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

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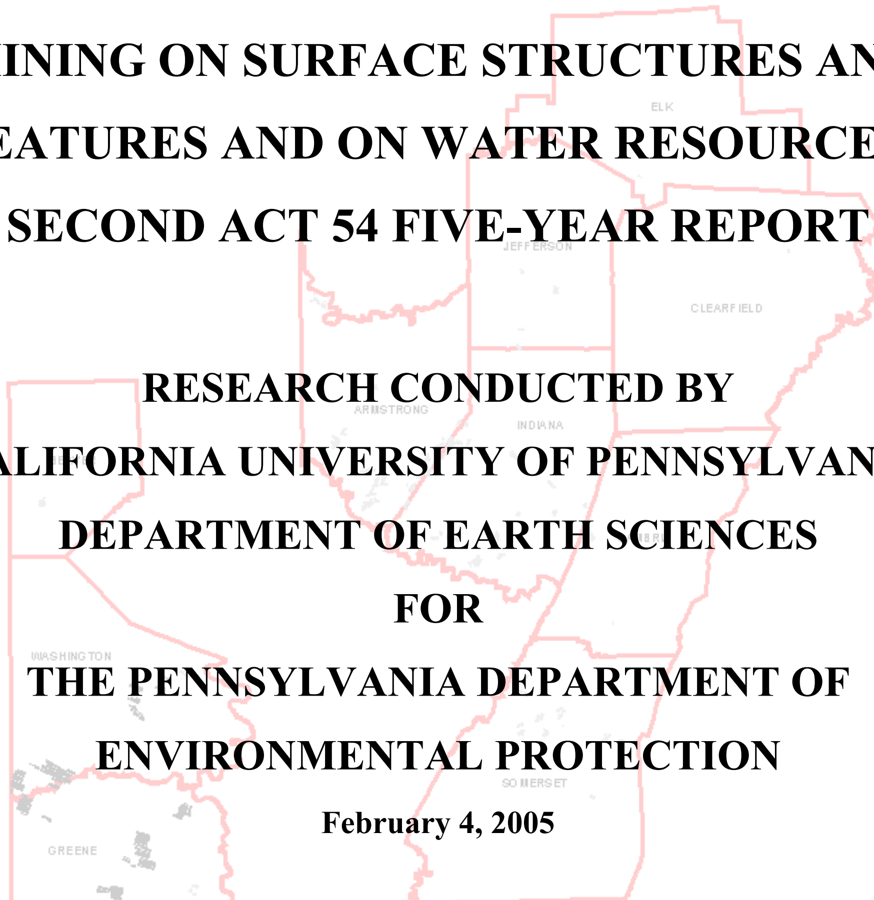

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Section XI: BRIEF SUMMARIES OF REPORTS GERMANE TO THIS STUDY

XI.A. Overview

Because the PA DEP, the Citizens Action Council, other citizen organizations, private citizens, and state legislators determined that the first five-year report for ACT 54 had shortcomings, the PA DEP produced a supplemental report (2001 Supplement). It also commissioned four studies as an outgrowth of studies conducted by the Audubon Society. These studies are 1) *Remote Sensing of Forestland above Longwall Mines,* 2) *Study of Effects of Longwall Mining on Streams, Wetlands, and Riparian Areas,* 3) *Effects of Longwall Mining on Real Property Value and the Tax Base of Greene and Washington Counties, and* 4) *Effects of Undermining Interstate Route 70 South Strabane Township, Washington County*. The MOU requires the University to summarize these studies.

This section contains brief summaries of these four reports. The University's researchers recognize that all such reports, including the present report, have shortcomings, but their charge from the PA DEP was **to summarize**, *not* to criticize the reports commissioned by the Department. Thus, the University's researchers pass no judgments on the following reports, allowing them to stand as separate entities. ***In addition, any findings or recommendations in the reviewed reports do not appear among those findings and recommendations submitted by the University's researchers. The University is NOT responsible for the methods, content, findings, and conclusions of the summarized reports.***

The summaries are presented as lengthy abstracts. They do not require a "third person" approach because they are summarized in the context of the foregoing statements. The structure of the individual reports dictates the topical units of the summaries (e.g., Purpose).

XI.B. Summary of "Remote Sensing of Forestland above Longwall Mines: Washington and Greene Counties, Pennsylvania" (Authorship: D'Appalonia)

XI.B.1. Purpose

The objective of this study was to test the application of remote sensing for evaluating the effects of subsidence caused by the longwall mining of the Pittsburgh coal seam on a forest canopy. Longwall mining panel widths typically ranged from 400 to 1,200 feet and panel lengths from 3,000 to 24,000 feet. Techniques employed included airborne multispectral scanning, satellite color infrared imagery, and airborne color infrared photography supplemented by field study. Specifically, the study explored the degree of stress on the tree canopy by examining trunk quality, crown quality, overall vigor, branch dieback, foliage transparency, and defoliation. Possible forestland impacts anticipated included soil moisture loss or gain and root damage. Subsidence has the potential to cause damage-- creation of basins, cracks, slides, scarps, root tearing, leaning of trees, changes to groundwater table. Instances of such subsidence effects were observed at panel boundaries. An earlier study in Ohio, West Virginia, and Pennsylvania examined surface soil moisture and tree growth at sites over newly-mined longwall panels and over unmined control areas and determined there to be no significant differences.

XI.B.2. Procedure

In the current study, three types of sites were selected: one that was undermined between 1995 and 1999, one undermined prior to 1995, and one that had not been undermined (control). Among the factors that influenced site selection were forest type (mixed mesophytic), extent of cover, density, condition, access, topography, soil types, location and orientation of mine panels, overburden depth, and hydrogeology. The canopies over three mines within each of the categories were selected for examination. Areas of stressed tree canopy within the study sites were identified on the imagery. Field reconnaissance at the sites was then undertaken to determine the causes of stress. The individual study sites ranged from 400 to 900 acres; the distressed sites from 1 to 10 acres; and the ground reconnaissance of tree species and causal factors approximately 1/2 acre.

After identifying areas of high canopy stress by remote sensing, the next step was to determine whether such areas could be linked to the physical dimensions of the longwall mine panels. Finally, the field reconnaissance team visited areas of predicted or identified subsidence effects. Overall crown vigor, twig or branch dieback, crown transparency, leaf defoliation, and general trunk health were considered. A search for ground disturbances (mostly ground cracks) was made at each field site.

XI.B.3. Results

The forestlands surveyed were observed to be generally healthy, and no areas in the imagery were found that indicated the presence of distinctive canopy stress along alignments of high strain. Evidence of canopy distress associated with longwall mine panel boundaries was not detected on the imagery, nor was there evidence of subsidence effects, such as ground cracks, directly affecting the trees. Evidence of insect infestations was common and showed some expectable seasonal progression.

In general, the plots of vigor rating did not indicate significant differences between undermined and control study sites. Results of the analyses around pool areas and between pools were similar for the most common tree types. Some species (black walnut and maple), however, that are more sensitive to soil moisture conditions showed lower percentages of healthy trees around subsidence pools. Slides and scarps were observed at the surface along panel boundaries with resultant root damage and tree inclination but tree canopies were still healthy.

XI.B.4. Recommendation

It is recommended that future studies retain the use of remote sensing as a preliminary investigative tool for locating areas of drainage or moisture impacts resulting from subsidence. Where canopy stress is limited to specific tree types, or to isolated subsidence features, high-resolution remote sensing can be a useful tool. Ground-based tree surveys to characterize forest health and to quantify forest canopy stresses are still necessary.

XI.C. Summary of "Study of the Effects of Longwall Mining on Streams, Wetlands, and Riparian Areas: Robinson Fork, Southern Washington County, Pennsylvania (Authorship: Earth Science Consultants, Inc.)

XI.C.1. Purpose

The principal purpose of this study was to determine and quantify the effects of longwall mining subsidence on streams, wetlands, and riparian areas within a selected valley floor setting. Secondary benefits would be the use of the results as a predictive tool and the development of an approach to monitor and mitigate such effects.

XI.C.2. Background

The stream chosen for study was Robinson Fork, a third-order stream located in West Finley Township, Washington County, Pennsylvania. The study area consists primarily of woodland, with secondary cropland and pastureland, and is underlain, in part, by Consol's Enlow Fork Mine. Pittsburgh coal was removed from the mine by the longwall method between 1995 and 1999, with the mined coal panels oriented perpendicular to the stream channel. Included in the study area are a 2,068 foot-long stream segment that had been undermined and a 3,011 foot-long segment, 2.4 miles upstream that had not been undermined. Each stream reach consists of a combination of diverse bedforms (riffles, runs, glides, and pools) that are defined by water depth, velocity, and turbulence.

XI.C.3. Procedure

Program activities included mapping of bedform features; land use mapping; stream transects; surveying of water surface and channel bottom slopes; water depth measurements; description of channel material; sediment thickness; bank heights, slopes, and materials; areas of aggradation and degradation; water velocities; water quality; riparian vegetation and wetlands studies; and fish and benthic macroinvertebrate analyses. Flora and fauna data were collected along 2,641 feet of the mined segment and along 2,756 feet of the unmined segment.

XI.C.4. Results

Most geomorphic, hydrologic, and biologic indices evaluated exhibited little or no variation between the mined and unmined segments. A significant difference, however, was found in the number and dimensions of bedforms, especially pools which tended to be longer, wider, and deeper in the mined segment. It is unlikely that the decrease in number of bedform units and their greater physical dimensions would be associated only with increases in discharge and/or other watershed factors. Other indices, including water velocity, areas of aggradation, bank degradation, thickness of pool sediments, longitudinal water and channel gradients, discharge, lateral channel morphology, and differences in stream bank erosion and deposition processes seem to be most likely related to natural factors and land use, rather than subsidence.

Some data suggest that greater slopes are characteristic between mine gates and lower gradients are associated with areas overlying gates. Loss of water (riffle) in one mined segment may be due to subsidence above a mine panel. Riffle dimensions may have increased on the downstream side of deep mine gates, and pool dimensions may have been enhanced on the upstream side of these structures.
<u>Water Quality</u>: The unmined segment was found to have higher metals concentrations (except for manganese) than the mined segment and the highest level of water hardness. The mined segment was characterized by the lowest total suspended solids, highest dissolved solids, lowest levels of turbidity, and lowest pH.

XI.C.4.a. Flora and Fauna

Floral and faunal analysis was based on "channel units" (CUs), *relatively discrete morphological stream features that are formed as the result of fluid mechanical processes and complex interactions between a stream and its surrounding watershed that occur during high flow events*. It is hypothesized that if the physical characteristics of the CUs are modified by subsidence, there may be associated effects on the stream biota. Along the unmined reach CUs show more heterogeneity of habitat, greater diversity, and more habitat complexity than along the mined reach. There are fewer CUs in the mined reach and they were, on average, longer, deeper, and wider than in the unmined reach.

XI.C.4.b Fish

Species richness and biomass data were assessed. There is an adequate range of habitat types and complexity among CUs, particularly in the unmined reach. The mean species richness in the mined reach is greater than in the unmined reach, but no significant differences were detected between CUs by reach type (e.g., pools, etc.). Fish biomass in the mined and unmined reaches was not significantly different. Hence, the direct effect of subsidence cannot be separated from other factors with regard to the fish populations.

XI.C.4.c. Benthic Macroinvertebrates

Three riffles and three pools in each study segment of Robinson Fork were examined for benthic macroinvertebrates in terms of total number of taxa, percentages of taxa, percentage of dominant taxon, and abundances of certain indicator taxa. The assemblages in pool CUs are characteristic of a eutrophic, low-order, warm water stream, and moderate impairment was found in both segments. There is uniform relative abundance between indicator groups in the mined and the unmined riffle CUs, and low diversity and few individuals in pool CUs in both the mined and unmined segments. Greater diversity was found in the mined segment than in the unmined segment. The riffle CUs in both study areas have similar diversity.

XI.C.4.d. Riparian Vegetation

The riparian zone was considered to extend 10 meters from the edge of the active channel onto the floodplain. Eleven transects, each 5 meters wide, were examined along each study area. A species was considered to be prevalent if it had more than 20% coverage within the plot. The number of plant species within the mined segment (234) was very close to the number within the unmined segment (246), while the unmined segment had a higher proportion of exotic species (25% to 17%). Generally, the prevalent tree, shrub, and herbaceous plant species were very similar in both segments. Land use, canopy cover, and riparian vegetation structure along with overall riparian vegetation community were very similar between the two reaches, with no discernable differences that could be attributed to subsidence.

XI.C.4.e. Wetlands

The wetlands contain hydric (poorly-drained) soils and wetland hydrology.
Only one significant wetlands area was found in the mined reach. This area was probably at its present location as an isolated wet area before mining, and some evidence exists that this wetland is substantially larger following subsidence (as it is in the center of a mined panel). There is no indication that jurisdictional wetland was lost because of dewatering resulting from undermining.

XI.C.5. Summary

Broad conclusions: (1) any changes due to subsidence are difficult to identify and are relatively minor, (2) the limited scope of this study precludes its use as a comparative standard to all streams underlain by longwall panels, (3) the time period of the study was too short to allow for seasonal changes and long-term effects, (4) the limited length of channel provided statistically restricted data, and (5) the paucity of pre-mining data limited comparisons.

XI.C.6. Recommendations

Approaches for mitigation and monitoring should not currently be recommended. Future studies should be broader in scope and duration, and should be performed both before and after mining. Prior to longwall mining piezometers should be installed, a program of water level measuring should be initiated, and a survey of seep and spring locations should be made. Following longwall mining, monitoring should be done on a quarterly basis. After the first year, the area should be reevaluated in the 3rd and the 5th years for long-term effects. Aerial photography should be generated before, during, and after mining.

XI.D. Summary of "Effects of Longwall Mining on Real Property Value and the Tax Base of Greene and Washington Counties, Pennsylvania" (Authorship: Resource Technologies of State College)

XI.D.1. Introduction

More than 50,000,000 tons of coal are extracted each year from deposits in Greene and Washington Counties, mostly by longwall mining of the Pittsburgh coal seam. Surface deformation (subsidence) invariably occurs as the result of the removal of longwall "panels." Such panels are typically 1,000 ft. wide and 10,000 ft. long. Greater panel widths lead to greater subsidence across a larger area, whereas panel lengths have no effect on severity of subsidence, but will increase mine efficiency and economics. No longwall panels are located under urban areas in either county, nor, for the most part, are they beneath areas of suburban development.

Act 54 of 1994 eliminates most rights that surface property owners had to the support of the underlying coal. On the other hand, it requires coal companies to compensate homeowners for damages caused by underground mining.

XI.D.2. Purpose

The purpose of this report was to determine whether any of the following exist: a relationship between longwall mining and the overall value of land parcels in these counties; the effect of longwall mining on the rate of coal extraction; the effect of rate of extraction on tax receipts; how tax revenues on longwall coal reserves, insurance claim payments, and coal company settlements offset potential property value losses; whether properties undermined by longwall operations change in value; if there are changes in property value that correlate with the opening and closing of longwall operations; and whether the announcement of future mining causes a reduction in property values.

XI.D.3. Procedure

Geographic Information Systems software (GIS) was used to relate underground mining to surface property, and every property in the counties that was undermined by longwall was identified. All surface properties were assigned to a control area, a mine area, or an "outside" area (neither mine or control). Assessed values, fair market values, and sales records of surface properties above longwall mines in Washington and Greene counties over a ten-year period were examined and compared with the same measures of surface properties in control areas. Tax roll information was obtained from both counties and coal settlements, and the insurance claims were analyzed. All sales occurring after 1995 were examined and 15,529 were considered valid (i.e., excluded were sales to family members or coal operators). All state numbered highways and areas with public sewer and water were mapped. Property tax revenues generated in the two counties from both coal extraction and coal reserves were analyzed. A correlation was assumed if the "county value" (an estimation of market value) changed and the property was undermined in the three years prior to the value change. The analysis also assumed that property owners would seek reassessment after mining had occurred.

XI.D.4. Results

Comparing sales data and county value data, found no statistically significant correlation between the presence of longwall mining and general or average property values. The percentage of sales less than county value is no higher in longwall areas than in either the control areas or the county as a whole. Of all valid sales, 2,933 (18%) sold for less than county value; 12,596 (72%) sold for more. Patterns of net gain or loss do not correlate with the location of longwall mining. In fact, the availability of services, particularly on-site sewer and water, is much more significant in determining property values than any other factor. Indeed, longwall mining may result in an increase in property values because of water lines added by coal operators and, thus, added fire protection. While values do not appear to have declined any more near longwall areas than elsewhere in the economically depressed rural areas of the counties, site specific exceptions related to water loss do occur.

There appears to be a slight negative correlation between the presence of longwall activity and county assessment value. Properties above longwall mining receive an assessment reduction at a greater frequency than the total population of properties. The relationship between appeal results and value is not consistent, nor is the relationship of appeal results and reassessment to the damages paid. Proximity to longwall operations appears to affect the counties' assessment of improved property value. Properties above longwall mining receive an assessment decrease at a slightly greater frequency, but the reduction in county value is not a significant portion of the total tax base. In fact, the total value of coal company settlements is greater then the total reduction in county values.

XI.E. Summary of "Effects of Undermining Interstate Route 70 South Strabane Township Washington County, Pennsylvania" (Authorship: GeoTDR, Inc.)

XI.E.1. Background

As underground mining occurs, caving and fracturing will be propagated upward through the rock mass. The resultant downward surface movement (subsidence) is a consequence of this progression of shearing, fracturing, and caving within the overburden. This behavior is controlled by rock mass characteristics, mine geometry, and mine face advance rate, and as subsidence occurs, the ground surface deforms into the shape of a trough that elongates as mine face advances. Outside the margins of the longwall panel, there is no subsidence.

Mine 84 Co. proposed the extraction of coal from two coal panels in the Pittsburgh coal seam by longwall mining at depths from 559 to 651 beneath Interstate-70. Longwall panels and chain pillars were planned to maximize support for the highway. P.L. 1409, as amended, provides for the establishment of a commission to hear claims of owners of mineral rights (typically coal) underlying land owned by the Commonwealth. Results of the hearing were that the owners were permitted to remove all the coal and were relieved of any responsibility or liability for any damages to the surface such removal might entail. While the Commonwealth had the right to purchase the coal in place, it was determined that the price ($40,449,024) would greatly exceed the cost for precautionary measures and subsequent repairs ($2,153,370).

XI.E.2. Purpose

GeoTDR, Inc.'s charge was to prepare a report summarizing the effects of undermining a 1.5 mile segment of I-70 in South Strabane Township, Washington Co., PA from Nov. 1999 to Oct. 2000. Included in the scope of the work were: gathering information describing transportation structures present prior to mining, precautionary measures taken before and during mining, road damage and subsidence effects after mining, costs incurred in monitoring and repair, reports of accidents possibly associated with the mining, and assessment of the accuracy of subsidence prediction techniques. Information was to be collected from a variety of sources, but principally from PennDOT. The most immediate concern was to ensure safety of the driving public during and after mining.

XI.E.3. Procedure

Among the precautionary measures taken prior to mining were the temporary support of an overpass because of a preexisting condition, dismantling of some overhead signs, the reduction of speed limits to 40 mph in places, provision for lane closures and detours, visual monitoring patrols, and real-time monitoring of ground movement. In addition, Eighty-Four Mining Co. was required to develop a subsidence control plan and a mathematically derived subsidence prediction model. An instrument package consisting of 32 tiltmeters was put in place and tied into a call-back alarm system. The predicted maximum tilt was 0.016 ft/ft, so an initial alarm level of 0.002 ft/ft was set. If the alarm was triggered, the datalogger initiated a telephone call to PennDOT personnel who were on duty 24 hours a day, 7 days a week. At that point, real time monitoring of the tiltmeters began. Based on this monitoring, officials could make a decision to alert other agencies to increase the frequency of visual monitoring to determine if lane closures were warranted. Thus, automated monitoring provided quantitative information upon which rational decisions could be made.

XI.E.4. Results

The ground surface ultimately deformed into a trough with maximum subsidence of three to five feet with surface tilting occurring around the margins of the trough. Precursor movement occurred ahead of the mine face, and outside the edges of the panel being mined. Predicted subsidence profiles, however, differed from the actual measured subsidence. As a consequence of differential tilt, ground surface, pavement and structures were subjected to greater curvature and larger curvature strain than anticipated. Buried culverts and an overpass along the undermined section of I-70 were not damaged, but longitudinal cracks developed between lanes, as did transverse bumps. This led to temporary lane closures as cracks were filled and bumps milled down. Along secondary roads, some transverse cracking occurred and the wall blocks in a railroad bridge abutment cracked and shifted. As to accidents, it was concluded that factors other than mining or construction activities were the causes of any accidents that did occur in this location during the period of interest.