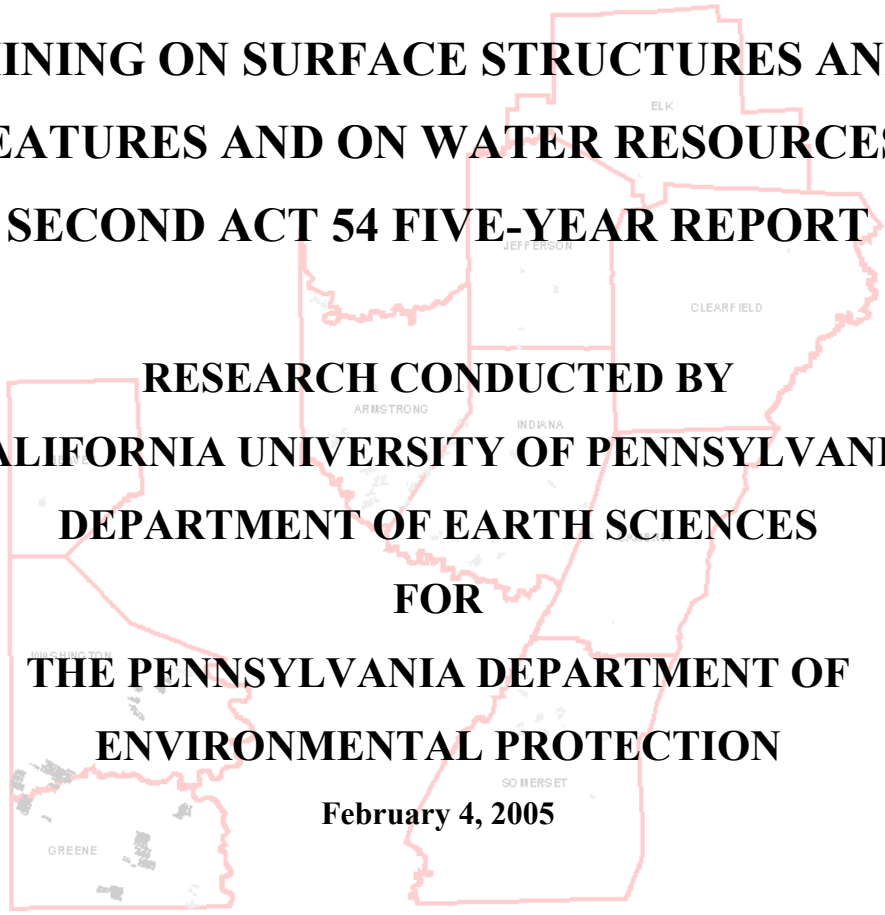
THE EFFECTS OF SUBSIDENCE RESULTING FROM UNDERGROUND BITUMINOUS COAL MINING ON SURFACE STRUCTURES AND FEATURES AND ON WATER RESOURCES: SECOND ACT 54 FIVE-YEAR REPORT



RESEARCH CONDUCTED BY

CALIFORNIA UNIVERSITY OF PENNSYLVANIA

DEPARTMENT OF EARTH SCIENCES

FOR

THE PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION

February 4, 2005

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- Plate 12 is a display of all Room-and-Pillar and Retreat mining for the study period.
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- Insets on individual plates show the entire respective county.
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- All labeling is accurate *for the time of collection*.

Plates that have the term "study period" should be interpreted as meaning the assessment period, August 21, 1998 through August 20, 2003

Section I: THE CONTEXT OF THIS REPORT

I.A. Overview

This section provides the reader with a context for the report, including the legal impetus behind the report. It also provides the reader with brief explanations of the mining processes and geology of western Pennsylvania.

I.B. The Nature of This 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 (see Plate I). The impetus for this document derives from the requirements of the amended Bituminous Mine Subsidence and Land Conservation Act, *act of April 27, 1966 (1st 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 (see IB below). Under the mandate of Act 54, the Pennsylvania Department of Environmental Protection (hereafter PA DEP or the Department) must issue a report on the complex effects of underground mining during five-year increments. This document is the second such report.

This report is also an outgrowth of the first, a document that was supplemented after its initial release in June 1999. Because the effects of mining vary in degree and intensity with geological, hydrological, and demographic circumstances, such a supplement was almost inevitable as citizens voiced unanticipated concerns during a public meeting on the report. Pennsylvania's mines are numerous and widespread, underlying segments of a 10,000 square-mile area. The consequence of having numerous mines over such an extensive region is great complexity. Natural and human interrelationships with mining activities abound. Also, not all information germane to mining is available universally. Some information is proprietary and other information is restricted because of litigation. In addition, some consequences of bituminous underground mining remain either undocumented or poorly documented at the time of this writing, making a complete inventory and analysis of all effects beyond reach.

I.C. Requirements of the Amended Bituminous Mine Subsidence and Land Conservation Act of 1966

When in its Session of 1994, the General Assembly of the Commonwealth of Pennsylvania amended a 28-year-old act designed to protect public health, welfare and safety by regulating the underground mining of bituminous coal, it addressed a broad spectrum of mining related issues, including the process of permitting mining activities and compensating surface landowners for losses incurred as a result of the underground mining of bituminous coal. The 1994 amendments to the Bituminous Mine Subsidence and Land Conservation Act (hereafter, BMSLCA), known as Act 1994-54 or commonly as Act 54, provide "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 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. Under the provisions of the act, the PA DEP is also required to present these data and analyses in reports.

Although the Department is responsible for data 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. The Department is required to present any relevant findings to the Governor, the General Assembly, and to the Citizens Advisory Council of the Department at five-year intervals. In making its report, the Department or its designated research entity is not empowered to elicit additional information or data from a mine operator, except for reports on all water loss incidents or claims of water loss.

I.D. Memorandum of Understanding between the Department of Environmental Protection and California University of Pennsylvania

Under the conditions of a memorandum of understanding (hereafter, MOU) between the PA DEP and California University of Pennsylvania (hereafter, the University) that commenced on March 22, 2004, the University agreed to provide the Department with a report on and an analysis of information contained in underground mine permit applications, monitoring reports, enforcement records and data submitted by mine operators for purposes of determining, to the extent possible, the effects of underground mining on subsidence of surface structures and features and on water resources. The report prepared under this MOU focuses primarily on mining-related effects that occurred in the bituminous coal fields during the period 21 August 1998 to 20 August 2003 (hereafter, the "assessment period"). Secondarily, the report covers some effects tangential to this period. The report, additionally, addresses certain concerns that were left unresolved in the report prepared by the PA DEP for the previous five-year assessment period. The Department is responsible for distributing the report to the Governor, the General Assembly, and the Citizens Advisory Council and for posting the final report on the Department's Web site.

Under the terms of the MOU the University acquired the services of consulting professionals recognized in the field for performing all analytical work in conjunction with the University staff. Specialists in stream ecology and in wetlands assessed as many streams and wetlands as could be observed between 22 March 2004 and 28 August 2004 (hereafter, the "study period," as distinguished from the "assessment period" defined above).

I.E. Coal Caucus of the General Assembly Sponsored Meeting of 8 February 2000

After the publication of the first five-year Act 54 report in June 1999, the Coal Caucus of the General Assembly convened a meeting in Belle Vernon, Pennsylvania, to discuss the implications and nature of the report. Those present at the meeting raised a number of concerns about both the report and mining's effects on surface features and water resources. In an attempt to address those concerns, the PA DEP produced in February

2001 a supplement to the first report. One of those concerns was that the Department had produced a report through its own efforts, a process that was perceived to limit the veracity of the report *regardless of its level of objectivity*. Because Section 18.1 (see section I.A above) authorizes the use of an outside entity to conduct research on coal mining's effects, the Department entered into the MOU with the Department of Earth Sciences of the University (see section I.C above) to enlist the efforts of professionals with no affiliation to the PA DEP.

The University's Act 54 research team for the second five-year Act 54 assessment period attempts in this report to address many of the concerns raised by participants in the 8 February 2000 Coal Caucus meeting. To do this, the researchers provide analyses, rather than mere tabulations of data. Given the limited study period (160 days) under which the research for this report had to be completed, the resultant product introduces information that bespeaks the need for further research and analysis. Nevertheless, this research into the effects of coal mining results in numerous findings about the effects of underground coal mining on surface features, processes, and water resources.

I.F. Brief Statement on Mining Methods and Their Effects on Natural and Artificial Surface Features and Processes

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 thick 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 workings.

I.G. Brief Statement on the Surface Effects of Mining

Although mining can occur hundreds of feet below the surface, it can alter the surface through a process called subsidence. Both full-retreat and longwall mining remove all support for the overburden immediately above the mined sections. The effect of such mining is a collapse of the overburden into the cavity left behind when the coal is removed. At the surface, the collapse translates into a sometimes-contemporaneous subsidence of Earth's surface over the longwall panel or full-retreat mine; lagging subsidence occurs over a period of just a few years on average. Subsidence above room-and-pillar mines, by contrast, usually, but not necessarily, lags for long periods behind the extraction of coal; instances of subsidence over room-and-pillar mines can occur many decades after coal extraction.

Diagrammatic models can generally characterize the effects of underground mining, but subsidence varies with mine method, mine depth, and overburden rock type. The surface above a longwall panel, for example, often subsides in an elliptical pattern that extends beyond the area immediately above the extracted coal. Along the boundary of the ellipse, tension (a pulling apart) causes cracks or fractures as the ground slumps toward the center of the panel, whereas in the central long axis of the ellipse, compression (a coming

together) forces the ground to compact. The cracks can continue through roads, driveways, and buildings, causing minor to extensive damage. Compression can cause bumps to form, damming streams when they run transversely to stream flow and heaving structures from their ordinary elevations. These and other effects are described in the first Act 54 report. The effects of subsidence are also exacerbated by land use. A seemingly empty field might have a subsidence-affected stream, spring, well, gas pipeline, or wetland. Dwellings and outbuildings can be affected, as well as roads, railroads, and power lines. In short, any surface feature or process that overlies a mine can potentially suffer a subsidence-related impact, and any economic entity overlying a mine can potentially suffer a change in value.

I.H. Primer on Mining and Subsidence in the First Act 54 Report (1999)

Although a comment in the Coal Caucus meeting mentioned above criticized the first Act 54 report because it contained more words devoted to a "primer" on mining and subsidence than those devoted to the reportable data on mining's effects during the assessment period, the University believes that the primer in that document serves a continuous public need. As mining progresses beneath properties and communities that escaped the effects of subsidence during the centuries-long era of coal mining, new groups, and even new generations, of citizens will encounter the effects of subsidence.

Because that primer now exists and is available through the PA DEP, this report includes primers on methodologies and on analyses where such information serves the purpose of explaining a particular set of data, findings, results, analyses, or conclusions. There is, for example, an explanation of the geohydrological conditions in southwestern Pennsylvania in section V of this report. The primer of mining and subsidence found in the first Act 54 report serves as the primer for this report and provides most of the context needed to understand this report. However, to expedite the reading of this report for those unfamiliar with mining, the University presents a few cursory notes on mining in the following. (Those familiar with mining need not peruse the following).

Western Pennsylvania is a region of layered sedimentary rocks (rocks composed of naturally cemented particles of other rocks, precipitated salts, and organically produced materials, such as the woody tissue of plants) that formed prior to 245 million years ago. Inter-layered with strata of sandstones, siltstone, limestone, and shale are the coal seams that lie at various depths. The layers of rocks are generally horizontally oriented, but they also show dip, or tilt, in one direction or another like the pages of a book whose spine lies upon another book. They can also show warp, or folding, like a flat-lying ream of paper with a coin, or coins, beneath it, or like a ream supported only along its edges, causing a sag in the middle. The coal seams mimic the orientation of the sedimentary rocks around them.

Wherever these coal seams are thick and extensive, mine operators can extract the coal through the longwall mining method, a procedure whereby the operators remove segments of coal from a progression of panels, each hundreds of feet wide by thousands of feet long. Wherever the coal seams are thin and wherever support is required between longwall panels, operators employ the room-and-pillar method of extraction. In such a method, coal is removed in "rooms" but not from the supporting columns of coal called pillars or stumps.

Removal of a coal seam in part or whole means the removal of support for overlying rock strata. Without support, the layers collapse into the cavity that is left by the extraction of coal. The collapsing strata, however deep, affect the surface rock and soil, displacing them from their previous supported orientation. The ground surface can sink, or subside, and it can also heave. Subsidence, as the process is called, is complex, producing both upward and downward movements of surface material, including the natural and artificial entities on the surface, such as streams and houses.

Subsidence produces tensional forces as a zone above a longwall panel, for example, sags toward the middle of the panel, "stretching" the ground along the perimeter of the zone, tilting it toward the center and opening cracks in it. It can produce compression forces as

well. Ground that pulls apart in one place causes ground to come together in an adjacent place. Such compression produces "bumps."

The effects of subsidence are both apparent and hidden. A tilted and displaced house is easy to see. Displaced ground water is usually not apparent except as it affects the flow of a stream whose water it supplies. The displaced ground water is, however, detected by the homeowner who suffers a diminution or depletion of his or her well water.

When mine subsidence generates a negative impact in the eyes of the surface owner or state agency in charge of the surface entity (e.g., stream), Act 54 provides the mechanism for restitution to the owner or for restoration of the natural entity. As stated above, a more comprehensive explanation of mining and subsidence can be found in the "primer" of the first Act 54 report.

I.I. Regional Geological and Hydrological Contexts of the Study Area

The report evaluates geologic conditions in mined areas to identify factors that increase the probability of subsidence-affected springs and wells. It presents findings on these. In general, Pennsylvania has ground water and surface water. Ground water is present in vertical and sub-vertical rock fractures (joints) and in pores within individual rock units. Surface water is present in springs (the surface release point of ground water), streams, and wetlands. In the region of the longwall mines of Washington and Greene counties, the sedimentary rocks are highly indurated (hardened, composed of well cemented sedimentary grains), making them less likely to contain water between individual sedimentary grains (intergranular water), whereas in the vicinity of most room-and-pillar mines that lie northeast of the longwall mines the rocks are more likely to contain intergranular water as well as water in fractures. Exceptions occur. The Carmichaels Formation, for example, is an unconsolidated sedimentary deposit that is composed of poorly sorted clays, silts, sands, and gravels up to 80 feet in thickness. The formation can be water-bearing, and it lies in the uplands along the reaches of the Monongahela River and its tributaries.