SECTION X: Recommendations

X.A – Overview

PADEP tasked the University with providing data-based recommendations on how to improve the implementation of Act 54. Below, the University first provides general recommendations for improving data submission and storage at PADEP. Second, the University makes specific suggestions based on the results from previous sections. The aim of these recommendations is to enhance PADEP's regulatory efficiency and their ability to more effectively evaluate the impacts of mine subsidence.

X.B – General Recommendations

1. Lack of uniformity in data submitted by the mine operators in fulfillment of permit requirements strongly hampers both enforcement of regulations and required Act 54 reporting. To enhance the efficacies of the regulatory and reporting processes, all data should be usable in spatially-explicit formats and/or readable by standard analytic software. The following recommendations address aspects of non-uniformity in data submission that were found by the University to hinder consistent regulation and reporting:
    - **a.** *All information should be submitted in electronic form*
    - **b.** *A protocol for submission of each type of data should be developed and disseminated. These protocols would specify:*
        - **i.** *File type (e.g. spreadsheet, geospatial format, etc.)*
        - **ii.** *Required metadata*
        - **iii.** *Required data, standard units of measurement for the data, and required precision of the data*
        - **iv.** *File formatting requirements (e.g. content and order of columns)*
        - **v.** *Time window in which data must be submitted*
    - **c.** *A protocol for PADEP's rapid checking of the incoming data and returning it if non-compliant should be developed and implemented.*

2. The University's efforts at data discovery were quite difficult, for both the data received by the PADEP from the mine operators and the data generated internally by PADEP. This was true in the 3rd Act 54 assessment as well. Some data was in BUMIS, although a significant amount of that was incomplete or in error (e.g. 25% of stream investigations from 3rd assessment were still not in BUMIS and 30% of features with a reported effect in the 4th assessment lack a unique identifier; Section II. B.2.3). Some data was in paper files at the CDMO. Some data was in paper files on PADEP personnel desks with no record that it had ever been submitted and/or removed from the file system. Some data was in spreadsheets on the computers of individual DEP personnel or PADEP servers but not readily available to the University or the general public. These last two types of locations were the most challenging since the University was dependent on PADEP personnel to volunteer the information. The University therefore makes the following recommendations to improve data storage:
    - **a.** *BUMIS:*
        - **i.** *Written protocols for data entry should be developed and implemented.*

   ii. *Quality control and quality checking protocols should be developed and implemented.*
   iii. *ALL information that can be georeferenced and is pertinent to permitting, regulation, and reporting should be included in BUMIS to create a true information system where all relevant information can be accessed.*
   iv. *Requiring submission of information from the mining operators and from DEP field agents in standardized formats (see Section X.B.1 above) will greatly facilitate the efficiency with which the above steps can be implemented.*

b. *For both spatial and non-spatial information, it is possible to link all pertinent information in a single electronic system. For example, the construction industry is rapidly implementing such systems and finding that they reduce liability, increase enforceability of contracts and generally greatly improve operating efficiency. Mining operations are likely to move in this direction as well. The PADEP would be wise to anticipate this and develop standards for data and record submission and tracking that can used by mining operators as they develop/implement such software. Planning those requirements in advance of the mine operator's adoption of such management systems will be far less expensive and frustrating to the operators than the development of conversion methods from their system to the DEP's system a posteriori.*

3. Analysis of the reported effects entered in the BUMIS database was challenging for the University. The largest of these challenges was comparing the features in BUMIS to the features labelled on the six-month mine maps. Features on the six-month maps are not labelled as specified in the PA Code, which requires a numerical identifier for structures and other surface features (PA Code, Title 25 Chapter 89.154b). Subsequently, the features cannot be matched with the information in BUMIS. All reported effects required additional information to be located. Again, the University notes that ~30% of reported effects listed in BUMIS could not be located from the six-month mine maps. The following recommendations will aid future analyses:
   a. *Six-month mine maps:*
      i. *Structures and surface features should be labelled with a unique numerical identifier whereby that feature can be identified solely by its numerical identification for a given mine.*
      ii. *All structures and surface features required to be identified should be identified within at least 200-ft of previous and active mining.*
   b. *BUMIS*:
      i. *All features should be input in BUMIS with geographic coordinates from either field GPS devices or computer geographic information system software. The coordinates should be given to the tenth of a second or to the ten-thousandths of a degree. Less than 1% of the reported effects were given coordinates.*
      ii. *Feature identification should match that of the six-month mine maps. Features should be able to be identified by feature number alone. Features should be identified by type, use, or property parcel.*

iii. *Information for a particular feature should be checked for accuracy before the case is closed. Information found in the BUMIS comments section suggests that many of the features are inaccurately labelled from initial inputs.*

4. The overlap between the 4th Act 54 assessment period and the University's budgeted time frame for data collection presented unforeseen challenges. PADEP's schedule for submission of six-month mining maps and hydrologic monitoring reports resulted in the arrival of some maps and hydrologic monitoring data at CDMO well after the University's collection period. Additionally much time and effort was spent continually updating the Act54GIS database as new data became available.

   The University recommends that future reports avoid significant overlap between the assessment period and the report preparation time period. The University suggests that PADEP aim for six months of overlap between the two periods to facilitate a timely report yet avoid unnecessary data updates.

X.C – Recommendations for Act 54: Structures

1. PA Code requires that all "dwellings, public buildings and facilities, churches, schools, hospitals and impoundments with a storage capacity of 20 acre-feet" be labelled with an identifying number on the six-month mining maps (PA Code, Title 25, Chapter 89.154b). However, the University found that many structures on the maps were not adequately labelled. Dwellings and barns are often labelled as simply D or B, respectively, which complicates efforts to determine the location of the impacted structure and its relation to mining. As a result of the inadequate labelling on the maps, the structure information in BUMIS also lacked unique ids. BUMIS also commonly misclassified structural features. For example, the feature type for structural impacts was sometimes listed as land or spring but further review of information and comments revealed the feature to be a dwelling or a garage.

   The University recommends that PADEP enforce proper labelling of features on six-month mining maps with identifying numbers to facilitate the tracking of undermined structures and mining-related impacts. The University recommends that PADEP adopt the quality checking protocols suggested above to ensure BUMIS accuracy.

X.D – Recommendations for Act 54: Water Supplies

1. PA Code also requires that all water supplies be labelled with an identifying number on the six-month mining maps (PA Code, Title 25, Chapter 89.154b). The University found that water supplies are often simply listed as W1 (i.e. well 1 on property) or S1 (i.e. spring 1 on property) but several W1 or S1 designations exist on a single map because most properties have at least one water supply. This compromised the linking of

information between the six-month mine maps and the BUMIS database for effective analysis.

The University recommends that PADEP adopt a numerical ID preceding the W1 or S1 identifier to allow more efficient tracking of undermined water supplies.

X.F – Recommendations for Act 54: Groundwater

1. TGD 563-2000-655 specifies the frequency of stream flow monitoring that is required before, during, and after mining (PADEP 2005). These monitoring guidelines are distinct from the "Hydrologic Monitoring Plan" required as part of module 8 in permit applications (section 8.15) which outlines the sampling of water quality and quantity at a set of surface water stations, wells, piezometers, and springs (PADEP 2012). While technical guidance specifies measurement of flow and groundwater elevations on a daily basis during periods of undermining, it is not clear that all of these data are consistently reported in the hydrologic monitoring reports. The majority of the reported data is quarterly sampling. In general, we found a quarterly sampling frequency inadequate to characterize impacts to system hydrology. However, even daily sampling frequency cannot necessarily capture rapid changes occurring during subsidence.

   The University recommends that the frequency of sampling be increased to sub-daily time increments (e.g., hourly or at 15 min intervals), particularly during periods just before, during, and just after undermining.

2. The "Hydrologic Monitoring Plan" required in the mine permit application offers a great deal of flexibility in the selection of the locations of sampling locations (PADEP 2012). However, the hydrogeology of the region, particularly the hydrologic response to the disturbances associated with undermining, seems to occur across a continuum from the hilltop to the valley bottom. Using the hydrologic monitoring points provided, the University found it difficult, if not impossible, to reconstruct the processes occurring from hilltop to valley bottom.

   The University recommends that review of hydrologic monitoring plans be designed so that hydrologic monitoring points are arranged along at least one continuous transect from hilltop to valley bottom.

3. The reporting of monitoring results has undergone substantial change over the course of this assessment period. Hydrologic monitoring reports (HMRs) were submitted electronically beginning in the second quarter of 2012. However, these data arrive in an inconsistent format requiring substantial time and effort to reorganize and analyze the data.

   The University strongly recommends that electronic submission continue and be expanded wherever possible. Moreover, the University recommends a consistent, organized format be established for electronic submission of hydrologic monitoring

results, allowing seamless synthesis of these data for comprehensive analysis of water balance.

4. The HMRs are stored in a separate portion of the permit files, isolated from both the permitting data and the water loss investigations. In addition, these HMR data are also isolated from other relevant data in other modules such as overburden stratigraphy. The simple comparison among these data sets that is necessary for assessment of water losses, inference of hydrologic change, etc. requires substantial logistical overhead to gather and synthesize the data on an *ad hoc* basis. This cost in time and energy is exacerbated by the incremental revisioning of permits.

   The University recommends that HMR data be stored as part of a larger information system, either incorporated into existing systems (e.g. BUMIS) or preferably, the next generation data systems with spatial querying capabilities described above (Section X.B.2.b). This data system would ideally allow direct appending of revisions to existing permit module text, providing examination of permit revisions in context. This data organization would enhance the ability of the PADEP and citizens of the Commonwealth to comprehensively evaluate the changes in water balance occurring above underground mining.

5. Understanding the processes causing losses of water sources following underground mining is challenging given the limited understanding of the well stratigraphy or how they are completed. Supplemental data sources were consulted to determine local aquifer stratigraphy, though with limited success. This data gap results from the legacy of decisions made about well completion reporting in the Commonwealth and retrospective change is not likely. However, future data, if available, would enhance the ability to understand and potentially prevent water loss.

   The University recommends that stratigraphic logs of all wells or piezometers completed as part of the underground mining permitting process be submitted to existing state data bases such as the Pennsylvania Ground Water Information System (PAGWIS). The University recognizes that such reporting is not required by existing regulations, but the addition of these new data to the existing data resources would benefit the citizens of the Commonwealth in general and should be encouraged. Moreover, it would allow more rapid and effective assessment of water loss in undermined areas.

6. The maturation of hydrologic monitoring of surface water systems and mitigation strategies to address surface water impacts has highlighted the limited understanding of hydrologic processes on the hillslopes. Hydrologic monitoring of changes in spring flow is the smallest HMR data set. Hydrologic changes occurring in hillslopes cannot be characterized as data simply do not exist to evaluate changes in hillslope hydrology.

   The University recommends that additional monitoring of changes to hillslope moisture status be added to the technical guidance allowing the assessment of changes in hillslope soil moisture patterns. These data may be more sensitive to long term changes and the

potential "healing" of hydrologic system following mining. Ideally, these data would be collected as part of the transects mentioned above.

X.G – Recommendations for Act 54: Streams

1. In general, standardized, electronic formats for flow and biology data submission are lacking. Stream flow maps and accompanying data are currently submitted to PADEP on a monthly basis by mine operators (Section VII.D). While these data are not required by the mine permit application, they are extremely useful in determining the nature and severity of stream impacts. Unfortunately, it is difficult to use these data to draw general conclusions about the impacts of mining on stream flow due to a lack of standardization across mines. As for the biology data, module 8 of the mine permit application provides forms for the submission of pre- and post-mining biological data (Forms 8.8C and 8.8D). However, mine operators do not typically use these forms and instead create their own. One consequence is that data on macroinvertebrate community composition, which is required by Form 8.8C, is only occasionally submitted.

   The University recommends that submission of monthly stream flow maps and data continue. To maximize the utility of these data, the University also recommends that PADEP develop a standardized electronic format for submission. The University encourages the display of active and inactive augmentation wells on maps to aid in identifying streams experiencing flow loss and the severity of the impact. The University also encourages the use of spreadsheets to explicitly quantify the lengths of flow loss. Maps are useful in identifying the locations of flow loss, but spreadsheets would facilitate statistical analysis of flow loss lengths.

   The University also recommends that PADEP re-work Forms 8.8C and 8.8D for biological data submission. Mine operators have developed significant improvements over these forms that allow data to be readily exported to statistical programs for analysis. PADEP biologists should also request and store all macroinvertebrate taxon-level data associated with a particular TBS. Evaluation of TBS and its associated metrics can provide insight into the degree of impact and/or recovery, but data on community composition can explain how *a community is affected by subsidence and/or mitigation.*

2. TGD 563-2000-655 currently requires that all Total Biological Scores (TBS) be collected between October and May (PADEP 2005). The University found that even within this index period, TBS varies significantly with month of sampling. On average, TBS collected in October and November were 10 points lower than TBS collected in December-March (Figure VII-5).

   The University recommends that the PADEP's index period be shortened to December-May and that PADEP encourage operators to concentrate TBS sampling efforts in December-March. The shorter index period would eliminate the need to consider month of sampling when assessing the impact of mining and degree of recovery for stream macroinvertebrate communities.

3. PADEP's methodology for tracking stream impacts changed between the 3rd and 4th Act 54 assessment periods following implementation of TGD 563-2000-655 (Figure VII-7). Determining the number of stream impacts and their final resolution now requires consultation of BUMIS agent observation files and SSA stream data logs. The BUMIS observations are written in a narrative style that makes extraction of relevant data challenging while the SSA stream data logs lack a standardized format and they are not stored in place that is readily accessible to citizens of the Commonwealth.

   The University recommends that PADEP develop a written policy for tracking stream impacts along with a centralized and standardized database system that incorporates all relevant data, including maps, photos, narratives, and raw data. Because BUMIS was not designed to track the complex nature of stream impacts, a novel information system may be required. The University also recommends that PADEP request and store all flow and biology data collected by the mine operator following mitigation to avoid the perception of selective data submission.

4. TGD 563-2000-655 requires that stream flow must return to a "normal range of conditions" following mining-induced impacts (PADEP 2005). The normal range of conditions is to be based on a minimum of two years of flow data. However, the University found that PADEP determinations of flow recovery were typically based on inadequate flow measurements and idiosyncratic methods of analysis (Section VII.G.2).

   Additionally, it was discovered that the PADEP flow assessments utilize two different measures of stream flow (Section VIII.B.4). One measure is the percent of the stream length experiencing flow loss. The other measure is a volumetric flow rate, typically measured as gallons of water passing a fixed point on the stream per unit time.

   The University recommends that PADEP establish a more rigorous protocol for assessing impacts on stream flow. PADEP must first establish a standard measure of stream flow. The University suggests that volumetric flow rates be selected as the standard, as these measures precisely quantify stream flow while percent flow loss simply reflects the presence or absence of water. Following mining, it is possible that flow may return, but at a lower volume than was present prior to mining. Volumetric flow rate measures would capture this variation, but percent flow loss would not. Once a standard measure is in place, PADEP must ensure that mine operators comply with TGD 563-2000-655 and submit at least two years of pre-mining stream flow data. Finally, PADEP should establish quantitative guidelines for determining what degree of variation indicates an adverse effect of mining on stream flow.

5. TGD 563-2000-655 requires that flow loss mitigation plans "should provide for surveys of the macroinvertebrate community…as soon as practicable after flow has recovered or been restored" (PADEP 2005). However, Bailey Mine is the only longwall mine submitting post-mining macroinvertebrate data in a timely fashion following mining-induced flow loss. After the University's data collection period had ended, the University learned that PADEP had received biology data from Cumberland and Emerald Mines in

August 2013 but that the data had been misplaced for several months. As a result, the data were not available to the University until April 2014 – well after the data collection period. PADEP also asserts that data from Enlow Fork Mine was requested in February 2014 and received in March 2014. These data were received well after the University's data collection period and were never made available to the University.

The University recommends that PADEP establish strict schedules for the submission of biology data following flow loss mitigation and flow recovery.

The University also recommends that biological samples collected after grout mitigation at sites experiencing flow loss impacts be explicitly labelled as "post-grouting" to facilitate determination of the effectiveness of this technique.

6. TGD 563-2000-655 allows for the use of control streams to determine whether changes in undermined streams are related to mining. Control streams must match the undermined streams in the following ways (PADEP 2005):
    a. Drainage area and yield
    b. Stream gradient
    c. Habitat and canopy cover
    d. Watershed topography
    e. Watershed land use
    f. Surface geology
    g. Streambed substrate
    h. Physical and chemical parameters

    The University's assessment of the available data suggests that control sites are not selected in the rigorous manner required by TGD 563-2000-655. When the University could locate the rationales underlying control stream selection in the paper files at CDMO, selections were based almost exclusively on watershed land use and watershed size. Indeed, the rationale from one mine operator indicates that CDMO has identified these two characteristics as the most important parameters for comparing undermined and control sites (Wallace & Pancher, Inc. 2013). However, the University knows of no analysis by PADEP that has formally tested this idea. The University's analysis in Section VII.C.2 indicates that stream habitat and pH are actually more important predictors of stream biology than watershed land use or size (Table VII-4). It should be noted that the University could not test the importance of other factors, such as surface geology and streambed substrate, due to a lack of available data.

    Even with careful selection of control streams, these streams may not accurately reflect the pre-mining conditions of undermined streams. Following restoration, the University noted that Total Biological Scores on undermined streams were occasionally much higher than those observed on the control streams (e.g. Section VIII.C.2). Such cases suggest that either restoration is enhancing stream habitat above and beyond pre-mining conditions or control streams are an inadequate comparison.

The University recommends that PADEP and mine operators utilize control streams only in extreme circumstances to evaluate recovery of undermined streams. While this assessment saw the lingering effects of mines moving into compliance with TGD 563-2000-655, with all active mine permits now having been issued or renewed after implementation of TGD 563-2000-655, two years of pre-mining flow data and TGD compliant pre-mining Total Biological Scores should be required of all mining operators.

7. An important function of the Clean Streams Law of Pennsylvania (Act of 1937, P.L. 1987, No. 394) is "regulating the impact of mining upon water quality, supply, and quantity". While TGD 563-2000-655 and the mine permit application provide for an assessment of stream flow and biological recovery, it does not currently assess impacts to stream water quality. Using data from one mine, the University found that streams affected by mining-induced flow loss have significantly elevated conductivity and pH (Table VII-10). On average, the increase in conductivity following mining exceeds the U.S. EPA's benchmark for aquatic life in the Western Allegheny Plateau ecoregion (U.S. EPA 2011). Furthermore, the University found that these chemical parameters show no sign of returning to pre-mining levels over time (Section VII.J.2).

   The University recommends that PADEP closely monitor data on stream physiochemistry to determine if the changes in water quality detected by the University are a general trend associated with mining-induced flow loss. The University also suggests that future Act 54 reports follow up on this finding and assess the nature of the relationship between water quality and macroinvertebrate community composition at mined sites.

8. Grouting is a commonly utilized by mine operators to mitigate flow loss impacts to streams (Table VII-14). However, PADEP does not require mine operators to report the length of streams that are grouted. Because many of the sites that require grout mitigation are in highly forested areas that are inaccessible to heavy equipment, access roads are often built to move equipment to the restoration area (Section VII.I.5-6). PADEP does not require formal quantification of access road lengths.

   The University recommends that PADEP require mine operators to formally quantify the length of grouting and access road construction. This information would aid in monitoring the extent of mitigation and in evaluating the ecological impact of stream mitigation on surrounding terrestrial ecosystems.

X.H – Recommendations for Act 54: Wetlands

1. PADEP requested that the University report on the number of wetlands undermined. However, the University discovered that individual wetland patches identified on the maps were grouped together as a single wetland for evaluation of gains and losses in the mine operator's data tables (Section IX.B.1). The method underlying the decision to group certain wetland patches could not be identified. The seemingly random grouping prohibited numeration of undermined wetlands and also made it impossible to determine the relationship between wetland gains/losses and geological parameters, such as overburden depth, slope position, etc.

The University recommends that PADEP identify the mechanism underlying wetland grouping. If the grouping is a result of hydrological and biological connectivity between wetland patches, then the practice of grouping may be relevant to assessments of mining-induced gains and losses. However, if the grouping reflects data collection methods or other factors unrelated to wetland ecology, then PADEP should request that mine operators discontinue the practice.

2. TGD 363-0300-001 requires a wetland replacement ratio of 1:1 in terms of area and function for all impacted wetlands (PADEP 1997). In this assessment, Cumberland Mine experienced a net loss of 4.84 wetland acres, the bulk of which were palustrine emergent wetlands. While the two mitigation sites created a total of 5.25 wetland acres to offset these losses, just 2.31 acres were designed to be palustrine emergent wetlands.

   The University recommends that PADEP provide greater oversight of the 1:1 replacement ratio for both wetland acreage and wetland function/type. Palustrine emergent wetlands in particular provide plant habitat, detrital inputs, and can influence nutrient cycling (Mitsch et al. 2009) and take less time to establish relative to scrub-shrub and forested wetlands.

References

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