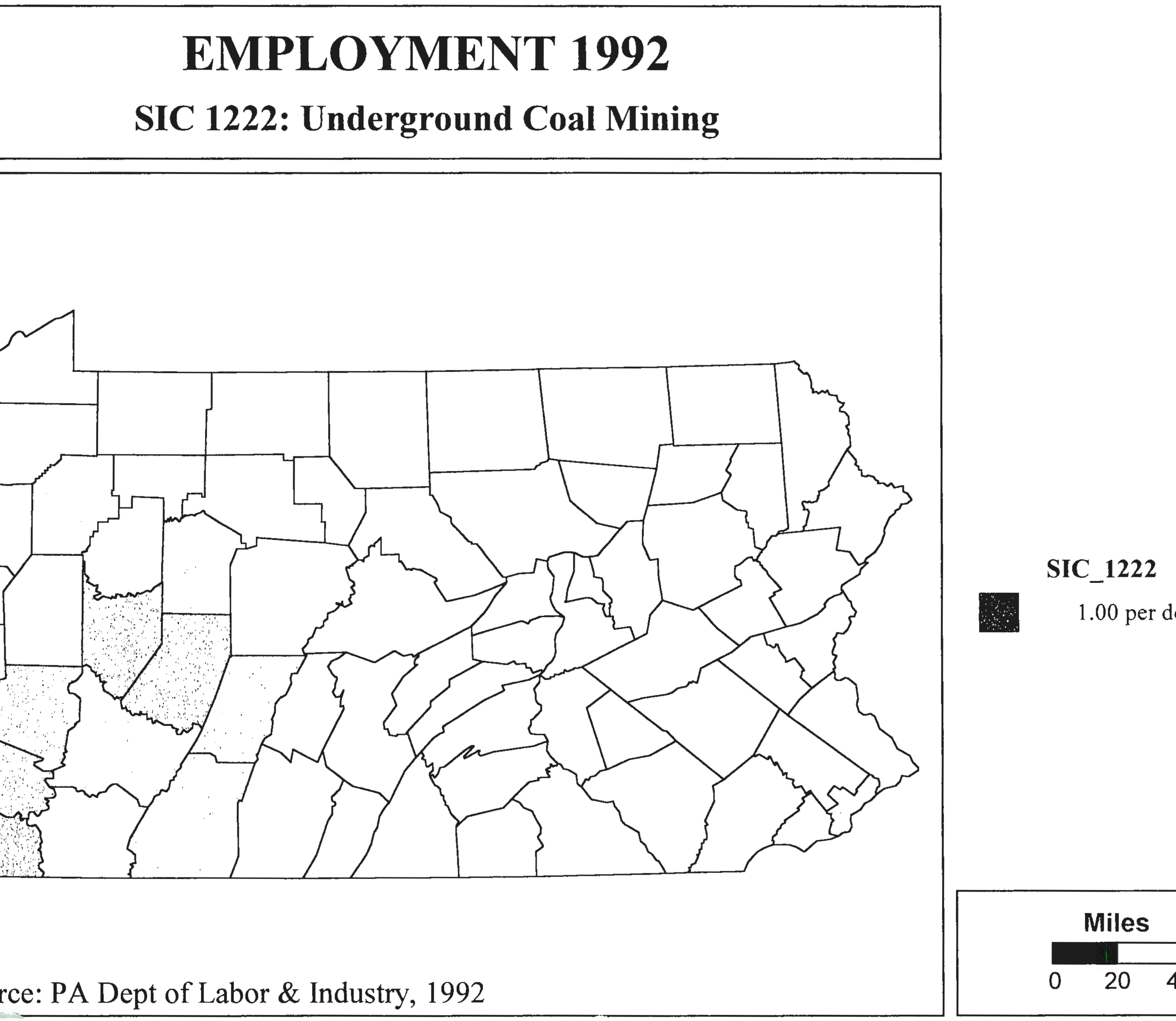

of Population and Housing, 1990

# MAJOR PENNSYLVANIA INDUSTRIES

## COAL MINING EMPLOYMENT, 1992

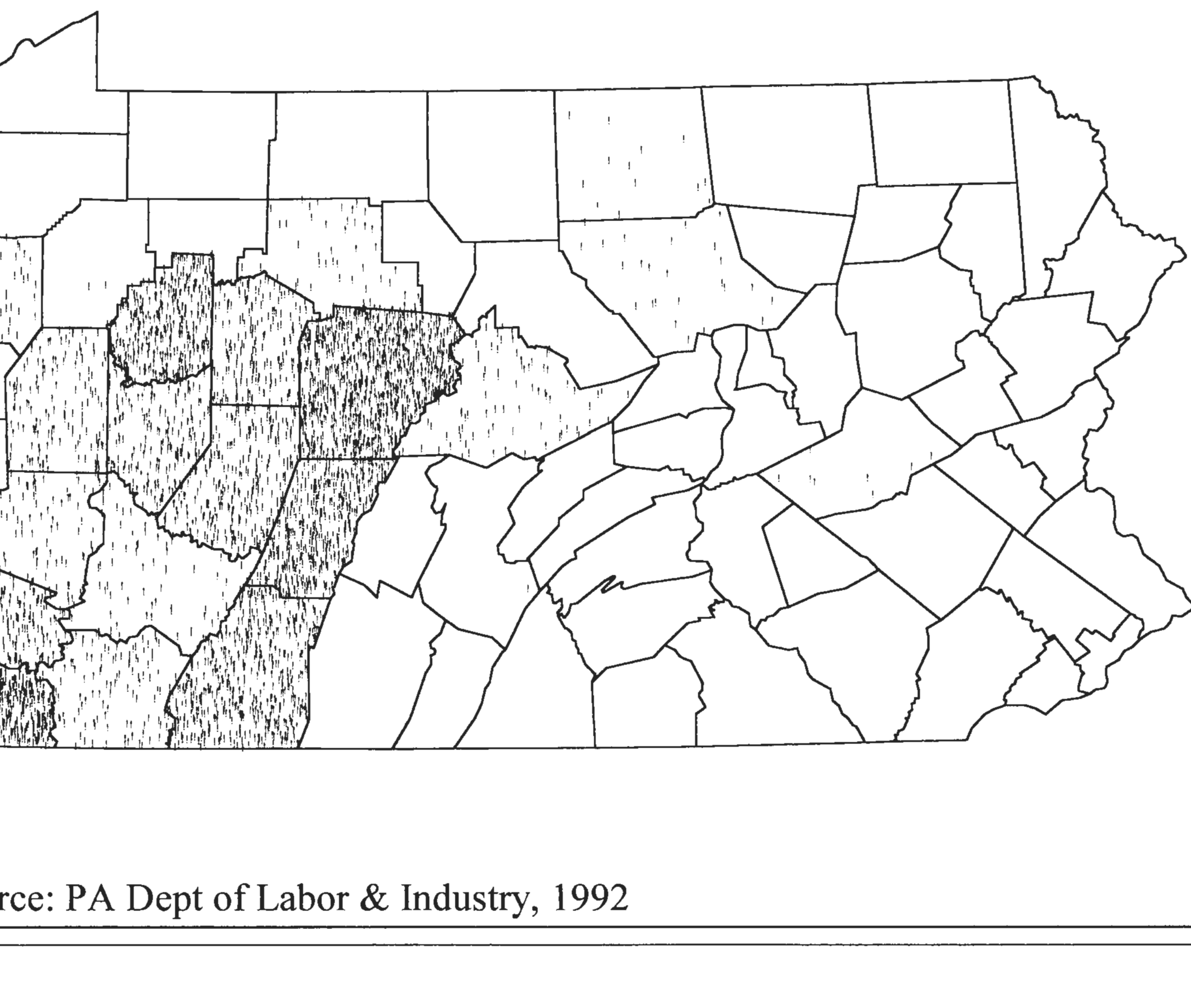
| SIC | SIC 12 | 1221 | 1222 | 1231 | 1241 |
|---|---|---|---|---|---|
| PA TOT93 | 13656 | 4402 | 6646 | 1365 | 1243 |
| Greene | 2055 | 544 | 1511 | 0 | 0 |
| Indiana | 1870 | 276 | 1428 | 4 | 162 |
| Washington | 1425 | 280 | 1012 | 0 | 133 |
| Armstrong | 1159 | 190 | 894 | 0 | 75 |
| Schuylkill | 1116 | 8 | 12 | 949 | 147 |
| Clearfield | 1078 | 958 | 30 | 0 | 90 |
| Somerset | 1047 | 514 | 312 | 14 | 207 |
| Cambria | 973 | 428 | 466 | 5 | 74 |
| Allegheny | 779 | 86 | 683 | 0 | 10 |
| Clarion | 379 | 359 | 0 | 0 | 20 |
| Luzerne | 377 | 0 | 0 | 336 | 41 |
| Jefferson | 336 | 184 | 96 | 0 | 56 |
| Butler | 211 | 145 | 0 | 0 | 66 |
| Westmoreland | 147 | 67 | 74 | 0 | 6 |
| Fayette | 143 | 117 | 0 | 0 | 26 |
| Mercer | 92 | 66 | 0 | 0 | 26 |
| Centre | 91 | 82 | 3 | 0 | 6 |
| Franklin | 68 | 0 | 68 | 0 | 0 |
| Beaver | 58 | 7 | 0 | 0 | 51 |
| Elk | 46 | 46 | 0 | 0 | 0 |
| Philadelphia | 44 | 0 | 44 | 0 | 0 |
| Northumberland | 36 | 0 | 0 | 36 | 0 |
| Lycoming | 25 | 25 | 0 | 0 | 0 |
| Lawrence | 24 | 4 | 0 | 0 | 20 |
| Venango | 22 | 2 | 13 | 0 | 7 |
| Lackawanna | 17 | 0 | 0 | 3 | 14 |
| Dauphin | 13 | 0 | 0 | 13 | 0 |
| Tioga | 13 | 13 | 0 | 0 | 0 |
| Berks | 6 | 0 | 0 | 0 | 6 |
| Montour | 4 | 0 | 0 | 4 | 0 |
| Columbia | 1 | 0 | 0 | 1 | 0 |
| Huntingdon | 1 | 1 | 0 | 0 | 0 |

SOURCE: PA DEPT OF L&I, 1993; COUNTY BUS. PATTERNS, 1992; MANUFACTURING USA (1993ED)


EMPLOYMENT 1992
SIC 1222: Underground Coal Mining
SIC_1222
1.00 per d
Miles
0
20
4
rce: PA Dept of Labor & Industry, 1992

# EMPLOYMENT 1992

## SIC 1221: Surface Coal Mining



rce: PA Dept of Labor & Industry, 1992

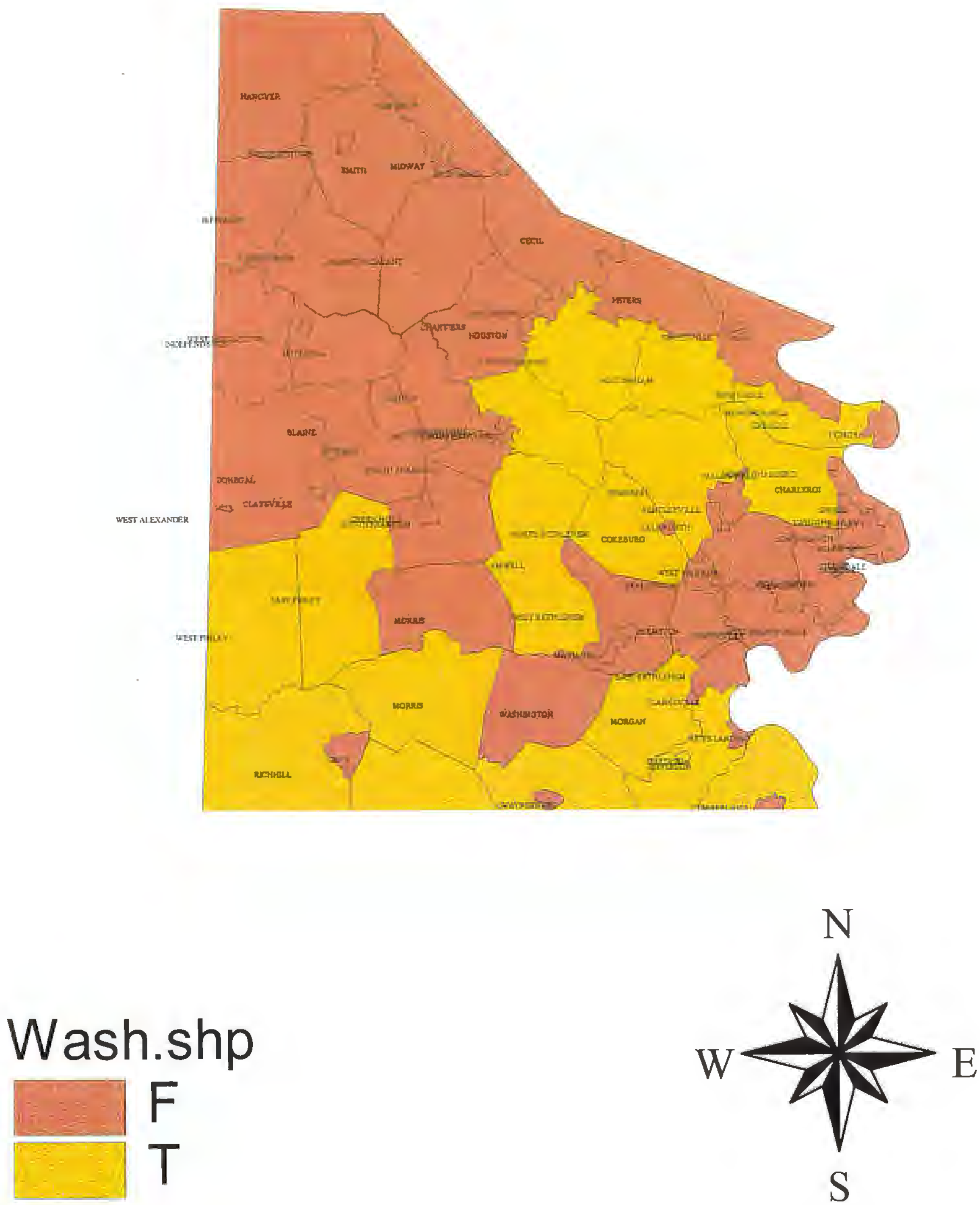
SIC_1221

1.00 per d

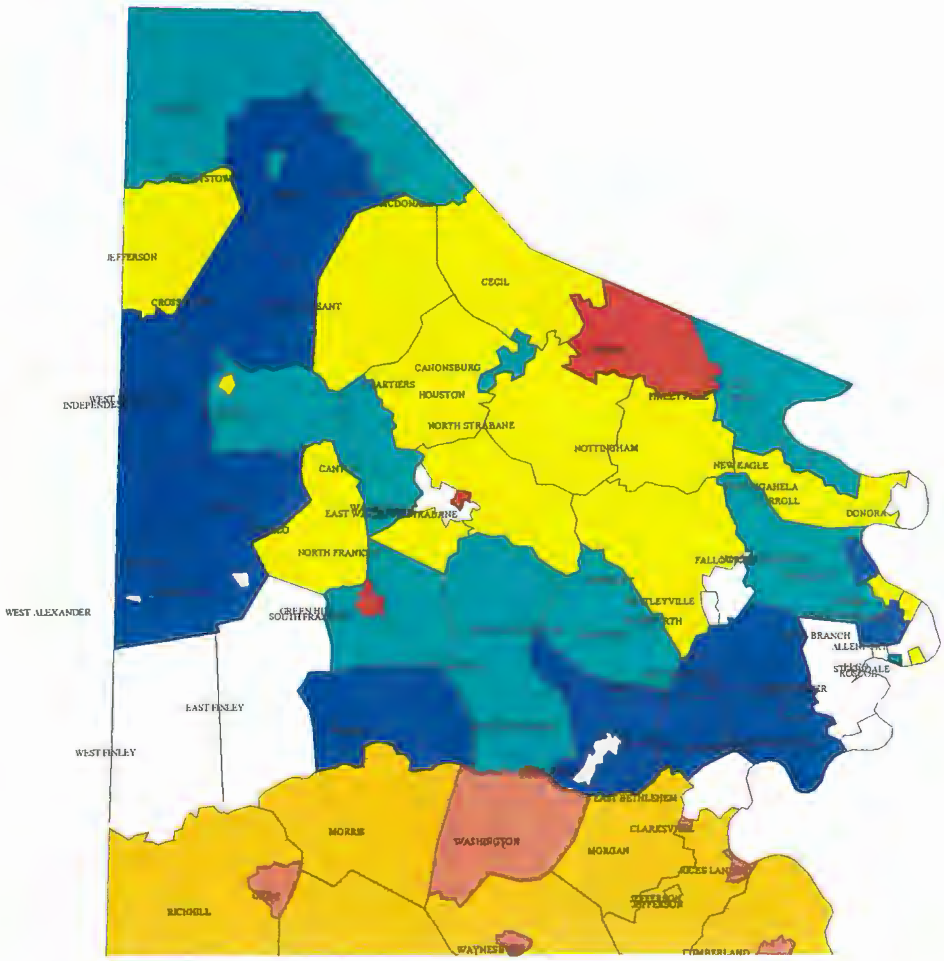
Miles

0 20 4

## Municipalities with Coal Mines
## Greene and Washington Counties, 1996

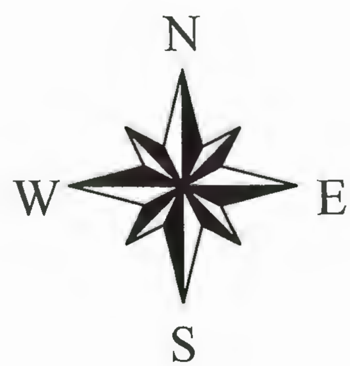


# Per Capita Income, 1989




Wash.shp

| | |
|---|---|
| (white) | 7749 - 9713 |
| (dark blue) | 9714 - 10930 |
| (teal) | 10931 - 12212 |
| (yellow) | 12213 - 17021 |
| (red) | 17022 - 24417 |




Source: Census of Population and Housing, 1990

## EMPLOYMENT BY INDUSTRY FOR MCD'S WITH AND WITHOUT COAL MINES, 1990

| | | PERCENTAGE OF TOTAL EMPLOYMENT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ME | Coal Mine | AGRIC | MINING | CONST | MANUF | TRANSPORT | COMM, PU | WH TRADE | RE TRADE | FIRE | SERVI |
| nsylvania | | 1.8 | 0.6 | 6.1 | 20.0 | 4.4 | 2.5 | 4.3 | 17.1 | 6.5 | 3 |
| | | | | | | | | | | | |
| ter township | yes | 8.2 | 6.1 | 11.9 | 9.0 | 2.9 | 6.3 | 1.5 | 15.5 | 4.9 | 2 |
| nberland township | yes | 2.6 | 12.9 | 11.2 | 6.9 | 2.9 | 7.2 | 5.2 | 13.4 | 2.9 | 3 |
| nklin township | yes | 1.4 | 8.2 | 7.4 | 7.2 | 3.9 | 3.7 | 2.1 | 21.0 | 3.1 | 3 |
| erson township | yes | 2.1 | 10.7 | 5.8 | 7.8 | 7.0 | 6.2 | 2.2 | 16.3 | 3.7 | 2 |
| rgan township | yes | 0.7 | 18.4 | 5.2 | 10.7 | 5.6 | 3.0 | 3.0 | 12.2 | 3.1 | 3 |
| rris township | yes | 5.2 | 3.9 | 6.5 | 17.5 | 5.0 | 6.5 | 8.9 | 13.1 | 1.0 | 2 |
| y township | yes | 2.2 | 16.0 | 8.5 | 8.0 | 4.2 | 2.8 | 3.8 | 16.2 | 6.0 | 2 |
| hhill township | yes | 7.9 | 7.6 | 9.3 | 12.7 | 5.9 | 9.0 | 2.3 | 9.3 | 1.7 | 2 |
| yne township | yes | 3.4 | 12.6 | 10.4 | 12.4 | 5.9 | 2.0 | 3.6 | 14.6 | 2.0 | 2 |
| iteley township | yes | 6.3 | 9.1 | 11.2 | 8.1 | 7.0 | 1.8 | 5.6 | 14.4 | 1.1 | 3 |
| h Coal Mine | | 2.9 | 11.1 | 8.6 | 8.7 | 4.5 | 5.1 | 3.5 | 15.6 | 3.2 | 3 |
| | | | | | | | | | | | |
| ppo township | no-t | 2.3 | 4.7 | 15.7 | 8.7 | 14.0 | 7.6 | 2.9 | 11.0 | 0.0 | 2 |
| nkard township | no-t | 1.8 | 18.5 | 5.4 | 13.3 | 7.6 | 1.2 | 2.2 | 16.1 | 2.5 | 2 |
| eport township | no-t | 2.1 | 8.2 | 13.4 | 11.3 | 14.4 | 6.2 | 6.2 | 4.1 | 0.0 | 2 |
| more township | no-t | 4.6 | 12.8 | 9.2 | 11.0 | 8.3 | 0.0 | 3.7 | 11.9 | 1.8 | 3 |
| y township | no-t | 3.8 | 0.0 | 15.4 | 9.0 | 5.1 | 7.7 | 5.1 | 19.2 | 3.8 | 2 |
| ene township | no-t | 8.5 | 15.5 | 6.0 | 10.5 | 3.0 | 5.5 | 2.0 | 11.0 | 6.5 | 2 |
| kson township | no-t | 2.7 | 11.7 | 20.2 | 6.4 | 7.4 | 3.7 | 1.6 | 3.2 | 3.2 | 3 |
| nongahela township | no-t | 0.5 | 17.9 | 3.7 | 6.6 | 5.8 | 6.9 | 2.5 | 17.2 | 3.4 | 3 |
| inghill township | no-t | 0.0 | 1.9 | 29.9 | 10.3 | 4.7 | 6.5 | 0.9 | 13.1 | 0.0 | 3 |
| shington township | no-t | 3.2 | 9.4 | 7.1 | 8.2 | 7.5 | 5.9 | 4.3 | 21.0 | 4.1 | 2 |
| hout Coal Mine | | 2.4 | 13.8 | 8.5 | 9.7 | 7.3 | 4.5 | 2.8 | 15.0 | 3.0 | 2 |
| | | | | | | | | | | | |
| michaels borough | b | 0.0 | 11.3 | 7.0 | 5.9 | 7.0 | 6.5 | 3.8 | 14.0 | 3.8 | 3 |
| rksville borough | b | 0.0 | 3.3 | 5.0 | 18.3 | 5.0 | 3.3 | 13.3 | 23.3 | 0.0 | 2 |
| ensboro borough | b | 0.0 | 20.6 | 7.2 | 11.3 | 4.1 | 2.1 | 3.1 | 10.3 | 11.3 | 2 |
| ferson borough | b | 0.0 | 7.5 | 16.7 | 3.3 | 8.3 | 6.7 | 5.0 | 19.2 | 1.7 | 2 |
| es Landing borough | b | 0.0 | 15.0 | 15.7 | 5.5 | 3.9 | 2.4 | 1.6 | 17.3 | 7.9 | 2 |
| ynesburg borough | b | 0.7 | 4.7 | 3.1 | 5.9 | 3.7 | 2.4 | 3.6 | 21.1 | 4.0 | 4 |
| oughs | | 0.5 | 6.7 | 5.1 | 6.3 | 4.3 | 3.0 | 3.8 | 19.8 | 4.3 | 4 |
| | | | | | | | | | | | |
| ene County | | 2.4 | 11.0 | 8.0 | 8.5 | 5.0 | 4.6 | 3.4 | 16.2 | 3.3 | 3 |

rce: Census of Population and Housing, 1990

# LABOR FORCE OF GREENE COUNTY MCD'S WITH AND WITHOUT COAL MINES

| | | Males over 16 Years Old | | | | | Females over 16 Years Old | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ME | Coal Mine | Employed | Unemployed | UnempRate | Not in LF | LFPR | Employed | Unemployed | UnempRate | Not in LF | LFPR | Uner |
| nsylvania | | 2952871 | 198697 | 6.3 | 1248442 | 71.6 | 2481661 | 146098 | 5.6 | 2346437 | 52.8 | |
| nter township | yes | 339 | 55 | 14.0 | 150 | 72.4 | 249 | 19 | 7.1 | 306 | 46.7 | |
| mberland township | yes | 1267 | 134 | 9.6 | 953 | 59.5 | 724 | 116 | 13.8 | 1976 | 29.8 | |
| nklin township | yes | 1145 | 156 | 12.0 | 606 | 68.2 | 846 | 85 | 9.1 | 1451 | 39.1 | |
| ferson township | yes | 518 | 43 | 7.7 | 378 | 59.7 | 398 | 25 | 5.9 | 642 | 39.7 | |
| rgan township | yes | 486 | 141 | 22.5 | 330 | 65.5 | 347 | 34 | 8.9 | 961 | 28.4 | |
| rris township | yes | 230 | 28 | 10.9 | 109 | 70.3 | 153 | 6 | 3.8 | 159 | 50.0 | |
| ry township | yes | 396 | 49 | 11.0 | 229 | 66.0 | 254 | 14 | 5.2 | 417 | 39.1 | |
| chhill township | yes | 222 | 52 | 19.0 | 141 | 66.0 | 132 | 13 | 9.0 | 266 | 35.3 | |
| yne township | yes | 263 | 52 | 16.5 | 155 | 67.0 | 181 | 26 | 12.6 | 285 | 42.1 | |
| iteley township | yes | 164 | 16 | 8.9 | 70 | 72.0 | 121 | 13 | 9.7 | 141 | 48.7 | |
| th Coal Mine | | 407430 | 58806 | 12.6 | 252801 | 64.8 | 275805 | 28431 | 9.3 | 534924 | 36.3 | |
| eppo township | no-t | 101 | 36 | 26.3 | 106 | 56.4 | 71 | 15 | 17.4 | 161 | 34.8 | |
| nkard township | no-t | 509 | 105 | 17.1 | 259 | 70.3 | 338 | 20 | 5.6 | 601 | 37.3 | |
| eport township | no-t | 61 | 17 | 21.8 | 37 | 67.8 | 36 | 7 | 16.3 | 86 | 33.3 | |
| more township | no-t | 76 | 15 | 16.5 | 48 | 65.5 | 33 | 2 | 5.7 | 92 | 27.6 | |
| ay township | no-t | 52 | 3 | 5.5 | 29 | 65.5 | 26 | 7 | 21.2 | 48 | 40.7 | |
| eene township | no-t | 125 | 12 | 8.8 | 69 | 66.5 | 75 | 7 | 8.5 | 122 | 40.2 | |
| kson township | no-t | 113 | 15 | 11.7 | 78 | 62.1 | 75 | 6 | 7.4 | 128 | 38.8 | |
| onongahela township | no-t | 383 | 58 | 13.2 | 292 | 60.2 | 258 | 18 | 6.5 | 445 | 38.3 | |
| ringhill township | no-t | 75 | 20 | 21.1 | 96 | 49.7 | 32 | 5 | 13.5 | 146 | 20.2 | |
| ashington township | no-t | 254 | 27 | 9.6 | 100 | 73.8 | 184 | 25 | 12.0 | 200 | 51.1 | |
| thout Coal Mine | | 1749 | 308 | 15.0 | 1114 | 64.9 | 1128 | 112 | 9.0 | 2029 | 37.9 | |
| rmichaels borough | b | 95 | 11 | 10.4 | 79 | 57.3 | 91 | 3 | 3.2 | 139 | 40.3 | |
| arksville borough | b | 37 | 3 | 7.5 | 43 | 48.2 | 23 | 10 | 30.3 | 60 | 35.5 | |
| eensboro borough | b | 58 | 2 | 3.3 | 65 | 48.0 | 39 | 2 | 4.9 | 103 | 28.5 | |
| fferson borough | b | 73 | 7 | 8.8 | 57 | 58.4 | 47 | 8 | 14.5 | 85 | 39.3 | |
| ces Landing borough | b | 78 | 8 | 9.3 | 80 | 51.8 | 49 | 7 | 12.5 | 149 | 27.3 | |
| aynesburg borough | b | 893 | 196 | 18.0 | 499 | 68.6 | 711 | 124 | 14.9 | 1087 | 43.4 | |
| roughs | | 1234 | 227 | 15.5 | 823 | 64.0 | 960 | 154 | 13.8 | 1623 | 40.7 | |
| eene County | | 8013 | 1261 | 13.6 | 5058 | 64.7 | 5493 | 617 | 10.1 | 10256 | 37.3 | |

-e: Census of Population and Housing, 1990

## COMPARISON OF GREENE COUNTY MCD'S WITH COAL MINES TO THOSE WITHOUT

| | NAME | CoalMine | LAND AREA | Persons | LT 18 Pc | GT 65 Pc | Med Age | PC INC | MED HH INC | MED FAM INC | TOTAL PO |
|---|---|---|---|---|---|---|---|---|---|---|---|
| nsyl | Pennsylvania | | 44819.62 | 11881643 | 23.5 | 15.4 | 34.0 | $14,068 | $29,069 | $34,856 | 12836 |
| ene | Franklin township | yes | 40.89 | 5562 | 26.0 | 18.5 | 35.5 | $14,352 | $24,974 | $31,015 | 10 |
| ene | Perry township | yes | 30.28 | 1719 | 24.8 | 14.4 | 35.4 | $10,588 | $22,656 | $27,833 | 2 |
| ene | Morgan township | yes | 24.54 | 2887 | 23.1 | 15.0 | 34.4 | $8,499 | $19,514 | $24,071 | 4 |
| ene | Morris township | yes | 35.80 | 898 | 27.3 | 12.9 | 32.0 | $9,263 | $22,976 | $24,737 | 1 |
| ene | Richhill township | yes | 56.00 | 1102 | 28.1 | 13.2 | 32.3 | $8,450 | $19,602 | $23,229 | 2 |
| ene | Jefferson township | yes | 21.64 | 2536 | 24.1 | 18.5 | 36.6 | $11,084 | $23,575 | $27,612 | 3 |
| ene | Whiteley township | yes | 31.22 | 766 | 31.6 | 9.8 | 30.9 | $8,123 | $16,842 | $18,875 | 2 |
| ene | Center township | yes | 48.64 | 1460 | 27.9 | 11.3 | 31.5 | $9,199 | $21,648 | $24,853 | 3 |
| ene | Cumberland township | yes | 38.26 | 6742 | 26.3 | 18.9 | 35.5 | $9,089 | $18,102 | $23,185 | 16 |
| ene | Wayne township | yes | 39.48 | 1317 | 29.9 | 11.6 | 31.1 | $8,570 | $20,750 | $25,521 | 2 |
| | Average w/Coal Mines | | 36.68 | 24989 | 26.1 | 16.4 | 33.53 | $10,425 | $21,064 | $25,093 | 49 |
| ene | Monongahela township | no-t | 17.27 | 1858 | 26.9 | 17.2 | 35.1 | $11,345 | $20,931 | $25,357 | 3 |
| ene | Washington township | no-t | 27.00 | 1071 | 31.3 | 9.3 | 31.7 | $9,342 | $24,750 | $26,350 | 1 |
| ene | Gilmore township | no-t | 21.69 | 365 | 33.2 | 9.6 | 30.5 | $7,168 | $14,423 | $18,125 | 1 |
| ene | Aleppo township | no-t | 27.27 | 656 | 27.4 | 15.1 | 34.6 | $7,119 | $15,455 | $19,559 | 2 |
| ene | Jackson township | no-t | 29.42 | 546 | 27.7 | 12.5 | 35.3 | $7,786 | $17,109 | $20,385 | 1 |
| ene | Greene township | no-t | 18.60 | 494 | 26.9 | 17.0 | 35.5 | $9,758 | $25,000 | $25,313 | |
| ene | Gray township | no-t | 3.30 | 220 | 23.2 | 21.4 | 36.3 | $9,262 | $17,250 | $24,688 | |
| ene | Dunkard township | no-t | 31.66 | 2386 | 24.9 | 17.2 | 34.9 | $8,941 | $17,547 | $20,863 | 4 |
| ene | Springhill township | no-t | 22.10 | 506 | 30.0 | 11.5 | 30.7 | $5,609 | $11,023 | $10,714 | 2 |
| ene | Freeport township | no-t | 8.66 | 327 | 29.4 | 12.8 | 31.6 | $7,893 | $13,750 | $23,000 | 1 |
| | Average w/oCoal Mines | | 22.15 | 8429 | 27.4 | 15.0 | 33.62 | $9,044 | $17,724 | $21,435 | 19 |
| ene | Greensboro borough | Boro | 0.11 | 307 | 25.1 | 24.4 | 39.4 | $10,999 | $21,625 | $25,625 | |
| ene | Rices Landing borough | Boro | 0.77 | 457 | 23.4 | 22.3 | 38.7 | $8,367 | $14,524 | $20,536 | 1 |
| ene | Waynesburg borough | Boro | 0.83 | 4270 | 20.1 | 17.3 | 29.6 | $9,321 | $19,328 | $26,835 | 8 |
| ene | Carmichaels borough | Boro | 0.18 | 532 | 22.6 | 20.7 | 36.9 | $10,745 | $22,019 | $24,489 | |
| ene | Clarksville borough | Boro | 0.10 | 211 | 24.6 | 25.6 | 39.8 | $10,909 | $20,500 | $22,250 | |
| ene | Jefferson borough | Boro | 0.19 | 355 | 25.4 | 15.8 | 33.9 | $10,934 | $23,750 | $32,708 | |
| | Average of Boros | | 0.36 | 6132 | 21.2 | 18.5 | 36.40 | $9,605 | $20,291 | $25,407 | 11 |
| ene | Greene County | | 575.91 | 39550 | 25.6 | | 34.2 | $10,005 | $19,903 | $25,284 | 81 |

JRCE: CENSUS OF POPULATION & HOUSING, 1990

## COMPARISON OF WASHINGTON COUNTY MCD'S WITH COAL MINES TO THOSE WITHOUT

| ME | CoalMine | LAND AREA | Persons | LT 18 Tot | GT 65 Tot | Med Age | PC INC | MED HH INC | MED FAM INC | TOTAL PC |
|---|---|---|---|---|---|---|---|---|---|---|
| th Bethlehem township | yes | 22.30 | 1864 | 26.4 | 14.6 | 33.6 | $11,800 | $26,990 | $30,536 | 22 |
| th Strabane township | yes | 27.30 | 8157 | 21.8 | 15.6 | 37.2 | $15,825 | $35,910 | $40,784 | 34 |
| st Finley township | yes | 39.12 | 972 | 31.0 | 10.4 | 33.6 | $9,540 | $25,385 | $27,562 | 15 |
| nerset township | yes | 32.05 | 2947 | 25.4 | 12.6 | 34.8 | $13,529 | $27,310 | $28,866 | 51 |
| th Strabane township | yes | 23.12 | 7676 | 21.6 | 22.4 | 39.6 | $17,021 | $31,000 | $37,388 | 56 |
| tingham township | yes | 20.29 | 2303 | 24.9 | 10.1 | 34.5 | $13,689 | $33,350 | $36,971 | 16 |
| well township | yes | 44.84 | 4176 | 27.8 | 10.1 | 32.8 | $11,483 | $30,042 | $32,500 | 40 |
| roll township | yes | 13.51 | 6210 | 21.0 | 19.6 | 39.5 | $13,405 | $29,765 | $33,655 | 43 |
| owfield township | yes | 21.28 | 4972 | 21.3 | 18.4 | 39.1 | $12,033 | $29,287 | $32,313 | 36 |
| t Finley township | yes | 35.13 | 1479 | 31.0 | 9.8 | 31.0 | $9,124 | $23,750 | $25,714 | 28 |
| h Coal Mines | | 278.94 | 40756 | 23.4 | 16.4 | 35.6 | $13,910 | 29278.9 | 32628.9 | 341 |
| | | | | | | | | | | |
| on township | no-t | 15.37 | 6322 | 23.0 | 15.6 | 36.4 | $12,076 | $29,140 | $34,048 | 41 |
| pewell township | no-t | 20.53 | 942 | 28.0 | 9.9 | 32.8 | $11,263 | $27,102 | $30,577 | 9 |
| ine township | no-t | 11.85 | 682 | 26.0 | 10.3 | 32.8 | $9,965 | $26,033 | $27,667 | 10 |
| nover township | no-t | 47.56 | 2883 | 25.2 | 11.0 | 33.5 | $12,212 | $30,268 | $33,618 | 32 |
| ffalo township | no-t | 20.34 | 2148 | 26.0 | 12.6 | 34.5 | $12,771 | $31,473 | $36,406 | 12 |
| t Bethlehem township | no-t | 5.11 | 2799 | 24.6 | 19.5 | 36.6 | $8,867 | $18,819 | $23,222 | 62 |
| st Pike Run township | no-t | 16.29 | 1818 | 23.5 | 18.1 | 37.3 | $10,657 | $24,018 | $28,622 | 17 |
| negal township | no-t | 41.37 | 2347 | 25.9 | 14.4 | 34.8 | $10,806 | $23,804 | $27,700 | 30 |
| ss Creek township | no-t | 27.61 | 1727 | 25.6 | 14.4 | 34.2 | $10,727 | $25,761 | $30,727 | 1 |
| st Bethlehem township | no-t | 22.15 | 1609 | 25.4 | 15.5 | 36.3 | $10,042 | $21,571 | $25,664 | 2 |
| rth Franklin township | no-t | 7.28 | 4997 | 22.7 | 20.3 | 39.7 | $13,279 | $32,015 | $35,496 | 4 |
| cil township | no-t | 26.34 | 8948 | 23.9 | 12.6 | 34.4 | $15,084 | $32,527 | $35,786 | 5 |
| artiers township | no-t | 24.52 | 7603 | 21.0 | 19.3 | 38.6 | $13,886 | $27,278 | $32,407 | 7 |
| unt Pleasant township | no-t | 35.63 | 3555 | 25.3 | 13.2 | 34.6 | $12,842 | $30,193 | $32,177 | 2 |
| nton township | no-t | 14.89 | 9256 | 23.8 | 14.3 | 35.1 | $11,328 | $25,037 | $28,622 | 14 |
| rris township | no-t | 28.37 | 1145 | 27.5 | 11.0 | 32.5 | $10,923 | $29,444 | $31,667 | 1 |
| ith township | no-t | 34.38 | 4844 | 22.6 | 18.4 | 36.8 | $10,371 | $21,862 | $25,588 | 7 |
| ependence township | no-t | 25.76 | 1868 | 27.0 | 13.8 | 34.6 | $10,148 | $23,917 | $27,687 | 2 |
| uth Franklin township | no-t | 20.58 | 3665 | 30.6 | 7.6 | 31.4 | $11,233 | $29,691 | $30,700 | 4 |
| ers township | no-t | 19.59 | 14467 | 26.1 | 10.8 | 36.8 | $24,417 | $53,045 | $56,219 | 3 |
| binson township | no-t | 21.16 | 2160 | 24.7 | 14.9 | 35.0 | $11,182 | $24,500 | $30,817 | 2 |
| ferson township | no-t | 22.64 | 1212 | 23.4 | 15.7 | 37.6 | $13,555 | $28,687 | $34,125 | |
| thout Coal Mines (1) | | 509.34 | 86997 | 24.6 | 14.3 | 35.3 | $12,153 | $28,008 | $31,797 | 82 |

..RCE: CENSUS OF POPULATION & HOUSING, 1990 nt'd

# COMPARISON OF WASHINGTON COUNTY MCD'S WITH COAL MINES TO THOSE WITHOUT

| ME | CoalMine | LAND ARE/ | Persons | LT 18 Tot | GT 65 Tot | Med Age | PC INC | MED HH INC | MED FAM INC | TOTAL POV |
|---|---|---|---|---|---|---|---|---|---|---|
| g Branch borough | Boro | 3.19 | 482 | 20.1 | 15.8 | 40.1 | $10,422 | $26,053 | $28,125 | 49 |
| uston borough | Boro | 0.37 | 1445 | 19.9 | 20.9 | 38.1 | $11,043 | $21,591 | $27,407 | 175 |
| Donald borough | Boro | 0.32 | 1809 | 22.4 | 18.9 | 36.6 | $11,647 | $23,165 | $31,023 | 325 |
| dway borough | Boro | 0.44 | 1043 | 23.0 | 17.2 | 35.2 | $12,076 | $26,146 | $29,940 | 64 |
| rianna borough | Boro | 1.95 | 616 | 26.1 | 19.2 | 34.3 | $9,288 | $19,250 | $23,750 | 131 |
| en Hills borough | Boro | 0.92 | 21 | 28.6 | 14.3 | 35.3 | $17,771 | $50,927 | $50,927 | 0 |
| t Washington borough | Boro | 0.45 | 2126 | 19.3 | 16.5 | 34.5 | $20,184 | $30,427 | $43,929 | 231 |
| nlevy borough | Boro | 0.50 | 417 | 18.7 | 20.9 | 40.7 | $12,916 | $25,577 | $28,875 | 51 |
| o borough | Boro | 0.28 | 373 | 20.9 | 22.0 | 39.6 | $9,327 | $21,346 | $25,000 | 50 |
| leyville borough | Boro | 0.17 | 446 | 18.6 | 20.2 | 34.0 | $11,181 | $15,972 | $26,563 | 77 |
| sworth borough | Boro | 0.74 | 1048 | 19.9 | 26.8 | 41.1 | $9,481 | $18,214 | $22,969 | 188 |
| shington city | Boro | 2.94 | 15864 | 20.4 | 18.5 | 33.5 | $9,492 | $16,365 | $21,985 | 3755 |
| ilight borough | Boro | 1.61 | 252 | 17.1 | 17.1 | 39.6 | $11,487 | $22,857 | $30,455 | 14 |
| st Alexander borough | Boro | 0.18 | 301 | 26.9 | 18.6 | 37.8 | $8,589 | $19,821 | $21,875 | 27 |
| st Middletown borough | Boro | 0.41 | 166 | 19.3 | 19.3 | 37.6 | $13,043 | $27,917 | $29,625 | 11 |
| st Brownsville borough | Boro | 1.29 | 1170 | 21.4 | 19.1 | 37.8 | $9,181 | $17,750 | $22,262 | 196 |
| ckdale borough | Boro | 0.27 | 630 | 21.6 | 17.5 | 36.7 | $13,014 | $20,667 | $25,385 | 114 |
| v Eagle borough | Boro | 1.03 | 2172 | 19.3 | 20.6 | 39.0 | $11,273 | $22,188 | $27,589 | 183 |
| nongahela city | Boro | 1.93 | 4928 | 17.5 | 25.9 | 42.2 | $11,347 | $18,849 | $23,614 | 696 |
| rth Charleroi borough | Boro | 0.26 | 1562 | 18.4 | 25.6 | 41.7 | $10,715 | $18,311 | $24,583 | 302 |
| ers borough | Boro | 0.97 | 1284 | 17.4 | 23.3 | 42.4 | $14,487 | $30,107 | $33,125 | 58 |
| scoe borough | Boro | 0.20 | 872 | 16.6 | 25.1 | 43.4 | $11,454 | $21,417 | $28,333 | 108 |
| ysville borough | Boro | 0.31 | 962 | 27.8 | 21.4 | 35.5 | $8,848 | $20,694 | $27,159 | 177 |
| rgettstown borough | Boro | 0.62 | 1634 | 20.1 | 23.7 | 40.0 | $12,097 | $22,333 | $29,559 | 230 |
| al Center borough | Boro | 0.11 | 184 | 27.2 | 17.4 | 34.5 | $9,440 | $15,250 | $28,750 | 24 |
| ifornia borough | Boro | 11.03 | 5748 | 11.4 | 15.1 | 23.0 | $7,749 | $16,811 | $27,432 | 1314 |
| nonsburg borough | Boro | 2.33 | 9200 | 19.8 | 22.3 | 38.8 | $11,157 | $22,015 | $28,667 | 1107 |
| nterville borough | Boro | 13.25 | 3842 | 22.0 | 22.0 | 39.8 | $10,152 | $20,403 | $23,913 | 638 |
| arleroi borough | Boro | 0.77 | 5014 | 18.2 | 28.4 | 41.6 | $10,419 | $15,789 | $22,485 | 1095 |
| keburg borough | Boro | 0.36 | 724 | 20.7 | 23.3 | 40.1 | $12,183 | $22,500 | $31,250 | 69 |
| emston borough | Boro | 9.61 | 770 | 25.3 | 18.2 | 37.4 | $10,166 | $22,500 | $25,833 | 122 |
| nora borough | Boro | 1.90 | 5928 | 20.3 | 28.4 | 41.8 | $8,914 | $16,620 | $20,713 | 1416 |
| enport borough | Boro | 2.05 | 595 | 16.1 | 25.9 | 44.1 | $9,713 | $20,132 | $24,808 | 101 |
| ntleyville borough | Boro | 3.69 | 2673 | 22.9 | 24.1 | 37.8 | $9,632 | $18,080 | $23,902 | 558 |
| allsville borough | Boro | 2.43 | 530 | 26.4 | 12.6 | 35.0 | $10,930 | $27,125 | $31,250 | 62 |
| roughs | | 68.87 | 76831 | 19.6 | 21.6 | 38.0 | $10,485 | $22,148 | $27,802 | 13718 |
| shington County | | 857.14 | 204584 | 22.5 | 17.5 | 36.5 | $12,744 | $25,469 | $31,239 | 25412 |

URCE: CENSUS OF POPULATION & HOUSING, 1990

# LABOR FORCE OF WASHINGTON COUNTY MCD'S WITH AND WITHOUT COAL MINES

| ME | Coal Mine | Males over the Age of 16 Employed | Unemployed | UnempRate | Not in LF | LFPR | Females over the Age of 16 Employed | Unemployed | UnempRate | Not in LF | LFPR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| nsylvania | | 2952871 | 198697 | 6.3 | 1248442 | 71.6 | 2481661 | 146098 | 5.6 | 2346437 | 52.8 |
| well township | yes | 1108 | 69 | 5.9 | 348 | 77.2 | 720 | 49 | 6.4 | 826 | 48.2 |
| roll township | yes | 1478 | 96 | 6.1 | 898 | 63.7 | 1114 | 92 | 7.6 | 1420 | 45.9 |
| t Finley township | yes | 339 | 43 | 11.3 | 146 | 72.3 | 215 | 16 | 6.9 | 315 | 42.3 |
| owfield township | yes | 1183 | 102 | 7.9 | 685 | 65.2 | 860 | 105 | 10.9 | 1136 | 45.9 |
| th Bethlehem township | yes | 442 | 31 | 6.6 | 233 | 67.0 | 338 | 22 | 6.1 | 366 | 49.6 |
| th Strabane township | yes | 2161 | 136 | 5.9 | 885 | 72.2 | 1789 | 74 | 4.0 | 1567 | 54.3 |
| tingham township | yes | 628 | 43 | 6.4 | 220 | 75.3 | 470 | 25 | 5.1 | 411 | 54.6 |
| nerset township | yes | 756 | 77 | 9.2 | 310 | 72.9 | 497 | 40 | 7.4 | 592 | 47.6 |
| th Strabane township | yes | 1892 | 71 | 3.6 | 770 | 71.8 | 1391 | 64 | 4.4 | 1947 | 42.8 |
| st Finley township | yes | 249 | 22 | 8.1 | 87 | 75.7 | 133 | 21 | 13.6 | 194 | 44.3 |
| h Coal Mine | | 10236 | 690 | 6.3 | 4582 | 70.5 | 7527 | 508 | 6.3 | 8774 | 47.8 |
| ine township | no-t | 160 | 23 | 12.6 | 79 | 69.8 | 137 | 4 | 2.8 | 115 | 55.1 |
| falo township | no-t | 586 | 25 | 4.1 | 205 | 74.9 | 387 | 18 | 4.4 | 441 | 47.9 |
| ton township | no-t | 2210 | 209 | 8.6 | 983 | 71.1 | 1872 | 130 | 6.5 | 1953 | 50.6 |
| il township | no-t | 2188 | 88 | 3.9 | 1198 | 65.5 | 1751 | 77 | 4.2 | 1737 | 51.3 |
| rtiers township | no-t | 1759 | 85 | 4.6 | 1036 | 64.0 | 1577 | 55 | 3.4 | 1684 | 49.2 |
| ss Creek township | no-t | 432 | 38 | 8.1 | 200 | 70.1 | 302 | 30 | 9.0 | 330 | 50.2 |
| egal township | no-t | 582 | 69 | 10.6 | 275 | 70.3 | 407 | 38 | 8.5 | 462 | 49.1 |
| t Bethlehem township | no-t | 454 | 102 | 18.3 | 435 | 56.1 | 329 | 40 | 10.8 | 788 | 31.9 |
| over township | no-t | 716 | 90 | 11.2 | 365 | 68.8 | 443 | 38 | 7.9 | 644 | 42.8 |
| ewell township | no-t | 272 | 18 | 6.2 | 60 | 82.9 | 184 | 8 | 4.2 | 160 | 54.5 |
| ependence township | no-t | 433 | 30 | 6.5 | 252 | 64.8 | 254 | 46 | 15.3 | 426 | 41.3 |
| erson township | no-t | 301 | 14 | 4.4 | 153 | 67.3 | 230 | 5 | 2.1 | 265 | 47.0 |
| rris township | no-t | 321 | 15 | 4.5 | 84 | 80.0 | 224 | 17 | 7.1 | 198 | 54.9 |
| unt Pleasant township | no-t | 967 | 41 | 4.1 | 324 | 75.7 | 676 | 38 | 5.3 | 700 | 50.5 |
| th Franklin township | no-t | 1157 | 86 | 6.9 | 515 | 70.7 | 913 | 13 | 1.4 | 1306 | 41.5 |
| ers township | no-t | 4146 | 135 | 3.2 | 1121 | 79.2 | 2771 | 108 | 3.8 | 2835 | 50.4 |
| inson township | no-t | 536 | 36 | 6.3 | 245 | 70.0 | 411 | 24 | 5.5 | 439 | 49.8 |
| th township | no-t | 1040 | 200 | 16.1 | 622 | 66.6 | 772 | 71 | 8.4 | 1171 | 41.9 |
| th Franklin township | no-t | 883 | 120 | 12.0 | 231 | 81.3 | 655 | 57 | 8.0 | 676 | 51.3 |
| on township | no-t | 1633 | 99 | 5.7 | 674 | 72.0 | 1274 | 64 | 4.8 | 1249 | 51.7 |
| st Bethlehem township | no-t | 334 | 47 | 12.3 | 228 | 62.6 | 231 | 25 | 9.8 | 389 | 39.7 |
| st Pike Run township | no-t | 373 | 48 | 11.4 | 295 | 58.8 | 264 | 16 | 5.7 | 450 | 38.4 |
| hout Coal Mine | | 21483 | 1618 | 7.0 | 9580 | 70.7 | 16064 | 922 | 5.4 | 18418 | 48.0 |

· Une

· Census of Population and Housing, 1990 'd

## LABOR FORCE OF WASHINGTON COUNTY MCD'S WITH AND WITHOUT COAL MINES

| | | Males over the Age of 16 | | | | | Females over the Age of 16 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ME | Coal Mine | Employed | Unemployed | UnempRate | Not in LF | LFPR | Employed | Unemployed | UnempRate | Not in LF | LFPR | Une |
| nport borough | b | 115 | 16 | 12.2 | 120 | 52.2 | 73 | 8 | 9.9 | 198 | 29.0 | |
| lsville borough | b | 110 | 24 | 17.9 | 53 | 71.7 | 90 | 14 | 13.5 | 113 | 47.9 | |
| leyville borough | b | 494 | 61 | 11.0 | 396 | 58.4 | 336 | 50 | 13.0 | 787 | 32.9 | |
| gettstown borough | b | 352 | 36 | 9.3 | 228 | 63.0 | 271 | 27 | 9.1 | 431 | 40.9 | |
| fornia borough | b | 1098 | 121 | 9.9 | 1209 | 50.2 | 1073 | 62 | 5.5 | 1638 | 40.9 | |
| onsburg borough | b | 2030 | 113 | 5.3 | 1216 | 63.8 | 1926 | 90 | 4.5 | 2298 | 46.7 | |
| terville borough | b | 690 | 90 | 11.5 | 668 | 53.9 | 451 | 69 | 13.3 | 1123 | 31.6 | |
| rleroi borough | b | 885 | 162 | 15.5 | 734 | 58.8 | 839 | 90 | 9.7 | 1515 | 38.0 | |
| sville borough | b | 163 | 18 | 9.9 | 138 | 56.7 | 143 | 10 | 6.5 | 272 | 36.0 | |
| l Center borough | b | 34 | 2 | 5.6 | 40 | 47.4 | 34 | 0 | 0.0 | 35 | 49.3 | |
| eburg borough | b | 172 | 8 | 4.4 | 112 | 61.6 | 108 | 14 | 11.5 | 189 | 39.2 | |
| mston borough | b | 156 | 18 | 10.3 | 120 | 59.2 | 117 | 10 | 7.9 | 194 | 39.6 | |
| ora borough | b | 918 | 218 | 19.2 | 932 | 54.9 | 800 | 127 | 13.7 | 1865 | 33.2 | |
| levy borough | b | 102 | 10 | 8.9 | 57 | 66.3 | 74 | 7 | 8.6 | 110 | 42.4 | |
| Washington borough | b | 554 | 40 | 6.7 | 217 | 73.2 | 488 | 20 | 3.9 | 439 | 53.6 | |
| borough | b | 80 | 6 | 7.0 | 45 | 65.6 | 55 | 6 | 9.8 | 112 | 35.3 | |
| worth borough | b | 196 | 33 | 14.4 | 172 | 57.1 | 155 | 16 | 9.4 | 294 | 36.8 | |
| eyville borough | b | 122 | 17 | 12.2 | 46 | 75.1 | 107 | 4 | 3.6 | 78 | 58.7 | |
| en Hills borough | b | 7 | 0 | 0.0 | 0 | 100.0 | 4 | 0 | 0.0 | 1 | 80.0 | |
| ston borough | b | 350 | 20 | 5.4 | 157 | 70.2 | 271 | 22 | 7.5 | 371 | 44.1 | |
| g Branch borough | b | 111 | 8 | 6.7 | 69 | 63.3 | 69 | 14 | 16.9 | 127 | 39.5 | |
| ianna borough | b | 85 | 37 | 30.3 | 107 | 53.3 | 86 | 17 | 16.5 | 143 | 41.9 | |
| Donald borough | b | 421 | 9 | 2.1 | 164 | 72.4 | 419 | 17 | 3.9 | 363 | 54.6 | |
| way borough | b | 250 | 26 | 9.4 | 109 | 71.7 | 189 | 11 | 5.5 | 249 | 44.5 | |
| Eagle borough | b | 478 | 54 | 10.2 | 323 | 62.2 | 401 | 30 | 7.0 | 511 | 45.8 | |
| th Charleroi borough | b | 286 | 42 | 12.8 | 237 | 58.1 | 231 | 18 | 7.2 | 499 | 33.3 | |
| coe borough | b | 189 | 16 | 7.8 | 133 | 60.7 | 137 | 9 | 6.2 | 265 | 35.5 | |
| ers borough | b | 302 | 26 | 7.9 | 180 | 64.6 | 256 | 18 | 6.6 | 302 | 47.6 | |
| kdale borough | b | 127 | 27 | 17.5 | 92 | 62.6 | 110 | 6 | 5.2 | 141 | 45.1 | |
| light borough | b | 63 | 6 | 8.7 | 32 | 68.3 | 44 | 2 | 4.3 | 57 | 44.7 | |
| t Alexander borough | b | 55 | 0 | 0.0 | 50 | 52.4 | 43 | 0 | 0.0 | 69 | 38.4 | |
| t Brownsville borough | b | 225 | 46 | 17.0 | 175 | 60.8 | 178 | 33 | 15.6 | 299 | 41.4 | |
| t Middletown borough | b | 54 | 4 | 6.9 | 17 | 77.3 | 22 | 2 | 8.3 | 44 | 35.3 | |
| ongahela city | c | 923 | 148 | 13.8 | 786 | 57.7 | 832 | 79 | 8.7 | 1411 | 39.2 | |
| hington city | c | 3022 | 443 | 12.8 | 2400 | 59.1 | 2714 | 304 | 10.1 | 4120 | 42.3 | |
| ough | | 15219 | 1905 | 11.1 | 11534 | 59.8 | 13146 | 1206 | 8.4 | 20663 | 41.0 | |
| hington County | | 46938 | 4213 | 8.2 | 25696 | 66.6 | 36737 | 2636 | 6.7 | 47855 | 45.1 | |

rce: Census of Population and Housing, 1990

## EMPLOYMENT BY INDUSTRY FOR MCD'S WITH AND WITHOUT COAL MINES, 1990
### WASHINGTON COUNTY

| | | | | | | PERCENTAGE OF TOTAL EMPLOYMENT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ME | Coal Mine | AGRIC | MINING | CONST | MANUF | TRANSPORT | COMM, PU | WH TRADE | RE TRADE | FIRE | SERVI |
| nsylvania | | 1.8 | 0.6 | 6.1 | 20.0 | 4.4 | 2.5 | 4.3 | 17.1 | 6.5 | |
| well township | yes | 0.0 | 1.1 | 7.4 | 30.9 | 3.2 | 0.0 | 2.7 | 17.6 | 1.1 | |
| roll township | yes | 2.6 | 3.6 | 7.2 | 21.0 | 6.6 | 3.8 | 3.3 | 24.5 | 2.1 | |
| : Finley township | yes | 1.5 | 4.5 | 6.0 | 12.5 | 6.0 | 2.0 | 4.5 | 17.0 | 5.0 | |
| owfield township | yes | 3.7 | 6.3 | 5.7 | 17.0 | 6.5 | 4.5 | 4.3 | 20.2 | 3.3 | |
| th Bethlehem township | yes | 2.0 | 0.7 | 5.7 | 21.2 | 3.7 | 4.0 | 4.0 | 25.9 | 4.4 | |
| th Strabane township | yes | 2.4 | 1.4 | 7.1 | 23.1 | 4.8 | 2.6 | 3.2 | 20.7 | 2.6 | |
| tingham township | yes | 0.0 | 1.0 | 5.6 | 18.0 | 8.5 | 1.3 | 3.2 | 21.2 | 4.8 | |
| nerset township | yes | 1.6 | 1.1 | 8.0 | 4.5 | 1.8 | 1.7 | 2.9 | 20.8 | 2.0 | |
| th Strabane township | yes | 0.8 | 1.4 | 6.3 | 20.0 | 3.6 | 1.0 | 4.1 | 21.9 | 4.0 | |
| st Finley township | yes | 1.5 | 1.9 | 6.1 | 23.8 | 5.4 | 1.8 | 4.7 | 23.0 | 3.4 | |
| h Coal Mine | | 1.6 | 2.0 | 6.6 | 18.9 | 4.7 | 2.0 | 3.9 | 22.1 | 3.2 | |
| ne township | no-t | 0.8 | 1.2 | 7.3 | 17.4 | 6.8 | 2.6 | 5.6 | 17.6 | 3.6 | |
| falo township | no-t | 1.1 | 1.3 | 12.4 | 16.8 | 4.3 | 2.2 | 6.7 | 18.3 | 5.4 | |
| ton township | no-t | 0.3 | 4.4 | 6.4 | 15.6 | 5.1 | 4.1 | 3.9 | 19.2 | 1.2 | |
| il township | no-t | 0.4 | 0.4 | 4.6 | 20.7 | 2.5 | 2.0 | 3.9 | 23.4 | 3.0 | |
| rtiers township | no-t | 2.4 | 1.7 | 7.3 | 18.7 | 3.9 | 2.2 | 4.8 | 15.1 | 7.3 | |
| ss Creek township | no-t | 1.3 | 1.6 | 8.5 | 10.5 | 7.2 | 4.6 | 4.2 | 24.2 | 2.3 | |
| negal township | no-t | 0.0 | 0.0 | 13.2 | 10.3 | 2.9 | 0.0 | 4.4 | 16.2 | 0.0 | |
| t Bethlehem township | no-t | 0.0 | 15.7 | 7.5 | 23.6 | 2.5 | 2.5 | 2.5 | 18.2 | 3.2 | |
| nover township | no-t | 4.8 | 2.9 | 9.8 | 25.9 | 4.5 | 2.7 | 3.4 | 14.9 | 4.0 | |
| pewell township | no-t | 4.4 | 4.8 | 7.0 | 10.6 | 3.7 | 2.2 | 5.9 | 11.7 | 6.2 | |
| ependence township | no-t | 4.0 | 0.9 | 9.2 | 16.0 | 7.6 | 3.5 | 4.8 | 20.8 | 3.1 | |
| ferson township | no-t | 0.0 | 1.7 | 6.2 | 17.3 | 2.5 | 2.9 | 3.4 | 21.1 | 4.4 | |
| rris township | no-t | 1.7 | 1.1 | 4.5 | 19.9 | 6.8 | 4.0 | 2.8 | 25.0 | 4.5 | |
| unt Pleasant township | no-t | 2.0 | 7.9 | 8.6 | 11.4 | 3.3 | 2.7 | 1.7 | 21.2 | 3.7 | |
| rth Franklin township | no-t | 5.1 | 0.7 | 9.4 | 21.8 | 6.1 | 0.2 | 4.2 | 20.8 | 3.1 | |
| ers township | no-t | 0.8 | 2.6 | 5.7 | 13.0 | 2.5 | 1.0 | 5.0 | 17.9 | 6.9 | |
| binson township | no-t | 0.0 | 3.7 | 8.9 | 22.2 | 4.4 | 0.0 | 3.0 | 26.7 | 3.7 | |
| ith township | no-t | 1.1 | 11.7 | 6.3 | 11.7 | 6.8 | 0.6 | 4.0 | 19.9 | 2.0 | |
| ith Franklin township | no-t | 1.6 | 4.1 | 8.4 | 21.4 | 3.1 | 5.8 | 5.8 | 18.1 | 2.9 | |
| on township | no-t | 0.0 | 1.7 | 8.7 | 16.2 | 4.4 | 1.3 | 0.9 | 27.1 | 5.2 | |
| st Bethlehem township | no-t | 0.0 | 0.0 | 36.4 | 36.4 | 0.0 | 0.0 | 0.0 | 27.3 | 0.0 | |
| st Pike Run township | no-t | 0.6 | 1.6 | 3.1 | 28.3 | 12.9 | 3.3 | 0.9 | 23.7 | 4.6 | |
| hout Coal Mine | | 1.5 | 2.4 | 7.9 | 18.3 | 4.7 | 2.7 | 4.6 | 19.0 | 4.4 | |

: Census of Population and Housing, 1990 t'd

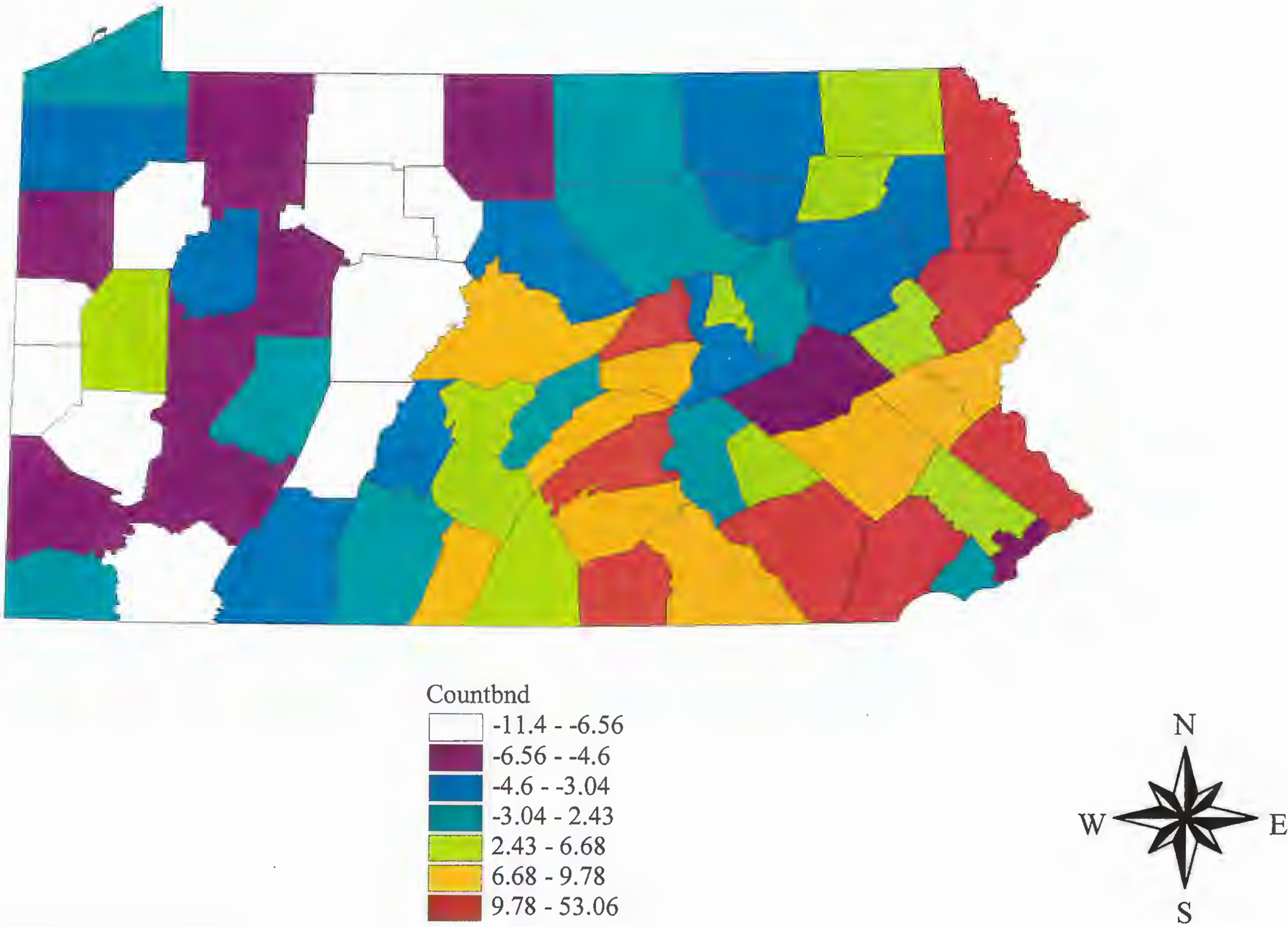
# EMPLOYMENT BY INDUSTRY FOR MCD'S WITH AND WITHOUT COAL MINES, 1990

## WASHINGTON COUNTY

| | | PERCENTAGE OF TOTAL EMPLOYMENT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ME | Coal Mine | AGRIC | MINING | CONST | MANUF | TRANSPORT | COMM, PU | WH TRADE | RE TRADE | FIRE | SERV |
| nport borough | b | 12.9 | 0.4 | 9.4 | 21.5 | 8.1 | 3.3 | 2.2 | 13.8 | 2.9 | |
| llsville borough | b | 2.3 | 1.8 | 7.1 | 17.7 | 2.1 | 4.7 | 3.2 | 18.2 | 6.3 | |
| tleyville borough | b | 5.4 | 2.0 | 13.0 | 23.7 | 3.5 | 2.2 | 2.8 | 14.1 | 3.2 | |
| gettstown borough | b | 3.4 | 3.2 | 7.0 | 27.3 | 7.5 | 0.8 | 5.5 | 16.4 | 3.6 | |
| fornia borough | b | 0.0 | 1.1 | 12.2 | 23.9 | 2.8 | 2.2 | 7.2 | 16.7 | 5.6 | |
| onsburg borough | b | 1.4 | 1.5 | 3.1 | 21.8 | 6.7 | 1.2 | 2.1 | 18.7 | 8.9 | |
| terville borough | b | 1.8 | 7.6 | 8.2 | 12.3 | 2.3 | 1.2 | 5.3 | 15.2 | 5.3 | |
| rleroi borough | b | 0.2 | 2.1 | 6.8 | 21.2 | 7.1 | 2.7 | 4.1 | 17.8 | 6.6 | |
| ysville borough | b | 1.1 | 2.1 | 9.4 | 15.9 | 4.8 | 3.1 | 3.0 | 17.0 | 4.7 | |
| l Center borough | b | 7.9 | 2.2 | 8.6 | 18.0 | 4.2 | 2.4 | 5.3 | 14.5 | 3.5 | |
| eburg borough | b | 2.4 | 3.2 | 11.3 | 18.7 | 10.1 | 3.2 | 2.8 | 18.1 | 5.0 | |
| emston borough | b | 1.3 | 2.3 | 8.8 | 14.8 | 4.6 | 5.9 | 4.4 | 24.1 | 5.2 | |
| nora borough | b | 3.3 | 6.3 | 7.7 | 16.0 | 5.4 | 2.9 | 4.2 | 20.0 | 2.3 | |
| nlevy borough | b | 0.0 | 1.9 | 7.0 | 13.5 | 4.3 | 4.3 | 2.9 | 24.2 | 5.0 | |
| t Washington borough | b | 0.6 | 2.1 | 4.3 | 20.4 | 3.6 | 1.9 | 6.8 | 19.5 | 6.0 | |
| borough | b | 1.8 | 1.7 | 8.4 | 16.7 | 4.7 | 1.6 | 5.0 | 20.8 | 7.9 | |
| worth borough | b | 2.7 | 3.0 | 13.9 | 13.8 | 4.9 | 3.6 | 3.9 | 17.9 | 6.4 | |
| eyville borough | b | 1.7 | 2.1 | 8.3 | 15.3 | 3.5 | 1.9 | 6.4 | 17.5 | 8.6 | |
| en Hills borough | b | 3.1 | 1.9 | 7.6 | 20.9 | 8.9 | 3.1 | 6.0 | 17.5 | 3.3 | |
| ston borough | b | 0.0 | 0.6 | 6.7 | 22.1 | 5.2 | 1.2 | 4.0 | 21.5 | 5.2 | |
| g Branch borough | b | 2.1 | 1.6 | 5.8 | 24.2 | 10.9 | 3.0 | 4.6 | 22.4 | 4.1 | |
| rianna borough | b | 8.5 | 4.5 | 8.5 | 14.6 | 8.9 | 3.8 | 5.4 | 17.0 | 3.0 | |
| Donald borough | b | 0.6 | 4.4 | 5.4 | 21.5 | 6.0 | 1.4 | 4.0 | 20.6 | 4.2 | |
| lway borough | b | 1.2 | 1.7 | 5.8 | 20.2 | 4.0 | 2.0 | 5.4 | 18.7 | 4.3 | |
| v Eagle borough | b | 0.9 | 1.1 | 4.7 | 18.5 | 2.9 | 2.7 | 3.4 | 24.0 | 9.9 | |
| th Charleroi borough | b | 0.0 | 1.7 | 4.6 | 28.3 | 8.4 | 0.0 | 8.0 | 20.7 | 1.3 | |
| coe borough | b | 0.0 | 1.9 | 1.9 | 18.7 | 9.3 | 7.5 | 7.5 | 19.6 | 0.9 | |
| ers borough | b | 1.3 | 2.6 | 10.0 | 13.9 | 6.2 | 4.2 | 4.9 | 21.3 | 6.3 | |
| ckdale borough | b | 0.9 | 0.7 | 4.0 | 17.1 | 3.8 | 2.7 | 4.3 | 21.0 | 3.1 | |
| light borough | b | 2.0 | 0.0 | 9.2 | 19.4 | 20.4 | 0.0 | 5.1 | 13.3 | 2.0 | |
| st Alexander borough | b | 2.8 | 5.7 | 6.9 | 18.9 | 6.0 | 1.9 | 4.1 | 18.4 | 2.8 | |
| st Brownsville borough | b | 0.0 | 3.2 | 5.7 | 16.4 | 9.7 | 1.2 | 4.2 | 20.8 | 1.5 | |
| st Middletown borough | b | 11.3 | 1.8 | 8.1 | 21.7 | 10.5 | 6.0 | 2.1 | 10.5 | 2.1 | |
| nongahela city | c | 2.6 | 0.0 | 10.5 | 31.6 | 9.2 | 0.0 | 2.6 | 14.5 | 0.0 | |
| shington city | c | 1.4 | 6.1 | 7.8 | 19.6 | 4.2 | 3.9 | 4.1 | 15.9 | 1.6 | |
| ough | | 2.0 | 2.2 | 7.4 | 17.9 | 5.3 | 2.6 | 4.8 | 19.2 | 5.4 | |
| shington County | | 1.8 | 2.2 | 7.4 | 18.2 | 5.0 | 2.5 | 4.6 | 19.6 | 4.7 | |

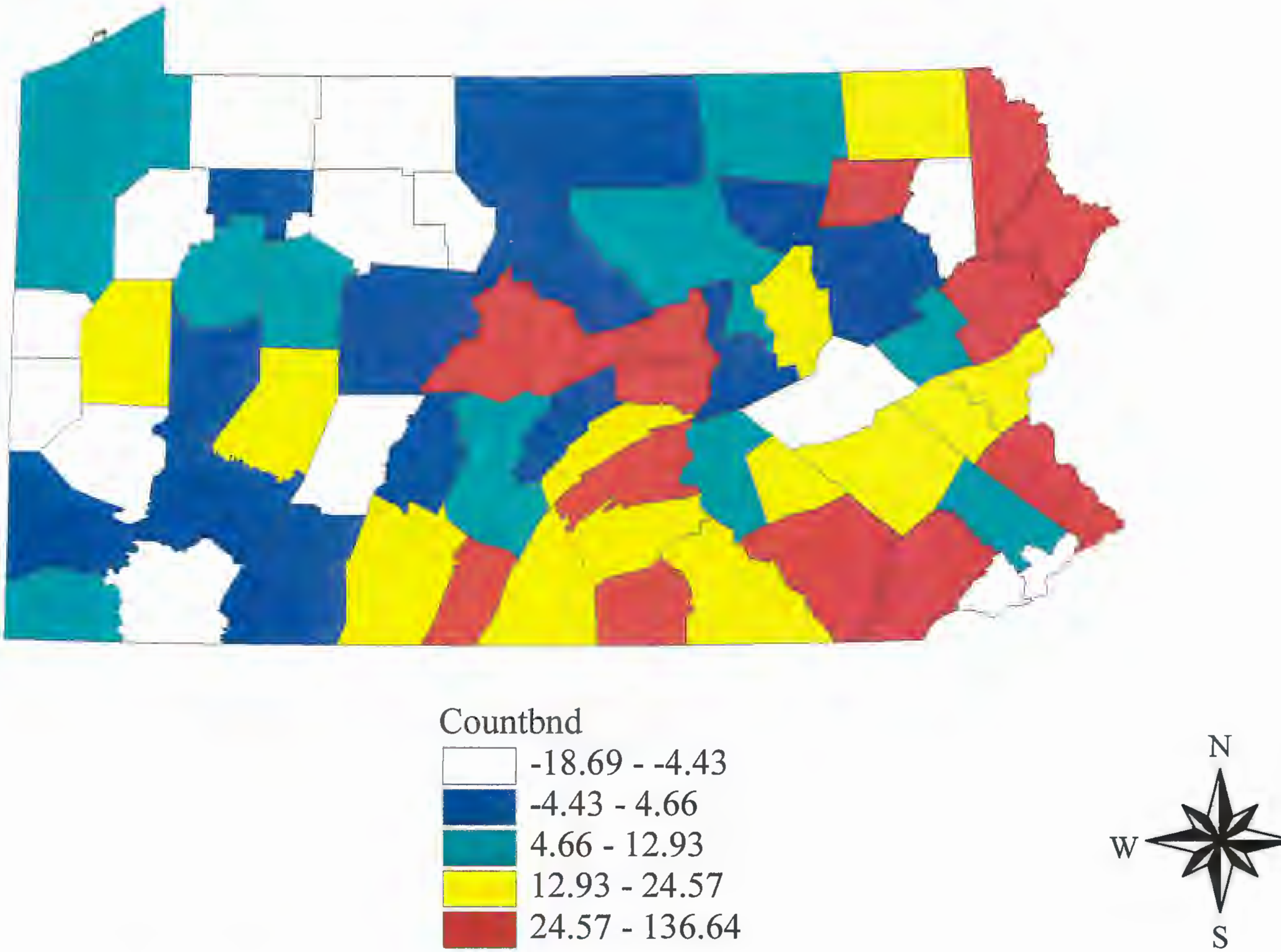
rce: Census of Population and Housing, 1990

# Percentage Change in Population, 1980 -- 1990



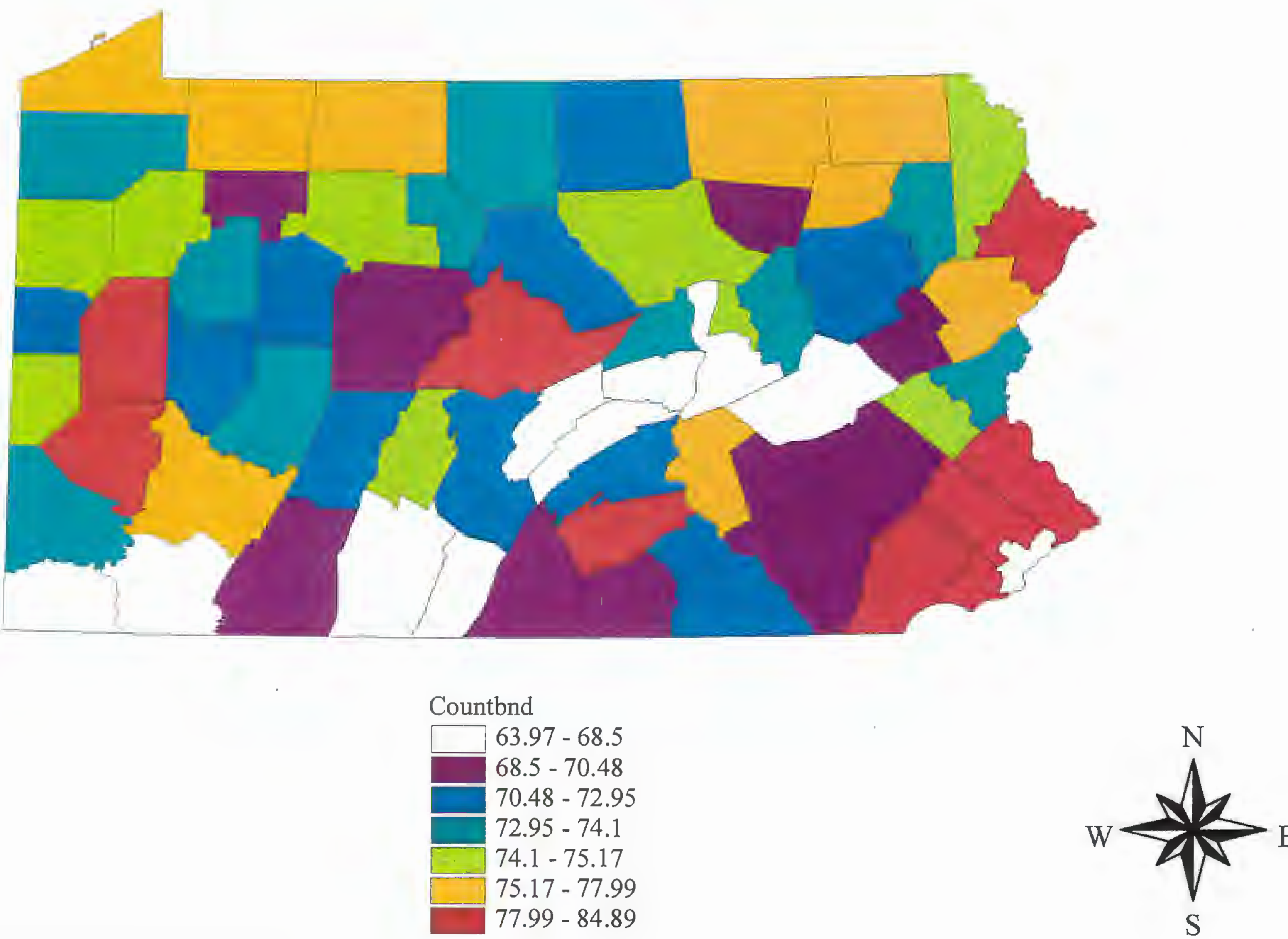

of Population and Housing, 1990

# Percent Change in Population, 1970 -- 1990




nsus of Population and Housing, 1990

# High School Grads as a Percent of Persons Over 25, 1990




s of Population and Housing, 1990

# CHAPTER 10

# LONGWALL MINING IN SOUTHWESTERN PENNSYLVANIA: PERCEPTIONS OF NEAR-BY RESIDENTS

Thomas B. Barley
Thomas B. Barley & Associates
Pittsburgh, Pennsylvania

and

Gordon Lewis, Ph.D.
Carnegie Mellon University
Pittsburgh, Pennsylvania

## 1.0 INTRODUCTION

The objective of this study is to find out what effects, if any, longwall mining has on the lives of residents who live near areas where longwall mining is utilized. This study uses discussion groups which were assembled for the purpose of learning residents' opinions and reactions to longwall mining.

## 2.0 SCOPE OF THIS STUDY

There are two characteristics of the present study that are important to emphasize: First, because the purpose of this study is to explore possible effects on people who have experience with longwall mining, the residents were drawn from the areas within the counties where longwall mining is being or has been used. As a result, although the characteristics of the people who participated are very similar to the characteristics of the population of the counties from which they come, the opinions of those who participated in this study are not necessarily representative of the population of Washington or Greene counties as a whole. What makes these participants different from a random set of people from their county is that they all live near or over a longwall mine.

Second, both of the discussion groups were necessarily limited in size so that each of the people would have a chance to speak. Because the number of participants was limited, this report focuses on the issues that were raised and not on the number of times an issue was cited or the proportion of people who mentioned an issue. Measuring prevalence within a population requires a more extensive study, but the value of in-depth discussions of the type described here is that one gets a sense of the breadth of issues, the kinds of experiences that individual residents have had.

Before presenting results, the report begins with a description of the way in which participants were selected and the way in which the discussion groups were conducted.

## 3.0 METHODOLOGY

The basic methodology of this study utilizes focus groups. The rationale for using focus groups and the procedures used for assembling the focus groups are explained in Sections 3.1 through 3.4.

Section 3.5 explores the extent to which the focus groups that actually occurred were similar or dissimilar to the populations in the counties from which the participants came. Sections 3.6 and 3.7 describe the conduct of the focus groups and the manner in which the information was analyzed.

## 3.1 FOCUS GROUPS

Focus groups are routinely used in exploratory social research where the concern is to determine how a population perceives an idea or an event. Focus groups consist of a number of people who are brought together by a facilitator to discuss a set of issues. The role of the facilitator is to present the focal issue, to give free rein to the participants, and to bring them back to the issue they were discussing if the speakers begin to digress.

Professionally trained facilitators typically use a study guide, which lists sub-issues to be explored through non-directive probes if needed. Copies of the study guides for the current study are contained in Appendices A and B. The methodology involved in assembling the residents' focus groups for this study is explained in the following sections.

## 3.2 IDENTIFYING THE AREAS OF INTEREST

The first step in assembling the focus groups from Greene and Washington counties was to identify the geographic areas of interest, the areas in which longwall mining had occurred, is presently occurring, or is scheduled to occur. In both counties, the specific geographic sites of longwall mining were estimated from a map of coal mine holdings produced by the Bureau of Deep Mine Safety (c. 1996), supplemented with information about current activity obtained through discussions with people from Washington and Greene counties.

A list of the actual streets and roads within the target areas was developed by transferring the mining areas from the mine map onto a Street and Road Atlas of Southwestern Pennsylvania (Rand McNally). Using the Rand Street Atlas, the investigators identified the specific streets and roads in proximity to longwall mining operations.

### 3.3 CONSTRUCTION OF SAMPLE FRAMES

For Washington County, the sample frame, a list of potential participants, was developed by locating the listed streets and roads in a Dickerson Criss-cross Directory. Criss-cross directories are organized by place and make it possible to locate residents who live on specific streets or roads. Using the eight rural roads and 12 suburban streets identified from the maps, a sample frame of 112 residents was created for Washington County.

In Greene County, no criss-cross directories were available, so an alternative procedure was developed. Rural roads were identified using the methodology outlined in Section 3.2. Then the telephone directory for Greene County was scanned for residents who lived on the relevant roads until 100 names were obtained. The names that were found represented all of the 11 roads which had been identified from the maps as roads in proximity to longwall mining.

The sample frame of mental health professionals practicing in Washington or Greene counties was compiled from lists of practitioners provided by mental health agencies in those counties. The sample frame contained 26 names of practitioners affiliated with mental health agencies.

### 3.4 RECRUITING PROCEDURE

Telephone calls were made to every resident member of both the Washington and Greene county sample frames as well as all members of the mental health professional sample frame. Table 1 shows the number of people who were called, the number who agreed to come to a focus group, and the number who actually attended. It also shows the percent of those called who said they would come, and the percent of those who said they would come who showed up.

**TABLE 1**
**FOCUS GROUP RECRUITING RESULTS**

| COUNTY/ GROUP | SAMPLE FRAME | PHONE CALLS | ACCEPTED (% YIELD) | SHOWED (% YIELD) |
|---|---|---|---|---|
| Washington | 112 | 112 | 14 (12.5%) | 10 (71%) |
| Greene | 100 | 100 | 12 (12.0%) | 11 (92%) |
| Mental Health | 26 | 26 | 4 (15.4%) | 2 (50%) |

The percent who said they would come was quite consistent for the Washington residents, Greene residents, and mental health professionals: 12.5%, 12.0%, and 15.4%, respectively. The percent who actually showed up for the focus group was 71%, 92%, and 50%, respectively. Typically, from 70 to 75 percent of those who are scheduled for a focus group show up. The results for Washington County are obviously within that range. The results for Greene County are higher than customary, though the difference is not statistically significant. The percent of mental health professionals who showed up is lower than expected, although the difference is not statistically significant.

## 3.5 DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

The preceding section described the procedures that were followed in assembling the focus groups. The purpose of this section is to compare the demographic characteristics of those who participated in the focus groups with the demographic characteristics of the populations of the counties in which the participants live.

Before describing the comparisons, a few words of explanation are needed. The data for Greene and Washington counties come from the 1990 Decennial Census (U.S. Bureau of the Census). One of the characteristics that will be noticed in Tables 2 and 3 is that the number of people varies by characteristic. For income and size of household, the numbers are based on "households" for which in 1990 there were 14,585 in Greene County. For gender, the number is based on all people in the county, 39,550. Education is based on those age 25 and older, and marital status is based on persons age 15 and over. The Bureau of Census reports age for all persons, but in Tables 2 and 3 we have included only those 20 years old or over, because those below age 20 were not invited as participants for the focus groups.

Table 2 compares the population of Greene County and the focus group from Greene County on each of the six characteristics. The columns present the characteristics, the number (N) of persons in that category for the county as a whole, the percent of the relevant population in that category, and the expected number of persons with that characteristic if 11 people, the number of people in the Greene County focus group, were drawn at random from the population as a whole. The expected numbers were rounded to the closest integer. Because of rounding, the sum of the integers does not always equal the total number of expected cases.

The first comparison in Table 2 shows that one would expect six of the focus group members to be less than 50 years old; eight of the actual focus group members were. The difference is not large, however, and like all of the comparisons to be seen in Tables 2 and 3, is sufficiently small that it could have arisen by chance. There are no major differences for any of the characteristics in Table 2. Income, education, marital status, and gender all appear reasonably close to what one would have expected from a random selection of 11 people from the population. Household size is a little different, and it may reflect a pattern of families with children being more likely to live in the rural areas than for younger singles, widows, or elderly. Even here, however, the difference in the distribution is not statistically significant.

Table 3 shows similar results when Washington County as a whole is compared to the Washington County focus group. There is one comparison that stands out as being possibly noteworthy, and that is the age distribution. The focus group had no one under age 40, whereas the expected number of people from 20 to 39 years old is 4 out of 10. Eight of the focus group participants were from 40 to 59 years old, and only 3 were expected to be in that range. Again, however, even this difference is not significant.

In conclusion, the processes used to identify and invite residents for the focus groups produced two groups that appear representative of the counties in which they live.

**TABLE 2**

**GREENE COUNTY**

| 1990 Census Focus Group | | | | |
|---|---|---|---|---|
| **Characteristic** | **N** | **Percent** | **Expected** | **Actual** |
| Age | | | | |
| 20-29 | 5,107 | 18.22 | 2 | 0 |
| 30-39 | 6,261 | 22.34 | 2 | 4 |
| 40-49 | 4,956 | 17.69 | 2 | 4 |
| 50-59 | 3,369 | 12.02 | 1 | 1 |
| 60-69 | 3,647 | 13.01 | 1 | 2 |
| 70+ | 4,683 | 16.71 | 2 | 0 |
| Total | 28,023 | 100.00 | 11 | 11 |
| Income ($) | | | | |
| <200,000 | 7,327 | 50.24 | 6 | 4 |
| 20,000-29,999 | 2,443 | 16.75 | 2 | 3 |
| 30,000-39,999 | 1,886 | 12.93 | 1 | 1 |
| 40,000-49,999 | 1,294 | 8.87 | 1 | 1 |
| 50,000+ | 1,635 | 11.21 | 1 | 2 |
| Total | 14,585 | 100.00 | 11 | 11 |
| Education | | | | |
| LT High School | 8,151 | 32.00 | 4 | 0 |
| High School | 11,061 | 43.42 | 5 | 6 |
| Some College | 3,375 | 13.25 | 1 | 2 |
| College Grad. | 1,827 | 7.17 | 1 | 2 |
| Grad. School | 1,059 | 4.16 | 0 | 1 |
| Total | 25,473 | 100.00 | 11 | 11 |
| Marital Status | | | | |
| Single | 7,152 | 22.87 | 3 | 2 |
| Married | 18,740 | 59.91 | 7 | 7 |
| Divorced | 2,184 | 6.98 | 1 | 2 |
| Widowed | 3,203 | 10.24 | 1 | 0 |
| Total | 31,279 | 100.00 | 11 | 11 |
| Household Size | | | | |
| 1 | 3,547 | 24.32 | 3 | 0 |
| 2 | 4,541 | 31.13 | 3 | 4 |
| 3 | 2,667 | 18.29 | 2 | 0 |
| 4 | 2,299 | 15.76 | 2 | 5 |
| 5 | 1,110 | 7.61 | 1 | 2 |
| 6+ | 421 | 2.89 | 0 | 0 |
| Total | 14,585 | 100.00 | 11 | 11 |
| Gender | | | | |
| Female | 20,736 | 52.43 | 6 | 5 |
| Male | 18,814 | 47.57 | 5 | 6 |
| Total | 39,550 | 100.00 | 11 | 11 |

TABLE 3

WASHINGTON COUNTY

| 1990 Census Focus Group | | | | |
|---|---|---|---|---|
| **Characteristic** | **N** | **Percent** | **Expected** | **Actual** |
| Age | | | | |
| 20-29 | 25,781 | 16.93 | 2 | 0 |
| 30-39 | 35,532 | 21.37 | 2 | 0 |
| 40-49 | 26,226 | 17.22 | 2 | 3 |
| 50-59 | 20,277 | 13.32 | 1 | 5 |
| 60-69 | 23,323 | 15.32 | 2 | 0 |
| 70+ | 24,125 | 15.84 | 2 | 2 |
| Total | 152,264 | 100.00 | 10 | 10 |
| Income ($) | | | | |
| <200,000 | 31,256 | 39.71 | 4 | 2 |
| 20,000-29,999 | 14,020 | 17.81 | 2 | 3 |
| 30,000-39,999 | 11,621 | 14.77 | 1 | 3 |
| 40,000-49,999 | 8,012 | 10.18 | 1 | 0 |
| 50,000+ | 13,796 | 17.53 | 2 | 2 |
| Total | 78,705 | 100.00 | 10 | 10 |
| Education | | | | |
| LT High School | 37,412 | 26.78 | 3 | 1 |
| High School | 59,055 | 42.27 | 4 | 3 |
| Some College | 24,207 | 17.33 | 2 | 2 |
| College Grad. | 12,431 | 8.90 | 1 | 3 |
| Grad. School | 6,610 | 4.73 | 0 | 1 |
| Total | 139,715 | 100.00 | 10 | 10 |
| Marital Status | | | | |
| Single | 39,658 | 24.25 | 2 | 2 |
| Married | 96,611 | 59.07 | 6 | 8 |
| Divorced | 10,662 | 6.52 | 1 | 0 |
| Widowed | 16,616 | 10.16 | 1 | 0 |
| Total | 163,547 | 100.00 | 10 | 10 |
| Household Size | | | | |
| 1 | 19,209 | 24.41 | 2 | 2 |
| 2 | 25,849 | 32.84 | 3 | 2 |
| 3 | 14,475 | 18.39 | 2 | 2 |
| 4 | 12,295 | 15.62 | 2 | 4 |
| 5 | 5,130 | 6.52 | 1 | 0 |
| 6+ | 1,747 | 2.22 | 0 | 0 |
| Total | 78,705 | 100.00 | 10 | 10 |
| Gender | | | | |
| Female | 106,789 | 52.20 | 5 | 6 |
| Male | 97,795 | 47.80 | 5 | 4 |
| Total | 204,584 | 100.00 | 10 | 10 |

Because the focus group with mental health providers contained only two people there is nothing to be gained by attempting a comparison of the characteristics of the participants to the characteristics of the profession at large. One of the participants was a male and the other a female. Both lived in Washington County. Both had been mental health professionals for a number of years.

## 3.6 CONDUCTING THE FOCUS GROUPS

All three focus groups were conducted on separate evenings between May 5 and May 15, 1998. The Greene County focus group met in Waynesburg, PA, and the other two groups met in Washington, PA. In each case the facilitator was Thomas Barley, professionally trained in the conduct of focus groups. Each of the groups met from 6:00 pm to 9:00 pm, and the discussions were videotaped so that the comments could be transcribed. Participants were promised anonymity, and the videotapes were destroyed after the transcription of comments was completed.

## 3.7 ANALYSIS OF THE FOCUS GROUP DISCUSSIONS

After each discussion was held, the tapes were reviewed by the facilitator and the comments were categorized into five major areas:

Physical and environmental issues

Economic issues

Social and psychological issues

Effects on the community

Perceptions by mental health service providers

The first four areas come from the focus groups with the residents; the last area is based on the focus group with the psychologists. The following sections present each of the major issue areas in a separate table and summarize the comments within each area. The detailed comments on which the following tables are based can be found in Appendix C.

## 4.0 PHYSICAL AND ENVIRONMENTAL ISSUES

The comments of the participants in the focus groups with residents from Washington and Greene counties contained a large number of issues about physical and environmental issues. These are shown in Table 4.

### 4.1 HOMES

Table 4 shows the comments separately by county. The first several problems experienced with homes are common to both counties: cracked foundations, cracked walls, door and window problems, and home sinkage. Some of the problems were mentioned in one county but not in the other, for example, farm buildings leaning and "home destroyed by methane gas explosion."

### 4.2 ROADS

In addition to problems with building structures, participants cited problems with roads. Cracks in roads and bridges was mentioned in both counties, and so was the problem of maintaining roads only up to where the public road and the road to the mine intersect. In Greene County, where longwall mining has been going on for a longer time, there were more specific comments about the nature of the problems with the roads.

**TABLE 4**

**PHYSICAL AND ENVIRONMENTAL ISSUES**

| WASHINGTON COUNTY | GREENE COUNTY |
|---|---|
| 4.1 HOMES AND BUILDINGS<br>- Cracked foundations<br>- Cracked walls<br>- Doors and windows out of plumb<br>- Home sinkage<br>- Foundation cave ins<br>- Loss of value in home<br>- Loss of property control | 4.1 HOMES AND BUILDINGS<br>- Cracked foundations<br>- Cracked walls<br>- Doors and windows out of plumb<br>- Home sinkage<br>- Roofs buckled<br>- Farm building structures leaning (i.e. barns, silos, equipment buildings)<br>- Home destroyed by methane gas explosion<br>- Loss of value in house |

TABLE 4 (Continued)

| WASHINGTON COUNTY | GREENE COUNTY |
|---|---|
| 4.2 ROADS<br>- Cracking<br>- Bridge structures cracked<br>- Road maintenance only to mining entrances | 4.2 ROADS<br>- Cracking and humping<br>- Liter from mining crew trucks<br>- Sink holes in road<br>- Over-the-road trucking & heavy equipment damage<br>- Damage to private vehicles due to coal on road<br>- Bridge structures cracked<br>- Road maintenance only to mining entrances |
| 4.3 ENVIRONMENT<br>- Coal Co. workers destructive to land and property<br>- Subsidence cracks and troughs in rural land<br>- Water streams are contaminated with aluminum or sulfur running through<br>- Land slides and erosion | 4.3 ENVIRONMENT<br>- Land slides & erosion<br>- Large farm field subsidence (10' to 12' diameter)<br>- Growing field and crop destruction<br>- Cracked ponds causing seepage<br>- Acres of dead trees<br>- Subsidence cracks & troughs in rural land |
| 4.4 ANIMALS<br>- Death of pets from drinking water<br>- Pets injured by coal co. contractor | 4.4 ANIMALS<br>- Loss of dairy herd<br>- Loss of other cattle<br>- Loss of pets |
| 4.5 WATER<br>- Methane gas in water wells<br>- Water loss in wells<br>- High costs of development of alternative sources<br>- Inconvenience of water buffalos<br>- Ongoing cost of acquiring alternative source<br>- No help from DEP to improve conditions; called in federal government<br>- High costs of purification system | 4.5 WATER<br>- High cost to connect to municipal water source<br>- High ongoing acquisition expenses<br>- High development costs for alternative sources<br>- Loss of spring development<br>- Contamination of hauled water in buffalos<br>- High cost of filtration systems<br>- Methane in wells with no gas detectors<br>- Loss of water |
| 4.6 GAS | 4.6 GAS<br>- Underground gas lines broken<br>- High cost to acquire natural gas source<br>- High ongoing gas costs<br>- Gas wells plugged<br>- Never had to pay for gas before |

## 4.3 ENVIRONMENT

With regard to the environment, in the Washington County focus group the comment was made that "water streams are contaminated with aluminum or sulfur." In the Greene group the comments focused more on damage to farms, both from subsidence and from field and crop destruction. One person commented on "acres of dead trees." Both groups talked about land slides, erosion, and cracks opening up in fields.

### 4.4 ANIMALS

In both counties there were reports of animals, both pets and commercial animals, that had died. At least some of the deaths were attributed to the nature of the drinking water post longwall mining.

### 4.5 WATER

Water issues included: methane in the water, the loss of water, the inadequacy and cost of alternative water sources, the inconvenience of "water buffalos" (temporary water storage tanks), and the ongoing cost of water which used to be free.

### 4.6 GAS

Issues concerning natural gas were raised in Greene County, but not in Washington. Those issues included disruption or capping of existing natural gas wells and the cost of acquiring alternative sources for natural gas. (Other issues involving methane are included in sections 4.1, 5.1, and 6.6.)

## 5.0 ECONOMIC ISSUES

The second major set of concerns, shown in Table 5, involved economic, financial, legal, and employment issues.

### 5.1 PROPERTY VALUES

With regard to property values, participants from the two counties expressed similar concerns about declining value of their property due to methane, contaminated water, and structural damage to their homes. One of the people in Greene County also spoke about the lost use of his land as a dairy farm.

## 5.2 PROPERTY RIGHTS

In terms of property rights, issues were raised about the status of mining technology when the property owners had bought their land and the current status of mining technology and about not being able to get the coal companies to drill new water wells or take responsibility for home damages in some cases.

**TABLE 5**

**ECONOMIC ISSUES**

| WASHINGTON COUNTY | GREENE COUNTY |
|---|---|
| 5.1 PROPERTY VALUES<br>- Value declined due to methane<br>- Loss of value due to cracks in earth and home<br>- Loss of value due to contaminated water | 5.1 PROPERTY VALUES<br>- Loss of dairy farm due to water problems<br>- Will not get value out of home if forced to move<br>- Contamination of water will cause loss in value<br>- Methane on property will cause loss in value |
| 5.2 PROPERTY RIGHTS<br>- Bought property based on "guarded" classification which is now changed. Citizens can do nothing<br>- No permission to dig new septic system<br>- Water dried up but mining co. not drilling | 5.2 PROPERTY RIGHTS<br>- Cemetery makers moved or destroyed<br>- Home 200' from longwall panel but coal co. would not take responsibility for damage<br>- Water dried up; had to finance connection to municipal water supply |
| 5.3 FINANCIAL EFFECTS<br>- Legal costs, structural engineers, water testing and development can cost $20,000 to $50,000<br>- Legal costs ongoing<br>- Mining companies ... allege they own coal rights but homeowners have to pay to verify that<br>- Loss of income due to home damage<br>- Loss of savings to pay documentation costs | 5.3 FINANCIAL EFFECTS<br>- Loss of income from loss of farm<br>- No bank loans for damaged property<br>- Loss of savings to pay legal costs<br>- Ongoing legal costs to enforce Act 54 |
| 5.4 LEGAL ISSUES<br>- No agency empowered to ensure compliance with Act 54 for all homeowners affected<br>- No consistent application of the law. One set for homeowners and another set for mining companies<br>- Loss of confidence in state legislative bodies<br>- Act 54 says homeowner must prove damage<br>- No impact study on harm to residents<br>- Length of legal agreement and gag order is between 7 and 35 years | 5.4 LEGAL ISSUES<br>- Farm foreclosure due to discontinued dairy operations<br>- Burden on homeowner for proof of damage<br>- We have more liberal laws on longwall mining than other countries do<br>- Laws may be in the making to regulate the expulsion of methane gas<br>- The coal companies are giving small jobs to many lawyers to develop "conflict of interest" to make it difficult to hire a lawyer |

**TABLE 5 (Continued)**

| WASHINGTON COUNTY | GREENE COUNTY |
|---|---|
| 5.5 EMPLOYMENT<br>- Lost many jobs in this county due to longwall technology<br>- With the loss of coal jobs no replacement industry has been found | 5.5 EMPLOYMENT<br>- Coal mining provides many jobs in this county<br>- Lost many jobs due to longwall technology<br>- Many of the miners are working a lot of overtime but no new jobs are being created<br>- As mining operations close some people are either losing jobs or seniority on future mining jobs |

## 5.3 FINANCIAL ISSUES

Financial effects focused on both the expenses incurred for legal and engineering fees, costs of repairs to home, loss of income due to home damage, and loss of income from interruption of economic activity.

## 5.4 LEGAL ISSUES

The legal issues that were raised by the discussants covered a number of issues, but the thrust of them seems to be a feeling that neither the legislative nor the executive branch of government would give them assistance and that the home owners were on their own to find and pay for legal help. One member from Greene County expressed the opinion that "the coal companies are giving small jobs to many lawyers to develop 'conflict of interest' to make it difficult to hire a lawyer."

## 5.5 EMPLOYMENT

On the issue of employment, comments in Greene County were divided on whether longwall technology had provided or reduced jobs. In Washington County, the opinions expressed were that longwall technology had cost jobs.

# 6.0 ECONOMICAL ISSUES

A variety of comments have been grouped together under the topic of social and psychological effects.

## 6.1 PSYCHOLOGICAL EFFECTS

Psychological effects included depression, anxiety, stress, and memory loss. In some cases the discussant talked about his own "loss of the will to live" or concern about the possibility of suicide by other members of the family. It is noteworthy that most of the discussion of psychological effects of longwall mining came from Washington County participants. The Greene County participants mentioned simply frustration, anxiety, stress, and fear.

## 6.2 PHYSICAL HEALTH ISSUES

Washington County discussants also made more comments about physical health issues, including cardiac problems, respiratory problems, and loss of memory. Residents from both counties mentioned dizziness from methane.

## 6.3 SOCIAL ISSUES

In terms of social issues, discussants from Washington and Greene counties talked about loss of privacy and loss of control of time. In addition, those from Washington County cited a variety of ways in which they thought that longwall mining had negatively affected their lives, from loss of long term friendships to loss of personal security.

## 6.4 NOISE

In the case of noise, there was no major discussion by those from Washington County, but in the Greene County focus group several comments were made about drilling, vent fans, conveyers, and truck transport.

## 6.5 TEMPORARY ACCOMODATIONS

Several comments were made that pertained to not knowing how long one would be have to live with temporary arrangements concerning water or housing.

## 6.6 SAFETY

The final issue in Table 6 is safety, an area that was discussed by several of the participants. The safety issues that were cited in the Washington County focus group involve danger of home collapse, danger from living in a home that is not level, and the danger of methane. The issues in the Greene group were entirely on the explosion danger of methane.

**TABLE 6**

**SOCIAL AND PSYCHOLOGICAL ISSUES**

| WASHINGTON COUNTY | GREENE COUNTY |
|---|---|
| 6.1 PSYCHOLOGICAL EFFECTS<br>Depression<br>Anxiety and stress<br>Memory loss<br>Loss of the will to live<br>Loss of my wife even if still in the house because she is consumed with home damage problems<br>Feeling severe cynicism toward state government officials and legislators because of betrayal<br>Effects on children have caused speech patterns to be affected because of anxiety and trauma<br>Loss of respect from miners and contractors<br>Desire for suicide from severe depression<br>Serious frustration and confusion developed from mining company officials who are lying to residents | 6.1 PSYCHOLOGICAL EFFECTS<br>Frustration<br>Anxiety and stress<br>Fear |
| 6.2 PHYSICAL HEALTH ISSUES<br>Dizziness from the methane<br>Cardiac problems<br>Respiratory problems<br>Severe nervous problems<br>Loss of memory<br>Loss of vacation time needed to rejuvenate | 6.2 PHYSICAL HEALTH ISSUES<br>Dizziness from methane<br>Children's health and digestion affected |
| 6.3 SOCIAL ISSUES<br>Loss of privacy<br>Loss of control of time<br>Loss of personal security<br>Loss of long term friendships<br>Experience bitterness and hatred<br>Loss of enjoyment derived from home and property<br>Death treats to family | 6.3 SOCIAL ISSUES<br>Loss of privacy<br>Loss of control of time<br>Frustration with friend on "gag" orders |

TABLE 6 (Continued)

| WASHINGTON COUNTY | GREENE COUNTY |
|---|---|
| 6.4 NOISE<br>[Some noise was noted, but no major discussion followed] | 6.4 NOISE<br>Drilling noise<br>24 hour mining vent fans<br>Above ground conveyers<br>Coal truck transport 24 hours |
| 6.5 TEMPORARY ACCOMMODATIONS<br>Lost water; hauled water to holding tank. Took 3 years to get new well plus install new filter system<br>Lived in motor home 3 months and motel for 2-3 months. Drove 40 miles to get children to school, then a rental home for 1 year.<br>When you have subsidence insurance they fight mining company for policy while paying you off. | 6.5 TEMPORARY ACCOMMODATIONS<br>When house has been "cribbed" and people relocated to a motel, the period of time is determined by the coalcompany |
| 6.6 SAFETY<br>Part of home structure about to collapse (i.e. basement walls)<br>Because home is on a slant from mining operations this effects my knees, ankles and hips and personal balance<br>Methane escapes on property; that could be explosive<br>Can light the water from my tap<br>Children hurt on the boards holding up the home structure together and we are not sure who has the liability | 6.6 SAFETY<br>1992 mine explosion caused 9 deaths<br>Explosion of a home about 1 mile away caused trauma to children<br>Methane gas was in the well inside the home<br>The home was leveled |

## 7.0 EFFECTS ON THE COMMUNITY

Table 7 summarizes the community wide issues that were raised by participants: taxes, traffic, and community polarization.

### 7.1 TAX ISSUES

In Washington County, participants stated that due to county real estate tax provisions, tax revenues were lost when residents were temporarily relocated from their home and that tax revenues have been lost due to job cutbacks in the mining industry. Comments were also made that some citizens were angry that tax dollars, instead of mining company dollars, were used to retrain displaced miners. Greene County participants said that their county residents' tax burden has increased as a result of coal property with depleted resources being taken off the tax rolls as mining operations moved forward.

## 7.2 TRAFFIC

Focus group participants from both counties expressed concern with traffic congestion. Washington County participants focused their comments on the traffic problems associated with road damage, while Greene County participants commented on traffic congestion that is caused by lengthy coal trains blocking roads and the lack of state agency response to needs of residents located on roads beyond mine entrances.

## 7.3 COMMUNITY ISSUES

With respect to community issues, Washington County focus group participants were more vocal than their counterparts in Greene County. Washington participants commented that they see their community becoming polarized in their feelings about the coal companies and their operations. One Washington participant commented that because of the "economy and the pro and con factions in the community, there was potential (for) violence". In the Greene County focus group, the issue of conflict surfaced simply in the statement that there is "some conflict between miners and the community."

**TABLE 7**

**EFFECTS ON THE COMMUNITY**

| WASHINGTON COUNTY | GREENE COUNTY |
|---|---|
| 7.1 TAX ISSUES<br>- County lost tax revenue on residents who were temporarily relocated<br>- Sales tax collections have been effected by loss of income from loss of jobs<br>- Hidden tax burden to community<br>- Federal grant for $5.1 million given to retraining center at California University to retrain 1200 displaced miners. Citizens angry that tax dollars spent rather than mining company dollars | 7.1 TAX ISSUES<br>- As mine moves along the coal seams, they take the used property off the tax rolls and leave the residents to pay for projects<br>- As properties leave the tax rolls, the residents' tax burden increases |

**TABLE 7 (Continued)**

| WASHINGTON COUNTY | GREENE COUNTY |
|---|---|
| 7.2 TRAFFIC<br>- Highway damages such as the cracks and bumps are causing a lot of traffic congestion throughout the county<br>- Craters in the road caused an impasse<br>- While the traffic is delayed the mining company argues with the County over who should pay for repairs | 7.2 TRAFFIC<br>- Caused by extended coal trains<br>- The State of Pennsylvania to build an overpass; by the time it's finished the coal trains will be gone because the mining company will have moved<br>- Several times emergency vehicles could not get through the roads being crossed by coal trains<br>- Traffic blocked for 5 hours by disabled coal train<br>- Roads not plowed past the mining entrances. Difficult to use roads beyond the mine entrances<br>- State agencies do not respond to the needs of residents beyond these entrances |
| 7.3 COMMUNITY ISSUES<br>- Undermined homes are bought by the mining companies at a fraction of the value and then resold to mining company employees<br>- People are forced to take a "pro" or "con" position on the mining company. People's actions are then judged based on their position<br>- The economy of Washington County has been seriously affected by longwall technology<br>- Potential violence exists in this community because of the economy and the "pro" and "con' factions | 7.3 COMMUNITY ISSUES<br>- The new school building ... with the ground shaking it is beginning to come apart<br>- There is some conflict between the miners and the community |

## 8.0 PERCEPTIONS BY MENTAL HEALTH SERVICE PROVIDERS

One of the two psychologists who participated in a discussion group had patients who lived in proximity to longwall mining. The other did not. Their observations centered on issues of stress and stress management as it applies to the effects of longwall mining, on the nature of the population in Greene and Washington counties, and on the potential for relief of stress from the effects of longwall mining.

One believed that even before the mining occurs some of the stress arises "because of the mixed messages (residents) receive from both coal company officials and ... (other) residents."

One psychologist said that "Stress management remedies indicate that ... patient(s) must: 1) change their environment ... (but) you know no one is going to stop the longwall mining; 2) employ rational motive therapy ... but these residents are not being irrational because the mining is a real threat;

3) use mental focus and breathing techniques due to the reality that these people have in fact lost control of part of their lives ..."

Both therapists were quick to point out, however, that most residents they know would be unlikely to change their living environment. One said that "therapy for these people is going to have to consist of teaching people how to let go of something they have spent a lifetime acquiring".

One psychologist stated that because "most rural people ... (will) not show up in a therapist's office" that "churches may be the places where ... therapy will have to be conducted". Some extended suggestions were offered about how that might be established.

Echoing the concerns expressed in Section 6.5, one of the psychologists noted that "living in a motel is (not) a good thing for families because of the cramped quarters, meals out ... it is difficult ... no one can have any privacy."

**TABLE 8**

**PERCEPTIONS BY MENTAL HEALTH PROFESSIONALS**

| | |
|---|---|
| - Many residents experience pre-mining anxiety and stress because of the mixed messages received from both coal company officials and (other) residents | - The PUSH (an activist) organization works for these people (as a support group) because it is an angry crowd ... it works for men especially |
| - It is almost like being handicapped because coal companies are saying 'you will be whole again' but reality is that you will never be the same again | - Often we do (psychological) assessments after the fact similar to that which was done with Vietnam Veterans with Post Traumatic Stress Syndrome |
| - Stress management remedies indicate that patients must: 1) change environment; 2) employ rational motive therapy, 3) use mental focus and breathing techniques | - You can assess anxiety with various instruments ...what you (need to) do is track them over time |
| - I've been at meetings where grown men are crying | - I don't know of any personal injuries (to homeowners) because mining companies are very careful about that...they evacuate all homeowners who might be injured |
| - Therapy for these people is going to have to consist of teaching people how to let go of something they have spent a lifetime acquiring | - I don't think that living in a motel is a good thing for families because of the cramped quarters, meals out....it is difficult...no one can have any privacy |
| - Most of these rural people ..would not show up in a therapist's office | - A lot of people may go to their General Practitioner and get medication...antidepressants are being used with cases of depression |

**TABLE 8 (Continued)**

| | |
|---|---|
| - Churches may be the places where this kind of therapy will have to be conducted | - I have a problem putting people on medication if they have a good reason to be upset... such as situational anxiety |
| - The ministers who are also mental health people would be good to talk to; they may have to set up support groups | - The problem is widespread, but no one is looking after the mental health of the affected people |

One mental health therapist said she thought many people go to their General Practitioner and get medication (rather than therapy) because antidepressants are being used with cases of depression. She also said, however, that she had "a problem putting people on medication if they have a good reason to be upset."

The final comment among the mental health focus group participants was that "the problem (of stress from longwall mining) is widespread but no one is looking after the mental health of the affected people".

## 9.0 CONCLUSION

This study has examined the perceptions of a sample of residents and mental health professionals from Washington and Greene counties of southwestern Pennsylvania. The opinions sought from the focus groups centered on the social, economic and environmental issues that surround the development of longwall mining in southwestern Pennsylvania. The organization of the study's resulting comments takes place in the following areas: Physical and Environmental Issues; Economic Issues; Social and Psychological Issues; The Effects on the Community and The Perceptions of Mental Health Professionals.

The topic that received the most discussion in the Physical and Environmental category was the contamination and loss of water. The comments of all participants indicated agreement that this was the most serious problem that they faced. The participants comments on the contamination and loss of water indicated that this problem was very costly in terms of its impact on the health of individuals, livestock, and pets. The participants said that the alternative water solutions that they have been provided have not met their health and economic requirements. The topic that received the second most discussion from focus group participants in the Physical and Environmental category, was that of damage to homes and buildings. Participants cited cracked walls and foundations, door and windows being out of plumb, buckled roofs and sunken buildings as problems.

On economic issues, participants comments, while indicating that property rights and values are significant issues, came to rest in the area of financial impact. From both Washington and Greene counties, focus group participants who had been directly affected commented that it has been financially a very difficult time due to high legal and documentation costs, costs that cannot be recovered in most settlements.

In addition to the effects on individuals and families, the participants also spoke of deterioration in relations between former friends and of polarization of the community regarding longwall mining and the coal companies.

The anxiety, frustration, depression and fear that participants spoke of are a justifiable source of concern based on the comments by the mental health professionals. As one mental health professional put it: "the problem is wide spread, but no one is looking after the mental health of the affected people."

## APPENDIX A

## LONGWALL MINING
## HOME OWNER DISCUSSION GUIDE

Today we are discussing your opinions and feelings about the social, economical and environmental issues that are associated with longwall mining in Washington/Green Counties. Our research will help those organizations that are interested and committed to these issues; therefore, we encourage your honesty and candor throughout our discussion.

1. In general, are there issues that have affected your life as a result of longwall mining in this area? (Please jot those issues on the pad in front of you. We are going to discuss each one separately.)

2. Let me ask each of you to read your list of issues (Asst. Moderator to write summary). Are there any issues that you have not mentioned to this point? (PROBE: General, Social, Economic, Environmental, Health & Mental Health)

3. Has anyone here experienced an incident which, in your view, may have or would have an impact on you or your family? (PROBE: specific incidents and impact)

4. Are there any general issues surrounding longwall mining that, in your opinion, have affected your community, its pride or cultural heritage? (PROBE: For specificity)

### SOCIAL/ECONOMIC

5. Have you been involved in any longwall mining incidents that have affected your personal safety or private property rights? If so, what were the incidents and how did they affect your personal safety and property rights? (PROBE: For details)

    5a. Were there any incidents related to longwall mining that affected your home or the value of your property? If so, would you describe the incident and the affect that it had on your home or property? (PROBE: For details)

    5b. Did any incidents caused by longwall mining involve temporary housing relocation, the temporary use of alternate power due to service disruption or the need for alternate water supplies? If so, would you describe the incident and how it affected your housing and/or its amenities. (PROBE: For details)

    5c. Were there any incidents resulting from longwall mining that caused you or your family to sustain any legal costs? (PROBE: For specific incidents and associated legal costs.)

    5d. What incidents of longwall mining have affected the environment in general in your area? (PROBE: For specifics.)

6. Longwall mining employs a large number of people in this area. In your opinion, how could these employers balance the maintenance of job opportunities with corporate responsibility to the community and its environment? (PROBE: Determine if residents have ideas that are specific and factual such as infrastructure damage.)

**ENVIRONMENTAL/MENTAL HEALTH**

7. What are the major environmental issues that have effected this area as a result of longwall mining? (PROBE: For water deterioration, infrastructure damage, Air Quality, Water Quality, Methane Discharge or Acid Mine discharge)

8. In your opinion, are there any of the issues we just spoke of affecting the community tax base or costs to your township? (PROBE: Knowledge of specific cases)

9. In your opinion, has longwall mining affected the available jobs in your community? (PROBE: For employment status knowledge)

10. In your opinion, has longwall mining affected the mental health of people in your area? If so, how? (PROBE: For specifics)

11. Often mining companies will offer to compensate property owners for mine subsidence damage. They have included a requirement that property owners not discuss the terms of their agreement with anyone. Do you have any knowledge of these so-called "gag orders"? (PROBE: For specifics)

12. Are there any issues we have not discussed that you feel strongly should be included in this research? (PROBE: For specifics)

## APPENDIX B

## LONGWALL MINING
## MENTAL HEALTH PROFESSIONAL
## DISCUSSION GUIDE

Today we have asked you to come here to assist us with research we are doing that examines the health and mental health issues that surround longwall mining in Southwestern Pennsylvania. Specifically, your opinions will help those organizations that are interested in and committed to those issues; therefore, we encourage your honesty and candor throughout our discussion.

1. In general, what issues surrounding longwall mining have affected the mental health of people in your area? (Please jot those issues on the pad in front of you. We will be discussing each one separately. Then have each read.)

2. Let me ask each of you to read your list of issues (Asst. Moderator to write summary). Are there any issues that you have not mentioned to this point? (PROBE: Specific relation between issues and MH cases)

3. To your knowledge, have homeowners in this area sustained any physical trauma as a result of longwall mining? If so, what types of trauma have been experienced? (PROBE: For details)

4. To your knowledge, have there been any changes in people's respiratory system based on any changes in air quality as a result of longwall mining? Why have people been affected as you have indicated? (PROBE: For causes of specific problems)

5. To your knowledge, have longwall mining operations affected the traffic and/or road dust in your area? In turn has this effect caused people to sustain mental health problems? (PROBE: Relationship between issues and specific problems)

6. Has longwall mining generated noise in the community? How has this issue affected people? (PROBE: For details, if any)

7. Are you aware of any people in your area who have experienced any anger as a result of longwall mining operations? How has this issue affected family members' relationship with one another? (PROBE: For details and specific case examples).

8. Now let us examine the issue of anxiety and its related stress. The longwall mines are required to notify residents in advance of the mining operations coming into a specific area. This means that families are waiting to see what will happen to themselves when the mining begins. Do you know of families whose stress/anxiety levels have been affected by this issue? (PROBE: For case specifics)

9. To your knowledge have people experienced anxiety or frustration as a result of longwall mining operations? (PROBE: For specific cases and possible relation to mining activities.)

10. To your knowledge, have self esteem concerns arisen from either environmental or employment issues as a result of longwall mining? If so, how? (PROBE: For case specifics).

11. Are you aware of cases of alcoholism that have arisen due to longwall mining in recent years? What are those cases and how have they affected the people of your area? (PROBE: For case specifics)

12. Are there any longwall mining issues that have affected children, in your opinion? If so, what are the issues and how have they affected children? (PROBE: For specific cases)

13. Are there any issues or cases that we have not discussed that should be included in this research? (PROBE; For others)

## APPENDIX C
## COMMENTS BY FOCUS GROUP PARTICIPANTS

## 4.0 PHYSICAL AND ENVIRONMENTAL ISSUES

This section presents Greene and Washington Counties' residents' perception of the economic and environment's issues as a result of longwall mining operations in the affected areas. This section includes comments on physical property damage that includes home and building damage, road damage, land and ecological damage. The residents' comments also address utility, noise, financial and legal issues.

### 4.1 HOMES AND BUILDINGS

- "My foundation was seriously cracked ... so were my walls and my windows were out of plumb ... then my home sunk a few feet and the roof buckled ..."
- "They just destroyed the home I waited all my life to have ... but my windows won't go up and down ... the walls are cracked ... I'm too old to start over now ..."
- "The legislators passed Act 54 and they were only looking at the economics and the politics, not the potential damage to individual's homes and property ... I really don't think they looked at the full impact when coal was actually mined and the houses would actually fall and the well water would actually be lost ... and we are in the period between passing Act 54 and whether it was any good or not ... and I experience anxiety and cynicism toward federal, state and local government ... and some mining companies are (nearing bankruptcy) ..."
- "I saw the house across the street actually tilt ... and we expressed concern to the coal company and they told us it was an optical illusion ..."
- "Part of my foundation caved in and then I noticed the road cracking in front of my house ..."

### 4.2 ROADS

- "On (Route) 218 they had to replace the whole bridge as it goes into Blacksville there... after some months of hassling the coal company paid ..."
- "I seen many sink holes in our roads here ..."
- "There is a lotta damage from over the road truckin' and heavy equipment ..."
- "The roads are maintained only up to the mine entrances and not beyond ..."

- "Your drive along the road and chunks of coal fall right on your vehicle from the conveyer over the road ..."

## 4.3 ENVIRONMENT

- "I had a white milky liquid coming into the stream that runs through my property ..."
- "Take a ride up (Route) 218 there where the shaft is ... everything is green on the hill but the valley is nothin' but dead trees and shrubs ..."
- "Behind the house across the street there is huge slips (erosion) on her hill ..."
- "On my farm there is very large, like 10' to 12' in diameter, cracks in my growin' field ..."
- "I have a crack in one of the ponds on my property and I don't know where the seepage is going ..."
- "The coal company workers when they come for pre-mining preparation are very destructive to our land and property ..."

## 4.4 ANIMALS

- "My pets died due to the contaminated drinking water on my land ..."
- "The coal company workers injured my pets too ..."
- "On April 6 I had 14 cows sick from the chlorine in the water that was supplied ... they had temperatures of 105 degrees ..."
- "They said I had to put water treatment in my tanks so I could ship grad A milk ... but the coal company did nothin' ... so on September 6, 1995 I liquidated my dairy operation ..."

## 4.5 WATER

- "I lost my water due to methane contamination ... effectively de-watering an entire working farm ..."
- "I was lucky I got some of the water back in my well but it's orange now ... So I had to pay for a filtration system plus and ongoing expense of changing the filters every month ..."
- "The mining people say, 'You're going to lose your water, but it'll be back' ... no banks goin' to give you a mortgage on that ..."

- "You know them water buffalos they give you, well they can't be cleaned ... they freeze in the winter ... and they are ... inconvenient ..."

- "I got no help from the DEP to improve my water conditions so I called the federal government and got help ..."

- "I had wells before the mining ... now I got city water and a bill every month ..."

- "The cost of water development is very high and you have to do it before they come to do pre-mining preparation ..."

- "Water loss and contamination is the biggest problem we face ..."

### 4.6 GAS

- "My underground lines from my gas well broke from the ground crackin' ..."

- "The cost of getting natural gas piped in is not only high but you pay every month ... I didn't have all those expenses before ..."

- "Finally after all the trouble they came and plugged my gas wells ..."

- "I got just too many methane gas vent pipes on my property ... and not one of them has a gas detector to check levels goin' into the air ..."

## 5.0 ECONOMIC ISSUES

### 5.1 PROPERTY VALUES

- "My home value has declined due to damage and the methane all over my property ..."

- "I can't never get the value out of my house because of the contamination in the water ..."

- "The loss of (market) value of home due to cracks in the earth, cracks in patio, porch and walls and floor ..."

- "My husband works at Western Center and we might have to move ... we are never gonna get the value out of our house ... we don't have a future ..."

- "Some of the houses that were undermined were bought at a fraction of their value and resold to mining company employees ..."

## 5.2 PROPERTY RIGHTS

- "Some of our cemetery markers were violated because they were moved, cracked, or destroyed ..."
- "That house was 200 feet from the longwall panel and the coal company would not take the responsibility for any damage ..."
- "They contaminated my water then it dried up and I had to pay to connect to the municipal water source ..."
- "When there's no compensation from the coal company ... most people in this county don't have enough money to fight ..."
- "We bought our property based on the "guarded" classification ... recently that classification was changed and citizens can do nothing about that change ..."
- "I can't get permission to dig a new septic system because of the mining ..."
- "You could buy the coal rights under your property but it's too expensive ..."

## 5.3 FINANCIAL ISSUES

- "The average legal costs for lawyers, structural engineers and water testing and development can be $20,000 to $50,000 ..."
- "The legal costs are ongoing and never stop ... to fight for homeowner rights ..."
- "Mining companies alleged that they own coal rights under properties but property owners have to verify that with a deed search ... it costs the owner money to do that ..."
- "It seems to be necessary that the coal companies are not cooperative ..."
- "I lost all my income from my dairy operation ..."
- "In my case I have used up most of my savings for the documentation costs to fight the coal company ..."
- "You can't get my bank loans to help you repair all the damages to your home ..."

## 5.4 LEGAL ISSUES

- "You have to hire an attorney just to enforce Act 54 against the coal companies ..."

- "Why is no agency empowered to ensure compliance with Act 54 for all the homeowners that are affected? ..."

- "The usual mining agreements call for a minimum of $5,000 to a maximum of $15,000 or usually 3% value of the house ..."

- "The letter of notice can come to you 6 months to 5 years before they actually mine your property ..."

- "The length of the legal agreement and gag order is between 7 and 35 years ..."

- "The coal companies are required to give you ... I think ... $140 per day if you are relocated for a temporary time ... the length of time is determined by the coal company ..."

- "There is no consistent application of the law ... there is one set of laws for the homeowner and another set for the coal companies ..."

- "There is no legally sponsored impact study to collect data on harm to property owners ..."

- "Act 54 says homeowner responsible to prove damages ..."

- "We have more liberal laws on longwall mining than other countries ..."

- "The coal companies are giving small legal jobs to many lawyers to develop "conflict of interest" problems for people who need to hire them ... I had a real hard time finding a lawyer ..."

- "I hope there will be laws in the making to regulate the expulsion of methane gas ..."

## 5.5 EMPLOYMENT

- "A lotta jobs in Greene County depend on them coal mines ... that's positive ..."

- "I heard you say (previous participant) that longwall jobs are a positive thing ... that's not a positive thing ... there were plenty of jobs in pillar mining and regular coal construction ... The mining industry was providing jobs but with longwall mining the machines are gettin' lots of work ... the coal companies are makin' lots of money ... but there's not a lot of miners ..."

- "With longwall technology we've lost a lot of jobs in Washington County ..."

# 6.0 SOCIAL AND PSYCHOLOGICAL ISSUES

## 6.1 PSYCHOLOGICAL EFFECTS

- "I am going through serious depression because of the anxiety and stress that I feel because of the damage to our property ... We waited a long time and saved hard to get our home ..."
- "My child's speech patterns were affected by the anxiety and trauma she felt ... she is still afraid something might happen to our house again at night when she's sleeping ..."
- "Well I don't know about you people ... but I can't concentrate anymore because of this ..."
- "I've been so depressed I've lost my will to live ... as well as my dignity and self- esteem ..."
- "My husband constantly wants to commit suicide from his depression ... my daughter is getting married (in two months) and she's afraid her father won't be alive for her wedding ..."
- "I feel we have no future ... I think we have lost our future ..."
- "My family and I are deeply frustrated and confused because the mining company officials are always lying to us ..."
- I'm afraid of what's going to happen to us when they start mining ... after hearing all this ..."

## 6.2 PHYSICAL HEALTH ISSUES

- "I have experienced dizziness from the methane in the air around my property ..."
- "I developed cardiac problems as a result of all this mining damage ..."
- "You are not the only one ... I have got respiratory and severe nerve problems from all this ..."
- "My children have experienced digestion problems as a result of their fear ..."

## 6.3 SOCIAL ISSUES

- "I live in the country ... I might as well live in the city of Washington with all the privacy I get with the coal company contractors all over my property and in my house ..."
- "Them guys never tell you when they're gonna come so you don't ever have control over your own time ..."

- "I lost many of my long term friends who work in mining because I'm fighting the coal company for my rights ..."
- "They are diggin' up your yard and pounding on your house ... they start at 7 o'clock and I left the house at 7 o'clock in the morning ..."
- "You experience a loss of enjoyment from owning your home and property ..."
- "I feel bitterness and hatred towards people associated with mining ..."
- "Many times I've had death threats against me and a loss of personal security ..."
- "I am frustrated with my friend who is on a gag order because she won't talk about what the mining company offered her ..."
- "I have lost my wife because she is so consumed with the damage problems to our home ..."
- "I maintain severe cynicism towards government and legislative officials ..."

## 6.4 NOISE

- "There is a lot of drilling noise around my house ..."
- "Those vent fans up near the mine shaft are goin' 24 hours a day ..."
- "The coal conveyers are always clanking and grinding near my property ..."
- The coal trucks are goin' back and forth all day and night on the road by me ..."

## 6.5 TEMPORARY ACCOMMODATIONS

- "I lost my water and they hauled water into a holding tank for three years ... then they finally dug another well and put in a new system ..."
- "Me and my family lived in a motor home for 3 months ... then in a motel for 2 or 3 months. We had to drive 40 miles to get the children to school ... Then we rented a house for a year ..."
- "When your house is "cribbed" and people are relocated to a motel the time is stipulated by the coal company ..."
- "When you have subsidence insurance they fight the coal company while paying you off ..."

### 6.6 SAFETY

- "A house blew up over on (Route) 218 due to methane and people were in it ... and all that's left is the chimney ... people were burned bad ..."
- "They had a well inside the house ... methane collected in there and boom she just went ..."
- "Part of my home structure is about to collapse ..."
- "Because my home is on a slant from the mining operation ... this has affected my knees, ankles, hips and my personal balance ..."
- "The methane that escapes on my property could be explosive ..."
- "I can light the water coming from the tap in my house ..."
- "My children and some neighbor kids got hurt on the boards holding up my house ... I'm not sure who has liability ..."
- "In 1992 the mine explosion caused 9 deaths ..."
- "The house that exploded about one mile from us caused my child to experience a lotta trauma ..."
- "One time they had a medical emergency that took place up above the mine entrance and the ambulance couldn't pass through the road ..."

## 7.0 EFFECTS ON THE COMMUNITY

These effects encompass tax issues, traffic problems and general effects on the fabric of community life.

### 7.1 TAX ISSUES

- "The county lost tax revenue on residents who were temporarily relocated ..."
- "As the mine moves along the seams they take the used up property off the tax rolls and leave the residents to pay for the ... (expletive deleted) ... damages ..."
- "As the mining operations close and move, people in the community are losing jobs or seniority in future mines ..."
- "When mining property is taken off the tax rolls ... the resident property tax increases ..."

- "The economy of Washington County has been severely affected by longwall technology ..."
- "Longwall technology (is) a real threat to jobs in our community ..."

## 7.2 TRAFFIC

- "A lotta our congestion here in Greene County is caused by those long coal trains ..."
- "The state of Pennsylvania has been going to build an overpass here but by the time it's finished the coal trains will be gone because the mine has moved ..."
- "Traffic has been blocked by as much as 5 hours by a disabled coal train ..."
- "State agencies do not respond to the needs of residents on roads past mining entrances ..."
- "There's lots of times when emergency vehicles can't get through roads blocked by coal train crossings ..."
- "Because them roads aren't plowed past the mine entrances ... they are difficult to use ..."
- "Many craters are formed on the roads around here and they cause delays in the traffic ..."
- "Then there is always the arguments as to who should pay to fix the roads ... the county or the coal company ..."

## 7.3 COMMUNITY SPIRIT

- "People in this community are forced to take a position pro or con for the coal company ... and people's actions are judged by their position ..."
- "You know there is potential violence that could erupt between the pro and con factions in this community ..."
- "The hidden costs to the community are very high ... for example, a federal grant for 5.1 million dollars was given to a retraining center at the University of California to retrain 1200 to 1500 displaced miners ... The citizens were angry that tax dollars were spent instead of mining company money ..."

# 8.0 PERCEPTIONS BY MENTAL HEALTH SERVICE PROVIDERS

- "Many of the residents are experiencing pre-mining anxiety and stress because of the mixed messages they're getting from the coal companies and other experienced residents ..."

- "... its almost like being handicapped because the coal companies are saying 'you'll be whole again,' but the reality is that you will never be the same again ..."
- "Stress management remedies indicate that the patient must: 1) change their environment ... (but) you know no one is going to stop the longwall mining; 2) employ rational motive therapy ... but these residents are not being irrational because the mining is a real threat; 3) use mental focus and breathing techniques due to the reality that these people have in fact lost control of part of their lives ..." indicate that the patient must: 1) change their environment ... you know no one is going to stop the longwall mining; 2) employ rational motive therapy ... but these residents are not being irrational because the mining is a real threat; 3) use mental focus and breathing techniques due to the reality that these people have in fact lost control of part of their lives ..."
- "I've been at meetings where grown men are crying ..."
- "Therapy for these people is going to have to consist of teaching people how to let go of something they have spent a lifetime acquiring ..."
- "Most of these rural people ... would not show up in a therapist's office ..."
- "Churches may be the places where this kind of therapy will have to be conducted ..."
- "The ministers who are also mental health people would be good to talk to ... they may have to set up support groups ..."
- "The PUSH organization works for these people (as a support group) because it is an angry crowd ... it works for men especially ..."
- "Often we do (psychological) assessments after the fact similar to that which was done with Vietnam Veterans with Post Traumatic Stress Syndrome cases ..."
- "You can assess anxiety with a variety of instruments ... what you (need to) do is track them over time ..."
- "I don't know of any personal injuries (to homeowners) because mining companies are very careful about that ... they evacuate all homeowners who might be injured ..."
- "I don't think that living in a motel is a good thing for families because of the cramped quarters, meals out ... it is difficult ... no one can have any privacy ..."
- "A lot of people may go to their General Practitioner and get medication ... antidepressants are being used with cases of depression ..."
- "I have a problem putting people on medication if they have a good reason to be upset ... such as situational anxiety ..."
- "The problem is widespread, but no one is looking after the mental health of the affected people ..."

# CHAPTER 11

# PROPERTY VALUE, TAX REVENUE AND UNDERGROUND COAL MINING PRACTICE IN SOUTHWESTERN PENNSYLVANIA

Kristen Strellec
with Scott Farrow, Ph.D.
Dames & Moore
Pittsburgh, Pennsylvania

## 1.0 INTRODUCTION

Property values are an important link between local conditions, personal well-being and public revenues. In the case of high extraction underground coal mining in Greene and Washington counties in Southwestern Pennsylvania, property owners whose property might be affected by mining related activity include residential, commercial, industrial and public owners of the surface as well as owners of the subsurface mineral property. For each owner, property values integrate many different objective and subjective elements. This report is a survey of economic factors potentially affecting property owners as a result of high extraction coal mining as well as issues related to coal mining and public revenues.

The purpose of this survey is to determine if there are potentially significant impacts on these other property owners after mitigation and compensation has occurred. The baseline for determining potential impact in this paper is a with and without mining scenario as it is not possible to distinguish the potential impact of alternative extraction methods on property values at this time. As detailed property value studies specific to mining and the region do not exist, it is not possible to say that property values are definitely affected nor to distinguish any difference in impact between mining practices that result in immediate damage compared to the potential for delayed damage. However, an extensive quantitative literature, reviewed in Appendix A, links reductions in property values to what some perceive as locally undesirable land uses. This literature suggests that the economic burden of proof lies with those who assume no impact on property value.

A variety of data sources are used to determine the potential for impacts. For this report, information was collected from a variety of sources including: (1) personal interviews with local, state, and federal government officials; industry representatives; public utility representatives; and real estate professionals in the region; (2) site visits to review both mine maps and mine permit applications filed with the Pennsylvania Department of Environmental Protection (DEP); (3) the existing economics literature, community newspapers and secondary sources pertaining to key issues of the study; and (4) reviewing data collected by the U.S. Department of Interior (1996).

Identification of potential economic impact does not indicate actual impact. Detailed research methods are available to separate the many confounding factors that affect property value and are discussed in this report. Such detailed studies would be necessary to determine if the potential impacts identified here are supported by site specific transactions data for property sales. To the extent that government agencies are tasked with maintaining property value subject to various conditions, program evaluation by such agencies may be incomplete without such studies.

## 1.1 LAND AND PROPERTY POTENTIALLY AFFECTED BY UNDERGROUND MINING

The area of land and the number of property owners potentially affected by high extraction underground, especially longwall, mining will increase in the forseeable future. Important public revenue issues are also related to both the mining and the extraction of coal reserves, most notably for Greene County. Nine underground coal mines are currently active in Washington and Greene counties. Of these mines, eight use the longwall mining technique for at least 70% of their total production. Information on longwall coal production in the region appears in Table 1. In 1993, the region produced roughly 21.8 million tons of coal through longwall production, representing approximately 95% of Pennsylvania's total longwall coal production. Longwall production and its areal extent is expected to continually increase in the region over the next twenty years, with forecasts in the range of 37.6-41.8 million tons by the year 2010 (U.S. Department of the Interior, 1996b). The vast majority of the increase in production is expected to take place in Greene county.

Portions of thirteen townships in Greene County and ten in Washington County are potentially affected by underground coal mining. Based on information collected from the recent mining permit applications filed with the PA DEP (see Table 2), approximately 79,000 acres in the region are currently part of a mine subsidence control plan area, i.e. the area in which actual mining is allowed to take place. This table does not include historical acreage that has been removed from the permitted area; hence the total area related to recent mining is larger.

The number of property owners potentially affected by underground coal mining can be estimated based on existing permitted areas. Table 3 shows the estimated number of surface property owners in the permitted area of the Bailey and Enlow Fork Mines. The Bailey Mine lies under a total of 982 surface property owners, primarily in West Finley and Richhill townships. In terms of residential property owners, 187 houses and 60 mobile homes/trailers are in the subsidence control plan area. Other structures include 196 barns, 27 commercial buildings, and 7 cemeteries. The Enlow Fork Mine lies under structures of 299 surface property owners. The total structures include 206 houses, 24 mobile homes/trailers, 135 barns, 2 commercial buildings, and 9 cemeteries. As the Bailey Mine accounts for approximately 26 percent of the regional area that is part of a subsidence control plan, an estimate based on a uniform distribution of ownership is that the property of approximately 4,000 owners lies above the currently permitted area of underground mines in these two counties.

**Table 1**

**Longwall Coal Production in Washington and Greene Counties By Mine (000 tons)**

| Mine | County | 1985 | 1990 | 1993 | 1993 Production Type | |
|---|---|---|---|---|---|---|
| | | | | | Continuous | Longwall |
| Emerald | Greene | 1,812 | 1,627 | 3,180 | 20% | 80% |
| Cumberland | Greene | 2,126 | 3,152 | 2,385 | 12% | 88% |
| Dilworth | Greene | 1,615 | 2,191 | 1,175 | 15% | 85% |
| Warwick | Greene | NA | NA | 753 | 30% | 70% |
| Bailey | Greene / Washington | 1,156 | 5,583 | 6,873 | 15% | 85% |
| Enlow Fork | Greene / Washington | NA | NA | 5,640 | 15% | 85% |
| Eighty-Four | Washington | NA | 1,310 | 72 | 10% | 90% |
| Maple Creek | Washington | 1,232 | 2,076 | 1,726 | 19% | 81% |
| **Total** | | **7,941** | **15,939** | **21,804** | | |
| PA Total | | 12,165 | 18,892 | 23,065 | | |
| Region % of State Longwall Production | | 65% | 84% | 95% | | |

Source: U.S. Department of the Interior, 1996, Support Tables, Valid Existing Rights

## Table2

## Active Underground Coal Mines in Washington and Greene Counties

| Mine | Year of Initial Installation | County | Townships Affected | Date of Permit Reviewed | Surface Area Affected (acres) | Under-ground Mine Plan Area (acres) | Subsidence Control Plan Area (acres) | Anticipated Annual Tonnage (Millions) | Estimated Remaining Mine Life (years) | Over-burde Thickne (feet) |
|---|---|---|---|---|---|---|---|---|---|---|
| Emerald | 1982/93 | Greene | Whiteley, Franklin, Center | Feb-97 | 180.8 | 14,594 | 8,063 | 6 raw | 15-20 | 450-110 |
| Cumberland | 1980/94 | Greene | Wayne, Perry, Whiteley | Mar-95 | 212.8 | 21,449 | 8,028 | 4.7 raw | 12-17 | 900 |
| Dilworth | 1984/92 | Greene | Jefferson, Cumberland, Morgan | Mar-96 | 115.3 | 11,336 | 6,312 | 1.2-2 | 12-17 | 500-80 |
| Bailey | 1985/86/92 | Greene<br>Washington | Richhill<br>West Finley | Dec-96 | 734.3 | 29,548 | 20,747 | 10 clean | 13 | 320-104 |
| Enlow Fork | 1991/92 | Greene<br>Washington | Richhill, Morris<br>East Finley, West Finley | Aug-96 | 274.2 | 18,245 | 17,157 | 6 | 17 | 450-122 |
| Eighty-Four | 1974/87 | Washington | S. Strabane, N. Strabane, N. | Mar-97 | 265.0 | 35,458 | 9,526 | 6 clean | 13 | 400-80 |
| Hillsboro | NA | Washington | North Bethlehem | Feb-97 | 69.4 | 8,428 | 3,568 | 4 clean | 10 | 450 |
| Maple Creek | 1980/89 | Washington | Somerset, Fallowfield, | Dec-96 | 179.8 | 16,871 | 5,893 | 1.2-2.2 | 10-13 | 350 |
| TOTAL | | | | | 2031.5 | 155,929 | 79,294 | | | |

Notes: Does not include Mathies or Dillworth Mines; All mines listed are mining the Pittsburgh coal seam; Source: Mining Permits for date listed filed at DEP office

**Table 3**

**Structures Potentially Affected by Bailey and Enlow Fork Mines**

| | Total Tax Parcels/ Surface Property Owners Affected | Dwellings | Trailer / Mobile Homes | Barns | Commercial Buildings | Cemeteries |
|---|---|---|---|---|---|---|
| **Enlow Fork** | | | | | | |
| Morris | 86 | 70 | 4 | 50 | 2 | 2 |
| East Finley | 116 | 48 | 7 | 35 | | 3 |
| West Finley | 97 | 88 | 13 | 50 | | 4 |
| **Bailey** | | | | | | |
| West Finley | 686 | 61 | 20 | 48 | 12 | |
| Richhill | 278 | 124 | 37 | 147 | 13 | 7 |
| Gray | 18 | 2 | 3 | 1 | | |

Notes: Bailey includes all surface property owners; Enlow Fork only includes surface owners that have a structure affected

Source: Enlow Fork data from Exhibit 18.1 (Structure Inventory) in permit application, 1/13/95
Bailey data from Exhibit 18.1 (Structure Inventory) and Exhibit 19.3 (Surface Ownership) in permit application, 2/2/96.

## 1.2 STRUCTURE OF THE REPORT

Potential impacts on surface property values are discussed below in Section Two. Attention is paid to the different types of various property owners who may be affected by mining. This section also reviews the professional literature linking residential property values with locally unwanted land uses and illustrates how the concepts, methodologies, and results are likely to apply to high extraction underground coal mining.

Section Three reviews issues related to subsurface property values unrelated to the coal being mined. Section Four is a discussion of public revenue impacts. Primary focus is placed on the link between public revenues, coal taxation by local governments, and coal depletion. Section Five presents the project summary and conclusions. The appendices include a literature review of related property value studies (Appendix A) and a summary of coal tax procedures (Appendix B).

# 2.0 POTENTIAL IMPACTS ON SURFACE PROPERTY VALUES

Underground coal mining practices potentially affect a variety of private surface landowners, public utilities, public land and infrastructure. The private surface property affected may be residential, commercial, industrial, or agricultural land. This section reviews potential property value impacts associated with each type of property owner. A summary of the factors associated with underground coal mining that may impact residential surface property values appears in Table 4, while those affecting other types of surface property owners appears in Table 9.

## 2.1 RESIDENTIAL PROPERTY

Of the various real or perceived impacts of underground coal mining on residential property values listed in Table 4, those pertaining to direct subsidence damage have been the primary focus of existing legislation to date (Environmental Law Institute, 1998). Hence, they are discussed first.

### 2.1.1 Compensation and Repair of Direct Subsidence Damage

High extraction coal mining produces highly variable effects on surface structures above mines, ranging from unnoticeable to irreparable damage. The actual damage that results depends on a variety of factors, including (1) overburden depth and characteristics, (2) mining methods, (3) percentage of coal extracted, (4) structural characteristics of the building, (5) location of the structure in relation to the longwall panel, (6) coal seam characteristics, and (7) pre-mining damage minimization measures taken (Parizek and Ramani, 1996; Peng and Luo, 1997).

The area of influence of subsidence and horizontal displacement due to high extraction mining may include the centers and margins of longwall, a topic discussed more extensively in other reports prepared for this project.

Under Pennsylvania Law (McElfish, 1998), coal mine operators are required to repair or compensate property owners for subsidence damage to the structures listed, and to the extent technologically and economically feasible, correct any material damage to surface lands. Operators are also required to restore or replace private water supplies that have been affected by contamination, diminution, or interruption with an alternative permanent source. However, temporary water storage tanks, commonly referred to as water buffaloes, may be used for extended periods of time.

Table 4

**Factors That May Reduce Residential Property Value**

| Direct Subsidence Damage | Nuisance Effects | Health / Safety Concerns | Potential Post-Mining |
|---|---|---|---|
| **house structure**<br>Foundation, floors, walls<br>Ceilings, windows, doors<br>Electrical wiring / plumbing<br>roofs, gutters, chimneys<br><br>**Surface land**<br>ground cracks<br>lot drainage problems<br><br><br>**Permanently affixed structures**<br>Garages, sheds<br>patios, walks, driveways<br>Customer-owned utilities/cables<br>fences and other enclosures<br>septic treatment facilities<br>Retaining walls<br>Swimming pools<br><br>**water supplies**<br>Contamination<br>Diminution or disruption | **noise pollution**<br>coal truck traffic<br>air shafts / fans<br>general operations / blasting<br><br>**visual / aesthetic**<br>clear-cutting of trees<br>power transmission lines<br>temporary water tanks<br>structure support measures<br>jacking foundations<br>banding structure<br>abandoned houses<br>boarded-up / unrepaired<br>valley fill operations<br><br>**general inconveniences**<br>violation of privacy<br>pre-mining surveys<br>disruption of lifestyle<br>relocation during mining<br>traffic delays<br>increased road repair | water contamination<br><br>methane gas releases<br><br>increased truck traffic accidents<br><br>natural gas explosions<br><br>landslides<br><br>psychological stress | subsidence future damages<br><br>acid mine drainage<br><br>methane releases |

Source: compiled from existing literature and personal interviews.

The data sources identified in the introduction indicate that current homeowners are generally being compensated for these directly observable subsidence-related damages, either through private agreements with the coal operators or from individually purchased subsidence damage insurance.[281] In 1998, the PADEP is collecting information from coal mine operators to more completely evaluate these activities.

281. Homeowners that carry subsidence insurance are required to pursue all other means of compensation first; hence, most of the damage claims that were filed with the DEP in 1996 were associated with abandoned mines (Schurr, 1997). Mine subsidence insurance was established in 1961 and is administered by the Pennsylvania Department of Environmental Protection. Both residential and non-residential policies are available. The annual premium for residential subsidence insurance in Pennsylvania is $1 per $1,000 insured value, up to $91 for the maximum $100,000 coverage. Commercial property owners pay a higher rate (McElfish and Beier, 1996).

The timing of subsidence events from high extraction mining is an important issue in determining whether these damages are actually fully covered under existing legislation. With high extraction methods, most subsidence occurs immediately, but a small fraction may not occur until long after mining (Werner, 1994; Peng and Luo, 1997). However, homeowners who continue to purchase subsidence insurance through the DEP would continue to be covered (Schurr, 1997).

Recent estimates for some costs when mining or subsidence occurs have been reported by the Environmental Quality Board (1997, p. 2388) as:

- Premining structure surveys cost $300-$800 per property and water survey cost $500-$1,500 .
- The typical cost of repairing a subsidence damaged structure is $30,000-$40,000.
- The typical cost of replacing a water supply at an underground coal mine site is $5,000-$10,000. In addition, the cost of providing temporary water is $1,000-$2,000.

These costs are the focus of existing mine legislation that require the mining operation to carry out a variety of mitigating, replacement or compensating actions.

The activities of citizen groups who oppose high extraction mining indicate that some homeowners feel that they are not being fully compensated for subsidence-related damages related to mining. Discussions with individuals in the region indicate that concerns exist regarding: potential structural damage that is not visible (or detectable) by them and has not been repaired; that replacement water supplies do not have the same value (more expensive to operate, quality concerns, differences in taste, etc.); or that structural damage will continue to occur in the future among other issues. Whether these concerns impact house values in the region depends on the perceived risks and subjective values of the entire mix of buyers and sellers acting in the market. Therefore the impact of these issues cannot be determined without a more detailed market analysis.

### 2.1.2 Potential Indirect Impacts and Timing

Focusing solely on direct subsidence-related damages ignores the fact that house prices in the region may also be impacted by the remaining factors listed in Table 4. The negative effect on house prices due to nuisance impacts, perceived health and safety concerns, and uncertain future impacts likely similar to those of underground coal mining is well documented in the economics literature

(Farber, 1998; Appendix A). That literature examines the effects of landfills, toxic waste sites, transportation activity, and waste-to-energy incinerators on local real estate markets. Table 5 presents the findings of four such studies. The results consistently show that house values decline when an undesired facility or activity is introduced in the local area, largely due to these types of impacts. In general, houses within a 2-mile radius of the unwanted land use were most affected. For nonhazardous land uses, the impacts tend to extend out to a 3-mile radius, while the impacts of hazardous sites can affect a 6-mile area. While these cases are not exactly analogous to high extraction underground mining, they suggest the presence of broad based impacts on property values from sites whose physical extent is typically less than a large mine. The implication of the existing literature is that the potential impacts on the housing market in the region are not limited to houses that are directly undermined or are projected to be undermined, but includes all properties that are subject to effects that are perceived as undesirable.

In the studies in Table 5, the estimated distance premium represents the impact on property values of homes affected by the land use unwanted by some surface owners. For example, consider two houses that are identical in every way, except one is located one mile from a toxic waste site and the other is located two miles from the site. Kohlhase (1994) found that on average, the house located one mile from the site sold for $2,360 *less* than an identical house that was located two miles away. In other words, house prices increased by an average of $2,360 per mile until one moved approximately 6 miles away from a toxic waste site (houses beyond 6.2 miles of the site were not affected). Dividing this figure ($/mile) by the average selling price of homes in the area yields the distance premium in terms of percent per mile. In the previous example, the house located one mile from the site sold for 3.0% *less* than an identical house that was located two miles away. An important distinction between these studies and the situation in mining regions is the legal separation of the surface and mineral rights. It is possible that if surface owners are fully informed of potential impacts prior to acquiring the property then property value impacts may be reduced, because the purchaser would likely have paid a lower price initially. These issues regarding the information known to buyers as well as any lasting stigma effect of activity are the subject of current economics research (Hite, 1998; McCluskey, 1998).

**Table 5**

**Property Value Studies of Controversial Land Uses**

| | Land Use / Location | Time Periods Analyzed | Distance Premium | | Area Affected | |
|---|---|---|---|---|---|---|
| | | | $/mile | %/mile | Most | Max |
| Kiel and McClain (1995) | municipal waste-to-energy incinerator (N. Andover, MA) | pre-rumor<br>rumor<br>construction<br>on-line<br>ongoing | <br><br>$2,283<br>$8,100<br>$6,607 | <br><br>1.7%<br>3.2%<br>2.7% | <br><br>2<br>2<br>2 | <br><br>3.5<br>3.5<br>3.5 |
| Kohlhase (1994) | 6 toxic waste sites (Harris Cty., TX) | prior to EPA announcements; after site identified as NPL by EPA | $2,360 | 3.0% | NA | 6.2 |
| Nelson et. al. (1992) | municipal landfill (Ramsey, MN) | operation | $5,000 | 6.2% | 2 | 2.5 |
| Smolen et. al. (1992) | hazardous waste landfill (Toledo, OH) | operation | $12,100 | NA | NA | 5.8 |

With regard to potential impacts from high extraction coal mining, any impacts on property values would vary spatially in the area, with houses that are directly affected by undermining experiencing the greatest loss. While some agreements between coal operators and residential property owners who are directly damaged contain provisions for a payment for inconveniences, other home owners that are subject to the more indirect effects are not known to receive compensation.

### 2.1.2.1 Timing of Impacts From Unwanted Facilities and Potential Application to Mining

The economics literature also documents that the impacts of locally unwanted land uses on house values tend to vary over time due to changes in both real and perceived impacts associated with the activity. For example, there are several distinct time periods in underground coal mining where the impacts on property values are likely to vary. These stages are: (1) initial property values prior to any announcement about mining activity; (2) the rumor stage, when a new mine is proposed in the region; (3) the mine permitting stage, when individual houses are identified as part of a subsidence control plan; (4) the actual mining and expected subsidence period; and (5) the post-mining period when subsidence may or may not be believed to be a danger.

During the first stage, no significant price-distance effect to the eventual mine site should exist. House prices at this stage should simply reflect the various structural and neighborhood characteristics of the market. The second stage begins once the community becomes aware of the proposed mine. Uncertainty arises as to whether the permit will be approved and what the various effects of mining activity will be. This uncertainty may be reflected in the local real estate market as lower selling prices and/or longer listing periods. The third stage begins when the actual mining permit is approved by the DEP. During this stage the mine is considered a certainty, but the exact effects underground mining are still unknown. A price-distance effect on house prices becomes more likely and larger. The fourth stage begins when actual undermining and subsidence takes place and continues through the compensation and repair period. Knowledge of the effects of underground mining accumulates through this period. The final stage consists of the post-mining period after the mine has closed. Houses that were not undermined may return to housing market conditions similar to the first stage after any adjustments for permanent changes. The degree to which the market for houses that were undermined returns to normal may depend on how the participants view the risk of future effects. If they believe future damages are likely to occur or that some stigma is attached to the property (McCluskey, 1998), the potential exists for any negative impacts to persist into the future.

The timing of these phases can differ significantly between high extraction and standard room and pillar mining. The economic impact is ambiguous. Generally, delaying damage will reduce cost. However, the degree of certainty of mitigation or compensation in the near term can reduce the cost of earlier impacts.

Property values in the region can also be affected by changes in regulations. For instance, property values may have been impacted in August, 1994 when Act 54 became effective. Act 54 deleted section 4 of the BMSLCA (52 P.S. 99 1406.4) which provided protection to pre-1966 dwellings and repealed section 15 (52 P.S. 99 1406.15) which provided surface owners with an opportunity to purchase coal support beneath their properties to prevent damage. At the same time, it added requirements for compensation and other action. The net effect of these changes cannot be estimated without further study.

### 2.1.2.2 Market Response: Supply and Demand for Housing

Throughout the different stages, underground coal mining can impact property values from both the supply and demand side. On the demand side, employment from the mine and related activity increases the demand for housing. This effect can be significant in areas such as Washington and Greene county where 2 and 11 percent respectively of employment is in the mining industry (Van Landingham, 1998) and indirect demands increase the effect. Demand may decrease from others who are aware that underground mining takes place in the area and who are concerned about real or potential effects from mining. Whether the various impacts are real or imaginary may not be the critical issue, since individuals often act on the basis of perceptions as well as fact.

Slovic (1987) summarizes the psychological literature on risk perception. Among the factors listed by Slovic that may increase risk perceptions from high extraction mining are the potential to be uncontrolled ( by the surface owner), not equitable, not easily reduced and involuntary. Factors listed by Slovic that may reduce risk perceptions are the generally observable nature of damage, effects are immediate, and known to science and to those exposed. As risk perceptions are individually held, different individuals may have very different views on some of these items.

On the supply side, even though land may be relatively inexpensive in areas projected to be undermined, contractors may be hesitant to build and lenders may be reluctant to extend credit on these properties. Consequently, the supply of houses may be less than would have existed in the absence of mining.

It should be noted that *individual* perceptions may have little impact on the overall housing market of the region. For example, assume most residents in the region are generally unconcerned with the effects associated with underground coal mining. While an individual may have a strong aversion to the activity and be willing to sell at a sizable discount, the homeowner may still be able to sell at the current market price of a similar house not affected by mining. Conversely, if local residents in general are concerned about effects, even if some are not, then house prices will likely decline.

#### 2.1.2.3 Information and Public Awareness

The question remains as to whether or not house buyers in the region are fully aware of the potential for underground coal mining to occur. Some current homeowners have stated that they were assured by local lawyers and real estate agents that the area had been mined out long ago and that future mining was not a threat (Stranahan, 1997a). Buyers from the local area would likely be informed given the publicity the issue has received. By law, the potential for underground mining has to be included in the property disclosure statement that the seller fills out and signs. However, real estate agents are only required to inform the buyer if the owner explicitly tells the agent that the house is projected to be undermined (C. Wiles, 1997). However, even if buyers are initially unaware of the potential for mining, an appraiser may uncover it during the mortgage application (C. Wiles, 1997) and prior to closure the property. In a different application involving landfills, recent research (McCluskey, 1998) indicates that many property owners were uninformed about the presence of landfills that affected local property value.

### 2.1.3 Housing Market Data

While both negative and positive factors from high extraction underground coal mining are likely reflected in property values in the region, local studies relating to mining in comparable detail to those discussed on Section 2.1.2 are not known to exist. Historical data of relevant summary statistics such as number of houses sold, average time on the market, average selling price of homes, and the difference between asking price / selling price are not kept by the county tax assessors. Although such data are potentially available for Washington County from 1980 to present through West Penn Multi-List, they are not available for Greene County, where such data are likely to be more meaningful in the context of the impacts of underground mining on property values.

One statistical source of aggregate property value data is the Census of Population and Housing. Census data for the 1980 and 1990 owner reported, median market value for houses in both counties appear in Tables 6 and 7. Table 6 shows the median values in Washington County for the top 25 townships, ranked by the 1996 assessed values of coal, and the percentage change in median values from 1980 to 1990. Ten of these townships are currently affected by an underground coal mine. Of these, nine experienced a lower percentage change in housing value between 1980 and 1990 than the overall county level of 37.47 percent. On average, townships that are currently over an active underground coal mine changed 32.67 percent (about 5% less than the county average), with those townships that have a large geographical area over a mine changed by 31.19 percent (over 6% less than the county average). Townships in the ranking that are not currently over a mine experienced a change of 36.93, much closer to the county average. Compared to other regional real estate markets, Washington County is roughly consistent with other counties such as Somerset and Westmoreland in the Pittsburgh area. However, the rate of increase is substantially below that of Fayette County and the state average as shown in Table 6.

## Table 6

**Median Value of Housing in Washington County, 1980-1990**
**Top 25 Townships in Terms of Assessed Values of Coal in 1996**

| Township | Ranking Assessed Value | Active Underground Coal Mines | Area Affected | 1980 Median Market Value | 1990 Median Market Value | 1980-1990 Percent Change |
|---|---|---|---|---|---|---|
| Nottingham | 5 | Mathies, Mine 84 | Large | $58,500 | $75,000 | **28.21%** |
| North Strabane | 18 | Mathies, Mine 84 | Large | $53,000 | $71,200 | **34.34%** |
| Somerset | 7 | Maple Creek | Large | $44,800 | $58,700 | **31.03%** |
| West Finley | 14 | Enlow Fork, Bailey | Large | $30,700 | $41,500 | **35.18%** |
| North Bethlehem | 13 | Mine 84, Hillsboro | Medium | $38,200 | $53,600 | 40.31% |
| Amwell | 1 | Mine 84 | Small | $41,200 | $56,300 | **36.65%** |
| Carrol | 19 | Mathies, | Small | $43,600 | $57,100 | **30.96%** |
| East Finley | 6 | Enlow Fork | Small | $40,800 | $52,900 | **29.66%** |
| Fallowfield | 15 | Maple Creek | Small | $38,500 | $48,900 | **27.01%** |
| South Strabane | 8 | Mine 84 | Small | $53,600 | $72,800 | **35.82%** |
| Blaine | 22 | | | $38,500 | $49,800 | **29.35%** |
| Buffalo | 11 | | | $47,800 | $63,300 | **32.43%** |
| Canton | 16 | | | $41,000 | $55,200 | **34.63%** |
| Cecil | 21 | | | $43,100 | $63,900 | 48.26% |
| Cross Creek | 9 | | | $30,100 | $44,900 | 49.17% |
| Donegal | 2 | | | $39,800 | $47,500 | **19.35%** |
| Hopewell | 10 | | | $39,700 | $56,300 | 41.81% |
| Independence | 12 | | | $32,100 | $44,300 | 38.01% |
| Jefferson | 24 | | | $44,400 | $57,100 | **28.60%** |
| Morris | 3 | | | $37,300 | $55,200 | 47.99% |
| Mount Pleasant | 4 | | | $43,500 | $61,400 | 41.15% |
| North Franklin | 25 | | | $51,400 | $67,700 | **31.71%** |
| Smith | 23 | | | $28,400 | $40,300 | 41.90% |
| South Franklin | 17 | | | $51,300 | $72,900 | 42.11% |
| West Bethlehem | 20 | | | $31,300 | $39,900 | **27.48%** |
| **Averages** | | | | | | |
| With Active Mine | | | | | | 32.67% |
| With Large Active Mine | | | | | | 31.19% |
| Without Active Mine | | | | | | 36.93% |
| **Washington County** | | | | $38,700 | $53,200 | 37.47% |
| **Fayette County** | | | | $26,900 | $53,400 | 98.51% |
| **Somerset County** | | | | $32,100 | $43,400 | 35.20% |
| **Westmoreland County** | | | | $42,300 | $56,000 | 32.39% |
| **Pennsylvania** | | | | $39,100 | $69,100 | 76.73% |

Notes: Bold indicates percentage change for townships is less than Washington County average.
Sources: U.S. Bureau of the Census, 1980, 1990.

Table 7 shows the median values in Greene County for the top 20 townships in terms of 1996 assessed values of coal, and the percentage change in median values from 1980 to 1990. Thirteen of these townships are currently over an underground coal mine. Of these, eight experienced a lower percentage change than the overall county level of 22.76 percent. On average, townships that are over an active underground coal mine changed 20.40 percent, with those townships that have a large geographical area over a mine changed by 15.43 percent. Townships that are not currently above high extraction mines experienced a change of 41.74 percent, much higher than the overall county average. Given the large number of townships affected, it may be more meaningful to compare the overall county average of 22.76 percent to surrounding counties. Washington County, Somerset County, Westmoreland County, and Fayette Counties all experienced much greater changes: 37.47 percent, 35.20 percent, 32.39 percent, and 98.51 percent respectively.

Readers are cautioned that while these data are consistent with an impact from mining these aggregate data could also be affected by other causes such as: distance from Pittsburgh, employment opportunities in the area, and so on. Statistical analysis of market data and other factors, such as were used in the studies in Table 5, can help to separate the impact of these potentially confounding factors.

## Table 7

**Median Value of Housing in Greene County, 1980-1990**
**Top 20 Townships in Terms of Assessed Values of Coal in 1996**

| Township | Ranking Assessed Value | Active Underground Coal Mines | Area Affected | 1980 Median Market Value | 1990 Median Market Value | 1980-1990 Percent Change |
|---|---|---|---|---|---|---|
| Richhill | 1 | Bailey, Enlow Fork | Large | $31,000 | $35,200 | 13.55% |
| Jefferson | 8 | Dilworth | Large | $33,500 | $39,300 | 17.31% |
| Wayne | 4 | Cumberland | Medium | $23,800 | $26,800 | 12.61% |
| Franklin | 6 | Emerald | Medium | $45,100 | $58,200 | 29.05% |
| Dunkard | 11 | Warwick, Dunkard, | Medium | $20,200 | $23,200 | 14.85% |
| Cumberland | 13 | Dilworth | Medium | $27,900 | $33,400 | 19.71% |
| Morris | 2 | Enlow Fork | Small | $29,200 | $39,600 | 35.62% |
| Center | 3 | Emerald | Small | $30,800 | $40,800 | 32.47% |
| Whiteley | 5 | Cumberland, | Small | $35,600 | $43,800 | 23.03% |
| Perry | 16 | Cumberland | Small | $38,800 | $46,700 | 20.36% |
| Gray | 17 | Bailey | Small | $33,300 | $36,400 | 9.31% |
| Greene | 19 | Warwick | Small | $33,200 | $44,500 | 34.04% |
| Morgan | 18 | Dilworth | Small | $26,900 | $27,800 | 3.35% |
| Jackson | 7 | | | $23,400 | $35,600 | 52.14% |
| Gilmore | 9 | | | $30,600 | $35,600 | 16.34% |
| Aleppo | 10 | | | $19,000 | $36,100 | 90.00% |
| Washington | 12 | | | $44,100 | $54,800 | 24.26% |
| Freeport | 14 | | | $22,500 | $24,500 | 8.89% |
| Springhill | 15 | | | $9,900 | $14,999 | 51.51% |
| Monongahela | 20 | | | $26,300 | $39,200 | 49.05% |
| **Averages** | | | | | | |
| With Active Mine | | | | | | 20.40% |
| With Large Active Mine | | | | | | 15.43% |
| Without Active Mine | | | | | | 41.74% |
| **Greene County** | | | | $31,200 | $38,300 | 22.76% |
| **Fayette County** | | | | $26,900 | $53,400 | 98.51% |
| **Somerset County** | | | | $32,100 | $43,400 | 35.20% |
| **Westmoreland County** | | | | $42,300 | $56,000 | 32.39% |
| **Pennsylvania** | | | | $39,100 | $69,100 | 76.73% |

Sources: U.S. Bureau of the Census, 1980, 1990.

#### 2.1.3.1 Interviews

Personal interviews were conducted with property tax assessors from both counties and several real estate agents and appraisers in the area to obtain subjective information about the local housing market. Tax assessors from both counties suggested that high extraction coal mining may have a negative impact on house values in the region, and the Greene county tax assessor officially stated that he thinks it already has negatively affected values (Riley, 1997 and Fraser, 1997). While effort was made to contact numerous real estate agents and appraisers, few chose to respond. Some who responded indicated that high extraction mining has definitely had an impact on the time a house stays on the market (or a house's desirability), with buyers often deciding not to purchase a house once they become informed that it is projected to be undermined in the next five years (C. Wiles, 1997; R. Wiles, 1997; anonymous real estate agent, 1997). One appraiser stated that he does not believe that longwall mining has had a significant impact on overall house values in the region. He felt that some of the higher price homes may have been affected, but he believes the impact will be temporary. To date, the fact that a house is to be undermined does not affect his appraisal value. (R. Wiles, 1997).

Based on newspaper articles, the presence of citizen action groups, and hearing records, a visible level of community concern exists in the region, particularly in Washington County. Known community opposition groups include People United to Save Homes (P.U.S.H.) and Nottingham Neighbors in Washington County and POWER in Greene County. While homeowners were not surveyed for this study, the following observations were made by Parizek and Ramani (1996, pp. 183-184) during their interviews with local residents for a study on pre-mine monitoring and water supply replacement. Parizek and Ramani indicated that:

> Some property owners had high levels of anxiety regarding their decision to sell or remain on their property. They feared that they would not be able to find a replacement home or property equal to their present one.
>
> Some were concerned that if a number of homes were to be purchased by the coal operator and abandoned next door to them, there would be little chance that public water would be extended to the few remaining homes.
>
> Others feared that flooding of their property might result following mine closure.

Many home owners objected to using water stored in temporary water tanks on their property. They objected to the taste of chlorine, some were fearful that the water was unsafe for drinking, others complained of tastes, odors, and algae build-up.

### 2.1.4 Potential for Further Study

By focusing on particular mining locations, the methodology used in the property value literature can be applied to estimate the impacts of underground coal mining and valley fill practices (the placing of mine waste in natural hollows or valleys) on residential property values in the region. The results of such a study would be useful to local homeowners, real estate developers, mortgage lenders, appraisers, realtors, tax assessors, and public policy makers.

Based on the preliminary investigation in this report, agencies with responsibility for preserving property value could conduct a study of residential property values in one or more areas affected by high extraction underground mines. Two general methodologies could be used to further analyze the impacts on property values in the region: the hedonic approach or the repeat sales approach. Both are based on two common premises: (1) within a housing market, the difference in sales values between homes can be explained by the difference in qualities of the homes; and (2) home buyers will pay less for homes which are closer to an underground coal mine (a valued disamenity) and that this price differential reflects the marginal value of all of the negative effects associated with the mine. More formally, the value of houses sold at any time period will be a function of the structural characteristics of the house, which do not change over time, and environmental and neighborhood characteristics which change over time.

The hedonic approach analyzes all arms-length sales within a local housing market in order to explain differences between levels of house prices according to housing characteristics, including environmental and neighborhood attributes. The repeat sales approach only analyzes houses within the market which have sold more than once. This approach focuses upon explaining differences in appreciation rates according to environmental and neighborhood characteristics. Because structural characteristics do not change over time, they are not included in the model and hence do not have to be collected. If however, mining related repairs have occurred, then such information can be used in the analysis. The other data requirements of both approaches are very similar.

Proximity to a mine could be measured according to three categories for any approach taken: (1) part of a subsidence control plan and potentially subject to both direct subsidence effects and nuisance effects; (2) close to a mine and potentially subject only to nuisance effects; and (3) far enough away from the mine not to be affected. Differences between houses that are close and houses not affected represent the differences in property values associated with pure nuisance effects, while differences between houses that are part of a subsidence control plan and houses that are not affected measure differences in property values associated with the combined subsidence and nuisance effects. Alternatively, a distance measure to the active, underground location of the mine could be used.

Property value studies such as these could usefully be carried out by the Department of Environmental Protection in its review of Act 54 or by the U.S. Department of the Interior in its supervisory role of mining regulator.

## 2.2 AGRICULTURAL PROPERTY

Agricultural property is a second type of land use. The impact of high extraction coal mining on agricultural property values in the region is unclear although various concerns have been raised (see Table 8). In most cases, direct subsidence damage to agricultural structures is covered under Act 54. No detailed reports or quantitative data pertaining to the impacts of high extraction on agricultural production in the region have been found although newspaper coverage has mentioned such impacts (e.g. Hopey, 1998.).

## Table 8

### Perceived Factors That May Negatively Affect Non-Residential Property

| Property Type | Direct Subsidence Damage | Indirect Effects |
|---|---|---|
| **Agricultural** | structures<br>barns and silos<br><br>surface land<br>ground cracks, sinkholes, or troughs<br>changes in surface drainage / ponding<br>loss of soil moisture<br><br>water supplies - irrigation<br>water supplies - livestock consumption<br>contamination, diminution, or disruption | change in land productivity / crop yields<br><br>more frequent flooding of stream terrace soils<br><br>increased severity of droughts in some areas<br><br>subsided land difficult to plow or prepare<br><br>replacement water supplies may not be suitable for livestock (volume and/or quality) |
| **Commercial / Industrial** | building structures<br><br>fences / enclosures, sidewalks, parking lots<br><br>machinery and equipment<br><br>methane migration into buildings<br><br>surface land<br>cracks, sinkholes, drainage problems<br><br>water supplies<br>contamination, diminution, or disruption | production delays<br>damage to machinery/equipment<br>temporary loss of utility service<br><br>loss of business days<br>closure during mining/subsidence period<br><br>impacts on local business environment<br>future growth potential of region<br>support business, customers, etc. |
| **Public Utilities** | pipelines<br><br>transmission stations<br>facilities and equipment | increased operating costs<br>monitoring / protecting pipelines<br><br>potential natural gas explosions |
| **Infrastructure** | roadways<br>pavements, shoulders, drainage facilities<br><br>bridges | pavement damage from coal truck traffic |
| **Parks / Recreation** | public buildings<br><br>fences / enclosures, sidewalks, parking lots<br><br>surface land<br>cracks, sinkholes, drainage problems<br><br>water supplies<br>contamination, diminution, or disruption<br>loss of springs or stream miles | impacts on wildlife in the area<br>potential loss in biodiversity<br>negative effects on downstream fisheries<br><br>loss in number of days open to public use<br>closure during mining/subsidence period |

### 2.2.1 Impacts on Agricultural Cropland

Greene County is comprised primarily of woodland, pastureland, and hayland and does not have a large cropland area to be affected (Moyer, 1997). Washington County does have a few good cropland areas, but the extent to which they are affected by underground coal mining is not known (Moyer, 1997).

Under PA Code 89.121 coal operators are required to report investigations of impacts on prime farmland to the Soil Conservation Service. Under subsection (e) soil productivity for prime farmlands shall be returned to equivalent levels of yield as nonmined land of the same soil type in the surrounding area under equivalent management practices. However, under subsection (b), land that has not been historically used as cropland is not considered to be prime farmland and the performance standard does not apply in this case. As a result, few soil reconstruction plans are filed with the Soil Conservation Service (Moyer, 1997).

The potential impacts on crop production are primarily related to pollution, physical diminution of water supplies or ponding. To date, most complaints from agricultural interests have been in relation to water loss or contamination and its impact on livestock production (Moyer, 1997). Two anecdotal cases in Greene County of high extraction mining affecting agriculture are:

> A dairy farmer in Greene County reported that the water supply provided by the coal operator was not suitable for livestock consumption and shifted to beef production with an 80 percent decline in revenues. Compensation occurred but the farmer indicated continuing dissatisfaction (Hopey, 1998).
>
> In Khedive, Greene County, longwall mining resulted in substantial subsidence and flooding of an area of prime agricultural land. Although the coal operator wanted the area to be recognized as an official wetland , the county refused (Fraser, 1997)

### 2.2.2 Loss of Investment Options

Options to develop property can be valuable, an economic factor that does not seem to be addressed in current regulations. For instance, coal operators are required to restore affected water supplies to the level of their current use. However, if property owners want to expand their livestock herds, there may not be adequate water supplies available. Hence, they would lose their option to expand. Second, coal operators are not required to provide compensation equal to the cost of replacement to the owner for irreparably damaged barns and silos if it is shown that they were being used at the time of damage for a different purpose than that for which they were originally constructed. An operator is required to provide for the reasonable cost to replace the damaged structure with a structure satisfying the functions and purposes served by the structure before the damage occurred. However, the fact that an owner was not using a barn or silo at the time of damage does not necessarily mean he would not use it for such purposes in the future.

## 2.3 COMMERCIAL AND INDUSTRIAL PROPERTY

Under Act 54, coal operators are required to repair, replace, or compensate owners for material damages from subsidence to commercial and industrial buildings and all permanently affixed appurtenant structures. Damages to surface land and water supplies are also covered (Environmental Law Institute, 1998). It is not clear whether costs incurred from production delays or number of operating days lost if businesses close during the undermining and subsidence period are compensated by coal operators. If local commercial and industrial property owners are not entitled to compensation for these issues, property values may be impacted. A similar potential exists for positive and negative impacts on commercial and industrial property. Some businesses may exist only because of the added activity of high extraction mining. Other business may be reduced if buyers or sellers feel that the future economic growth potential for the region in terms of support businesses, customers, etc. is limited. The value of commercial and industrial property has been little studied for its links to local environmental conditions and no studies are known that quantify such impacts.

## 2.4 PUBLIC UTILITIES

Public utilities own equipment, land and easements in the region; potential impacts focus on damage to equipment and infrastructure. The water and gas utilities, whose pipelines are underground, are the utilities most affected by high extraction underground coal mining. The above ground equipment of telephone and electric companies have not raised the same level of concern regarding the issue.

Gas company officials in particular are concerned about the effect that longwall mining has on the integrity and safety of the gas lines, which operate under pressure. As the high extraction mining occurs, pipelines crossing the mining area may sag, creating a washboard effect. The sags can cause severe strains on the pipeline. Under current regulations, coal operators describe methods of mitigating damage to utilities as part of their subsidence control plan filed with the DEP. The utilities can then have experts provide comments or objections to the DEP who decides whether or not the objections are valid. Any appeals are filed with the Environmental Hearing Board. If a coal operator follows the mitigation procedures outlined in the approved subsidence control plan, utilities are not able to recover any damages incurred as a result of subsidence damage. However, the court may reward damages if it can be shown that the coal operator did not implement the approved measures (Klein, 1997).

Recently proposed changes to legislation would give mine operators the option to either minimize damage or destruction of utility lines *or* minimize disruption of utility service. The revision is intended to provide mine operators flexibility in complying with utility protection requirements. The revision allows use of measures such as supporting utility lines, taking surface measures to mitigate subsidence damage, providing utility customers with alternative service and demonstrating that utility lines are unlikely to be damaged by subsidence (Pennsylvania Bulletin, 5/10/97, p. 2386).

The gas and water utilities are concerned that coal operators will focus merely on minimizing disruption by providing alternative service. Alternative service for water is generally in the form of portable water supplies, while alternative service for gas involves laying electrical lines or providing propane to affected customers. Focusing on minimizing disruption of service could increase the cost of repairs and replacements of transmission lines by the utilities (Regan, 1997; Sumner, 1997). Coal operators maintain that the utilities laid their transmission lines long after the coal rights were separated from surface rights, and that the utilities should have foreseen the potential for future underground mining.

No studies estimating the total miles of transmission lines affected by high extraction underground coal mining or anticipated subsidence damage cost for either industry were found. Both types of pipelines vary significantly in terms of their characteristics such as pipe diameter, materials used, depth laid, etc. Hence, damage estimates would have to be done on a case by case basis.

However, the following information provides some indication of the cost to be borne by one or another of the concerned parties:

> One utility reported spending more than $250,000 over the past five years to protect its pipelines from subsidence damage (Pennsylvania Bulletin, 5/10/97, p. 2383).
>
> A commentator representing a water utility indicated his company will have to spend between $3.5 and $4 million to replace water lines damaged by subsidence damage (Pennsylvania Bulletin, 5/10/97, p. 2383).
>
> A 30-inch water main serving 40,000 Washington-area customers had to be relocated at an estimated cost of $3 million. The two parties involved, Pennsylvania American Water Co. and Eighty-Four Mining Co. reached a private settlement and no details were released as to amounts borne by each party (Stranahan, 1997a).

### 2.5 Public Roads and Bridges

Public property such as public roads and bridges are affected both by subsidence damage and truck damage from road haulage of coal. In the case of subsidence, damage may occur to pavements, shoulders and drainage facilities. Areas forecast to be affected are identified in the five-year projections of the operator's permit application as well as in the six-month mining maps that an operator files. The coal operator bears the direct costs for all repair due to subsidence damage. According to Clark (1997), in most cases, the coal operator performs the actual repair work to the roads themselves; however, emergency repair is occasionally done by the Pennsylvania Department of Transportation (PennDOT), who then bills the operator. Bridge repair from subsidence damage may be designed by PennDOT and fixed by the coal operator or both designed and repaired by the operator directly. All work done by the operator is supervised and inspected by PennDOT. Generally, roads damaged by subsidence are repaired within approximately four weeks (except in the winter when roads may just be patched until summer) and there are no known instances where an operator in S. W. Pennsylvania has not repaired subsidence damage (Clark, 1997).

An example of this practice is that one coal operator recently relocated approximately one-half of a mile of roadway. Longwall mining settled the portion along Route 21 in Khedive, Greene county, approximately four feet. As a result, the road was lower than an adjacent stream and flooded. The coal operator moved the road approximately 20 feet to the south. Because the operator had purchased the affected adjacent properties prior to mining, there were no disputes (Clark, 1997).

Regular roadways are maintained at a level to support coal truck traffic by PennDOT. An estimated cost of resurfacing due to road damage is included in the license fees and taxes that the truck operator pays at both the state and federal level. In order to use roads not intended for truck traffic, the operator is required to post a bond to cover damages. The amount of the bond depends on the road that is affected (Clark, 1997).

As mentioned in Section 2.1.2, changes in transportation use have been identified in other applications as a component of lost property value. Repair work in general results in inconvenience or nuisance costs to the region in terms of increased traffic delays and congestion, and may also have safety implications in terms of number of traffic accidents due to impaired driving conditions. These issues are likely to continue for some time as an estimated 790 miles of roadway in Greene County and 969 miles in Washington County are over remaining coal reserves (U.S. Department of the Interior, 1996a, Table C-7.2).

## 2.6 PARKS AND RECREATION AREAS

Economists values parks and recreation areas as the subjective value that the community places on them, and not the actual real estate value of the land. Under current legislation, coal operators are required to repair, replace, or compensate owners for material damages from subsidence to recreational buildings and all permanently affixed appurtenant structures (Environmental Law Institute, 1998).

The subjective value that local residents place on such publicly owned property could be negatively affected by factors such as loss of springs or stream miles, impacts on wildlife in the area, or water pollution from acid mine drainage. Related issues have been studied in other locations such as probability of catching fish, diversity, visibility, and so on (Freeman, 1997). In addition, if such areas are closed during the undermining and subsidence period, local residents are not able to benefit from their use during that period although any loss would be reduced by the availability of substitute recreation areas. A plan to mine under a state park in the region appears to have been abandoned at the current time (Hopey, 1998; Stranahan, 1997b.)

## 3.0 IMPACTS ON SUBSURFACE PROPERTY VALUES

High extraction coal mining also affects other subsurface mineral property rights owners. The following provides a brief discussion of the keys issues associated with other owners of coal and methane gas in the region.

### 3.1 METHANE GAS

In Pennsylvania, questions exist regarding methane (natural gas) ownership although this is not unique to high extraction mining. The federal Energy Policy Act of 1992 requires states to enact legislation clarifying coalbed methane (CBM) ownership. States that do not, such as Pennsylvania, are subject to federal CBM ownership regulations, which requires that pooling arrangements be established. Pooling requires that gas production royalties be paid into an escrow account, so that conflicts regarding who is entitled to royalties do not jeopardize the development of profitable projects (United States, 1992).

Historically, coal operators have viewed CBM solely as a safety hazard to manage during mining, and common practice is to vent the methane in order to extract coal safely. The methane released into the atmosphere as a result of mining can be thought of as a lost potential resource - the owner of the gas property right (whomever that is determined to be) no longer has the option to develop the methane in the future. Current debates about international agreements to control greenhouse gas emissions are a major source of uncertainty about the value of the option to control methane. Methane is one of the most potent greenhouse gases and should agreements be reached, the ability to control such releases may become either a requirement or a valuable commodity to be sold.

The EPA's Coalbed Methane Outreach Program is working with the coal industry to develop programs that maximize the production of both energy resources contained in coal seams: the coal and the coalbed methane. CBM recovery is expected to increase in the region, and two projects are currently known to exist. The two projects are:

> Appalachian-Pacific Coal Mine Methane Power Company, in conjunction with West Virginia University and Equitable Resources, is evaluating the technical and economic viability of CBM management and utilization systems for coal mines belonging to Cyprus Amax Coal Co. in S.W. Pennsylvania. At the Cyprus Cumberland and Emerald active longwall mines, gob

methane is used to generate electricity (10 megawatts) at the mine site for use by the mine. (Gould, 1997).

CBE, Inc. of Pittsburgh has a gob gas and methane recovery project in Greene

County in conjunction with Consol. They began selling gas in February, 1997, and currently have seven wells under production in the Pittsburgh seam producing an average of 57-60 mcf per day. CBE purchased all rights to the gas to eliminate ownership questions (Gould, 1997).

### 3.2 OTHER COAL OWNERS

A different coal operator may eventually plan to mine in a coal seam above the extracted seam. The overlying coal seam and surrounding rock is also likely to be fractured as a result of subsidence, which may increase mining costs or leave the overlying coal unminable in the future due to technological or economic constraints. This would result in a loss of property value to the party owning the overlying coal rights and a potential loss in public revenue as the seam would be considered as inactive, rather than reserve, for tax assessment purposes (Fraser, 1997).

## 4.0 PUBLIC REVENUES

Local governments rely heavily on property taxes as a source of revenue including those on extractable resources such as coal. High extraction underground coal mining affects public revenues as the value of subsurface property changes and as surface property values potentially change. This section examines key issues related to real estate taxation, underground coal mining, and the flow of public revenues.

### 4.1 SUBSURFACE PROPERTY

Tax revenues from subsurface property are an important source of local revenue, especially for school districts which may receive more than a third of their revenue from property taxes in coal. The existence of high extraction mining at least moves the receipt of revenues forward compared to slower methods which would generally be considered a benefit. If mining could not exist without high extraction methods, then large tax revenues would be lost, although revenue requirements might also fall. This section first describes coal tax procedures, then discusses the role of coal tax revenue in local budgets.

## 4.2 SURFACE PROPERTY

There are two major tax issues related to surface property values. The first involves any negative or positive impacts on local property values as a result of underground coal mining as discussed in Section 2 of the report. Any decrease in assessed property values results in a decrease in the tax base, and hence tax revenues. If appreciation rates are negatively affected, assessed property values and the tax base increase over time, but at a lower rate than what would have existed in the absence of mining. Also, if mining discourages investment in the region, the future tax base would be lower than what would have existed in the absence of mining. These can be thought of as a loss in potential tax revenues. The potential loss may be wholly or partially offset by increased property taxes from residential, industrial and commercial activity related to mining.

The second major area involves surface properties that are purchased by coal operators either for their own uses or as part of their property management activity. Coal operators often purchase surface property in advance of underground mining. After mining is complete, the operator may: retain ownership; sell the property back to the original owner or to other individuals; or transfer the property to public use. (The latter generally involves land that does not contain structures). Two assessment questions are related to surface properties. They are:

> Some homes that are purchased by coal operators prior to mining suffer irreparable damage which is not repaired by the operator. The houses are boarded up and abandoned or completely demolished. These properties represent a direct loss to the tax base, as they are removed from the tax books or assessed at salvage value (Fraser, 1997).
>
> Questions have been raised concerning the assessed values of surface properties that are owned by coal operators, specifically whether they are too low. Such property is taxed as a lot, agricultural land, or industrial land, depending on the historical classification of the deed in question. Land taxed as a lot or agricultural may become classified as industrial when an operator places a structure and/or shaft on the property. Necessary machinery/equipment and degasification holes for methane are not taxable, and hence cannot result in a change of the classification (Fraser, 1997). The main concern seems to be how expansions/investments in operations are monitored and assessed.

### 4.2.1 Coal Tax Procedures

Most of the public coal-based tax revenue is from local real estate property taxes as there are no state level severance taxes in Pennsylvania. Coal taxation procedures vary from county to county which has created a confusing system. The problem of assessing the value of property is significant for mineral properties because of uncertainties about the nature and value of the underground resource. In Greene and Washington counties a tax based on market value is collected. Market value is determined by local authorities and then an assessed value is calculated based upon a valuation formula accepted in the particular jurisdiction. The tax to be levied is the assessed value multiplied by the local millage (tax) rate. This process is discussed in more detail in Appendix B.

### 4.2.2 Coal Tax Revenues

Estimated coal tax revenues received by Greene and Washington Counties during the period 1995-1997 appear in Table 9. These figures were calculated using tax rates and assessed values of coal provided by the county tax assessors; 1997 calculations were based on county estimates of assessed values of coal. The importance of coal tax revenues to the entire county (school districts are discussed separately) differs significantly between Greene and Washington County. The coal tax revenues can be compared to three different revenue measures in each county: total property taxes, total county tax revenue, and total revenue. The latter figure is significantly larger than the tax revenue figures due to inter-governmental transfers that provide over half of each country's total revenue. In Greene County, coal taxes (as a percent of 1992 data) are almost 50 percent of both property and total tax revenue while comprising about 16 percent of all revenue. The corresponding percentages for Washington County are much lower. Coal tax revenues comprise only about 5 percent of property and total tax revenues and about 2 percent of total revenue received by the county. The remainder of this section provides more detail on coal tax revenues.

In 1996, Greene County received approximately $11.4 million in total coal tax revenues: 73.6% ($8.4 million) went to the individual school districts; 19.3% ($2.2 million) went to the individual townships; and 7.1% ($0.8 million) went directly to the county. Washington County received approximately $5 million in total coal tax revenues: 76% ($3.9 million) went to the individual school districts; 15.9% ($0.8 million) went to the individual townships; and 8.1% ($0.4 million) went directly to the county. In 1997, total tax revenues are expected to decline by approximately $1.3 million in Greene County and increase by approximately $1.5 million in Washington County.

**Table 9**

**Coal Tax Revenues (1995-1997)**

| County | 1995 | 1996 | 1997* |
|---|---|---|---|
| **Greene County** | | | |
| School Districts | $8,217,174 | $8,425,127 | $7,167,645 |
| County | $2,037,587 | $2,214,677 | $2,260,756 |
| Townships | $807,417 | $808,411 | $691,324 |
| **Total** | $11,062,177 | $11,448,215 | $10,119,726 |
| **Washington County** | | | |
| School Districts | NA | $3,853,212 | $5,003,329 |
| County | NA | $803,634 | $1,063,083 |
| Townships | NA | $408,982 | $502,664 |
| **Total** | NA | $5,065,828 | $6,569,076 |

Notes: *1997 calculations based on county estimates of assessed values of coal
Source: calculated using millage (tax) rates and assessed values provided by county tax assessors

### 4.2.2.1 Coal Tax Revenues for Individual School Districts

The impact of changes in tax revenues varies by school district. Greene County has five school districts, all of which receive some tax revenues from coal. Information for the individual districts appears in Table 10. In 1996 in Greene County, two school districts received more than a third of their total tax revenues from coal: West Greene (65%) and Central Greene (41%).

With the exception of West Greene which is expected to receive a slight increase in revenues, all of the school districts are expected to receive less coal revenues in 1997. Central Greene will be most affected, with an estimated loss of $1.46 million in coal tax revenues.

**Table 10**

**Coal Tax Revenues and Percentage of Total Property Tax Revenues by School Districts in Greene County**

| | 1993* Share | 1996 Coal Taxes | 1996 Share | 1997* Coal Taxes | 1997* Share | Change 1997-1996 |
|---|---|---|---|---|---|---|
| **West Greene** | 70% | $3,417,806 | 65% | $3,796,903 | 67% | $379,097 |
| **Central Greene** | 55% | $3,938,208 | 41% | $2,476,284 | 30% | ($1,461,924) |
| **Jefferson-Morgan** | 35% | $603,963 | 20% | $489,415 | 16% | ($114,548) |
| **Southeastern Greene** | 15% | $301,082 | 13% | $281,525 | 12% | ($19,558) |
| **Carmichaels Area** | 15% | $164,068 | 7% | $123,519 | 5% | ($40,549) |
| **Total** | | $8,425,127 | | $7,167,645 | | ($1,257,482) |

Notes: * indicates estimate by Greene County tax assessor
Source: Calculated based on school millages and assessed values provided by Greene County tax assessor

Washington County has fifteen school districts, and all but one receive tax revenues from coal. Information for the individual school districts appears in Table 11. In 1996, three school districts received more than $0.5 million from coal taxes: McGuffey, Trinity, and Avella Area. Coal assessments accounted for approximately 5% of total assessed property values for Trinity school district. This implies that although the revenues are significant ($0.8 million), Trinity may be less dependent on coal in the long run than McGuffey and Avella Area, where coal assessments accounted for approximately 16% and 22% of toal assessed property values respectively. In 1997, coal tax revenues are expected to increase for four school districts and decrease for five school districts. McGuffey is expected to experience the greatest increase, approximately $1.17 million, while Bentworth is expected to experience the greatest loss, approximately $0.1 million.

A study ranking the school districts in Pennsylvania in terms of wealth per student was conducted in 1991. With the exception of Peters Township in Washington County which was classified as very wealthy, all of the remaining school districts in the region were classified as poor or very poor (Center for Rural Pennsylvania, 1991). Currently, most local funding for education comes from property taxes.

**Table 11**

**Coal Tax Revenues and Percentage of Total Assessed Property Values**
**School Districts in Washington County**

| | Coal Taxes | Coal Taxes | Change | %Total Assessed 1996 | 1997 |
|---|---|---|---|---|---|
| McGuffey | $1,127,957 | $2,297,470 | $1,169,513 | 16% | 34% |
| Trinity | $791,911 | $889,658 | $97,747 | 5% | 6% |
| Avella Area | $517,472 | $509,747 | ($7,725) | 22% | 22% |
| Bentworth | $302,666 | $198,666 | ($104,000) | 10% | 6% |
| Ringgold | $310,063 | $302,816 | ($7,247) | 3% | 3% |
| Fort Cherry | $316,514 | $318,088 | $1,574 | 8% | 8% |
| Canon-McMillan | $136,950 | $150,038 | $13,088 | 1% | 1% |
| Charleroi | $122,645 | $114,673 | ($7,972) | 2% | 2% |
| Burgettstown | $86,633 | $86,633 | $0 | 2% | 2% |
| Bethlehem Center | $82,236 | $82,236 | $0 | 3% | 3% |
| California | $25,690 | $20,828 | ($4,862) | 1% | 1% |
| Chartiers-Houston | $23,805 | $23,805 | $0 | 0% | 0% |
| Peters Township | $7,216 | $7,216 | $0 | 0% | 0% |
| Washington | $1,455 | $1,455 | $0 | 0% | 0% |
| Brownsville | $0 | $0 | $0 | 0% | 0% |
| Total | $3,853,212 | $5,003,329 | $1,150,117 | 4% | 5% |

Source: calculated using millage rates and assessed values provided by county tax assessors

An issue is how the school districts that are heavily dependent on coal tax revenues will be able to support their schools as the coal is mined and eventually depleted. If the school age population declines proportionally there would be little problem. However, in other locations in the United States related to energy development, the boom and bust flow of public revenues has created problems (Cummings, et. al., 1978). Economists have studied conditions to sustain a level of economic well being in an area. In general, the theoretical result is that private or public investors should reinvest the part of the profit that are due to quality of the energy resource (Solow, 1991; Farrow, 1998). Economists think that investments in education are one possible response to sustainability.

#### 4.2.2.2 Coal Tax Revenues for Individual Townships

Greene County has twenty-six townships and boroughs of which twenty-two have some coal reserves. Table 12 presents information pertaining to coal tax revenues and assessed values for the individual townships for the period 1995 - 1997. In terms of tax revenues, Wayne, Perry, Center, and Richhill Townships have received the most benefits during the period. In 1996, these four townships received approximately $443,988 in coal tax revenues, representing 55% of the total received by individual townships. However, in 1997 both Wayne and Perry Townships are expected to experience substantial decreases in coal tax revenues, $65,991 and $86,143 respectively. In terms of relative importance of coal property taxes, coal represented more than 50 percent of total assessed property values for six other townships in the county.

Washington County has sixty-seven townships and boroughs of which fifty-one have some coal reserves. Information pertaining to coal tax revenues and assessed values for the individual townships for the period 1996 - 1997 appears in Table 13. In terms of tax revenues received, Mount Pleasant, Nottingham, Amwell, and Morris Townships received the most benefits. Somerset Township is expected to experience the greatest decrease in revenues in 1997 ($12,150), while East Finley, West Finley, Morris and South Franklin Townships are expected to experience an increase in coal tax revenues.

An issue between the coal companies and the counties to date has been the timing of filing depletion reports with the County Board of Assessment. If depletion reports are filed slowly, the tax revenues represent a windfall to the county, townships, and school districts to which they have been paid since taxes paid by coal operators on depleted reserves are not refunded unless an error was made directly by the tax assessor (Riley, 1997). However, the result of delayed reporting has been that significant changes in tax revenues occur at one time, often unexpectedly. The major impact has been felt by the individual school districts, many of which rely heavily on coal tax revenues.

## Table 12

### Coal Assessments and Tax Revenues by Townships
### Greene County

| Township | Coal Tax Revenues 1995 | Coal Tax Revenues 1996 | Coal Tax Revenues 1997 | Change in Revenues 1995-96 | Change in Revenues 1996-97 | %Coal of Total Assessed Property Values 1995 | %Coal of Total Assessed Property Values 1996 | %Coal of Total Assessed Property Values 1997 |
|---|---|---|---|---|---|---|---|---|
| Wayne | $190,629 | $190,547 | $124,557 | ($82) | ($65,991) | 74.8% | 74.3% | 64.4% |
| Perry | $93,699 | $93,699 | $7,555 | $0 | ($86,143) | 58.8% | 58.1% | 10.0% |
| Center | $81,424 | $81,424 | $83,714 | $0 | $2,290 | 59.5% | 59.3% | 59.7% |
| Richhill | $78,722 | $78,318 | $106,450 | ($405) | $28,132 | 71.2% | 71.0% | 76.9% |
| Jefferson | $53,028 | $53,028 | $44,704 | $0 | ($8,324) | 30.6% | 30.7% | 27.1% |
| Franklin | $49,384 | $49,384 | $48,612 | $0 | ($771) | 19.8% | 19.5% | 19.1% |
| Whiteley | $47,942 | $47,942 | $66,951 | $0 | $19,009 | 72.2% | 71.7% | 65.4% |
| Jackson | $35,420 | $34,325 | $34,068 | ($1,095) | ($257) | 73.5% | 72.8% | 72.6% |
| Aleppo | $28,571 | $24,913 | $25,539 | ($3,657) | $626 | 57.9% | 54.4% | 54.9% |
| Dunkard | $25,584 | $25,584 | $24,758 | $0 | ($825) | 24.1% | 24.2% | 23.5% |
| Springhill | $23,014 | $11,822 | $11,822 | ($11,192) | ($0) | 52.4% | 35.9% | 35.8% |
| Morris | $22,111 | $30,955 | $49,648 | $8,844 | $18,693 | 55.7% | 55.6% | 66.8% |
| Cumberland | $18,002 | $18,002 | $13,553 | $0 | ($4,449) | 7.7% | 7.6% | 5.7% |
| Washington | $17,342 | $23,046 | $23,046 | $5,704 | ($0) | 34.4% | 34.0% | 33.3% |
| Gray | $15,374 | $15,374 | $2,655 | $0 | ($12,719) | 82.7% | 82.8% | 45.8% |
| Gilmore | $14,724 | $14,617 | $13,012 | ($106) | ($1,605) | 76.9% | 76.9% | 66.1% |
| Freeport | $4,573 | $4,360 | $4,360 | ($212) | $0 | 49.9% | 48.4% | 48.6% |
| Morgan | $3,485 | $5,735 | $3,309 | $2,250 | ($2,426) | 4.3% | 4.3% | 2.5% |
| Rices Landing | $2,646 | $3,591 | $1,482 | $945 | ($2,110) | 8.6% | 8.6% | 3.8% |
| Greene | $1,349 | $1,349 | $1,314 | $0 | ($35) | 7.1% | 7.1% | 4.8% |
| Jefferson Bgh | $201 | $201 | $91 | $0 | ($110) | 3.9% | 3.7% | 1.6% |
| Monongahela | $177 | $177 | $106 | $0 | ($72) | 0.4% | 0.4% | 0.3% |
| **Total:** | $807,399 | $808,393 | $691,307 | $994 | ($117,087) | | | |

Source: calculated using tax rates and assessed values provided by county tax assessors

## Table 13

### Coal Assessments and Tax Revenues by Townships: Washington County

| | Assessed Coal Values | | | Coal Tax Revenues | | |
|---|---|---|---|---|---|---|
| | Coal 1997 | Change 1996-1997 | % Total 1997 | Revenues 1996 | Revenues 1997 | Change 1996-1997 |
| Amwell | $5,824,275 | $643,896 | 26% | $25,902 | $29,121 | $3,219 |
| Donegal | $3,879,369 | $0 | 29% | $23,276 | $23,276 | $0 |
| Morris | $3,783,780 | $306,893 | 45% | $24,338 | $37,838 | $13,500 |
| Mount Pleasant | $3,162,407 | $16,356 | 15% | $31,461 | $31,624 | $164 |
| Nottingham | $2,574,051 | ($59,317) | 14% | $26,860 | $26,255 | ($605) |
| East Finley | $7,553,185 | $4,922,512 | 58% | $21,045 | $60,425 | $39,380 |
| Somerset | $1,235,414 | ($1,350,054) | 8% | $23,269 | $11,119 | ($12,150) |
| South Strabane | $2,894,759 | $490,935 | 4% | $14,423 | $17,369 | $2,946 |
| Cross Creek | $2,131,313 | ($58,175) | 19% | $18,173 | $17,690 | ($483) |
| Hopewell | $1,937,779 | $0 | 34% | $23,253 | $23,253 | $0 |
| Buffalo | $1,800,299 | $0 | 15% | $12,602 | $12,602 | $0 |
| Independence | $1,496,779 | ($26,250) | 18% | $13,707 | $13,471 | ($236) |
| North Bethlehem | $1,318,210 | ($600) | 16% | $21,101 | $21,091 | ($10) |
| West Finley | $9,812,538 | $8,519,564 | 70% | $5,172 | $39,250 | $34,078 |
| Fallowfield | $1,174,664 | ($83,042) | 6% | $17,608 | $19,969 | $2,361 |
| Canton | $1,150,712 | $0 | 3% | $5,178 | $5,178 | $0 |
| South Franklin | $2,462,914 | $1,467,468 | 13% | $7,764 | $19,211 | $11,446 |
| North Strabane | $1,073,148 | $154,154 | 1% | $10,550 | $12,320 | $1,770 |
| Carrol | $747,697 | $0 | 2% | $2,692 | $2,692 | $0 |
| West Bethlehem | $698,510 | $0 | 13% | $11,316 | $11,316 | $0 |
| Cecil | $694,079 | $0 | 1% | $11,105 | $11,105 | $0 |
| Blaine | $517,560 | ($27,952) | 13% | $4,637 | $4,399 | ($238) |
| Smith | $480,517 | $0 | 3% | $5,766 | $5,766 | $0 |
| Jefferson | $455,048 | $0 | 7% | $19,795 | $19,795 | $0 |
| North Franklin | $427,219 | ($3,500) | 1% | $6,461 | $6,408 | ($53) |
| Union | $291,344 | ($29,055) | 1% | $2,243 | $2,622 | $379 |
| Chartiers | $264,495 | $0 | 1% | $2,380 | $2,380 | $0 |
| Robinson | $142,405 | $0 | 1% | $1,424 | $1,424 | $0 |
| West Pike Run | $136,346 | $0 | 2% | $1,363 | $1,363 | $0 |
| California Bgh | $61,767 | ($58,175) | 0% | $3,958 | $2,038 | ($1,920) |
| Peters | $100,225 | $0 | 0% | $1,203 | $1,203 | $0 |
| East Bethlehem | $86,517 | $0 | 1% | $1,817 | $1,817 | $0 |
| Deemston | $63,151 | $0 | 2% | $853 | $979 | $126 |
| Marianna | $60,000 | $0 | 4% | $1,776 | $1,776 | $0 |
| New Eagle | $49,815 | $0 | 1% | $1,494 | $1,494 | $0 |
| Long Branch | $41,805 | $0 | 2% | $393 | $393 | $0 |
| Bentleyville | $26,450 | $0 | 0% | $503 | $503 | $0 |
| Centerville | $24,200 | $0 | 0% | $629 | $629 | $0 |
| Green Hills | $22,742 | $0 | 5% | $114 | $114 | $0 |
| Monongahela City | $22,588 | $0 | 0% | $474 | $474 | $0 |
| **Total** | $60,747,597 | $14,825,658 | | $408,982 | $502,664 | $93,683 |

Source: calculated using tax rates and assessed values provided by county tax assessors
Notes: Does not include areas with less than $20,000 in assessed values, which are reflected in totals.

## 5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This paper surveyed the potential links between modern underground coal mining practice, property value and local public revenues. Although Federal law regarding surface damage from underground mining requires that "repair of damage shall include rehabilitation, restoration, or replacement... while compensation ...shall be in the full amount of the diminution in value resulting from the subsidence"[282], no reliable statistical evidence from market based studies of property value appear to exist in the region. However, census data at the township level are consistent with housing values rising more slowly in major areas of underground mining. The distinction between property owners directly affected and those indirectly affected has also not been evaluated. The economic literature on property value and analogous, though not equivalent, activities to that of mining suggests that it is very likely that property not directly affected by subsidence may also decrease in value. However, in contrast to the existing applications in the economic literature, the importance of the mining industry to the region provides significant direct and indirect employment opportunities that tend to increase the value of property compared to a scenario with no mining in the region.

The existence of repair and compensation programs by coal companies, contrasting anecdotes of problems, and an economic literature quantifying the negative impacts of some types of locally unwanted land uses indicates that the question of property value impacts can only be resolved by a location and industry specific study. Such a study could be carried out by an agency whose statutory mission includes responsibility for maintaining property value. In the absence of such a study, it does not appear possible to evaluate whether current practices achieve program objectives.

The coal industry also provides substantial direct tax revenue to various taxing districts in the region. Recent concerns for sustainable use of natural resources suggest that both the uses of the revenue and planning for changes in tax income could be a subject for review at the local level.

## 6.0 REFERENCES

Beveridge, S., 1996. "Bentworth Deals with a Coal? Hard Fact," *The Washington Observer-Reporter*, October 17, 1996, A1.

282. 30 U.S.C. section 1309a(a)1 (or 30 CFR 817.121c(2).

Bissell, P. E., 1982. *Economic Analysis of a Severance Tax on Pennsylvania Bituminous Coal Production*, Ph.D. dissertation, Department of Mineral Economics, The Pennsylvania State University, August 1982.

Bureau of the Census, 1980. *Census of Housing, Pennsylvania*, U.S. Department of Commerce, Economics and Statistics Division, U.S. Government Printing Office, Washington, DC.

Bureau of the Census, 1990. *Census of Housing, Pennsylvania*, U.S. Department of Commerce, Economics and Statistics Division, U.S. Government Printing Office, Washington, DC.

Center for Rural Pennsylvania, 1991. *Rich Schools - Poor Schools: Challenges for Rural and Urban Pennsylvania*, Technical Paper No. 8, Harrisburg, PA.

Clark, Ron, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with Ron Clark, Maintenance Division, Pennsylvania Department of Transportation, May 20, 1997.

Cummings, R., W. Schultze and A. Mehr, 1978. "Optimal Investment in Boomtowns," *Journal of Environmental Economics and Management*, (5)252-267.

Environmental Quality Board, 1997. Rules and Regulations and Proposed Rulemaking: 25 PA Code Ch. 89, *Pennsylvania Bulletin*, Vol. 27, No. 19, May 10, 1997, pp. 2371-2401.

Farber, Steve, 1998. "Undesirable facilities and property values: a summary of empirical studies,: Ecological Economics. 24:1-14.

Farrow, S., 1997. "Environmental Equity and Sustainability: Rejecting the Kaldor-Hicks Criteria," forthcoming, *Ecological Economics*, 1998.

Gould, Courtland, 1997. Personal Communication, Kristen Strellec, of Dames & Moore, with Courtland Gould, reporting on a coalbed methane conference, 1997.

Fraser, John, 1997. Personal communications, Kristen L. Strellec, of Dames & Moore, with John Fraser, Coal Tax Assessor, Greene county, March 18 - 27, July 17 1997.

Hite, D., 1998. "Information and Housing Value," forthcoming, *Land Economics*, 1998.

Hopey, D., 1998. "Longwall mining causes damaging land subsidence," *Pittsburgh Post-Gazette*, April 19, 1998.

Intergovernmental Panel on Climate Change, 1996. *Climate Change: 1995,* Cambridge University Press.

Jarosz, A., M. Karmis, and A. Sroka, 1990. Subsidence Development with Time - Experiences from Longwall Operations in the Appalachian Coalfield, *International Journal of Mining and Geological Engineering*, Vol. 8, pp. 261-273.

Kiel, K. A., and K. T. McClain, 1995. "House Prices During Siting Decision Stages: The Case of an Incinerator from Rumor Through Operation," *Journal of Environmental Economics and Management*, Vol. 28, No. 2, pp. 241-255.

Kohlhase, J. E., 1991. "The Impact of Toxic Waste Sites on Housing Values," *Journal of Urban Economics*, Vol. 30, pp. 1-26.

Klein, Mike, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with Mike Klein, Attorney, May 19, 1997.

Kohl, Barbara, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with Barbara Kohl, Vice President, West Penn Multi-List, May 19, 1997.

McCluskey, J., 1998. "A Dynamic Model of Housing Values and a Test of the Existence of Property Value Stigma Effects," mimeo, Department of Agriculture and Natural Resources, Univ. of California at Berkeley, 1998.

McElfish, J. M., Jr. and A. E. Beier, 1996. "Underground Mining - Subsidence," Chapter 8 in *Environmental Regulation of Coal Mining: SMCRA?s Second Decade*, Environmental Law Institute.

McElfish, J.M. Jr. "Regulation of Longwall Mining and Valley Fill Practices in Pennsylvania," Background Report prepared for *Coal Mining Project*, Audobon Society of Western Pennsylvania, 1998.

Moyer, Robin, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with Robin Moyer, Soil Conservation Service, Pittsburgh, June 26, 1997.

Nelson, A. C., J. Genereux, and M. Genereux, 1992. "Price Effects of Landfills on House Values," *Land Economics*, Vol. 68, No. 4, Nov. 1992, pp. 359-365.

Oak Ridge (Oak Ridge National Laboratory), 1994. *Estimating Externalities of Coal Fuel Cycles*, Report No. 3 on the External Costs and Benefits of Fuel Cycles, Prepared by Oak Ridge National Laboratory and Resources for the Future for U.S. Department of Energy, September 1994.

Parizek, R. R., and R. V. Ramani, 1996. Longwall Coal Mines: *Pre-Mine Monitoring and Water Supply Replacement Alternatives*, Final Report on Legislative Initiative Program 181-90-2658, Environmental Resources Research Institute.

Peng, S. and Y. Luo, 1997. "Models Predict Subsidence Influence," *Coal Age*, February, 1997.

Pennsylvania Agricultural Statistics Service, various years 1985-1995. *Crop and Livestock Annual Summary*, Pennsylvania Department of Agriculture.

Pennsylvania Center (The Pennsylvania Center for the Study of Labor Relations, IUP), 1994. *Implications of a Comprehensive Pennsylvania Coal Policy for Economic Development and Taxation*, Draft Report prepared for the Center for Rural Pennsylvania.

*P.U.S.H. et al. v. DEP and Eighty-Four Mining Company*, EHB Docket Nos. 95-232-R (Consolidated) (Opinions and Orders issued November 27, 1996, and December 23, 1996).

Regan, Dan, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with Dan Regan, PA Gas Association, May 13, 1997.

Riley, Gary, 1997. Personal communications, Kristen L. Strellec, of Dames & Moore, with Gary Riley, Tax Assessor, Washington county, March 18 - 27, July 17, 1997.

Ruane, L.V., 1995. Written correspondence, Charles R. Murray with Lawrence V. Ruane, Administrator, PA DEP Mine Subsidence Insurance, June 30, 1995.

Schultze, W. approx title "Boom and Bust in Energy Towns of Colorado," *Journal of Environmental Economics and Management.*

Schurr, Larry, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with Larry Schurr, PA DEP, subsidence insurance division, June 26, 1997.

Smolen, G. E., G. Moore, and L. V. Conway, 1992. "Economic Effects of Hazardous Chemical and Proposed Radioactive Waste Landfills on Surrounding Real Estate Values," *The Journal of Real Estate Research*, Vol. 7, No. 3, Summer 1992,pp. 283-295.

Smydo, J., 1997. "Coal Values Costly to County, McGuffey,?" *The Washington Observer-Reporter*, March 14, 1997, A1:2.

Solow, R., 1991. An Almost Practical Step for Sustainability, *Marine Policy.*

Stranahan, S. Q., 1997a. "PA Coal Dispute that Runs Deep," *The Philadelphia Inquirer*, February 2, 1997, D12.

Stranahan, S. Q., 1997b. "Gas Company Raises Fears of Mining Below," *The Philadelphia Inquirer*, May 16, 1997, C1:8.

Strellec, K. L., 1994. *A Comparison Between Continuous Distance and Discrete Zones in Hedonic Housing Studies*, Department of Mineral Economics, The Pennsylvania State University, December 1994.

Sumner, David, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with David Sumner, Legislative Director, PA Gas Association, May 19, 1997.

United States, 1992. *Energy Policy Act of 1992, Section 1339*, U.S. Government Printing Office, Washington, DC.

U.S. Department of the Interior, 1996a. *Valid Existing Rights: Draft Economic Analysis*, Draft Report prepared by the U.S. Geological Survey and Office of Surface Mining Reclamation and Enforcement, March 1996.

U.S. Department of the Interior, 1996b. *Valid Existing Rights: Draft Economic Analysis*, Unpublished Support Tables for Draft Report prepared by the U.S. Geological Survey and Office of Surface Mining Reclamation and Enforcement, March 1996.

VanLandingham, W., 1998. "Socioeconomic Profile of Washington and Greene Counties," Prepared for *The Coal Mining Project*, Audubon Society of Western Pennsylvania, 1998.

Washington County Planning Commission, 1996. *Washington County Facts*, Washington County Planning Commission, Washington, PA.

Werner, E., 1994. "Conceptual Models Used for the Analysis of Hydrogeologic Effects Caused by Full-Extraction Coal Mining in the Appalachian Plateau," *Proceedings From the Annual Summer Symposium of the American Water Resources Association, Jackson Hole, Wyoming,* 1994, pp. 275-284.

Wiles, Christi, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with Christi Wiles, Realtor, May 22, 1997.

Wiles, Ron, 1997. Personal communication, Kristen L. Strellec, of Dames & Moore, with Ron Wiles, Real Estate Appraiser, May 23, 1997.

## APPENDIX A: LITERATURE REVIEW OF PROPERTY VALUE STUDIES

This section reviews the economic research on the relationships between local environmental quality and house prices. The review is a revised version of the one contained in Strellec (1994). A related review has recently been completed by Farber (1998.)

Ridker (1967) was the first economist to use residential property value data as the basis for estimating the benefits of changes in environmental quality. In his efforts to measure the impact of air pollution on residential property values, he reasoned:

> If the land market were to work perfectly, the price of a plot of land would equal the sum of the present discounted streams of benefits and costs derivable from it. If some of its cost rise, (e.g., if additional maintenance and cleaning costs are required) or if some of its benefits fall (e.g., if one cannot see the mountains from the terrace) the property will be discounted in the market to reflect people's evaluation of these changes. Since air pollution is specific to locations and the supply of location is fixed, there is less likelihood that the negative effects of pollution can be significantly shifted on to other markets. We should therefore expect to find the majority of effects reflected in this market, and we can measure them by observing associated changes in property values (p. 25).

The main criticism of this early work was that it was largely *ad hoc* with no firm theoretical foundation having been established for the approach. It was Rosen (1974) who provided an economic rationale for the conceptual basis of the hedonic pricing technique.

Rosen (1974) modeled differentiated goods as single commodities that are distinguished by the amounts of various characteristics they contain. The consumers of the different varieties derive satisfaction from the characteristics of the commodity, whereas the producers (sellers) of the commodities incur costs that are dependent on the varieties they provide. The interactions of the consumers and producers in a competitive market for a differentiated product determine the equilibrium hedonic price schedule. A review of the Rosen model as it relates to the choice of residential location can be found in Strellec (1994).

A large number of empirical studies have applied the hedonic approach to examine the effect of air pollution on property values (for example Ridker and Henning, 1967; Harrison and Rubinfeld, 1978; Murdoch and Thayer, 1988; Brucato, Murdoch, and Thayer, 1990). While such studies have contributed greatly to the field, they do not measure the disamenity on a geographic scale, i.e. proximity, and are hence beyond the scope of this review. Such studies generally employ proxy variables for air quality, such as sulfate measures (Ridker and Henning, 1967) or visibility (Brucato, Murdoch, and Thayer, 1990). For a review of these studies see Smith and Huang (1993).

Other studies have applied the hedonic technique to measure the effect of proximity from a noxious facility. Nelson, Genereux, and Genereux (1992) examined the effect of distance from a landfill in Ramsey, Minnesota for the period 1979 through 1989. The analysis proceeded in two phases. First, proximity was measured using one-half mile concentric zones to determine at what distance landfill price effects were insignificant. Although specific details were not reported, this distance was found to be between 2.0 and 2.5 miles. Second, proximity was measured using straight-line distance for homes within a two mile radius. The authors found that house values rose by nearly $5,000 for each mile it is located away from the landfill, or roughly 6.2% per mile.

Kohlhase (1991) examined the effect of distance from ten toxic waste dumps in Houston's Harris County for three separate time periods: prior to the creation of Superfund (1976), coinciding with the creation of Superfund (1980), and after all sites had been announced placed on the National Priorities List by the EPA (1985). Proximity was measured using straight-line distance to the nearest site, and entered the model both directly and as the square of distance. This quadratic formulation was used to allow for a nonlinear price-distance relationship. The initial study was limited to houses located within a seven mile radius of the nearest site. A distance premium could only be detected in 1985. Kohlhase concluded that prior to the EPA's announcements, consumers were indifferent or unaware of the potential health hazards associated with proximity to the dumps. She states "...consumers did not internalize the danger until confronted with federal documentation and ensuing publicity (p.11)." For 1985, housing prices were found to increase at a decreasing rate up to 6.2 miles.

Smolen, Moore, and Conway (1992) examined the effect of distance from a hazardous waste landfill on property values in the Toledo, Ohio, area for the period 1986 through 1990. The sample area was subdivided into the centroid ranges 0-2.6 miles, 2.61-5.75 miles, and greater than 5.75 miles. Rationale for the three distance ranges was to obtain approximately equal sample sizes within each range. The authors estimated a separate regression equation for each zone, using straight-line distance as a measure of proximity. Distance premiums were significant for only for the 0-2.6 mile range and the 2.61-5.75 mile range, estimated at $12, 061 and $12,106 per mile respectively.

In the second part of their study, Smolen, Moore, and Conway (1992) use the same model to examine the price-distance effect of a proposed low-level radioactive waste landfill on property values in Sylvania, Ohio for three different periods: prior to the announcement (1988), the year of the announcement (1989), and after the proposal was rescinded (1990). A distance premium was observed in the 1989 data extending out to the 5.75 mile range. However, the distance variable was insignificant both before the announcement of the proposal and after the proposal was rescinded. The authors concluded that "the local real estate market was clearly responsive to bad news announcements, but demonstrated an ability to recover quickly once the perceived threat was removed (p. 293)."

Gamble and Downing (1982) present the results of two studies. In the first, they examined the price-distance effect of four nuclear power plants in the Northeastern United States on a sample of homes located within a 20-mile distance that sold between 1975 and 1977, i.e. prior to the Three Mile Island (TMI) accident. The coefficient on distance was found to be insignificant for all four areas, suggesting that these nuclear power plants had no adverse effect on property values.

The second part of their study examined house sales within 25 miles of TMI both before (January 1977-March 1979) and after the accident (last nine months of 1979). Separate linear regressions for before and after found distance to be significant before (with a distance premium of $163/mile) but not after the accident. Results of a pooled regression yielded similar distance premiums. However, the dummy variable "after accident" and an interaction term (distance x after accident) were not significant in either specification, implying that there were no significant differences in house prices for the two periods.

In order to examine the possibility that the price-distance relationship was not linear or logarithmic in nature, the authors substituted a dummy variable "close to TMI" for distance in each of the previous specifications. "Close to TMI" was defined in two ways: 0-5 miles and 0-2 miles. Within five miles of TMI, house prices were significantly lower than the rest of the sample, with no evidence that the accident had an effect on prices. However, no significant difference between house prices within two miles of the plant and the rest of the sample were found. Hence, the authors concluded that some factor other than TMI, not identified in the model, was responsible for the variation in house prices. Subsequent regressions were run to examine if there were differential effects in terms of either direction from TMI or value class of property, but no effects attributable to the accident were found.

Twark, Eyerly, and Downing (1990) extend the previous study to include the years 1980, 1981, and 1986. Proximity was measured using four dummy variables representing various distance zones: 0-2 miles, 2-5 miles , and 5-10 miles, with the 10-25 mile zone representing the control area. Contrast procedures were used to test whether the coefficients before the accident were significantly different from coefficients after the accident. Before the accident, the 0-2 mile zone was negative but not statistically different from the control area, while the two more distant zones were both negative and significant. After the accident, the 0-2 mile zone was more negative and significant, while the 2-5 mile zone remained virtually unchanged. The contrast procedure found no significant differences between Before and After coefficients for either zone. The 5-10 mile zone was positive, and the contrast procedure indicated a significant difference between Before and After coefficients. A separate regression run using the 1986 data revealed a negative value for the 0-2 mile zone similar to the level prior to the accident at TMI. The other two zones which had values lower than the control area before the accident, had higher values than the control area in 1986 and the difference was significant.

Reichert, Small, and Mohanty (1992) used both a survey approach and a hedonic model to examine the effects of proximity from five municipal landfills in Cleveland, Ohio. In their hedonic analysis, the authors examined house sales within a one-mile radius for the period 1985-1989. Neither the exact specification of the model nor the complete results are given; however, the authors report that housing prices *declined* by $12,850 for each mile away from a landfill. Separate hedonic models were then estimated for each landfill in the study, but only the results of two are presented.

The first began operation in 1986, which enabled the authors to examine whether the commencement of operations had a delayed impact on housing prices. A dummy variable was included that identified sales that took place at least one year after commencement of operations. A statistically significant negative coefficient (-$8,813) on distance was again found; however, the coefficient on the dummy variable that divides the time periods had a negative and significant coefficient of -$2,924. The value represented 6.1% of the average housing price in the area. The authors suggest that the negative coefficient on distance could be due to the fact that average housing values decline by about $14,000 as one moves out one mile from the landfill.

For the second site, the coefficient on distance was initially negative (-$971) but insignificant. A smaller region just north of the landfill was selected for further study. Here the landfill was separated from an expensive residential community by an active set of railroad tracks. Houses directly north of the landfill were believed to be subject to both a potential landfill and a railroad effect. A dummy variable was included to measure the combined effect. Houses located near the far northeast and northwest corners of the landfill and adjacent to the railroad track were assumed to be subject primarily to the railroad effect. The "pure" railroad effect was measured using a second dummy variable. The landfill effect was represented by the difference between the two coefficients. Approximately 19.2% of the observations in the reduced model were subject to the combined effects, while 22.4% fell in the pure railroad effect area. Both the coefficients on the combined effect and the pure railroad effect were negative and significant (-$12,787 and -$6,722 respectively). The authors attributed the difference of $6,065 to the landfill. This represented a decline of 5.5% compared to the average selling price in the area, which was somewhat consistent with the 6.1% decline reported for the first landfill.

Thayer, Albers, and Rahmatian (1992) examined the relationship between housing prices and proximity to hazardous and nonhazardous disposal sites in the Baltimore County area for the period 1985-1986. A set of benchmark equations were estimated with the dependent variable actual sales price using linear, semi-log, and log linear forms. Proximity was measured as straight-line distance to nearest site. The linear form yielded a significant distance premium of approximately $1,349 per mile. The semi-log equation produced similar results, with a significant distance premium of $1,701 per mile. The log linear form estimate was not statistically significant; however, it resulted in $327 per mile, a much lower estimate than the other two forms. Based on subsequent analysis, the authors concluded that there was sufficient evidence to support the hypothesis of a leveling of the hedonic price gradient some distance from the waste site. A linear functional form demonstrated two breakpoints, at one and four miles. The semi-log form showed less evidence of leveling, particularly for division values less than five miles.

The authors used two schemes to incorporate the concept of a leveling hedonic price function into the benchmark equations. The data was divided into three distance zones: less than one mile, between one and four miles, and greater than four miles. First, zones were assigned discrete values 1, 2, and 3.

From this procedure, the coefficient representing the value of a movement across boundaries was found to be $4,380 ($5,320) in the linear (semi-log) model. A home two zones removed would be worth approximately twice the value for one zone. In the second scheme, each of the three zones was represented by a dummy variable, which allowed for unequal differences between zones to be identified. For the linear form, the difference between a Zone 2 and a Zone 1 house was about $11,500, while the difference between houses in Zone 3 and Zone 2 was about $2,400.

In the final part of their paper, the authors examine the difference between hazardous and nonhazardous sites using the original benchmark specifications. The price gradient for distance from hazardous waste sites was approximately $2,194/mile ($2320/mile) for the linear (semi-log) form. The price gradient for the nonhazardous waste site, obtained by adding the two coefficients, were $761/mile and $1370/mile for the linear and semi-log forms, respectively. The authors assumed that nonhazardous waste sites had only aesthetic effects, so that the linear (semi-log) results implied that 35% (60%) of total value was for the nuisance component of proximity, with the remaining portion of value attributed to the health consequences of a hazardous site.

Kiel and McClain (1995) measured the impact of a waste-to-energy incinerator in North Andover, Massachusetts over the period January 1974 through May 1992. The study period was divided into five stages according to the level of risk as perceived by local residents: pre-rumor, rumor, construction, on-line, and ongoing operations.

The pre-rumor stage represents a four year period prior to any mention of the possibility of an incinerator being built. During this period, there should be no significant price-distance effect to the eventual site. The rumor stage begins in 1979, when the community became aware of the proposed project. At this stage there is considerable uncertainty concerning: (1) whether or not the facility will be built, and (2) the environmental effects the facility will have on the community. However, homeowners may be concerned about potential property value loss and/or negative health effects of the facility. If they believe that the facility is likely to built and view it as a disamenity, a price-distance effect may appear.

The construction phase begins in 1981, when a contract was signed with the facility provider. During this stage, the incinerator is taken to be a certainty, but the environmental effects are still unknown. A price-distance effect becomes more likely. The on-line stage commences in 1985, when the facility began operation. Knowledge accumulates over this period until no more uncertainty exists about the negative effects of the facility. Housing prices should make their final adjustment. Three years was considered sufficient time for this process, and 1989 was chosen as the beginning of the ongoing phase. This stage should be similar to the pre-rumor stage if residentÕs fears were unfounded or new buyers were indifferent to the facility. A more detailed explanation of the rationale behind dividing the sample into these five stages can be found in the original study.

The authors found strong evidence of price declines in the construction, on-line, and ongoing stages of operation. The distance premiums calculated for these periods were $2,283 per mile, $8,100 per mile, and $6,607 per mile respectively. The persistence of a distance premium through the ongoing stage suggests that either the facility is viewed by residents as a permanent disamenity or full adjustment of the real estate market takes longer than the time covered by the study.

## BIBLIOGRAPHY


Brucato, P. B., J. C. Murdoch, and M. A. Thayer, 1990. "Urban Air Quantity Improvements: A Comparison of Aggregate Health and Welfare Benefits to Hedonic Price Differentials," *Journal of Environmental Management*, Vol. 30, No. 3, April 1990, pp. 265-279.

Farber, S., 1998. Undesirable facilities and property values: a summary of empirical studies,: Ecological Economics. 24:1-14.

Gamble, H. B., and R. H. Downing, 1982. "Effects of Nuclear Power Plants on Residential Property Values," *Journal of Regional Science*, Vol. 22, No. 4, pp. 457-478.

Harrison, D., and D. L. Rubinfeld, 1978. "Hedonic Housing Prices and the Demand for Clean Air," *Journal of Environmental Economics and Management*, Vol. 5, pp. 81-102.

Kiel, K. A., and K. T. McClain, 1995. "House Prices During Siting Decision Stages: The Case of an Incinerator from Rumor Through Operation," *Journal of Environmental Economics and Management*, Vol. 28, No. 2, pp. 241-255.

Kohlhase, J. E., 1991. "The Impact of Toxic Waste Sites on Housing Values," *Journal of Urban Economics*, Vol. 30, pp. 1-26.

Murdoch, J. C., and M. A. Thayer, 1988. "Hedonic Price Estimation of Variable Urban Air Quality," *Journal of Environmental Economics and Management*, Vol. 15, No. 2, June 1988, pp. 143-146.

Nelson, A. C., J. Genereux, and M. Genereux, 1992. "Price Effects of Landfills on House Values," *Land Economics*, Vol. 68, No. 4, Nov. 1992, pp. 359-365.

Reichart, A.K., M. Small, and S. Mohanty, 1992. "The Impact of Landfills on Residential Property Values," *The Journal of Real Estate Research*, Vol. 7, No. 3, Summer 1992, pp. 297-313.

Ridker, R. G., 1967. *Economic Costs of Air Pollution: Studies in Measurement*, New York, Praeger.

Ridker, R. G., and J. Henning, 1967. "The Determinants of Residential Property Values with Special Reference to Air Pollution," *The Review of Economics and Statistics*, Vol. 49, No. 2, May 1967, pp. 246-257.

Rosen, S., 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy*, Vol. 82, pp. 34-55.

Smith, V. K., and Huang, J.C., 1993. "Hedonic Models and Air Pollution: Twenty-Five Years and Counting," *Environmental and Resource Economics*, Vol. 3, No. 4, pp. 381-394.

Smolen, G. E., G. Moore, and L. V. Conway, 1992. "Economic Effects of Hazardous Chemical and Proposed Radioactive Waste Landfills on Surrounding Real Estate Values," *The Journal of Real Estate Research*, Vol. 7, No. 3, Summer 1992,pp. 283-295.

Strellec, K. L., 1994. *A Comparison Between Continuous Distance and Discrete Zones in Hedonic Housing Studies*, M.S. professional paper, Department of Mineral Economics, The Pennsylvania State University, December 1994.

Thayer, M., H. Albers, and M. Rahmatian, 1992. "The Benefits of Reducing Exposure to Waste Disposal Sites: A Hedonic Housing Value Approach," *The Journal of Real Estate Research*, Vol. 7, No. 3, Summer 1992, pp. 265-282.

Twark, R. D., R. W. Eyerly and R. H. Downing, 1990. "The Effect of Nuclear Power Plants on Residential Property Values: A New Look at Three Mile Island," The Pennsylvania State University, Working Paper #90-10, 1990.

## APPENDIX B

### Coal Property Tax Procedures in Washington and Greene Counties

Standard procedures determine actual public revenue and so the practical details of assessment are important. Washington County has two classifications of coal for assessment purposes, active and reserve. "Active" consists of coal that is permitted to be mined. The approximate range of market value for tax purposes is $1,200-$4,000 per acre depending on specific property factors. The assessed value of coal is calculated as 25 percent of market value (Riley, 1997). Reserve coal is valued at a constant rate of $800 per acre regardless of the characteristics of the coal for the mine involved. This rate was set in agreement with major coal companies in the region in 1978, and has not been changed since (Riley, 1997). However, individual exceptions have been made and others have been challenged in court, for instance:

> On March 6, 1997 a Common Pleas Judge lowered the value from $740 per acre, set after an appeal in 1994, to $161 per acre for more than 20,000 acres of coal reserves owned by K&H Coal and Penn Central (Smydo, 1997).

Greene County uses three classifications of coal for assessment purposes: active, reserve, and inactive. All three are assessed by taking into account the characteristics of the coal for the mine involved. Actual assessment is conducted by Resources Technologies Corporation, a consulting firm specializing in assessments of unique real estate properties such as coal reserves. Active consists of permitted coal and the approximate range of market value for tax purposes is $3,000-$15,000 per acre. Reserve coal is not permitted but has the potential to be mined in the near future; the approximate range is $800-$1,500 market value per acre. Inactive includes both support coal left behind in abandoned mines and coal seams that are under 41 inches, and hence uneconomical to mine at current prices and technology. The approximate range is $1-$500 market value per acre. Assessed value of coal is calculated as 30 percent of market value (Fraser, 1997). Both counties have been working to update their assessments (Riley, 1997; Fraser, 1997).

# SECTION D

# PROJECT BIOGRAPHIES

# CHAPTER 12

# PROJECT BIOGRAPHIES

**Derek J. Steele** is a graduate coal mining engineer who received his education and training in the mining industry in the United Kingdom. Following his early experience in underground coal mines, he became a supervisor of a longwall coal face operation, and subsequently attained the position of underground manager with responsibilities for the operation of 5 longwall faces. These faces extracted coal from beneath agricultural lands, and both residential and industrial premises. During his subsequent experience as a Principal Lecturer in Mining Engineering at a Polytechnic Institute, Mr. Steele specialized in teaching and research in ground control in underground coal mining, subsidence engineering, and mine ventilation.

Mr. Steele joined Dames & Moore in 1976 where he has supervised the firm's mining services out of the Cincinnati Ohio office. During the past 22 years, he has been involved, as principal consultant, in more than 350 mining projects undertaken, primarily in the Appalachian and Illinois Basin Coalfields. Numerous projects have involved longwall mining including the design of operations, operational performance, ventilation, ground control, and the effects of undermining on the surface. Site-specific investigations have been completed to determine the extent to which surface structure may be impacted by subsidence and lateral movements induced by mining.

**James M. McElfish, Jr.** directs the Mining Center at the Environmental Law Institute in Washington, D.C. An attorney, he is co-author of *Environmental Regulation of Coal Mining: SMCRA's Second Decade* (1990) and *Hard Rock Mining: State Approaches to Environmental Protection* (1996), as well as numerous book chapters and articles on mining, enforcement, state environmental law, water, and land use. Before joining the Institute, he was in private practice in Washington, D.C., and prior to that served in the Solicitor's Office in the U.S. Department of the Interior. He is a graduate of Dickinson College and Yale Law School.

**Milena F. Bucek, Ph.D., P.G.** received her masters degree in hydrogeology and engineering geology from Charles University, Prague, Czechoslovakia and her doctorate in geology from Pennsylvania State University, University Park, Pennsylvania. As a consultant, she specializes in groundwater studies that relate to coal mining and hydrological consequences, groundwater contamination and remediation studies, environmental assessments, water supply development, regulatory compliance, and expert testimony.

**Richard S. diPretoro** is an independent consulting geologist recently relocated to Pittsburgh from Morgantown, West Virginia. He graduated in 1970 with a B.A. in Earth Science from Dartmouth College and in 1986 received his M.S. in Geology from West Virginia University. He has published professional papers on the subject of his masters research, premining prediction of acid mine drainage. He is a registered professional geologist in Kentucky and Pennsylvania. He worked from 1972-1975 as a rank-and-file underground coal miner near Moundsville, West Virginia. In 1991, he received an environmental fellowship from the German Marshall Fund of the U.S. to travel to Europe to study the technology and regulation of longwall coal mining.

Mr. diPretoro's consulting practice, begun in 1983, mainly involves advising citizens and conservation groups worldwide on the environmental effects of coal, limestone, hard rock, and other mining operations.

**Dr. David A. Newman** is the owner and president of Appalachian Mining & Engineering, Inc. He is a mining engineer and geologist by training and has practiced in these professions for fourteen years. His areas of expertise are mine ground control and design, mine ventilation, rock and soil mechanics, slope stability, geological characterization of coal reserves, and mineral reserve evaluations. The focus of his engineering practice is on stability problems at underground and surface mines. These problems include slope failures, landslides, roof falls, pillar crushing, floor failure, the design and planning of underground mines in multiple seam scenarios, and the prediction and remediation of mine subsidence.

In 1977, Dr. Newman graduated from Vassar College with an A.B. in Geology and began working for ATEC and Associates as an assistant drill manager. He went on to receive an M.S. and a Ph.D. in Mining Engineering from The Pennsylvania State University. After graduation, he was an assistant professor of mining engineering at the University of Kentucky. Dr. Newman incorporated Appalachian Mining & Engineering, Inc. (AME) in 1988 as an engineering consulting firm specializing in rock and soil mechanics investigations, geotechnical engineering, subsidence prediction and abatement, blast design and evaluation, mine design and ground control, slope stability, mine property valuation and reserve analysis, coal refuse impoundment design and stability assessment. Geolab, a state-of-the-art materials testing laboratory, with a computer controlled

200,000-pound capacity load frame, was started in 1990 to add strength and material property testing capability to AME.

AME has conducted and supervised subsidence projects in Pennsylvania, Kentucky, Virginia, West Virginia, Indiana, and Illinois. These projects include subsidence prediction for undermining gas transmission lines, utility poles and towers, gas wells, water lines, mine slopes, large surface fills, bodies of water on the surface and inundated underground mine workings, examination of damage claims, and litigation support. In examining mine subsidence, AME employs both computer modeling and analytical methods in order to develop subsidence contour maps, calculate surface strains, and deformation.

Dr. Newman is a registered engineer in Kentucky, West Virginia, Virginia, and Indiana. He is a professional geologist in Kentucky. He has three patents and has published twenty-three professional papers in journals and for conferences on various mining and rock mechanics related topics.

**Dr. Jan W. Briedé** received his Ph.D. from New Mexico State University. He has more than 20 years' experience in academia, consulting and industry. His specialties include ecosystem restoration, reclamation, wetland science, permitting, and ecological risk assessment. His mining experiences include:

- 1980-81 – Development of a decision support system for the selection of native plant species in mineland reclamation. The model was prepared for Utah's abandoned mineland program and was tested on abandoned uranium mines in southeastern Utah.
- 1981 – Pre-mining vegetation survey of the Burnham Coal Mine (Consolidated Coal) near Ship Rock, New Mexico.
- 1981 – Design and planting of an artificial wetland filter/sedimentation pond for a uranium mine and enrichment plant in South Central Wyoming.
- 1991-92 – Environmental Specialist, P&M Coal. Permitting, including renewal of existing permits and development of a new permit; supervision of reclamation; performance standard development; compliance; monitoring; and post mining vegetation surveys. A special project included research on the effect of top soil depth and reclamation success.
- 1993 – Invited by the State of New Mexico to assist with the development of its new Hard Rock Mining Legislation (New Mexico Mining Act Rules, July 12, 1994).

- 1994-95 – Managed an inventory of bat use of abandoned mine portals and shafts in Pennsylvania, prior to closure.
- 1996 – Edited various chapters of the upcoming book on the reclamation of drastically disturbed lands being published by Agronomy Society of America and the American Society for Surface Mining and Reclamation.
- 1997 – Conducted research on the regional ecological effects of longwall mining for the Audubon Society of Western Pennsylvania.

Related experience of Jan Briedé, between 1981 and 1991, include work in ecosystem restoration, revegetation, reforestation, and land management in Nepal, Yemen and New Mexico.

**Mr. David A. Dixon** is a Project Biologist with Dames & Moore, with more than 19 years of experience. Mr. Dixon in an aquatic biologist by training, and has conducted numerous ecological assessments in the midwest and eastern United States. His expertise includes ecological field investigations consisting of wetlands evaluation and delineation, reconnaissance for sensitive or critical habitats and threatened or endangered species, and the field characterization of site flora and fauna.

Mr. Dixon's experience with environmental issues relating to coal mining commenced in 1980 in Lexington, Kentucky, where he conducted numerous environmental assessments over a 10-year period, involving stream biology, surface and groundwater hydrology, geology, soils, and vegetation to prepare probable hydrological consequences of mining determinations designed to meet Kentucky Department for Surface Mining permitting requirements for various coal mining companies.

At Dames & Moore, Mr. Dixon has served as principal investigator for numerous Phase I Environmental Site Assessments and Material Compliance Assessments of coal mining properties in Illinois, Kentucky, Maryland, Pennsylvania, Tennessee, Virginia, and West Virginia.

Mr. Dixon has also conducted field investigations associated with wetlands evaluation and delineation for industrial clients in Alabama, Georgia, Indiana, Kentucky, Missouri, and Ohio. Components of the study scope included site reconnaissance for presence of wetland hydrology, hydric soils, and hydrophytic vegetation, regulatory contacts with the U.S. Army Corps of Engineers, aerial photograph review, and report write-up.

**Cindy Tibbott** has worked for the Pennsylvania Field Office of the U.S. Fish and Wildlife Service (FWS) since 1984 as an Environmental Contaminants Specialist, working on issues related to water quality, wetlands, and chemical contamination. She holds a B.S. degree in biology from the College of William and Mary in Virginia. The FWS, a bureau within the U.S. Department of the Interior, serves to "provide the federal leadership to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of people."

**H. Wade VanLandingham, MURP,** is an economic development consultant in Pennsylvania who specializes in economic development, market analysis, feasibility studies, targeted marketing, and survey research. He holds a B.A. in economics from the University of Florida and a Master of Urban and Regional Planning from the University of New Orleans. He conducted 33 semester hours of post-masters study at Penn State University.

Wade VanLandingham has wide experience in all types of community and regional planning. He has directed, or been involved with, Comprehensive Planning efforts for areas as diverse as: New Orleans, Louisiana; Warriors Mark Township (Huntingdon County); Clearfield County; and Corwensville Borough. In addition, Mr. VanLandingham has directed, or served as chief planner for, many economic development projects, including an Overall Economic Development Strategy for Warren County, Pennsylvania; a Business Development Strategy for Altoona, Pennsylvania; and a Downtown Revitalization Strategy for Tyrone Borough (Blair County). Other community planning experience includes two years as Neighborhood Planning Coordinator for the City of New Orleans and Neighborhood Improvement Study for State College.

After spending six years as Assistant Director of the Local Economic Development Assistance Project in the College of Human Development at Penn State, Mr. VanLandingham was a Principal in the Stormstown Group, a private consulting firm specializing in economic development planning and market analysis. He joined Richard C. Sutter and Associates as Senior Community/Economic Planner in 1989.

Mr. VanLandingham has provided numerous economic development and small business assistance training sessions for the Pennsylvania Department of Community Affairs and the Division of Continuing Education at Penn State. He has taught courses in planning theory, community systems, regional analysis, economic development, and public policy for the Department of

Community Studies at Penn State.

**Thomas B. Barley** has served as a marketing executive for Eastman Kodak Company, Young and Rubicam Advertising and Xerox Corporation. He has also served on the faculties of several universities including Syracuse University, the University of Maryland System and currently is on the faculty of the College of Business Administration at the University of Pittsburgh. Barley founded Thomas Barley and Associates 10 years ago to serve both the private and non profit sectors and has been published in the marketing literature and many academic and practitioner conferences.

**Gordon H. Lewis, Ph.D.,** associate professor of sociology and public policy at the H. John Heinz, III, School of Public Policy and Management, Carnegie Mellon University, works primarily on issues of welfare, health, and organizational analysis.

His work on general welfare involves the integration of income transfer programs such as Aid to Families with Dependent Children (AFDC), Food Stamps, the Earned Income Tax Credit, and federal and state taxes. Recent publications include *Income Transfer Analysis*, with Richard J. Morrison, and *Microsimulation Techniques for Tax and Transfer Analysis*, with Richard C. Michel (eds.). Professor Lewis has been principal investigator on work for the Food and Nutrition Service and for the Pennsylvania Department of Welfare. He has done work for the Congressional Budget Office, the General Accounting Office, and the Committee on Ways and Means, U.S. House of Representatives. In 1989, he was appointed to the National Academy of Science panel on Evaluation of Microsimulation Models for Social Welfare Programs, and during the 1989-90 academic year he was a Visiting Scholar at The Urban Institute.

His work on health has ranged from the clinical diagnosis of liver disease to the evaluation of the extent of continuous coverage and the nature of medical services for the Medicaid-eligible population in Pennsylvania. Current work includes evaluation of the Special Supplemental Food Program for Women, Infants, and Children (WIC) in Allegheny County.

Since coming to Carnegie Mellon, Professor Lewis has supervised over 20 different evaluations involving organizational performance. These have included evaluations of the Low Income Home Energy Assistance Program, Allegheny County Mental Health and Mental Retardation Department, and the Pennsylvania Office of Mental Health.