SECTION IV: Effects of Mining on Structures

IV.A – Overview

The University was tasked with collecting information on structures undermined by bituminous coal mines during the 4th Act 54 assessment period. Overall, the University analyzed a total of 482 reported effects to surface structures that were tracked by PADEP. A total of 389 reported effects occurred during the 4th assessment period with 19 occurring at non-active mining operations. Another 93 reported effects occurred during the 3rd assessment period but were resolved in the current assessment period (Appendix B). The majority of the company liable structure reported effects (230 out of 238) were associated with subsidence from longwall mining. Structure effects are listed by mining type, structure type, time to resolution, and determination of liability. Further analysis examines the relationship between structure effects and several physical characteristics – overburden, horizontal surface distance to mining, and topography.

IV.B – Reported Effects

Subsidence related impacts are tracked within the BUMIS database (see Section II). The University periodically received output from BUMIS and used this information to assist in its analysis. The BUMIS database is meant to track all features, i.e. surface structures (dwellings, barns, etc.), water supplies (wells, springs, etc.), and water resources (streams, wetlands, etc.) undermined by bituminous coal mining operations. In the 3rd assessment report, information was presented on relevant characteristics of these features (Iannacchione et al. 2011a; Iannacchione et al. 2011b). At that time, it was possible to find a physical location for the majority of these features and to match these occurrences with a BUMIS record. This was not the case during the 4th assessment period. BUMIS did not contain enough information to match structures projected on maps with a BUMIS record. Therefore information on the number and kind of structures undermined during the 4th assessment period is not presented.

To help rectify this situation, PADEP agreed to provide adequate location information for only those features known to be a structure or water supply ‘reported effect’. A reported effect occurs when a feature is thought to be impacted by subsidence. Mine operators, residents, or agents of PADEP request that a feature be considered for repair or compensation. A reported effect can be found to be ‘company liable’ or it may be classified as ‘not due to underground mining’.

Two issues occurred when analyzing the reported effects database extracted from BUMIS. First, the ‘feature type’ associated with the reported effect database was not adequately classified. Second, the ‘feature use’ was not always entered into BUMIS, resulting in a large number of ‘unknown’ uses.

The University’s contract with PADEP called for an analysis of subsidence related problems (reported effects) by feature type. In the past, three general feature types were analyzed: structures, water supplies, and land (Figure IV-1). Unfortunately, the BUMIS database contains significant occurrences in which structures were classified as land features and *vice versa*. The same problem was true of BUMIS water supply data analyzed in Section V. Land reported effects, referred to as land damage problems in BUMIS, could not be accurately located and are therefore only reported in the aggregate. Figure IV-1 shows the distribution of the three feature categories used in the University's current analysis: 1) structures, and 2) water supplies, and 3) land (Figure IV-1). The total number of reported effects for the 4th assessment period was slightly higher than that listed in the 3rd assessment period, 1,247 to 1,350. The number of structure reported effects decreased approximately 15% from 456 to 389.

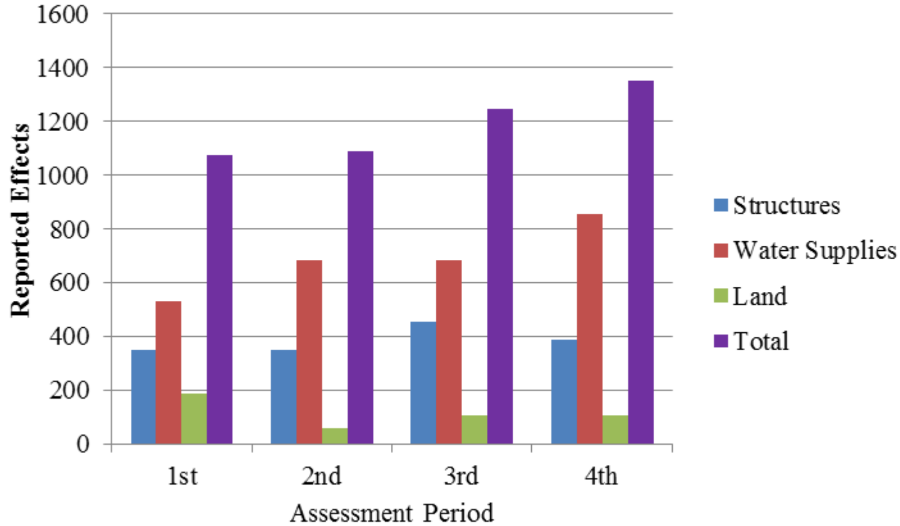

Figure IV-1. Numbers of reported effects over the four Act 54 assessment periods, sorted by feature type.

These two issues 1) failure to locate the exact surface position of features listed in BUMIS and 2) mislabeling of 'feature type' and 'feature use' limited the University's ability to analyze structures, water supply, and land reported effects.

IV.C – Data Sources

The number and characteristics of structures undermined and affected by underground bituminous coal mining were determined by examining the following sources: the BUMIS database, six-month mining maps, paper files at the CDMO, damage reports faxed to the CDMO by mine operators, interviews with technical staff at the CDMO, Surface Subsidence Agent reports, and company-supplied AutoCAD mine maps.

IV.C.1 – Structures Tracked by PADEP

Pennsylvania regulations require that approved subsidence control plans contain information about structures that will be undermined (Pennsylvania Code, Title 25, Chapter 89.142a). The parts of the code of particular relevance to this report are summarized below.

IV.C.1.a – Overburden Less Than 100-ft

§ 89.142a(a) requires the mine to maintain stability beneath structures when mining under overburden less than 100-ft.

IV.C.1.b – Pre-mining Surveys

§ 89.142a(b) requires that the mine operator conduct pre-mining surveys of:
- Dwellings,
- Buildings accessible to the public,
- Noncommercial buildings customarily used by the public, and
- Barns, silos, and certain agricultural structures.

The surveys must be conducted prior to the time the structure lays within a 30-degree angle of the underground mine. Surveys must describe the pre-mining condition of the structure and, if the structure is historically or architecturally significant, the presence of any architectural characteristics that will require special craftsmanship to restore or replace.

IV.C.1.c – Mining Beneath Protected Structures

§ 89.142a(c) sets the default standard for mining beneath structures and features as 50% coal support, although the PADEP may require a greater percentage. This requirement is only for a limited class of structures and features, i.e. public buildings, 20 acre-ft. impoundments, etc. Subsection (c) also clarifies alternatives to the coal support standard including surface measures that may be undertaken in conjunction with planned and controlled subsidence.

IV.C.1.d – Prohibition on Irreparable Damage to Dwellings and Agricultural Structures Greater Than 500-ft^2

§ 89.142a(d) prohibits a mine operator from mining in a manner which would cause irreparable damage to dwellings and permanently affixed appurtenant structures, barns, silos, and certain permanently affixed structures of 500-ft^2 or more used for agricultural purposes. The proposed mining can occur if the mine operator obtains the consent of the structure owner to allow the damage to occur. Alternatively, the proposed mining can proceed if the mine operator, prior to mining, implements measures approved by the Department to minimize or reduce the irreparable damage which would result from subsidence.

IV.C.2 – University's Process for Tracking Structures

To comply with the standards discussed above, the University developed a process to compile and categorize information about structures in the Act54GIS database.

First, the University used a 200-ft buffer zone around all areas mined as a basic criterion for inventorying undermined structures (see Section II.C.4). The buffer starts at the edge of a mining extent and extends outward 200-ft. If a structure fell within the 200-ft buffer, it was considered undermined. All structures that fell outside the 200-ft buffer zone were eliminated with one exception. If a structure was outside the buffer but associated with a reported effect within or prior to the 4th assessment period, it was retained. To further refine the structure inventory to comply with PADEP standards, the size of each structure was calculated within Act54GIS. Those structures that did not meet the minimal square footage requirements ($\geq$ 500-ft^2) as outlined in § 89.142a (f)(1)(v) were eliminated from the inventory. Exceptions to this size restriction were dwellings, garages, barns, silos, public and commercial buildings and towers, churches, and cemeteries.

Next, basic information about each structure was collected and entered into the Act54GIS database. This information consisted of:

- Property owner (name)
- Property ID (number)
- Property number (typically the tax ID)
- County
- Feature ID
- Feature number (number)
- Feature type (three general categories: structures; water supplies; and land)
    - Structures – residence, barn, building, garage, outbuilding, shed, silo, trailer, septic system, etc.
    - water supply -- spring, well, pond, etc.
    - land -- field flooding, soil heave, driveway/road damage, mass wasting, etc.
- Feature use (Residential, Recreational, Agricultural, Community/Institution, Public, Commercial, Industrial, and Unknown)

Following construction of the structure inventory, the University's Act54GIS database was linked to BUMIS to obtain additional information on structures with reported effects. Linking the two databases required the University to construct a common identification number for features that occurred in both datasets. Common identification numbers had to be created because existing identifiers often did not match between the two datasets and BUMIS lacked unique identifiers for many features (see Section II.B.2.3 for additional information on feature identifiers). By linking the two databases, the University determined which structures in the inventory had reported effects. For those with a reported effect, the following characteristics were recorded:

- Reported Effects ID (number)
- Occurrence of Additional Reported Effects (number)
- Claim ID (structure assessment number)
- Cause (mining or other)
- Description of the Reported Effect
- Occurrence Date
- Intermediate Resolution Date
- Final Resolution Date
- Resolution Status

Lastly, ArcGIS tools were utilized to measure the overburden depth (ft.), distance to mining (ft.), and topographic location (i.e. hilltop, hillside, valley bottom) for all structures with reported effects. Analyses were then performed to determine trends associated with structural damage and underground coal mining.

IV.D – Summary Information about Structures Undermined During the 4th Assessment Period

A total of 389 reported effects pertaining to structural damage were reported during the 4th assessment period (Table IV-1). The reports came from the 46 active mines as well as six inactive mines. Approximately 81% of the total reported effects are a result of longwall mining. This is due to the planned subsidence caused by longwall mining.

Table IV-1. Number of reported structural damage effects by mine type.

Mine Type	Reported Effects
Room-and-Pillar	48
Pillar Recovery	7
Longwall	315
Mines not in operation during 4th assessment (Not-active)	19
TOTAL	389

Act 54 requires that all structures impacted by underground coal mining be repaired or that the owner compensated. Of the total 389 reported effects, 238 were considered “Company Liable” (Table IV-2), indicating that the damages were related to mining and that the company was responsible for repairs or compensation. Two-hundred-and-thirty or 96.6% of the “Company Liable” effects occurred in association with longwall mining. In contrast, five “Company Liable” effects occurred over room-and-pillar mining, and the remaining three effects occurred over non-active mines. The high number of “Company Liable” effects for longwall mining can be attributed to the formation of the subsidence basin. Generally, impacts occur when coal extraction ratios beneath a structure are above 0.7 (Section III.D). This implies that all of the coal has been removed leaving no support for the overlying rock. An effective means of preventing impacts to structures is the implementation of support pillars with adequate stability to support the roof rock from caving. To increase extraction efficiency, full-extraction mining methods, such as longwall mining and pillar recovery, either do not use or remove those pillars. The result is planned subsidence which can impact structures. Most of the effects over room-and-pillar mining or inactive mines were caused by local subsidence events from old mining.

Table IV-2 lists the final resolution status for the 330 reported effects that were resolved during the 4th assessment period. The average time to resolution for these reported effects was 169 days. Companies can resolve structure effects through a number of routes. BUMIS classifies these final resolutions into the following categories:

- Unspecified agreements
- Company purchased property
- Pre-mining agreements
- MSI
- Repaired
- Resolved
- Landowner negotiations

In the 4th assessment, most structure impacts were mitigated through unspecified agreements, pre-mining agreements, or by the company purchasing the property (Table VI-2).

Table IV-2. Determination of liability based on final resolution status as of 20 August 2013.

Final Resolution		**Number**	**Average Time to Resolution (Days)**
Class	**Category**		
Company Not Liable (Unaffected/No Liability)	Damage Claim Form Not Returned to CDMO	27	184
	No Liability	1	61
	Not Due To Underground Mining	59	74
	Withdrawn	6	414
Company Liable (Assigned/Assumed Liable)	Agreement (Pre Mining)	41	106
	Agreement (Unspecified)	116	279
	Closed/Info Appended to Another Case	1	0
	Company Purchased Property	66	40
	Compensated	2	581
	Landowner Negotiations	1	710
	Repaired	9	284
	Resolved	1	127
TOTAL		330	169

Fifty-nine of the reported structural effects were unresolved as of 20 August 2013. These reports are given an interim resolution status by PADEP until a final resolution can be reached. Table IV-3 lists the unresolved effects and their interim resolution status. The majority of unresolved structure effects are considered to be “Currently Monitoring” by PADEP. This interim resolution status implies that most reported effects require a period of observation before a final resolution can be assigned. It should be noted that nine of these cases occurred during the 3rd assessment period.

Table IV-3. Status of unresolved effects (n = 59) for reported structural effects as of 20 August 2013.

Category	**Number**
Awaiting Additional Info From Operator	1
Currently Monitoring	52
Damage Claim Form Sent To Owner	1
DEP Supported Claim	1
Performing Repairs	1
Under Appeal	1
Unresolved/Pending Investigation	2
TOTAL	59

The time to resolution for the 330 resolved effects for this reporting period is shown in Figure IV-2. The time to resolution was calculated by subtracting the final resolution date from the date the effect was reported. The plot shows that 75% of all reported effects reach a final resolution within 180 days, while the initial third of these reported effects are given a final resolution within the same day. These quick resolution times are likely associated with structures that have pre-mining agreements in association with longwall mining or with structures in close proximity to mining (see below). Ninety-eight percent of all reported effects were resolved within 2 years.

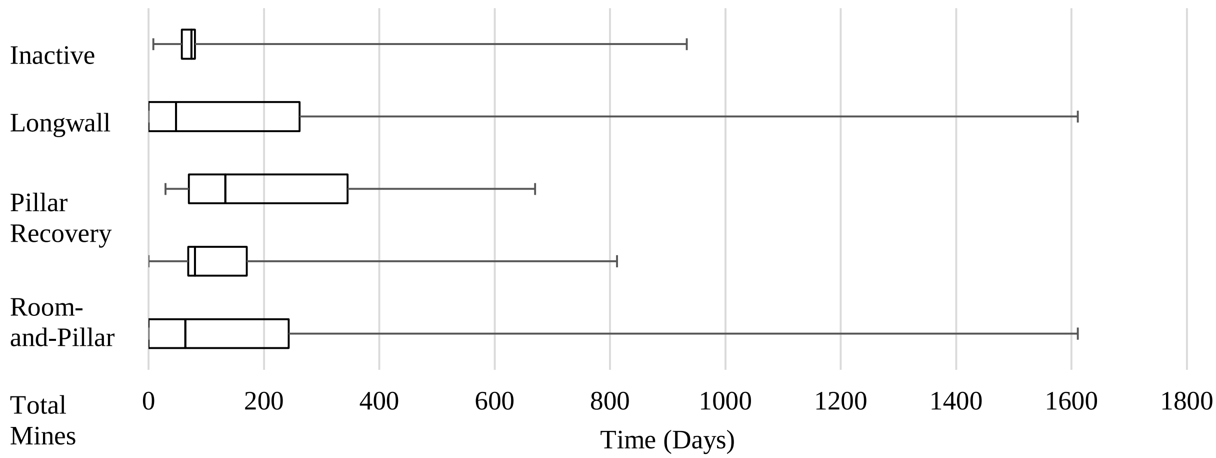

Figure IV-2. Box and whisker plot of the time to resolution of the 330 resolved structure reported effects sorted by mining type as of 20 August 2013.

In general, reported effects with the longest resolution times are those that required repairs from the company (Figure IV-3). Reported effects with the quickest time to resolution are those that are determined to be "No Liability," indicating that mining was not responsible for the impact (Figure IV-3). For these effects, investigations often reveal that mining is distant from the structure and thus unrelated to the effect. When classifying the average time to resolution by mining type, the University found that the longest average time to resolution occurred in inactive mines for structures where an agreement/compensation was required to mitigate the effect. Here, an outlier case that took 933 days to resolution pulled the average higher. This outlier case involved a structure that had been monitored for several years over the inactive Maple Creek longwall mine. The reported effect is resolved and considered "Company Liable" since the monitored ground movements supported a relation to mining activity.

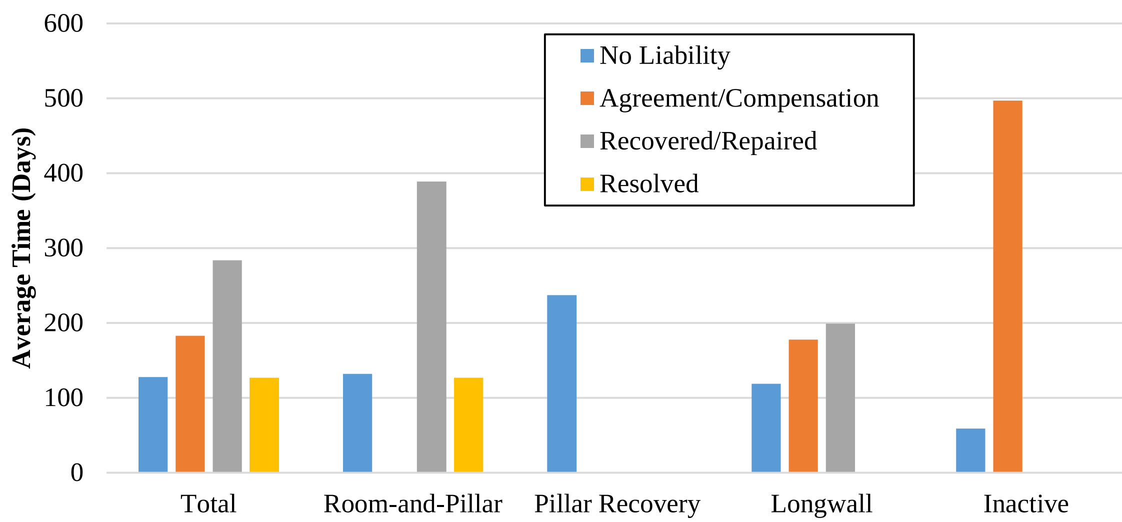

Figure IV-3. The average number of days required to resolve the reported structural effects (N=330) classified by mining type and categorized based on the resolution status as of 20 August 2013.

Figure IV-4 classifies the reported structural effects by structure type. Besides land, barns and dwellings are the next most common structural features with reported effects. Structural features classified as land represent nearly 55% of the total structural reports. The University believes that structures classified as land reported effects in BUMIS may be mislabeled. The University noted that often the reported feature type in BUMIS did not accurately describe the feature that sustained structural damage. For example, a feature listed as a spring sometimes described damage that occurred to a dwelling (Figure IV-4).

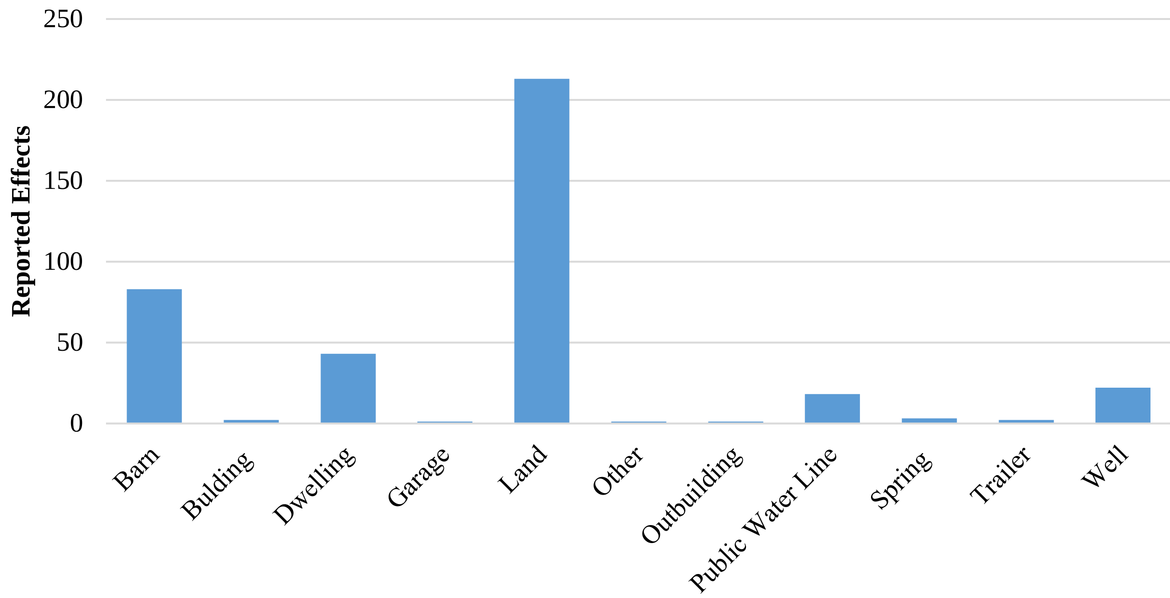

Figure IV-4. Total structure reported (n=389) as of 20 August 2013 classified by feature type.

Structure reported effects can also be classified by use. However, in BUMIS, 46% of all reported structural effects for this assessment period were classified as “Unknown” use (Figure IV-5). The most common uses for structures with reported effects were “Residential” followed closely by “Agricultural”. These two uses represent 47.6% of the total reported structural effects.

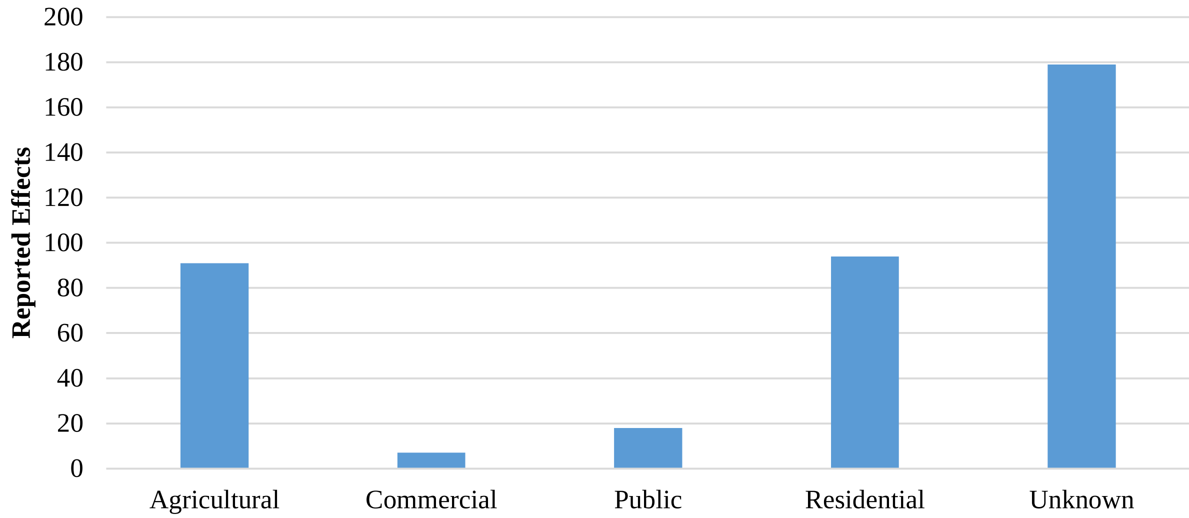

Figure IV-5. Total structure reported effects (n=389) as of 20 August 2013 classified by feature use.

IV.E - Comparison to Previous Act 54 Reports

Since the creation of Act 54, three reports have been submitted regarding the effects of underground bituminous coal mining on surface features. The data collected in these reports allows for comparison with the 4th assessment period.

Figure IV-6 illustrates the total number of structure reported effects for each Act 54 reporting period. The trend is generally upward. However, there is a drop in the number of structure reported effects between the 3rd and 4th assessments. The decrease in mining activity, especially longwall mining, has likely contributed to the decline in structure reported effects.

Figure IV-5. Comparison of total structure reported effects from the four Act 54 assessments.

IV.F – Characteristics of Company Liable Structure Effects

The University was able to accurately locate 195 of the 230 company liable structure effects, many with multiple effects, and perform rudimentary analysis. For example, overburden of company liable structure effects clusters about the two unique mine types, longwall and room-and-pillar (Figure IV-6). The data points over longwall mines were far more numerous with much higher overburdens then the room-and-pillar mines.

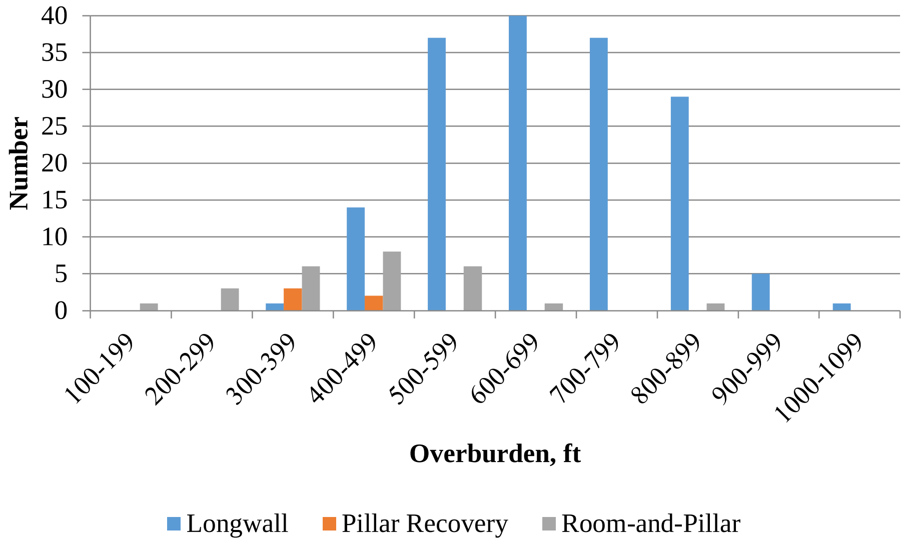

Figure IV-6. Overburden distribution of company liable structure effects. Note that the majority of the occurrences are over longwall mines.

Western Pennsylvania is known for its topographic relief where mass wasting (landslides) commonly occur along hillsides. Under these conditions, the effects of subsidence on structures could be enhanced. One-hundred and seventy-six of the 230 company liable structure effects, some with multiple problems, were accurately located within either the tops of the hills, along the hillside slopes, or within the valley bottoms (Figure IV-7). Sixty-nine percent of all company liable structure effects are located along the hillside. Hillsides should be considered areas of elevated risk for structure affected by subsidence.

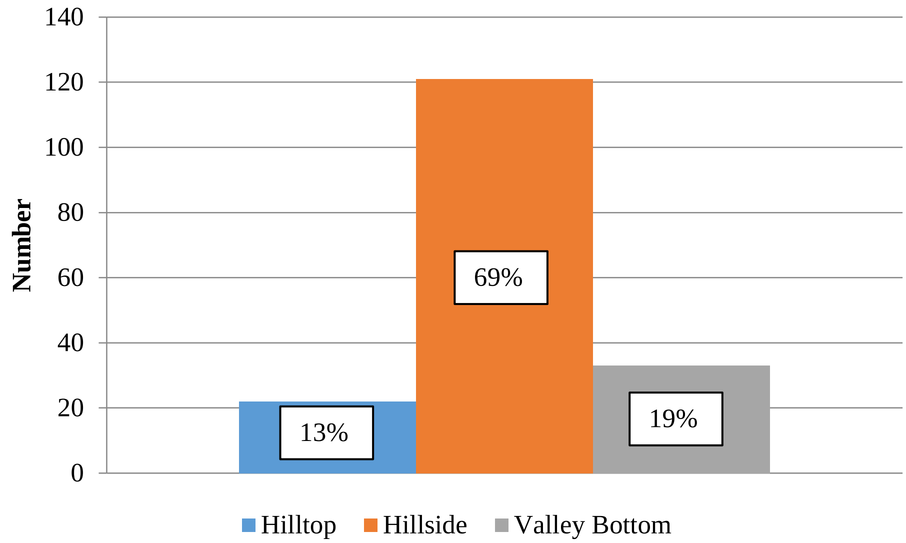

Figure IV-7. Company liable structure effects categorized by their topographic location.

The influence of mining on company liable structure effects was examined by placing the data into one of four categories: 1) above the 'full extraction' panel [longwall or pillar recovery panels], 2) above the room-and-pillar developments, 3) inside the 200-ft buffer but outside the mine, and 4) outside the 200-ft buffer (Figure IV-8). Not surprising, significant numbers of company liable structure effects occur above the longwall panels, but it should also be noted that significant numbers lie outside the 200-ft buffer. Many of these were found to be company liable because they were undermined in early assessment periods or they didn't reach a resolution until the 4th assessment period.

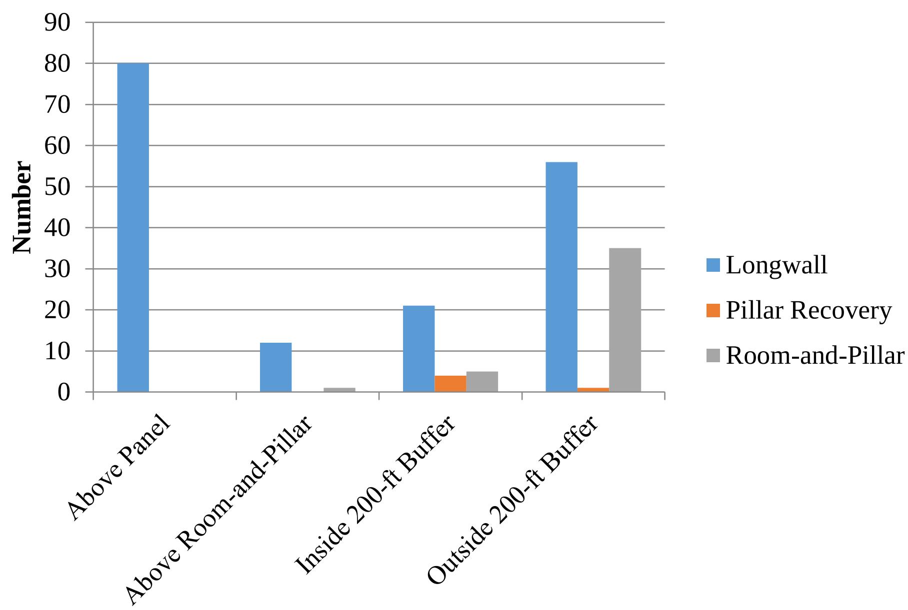

Figure IV-8. Location of the company liable structure effects with respect to the position of key mining zones. These zones were based on mining during the 4th assessment period.

IV.G – Summary Points

Three hundred and eighty-nine structure reported effects occurred during the 4th assessment period. Three hundred and fifteen were from the seven longwall mines, 48 from room-and-pillar mines, and seven from pillar recovery mines. Nineteen were from Non-active neighboring mines (see Appendix B for a list of these mines). An additional 93 effects were carryovers from the 3rd assessment period. Of the 389 structure reported effects, 59 were not resolved at the end of the 4th assessment period. Of the 330 resolved cases, 75% reached a final resolution within 180 days. Of the resolved cases, 238 were found to be company liable structure effects, or 61% of the total. The vast majority of the company liable structure effects occurred over longwall panels (230 out of 238).

The University had difficulty matching feature types shown on six-month mining maps (insufficient labeling information) with reports in BUMIS. In addition, many reported effects in BUMIS were incorrectly labeled by feature type and use.

References

Iannacchione, A., S.J. Tonsor, M. Witkowski, J. Benner, A. Hale, and M. Shendge (2011a) "The Effects of Subsidence Resulting from Underground Bituminous Coal Mining on Surface Structures and Features and on Water Resources, 2003-2008," University of Pittsburgh, http://www.portal.state.pa.us/portal/server.pt/community/act_54/20876.

Iannacchione, A., M. Witkowski, J. Benner, A. Patil, and N. Iannacchione (2011b) "Surface Structures Impacted by Subsidence from Pennsylvania Coal Mines, 2003 to 2008," 30th International Conference on Ground Control in Mining, Morgantown, WV, July 26-28, 2011, pp. 286-295.