SECTION 13: Summary and Conclusions

13.A - Overview

Section 18.1 of the Bituminous Mine Subsidence and Land Conservation Act requires PADEP to compile, on an ongoing basis, information from mine permit applications, monitoring reports, and enforcement actions. This law also requires PADEP to report its findings regarding the effects of underground coal mining on overlying land, structures, and water resources to the Governor, General Assembly, and Citizens Advisory Council at five-year intervals. This is the 5th such report and the third completed by the University of Pittsburgh.

13.B – Bituminous Coal Mining in Pennsylvania during the 5th Assessment Period

In the 5th assessment period there were 49 active mines whose conditions were tracked from August 21, 2013 to August 20, 2018. There were seven longwall mines, 38 room-and-pillar mines, and four pillar recovery mines. A total of 28,854 acres were mined, with longwall mining accounting for 62 % of the total, room-and-pillar 29 %, and pillar recovery 9 %. This represents an 7 % decrease in bituminous coal production from underground mines in Pennsylvania, but an increase of 6 % in the number of mines compared to the previous 5-year reporting period. Eleven companies operated these 49 mines.

During the 5th assessment period, 455 structural reported effects occurred as a result of 49 active and six inactive operations undermining a total of 3,612 structures. The mines employed three mining methods, longwall, room-and-pillar, and pillar recovery. Two hundred forty-seven reported effects had a final resolution holding the mine operator liable for the reported effect. Reaching a final resolution, took an average of 162 days. The longwall mines had 92.7 % of the structural company liable effects. The most common resolution type was an unspecified agreement. The most common structure undermined was a dwelling. The number of reported effects from the inactive mines was large compared to previous assessment periods: 64 reported effects for structures with 15 being company liable; 14 reported effects for water supplies with 1 being company liable and two interim resolution; and, 14 reported effects for land with four being company liable.

The longwall mines undermined the most water supplies (1,651, or 70.1 % of all undermined water supplies) in the 5th assessment. They also had the highest number of reported effects (233, 61.4 % of all reported effects) and company liable impacts (158, 82.3 % of all company liable effects). This is expected over longwall mines because of the larger number of cracks and fissures within the overburden subjected to subsidence. The overall impacts from room-and-pillar mining decreased from the 3rd and 4th assessment and the company liable water supply effect per acre mined was 75 % less than longwall mines, suggesting the importance of ground support by the coal pillars. Pillar recovery was the mining type with the fewest total impacts as well as company liable impacts. Although subsidence is expected with pillar recovery in the areas where the pillars are extracted, it is important to note that there are usually no water supplies located over these areas. In pillar recovery mining, a high extraction ratio can be achieved in specified areas where there are no water supplies located. Because longwall extracts a large area of coal over a relatively short period of time, these operations cannot as easily avoid areas with high water supply densities.

During the 5th assessment period, there were 379 reported effects to water supplies. Of these, 73 (19 %), including many reported late in the assessment period, remained unresolved at the end of the 5th reporting period and therefore cannot be included in the analysis of resolution time and resolution type. Among those that were resolved, the average time to resolution was 186 days. Of the 306 resolved effects, 63 % (192) were determined by PADEP to be due to underground mining. The mine operator was held responsible for the resolution of those cases. For those resolved effects for which the operator was held responsible the average time to resolution was 305 days. Fifty-four percent of all company-liable water supply effects were settled through an agreement between the mine operator and the property owner.

One hundred twenty-four (124) land reported effects occurred from 21 August 2013 to 20 August 2018 from the 49-active longwall, room-and-pillar, and pillar recovery mines as well as seven inactive mines. Sixty-six were found to be company liable. Most (80 %) of the total land reported effects occurred over the six active longwall mines. Nearly all (95 %) of company liable impacts occurred over longwall mines. Active room-and-pillar and pillar recovery operations had nine reported effects. Of these, eight had a final resolution determined to be company not liable. A significant increase (14) in reported land effects were reported over inactive mines.

Measures to protect the hydrologic balance continue to evolve. One challenge for implementation of these protections is that surface water impacts are not integrated into larger surface water protection in the PADEP such as the 303(d) listing of impaired streams. Water quality parameters required for monitoring are designed to assess acidic mine drainage impacts and do not necessarily allow evaluation of water quality implications of emerging processes such as the impacts of stream grouting or subsidence impacts on septic systems. As the PADEP evaluates methods to assess changes in surface water flows after mining, biases in the pre- and post-mining data sets need to be assessed when using these data to demonstrate flow recovery. An alarmingly high proportion of SRE reports did not contain the amount of monitoring data suggested by technical guidance. Gaps in flow data can violate assumptions underlying more sophisticated flow evaluation methods.

Groundwater monitoring is conducted quarterly. This schedule does not capture changes in groundwater occurring during undermining that can be reliably compared with related changes in surface water conditions. This limits evaluation of subsidence effects on groundwater and the associated impact to surface waters. Most of the water sources used for 92 augmented streams were groundwater sources.

During the 5th assessment period, longwall coal operations undermined 86 miles of streams. Those 86 miles of streams comprise 148 separate undermined stream reaches, of which 59, or 40 % experienced impacts from underground coal mining. If a stream reach was impacted, it was often impacted multiple times. The PADEP data indicate 179 total impacts during the assessment period. This translates to an average of 3.03 impacts for every impacted stream reach with 27.26 total miles of streams experiencing either flow loss or pooling. The University showed in the 4th assessment report (Figure VII-7 in Tonsor et al. 2014) that on average the Total Biological Score (TBS) declined significantly for streams with reported impacts following undermining.

A total of 82 stream recovery evaluation (SRE) reports were submitted to PADEP following mitigation with the intention of demonstrating stream recovery. Of the 82 SRE reports submitted in the 5th assessment period, mining operators were released from further responsibility for 42 of the streams evaluated. Forty SREs remain unresolved. Many more stream impacts have not yet had an SRE report submitted to the DEP, indicating that the majority of the 179 stream impacts during the 5th assessment period have yet to be resolved and released.

Heaves and fractures in stream beds can occur following undermining. Fracture sites under those conditions have occurred at distances as long as 1,500-ft from the mining front. During the 5th assessment period, 12 instances of fish kills resulting from flow loss on nine undermined streams were reported with an additional fish kill due to contaminated augmentation water. Gate cuts were completed in a total of 29 instances during the fifth reporting period. In addition, 24 gate cuts that were completed in the 4th assessment period were released during the 5th assessment. The 4th assessment (Tonsor et al. 2014) reports that, on average, gate cuts and the subsequent stream and streamside restoration restore stream function. TBS scores pre-mining and post gate cut restoration are statistically indistinguishable.

Grouting was performed 60 times on 46 streams during the 5th assessment, for a total of 8.65 miles of grouted stream beds. About 1/8th of grouted streams are re-grouted when the first grouting is not effective. Synthetic stream liners were employed in two places on Polen Run for which grouting was predicted to be ineffective, for a total of 4,500 ft of liner installation. Alluvial amendments using bentonite clay were employed on five streams during the 5th assessment period, covering 8,925 ft of stream bed.

Longwall mines undermined an estimated 90.7 acres of wetlands in the data evaluated for the 5th assessment. In four of the longwall mines, there was a slight net gain of wetland acreage. Enlow Fork mine was the only mine with a net loss (27 acres) of wetlands. The Dutch Run and Whiteley Creek mitigation projects were implemented to compensate for losses over Cumberland mine during the 4th assessment and created 5.08 acres of wetland, less than the mitigation target of 6.19 wetland acres.

The PADEP tasked the University with providing data-based recommendations on how to improve the implementation of Act 54. The aim of these recommendations is to enhance PADEP's regulatory efficiency and their ability to more effectively evaluate the impacts of mine subsidence. In summary, the recommendations fall into three broad categories:

1. Continued modernization and improvement of data infrastructure.
    a. The data infrastructure underlying BUMIS needs to be modernized to allow interaction among data tools for employees across PADEP. Examples of this need are provided throughout the report.
    b. The barriers to electronic submission of data need to be eliminated. The transcription and organization necessary to answer simple hydrological questions wastes PADEP effort and slows progress toward effective regulatory activity.
2. Development of hydrological metrics and methods.

   a. Available data are not comprehensively used. For example, groundwater HMR data are not used to evaluate stream recovery. This has the potential to lead to remedies that do not ultimately preserve the hydrologic balance.
   b. Current hydrological evaluations lack unambiguous means to measure pre- and post-mining flow ranges. Better frameworks for how to use the data result in better data submissions and clarity in the decision-making process.
3. Strategic foci to evaluate emerging potential impacts.
   a. Water quality HMRs are underutilized in assessment of subsidence impacts. Minor adjustments to the required chemical parameters to be measured can provide insight into the impacts of changing landscapes and mitigation practice.
   b. The widespread practice of company purchase of undermined properties has the potential to change the tax base and social fabric of undermined areas. These changes should be evaluated.
   c. The subsidence impacts in inactive mines during this assessment period creates the potential for extended responsibilities for mine operators that are not expected, both through time and across space. Processes driving these impacts can be clarified.

13.C – Conclusions

13.C.1 Persistent Challenges in Data Infrastructure

Data collection, organization, and QA/QC checking remains the largest proportion of total University effort on this project. As with the 4th assessment, mining data came primarily from three sources – 1) six-month mining maps provided by PADEP; 2) maps and other spatial data provided by mine operators to PADEP including six-month mining plus maps, environmental resource maps, and subsidence control plan maps; and 3) PADEP's Bituminous Underground Mining Information System (BUMIS). Actions taken by PADEP during the 5th assessment period enhanced the University's ability to complete analyses. Rectified versions of mine maps were provided to the University, removing a substantial duplication in effort between the PADEP and the University assessment process as the University no longer had to rectify the maps independently. An entire section for tracking stream impacts has been added to the BUMIS, enabling more effective examination of stream impacts and mitigation.

Despite these improvements, other data sets required substantial digitization and processing to answer questions about hydrologic conditions. Stream Recovery Evaluation (SRE) reports contain substantial measurements of flow conditions in impacted reaches both before and after mining. However, these data are apparently only available in hard copy form. Hydrologic monitoring reports (HMRs) continue to be a primary source of hydrologic information. At the end of the last assessment, these reports were included in permit files on compact discs as spreadsheet files. During most of the 5th assessment these reports were once again submitted in hard copy format. Digitization of these documents also required significant effort. Hard copy submittal requires substantial additional effort by PADEP staff to conduct routine analyses.

BUMIS was built 25 years ago, presumably in the dBase system, or another competitor at that time. This foundation on a legacy software architecture does not necessarily allow more with less. Rather, in some cases, it seems to require more work to complete tasks, work that detracts from already thin resources. Thus, while it may seem expensive to make an up-front investment in new software, continuing with the current system has substantial hidden costs in its inefficiencies.

The mining that Act 54 regulates stretches across large areas of southwestern Pennsylvania. Management of the array of subsidence impacts, where effects are significant in one location but relatively minor in the next stream valley, is not simple even on a single mine basis. The increasing range of operators and variability in their internal workflows and reporting complicate the regulation process even further. And while individual structures and water supplies can be assigned responsibility relatively clearly, surface and ground waters that flow across boundaries require substantial effort to manage effectively. Therefore, management of subsidence impacts and subsidence repairs requires sophisticated information management systems.

Despite the complicated data management needs, BUMIS, a database created in a software architecture predominant at the start of the desktop digital revolution, remains the foundation of information management in the regulation of mining related subsidence impacts in Pennsylvania. This aged software foundation creates substantial work in a modern computing environment. It is exceedingly difficult to interface old dBASE infrastructure with modern geographic information systems (GIS). For example, ESRI, the manufacture of the most common commercial GIS product only minimally supports files native to dBASE. Therefore, locations collected with global positioning systems need to be entered into a GIS to be mapped, but also need to be entered into BUMIS. Double entry is problematic from a data standpoint (key stroke errors are very problematic for data quality control). However, it is also a large time commitment for skilled DEP employees, the kind of process that could be automated with investment in information management systems. Beyond the data entry workload implications of fragmented data systems, when state professionals need the data, they may have to open two or three different, and potentially contradictory, packages to track the data down. With modern systems, a single entry (or even better, direct download) of important coordinates would be distributed automatically to all the relevant locations where that data needs to be stored.

Technically all of these systems can be made to work together. However, the scale of that endeavor quickly grows with the variety of software a modern office will encounter. This melding of software quickly becomes unwieldy and a drag on productivity. This drag is exacerbated by the growing unfamiliarity with legacy software systems as institutional information technology services grow younger. People will have to learn how to make these fixes on the job, in time constrained environments. This is not an optimal development environment. Further the unfamiliarity with legacy systems may lead to help tickets on these systems languishing as other easily solved problems are addressed first by default. Reliance on a legacy information system in an environment requiring complicated management decisions is not optimal.

The PADEP works hard to smooth data workflows and assure data quality is maintained. However, the people doing this work cannot transform the data systems alone. The transition to a modern information management system will require substantial investment, an investment that has been deferred. Without a change in resources for valuation of data tools, the next assessment will likely include similar pleas for changes in data management. The progress in this assessment is encouraging and likely will continue. But to take the next step and embrace the ability to do more with less, achieving the needed investment will require advocates from the bottom to the top of the organization and the Commonwealth.

13.C.2 Comprehensive Evaluation of Subsidence Impacts

Subsidence impacts a complex set of interacting systems and therefore is hard to explain simply. Consider the evolution of Act 54 provisions over the last twenty-five years. When the legislation was passed, impacts to surface water systems were addressed with generalities. Since, PADEP has created policy (e.g., technical guidance documents) to protect surface water systems and define measures of system recovery. Yet, this guidance continues to evolve as the PADEP explores methods to document changes in flow following undermining (Hittle and Risser 2019).

There is pressure to distill management practices to a set of best practices. Best practices are effective in well constrained systems, where impacts can be reliably predicted. However, in systems where impacts are not predictable and/or the effectiveness of fixes has not been demonstrated, they can result in sub-optimal outcomes (i.e., resources may not be fully protected).

Attempts to simplify management of subsidence need to be coupled with comprehensive examination of the larger implications. For example, PADEP and the mine operators have developed effective means to ensure most individual landowners are compensated for damage to their property from subsidence impacts. This is a strength of the program. However, this focus on parcels may be missing important transformations on the larger landscape as operator purchases of undermined properties alter fundamental land uses. These are trends that can only be discerned by stepping back and examining the mitigation in aggregate.

The need to comprehensively examine subsidence impacted systems is probably most pressing in hydrologic systems. Policy on surface water repair has matured into a process centered around stream recovery evaluation reports. However, while the PADEP collects data on both groundwater and wetland systems, these data are rarely integrated into assessments of hydrologic impact and repair. A test for groundwater impairment is not clearly defined. (e.g., In surface water systems, changes in the range of flows are evaluated with data collected from defined time frames relative to mining. In groundwater, changes in aquifer storage are acknowledged as a possibility, but thresholds and timeframes of changes in water storage, water chemistry, or aquifer hydraulic conductivity to determine an impact or evaluate recovery are not defined.) Wetlands are evaluated in terms of no net loss, following federal policies, however, abrupt changes in mapped wetland density (Section 11) can obscure measures of net loss. Continued integration of groundwater and wetland data into evaluations of hydrological impacts provides important checks on data quality and consistency. High quality data are vital to protecting hydrologic systems in the Commonwealth and the benefits citizens of the Commonwealth derive from these hydrologic systems.

Finally, during this assessment, unexpected impacts were observed. Far-field subsidence impacts occurred at distances well beyond those predicted by models accepted by the ground control scientific and engineering community. Company liable subsidence impacts occurred over inactive mines. These cases, if rare, might be aberrations. However, multiple far-field effects were recorded at distinct mines. Evaluation of whether these cases are "noise" or indicative of important emergent processes to consider fundamentally require a holistic approach.

These comprehensive evaluations require allocation of effort and continued defense of this allocation, as immediate concerns can sap resources from comprehensive approaches. The improved data management infrastructure advocated above makes this allocation easier. Comprehensive assessment is harder if data tools are ineffective. Continual movement toward an integrated analytical approach to subsidence effects would improve protections for the Commonwealth.

XI.D – References

Hittle, E., and D.W. Risser. (2019) "Estimation of base flow on ungaged, periodically measured streams in small watersheds in western Pennsylvania (No. 2018-5150)". US Geological Survey.

PADEP. (2005) "Surface Water Protection – Underground Bituminous Coal Mining Operations," Technical Guidance Document 563-2000-655, October 8, 2005, 43 p.

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