SECTION X: Discussion, Summary, and Conclusions

X.A – Discussion

The previous nine sections described in-detail the various important aspects of underground bituminous coal mining and its impact on structures, water supplies, land, streams, and wetlands. Much of the report was dedicated to explaining how impacts occur and documenting how mining operations complied with the legislative mandates set forth in ACT 54. This was summarized by examining the compliance actions by the numbers and kinds of reported effects still unresolved from the 2nd assessment period and that occurred during the 3rd. This analysis, by its nature, examined how effectively the mining operations and PA DEP contributed to compliance actions. The key questions answered were: what impacts have occurred, how have these impacts been resolved, and how long has it taken to resolve them?

The protocols for assessing structures, water supplies and land reported effects are relatively robust and have remained constant over the 3rd assessment period. Protocols for assessing streams and wetlands changed significantly (Section VIII and IX). For this reason, the discussion on compliance assessment focuses on structures, water supplies, and land reported effects.

X.A.1 - Structure, Water Supplies, and Land Reported Effects

This is what was reported regarding structures, water supplies and land reported effects:

- Of the 275 reported effects that occurred during the 2nd assessment period, 212 were resolved and the remaining 63 had Interim Resolution in place at the end of the 3rd assessment period.
- 1,247 reported effects occurred during the 3rd assessment period. Thirty-nine were found at closed mines, the other 1,208 occurred at 36 of the 50 active mines studied in this report. Fourteen mines did not have a reported effect.

X.A.1.a - 2nd Assessment Period

The 275 reported effects unresolved at the end of the 2nd assessment were distributed over 15 active and 10 closed mining operations (Figure X-1). The active mines accounted for 143 reported effects while the closed mines had 132 (Appendix B2). Impacts to water supplies accounted for the most reported effects with 244 (88.7-pct of the total), followed by structures with 26 (9.5-pct) and land with 5 (1.8-pct). Resolutions occurred in 212 cases with 93.4-pct or 198 classified as Company Liable. Only 14 Company Not Liable cases occurred. Lastly, 63 Interim Resolutions from the 2nd assessment period remained at the end of the 3rd assessment period.

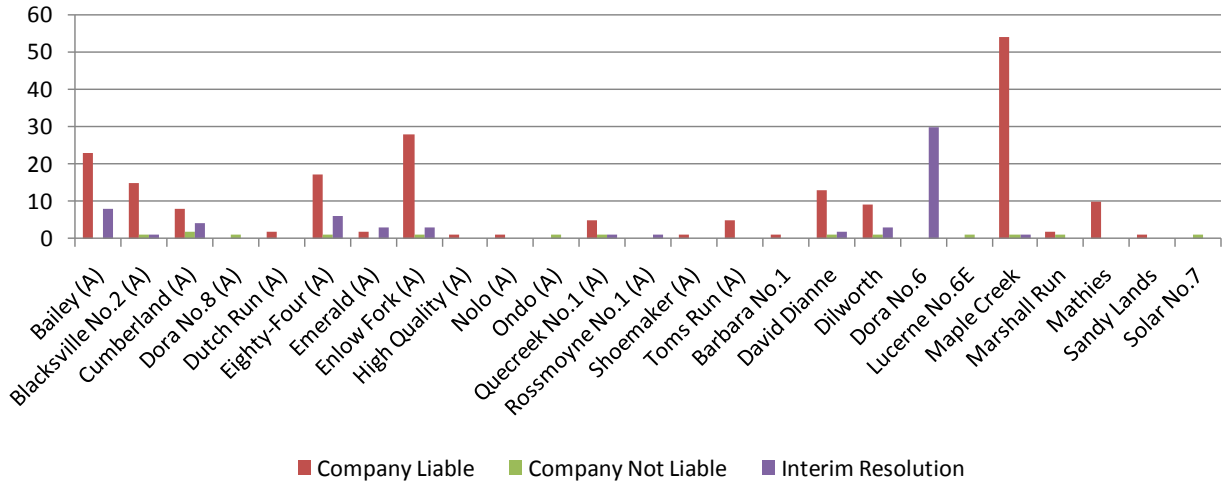

Figure X-1 – Number of Company Liable, Company Not Liable, and Interim Resolutions for the 25 mines where reported effects occurred but were not resolved in the 2nd assessment period. Note: The (A) indicates active mines.

A projection of reported effects liability was made by examining the resolution trends of the 2nd assessment cases resolved during the 3rd (Table X-1). Projecting past trends forward yielded 257 Company Liable reported affects and 18 Company Not Liable.

Table X-1 – Projected resolution status of all reported effects from the 2nd assessment period.

	Reported Effect (2nd)*			
Resolution	**Actual**	**Actual Percent**	**Projected**	**Projected Percent**
Company Liable	198	72.0	257	93.4
Company Not Liable	14	5.1	18	6.6
Interim Resolution	63	22.9	0	0

* - 2nd refers to occurring in the 2nd assessment period.

The average days to achieve one of the four major categories of resolutions for all 275 reported effect was 1,711 with a standard deviation of 889 (Table X-2). The median number of days was 1,797. The median value is used as a measure of location when a distribution, such as this one, is skewed. The median is a useful tool to reduce the importance attached to outliers, i.e. in this data there were a small percent of cases still litigation that tended to skew the average values. Reported effects with a final resolution of Company Liable had an average of 1,426 days and a median of 1,435. Company Not Liable cases had less days with an average of 945 and a median of 412. Interim resolutions at the end of the 3rd assessment period have the highest days with an average of 2,777 and a median of 1,867. Clearly, these 63 cases represented some of the most difficult to resolve. Thirty of these cases were associated with the Dora No.6 Mine flooding incident discussed in Section IV.L of the Conte and Moses report (2005). The Dora No.6 Mine was a room-and-pillar mine in the Lower Kittanning Coalbed where 39 water supplies had sulfate levels in the range of 250-mg/l, indicating the supplies were influenced by mining operations. Thirty of the 39 were found in BUMIS where the Interim Resolution reported "Treatment system installed by DEP-BAMR (Bureau of Abandoned Mine Reclamation)." Since these impacts are being mitigated by a state agency, they should not be used to assess industry

compliance. A revised Interim Resolution, minus the Dora No.6 cases, at the end of the 3rd assessment period showed an average of 2,477 days and a median of 2,545 (Table X-2).

Table X-2 - Summary of days to achieve various resolutions of reported effects occurring during the 3rd assessment period at active and inactive mines.

Reported Effects (2nd)	Average, days	Standard Deviation, days	Median, days	Min., days	Max., days	Number
All Active and Closed Mines	1,711	889	1,797	63	3,572	275
Company Liable	1,426	698	1,435	199	3,271	198
Company Not Liable	945	949	412	63	2,684	14
Interim Resolution	2,777	457	3,108	1,867	3,572	63
Interim Resolution without Dora No.6	2,477	456	2,545	1,867	3,572	33
Outstanding	-	-	-	-	-	0

* - 2nd refers to occurring in the 2nd assessment period.

All of the 63 Interim Resolutions were classified as water supply loses. Thirteen Interim Resolutions categories are shown in Table X-3. Typically the resolution path to a water supply reported effect was multi-step. Temporary water was supplied and then the logistics of providing a long term solutions was investigated and agreed upon by the landowner. Often a period of monitoring was required to assess when the impact had stabilized its influence on the water supply. In addition, this process often required O&M determinations which were time consuming. It is difficult to know which step or process took the most time because a reported effect may have multiple Interim Resolutions. Therefore, the Interim Resolution found in BUMIS will depend, in part, on the step it currently occupied when the data base was queried.

Table X-3 – Average and median values of days for 63 water supply Interim Resolutions sorted by resolution type.

Interim Resolution (2nd assessment period)	Average, Multiple Cases, days	Median, days	One Case, days	Number
Agreement Pending	-	-	1,965	1
Implementing Water Supply Replacement Plan	2,528	2,528	-	2
In Litigation	2,220	2,220	-	2
In Negotiation	2,364	2,364	-	2
O&M Review	2,828	2,976	-	5
O&M Bond Requested	2,543	2,861	-	3
Pending Owner Approval	2,849	2,849	-	5
Public Water/O&M Pending	1,996	1,979	-	3
Temporary Water/Awaiting Public Water	2,412	2,597	-	3
Temporary Water	-	-	1,867	1
Well, Spring/O&M Pending	2,172	2,108	-	5
Water Supply Replacement Plan Under Development	-	-	3,572	1
Treatment system installed by DEP-BAMR	3,108	3,108	-	30

X.A.1.b - 3rd Assessment Period

The 1,247 reported effects were distributed over 36 of the active mining operations (Active Mines -1,208 reported effects) while 16 closed mines accounted for another 39 (Appendix B1).

For the 3rd assessment period, water supplies accounted for the most reported effects with 683 (54.8-pct of the total), followed by structures with 456 (36.6-pct) and land with 108 (8.6-pct). Resolutions occurred in 896 cases with 621 being classified as Company Liable and 275 as Company Not Liable (Table X-4). Lastly, there were 262 Interim resolutions and 89 Outstanding Resolutions at the end of the 3rd assessment period. The projection of mining operations liability towards reported effects was again made using trends established above for the 2nd assessment cases resolved during the 3rd (Table X-1). Projecting past trends forward yielded 949 Company Liable reported affects and 298 Company Not Liable.

Table X-4 – Number of actual and projected resolution status for all reported effects from the 3rd assessment period.

	Reported Effect			
Resolution (3rd)*	**Actual**	**Actual Percent**	**Projected**	**Projected Percent****
Company Liable	621	49.8	949	93.4
Company Not Liable	275	22.1	298	6.6
Interim Resolution	262	21.0	0	0
Outstanding Resolution	89	7.1	0	0

* - 3rd refers to occurring in the 3rd assessment period
** - from 2nd assessment projections

The average days to achieve one of the major categories of resolutions and sorted by impact class are shown in Table X-5. Reported effects with a final resolution of Company Liable and Company Not Liable have relatively low median values ranging from 145 to 348 days. Unresolved cases, i.e. Interim and Outstanding Resolutions at the end of the 3rd assessment period, have relatively high median values ranging from 249 to 593 days.

Table X-5 - Summary of days to achieve various resolutions of reported effects occurring during the 3rd assessment period at active and inactive mines sorted by impact class.

Resolution Category	**Impact Class**	**Average, days**	**Standard Deviation, days**	**Median, days**	**Min., days**	**Max., days**	**Number**
All Active and Closed Mines		293	336	168	0	1,662	1,247
Company Liable	Structures	246	281	151	0	1,253	301
	Water Supplies	293	348	146	0	1,615	270
	Land	249	279	158	0	1,253	50
Company Not Liable	Structures	153	191	84	0	851	59
	Water Supplies	112	145	64	0	930	179
	Land	147	209	56	0	1,048	37
Interim Resolution	Structures	348	278	266	21	1,054	72
	Water Supplies	535	403	382	8	1,662	174
	Land	371	287	249	85	901	16
Outstanding	Structures	490	387	484	33	1,492	24
	Water Supplies	451	460	288	1	1,662	60
	Land	530	354	593	89	933	5

The 12 most used final resolutions used during the 3rd assessment period are shown in Table X-6. Company Purchase Property had the least amount of days to resolution, averaging 66 days with a median of two. This indicates that the decision to buy, on the company's part, and sell, on the owner's part, was made relatively soon after a reported effect was filed. The PA DEP was able

to establish Not Due to Underground Mining (Company Not Liable) in an average of 126 days with a median of 66. Conversely, Agreements (Company Liable) between the company, land owners, and the PA DEP averaged 323 days with a median of 249. The final resolutions that took the most days were Compensation and Public Water Supply averaging 395 and 463 respectively with median values of 373 and 448.

Table X-6 - Summary of days to achieve various resolutions of reported effects occurring during the 3rd assessment period at active and inactive mines sorted by impact class.

Resolution Category	Average, days	Standard Deviation, days	Median, days	Min., days	Max., days	Number
Not Due to Underground Mining	126	163	66	0	1,048	237
Agreement	323	302	249	0	1,253	192
Company Purchased Property	66	148	2	0	934	132
Compensation	395	263	373	0	1,219	78
Repair & Resolved	276	314	154	0	1,222	76
Public Water Supply (Wells/Spring)	251	322	94	0	1,197	65
Undisclosed & Unspecified	343	396	133	0	1,221	36
Water Supply Recovered	168	263	92	0	1,116	19
Public Water Supply (Public)	463	448	343	0	1,490	18
Withdrawn	164	154	167	0	535	14
No Actual Problem	70	92	18	0	223	10
No Liability	158	315	45	0	930	8

Lastly, the skewed nature of the data was evaluated by examining the relative distribution in the form of percentiles for the nine most common final resolution categories (Table X-6). A percentile is the value of a variable below which a certain percent of observations fall. For example, for the nine final resolution categories shown in Figure X-2, the 80th percentile is the value below which 80-pct of the observations are found. This value was approximately 600. So for the most common resolutions 80-pct of all cases were solved in the first 600 days after the date of occurrence. During this timeframe, PA DEP made sure the case was valid, the impact was stabilized and an amicable resolution between the coal operation and property owners was reached. It also highlights reason why other 20-pct of the cases were taking longer.

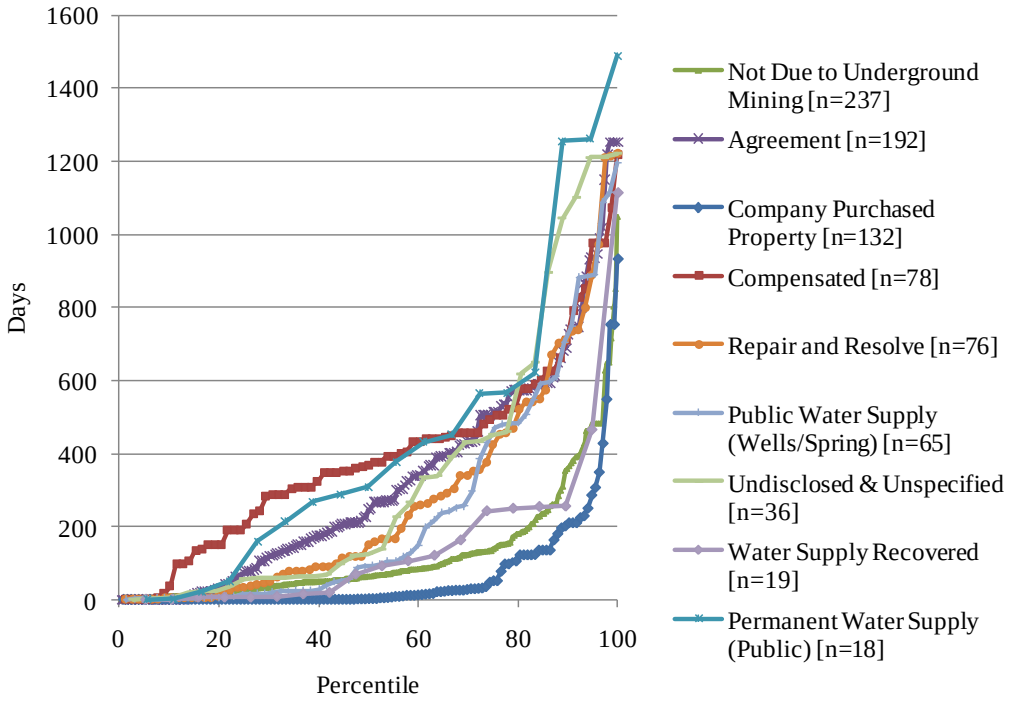

Figure X-2 - Distribution of days to final resolution for nine of the most common categories.

X.A.2 – Comparison of the 3rd Assessment with the 2nd

In almost every category, more mining and more impacts were measured during the 3rd assessment in comparison to the 2nd. For example, 34,051 acres and 3,033 properties were undermined in the 2nd assessment compared to 38,256 acres and 3,587 properties in the 3rd. That is a 12-pct increase in acres and an 18-pct increase in properties. Room-and-pillar mining with and without pillar recovery more than doubled, increasing from 6,544 to 13,649 acres. The number of structures inventoried increased from 3,656 to 3,787. Less longwall mining occurred, dropping by 11-pct from 27,507 acres to 24,607. The total number of water suppliers undermined was not mentioned in the 2nd assessment report so a comparison could not be made.

Reported effects related to structures, water supplies, and land, increased 14-pct from 1,090 to 1,247. Structure reported effects increased 31-pct from 348 to 456, water supplies remained virtually the same, and land reported effects increase 86–pct from 58 to 108. The University could not determine all the factors that might have influenced these increases, but mining in more populated areas is one possible reason. Another could be better record keeping practices.

The length of streams undermined were virtually the same over the two assessment periods (113.7 miles in the 3rd and 115.5 miles in the 2nd). However, the length of streams over longwall panels dropped by 10-pct (97 miles in the 2nd and 88 miles in the 3rd). During this same period the number of stream investigation reports more than doubled, rising from 22 to 55. These trends clearly indicate a greater effort by companies and the PA DEP to more accurately characterize the flow and the biological health of streams. The total acres of wetlands undermined increased from 77.8 in the 2nd assessment to 93.9 in 3rd (Figure X-3). As stated in

the Section IX, these totals will likely increase in magnitude as more efforts are made by the mining operations to adequately characterize wetlands.

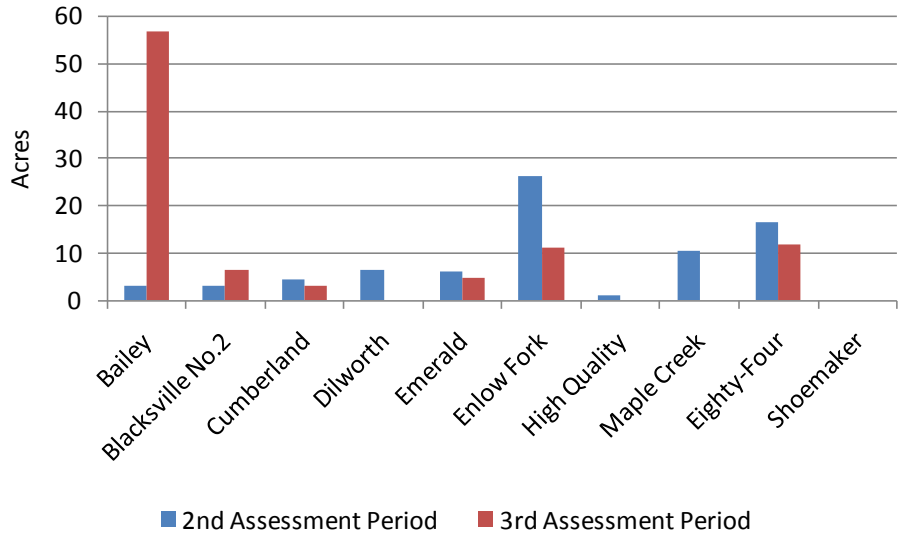

Figure X-3 - Acres of wetlands for the 2nd and 3rd Assessment periods sorted by mine.

X.B – Summary

The University was contracted in 2009 to conduct the 3rd assessment, covering the period from August 21, 2003 to August 20, 2008 (*3rd assessment period*). The following are summary statistic developed from each of the previous nine sections. For a more detailed summary, see the Summary Points at the end of each section.

X.B.1 - Inventory of Mining Related Activity

- 50 underground bituminous mines operated in Pennsylvania
  - 36 room-and-pillar mines
  - 8 longwall mines
  - 6 room-and-pillar mines with pillar recovery
- 38,256 acres of surface land undermined
  - By mine type
    - 24,607 acres of land (64.3-pct of total) by longwall mines
    - 11, 552 acres (30.2-pct) by room-and-pillar mines
    - 2,097 acres (5.5-pct) by pillar recovery mines
  - By mining method
    - 20,375 acres (53.3-pct of total) from the longwall
    - 17,605 acres (46.0-pct) from room-and-pillar (also includes main, gate road, and bleeder entries at longwall mines)
    - 276 acres (0.7-pct) from the pillar recovery
- 3,587 surface properties undermined
  - 1,738 properties (48.5-pct) from room-and-pillar mines
  - 1,572 properties (43.8-pct) from longwall mines

  - 277 properties (7.7-pct) for pillar recovery mines
- 6 coalbeds mined
  - Pittsburgh
    - Thickest and most persistent
    - 8 longwall mines in Greene and Washington Counties
    - 1 room-and-pillar mine (Ridge) in Armstrong County
  - Sewickley
    - 5 room-and-pillar with pillar recovery mines in Greene County
  - Upper and Lower Freeport and Kittanning
    - 36 room-and-pillar mines
    - 8 different counties (Armstrong, Beaver, Cambria, Clearfield, Elk, Indiana, Jefferson, and Somerset)

X.B.2 – Inventory of Structures Impacts

- 3,735 inventoried structures undermined
- 31 different feature types recognized
  - 1,502 were dwellings, 593 garages, 357 barns, 264 sheds, 230 trailers, 169 outbuildings, 95 buildings, 35 silos, 32 pools, and 21 septic systems
  - Less frequent but yet notable structural features included cemeteries, towers, churches, schools, bridges, and dams
- 1,856 structures from longwall mines,
  - 427 reported effects from longwall mines,
  - 352 final resolution taking an average of 238 days,
  - 63 cases with Interim Resolution
  - 12 had no interim or final resolution at the end of the 3rd assessment period with an average length of time of 689 days
- 1,879 structures from room-and-pillar mines (with and without pillar recovery)
  - 29 reported effects
  - 7 final resolution of Company Not Liable with an average days to resolution of 107
  - 18 interim resolution
  - 3 outstanding
- Mitigation measures practiced
  - Banding, bracing, bridging, trenching, and cribbing

X.B.3 – Inventory of Water Supplies Impacts

- 2,789 wells, springs, and ponds were undermined
  - 1,212 from room-and-pillar mines
  - 1,502 from longwall mines
  - 75 from pillar recovery mines
- 683 reported effects were associated with the undermined water supplies
  - 238 from room-and-pillar mines
  - 20 from room-and-pillar with pillar recovery mines
  - 397 from longwall mines

  - 28 from post-closure mines
  - 267 classified as Company Liable
  - 182 classified as Company Not Liable
  - 234 classified as unresolved where an Interim Resolution or Outstanding resolution existed at the end of the 3rd assessment period
  - 212 of the 244 unresolved cases from the 2nd assessment were resolved. The remaining 32 were still unresolved as of August 20, 2008
  - 74-pct of reported effects were associated with water supply diminution
  - 66-pct of the reported effects were resolved as of the end of the assessment period
  - 34-pct of cases were still awaiting a final resolution
  - 57-pct, of resolved cases were Company Liable
- The number of days associated with water supply cases
  - 143 days required for a final resolution for room-and-pillar mines
  - 115 days for room-and-pillar with pillar recovery mines
  - 274 days for longwall mines
  - 259 days for closed mines
  - 12 cases exceeding three years without a final resolution

X.B.4 – Inventory of Land Impacts

- 108 land reported effects
  - 87 had final resolutions, taking an average of 206 days
    - 57-pct, or 50 assigned as Company Liable
    - 43-pct, or 37 assigned as Company Not Liable
  - 13 active and closed mines
    - 9 longwall mines with 88.9-pct of reported effects
    - 4 room-and-pillar mines with 11.1-pct of reported effects
  - 21 did not have a final resolution as of August 20, 2008
    - 18 with an Interim Resolution
    - 3 with Outstanding reported effect
- 5 additional land reported effects remained unresolved from 2nd assessment period

X.B.5 – Inventory of Stream Impacts

- 113.7 miles of streams undermined
  - 87.9 miles (77.3-pct of total) for longwall mines
  - 21.2 miles (18.6-pct) for room-and-pillar mines
  - 4.6 miles (4.1-pct) for room-and-pillar mines with pillar recover
- 55 stream investigation were made by the PA DEP
  - Twenty of these investigations were resolved during the 3rd assessment period
  - For every two miles of stream undermined, there was an investigation of stream flow diminution or pooling (average)
  - 688 day for a final resolution (average)
- Approximately half of the streams surveyed for macroinvertebrate diversity and composition had TBS below a PA DEP recommended indicating a negative influence on the TBS.

    - Various land use practices were the likely source of the negative influence with underground mining as the most likely but other practices such as agriculture were also present
    - It is not possible to compare these values with pre-mining conditions since no TBS scores are available, therefore, ascertaining the effect of mining per se was not possible
- 6 stream surveys at the Bailey Mine could be statistically compared to that mine's control stream value
    - Average post-mining TBS was highly significantly below the control stream score (i.e. more than two standard deviation of the mean below the control TBS), indicating the stream had not, on the average, attained recovery
    - 2 streams were within the 12-pct difference of the control stream indicating recovery or maintenance of pre-mining biological health and had therefore substantially recovered
    - 4 streams were far from attaining recovery

X.B.6 – Inventory of Wetlands Impacts

- 93.9 acres of wetland were measured
- 85 wetlands identified
- These numbers were developed, for the most part prior to the new TGD and therefore will undoubtedly increase as more detailed wetland assessments occur in the future

X.B.7 – Inventory of Impacts to I79

- 9 longwall panels were extracted under I79
- Observed features
    - Tension type distress features, i.e. longitudinal and transverse cracking, began to impact the highway immediately prior to and during the undermining of the highway by the longwall face
    - Compression type distress features, i.e. blowups or heaving, were more common after the longwall face had passed underneath the highway
- Some of the effects were transitory – associated with the passage of the dynamic subsidence wave
    - Successfully managed through traffic controls and temporary support measures
- Some of the impacts were permanent
    - Addressed through routine road maintenance such as milling, patching, repaving, and straightening guardrails
- Preemptive action was taken to prevent a potential catastrophic differential subsidence event of the bridges carrying I79 over Mooney (Tower) Road
- Over 19 million dollars was spent by PennDOT to monitor and rehabilitate sections of I79 impacted by longwall mining

X.C – Conclusions

Underground bituminous coal mining is a large and significant industry within the Commonwealth of Pennsylvania with a legacy of environmental consequence. For example, every day 13.5 acres of land are undermined by longwall mining. Laws and regulations have been promulgated requiring companies involved in this industry to remedy mining damage caused to homes, businesses, and land, replace impaired water supplies, and repair impacts to streams and wetlands. The regulations and technical standards set by the PA DEP have been put in place to assure that coal operations comply with ACT 54 of the Bituminous Mine Subsidence & Land Conservation Act and other related legislation. These regulations and standards require operations to address impacts when a mining permit is submitted and as permits are modified and extended. One of the special provisions of ACT 54 is the requirement by the PA DEP to produce an assessment of the surface impacts of mining every five years, hence this report.

Underground bituminous coal mines vary in size and in their manner of operation. Longwall mines are large, averaging 3,505-acres of surface land in size and mining at a rate of a little more than 58-acres/month. Several of these longwall operations were among the most productive underground coal mines in the US. The average longwall overburden was 687-ft. The High Quality Mine is classified as shallow (338-ft) and the Blacksville No.2 as deep (887-ft). The other six longwalls in this study are classified as average overburden. This data implied that a high percentage of impacts were expected with the extensive areas mined by longwall panels.

The average room-and-pillar mine undermined 321-acres of surface land and mined at a rate of a little more than 5-acres/month. The average overburden for these mines was 276-ft. Based on their overall overburden characteristics, 26 mines were classified as average, five as shallow, and five as deep. The average size of room-and-pillar mines with pillar recovery was 46-acres, representing about 15-pct of the total area mined for these six mines. The individual pillar recovery sections were relatively small, typically less than 1000-ft in length. These areas were mainly contained within production panels with overburden averaging 378-ft. Unlike longwall mines, these room-and-pillar mines generally didn't have subsidence impacts, especially since the pillar recovery method accounted for such a small portion of the total.

X.C.1 - How are Structures Impacted?

Twenty-three percent of the 3,735 structures located over longwall panels had reported effects. The topographic condition of the structure, i.e. hill top, hillside, or valley bottom, didn't have a significant influence on reported effects. Conversely, only 1.5-pct of the structures over room-and-pillar mines had reported effects. This was largely due to the pervasive use of "safe" pillar designs that minimizes unplanned mine subsidence.

However, pillar failure was the overwhelming cause of the 21 reported effects cases listed in BUMIS for room-and-pillar mines. The University analyzed the stability characteristics of pillars systems and found them to be adequate. Minor changes in the assumed conditions can significantly increase the risk for unstable conditions in the pillars and adjacent roof and floor strata. For example, floor heave on a wide scale is capable of producing a local subsidence basin.

The most notable structure impact was the Ryerson Station Dam in Greene County. The dam was never undermined. DCNR and the mine operator had an agreement to leave a block of solid coal underneath the dam. The PA DEP investigated the impacts and, in 2010, concluded that damage was caused by longwall mining at the Bailey Mine.

X.C.2 - How are Water Supplies Impacted?

Approximately one-quarter (683) of the 2,789 water supplies undermined had reported effects. Longwall mining accounted for 58.1-pct and room-and-pillar mines, with and without pillar recovery, account for the remaining 41.9-pct. With water supplies, impacts typically can be attributed to the formation of the subsidence basin but they can also occur in room-and-pillar mines, especially when these mines are relatively shallow. The topographic character of the surface did have an influence. Approximately 80-pct of water supplies remained viable after being undermined for all settings except for shallow hilltops where the impact rate was 75-pct and deep valley bottoms with 100-pct viability.

The relationship between the structures distance from a longwall panel and the reported effects provided insight as to what resolution outcome can be expected as the distance from mining increases. Approximately 77-pct of company liable impacts occurred within the 35-deg projection angle (RPZ). Nearly 86-pct of cases outside of the RPZ were determined as Company Not Liable. The final resolution of Repaired and Pre-Mining agreements occurred most often when structures were located very near to a longwall panel (< 35-deg). Conversely, when the projection angle was large (> 35-deg), companies more often resorted to purchasing properties as a final resolution.

For longwall mines the water supplies located over the mid or quarter-panel regions of the panel were 22 and 21-pct likely to be impacted, respectively. When located over the gate roads or outside of mining the likelihood of impact decreased to 18 and 17-pct, respectively. There was no data that would suggest that the shallow aquifer systems above deep longwall panels were being lost to mine inflow. Lastly, headwater springs were no more likely to be impaired by subsidence than any of the other water supplies undermined by longwall mining. However, any impairment to springs in headwater areas can have a significant impact on the biological health of the streams they are contributing to.

X.C.3 - How are Lands Impacted?

The 3,735 properties produced 108 reported effects for a rate of occurrence averaging less than 3-pct. Properties over longwall mines had a reported effects rate of 6.3-pct. Room-and-pillar mines, with and without pillar recovery, had close to zero (0.02) land reported effects. Therefore, land reported effects occurred mainly at longwall mines. The University identified 76 land reported effects that were classified into five categories: *mass wasting, tension cracks, settlements, compression ruptures, and unknown*.

- 37, or 48.7-pct, cases with tension cracks varying in scale and impact,

- 20, or 26.3-pct, cases with mass wasting ranging from large landslides hundreds of feet across (estimated from PA DEP photographs) to small mass soil movements that produced hump, rolls, and slips in the surface,
- 12, or 1.58–pct, settlement cases often disrupting drainage patterns resulting in ponding of water in fields, pastures, and residential lawns.
- 7, or 9.2–pct, cases of unknown cause.

Compression ruptures were found in steep-sided valley stream bottoms over the Bailey, Blacksville No.2, Cumberland, and Enlow Fork Mines that often trend in a Northwest to Northeast direction. These compression rupture features were caused by significant levels of horizontal stresses found in Pennsylvania's near-surface strata. Stress concentrations can be locally influenced by the shape and orientation of the stream valley and the physical properties of the bed rock strata. When compression ruptures occurred, they had an adverse impact on land in general and streams in particular.

X.C.4 - How are Interstate Highways Impacted?

I79 was impacted through traffic restrictions over recently mined longwall panels through:

- Vertical curvature and reduced sight distances of the highway, and
- Expenditure of over 19 million dollars to monitor and rehabilitate sections of the highway.

However, traffic flow was safely maintained at all times and no driving related injuries were reported as a result of longwall mining. The majority of the damages noted consisted of longitudinal cracking, mainly along the edges of the highway, and heaving, mainly along transverse joints. The vast majority of highway deformations were transient, i.e. occurring over relatively short periods of time (7 months). As a result, highway monitoring and rehabilitation efforts were concentrated over a relatively short span of time for each panel mined. Therefore, it was more cost effective to allow longwall mining to proceed than to condemn the coal needed to provide support for the highway.

X.C.5 - How are Streams Impacted?

All stream impacts have occurred over longwall mines. The length of streams undermined by longwall mines actually decreased from 97 miles during the 2nd assessment period to approximately 87.9 miles in the 3rd. At the same time the number of stream investigations more than doubled from 22 to 55. This increase is, in part, due to the greater emphasis being placed by the PA DEP to monitor stream conditions and to initiate investigations when impacts are discovered.

During the 3rd assessment period, a new protocol was implemented for examining the biological health of a stream. Its purpose is to help determine when streams are impacted and when they have been restored to their pre-mining states. Currently, there isn't enough pre-mining data to adequately determine which streams have been impacted and to what degree these impacts have occurred. As noted, the TBS values generated by this study do indicate that several streams have had negative impacts to their biological diversity when compared to a local control stream where

mining has not occurred. However, the use of a single control stream for each mine may not adequately represent the diversity of stream characteristics in the undermined area.

The issue associated with controls streams should not be a problem in the future since new mining permits and permit revisions must contain pre-mining TBS values. Assessing stream impacts during the permit approval process requires the mining companies to take more pro-active approaches. This involves implementing mitigation controls that will help to retain flow and promote biologic diversity.

X.C.6 - How are Wetlands Impacted?

While this question can't be adequately addressed in this report, the necessary protocols to answer it in the future have been implemented during the 3rd assessment period. The recent permit revisions for longwall mines that have been submitted to the PA DEP reflect these changes. The 93.9 acres of wetlands identified in this study will likely increase in magnitude as more efforts are made by the mining operations to adequately characterize wetlands.

X.C.7 - Is ACT 54 working and is there Compliance?

The University understands that hardships are being experienced by citizens when their properties are undermined and impacts occur. The State legislature has put into place legislation from which regulations and standards have been developed to make sure these citizens are compensated.

The University has determined that for structures, water supplies, and land reported effects, 80-pct of all cases were solved in the first 600 days after the date of occurrence. The PA DEP is tasked to make sure that each case is handled in a fair manner and that the best scientific data available is used to resolve the reported effect. These processes take time. The system in-place that achieves a successful resolution in 80-pct of the cases in the first 600 days seems adequate. However, the other 20-pct of the case are lingering for much longer time frames and efforts should be continually made to resolve these cases.

The University further believes that the PA DEP has implemented appropriate protocols to assure that mining companies mitigate impacts to streams and wetlands undermined in the future. The efforts to remediate these impacts by mining companies are in many cases significant and will hopefully have the intended outcome.