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Subsidence Information for Underground Mines—Literature Assessment and Annotated Bibliography

By A. J. Fejes, R. C. Dyni, J. A. Magers, and L. B. Swatek



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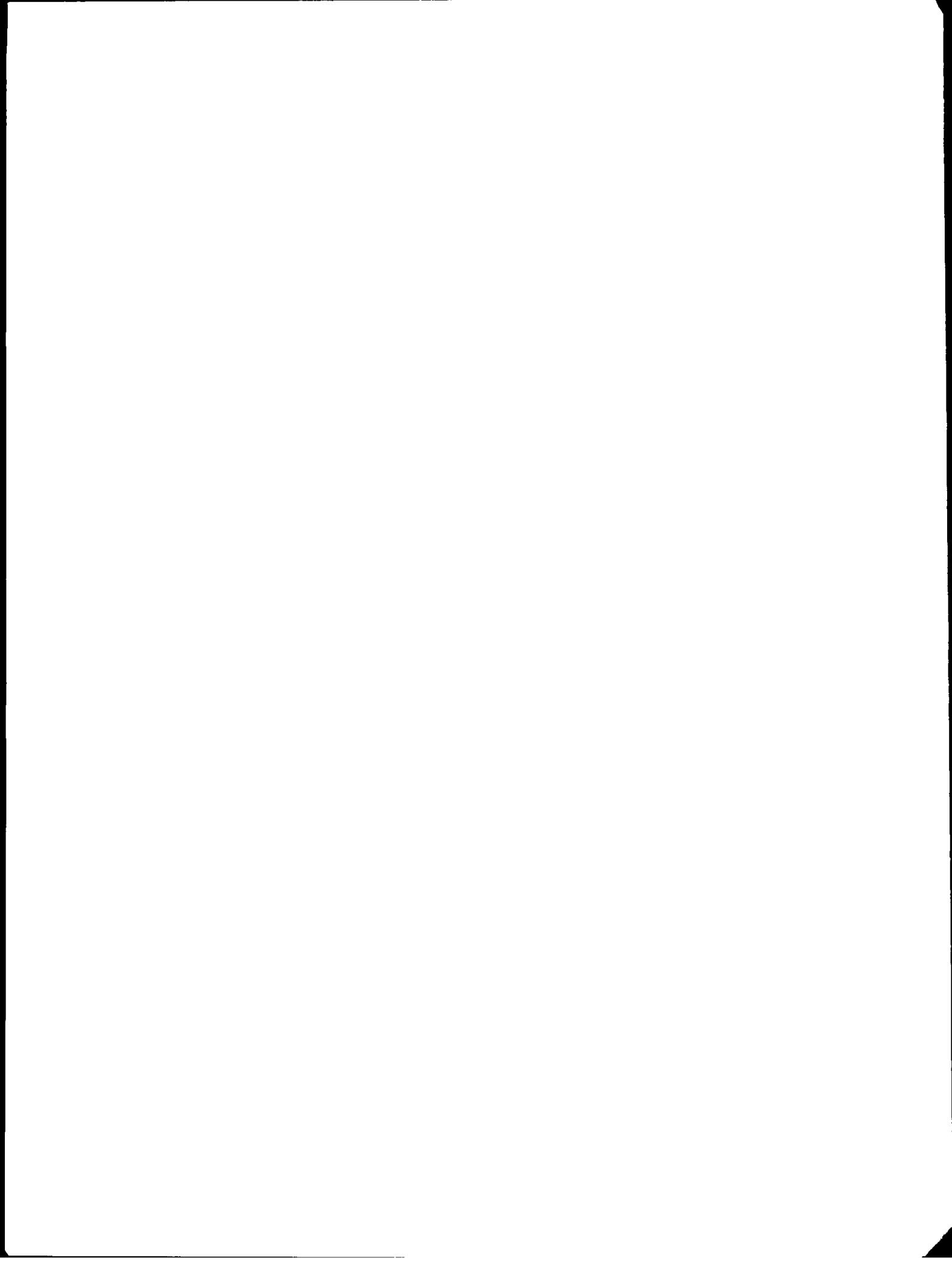
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SUBSIDENCE INFORMATION FOR UNDERGROUND MINES--LITERATURE ASSESSMENT AND ANNOTATED BIBLIOGRAPHY

By A. J. Fejes,¹ R. C. Dyni,² J. A. Magers,³ and L. B. Swatek⁴

ABSTRACT

The purpose of this Bureau of Mines report is to provide mining industry personnel and regulatory authorities with a subsidence-reference list and annotated bibliography that will aid them in locating subsidence information and in developing their own subsidence information sources. Over 700 references are listed in the Bureau's subsidence information center bibliography; approximately 600 of these references were obtained for assessment. Of these 600 references, 167 were selected to be rated, categorized, and annotated. All literature referenced in this report was published prior to 1984. Table 1 is a cross-referenced index that classifies and rates selected references with respect to specific keywords. References are rated not on quality of content but rather on applicability to given subject areas. Appendix A is an annotated bibliography of the references listed in table 1 and provides further information on each article to aid the user in selecting articles for specific areas of subsidence technology. Appendix B is a copy of the subsidence information center bibliography.

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INTRODUCTION

This Bureau of Mines report identifies sources of subsidence information that are often unknown or unavailable to mine industry personnel. Its purpose is to assist the mining industry and regulatory authorities by providing a subsidence-reference list and annotated bibliography that will aid them in locating subsidence information and in developing their own subsidence information sources.

A subsidence information center was started at the Bureau's Denver (CO) Research Center in 1980 to create a single, central, and comprehensive source of available state-of-the-art subsidence literature and provide this information to mine operators attempting to limit or control mining-related subsidence damage. An intensive literature search was performed to compile a comprehensive subsidence bibliography. This search included the use of computerized information retrieval systems, published bibliographies, and individual assessments of subsidence article bibliographies. At the end of 1983, the bibliography contained over 700 references with approximately 600 subsidence references available for consultation at the Bureau's Denver Research Center. From these available references, articles were selected and annotated; the procedures used for selecting articles are described later in this report. All annotated articles in this report are on file at the research center.

The Surface Mining and Reclamation Act of 1977, Section 516 (b)(1) of Public Law 95-87, requires mine operators to adopt "...measures consistent with known technology in order to prevent subsidence causing material damage...."

This report outlines available literature that pertains to state-of-the-art subsidence technology, developed in the United States and abroad, that will assist persons developing subsidence control plans. Included in the literature is information on subsidence-prediction methods, subsidence-related material damage, subsidence-control measures, subsidence-monitoring procedures, and subsidence law.

This report describes subsidence technology required by mine planners, keywords developed for characterization of references, rationale used for selecting and rating references in appendix A, and availability of references.

Table 1 lists 167 references selected for annotation. It identifies the content of each reference and rates the content of each reference with respect to its applicability to the given subject areas. The table is cross-referenced, subject versus reference, to assist users in locating information on a specific area of subsidence technology or on a specific subsidence reference.

Appendix A is an annotated bibliography of the references in table 1 and provides further information on each article. Included in each annotation is bibliographic information and a brief description of the content, ease of use, and applicability of subsidence information.

Appendix B is the subsidence information center bibliography, including all references in appendix A. Of the 767 references listed in appendix B, approximately 600 were assessed for possible inclusion in appendix A. The remaining articles were not assessed because they were out of print, not available in English, or not attainable.

Since most engineers who apply the subsidence technology have neither the time nor money to expend on an extensive search for subsidence literature, it was felt that it would be appropriate to assess only those articles that are readily available to U.S. subsidence engineers and mine planners. However, all references were included in appendix B for completeness. Of the approximately 600 references obtained for assessment, only 167 articles were annotated. These articles were considered by the authors to be representative of state-of-the-art technology for the given key subject areas. The annotation of over 600 articles would provide an unwieldy reference that would have been costly and time consuming to produce.

ACKNOWLEDGMENTS

Larry R. Powell, geologist, Twin Cities (MN) Research Center, Merle T. Bernstein, librarian, Twin Cities (MN) Research Center, and Betsy Chapel, librarian, Denver (CO) Research Center, are acknowledged for their efforts in obtaining and providing subsidence references assessed in this report.

This project received strong support and encouragement from the Office of Surface Mining and was developed and closely coordinated with that organization from the outset.

SUBSIDENCE TECHNOLOGY REQUIRED BY MINE OPERATORS

To control, mitigate, or prevent mining-related subsidence damage, mine planners must be able to adequately estimate the location and magnitude of vertical and horizontal displacement, curvature, tilt, and strain at the ground surface. Although it is impossible to totally eliminate surface effects from underground mining, adequate subsidence-prediction methods used in conjunction with proper mine-design and damage-mitigation techniques can minimize adverse surface effects.

State-of-the-art subsidence technology is scattered throughout numerous institutions and is unknown or unavailable to many mine planners. This report attempts to minimize this problem by locating, assessing, rating, and categorizing this information with respect to five key subjects: (1) prediction methods, (2) material damage, (3) subsidence control, (4) subsidence monitoring, and (5) subsidence law. Information relating to these subjects can assist mine operators in complying with Public Law 95-87.

REFERENCE ASSESSMENT, RATING, AND CATEGORIZATION

The following five key subjects were used to assess, rate, and categorize subsidence literature. They represent the areas of subsidence technology that will assist mine planners in developing a subsidence-control plan in accordance with Public Law 95-87.

1. Prediction Methods

- Means of predicting vertical ground displacements at the surface.
- Means of predicting horizontal ground displacements at the surface.
- Applicability to the Appalachian Coal Region.
- Applicability to the Illinois Coal Basin.
- Applicability to the Rocky Mountain Coal Region.

2. Material Damage

- Damage to surface structures.
- Damage to subsurface structures.

- Hydrologic damage to surface water including rivers, streams, and surface drainage.

- Hydrologic damage to ground water systems.

3. Subsidence Control

- Controlling subsidence with properly designed underground-mine layouts.

- Controlling or limiting subsidence with backfilling techniques.

- Minimizing structural damage through design and construction (surface measures).

4. Subsidence Monitoring

- Design of monitoring systems for measuring surface effects.

- Instrumentation required for monitoring systems.

- Survey methods for measuring vertical and horizontal displacements.

- Surveying required for subsidence monitoring.
- Data processing methods for subsidence data and information.

5. Subsidence Law

- Federal laws that relate to mining subsidence.
- Laws that relate to mines in the Appalachian Coal Region.
- Laws that relate to mines in the Illinois Coal Basin.
- Laws that relate to mines in the Rocky Mountain Coal Region.
- Laws in foreign countries that relate to mining subsidence.

All subsidence references listed in appendix B were analyzed to determine their applicability to these five key

subjects. If the reference was germane to one or more keywords, an attempt was made to obtain the article. If the article was obtained and selected for annotation, it was assessed and rated with respect to each key subject.

Each reference was rated either S, G, or E to indicate its relevancy in the specific area (key subject). The rating S signifies a satisfactory reference that contains general information of limited scope. A rating of G indicates a good reference that contains a full breadth of information on the given subject but lacks specific information. A rating of E indicates an excellent reference because it contains specific, comprehensive information. The absence of a rating indicates that the reference does not pertain to that key subject.

AVAILABILITY OF INFORMATION

Prior to the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87), there was limited concern in the United States about the problem of mine subsidence. Thus, subsidence research for U.S. mining conditions was limited. In contrast, European mining engineers were greatly concerned with mine subsidence because of high population densities that increased the probability of damage to surface structures. Therefore, most state-of-the-art subsidence technology is derived from European experience. However, it is not known how much, if any, of this foreign technology is applicable to U.S. conditions, and information that does apply might be difficult to obtain. Good sources of subsidence information in the United States are colleges and universities with mining departments, and a few State and Federal agencies.

Federal agencies that might have subsidence information include mining-research and mining-regulatory agencies, such as the Bureau of Mines, the U.S. Department of Energy, the U.S. Geological Survey, and the Office of Surface Mining Reclamation and Enforcement. State agencies that may have access to subsidence information include State mining and geological surveys. In addition, the articles annotated in appendix A are available for consultation at the Denver (CO) Research Center.

Based on the number of subsidence articles published since 1977, the amount of subsidence research being performed in the United States has increased dramatically, and there will no doubt be a further concentration of research on this subject in the future.

TABLE 1. - Categorization and rating of selected subsidence references contained in appendix A

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
PREDICTION METHODS																								
Ground displacement:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vertical.....	-	S	G	E	-	-	G	-	-	-	-	-	-	-	-	-	S	-	E	E	-	S	-	-
Horizontal.....	-	-	-	E	-	-	-	-	-	-	-	-	-	E	-	-	S	-	E	E	-	S	-	-
Location:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Appalachian Coal Region....	-	-	-	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Illinois Coal Basin.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rocky Mountain Coal Region	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MATERIAL DAMAGE																								
Structural:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surface damage.....	-	-	-	-	-	-	-	E	-	-	-	-	-	-	G	-	-	G	-	-	E	E	S	G
Subsurface damage.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	E	-	-
Hydrological:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surface water.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ground water.....	-	-	-	-	-	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-
SUBSIDENCE CONTROL																								
Mine design.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Backfilling.....	-	-	-	-	G	-	-	-	-	G	E	G	-	-	-	-	S	-	-	-	E	E	S	-
Surface measures.....	-	-	-	-	-	-	-	-	E	-	-	-	-	-	-	-	-	-	-	-	-	E	-	-
SUBSIDENCE MONITORING																								
Monitoring network:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Design.....	G	-	-	-	-	S	G	G	-	-	-	-	E	-	-	-	-	-	-	-	-	S	-	-
Installation.....	G	-	-	-	-	G	-	G	-	-	-	-	E	-	-	-	-	-	-	-	-	S	-	-
Equipment.....	G	-	-	-	-	G	S	G	-	-	-	-	E	-	-	-	-	-	-	-	-	S	-	-
Surveying:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methods.....	-	-	-	-	-	G	S	G	-	-	-	-	-	-	S	-	-	-	-	-	-	S	-	-
Equipment.....	-	-	-	-	-	G	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-
Data processing.....	-	-	-	-	-	G	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUBSIDENCE LAW																								
Federal.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Appalachian Coal Region....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	E	-	-	-	-	-	-	-	-
Illinois Coal Basin.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rocky Mountain Coal Region..	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Foreign.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	E
- No practical application.																								
E Excellent. G Good. S Satisfactory.																								

	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	
PREDICTION METHODS																									
Ground displacement:																									
Vertical.....	S	-	-	S	-	-	-	-	-	E	S	G	S	-	E	E	E	E	E	G	G	-	-	G	
Horizontal.....	-	-	-	S	-	-	-	-	-	E	S	G	S	-	E	E	E	E	E	G	G	-	-	G	
Location:																									
Appalachian Coal Region....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Illinois Coal Basin.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Rocky Mountain Coal Region	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MATERIAL DAMAGE																									
Structural:																									
Surface damage.....	-	-	G	G	-	S	-	-	-	-	-	-	-	S	-	-	-	G	-	-	G	-	-	G	
Subsurface damage.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	-	-	-	-	-	G	
Hydrological:																									
Surface water.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	G	
Ground water.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	
SUBSIDENCE CONTROL																									
Mine design.....	-	-	-	-	-	S	-	-	-	-	-	-	G	G	-	-	-	G	-	-	-	-	-	G	
Backfilling.....	-	E	-	-	-	-	-	-	-	-	-	E	G	S	-	-	-	-	-	-	G	-	-	G	
Surface measures.....	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	-	G	
SUBSIDENCE MONITORING																									
Monitoring network:																									
Design.....	-	-	-	-	-	-	G	G	G	-	-	-	S	-	-	-	-	G	-	-	-	-	-	-	
Installation.....	-	-	-	-	-	-	E	G	G	-	-	-	S	-	-	-	-	S	-	-	-	-	-	-	
Equipment.....	-	-	-	-	-	-	G	G	G	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	
Surveying:																									
Methods.....	-	-	-	-	-	-	S	S	G	-	-	-	-	-	-	G	-	E	-	-	-	-	-	-	
Equipment.....	-	-	-	-	-	-	S	S	S	-	-	-	-	-	-	G	-	G	-	-	-	-	-	-	
Data processing.....	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-	E	-	-	-	-	-	-	
SUBSIDENCE LAW																									
Federal.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	-	-	-	
Appalachian Coal Region.....	-	-	-	-	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Illinois Coal Basin.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Rocky Mountain Coal Region..	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Foreign.....	-	-	-	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	

- No practical application. E Excellent. G Good. S Satisfactory.

	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120		
PREDICTION METHODS																										
Ground displacement:																										
Vertical.....	-	S	S	G	E	-	G	S	-	-	-	-	-	-	-	S	G	S	E	E	-	-	S	-	-	
Horizontal.....	-	S	S	G	E	-	G	S	-	-	-	-	-	-	-	S	G	-	-	E	-	-	S	-	-	
Location:																										
Appalachian Coal Region....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Illinois Coal Basin.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Rocky Mountain Coal Region	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
MATERIAL DAMAGE																										
Structural:																										
Surface damage.....	-	-	-	-	E	-	-	-	S	G	-	-	-	-	-	S	G	G	S	-	S	-	-	G	G	
Subsurface damage.....	-	-	-	-	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hydrological:																										
Surface water.....	-	E	-	-	G	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ground water.....	-	E	-	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
SUBSIDENCE CONTROL																										
Mine design.....	-	-	-	-	-	-	-	-	G	E	S	-	-	-	-	-	G	-	-	-	-	-	-	S	-	
Backfilling.....	-	-	-	-	-	-	-	-	S	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Surface measures.....	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	
SUBSIDENCE MONITORING																										
Monitoring network:																										
Design.....	G	-	-	-	-	S	-	-	-	-	-	S	E	-	S	-	G	-	-	-	S	-	-	S	-	
Installation.....	G	-	-	-	-	S	-	-	-	-	-	S	E	-	S	-	-	-	-	-	-	-	-	-	-	
Equipment.....	G	-	-	-	-	S	-	-	-	-	-	S	E	G	S	-	-	-	-	-	-	-	-	-	-	
Surveying:																										
Methods.....	E	-	-	-	-	S	-	-	-	-	-	S	E	G	S	-	S	-	-	-	-	-	-	G	G	
Equipment.....	S	-	-	-	-	S	-	-	-	-	-	S	E	G	S	-	S	-	-	-	-	-	-	G	G	
Data processing.....	G	-	-	-	-	S	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
SUBSIDENCE LAW																										
Federal.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Appalachian Coal Region.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Illinois Coal Basin.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Rocky Mountain Coal Region..	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Foreign.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
- No practical application. E Excellent. G Good. S Satisfactory.																										

	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167
PREDICTION METHODS																							
Ground displacement:																							
Vertical.....	-	S	-	-	S	-	S	G	-	E	-	-	G	-	-	G	G	-	-	E	-	S	E
Horizontal.....	-	S	-	-	S	-	S	-	-	E	-	-	G	-	-	G	G	-	-	E	-	S	E
Location:																							
Appalachian Coal Region....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Illinois Coal Basin.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rocky Mountain Coal Region	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MATERIAL DAMAGE																							
Structural:																							
Surface damage.....	-	S	-	-	-	-	S	-	-	-	-	-	-	-	E	-	S	-	-	G	S	S	-
Subsurface damage.....	-	S	-	-	-	-	-	-	-	-	-	-	-	-	G	-	-	-	-	-	S	S	-
Hydrological:																							
Surface water.....	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	S	-
Ground water.....	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	S	-
SUBSIDENCE CONTROL																							
Mine design.....	-	S	S	G	S	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	-
Backfilling.....	-	-	-	-	-	-	-	-	-	-	-	E	-	-	-	-	-	-	-	-	S	S	-
Surface measures.....	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUBSIDENCE MONITORING																							
Monitoring network:																							
Design.....	-	-	G	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Installation.....	-	-	S	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equipment.....	-	-	S	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surveying:																							
Methods.....	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equipment.....	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-
Data processing.....	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUBSIDENCE LAW																							
Federal.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-
Appalachian Coal Region....	-	-	-	-	-	-	-	-	-	-	E	-	-	-	-	-	-	-	-	-	-	-	-
Illinois Coal Basin.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rocky Mountain Coal Region..	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Foreign.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- No practical application. E Excellent. G Good. S Satisfactory.																							

APPENDIX A.--ANNOTATED BIBLIOGRAPHY OF SELECTED REFERENCES

1. Abel, J. F. Surface Subsidence Monitoring Guidelines. (U.S. Geol. Surv. contract 14-08-0001-18822, CO School Mines). June 30, 1982, 11 pp.

Contains suggested guidelines for monitoring subsidence over longwall and room-and-pillar retreat mines. Included are details on monument-layout patterns, monument construction and installation, monument spacing, survey timing, and strain-measurement procedures. A rationale is provided for these guidelines.

Should be useful for those planning a subsidence-monitoring program.

2. Abel, J. F., and D. W. Gentry. A Longwall Subsidence Prediction Model. Pres. at Am. Soc. Civil Eng. Natl. Spring and Continuing Education Conv., Pittsburgh, PA, Apr. 24-28, 1978, session 71. ASCE preprint 3293, pp. 56-76.

Presents a preliminary subsidence-prediction model for the York Canyon coal seam. Data for the model were obtained from an instrumentation program implemented at the York Canyon Mine, near Raton, NM. The prediction model provides an excellent fit to collected data, however, the application of this model to other geologic environments is unproven.

Should be useful in predicting subsidence over coal mines with geology similar to that found at the York Canyon Mine. The accuracy of this model, however, has not yet been proven.

3. Adamek, V., and P. W. Jeran. Evaluation of Existing Predictive Methods for Mine Subsidence in the U.S. Chapter 7 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 3, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 88-89.

Two existing prediction methods are evaluated for use in the United States; an influence function (Bals theory), and a profile function (hyperbolic). These methods were applied to several field-measured subsidence profiles over U.S. coal mines. The results of these comparisons are described in detail. An appendix provides information of the application of Bals theory.

These prediction methods might be found useful in areas where stratigraphic conditions are not conducive to bridging. However, no proof of validity for these methods in any area of the United States is offered.

4. _____. Evaluation of Surface Deformation Characteristics Over Longwall Panels in the Northern Appalachian Coalfield. Chapter 17 in State-of-the-Art of Ground Control in Longwall Mining and Mining Subsidence (Soc. Min. Eng. AIME Fall Meeting, Honolulu, HI, Sept. 4-9, 1982). Soc. Min. Eng. AIME, Littleton, CO, 1982, pp. 183-198.

Details the characteristics of surface deformations, including subsidence, inclination, curvature, and horizontal strain. These characteristics, based on data obtained by direct field measurements over three longwall panels in the northern Appalachian coalfield, are compared with computed values determined by Bals' and Knothe's prediction theories. The results of the comparison are discussed and conclusions are drawn as to the effectiveness of the two theories.

Provides an excellent analysis on the validity of two European surface-deformation prediction theories when applied to geological conditions found in the Appalachian Coal Region. The material is intended for use by persons familiar with subsidence engineering.

5. Allen, A. S., and C. W. Anderson. Recent Developments in the Use of Mine Waste for Subsidence Control. Paper in Proceedings of the 4th Mineral Waste Utilization Symposium (cosponsored by BuMines and IIT Res. Inst., Chicago, IL, May 7-8, 1974). IIT Res. Inst., Chicago, IL, 1974, pp. 213-221.

Provides information on pumped-slurry backfilling procedures used for controlling subsidence in abandoned room-and-pillar mines that have become flooded or are otherwise inaccessible. The article describes a demonstration project performed in Scranton, PA, in 1972, and details the use of mine waste as fill material. Recommendations are made for further hydraulic-backfilling research.

Good, informative source of background information on backfilling methods for abandoned coal workings. However, it does not contain technical information on backfilling methods and procedures.

6. Allgaier, F. K. Subsidence Monitoring Over Western Coal Mines. Chapter 12 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 156-161.

Briefly describes the subsidence-monitoring equipment and procedures used at five coal mines in Colorado and Utah. Contains information on network layout, monument location and installation, monument construction, survey equipment, and data processing. Illustrations and drawings are provided.

Does not provide a comprehensive study of subsidence-monitoring methods and techniques. It is, however, easy to read and understand and does provide information on basic monitoring procedures. It is a good reference for those who are planning a subsidence-monitoring program but are unfamiliar with existing procedures.

7. _____. Surface Subsidence Over Longwall Panels in the Western United States. Chapter 18 in State-of-the-Art of Ground Control in Longwall Mining and Mining Subsidence (Soc. Min. Eng. AIME Fall Meeting, Honolulu, HI, Sept. 4-9, 1982). Soc. Min. Eng. AIME, Littleton, CO, 1982, pp. 199-209.

Describes an ongoing research program being conducted in central Utah on surface subsidence prediction. The geology, mine plan, and survey network is outlined for the three study sites involved. A brief discussion of several prediction methods is presented, followed by a comparison of measured values from the study sites with results of two prediction methods; the NCB (National Coal Board) method, and the Donets profile function developed for the Donets coalfield in the Soviet Union.

Would be helpful to the mine operator interested in subsidence prediction methods. Also included is a brief discussion of subsidence monitoring and surveying techniques.

8. _____. Surface Subsidence Over Longwall Panels in the Western United States: Monitoring Program and Preliminary Results at the Deer Creek Mine, Utah. BuMines IC 8896, 1982, 24 pp.

A preliminary report on a case history study being performed over four adjacent longwall panels located in central Utah. Provides a description of the site, localized geological data, and preliminary subsidence results. Discusses the design of a subsidence-monitoring system including monument location, monument spacing, monument construction, installation procedure, survey schedule, and survey procedures.

Provides the basic information needed for a general understanding of subsidence monitoring design, procedures, and equipment. Information from the case study can be used to estimate labor, time, and economic requirements for similar monitoring projects.

9. Arup, O. N., and R. S. Jenkins. The Design of a Reinforced-Concrete Factory at Brynmawr, South Wales. Paper in Proceedings of the Institution of Civil Engineers, v. 2. pt. 3, No. 3, Dec. 1953, pp. 345-397.

Describes construction of a factory over abandoned room-and-pillar and longwall coal workings. Contains technical information and the rationale for the ground survey, ground treatment, foundation, and structural design work required. The appendix provides tables that indicate the mathematics involved in the design theory. Numerous photographs, drawings, and diagrams are also included.

Excellent reference for those planning to build structures in areas of possible mine subsidence. It relates directly to structures being built over abandoned workings, but can be applied to current or future mining areas where the mining method and layout are known. Would be most easily understood by someone with a background in building design or construction.

10. Ashmead, D. C. How the Kingston Coal Company Reduces Subsidence and Conserves Coal by Rock Filling and Silting. *Coal Age*, v. 20, Aug. 1921, pp. 167-171.

Investigates backfilling methods used by the Kingston Coal Co. in Pennsylvania. Specific sections detail the composition of the silt and fill, the construction of the pumping lines, the maintenance of the lines, the backfilling procedures, and the overall effectiveness of the system.

Provides good information on a specific backfilling system for an underground mining operation and should be of use to those interested in backfilling techniques.

11. Australasian Institute of Mining and Metallurgy. Proceedings of the Jubilee Symposium on Mine Filling (Mount Isa, Australia, Aug. 19-22, 1973). 1973, 282 pp.

Details research on fill properties and filling techniques.

Should be of use to those interested in controlling subsidence by backfilling methods.

12. Aynsley, W. J., and G. Hewitt. Subsidence Observations Over Shallow Workings, Including Pneumatic Stowing and Rapidly-Advancing Faces. *Min. Eng.* (London), v. 120, Apr. 1961, pp. 552-569.

Discusses the effects of packing and stowing systems on surface subsidence and resulting surface damage in shallow workings. Compares amounts of subsidence recorded for different packing and stowing systems where both a full and partial area of influence have been worked. Also compares the surface effects of subsidence from rapidly advancing faces versus conventional machine mine workings. Application of this research is presented in a case-history study of an undermined viaduct in England. Numerous tables present clearly the data used to outline results and draw conclusions. A discussion of the paper by knowledgeable subsidence researchers with the authors follows the text.

Good reference for techniques on limiting the amount of subsidence with the use of backfilling methods. A technical background in mining engineering is recommended.

13. Barla, G. B., and S. Boshkov. Investigations of Differential Strata Movements and Water Table Fluctuations During Longwall Operations at the Somerset Mine No. 60 (Dep. Energy contract ET-76-C-01-9041, Columbia Univ.). 1978, 49 pp.; NTIS FE-9041-1.

Results of research done at the Somerset Mine No. 60 near Washington, PA, involve the instrumentation and monitoring of water table fluctuations and differential strata movements over a longwall coal mine. A description of the instrumentation and results of the study are included. Numerous photographs, drawings, and diagrams supplement the text.

Should be useful to those planning to monitor the hydrologic effects of longwall mining. This publication is most easily used by those familiar with geomechanical logging techniques.

14. Barr, B. I. G., and R. Delpak. Prediction of Ground Movement in Areas of Mining Subsidence. *Highway Eng.*, v. 21, June 1974, pp. 18-22, 36.

Deals with the estimation of surface strains and deflections caused as a result of longwall mining. The Sims-Bridle method of predicting displacements is discussed and displacement-calculation procedures are detailed. Sample calculations and a computer-program flow chart for the prediction method are also provided.

Could be useful for predicting strain over a longwall panel. However, this method was developed for geologic conditions found in England and therefore does not necessarily apply directly to U.S. coalfields.

15. Beevers, C., and K. Wardell. Recent Research in Mining Subsidence. Trans. Inst. Min. Eng. (London), v. 114, 1954-55, pp. 223-253.

Describes precise subsidence surveying techniques used in the Yorkshire Coalfield in England. Conclusions based on these measurements are made relating to maximum possible subsidence, angle of draw, and the general development of ground movement. Discusses the importance of traveling or dynamic ground movements and the variations in normal subsidence development that occur when packing is increased or partial extraction by strip working is used. Also discusses the question of surface damage to structures and the possibility of minimizing such damage by special underground layout. A successful case of minimizing damage to a large building by a deliberate cancellation of strains is described in detail.

Good reference on the minimization of subsidence damage through underground layout. Although only one example is described, it demonstrates that with proper mine design, surface damage can be reduced.

16. Bise, C. J. Pennsylvania's Subsidence-Control Guidelines: Should They Be Adopted by Other States? Min. Eng., v. 33, Nov. 1981, pp. 1623-1628.

Analyzes the Pennsylvania Bituminous Mine Subsidence Act of 1966--the only comprehensive subsidence act passed by any State--and discusses its applicability to other States. Notes the provisions and guidelines of the act, briefly analyzes the current state-of-the-art in subsidence damage prevention and control, and lists several recommendations for altering the application guidelines of the act for different mining areas.

Excellent reference for those concerned with mine subsidence laws in Pennsylvania.

17. Bojarski, Z., and A. Szczurowski. Report Prepared for the Coal Committee, U.N. Economic Commission for Europe on "The Exchange of Experiences in the Field of Coal Working Under Buildings and Industrial Plants." Central Min. Inst., Res. Center for the Deposit and Surface Protection, Katowice, Poland, Dec. 1978, 27 pp.

Provides detailed information on the mining of safety pillars. Included is an analysis of the profitability and possibility of working within safety pillars, detailing the measures used to reduce the subsequent mining damage. Also included is a description of the characteristics of ground deformations and the methods for predicting these deformations caused by underground mining. Five case studies of extracting coal seams within safety pillars in Poland are given at the end.

Good reference for safety pillar extraction. Based on research done in Poland, but the general principles of ground deformations and measures to reduce mining damage may be useful.

18. Branthoover, G. L., and J. W. Richards. Mine Subsidence Control Using Foundation Grouting, Southwestern Pennsylvania. Paper in Proceedings of the 18th Annual Engineering Geology Soils Engineering Symposium (Boise, ID, Apr. 2-4, 1980). PA Dep. Environ. Resour., 1980, pp. 323-337.

Provides an overview of a subsidence investigation program that includes core borings, borehole television, joint and fracture studies, and rock mechanics analyses. Briefly describes a stabilization procedure that uses modified foundation grouting to minimize structural damage caused by surface movement. Also included is a postconstruction analysis of the data gathered from several multiple-point rod extensometers, illustrating how proper structural design can minimize subsidence damage.

Provides useful information for minimizing structural damage caused by subsidence. A technical background in structural engineering would be helpful in the use of this material.

19. Brauner, G. Critical Review of Present-Day Theory and Practices in the Prediction of Surface Deformation Caused by Mining (BuMines grant G0100749 (MIN-28), MI Technol. Univ.). Dec. 1969, 57 pp.

Gives a review of subsidence-prediction methods currently being used, with emphasis on European methods. The methods are divided into two groups, based on mathematical expressions either for the trough profile or for the influence of infinitesimal extraction elements. The fundamental relationships common to all methods are the principles of superposition and of equivalent-extraction areas. Also included are modifications for the case of inclined strata, as well as a brief review of experimental and theoretical model investigations.

Excellent reference for details on subsidence prediction methods. The material is best suited to those with a technical background.

20. _____. Subsidence Due to Underground Mining (In Two Parts). 1. Theory and Practices in Predicting Surface Deformation. BuMines IC 8571, 1973, 56 pp.

Details two mathematical methods of predicting mine subsidence: the trough profile and the influence of infinitesimal extraction elements. The fundamental relationships of each method involve the principle of superposition and the principle of equivalent-extraction areas. Also included are analyses of horizontal displacements and deformations, surface displacements over inclined seams, time effects, and physical and abstract models.

Excellent reference for the prediction of surface deformations. A technical background would be helpful but not necessary for the use of this material.

21. _____. Subsidence Due to Underground Mining (In Two Parts). 2. Ground Movements and Mining Damage. BuMines IC 8572, 1973, 53 pp.

Discusses in detail the practical implications of ground movements involving surface structures and shafts. Included in this discussion are descriptions of ground movements and surface damage, structural precautions against mining damage, underground precautions against mining damage, mathematical relationships, and the influence of rock movements on shafts.

Excellent source for information concerning mining-related structural damage and methods of avoiding or limiting structural damage. The information is presented in a straightforward manner and can be easily understood by those with a technical background.

22. Breeds, C. D. A Study of Mining Subsidence Effects on Surface Structures With Special Reference to Geological Factors. Ph.D. Thesis, Univ. Nottingham, England, 1976, 250 pp.

A comprehensive treatment of mining-related structural damage. Included is a history and appraisal of early prediction methods and a description of the prediction methods currently used in England. It contains detailed information on foundation engineering in relation to mine subsidence, structural design for structures in areas of mine subsidence, components of mining damage, structural response to underground mining, and methods for protecting existing structures through underground layout and surface precautions. Case studies provide information on the effectiveness of surface precautions used to minimize structural damage.

Excellent reference on protecting existing surface structures from severe subsidence damage. Although the subsidence prediction methods used in England are not always valid for U.S. geologic conditions, the theories involved for underground mine planning and surface-precaution methods are valid for the United States.

23. Briggs, H. Mining Subsidence. Edward Arnold & Co., London, 1929, 215 pp. Comprehensive study of mine subsidence. Provides information on British subsidence laws, historical subsidence theories, partial-extraction mining, backfilling techniques, and case study subsidence observations. These observations were recorded over British, Indian, and American coal mines. Numerous diagrams and drawings help clarify technical information found in the text.

Although written in 1929, still provides valuable subsidence information and is an excellent source of background information on many aspects of subsidence engineering.

24. Bruhn, R. W., W. S. McCann, R. C. Speck, and R. E. Gray. Damage to Structures Above Active Underground Coal Mines in the Northern Appalachian Coal Field. Pres. at 1st Conf. on Stability in Underground Mines (Vancouver, British Columbia, Canada, Aug. 16-18, 1982). AIME, 1982, 21 pp.

Presents the results of a characterization study of subsidence damage to 134 homes located over active underground coal mines in the northern Appalachian coalfield. A summary of the types and locations of damage found in the homes is given, along with a summary of the various methods of underground mining that caused the damage. Proposes a subsidence-damage classification system that provides a uniform and consistent method for defining levels of subsidence damage to homes in the northern Appalachian coalfield. The influence of structural, site, geologic, and mining factors on damage severity is also examined.

Results can be used to determine what types of structural damage might be encountered when using mining methods similar to those used in the northern Appalachian coalfield region.

25. Bumm, H., G. Schweden, and G. Finke. The Mining Subsidence in the Harbours of Duisburg-Ruhrort. Bull. of the Permanent Int. Assoc. of Navigation Congr., Brussels, v. 3, No. 21, 1966, pp. 3-29.

Discusses mining-extraction methods used to control subsidence effects on the Rhine River in the Federal Republic of Germany. Valuable coal deposits located under the Rhine River have not been mined until recently because of possible damage to shipping channels. Provides details on preliminary planning, exploratory operations, extraction methods, damage prediction, damage mitigation, and final damages.

Concerns subsidence problems in the Federal Republic of Germany, but the theories and engineering methods used could possibly be applied to similar U.S. mine subsidence problems.

26. Buntain, M. E. Longwall Growth in the U.S. May Depend on How Well Subsidence is Controlled. Coal Min. Process., v. 12, No. 12, 1976, pp. 71-74, 88-89.

Discusses factors affecting subsidence resulting from longwall mining. This includes angle of draw, geology, width of extraction, and rate of advance. Also contains information on subsidence-control techniques such as backfilling and partial extraction. Concludes with background information on British subsidence laws and compensation requirements.

Good reference for those interested in subsidence effects from longwall coal mining and possible methods of reducing this subsidence. Case history data on partial-extraction methods used in England are also provided.

27. Carlson, E. J. Hydraulic Model Studies for Backfilling Mine Cavities. Bureau of Reclamation Rep. REC-ERC-73-19, Oct. 1973, 36 pp.; NTIS PB 225 613.

Presents results of tests done to investigate the effects of various backfilling parameters on deposition patterns. Parameters studied include slurry concentration, injection velocity, and floor slope. Test results are clearly presented in tables.

Should be useful for determining the backfilling parameters required to obtain a desired deposition pattern, however, it does not provide any information on the practical application of backfilling. Procedures and equipment are described in other publications.

28. Carlson, E. J. Hydraulic Model Studies for Backfilling Mine Cavities (Second Series of Tests). Bureau of Reclamation Rep. REC-ERC-75-3, Mar. 1975, 38 pp.; NTIS PB 241 510.

Presents results of backfilling tests done to investigate the effects of various backfilling parameters on deposition patterns for five specific mine conditions. The following mine conditions with slurry injection were simulated: (1) sloping floor with cavity submerged, (2) level floor with cavity submerged, (3) level floor with cavity dry, (4) simulated mine with and without blind entries, and (5) corridors and rooms in which there were roof falls and cavities in the roof over the roof falls.

Should be useful to persons backfilling in conditions similar to those represented by the hydraulic models.

29. Chen, C. Y., Y. N. Chen, and D. V. Goffney. Architectural Measures To Minimize Subsidence Damage. Appalachian Regional Commission Rep. ARC-73-111-2551, 1974, 130 pp.; NTIS PB 242 466.

Evaluates proposed guidelines, rules, and suggested practices to be used in the design and construction of surface structures and underground utilities to minimize subsidence damage due to underground mining. Included in this evaluation are analyses of subsidence mechanics, subsidence parameters, structural damage, and damage minimization measures.

Although the purpose is to assist the architectural and engineering professions with the design and construction of structures to minimize subsidence damage, much of the information is of a general nature and can be used as a reference for subsidence prediction and control.

30. Chen, C. Y., D. E. Jones, and D. K. Hunt. Government Regulation of Surface Subsidence Due To Underground Mining. Chapter 22 in State-of-the-Art of Ground Control in Longwall Mining and Mining Subsidence (Soc. Min. Eng. AIME Fall Meeting, Honolulu, HI, Sept. 4-9, 1982). Soc. Min. Eng. AIME, Littleton, CO, 1982, pp. 245-252.

Describes mine subsidence laws in the United States. Background information on physical, economical, and psychological effects of subsidence are provided. Also included is a historical review of regulatory measures to control subsidence. The main text contains a brief description and explanation of Public Law 95-87--The Surface Mining Control and Reclamation Act of 1977--and OSM (Office of Surface Mining) responsibilities and regulatory duties.

Excellent reference for those concerned with U.S. subsidence regulations. Although not extremely detailed, it does provide an overview of OSM requirements.

31. Coal Mining and Processing. Can Mining Operations Be Planned To Minimize Subsidence? V. 4, No. 9, 1967, pp. 38-41, 47.

Discusses the use of underground measures as a means of minimizing subsidence. Provides information on pillar size as related to depth, the strata bridge, longwall partial extraction, and advancing versus retreating longwall faces.

Provides good background information on mine design methods limiting or controlling mine subsidence. However, it does not contain specific technical information on mine-design procedures.

32. Coates, D. F., and M. Gyenge. Incremental Design in Rock Mechanics. Min. Res. Centre, Mines Branch, Dep. Energy, Mines and Resour., Canada, Mines Branch Monograph 880, 1973, pp. 5-1--5-15.

Formulates mathematical subsidence-prediction methods for underground mining operations. These methods can be used to calculate subsidence over flat-lying ore bodies, steeply dipping veins, and massive ore bodies that lead to cover caving. The calculations of horizontal displacements and strains are also detailed. Included are numerous sample problems that are solved using the described methods.

Excellent paper on mathematical subsidence prediction methods. The example problems are useful in gaining an understanding of the material. The text is straightforward, and persons with a technical background should have little trouble understanding it.

33. Colaizzi, G. J., R. H. Whaite, and D. L. Donner. Pumped-Slurry Backfilling of Abandoned Coal Mine Workings for Subsidence Control at Rock Springs, Wyo. BuMines IC 8846, 1981, 100 pp.

Describes in detail a pumped-slurry backfilling demonstration project for abandoned mine workings. Also contains background information on other hydraulic backfilling methods such as controlled and blind flushing, but the most detailed analysis concerns the pumped-slurry method. Detailed descriptions of drilling operations, slurry components, mixing plants, slurry pumps, injection operations, and costs are provided. Also included are photographs and explanatory sketches of operations and equipment.

Excellent reference on backfilling procedures, benefits, and costs. Can be used by persons planning to prevent excessive subsidence damage to specific sites by using backfilling methods.

34. Colorado School of Mines. Rock Mechanics Instrumentation Program for Kaiser Steel Corporation's Demonstration of Shield-Type Longwall Supports at York Canyon Mine, Raton, New Mexico (U.S. Dep. Energy contract AC01-74ET12530). 1981, 303 pp.; NTIS DOE/ET/12530-1.

Chapter 5 describes the surface instrumentation used to measure vertical and horizontal movement and extent of surface subsidence. The measured results are then compared with results of predictions made by the National Coal Board of Great Britain. The layout of the surface subsidence monitoring network, the spacing of the monuments, and the construction of the monuments are described. The surveying methods, instrumentation, and data processing system used are also mentioned. Chapter concludes with a discussion of the subsidence and horizontal-strain models developed for the York Canyon Mine and how they compare with the National Coal Board strain-prediction model.

Would be useful to those interested in establishing a surface subsidence monitoring network. A reference to a report with a more detailed discussion about the installation and monitoring of the subsidence monitoring network is given. The performance of the National Coal Board prediction model may also be of interest.

35. Conroy, P. J., and J. H. Gyarmaty. Planning Subsidence Monitoring Programs Over Longwall Panels. Chapter 20 in State-of-the Art of Ground Control in Longwall Mining and Mining Subsidence (Soc. Min. Eng. AIME Fall Meeting, Honolulu, HI, Sept. 4-9, 1982). Soc. Min. Eng. AIME, Littleton, CO, 1982, pp. 225-234.

Presents guidelines for the design and implementation of a comprehensive subsidence monitoring program. The layout of survey networks is discussed, detailing the construction and use of both surface and subsurface subsidence monitoring equipment. An emphasis is placed on the monitoring of horizontal displacements. A useful table that itemizes equipment costs and labor for the installation and monitoring of a typical network as described in the text is given.

Should be very useful in the design of a subsidence control program; it is complete and easy to use.

36. Conroy, P. J., and J. H. Gyarmaty. Subsidence Monitoring--Case History. Chapter 11 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 148-153.

Summarizes subsidence research performed at a minesite in West Virginia. A generalized geological description of the site is included to allow a comparison of subsidence data with those of similar sites. Configurations of underground and surface instruments are described and illustrated. Problems with the installation of the multiple-point borehole extensometer, the full-profile borehole inclinometer, the extensometer, and the automatic data acquisition system are discussed and solutions to these problems are provided. Plans for continued surface monitoring are also included. The conclusion discusses the effectiveness and utilization of each instrument.

Should be of use to those planning a subsidence monitoring program.

37. Conroy, P. J., J. H. Gyarmaty, and M. L. Pearson. Demonstration of Subsidence Monitoring Systems (U.S. Dep. Energy contract AC01-78ET10029, Dames and Moore). 1981, 181 pp.; NTIS DOE/ET/10029-T1.

Provides an excellent source of information on the installation, monitoring, and evaluation of three subsidence monitoring instrument systems: structure performance, performance of supported systems, and performance of caving systems. A comprehensive study of 12 instruments was conducted. Performances of each of the selected instruments are reviewed and recommendations are made on the applicability of instrument systems to monitoring requirements.

Contains a comprehensive study of 12 instruments and how they relate to the three subsidence monitoring systems. Information of this type would be very helpful to those considering instrumentation to best suit the needs of the mine and the type of information desired.

38. Cooley, W. C. Survey of Foreign Technology for Stowing in Underground Coal Mines. Final report on BuMines contract J0275041 with Terraspace, Inc., Rockville, MD. Rep. TR-420-1, May 30, 1978, 60 pp.

Contains a historical summary of foreign technology concerning stowing (backfilling) as a means of limiting subsidence. Translated information includes selected parts of 2 books and 10 papers from the Soviet Union, 8 papers from Poland, and 3 papers from the Federal Republic of Germany. Also included is information on stowing systems, equipment, and instrumentation. Research and development needs for developing economically viable stowing methods for U.S. mining conditions are outlined. A bibliography of this literature and other foreign articles concerning stowing is provided.

Excellent source of information on backfilling methods used to limit subsidence. It is informative and can be used by those without a technical background.

39. Cortis, S. E. Coal Mining and Protection of Surface Structures Are Compatible. Min Congr. J., v. 55, June 1969, pp. 84-89.

Summarizes the various formulas, regulations, and standards developed in Pennsylvania that are used to determine the minimum size of support areas to be left in place for the prevention of damage to surface structures. Also included is an explanation of the provisions relating to the opening, reopening, or continued operation of a mine, and the responsibilities of the mine operator.

Good reference for Pennsylvania's Bituminous Mine Subsidence and Land Conservation Act of 1966.

40. Daemen, J. J. K., and M. Hood. Subsidence Profile Functions Derived From Mechanistic Rock Mass Models. Chapter 9 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 124-139.

Examines the use of mechanistic subsidence models including the possibilities and problems associated with estimating the large-scale rock parameters needed to use some of the elastic solutions for subsidence calculations by treating the solutions as profile functions.

Excellent reference for understanding mechanistic subsidence models. The text is straightforward and can be easily understood by those with a technical background.

41. Dahl, H. D., and D. S. Choi. Measurement and Prediction of Mine Subsidence Over Room and Pillar Workings in Three Dimensions. Chapter 3 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 34-47.

Uses the results of a subsidence survey taken over a room-and-pillar panel in northern West Virginia to compute ground strains with the use of a numerical model. Also included are short discussions on the geology and mining method, as well as a short description of the survey network and of the observation procedures.

Only a qualitative evaluation of the techniques and procedures used in a subsidence study is given. Should be of some use for gaining an understanding of how to relate a subsidence model to actual field measurements.

42. _____. Some Case Studies of Mine Subsidence and Its Mathematical Modeling. Paper in Proceedings of the 15th U.S. Symposium on Rock Mechanics, ed. by E. R. Hoskins, Jr. (Custer State Park, SD, Sept. 17-19, 1973). ASCE, 1975, pp. 1-21.

Compares a mathematical subsidence-prediction model with field data obtained over longwall and room-and-pillar mines in southwest Pennsylvania. The model is a three-dimensional analytical model that incorporates a frictional yield criterion in the constitutive relation. In addition, the effect of topography on subsidence is presented and discussed.

Only a basic overview of the mathematical model and the success of its results are provided. There is insufficient detail to enable one to use the subject model as a predictive tool.

43. Dobson, W. D., E. L. Potts, R. G. S. Roberts, and K. Wilson. The Coordination of Surface and Underground Development at Peterlee, Co., Durham. Trans. Inst. Min. Eng. (London), v. 119, 1959-60, pp. 279-300.

Describes the results of subsidence research performed in 1958 in Durham, England. Results of subsidence surveys are presented in numerous graphs. Layout and design procedures for a subsidence monitoring network are also included. Procedures for coordinating surface and underground development in order to minimize subsidence are also provided.

Good source of background information on subsidence research methods. The material presented is best suited for those with a background in subsidence engineering.

44. DuMontelle, P. B., S. C. Bradford, R. A. Bauer, and M. M. Killey. Mine Subsidence in Illinois: Facts for the Homeowner Considering Insurance. IL Geol. Surv., Environ. Geol. Notes 99, Aug. 1981, 24 pp.

Covers the geology of Illinois, the areas undermined, the mining methods used, the types of subsidence, and the effects of subsidence, all in language easy to understand. Also covered are surface conditions that might be mistaken for mine subsidence.

Although informative for Illinois homeowners, it cannot be used directly by mine operators concerned with avoiding or controlling subsidence. However, it does illustrate subsidence damage potential and its possible extensiveness.

45. Dunn, J. R., G. M. Banino, and W. D. Ernst. The Physical and Chemical Characteristics of Available Materials for Filling Subsurface Coal Mines (contract J0155182, Dunn Geoscience Corp.). BuMines OFR 151-77, 1977, 282 pp.; NTIS PB 274 702.

Studies the critical physical and chemical characteristics of available high-bulk materials that might possibly be used to fill abandoned rooms in anthracite coal mines of eastern Pennsylvania and bituminous coal mines of western Pennsylvania. Also included is a discussion on possible mixtures of materials that could react chemically to form concretelike masses. The possibilities of emplacing mine fill material using turbidity currents and mud flow are also given.

Excellent reference for those interested in the characteristics of backfilling materials. The text is complete and supplemented with descriptions of sample locations and field descriptions.

46. Enzian, C. Hydraulic Mine Filling, Its Use in the Pennsylvanian Anthracite Fields, a Preliminary Report. BuMines B 60, 1913, 77 pp.

Outlines the use of hydraulic backfilling methods in preventing loss of unmined coal in pillars and in protecting surface property from damage by subsidence. Included is information on filling materials, fill transportation, bulkhead construction, mining method filling variations, filling effects on ventilation and drainage, and filling costs. A selected bibliography of hydraulic mine filling publications is also provided.

Provides a comprehensive study on hydraulic mine filling methods and procedures. Although printed in 1913, the theories and methods discussed can still be applied to current mining practices. Could be used by those wishing to prevent damage to valuable surface features through the use of underground precautionary methods.

47. Evans, D. W., and G. J. Colaizzi. Control of Mine Subsidence Utilizing Coal Ash as a Backfill Material. Paper in Second Conference on Ground Control in Mining, ed. by S. S. Peng and J. H. Kelley (Morgantown, WV, July 19-21, 1982). WV Univ., Morgantown, WV, 1982, pp. 222-228.

A guide for backfilling mines with coal ash to provide surface support and minimize mine subsidence. Important factors to consider prior to implementing a backfilling program are outlined. Two graphs illustrate gradations for bottom ash and fly ash. Economic feasibility for specific circumstances is also discussed.

Good guide to the applicability, technique, and feasibility of backfilling. It would be most useful to those with a background in mine engineering.

48. Farran, C. E. The Effect of Mining Subsidence on Land Drainage. J. Inst. Water Eng., v. 6, No. 7, 1952, pp. 482-503.

Discusses the effects of longwall mining subsidence on flat, low-lying land in England. It contains information on the collieries, amount of subsidence, nature of the ground, hydrologic characteristics of the area, principles of remedial drainage, and work to improve flood-control structures and drains. The appendix contains additional information on the main features of the pumping stations used in the study area.

An excellent reference for those concerned with flooding or drainage problems that might result from the underground mining of coal. The article is short and lacks detail, but should provide useful information on undermining areas with little topographic relief.

49. Flaschentrager, I. H. Considerations on Ground Movement Phenomena Based on Observations Made in the Left Bank Lower Rhine Region. Paper in Proceedings of the European Congress on Ground Movement (Leeds, England, Apr. 9-12, 1957). London Harrison, 1957, pp. 58-73.

Presents research conducted to study the influence of incomplete convergence at the edge of workings on surface subsidence. The data are collected from mines where stowing is used. Included are the results of underground surveys to measure roof and floor convergence along with convergence curves for clay, shale, and sandstone. A formula for calculating surface subsidence is given followed by a discussion of the factor of effect, the subsidence factor, and the limit angle.

The research presented was conducted in European coal mines where stowing is used, a practice rarely found in the United States. A technical background is suggested for full understanding of this material.

50. Gaffney, D. V., M. M. Stewart, N. K. Chakravorti, and R. M. Hays. Feasibility of Using Cemented Backfill in Active Underground Coal Mines To Prevent Subsidence (BuMines contract JO295001, Michael Baker, Jr., Inc.). BuMines OFR 92-82, 1981, 218 pp.; NTIS PB 82-244252.

Details the feasibility of using cemented backfill in active underground coal mines to minimize or prevent subsidence. Specific sections deal with mining methods, materials, and techniques for cemented backfilling; stowing methods, materials, and systems considerations; health, safety, and environmental concerns; and the feasibility of potential systems. Also included is a hypothetical case history that evaluates cemented backfilling techniques.

Excellent, comprehensive reference on cemented backfilling materials and procedures. The text is clearly written and is easily understood.

51. Geddes, J. D. The Effect of Horizontal Ground Movements on Structures. Paper in the Proceedings of the Conference on Large Ground Movements and Structures (Cardiff, Wales, July 4-7, 1977). Univ. of Wales Inst. of Sci. and Technol., Cardiff, Wales, 1977, pp. 623-646.

Details the interaction between soils and horizontal building foundation surfaces on which loading resulting from ground movements is delivered in the form of shearing (frictional) stresses. This problem is discussed and some factors of importance are described and illustrated by laboratory and field experiments. Attention is focused on actual structural damage caused by underground mining operations.

Should be of use in investigating the effects of mine subsidence on horizontal-foundation surfaces.

52. Geddes, J. D., and D. W. Cooper. Structures in Areas of Mining Subsidence. Struct. Eng., v. 40, No. 3, 1962, pp. 79-93, 377-381.

Examines work done on structural design methods used in areas with potential subsidence problems, ranging from foundations offering maximum resistance to earth movements, to articulated frames offering little or no resistance. Included is an explanation of subsidence mechanics, illustrating both horizontal and vertical ground deformations.

Good source of general information on different types of structural designs used in potential mine subsidence areas. The explanations of subsidence mechanics may also be of some use for subsidence prediction.

53. General Assembly of Pennsylvania. Bituminous Mine Subsidence and Land Conservation Act. Commonwealth of PA, 1966, 12 pp.

Contains laws enacted in 1966 to protect the public health, welfare, and safety by regulating the mining of bituminous coal; declaring the existence of a public interest in the support of surface structures, forbidding damage to specified classes of existing structures from the mining of bituminous coal; requiring permits, and in certain circumstances bonds, for the mining of bituminous coal, providing for the filing of maps or plans with recorders of deeds; providing for the giving of notice of mining operations to political subdivisions and surface land owners of record; requiring mine inspectors to accompany municipal officers and their agents on inspection trips; granting powers to public officers and affected property owners to enforce the act; requiring grantors to certify as to whether any structures on the lands conveyed are entitled to support from the underlying coal and grantees to sign an admission of a warning of the possible lack of any such right of support; providing for acquisition with compensation of coal support for existing structures not protected by this act, and future structures; and imposing liability for violation of the act.

Excellent reference for those concerned with subsidence laws in Pennsylvania.

54. Geng, D. Y., and S. S. Peng. Surface Subsidence, Overburden Behavior, and Structural Damages Due to Longwall Mining--Two Case Studies. Dep. Min. Eng., WV Univ., Morgantown, WV, Nov. 1983, 19 pp.

Investigates the subsidence caused by two longwall panels. The data were analyzed in terms of zone of advance influence and delay angle of maximum subsidence velocity. Illustrates the effects of locating structures over the panel center and near the gob edges. Recommendations for reducing subsidence damage are also included.

May assist those interested in structural damage caused by longwall mining operations. The text is limited in detail but may provide some useful background information.

55. Gentry, D. W. Rock Mechanics Instrumentation Program for Kaiser Steel Corporation's Demonstration of Shield-Type Longwall Supports at York Canyon Mine, Raton, New Mexico (Kaiser Steel Corp. contract RD-R-0174). CO School Mines, July 1976, 456 pp.

Presents the results of a rock mechanics instrumentation program designed to determine the rock mass response due to longwall mining of a thick coal seam. Measurements were made in the rock along the ground surface, above the coal seam, in the coal seam, and immediately below the coal seam of a longwall mining operation in New Mexico. Included are details on the pertinent geology and on surface and subsurface instrumentation plans and procedures.

Provides useful information on monitoring techniques for subsidence investigation. The sections detailing the actual design and construction of a survey network should be useful to those interested in monitoring subsidence.

56. Gentry, D. W., and J. F. Abel. Surface Response to Longwall Coal Mining in Mountainous Terrain. Bull. Assoc. Eng. Geol., v. 15, No. 2, Dec. 1978, pp. 191-220.

Presents procedures for monitoring subsidence in rugged terrain. Describes in detail network layout and design procedures along with monument construction and installation. Also included is a brief outline on the use of a multiple-position borehole extensometer. The relationship between the geology of the site and preliminary subsidence data is also discussed.

Easily understood and would be very useful during the initial planning of a subsidence monitoring program.

57. Gentry, D. W., and C. L. Stewart. Characterization of Subsidence Over Multiple Lift Longwall Panels (U.S. Dep. Energy contract AC22-80PC-30118, Mine Subsidence Eng. Co.). Final Tech. Rep., 1982, 135 pp.; NTIS DOE/PC/30118-T4.

Describes the procedures and equipment used in installing and removing a subsidence monitoring network in rugged terrain. It also includes procedures for obtaining special service use permits from the Forest Service. The equipment and techniques used in surveying the network are also briefly discussed.

Good reference for those requiring information on the installation and removal of subsidence monitoring networks in rugged and remote terrain.

58. Girrens, S. P., C. A. Anderson, J. G. Bennett, and M. Kramer. Numerical Prediction of Subsidence With Coupled Geomechanical-Hydrological Modeling. Chapter 5 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 63-70.

Investigates the development of a coupled finite element geomechanical-hydrology code applied to the problem of predicting ground water disturbances associated with mine subsidence. Included in this investigation are analyses of hydrologic modeling, coupled subsidence-hydrology modeling, and code qualification studies for subsidence modeling. A section on the incorporation of field measurements and numerical models is also included.

Should be useful for information on the coupling between geomechanical deformation models and ground-water-flow models. A background in hydrology would be useful for the use of this material.

59. Glover, C. M. H., and N. E. Webster. The Law Relating to Damage by Mining Subsidence and Its Effect on Mining Practice. Trans. Inst. Min. Eng. (London), v. 118, 1958-59, pp. 75-99, 456-459.

First section discusses the laws and regulations relating to mine subsidence areas in Great Britain. The second section contains general information regarding the mechanics of subsidence because of underground mining, including discussions of calculations, precautionary measures, and methods of working.

Section on subsidence mechanics may be useful for general information on subsidence prediction methods.

60. Gray, R. E., and R. W. Bruhn. Subsidence Above Abandoned Coal Mines. Chapter 23 in State-of-the-Art of Ground Control in Longwall Mining and Mining Subsidence (Soc. Min. Eng. AIME Fall Meeting, Honolulu, HI, Sept. 4-9, 1982). Soc. Min. Eng. AIME, Littleton, CO, 1982, pp. 253-271.

Reviews the development of coal mining in the United States, including room and pillar mining, longwall mining, and stope mining in steeply dipping seams. A discussion on subsidence characteristics is included detailing subsidence modes, time effects, and overburden thickness and lithology. Analyzes subsidence over abandoned mines, and proposes methods for the prevention and control of abandoned mine subsidence. Useful tables are included that summarize backfilling and selective support methods. These tables include a cost summary for each method.

Good reference for an analysis of subsidence above abandoned coal mines. Many of the details discussed are also an excellent source of general information on subsidence damage and prevention.

61. Gray, R. E., J. C. Gamble, R. J. McLaren, and D. J. Rodgers. State of the Art of Subsidence Control. Appalachian Regional Commission Rep. ARC-73-111-2550, 1974, 182 pp.

Discusses methods of controlling or preventing surface subsidence damage above active and abandoned mines. For abandoned mines, selective support methods, such as grout columns, deep foundations, and piers; and filling methods, such as hydraulic flushing, pneumatic filling, fly ash injection, grouting, blasting, and overexcavation, are described and approximate costs presented. Techniques to evaluate subsidence potential are included. For active mines, principles of subsidence development above tabular deposits are discussed, including a review of research studies and predictive methods. Subsidence control, by cancelling or selectively positioning surface strains and subsidence prevention by subsurface support are described with examples. Annotated bibliographies are included at the end of the report.

Provides useful information on methods of minimizing subsidence because of underground mining operations, and should be useful to those interested in controlling subsidence.

62. Gray, R. E., and J. F. Myers. Mine Subsidence and Support Methods in the Pittsburgh Area. *J. Soil Mech. and Foundations Div., Proc. ASCE*, v. 96, No. SM4, 1970, pp. 1267-1287.

Contains a selected history of mining and mining-subsidence research in the Pittsburgh, PA, area. Topography and geology of the area are described in detail. Also included are descriptions of subsidence control methods such as complete grouting of the mine, drilled piers, and stabilization utilizing grout columns. Partial- and full-extraction mining methods in conjunction with specialized building construction methods, which may minimize subsidence damage, are briefly outlined. Also provides specific case history subsidence data from Pittsburgh area coal mines.

Good reference on subsidence control methods that have been successfully used in the Appalachian Coal Region. Although this information was obtained from case histories, the technology used can be applied to today's mining conditions.

63. Grond, G. J. A. A Critical Analysis of Early and Modern Theories of Mining Subsidence and Ground Control. Powney-Parker Publicity Services, Ltd., 1st ed., 1953, 57 pp.

Provides a critical analysis of European subsidence prediction methods. The analysis considers both early and modern prediction theories. Numerous diagrams and drawings help explain each theory. Because of the wide scope, the discussion on each theory does not go into great detail.

Excellent reference on subsidence prediction methods. Although not detailed enough for practical application, it does offer enough information to select a method for possible specific application. A technical background is recommended for a full understanding of this report.

64. Hall, B. M. Subsidence Prediction Methods and Instrumentation for Caved Longwall Coal Mines. MREM R107, Northwestern Univ., Evanston, IL, Aug. 1980, 128 pp.

Evaluates the available methods for predicting subsidence over caved longwall coal mines. The emphasis of this study includes evaluation of the ability of 33 subsidence models to predict subsidence, examination of the assumptions in the models, and indication of the areas for improvement. The data from four instrumented longwall panels are presented to determine which geologic traits influence the amount and pattern of subsidence, and if in situ data can be obtained to improve the prediction methodology.

Excellent reference for comparing the effectiveness of existing subsidence prediction methods. The text is easily understood, and is supplemented with various charts, graphs, and illustrations.

65. Hall, B. M., and C. H. Dowding. Prediction of Subsidence From Full Extraction Coal Mining. *Int. J. Rock Mech. Min. Sci. and Geomech. Abstr.*, v. 19, No. 3, June 1982, pp. 305-312.

Examines available methods for predicting subsidence over longwall panels. The methods are divided into two approaches, the empirical and the phenomenological. The empirical methods are derived by correlating experiences and observations of previously mined longwall panels, and the phenomenological methods model the physical behavior of the earth materials during the study of subsidence.

Provides useful definitions of both empirical and phenomenological subsidence prediction methods. The material is straightforward and easily understood.

66. Hargraves, A. J. (ed.). Subsidence in Mines. (Proc. 4th Annu. Symp. on Subsidence in Mines, Wollongong, Australia, Feb. 20-22, 1973). Illawarra Branch, Australasian Inst. Min. Metall., 1973, 110 pp.

Collection of several papers given at the Fourth Annual Symposium, Wollongong University, Australia. The topics include prediction methods, monitoring techniques, mine design, hydrological effects, and structural problems as related to mine subsidence. Coalfields in Australia, England, and the United States are discussed.

These papers are clear and easy to understand. Discussions held at the conclusion of each paper help to gain further insight into the topics covered and to clarify some points that may otherwise have been ambiguous.

67. Hiramatsu, Y., and Y. Oka. Precalculation of Ground Movements Caused by Mining. *Int. J. Rock Mech. Min. Sci.*, v. 5, Feb. 1968, pp. 399-414.

Describes the principles and techniques for a method of predicting ground movements caused by mining coal seams or ore bodies. This method is based on functions of influence that through integration provide influence factors. This method calculates subsidences, horizontal displacements, inclinations, strains, and curvatures. The details of the calculations are illustrated with an example.

Contains an excellent explanation of an influence function subsidence prediction method using extensive mathematical techniques. This method takes into account ground properties, thus it can be used for a variety of locations. The text should be easily understood by those with a technical background.

68. Hood, M., R. T. Ewy, and L. R. Riddle. Empirical Methods of Subsidence Prediction--A Case Study. Chapter 8 in *Workshop on Surface Subsidence Due to Underground Mining*, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 100-122.

Compares subsidence profiles above two adjacent longwall retreat panels in Illinois with profiles predicting subsidence behavior obtained using (1) National Coal Board (reference 101) method, (2) the profile function method, and (3) the influence function method. The relationship between surface curvature and strain is also examined. Problems associated with the calculation of surface curvatures from vertical displacement data are highlighted and a recommendation is made for future studies to consider direct measurement of this parameter.

Clearly illustrates the effectiveness of three subsidence prediction methods with actual measurements taken over longwall panels in Illinois. A technical background would be helpful but not necessary for the use of this material.

69. HRB-Singer, Inc. (State College, PA). Proposed Techniques for Evaluating Subsidence Risk and Planning and Engineering Alternatives for Use by Housing and Urban Development (HUD) and Local Governments (Task E) (HUD contract H-2385). 1977, 120 pp.; NTIS PB 81-100992.

Discusses techniques for evaluating subsidence risk and planning and engineering alternatives for adjusting to hazards resulting from three types of conditions: (1) subsidence related to underground mining, (2) subsidence occurring in organic wetlands, and (3) subsidence occurring in karst terrains. The first section details the use of land-use planning as a hazard reduction technique. This includes geologic evaluations as the basis for developing land-use plans and policies, planning and environmental reviews, and explanations of the roles of key agencies in land-use planning activities. The second section contains analyses of subsidence prediction and damage minimization techniques for each of the three subsidence conditions.

Good reference for land-use planning as a technique for avoiding subsidence damage. The subsidence prediction descriptions and minimization techniques should also be useful for minimizing damage resulting from underground mining.

70. Hurst, G. Avoiding Subsidence Effects in Surface Buildings. *Colliery Eng.*, v. 25, No. 291, May 1948, pp. 158-163; v. 25, No. 292, June 1948, pp. 194-198; v. 25, No. 293, July 1948, pp. 230-234.

Guide for designing buildings to avoid the detrimental effects of subsidence. The basic concept presented is to resist the bending moments and horizontal forces arising from subsidence. A brief discussion of releveling techniques for structures affected by subsidence is included.

Good, comprehensive article for foundation design in subsidence-prone areas. Several illustrations of building foundations are presented in plan and cross-sectional view. Although written in 1948 the procedures should still be of use today.

71. Illinois Department of Mines and Minerals, Land Reclamation Division. The Surface Coal Mining Land Conservation and Reclamation Act, June 1, 1980. 1983, 40 pp.

Section 4.02 gives a brief description of the mine operator's responsibilities for the treatment of subsidence due to underground mining in Illinois.

Should be of interest to those concerned with the mine operator's responsibilities in Illinois.

72. Institute of Civil Engineering (London). Ground Subsidence. Thomas Telford Ltd., 1977, 99 pp.

Provides guidance to good practice for the civil engineer who is not a specialist in the area of ground subsidence. It is divided into seven sections dealing with the causes and effects of both natural and induced surface subsidence. These sections include causes of ground subsidence, identification and investigation, preventive measures, structures, communication, land drainage, and services. It also provides an introduction to the extensive literature on more specialized aspects of ground subsidence.

Provides a comprehensive study on state-of-the-art British subsidence technology; well organized and easy to read and understand. Would be helpful to those interested in a general overview in subsidence engineering.

73. Jones, C. J. F. P., and J. B. Bellamy. Computer Prediction of Ground Movements Due to Mining Subsidence. *Geotechnique*, v. 23, No. 4, 1973, pp. 515-530.

Examines a method of determining displacement, strain, and stress components of ground deformation due to underground mining based upon the theory of elasticity and the principle of superposition. A discussion is included that describes this prediction method, evaluates its applications, and shows that, by programming this method for a computer, accurate predictions of ground deformations are easily obtained, which enables realistic allowances to be made for the effects of subsidence in a structural design.

Good reference for subsidence modeling using computer methods. The information is more theoretical than practical, and no programming specifics are given.

74. Kapp, W. A. Subsidence Due to Underground Coalmining. Mine and Quarry Mechanisation, 1972, pp. 115-121.

Presents general characteristics of subsidence over underground coal mines, including subsidence mechanics, surface and structural effects, methods of protecting the surface, and precautions for mining under water. Also included are several case studies of Australian coal mine subsidence.

Although general and lacking detailed information, is a source of general information on the causes, effects, and prevention of subsidence due to underground coal mining.

75. _____. Subsidence Investigations in the Northern Coalfield, New South Wales, and Their Application to the Design of Mine Layouts in Residential Areas. Pres. at 11th Commonwealth Min. and Metall. Congr., Hong Kong, May 1978. Inst. Min. and Metall., London, Paper 32, 1978, 11 pp.

Summarizes the results of subsidence surveys over longwall, shortwall, and room-and-pillar panels in New South Wales, Australia. Examines the relationships between surface subsidence and underground extraction, and includes descriptions of the mining methods, survey procedures, mine layouts, and surface features of the case studies examined.

Good reference for understanding the general relationships between subsidence and underground mining. Case studies provide background information for several mining methods and their resulting ground deformations.

76. Karmis, M., and C. Haycocks. Computer Simulation of Mining Subsidence Using the Zone Area Method. Dep. Min. and Miner. Eng., VA Polytechnic Inst. and State Univ., Mar. 1983, 62 pp.

Presents a zone area method computer program designed to predict a complete subsidence profile for seam gradients up to 20°. A detailed description of the zone area method of subsidence modeling and how the computer program was developed to use this method is included. Results from four field studies in the Appalachian coalfield were compared to computer predictions with good agreement.

Describes a potentially effective method for predicting a subsidence profile for both longwall and room-and-pillar mining operations; however, this method presupposes that a computer capable of extensive calculations is available to the mine operator.

77. Karmis, M., C. Haycocks, I. Eitani, and B. Webb. A Study of Longwall Subsidence in the Appalachian Coal Region Using Field Measurements and Computer Modeling Techniques. Paper in Proceedings of the First Conference on Ground Control in Mining (Morgantown, WV, July 27-29, 1981). WV Univ., Morgantown, WV, 1981, pp. 220-229.

Describes the use of field measurements and computer-modeling techniques to develop some basic relationships between longwall subsidence and related parameters. Summarizes regional subsidence trends of the Appalachian Coal Region. A brief reference is made to the zone-area method of subsidence prediction.

Would be valuable to those who are interested in subsidence patterns in the Appalachian Coal Region.

78. Kentucky Department for Natural Resources and Environmental Protection, Bureau of Surface Mining Reclamation and Enforcement. Permanent Program Regulations for Surface Coal Mining and Reclamation Operations and Coal Exploration Operations. 405 KAR 8:040E, sec. 26, Apr. 1982, 52 pp.

Deals with the legal considerations of mine subsidence and the precautions and procedures to be followed by the mine operator.

Subsidence control section should be useful to those interested in the legal considerations of subsidence for the State of Kentucky.

79. King, H. J., and M. B. Jones. The Measurement of Mine Subsidence. *Mine and Quarry Eng.*, v. 22, No. 3, 1956, pp. 106-113.

Details the construction, installation, and operation of two instruments designed to measure surface strain and tilt due to underground mining. Also included is a general discussion on strain and tilt characteristics.

Should be of use to those interested in instrumentation for strain and tilt investigations. The details are limited to the general construction of the instruments, and no specific plans or dimensions are given.

80. King, R. P. Evaluation of Surface Subsidence and Horizontal Strain at York Canyon Mine, New Mexico. M.S. Thesis, CO School Mines, Golden, CO, 1980, 197 pp.

Presents the results of a rock mechanics instrumentation program designed to determine surface response due to longwall mining in thick coal at the York Canyon Mine near Raton, NM. Describes the layout, design, and instrumentation of the subsidence monitoring network over the York Canyon Mine. Provides a general analysis of the characteristics of surface subsidence, and details the development of a subsidence prediction model that is patterned after the National Coal Board's Subsidence Engineers' Handbook.

Good reference for information on subsidence monitoring techniques and analyses of ground deformations. The instrumentation described should be useful to those designing a subsidence monitoring network.

81. King, H. J., B. N. Whittaker, and C. H. Shadbolt. Effects of Mining Subsidence on Surface Structures. Paper in International Symposium on Mining and the Environment (London, England, June 4-7, 1974). *Inst. Min. and Metall.*, London, 1975, pp. 617-642.

Describes monitoring techniques used to determine the effectiveness of trenching to reduce the amount of damage to surface structures from underground mining. This effectiveness is discussed in detail, and the general criteria important in the design of surface structures in mining areas are described.

Good source of information on the effectiveness of trenching in minimizing structural damage due to mine subsidence.

82. Knothe, S. Observations of Surface Movements Under Influence of Mining and Their Theoretical Interpretation. *Colliery Eng.*, v. 36, 1959, pp. 24-29.

Details a method for predicting subsidence caused by underground coal mining by evaluating profile and influence functions. Is supplemented with various charts and diagrams to aid in the understanding of the material.

An excellent subsidence prediction method for horizontal seam mining operations; is highly detailed, and a background in subsidence engineering is recommended.

83. Kochmanski, T. Comparison of the Accuracy of Three Methods of Calculation According to the Theories of K. Kochmanski, S. G. Avershyn, W. Budryk, and S. Knothe. *Natl. Sci. Assoc., BuMines Spec. Foreign Currency Sci. Inf. Program Transl.*, 1974, 54 pp.; NTIS TT-74-54013.

Details the differences between subsidence measured by means of geodetic surveys and subsidence calculated using the Avershyn, Budryk-Knothe, and Kochmanski theories of subsidence prediction. From these differences several indexes are calculated, including estimators of variance and the sizes of the surfaces between the practical and theoretical subsidence curves.

Should be useful in demonstrating the extent to which the Avershyn, Budryk-Knothe, and Kochmanski theories are able to predict subsidence. The text has been translated from Polish to English and may sometimes be difficult to understand.

84. Kolesar, J. E., E. C. Palmer, and V. A. Scovazzo. Subsidence Monitoring Plan of Longwall Panels--A Case Study Kitt Mine No. 1. Chapter 18 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 225-229.

Details a proposed-rock mass-response instrument plan for a longwall mining operation. Included are descriptions of the surficial, interburden, and in-mine subsidence-monitoring instrumentation construction plans and practices proposed for use at the minesite.

Provides useful information on construction and design techniques for subsidence monitoring networks. A useful diagram detailing the construction of a concrete survey monument is also included.

85. Kowalczyk, Z. Effect of Mining Exploitation on the Ground Surface and Structures in Heavily Industrialized and Populated Areas. Canadian Inst. Min. and Metall. Trans., Min. Soc., Nova Scotia, v. 69, 1966, pp. 387-393.

Describes a proposed subsidence prediction theory that would permit the determination of surface deformations for planned underground exploitation. The relations between surface subsidence and various methods of mining are analyzed, and allowable horizontal deformations for protected objects, according to the degree of their significance, are reviewed.

A useful reference for details on a subsidence prediction method designed for underground mining operations. The sections dealing with the relations between subsidence and mining methods, and allowable horizontal deformations for structures may also be of use. This article is translated from Polish to English and may sometimes be difficult to understand.

86. Kratzsch, H. Mining Subsidence Engineering. Springer, 1983, 535 pp.

Deals with the current state of international knowledge on strata and ground movement over mine workings. Included are detailed descriptions of the damaging effects to mine shafts and the ground surface. Methods to reduce mining damage and laws governing mining damage are also discussed.

Excellent working aid for the mine surveyor, the mining engineer, the architect, and the civil engineer for dealing with mine subsidence problems.

87. _____. Reduced Subsidence by Planned Extraction. Bergbau Arch. (Essen), v. 25, No. 5, Dec. 1964, pp. 15-21.

Examines the influence of the location of mine workings on the stresses affecting a building. The stresses induced by working two seams and the problems associated with determining stresses generated by working a steeply inclined seam are also discussed. Included are several examples on how to sequence mining operations to reduce damage to surface structures.

Useful to those planning mines in areas with existing structures. Mine design and sequencing procedures are described. It is sometimes difficult to understand due to the German-to-English translation. A technical background in subsidence engineering is suggested for full understanding of the subject matter.

88. Lee, K. L., and M. E. Strauss. Prediction of Horizontal Movements Due to Subsidence Over Mined Areas. Paper in International Symposium on Land Subsidence (Tokyo, Japan, Sept. 14-18, 1969). Int. Assoc. Sci. Hydrol., United Nations Educational Sci. and Cultural Assoc., v. 2, 1969, pp. 512-522.

Reviews some qualitative and quantitative interrelations among vertical subsidence, geological conditions, and resulting horizontal movements. Also included is a discussion of a case history of horizontal movements that develop as a result of subsidence over a sulfur mining area. An evaluation of the finite element method of subsidence analysis is also given.

Provides general information on the interrelations among several subsidence parameters, and should be of some use for applications to subsidence predictions over underground coal mining operations.

89. Louis, H. A Contribution to the Theory of Subsidences. Trans. Inst. Min. Eng. (London), v. 64, 1922, pp. 257-273.

Details the derivation of a subsidence prediction theory based upon Coulomb's theory of earth pressure. A discussion of this theory by experts in the field is given.

Provides information on a subsidence prediction theory based on Coulomb's theory of earth pressure. The text is brief, and is not highly detailed.

90. Mahar, J. W., and G. G. Marino. Building Response and Mitigation Measures for Building Damages in Illinois. Chapter 20 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 238-252.

Summarizes observations made on building response to mine subsidence and discusses techniques for mitigation of building damage. The first section describes the typical geologic and mining conditions at various sites in Illinois. Building response to pit and sag subsidence over these sites is discussed in the second section and the third section describes mitigation techniques used to prevent or minimize building damage. A summary of the observations and critical parameters is given.

Contains useful information on techniques to minimize subsidence related building damage. The section detailing building response to subsidence should also be helpful in determining what damage might be expected over a mining operation.

91. Mainil, P. Contribution to the Study of Ground Movement Under the Influence of Mining Operations. Int. J. Rock Mech. Min. Sci., v. 2, No. 2, 1965, pp. 225-243.

Reviews various types of mining methods and defines the characteristic ground deformations for each case. Also explains the complexity of ground deformations caused by different types of mining. Includes numerous charts, graphs, and figures.

Should be valuable to those interested in understanding the influence of mine operations on ground movement. A background in mine engineering is recommended for the comprehension of this material.

92. Marr, J. E. The Application of the Zone Area System to the Prediction of Mining Subsidence. Min. Eng. (London), v. 176, No. 135, Oct. 1975, pp. 53-62.

Outlines the introduction and initial development of the zone area system in the European continental countries and the early difficulties experienced in applying the system to British mining circumstances. The British systems of subsidence estimation developed during the past three decades are briefly described along with their limitations. The development of the zone area system and the resolution of the early difficulties with British conditions are described in detail, including the added allowances required for the effects of depth, seam inclinations, and pillars of coal left in situ. Reference is made to the use of computers for carrying out the mathematical calculations of subsidence values and the reproduction of subsidence contours.

Good reference for details on the zone area method of subsidence prediction. The material is not highly technical and should be easily understood.

93. _____. A New Approach to the Estimation of Mining Subsidence. Trans. Inst. Min. Eng. (London), v. 118, 1958-59, pp. 692-706.

Details the application of a general mathematical equation, which was derived from a study of subsidence profiles, to two example mining operations. Specific sections deal with the angle of draw and the width-depth ratio for level strata, and the relationship between angles of draw and the inclination of strata. Also included is a discussion on the accuracy to which subsidence estimates can be carried out when applied to local conditions.

Provides useful information on a subsidence prediction method based on actual subsidence observations. The text is not highly detailed, but should provide enough practical information to be of use to those interested in subsidence prediction methods.

94. Marr, J. E., and J. F. Ward. Some Practical Aspects of Precise Subsidence Surveying. Trans. Inst. Min. Surveyors, 1952, 17 pp.; available upon request from A. J. Fejes, BuMines, Denver, CO.

Evaluates survey techniques and details the design and construction of survey monuments used to monitor ground movements over longwall mining operations. Included are discussions of survey methods and their accuracies, as well as complete descriptions and illustrations of subsidence survey monuments.

Should be of use to those interested in survey monument design and construction, and in surveying techniques appropriate to subsidence investigations.

95. McClain, W. C. Surface Subsidence Associated With Longwall Mining. Trans. AIME, v. 235, 1966, pp. 231-235.

Examines the characteristics of subsidence due to longwall mining and the resulting damages to surface structures. Included is a general review of subsidence mechanics and a discussion on protective measures used to minimize damage to surface structures.

Provides general information on subsidence mechanics and structural damages related to subsidence. Is qualitative, and few details are given.

96. Miller, M. J., R. E. Panton, and J. R. Steiding. A Comprehensive Program for Dealing With Mine Subsidence Emphasizing Local Government Options. Appalachian Regional Commission Rep. ARC-73-163-2559, 1976, 156 pp.

Defines and evaluates potential subsidence risk within the four anthracite coalfields of northeastern Pennsylvania with an emphasis on an evaluation of surface (e.g., land use) and subsurface (subsidence potential) conditions. Using a "situation" format, potential subsidence parameters are outlined by coalfield area and further refined to delineate 119 municipalities that face specific potential subsidence problems. Illustrates feasible mitigation options for dealing with subsidence including physical stabilization, architectural measures, insurance, land-use controls, mining controls, and coordination of surface and subsurface development. Translates these generalized plan-and-program recommendations into specific programs for each of the 119 communities directly impacted by subsidence difficulties within the northeastern Pennsylvania anthracite coalfields. Also included are synoptic plan evaluations and generalized subsidence-risk maps for each community, along with an explanation of their purpose and use.

Provides a useful evaluation of potential subsidence risk and mitigation measures for areas within the northeastern Pennsylvania anthracite coalfields.

97. Milliken, B. E. Coal Mine Subsidence Surveys, Illawarra Escarpment, New South Wales, Australia. Paper in Proceedings, Third Canadian Symposium on Mining Surveying and Rock Deformation Measurements (Sudbury, Ontario, Canada, Oct. 10-12, 1979). Can. Inst. Surv., 1979, pp. 87-124.

Details the survey work performed for a subsidence monitoring project. Included are discussions on the types of survey monuments used in the survey networks, various survey methods involving normal and more precise accuracies for the vertical and horizontal displacement of survey monuments, and the role of the computer in the reduction and presentation of the data.

Should be a useful source of information concerning various survey techniques used in subsidence studies. The sections on monument layout and installation should also be of interest.

98. Moore, R. C., and M. A. Nawrocki. Effects of Subsidence From Thick Seam Coal Mining on Hydrology (contract JO295012, Hittman Associates, Inc.). BuMines OFR 93-80, 1980, 245 pp.; NTIS PB 80-219280.

Estimates what effects the underground mining of thick coal seams in the western United States would have on the surrounding water resources. Details include the identification of thick coal seams in the United States, a foreign literature search, predictions of hydrologic impacts, an analysis of 10 study sites, and conclusions and recommendations.

Should be useful to those interested in information concerning hydrologic changes due to subsidence.

99. Munson, D. E., and S. E. Benzley. Analytical Subsidence Model Using Void-Volume Distribution Functions. Paper in Proceedings, 21st U.S. Symposium on Rock Mechanics (Rolla, MO, May 28-30, 1980). Univ. MO, Rolla, MO, 1980, pp. 299-307.

Presents an analytic theory of subsidence that acts as a framework describing both the time-dependent and time-independent aspects of the subsidence process. Also included is a description of the numerical tests performed on this proposed model using a finite element computer program.

Provides a subsidence model that can examine the deformational modes of subsidence.

100. Munson, D. E., and W. F. Eichfeld. Evaluation of European Empirical Methods for Subsidence in U.S. Coal Fields (U.S. Dep. Energy contract SAND 80-0537, Sandia Natl. Lab.). 1980, 27 pp.; NTIS SAND-79-2355 C.

Analyzes the applicability of European subsidence prediction methods for U.S. mining conditions through application to those domestic longwall mines where the subsidence process has been documented. Included are descriptions of graphical methods, profile functions, and influence functions.

Provides a good evaluation of European prediction techniques and how well they relate to U.S. mining practices. The text is supplemented with various charts and graphs that allow for an easier understanding of the material.

101. National Coal Board, Production Department. Subsidence Engineers' Handbook. 1975, 111 pp.

Details various aspects of subsidence engineering, including prediction methods, subsidence mechanics, and structural precautions against subsidence damage. Specific sections deal with the prediction of maximum subsidence and complete subsidence profiles, horizontal strains, the relationship of subsidence to the position of the excavation and to time, relationships between ground movement and surface damage, and general and specific structural precautions to minimize subsidence damage. Also included are case histories of observation lines illustrating the extent of subsidence over specific sites.

Intended as a reference book for engineers and surveyors who are concerned with subsidence engineering and who are acquiring a specialist knowledge of the subject. Very little general explanatory material has been included, and therefore the handbook is not suitable for background reading by nonspecialist engineers or surveyors.

102. Oravec, K. I. Measurement of Surface Displacements Caused by Extraction of Coal Pillars. Paper in the Proceedings of the Conference on Large Ground Movements and Structures (Cardiff, Wales, July 4-7, 1977). Univ. of Wales Inst. of Sci. and Technol., Cardiff, Wales, 1977, pp. 60-85.

Summarizes the procedures used in a subsidence research study conducted over a bord-and-pillar mining operation. Details are given on instrumentation used to determine surface subsidence, lateral displacements, and development and extent of the cave in relation to the mining geometry. Also included are discussions on data handling and preprocessing methods.

Should be useful to those interested in monitoring ground deformations over bord-and-pillar mining operations. Details a study performed over a specific site, but the discussions and descriptions should be of use for information on subsidence monitoring techniques.

103. Orchard, R. J. Prediction of the Magnitude of Surface Movements. Colliery Eng., v. 34, 1957, pp. 455-462.

Examines various aspects of subsidence due to underground mining. The effects of packing on ground movements are discussed, followed by an analysis of the relationship among subsidence, seam depth, and horizontal strain. Tensile strain, compressive strain, and the relationship of strain, to slope are each evaluated separately.

A good, comprehensive evaluation of the characteristics of subsidence due to underground mining. Data from several case studies are included to help visualize the concepts in the text.

104. _____. Recent Developments in Predicting the Amplitude of Mining Subsidence. J. Royal Inst. Chartered Surveyor, No. 33, May 1954, pp. 864-876.

Evaluates the amplitude of subsidence caused by underground mining through the examination of several influencing parameters, including method of mining, geological conditions, rate of face advance, and time factors. A comparison of subsidence amplitude under differing mining conditions is also included. Reference is made to the partial subsidence curve, and how this curve can be used for practical applications.

Gives a brief overview of how the amplitude of subsidence can be predicted. The text is qualitative, but enough information is provided to allow for practical applications of the material.

105. _____. Surface Effects of Mining--The Main Factors. Trans. Inst. Min. Eng. (London), v. 116, 1956-57, pp. 941-958.

The various factors affecting surface movements are summarized and the manner in which they influence the shape of the subsidence trough is described. Contains a discussion of the importance of the width-depth ratio in determining the maximum amplitude of subsidence. Also included is a brief discussion of surface damage and methods for reducing this damage.

Clear and easy to understand; would be a good reference for those interested in the basic principles of mining subsidence.

106. _____. Surface Subsidence Resulting From Alternative Treatment of Colliery Goaf. Colliery Eng., v. 41, Oct. 1964, pp. 428-435.

Compares surface subsidence caused by both total- and partial-extraction methods when allowing caving rather than using strip-packing or solid-stowing techniques in the gob. Roadways and packs and their effects upon convergence are discussed in relation to "effective" panel width and maximum subsidence. Numerous charts and graphs are included.

Good reference for those interested in using stowing methods to limit the amount of surface subsidence.

107. Orchard, R. J. Working Under Bodies of Water. Min. Eng. (London), v. 134, No. 170, Mar. 1975, pp. 261-270.

Discusses the consequences of extracting coal reserves located under bodies of water. Specific examples are cited that detail the results of mining beneath rivers, reservoirs, triassic sandstones, and aquifers. Suggestions to minimize the risk of mining beneath bodies of water are included.

Details the effects of subsidence on bodies of water above underground mines; should be useful to those interested in the effects of mining on overlying bodies of water.

108. O'Rourke, J. E. Monitoring Subsidence in the West: Problems and Analysis. Chapter 13 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 164-179.

Describes results of a project for the design and demonstration of subsidence monitoring systems for underground coal mines. Included are descriptions of the instrumentation systems, the site conditions, problems of installation, resulting recommendations, and subsidence data.

Should be useful to those interested in various aspects of subsidence monitoring networks, including instrumentation and network construction.

109. O'Rourke, J. E., R. M. Mabry, B. B. Ranson, and K. O'Connor. Subsidence Monitoring Systems for Undermined Areas (Dep. Energy contract ET-76-C-01-9123, Woodward-Clyde, Consultants). 1977, 304 pp.; NTIS FE/9123-1.

Examines the movement and stresses that accompany underground mining. The major applications of subsidence monitoring are reviewed, and the relevant data measurements for a cost-effective monitoring program are identified for each. Seven sets of measurements are repeatedly encountered, and these are formalized as individual measurement systems. Specifications for each of the measurements in each system are developed. Basic properties such as availability, cost, and ease of use are listed for over 100 instruments potentially useful for subsidence monitoring. Detailed information is provided on installation and operation procedures for the most effective instrument of each measurement. Finally, the measurement systems with their associated instrumentation are ranked according to cost and time limitations, versatility of the component equipment, and previous service experience by users.

Excellent source of information on subsidence monitoring instrumentation. The specifications given should be helpful in determining which type of instrument is best suited for a particular location.

110. O'Rourke, J. E., K. M. O'Conner, and P. H. Rey. Instrumentation Systems for Subsidence Monitoring of Longwall Panels. Chapter 21 in State-of-the-Art of Ground Control in Longwall Mining and Mining Subsidence (Soc. Min. Eng. AIME Fall Meeting, Honolulu, HI, Sept. 4-9, 1982). Soc. Min. Eng. AIME. Littleton, CO, 1982, pp. 235-244.

Evaluates specific geotechnical instrumentation used to provide overburden and surface-subsidence data. Instrumentation for monitoring ground-surface deformations, subsurface deformations and mine-level stresses are discussed; these discussions include both construction and monitoring techniques.

Provides a good analysis of several types of subsidence monitoring instrumentation. Descriptions of two case studies are included, which detail the operation and construction of the equipment described, and should be of use to those interested in determining what instrumentation is needed to monitor a particular site.

111. Panek, L. A. Methods and Equipment For Measuring Subsidence. Paper in Third Symposium on Salt, ed. by J. L. Rau and L. F. Dellwig (Apr. 22-24, 1969, Cleveland, OH). Northern OH Geol. Soc., Inc., Cleveland, OH, v. 2, 1970, pp. 321-338.

Describes measurement techniques and equipment that are appropriate for determining the horizontal and vertical components of displacement and strain, tilt and curvature. Particular attention is given to the principal characteristics and uses of monuments, extensometers, tapes, electronic distance-measuring instruments, theodolite, alignment telescope, spirit level, tilt meter, and borehole inclinometer probe.

Should be useful for reviewing the characteristics of mining-related ground deformations, and choosing equipment that can be used to monitor these movements.

112. Parate, N. S. Reducing the Effects of Mining Subsidence on Surface Structures. Colliery Eng., v. 44, May 1967, pp. 190-195.

Investigates the mechanics of subsidence and methods of reducing subsidence damage to surface structures. Included are discussions on the nature of subsidence, amplitude of subsidence, subsidence profiles, area of influence, amplitude of strain, time factor, reduction of subsidence effects, and design of new structures.

Provides general information on subsidence mechanics and subsidence minimization techniques.

113. Peng, S. S. Surface Subsidence. Chapter 9 in Coal Mine Ground Control, Wiley, 1978, pp. 281-342.

Classifies ground movement theories into two broad categories: descriptive theories and continuum mechanics theories. The specifics of each category are discussed in detail. Gives an analysis of subsidence trough determination including descriptions of subsidence profiles, strains, profile slopes, and profile curvatures. Also includes a discussion of subsidence measurement techniques, as well as evaluations of surface damage and damage minimization techniques.

Should be useful for gaining a basic understanding of various subsidence prediction theories. The section on subsidence measurement techniques should also be beneficial for those planning to monitor subsidence.

114. Peng, S. S., and S. L. Cheng. Predicting Surface Subsidence for Damage Prevention. Coal Min. Process., v. 18, No. 5, 1981, pp. 84-95.

Provides background information on subsidence engineering. Includes descriptions of caving mechanisms and outlines specific subsidence controlling factors. Reference is made to subsidence related structural damage and damage prevention techniques. An empirical subsidence prediction method is discussed. Charts and graphs are used to supplement the text.

Good reference for those interested in background information on subsidence. Is technical in nature but is written at a level that is easy to understand.

115. Peng, S. S., and C. T. Chyan. Surface Subsidence, Surface Structural Damages and Subsidence Predictions and Modeling in the Northern Appalachian Coalfield. Chapter 6 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 73-84.

Provides a summary document of five previously published papers on subsidence over 24 longwall panels and 5 room-and-pillar sections in the northern Appalachian coalfield. Includes the physical characteristics of 54 surface subsidence profiles collected for longwall and room-and-pillar mining. Prediction and modeling of surface subsidence using empirical and analytical methods are discussed in detail. There is also a general discussion of surface structural damage.

Excellent examination of surface subsidence in the northern Appalachian coalfield. Angle of draw and subsidence factor estimates are provided as well as techniques for predictive and modeling surface subsidence. This material should be useful for predicting subsidence in the northern Appalachian coalfield.

116. Peng, S. S., and D. Y. Geng. Methods of Predicting the Subsidence Factor, Angle of Draw and Angle of Critical Deformation. Chapter 19 in State-of-the-Art of Ground Control in Longwall Mining and Mining Subsidence (Soc. Min. Eng. AIME Fall Meeting, Honolulu, HI, Sept. 4-9, 1982). Soc. Min. Eng. AIME, Littleton, CO, 1982, pp. 211-221.

Analyzes the effects of geology and mining methods on subsidence factor, angle of draw, and angle of critical deformation based on the results of 40 longwall subsidence profiles in the northern Appalachian coalfield. Several equations are derived that show the relationships among those parameters. These equations are transferred and plotted in the form of several monographs for convenience of application.

Excellent reference for methods of predicting surface subsidence factor, angle of draw, and angle of critical deformation, which take into account the effect of geology and mining conditions. Is rather detailed and would best be understood by those with a technical background.

117. Peng, S. S., K. K. Kohli, and S. L. Cheng. Surface Subsidence and Structural Damages Due to Underground Longwall Coal Mining--A Case Study. Paper in Proceedings, 21st U.S. Symposium on Rock Mechanics (Rolla, MO, May 28-30, 1980). Univ. MO, Rolla, MO, 1980, pp. 275-284.

Presents a case history of surface subsidence over a longwall section at an eastern Ohio mine. Included are surface subsidence monitoring plans, measured subsidence results, and subsequent surface structural damages.

Would be helpful to a mine operator interested in monitoring surface subsidence. Items are not presented in great detail.

118. Pennsylvania Department of Mines. Anthracite Mining Laws of Pennsylvania. 1954, 240 pp.

Contains laws, enacted in 1954, that pertain to subsidence resulting from anthracite mining in northeastern Pennsylvania.

Would be of interest to those concerned with subsidence-related laws in northeast Pennsylvania.

119. Perz, F. Mathematical Relationships and Subsidence Troughs. Mine and Quarry Eng., v. 23, June 1957, pp. 256-260.

Describes a subsidence prediction method that uses mathematical relationships to model the formation of subsidence troughs above mine workings. This theory takes into account the properties of overlying strata.

Should be of use to those interested in subsidence prediction. The derivation of the theory is straightforward, and should be easily understood by those with a technical background.

120. Priest, A. V., and R. J. Orchard. Recent Subsidence Research in the Nottinghamshire and Derbyshire Coalfield. Trans. Inst. Min. Eng. (London), v. 117, 1957-58, pp. 499-512.

Describes an attempt to monitor vertical and horizontal subsidence displacements such that appropriate steps could be taken to prevent or reduce structural damage to existing pipelines and buildings in the Nottinghamshire and Derbyshire coalfield, England. The field methods and instruments that were used to monitor ground movements are briefly discussed. The steps taken to prevent structural damage are discussed in detail and include changes in mine design, modifications of pipelines, and detailed inspections of buildings.

Provides a good example of how subsidence is monitored, and how the subsequent data can be used to reduce structural damage to surface and subsurface facilities. Is easy to read and understand and the techniques described can be applied over a wide range of mining conditions.

121. Public Record Corporation (Denver, CO). The Code of Colorado Regulations. 2 CCR 407-2, 1980, pp. 91-96, 285-288.

Pertinent sections deal with the responsibilities of the mine operator in regard to subsidence due to underground mining in Colorado.

Should be of use to those interested in the responsibilities of the Colorado mine operator with regard to subsidence.

122. Pytlarz, T., and K. Trojanowski. Subsidence Calculation With an Arbitrary Shape of the Exploitation Area by the Segment Network Method on Basis of S. Knothe's Theory. 1974, 52 pp; NTIS TT 74-54011.

Details a method for calculating surface subsidence using Knothe's theory of the exploitation effect on the ground surface for the case of a spatial problem with an arbitrary shape of the given exploitation area.

Provides a detailed analysis of a derivation of Knothe's theory for subsidence prediction, and is best suited to those with a technical background. Is supplemented with various charts and graphs to aid in the understanding of the material.

123. Rellensmann, O., and E. Wagner. The Effect on Railways of the Ground Movements Due to Mining. Paper in Proceedings of the European Congress on Ground Movement (Leeds, England, Apr. 9-12, 1957). London Harrison, 1957, pp. 74-82.

Analyzes partial-extraction methods that can be used to minimize subsidence damage to railway lines. The analysis includes discussions on the use of safety pillars and various mine designs. A short explanation of the mechanics of ground deformations is also given.

Provides general information on measures used to safeguard railway lines from subsidence damage. The section on the mechanics of ground deformations is also of a general nature.

124. Salamon, M. D. G. The Role of Linear Models in the Estimation of Surface Ground Movements Induced by Mining Tabular Deposits. Paper in Proceedings of the Conference on Large Ground Movements and Structures (Cardiff, Wales, July 4-7, 1977). Univ. of Wales Inst. of Sci. and Technol., Cardiff, Wales, 1977, pp. 187-208.

Gives a brief summary of the principles involved in treating tabular excavations as displacement discontinuities, the outlines of which coincide with the plan of the excavations. A more detailed discussion is included that evaluates the application of these principles to the prediction of displacements at the ground surface and to the protection of structures on the surface.

Should be of some use to those interested in a tabular deposit subsidence prediction method. A technical background would be helpful in the understanding of this material.

125. Savage, W. Z. Prediction of Vertical Displacements in a Subsiding Elastic Layer. Geophys. Res. Letters, v. 8, No. 3, 1981, pp. 195-198.

Quantitatively discusses a method of modeling subsidence over an underground cavity. The model assumes the subsiding region to be an infinitely long elastic layer that rests on a rigid base and deforms under its own weight into an opening under its lower surface. An approximate analytic solution based on Fourier transform methods is found for vertical displacements of the ground surface and the roof of the opening when the layer thickness is much greater than the width of the opening.

Should be of use for predicting subsidence over some coal mining operations. A technical background is recommended for the use of this material.

126. Savage, W. Z. Prediction of Vertical Displacements in a Subsiding Elastic Layer--A Model for Subsidence in Karst Terrains. U.S. Geol. Surv. OFR 79-1094, 1979, 13 pp.

Details a subsidence model in which a subsiding region is modeled as an infinitely long elastic layer resting on a rigid base and deforming under its own weight into an opening at its lower edge. An approximate solution for vertical displacements on the ground surface and over the opening is found for the case when the layer thickness is much greater than the width of the opening. This solution is most appropriate for predicting subsidence up to incipient failure in karst terrains due to the restricted form of the boundary conditions.

Although this prediction method is modeled for karst terrains, it may be useful for the prediction of subsidence over certain coal mining operations. A technical background is recommended for the use of this material.

127. Schmechel, F. W., W. F. Eichfeld, and W. P. Santy. Automated Data Acquisition for Subsidence Characterization. Pres. at Soc. Min. Eng. AIME Fall Meeting, New Orleans, LA, Feb. 18-22, 1979. Soc. Min. Eng. AIME preprint 79-132, 12 pp.

Reviews the design and installation of an automatic data-acquisition system over a coal mine in Illinois. The purpose of the system was to monitor and record ground deformations associated with underground mining operations. A discussion of the results of the study is included.

Should be of use to those interested in information on an automatic system for subsidence data collection. The text is brief, but supplies useful information on the construction of the system.

128. Shadbolt, C. H. Mining Subsidence--Historical Review and State of the Art. Paper in Proceedings of the Conference of Large Ground Movements and Structures (Cardiff, Wales, July 4-7, 1977). Univ. of Wales Inst. of Sci. and Technol., Cardiff, Wales, 1977, pp. 705-748.

Discusses various subsidence parameters and their effects as they relate to mine extraction dimensions. Various means of reducing subsidence damage are explained. Also included is a historical review of the theories and the work carried out by early subsidence investigators.

Good, informative source of background information on subsidence engineering.

129. Singh, T. N., and R. N. Gupta. Influence of Parameters of Packing on Surface Protection. J. Mines, Met. Fuels, v. 16, Feb. 1968, pp. 37-52.

Presents a brief review of packing as a method of surface ground control. Subsidence mechanics are briefly outlined, followed by a discussion on the economic aspects of packing. The various packing parameters are defined and include the following: compressibility, consolidation, cementation, packing efficiency, and pack density. The results of previous research are summarized for each parameter.

Provides useful information on the angle of draw in mining subsidence.

130. Singh, T. N., and B. Singh. Angle of Draw in Mine Subsidence. J. Mines, Met. Fuels, v. 16, July 1968, pp. 253-258.

Analyzes the effect of different natural and operational factors on the magnitude of the angle of draw in mine subsidence with reference to the mechanism of draw. Also included is a discussion on the importance of angle of draw measuring methods.

Should be somewhat useful to those wanting a brief review of packing parameters and various packing materials.

131. Skinderowicz, B. Subsidence Prediction and Control, Phase 1: The State of Knowledge in Poland Concerning the Influence of Mining Exploitation on the Surface (U.S. Dep. Energy contract DOE/TIC-11481, Central Min. Inst., Katowice, Poland). Final Rep., Phase 1, 1978, 39 pp.; NTIS DOE/TIC-11481.

Examines the geologic and mining conditions and subsidence problems of 12 coal mines located in the Appalachian Region, the Illinois Basin, and the Rocky Mountain Region. On the basis of the mines inspected, remarks and suggestions are made concerning subsidence prediction and control. Also included is a state-of-the-art compendium of Polish subsidence technology that might be applied to U.S. mining conditions.

Excellent reference on Polish subsidence prediction theories and how these theories might be applied to U.S. mining conditions. Material is technical and would be best suited to those with a technical background. The section detailing specific U.S. minesites might be useful in determining the extent of subsidence over mines using similar extraction methods.

132. Southwestern Illinois Metropolitan and Regional Planning Commission. Mine Subsidence: A Guidebook for Local Officials. IL Dep. Mines and Miner., 1983, 148 pp.

Designed for Illinois community officials. Details the behavioral characteristics of subsidence and examines a series of options available to local government officials to deal with subsidence. These options include the Illinois Mine Subsidence Insurance Program, a mine subsidence preparedness plan, public facility construction policies, land development ordinances, and underground mine permit processes.

Contains information that should be of use to those interested in Illinois government options and procedures for dealing with mine subsidence.

133. Speck, R. C., R. W. Bruhn, and R. E. Gray. Instrumentation Plan for Monitoring Ground Movements Associated With Pillar Extraction Mining at the Kitt No. 1 Mine in Northern West Virginia. Chapter 19 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 231-236.

Discusses the design and installation of instrumentation to monitor the ground movements associated with pillar-extraction mining. Included are details of the surface, subsurface, and mine level instrumentation.

Provides information on instrumentation used for monitoring of mining related ground movements. The descriptions are qualitative, and few details on the actual instrumentation are provided.

134. Sturges, F. C., and J. H. Clark. Fly Ash--The Answer to Mine Subsidence Protection? Coal Min. Process., v. 7, No. 4, 1970, pp. 69-73, 88-89.

Discusses several applications and procedures for using fly ash to minimize mine subsidence damage due to underground mining operations. Included is a discussion on the support characteristics of fly ash.

Should be of some use to those considering the use of fly ash as a backfilling material.

135. Sutherland, H. J., and D. E. Munson. Subsidence Prediction for High Extraction Mining Using Complementary Influence Functions (U.S. Dep. Energy contract DE-AC04-76DP00789, Sandia Natl. Lab.). Feb. 1983, 31 pp.; NTIS SAND82-2949.

Details the use of complementary influence functions in describing surface subsidence caused by high-extraction underground mining. The analysis framework is reported in two forms: the first is for the complete complementary influence function formulation, the second is the degenerate case of the complementary influence functions applied to a longwall geometry. The former is solved analytically; the latter graphically. Both are illustrated with analyses of actual case histories.

Should be useful for details on a method of predicting subsidence over high-extraction underground mining operations.

136. Sutherland, H. J., and K. W. Schuler. A Review of Subsidence Prediction Research Conducted at Sandia National Laboratories. Chapter 1 in Workshop on Surface Subsidence Due to Underground Mining, ed. by S. S. Peng and M. Harthill (Morgantown, WV, Nov. 30-Dec. 2, 1981). WV Univ., Morgantown, WV, Mar. 1982, pp. 1-14.

Reviews the results of the subsidence research program at Sandia National Laboratories. The manuscript highlights the following: the application of empirical methods to the subsidence above longwall panels in the United States; the use of the "rubble model" to describe the behavior of broken strata as it distends when it falls to the mine floor and then is subsequently compacted as it is loaded by overlying strata; and the application of physical modeling techniques (centrifuge simulations) and numerical techniques to study the failure mechanisms in highly structured stratigraphy. The capabilities of the modeling and numerical techniques are illustrated by comparing their predictions to the results of a field case that has complicated stratigraphy.

Good reference for the results of subsidence research conducted at Sandia National Laboratories.

137. Swain, H. Successful Design for Mining Subsidence. *Archit. J.*, v. 143, May 1974, pp. 1047-1054.

Describes a building construction system (CLASP) designed for structures located over undermined areas. Rather than depending on strength, the buildings are designed to depend on lightness and flexibility to withstand the effects of mine subsidence. There is a brief description of the design of these articulated buildings and their key component: the diagonal spring-loaded wind brace. These braces permit the buildings to resist wind forces but compress to allow the building frame to adjust to subsidence. CLASP buildings were tested for 14 years; the results of a damage survey are provided.

Excellent reference for those planning to build structures on areas that might be subjected to subsidence.

138. Tandanand, S., and L. R. Powell. Assessment of Subsidence Data From the Northern Appalachian Basin for Subsidence Prediction. BuMines RI 8630, 1982, 14 pp.

Investigates data collected from 16 longwall panels in the northern Appalachian basin, paying particular attention to the effects of rock lithology, excavation width, and panel depth on the subsidence factor. Based on this data, the subsidence factor is expressed in terms of the width-to-depth ratio by an exponential equation. The parameters of the equation vary with the lithology of the site.

Discusses a method of subsidence prediction that takes into account the lithology of a particular site. The analysis is rather technical, and therefore a technical background would be helpful for the understanding of this material.

139. Tanious, N. S. Mining Subsidence. M.S. Thesis, Univ. MN, Minneapolis, MN, July 1975, 127 pp.; NTIS PB 252 455.

Details the method of analysis and procedures used for formulating a digital computer numerical method for predicting subsidence over flat-lying, seam-type deposits. Also reviews existing approaches to subsidence prediction, and provides a listing of the computer program.

Details a useful computer programmed subsidence prediction method. The computer program listed in the report is supplemented with useful operating procedures and descriptions, but the text is rather detailed and therefore a background in computers and engineering is recommended.

140. Tennessee Department of Conservation. Tennessee Coal Surface Mining Law of 1980. Title 59, ch. 8, 1980, pp. 29-32.

Section 59-8-312 details the rules and regulations pertaining to surface effects of underground coal mining operations in Tennessee.

Section 59-8-312 should be of use to those interested in the regulations pertaining to subsidence in Tennessee.

141. Tilton, J. G. The Effect of Subsidence on Pipelines. Pres. at Soc. Min. Eng. AIME Annu. Meeting, New York, NY, Feb. 27-Mar. 3, 1966. Soc. Min. Eng. AIME preprint 66FM41, 34 pp.

Details the damaging effects of subsidence on pipelines, and suggests remedial measures to minimize this damage. The text is supplemented with both plans for subsidence-resistant pipeline designs and photographs detailing the types of damage that may be encountered in a subsidence-prone area.

Excellent information on subsidence-related damages to pipelines and on measures to prevent these damages.

142. Trent, B. C. A Computerized Subsidence Model. Pres. at Soc. Min. Eng. Annu. Meeting, New Orleans, LA, Feb. 18-22, 1979. Soc. Min. Eng. AIME preprint 79-86, 11 pp.

Details a two-dimensional computer code that couples near- and far-field response in order to effectively model subsidence caused by underground openings. Two sample problems are included that illustrate the important features of the code.

Useful for understanding this specific computer-coded subsidence model. Details the theory, but no programming specifics are given.

143. Trojanowski, K. Application of the Segment Network of Even Effects for Calculation of Subsidence According to K. Kochmanski Theory. 1974, 39 pp.; NTIS TF-74-54015.

Details the application of the K. Kochmanski theory of a network nomogram to the calculation of subsidence over a horizontally extending coal seam. The text is translated from Polish to English.

Should be a useful reference for the details on the use of the K. Kochmanski theory for subsidence prediction. The text is rather detailed, but not highly technical.

144. U.S. General Accounting Office. Alternatives to Protect Property Owners From Damages Caused by Mine Subsidence. Rep. CED-79-25, Feb. 14, 1979, 50 pp.; NTIS PB 290 869.

Presents information on the extent of surface subsidence within the United States and its possible economic and social effects. More specific detail is provided for States experiencing acute subsidence damage problems; photographs are used to illustrate this damage. Legislation at the Federal, State, and local levels is briefly discussed, but inadequate detail limits usage to background information. There is also a brief discussion on the relationship between partial- and total-extraction mining methods and resulting surface subsidence.

Clearly defines the significance and magnitude of the subsidence problem within the United States; however, provides little information on methods for preventing subsidence-related damage.

145. Utah Board and Division of Oil, Gas, and Mining. Coal Mining and Reclamation Permanent Program, Chapter 1. Final Rules. Rev. Sept. 20, 1982, 300 pp.

Contains information concerning the regulations pertaining to surface effects of underground coal mining activities in Utah.

Should be of use to those interested in Utah's regulations concerning the surface effects of underground coal mining in Utah.

146. Voight, B., and W. Pariseau. State of Predictive Art in Subsidence Engineering. ASCE J. Soil Mech. Foundations Div., v. 96, No. SM2, Mar. 1970, pp. 721-750.

Gives a qualitative review and critique of existing approaches to subsidence prediction. Specific sections deal with both the empirical and phenomenological methods. Also included are discussions on subsidence damage prediction and alleviation, including details on engineering design precautions and surface considerations.

Provides a general discussion on existing approaches to subsidence prediction. Few details of the actual prediction methods are given.

147. Von Schonfeldt, H., F. D. Wright, and K. F. Unrug. Subsidence and Its Effects on Longwall Mine Design. Min. Congr. J., v. 66, No. 5, 1980, pp. 41-45, 53.

Examines the characteristics of subsidence resulting from longwall extractions. Specific sections qualitatively discuss the caving of strata, the effect of panel width and depth on settlement, and considerations governing panel design. Also included is a detailed section on subsidence monitoring that describes installation procedures and survey costs.

Provides general information on subsidence due to longwall mining. The section on subsidence survey networks should be of use to those interested in monitoring subsidence.

148. Wardell, K. Design of Partial Extraction Systems in Mining. Paper in Proceedings of the Fourth Annual Canadian Rock Mechanics Symposium (Ottawa, Mar. 29-30, 1967). Dep. Energy, Mines, and Res., Ottawa, Canada, 1967, pp. 271-296.

Presents an overview of partial-extraction mining methods and presents the various parameters involved with each method. Also included is a discussion of the mechanics of panel-and-pillar and room-and-pillar extraction. These two methods of extraction are compared and illustrated with examples.

Provides good information on partial-extraction techniques for reducing subsidence effects from underground mining. This material should be of use to those designing mine operations to minimize subsidence.

149. _____. Ground Subsidence and Control. Min. Congr. J., v. 55, No. 1, 1969, pp. 36-42.

Evaluates the mechanics of subsidence and explains how the panel-and-pillar mining system can be used to minimize ground deformations. The section on subsidence mechanics includes an explanation of ground deformation parameters along with mathematical formulas used for subsidence prediction. Also included is a discussion on the effects of subsidence on surface structures, as well as a general explanation of leveling procedures used for monitoring subsidence.

Provides a basic analysis of the mechanics of subsidence due to underground mining. The information is not greatly detailed, but is sufficiently complete for a general understanding.

150. Wardell, K. The Minimisation of Surface Damage by Special Arrangement of Underground Workings. Paper in Proceedings of the European Congress on Ground Movement (Leeds, England, Apr. 9-12, 1957). London Harrison, 1957, pp. 13-20.

Contains a basic explanation of harmonic mining methods designed to negate the effects of surface strains thereby minimizing surface damage. Also included is an analysis of ground movements that result from an advancing face, and this is incorporated into the explanation of harmonic mining methods. Several case studies involving these methods are qualitatively discussed.

Good reference for a general explanation of harmonic mining methods. The text is not technical in nature, and no detailed information is given.

151. _____. The Protection of Structures Against Subsidence. Chartered Surveyor, v. 90, No. 10, Apr. 1958, pp. 573-579.

Emphasizes the main principles of the ground deformation process that pertain directly to the protection of surface structures. A short section dealing with the protection of structures by mining precautions is followed by a detailed discussion on the protection of structures by structural design considerations.

Should be of some use to those concerned with protecting surface structures from the effects of subsidence.

152. _____. Some Observations on the Relationship Between Time and Mining Subsidence. Trans. Inst. Min. Eng. (London), v. 113, 1953-54, pp. 471-483, 799.

Discusses the importance of the time factor in the study of mining subsidence and the limitations of existing methods of analysis. Also given is a new basis on which to compare time-subsidence observations obtained under varying conditions. The movements accompanying an advancing face and the way in which they are influenced by the time factor are also discussed.

Provides useful information on the time factor in mining subsidence studies, and should be helpful to those interested in subsidence prediction.

153. Weir, A. M. An Appraisal of Subsidence Observation. Colliery Guardian, v. 209, Oct. 16, 1964, pp. 513-518.

Evaluates the design and construction of a subsidence monitoring network, and discusses methods for observation and data interpretation. Specific sections deal with subsidence monument design, network layout, and observation of ground movements. Also included is a detailed explanation of a mathematical solution for the principle strains of a biaxial system.

Provides general information on the layout and design of a subsidence monitoring network. The text is qualitative, and little detail is given.

154. Weston, J. G. The Determination of Subsidence Profiles by Mathematical Functions. Min. Eng. (London), v. 137, Apr. 1978, pp. 493-500.

Examines the similarity between the hyperbolic tangent function and a long-wall subsidence profile and shows how the differentials of the function can be used to determine gradient change, surface curvature, strain and horizontal displacement. Also describes the application of this function to single panel and multipanel partial-extraction systems. A zone area system based on the use of the function and a computer method of subsidence prediction based on the National Coal Board Subsidence Engineers' Handbook is also described.

Provides an excellent description of a subsidence prediction method that makes a correlation between a mathematical function and actual subsidence profiles. The text is brief, but detailed enough to permit a clear understanding of the subject matter.

155. West Virginia Department of Natural Resources. West Virginia Surface Mining Reclamation Regulations. Ch. 20-26, sec. 7, 1982, pp. 7-19--7-21.

Paragraph 7C provides details on the subsidence related responsibilities of the mine operator in West Virginia.

Useful to those interested in the responsibilities of the mine operator in West Virginia.

156. Whaite, R. H., and A. S. Allen. Pumped-Slurry Backfilling of Inaccessible Mine Workings for Subsidence Control. BuMines IC 8667, 1975, 83 pp.

Summarizes the materials and procedures used and the results obtained in a study of a hydraulic backfilling technique whereby fill material is pumped as a slurry through a closed system and widely distributed in inaccessible mine workings from a single borehole. Included are observations from several case studies where this technique was employed.

Provides useful information on the materials and techniques used for single-borehole hydraulic backfilling. The project evaluation should be of interest to those considering this method for subsidence reduction.

157. Whetton, J. T. and H. J. King. The Time Factor in Mining Subsidence. Paper in Proceedings, International Symposium on Mining Research, ed. by G. B. Clark (Rolla, MO, Feb. 1961). Pergamon, v. 2, 1962, pp. 521-539.

Summarizes the research conducted at four coal mines in England on the factor of time in mining subsidence. The first section reviews previous attempts by researchers to understand the factors that affect the rate of subsidence at the ground surface. Measurements of vertical and horizontal movements were taken at each of the four mines to collect information on subsidence development in relation to coal face advance. For each site, information on the geology, mine layout, data collection system, and subsequent findings are supplied.

Not a practical guide, however, it does provide general information on various factors in mining that affect the rate and character of subsidence.

158. Whittaker, B. N. Investigation and Evaluation Studies of Surface and Subsurface Drainage Pattern Changes Resulting From Longwall Mining Subsidence. Pres. at 1st Int. Mine Drainage Symp., Denver, CO, May 20-23, 1979, 25 pp.; available upon request from A. J. Fejes, BuMines, Denver, CO.

Contains a general review of mining subsidence characteristics associated with longwall mining and discusses the impacts of subsidence on surface- and subsurface-drainage patterns. Several case studies are cited that describe ground permeability changes between the surface and the mining horizon. Also included are descriptions of test instruments designed to investigate the zones of increased permeability resulting from longwall extraction.

May be useful for the study of the effects of subsidence on surface- and subsurface-drainage patterns. The details of the test instrumentation may also be of value to persons interested in monitoring ground deformation.

159. Whittaker, B. N., and C. D. Breeds. The Influence of Surface Geology on the Character of Mining Subsidence. Paper in International Symposium, the Geotechnics of Structurally Complex Formations (Capri, Italy, 1977). Assoc. Geotechnica Ital., Milan, Italy, v. 1, 1977, pp. 459-468.

Describes the principles of mining subsidence associated with the working of predominantly level coal seams. Descriptions are given of the surface rock formations overlying the major coalfields in England. Subsidence data, which have been collected from numerous observation sites, are presented and analyzed. Examples of surface rock formation responses to mining subsidence are also given.

Excellent reference for relating geology to mining subsidence effects. A background in mine engineering would be helpful for understanding this material.

160. Whittaker, B. N., and H. I. Hazine. Simulation of Surface Subsidence Due to Longwall Mining. Paper in Proceedings, 19th U.S. Rock Mechanics Symposium (State-line, NV, May 1-3, 1978). Mackay School of Mines, Reno, NV, 1978, pp. 221-228.

Briefly reviews mining subsidence knowledge and related problems due to longwall extraction of coal seams in England. Special consideration is given to simulation of surface subsidence by a finite element method. The results of isotropic and anisotropic solutions are presented and discussed. Also included is a discussion on the treatment of surface strain and the validity of deriving strain from ground curvature. Findings on the modeling of surface subsidence using a finite element method are given, and include examples of its application to mining subsidence problems in England.

Provides a good review of subsidence prediction using a finite element method. Although this method was designed for use in England, its basic principles should be applicable in the United States.

161. Wildanger, E. G., J. Mahar, and A. Nieto. Sinkhole-Type Subsidence Over Abandoned Coal Mines in St. David, Illinois. Mine Subsidence Report, St. David, Illinois. Dep. Civil Eng. and Geol., Univ. IL, Urbana, IL, June 1980, 88 pp.

Examines the geologic conditions, mining history, and subsidence trends of the St. David, IL, region. Also examines the damages resulting from subsidence in the area. A large section is devoted to detailed analyses of sinkholes and the mechanisms of sinkhole formation.

Information on sinkhole mechanics should be of use for the understanding of sinkhole formation. The remaining text might be useful for correlating the results of this study with mining conditions similar to that of the St. David, IL, area.

162. Wohlrab, B. Effects of Mining Subsidence on the Ground Water and Remedial Measures. Paper in International Symposium on Land Subsidence (Tokyo, Japan, Sept. 14-18, 1969). V. 2, Int. Assoc. Sci. Hydrol., United Nations Educational Sci. and Cultural Assoc., 1969, pp. 502-512.

Discusses the effects of mining subsidence on ground water. Specific sections qualitatively evaluate components of ground movement caused by underground mining, disorders of water utilization as a result of ground movements, and remedial measures taken to minimize ground water changes.

Provides general information on the effects of subsidence on ground water. The suggested preventative measures may be of some use to those interested in minimizing damage to local ground water.

163. Wood, P. A. Underground Stowing of Mine Waste. Int. Energy Agency Coal Rep. I CTIS/TR23, Swiftprint of New Malden, Ltd., London, Apr. 1983, 67 pp.

Evaluates the effectiveness of mine waste as a backfilling material for use in active and abandoned coal mines. The characteristics of the mine waste material that might influence the choice of handling techniques are also discussed. Handling techniques considered are roadside packing; mechanical, pneumatic, and hydraulic transport and emplacement; and flushing.

Provides good information on methods of using mine waste as a backfilling material and should be of use to those interested in backfilling techniques.

164. Yokel, F. Y., L. A. Salomone, and R. M. Chung. Construction of Housing in Mine Subsidence Areas. Geotechnical Eng. Group, Structural and Material Div. Center for Building Technol., Natl. Eng. Lab., Natl. Bureau of Standards, Jan. 1981, 24 pp.; NTIS NBSIR 81-2215.

Evaluates criteria for site exploration, risk assessment, site development, and housing construction in areas of actual and potential mine subsidence. Suggested measures to mitigate damage to housing in areas where subsidence might occur as a result of past or future underground mining are also given. Included in the appendix is a detailed explanation of a mathematical model that can be used for the prediction of subsidence profile characteristics.

Contains an excellent description of a subsidence prediction method, as well as a good discussion of mitigating damage to housing in subsidence prone areas.

165. Young, L. E. Surface Subsidence in Illinois Resulting From Coal Mining. IL Geol. Surv. Bull. 17, 1916, 113 pp.

Examines subsidence due to mining operations in Illinois. Specific sections deal with geologic conditions that affect subsidence, damage caused by removal of coal, case history subsidence data recorded by State districts, surface protection measures, and investigations of subsidence.

Although published in 1916, contains information on subsidence engineering that is still of use.

166. Young, L. E., and H. H. Stoek. Subsidence Resulting From Mining. Univ. IL Eng. Experimental Station Bull. 91, v. 13, No. 49, Aug. 1916, 205 pp.

Details many aspects of subsidence due to underground mining. Included are seven chapters that discuss the effects of subsidence, pertinent geologic conditions, subsidence theories, subsidence mechanics, physical modeling techniques, subsidence minimization procedures, and various legal considerations.

Although published in 1916, contains information that should be helpful in understanding various aspects of mining related subsidence. The text is clearly written and is supplemented with numerous charts and graphs.

167. Zenc, M. Comparison of Bals' and Knothe's Methods of Calculating Surface Movements Due to Underground Mining. Int. J. Rock Mech. Min. Sci., v. 6, 1969, pp. 159-190.

Discusses the theoretical analysis of Bals' and Knothe's methods of subsidence prediction. A preliminary calculation is made of surface movements according to both methods and compared with the results of measurements in the Ostrava-Karvina Coal Basin in Poland.

Provides an excellent comparison between Bals' and Knothe's theories of subsidence prediction. The comparison of these theories to measured values clearly illustrates the accuracy of each method for conditions found in Poland.

APPENDIX B.--COMPREHENSIVE BIBLIOGRAPHY

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2. ABEL, J. F., AND D. W. GENTRY. A LONGWALL SUBSIDENCE PREDICTION MODEL. PRES. AT AM. SOC. CIVIL ENG. NATL. SPRING CONV. AND CONTINUING EDUCATION, PITTSBURGH, PA, APR. 24-28, 1978, SESSION 71. ASCE PREPRINT 3293, PP. 56-76.
3. ABEL, J. F., AND F. T. LEE. LITHOLOGIC CONTROLS ON SUBSIDENCE. PRES. AT SOC. MIN. ENG. AIME FALL MEETING, MINNEAPOLIS, MN, OCT. 22-24, 1980. SOC. MIN. ENG. AIME PREPRINT 80-314, 16 PP.
4. _____. SUBSIDENCE POTENTIAL IN SHALE AND CRYSTALLINE ROCKS. U.S. GEOL. SURV. OFR 80-1072, MAY 1980, 99 PP.
5. ADAMEK, R., AND J. LOJAS. EKSPLOATACJA INSTALACJI POKSADZKOWYCH GLEBOKICH KOPALN (OPERATION OF HYDRAULIC STOWAGE INSTALLATIONS IN DEEP MINES). PRZEGL. GORN., V. 24, NO. 6, 1968, PP. 262-275.
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