# SECTION III: Underground Bituminous Coal Mining During the 4th Assessment Period

## III.A - Overview

A total of 31,343 acres of Pennsylvania land were undermined by bituminous coal mines between 21 August, 2008 and 20 August, 2013 (4th assessment period). That represents a decrease of ~18% compared to acreage undermined during the 3rd assessment period (38,256 acres). There are two reasons for this reduction in acres mined: 1) In the 4th assessment period a significant portion of the coal mined from the Bailey mine came from lands in West Virginia (Figure III-1); and 2) a reduction in the demand for Pennsylvania coal, especially during 2011 and 2012 where coal production dropped from 59.2 to 54.7 million tons (U.S. Energy Information Administration 2013). The downward trend is further indicated in the total number of mines in operation during the 4th assessment period, reduced from 50 to 46. Longwall mines decreased from eight to seven, room-and-pillar mines from 36 to 34, and pillar recovery mines from six to five.

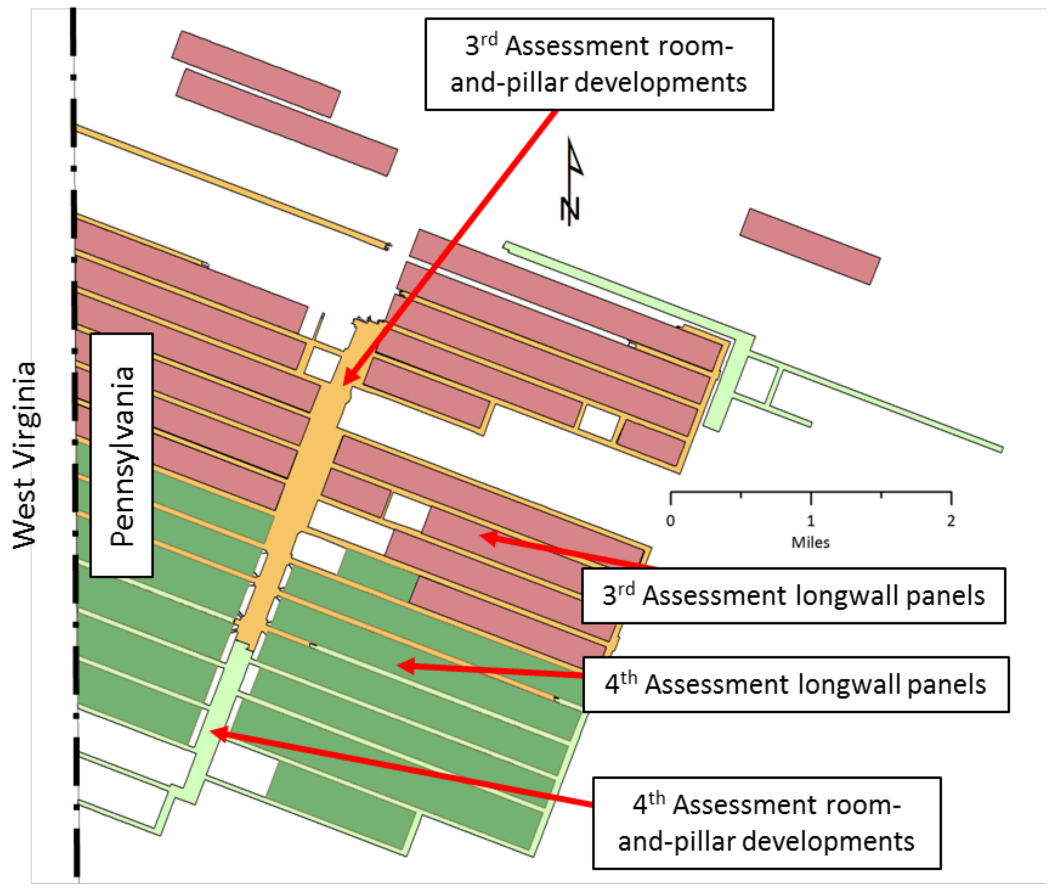


*Figure III-1. Aerial distribution of room-and-pillar developments and longwall panels mined during the 3rd and 4th assessment periods at the Bailey Mine in Greene County, Pennsylvania. Note that a significant portion of the 4th assessment period longwall panels on the western side of the Bailey Mine extend into West Virginia, reducing the extent of mining in Pennsylvania. The cyan color indicates longwall panels mined during the 3rd assessment period while green indicates panels mined in the 4th period.*

This section contains detailed analysis of 46 mines identified as active during the 4th assessment period and sorted by the type of mine, mining method, coalbed, overburden (depth of mining), size, and location. The University accomplished this by collecting and analyzing both the six-month mining maps that are part of every mine's permit files and company supplied digital maps

## III.B – Mines in Operation during the 4th Assessment Period

The identity of the mines that operated during the 4th assessment period were determined with PADEP assistance and by analysis of coal production records contained within the Mine Safety and Health Administrations (MSHA) Mine Data Retrieval System, six-month mine maps collected from the PADEP, and records contained within the Bituminous Underground Mining Information System (BUMIS). Areas within individual mines where active mining operations took place were determined from six-month mining maps and through digital maps obtained from the mine operators (See Section II.B.2). For some mines, it was difficult to determine the exact location of production faces based on available maps. In these cases, the approximated mining location was determined by interpolating between points with known dates. All of the controlling companies with active mining operations (Table III-1) provided digital maps and other information with the exception of Severstal Resources. In many cases, the digital maps included additional details that increased the accuracy of the University's estimates of the extent of mining. A list of all active 4th assessment period mines is provided in Appendix B.

### III.B.1 – Companies Operating Mines

Six controlling companies worked 46 underground coal mines during the 4th assessment period (Table III-1). Several of these controlling companies are comprised of subsidiary operating companies. Of the 10 operating companies, only two are independently owned, Rosebud Mining and TJS Mining. Others, for example Consol Energy and Alpha Natural Resources, are among the largest solid fuel energy companies in North America.

*Table III-1. Active mines sorted by mining company.*

| Controlling Company | Operator | Mine | # | Acreage |
|---|---|---|---|---|
| Alpha Natural Resources | AMFIRE Mining Co. | Barrett, Dora 8, Gillhouser Run, Madison, Nolo, Ondo | 6 | 2,052.2 |
| | Emerald Coal Resources LP | Emerald | 1 | 2,083.0 |
| | Cumberland Coal Resources LP | Cumberland | 1 | 2,652.9 |
| Consol Energy Inc. | Consol Pennsylvania Coal Co. LLC | Bailey, BMX, Enlow Fork | 3 | 10,316.7 |
| | Eighty-Four Mining Co. | Mine 84 | 1 | 66.8 |
| | Consolidation Coal Co. | Blacksville 2 | 1 | 1,885.9 |
| Mepco Intermediate Holdings LLC | Dana Mining Co. | Crawdad 1, Prime 1, Titus Deep, 4 West | 4 | 1,574.6 |
| Rosebud Mining Co. | | Beaver Valley, Cherry Tree, Clementine 1, | 20 | 8,279.6 |

| | | | | |
|---|---|---|---|---|
| | | Darmac 2, Dutch Run, Harmony, Heilwood, Knob Creek, Little Toby, Logansport, Long Run, Lowry, Penfield, Rossmoyne 1, Starford, TJS 6, Toms Run, Tracy Lynne, Twin Rocks, Windber 78 | | |
| Severstal Resources | Rox Coal Inc. | Agustus, Geronimo, Horning Deep, Kimberly Run, Miller Deep, Quecreek No.1, Roytown, Sarah | 8 | 2,422.2 |
| TJS Mining Inc. | | TJS 5 | 1 | 9.5 |
| | | Total | 46 | 31,343 |

The size of companies mining in Pennsylvania and the scale of their operations varies considerably (Figure III-2). Both Alpha Natural Resources and Consol Energy are comprised of three separate operating companies. The company with the most mines is Rosebud Mining, while the company with the greatest mined acreage is Consol Energy, Inc.

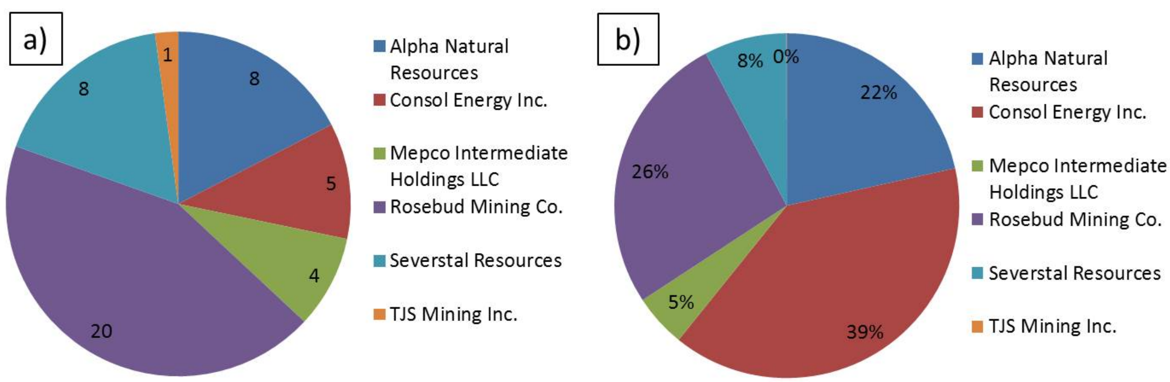


*Figure III-2. a) The number of mines operated by each company. b) The percentage of total acres mined by each company. NOTE that Consol Energy has only five mines but 39% of the acreage mined.*

### III.B.2 – Types of Mining Operations

Three general types of mines are used in Pennsylvania to extract bituminous coal resources: room-and-pillar (RP); room-and-pillar with pillar recovery (PR); and longwall (LW). All three types require room-and-pillar developments where 16 to 20-ft wide entries and cross-cut passages are driven, with interspersed pillars of un-mined coal of varying shapes and sizes. Room-and-pillar mines are comprised exclusively of room-and-pillar developments whereas pillar recovery and longwall mines also utilize full extraction techniques to remove the pillar supports, initiating subsidence of the overburden.

Thirty-four room-and-pillar mines operated during the 4$^{th}$ assessment period (Table III-2). Room-and-pillar mines are found in seven counties: Armstrong, Beaver, Cambria, Elk, Indiana, Jefferson, and Somerset. In these counties, the Freeport and Kittanning Coalbeds are the dominant minable coalbeds.

*Table III-2. Thirty-four room-and-pillar mines with operating company, coalbed, county, and Mine Code information.*

| | **Mine** | **Operating Company** | **Coalbed** | **County** | **Mine Code** |
|---|---|---|---|---|---|
| 1 | Agustus | Severstal Resources | Upper Kittanning | Somerset | Ag |
| 2 | Barrett Deep | AMFIRE Mining Co. LLC | Lower Kittanning | Indiana | Br |
| 3 | Beaver Valley | Rosebud Mining Co. | Upper Freeport | Beaver | Bv |
| 4 | Cherry Tree | Rosebud Mining Co. | Upper Freeport | Clearfield | Ch |
| 5 | Clementine 1 | Rosebud Mining Co. | Lower Kittanning | Armstrong | Cl |
| 6 | Darmac 2 | Rosebud Mining Co. | Upper Freeport | Indiana | Dm |
| 7 | Dora 8 | AMFIRE Mining Co. LLC | Lower Kittanning | Jefferson | D8 |
| 8 | Dutch Run | Rosebud Mining Co. | Upper Freeport | Indiana | Dr |
| 9 | Geronimo | Severstal Resources | Lower Kittanning | Somerset | Gr |
| 10 | Gillhouser Run | AMFIRE Mining Co. LLC | Lower Freeport | Indiana | Gh |
| 11 | Harmony | Rosebud Mining Co. | Upper Kittanning | Clearfield | Hy |
| 12 | Heilwood | Rosebud Mining Co. | Lower Kittanning | Indiana | Hw |
| 13 | Horning Deep | Severstal Resources | Lower Freeport | Somerset | Hr |
| 14 | Kimberly Run | Severstal Resources | Lower Kittanning | Somerset | Kr |
| 15 | KnobCreek | Rosebud Mining Co. | Upper Kittanning | Indiana | Kc |
| 16 | Little Toby | Rosebud Mining Co. | Lower Kittanning | Elk | Lt |
| 17 | Logansport | Rosebud Mining Co. | Lower Kittanning | Armstrong | Lg |
| 18 | Long Run | Rosebud Mining Co. | Lower Kittanning | Armstrong | Lr |
| 19 | Lowry | Rosebud Mining Co. | Lower Kittanning | Indiana | Ly |
| 20 | Madison | AMFIRE Mining Co. LLC | Upper Freeport | Cambria | Ma |
| 21 | Miller Deep | Severstal Resources | Upper Freeport | Somerset | Md |
| 22 | Ondo | AMFIRE Mining Co. LLC | Lower Kittanning | Indiana | On |
| 23 | Penfield | Rosebud Mining Co. | Lower Kittanning | Clearfield | Pf |
| 24 | Quecreek 1 | Severstal Resources | Upper Kittanning | Somerset | Qc |
| 25 | Rossmoyne 1 | Rosebud Mining Co. | Upper Freeport | Indiana | Rm |
| 26 | Roytown | Severstal Resources | Upper Kittanning | Somerset | Rt |
| 27 | Sarah | Severstal Resources | Upper Kittanning | Somerset | Sa |
| 28 | Starford | Rosebud Mining Co. | Lower Kittanning | Indiana | St |
| 29 | TJS 5 | T.J.S. Mining, Inc. | Upper Kittanning | Armstrong | T5 |
| 30 | TJS 6 | Rosebud Mining Co. | Upper Freeport | Armstrong | T6 |
| 31 | Toms Run | Rosebud Mining Co. | Upper Freeport | Indiana | Tr |
| 32 | Tracy Lynne | Rosebud Mining Co. | Lower Kittanning | Armstrong | TL |
| 33 | Twin Rocks | Rosebud Mining Co. | Lower Freeport | Cambria | Tw |
| 34 | Windber 78 | Rosebud Mining Co. | Upper Kittanning | Cambria | W7 |

Five pillar recovery mines were active during the 4th assessment period (Table III-3). These mines were operated by two companies: AMFIRE and Dana Mining Co. In all five operations, pillar recovery occurred in relatively small mining blocks, typically less than 1,000-ft in length. These areas were mostly within production panels but occasionally occurred along main entries as the mining operations retreated from the mine’s reserves.

*Table III-3. Five pillar recovery mines with operating company, coalbed, county, and Mine Code information.*

| | Mine | Operating Company | Coalbed | County | Mine Code |
|---|---|---|---|---|---|
| 1 | 4 West | Dana Mining Co. | Sewickley | Greene | Fw |
| 2 | Crawdad 1 | Dana Mining Co. | Sewickley | Greene | Cd |
| 3 | Nolo | AMFIRE Mining Co. LLC | Lower Kittanning | Indiana | No |
| 4 | Prime 1 | Dana Mining Co. | Sewickley | Greene | Pr |
| 5 | Titus Deep | Dana Mining Co. | Sewickley | Greene | Tt |

Figure III-3 shows the four Dana Mining operations, all within the Sewickley Coalbed in southern Greene County near the West Virginia state line. In this figure, the room-and-pillar and pillar recovery areas during the 3rd and 4th assessment periods are shown. The small size and sporadic coverage of pillar recovery sections are evident.

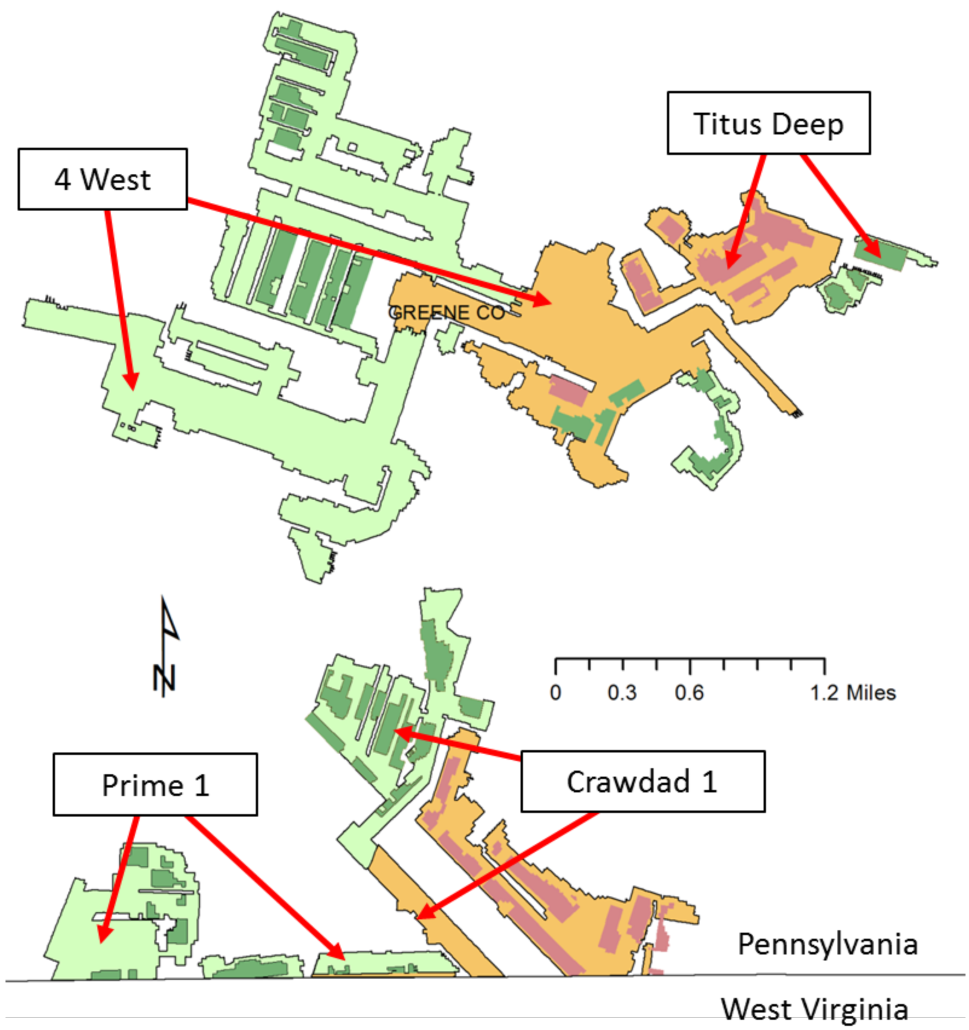


*Figure III-3. Four pillar recovery operations in the Sewickley Coalbed of Greene Co. The light green represents room-and-pillar development during the 4th assessment period while the orange shows the 3rd assessment period areas. Dark green and red areas represent pillar recovery sections during the 4th and 3rd assessment periods, respectively.*

Seven longwall mines were active during the 4th assessment period (Table III-4). Consol Energy and Alpha Natural Resources managed all seven longwall mines. Many of these operations were among the most productive underground coal mines in the nation (Fiscor 2013). During this period one mine closed, Mine 84, and another opened, BMX.

*Table III-4. Seven longwall mines with operating company, coalbed, county, and Mine Code information.*

| | Mine | Company | Coalbed | County | Mine Code |
|---|---|---|---|---|---|
| 1 | Bailey | Consol Pennsylvania Coal Co. LLC | Pittsburgh | Greene | By |
| 2 | Blacksville 2 | Consol Coal Co. | Pittsburgh | Greene | Bk |
| 3 | BMX* | Consol Pennsylvania Coal Co. LLC | Pittsburgh | Greene | Bx |
| 4 | Cumberland | Cumberland Coal Resources LP | Pittsburgh | Greene | Cu |
| 5 | Emerald | Emerald Coal Resources LP | Pittsburgh | Greene | Em |
| 6 | Enlow Fork | Consol Pennsylvania Coal Co. LLC | Pittsburgh | Washington | Ef |
| 7 | Mine 84 | Eighty-Four Mining Co. | Pittsburgh | Washington | Eg |

* - The BMX mine has yet to commence longwall mining

### III.B.3 – Age of Mining Operations

Underground bituminous coal mines operating within the 4th assessment period have been in service for varying lengths of time (Table III-4). Of the 46 mines operating during the 4th assessment period, 11 began and seven ceased operation during this assessment period.

*Table III-4. Age of mines operating during the 4th assessment period. NOTE: this analysis only goes back in time to the passage of Act 54 in 1994. Room-and-pillar = blue, pillar recovery = orange, and longwall = red.*

| Mine | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Years in Operation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agustus | | | | | | | | | | | | | | | | | | | | | | 16.3 |
| Barrett Deep | | | | | | | | | | | | | | | | | | | | | | 3.3 |
| Beaver Valley | | | | | | | | | | | | | | | | | | | | | | 15.6 |
| Cherry Tree | | | | | | | | | | | | | | | | | | | | | | 9.4 |
| Clementine 1 | | | | | | | | | | | | | | | | | | | | | | 13.2 |
| Darmac 2 | | | | | | | | | | | | | | | | | | | | | | 23.9 |
| Dora 8 | | | | | | | | | | | | | | | | | | | | | | 14.9 |
| Dutch Run | | | | | | | | | | | | | | | | | | | | | | 16.0 |
| Geronimo | | | | | | | | | | | | | | | | | | | | | | 11.9 |
| Gillhouser Run | | | | | | | | | | | | | | | | | | | | | | 12.0 |
| Harmony | | | | | | | | | | | | | | | | | | | | | | 4.8 |
| Heilwood | | | | | | | | | | | | | | | | | | | | | | 5.3 |
| Horning Deep | | | | | | | | | | | | | | | | | | | | | | 5.1 |
| Kimberly Run | | | | | | | | | | | | | | | | | | | | | | 6.1 |
| Knob Creek | | | | | | | | | | | | | | | | | | | | | | 4.9 |
| Little Toby | | | | | | | | | | | | | | | | | | | | | | 11.8 |
| Logansport | | | | | | | | | | | | | | | | | | | | | | 13.7 |
| Long Run | | | | | | | | | | | | | | | | | | | | | | 2.7 |
| Lowry | | | | | | | | | | | | | | | | | | | | | | 8.7 |
| Madison | | | | | | | | | | | | | | | | | | | | | | 10.7 |
| Miller Deep | | | | | | | | | | | | | | | | | | | | | | 13.8 |
| Ondo | | | | | | | | | | | | | | | | | | | | | | 12.1 |
| Penfield | | | | | | | | | | | | | | | | | | | | | | 8.1 |
| Quecreek 1 | | | | | | | | | | | | | | | | | | | | | | 15.1 |
| Rossmoyne 1 | | | | | | | | | | | | | | | | | | | | | | 9.3 |
| Roytown | | | | | | | | | | | | | | | | | | | | | | 9.2 |
| Sarah | | | | | | | | | | | | | | | | | | | | | | 17.2 |
| Starford | | | | | | | | | | | | | | | | | | | | | | 5.3 |
| TJS 5 | | | | | | | | | | | | | | | | | | | | | | 5.4 |
| TJS 6 | | | | | | | | | | | | | | | | | | | | | | 6.1 |
| Toms Run | | | | | | | | | | | | | | | | | | | | | | 18.2 |
| Tracy Lynne | | | | | | | | | | | | | | | | | | | | | | 16.7 |
| Twin Rocks | | | | | | | | | | | | | | | | | | | | | | 13.8 |
| Windber 78 | | | | | | | | | | | | | | | | | | | | | | 7.9 |
| 4 West | | | | | | | | | | | | | | | | | | | | | | 8.4 |
| Crawdad 1 | | | | | | | | | | | | | | | | | | | | | | 36.2 |
| Nolo | | | | | | | | | | | | | | | | | | | | | | 13.5 |
| Prime 1 | | | | | | | | | | | | | | | | | | | | | | 39.0 |
| Titus Deep | | | | | | | | | | | | | | | | | | | | | | 29.0 |
| Bailey | | | | | | | | | | | | | | | | | | | | | | 32.0 |
| Blacksville 2 | | | | | | | | | | | | | | | | | | | | | | 30.7 |
| BMX | | | | | | | | | | | | | | | | | | | | | | 2.7 |
| Cumberland | | | | | | | | | | | | | | | | | | | | | | 39.7 |
| Emerald | | | | | | | | | | | | | | | | | | | | | | 38.6 |
| Enlow Fork | | | | | | | | | | | | | | | | | | | | | | 30.7 |
| Mine 84 | | | | | | | | | | | | | | | | | | | | | | 17.0 |

## III.C – Stratigraphic Influences On Mining

The Commonwealth of Pennsylvania has significant reserves of coal. This resource is arranged in beds contained within the Pennsylvanian and Permian Systems. No Permian Coalbeds were mined in PA using underground methods during the 4th assessment period. Rocks within the Pennsylvanian System range from 299 to 318-million years old (U.S. Geological Survey

Geologic Names Committee 2007) and range in thickness from 1,300 to 1,500-ft (Edmunds et al. 1999). In this region, the Pennsylvanian System contains six formations:

- Uniontown – late Pennsylvanian shales, sandstones, and thin coalbeds
- **Pittsburgh – minable coalbeds,** shales, sandstones, and limestones
- Casselman - claystones, shales, sandstones, and thin limestones
- Glenshaw – claystones, shales, sandstones, and thin limestones
- **Allegheny – minable coalbeds,** shales, claystones, sandstones, and limestones
- Pottsville – early Pennsylvania shales and sandstones

The Casselman and Glenshaw Formations combine to form the Conemaugh Group and the Pittsburgh and Uniontown Formations form the Monongahela Group. The Pottsville Formation and the Conemaugh Group, sometimes referred to as the lower and middle barren formations, are typically void of minable coalbeds. The two prominent coal-bearing formations are the Allegheny and the Pittsburgh. The older Allegheny Formation contains the Freeport and Kittanning Coalbeds while the younger Pittsburgh Formation contains the Pittsburgh and Sewickley Coalbeds (Figure III-5).

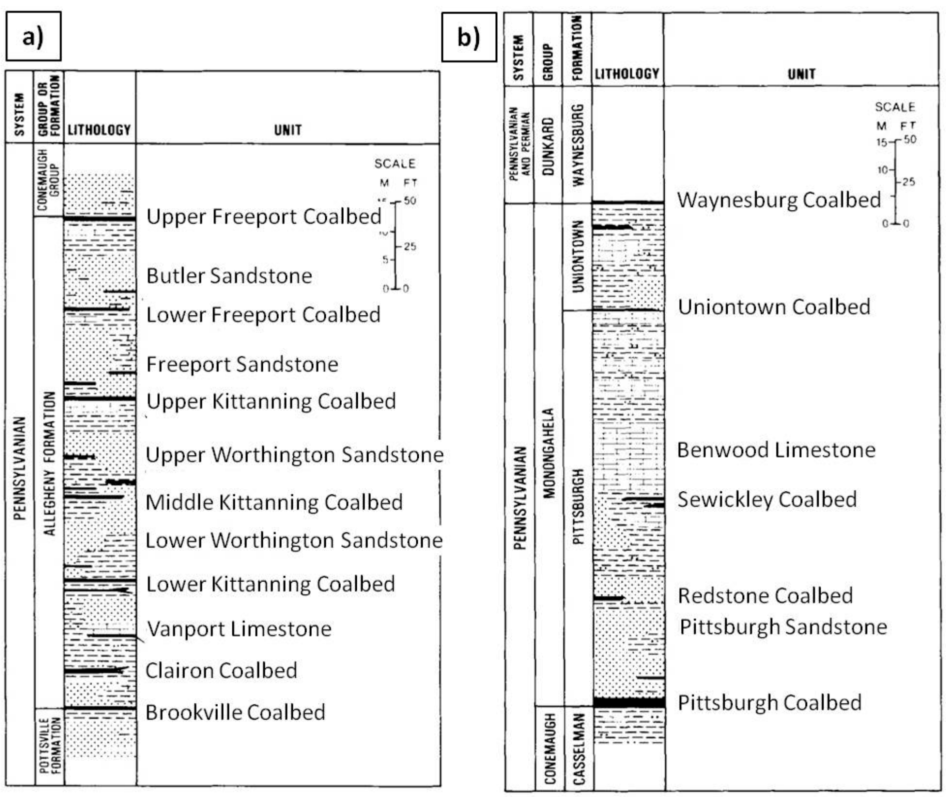


*Figure III-5. Generalized stratigraphic sections of the a) Allegheny and b) Pittsburgh Formations of western Pennsylvania (Edmunds et al. 1999).*

### III.C.1 – Coalbeds Mined

Six coalbeds were mined during the 4th assessment period. Four of the coalbeds are contained within the Allegheny Formation and two within the Pittsburgh Formation (Table III-6). The Allegheny Formation contains 35 mines while the Pittsburgh Formation has 11 mines. The

Allegheny Formation ranges from 270 to 330-ft thick so the distance between the Lower Kittanning and Upper Freeport Coalbeds is relatively moderate (Edmunds et al. 1999). The Pittsburgh Formation averages 240-ft thick with the distance between the Pittsburgh and Sewickley Coalbeds averaging 125-ft. The Allegheny and Pittsburgh Formations are separated by the Conemaugh Group, ranging in thickness from 520-ft in western Washington County to 890-ft in Somerset County (Edmunds et al. 1999). This more significant vertical separation has coalbeds associated with these two formations outcropping in different areas. It is logical, for comparison sake, to group and analyze these coalbeds by formation.

*Table III-6. Coalbeds with active mines, listed by number and Formation.*

| Formation | Coalbed | Number of Mines | |
|---|---|---|---|
| | | 3rd Assessment | 4th Assessment |
| Pittsburgh | Sewickley | 5 | 4 |
| | Pittsburgh | 9 | 7 |
| Allegheny | Upper Freeport | 14 | 9 |
| | Lower Freeport | 2 | 3 |
| | Upper Kittanning | 8 | 8 |
| | Lower Kittanning | 12 | 15 |
| | Total | 50 | 46 |

The number of mines that operated in a particular coalbed was not necessarily a good indicator of the total area that was undermined. Figure III-6 shows the relationship between the areas mined in a particular coalbed versus the number of mines operated in this coalbed. For example, five of the seven mines in the Pittsburgh Coalbed were large longwall operations and their corresponding footprint on the surface was equally large. The two Pittsburgh Coalbed mines that did not fit this profile are BMX, a new operation, and Mine 84, closed in 2009. The reason for such a concentration of longwall mines in the Pittsburgh Coalbed is the consistent thickness (5 to 11-ft) extending over large areas. These are near perfect conditions for longwall mining. The thinner, less consistent coalbed of the Allegheny Formation is better suited for the more flexible room-and-pillar mining method. The only other coalbed to show reduced surface areas undermined from the 3rd to the 4th assessment period is the Lower Kittanning (Figure III-6).

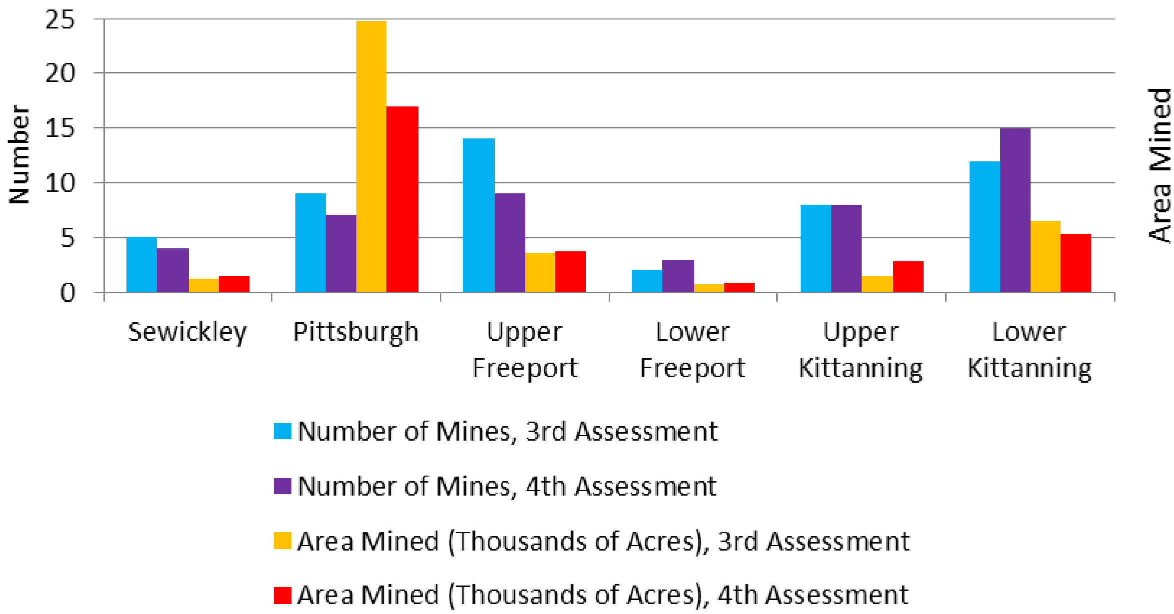


*Figure III-6. The distribution of acres undermined between the 3rd and 4th assessment periods based on the coalbed mined. Mining in the Sewickley, Pittsburgh, and Lower Kittanning Coalbed all showed reductions in areas mined while mining in the Upper Freeport, Lower Freeport, and Upper Kittanning Coalbeds showed slight increases. The surface areas undermined by the Pittsburgh Coalbed longwall mines decreased by 31% from the 3rd to 4th assessment period.*

## III.D –Mining Methods

Three distinct *mining methods* are currently used to extract underground bituminous coal reserves in Pennsylvania: Room-and-Pillar (RP), Pillar Recovery (PR), and Longwall (LW). The room-and pillar development dominates with 59.5% of the total acreage of all methods used (Table III-7).

It is important to distinguish between mining methods in terms of the acreage undermined because the methods vary in expected amount of subsidence. One technique for predicting the degree to which a mining method can cause subsidence is the calculation of the extraction ratio. The extraction ratio, Re, is equal to the extracted area divided by the original area before mining. If all of the coal is mined, Re equals 1.0, conversely, if none of the coal is mined, Re equals zero. The formula for calculating Re is:

$$Re = \frac{Extracted\ area}{Original\ area} = \frac{(pl1 + rw)(pl2 + rw) - (pl1 \times pl2)}{(pl1 + rw)(pl2 + rw)}$$

Where: pl1 = pillar length (Figure III-7)
pl2 = pillar width
rw = room width

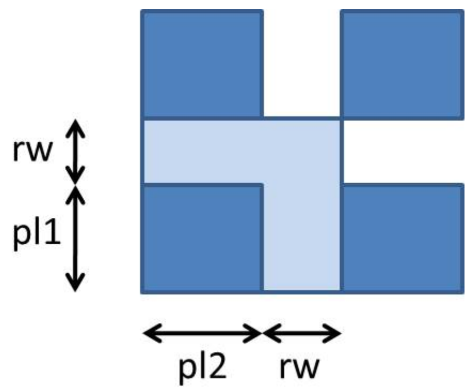


*Figure III-7. Parameters, pillar length (pl1), pillar width (pl2), and room width (rw), used to calculate the extraction ratio.*

For example, a typical longwall mine has both room-and-pillar developments and longwall panels. Mining these longwall panels, where the extraction ratio is close to 1.0, causes the surface to subside. The subsidence results in the formation of a basin-shaped trough (see Introduction). Longwall panels are surrounded by room-and-pillar sections. The University measured the Re for a wide range of mining methods and found that room-and-pillar developments have Re values between 0.4 and 0.7 (Table III-7). Room-and-pillar developments do not generally directly cause measureable surface subsidence (i.e. subsidence > 0.5-in). However, subsidence impacts can occur above room-and-pillar sections when they are located adjacent to longwall panels or pillar recovery areas. Pillar recovery mining in Pennsylvania extracts on average more than 70% of the coal but, unlike longwall panels, rarely removes all of the supporting pillars. This results in Re values somewhere between 0.7 and 1.0 (Table III-7). Pillar recovery mining does produce a surface subsidence basin and, at low overburdens, can produce subsidence impacts.

*Table III-7. Acres mined by mining method and extraction ratio.*

| **Mining Method** | **Extraction Ratio, Re** | **Surface Area Undermined** | |
|---|---|---|---|
| | | **Acres** | **%** |
| Room-and-Pillar Developments | 0.4 to 0.7 | 18,680.5 | 59.6 |
| Pillar Recovery | 0.7 to 1.0 | 282.8 | 0.9 |
| Longwall | 1.0 | 12,380.0 | 39.4 |
| | Total | 31,343 | 100 |

### III.D.1 – Area Undermined by Room-and-Pillar Developments

All 46 mines operated during the 4$^{th}$ assessment period used room-and-pillar developments ranging in size from 1,293.4-acres at Enlow Fork to 9.5-acres at TJS 5 (Figure III-8). The average area underlain by room-and-pillar developments was 406.1-acres with an average mining rate of 6.1 acres/month.

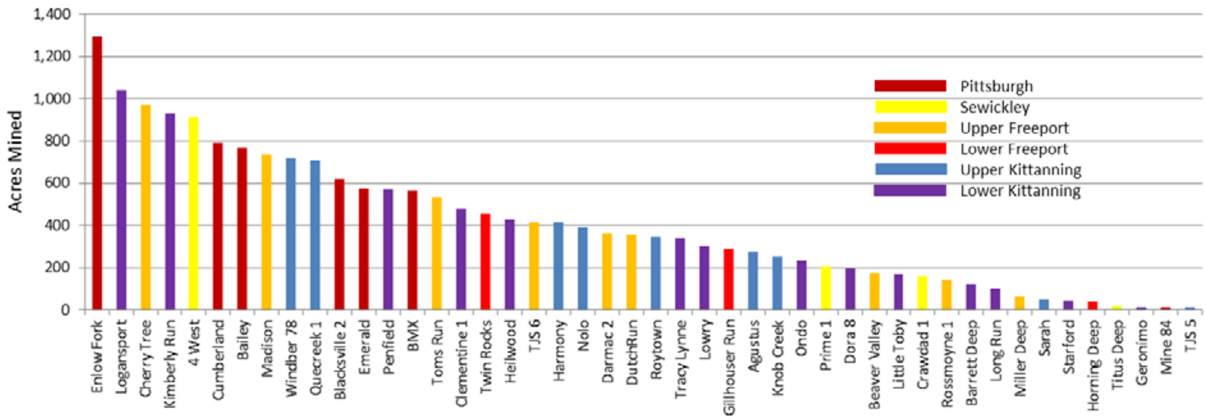


*Figure III-8. Areas mined and coalbeds for 46 mines with room-and-pillar developments. It should be noted that areas mined in West Virginia at the Bailey Mine were not considered in this analysis.*

Room-and-pillar mining occurred in all six coalbeds. Those in the Pittsburgh and Sewickley Coalbeds should be looked at differently than the others since this is where all the longwall and pillar recovery mining occur. In these areas, room-and-pillar developments can be located near or next-to full extraction mining and subsidence effects can be felt significant distances away. Conversely, for developments in the Kittanning and Freeport Coalbeds, measurable subsidence is unlikely to be observed.

There are two conditions that represent exceptions to the above statements and may result in subsidence impacts with room-and-pillar mining developments:

- Pillar-punching – Typically pillar punching, or floor heaving, occurs when pillars are pressed into claystone layers in the mine's floor. One pillar-punching episode (Figure III-9) was noted during the 3rd assessment period (Iannacchione et al. 2011) but none were documented during the 4th assessment period. It should be noted that the University relies mainly on information contained on six-month mining maps to identify this phenomenon, i.e. written observations contained on the maps.

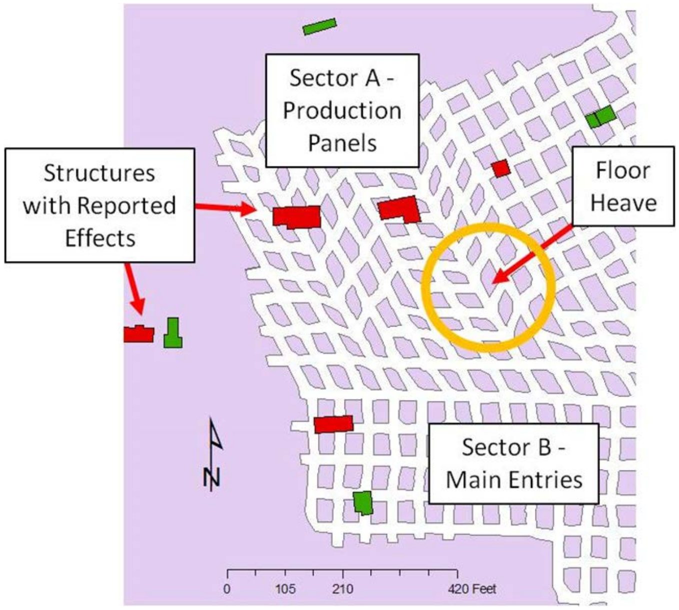


*Figure III-9. Area within the Ondo Mine where five structures with reported effects occurred within two distinct pillar layouts, A & B. Note – Red = structures with reported effects, and Green = structures without reported effects (from Iannacchione et al. 2011, Figure V-10).*

- Long-term pillar instability – Long-term pillar instability can occur when the strength of the coal pillar ($S_p$) is exceeded by the overburden pressure ($\sigma_p$) applied by the weight of the overburden rock ($\sigma_p$).

$$Potential\ for\ pillar\ failure\ or\ Safety\ Factor\ (SF) = \frac{S_p}{\sigma_p}$$

Where: $S_p$ = Strength of coal pillars
$\sigma_p$ = Overburden pressure on the pillar

The overburden pressure on the pillar is dependent on the weight of the overburden rock ($\sigma_i$) and the extraction ratio, Re (Figure III-10).

$$\sigma_p = \frac{\sigma_i}{(1 - Re)} = \sigma_v \times \frac{(pl1 + rw)^2 - (pl2 + rw)^2}{(pl1 \times pl2)^2}$$

Where: $\sigma_v = h \times W \times SG$
h = depth of mining
W = specific weight of water
SG = specific gravity of the overburden

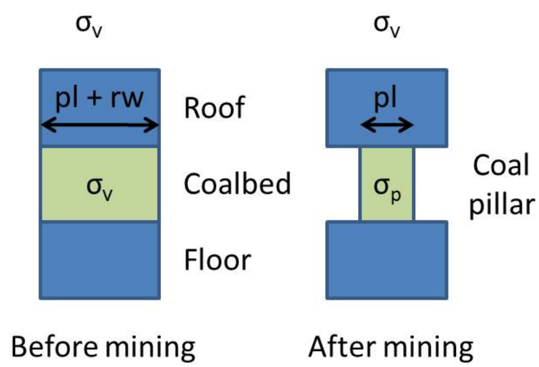


*Figure III-10. Parameters important for determining the stability of coal mine pillars used in room-and-pillar developments.*

Today in Pennsylvania most room-and -pillar developments are designed with extraction ratios of 0.5 to 0.7 and under 1,000-ft of overburden. If either of these parameters are increased, pillar instabilities could result and subsidence related impacts could occur at the surface.

### III.D.2 – Area Undermined by Longwall Panels

Fifty-two longwall panels in six mines extracted coal under 12,380 acres of surface land (Table III-8). The average panel size is 238.1-acres with a standard deviation of 121.6 acres. The largest panels are over 400-acres in size. The average panel width is now 1,290-ft with many of the newest panels approaching 1,500-ft. The average panel length is 8,536-ft. The average length of time to mine a standard size panel is almost 300 days. In general, the panels in the 4$^{th}$ assessment period mined approximately 1-acre/day. In comparison, room-and-pillar developments mine at a much slower rate, i.e. on average five acres/month (see Section III.D.1).

*Table III-8. Longwall panel size, shape, and mining history.*

| Mine | Panel | Start | End | Days | Acreage | Acres /day | Width | Length | Status |
|---|---|---|---|---|---|---|---|---|---|
| Bailey | 10I | 8/21/2008^ | 11/3/2008 | 74 | 73.5 | 0.99 | 1095 | 10410 | C$^{+}$ |
| | 11I | 11/18/2008 | 7/22/2009 | 246 | 305.9 | 1.24 | 1088 | 12046 | C |
| | 12I | 8/4/2009 | 5/31/2010 | 300 | 328 | 1.09 | 1163 | 12066 | C |
| | 13I | 6/7/2010 | 3/19/2011 | 285 | 328.7 | 1.15 | 1164 | 12023 | C |
| | 14I | 3/25/2011 | 12/18/2011 | 268 | 304.5 | 1.14 | 1089 | 11900 | C |
| | 15I | 12/30/2011 | 2/6/2013 | 404 | 416.2 | 1.03 | 1480 | 12084 | C |
| | 16I | 2/28/2013 | 8/20/2013* | 173 | 188.8 | 1.09 | 1475 | 5489 | Active |
| | 12H** | 6/28/2008 | 1/24/2009 | | 194.7 | 0.93 | 1071 | 7744 | C |
| | 13H** | 1/25/2009 | 8/24/2009 | | 183.6 | 0.87 | 1085 | 7255 | C |
| | 14H** | 9/3/2009 | 7/6/2010 | | 229.8 | 0.75 | 1475 | 6671 | C |
| | 15H** | 7/15/2010 | 4/28/2011 | | 207.1 | 0.72 | 1460 | 6013 | C |
| | 16H** | 10/31/11 | 2/27/2012 | | 184.5 | 1.55 | 1490 | 5357 | C |
| | 17H** | 10/31/12 | 2/20/13 | | 162.3 | 1.45 | 1493 | 4713 | C |
| Blacksville 2 | 14-W | 9/20/10 | 5/24/11 | 246 | 264.7 | 1.08 | 1076 | 10598 | C |
| | 15-W | 1/21/10 | 9/10/10 | 232 | 232 | 1 | 1081 | 9142 | C |
| | 16-W | 3/17/09 | 1/13/10 | 302 | 228.1 | 0.76 | 1086 | 9166 | C |

| Mine | Panel | Start | End | Days | Acreage | Acres /day | Width | Length | Status |
|---|---|---|---|---|---|---|---|---|---|
| | 17-W | 6/6/11 | 9/2/12 | 454 | 229.8 | 0.51 | 1094 | 11822 | C |
| | 18-W | 2/29/12 | 5/30/13 | 456 | 298.5 | 0.65 | 1066 | 9257 | C |
| | 19-W | 6/8/13 | 8/20/13 | 73 | 10 | 0/14 | 1100 | 405 | Active |
| Cumberland | LW54 | 8/21/2008^ | | | 37.1 | | 1355 | 1183 | C |
| | LW55 | 10/3/2008 | 2/22/2009 | 142 | 211.8 | 1.49 | 1355 | 6653 | C |
| | LW56 | 3/16/2009 | 9/30/2009 | 198 | 270.5 | 1.37 | 1354 | 8636 | C |
| | LW57 | 10/20/2009 | 4/28/2010 | 190 | 258.6 | 1.36 | 1390 | 8101 | C |
| | LW58 | 6/2/2010 | 3/24/2011 | 295 | 349 | 1.18 | 1408 | 10771 | C |
| | LW59 | 4/9/2011 | 12/3/2011 | 238 | 354.4 | 1.49 | 1397 | 11007 | C |
| | LW60 | 12/8/2011 | 4/19/2012 | 133 | 172.3 | 1.30 | 1409 | 5301 | C |
| | LW60 A | 5/7/2012 | 9/2/2012 | 118 | 149.3 | 1.27 | 1388 | 4688 | C |
| | LW61 | 9/18/2012 | 9/20/2013* | 367 | 58.9 | 0.16 | 1564 | 1640 | Active |
| Emerald | B6 | 9/15/2008 | 2/18/2009 | 156 | 126.9 | 0.81 | 1428 | 3838 | C |
| | B7 | 3/18/2009 | 8/11/2010 | 511 | 387.1 | 0.76 | 1428 | 11811 | C |
| | C1 | 8/21/2008^ | 6/19/2009 | 302 | 170.1 | 0.35 | 1231 | 5998 | C |
| | C2 | 8/13/2009 | 5/24/2011 | 649 | 372.5 | 0.57 | 1436 | 11277 | C |
| | C3 | 7/11/2011 | 8/20/2013 | 771 | 312.9 | 0.41 | 1246 | 10721 | C |
| | E1 | 5/25/2011 | 3/7/2012 | 287 | 106.1 | 0.37 | 1433 | 3202 | C |
| | E2 | 4/4/2012 | 8/20/2013* | 503 | 33.2 | 0.07 | 1433 | 832 | Active |
| Enlow Fork | E17 | 2/10/2008 | 9/30/2008 | 233 | 4.9 | 0.02 | 1061 | 11824 | C |
| | E18 | 8/21/2008^ | 3/12/2009 | 203 | 305.5 | 1.50 | 1068 | 12245 | C |
| | E19 | 3/16/2009 | 10/4/2009 | 202 | 305.8 | 1.51 | 1091 | 12227 | C |
| | E20 | 10/5/2009 | 6/14/2010 | 252 | 304.7 | 1.21 | 1086 | 12207 | C |
| | E21 | 6/18/2010 | 3/31/2011 | 286 | 415.8 | 1.45 | 1487 | 12232 | C |
| | E22 | 3/2/2011 | 2/13/2012 | 348 | 407.6 | 1.17 | 1484 | 11981 | C |
| | E23 | 2/8/2012 | 2/15/2013 | 373 | 411.3 | 1.10 | 1487 | 12085 | C |
| | E24 | 2/11/2013 | 8/20/2013* | 190 | 233.8 | 1.23 | 1487 | 12085 | Active |
| | F16 | 8/21/2008^ | 10/31/2008 | 71 | 78.4 | 1.10 | 1087 | 3144 | C |
| | F17 | 10/22/2008 | 6/26/2009 | 247 | 303.2 | 1.23 | 1091 | 12142 | C |
| | F18 | 6/12/2009 | 1/22/2010 | 224 | 303 | 1.35 | 1091 | 12153 | C |
| | F19 | 1/16/2010 | 9/10/2010 | 237 | 302.4 | 1.28 | 1078 | 12156 | C |
| | F20 | 9/16/2010 | 9/17/2011 | 366 | 412 | 1.13 | 1485 | 12103 | C |
| | F21 | 9/14/2011 | 9/11/2012 | 363 | 400 | 1.10 | 1502 | 11750 | C |
| | F22 | 8/30/2012 | 8/1/2013 | 336 | 387.6 | 1.15 | 1490 | 11381 | C |
| | F23 | 7/27/2013 | 8/20/2013* | 24 | 6.4 | 0.27 | 1484 | 188 | Active |
| Mine 84 | 10B | 12/3/2008 | 3/6/2009 | 93 | 56.2 | 0.6 | 1153 | 2144 | C |

* - Ongoing
^ - Panel started in 3rd assessment period
$^{+}$ - Panel completed during the 4th assessment period
** - Part of the panel was mined in West Virginia

The 52 longwall panels are all located in Greene and Washington Counties (Figure III-11). This figure illustrates the significant differences in mine layouts. The Enlow Fork is extracting panels in a regular pattern, while the Cumberland and Emerald panels are spread over more irregular blocks of reserves. The shorter panels typically represent mining over the start or end of the assessment period. The lone panel at Mine 84 represents the final segment of mining in late 2008, early 2009. Lastly, please note that all of the panels are oriented approximately N 60 W. This orientation originated in earlier Pittsburgh Coalbed room-and-pillar mines prior to the introduction of longwall mining. Planes of weakness within the coalbed, called face and butt cleat, are oriented parallel and perpendicular to the N 60 W orientation, and allowed for the most efficient and effective means of extracting the coal with conventional mining techniques.

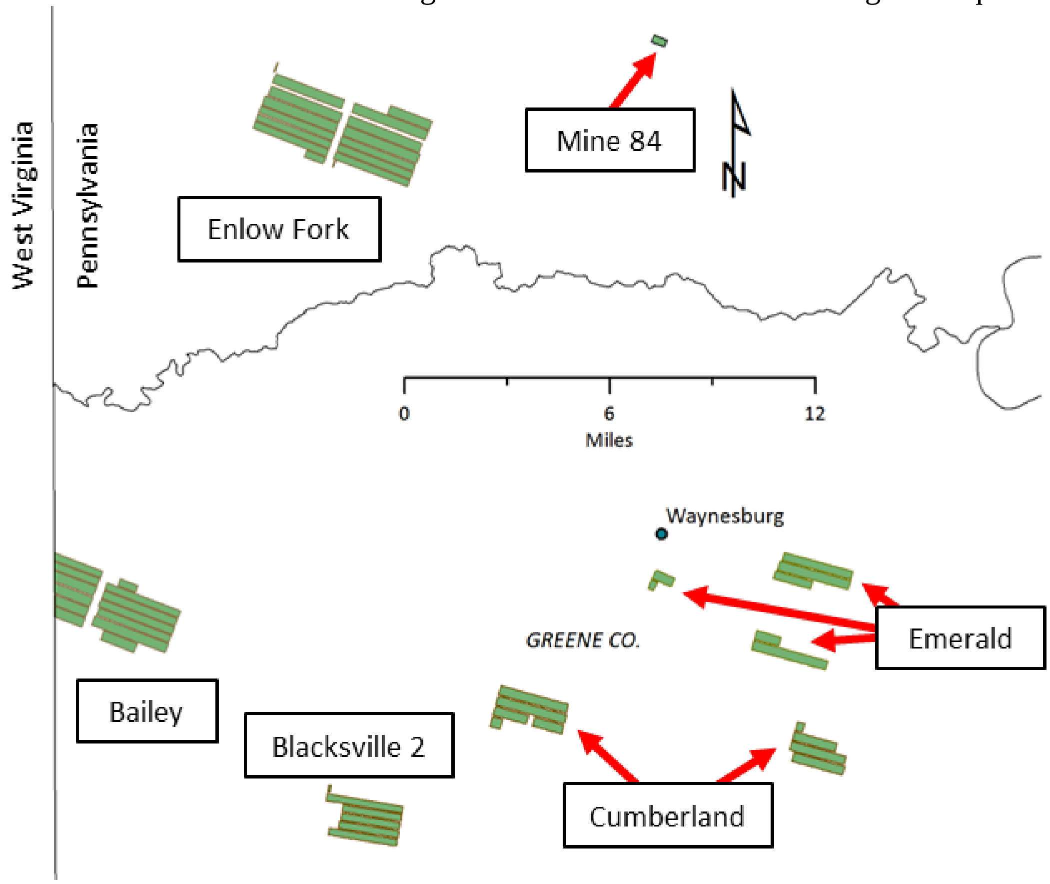


*Figure III-11. Six underground coal mines with 52 longwall panels extracted during the 4th assessment period.*

## III.D.3 – Area Undermined by Pillar Recovery Panels

Five mines used pillar recovery mining methods, mining under 282.8-acres of land (Table III-9). The total areas undermined by this mining method were almost identical to those in the 3rd assessment period (276-acres). In general, pillar recovery is practiced close to West Virginia in the Sewickley Coalbed. The panels containing the pillar recovery areas are typically small (< 20-acres) and occur in rural areas impacting only a few water supplies or structures (see Sections IV and V).

*Table III-9. Areas undermined by room-and-pillar mines with pillar recovery, 3rd and 4th assessment period.*

| **Mine Name** | **Coalbed** | **Room and Pillar, Acres** | | **Pillar Recovery, Acres** | |
|---|---|---|---|---|---|
| | | **3rd** | **4th** | **3rd** | **4th** |
| Nolo | Lower Kittanning | 880 | 388.2 | 50 | 22.2 |
| Crawdad 1 | Sewickley | 326 | 159.9 | 86 | 75.6 |
| 4 West | Sewickley | 407 | 928.7 | 9 | 127.6 |
| Titus | Sewickley | 187 | 18.9 | 73 | 21.6 |
| Prime 1 | Sewickley | - | 206.4 | - | 35.8 |
| Dooley Run | Sewickley | 21 | - | 30 | - |
| Dunkard 2 | Sewickley | - | - | 49 | - |
| Total | | 1,821 | 1,702.1 | 276 | 282.8 |

## **III.E – Mining in Different Counties**

As has been noted above, the distribution of mining activity is not uniform across western Pennsylvania. Mining activity in any particular area is connected to three general factors:

1) The occurrence of coal bearing strata, i.e. the Allegheny and Pittsburgh Formations,
2) The coalbed overburden, i.e. at present very little coal greater than 1,000-ft deep is being mined in Pennsylvania, and
3) The economic value of the coalbeds, i.e. coal thickness, quality, accessibility, ownership, etc.

The unique reaction to the three mining factors listed above, produces a wide range of mining activity that is best characterized by county (Figure III-12). Ten counties contained active underground bituminous coal mines during the 4th assessment period. Greene County accounted for 40.3 % of the total area mined and Washington County nearly half that with 19.0%. Armstrong, Cambria, Clearfield, Indiana and Somerset Counties have similar percentages and together accounted for approximately 39.0% of the acreage undermined. Beaver, Jefferson, and Elk have only one relatively small room-and-pillar mine each (Table III-10) and accounted for 1.7% of the total.

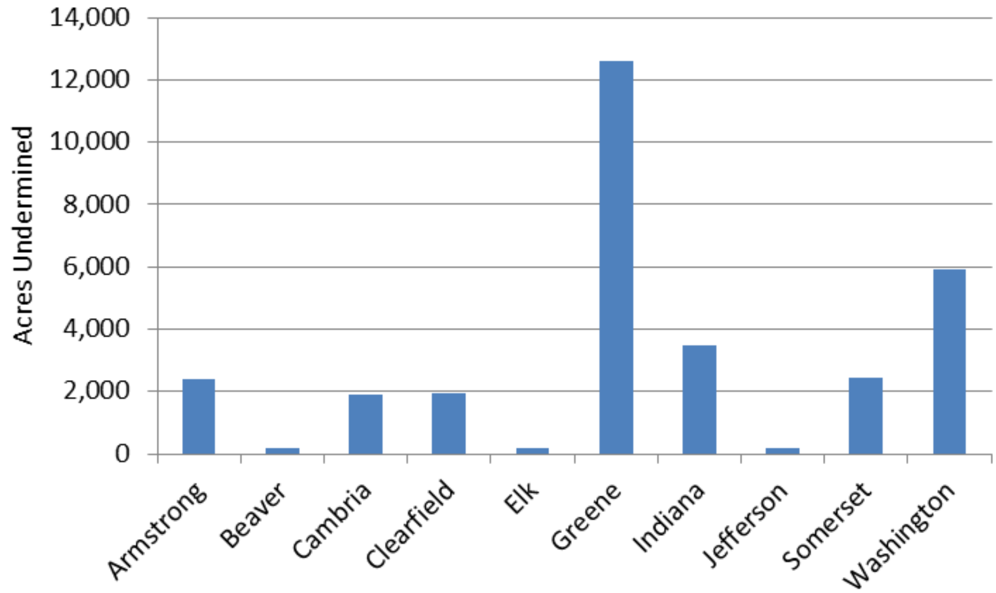


*Figure III-12. Areas undermined by county.*

*Table III-10. Acres undermined in the ten counties producing underground bituminous coal in Pennsylvania.*

| County | Acres | % of Total Acres |
|---|---|---|
| Armstrong | 2,400.5 | 7.7 |
| Beaver | 172.7 | 0.6 |
| Cambria | 1,911.0 | 6.1 |
| Clearfield | 1,955.2 | 6.2 |
| Elk | 168.6 | 0.5 |
| Greene | 12,637.1 | 40.3 |
| Indiana | 3,536.8 | 11.3 |
| Jefferson | 196.4 | 0.6 |
| Somerset | 2,422.2 | 7.7 |
| Washington | 5,942.7 | 19.0 |
| Total | 31,343 | 100 |

## III.F – Variations in Overburden

The variability in the overburden characteristics of the 46 mines studied is significant and important because differences in overburden can affect structures, water supplies, and land in different ways. The shallowest overburden was projected at less than 100-ft in eight room-and-pillar mines; while four mines, all longwall, had maximum overburdens over 1,000-ft.

### III.F.1 – Overburden Categories

It is useful to categorize the relative overburden conditions associated with a mine or a mining method. To this end, the University calculated the average, standard deviation, minimum, and maximum overburden conditions for each mine. These conditions were grouped into three distinct overburden categories; shallow, average, and deep and also grouped by mining type. The average overburden category comprised all mines whose values fell within one standard deviation of the mean. This accounted for approximately 2/3 of the mines. The other 1/3 were split between shallow and deep. The category shallow contained mines that had an average overburden greater than one standard deviation below the mean. Conversely, the category deep contains mines that had an average overburden greater than one standard deviation above the mean (Table III-11).

Three categories are determined for each of the three types of mines, yielding nine boundary values. When each of these boundary values for the 3rd and 4th assessment period is analyzed (Table III-11), all show an increase, indicating a measurable rise in the depth of mining occurred between periods.

*Table III-11. Definitions of the overburden categories for the three mining types are shown. Ranges were based on the individual average overburdens measured for each mine.*

| Type of Mine | Overburden Category | | | | | |
|---|---|---|---|---|---|---|
| | Shallow, ft | | Average, ft | | Deep, ft | |
| | 3rd Assessment Period | **4th Assessment Period** | 3rd Assessment Period | **4th Assessment Period** | 3rd Assessment Period | **4th Assessment Period** |
| Room-and-Pillar | < 185 | **< 200** | 185 to 397 | **200 to 562** | > 397 | **> 562** |
| RP with Pillar Recovery | < 283 | **< 391** | 283 to 473 | **391 to 685** | > 473 | **> 685** |
| Longwall | < 525 | **< 627** | 525 to 850 | **627 to 939** | > 850 | **> 939** |

### III.F.2 – Longwall Mine Overburden

The seven longwall mines varied in overburden from a minimum of 299-ft at the Emerald Mine to a maximum of 1,230-ft at the BMX Mine (Table III-12). The average longwall overburden was 783-ft with a standard deviation of 156-ft. That is approximately 115-ft greater than the average longwall overburdens during the 3rd assessment period. These data suggest that significant increases in the longwall overburden are occurring. Since there is a relationship between overburden and the maximum amount of vertical subsidence, one could suggest that less dramatic impacts on water supply and structures should be occurring. Using the overburden categories discussed in Section III.F.1, five mines were average with one shallow and one deep (Table III-12).

*Table III-12. Overburden characteristics for longwall mines.*

| Mine | Avg. | Median | SD* | Min. | Max. | Category |
|---|---|---|---|---|---|---|
| Bailey | 717 | 719 | 127 | 374 | 1067 | Average |
| Blacksville 2 | 920 | 913 | 98 | 699 | 1155 | Average |
| BMX | 971 | 994 | 151 | 548 | 1230 | Deep |
| Cumberland | 867 | 873 | 137 | 565 | 1185 | Average |
| Emerald | 638 | 633 | 121 | 299 | 959 | Average |
| Enlow Fork | 688 | 696 | 90 | 465 | 919 | Average |
| Mine 84 | 575 | 581 | 78 | 445 | 699 | Shallow |

* SD – Standard Deviation

The spread in the overburden distribution for each of the seven longwall mines is shown in Figure III-13. The range in overburden conditions found within the Bailey and Emerald Mines is the greatest amount these mines. The BMX and Mine 84 had a very small foot-print during the 4th assessment period.

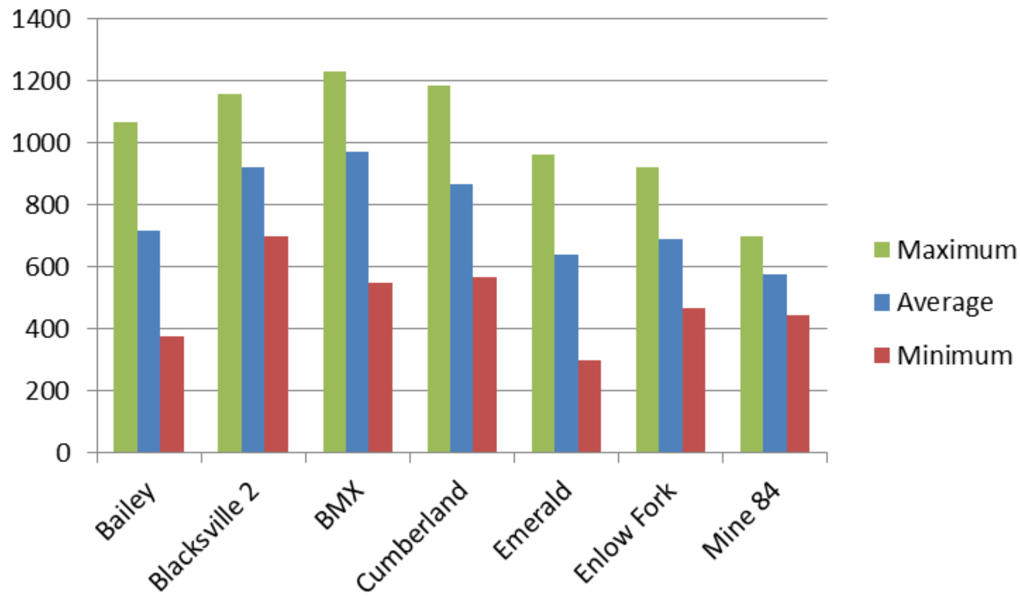


*Figure III-13. The distribution in overburden within each of the seven longwall mines.*

### III.F.3 – Room-and-Pillar Overburden

When compared to the seven longwall mines above, the 34 room-and-pillar mines had less overburden with an average of 381-ft. The lowest overburden occurred at the Lowry Mine, 52-ft, and the highest at Toms Run, 863-ft (Table III-13).

*Table III-13. Overburden characteristics for room-and-pillar mines sorted from highest to lowest.*

| Mine Name | Avg. | Median | SD* | Min. | Max. | Category |
|---|---|---|---|---|---|---|
| TJS 5 | 643 | 661.5 | 56 | 494 | 712 | Deep |
| Toms Run | 573 | 615 | 145 | 136 | 863 | Deep |
| Penfield | 506 | 502 | 82 | 165 | 704 | Average |
| Logansport | 476 | 483 | 65 | 373 | 622 | Average |
| Tracy Lynne | 470 | 459 | 76 | 305 | 697 | Average |
| Heilwood | 438 | 449 | 77 | 104 | 575 | Average |
| Clementine | 425 | 443 | 49 | 306 | 518 | Average |
| Windber 78 | 406 | 406 | 59 | 249 | 528 | Average |
| Quecreek | 395 | 401 | 84 | 227 | 594 | Average |
| Sarah | 381 | 402 | 70 | 209 | 504 | Average |
| Roytown | 377 | 397 | 47 | 225 | 464 | Average |
| Gillhouser Run | 374 | 382 | 52 | 178 | 509 | Average |
| Darmac 2 | 372 | 352 | 95 | 188 | 605 | Average |
| CherryTree | 371 | 376 | 62 | 162 | 561 | Average |
| Lowry | 365 | 365 | 89 | 52 | 516 | Average |
| Harmony | 361 | 375 | 45 | 106 | 415 | Average |
| Ondo | 348 | 374 | 105 | 83 | 508 | Average |
| Starford | 335 | 343.5 | 66 | 181 | 474 | Average |
| Barrett | 330 | 356 | 83 | 99 | 458 | Average |
| Beaver Valley | 315 | 303 | 48 | 183 | 414 | Average |
| Dutch Run | 308 | 298 | 71 | 167 | 500 | Average |
| Horning Deep | 287 | 289 | 100 | 121 | 419 | Average |
| Dora 8 | 275 | 208 | 155 | 95 | 538 | Average |
| Twin Rocks | 275 | 271 | 21 | 220 | 334 | Average |
| Long Run | 268 | 267 | 34 | 95 | 327 | Average |
| Madison | 262 | 245 | 51 | 181 | 414 | Average |
| Little Toby | 257 | 265 | 47 | 107 | 340 | Average |
| Agustus | 238 | 236 | 28 | 189 | 304 | Average |
| Knob Creek | 236 | 234 | 46 | 129 | 339 | Average |
| TJS 6 | 223 | 222 | 80 | 68 | 491 | Average |
| Kimberly Run | 207 | 208 | 46 | 95 | 317 | Average |
| Geronimo | 190 | 179 | 34 | 142 | 256 | Shallow |
| Miller Deep | 175 | 176 | 6 | 150 | 195 | Shallow |
| Rossmoyne 1 | 160 | 165 | 41 | 100 | 300 | Shallow |
| Total | Avg. = 355 | | | Min. = 52 | Max. = 863 | |

* SD – Standard Deviation

The spread in average overburden for each of the 34 room-and-pillar mines is shown in Figure III-14. In this figure, the two deepest mines, TJS 5 and Toms Run, were greater than one standard deviation for the average of all room-and-pillar mines (355-ft), whilst Geronimo, Miller Deep, and Rossmoyne 1 were one standard deviation less than the average. Seven mines had an overburden less than 100-ft. Portions of 17 mines had overburdens greater than 500-ft.

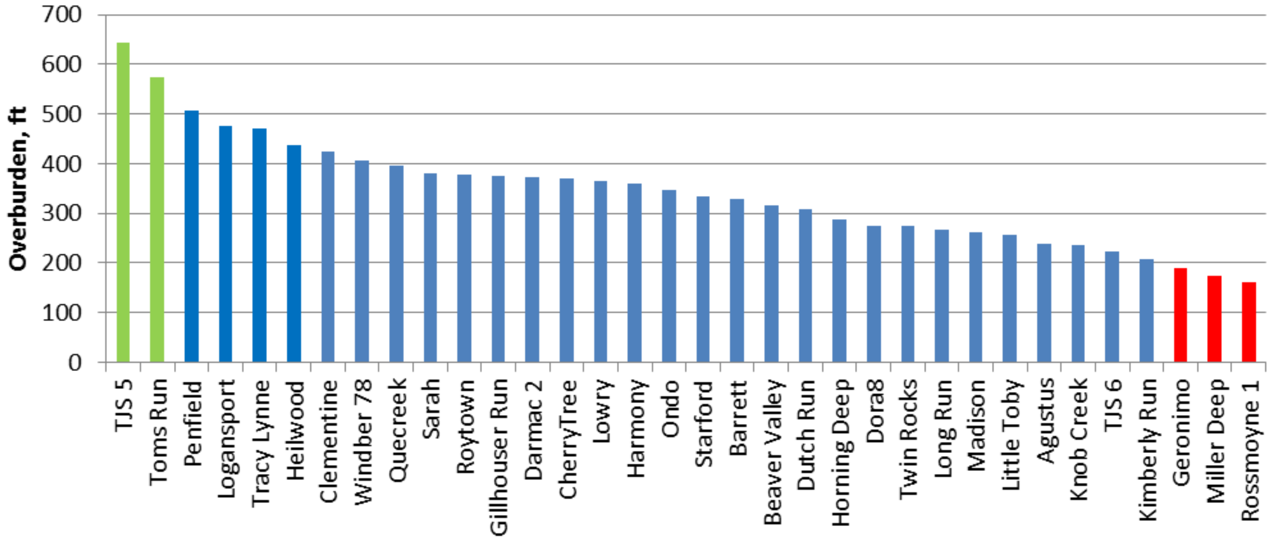


*Figure III-14. Distribution of average overburdens for the 34 room-and-pillar mines. Note green mines are classified as deep, blue as average, and red as shallow overburden mines.*

### III.F.4 – Room-and-Pillar with Pillar Recovery Overburden

When compared to the 34 mines above, the five room-and-pillar mines with pillar recovery were higher in overburden with an average of 540-ft and a standard deviation of 147-ft. The lowest overburdens, 130-ft, occurred at the Titus Deep (Table III-14) a mine that is classified as a shallow overburden pillar recovery mine. The Crawdad mine is classified as deep while the other four mines are classified as average overburden (Table III-14).

*Table III-14. Overburden characteristics for room-and-pillar mines with pillar recovery.*

| Mine | Avg. | Median | SD* | Min. | Max. | Category |
|---|---|---|---|---|---|---|
| 4 West | 548 | 566 | 138 | 138 | 845 | Average |
| Crawdad | 728 | 734 | 25 | 674 | 772 | Deep |
| Nolo | 405 | 421 | 54 | 229 | 512 | Average |
| Prime 1 | 574 | 564 | 112 | 364 | 846 | Average |
| Titus Deep | 304 | 314 | 66 | 130 | 420 | Shallow |
| Total | 540 | 543 | 147 | 130 | 846 | |

* SD – Standard Deviation

The overburden distribution for the five room-and-pillar mines with pillar recovery is shown in Figure III-15. The significant spread between minimum and maximum overburdens is evident for all of the mines except Crawdad. The 4 West Mine has the largest variations in overburden.

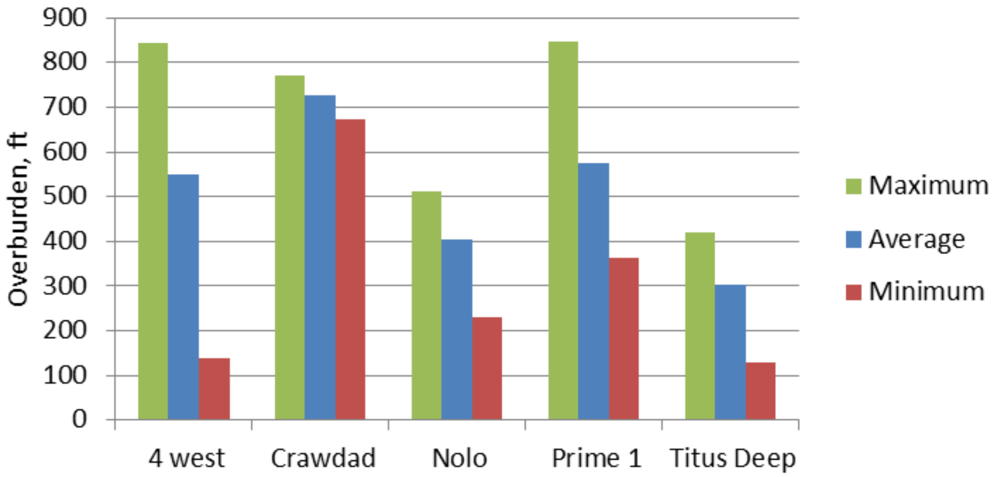


*Figure III-15. The distribution in overburden within each of the five pillar recovery room-and-pillar mines.*

## III.G – Area and Surface Properties Undermined Organized by Mine

Surface properties within 1,000-ft of mining were identified and located by the University within ArcGIS to aid in the location of surface structures and water supplies. Figure III-16 provides an example of surface properties within a 1,000-ft buffer of the Windber 78 Mine. If any part of the property is within the 1,000-ft buffer, information on the acreage and ownership were collected.


*Figure III-16. Surface properties (Pink) and the 1,000-ft buffer around the extent of Windber 78 mining.*

The number and size of properties that are undermined and/or in the buffer area provide an indirect means to estimate the potential for subsidence related impacts. The average property is 29.1 acres. Properties range from as little as 0.1 acres to as large as 587.4-acres (Table III-15). Each property has the potential for at least one structure and a water supply. Therefore, it is expected that the smaller the average property size over a mine, the more structures and water supplies undermined per acre mined. For example, five mines, Geronimo, Toms Run, Lowry, Heilwood, and Miller Deep, all have an average property size of less than five acres. In comparison, four mines, Titus Deep, Little Toby, Dora 8, and Barrett Deep, all have an average property size greater than 60-acres.

*Table III-15. Surface properties within 1,000-ft of mining during the 4th assessment period.*

| **Number of Properties** | **Total Property Area, Acres** | **Avg.** | **SD** | **Min.** | **Max.** |
|---|---|---|---|---|---|
| 6,744 | 131,542 | 29.1 | 18.7 | 0.1 | 587.4 |

## III.H – Future Mining Trends

Below, the University estimates the amount and character of future underground bituminous coal mining in Pennsylvania. This was accomplished by collecting information on past underground mining within the Pittsburgh Coalbed in Washington and Greene Counties and identifying future areas of mining.

### III.H.1 - Trends in Pittsburgh Coalbed Longwall Mining

Since its introduction in 1971 to the Pittsburgh Coalbed of southwestern Pennsylvania, 12 mines have used the longwall mining method (Figure III-17a). In the 1970's, longwall panels were sized to fit within existing production panels commonly used in Pittsburgh Coalbed room-and-pillar mines. These early longwall mines include Blacksville 1, Emerald, Gateway, Humphrey No.7, Maple Creek and Mine 84. In the 1990's the size of longwall panels began a dramatic expansion in size and in layout. Today, Pittsburgh Coalbed mines are designed exclusively around the longwall method. These mines include Bailey, Blacksville 2, Cumberland, Emerald, Enlow Fork, and BMX. The overburden in the remaining unmined portions of the Pittsburgh Coalbed ranges from less than 300-ft in the northwest portion of the basin to as much as 1,433-ft in the southwestern portion of Greene County (Figure III-17b).

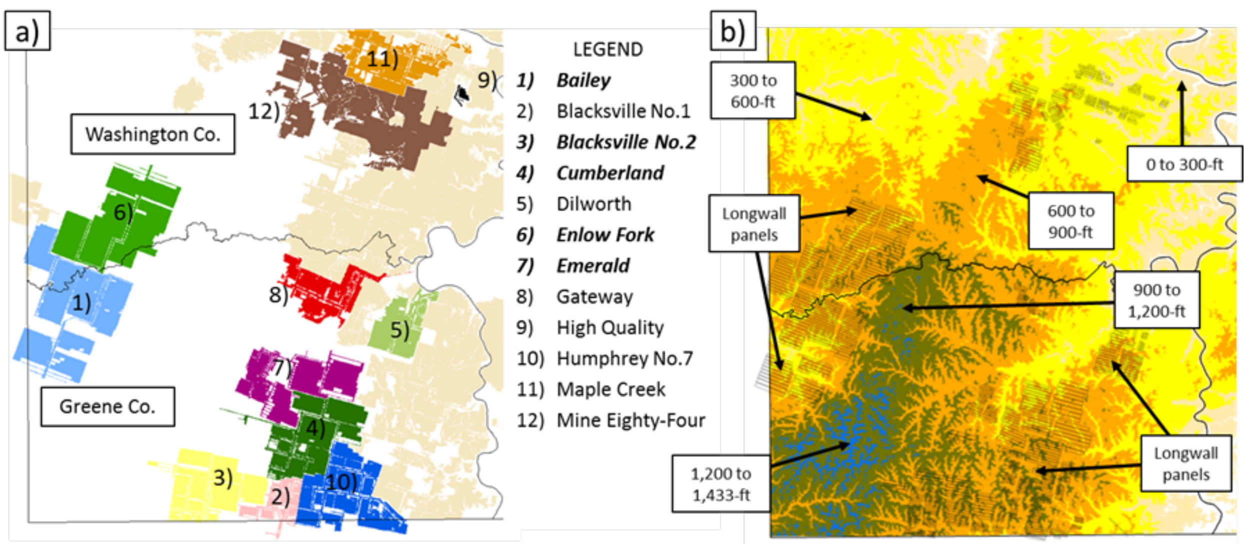


*Figure III-17. a) Location and names of the 12 longwall mines (LW) in the Pittsburgh Coalbed of Pennsylvania (The bold & italic are active at the time of the report) and b) Overburden map showing panels mined prior 2013.*

By 2008, longwall panels had grown to enormous sizes and now range between 1,200 and 1,500-ft in width and often over 10,000-ft in length (see Table III-8). This change is best illustrated in Figure III-18. When the size of longwall panels are graphed against year of completion, a zone of practical layout size through time is evident. For any given year, technology limitations represent a major restriction above the zone of practical panel layout design. Below this zone, mines are affected by adverse property, geologic or mining conditions (Figure III-18). Adverse property conditions include lease boundaries, gas wells and important surface structures or features. Adverse geologic conditions are mainly associated with localized areas of low, or no, coal but could also be related to any rapid change in the elevation of the coalbed, i.e. rolls, faults, etc.

Adverse mining conditions consist of unstable strata or excessive gas emissions. Clearly, the width of longwall panels is expected to continue to increase. Wider longwall panels would produce fewer gateroad entries, reducing the areas of high strain along the margins of the subsidence basin. In addition, few stream segments would be located above gateroads, reducing the frequency of associated stream pooling above the adjacent panels.

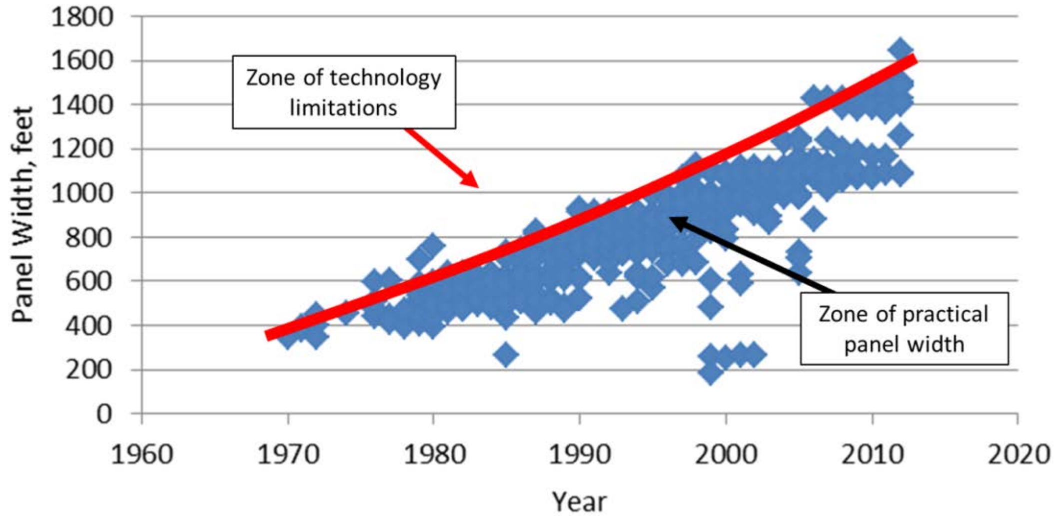


*Figure III-18. The graph shows how longwall panel designs have gradually grown through time. Two zones are illustrated: technology limitation and average longwall panel design (delineated by red line).*

### III.H.1 – Size and Location of Pittsburgh Coalbed Longwall Panels

Past underground coal mine layouts are compiled and displayed in Figure III-19. The location of unmined Pittsburgh Coalbed is calculated to underlay approximately 308,000-acres of surface land. If we assume that all future Pittsburgh Coalbed extraction will be done with the longwall mining method and that 50% will not be mined due to adverse coal thickness or land ownership, then approximately 154,000 acres of coal remain. During the 3$^{rd}$ and 4$^{th}$ assessment period, an average of 4,161-acres were longwall mined every year within Greene and Washington Counties. If this rate of mining continues, it will take approximately 37 years to mine the remaining Pittsburgh Coalbed.

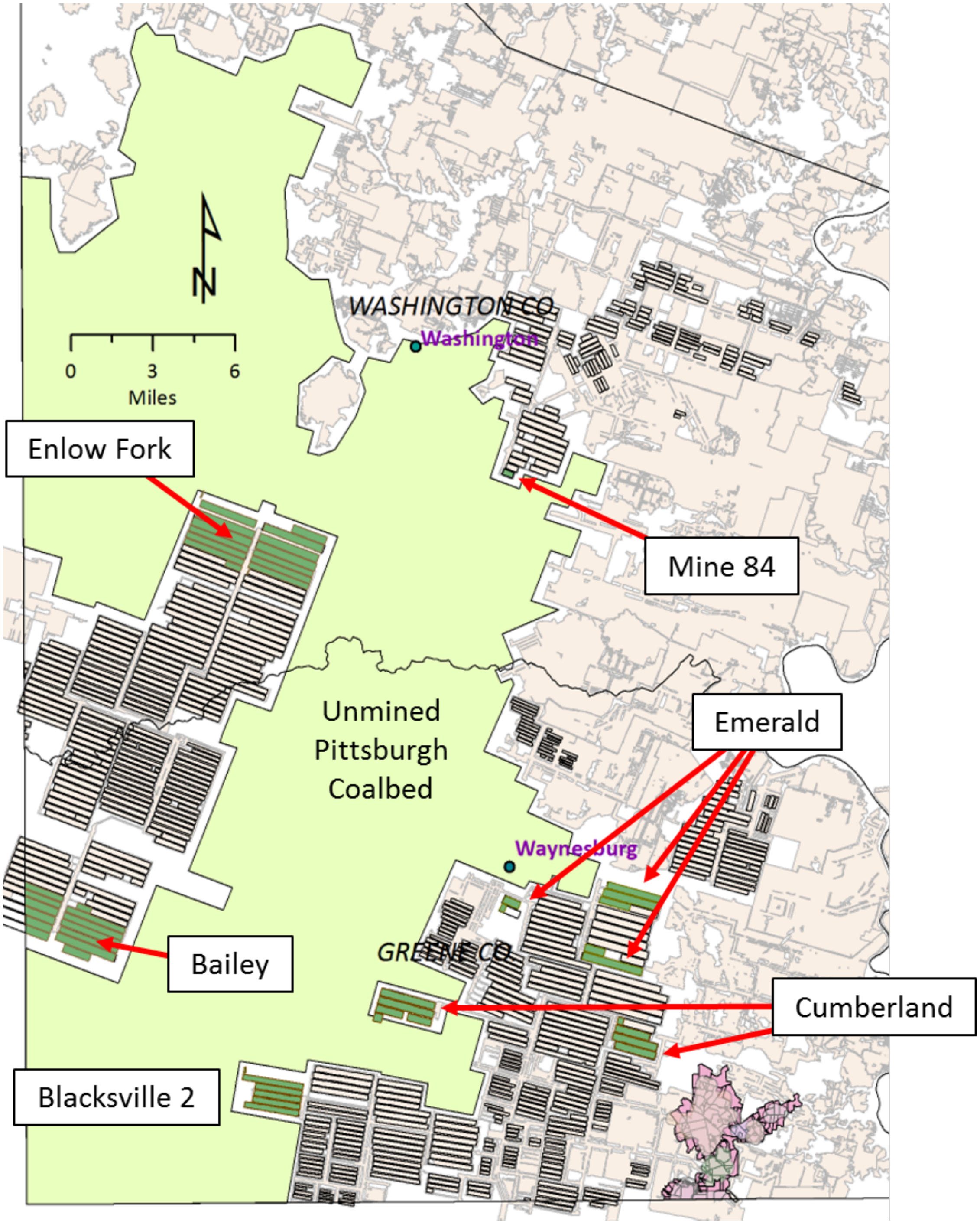


*Figure III-19. Longwall panels mined and unmined reserves of the Pittsburgh Coalbed in Washington and Greene Counties, Pennsylvania. Grayed-out areas represent past room-and-pillar mining within the Pittsburgh Coalbed.*

## III.I – Summary

Forty-six mines operated during the 4th assessment period and are classified as room-and-pillar, room-and-pillar with pillar recovery, or longwall. Six controlling companies owned eleven operating companies and undermined 31,343 acres of surface land. This represents a ~18% decrease in the area mined during the 3rd assessment period. Thirty-four mines are room-and-pillar, seven longwall, and five room-and-pillar with pillar recovery. The following points summarize the findings:

- The decline in areas mined is related to significant portions of the Bailey mine operating in West Virginia and the lower demand for coal to generate electricity.
- The surface areas undermined by the longwall mines reduced 31% from the 3rd to 4th assessment period. Since longwall mining produces the highest numbers of subsidence related impacts, the amount of reported effects was expected to decrease. However, this is not the case (see Section IV and V).
- Consol Energy mined under the most land, 12,269.4-acres, and Rosebud Mining had the most mines, 20.
- Eleven new mines started during the 4th assessment period and seven others ceased operation.
- Six coalbeds, the Sewickley, Pittsburgh, Upper Kittanning, Lower Kittanning, Upper Freeport, and Lower Freeport, are mined in two formations, the Pittsburgh and Allegheny.
- Mining methods are strongly correlated with extraction ratio (Re): longwall panel Re ~ 1.0; room-and-pillar developments Re - 0.4 to 0.7; and pillar recovery Re = 0.7 to 1.0.
- Pillar punching and long term pillar instability are two factors that produce subsidence, impacting surface structures and water supplies, even at low extraction ratios, Re < 0.7.
- Fifty-two longwall panels mined underneath 12,380-acres of surface land.
- The average longwall panel covers 238.1-acres, takes almost 280 days to mine, and extracts surface lands at an average rate of 0.97 acres/day.
- Longwall mining undermines surface lands at almost five times the rate of room-and-pillar development.
- Less than 1% of the coal extracted during the 4th assessment period was mined using the pillar recovery mining method.
- Pillar recovery panels are typically small and irregularly shaped.
- Approximately 40% of the acreage undermined by bituminous coal mining in Pennsylvania is within Greene County; 19% in Washington County; and ~41% in the combined counties of Armstrong, Beaver, Cambria, Clearfield, Elk, Indiana, Jefferson, and Somerset.
- Three overburden categories are established for each mining method; shallow, average, and deep. Shallow and deep categories are defined as differing by one standard deviation from the average overburden for each of the three mining methods.
- In general, longwall mining operations are operating under approximately 100 additional feet of overburden then during the 3rd assessment period.
- The forty-six mines undermined portions of 6,744 surface properties.

- If coal extraction trends over the last ten years continue into the future, there could be only 37-years of longwall mining left within the Pittsburgh Coalbed of southwestern Pennsylvania.

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