The Proximity of Underground Mines to Urban and Developed Lands in Illinois

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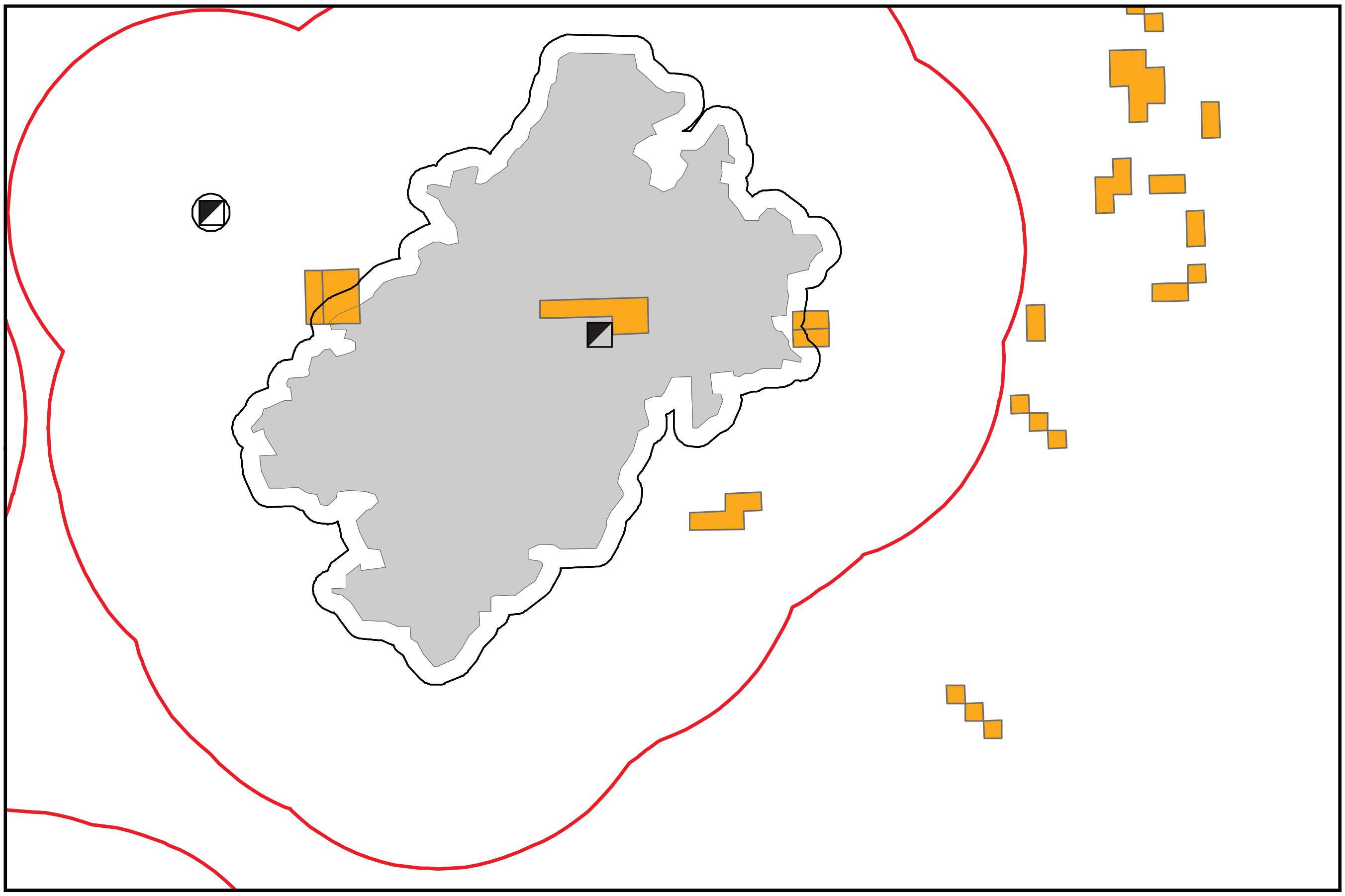

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Front Cover: *Map showing the relationship of Zones 1 and 2 to mined areas and urban land cover classifications.*

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CONTENTS

Abstract

Mine subsidence is the downward movement of the ground surface after a failure of support in an underground mine. Mine subsidence can take place gradually or quickly and can happen over a large area or as a pit that opens at the surface. Both types of downward movement can cause damage to overlying structures and subsequent loss of property value. Although most mine subsidence events in Illinois are related to coal mines due to the extensive area underlain by these mines, subsidence can occur over other mine types as well. It is important that planners, developers, local government officials, and landowners are made aware of the general locations of undermined areas and their potential impact on existing communities and future development.

This study, an update of Treworgy and Hindman (1991), provides statistics on the proximity of urban areas to coal and non-coal underground-mined areas in Illinois. This present report reflects newly available data and improved assessment methodology. Geographic Information Systems (GIS) software is used to spatially overlay and combine zones of underground mine proximity with recent land cover maps and U.S. Census Bureau data. Additionally, GIS is used to calculate the resulting statistics, tables, and maps. This information provides the most detailed view to date of the exposure of housing units and developed land areas to the potential of mine subsidence.

Results of this study found that an estimated 333,000 housing units, representing a population of roughly 875,000, (average 2.63 people per household; U.S. Census Bureau 2008b) are located in close proximity to underground mines and may potentially be exposed to subsidence. Approximately 201,000 acres of urban and developed lands overlie or are immediately adjacent to underground mines. Of these, 65% (130,000 acres) falls within Zone 1 (land in Illinois overlying or immediately adjacent to underground mines) and 35% (71,000 acres) in Zone 2 (additional area to reflect potential mine boundary uncertainties). Similarly, of the total housing units, 65% (219,000 units) is located within Zone 1 and 35% (114,000 units) within Zone 2.

Introduction

Mine subsidence—the sinking of the land surface due to the failure of pillars, floor, or roof strata in an underground mine—can take place gradually or suddenly; it may develop as a sag over a large area or open up as a pit at the surface (Bauer 2006). The ground movement may result in damage to overlying structures and reduced property values.

Since 1810, more than 3,800 underground coal mines have operated in Illinois; all but 12 have been abandoned at the time of this report. An additional 363 known underground mines have extracted industrial minerals and metals, including clay, fluorspar, lead, zinc, dolomite, limestone, ganister, and tripoli; all but 10 of these industrial mines have been abandoned at the time of this report. Although subsidence has occurred over all types of mines in Illinois, most subsidence is related to coal mines because of the extensive areas underlain by these mines. However, one of the state's largest subsidence events occurred near Galena over a lead and zinc mine (Touseull and Rich 1980).

Damage caused by ground movement is not insured under conventional property insurance. In 1979, Illinois became the second state in the nation to pass legislation (the Mine Subsidence Insurance Act) ensuring the availability of insurance for mine subsidence damage to structures. The Illinois Mine Subsidence Insurance Fund (IMSIF) monitors subsidence claims and reimburses private insurance companies for claims paid for mine subsidence damage.

Although the presence of underground mines in an area does not mean that subsidence will or could take place, owners of property in the vicinity of mines should review their insurance coverage or consult with experts who can assess the potential for subsidence at that specific location (Bauer 2006).

This study revises and updates the numbers of acres and housing units potentially affected by underground mining in Illinois. Although this report is a revision of the study by Treworgy and Hindman (1991), it has been substantially modified to reflect new data and to document assessment assumptions, procedures, and improvements made to the previous assessment methodology. It is important to note that a direct comparison to the results in the 1991 study is inappropriate, due to differences in land use classifications, census data resolution, and GIS calculation methodologies. A listing of similarities and differences in data and methodology between the two studies can be found in Table 1.

Assessment of Mine Proximity to Urban and Developed Lands

Geographic Information Systems (GIS) software was used to assess the proximity of underground mines to urban and developed areas in Illinois. Geospatial map layers for underground coal and industrial mines, land cover, and U.S. census blocks were spatially combined, and GIS was used (1) to spatially apply zones of specific distance from the mines to individual mine-extent boundaries, and (2) to calculate and tabulate statistics on the acreages and numbers of housing units within each zone and land cover classification. The data used in this study are described herein, and technical details of the GIS-based assessment methodology are provided in Appendix 1. The data used in this study come from a variety of digital and paper sources (Table 2) and are best suited for regional assessments rather than site-specific evaluations.

The accuracy of geospatial data depends on the resolution of data collection or the scale of the source material and the standards, equipment, and procedures used to compile the information. In general, the larger the native scale of the data or source map material, the more accurate the positions of features are on the final map product. However, accuracy can vary widely between maps of the same scale. For example, old maps of underground mines can be particularly inac-

Table 1 Similarities and differences in data and methodology between the Treworgy and Hindman (1991) study and the present study.

Data	1991 study	2008 update
Zone 1 width		
Coal mines	500 feet	Mine depth, rule-based method
Non-coal mines	500 feet	500 feet
Zone 2 width		
Coal mines	1,000 feet	1,000 feet
Non-coal mines	Based on Zone 2 width table	Based on Zone 2 width table
Land use		
Source	USGS Land Use/ Land Cover	IDNR[1] Satellite Imagery Land Cover
Date	1969–1981	1999–2000
Class	Residential Other Urban Nonurban	Low-medium density developed High density developed Urban open space Nonurban
Urban buffer	Incorporated	--
Census		
Scale	Tracts, block groups, enumeration districts	Blocks
Date	1980	2000
Application	Housing unit summation and distribution by township, 90% of the total evenly distributed across residential areas; 10% evenly distributed across the remaining lands	Even distribution of housing units across census block area

[1]Illinois Department of Natural Resources.

Table 2 Original map scale, date, and source of digital data used to evaluate the proximity of urban and developed areas to underground mines.

Data set	Scale	Date	Source
Coal mines	1:1,200–1:120,000	January 2007	Illinois State Geological Survey
Other mines	1:1,200–1:63,500	January 2008	Illinois State Geological Survey
Land cover	1:100,000 30-m resolution	1999–2000	Illinois Department of Natural Resources
Census blocks	1:100,000	2000	U.S. Census Bureau (2000b)
Census statistics	Tabular data	2000	U.S. Census Bureau (2000a)

curate because the surveyors had few locational control points and generally worked under difficult conditions. Once a mine is abandoned, there is no easy, inexpensive method of verifying its boundaries below the surface.

Additionally, the process of digitizing source maps or translating scanned paper source maps to real-world geographic coordinates can introduce locational errors. For example, for maps at a scale of 1:24,000, features could be offset 100 feet or more from their true position. On maps at a less-detailed 1:250,000 scale, features could be offset by as much as 500 feet.

Coal Mines

The Illinois State Geological Survey (ISGS) maintains a digital database containing the location and extent of underground coal mines. The most detailed (largest-scale) source map available (generally 1:1,200 to 1:24,000) for each mine has been used to make additions and revisions to the database, and active mines are updated annually. In addition, 102 quadrangle maps (1:24,000) have been completed since 1999, and these revised map areas have also been incorporated into the database. Where quadrangles have not been studied in detail, map areas contain the original digital mine outline data, which were hand-drawn on base maps at a scale of 1:62,500 and digitized in the early 1980s.

The geospatial mine data used in this project reflect all known underground mining as of January 2007. Map points (mine entrances and uncertain underground mine locations) and map polygons (definite and indefinite underground mine boundaries) are included. Unmined blocks of coal within the mine perimeter are delineated if they cover an area of at least 16,000 square feet.

In Fulton, Grundy, Jackson, Knox, Peoria, Stark, and Williamson Counties, some shallow underground mines have been mined through by subsequent surface mining and no longer exist. However, all underground coal mines were included in this study due to the difficulty of identifying such cases in which underground mines may have been mined through by surface methods. In all cases, these re-mined areas involve small mines in rural areas and have no significant effect on the study results.

Mines Producing Industrial Minerals and Metals

In their 1991 study, Treworgy and Hindman collected information on 356 industrial mineral and metal mines and compiled a database containing information about these mines from mine maps and other sources including reports, field notes, and topographic maps. Refer to their work for more detailed information regarding the development of the database. Seven additional underground industrial mineral mines have opened since the 1991 study (Table 3; Z. Lasemi, personal communication 2008), and point representations for these mines were added to the geospatial database using location information and aerial photography.

Zones of Mine Proximity

The potential for mine subsidence in an area depends on many factors, but a key factor is the proximity of the area to underground mines. We used GIS software to define and spatially apply two zones around each mine (Figure 1). Zone 1 includes the land over or adjacent to mines that, on the basis of the mapped extent and general depth of the mine, could be affected by subsidence. Zone 2, which surrounds Zone 1, represents additional land that could be affected due to uncertainty about the exact location of the mine and the extent of its workings. These zones are associated only with known underground mines. Areas outside these two zones also could be undermined. Old, undocumented mine openings have been discovered in many parts of the state, even in areas not known to contain minable deposits. Although the potential for subsidence exists in these places, most undocumented mines were prospect pits or short-term operations that undermined only a few acres.

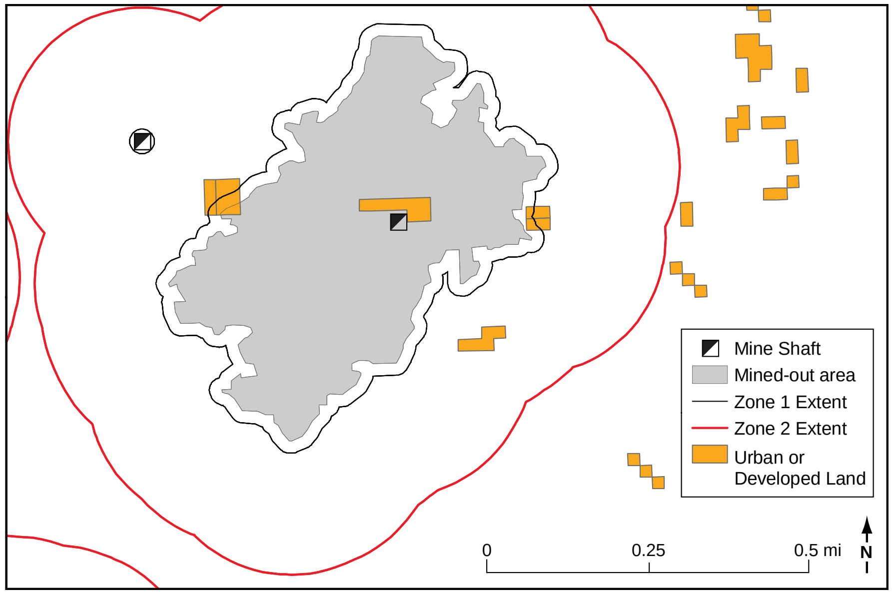

Figure 1 Map showing the relationship of Zones 1 and 2 to mined areas and urban land cover classifications. Zone 1 includes land directly over the mapped extent of the mine plus some adjacent land. Zone 2 includes additional land adjacent to the mine, beyond the Zone 1 boundary.

Table 3 Underground mines producing industrial minerals and metals, compiled by county and commodity, 2008.

County	Mineral (number of mines)	Total
Adams	limestone (4)	4
Alexander	ganister (2); tripoli (4)[1]; clay[1]	6
Calhoun	clay (5)	5
Carroll	lead (2)	2
Cook	dolomite (1)	1
DuPage	dolomite (1)	1
Greene	limestone (1)	1
Hardin	fluorspar (130)[2]; lead (1)[2]; zinc[2]	131
Henderson	limestone (1)	1
Jackson	clay (1)	1
Jo Daviess	lead (93)[3]; zinc (9)[3]	102
Johnson	limestone (1)	1
Kane	dolomite (2)	2
La Salle	clay (6); limestone (2)	8
Livingston	clay (1)	1
McDonough	clay (3)	3
Madison	clay (2); limestone (2)	4
Marshall	clay (1)	1
Monroe	limestone (2)	2
Pike	limestone (3)	3
Pope	fluorspar (51)[4]; lead (7)[4]; zinc[4]; barite (4)[4]	58
Randolph	limestone (3)	3
Rock Island	clay (1)	1
Saline	fluorspar (2)[5]; lead[5]	2
Scott	clay (1)	1
Union	clay (12); tripoli (2)	14
Will	dolomite (4)	4

[1] Two of the tripoli mines also mined clay.
[2] Twenty-nine of the fluorspar mines also produced lead; 10 produced zinc; and 4 produced lead and zinc.
[3] Fifty-four of the lead mines also produced zinc.
[4] Twenty-five of the fluorspar mines also produced lead; 3 produced zinc; 2 produced lead and zinc; and 1 produced barite.
[5] One fluorspar mine also produced lead.

Zone 1 Zone 1 is defined as the area directly over the mapped extent of the mines and the adjacent land extending some distance beyond the mine boundaries. Land adjacent to a mine is included in this zone because subsidence resulting from the collapse of an underground mine can spread sideways as it moves upward to the land surface. Lateral propagation of subsidence, a function of the depth to the mine, the local geology, and other factors, is not highly predictable. Bauer and Hunt (1982) state that the distance subsidence can propagate laterally from a mine is generally much less than the depth from the land surface to the mine.

The present study's methodology uses a rule-based approach to assign areas that have the potential to be affected by subsidence from underground coal mines. That is, the horizontal distance outside the mine edge (collapsed area) that may be affected is dependent on the depth of mining (Figure 2). For underground coal mines, Zone 1 for this study is based on a 30-degree angle of draw from the depth of the mine-edge boundary. Bauer and Hunt (1982) found from subsidence case histories in Illinois that the angles of draw range from 12 to 26 degrees and that the regional composition of roof rock material seems to have less influence on the angle of draw than does the proximity of geologic structures (faults and monoclines) to the mines.

Because an assessment of geologic structures in close proximity to all underground coal mines was beyond the scope of this study, a conservative angle of draw of 30 degrees was used for all coal mine data assessed. The angle of draw was applied to coal seam depth information for each specific mine location and is measured from the mine's outer boundary. As an example, this methodology produces a 173-foot-wide zone (outward from the boundary of the mine) for a mine at a depth of 300 feet and a 520-foot-wide zone for a mine at a depth of 900 feet. This angle of draw is viewed as conservative as it defines a point where no vertical subsidence occurs. The damaging differential movements that would affect a structure are well inside this point, closer to the edge of the mine (i.e., the collapsed area underground).

The angle of draw approach based on mine depth is a more robust tool for delineating areas potentially affected by subsidence than uniform handling. Instead of a constant buffer distance of 500 feet (Treworgy and Hindman 1991), the new methodology equates to 0.57 times the depth of the mine. This angle of draw results in a Zone 1 buffer distance ranging from less than 50 feet to more than 500 feet, when all mines in the state are considered. The application of the new rule-based Zone 1 buffers decreases the total potentially affected housing units by approximately 7% (compared with the constant Zone 1) and offers a more realistic damage assessment result related to potential subsidence near coal mines.

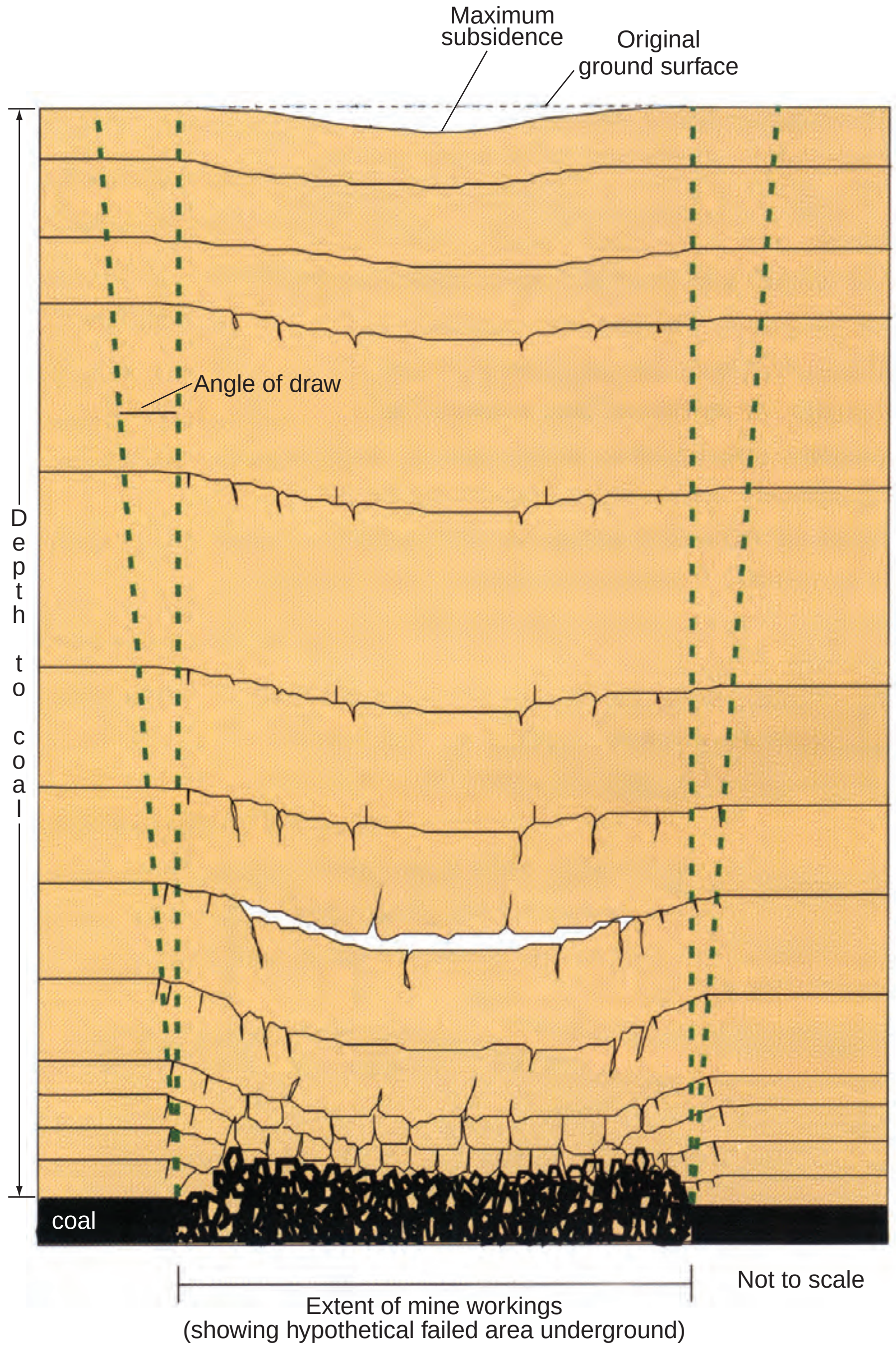

Figure 2 Cross section illustrating angle of draw, measured from the depth of the mine extent boundary (Peug and Chiang 1984, New South Whales Coal Association 1989, Bauer 2008).

As in the 1991 study, mines other than coal mines received a conservative Zone 1 distance of 500 feet, although mines for some of the industrial minerals tend to have more competent workings than coal mines due to the nature of the rock material they are in. Thus, the subsidence-related Zone 1 buffer distance of 500 feet is likely unrealistically high; however, adjustment of this distance was beyond the scope of our study and would require an assessment of the type of rock mined and the mining method, among other factors.

Zone 2 Zone 2 represents areas outside the mapped extent of the mines but within a distance that could be affected by subsidence if the mine boundaries are inaccurate or uncertain. Uncertainties about the positions of mine boundaries arise from two sources: (1) incomplete or imprecise maps of mine workings and (2) errors in compilation and digitizing.

In the 1991 study, it was assumed that, in all coal mines and in many industrial mineral and metal mines, errors from these two sources generally would not exceed 1,000 feet. For most mines, Zone 2 is defined as the area extending 1,000 feet beyond Zone 1. Zone 2 was expanded for certain industrial mineral and metal mines that were located on the basis of small-scale source maps. When only a general location description (e.g., "3 miles west of town") was available for a mine, Zone 2 was centered on the approximate location indicated and was enlarged according to the general quality of the description (Table 4).

Designation of an area as Zone 1 or Zone 2 cannot be directly translated into subsidence risk. Although the potential for mine subsidence is generally higher in Zone 1 than in the adjacent Zone 2, the potential for subsidence may be low in some areas designated Zone 1 and high in others. Other factors in addition to proximity to and depth of the mine include coal thickness, the geology of the roof and floor, the size and placement of the mine pillars, and previous subsidence at the site. All of these factors help determine the potential for mine subsidence in an area. Precise estimates of the subsidence potential cannot be made until the interaction of these factors is better understood.

Land Cover

Due to the discontinuation of updates to the U.S. Geological Survey land use and land cover data (U.S. Geological Survey 1986, Price et al. 2006), which were last collected and characterized in the 1980s, those data are now deemed "historical." To continue to use this outdated data set's classification scheme would introduce serious error into estimates of potentially affected lands, especially for metropolitan areas and other rapidly expanding urban areas.

The satellite imagery-based Land Cover of Illinois data set used in this study represents land cover in Illinois from the years 1999–2000 (Illinois Department of Natural Resources et al. 2003). The data are shown at a scale of 1:100,000 with a native resolution (pixel size) of 30 m. Unfortunately, the new classification schema is not directly comparable to the 1980s data; the main practical difference is the discontinuation of the term "Residential Areas."

The land cover classification schema distinguishes between several types of developed land cover (i.e., "built-up" land containing man-made structures) and non-developed (i.e., vegetated, barren, or water-covered) lands. Some of those classifications were combined for the purpose of this study. The classification scheme used in the 1999–2000 Land Cover of Illinois data set uses the following *urban* area land cover classifications:

- *Low-medium density developed:* Up to 50% of the land surface is covered with man-made structures, intermixed with other cover such as *urban open space* and *forest & partial forest/savanna* lands. These structures include surfaces that have been developed—or "built-up"—such as buildings, roadways, parking lots, driveways, and other impervious surfaces.
- *High density developed:* All, or nearly all, of the land surface is covered with man-made structures.
- *Urban open space:* Parks, golf courses, cemeteries, and other grassland-like cover within urban and developed areas are included in this classification. Areas of *low-medium density* developed lands are intermixed with *urban open space* (Illinois Department of Natural Resources et al. 2003).

In this report, the term *developed* land is used preferentially to the term *built-up* land. The classification *low-medium density* developed land may serve as a gross proxy for the *Residential* areas used in the 1991 study, but the terms and the areas they represent are not directly comparable. Other land cover classes not listed were reclassified to the *non-urban* category. Surface waters were omitted from the areal calculations.

Table 4 Width of Zone 2 assigned to industrial mineral and metal mines (Treworgy and Hindman 1991).

Source of mine outline or location	Width of Zone 2 (feet)
Original mine map; four reference points	1,000
Original mine map; registered using landmarks	1,000
Topographic map (mine shafts)	1,000
Map with topography or with scale larger than1:24,000	1,000
Map without topography and scale smaller than 1:24,000	2,320
Legal description with footages or good landmarks	1,000
Legal description of a 10-acre parcel within a section	1,660
Legal description of a 40-acre parcel within a section	2,320
Legal description of a 160-acre parcel within a section	3,640

Number of Housing Units

Census block outlines and statistical data on housing units (U.S. Census Bureau 2000b) were used to estimate the number of housing units in close proximity to underground mines. A census block (subdivision of a census tract) is the smallest geographic area used by the Census Bureau in the tabulation of housing unit-level survey data. Census blocks provide for a finer resolution of study than the data available for the 1991 report. That report was based on a mixed scale of census tracts, block groups, and enumeration districts. In urban areas, census blocks often represent individual street-bounded city blocks but may include larger areas; blocks may be up to many square miles in area, especially in rural locations. Nationwide census block coverage was first established during the 1990 Census (U.S. Census Bureau 2008a).

Housing units are defined as any residential unit (house, apartment, mobile home, etc.) intended for use as separate living quarters. Census block data do not contain information about commercial or industrial structures (U.S. Census Bureau 2008a). A count of housing units per block is provided in the census data, although the spatial distribution of housing units was not known. Thus, for our study, a uniform distribution of housing units over the entire census block area was assumed.

The calculated housing unit density per block was spatially merged with the data on land cover and undermined areas and was used to calculate the approximate number of homes in Zone 1 and 2 areas. This value, then, is a calculated estimate and not an actual count of residences in these zones. Because the census blocks tend to be smaller in urban areas, the census block represents a fairly accurate boundary for calculating housing density and tabulating housing units for Zones 1 and 2 in these areas. In rural areas, although the census blocks tend to be larger, the low density of housing units is less affected by spatial merging, and the census blocks are appropriate for regional calculations in these areas.

Results

Distribution of Undermined Land within Illinois

This study found that approximately 1,676,000 acres in Illinois are in close proximity to underground mines, including 201,000 acres of urban and developed lands that may be exposed to subsidence. Of these urban areas, 90,000 acres are within low-medium density developed areas (predominantly residential), another 49,000 acres are within high density developed areas, and 62,000 acres are within other urban areas.

Approximately 130,000 acres of urban and developed lands fall within Zone 1 (undermined areas or lands within a 30-degree angle of draw from the depth of the mine-edge boundary) and 71,000 acres are in Zone 2 (additional area to reflect potential mine boundary uncertainties). An estimated 333,000 housing units are within these zones; approximately 219,000 housing units are in Zone 1, and 114,000 housing units are in Zone 2.

Of the 79 counties studied, 7% of the low-medium density developed land in these counties is within Zone 1; the range is from 0 to 63% in individual counties. St. Clair County has the most acres of low-medium density developed land in Zone 1 (Figure 3); its nearly 10,000 acres represent approximately 17% of the statewide total.

Distribution of Undermined Land within Counties

The acreages of each county in Zone 1 and Zone 2 are listed in Tables 5 and 6, respectively, as subdivided by land cover classification. For example, 273 acres (8.2%) of the low-medium density developed land in Bond County are in Zone 1 (Table 5), and 92 acres (2.8%) are in Zone 2 (Table 6). Table 7 shows the land-classified acreage of Zones 1 and 2 combined. In Bond County, an estimated 5,275 acres (2.2% of the total county acreage) and an estimated 795 housing units (11.9% of the county housing total) are within Zones 1 and 2.

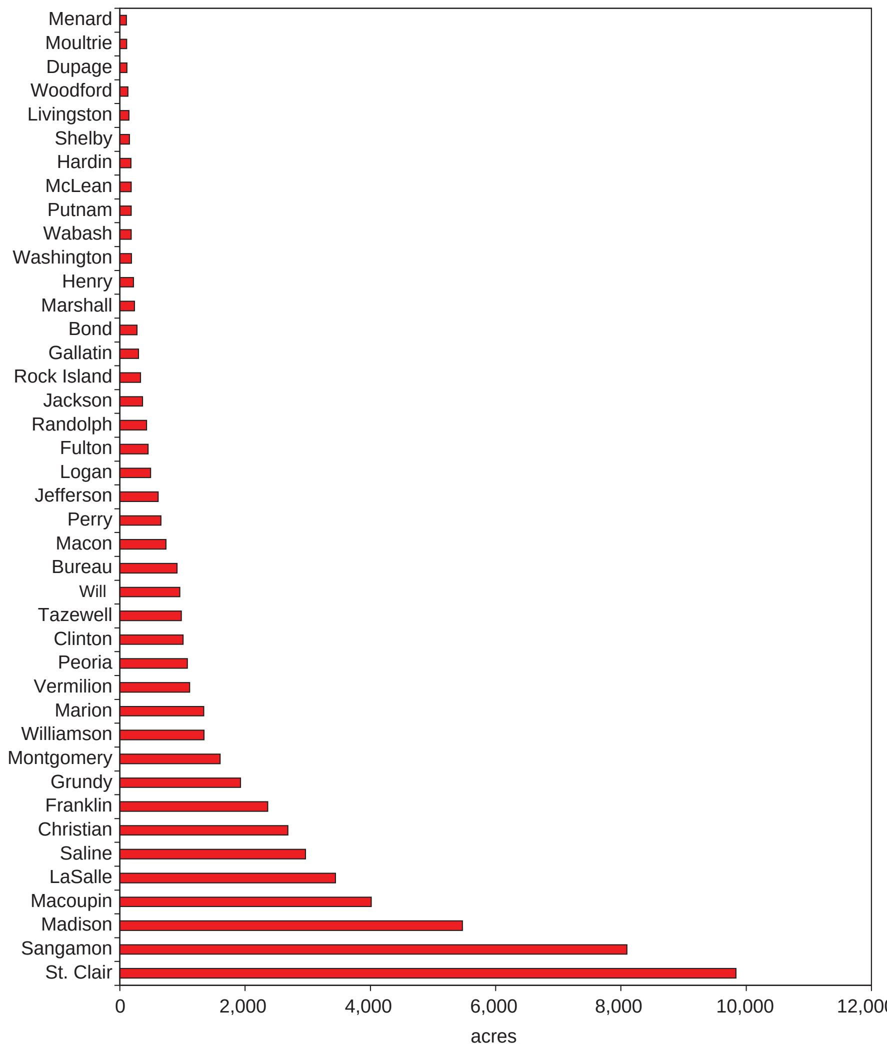

Figure 3 Low-medium density developed acreage in Zone 1, by county (only counties having at least 100 acres of low-medium density developed land in Zone 1 are shown).

Table 5 Acreage and percentage of land in Zone 1, by county and land use category.[1, 2]

County	Low-medium density (acres)	Low-medium density (%)	High-density (acres)	High-density (%)	Urban open space (acres)	Urban open space (%)	Rural area (acres)	Rural area (%)	Total area (acres)	Total area (%)	Housing units (units)	Housing units (%)
Adams	38	0.6	55	0.7	2	0.0	524	0.1	619	0.1	66	0.2
Alexander	0	0.0	7	0.5	0	0.0	125	0.1	132	0.1	1	0.0
Bond	273	8.2	51	3.6	175	17.0	2,491	1.1	2,990	1.2	706	10.6
Brown	0	0.0	0	0.0	0	0.0	1	0.0	1	0.0	0	0.0
Bureau	913	21.0	411	9.0	896	20.3	6,687	1.2	8,907	1.6	3,468	22.6
Calhoun	6	0.2	1	0.4	0	0.0	74	0.0	81	0.1	1	0.0
Carroll	0	0.0	0	0.0	0	0.0	36	0.0	36	0.0	0	0.0
Cass	1	0.0	0	0.0	0	0.0	6	0.0	7	0.0	0	0.0
Champaign	6	0.1	19	0.1	1	0.0	10	0.0	36	0.0	5	0.0
Christian	2,681	50.3	1,262	27.5	664	40.1	54,160	12.4	58,767	13.1	7,567	50.7
Clinton	1,009	19.8	692	17.6	512	30.5	17,736	6.2	19,950	6.7	3,021	22.0
Coles	10	0.2	11	0.2	0	0.0	0	0.0	22	0.0	40	0.2
Cook	5	0.0	7	0.0	0	0.0	0	0.0	12	0.0	7	0.0
Crawford	2	0.1	0	0.0	0	0.0	250	0.1	252	0.1	2	0.0
Cumberland	5	0.3	2	0.5	0	0.0	38	0.0	45	0.0	4	0.1
Douglas	18	0.9	88	2.0	0	0.0	9,454	3.7	9,560	3.6	38	0.5
DuPage	113	0.1	74	0.3	44	0.1	30	0.1	262	0.1	304	0.1
Edgar	4	0.2	8	0.4	0	0.0	1,578	0.4	1,590	0.4	9	0.1
Edwards	0	0.0	0	0.0	0	0.0	157	0.1	157	0.1	1	0.0
Franklin	2,359	63.4	1,113	52.6	5,137	76.4	99,754	40.7	108,363	42.1	11,741	65.4
Fulton	450	11.1	296	11.1	833	16.3	26,922	5.1	28,500	5.3	1,896	11.8
Gallatin	298	11.5	94	9.3	69	5.4	18,200	9.2	18,661	9.2	181	6.0
Greene	25	0.7	12	1.4	5	0.3	1,175	0.3	1,217	0.4	39	0.6
Grundy	1,926	26.2	672	26.1	1,119	36.8	10,363	4.1	14,080	5.3	5,723	38.4
Hamilton	89	2.9	38	4.8	0	0.0	6,118	2.3	6,245	2.3	43	1.1
Hancock	2	0.0	0	0.0	0	0.0	190	0.0	192	0.0	0	0.0
Hardin	178	7.4	88	8.4	103	20.1	3,786	3.5	4,155	3.7	177	7.2
Henderson	0	0.0	0	0.0	0	0.0	18	0.0	18	0.0	0	0.0
Henry	218	4.3	225	3.5	379	7.8	4,232	0.8	5,053	1.0	1,080	5.1
Jackson	364	11.8	237	7.9	932	12.9	13,401	3.8	14,934	4.1	2,623	10.0
Jasper	0	0.0	0	0.0	0	0.0	188	0.1	188	0.1	2	0.0
Jefferson	610	10.8	477	15.8	178	6.1	29,024	8.4	30,289	8.5	1,383	8.2
Jersey	2	0.0	0	0.0	0	0.0	73	0.0	75	0.0	3	0.0
Jo Daviess	25	1.1	53	1.3	33	1.7	2,720	0.7	2,831	0.7	132	1.1
Johnson	5	0.4	1	0.2	17	0.6	528	0.2	551	0.3	11	0.2
Kane	9	0.0	32	0.3	1	0.0	0	0.0	42	0.0	4	0.0
Kankakee	1	0.0	0	0.0	0	0.0	338	0.1	339	0.1	62	0.2
Knox	55	1.0	37	0.7	12	0.2	7,099	1.6	7,203	1.6	88	0.4
La Salle	3,444	20.1	1,386	24.0	1,963	19.8	8,224	1.2	15,017	2.1	14,795	32.0
Lawrence	0	0.0	0	0.0	0	0.0	575	0.3	575	0.2	2	0.0
Livingston	145	2.7	258	2.6	48	2.6	1,439	0.2	1,890	0.3	820	5.4
Logan	491	17.3	714	9.5	477	29.2	10,620	2.8	12,302	3.1	2,254	19.0
Macon	737	6.9	441	3.3	204	2.9	609	0.2	1,991	0.5	3,185	6.4
Macoupin	4,012	45.8	1,705	35.9	1,537	50.2	66,538	12.6	73,792	13.5	9,973	47.6
Madison	5,468	15.6	1,935	10.4	2,153	13.2	24,324	6.3	33,879	7.4	18,558	17.1
Marion	1,340	22.7	690	21.6	619	22.4	6,095	1.7	8,744	2.4	4,047	22.5
Marshall	233	13.9	247	7.1	158	16.6	2,901	1.2	3,539	1.4	978	16.6
McDonough	23	1.0	12	0.4	50	1.2	1,242	0.3	1,327	0.4	113	0.8
McLean	181	1.9	355	1.7	101	1.5	256	0.0	893	0.1	695	1.2
Menard	104	7.8	179	5.8	219	31.0	2,935	1.5	3,436	1.7	641	12.2
Mercer	68	4.1	52	2.6	91	4.5	6,670	1.9	6,881	1.9	297	4.2
Monroe	6	0.2	13	0.4	12	0.5	513	0.2	544	0.2	48	0.4
Montgomery	1,602	29.0	1,046	23.0	769	34.9	39,805	9.2	43,221	9.7	3,924	31.4
Morgan	0	0.0	0	0.0	0	0.0	13	0.0	14	0.0	0	0.0
Moultrie	108	8.2	71	2.5	57	7.8	435	0.2	670	0.3	438	7.7
Peoria	1,079	7.5	840	6.2	933	11.8	18,440	5.2	21,292	5.5	5,213	6.7
Perry	657	23.4	346	16.3	884	26.1	30,190	11.4	32,078	11.7	2,792	29.9
Pike	1	0.0	3	0.1	3	0.1	78	0.0	85	0.0	2	0.0
Pope	15	0.4	2	0.3	3	1.1	1,317	0.6	1,337	0.6	16	0.7
Putnam	181	17.3	23	5.3	424	26.5	1,652	1.7	2,279	2.2	583	20.3
Randolph	425	13.2	229	7.4	740	11.5	29,516	8.4	30,910	8.5	1,261	9.5
Rock Island	329	2.9	218	1.6	437	5.3	4,042	1.7	5,025	1.9	2,028	3.2
Saline	2,963	49.8	832	54.7	2,487	63.0	69,654	30.6	75,935	31.8	7,324	59.8
Sangamon	8,095	45.7	7,585	34.3	4,221	37.2	50,602	10.2	70,503	12.8	39,769	46.6
Schuyler	4	0.2	5	0.4	8	1.0	881	0.3	898	0.3	7	0.2
Scott	6	0.6	12	0.8	11	0.9	175	0.1	204	0.1	9	0.4
Shelby	154	4.7	144	5.2	157	14.3	3,135	0.7	3,589	0.8	631	6.4
St. Clair	9,836	29.3	3,316	20.2	3,384	23.1	37,142	10.5	53,677	12.9	37,087	35.6
Stark	1	0.1	0	0.1	0	0.0	208	0.1	209	0.1	2	0.1
Tazewell	982	8.0	411	2.3	661	8.2	2,555	0.7	4,609	1.1	4,281	8.1
Union	0	0.0	0	0.0	0	0.0	219	0.1	219	0.1	3	0.0
Vermilion	1,112	13.8	1,031	10.2	785	10.9	29,355	5.4	32,284	5.7	4,535	12.6
Wabash	181	10.0	64	13.6	3	0.5	13,497	9.8	13,746	9.8	130	2.3
Warren	1	0.0	0	0.0	0	0.0	610	0.2	611	0.2	5	0.1
Washington	184	6.5	228	9.8	124	6.8	10,948	3.1	11,485	3.2	353	5.5
White	68	1.3	67	3.7	24	2.0	15,312	5.1	15,471	5.0	125	1.7
Will	959	1.7	211	1.3	1,042	1.9	2,508	0.6	4,720	0.9	2,119	1.2
Williamson	1,345	28.6	495	16.8	4,376	34.4	65,566	27.1	71,782	27.4	8,515	31.3
Woodford	129	4.1	291	4.1	131	5.8	1,704	0.5	2,255	0.7	618	4.6
Total[2]	58,366	7.0	31,519	6.1	40,412	7.8	879,985	3.5	1,010,282	3.7	218,600	5.2

[1] For example, in Bond County, the 273 acres of low-medium density developed land in Zone 1 represents 8.2% of the total low-medium density developed land in the county.
[2] Note: figures have been rounded.

Table 6 Acreage and percentage of land in Zone 2, by county and land use category.[1, 2]

County	Low-medium density (acres)	(%)	High-density (acres)	(%)	Urban open space (acres)	(%)	Rural area (acres)	(%)	Total area (acres)	(%)	Housing units (units)	(%)
Adams	129	2.0	101	1.2	94	1.8	767	0.1	1,091	0.2	433	1.5
Alexander	20	2.0	15	1.1	0	0.0	6,409	4.4	6,444	4.3	61	1.3
Bond	92	2.8	26	1.8	31	3.0	2,136	0.9	2,285	1.0	89	1.3
Brown	1	0.1	1	0.1	0	0.0	1,537	0.8	1,539	0.8	9	0.4
Bureau	121	2.8	72	1.6	180	4.1	7,092	1.3	7,465	1.4	227	1.5
Calhoun	23	1.0	6	1.8	0	0.0	1,373	0.9	1,403	0.9	21	0.8
Carroll	3	0.2	1	0.0	0	0.0	694	0.3	698	0.2	10	0.1
Cass	8	0.5	18	1.1	21	1.6	893	0.4	941	0.4	15	0.3
Champaign	83	0.7	108	0.6	12	0.2	85	0.0	288	0.0	517	0.7
Christian	801	15.0	543	11.8	230	13.9	14,077	3.2	15,651	3.5	2,960	19.8
Clinton	681	13.4	442	11.3	209	12.5	8,891	3.1	10,224	3.4	2,104	15.3
Coles	75	1.6	63	1.1	10	0.5	91	0.0	238	0.1	334	1.5
Cook	24	0.0	12	0.0	23	0.0	18	0.0	77	0.0	55	0.0
Crawford	8	0.3	1	0.1	0	0.0	1,092	0.4	1,101	0.4	13	0.1
Cumberland	15	0.9	7	1.4	0	0.0	237	0.1	258	0.1	20	0.4
Douglas	20	1.0	27	0.6	0	0.0	3,470	1.4	3,517	1.3	56	0.7
DuPage	290	0.4	36	0.2	30	0.0	40	0.1	396	0.2	1,111	0.3
Edgar	11	0.4	21	0.9	0	0.0	3,036	0.8	3,067	0.8	22	0.3
Edwards	0	0.0	0	0.0	0	0.0	331	0.2	331	0.2	1	0.0
Franklin	393	10.6	307	14.5	529	7.9	11,387	4.6	12,616	4.9	2,076	11.6
Fulton	1,040	25.7	588	22.1	1,538	30.1	49,539	9.4	52,705	9.8	4,581	28.5
Gallatin	341	13.2	136	13.5	176	13.8	13,441	6.8	14,094	6.9	385	12.7
Greene	82	2.2	23	2.7	31	1.9	4,408	1.3	4,545	1.3	138	2.2
Grundy	814	11.1	326	12.7	529	17.4	8,443	3.4	10,113	3.8	2,383	16.0
Hamilton	40	1.3	5	0.7	0	0.0	2,518	0.9	2,563	0.9	20	0.5
Hancock	3	0.1	2	0.1	0	0.0	1,193	0.2	1,197	0.2	3	0.0
Hardin	443	18.4	67	6.4	136	26.4	18,181	16.8	18,827	16.8	563	22.9
Henderson	21	1.5	24	2.0	0	0.0	507	0.2	553	0.2	3	0.1
Henry	241	4.8	270	4.2	355	7.3	11,270	2.2	12,136	2.3	855	4.0
Jackson	323	10.5	123	4.1	498	6.9	12,691	3.6	13,634	3.7	2,551	9.7
Jasper	3	0.2	1	0.1	0	0.0	878	0.3	883	0.3	16	0.4
Jefferson	166	3.0	105	3.5	62	2.1	5,592	1.6	5,925	1.7	691	4.1
Jersey	15	0.5	2	0.2	2	0.2	1,117	0.5	1,136	0.5	48	0.5
Jo Daviess	264	12.2	341	8.6	284	15.0	23,434	6.3	24,324	6.4	1,135	9.5
Johnson	12	1.0	8	1.3	72	2.7	1,680	0.8	1,772	0.8	32	0.7
Kane	107	0.3	84	0.9	65	0.2	64	0.0	320	0.1	59	0.0
Kankakee	1	0.0	0	0.0	0	0.0	695	0.2	696	0.2	78	0.2
Knox	122	2.2	106	2.0	98	1.8	13,939	3.2	14,265	3.2	317	1.3
La Salle	1,292	7.5	637	11.0	1,152	11.6	14,682	2.1	17,762	2.5	3,596	7.8
Lawrence	0	0.0	0	0.0	0	0.0	803	0.3	804	0.3	3	0.0
Livingston	226	4.3	243	2.4	125	6.8	3,258	0.5	3,852	0.6	916	6.0
Logan	420	14.8	669	8.9	233	14.3	4,828	1.3	6,149	1.6	1,972	16.6
Macon	629	5.9	371	2.8	121	1.7	663	0.2	1,784	0.5	3,435	6.9
Macoupin	909	10.4	590	12.4	278	9.1	24,828	4.7	26,606	4.9	2,607	12.5
Madison	4,446	12.7	1,379	7.4	1,436	8.8	17,382	4.5	24,642	5.4	15,050	13.9
Marion	451	7.7	190	5.9	214	7.7	3,010	0.9	3,865	1.1	1,551	8.6
Marshall	110	6.6	151	4.3	136	14.2	4,829	2.0	5,226	2.1	439	7.4
McDonough	133	5.7	79	3.0	206	5.1	9,298	2.6	9,716	2.6	688	5.2
McLean	244	2.5	198	0.9	157	2.3	556	0.1	1,155	0.2	1,173	2.0
Menard	208	15.6	238	7.7	182	25.8	6,141	3.2	6,768	3.4	882	16.8
Mercer	101	6.1	47	2.4	142	7.1	9,766	2.8	10,057	2.8	470	6.7
Monroe	23	0.6	25	0.8	24	1.0	1,827	0.8	1,900	0.8	38	0.4
Montgomery	821	14.9	401	8.8	230	10.4	15,245	3.5	16,697	3.8	2,272	18.2
Morgan	30	0.8	15	0.3	34	1.1	1,511	0.4	1,589	0.4	69	0.5
Moultrie	22	1.7	2	0.1	10	1.4	541	0.3	575	0.3	91	1.6
Peoria	822	5.7	746	5.5	679	8.6	22,279	6.3	24,526	6.3	3,768	4.8
Perry	812	28.9	525	24.7	1,314	38.7	18,857	7.1	21,508	7.9	3,438	36.9
Pike	4	0.1	5	0.2	24	0.8	454	0.1	487	0.1	14	0.2
Pope	332	8.7	74	13.3	125	47.4	14,822	6.5	15,352	6.6	564	24.2
Putnam	57	5.4	24	5.6	52	3.3	1,454	1.5	1,587	1.6	151	5.3
Randolph	503	15.6	305	9.8	1,022	15.9	13,430	3.8	15,259	4.2	1,872	14.1
Rock Island	528	4.7	497	3.6	554	6.7	6,925	2.9	8,504	3.2	2,950	4.6
Saline	1,099	18.5	331	21.8	752	19.0	26,320	11.6	28,501	11.9	2,539	20.7
Sangamon	2,298	13.0	2,127	9.6	1,119	9.9	24,602	4.9	30,145	5.5	10,352	12.1
Schuyler	74	5.0	34	2.9	58	6.7	7,884	2.9	8,051	2.9	92	2.8
Scott	29	2.5	12	0.8	83	6.3	1,000	0.6	1,124	0.7	58	2.4
Shelby	189	5.8	187	6.8	77	7.1	8,162	1.7	8,614	1.8	584	5.9
St. Clair	4,768	14.2	1,555	9.5	1,728	11.8	24,429	6.9	32,480	7.8	15,447	14.8
Stark	34	4.9	27	4.0	2	0.2	2,247	1.2	2,310	1.3	20	0.7
Tazewell	660	5.4	402	2.2	666	8.3	1,959	0.5	3,687	0.9	3,258	6.2
Union	5	0.3	1	0.1	0	0.0	3,959	1.6	3,964	1.5	76	1.0
Vermilion	866	10.8	1,071	10.6	708	9.8	19,591	3.6	22,235	3.9	3,737	10.4
Wabash	76	4.2	8	1.6	22	3.1	5,621	4.1	5,727	4.1	161	2.8
Warren	2	0.1	5	0.2	0	0.0	2,747	0.8	2,754	0.8	20	0.3
Washington	248	8.8	139	6.0	172	9.3	4,653	1.3	5,212	1.5	672	10.6
White	99	1.9	13	0.7	49	4.0	4,493	1.5	4,654	1.5	189	2.6
Will	218	0.4	163	1.0	180	0.3	1,225	0.3	1,786	0.3	255	0.1
Williamson	784	16.7	407	13.8	1,792	14.1	24,566	10.2	27,549	10.5	4,618	17.0
Woodford	73	2.3	66	0.9	53	2.4	1,203	0.4	1,395	0.4	288	2.2
Total[2]	31,488	3.8	17,974	3.5	21,120	4.1	595,282	2.3	665,874	2.4	114,367	2.7

[1] For example, in Bond County, the 92 acres of low-medium density developed land in Zone 2 represent 2.8% of the total low-medium density developed land in the county.
[2] Note: figures have been rounded.

Table 7 Acreage and percentage of land in Zones 1 and 2 combined, by county and land use category.[1, 2]

County	Low-medium density (acres)	Low-medium density (%)	High-density (acres)	High-density (%)	Urban open space (acres)	Urban open space (%)	Rural area (acres)	Rural area (%)	Total area (acres)	Total area (%)	Housing units (units)	Housing units (%)
Adams	168	2.6	156	1.9	96	1.8	1,290	0.2	1,709	0.3	498	1.7
Alexander	20	2.0	22	1.5	0	0.0	6,534	4.5	6,576	4.4	62	1.4
Bond	365	11.0	76	5.4	207	20.0	4,627	2.0	5,275	2.2	795	11.9
Brown	1	0.1	1	0.1	0	0.0	1,538	0.8	1,540	0.8	9	0.4
Bureau	1,034	23.8	483	10.6	1,076	24.4	13,778	2.6	16,372	3.0	3,695	24.1
Calhoun	29	1.2	8	2.2	0	0.0	1,447	0.9	1,483	0.9	22	0.8
Carroll	3	0.2	1	0.0	0	0.0	730	0.3	734	0.3	10	0.1
Cass	9	0.5	18	1.1	21	1.6	899	0.4	947	0.4	15	0.3
Champaign	89	0.8	128	0.7	13	0.2	95	0.0	324	0.1	522	0.7
Christian	3,482	65.4	1,805	39.3	894	54.0	68,237	15.6	74,419	16.6	10,526	70.6
Clinton	1,690	33.2	1,135	28.9	722	43.0	26,627	9.3	30,174	10.1	5,125	37.4
Coles	85	1.8	74	1.3	10	0.5	91	0.0	260	0.1	374	1.6
Cook	29	0.0	19	0.0	23	0.0	18	0.0	89	0.0	62	0.0
Crawford	10	0.3	1	0.1	0	0.0	1,342	0.5	1,352	0.5	15	0.2
Cumberland	20	1.1	9	1.9	0	0.0	275	0.1	303	0.1	24	0.5
Douglas	38	1.8	115	2.5	0	0.0	12,923	5.1	13,077	5.0	94	1.2
DuPage	403	0.5	111	0.5	74	0.1	70	0.2	658	0.3	1,415	0.4
Edgar	15	0.6	29	1.3	0	0.0	4,614	1.2	4,657	1.2	32	0.4
Edwards	0	0.0	0	0.0	0	0.0	489	0.4	489	0.3	1	0.0
Franklin	2,752	73.9	1,420	67.1	5,667	84.3	111,141	45.4	120,979	47.0	13,818	76.9
Fulton	1,490	36.8	883	33.3	2,372	46.4	76,461	14.5	81,205	15.1	6,477	40.3
Gallatin	639	24.7	230	22.8	245	19.2	31,641	16.0	32,755	16.1	566	18.7
Greene	108	2.9	36	4.2	36	2.2	5,583	1.7	5,762	1.7	177	2.8
Grundy	2,741	37.2	998	38.8	1,648	54.2	18,806	7.5	24,193	9.1	8,106	54.3
Hamilton	129	4.1	43	5.5	0	0.0	8,636	3.2	8,808	3.2	63	1.6
Hancock	4	0.1	2	0.1	0	0.0	1,382	0.3	1,389	0.3	4	0.0
Hardin	621	25.8	155	14.8	239	46.5	21,967	20.3	22,982	20.5	740	30.1
Henderson	22	1.5	24	2.0	0	0.0	525	0.2	571	0.2	3	0.1
Henry	459	9.1	495	7.7	734	15.1	15,501	3.1	17,189	3.3	1,935	9.1
Jackson	687	22.3	360	12.0	1,429	19.9	26,091	7.4	28,568	7.8	5,175	19.6
Jasper	3	0.2	1	0.1	0	0.0	1,066	0.3	1,071	0.3	18	0.4
Jefferson	777	13.8	582	19.3	239	8.2	34,616	10.0	36,214	10.1	2,074	12.3
Jersey	16	0.5	2	0.2	2	0.2	1,190	0.5	1,211	0.5	50	0.6
Jo Daviess	289	13.4	395	10.0	317	16.8	26,154	7.0	27,154	7.1	1,267	10.6
Johnson	17	1.4	10	1.5	89	3.4	2,208	1.0	2,323	1.1	42	0.9
Kane	117	0.3	116	1.2	66	0.2	64	0.0	363	0.1	62	0.0
Kankakee	2	0.0	0	0.0	0	0.0	1,033	0.3	1,035	0.2	141	0.3
Knox	177	3.2	142	2.7	111	2.0	21,039	4.8	21,468	4.8	404	1.7
La Salle	4,736	27.6	2,023	35.0	3,115	31.4	22,906	3.3	32,779	4.6	18,391	39.8
Lawrence	1	0.0	0	0.0	0	0.0	1,378	0.6	1,379	0.6	5	0.1
Livingston	371	7.0	501	5.0	173	9.5	4,697	0.7	5,742	0.9	1,736	11.4
Logan	911	32.1	1,383	18.5	710	43.5	15,448	4.1	18,451	4.7	4,225	35.6
Macon	1,367	12.7	811	6.1	325	4.6	1,271	0.4	3,775	1.0	6,620	13.2
Macoupin	4,921	56.2	2,296	48.4	1,815	59.3	91,366	17.3	100,398	18.4	12,580	60.1
Madison	9,914	28.2	3,313	17.9	3,589	21.9	41,706	10.8	58,522	12.8	33,608	31.0
Marion	1,792	30.4	880	27.5	833	30.1	9,104	2.6	12,609	3.5	5,598	31.2
Marshall	343	20.5	398	11.5	293	30.8	7,730	3.2	8,765	3.6	1,417	24.0
McDonough	156	6.7	91	3.4	256	6.4	10,540	2.9	11,042	3.0	801	6.0
McLean	424	4.4	553	2.6	258	3.9	813	0.1	2,048	0.3	1,868	3.1
Menard	311	23.4	417	13.5	401	56.8	9,076	4.7	10,205	5.1	1,523	29.0
Mercer	170	10.2	99	5.0	232	11.7	16,436	4.7	16,938	4.8	767	10.9
Monroe	30	0.8	38	1.2	36	1.5	2,340	1.0	2,444	1.0	85	0.8
Montgomery	2,423	43.8	1,446	31.8	998	45.3	55,050	12.7	59,918	13.5	6,197	49.6
Morgan	30	0.8	16	0.3	34	1.1	1,524	0.4	1,603	0.4	70	0.5
Moultrie	130	9.9	72	2.6	68	9.2	976	0.5	1,245	0.6	530	9.3
Peoria	1,902	13.3	1,586	11.8	1,611	20.4	40,719	11.5	45,817	11.8	8,980	11.5
Perry	1,469	52.2	872	40.9	2,198	64.8	49,048	18.5	53,586	19.6	6,230	66.8
Pike	6	0.1	8	0.3	27	0.9	532	0.1	573	0.1	17	0.2
Pope	347	9.1	76	13.7	128	48.5	16,139	7.1	16,689	7.2	580	24.9
Putnam	237	22.7	47	10.9	476	29.7	3,106	3.2	3,866	3.8	734	25.5
Randolph	928	28.8	533	17.1	1,762	27.4	42,946	12.3	46,168	12.7	3,133	23.7
Rock Island	857	7.6	715	5.2	991	12.0	10,967	4.7	13,529	5.0	4,978	7.8
Saline	4,062	68.2	1,162	76.5	3,239	82.0	95,974	42.2	104,437	43.7	9,862	80.6
Sangamon	10,393	58.6	9,712	43.9	5,340	47.1	75,204	15.1	100,648	18.3	50,121	58.8
Schuyler	77	5.3	39	3.3	67	7.7	8,766	3.2	8,949	3.2	99	3.0
Scott	35	3.1	24	1.7	94	7.1	1,175	0.8	1,328	0.8	67	2.7
Shelby	342	10.5	331	12.0	234	21.4	11,297	2.4	12,204	2.6	1,215	12.3
St. Clair	14,604	43.5	4,871	29.7	5,111	34.8	61,570	17.5	86,157	20.6	52,534	50.5
Stark	35	5.1	28	4.1	2	0.2	2,455	1.4	2,519	1.4	22	0.8
Tazewell	1,643	13.4	813	4.5	1,327	16.5	4,514	1.2	8,296	2.0	7,540	14.3
Union	5	0.3	1	0.1	0	0.0	4,178	1.6	4,184	1.6	79	1.0
Vermilion	1,978	24.6	2,102	20.8	1,493	20.7	48,946	9.1	54,519	9.7	8,273	23.0
Wabash	258	14.2	71	15.2	25	3.6	19,118	13.9	19,472	13.8	291	5.1
Warren	3	0.2	5	0.3	0	0.0	3,358	1.0	3,366	1.0	25	0.3
Washington	432	15.3	367	15.8	296	16.1	15,602	4.5	16,697	4.7	1,025	16.1
White	167	3.2	80	4.4	74	6.0	19,804	6.6	20,125	6.5	314	4.3
Will	1,177	2.0	373	2.4	1,222	2.2	3,734	0.9	6,506	1.2	2,373	1.4
Williamson	2,129	45.3	901	30.6	6,168	48.5	90,132	37.3	99,330	37.9	13,132	48.3
Woodford	202	6.5	357	5.0	184	8.2	2,907	0.9	3,650	1.1	906	6.8
Total[2]	89,853	10.8	49,493	9.6	61,532	11.9	1,475,278	5.8	1,676,156	6.1	332,968	8.0

[1] For example, in Bond County, the 365 acres of low-medium density developed land in Zones 1 and 2 represent 11% of the total low-medium density developed land in the county.

[2] Note: figures have been rounded. Urban and developed lands constitute low-medium density, high density, and urban open space classifications. Combined total is 200,878 potentially affected acres.

Table 8 shows a comparison of the ranking of counties by total acreage and by estimated housing units in Zone 1. The magnitude of potential mine subsidence damage to structures in a county is related to the amount of development over underground mines. For example, Franklin County has the most total acreage in Zone 1, but, because the county has relatively little urban development, it has significantly fewer housing units in Zone 1 than do four counties having larger urban areas (Sangamon, St. Clair, Madison, and La Salle). La Salle County, which ranks nineteenth in acreage in Zone 1 (less than one-fifth the Zone 1 acreage of Franklin County), ranks ahead of Franklin County in number of housing units in Zone 1.

A closer examination of the top 15 counties from Figure 3 shows several counties that have relatively higher percentages of the total county's low-medium density developed land falling within Zone 1 (Figure 4). Three of these counties (Franklin, Christian, and Saline) have 50% or more of their low-medium density developed land in Zone 1, and nine additional counties have 20% or more of these lands in Zone 1. This situation is typically due to counties having either (1) relatively larger undermined acreages with relatively smaller towns in these areas (e.g., "rural" counties with mining, such as Saline or Franklin), or (2) larger acreages of developed land with mines located primarily within these areas (e.g., "urban" counties with mining, such as Sangamon County, which contains the city of Springfield, or St. Clair, which contains the St. Louis Metro East area).

Mined areas within typical "mining" counties often disproportionately underlie developed areas rather than adjacent rural areas. Most of the oldest mining operations in the state were located in and around populated areas because the towns served both as a source of labor and a market for the coal, and some mines were started along railroad lines to be near this transportation source and/or to supply passing trains. As the population increased over the years, the towns generally grew outward, over, and around these mines—and many towns continue to expand. See Appendix 2 for a series of maps, by county, that illustrate areas potentially affected by underground mining and their relationship to generalized urban areas.

Table 8 Ranking of the top 15 mining counties, by total acreage and estimated number of housing units in Zone 1.

Rank	County	Acreage in Zone 1	Rank	County	Housing units in Zone 1
1	Franklin	108,363	1	Sangamon	39,769
2	Saline	75,921	2	St. Clair	37,087
3	Macoupin	73,792	3	Madison	18,558
4	Williamson	71,782	4	La Salle	14,795
5	Sangamon	70,503	5	Franklin	11,741
6	Christian	58,767	6	Macoupin	9,973
7	St. Clair	53,677	7	Williamson	8,515
8	Montgomery	43,221	8	Christian	7,567
9	Madison	33,879	9	Saline	7,323
10	Vermilion	32,284	10	Grundy	5,723
11	Perry	32,078	11	Peoria	5,213
12	Randolph	30,910	12	Vermilion	4,535
13	Jefferson	30,289	13	Tazewell	4,281
14	Fulton	28,500	14	Marion	4,047
15	Peoria	21,292	15	Montgomery	3,924

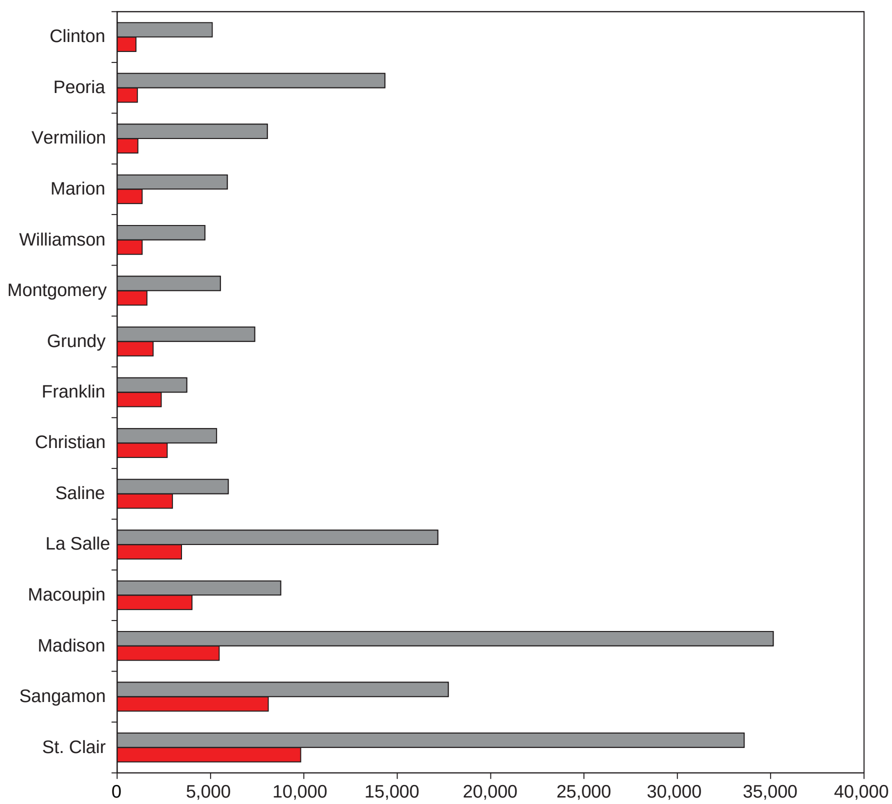

Figure 4 Comparison of low-medium density developed acreage in Zone 1 (red bar) with the total low-medium density developed acreage in select counties (gray bar). Only counties having a minimum of 1,000 acres of low-medium density developed land in Zone 1 are shown.

Additional Factors Related to Subsidence Potential

Factors other than the proximity to or depth of mines must be consid-

Table 9 Longwall mines and underground mines, by county.

County	Longwall mines (no.)	Underground mines (no.)
Bureau	9	38
Christian	1	17
Crawford	1[1]	9
Franklin	6	35
Grundy	47	232
Hamilton	2[1]	3
Jackson	1	143
Jefferson	31	5
Kankakee	6	9
Knox	1	42
La Salle	27	256
Livingston	3	44
Logan	1	9
Macon	3	5
Macoupin	4	69
Marshall	4	53
McDonough	1	143
McLean	3	6
Montgomery	2	20
Peoria	1	133
Putnam	4	4
Saline	2	164
Will	26	42
Williamson	4[1]	321
Woodford	2	4

[1] Includes mines that use high-extraction-retreat room-and-pillar methods.

ered in assessing the potential risk of subsidence in an area. For instance, the mining method used determines the amount of coal left in the mine (e.g., pillars) to support the overburden. Some form of room-and-pillar mining—in which 40 to 60% of the coal is commonly left in place to support the mine roof—was used in most Illinois mines. Over time, these pillars of coal may fail, but it is generally impossible to predict if and when failure will occur.

Two other mining techniques used in Illinois are longwall mining and high-extraction retreat room-and-pillar mining. With these techniques, most or all of the coal is removed from sections of the mine, causing planned subsidence of the ground surface very shortly after mining. Once ground movement ceases, there is little future risk of subsidence over these mine sections. The effects of specific mining methods on the subsidence potential must be evaluated on a site-by-site basis; these effects were not considered in this study. Longwall methods have been used in only a small percentage of the more than 3,800 underground mines in Illinois. Table 9 lists the total number of longwall mines and the total number of underground mines in each county assessed in this study.

Although a 10-foot-thick coal seam will be more likely to propagate more displacement at the surface than, for example, a 4-foot-thick coal seam, no attempt was made to differentiate subsidence magnitude based on coal thickness. The interaction of contributing factors (e.g., the geology of the roof and floor and the previous subsidence at the site) is not well understood and is too complex to include in this study. However, these factors should be considered to evaluate the subsidence potential at a specific site.

Conclusions

This study found that an estimated 333,000 housing units and approximately 201,000 acres of urban and developed lands are in close proximity to underground mines and may be exposed to subsidence. The total land area in Illinois overlying or immediately adjacent to underground mines is 1,676,000 acres. Planners, developers, local government officials, and landowners should be made aware of the general locations of these areas.

The tables in this report can be used to determine the amount of land within a county that lies in close proximity to underground mines. Maps are included that illustrate the general intersection of urban area land cover classifications with zones of proximity above and adjacent to the boundary of underground mines. These maps are not suitable for site-specific studies. Original individual mine maps must be used to delineate the position of mine boundaries accurately with respect to urban features.

County maps (1:100,000 scale) and quadrangle maps (1:24,000 scale) showing the general location of mined areas are available on the ISGS Web site (http://www.isgs.illinois.edu/maps-data-pub/maps.shtml). These areas continue to be studied to ensure the detailed quadrangle mined area maps depict the best-known position of mine boundaries with respect to individual properties, as located on a USGS topographic map base. Information on the availability of these mined-area maps and/or scanned source map images for many individual mines can be obtained from the ISGS.

Factors that contribute to subsidence potential (e.g., thickness of the coal, geology of the roof and floor, and previous subsidence at the site) should be considered when evaluating the subsidence potential of specific sites. As more is learned about these contributing factors, the assessment of exposure to potential mine subsidence can continue to be refined.

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Appendix 1: Detailed GIS Calculation Methodology

GIS Buffer Distance Calculations

Statewide vector data for underground coal and non-coal mines were sourced from yearly updated mined-out area GIS layers maintained by the ISGS. Statewide polygon layers for coal depths were sourced from previous mapping studies. Depth values were in increments of 100 feet (e.g. 50 feet, 150 feet, 250 feet). All vector data in this study were projected to a common working coordinate system (Lambert Conformal Conic, NAD27) with feet as the unit of measure.

Coal mine point and polygon layers were selected by coal seam and intersected with their respective coal seam depth layer. If a mine fell outside of a depth polygon, and thus did not intersect any mapped depth values, the mine was manually given an estimated depth value or a null value. Mines in minor coal seams for which the ISGS does not have depth layers were given a null depth value. Non-coal mines were also given a null depth value because the depth-dependent Zone 1 assignment was performed only on coal mines.

Three short integer fields were added to the mine GIS layers:

- ANGLE_DRAW = 30 OR NULL (for null depths)
- Z1_BUFFER = Depth × 0.577 (where tan(30°) = 0.577) OR = 500 (for null depth values)
- Z2_BUFFER = Z1_BUFFER + 1,000 (for coal mines) OR = Z1_BUFFER + Table 5 Width Value (for noncoal mines)

Creation of Final GIS Layer

Analysis tools from ESRI's ArcToolbox were used to create the final GIS layers. Using the buffer tool, a layer was created for each buffer zone (i.e., one layer for Zone 1 and another layer for Zone 2) using the three integer fields as the variable buffer distances. A union was then conducted that spatially combined these layers into a single layer that allowed for the differentiation of Zone 1 polygons from Zone 2 polygons. Finally, a union of the buffer zones, census data, and land cover data layers was conducted, which resulted in the final GIS data layer.

Tabulations and Final Data Results

Three Python programming language scripts were developed to calculate and tabulate data per county and to export the data in database file (.dbf) format for use in Tables 6, 7, and 8 (results for Zone 1, Zone 2, and Zones 1 and 2 combined, respectively). The scripts first calculated acres for each polygon by dividing the square footage by 43,560, and the housing fraction data attribute was calculated by multiplying acres by the density of housing units per acre (which was initially calculated in the census data before it was joined with other data layers). This process ultimately yields the number of housing units per polygon. Each script then sums and outputs the total acres and total housing units based on several expressions that select each land use classification as well as total land area (all land use classes except water) for each county. The data were then compiled in a Microsoft Access database to calculate percentages and exported to Excel for final formatting.