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GEOLOGICAL SURVEY CIRCULAR 747

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Environmental Geology, Allegheny County and Vicinity, Pennsylvania—Description of a Program and its Results

Prepared in cooperation with The Appalachian Regional Commission

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By Reginald P. Briggs

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Summary description of geologic and hydrologic studies

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Environmental Geology, Allegheny County and Vicinity, Pennsylvania—Description of a Program and its Results

By REGINALD P. BRIGGS

ABSTRACT

Past land-use practices, including mining, in Allegheny County, Pa., have resulted in three principal environmental problems, exclusive of air and water contamination. They are flooding, landsliding, and subsidence over underground mines. In 1973, information was most complete relative to flooding and least complete relative to landsliding.

Accordingly, in July 1973, the U.S. Geological Survey (USGS) and The Appalachian Regional Commission (ARC) entered into an agreement by which the USGS undertook studies chiefly aimed at increasing knowledge of landsliding and mine subsidence relative to land use, but having other ramifications as well, as part of a larger ARC "Land-use and physical-resource analysis" (LUPRA) program. The chief geographic focus was Allegheny County, but adjacent areas were included in some investigations.

Resulting products, exclusive of this report, are:

1. Forty-three provisional maps of landslide distribution and susceptibility and of land modified by man in Allegheny County, 1:24,000 scale, 7½-minute quadrangle format, released to open files.
2. Four USGS Miscellaneous Field Studies (MF) maps of Allegheny County showing (a) bedrock, MF–685A; (b) susceptibility to landsliding, MF–685B; (c) coal-mining features, MF–685C; and (d) zones that can be affected by flooding, landsliding and undermining, MF–685D; all at the scale of 1:50,000.
3. Two MF maps showing coal-mining activity and related information and sites of recorded mine-subsidence events, and one MF map classifying land surface by relative potentiality of mine subsidence, in Allegheny, Washington, and Westmoreland Counties, Pa., at a scale of 1:125,000—MF–693A through MF–693C.
4. A companion report to the Allegheny County map of susceptibility to landsliding—USGS Circular 728.
5. Five MF maps, largely in chart form, describing interaction of the shallow ground-water regime with mining-related problems, landsliding, heavy storm precipitation, and other features and processes, largely in Allegheny County—MF–641A through MF–641E.

Map products are directly applicable to general classification of land for susceptibility to landsliding and mine subsidence and, to a lesser extent, flooding and engineering characteristics. The hydrogeologic charts enable greater understanding of environmental effects of ground water. All products are guides to expected conditions, but none are substitutes for detailed investigations of specific sites by competent technical personnel on the ground.

Specific results and findings are:

1. Knowledge of susceptibility to landsliding in Allegheny County now is adequate for application to countywide land-use planning.
2. About 110 mi^2 (285 km^2), or 15 percent, of the county has some significant degree of susceptibility to landsliding.
3. Although a general classification of land in Allegheny, Washington, and Westmoreland Counties relative to mine-subsidence incidents was prepared, data are wholly inadequate for even moderately precise prediction of subsidence events over previously mined-out areas; the accumulation of adequate data might not repay the effort in terms of damage prevention.
4. Commonwealth-of-Pennsylvania regulations have been very successful in limiting mine-subsidence damage over areas mined after 1966.
5. Undermining and consequent subsidence may have affected the ground-water regime more widely than heretofore believed.

Except for the earth-disturbance inventory that resulted in the maps of susceptibility to landsliding and man-modified land, methods used in the studies largely were conventional. The inventory and ensuing analysis combined aerial photographic interpretation with field work and incorporation of existing data. The method worked very well for the purposes of defining distribution of landslides and areas having different susceptibilities to landsliding. However, if susceptibility to landsliding alone had been the goal, this could have been determined adequately by using photographs at smaller scales and appreciably less expenditure of effort per unit of ground area.

THE SETTING

Allegheny County (fig. 1), centered around Pittsburgh, Pa., has become over the last two centuries one of the important industrial centers of the United States, largely because of an original abundance of environmental resources: rivers and streams for transportation and water supply, timber for construction material, fuel and charcoal for the early iron furnaces, iron ore and limestone for the iron and steel industry, coal for fuel and coking, oil and gas, and others. These resources strongly counterbalanced the unfavorable configuration of the land surface, which is characterized by streams flowing in narrow steep-sided valleys at levels commonly 300 feet and locally more than 600 feet below intervening ridges, each ridge about the same height as its neighbor. In the early days of development, accessible flat-lying land therefore was limited to narrow flood plains, and these soon largely were preempted by industry for access to water power, water supply, and water transportation, and by railroads for access to industry and because of grade requirements. Residential and, to some extent, commercial development thus was forced to occupy adjacent slopes. This restricted condition prevailed until about 1900, but thereafter, development also spread along ridge crests, largely because of the trolley and the automobile which made the uplands generally and economically accessible.

Allegheny County today (1975) retains the impress of this topographically controlled development, for the majority of the county's 1,600,000 people still live and work in congested valleys or on their slopes. Ridge-top areas, however, also are widely developed, largely for low-density residential uses, particularly in the east and south. By U.S. Bureau of Census definition, about 430 mi² (1,114 km²) (60 percent) of the county's 728 mi² (1,886 km²) were considered urbanized in 1970 (fig. 2).

Of the original resources, rivers and streams remain, although modified extensively by locks, dams, and other works and affected by urban

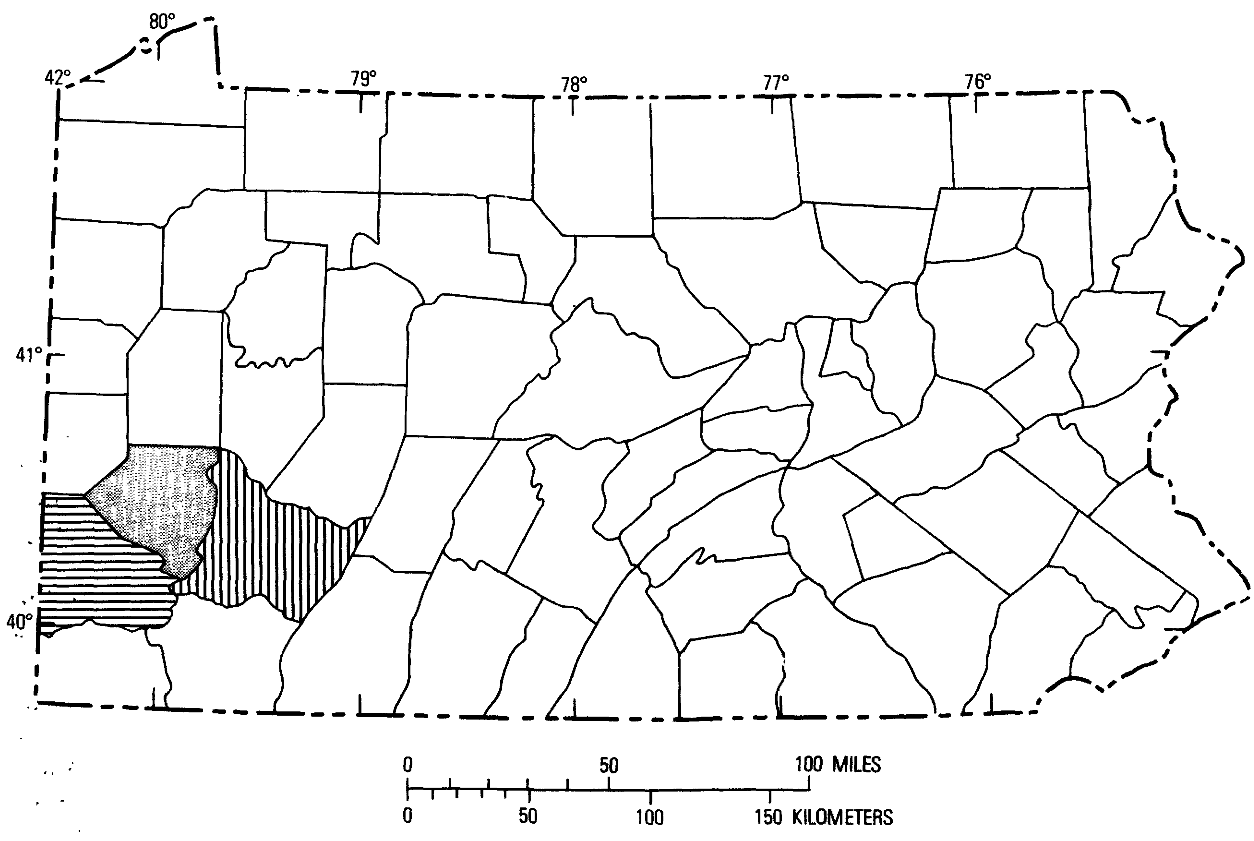

FIGURE 1.—County-outline map of Pennsylvania: Allegheny County is shown in gray, Washington County is indicated by horizontal lines, and Westmoreland County by vertical lines.

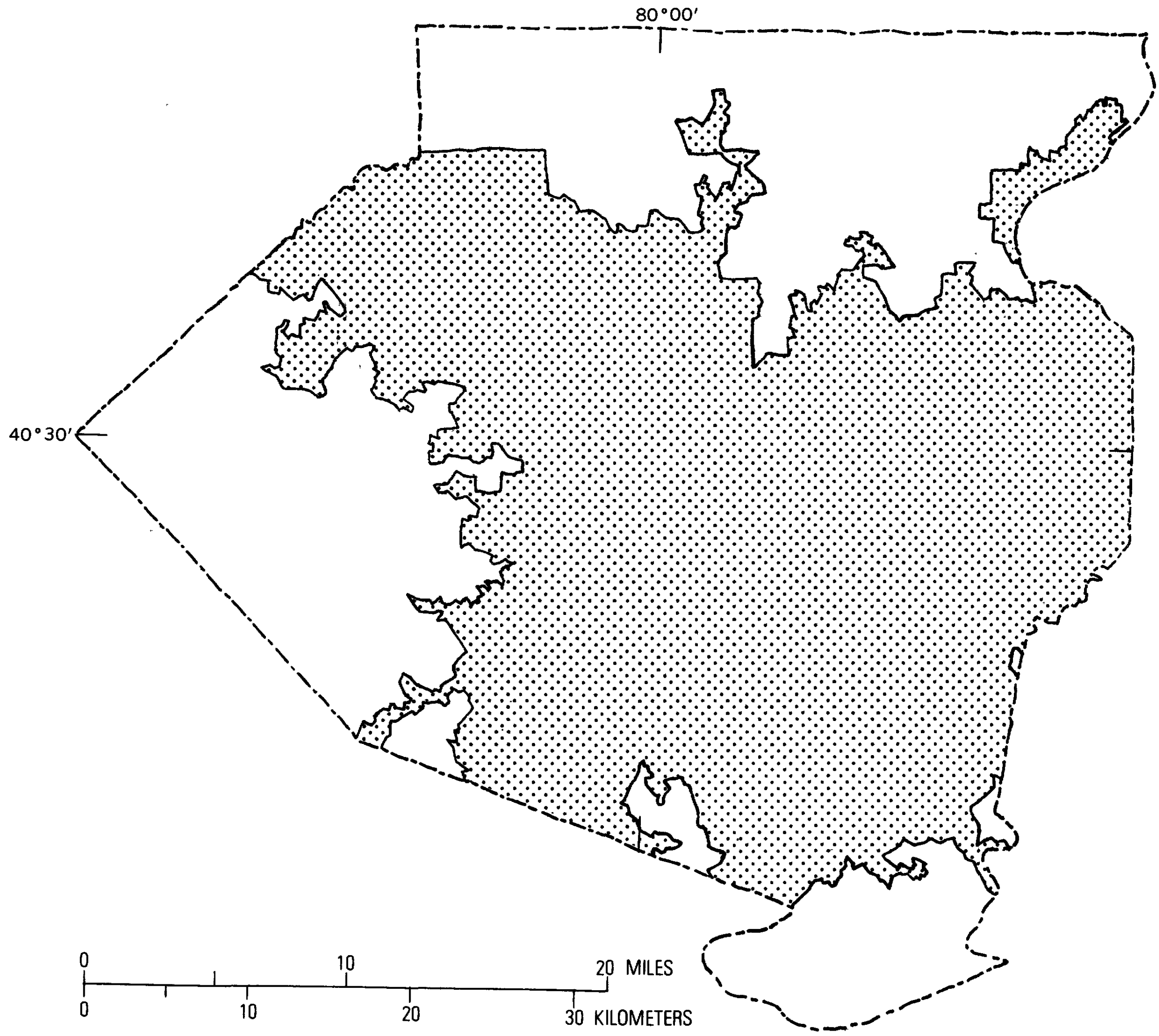

FIGURE 2.—Area urbanized in 1970, Allegheny County, Pa. Adapted from U.S. Department of Commerce, Bureau of Census.

and industrial contamination. Timber as an economic resource has disappeared from the county, although the lumber industry remains active elsewhere in western Pennsylvania. Local iron ore long has been supplanted in the area's iron and steel industry chiefly by ore from the Lake Superior region, and most limestone now is brought in by river barges. Coal has been mined out in much of the county, mostly underground but also by surface mining, although significant coal production still can be expected for some years, and coal in adjacent areas probably will be sufficient for power and industrial needs for many decades. Western Pennsylvania was the birthplace of the oil and gas industry, but production has not met local requirements for many years.

The legacies of two centuries of development are many. On the positive side is a varied, vital society, relatively stable in population, having established institutions and a broad economic base. Negative aspects include environmental problems. The consensus of the scientific and technical community of the region is that the principal problems of the physical environment, exclusive of urban and industrial contamination of air and water, are flooding, landsliding, and "mine subsidence," that is, surface subsidence due to underground mining. Other problems are mine-water discharge, effects of surface coal mining, foundation conditions, water supply, waste disposal, shortages of construction aggregates and other resources, and redistribution of earth materials during development.

PURPOSE AND SCOPE OF THIS REPORT

In planning the present series of studies, two basic questions, therefore, were raised. What areas of geologic and hydrologic knowledge were most needed to address the principal problems perceived? Which of these areas of deficient knowledge could be improved in a relatively short time, considering available manpower and support?

In early 1973, answers to the first question were: knowledge of flooding and areas susceptible to flooding was generally well advanced, due chiefly to work by the U.S. Army Corps of Engineers, the National Weather Service, and existing USGS hydrologic programs; knowledge of susceptibility to countywide landsliding was wholly inadequate for application to improved land-use planning; knowledge applicable to amelioration of the problem of surface subsidence over underground coal mines was fairly complete in some aspects and in others lacking or inadequate.

In response to the second question, it was decided to concentrate on landsliding, and to conduct the studies so that they applied to other problems as well.

This report describes and summarizes results of the studies, now complete, and their geologic and hydrogeologic products that are elements of the larger USGS contribution to a broad Appalachian Regional Commission (ARC) "Land use and physical resource analysis" (LUPRA) program; product applications are also discussed. USGS reports described herein contribute to ongoing USGS research on environmental problems of the greater Pittsburgh region, an area that includes Allegheny County and five adjacent counties.

The principal geographic focus of the USGS-LUPRA studies was Allegheny County, but three map products also include Washington and Westmoreland Counties (fig. 1), and results of other studies in Allegheny County also have broader application.

LIST OF FINAL REPORTS

The prime results of this effort have been published separately; the reader should treat these geologic and hydrogeologic products as appendices to this report. Maps are symbolized in black and white, allowing users to emphasize distinctions important to their purposes by adding colors. When ordering reports, references must be made to USGS series and number, for example, Miscellaneous Field Studies Map MF-641B. They may be acquired at the indicated prices from:

Branch of Distribution
U.S. Geological Survey
1200 South Eads Street
Arlington, Virginia 22202

Summary of the hydrogeologic regime as related to environmental characteristics, Allegheny County, Pennsylvania, by Seymour Subitzky. 1975. USGS Misc. Field Studies Map MF–641A. $0.75

Hydrogeologic framework and generalized shallow ground-water circulation system, Allegheny County, Pennsylvania, by Seymour Subitzky. 1975. USGS Misc. Field Studies Map MF–641B. $1.50.

Mining and related problems of the shallow hydrogeologic regime, Allegheny County, Pennsylvania, by Seymour Subitzky. 1975. USGS Misc. Field Studies Map MF–641C. $0.75

Heavy storm precipitation and related mass movement, Allegheny County, Pennsylvania, by Seymour Subitzky. 1975. USGS Misc. Field Studies Map MF–641D. $0.75

Some aspects of water quality as affected by land use in McLaughlin Run and Painters Run basins, Allegheny County, Pennsylvania, by Seymour Subitzky. 1975. USGS Misc. Field Studies Map MF–641E. $0.75

Maps of rock types in bedrock of Allegheny County, Pennsylvania, by W. R. Kohl and R. P. Briggs, 1975. 1:50,000 scale. USGS Misc. Field Studies Map MF–685A. $1.50

Map of susceptibility to landsliding, Allegheny County, Pennsylvania, by J. S. Pomeroy and W. E. Davies. 1975. 1:50,000 scale. USGS Misc. Field Studies Map MF–685B. $1.50

Map of coal-mining features, Allegheny County, Pennsylvania, by W. E. Davies, J. S. Pomeroy, and W. R. Kohl. 1976. 1:50,000 scale. USGS Misc. Field Studies Map MF–685C. $1.50

Map of zones where land use can be affected by landsliding, flooding, and undermining, Allegheny County, Pennsylvania, by R. P.

Briggs, and W. R. Kohl. 1975. 1:50,000 scale. USGS Misc. Field Studies Map MF–685D. $1.50

Map showing depth to the Pittsburgh coal bed, mining activity and related surface subsidence, Allegheny, Washington, and Westmoreland Counties, Pennsylvania, by K. O. Bushnell. 1975. 1:125,000 scale. USGS Misc. Field Studies Map MF–693A. $0.75

Maps showing depths to the Upper Freeport coal bed, mining activity, and related surface subsidence, and the Redstone coal bed mines, Allegheny, Washington, and Westmoreland Counties, Pennsylvania, by K.O. Bushnell and J. R. Peak. 1975. 1:125,000 scale. USGS Misc. Field Studies Map MF–693B. $0.75

Map showing areas that correlate with subsidence events due to underground mining of the Pittsburgh and Upper Freeport coal beds, Allegheny, Washington, and Westmoreland Counties, Pennsylvania, by K. O. Bushnell. 1975. 1:125,000 scale. USGS Misc. Field Studies Map MF–693C. $0.75

Landsliding in Allegheny County, Pennsylvania, by R. P. Briggs, W. E. Davies, and J. S. Pomeroy. 1975. USGS Circular 728. Free on application.

Environmental geology, Allegheny County and vicinity, Pennsylvania—description of a program and its results by R. P. Briggs. 1977. USGS Circular 747 (the present report). Free on application.

OPEN-FILE REPORTS

In addition to published reports, 43 maps of landslide susceptibility and man-modified land have been released in open file. Although data from these maps are included in published maps MF–685B and MF–685C, the open-file maps constitute sources of somewhat more complete and detailed information chiefly owing to their larger scale, 1:24,000 (1 in.=2,000 ft; 1 cm=240 m) as opposed to 1:50,000 (1 in.=4,170 ft; 1 cm=500 m), the scale of the final Allegheny County maps.

The open-file maps are available for public inspection and copies may be purchased at cost of reproduction from:

Department of Works
County of Allegheny
County Office Building, 5th floor
Forbes Avenue and Ross St.
Pittsburgh, Pennsylvania

In addition, the open-file maps may be inspected at:

U.S. Geological Survey Library
National Center
12201 Sunrise Valley Drive
Reston, Virginia 22092

The open-file landslide-susceptibility maps and land-modified-by-man maps include all of Allegheny County and immediately adjacent parts of neighboring counties. They were prepared on the 7½-minute-quadrangle format and are listed below alphabetically by quadrangle. The columns on the right list the open-file serial numbers for maps of the subjects. Authorship is shown by initials: William E. Davies—WED; John S. Pomeroy—JSP. Locations are shown on the index to 7½-minute quadrangles (fig. 3).

AERIAL PHOTOGRAPHS

Aerial photographs were found to be of significant value in the earth-disturbance inventory. As an example of their resolution, outdoor tennis and basketball courts are readily identified and differentiated by their line patterns. Details concerning the photography obtained specifically for the inventory are:

Project number (series): GS–VDGY.

Exposures and dates: 988 exposures made on April 14, 1973; 31 exposures made on May 6, 1973; 79 exposures made on December 3, 1973; total number of exposures required for stereoscopic coverage of Allegheny County and immediate vicinity—1,098.

Flight height above mean ground level: 6,000 ft (1,830 m). Nominal scale of contact prints: 1:12,000 (1 in.=1,000 ft; 1 cm=120 m).

Film: Panchromatic black and white

Information on acquiring series GS–VDGY photography is available from:

National Cartographic Information Center
U.S. Geological Survey
National Center
Reston, Virginia 22092

THE U.S. GEOLOGICAL SURVEY-APPALACHIAN REGIONAL COMMISSION INTERAGENCY AGREEMENT

The USGS participation in the ARC–LUPRA program is based on an interagency agreement

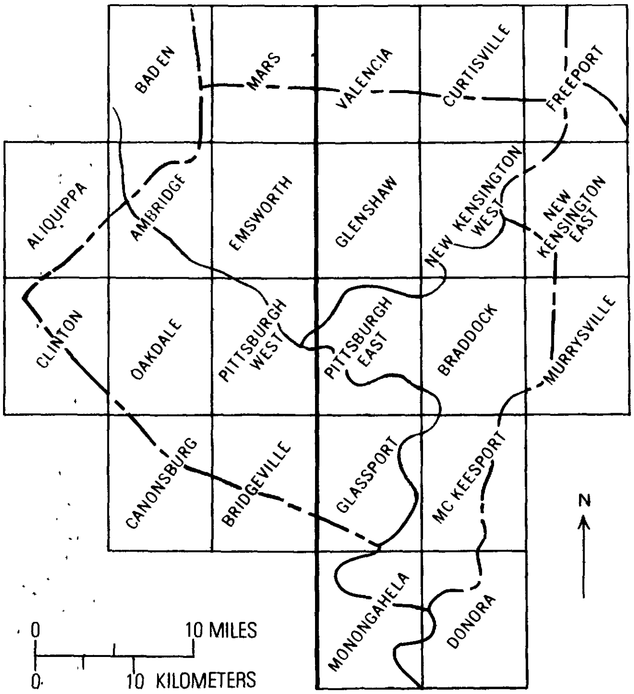

FIGURE 3.—Index to 7½-minute quadrangle maps, Allegheny County, Pa.

7½-minute quadrangles	Open-file numbers: Landslide susceptibility map	Open-file numbers: Land-modified-by-man map
Aliquippa (part of)—JSP ----	74-120 (both subjects on one map)	
Ambridge—JSP -------------	74-76	74-74
Baden (part of)—JSP --------	74-121 (both subjects on one map)	
Braddock—WED -------------	74-273	74-285
Bridgeville (part of)—WED --	74-274	74-286
Canonsburg (part of)—WED --	74-275	74-287
Clinton (part of)—JSP ------	74-234 (both subjects on one map)	
Curtisville (part of)—WED --	74-276	74-288
Donora (part of)—WED -----	74-277	74-289
Emsworth—JSP -------------	74-75	74-73
Freeport (part of)—WED ----	74-278	74-290
Glassport—WED ------------	74-279	74-291
Glenshaw—JSP --------------	74-118	74-119
Mars (part of)—JSP ---------	74-114	74-115
McKeesport—WED ----------	74-280	74-292
Monongahela (part of)—WED-	74-281	74-293
Murrysville (part of)—WED --	74-282	74-294
New Kensington East (part of)—WED ----------	74-283	74-295
New Kensington West—WED -	74-284	74-296
Oakdale—JSP ---------------	74-232	74-233
Pittsburgh East—JSP --------	74-229	74-231
Pittsburgh West—JSP -------	74-228	74-230
Valencia (part of)—JSP -----	74-116	74-117

(ARC contract No. 74–31) dated July 13, 1973, aimed chiefly at improving management of land resources in Allegheny County but also applicable to other areas in Pennsylvania and, to a lesser extent, West Virginia and Maryland. Work agreed upon was grouped into four discrete classes, as follows.

1. Geologic studies:
   (a) Earth-disturbance inventory and ananlysis of susceptibility to landsliding Allegheny County, Pa.
   (b) Maps showing underground coal-mining activity that can relate to surface subsidence, Allegheny, Washington, and Westmoreland Counties, Pa.
   (c) Integration of results of the geologic studies with existing data and summary of geologic and hydrogeologic results (this report).
2. Hydrogeologic studies:
   (a) Reconnaissance appraisal of the role of shallow groundwater in mining and slope-stability problems in Allegheny County, Pa., including problems associated with periods of intense precipitation such as accompanied tropical storm "Agnes" in June 1972.
3. Topographic studies:
   (a) Topographic map of the Monongahela River basin, Pennsylvania, West Virginia, and Maryland (fig. 4); 6 sheets, scale, 1:250,000.
   (b) Satellite-image mosaic of the Monongahela River basin, Pennsylvania, West Virginia, and Maryland (fig. 4); 1 sheet, scale, 1:250,000.
   (c) Slope maps.
      (i) Monongahela River basin, Pennsylvania, West Virginia, and Maryland (fig. 4); 24 maps, 4 maps of each of 6 sheets necessary to cover the basin showing different slope zones, steeper and gentler than (1) 8 percent, (2) 15 percent, (3) 25 percent, and (4) 36½ percent [20 degrees], scale, 1:250,000.
      (ii) Allegheny County, Pa., 4-zone (gentler than 8 percent, 8 to 16 percent, 16

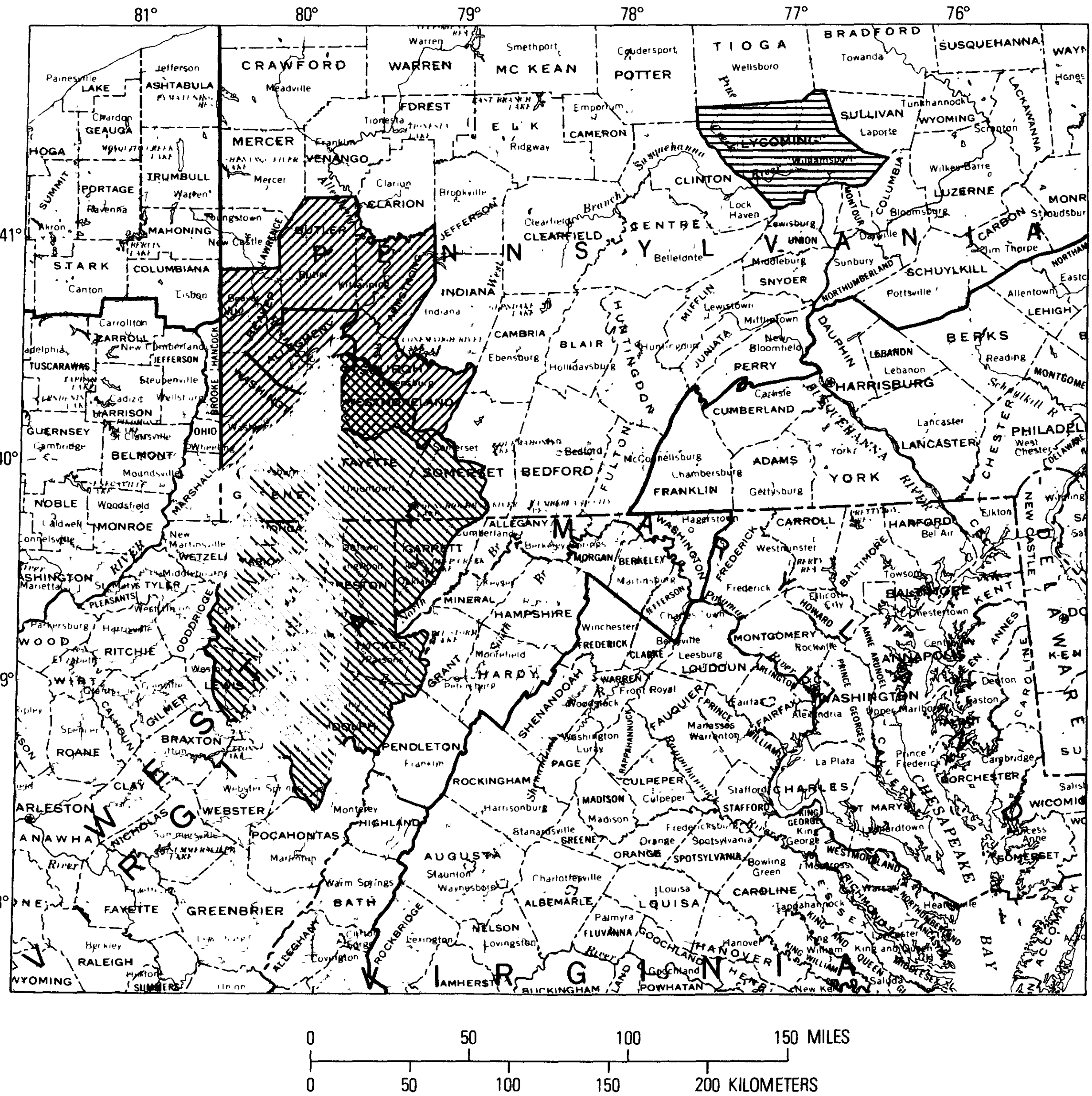

FIGURE 4.—Map of parts of Pennsylvania, West Virginia, Maryland, and adjacent States showing areas covered by ARC-LUPRA topographic, slope, and land-use work elements. The Monongahela River Basin is shown by northwest-southeast diagonal lines; the Greater Pittsburgh region by northeast-southwest diagonal lines; Allegheny County is outlined within Greater Pittsburgh region; Lycoming County is shown by horizontal lines.

to 25 percent, steeper than 25 percent) slope maps of the 23 7½-minute quadrangles that include Allegheny County (figs. 3 and 4), scale, 1:24,000.

(iii) Lycoming County, Pa. (fig. 4); 2 sheet 5-zone (gentler than 8 percent, 8–12 percent, 12–20 percent, 20–36½ percent [20 degrees], and steeper than

36½ percent) slope map, scale, 1:50,000.

4. Land-use studies:
   (a) Land-use maps
      (i) Greater Pittsburgh region, Pennsylvania (fig. 4); 26 black-and-white open-file sheets, scale, 1:50,000; and one all-inclusive multicolor sheet, scale, 1:125,000.
      (ii) Lycoming County, Pa. (fig. 4); two multicolor sheets, scale, 1:50,000.
   (b) Land-use-change map, 1969–73, Allegheny County, Pa. (fig. 4); four black-and-white open-file sheets, scale, 1:50,000.

Detailed description and discussion of topographic and land-use maps are beyond the scope of this report. Further information on these products is available from:

National Cartographic Information Center
U.S. Geological Survey
Reston, Virginia 22092
and
The Appalachian Regional Commission
1666 Connecticut Avenue, N.W.
Washington, D.C. 20235

OTHER PARTICIPANTS IN THE APPALACHIAN REGIONAL COMMISSION'S LAND-USE AND PHYSICAL-RESOURCE ANALYSIS PROGRAM

Department of Planning and Development, County of Allegheny (ACDPD).—Contributions of the ACDPD include: Analysis of previous landslide history, experience, and costs; analysis of previous governmental action in controlling development of areas susceptible to landsliding and other physical hazards; analysis of existing ordinances and preparation of model land-use-control ordinances; education of the public concerning landsliding and other hazards; and encouragement of adoption of land-use-control ordinances by local jurisdictions.

Center for the Study of Environmental Policy, the Pennsylvania State University (PSEP).—Until recently there has been available little systematized information on the perceptions of needs for geological data on the part of planners and decision makers in southwestern Pennsylvania. The PSEP work was designed to supply such information by a program of extensive interviews and mailed questionnaires, coupled with computer analysis of responses. The results are applicable to the ACDPD–LUPRA program as well as to the problem of effective dissemination of environmental information by the USGS and others. Study results were reported in detail to the ARC and have been briefed in a summary report titled: The Use of Geological Information in the Greater Pittsburgh Area (by Peter Wissel, Robert O'Connor, and Beverly Cigler, CSEP, PSU, January 1976, 23 p.)

LUPRA program management.—David A. Maneval and Hugh B. Montgomery are coordinating the LUPRA program for the ARC. They have redelegated general oversight of the program to an advisory panel established for the purpose by the ARC and composed of residents of Allegheny County and vicinity. Jonathan A. Green, private consultant, Chairman; H. Alan Speak, Southwestern Pennsylvania Regional Planning Commission; Suzanne M. Broughton, Allegheny County League of Women Voters; Bambridge E. Peterson, Allegheny County Council of Governments; Harry A. Barnett, Allegheny County Conservation District; Harry F. Ferguson, U.S. Army Corps of Engineers; and David W. Craig, Attorney.

ACDPD and PSEP investigators reported directly to the ARC; information on their results may be obtained on application to the ARC. USGS, ACDPD, and PSEP personnel conferred periodically with the LUPRA advisory panel for advice and exchange of information.

ACKNOWLEDGMENTS

USGS–LUPRA efforts in this series of studies profited from advice and other assistance kindly given by many persons, notably William C. Morrison and others of ACDPD; Beverly Ann Cigler and Peter A. Wissel of PSEP; Donald R. Williams of the Pittsburgh Subdistrict Office, Water Resources Division, USGS; Samuel E. Cortis and Thomas B. Alexander of the Division of Mine Subsidence Regulation, Pennsylvania Department of Environmental Resources; William W. Beck, Jr. of A. W. Martin Associates, King-of-Prussia, Pa.; and members of the LUPRA advisory

panel. Most importantly, without the support and encouragement by Hugh B. Montgomery of the ARC during planning and formulation stages, the studies would not have been possible.

LIMITS OF APPLICATION OF USGS-LUPRA REPORTS

In following sections of this report, methods used to prepare reports are described and potential applications are discussed.

Reports contain three kinds of information: (1) Maps generally applicable to classification of land relative to processes and problems, (2) tables and diagrams for better understanding of processes and for enhancement of map information, and (3) explanatory texts. Hydrogeologic reports here largely are tables and diagrams, containing map and text information. One geologic report, in addition to the present report, is in book form, but all others are maps, some accompanied by appreciable marginal information in texts, tables, diagrams, or subsidiary maps.

Maps are divided into separate zones or areas by lines and symbols, and map explanations and accompanying marginal information describe attributes of these areas. The maps are intended as tools for planning, at levels defined by the scales of the maps. Appreciable variation can be found within outlined areas, and boundaries between areas largely are gradational over tens and, locally, hundreds of feet. The information given for a particular symbolized area thus is a general statement of expected conditions and must not be taken as rigidly applicable to all localities within that symbolized area. The maps call attention to potential problems or likely attributes, but they must not be used as substitutes for detailed investigations of specific sites by competent technical personnel.

DESIGNED PRODUCT AUDIENCES

The USGS–LUPRA reports were designed chiefly for two potential user groups: (1) Persons concerned with problems of the environment but not having extensive technical training or background, such as interested private citizens and most of those responsible for making decisions affecting the public welfare and (2) a technical audience, principally engineers and engineering geologists and hydrologists but including other technically-oriented persons, such as some planners, contractors, and developers. In the discussion of potential report applications, the orientation of reports toward the first group is described as "nontechnical" that toward the second group as "technical." However, there is a broad and not well-defined overlap between technical and nontechnical reports and groups, so a nontechnical person can likely get understandable information from a report that is chiefly technical. On the other hand, a technical reader may find a nontechnical report very useful. Some of the reports are expected to appeal to wider audiences, such as scientists, for background for more detailed work on specific aspects of the physical environment, and high-school and college educators.

BASE MAPS

Base maps provide a frame of reference that enables readers to locate data points and other localities on the ground by reference to common, readily recognizable features such as roads, streams, and hills.

The base maps used during investigations and for the provisional products of the earth-disturbance inventory were USGS quadrangle topographic maps of the 7½-minute series at a scale of 1:24,000 (1 in.=2,000 ft; 1 cm=240 m). They are identified in figure 3.

The base map for final Allegheny County reports was prepared by reducing topographic maps of the 7½-minute series from a scale of 1:24,000 to 1:50,000, followed by preparation of a controlled mosaic. Scale 1:50,000 (1 in.= 4,170 ft; 1 cm=500 m) was selected to conform with the scale of the new county-base-map series of the Pennsylvania Bureau of Topographic and Geologic Survey.

The base map for the three mining-related reports that include Allegheny, Washington, and Westmoreland Counties was adapted from the USGS Greater Pittsburgh region topographic map at 1:125,000 (1 in.=2 mi; 1 cm= 1,250 m or 1.25 km). This also is the regional scale used by the Southwestern Pennsylvania Regional Planning Commission.

A variety of map scales and base materials were used in reports of the hydrogeologic studies.

GEOLOGIC STUDIES

EARTH-DISTURBANCE INVENTORY AND ANALYSIS OF SUSCEPTIBILITY TO LANDSLIDING

METHODOLOGY

An earth-disturbance inventory presents, in map form, surface features of the earth that differ from or contrast with an interpretive view of the expression that the ground surface would have if only continuous and gradual geologic processes, such as stream erosion and sedimentation, were acting upon it. An earth-disturbance inventory thus includes three general categories of features:

1. Those disturbances that chiefly involve earth materials in their natural setting and that may or may not have been caused or influenced by human activity—in Allegheny County chiefly landslide deposits from natural or man-modified slopes but also including features such as the surface expression of subsidence in areas that have been undermined.
2. Features that are the inadvertent effects of natural processes on earth materials that have been moved by man—in Allegheny County chiefly landslides from fills and embankments but also including such features as the expression of excessive erosion of rearranged earth materials and resulting sedimentation.
3. Earth features that are the intended or unavoidable results of human activity—examples: highway cuts and embankments, surface mines, mine dumps, slag heaps. This category approximates "disturbed ground" or "disturbed land" in common usage.

The inventory had two main steps: (1) interpretation of aerial photographs; (2) verification of findings in the field, largely by traversing the dense road network of the area, using off-the-road traverses as needed. Analysis of susceptibility to landsliding proceeded concurrently and involved the correlation of landslide distribution, as revealed by the inventory, with available geologic, geomorphic, and soil survey data.

The use of aerial photographs for mapping of surface features resulting from human activities is as old as aerial photography, but systematic interpretation of the phenomena of landsliding from aerial photography is relatively new. It was used extensively by USGS personnel during the San Francisco Bay region studies (SFBRS) in California and locally elsewhere.

The SFBRS landslide maps were made using existing aerial photographs, some older than 10 years at the time of the studies and all taken for different purposes at a variety of nominal contract-print scales, rarely much larger than 1:24,000 (1 in.=2,000 ft; 1 cm=240 m). Time available for field verification, or "ground truth," was minimal or, in some areas, lacking. Although this work was remarkably successful and the results were well received by potential users in the region, those who did the SFBRS mapping advised that better results could be obtained by using larger scale photography and by including an allowance of time for verification on the ground (Tor H. Nilsen, oral commun., 1972). This advice was accepted in planning the Allegheny County inventory. Moreover, the SFBRS photographic interpretation concentrated on landslides exclusively, but the scope of the Allegheny County inventory included man's surface effects, which are changing constantly. To show this, aerial photography as current as possible was planned.

Aerial photographs of Allegheny County were taken for the specific purpose of the study, largely in April, 1973, because photographs without the dense summer foliage were necessary. The nominal scale of contact prints of the photography is 1:12,000 (1 in.=1,000 ft;1 cm=120 m); they are black and white.

Aerial-photographic interpretation by the investigators, W. E. Davies and J. S. Pomeroy, was completed by June 1974. Field verification was accomplished during sporadic one- or two-week visits to Allegheny County. Investigations averaged about 3 weeks of interpretation and 1 week of field verification for each complete 7½-minute quadrangle (about 57 mi^2; 148 km^2), or 1 man-month per quadrangle.

Allegheny County includes about 728 mi^2 (1,886 km^2) and is equivalent in area to about 13 7½-minute quadrangle maps. However, because county and quadrangle map boundaries do not coincide, 23 separate quadrangle maps are required for countywide coverage (fig. 4), and these quadrangles also cover appreciable parts of adjacent counties. Because of this overlap and because aerial-photographic coverage extended short distances beyond the Allegheny County boundary, interpretation and verification was carried into small parts of the adjacent counties, with the result that a total of about 850 mi^2 (2,200 km^2) was inventoried.

REPORTS

Provisional maps are titled landslide-susceptibility and land-modified-by-man maps. They include all or almost all the area of 10 quadrangles (only 4 completely within Allegheny County) and parts of 13 quadrangles. Separate landslide-susceptibility and land-modified-by-man maps were prepared for each of 20 full or partial quadrangles; both landslide-susceptibility and land-modified-by-man information were combined on 3 partial quadrangles. In total, there thus are 43 separate maps, each at the scale of 1:24,000; they are listed earlier in this report.

The open-file maps of landslide susceptibility show the following by map symbols and lines:

Recent landslides.—Dominantly earth slumps and earth flows that are recorded historically or are characterized by fresh scars.

Debris slides.—Landslides primarily of rock, soil, and vegetation debris in steep narrow valleys.

Prehistoric landslide deposits.—Dominantly earth slumps and earth flows characterized by hummocky topography and slump benches.

Slopes with conspicuous soil creep.—Clayey soils, generally less than 5 ft (1.5 m) thick, commonly underlain by weathered shale and characterized by shallow, slow, but distinct, downslope movement.

Outcrop areas of thick "red beds" and associated rocks.—Weathered rock and related soil commonly result in soil creep and landsliding.

Relatively stable ground.

Steel slopes susceptible to rockfall.—Natural and cut slopes and cliffs, 15 to more than 150 ft high, (4.6 m to 46 m) mainly thick-bedded sandstone and limestone, having layers 1 to more than 10 ft (0.3 m to 3 m) thick, that are highly fractured and locally undercut by weathering of interbedded subordinate flaggy sandy shale and silty and clayey shale;

Manmade fill.—Heterogeneous soil and rock material.

Land modified-by-man maps show:

Surface (strip) mines, reclaimed and unreclaimed.—Primarily coal but includes some developed for sandstone and limestone.

Areas in which surface patterns are indicative of mine subsidence.

Areas of active, controlled, and extinguished mine and coal bed fires.—Generally confined to vicinity of outcrop of coal bed.

Refuse banks.—Primarily coal waste, most burned to ash and clinkers (red dog).

Quarries and pits.

Slag dumps.

Urban development.—Modification, primarily after 1969, includes removal of vegetation, removal and redistribution of topsoil, some excavation of bedrock, and placement of impervious streets and parking lots.

Predevelopment modification.—Ultimate land use not identified during investigation.

Land modified for transportation.—Modifications, primarily after 1969, include extensive deep excavations, redistribution of topsoil; and local removal of structures.

Earth and rock fill.—Primarily at industrial, commercial, educational, and housing sites and along transportation routes.

Nearly vertical cuts and cliffs.—Primarily cuts along highways and adjacent to commercial and industrial sites, highwalls in surface mines, and some natural cliffs.

Water impoundments.—Primarily farm ponds, reservoirs, and settling basins.

Information and insights resulting from the earth-disturbance inventory and analysis of susceptibility to landsliding contributed directly to four final reports of the USGS–LUPRA program. Two are described below; the other two, maps of mining features and zones that can be affected by landsliding, flooding, and undermining, are described in the later section concerning integration of results of the geologic studies. This separation, though somewhat artificial, has a logic because the latter maps also contain appreciable information that did not result from the inventory and analysis.

Map of susceptibility to landsliding, Allegheny County, Pennsylvania, by John S. Pomeroy and William E. Davies, 1975. U.S. Geological Survey Miscellaneous Field Studies Map MF–685B.—Scale, 1:50,000. Essentially all features shown on the provisional landslide susceptibility maps were transferred to the Allegheny County base map, within limitations imposed by scale, except that features outside the county boundaries were not transferred. Shown on this black-and-white map as highly sensitive to disturbance by man are areas mapped as recent landslides, prehistoric landslides, and slopes having three categories of susceptibility to landsliding. Also shown are steep slopes prone to rockfall and manmade fills that may be subject to failure. More than 2,000 recent and prehistoric landslide areas were mapped; slopes that may be susceptible to significant landsliding underlie about 110 mi^2 (285 km^2) or 15 percent of the county. Marginal sketches illustrate types of landslides and conditions typical of the area. A small-scale geologic map, columnar section, and explanatory text are included. Figure 5 is a reduced, simplified version of this map.

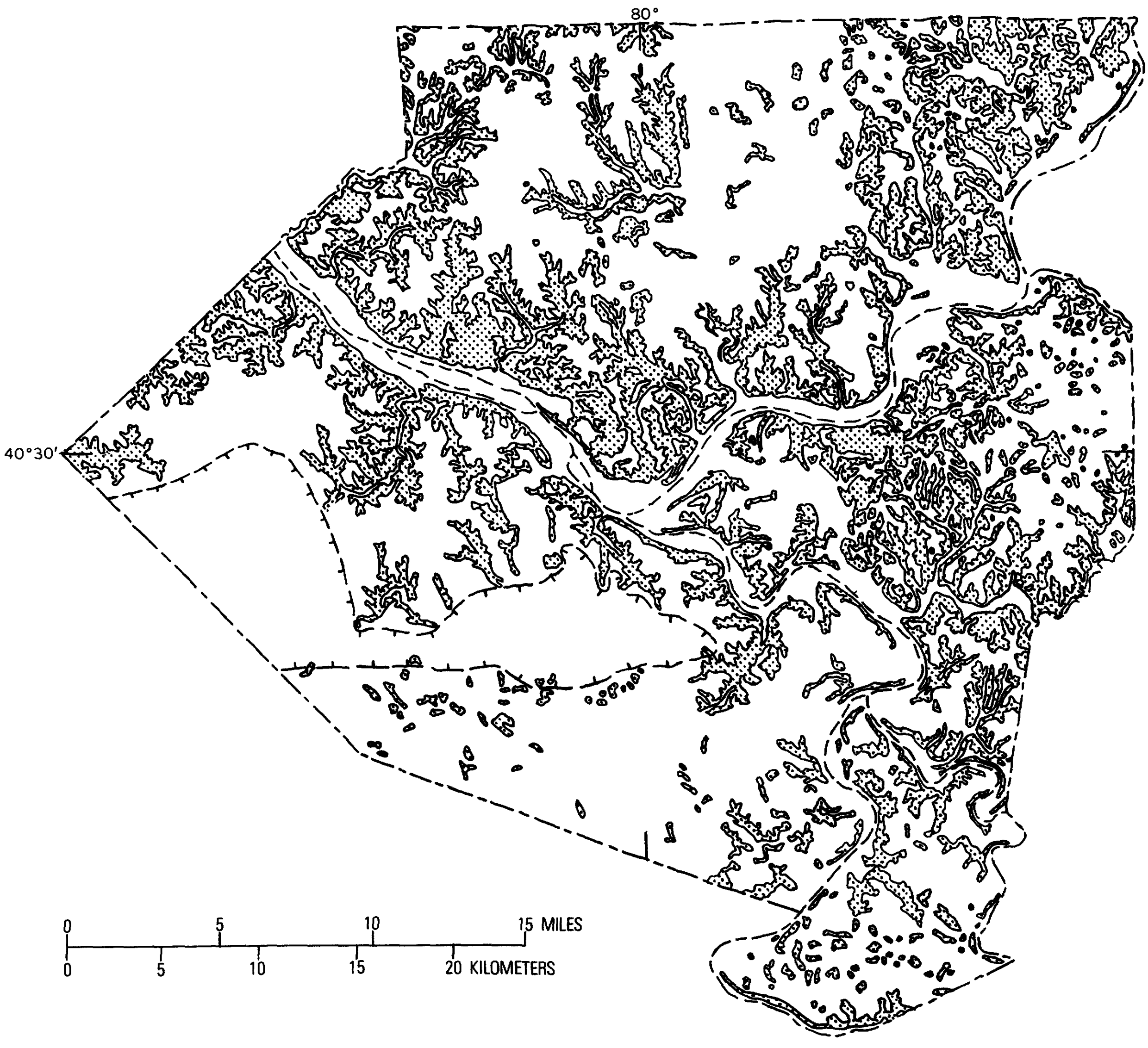

FIGURE 5.—Generalized map of susceptibility to landsliding in Allegheny County, Pa. Areas with some degree of susceptibility are shown by dotted pattern; area with variable susceptibility lies inside dashed and toothed line; areas with little susceptibility are unpatterned. Dashed lines show channels of Ohio, Allegheny, and Monongahela Rivers.

Landsliding in Allegheny County, Pennsylvania, by Reginald P. Briggs, William E. Davies, and John S. Pomeroy. 1975. U.S. Geological Survey Circular 728.—Owing to the limited space for marginal information on the map of susceptibility to landsliding (MF-685B), much information applicable to that map was assembled into this companion report. A small amount of information is repeated so that the reader will find the report useful if he does not at the same time have the map for reference. The report contains nontechnical advice to buyer, builder, and homeowner; describes actions to be avoided on susceptible slopes; describes geologic setting, geologic factors affecting susceptibility to landsliding, and selected landslide localities; and includes a glossary, photographs, and other illustrations.

APPLICATIONS OF REPORTS

The 1:24,000-scale provisional landslide-susceptibility maps and the resulting 1:50,000-scale map of susceptibility to landsliding (MF-685B) are directly applicable to the general classification of land on both nontechnical and technical levels. Nontechnical users can see which parts of the county are likely to be susceptible to landsliding by coloring as one group the map units bracketed as "highly sensitive to disturbance by man," whereas technical users can interpret the map-unit descriptions to find general degrees of susceptibility for their purposes. Because susceptibility to landsliding is a function of instability of materials on slopes, these maps also have direct bearing on foundation and earthworking conditions. The 1:50,000 scale map is more applicable to countywide planning owing to the format, and it has explanatory information that is oriented particularly toward the nontechnical reader. On the other hand, there is a slight loss of detail and content due to the reduced scale.

The companion report on landsliding (Circular 728) largely is intended for nontechnical users, but technical users may find that the discussions of geologic factors and setting are useful summaries and that the brief case histories of the selected landslide localities are helpful relative to other sites in the area.

The open-file maps of land-modified-by-man are basically nontechnical in nature, depicting changes in the land surface, and thus are directly applicable to land-use classification, including surface mining and earthworking activity. Abandoned surface mines are also important sites for current and potential disposal of solid waste, and slag dumps and coal-mine-refuse piles are current and potential sources of construction aggregates.

MAPS SHOWING UNDERGROUND COAL-MINING ACTIVITY THAT CAN RELATE TO SURFACE SUBSIDENCE, ALLEGHENY, WASHINGTON, AND WESTMORELAND COUNTIES, PENNSYLVANIA

METHODOLOGY

The first two of the three black-and-white maps (MF-693A and MF-693B) described below were compiled largely by conventional methods from existing map information, but the second required appreciable effort in the search for data, and both required development of new information on overburden thickness by comparing topography and geologic structure. In addition, the principal investigator, Kent Bushnell, was able to expand the content of the maps to include appreciable data on subsidence events through cooperation of William W. Beck, Jr. (A. W. Martin Associates, King-of-Prussia, Pa.) who had collected this information in the course of work on another project sponsored by the ARC. The third map (MF-693C) resulted from comparison of the first two and from consideration of geologic and mining factors. Tables accompanying the maps were prepared in part by comparing the incidence of subsidence events to housing-density information.

REPORTS

Although the USGS-ARC reports were intended to treat only parts of Washington and Westmoreland Counties, it was possible to expand the geographic focus to include these entire counties (fig. 1). The reports are:

Map showing depth to the Pittsburgh coal bed, mining activity and related surface subsidence, Allegheny, Washington, and Westmoreland Counties, Pennsylvania, by Kent Bushnell. 1975. U.S. Geological Survey Miscellaneous Field Studies Map MF-693A.—Scale 1:125,000. The map shows the extent of the coal bed and subdivides it on the basis of three periods of completed and potential mining (mined out before April 27, 1966; mined out between April 27, 1966 and June 30, 1974; potentially mineable after June 30, 1974) and three categories of overburden thickness—0 to 200 ft (0 to 61 m); 200 to 500 ft (61 to 152 m); greater than 500 ft (152 m). Locations of recorded damaging subsidence events are shown, and a table relates these locations to mining periods and thickness of overburden. Factors bearing on mining-induced surface subsidence and the incidence of subsidence are discussed in the accompanying text. To give the reader a view of the area potentially subject to subsidence from Pittsburgh coal-bed mining, the part of the three counties undermined for the Pittsburgh coal bed prior to June 30, 1974, is shown in reduced form in figure 6.

Map showing depth to the Upper Freeport coal bed, mining activity and related surface subsidence, and the Redstone coal bed mines, Allegheny, Washington, and Westmoreland Counties, Pennsylvania, by Kent Bushnell and John R. Peak, 1975. U.S. Geological Survey Miscellaneous Field Studies Map MF–693B.—Scale 1:125,000. This map shows and discusses the same subjects relative to the Upper Freeport coal bed as does the above map relative to the Pittsburgh coal bed. In addition, it shows the locations of some mines in the less important Redstone coal bed. Figure 7 shows at a reduced scale the extent of Upper Freeport undermining as of June 30, 1974.

Map showing areas that correlate with subsidence events due to underground mining of the Pittsburgh and Upper Freeport coal beds, Allegheny, Washington, and Westmoreland Counties, Pennsylvania, by Kent Bushnell. 1975. U.S. Geological Survey Miscellaneous Field Studies Map MF–693C.—Scale 1:125,000. The three-dimensional map data of the above two maps (MF–693A and MF–693B) were analyzed and combined to yield this two-dimensional classification of the land surface. Four basic categories include: (1) areas that correlate with high numbers; (2) moderate numbers; (3) minor numbers of damaging subsidence events due to present or potential undermining; (4) areas in which there is no foreseeable subsidence hazard from underground mining of the Pittsburgh and Upper Freeport coal beds. Figure 8 is a simplified re-

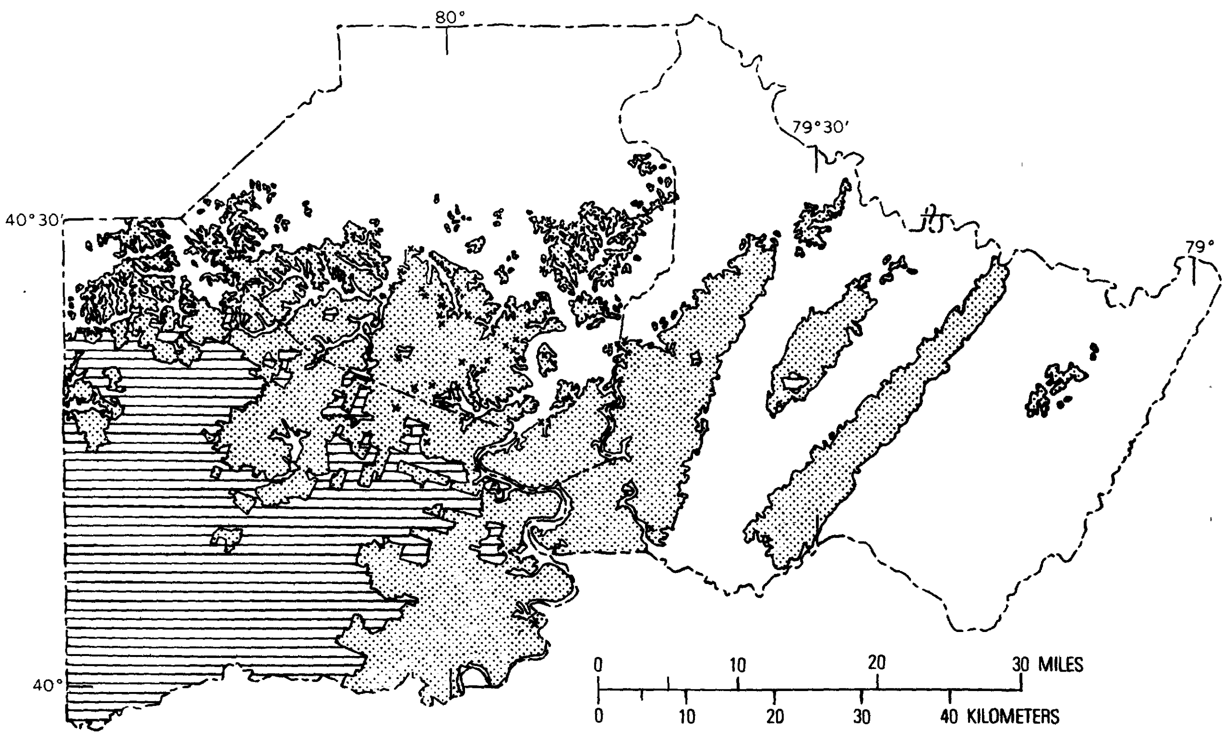

FIGURE 6.—Generalized map of Allegheny, Washington, and Westmoreland Counties, Pa., showing the Pittsburgh coal bed mined out before June 30, 1974 (dotted pattern), the Pittsburgh coal bed probably mineable after June 30, 1974 (horizontal lines), the recorded damaging surface-subsidence incidents over mined-out areas of the Pittsburgh coal bed (marked by X), and areas where the Pittsburgh coal bed is absent (no pattern).

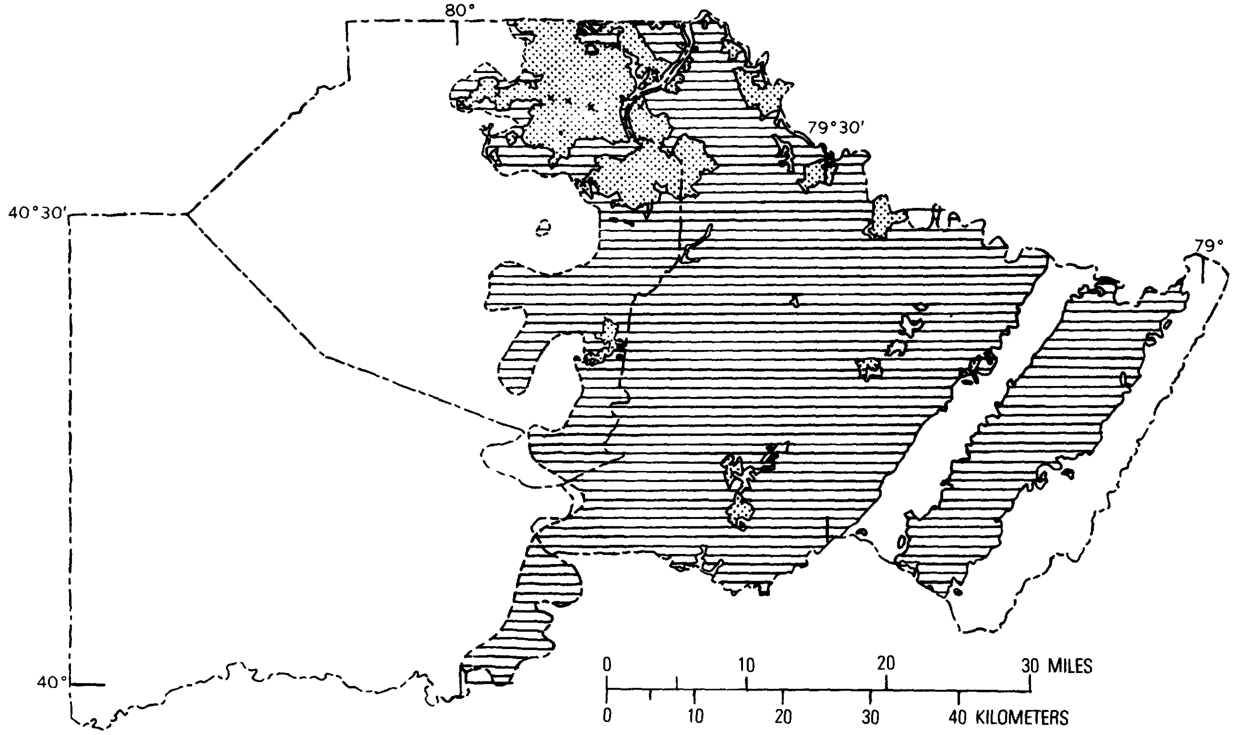

FIGURE 7.—Generalized map of Allegheny, Washington, and Westermoreland Counties, Pa., showing the Upper Freeport coal bed mined out before June 30, 1974 (dotted pattern), the Upper Freeport coal bed probably mineable after June 30, 1974 (horizontal lines), the recorded damaging surface-subsidence incidents over mined-out areas of the Upper Freeport coal bed (marked by X), and areas where the Upper Freeport coal bed is absent (no pattern).

duction of this map in which areas correlating with high and moderate numbers of events are combined.

APPLICATION OF MAPS

The abundant information on the first two maps largely will be meaningful only to the technical audience. The overburden-thickness information is applicable to the mine-subsidence problem, but thickness of overburden also bears directly on the potential for surface mining and thus also on resource considerations. Areas mined out and potentially mineable underground areas are factors in subsidence and resource potential, and undermining is a factor in ground-water supply and mine-water discharge.

The third map is a nontechnical report that is directly applicable to regional planning relative to the potential for damaging surface subsidence, one aspect of foundation conditions. From it also can be read the extent of undermining through 1966.

INTEGRATION OF RESULTS OF THE GEOLOGIC STUDIES WITH EXISTING DATA AND SUMMARY OF GEOLOGIC AND HYDROGEOLOGIC RESULTS

METHODOLOGY

The first map described below (MF–685C) is taken largely from the 1:24,000 scale provisional maps of land-modified-by-man, by reduction to scale 1:50,000 and compilation on the Allegheny County base map. Although most of the provisional maps contain information beyond the borders of Allegheny County, compilation on the county base map was restricted to Allegheny County only. Moreover, it was decided to transfer to the county base map only coal-mining and other mineral industry features. This decision was based largely on the fact that the other features on the maps of land-modified-by-man are related chiefly to development from 1969 to 1973. These maps, though differently derived and at different scales, approximate those of the USGS–LUPRA Allegheny County land-use-change map prepared by the USGS, description of

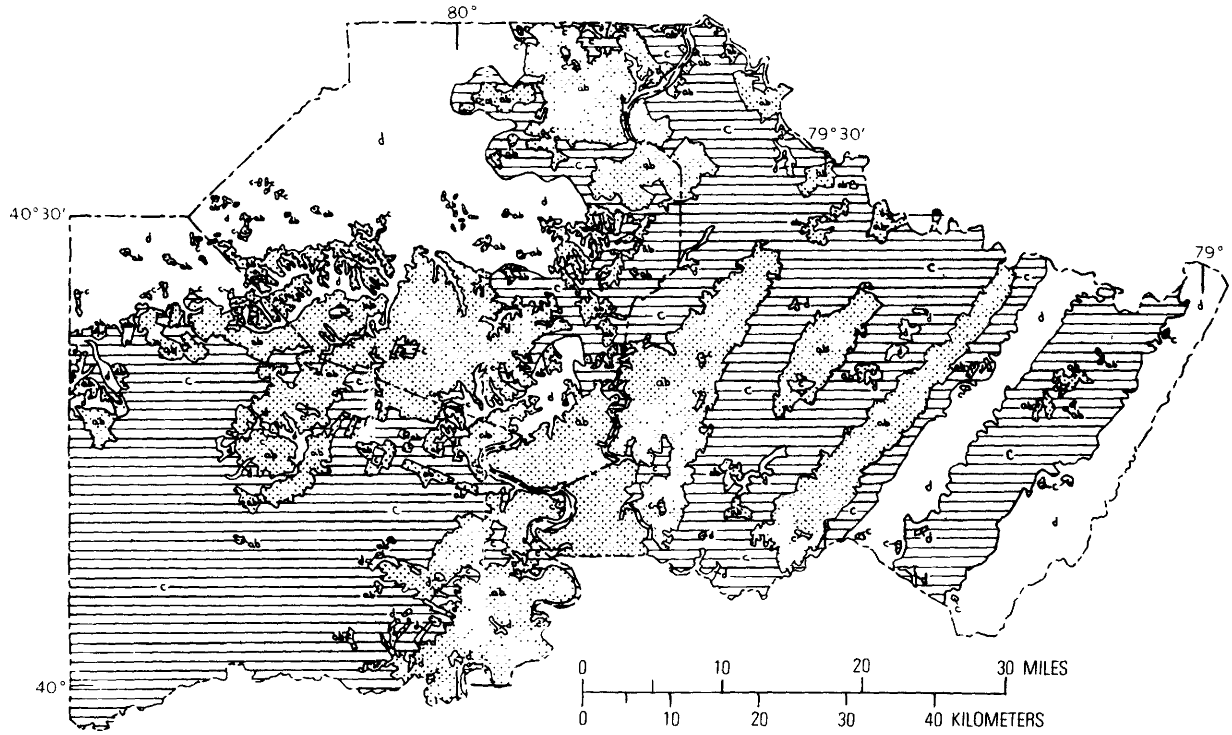

FIGURE 8.—Map of Allegheny, Washington, and Westmoreland Counties, Pa., showing generalized areas correlating with numbers of recorded damaging surface-subsidence incidents over mined-out areas, extrapolated to include areas of future coal mining. High and moderate numbers are indicated by ab and dotted pattern; minor numbers by c and horizontal lines; no correlation by d (unpatterned).

which is beyond the scope of this report. The resulting map of coal-mining features was completed by adapting map areas shown as undermined on the Pittsburgh coal bed (MF–693A) and Upper Freeport coal bed (MF–693B) maps described above.

The second map described below (MF–685D) was prepared by generalizing the map of susceptibility to landsliding (MF–685B) and the map of coal-mining features and combining the generalizations with a compilation and reduction of flood-prone area maps. Figure 9 shows the general limits of flood-prone areas in Allegheny County. The map of rock types in bedrock (MF–685A) is a combination of interpretations from soil-survey work and information chiefly from published geological and engineering reports.

Most compilation for integrated maps was by William R. Kohl; the present writer largely was responsible for the preparation of texts and tables and for the assembly of maps, texts, and tables for publication.

Illustrations accompanying this report summarizing the geologic and hydrologic studies were reduced by photomechanical transfer from the appreciably larger originals. The reductions were then simplified and generalized as page-size maps.

REPORTS

Map of coal-mining features, Allegheny County, Pennsylvania, by William E. Davies, John S. Pomeroy, and William R. Kohl. 1975. U.S. Geological Survey Miscellaneous Field Studies Map MF–685C.—Scale, 1:50,000. Three categories of information are shown: (1) extent of mined and mineable coal in the Pittsburgh and Upper Freeport coal beds; (2) surface features related to underground mining; and (3) features resulting from surface mining and other activity. Included in the second category are mine entries, mined-out areas, mine and coal-bed fire areas, refuse banks, and areas of probable past surface subsidence identified through aerial-photographic interpreta-

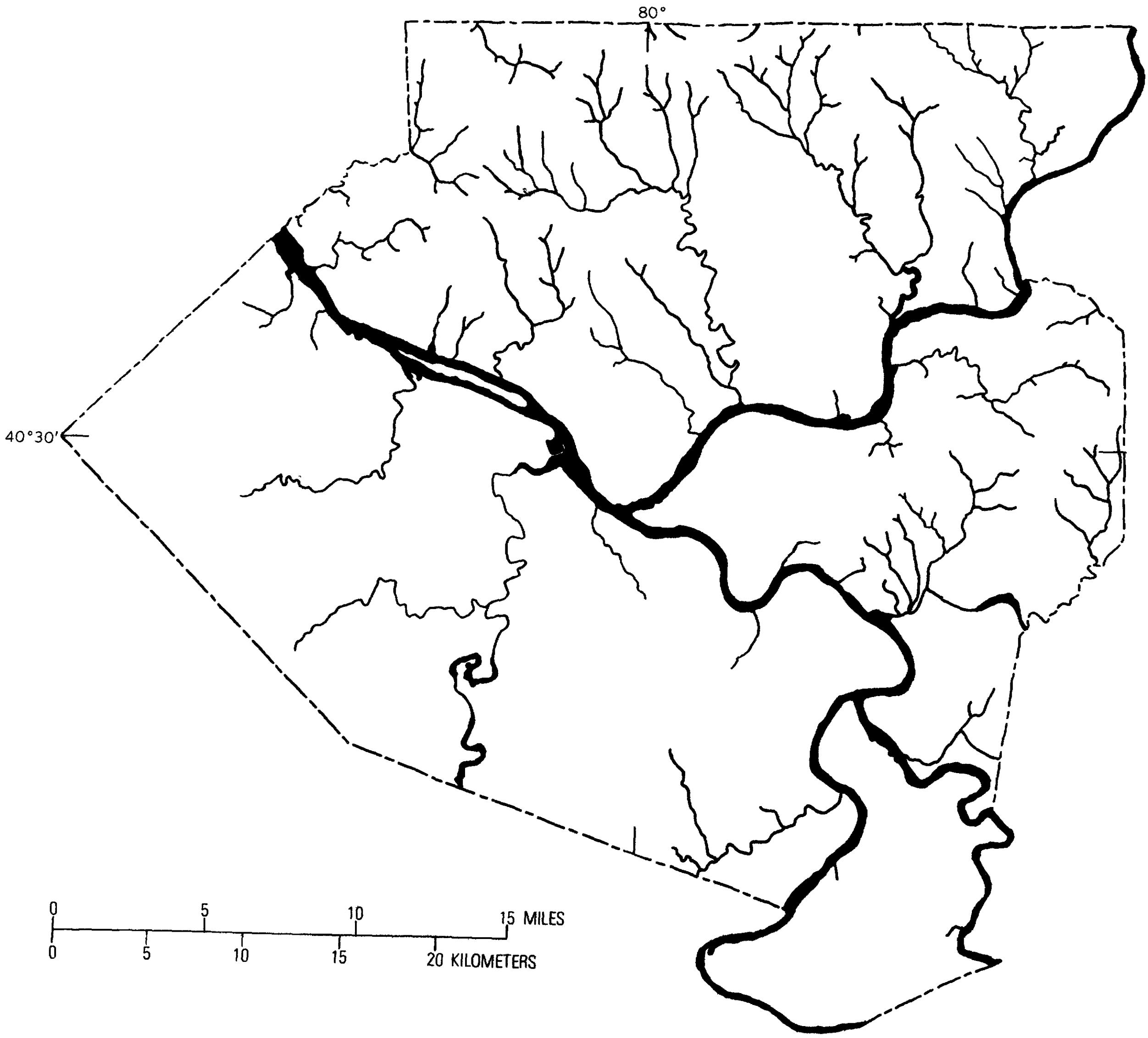

FIGURE 9.—Generalized map of flood-prone areas (shown in black) Allegheny County, Pa.

tion. In the third category are surface (strip) mine areas, surface-mine high walls, and slag dumps. Underground mining has taken place under about 250 mi^2 (648 km^2) or 35 percent of the county (fig. 10). Surface mining has disturbed about 30 mi^2 (78 km^2), or less than 5 percent of the county. The coal beds are related to the geologic setting by the accompanying small-scale geologic map and columnar section; a brief text supplies additional information.

Map of zones where land use can be affected by landsliding, flooding, and undermining, Allegheny County, Pennsylvania, by Reginald P. Briggs and William R. Kohl. 1975. U.S. Geological Survey Miscellaneous Field Studies Map MF–685D.—Scale, 1:50,000. This map provides a general land classification relative to the three named processes. Areas are numbered from slashed zero (Ø) to 3 depending on how many of the processes can affect a given locality. Letter suffixes identify which of the processes are of concern. The accompanying text compares effects of the processes, suggests how the map can be used, and lists sources of more detailed information. Figure 11 is a reduced and simplified version of the map.

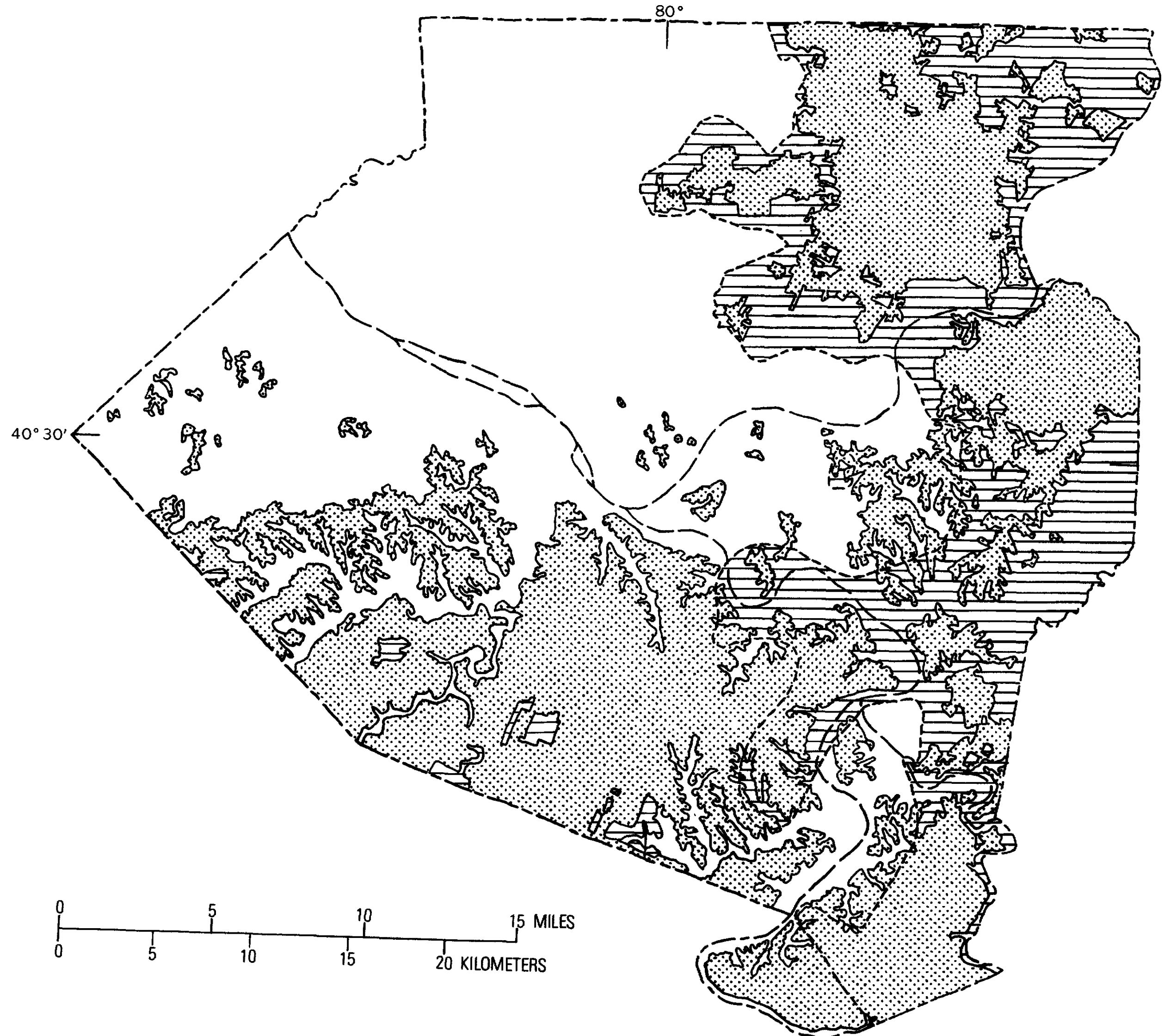

FIGURE 10.—Generalized map of underground coal mining in Allegheny County, Pa. Areas undermined before June 30, 1974 are dotted; areas of Pittsburgh and Upper Freeport coal beds probably mineable after June 30, 1974 are shown by horizontal lines; areas where coal beds are thin or absent are unpatterned. Short-dashed lines show approximate western limit of mineable Upper Freeport coal bed; long-dashed lines show channels of Ohio, Allegheny, and Monongahela Rivers.

Map of rock types in bedrock of Allegheny County, Pennsylvania, by William R. Kohl and Reginald P. Briggs. 1975. U.S. Geological Survey Miscellaneous Field Studies Map MF–685A.—Scale, 1:50,000. Five map units show the distribution of different assemblages of rock types in bedrock. Surficial deposits are shown only where relatively large areas of bedrock are concealed. A small-scale geologic map and columnar section relate bedrock types to conventional stratigraphy. One table describes the general engineering characteristics that may be found in bedrock units, and a second more detailed table presents characteristics of specific rock types. The text briefly describes the general geology and the principal categories of problems in environmental geology. Examples illustrate the use of map and tables in conjunction. A glossary is included.

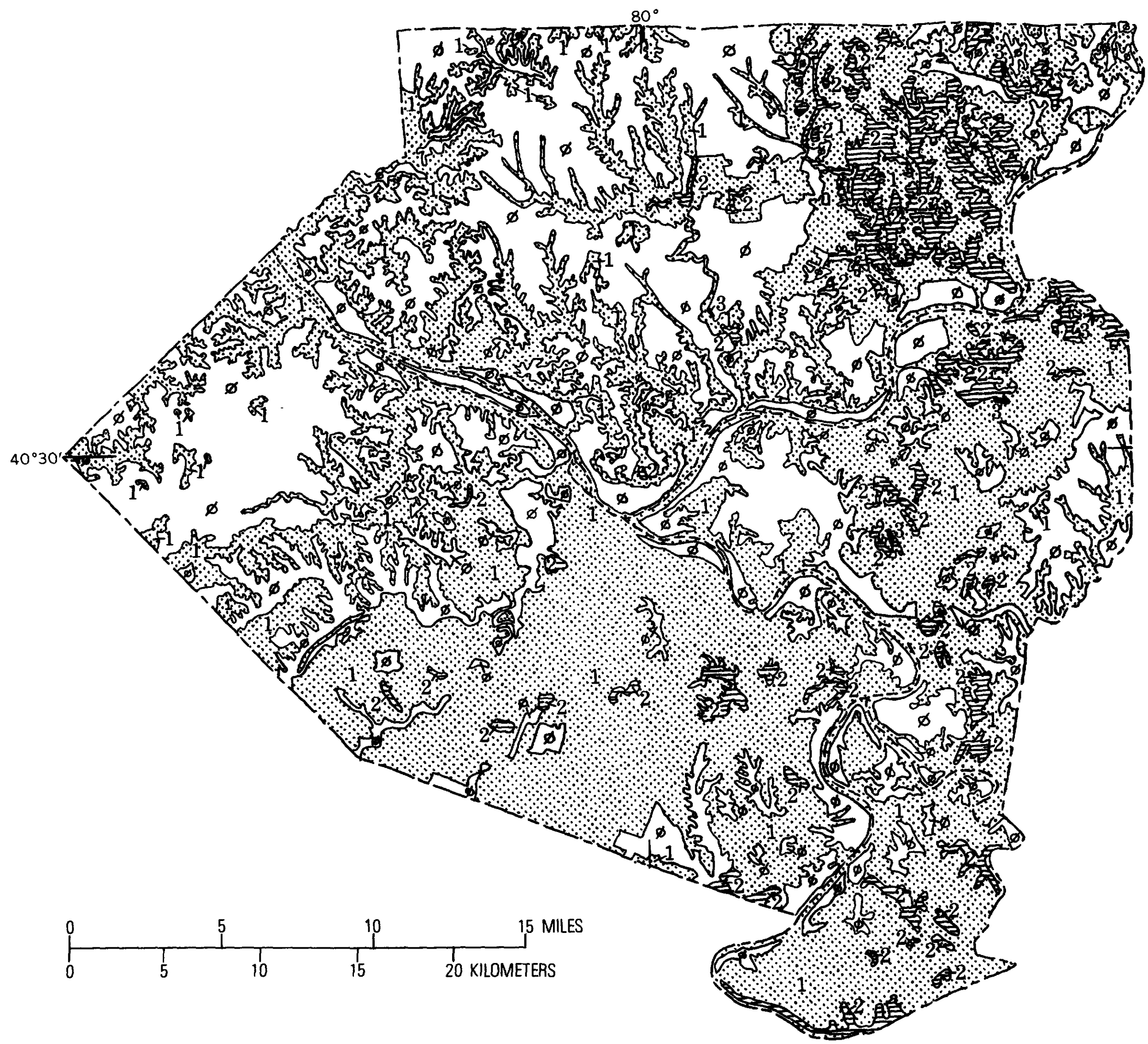

FIGURE 11.—Generalized map of Allegheny County showing areas that can be affected by one or more processes of flooding, landsliding, and undermining. Areas which can be affected by all three processes are indicated by 3 and black pattern; affected by two processes by 2 and horizontal lines; affected by one process by 1 and dotted pattern; unlikely to be affected by Ø and no pattern.

Environmental geology, Allegheny County and vicinity, Pennsylvania—description of a program and its results by Reginald P. Briggs. 1977. U.S. Geological Survey Circular 747.— This report.

APPLICATIONS OF REPORTS

The map of coal-mining features (MF–685C) has both technical and nontechnical applications. As examples of the former, surface mines are sites of current and potential storage of solid waste, and construction aggregates can be mined from coal-mine-refuse piles and slag dumps. In addition, the distribution of surface mines and areas undermined provides a view not only of areas currently affected by coal mining but also of areas that may be mined in the future. This view is important in both mineral-resource and environmental-problem considerations. Nontechnical users may find the map valuable for general land classification, provisional home-site selection, and recreation.

A general nontechnical land classification is provided by the map combining information on landsliding, flooding and undermining (MF–685D). The chief application is tentative identification of potential problems for the selection of sites for residential, public, commercial, industrial, and transportation purposes, but the information also may be applied to existing structures and other features.

The map of rock types in bedrock (MF–685A) is largely technical in content, but instructions are provided that will allow the nontechnical user to make provisional identifications of some engineering characteristics of bedrock, such as facility of excavation, stability of cut slopes, and foundation strengths. Specific rock-type characteristics, though largely from published sources, previously have not been assembled in one publication. The technical user may find this summary applicable to planning a variety of works.

The present report summarizes the studies and their reports and presents a general view of the principal factors that may limit land use for some purposes. It classifies the reports by potential applications, and with its small-scale illustrations provides a regional overview of environmental factors.

HYDROGEOLOGIC STUDIES

RECONNAISSANCE APPRAISAL OF THE ROLE OF SHALLOW GROUND WATER IN MINING AND SLOPE-STABILITY PROBLEMS, INCLUDING PROBLEMS ASSOCIATED WITH PERIODS OF INTENSE PRECIPITATION SUCH AS ACCOMPANIED TROPICAL STORM "AGNES" IN JUNE 1972, ALLEGHENY COUNTY, PENNSYLVANIA

METHODOLOGY

Ground water in rocks and soils above the levels of stream channels in adjacent valleys generally is considered shallow for present purposes. For example, in an area where topographic relief (the vertical distance from valley bottoms to adjacent ridge crests) is about 300 ft (91 m), the zone of shallow ground water is about 300 ft (91 m) thick beneath ridge crests, thinner beneath slopes, and very thin beneath valley bottoms. In Allegheny County, the shallow ground-water regime has been believed to be interrelated significantly with landsliding and mining, but the validity of this belief has not been systematically tested until the present study. The aim of the reconnaissance appraisal was to systematize and enhance knowledge of the shallow groundwater regime. There were no known precedents so the methodology used by the principal investigator, Seymour Subitzky, was innovative. The steps followed were:

1. A thorough search of the geologic, hydrologic, and engineering literature for data and theory relevant to the Allegheny County setting, and analysis of the results of the search.
2. A widespread series of interviews with technical personnel in a variety of employments, for the purpose of gleaning applicable unpublished data and unwritten insights.
3. Field investigations viable within the framework of available time and support.
4. Synthesis of results into reports.

Steps 2 and 3 continued simultaneously, and there were no firm time lines to other steps because obscurely published applicable material was found occasionally and analysis of some factors became possible only with synthesis relative to others. Step 2 was particularly time consuming, but produced valuable information.

REPORTS

The result of the reconnaissance appraisal is a series of five reports in chart form.

Summary of the hydrogeologic regime as related to environmental characteristics, Allegheny County, Pennsylvania, by Seymour Subitzky. U.S. Geological Survey Miscellaneous Field Studies Map MF–641A. The chief feature of this report is a table in which geologic units underlying the county at shallow depths are classified according to lithologic, structural, and hydrologic characteristics, mass-movement characteristics on natural and cut slopes, and response to heavy storm precipitation. The table is supported by a brief text.

Hydrogeologic framework and generalized shallow ground-water circulation system, Allegheny County, Pennsylvania, by Seymour Subitzky. U.S. Geological Survey Miscellaneous Field Studies Map MF–641B.—In this report, the regional framework is illustrated by a county map showing axes of folds and by cross sections perpendicular to fold axes. Probable paths of groundwater circulation are shown in larger scale cross sections selected as characteristic of the hydrogeologic setting. A third level of detail is added by a large-scale block diagram illustrating water circulation through rock fractures and along bedding planes. The accompanying text coordinates the illustration and adds other information.

Mining and related problems of the shallow hydrogeologic regime, Allegheny County, Pennsylvania, by Seymour Subitzky. U.S. Geological Survey Miscellaneous Field Studies Map MF–641C.—Local case histories of the interaction of underground coal mining and the ground-water regime are illustrated. Included are actual patterns of rock features over mined-out areas, traced from photographs of outcrops; an example of the effect of mining on water supply from shallow wells; a verified case of decline of ground-water level due to undermining; and an amplifying text.

Heavy storm precipitation and related mass movement, Allegheny County, Pennsylvania, by Seymour Subitzky. U.S. Geological Survey Miscellaneous Field Studies Map MF–641D.—The tracks of extratropical storms in the Ohio River basin between 1871 and 1972 are illustrated and are related to precipitation recorded at Pittsburgh. Landslides caused by tropical storm "Agnes" (June 1972), as determined by ACDPD, are located on a map at scale of 1:125,000 (1 in.=2 mi; 1 cm=1,250 m). The text and a table expand on the relationship between precipitation and landsliding.

Some aspects of water quality as affected by land use in McLaughlin Run and Painters Run basins, Allegheny County, Pennsylvania, by Seymour Subitzky. U.S. Geological Survey Miscellaneous Field Studies Map MF–641E.—These small basins, totaling about 12 mi^2 (31 km^2) in area, in many respects are typical of the setting of the parts of Pittsburgh's urban fringe that are closely underlain by mined-out coal beds. Two series of water-quality measurements were made, one during a period of low base flow and one during a period of high base flow, and the results are tabulated, shown by symbols on maps, and discussed in the accompanying text.

APPLICATIONS OF REPORTS

The summary of the hydrogeologic regime (MF–641A) supplies the basic background for the succeeding four reports, although in large part they can be used independently. The orientation of the summary largely is toward a technical audience. The two sheets of the hydrogeologic framework chart (MF–641B) provide technical and nontechnical readers with insight into the ways that shallow ground-water moves, and resulting applications to aspects of mine-water discharge and water supply both under natural conditions and as affected by fracturing related to mine subsidence. Further application is to the interplay of solid waste and ground-water circulation. The mining-and-related-problems chart (MF–641C) is oriented somewhat more toward the technical reader than is the hydrogeologic framework chart, and it focuses more closely on the effects of mine subsidence. The information in the fourth chart (MF–641D) largely is technical, but the nontechnical reader also will find the relation between heavy storm precipitation and landsliding of interest. Experience from tropical storm "Agnes" should prompt advance planning to ameliorate unstable conditions and thus reduce landsliding under future similar rainfall conditions. The technical report on the McLaughlin Run and Painters Run basins (MF–641E) enhances knowledge of the effects of undermining and urbanization on water quality. Recognition that similarly complex effects may apply in similar basins can be beneficial in water-supply planning and related efforts.

SUMMARY OF RESULTS AND FINDINGS

In table 1, potential applications of reports of the USGS–LUPRA geologic and hydrogeologic studies are summarized. Reports are identified by series (MF or Circular), numbers, and abbreviated titles.

LANDSLIDING

The open-file landslide-susceptibility maps at scale 1:24,000 and the Allegheny County map of susceptibility to landsliding (MF–685B) at scale 1:50,000 constitute a knowledge of distribution of landslides and susceptibility to landsliding that heretofore did not exist, and the map of zones (MF–685D) contains a nontechnical generalization of this information. The many landslides that resulted from tropical storm "Agnes" (MF–641D) demonstrate the marginal stability of many slopes. The report on landsliding in Allegheny County (Cir-

TABLE 1.—*Potential applications of reports*

[MF, Miscellaneous Field Studies Series; Open file, available for public inspection, but not printed for general distribution. N, for nontechnical audience; T, for technical audience; NT, chiefly for nontechnical, secondarily for technical audience; TN, chiefly for technical, secondarily for nontechnical audience, as defined in text. D, direct applications; I, indirect applications]

USGS publication series and number	Type of report	Scale of maps	Abbreviated title	County mapped or emphasized	Technical or nontechnical	Landsliding and cut-slope stability	Surface subsidence owing to undermining	Flooding on rivers and streams	Surface (strip) mining	Mine-water discharge	Water supply	Disposal of solid wastes	Construction aggregates resources	Earth working	Coal resources	Land classification and land-use control
MF–641A	Chart	----------	Summary of hydrogeologic regime ------	Allegheny County and vicinity.	T	D	-	-	-	I	D	-	-	-	-	I
MF–641B	----do -----	----------	Hydrogeologic framework -------------	---do ---------	TN	-	D	-	-	D	D	I	-	-	-	I
MF–641C	----do -----	----------	Mining and hydrogeologic regime -------	---do ---------	TN	I	D	-	-	D	D	I	-	-	I	I
MF–641D	----do -----	----------	Storm precipitation and mass movement--	Allegheny County	TN	D	-	D	-	-	-	-	-	-	-	I
MF–641E	----do -----	----------	Water quality, Painters Run, McLaughlin Run.	---do ---------	T	-	I	-	-	D	I	-	-	-	I	I
MF–685A	Map	1:50,000	Rock types in bedrock ---------------	---do ---------	TN	D	-	-	I	-	D	I	D	D	-	I
MF–658B	----do -----	1:50,000	Susceptibility to landsliding -----------	---do ---------	NT	D	-	-	-	-	-	-	-	D	-	D
MF–685C	----do -----	1:50,000	Coal-mining features ------------------	---do ---------	NT	-	D	-	D	I	-	I	D	I	D	I
MF–685D	----do -----	1:50,000	Zones—landsliding, flooding, undermining.	---do ---------	N	D	D	D	-	-	-	-	-	-	-	D
MF–693A	----do -----	1:125,000	Pittsburgh coal bed and subsidence -----	Allegheny, Washington, and Westmoreland counties.	T	-	D	-	I	I	I	-	-	-	D	I
MF–693B	----do -----	1:125,000	Upper Freeport coalbed and subsidence--	---do ---------	T	-	D	-	I	I	I	-	-	-	D	I
MF–693C	----do -----	1:125,000	Areas that correlate with subsidence events.	---do ---------	N	-	D	-	-	-	-	-	-	-	I	D
Circular 728	Book	----------	Landsliding -------------------------	Allegheny county and vicinity	NT	D	-	-	-	-	-	-	-	I	-	D
Open file	Maps	1:24,000	Landslide susceptibility (provisional)---	Allegheny quads.[1]	NT	D	-	-	-	-	-	-	-	D	-	D
Do --------	--do -----	1:24,000	Man-modified land (provisional) -------	---do ---------	NT	-	D	-	D	-	-	I	D	D	I	D

[1] 23 7½-minute quadrangle maps that include Allegheny County and closely adjacent areas.

cular 728), the Allegheny County rock-type map (MF–685A), and the hydrogeologic summary and framework charts (MF–641A and MF–641B) provide insight into factors that influence landsliding.

In summary, knowledge of susceptibility to landsliding now is wholly adequate for general planning in Allegheny County, and past and future detailed studies of specific slopes and landslide events now can be included in this countywide frame of reference. About 110 mi^2 (285 km^2) or 15 percent of Allegheny County has some significant susceptibility to landsliding.

FLOODING

Little USGS–LUPRA effort was directed at flooding by rivers and streams, due to the generally well-advanced work on the subject by previous workers, and the fact that needed studies of dynamic hydrologic processes were not so amendable to short-term attention as were the studies carried out.

However, the chart concerning heavy storm precipitation (MF–641D) deals with a flood-related incident and provides a compilation of flood history related to extratropical storms, and the 1:50,000-scale Allegheny County map of zones (MF–685D) combines information about distribution of flood-prone areas with information about landsliding and undermining.

MINE SUBSIDENCE

The problem of mine subsidence was addressed specifically. The map of Pittsburgh coalbed features in Allegheny, Washington, and Westmoreland Counties (MF–693A) and the similar map of Upper Freeport coalbed features and Redstone coalbed mines (MF–693B) are basic data contributions; these were synthesized to produce the map of areas that correlate with subsidence events (MF–693C) which classifies land relative to the potential threat of subsidence, at the regional scale of 1:125,000.

Areas identified as undermined in Allegheny County were adapted to the coal-mining features map (MF–685C) at scale 1:50,000 and were recombined with other information to yield the nontechnical map of zones (MF–685D) at the same scale. The hydrologic chart on mining and related problems (MF–641C) deals with the effects of undermining and subsidence on the shallow ground-water regime, and the McLaughlin Run and Painters Run basin chart (MF–641E) reflects this relationship in a local case history.

In the course of the Allegheny County earth-disturbance inventory an experiment was attempted to define subsided areas by aerial-photographic interpretation. The results were promising, although the method needs refinement.

Specific findings relative to undermining and subsidence are:

1. The record of subsidence events doubtless is very incomplete (MF–693A, MF–693B).
2. Legislation by the Commonwealth of Pennsylvania in 1966 enabled the development of regulations and the necessary administrative machinery to reduce the mine-subsidence hazard from post-1966 bituminous coal mining (MF–693C) to a minimum.
3. Damaging mine subsidence now is chiefly, but not exclusively, a threat over areas undermined many years ago which have relatively thin—less than 200 ft (61 m)—overburden (MF–693C).
4. Compared with flooding and landsliding, incidents of subsidence damage owing to undermining are infrequent and least expensive to the overall community. However, they probably are most damaging and expensive to the average individual involved in one of the relatively rare events (MF–685D).
5. Undermining and consequent subsidence have fractured overlying rocks widely and affected the shallow ground-water regime to an extent probably greater than heretofore believed (MF–641C).
6. A large effort would be required to allow even a moderately precise prediction of damaging subsidence events in undermined areas of the bituminous coal fields, and considering the relatively low level of subsidence losses, such an effort might not repay its costs. Possible lines of investigation are:
   (a) Expanding the record of subsidence events by research into historical records and coal-mining and en-

gineering records. Newspaper files have been searched with minimal results.

(b) Further refining knowledge of subsided areas by architectural studies, refined remote-sensing techniques, and fracture and geomorphic analysis.

(c) Seismic and other geophysical research over mined-out areas.

OTHER PROCESSES AND PROBLEMS

As indicated in preceding sections and summarized in table 1, USGS–LUPRA studies also apply to other environmental processes and problems, mainly the syntheses of existing information, such as the summary of hydrogeologic regime (MF–641A), the maps of coal beds in Allegheny, Washington, and Westmoreland Counties (MF–693A and MF–693B), and the Allegheny County rock-type map (MF–685A); the studies also resulted in new information and insights, such as the provisional maps of land modified by man, and the hydrogeologic charts on mining and related problems (MF–641C) and the McLaughlin Run and Painters Run basins (MF–641E). The more significant of these ancillary contributions relate to mine-water discharge, surface mining, foundation conditions, water supply, and land-use classification.

EVALUATION OF METHODOLOGIES

EARTH-DISTURBANCE INVENTORY

A distinction must be drawn between an inventory of landslides, which results in a map showing distribution of active landslides or landslide deposits, and an investigation of susceptibility to landsliding, which results in a classification of land by degrees of susceptibility. The provisional landslide-susceptibility maps, and the Allegheny County map of susceptibility to landsliding (MF–685B) include both types of information, whereas the map in the hydrogeologic chart on heavy storm precipitation and related mass movement (MF–641D) is a synoptic landslide-inventory map; figure 5 of this report is a small-scale map of susceptibility to landsliding, and the Allegheny County map of zones (MF–685D) is a map of areas susceptible to landsliding as well as to flooding and potential mine subsidence.

In the Allegheny County work many small significant active landslides were not discernable on the aerial photographs, despite their relatively large scale and excellent resolution. However, these small landslides were readily identifiable on the ground, so field verification was a necessity for a reasonably complete inventory of landslides.

On the other hand, experience gained in the Allegheny County terrane suggests that aerial-photographic interpretation and integration of the results with geologic, soils, and other data, that is, laboratory and office work alone, would have yielded an adequate map of susceptibility to landsliding, assuming only that investigators had a reconnaissance familiarity with the terrane as seen from the ground.

Extrapolating the Allegheny County experience in landslide studies to elsewhere in the Appalachian Plateau, the following general conclusions can be drawn:

1. If landslide inventories are required, the Allegheny County methodology probably is directly applicable. The aerial-photographic scale is appropriate, as is the allowance of time for interpretation and field verification, about one man month for the area included in each 7½-minute quadrangle. The basic data on geology, soils, and other features can be reasonably sparse and still result in a good inventory, for the inventory method basically is objective rather than interpretive. Investigators would gain necessary ground familiarity during the field verification stage of an inventory.
2. If maps of susceptibility to landsliding only are required, the general Allegheny County methodology is applicable in that the basic method included aerial-photographic interpretation and integration of results with other information. Aerial-photographic scale need not be so large; 1:24,000 scale or somewhat smaller would suffice provided photographic quality is good and photographic flights are during leafless seasons. Field verification could be minimal, providing investigators had a reasonable familiarity with the area and an adequate framework of geologic and other information. In summary, if good-quality aerial photography at an inter-

mediate scale, an adequate basic-data framework, and investigators generally familiar with the setting can be brought together, adequate maps of susceptibility to landsliding in the Appalachian Plateaus probably can be prepared quite rapidly.

The part of the earth-disturbance inventory that resulted in the provisional maps of man-modified land and was extrapolated in part to the coal-mining features map (MF–685C), was done simultaneously with the landslide parts of the investigation and probably accounted for less than one-fourth the total effort on the earth-disturbance inventory. Similar, though somewhat less detailed, work can be done over large areas using small-scale aerial photography, as has been demonstrated in the course of land-use mapping in the Greater Pittsburgh region and many other areas. It probably is uneconomic to use large-scale aerial photographs for making maps of man-modified land only. However, when coupled with a complete earth-disturbance inventory, such as was done in Allegheny County, large-scale aerial photographs can yield land-modified-by-man maps as a useful byproduct with economy of effort.

MAPS SHOWING UNDERGROUND COAL-MINING ACTIVITY THAT CAN RELATE TO SURFACE SUBSIDENCE

Principal methods used in compiling information for these three county maps are those common to many regional geologic studies. Chief innovations were the adaptation of statistical data on mine-subsidence events to the maps of Pittsburgh coal-bed and Upper Freeport coal-bed features (MF–693A and MF–693B, respectively), and the combination of these maps to produce the map of areas that correlate with subsidence events (MF–693C). Evaluation of the innovations must await distribution and the response of potential users to the reports.

INTEGRATION OF RESULTS OF THE GEOLOGIC STUDIES

The chief methods used to achieve the coal-mining features map (MF–685C) were evaluated above, and these methods were followed by conventional reduction and transfer of information and development of texts and illustrations. The Allegheny County map of zones (MF–685D) was prepared conventionally by simplifying landslide-susceptibility and undermined-area map data and combining the results with other data. Interpretation of soil-survey information and comparison with existing geological information resulted in the Allegheny County rock-type map (MF–685A). This method was quite successful in enhancing geologic knowledge in an area of complexly interlayered sedimentary rock; the methodology also should be applicable to other areas of similar geological character where modern soil surveys have been completed.

RECONNAISSANCE APPRAISAL OF THE ROLE OF SHALLOW GROUND WATER IN MINING AND SLOPE-STABILITY PROBLEMS

Briefly stated, the method included gathering information, identifying inadequacies of information, attempting to rectify these inadequacies within the time available, and synthesizing the information. The method worked well in Allegheny County largely because Pittsburgh and its vicinity includes a large technical and scientific community from which information and insights could be drawn. Lacking such information, the same methodology in the same time frame probably would have proved less productive elsewhere in the predominantly rural Appalachian Plateaus. Thus, the methodology probably is not directly extrapolatable, but the contributions to understanding contained in the hydrogeologic charts (MF–641A through MF–641E) are themselves capable of wider application. An innovation is the chart-like format of the products, but its evaluation must await user response.