EXECUTIVE SUMMARY
OF

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

RESEARCH CONDUCTED BY
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FOR
THE PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION

February 4, 2005

PURPOSE AND SCOPE OF THE REPORT

This report details impacts to natural and artificial surface processes and features caused by underground bituminous coal mining in western Pennsylvania between August 1998 and August 2003. The impetus for this document derives from the requirements of the amended Bituminous Mine Subsidence and Land Conservation Act (BMSLCA), act of April 27, 1966 (1^{st} Sp. Sess, P.L.31, No.1). The original act and its subsequent 1994 amendment, commonly called Act 54, were designed to regulate underground coal mining because it directly and indirectly affects the surface. Under the mandate of Act 54, the Pennsylvania Department of Environmental Protection (PA DEP) must issue a report on the complex effects of underground mining during five-year increments. This document is the second such report, and it covers an assessment period from August 21, 1998 through August 20, 2003.

Western Pennsylvania's underground bituminous coal mines are numerous and widespread. The consequence of having numerous mines over an extensive region is great complexity. Natural and human interrelationships with mining activities abound. Because the effects of mining vary in degree and intensity with geological, hydrological, and demographic circumstances, this document reports many effects of underground mining on water supplies, structures, streams, wetlands, land, and infrastructure in the context of resolutions to the sundry problems as required by the BMSLCA and Act 54 amendments.

Act 54 requires "remedies" for the "restoration or replacement" of lost, diminished, or contaminated water supplies and of damaged structures and properties affected by underground coal mining. In addition to restrictions and responsibilities that the BMSLCA amendments impose upon mine operators, Act 54 amendments impose responsibilities on the PA DEP. Section 18.1 of Act 54 requires the PA DEP to collect, compile, and analyze data from information contained in deep mine permit applications, in monitoring reports and other data submitted by operators, from enforcement actions and from any other appropriate source to ensure that remedies, restoration, and replacement have occurred or are occurring.

Although the PA DEP is responsible for data collection and analysis, it may, under the authority of Section 18.1, use the services of professionals or institutions recognized in the field, for the purpose determining the effects of deep mining on subsidence of surface structures and features and on water resources. For the writing of this report, the PA DEP turned to California University of Pennsylvania's Department of Earth Sciences (the University's researchers, the University). In March 2004, the PA DEP and the University agreed in a Memorandum of Understanding (MOU) that the University would fulfill the requirements of Act 54 under Section 18.1 by addressing ***to the extent possible*** 43 issues related to mine subsidence for the most recent Act 54 five-year assessment period.

The University's researchers uncovered data on the effects of mining on surface entities of any kind by examining the electronic dataset contained in the Bituminous Underground Mining Information System (BUMIS) maintained by the PA DEP and the paper files maintained in the California District Mining Office (CDMO). The University obtained information from other sources, as well, including direct contact with representatives of state agencies, townships, and private companies that have information on public utilities. The University also acquired information through primary field research on natural entities purportedly affected by mine subsidence. Using GIS software, the University presents in the report a number of color plates with maps of undermined natural and artificial features for which there was adequate cartographic data. The report also contains numerous graphs and tables that illustrate the data and support analyses.

Types of Mining and Mining Effects

This report relates types of underground mining methods to surface effects. Thus, it categorizes effects by 1) longwall mining, which removes large portions of a coal seam in *panels* hundreds of feet wide by thousands of feet long; 2) room-and-pillar mining, which removes coal, but leaves behind *pillars* (columns) of the coal seam for support of the overburden (rock layers that overlie the coal seam); and 3) full-retreat (room-and-pillar-retreat) mining, which removes the pillars. Both longwall and full-retreat mining have been called "high-extraction" mining because they remove, or attempt to remove, all the coal that is technologically possible to extract from a coal seam. Longwall mining is particularly feasible in coal seams of relatively uniform thickness. Room-and-pillar mining is more aptly suited to the extraction of coal from "pods" that are discontinuous or that variously thin and thicken throughout their extent.

Subsidence patterns and hydrologic effects differ for the three types of mining. Longwall mining causes ground movement and strata displacement over large areas approximating the dimensions of the extracted panels. These movements cause the land surface to sag or "subside" and to undergo dynamic compressive and tensional forces that can damage surface structures. These movements also cause rock strata between the mine and the surface to fracture, bend or shear, often altering patterns of groundwater flow. Full-retreat mining may cause effects similar to those of longwall mining although its effects tend to be less extensive because of the smaller size of the full-extraction area. Unlike the other methods, room-and-pillar mining is designed to prevent or minimize the potential for surface subsidence and damage to structures. It can, however, alter groundwater flow patterns and might affect wells and springs fed by aquifers adjacent to the developed mine workings.

EXTENT OF MINING

During the assessment period coal operators undermined a total of 37,458.6 acres in ten western Pennsylvanian counties. Most of the undermined acreage (over 27,000 acres) is attributable to longwall mines in Washington and Greene counties. Active mines during the period include nine longwall mines and, combined, 72 room-and-pillar mines and full-retreat mines.[1] These mines operated in the following ten counties:

Armstrong
Beaver
Cambria
Clearfield
Elk
Greene
Indiana

[1] Some full-retreat mining is incorporated in some room-and-pillar mines, whereas other full-retreat mining lies outside the boundary of room-and-pillar sections of some mines. High Quality Mine did not initiate its longwall operations until after the assessment period had ended.

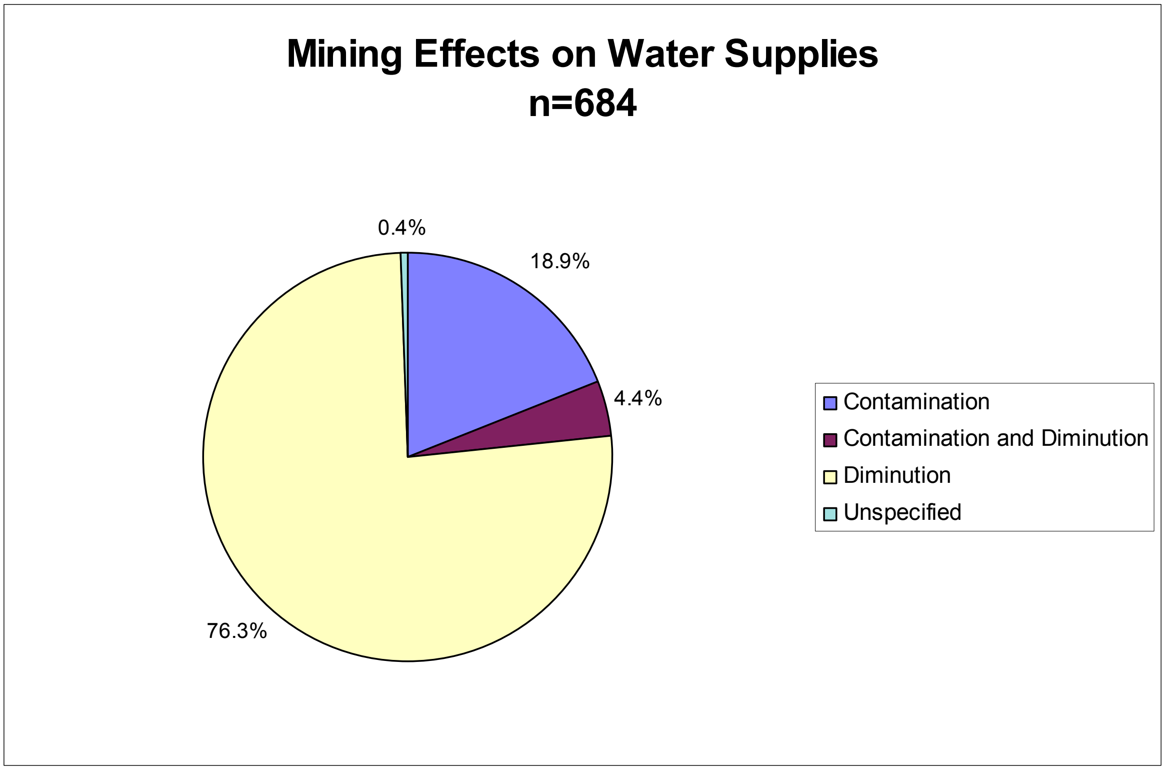
Jefferson
Somerset
Washington

BRIEF OVERVIEW OF THE AFFECTED SURFACE FEATURES

Because the mines operated beneath various types of land use and because mines varied in area, the effects were not uniform across the ten counties. This is evident by the amount of undermined infrastructure (i.e., state and township roads, pipelines for water and gas, electric power lines, railroad track) listed on the accompanying "scorecard" and shown on the maps in the report. Privately owned water supplies (springs, wells), structures, and roads vary in number and density (number per unit area) from county to county. During the assessment period underground coal mines operated beneath more than 3,000 properties containing more than 3,600 structures of various kinds (e.g., barn, house). Many coal operations also undermined some segments of western Pennsylvania's numerous streams and wetlands. Longwall mines, for example, undermined almost 100 miles of streams and almost 80 acres of wetlands in Washington and Greene counties (precise numbers follow). The University reports on the diverse and numerous surface entities potentially affected by underground mining in the following order: water supplies, structures, streams, wetlands, land, and infrastructure. Coverage of the topics varies with the availability of useful data.

EFFECT OF MINING ON WATER SUPPLIES

During the five-year assessment period, the CDMO received reports of 684 (including one post-mining from Dora 6 Mine) wells and springs as potentially impacted in some manner by mining for all of the underground bituminous coal mines in Pennsylvania. The pie diagram in Executive Summary Figure 1 below shows the relationship between reported water supply contamination and water supply diminution. Water loss, referred to here as diminution, can be either partial or complete. In those cases where water loss is partial it is possible that water quality can also be affected at the same time. This leads to a dual category of both contamination and diminution. Over 76 percent of *reported* water supply impacts resulted from alleged insufficient water quantity; almost 19 percent of reported water supply impacts resulted from contamination; and 4.4 percent of reported impacts resulted from combined causes: both diminution and contamination. These data do *not* reflect any investigation by the PA DEP through the CDMO or by the mining company as to the accuracy or validity of the reported water supply impact.

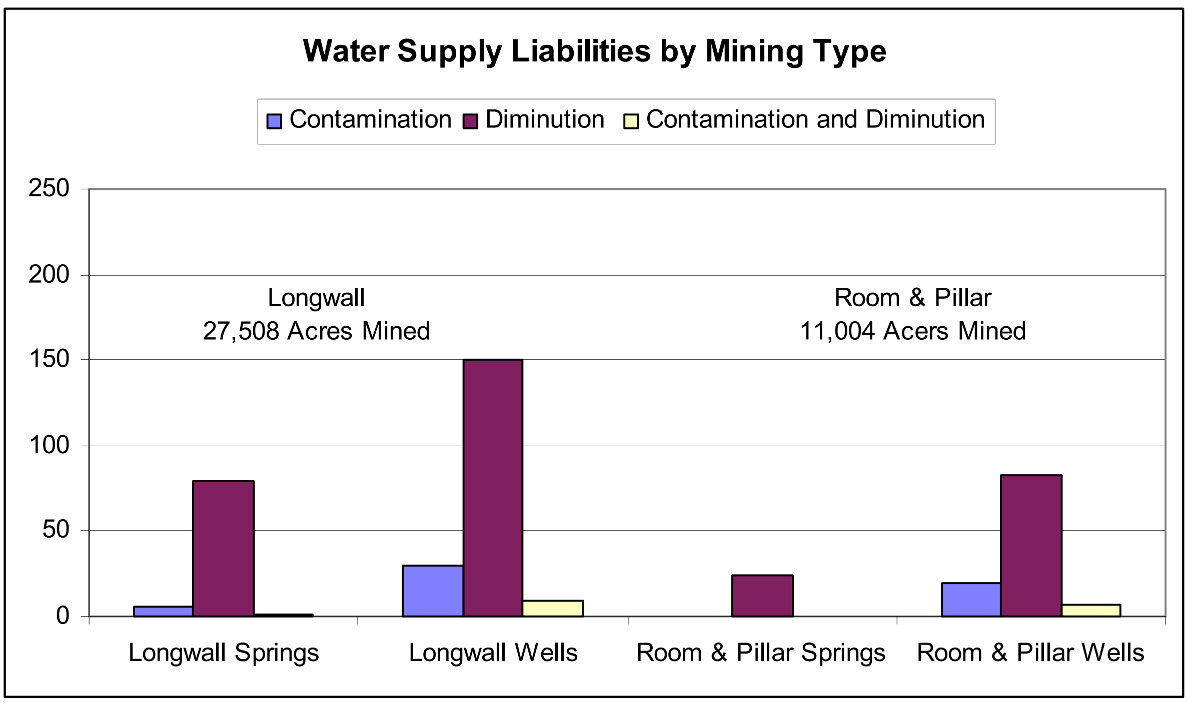


Executive Summary Figure 1. Types of problems that were reported during the assessment period.

Assigning Responsibility for and Resolving Water Source Problems

Mining companies must report all alleged water supply problems to the CDMO. However, Act 54 provides an opportunity for the mining company and the property owner to reach an agreement regarding a water loss or contamination without the involvement of the CDMO. This agreement could include water supply replacement, repair, recovery, treatment or financial compensation. If, however, the property owner is not satisfied with the mine operator's response, the property owner may file a water loss claim with PA DEP through the CDMO.

The University finds that 54.5 percent of the water losses reported to the CDMO were resolved without agency involvement. The large number of resolutions without CDMO involvement is a positive reflection on Act 54. However, owners of 45.5 percent of affected water supplies did file water loss claims with the CDMO, which investigated the claims to determine whether or not the mine operators had caused the water problems, as illustrated in Executive Summary Figure 2. The CDMO also oversaw procedures for a final resolution of all claims. The status of the final resolution of the reported impacts to water supplies, at the end of the assessment period, are presented in Executive Summary Table 1. The largest percentage of these data, 39.7 percent, lie in the category "No Liability" that indicates mining was not at fault. Nearly 22 percent of reported problems are awaiting final resolution as of this writing. This is followed by "Permanent Supply (Unspecified)" at 19.3 %.



Executive Summary Figure 2. Water supplies for which the coal operators were held accountable for problems.

The reasons for a finding of "no liability" by the CDMO vary on a case-by-case basis. Executive Summary Table 1 indicates that the category "no liability" constitutes nearly

40 percent of reported water loss incidents, and as such deserves its own independent analysis. The determination of mine operator liability is a difficult and often complicated process. Many factors must be considered in arriving at a conclusion that the operator is liable; some of the general factors include determination that a water loss exists. For example, a pump failure might be a mining related water loss, but it could also be a water supply maintenance issue; in other cases the water supply owner might not allow a site

Executive Summary Table 1. Resolution Status for 683 Water Claims. The number of problems in this table differs by one from the number in the pie diagram of figure IV.1 because the former includes a water problem associated with Dora 6 (see V.L) that the University later identified as one that is more appropriately included in the 42 post-mining problems that occurred during the assessment period. It also differs from the Scorecard total for water problems because the Scorecard number derives from those water sources *that could be mapped on the basis of accurate locations* contained in the Water Loss files of the CDMO and/or on the "six-month mine maps" submitted by the mine operators. The Scorecard also contains 42 post-mining water claims from Dora 6 (the one included in the assessment period plus 41 others filed prior to the assessment period).

CATEGORY	NUMBER	PERCENT
Agreement (Pre-Mining)	11	1.6%
Agreement (Unspecified in Records)	35	5.1%
Company Purchased Property	8	1.2%
Compensated	3	0.4%
No Actual Problem	9	1.3%
No Liability	271	39.7%
Permanent Supply (Public)	5	0.7%
Permanent Supply (Public & Agreement)	2	0.3%
Permanent Supply (Unspecified)	132	19.3%
Permanent Supply (Unspecified & Agreement)	1	0.2%
Permanent Supply (Well/Spring)	32	4.7%
Permanent Supply (Well/Spring & Agreement)	1	0.2%
Repaired	10	1.5%
Water Supply Recovered	7	1%
Withdrawn	8	1.2%
Resolution Pending	148	21.7%
TOTAL	**683**	**100%**

investigation that would result in a determination by the CDMO that there was no subsidence-related problem. *Mining related factors that influence the decision include:*

distance to mining; timing of the water loss in relationship to mining; overburden thickness, and the type and construction of the water source.

Legal Issues That Affect the Determination of "No Liability"

Legal issues also affect the determination of "no liability." These issues include 1) water losses that occurred prior to those covered by the original version of the BMSLCA and Act 54 amendments, 2) losses that do not meet the definition of a water supply as defined in Act 54, 3) claims filed, that upon investigation, are found not to be in the Commonwealth of Pennsylvania, and 4) water losses that are caused by activities other than underground bituminous coal mining. The determination of "No Liability" is the only category that is *entirely* within the PA DEP's control. All of the other categories require an action on the part of the mining company, and an agreement of the water supply owner. For longwall mines, the PA DEP through the CDMO averaged 58 days to make the determination of liability; for room-and-pillar mines the agency averaged 91 days.

Methods of Resolution

In both the room-and-pillar and the longwall cases, purchasing the property as a method of resolution appears to be the last resort. This conclusion is based on the very low number of occurrences and the longest amount of time that elapsed between the water loss and the final resolution date. It should be noted that *water loss might not be the sole reason for the purchase of the property*. Damage to buildings is expected to have more bearing on the decision to purchase the property than does water supply replacement based on the relative cost of a house versus a well.

Some affected water supplies required a permanent replacement. Permanent replacement supplies were established on average in 206 days for room-and-pillar mines and 441 days for longwall mines. These time periods include the amount of time needed to install the permanent water supply and, in addition, to negotiate any long-term maintenance cost. Frequently, the agreement on long-term maintenance costs extends the final resolution date.

The methods for replacing impacted water supplies differed on a case-by-case basis. For most of the 171 water supplies requiring a replacement supply or the elimination of contaminants in a water supply, the University found that the types of permanent "replacement" fell into four categories: 1) new well or spring (49% of cases), 2) public water (27%), 3) treatment (2%), and 4) unspecified method of "replacement." Because almost one half of these water supplies were replaced by a new well or spring, ground water was still present.

Survivability of Water Sources Over or Near Longwall Mines

Executive Summary Table 2 shows the survivability of a water source with respect to longwall mines during the assessment period. As the column labeled "Percent Survival" appears to indicate, distance to undermining is a control on survivability of a water source. The table also reveals the number of sources for which longwall mine operators were found liable for the water problems reported to the CDMO.

Executive Summary Table 2. Numbers of water sources, distance to mining, and percent survival for each distance range.

Distance Meters	n	Unaffected	Liability	No Liability	Pending	Percent Survival
0 - 100	805	628	106	13	58	79.3%
100 - 500	599	495	32	54	18	90.8%
500 - 1000	288	264	9	13	2	96.0%
1000 - 2000	181	167	4	10	0	97.7%

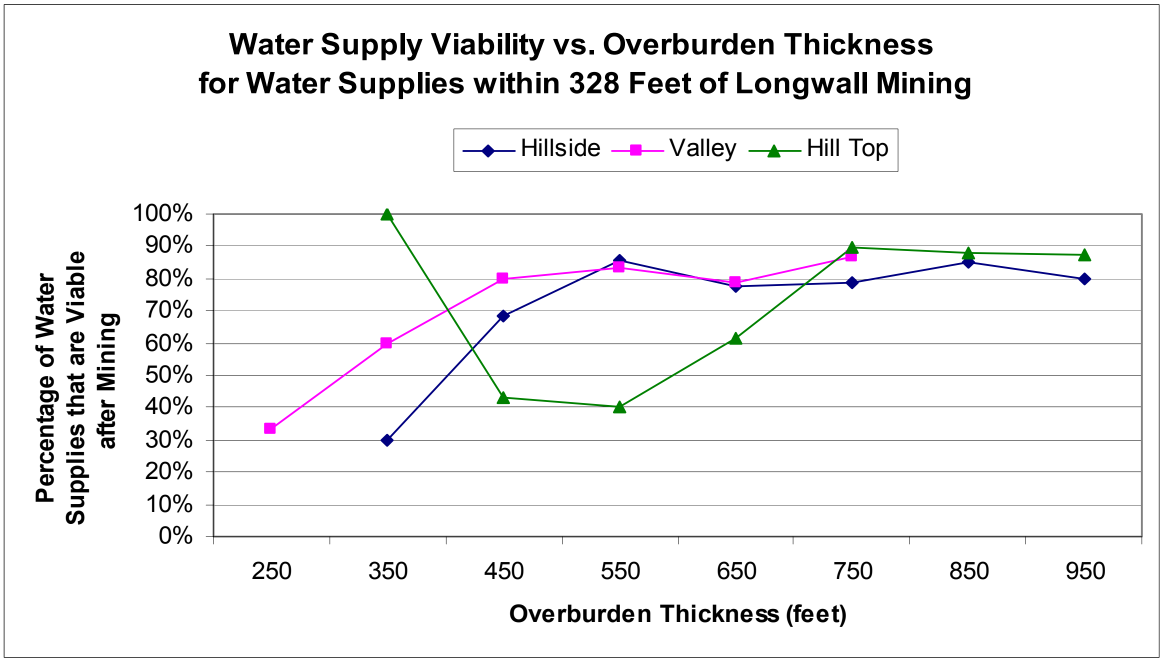
This data set contains 805 water supplies (springs and wells) within 328 feet (100 meters) of longwall mining. As the table reveals, not all water sources were affected by the underlying longwall mining, and for those sources closest to the undermining, 13 of the water source "problems" were not attributable to any mining operator and 628 sources were unaffected.

To determine whether or not the depth of a mine was a control on the survivability of water supplies over or near longwall mines, the University determined overburden thickness (depth to mine) for each of these water supplies and grouped overburden into

100-foot increments of depth. *The depth of wells was not included in this analysis*. The water supplies potentially affected during the assessment period were then separated into three classifications based on topographic setting. Valley supplies are defined as any source where the elevation is within 20 feet of the nearest valley floor. Hilltop supplies are located within 40 feet of hilltops, saddles, or peninsulas. All other water sources were classified as hillside sources. Executive Summary Figure 3 shows the relationship of water source viability to overburden thickness for each of the three topographic settings.

In some cases, there are very few water sources in a category. For example, hilltop sources between 300 and 400 feet of overburden had only two sources and both survived resulting in 100 percent viability. However, two data points do not constitute a statistically significant set of data, and should not be used to identify a trend. Similarly, in the hilltop source category, the interval from 400 to 500 feet had nine sources and the interval from 500 to 600 feet had five sources. As indicated above, variability in land use and demographics control the density of surface features, such as wells.

Hillside and valley sources show increased viability as depth increases up to 450 feet for valley sources and 550 feet for hillside sources. Hilltop sources are more problematical. Once the overburden thickness of hilltop locations equals 750 feet, these sources are on a par with the valley and hillside locations; however, at lower overburden thickness the hill top data are more erratic. The lower survivability at hilltop sites with shallow overburden thickness might be true, and would not be surprising due to the small recharge area available at hilltop sites; nevertheless, the results relative to hilltop sites are questionable due to the small number of water supplies below 700 feet of overburden in the study data. The topographic setting might not be the only control on water source viability.

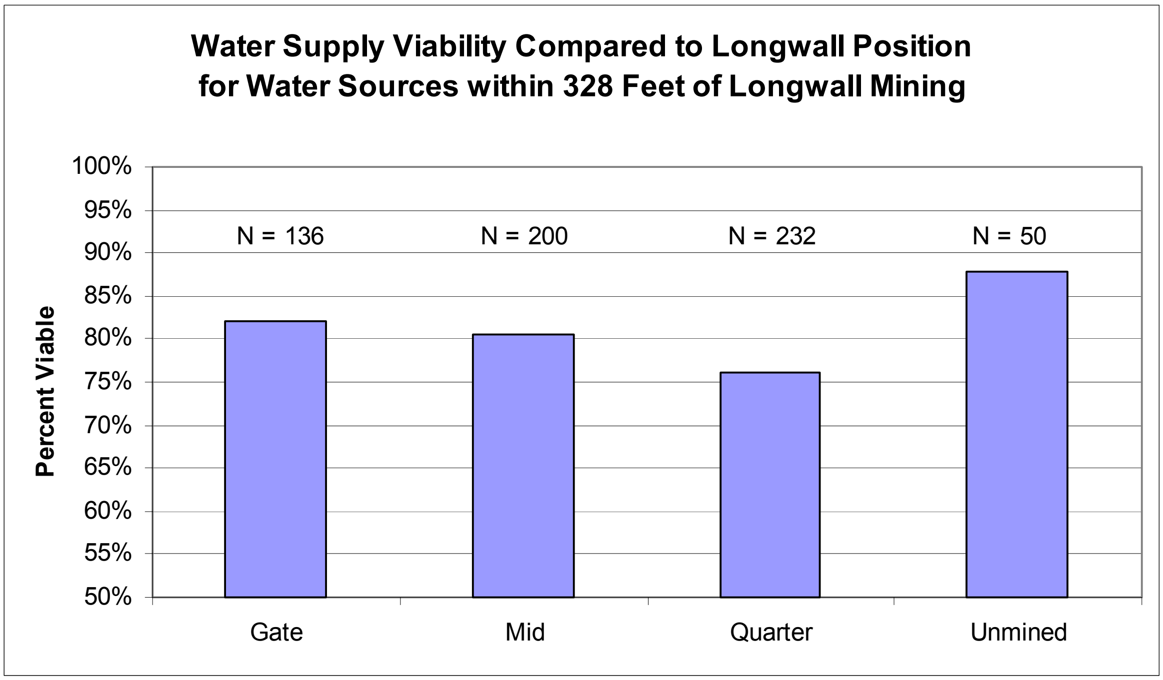


Executive Summary Figure 3.

Subsidence over longwall panels is not uniform, so the University sought to determine the effect of mining on water supplies at different positions over a longwall panel. The greatest subsidence occurs in the middle of the panel and the least subsidence occurs over the adjacent un-mined coal. In addition, as the longwall passes, the land surface in the center of the panel is first placed into tension and then into compression. Along the panel edges the land surface remains in tension (extension), and this tensional force is the cause of surface cracking. These changes in the near surface stress field can translate into changes to the ground-water flow system in the near surface fractures. In order to evaluate these differences, all water sources within 328 feet of longwall mining were sorted according to their positions in relation to longwall mining. By dividing each longwall panel transversely, the University's researchers selected four categories.

- Mid panel locations (25% to 75% of panel width)
- Quarter panel locations (0 to 25% and 75% to 100% of panel width)
- Gate locations (room-and-pillar mining around longwall panels)

- Un-mined (water supplies located over un-mined coal) The results of this division are revealed in Executive Summary Figure 4. Water sources over quarter panels, where extension causes surface cracking, were least viable.



Executive Summary Figure 4.

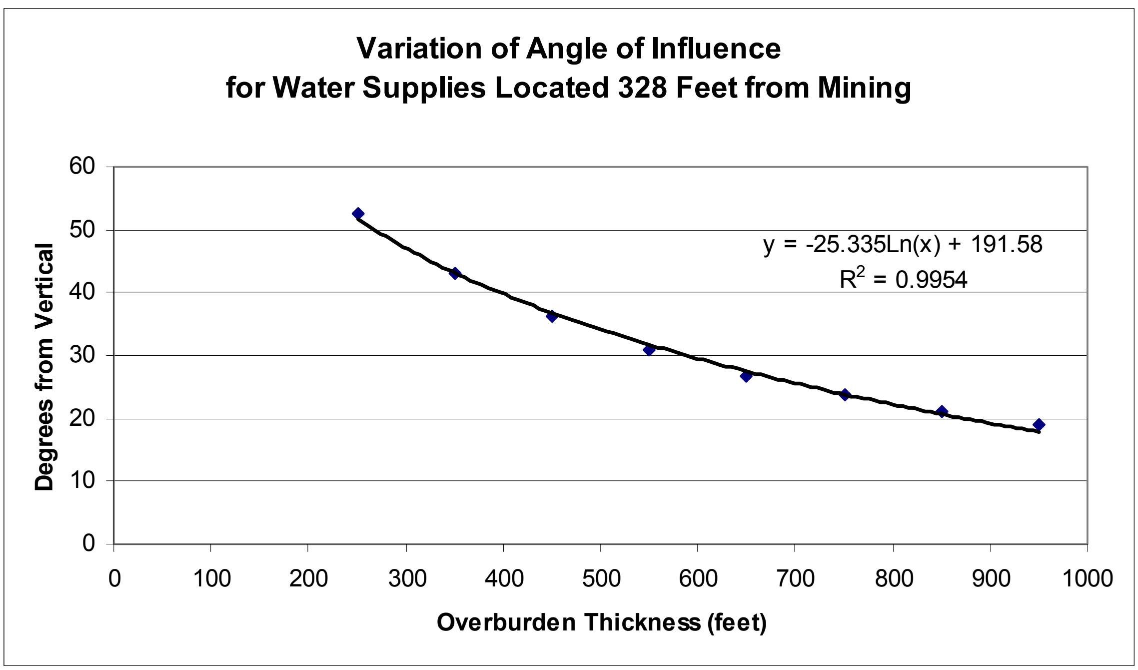
Other Controls on Water Supply Survivability during the Assessment Period

Weather related factors such as drought conditions are known to affect water supplies, and water loss reports increased for the assessment period from June through November, typically drier months than December through May. Also, the assessment period was a time of generally higher than normal temperatures and lower than normal precipitation, conditions that exacerbate water diminution that might be caused by subsidence.

The Presumptive Zone of Influence

Act 54 establishes a zone of presumptive liability for mining operations that is equal to the area of the mining operation plus an additional area bounded by the intersection of the surface and a line drawn from the base of the coal seam at an angle of 35 degrees from vertical. Within this zone, mining operations are presumed to be responsible for the damage, unless they can demonstrate that the water loss is due to another cause. Outside this zone, mine operators are responsible if the owner or the PA DEP can demonstrate that mining is responsible for the loss. This system is predicated on the belief that 35 degrees is a constant. Executive Summary Table 2 demonstrates that *at about 328 feet from the longwall panels 80 percent or more of the water supplies were viable, whereas at less than 328 feet the viability drops off quickly*. If this value of 328 feet is applied to known overburden thickness, the "angle of influence" can then be calculated for each given overburden thickness.

Executive Summary Figure 5 is a plot of how the "angle of influence" would vary with overburden thickness given a constant distance from mining.



Executive Summary Figure 5. The variation of the angle of influence with overburden thickness given a fixed impact distance

The plot in the above figure indicates that where thin overburden is present the angle of hydrologic influence would have to be increased to over 50 degrees to include those water supplies that are within 328 feet of longwall mining. Similarly, as the overburden thickness increases, the angle of hydrologic influence would have to be decreased to less than 35 degrees. At an overburden thickness of 950 feet the angle of hydrologic influence falls to less than 20 degrees.

The effect of distance from longwall mining to the water source is so significant that a presumption of liability based on an angle of hydrologic influence must be seriously questioned. If 80 percent viability of water supplies is used as a dividing line, then a presumptive zone of 328 feet from longwall panels is a better predictor than is a 35-degree angle of hydrologic influence, the current parameter established under Act 54. If a value other than 80 percent viability is preferred, then the formula provided in the figure and explained in the full report should be used to calculate the corresponding distance from longwall mining to be included in the presumptive zone.

EFFECT OF MINING ON STRUCTURES

The University obtained data on undermined and impacted structures from five sources:

- Six-month mining maps submitted to the California District Mining Office by mine operators
- BUMIS reports
- Paper files in the California District Mining Office
- Damage reports faxed to the California District Mining Office by mine operators
- Interviews with professional staff at the California District Mining Office

Background for Understanding Structure Claims

Unlike water supplies, there is no "presumptive zone of influence" for structures that lie beyond the immediate boundary of mining. A structure one inch off a line marking the surface boundary above an active mine must be treated on an individual basis. Investigators from the California District Mining Office who specialize in damage caused by subsidence assess each problem as it arises. Each such investigator or surface subsidence agent maintains a file of correspondence that includes letters to and from structure owners and mine operators. In numerous instances, the mediation of the surface subsidence agent prevents a problem from becoming a claim because of an amicable solution worked out between operator and owner (under the guidance of the surface subsidence agent). In such instances, no extensive record is necessarily kept beyond the initial faxed "problem" and the letters and notes that led to the resolution of the problem.

Number of Structures Undermined and Impacted

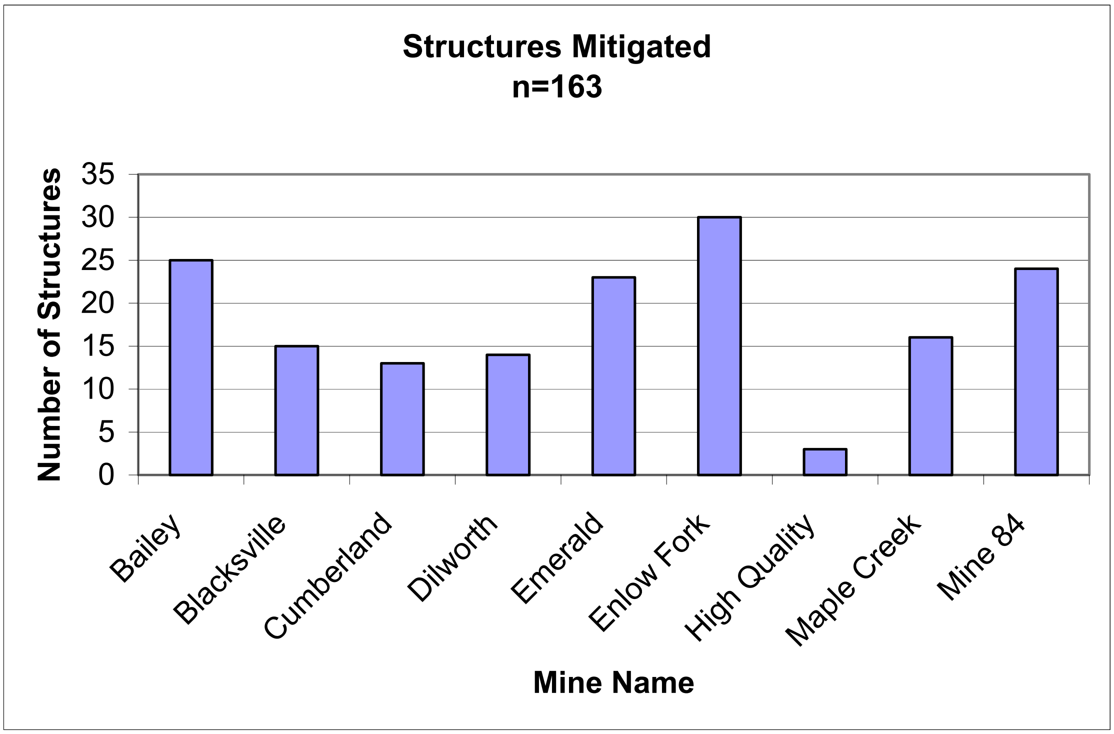
During the assessment period, 3,656 structures of various kinds on 3,033 properties were undermined. The CDMO received 348 faxed messages from mine operators indicating a structure "problem" during the assessment period. Of these faxed problems eventually 141 structures over 21 mines became claims (see Exec. Sum. Table 3). This number of claims represents 3.8% of the total undermined structures.

Executive Summary Table 3.

Mine	Problems With Claims	Problems Without Claims	Total Problems
BAILEY DEEP MINE	6	35	41
BLACKSVILLE 2 MINE	8	30	38
BURRELL DEEP MINE	2	1	3
CUMBERLAND MINE	5	11	16
DIANNE MINE (formerly DAVID DIANNE MINE	8	1	9
DILWORTH DEEP MINE	10	8	18
EMERALD DEEP MINE	9	16	25
EMILIE 1 & 2 MINE	1	1	2
EMILIE 4 DEEP MINE	1	0	1
ENLOW FORK MINE	7	27	34
HIGH QUALITY MINE	0	1	1
HUMPHREY 7 MINE	0	9	9
LION MINING/GROVE #1 DEEP MINE	2	0	2
LUCERNE 6E DEEP MINE	1	0	1
LUCERNE NO 6 DEEP MINE	0	1	1
MAPLE CREEK MINE	43	24	67
MATHIES MINE	6	0	6
MINE 84	17	32	49
QUECREEK NO 1	2	0	2
ROARING RUN	1	0	1
SARAH MINE	1	0	1
SOLAR NO 7 DEEP MINE	0	1	1
TANOMA DEEP MINE	7	9	16
URLING 1/3 DEEP MINE	2	0	2
WARWICK DEEP MINE 3	2	0	2
Total	**141**	**207**	**348**

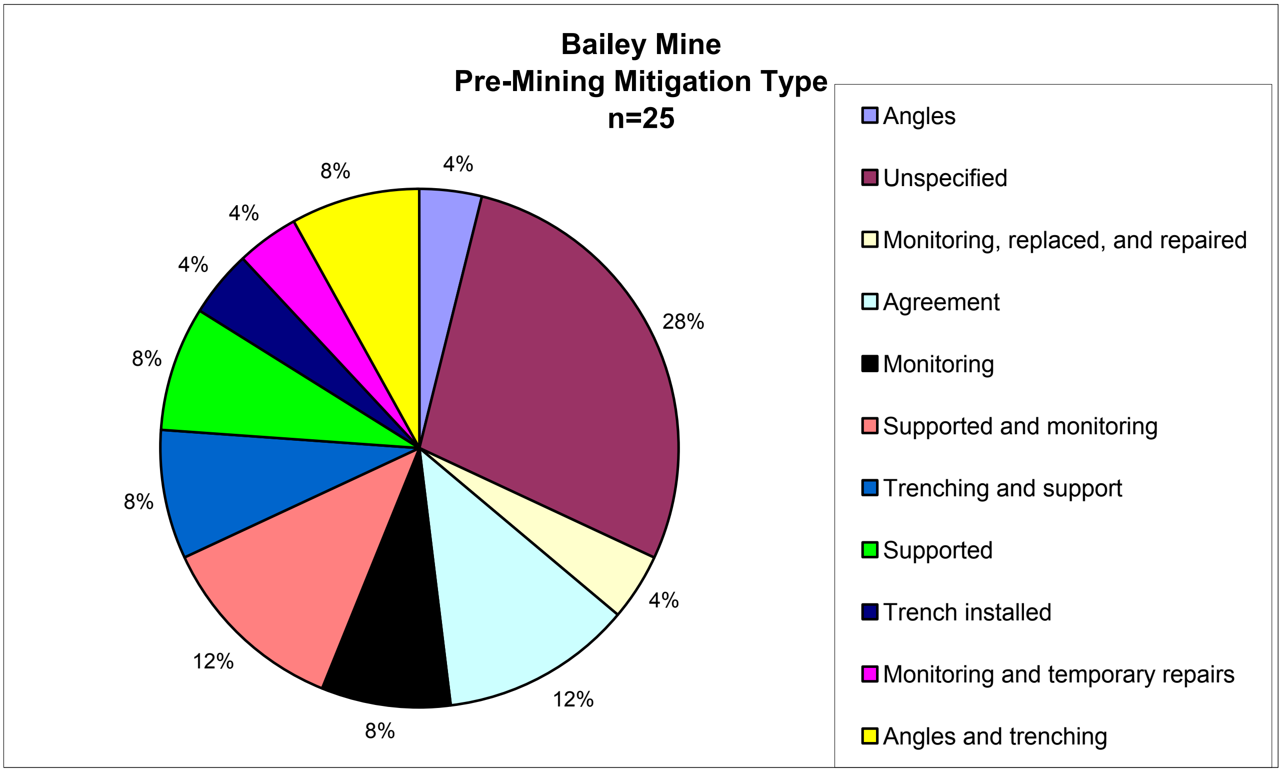
Mitigation Efforts

During the assessment period longwall mining companies attempted to mitigate damage for 163 structures prior to undermining (Exec. Sum. Fig. 6). Whether or not the mitigation served its purpose is unknown to the University's researchers because no crosschecking mechanism could be identified that would link pre-mining mitigation to survivability of the structure.



Executive Summary Figure 6. Number of structures for which the reports faxed by mine operators to the California District Mining Office had an entry on the line marked "Mitigation." This represents all longwall mines except Shoemaker, whose mining was conducted only partially within Pennsylvania during the assessment period.

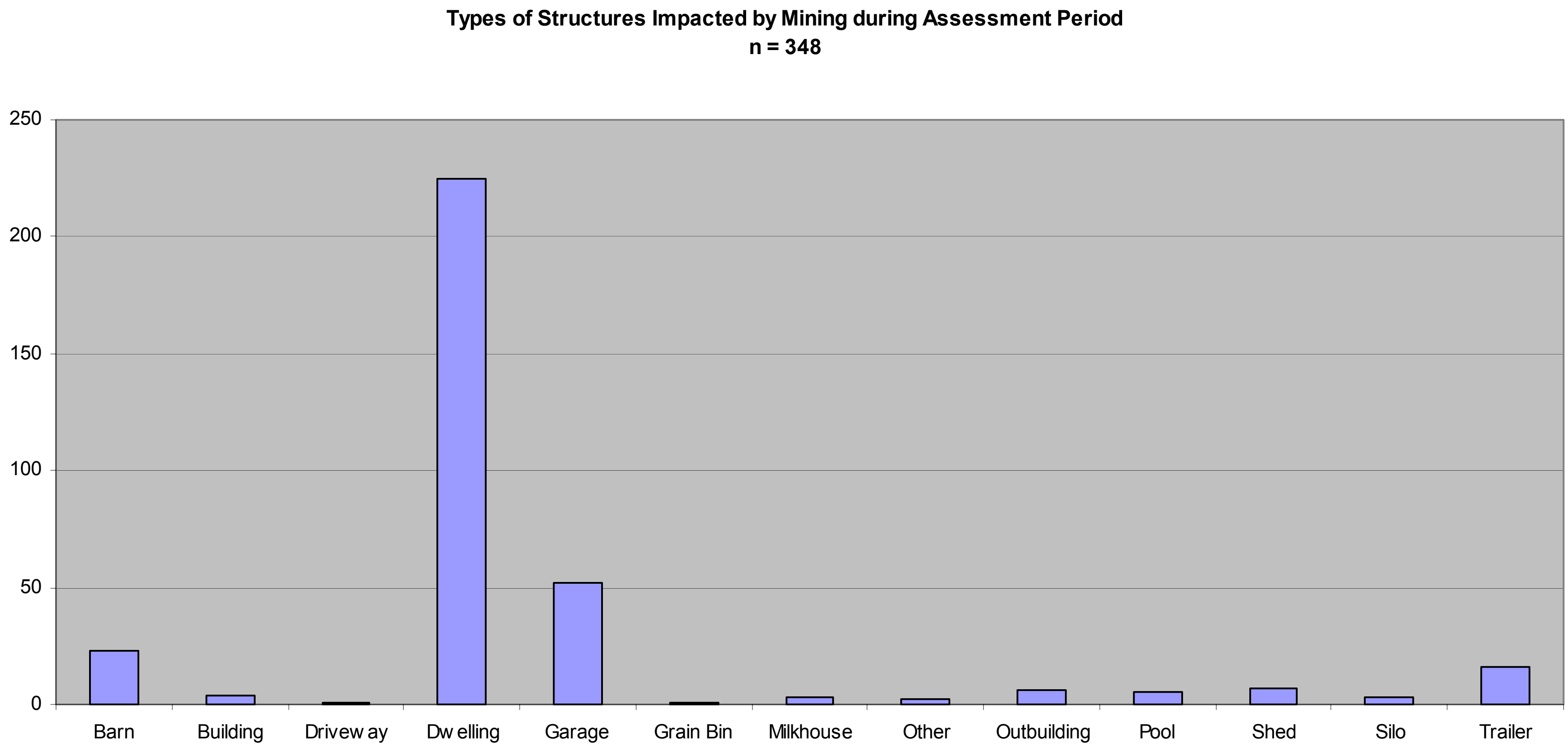
Mitigation is not a single methodology. Pre-mining mitigation is based upon the type of structure and the projected type of subsidence effect, such as compression or extension. Some buildings are isolated by trenches; others are reinforced in different ways. An example of the many methods used by mining companies appears in Executive Summary Figure 7, which shows methods used by a single mine to prevent potential damage or to minimize actual damage to structures.



Executive Summary Figure 7.

The 348 Structures with Alleged Problems

Sixty-four percent of the structures for which mine operators faxed reports of problems to the CDMO were dwellings. Other types of structures are shown in Executive Summary Figure 8. Some structures were unidentified as to type ("Other" in the figure). A few structures have a generic designation: "building."



Executive Summary Figure 8.

Estimate of the Magnitude of Impacts to Structures

Magnitude of impact is estimated for 70 structures undermined during the assessment period (see Exec. Sum. Table 4). The designators "slight damage," "moderate damage," and "severe damage" are derived from the estimates made by agents of the California District Mining Office who have personal experience with each of the 70 structure claims. For the PA DEP, a structure has suffered irreparable damage when its repair costs equal the current value of the structure.

Executive Summary Table 4.

Structures by Type of Construction	Slight Damage*	Moderate Damage**	Severe Damage***
All Masonry	1	2	2
Block Foundation, Aluminum Siding	1	2	3
Block Foundation	0	2	2
Block Foundation, Brick Veneer	1	3	9
Block Foundation and Modular	0	1	0
Block Foundation, Stone Veneer	0	1	2
Block Foundation, Wood Siding	0	2	3
Block Foundation, Vinyl Siding	1	0	3
Poured Concrete, Log	1	0	0
Chimney	1	0	0
Mobile Home	3	0	0
Wood Foundation, Wood Siding	1	0	0
Wood Siding	2	3	0
Poured Concrete, Wood Siding	0	0	1
Stone Foundation, Wood Siding	0	1	2
Stone Foundation, Brick Veneer	0	1	0
Greenhouse	0	0	1
Brick Veneer	0	1	1
No Data	2	3	5
Totals	14	22	34

* Slight Damage-Cosmetic Repairs
** Moderate Damage-Partial Replacement
*** Severe Damage-Foundation Replacement or High Repair Cost

EFFECT OF MINING ON STREAMS

Because of their size, longwall mines undermine more miles of streams than room-and-pillar mines. Longwall mine panels undermined 96.95 miles of streams during the assessment period, whereas room-and-pillar mines undermined 18.53 miles of streams (see Scorecard for individual mines).

Habitat assessment procedures and forms were used to score habitat assessments post-mining. Post-mining fish and macrobenthic communities were sampled during daylight hours (the report contains inventories of sampled fish). Fish communities were usually surveyed using a Smith-Root backpack-mounted pulse–DC electrofishing unit. A single electroshocking pass of approximately 200 yards, walking in a downstream to upstream direction was made at each of these sampled stations in accordance with USEPA procedures (USEPA 1990). Fish were enumerated, identified to species, and released alive after completion of the survey. At a couple of stations (as noted in the relevant station write-up), fish were dip netted, identified, and released in the field. Qualitative macroinvertebrate surveys were performed post-mining using dip-netting and handpicking of rocks. In most cases, benthic organisms were identified to the family level in the field and released alive. Because of time constraints, stream sites were randomly selected, and collected information was supplemented by pre-existing data gathered by the PA DEP's Regional Water Management Office for the Statewide Water Assessment Program (Regional Water Management biologists), the PA DEP's California District Mining Office biologist, and scientists contracted by Consol Energy.

The primary causes of stream problems associated with deep mining are increased sedimentation, pooling, and other channel alterations, such as increased erosion, resulting from subsidence of the stream bed above the mined panels, and flow diminution resulting from the fissuring of the underlying bedrock. The report contains field assessments made by the University and is divided into three groups of streams: 1) stream segments that were undermined during the assessment period, 2) stream segments that were undermined between 1994 and 1998 of special interest and mentioned in the 2001 Supplement to the first five-year report, and 3) stream segments that were undermined in the 1980s and according to PA DEP records, had mining-related effects. With more than 100 miles of undermined streams in the assessment period, most over longwall mines, the University's stream specialist had to choose a representative sample of streams for scientific observations and assessments. The University's charge was to determine whether or not potentially impacted or actually impacted streams were "attaining their use."

Number of Streams and/or Ponds Impacted by Mining during the Assessment Period

During the assessment period, problems were reported to the California District Mining Office for Dyers Fork and its tributaries, and to tributaries of Laurel Run, Enlow Fork, Robinson Fork, Mingo Creek, Spotted Tail Run, Dunkard Fork, and Roberts Run. Primarily, reported problems centered on low flow or on absence of flow. BUMIS records reveal that **22 streams and/or ponds** had an assigned "ST" claim number (ST0303 through ST0325) during the assessment period. Such a number is normally assigned to a stream that reportedly suffered an impact during the assessment period, *warranting an investigation by the California District Mining Office* (see section VII.K in report). Paper files housed in the California District Mining Office supplement BUMIS because they include reports of investigations by surface subsidence agents who made in situ observations after learning of reported stream impacts. These files indicate that agents of the California District Mining Office investigated streams in question within a reasonable period following the faxed report of a problem. Summaries of these investigations are included in the full report. Precise cartographic identification of the 22 stream sites and ponds impacted by mining and investigated by the California District Mining Office was not readily available to the University.

Among the streams observed in the field by the University were **those streams determined by the PA DEP to be in need of assessment because they were undermined during the assessment period and because they had a pre-mining Regional Water Quality Office (RWQO) assessment, but no post-mining assessment.** Executive Summary Table 5 shows the pre-mining assessment of the RWQO and the post-mining assessment of Dr. Daniel Keogh, the University's stream specialist.

Executive Summary Table 5. Streams determined by the PA DEP to be in need of assessment or investigation that the University observed because they were undermined during the assessment period and because they had a pre-mining R.W.Q.O. assessment but no post-mining assessment. This table does not include all streams that were undermined during the assessment period. That list can be found in a table in Appendix A. **UA** = not assessed by R.W.Q.O.; **A** = attaining; **I** = impaired; **AI** = attaining, impaired (for stream segments that were less inclusive than the University's assessed segment); **ABI** = attaining but impaired; **NA** = not attaining; **Agr** = agriculture is the cause of nonattainment; **Other** = causes other than mining and agriculture are the reason for nonattainment or impairment.

Stream Name	R.W.Q.O.-Assessment	Dr. Keogh's Assessment
Crabapple Creek	UA	ABI
Trib 32518 to Crabapple Creek	A	A
Enlow Fork	A,I	A
Kent Run	A	NA(Agr.)
Pumpkin Run	A	NA(Agr.)
Trib 40312 to S. Fork of Little Ten Mile	A	NA
Trib 40322 to S. Fork of Little Ten Mile	A	A
Trib 36989 to Little Chartiers Creek	A,I	ABI(Agr.),NA
Cherry Run	UA	A
Laurel Run 1.37-2.2 miles	A	NA
Laurel Run Down from Waynesburg	A	ABI(Other)
Robinson Fork B12, 13	I	ABI
Robinson Fork B14	I	A
Enlow Fork 7c	I	ABI
Enlow Fork 6c	I	A
Enlow Fork 8c, 9c, 10c	I	A
Hoovers Run 7s, 8s	A	A
Toms Run	UA	A
Patterson Run	UA	ABI(Agr.)
Muddy Creek	UA	ABI(Agr.)
Trib 36989 to Little Chartiers Creek	A,I	NA
Trib 36999 to Little Chartiers Creek	A	A
Smith Creek	I	ABI(Other)
Pursley Run	UA	A

EFFECT OF MINING ON WETLANDS

During the assessment period longwall mines undermined 73 wetlands listed on the National Wetland Inventory (NWI). The University's researchers visited 52 (71%) of these wetlands, but were unable to observe the remaining 21 because of postings by property owners.

The University's researchers chose the NWI as the basis for their study of wetlands because of the NWI's methodology, classification, and mapping. In the limited time of the study period (160 days, see Limitations in report), the University reasoned that the NWI classification system and inventory of mapped wetlands would facilitate the location and description of undermined wetlands. The University recognizes that some wetlands might not be listed and categorized on the NWI because they were created during the assessment period and that some of 21 unobserved NWI wetlands might have changed as a result of mining. Two information sources were used to determine how many wetlands were undermined during the report period:

- **a.** Mine permit files and six-month mining maps at the California District Mining Office
- **b.** National Wetland Inventory (U.S. fish and Wildlife Service, http://wetlands.fws.gov/)

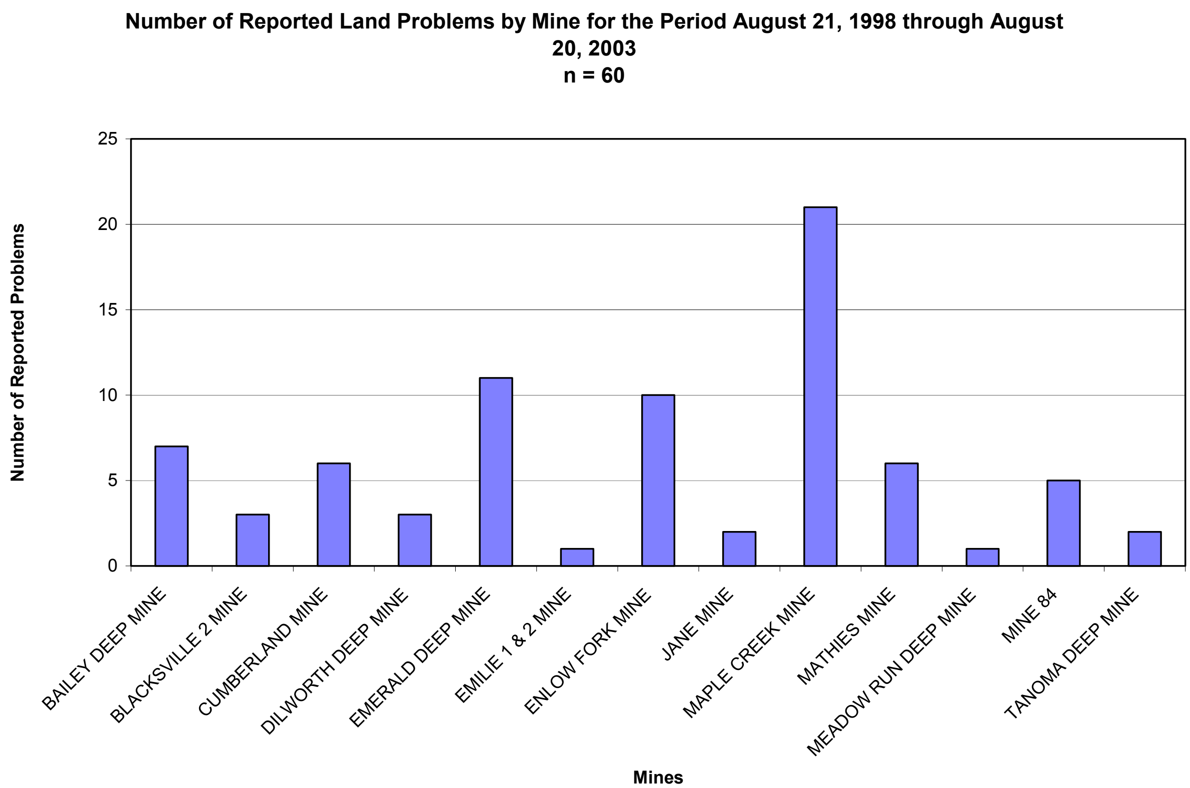
Field surveys to determine the current condition of these wetlands consisted of visual observations of all wetlands that could be observed from public roads or utility right-of-ways or without trespassing on posted private property. Wetlands that did not exhibit any evidence of change because of mining were categorized as "Unchanged." Wetlands that were apparently altered by undermining were categorized as "Altered," and wetlands that could not be observed (21) without trespassing on posted, private property were categorized as "Unknown."

Over the course of the assessment period, one NWI freshwater pond was lost. The pond covered 0.908 acre. During the same time, one NWI freshwater pond was gained. The pond covers approximately 0.18 acre.

EFFECT OF MINING ON LAND

Generally, many land problems are cracks (or fissures) and bumps that occur during or shortly after longwall mining commenced beneath a property. Fissures and bumps could, however, open over a period of three or more years. Changes in elevation also occur, particularly with the passage of a longwall panel during which the land surface moves in a wave at the mining "front." Such a wave produces not only tensional cracks, but also compressional features. Tilting of the land also occurs. Longwall mining is not the only cause of land problems. Room-and-pillar mines also have associated land problems.

For the assessment period the University found 60 reported land problems associated with 13 mines (Exec. Sum. Fig. 9).

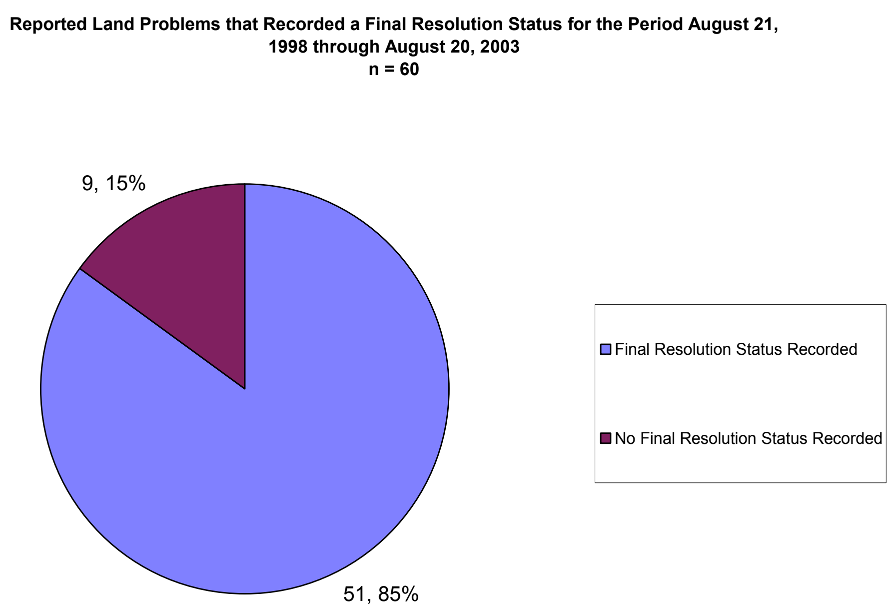


Executive Summary Figure 9.

It is possible that land problems other than those recorded in BUMIS occurred during the assessment period. For example, in reading through the California District Mining Office reports on investigations of streams, the University's investigators encountered a description of Tributary 32511 to Dunkard Fork that mentions compression bumps blocking the stream's normal flow (see report section VII.L). Should the bumps, if they were longer than the width of the stream be classified as a stream problem or a land problem? There is no mechanism by which the University could relate the bumps to any of the 60 land problems recorded in BUMIS.

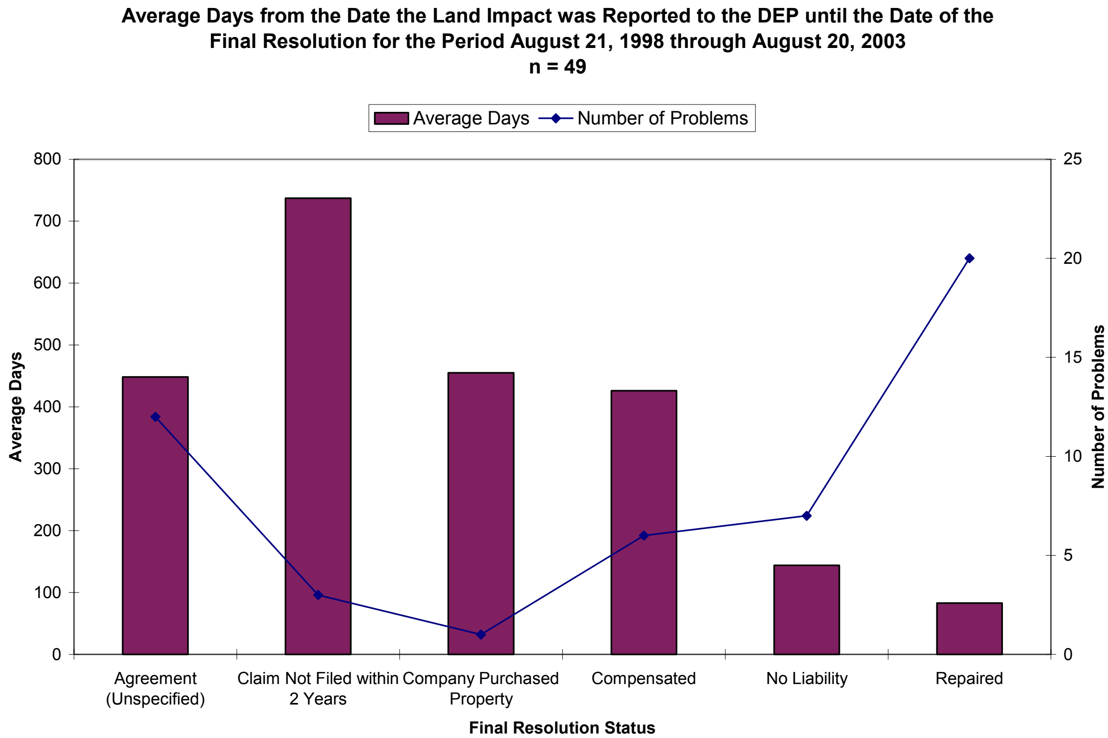
Resolution of Land Problems

Most of the land problems recorded in BUMIS were resolved by the end of the assessment period (Exec. Sum. Fig. 10).



Executive Summary Figure 10.

For the 49 land problems for which both a date of notification that a problem existed and a date of resolution are recorded in BUMIS, the average days till resolution depended upon the mechanism for resolution. Those property owners who had their land problems repaired had the shortest average wait time for final resolution.



Executive Summary Figure 11.

EFFECT OF MINING ON INFRASTRUCTURE

The University's researchers found that data on infrastructure are difficult to obtain. Agreements among utility companies and mines preclude public dissemination of knowledge about utility-mine interactions in most instances. Also, the utility companies refrain from describing incidents of subsidence covered by litigation.

The University did not get useful responses to inquiries about damage to township roads. Some promised information, but never forwarded it; others sent partial responses with a promise to send more information. For areas with longwall mines, for example, only one township responded with a specific report that included costs of repairs to an impacted road. During the assessment period, however, longwall mines undermined 15 townships and 81.39 miles of township roads.

During the assessment period, longwall mines undermined over 50 miles of major gas transmission pipelines. Interruptions to natural gas service temporarily affected 137 customers (Exec. Sum. Table 6).

Executive Summary Table 6. Gas transmission pipelines affected by subsidence during the assessment period.

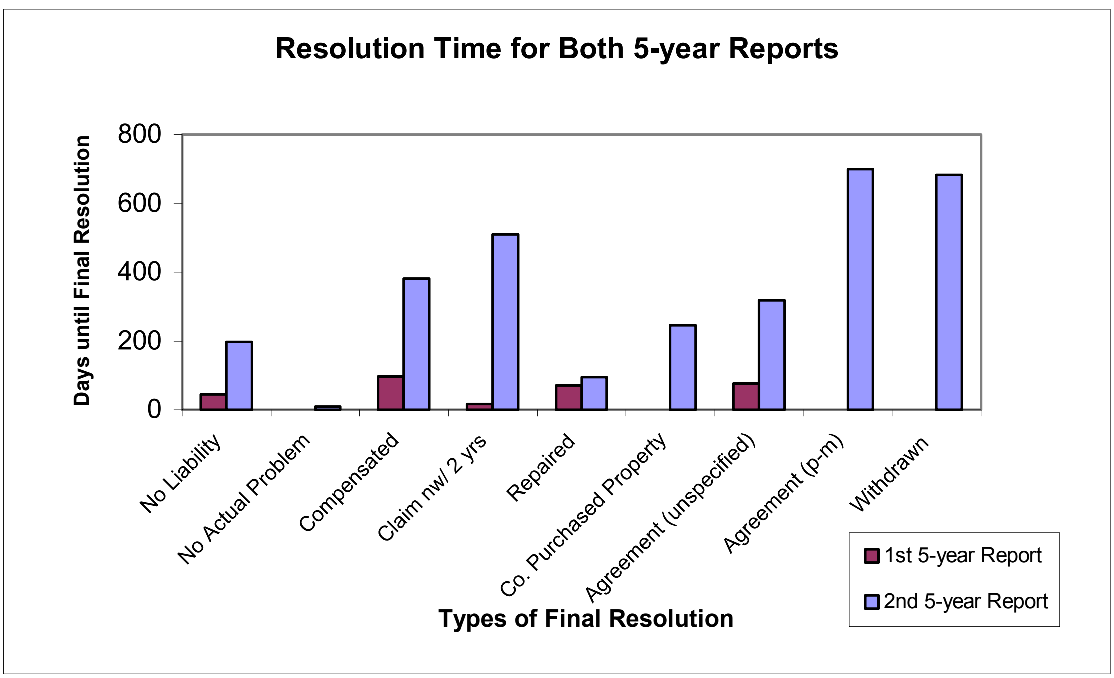
Mine Company	Location	Nature of the Damage	Customers Affected	Measures Taken To Repair The Damage
R.A.G	Gordon Hill, Waynesburg, PA	H-116 pipeline pulled and buckled	6	Various leaks were repaired and sections of pipeline replaced
R.A.G	Waynesburg, PA	H-103 pipeline pulled and buckled	6	Blanks were temporarily set & joints of pipes were installed
CONSOL	SR 218 Spraggs, PA	D-28 pipeline pulled out of coupling (4,375' pipeline)	25	600' of 2" plastic pipe was installed and gas service was reinstated
R.A.G. Emerald	Jefferson, PA	W-1492 pipeline pulled. Gas blew for 3 hours at 8 Psi	25	K&R Services installed 3' of 8" pipeline
R.A.G Emerald	Waynesburg, PA	M-32 pipeline pulled and buckled at various locations	17	Couplings and leak clamps were temporary used & joints of pipe were installed
R.A.G Emerald	Waynesburg, PA	F-114 Pipeline pulled and buckled at various locations	48	Couplings and leak clamps were temporary used & joints of pipe were installed
CONSOL	Sharpneck Hollow, Jefferson, PA	W-2718 pipeline pulled and buckled at various locations	10	Couplings and leak clamps were temporary used & joints of pipe were installed at 3 different locations

One railroad reported a section of damaged track during the assessment period. District 12 of the Pennsylvania Department of Transportation reported impacts to 110 miles of highway and District 11 reported an impact to a single road. The five-year report contains a summary of the commissioned report on subsidence that affected Interstate 70 during the assessment period.

CDMO ACTIONS AND A COMPARISON OF THE TWO ASSESSMENT PERIODS

Attempts to compare the first and second five-year Act 54 assessment periods are limited by the paucity of data for the first of the two periods. Improvements in record-keeping and the addition of staff after 1998 gave the second assessment period a more complete record of mining's effects and the actions taken to mitigate those effects and resolve problems attributed to mining.

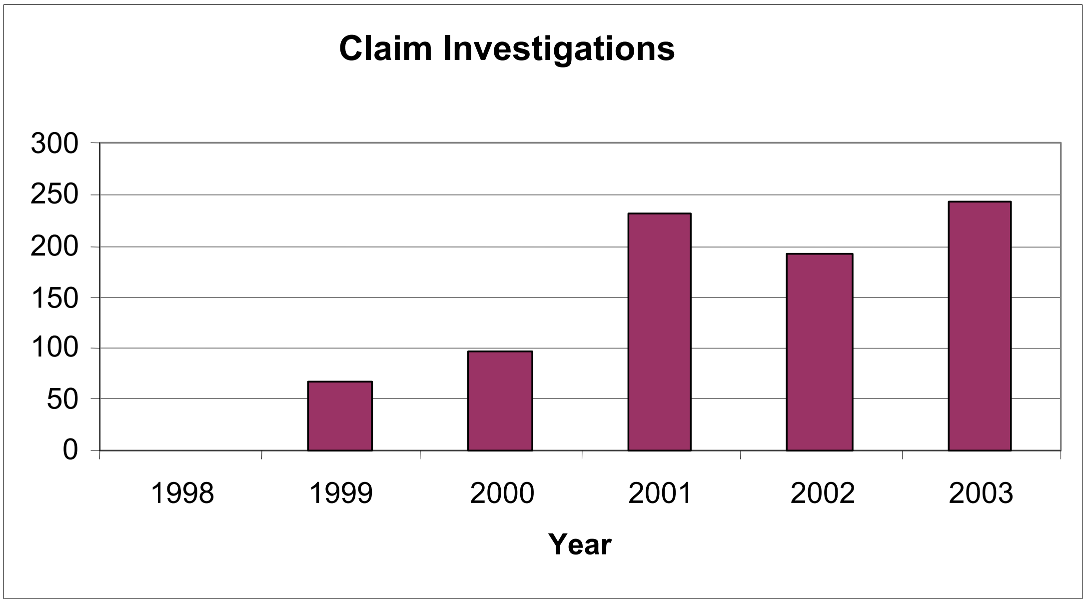
Commonsense tells us that many variables, some of which are unknown, come into play with regard to the effects of subsidence. These unknown variables might account for the lengthening of time for a finding of "no liability" during the second five-year period. The data shown in Executive Summary Figure 12 do not necessarily indicate anything negative about either Act 54 or the actions of the California District Mining Office. They might, in fact, indicate an increase in the thoroughness of investigations.



Executive Summary Figure 12.

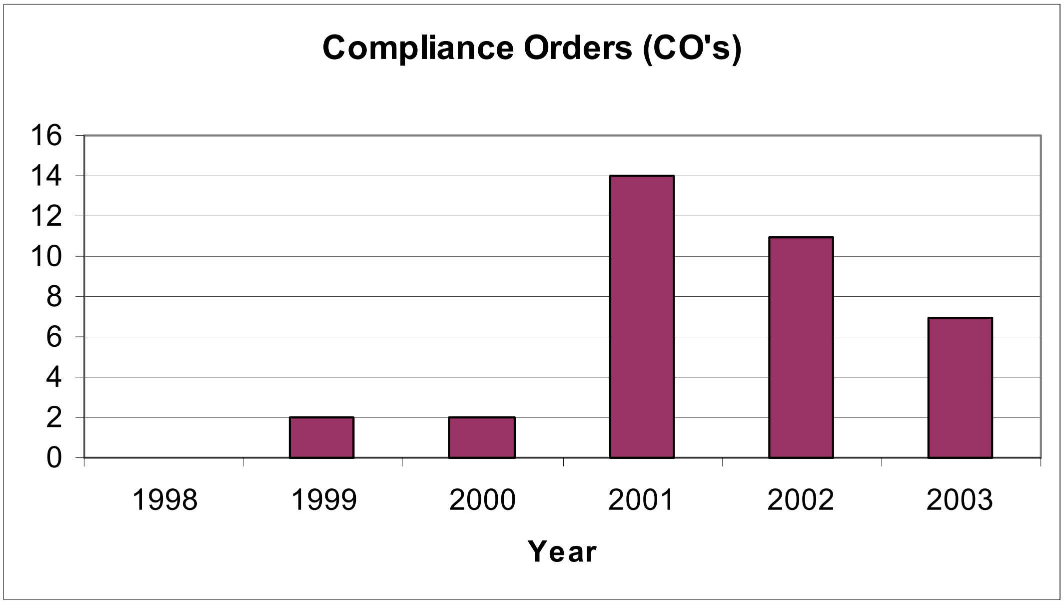
Actions of the California District Mining Office Germane to Act 54

An examination of the internal audit of the CDMO reveals the number of subsidence claims for which the Office conducted investigations. Although, technically, September through December of 2003 is not part of the assessment period, the period is included in Executive Summary Figure 13 to give a picture of the annual activity of the CDMO.



Executive Summary Figure 13.

To ensure compliance with the BMLSCA and the Act 54 amendments, the CDMO issued compliance orders to mine operators during the assessment period. Apparently, a compliance officer whose duties were *primarily* linked to compliance was not on staff during the first five-year period and did not come on staff until the second year of the second five-year period.



Executive Summary figure 14. Compliance Orders Issued during the second five-year period.

If a compliance order is issued, it automatically means that the mine operator will be assessed a civil penalty provided that it was not issued for damage to a structure (e.g., house, shed, driveway, etc). The civil penalty procedure commences once the operator has complied with the order. Sometimes the CDMO issues notices of violations (NOV) with a civil penalty, for instances in which a coal mining company has violated the regulations, such as not performing a pre-mining survey. The most common occurrence for a NOV is a water source missed in a pre-mining water supply or structure survey.

FINDINGS

The report has twelve sections, but not each section lends itself to the discovery of findings. The following is a listing of findings arranged by report section.

Findings of Section IV: Effect of Mining on Water Supplies

Although springs and wells are not inherently more susceptible to the impacts of mining under dry conditions as opposed to wet conditions, mining impacts on springs and wells are more prevalent in droughty weather than during weather with normal or above normal precipitation. Some mining impacts are tolerated and healed under wet *conditions, but the lack of excess water under dry conditions results in water loss or diminution.*

The rationale used by the California District Mining Office in determining liability for water loss or diminution is insufficiently documented within Bituminous Underground Mining Information System. Forty-five percent of the 268 determination of "No Liability" could not be associated with a basis for the decision.

Terminology entered into Bituminous Underground Mining Information System is not standardized.

Distance to mining is frequently not included in the Bituminous Underground Mining Information System dataset, but *"distance-to-mining" was by far the most significant factor cited in the determination of "no liability."*

Most mines have a small number of water supplies that are pending final resolution. Three mines, Maple Creek, Mathies, and David Dianne have an exceptionally large number of water supplies pending final resolution at the close of the assessment period, and many of these are long standing problems.

Of the 144 "final resolution pending" cases, 49 cases were found where the three-year time period was exceeded ("aged cases").

Findings of Section V: Water Inflow to Longwall Mines

Distance to mining is a very significant factor in mining's effect on water supplies in the study area. Water supplies that are less than 328 feet from mining have less than a 79 percent chance of surviving and as the distance to mining increases the odds of the water supply surviving also increase.

The majority of ground-water recharge did not flow into the mines of Washington and Greene counties during the study period.

The zone above the caved zone and below the shallow fracture zone remained largely unaffected hydrologically by longwall mining during the study period.

Almost ½ (49%) of water supply replacements over longwall panels during the study period was in the form of either new wells or springs, indicating the presence of ground water.

During the study period, Dilworth mine had a significantly greater ground-water inflow than the other longwall mines.

The Dilworth inflow was not representative of the inflow to Pittsburgh coal seam mines during the assessment period.

Findings of Section VI: Effects of Mining on Structures

During the assessment period 3,656 structures on 3,033 properties were undermined.

Although owner's of 9.5% (348) of structures undermined during the assessment period initially reported problems, owners of only 3.8% (141) of all undermined structures filed structure claims during the assessment period.

Much of the information required by the MOU regarding structures is unavailable, incomplete, or inconsistent, making a thorough, quantified assessment of the effects of subsidence on structures impossible to achieve. Nevertheless, agents of the California District Mining Office appear to work effectively to achieve resolutions for problems and problems with claims associated with structure impacts.

Pre-mining mitigation techniques to prevent or lessen potential damage caused by subsidence are not thoroughly documented.

The discovery of a supposed subsidence-related structure problem is not necessarily contemporaneous with the actual date of first occurrence.

The record of "date of first occurrence" for a subsidence-related "problem" as recorded in the Bituminous Underground Mining Information System is not necessarily the actual date of the problem's occurrence, but is often the date that a report of a problem is faxed by the mine operator to the California District Mining Office. This variation in dates of first occurrence makes the determination of time to final resolution tenuous at best. In addition, owners of structures, for various reasons, apparently do not always discover a structure problem contemporaneously with its first occurrence.

Timing of mining with respect to structure damage is not readily determinable from the six-month mining maps.

Distance to mining for structures lying directly above mine workings is usually recorded as "0." Depth to mine is not recorded in the Bituminous Underground Mining Information System for all structures.

A record of distance to type of mine subsidence effect (i.e., tension, compression) would enhance the ability of investigators in their attempt to quantify the effects of subsidence on structures.

The architectural type of construction is not recorded uniformly in either the paper files or in the Bituminous Underground Mining Information System. The University had to obtain structure type descriptions from the personal memories and files of the surface subsidence agents of the California District Mining Office.

Agents of the California District Mining Office know specific information about type of damage and type of structure, and they are aware of agreements among structure owners and mine operators. Agents also know the resolution status and the type of resolution for each structure claim.

The University finds that with the present available data, it cannot correlate among type of construction, mitigation technique, distance to mining, and timing of mining.

Findings of Section VII: Effects of Mining on Streams

Impairment resulting from the diminution of flow in streams is a potential problem primarily associated with headwater 1st and 2nd order streams. Only two 3rd order or higher streams (Laurel Creek and Enlow Fork) were reported to become impaired by loss of flow.

In many cases, stream flow eventually recovered on its own without intervention. These streams often had healthier riparian zones

The use of photodegradable polyurethane grout has not resulted in the sustained return to flow in Laurel Run.

Despite efforts to "grout," streams over the Waynesburg sandstone formation that were undermined by the Dilworth and Emerald mines have not returned to their sustained low flow conditions.

Affected streams had other impairment issues. Among the most serious of these were land use impairments caused by agricultural (and general farming) practices, especially the permitting of cattle and horses into the streams, the elimination of the riparian zone right up to the stream edge, and the leakage of septic tanks into the watershed.

Subsidence related pooling with accompanying bank erosion and sediment deposition is a potential problem associated with longwall mining. An insufficient number of room-and-pillar mines were involved in this study to make any statement regarding this method concerning pooling, nor any comparisons with longwall mining.

Pooling was not observed in streams with a gradient of 3 feet of rise per 100 feet of run or greater.

When the pre-mining data on a stream was unavailable (or nonexistent), the Act 54 University researchers could not accurately determine the extent of impairment that occurred as a result of subsidence related pooling and sedimentation.

Two species that are highly intolerant of disturbance and have requirements clean streams with high flow rate, the banded darter (Etheostoma zonale) and the variegated darter (Etheostoma variatum) were not found in any of the undermined stream segments, but were common in the un-mined section of Dunkard Fork in Ryerson State Park upstream from the confluence with Kent Run. Without pre-mining data, it cannot be determined whether these two species, which are not common in southwestern Pennsylvania, had occurred in the streams before undermining.

Restoration techniques to rectify subsidence related pooling, such as gate cutting, can alleviate problems, such as loss of riffle/run habitat and formation of long stretches of deep pools (These can be oxygen-depleted). Restoration of Enlow Fork over the 9C and 10C panels is an example of this. The amount of riffle habitat was restored to pre-mining conditions through the use of a combination of gate cutting, which occurred during 2000, to reduce the water level and the installation of log barriers, which occurred during 200, at strategic positions on bends to redirect the flow.

Findings of Section VIII: Effect of Mining on Wetlands

Over the course of the assessment period, one freshwater pond was lost. The pond covered 0.908 acre.

Over the course of the assessment period, one freshwater pond was gained. The pond covers approximately 0.18 acre.

During the assessment period neither a large net gain nor a large net loss of National Wetland Inventory wetlands occurred over longwall mines.

No regional base-level studies of wetlands served as a benchmark for evaluating wetlands that were undermined during assessment period.

Findings of Section IX: Effect of Mining on Land

Some land problems were observed by surface subsidence agents of the California District Mining Office, but were either not recorded in the Bituminous Underground Mining Information System or recorded in paper files. In such instances, the land problems were not cross-referenced with the faxed reports of land damage, making correlation of accidentally discovered land deformation and both faxed reports of land problems and land claims difficult, if not impossible to achieve.

Findings of Section X: Effect of Mining on Infrastructure: Impacts on Major Pipelines, Water Lines, Roads, and Railroads

Obtaining information from public utilities on the effects of subsidence on infrastructure is a chancy endeavor at best. Public utility companies appear to be reluctant to provide information about their interactions with mine operators. Local government agents, such as township employees appear to be slow to respond to requests for information about township roads damaged by mine subsidence.

No public authority appears to apply GPS or any other specific locator to identify segments of damaged infrastructure, making mapping of damaged features only an approximate enterprise.

Findings of Section XII: Actions Taken by the California District Mining Office

Comparisons of the five-year periods are not easily derived from the dataset and records of the California District Mining Office. Record keeping has been enhanced during the second Act 54 assessment period with the development of the Bituminous Underground Mining Information System.

The California District Mining Office appears to have been more active in its execution of the requirements of the BMLSCA, Act 54 amendments, during the second five-year Act

54 period than during the first five-year period, but the finding might reflect only a more thorough documentation.

The addition of a compliance officer has enhanced the effectiveness of the California District Mining Office in maintaining compliance with Act 54.

RECOMMENDATIONS

The following are recommendations from individual report sections.

Section IV: Effect of Mining on Water Supplies

The PA DEP should take immediate action to reduce the large number of aged water loss claims (those that have exceeded a three-year period).

The PA DEP should review the process of data entry into the Bituminous Underground Mining Information System to increase the coverage of data under all entry categories.

The PA DEP should either establish a set of standardized terms or commission a standardization of terms that would enhance the quantification of data recorded in the Bituminous Underground Mining Information System.

The PA DEP should record the "distance to mining" for every water loss problem and claim.

The PA DEP should determine either through its own effort or through the effort of the mine operator the exact coordinates via a GPS unit for every water source that is scheduled to be undermined.

During the course of the third five-year Act 54 period (August 21, 2003, to August 20, 2008) the California District Mining Office should determine the exact locations via GPS units of all water sources undermined and reported as losses, contaminations, or diminutions, and it should record in the Bituminous Underground Mining Information

System both the locations and the distances to the nearest mine. If possible, the location should indicate the relationship of the sources to the gates and longitudinal panel sections (two outer 25% sections of panels, inner 50%) and the depth to mining (the overburden thickness).

Section V: Water Inflow to Longwall Mines

With respect to springs and wells that are not directly undermined, Act 54 requires the use of the 35-degree angle of hydrologic influence. Analysis contained in this study supports a fixed distance approach as opposed to a fixed angle approach. The PA DEP through the California District Mining Office should consider the application of the fixed distance findings when evaluating water supply claims.

The PA DEP should designate the basis for a determination of "no liability. If possible, a check box system should be included in Bituminous Underground Mining Information System that will allow single or multiple factors leading to the determination of "no liability."

Because the basis for the determination of "no liability" is not part of the computer record unless it happens to be mentioned in the comment section that reflects the thoughts and observations of investigators, it is recommended that PA DEP initiate a study to investigate the cause of this apparent anomaly, and to recommend changes in data acquisition or data interpretation.

The California District Mining Office hydrologists should identify and map springs that have migrated (been replaced by down-slope springs) after subsidence-induced diminution or disappearance. Such mapping will enhance analysis of groundwater changes that might have occurred as a result of underground mining.

Section VI: Effect of Mining on Structures

Pre-mining mitigation techniques to prevent or lessen potential damage caused by subsidence should be thoroughly documented.

The record of "date of first occurrence" for a subsidence-related "problem" as recorded in the Bituminous Underground Mining Information System should be the actual date of the problem's occurrence, rather than the date that a report of a problem is faxed by the mine operator to the California District Mining Office. This would make an accurate determination of the time to resolution possible.

Timing of mining with respect to structure damage should be noted in the Bituminous Underground Mining Information System.

Depth to mine should be recorded for all undermined structures.

The California District Mining Office should record distance to type of mine subsidence effect (i.e., tension, compression) to enhance the ability of investigators to quantify the effects of subsidence on structures.

The California District Mining Office should record in the Bituminous Underground Mining Information System information on architectural type of construction.

To correlate among type of construction, mitigation technique, distance to mining, type and extent of damage, timing of mining, problem identification number, structure number, and claim number, the PA DEP should devise cross-referencing identification numbers for the Bituminous Underground Mining Information System.

Section VII: Effect of Mining on Streams

The habitat, fish, and macroinvertebrate data should be gathered prior to the undermining of a stream to make possible an evaluation of changes attributable to underground mining and a determination of whether or not such changes rise to the level of impairment.

Section VIII: Effect of Mining on Wetlands

Mining companies should be required to survey properties to be undermined to identify all National Wetland Inventory wetlands that lie within the permit boundaries plus wetlands not listed in the inventory. The wetlands should be assigned cartographic locations via GPS units and mapped for their area and type.

Module 15.4d (prior Module 8 and also, Module 4 in one instance) should require an assessment of wetlands based upon standards of the National Wetland Inventory.

All six-month mining maps should show the locations and dimensions of wetlands.

All information on wetlands should be electronically stored and mapped through latest GIS software.

Wetlands should receive more attention than they have been previously given because they provide habitats for a number of organisms, including migratory birds.

Section IX: Effect of Mining on Land

Land problems that are observed in the process of other investigations should be recorded and cross-referenced with the faxed reports of land damage, making correlation of accidentally discovered land deformation possible.

Section X: Effect of Mining on Infrastructure

The PA DEP should establish a reporting protocol with public utilities and with township and county authorities that includes the cooperative exchange of specific information about subsidence. Such information should include costs of repairs or replacement and exact location of any subsidence impact.

The Pa DEP should establish a reporting protocol with the Pennsylvania Department of Transportation that will enable any future Act 54 researchers to identify the extent and specific locations of damage to Commonwealth roads.

Other Recommendations

In addition to recommendations found at the ends of certain sections within the report, the University makes the following general recommendations with regard to the reporting process.

With regard to future Act 54 reports, the University recommends that the study period take place either contemporaneously with the assessment period or at increments during the assessment period. Such an approach would expedite the completion of the report upon the termination of the assessment period. (The contemporaneous writing of the report would, at the very least, aid in the accurate mapping of features)

The University also recommends the ongoing acquisition of certain data that were required by the MOU but found to be incomplete, conflicting, confusing, or missing in the electronic file system or in paper files. (Many details not recorded but germane to resolutions of problems lie in the memories of surface subsidence agents of the California District Mining Office. The agents might forget details.)

The University recommends that baseline field studies with a consistent methodology be established for all natural entities, particularly for streams.

CONCLUSIONS

1. *Because the same kinds of entities (e.g., brick houses, first-order streams of a given gradient or geomorphologic character) undergo multiple effects and degrees of impact by subsidence, a standardized terminology for all natural and artificial entities potentially affected by underground mining is essential for a scientific assessment of the effects of mining.*
2. *Baseline studies of natural phenomena potentially affected by underground mining are essential to accurate assessments of mining's impacts. This applies, in particular, to streams, wetlands, and groundwater.*

3. *A fixed distance based on the findings of this report is more appropriate than the 35-degree angle of draw to the assignment of liability and the prediction of survivability of springs and wells.*
4. *Increased use of GPS in identifying the locations of all phenomena potentially affected by underground mining will enhance a future Act 54 report.*
5. *Longwall mining has not dewatered the near-surface (that zone tapped by most wells) ground water zone in Washington and Greene Counties even though some water source owners have lost their personal water supplies. Near-surface ground water is not reporting to longwall mines to the detriment of the zone tapped by most wells in the two counties.*
6. *Not all water diminution of the assessment period is attributable to longwall mining because droughty conditions and above-normal temperatures reduced the influx of meteoric water reporting to the ground.*
7. *The majority of undermined structures do not appear to suffer damage from subsidence.*
8. *Some streams adversely affected by underground mining can recover their use in large measure after the application of restoration techniques.*
9. *Some streams suffering from diminution of flow caused by underground mining can recover their flow without PA DEP intervention.*
10. *Wetlands are largely unaffected by longwall mining.*
11. *Impacts to infrastructure are difficult to ascertain precisely because many different government agencies (e.g., state, township) have inadequate documentation and reporting protocols.*
12. *The California District Mining Office thoroughly investigates every claim, but it has too few staff members to cover all mining related effects.*