SECTION II: Methods: Constructing the Act 54 Geodatabase

II.A – Overview

This section provides an overview of the University's methods of data collection and compilation in preparation of the Act 54 report. The construction of the Act 54 Geographic Information System (Act54GIS) is described along with the various sources and software used in its creation and maintenance. The University also outlines the major challenges and limitations encountered in assembling the necessary information and makes recommendations for improving this process.

II.B – Introduction

Determining the impacts of mining is largely a spatial problem. Any impacts on the overburden strata, landscape, structures, streams, and wetlands are limited to an area immediately above and surrounding the area mined. Further, knowing the timing of undermining in relation to the timing of purported damage is crucial to determining the likelihood that the damage was in fact caused by mining. Thus determining the precise locations of all features of interest and areas mined is critical to mining regulation and to Act 54 reporting. Geographic information systems (GIS) are the standard method for working with spatially explicit data. A major part of the Act 54 reporting work involved the construction of the Act54GIS. Much effort was spent collecting available data, transforming and combining the data into user-friendly products for analysis, and updating the database as new spatial data became available.

Two main data collection efforts were made over a period of 14 months. At the outset of the project, 11 months before the end of the 4th reporting period, the University focused on collecting base data, such as the spatial information for roads, streams, bio-monitoring sites, and elevation. The University also collected all data on mining extents and undermined features that were available at that time. After the end of the 4th assessment period, from August 2013 to November 2013, the University focused on updating the mining extents and undermined features so that the spatial data reflected the status of mining as of August 2013 for as many mines as possible.

The overlap between the budgeted time frame for the University's data collection (1 September 2012 through 30 November 2013) and the 4th assessment period (21 August 2008 through 20 August 2013) was the result of discussions following the 2nd and 3rd assessments. In the 2nd assessment, Conte and Moses (2005) specifically indicated that "Such an approach would expedite the completion of the report upon the termination of the assessment period." Thus, a more timely production of the report seemed desirable. However, the overlap in timing presented several unforeseen challenges. The major difficulty created by the overlap was a consequence of PADEP's schedule of due dates for six-month mining maps. The due dates are staggered among the various mines so that the workload of reviewing and processing the maps is spread across time. While in and of itself a wise approach, this had the unfortunate consequence that for some mines the last maps of the reporting period did not arrive at PADEP until well after the University's contract budget and time frame for data collection had ended. While this is inefficient it is not a fatal problem. The remaining six-month maps can be incorporated in the next Act 54 report. Most importantly, their absence is not likely to qualitatively change the conclusions of this report. Table II-1 indicates the last month for which six-month maps were available and incorporated by the University. The challenges with the overlap argue for a middle ground in future reports, e.g. starting perhaps six months prior to the end of the assessment period.

II.B - Data Sources, Software, and Standardization

II.B.1 – Base Data

The first phase in developing the Act54GIS involved populating the database with base data to provide a spatially referenced framework to which all mining related information would be associated. Eighty-five GB of base data was acquired from the Pennsylvania Spatial Data Access (PASDA) geospatial clearinghouse maintained by The Pennsylvania State University (PSU), the Geography Division of the U.S. Census Bureau, and the U.S. Geological Survey:

- Roads:
  - Local roads created by Pennsylvania Department of Transportation (PennDOT): (http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=PaLocalRoads2014_02.xml&dataset=1038)
  - State roads created by PennDOT: (http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=PaStateRoads2014_02.xml&dataset=54)
- Hydrologic features:
  - Networked streams of Pennsylvania created by the Environmental Resources Research Institute (ERRI) at PSU (http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=netstreams1998.xml&dataset=16)
  - Small watersheds generated from the USGS Water Resources Division's major watersheds dataset by ERRI at PSU (http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=smallsheds.xml&dataset=14)
  - Waterbodies from the National Hydrography Dataset (NHD) created by the US Geological Survey (USGS) (http://nhd.usgs.gov)
- Political boundaries:
  - Statewide Pennsylvania county boundaries created by PennDOT (http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=PaCounty2014_02.xml&dataset=24)
- Elevation:
  - PAMAP Program LAS: 3.2 ft resolution LiDAR Digital Elevation Models (DEMs) (http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=PAMAP_DEM.xml&dataset=1247)

II.B.2 – Data on Mining Extents and Undermined Features

Following incorporation of the base data, the University added information on mine locations and undermined features. These data came from three different sources:

- Six-month mining maps submitted by the mine operator to PADEP

- Digital spatial data supplied by the mine operator to the University
- Bituminous Underground Mining Information System (BUMIS) Inventory

II.B.2.1 - Six-Month Mining Maps

Six-month mining maps are submitted by the mine operator to PADEP every six months. The maps depict:

- The location of any mining that occurred during the prior six months
- A prediction of mining during the following six months
- The locations of all surface features such as properties, structures, water supplies and utilities that might be impacted by mining and thus the subject of PADEP mining-related oversight.

Some maps included additional information on coal and surface elevation contours. In general, there was little standardization between maps in what information beyond the bulleted items (above) was included, even within the same operating company.

The University received 565 relevant six-month mining maps (644 GB) as Tagged-Image Format (TIF) or multi-resolution seamless image database (MrSID / SID) format images from the California District Mining Office (CDMO). Approximately 525 of the 565 six-month mining maps were used at some point. However the updates made necessary by the overlap in the reporting period and the University's data collection period, often resulted in more than one map collected for the same area. The University replaced any outdated maps with their newer versions. This resulted in a library of 258 most up-to-date mining maps.

Of the six-month mining maps ultimately used, 106 maps (41%) were received without spatial information, meaning that they lacked an association with a physical location that would allow them to be placed within the geospatial framework of the base GIS described in II.B.1. The University used a process called geo-referencing to assign these maps to the areas that they depicted.

To geo-reference the map images, the University employed two different strategies. In late 2012 and early 2013 during the first round of data collection six-month mining maps were geo-referenced using road intersections from the PennDOT state and local road layers retrieved from the PASDA website. The team would find an intersection on the six-month mining map and match it to the corresponding intersection on the roads layer. If an insufficient number of intersections were available, sharp bends in a road were used. For mines that had some digital information, roads were still used as the primary anchoring points, however, distinct shapes in the mining outline layer were used as second preference over sharp bends in the road. After August 2013, the University used the mining outline shape to geo-reference the new six-month mining maps, having already precisely geo-referenced mining outlines in previous six-month mining maps. Residual error for each map was recorded for each map as the root mean square error (RSME) of the list of control point residuals. In addition, the number of control points for each map was recorded. Since all but one mine employed more than one map, the mean of those numbers was also calculated for each mine. The University recommends that PADEP require electronic submission of all six-month mining maps with standardized geo-referencing.

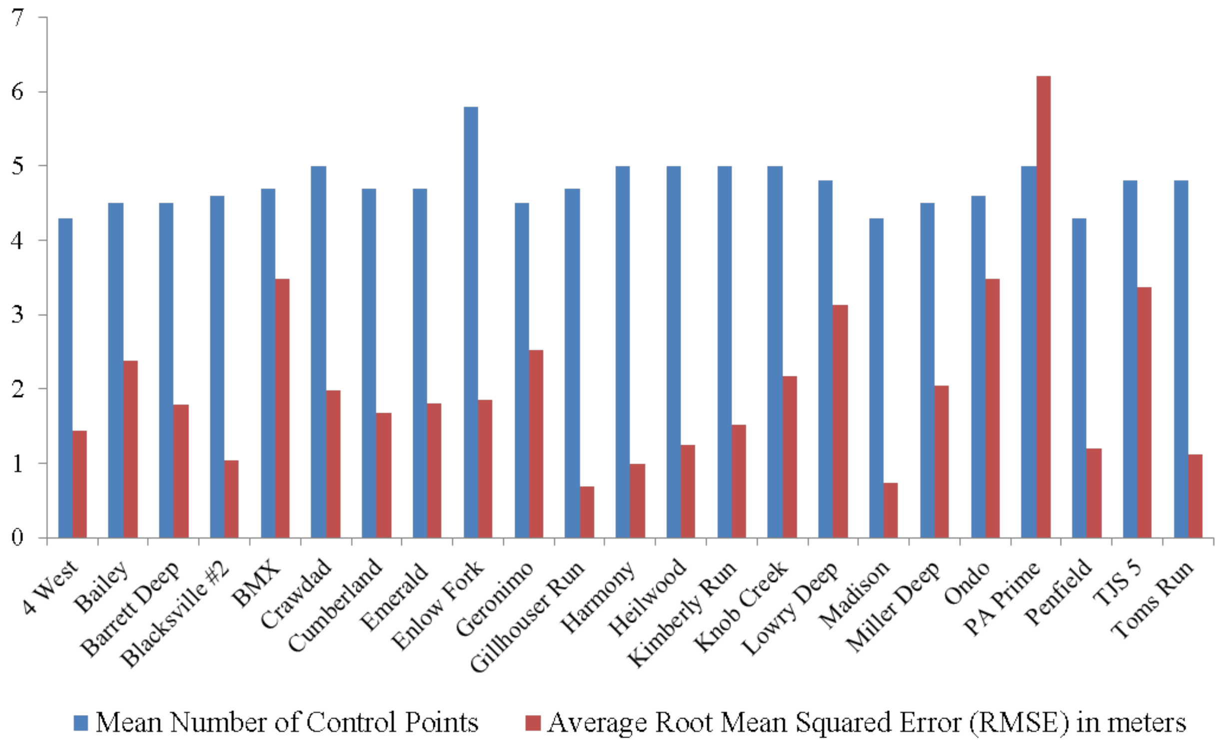

Figure II-1 - The mean number of control points and average root mean square error (in meters) for each mine in the study area for which the University geo-referenced maps. Mines that did not require geo-referencing on the part of the University are not represented in the figure.

For the 152 maps that had accompanying spatial information and were used by the University, the geo-referencing was supplied by PADEP. The legal use constraints on these spatial data require that the University provide the following disclaimer for all maps that follow in the report: "The georeferenced map layer on this product was provided by the Pennsylvania Department of Environmental Protection. This map was georeferenced using information considered to be the best historic data available. It is understood that there is an inherent loss of accuracy in the georeferencing process and the georeferenced map may not align correctly with base maps, real world locations, and/or established coordinate systems. The Department assumes no responsibility for the accuracy or completeness of this information."

II.B.2.2 – Mine Operator Data

University team members contacted and visited mine operator facilities to obtain digital spatial information that would accompany an electronic version of a six-month mining map. Many of the operators agreed to supply us with digital ArcGIS or AutoCAD files (Table II-1) to enhance accuracy by diminishing inherent errors associated with geo-referencing. These data were compared to the six-month mining map records, and were quite accurate. Since the ArcGIS Desktop software produced by the company Esri was the primary tool for the University's analysis, all AutoCAD files were converted into ArcGIS compatible files. The CAD files were initially opened in Autodesk's AutoCAD software and each of the features of interest were then exported individually as a separate CAD file. This suite of new CAD files was then imported one-by-one into ArcMap using Esri CAD-to-geodatabase tools.

II.B.2.3 – Bituminous Underground Mining Information System Inventory

The Bituminous Underground Mining Information System (BUMIS) Inventory is a database established and maintained by PADEP that is intended to track surface impacts related to underground bituminous mining activities. Surface features that may be impacted include structures, water sources (wells and springs), water bodies, streams, and utilities (water and sewer supply systems, power lines, gas lines, and roads). BUMIS is intended by PADEP to not only track impacts on surface features, but also to record corrective actions by the mine operators and regulatory actions by PADEP.

BUMIS cannot be relied upon as the authoritative source of information on undermined surface features, impacts or impact resolution. Spatial coordinates (i.e. longitude and latitude) were rarely provided in BUMIS during the 4th assessment period. As a result, the University had to rely on a feature's unique identification number to determine its spatial location from the six-month mining maps. Unfortunately over 40% of BUMIS features lacked a unique identification number. PADEP corrected approximately 250 errors in BUMIS but insufficiencies in data entry continued through the end of the University's assessment period. The University's final pass through BUMIS revealed that the percentage of features lacking a feature identification number remained around 30 percent. The University also discovered that some six-month mining maps that have feature identification numbers do not have unique feature identification numbers when multiple structures of a given type are present on a single property, a frequent occurrence. In such cases, barns, dwellings, and wells are labeled with a simple B, D, or W respectively. This becomes problematic when attempting to determine exactly which barn, dwelling, or well was impacted by mining. Less commonly, unique identifiers for properties varied between BUMIS and the six-month maps (tax identification numbers in one, tract identification numbers in the other), further complicating efforts to locate undermined and impacted features. Data entry errors are also frequent. For example, damage to wells is sometimes classified as "structure damage". Data entry is often incomplete with a feature lacking, for example, date of impact occurrence and depth to mining. In some cases, impacts are missing altogether. Most of the errors and inaccuracies in BUMIS result from an apparent lack of written protocols for data entry, and lack of quality control and error checking within PADEP.

BUMIS was not accessed by the University directly. Instead BUMIS data was downloaded by PADEP and made available to the University as Microsoft Excel spreadsheets. The University uploaded these spreadsheets into Microsoft Access and linked them to the Act54GIS to determine the locations of impacted features.

Table II - 1. Sources of data on mining extent and undermined features by mine. Information on the received file formats and the most recent month for which six-month mining maps were made available to the University is included. Not all six-month mining maps for the 4th reporting period were submitted in time for inclusion.

Mine	Data Source(s)	Data Format(s)	Month of Most Recent Available Data
Cumberland	Alpha Natural Resources	ArcGIS Shapefiles	Aug-13
Emerald	Alpha Natural Resources	ArcGIS Shapefiles	Aug-13
Barrett Deep	Amfire Mining Co LLC District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Aug-13
Gillhouser Run	Amfire Mining Co LLC District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jul-13
Madison	Amfire Mining Co LLC District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Mar-13
Nolo	Amfire Mining Co LLC & District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Nov-12
Ondo	Amfire Mining Co LLC District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Aug-13
Dora 8	Amfire Mining Co LLC District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Nov-12
Bailey	Consol PA Coal Co. LLC	AutoCAD file	Aug-13
Enlow Fork	Consol PA Coal Co. LLC	AutoCAD file	Aug-13
Blacksville 2	District Mining Office, California PA	Six-Month Mining Map	Jul-13
Eighty Four	District Mining Office, California PA	Six-Month Mining Map	Nov-11
BMX	Consol PA Coal Co. LLC District Mining Office, California PA	AutoCAD file Six-Month Mining Map	May-13

Mine	Data Source(s)	Data Format(s)	Month of Most Recent Available Data
4 West	MepCo District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jan-13
Prime 1	MepCo District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jul-13
Crawdad	MepCo District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jul-13
Titus Deep	Dana / MepCo District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jan-10
TJS 6	Penn View / Rosebud District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Aug-13
Clementine 1	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Dec-12
Lowry	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jul-13
Penfield	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Apr-13
Toms Run	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Mar-13
Windber 78	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Apr-13
Beaver Valley	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jan-13
Cherry Tree	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Apr-13
Darmac 2	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jun-13
Dutch Run	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jan-13

Mine	Data Source(s)	Data Format(s)	Month of Most Recent Available Data
Harmony	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jul-13
Heilwood	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Apr-13
Knob Creek	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Apr-13
Little Toby	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Nov-11
Logansport	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jan-13
Long Run	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Mar-13
Rossmoyne 1	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Mar-12
Starford	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Mar-13
TJS 5	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Oct-10
Tracy Lynne	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	May-13
Twin Rocks	Rosebud Mining Co District Mining Office, California PA	AutoCAD file Six-Month Mining Map	Jul-13
Kimberly Run	District Mining Office, California PA	Six-Month Mining Map	Aug-13
Horning Deep	District Mining Office, California PA	Six-Month Mining Map	Apr-13
Geronimo	District Mining Office, California PA	Six-Month Mining Map	Sep-09

Mine	Data Source(s)	Data Format(s)	Month of Most Recent Available Data
Sarah	District Mining Office, California PA	Six-Month Mining Map	Jul-13
Miller Deep	District Mining Office, California PA	Six-Month Mining Map	Feb-13
Quecreek 1	District Mining Office, California PA	Six-Month Mining Map	Mar-13
Roytown	District Mining Office, California PA	Six-Month Mining Map	May-13
Agustus	District Mining Office, California PA	Six-Month Mining Map	Aug-13

II.B.3 – Act 54 2nd and 3rd Assessment Spatial Data

Because the University created the spatial data for the 3rd Act 54 assessment in the form of a GIS database (Iannacchione et al. 2011), the data were readily available for use in the current assessment. Additionally, the University had acquired the spatial data from the California University of Pennsylvania's 2nd Act 54 report (Conte and Moses 2005). Therefore, all of the six-month maps and spatial layers from the 3rd report, and many of the same for the 2nd report were available to the University.

II.B.4 – Standardization of Datum and Coordinate Systems

Once collected, all spatial data sets were converted to a standard datum and coordinate system using the projection tools built into Esri's ArcGIS software. The North American Datum of 1983 (NAD 1983) was used as the earth-shape model for the Act54GIS. This datum associates its geographic coordinate system with the reference ellipsoid of the Geodetic Reference System of 1980. The University employed the Universal Transverse Mercator (UTM) coordinate system because it is an equal area projection that minimizes local distortion. Though the project was limited to Pennsylvania's state boundaries, using a standard projection allows the data to be available for broader use in the future. All mined areas for the 4th Act 54 assessment lie within Zone 17 North of the UTM coordinate system.

II.C – Data Layers Generated by the University

Using the data described above, the University generated relevant data layers for addressing the tasks set forth by PADEP. Specifically, the University generated the following the data layers for each mine, where applicable:

- Mining Extents
- Surface Features
- Overburden
- Buffers
- Stream Observations
- Stream Bio-monitoring Stations
- Topography
- Wetlands

II.C.1 – Mining Extents

In this report "mining extents" is defined as the area within which room-and-pillar, longwall, or pillar recovery mining took place between August 2008 and August 2013. These are represented by ArcGIS feature class polygons, and are separated by mining type. These digital files were compared to the mining extents stored in the 2nd and 3rd period databases. By comparing mining extents across the three reporting periods, the University was able to avoid overlaps and gaps in analysis coverage.

Most mining extents were provided by the mine operators at the outset of the project as digital files (see Section II.B.2.2). Mining extents that could not be collected digitally were traced by the team's GIS specialists using ArcMap's Editor tools and geo-referenced using six-month mining maps. After August 2013, the University team collected final updated digital files from operators employing longwall mining techniques, and traced the updated extents for the remaining room-and-pillar mines from six-month mining maps (Table II-1).

II.C.2 – Surface features

Property parcels, structures, water sources, water bodies, streams and miscellaneous utilities are considered surface features. As with the mining extents, most of the surface features were received digitally from mining companies and compared against six-month mining maps. The University created any missing layers from the six-month mining maps, with the exception of stream and utility layers; these features were obtained from the base data.

Additional information was calculated for the structure, water sources, and water bodies features. These data were added to the feature's attribute table, Esri's term for the tabular data associated with an ArcGIS file. The following fields were added:

- <u>Distance to Mining</u>: the straight line distance between each feature within the layer and the edge of mining; calculated for each mining method (Room-and-Pillar, Longwall, and Pillar Recovery) using ArcMap's Near tool.
- <u>Overburden underneath each feature</u>: the amount of rock between each feature and mining; calculated using the overburden raster values.
- <u>Proximity to Buffer</u>: classification of each feature as inside or outside of that layer's applicable buffer; calculated using ArcMap's Select By Location tool and the University-created buffers (see section II.C.4)
- <u>Topographic Category</u>: whether each feature within a layer is located on a hilltop, a slope, or a valley bottom; calculated using ArcMap's Select By Location tool and University-created topographic categories layer (see section II.C.7)

Lastly, data from BUMIS was also merged with the feature’s attribute data. If the feature was impacted and tracked in BUMIS, then the attribute table includes the following information regarding the status of the impact at PADEP:

- BUMIS Problem I.D.
- Due to Mining? (Yes/No)
- Date Entered in BUMIS
- Date Problem Occurred
- Interim Resolution Date
- Interim Resolution Timespan
- Final Resolution (Yes/No)
- Final Resolution Description
- Final Resolution Date
- Final Resolution Timespan

II.C.3 – Overburden

Overburden is defined as the amount of overlying rock between mining and the surface. Calculating overburden was not an automatic process as the data that the University obtained with respect to coal or surface elevation varied by mine. Depending on the data that were available, the University utilized one of two main protocols to generate overburden layers for each mine.

When overburden data was available, it was largely untouched by the University. Overburden rasters were given directly to the University for some mines. For other mines, overburden rasters were extrapolated from overburden contours using the ArcGIS “Topo to Raster” tool.

When coal and surface elevation contours were the only data layers available, a raster was extrapolated for both using ArcGIS's Topo to Raster tool with 30-m per pixel resolution. The surface elevation raster value was then subtracted from the coal elevation raster value using the ArcGIS Minus tool to get an accurate overburden layer. If a surface elevation contour was not available for a particular mine, the LiDAR DEMs collected for that mine were used as the elevation values.

Because of the varying information collected on overburden, no protocol was put into effect to standardize overburden resolution. The methods employed favored the lowest resolution, leading to a range of resolutions, with the lowest being 30-ft (9-m) per pixel, the highest being 119-ft (36-m) per pixel, and the most frequent value being 98-ft (30-m) per pixel. Metric overburden values were converted to feet.

II.C.4 – Buffers

The University created three buffers to model existing regulatory boundaries. All buffers were created using the combined mining extents for all employed mining methods. For example, if a mine employed both room-and-pillar and longwall mining methods, then the buffer was based on the combined mining extents.

1. A 1,000-ft uniform distance outer buffer was created for each mine to serve as the boundary inside which all features were tracked. Any feature that fell within 1,000-ft of mining was identified and, if possible, linked to the BUMIS inventory.

2. A 200-ft uniform distance outer buffer was applied to all mine maps in the study. This buffer was used as a boundary for the structure and stream feature inventories.

3. The Rebuttable Presumption Zone (RPZ), a variable outer buffer, was generated using overburden raster values (see Section I.B.3 for details on RPZ and Act 54). A buffer was created for each overburden pixel that intersected the mining extent layer using the following equation:

$$RPZ = O * tan(35^{\circ} * \frac{\Pi}{180})$$

(Where O = the overburden pixel value and RPZ = the buffer distance)

All pixel-buffer boundaries were dissolved, resulting in one RPZ buffer. This buffer was used as a boundary for water sources and water bodies feature inventory.

II.C.5 – Stream Observations

The University was tasked with assessing pre-mining and post-mining Total Biological Scores for five stream sites with flow loss impacts, five sites with pooling impacts, and five sites that were impacted during the 3rd Act 54 assessment. To supplement the data supplied by PADEP for this task, the University assessed the biological health of 19 stream sites. During each stream survey, a DeLorme Earthmate GPS PN-20 handheld unit was used to record the start and end points of the University's sampling locations. The start and end points of any dry stream segments that were observed were also recorded. Data were recorded with an accuracy of at least ±10 meters, with an emphasis on more accurate readings. All coordinates were converted from decimal degree minutes to decimal degrees and manually entered into the Act54GIS.

II.C.6 – Stream Bio-monitoring Stations

PADEP's regulation of mining effects on streams requires that mine operators sample stream macroinvertebrate communities prior to and after mining on all undermined streams. The mine operators or their consultants establish geo-referenced bio-monitoring stations for this purpose. PADEP provided the University with the coordinates of stream bio-monitoring stations established by or on behalf of the mine operators. The records supplied by PADEP were incomplete. The University discovered the coordinates of additional bio-monitoring stations in the paper files at CDMO and added these to the spatial database. All or very close to all bio-monitoring stations reported to PADEP were eventually included in the Act54GIS.

II.C.7 – Topography

Two data layers were created using the LiDAR DEMs from the PASDA website. The first, a hillshade layer, was created with the ArcGIS Hillshade tool and used for visualization purposes. Hillshade layers, when overlaid on an elevation raster, mimic shadows as they would naturally occur, given a particular sun angle. This is useful for distinguishing hilltops from valley bottom with the naked eye. The second layer is the hilltop, slope, and valley bottom or "HSV" data layer which classifies any given elevation value into these three topographic categories based on its surroundings. These data were used to determine if features in particular topographic categories were more or less impacted by underground mining.

To classify areas as sloped, the ArcGIS "Slope" tool was used on all DEMs. The tool was set to highlight any pixel in the DEM that had a greater than 2 percent rise and classify it as "slope". The result was a new raster that effectively separated sloped areas from the flat hilltops and valley bottoms.

To differentiate between hilltops and valley bottoms, the DEM within the 1,000-ft buffer for each mine was sectioned off into 750-m by 750-m blocks, for which the average elevation was calculated. This was done using the ArcGIS Block Statistics tool. Every pixel value that was not categorized as "slope" was then compared to the average of the block in which it was located. If its elevation was greater than the average, it was categorized as hilltop, and if it was less than or equal to the average, it was categorized as valley bottom. These pixel values were then merged into a single shapefile. Pixel values equal to the average were classified as valley bottom due to the topographic characteristics of the focal area that tends toward wide, flat valley bottoms, and sloped, rounded hills. The resulting product was visually checked and corrected for discrepancies.

II.C.8 – Wetlands

To identify the location of wetlands in areas of predicted subsidence associated with longwall mines, data was collected from two sources – the paper files at CDMO and digital files from Alpha Natural Resources, Inc. From the CDMO paper files, 72 maps were geo-referenced with an average of 4.61 control points and 1.73-m RMSE. These wetland maps included few features for geo-referencing, which introduced significant challenges in data creation. For some images, the mining extents were used as the anchor points for geo-referencing. In cases where images did not show significant features from the mining extents, the images were referenced to index maps, which were also geo-referenced using the mining extents. Once all maps were geo-referenced, pre-mining and post-mining wetland areas were traced. In some cases, wetlands were marked by the mining operators as points rather than explicitly delineated in geographic space. The points typically represented test pit locations within the wetlands. In those cases, the exact area of the wetland could not be traced and the test pit location was marked. Data from Alpha Natural Resources, Inc. was received in an Esri ArcGIS format and was incorporated directly into the University's spatial database.

<u>II.D – University GIS Database Structure</u>

For the 4th assessment period, the University team created a hierarchical organization system that employed both digital folders and ArcGIS personal geodatabases. Each mine was given its own parent folder, within which all of the data for that mine alone was stored. This led to a less centralized, but more accessible, data organization. Within the parent folder, each mine was required to have:

- A "personal" geodatabase containing all of the digital ArcGIS-format data layers collected or produced.
    - The ArcGIS personal geodatabase format is the same as that for Microsoft's Access database files (.mdb), allowing us to access the tabular information within the ArcGIS format layers in the more user-friendly setting of Microsoft Access.
- A folder of geo-referenced six-month mining maps
- A "Topography" folder containing rasters relating to elevation
- Original CAD files, if the data was received in Autodesk format
- A map file (.mxd) for ArcMap versions 10.0 and 10.1

While each mine had unique information, all were required to have certain features for analysis. Table II-2 shows the full list of required features.

Table II-2. Required layers, their locations, and origins.

Feature	Type	Location	Origin
Overburden Layer	Raster	Geodatabase	Collected
Mining Extent Layer(s)	Feature Class	Geodatabase	Collected
Structure Layer	Feature Class	Geodatabase	Collected
Water Sources Layer	Feature Class	Geodatabase	Collected
Water Bodies Layer	Feature Class	Geodatabase	Collected
Properties Layer	Feature Class	Geodatabase	Collected
Buffer Layers	Feature Class	Geodatabase	Created
LiDAR DEM	Raster	Topography Folder	Collected
Topographic Categories Layer	Shapefile	Topography Folder	Created
Geo-referenced Six-Month Mining Maps	Geo-TIF Images	Geo-referenced Maps Folder	Collected / Geo-referenced

In addition, each mine was given a two-letter file code that was applied to all of its associated files. For instance, for the first mine in an alphabetical sorting, 4 West Mine, the structures layer is called Fw_structures, and the overburden raster is called Fw_OBraster, because the code for 4 West is "Fw." Refer to Table II-3 for a full list of abbreviations.

Table II-3. Mine file code key.

Mine Name	Mine File Code
4 West	Fw
Agustus	Ag
Bailey	By
Barrett Deep	Br
Beaver Valley	Bv
Blacksville 2	Bk
BMX	Bx
Cherry Tree	Ch
Clementine 1	Cl
Crawdad	Cd
Cumberland	Cu
Darmac 2	Dm
Dora 8	D8
Dutch Run	Dr
Emerald	Em
Enlow Fork	Ef
Geronimo	Gr
Gillhouser Run	Gh
Harmony	Hy

Mine Name	Mine File Code
Heilwood	Hw
Horning Deep	Hr
Kimberly Run	Kr
Knob Creek	Kc
Little Toby	Lt
Logansport	Lg
Long Run	Lr
Lowry Deep	Ly
Madison	Ma
Miller Deep	Ml
Eighty Four	Eg
Nolo	No
Ondo	On
Prime 1	Pr
Penfield	Pf
Quecreek 1	Qc
Rossmoyne 1	Rm
Roytown	Rt
Sarah	Sa
Starford	St
Titus Deep	Tt
TJS 5	T5
TJS 6	T6
Toms Run	Tr
Tracy Lynne	Tl
Twin Rocks	Tw
Windber 78	W7

II.E – Summary

To fulfill the tasks outlined by PADEP, the University constructed the Act 54 Geographic Information System (Act54GIS). Data collection occurred in two main efforts: one before and one after the official end date of the 4th assessment period in August of 2013. The overlap between the University's budgeted data collection time frame and the Act 54 assessment period presented some challenges for data collection. First, the University spent substantial time continually updating the Act54GIS as new data became available. Second, PADEP's staggered schedule for submission of six-month mining maps resulted in some data being unavailable to the University for analysis.

The Act54GIS was populated with base data and data on mining extents and undermined features. The mining data came from three sources: the six-month mining maps, mine operators, and BUMIS. Though the data were received in various formats, all spatial data were converted to Esri ArcGIS files with a NAD 1983 UTM 17N map projection. Ultimately, the University generated a specific suite of data layers for all mines. These features were created using six-month mining maps where they could not be collected directly.

The organization of the University database focused on applying a standard template to each of the individual mines to facilitate data acquisition and identification for users. When looking into a mine's parent folder, the same organization and data layer types are present as those in another mine's parent folder.

References

Conte, D. and L. Moses (2005) "The Effects of Subsidence Resulting from Underground Bituminous Coal Mining on Surface Structures and Features and on Water Resources: Second Act 54 Five-Year Report," California University of Pennsylvania, http://www.portal.state.pa.us/portal/server.pt/community/act_54/20876

Iannacchione, A. S.J. Tonsor, M. Witkowski, J. Benner, A. Hale, and M. Shendge (2011) "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