2.14 LAND SUBSIDENCE

Subsidence is motion of the Earth's surface as it shifts downward relative to a benchmark (often sea-level) of the surrounding terrain. There are a number of causes for this effect. In Ohio the two primary causes are abandoned underground mines (AUMs) and karst.

Underground mining of coal began in the early 1800's and continues to current day. In the 1900's underground salt, limestone and gypsum mining began. Most mining is accomplished by direct human action utilizing heavy machinery to remove the material; however, with salt there are cases where pressurized water is used to wash-out the deposit (solution mining). All of these mines create voids under the Earth's surface. Several key factors determining the potential for these voids to collapse include depth, mining technique used, types of rock and or soils and development on the ground surface.

Abandoned underground coal mines in Ohio have the added environmental impact of discharging acidic water. It is common for coal mines to become charged with water. The collected water interacts with the remaining coal deposit and other materials becoming acidic. If acidic mine water is discharged into creeks or streams it can alter the chemical composition of the water habitat. Cases exist where changes in water acidity have caused sensitive aquatic life considerable harm.

Karst topography in Ohio is a landscape shaped by the dissolution of a soluble limestone or dolomite layers of bedrock. As surface water percolates down to the water table, it slowly dissolves away the limestone or dolomite creating voids under the Earth's surface. In cases where a visible depression is present, surface water may flow directly to the water table. Depending on the depth of the void, there may be no observable ground surface deformation. Deep voids may exist at or below the water table and, as a result, the rock is replaced by water. Long-term changes in the water table could destabilize deep voids resulting in surface deformation as observed in southern Missouri and northern Arkansas. Shallow voids are often underground caves or caverns, which lack any replacement support. With time, the roof of these voids may collapse and result in ground failure.

Once a hole or fissure appears in a karst area, surface water can travel directly to the aquifer bypassing the natural filtration and cleaning processes. The result has been contamination of aquifers from farm chemicals, animal waste, along with oil and gasoline from roadway runoff. Cases exist where aquifer contamination resulted in making the water unfit for human consumption. Also, karst topography can result in unusual flooding when water tables are high. Such flooding issues are difficult to address.

The last form of land subsidence in Ohio is associated with soils, which dramatically expand when wet and contract when dry. Structures built on these soils can experience significant shifting as the ground saturates and dries.

Currently there are no commercial insurance carriers which offer mine subsidence coverage in Ohio. In response to gaps in commercial insurance availability, the Ohio FAIR Plan underwriting association was established in 1968 to provide a variety of essential insurance products for eligible properties unable to obtain insurance through the voluntary market. The Ohio Mine Subsidence Insurance Underwriting Association provides eligible Ohio counties with mine subsidence insurance (see Map 2.14.a). Under the program 26 primarily Appalachian counties (Region 3) are required to carry mine subsidence insurance at a cost of one dollar annually. Additionally, eight counties in Region 2 and three counties in Region 1 are eligible to obtain insurance at the owner's discretion at a cost of five dollars annually. The remaining 51 counties are not eligible for mine subsidence insurance.

HAZARD PROFILE

Location

Beginning in the 1700s and continuing to today there has been considerable coal mining in the Appalachian region of Ohio. In addition to coal, several salt, clay and gypsum mines opened in counties close to Lake Erie. Finally in central and southwestern Ohio there are several isolated mines (see Map 2.14.a).

The majority of abandoned mines are located in, or directly adjacent to, Region 3, and most of these were coal mines. Coal mine depths can range from less than 100 feet below the surface to 1,000 feet or more. There are a number of methods which can be employed to remove a coal deposit, whether accomplished by hand/pick or machines. As the coal vein is removed, oftentimes pillars of coal are left at intervals to support the mine roof. In some cases as the mine vein is depleted and miners withdraw, the pillars were removed. In these situations the depth of the mine becomes important. Deeper mines, with solid layers of rock (*i.e.*, strata) above the void and limited soil at the surface, are less likely to fail than those closer to the surface. The ODNR, Division of Geological Survey and the Ohio Department of Transportation (ODOT) have developed profiles of voids, support strata composition and surface soils for a limited number mines to assist in understanding the potential for subsidence events. Analysis requires experts trained in geology and significant time, which limits the number of sites assessed.

Other minerals mined include gypsum, clay and limestone, primarily in Ottawa, Preble and Butler Counties. Finally, very limited exposure to abandoned mines exists in Hamilton, Lucas, Erie, Delaware and Licking Counties, where the mineral being extracted was not available.

Karst features are associated with the western third of Ohio, excluding the far northwestern counties of Williams, Fulton and Defiance (see Map 2.14.b). Nearly all of Region 1 and the far western sections of Regions 2 and 3 are impacted by karst geology. The limestone, shale and dolomite layers were deposited between 408 and 505 million years ago as the floor of an ancient sea. Later, the continental plate would rise above the existing sea level creating dry land and vast salt deposits. These sedimentary rock layers are naturally porous and dissolve into the water which passes through them.

The current landscape in the karst region of Ohio was created by glaciers as they advanced from the north reaching to the Ohio River roughly 14,000 years ago. When the last glacier receded it left behind a layer of unconsolidated material in a wide range of depths. The shallower the loose material layer, the greater the chance of water penetrating to the underlying bedrock, resulting in a void or ground deformation occurring. This is represented by the probable karst areas on the map which group into two significant clusters. In the south, the greatest impacted counties include Brown, Adams and Highland. In the north, the greatest impacted counties include Seneca, Huron, Erie, Sandusky and Ottawa.

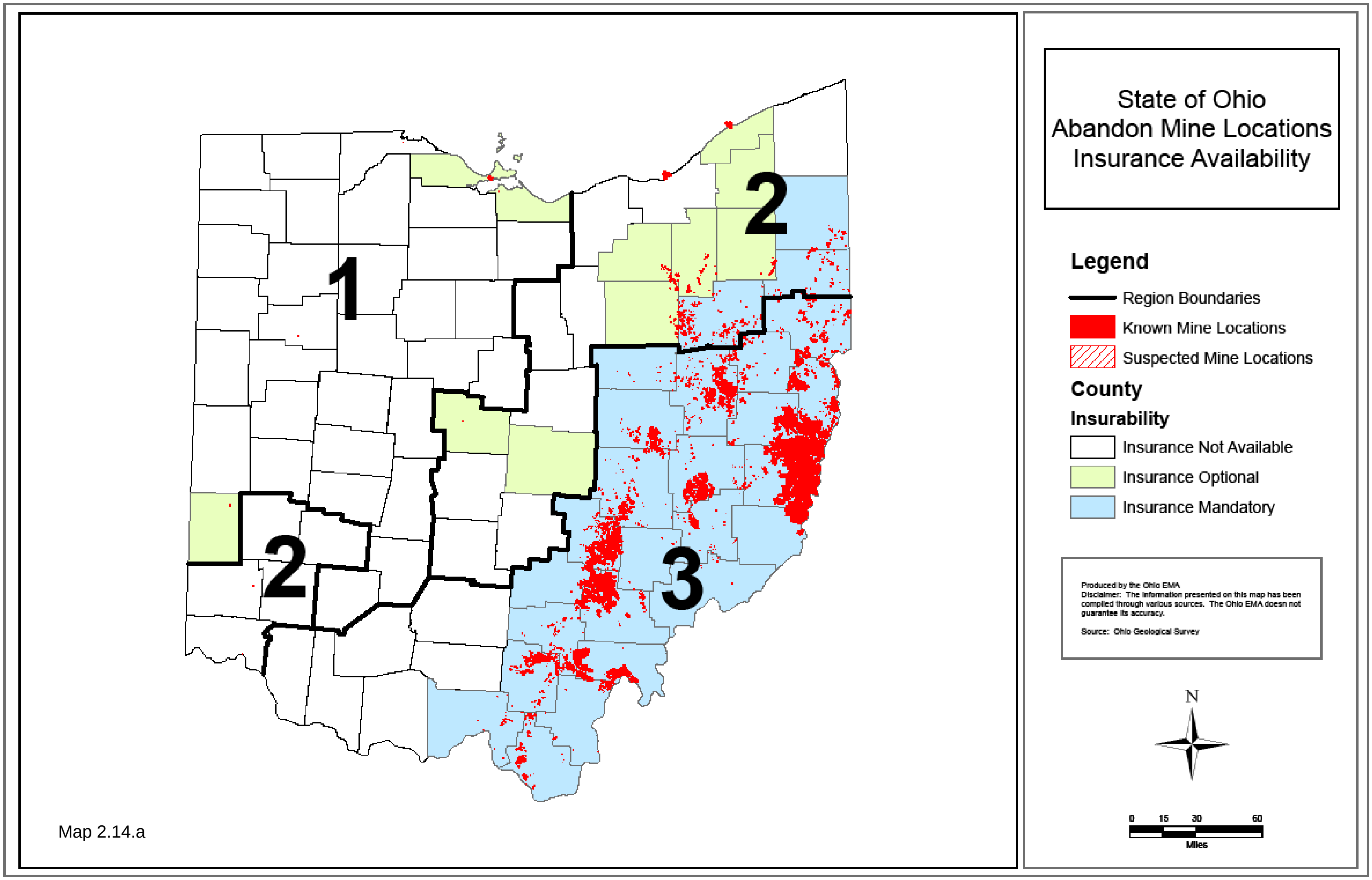
Areas which are reclaimed strip mines and other type of soils poorly suited for development are often mapped by local communities and the Ohio Department of Natural Resources. Ohio's built environment exposure to this type of hazard is very limited.

LHMP Data

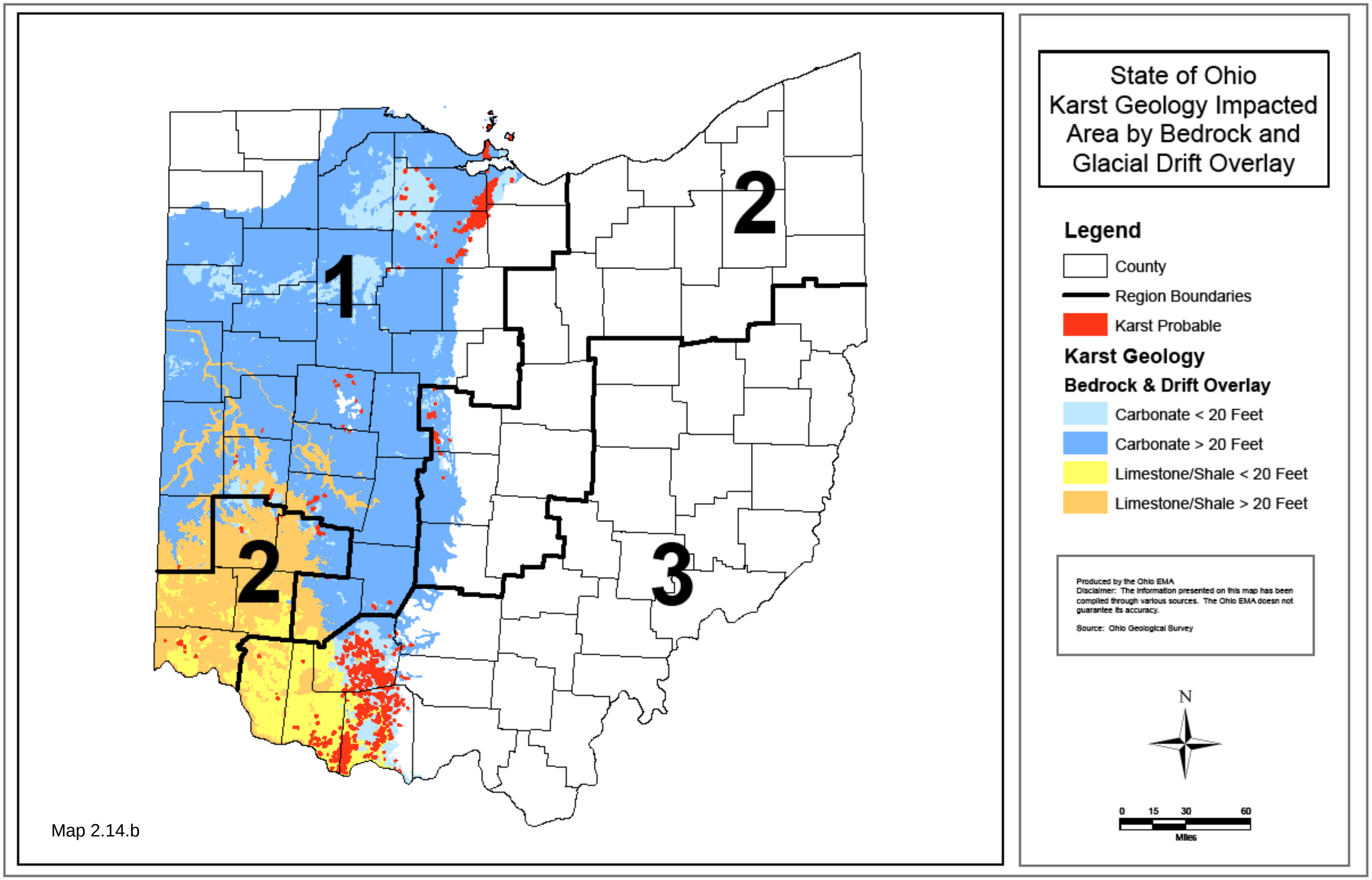
The City of Bellevue is located within the Bellevue-Castalia Karst Plain and resides within four counties; Erie, Huron, Sandusky, and Seneca. Of these counties, only Sandusky County's LHMP indicated that land subsidence was a hazard risk. They recognized that land subsidence, in the form of sinkholes, has a potential to occur; but also notes that there have been no incidents of land subsidence that has resulted in the damage of structures, personal injury, or loss of life. An area of concern for Sandusky County, in regards to land subsidence, is a Class I dam that is located in the southeastern portion of the county.

However, Sandusky County, at this time, considers land subsidence and dam failure as having a low mitigation potential and have no current mitigation activities or plans for them.

<u>SHARPP</u>. Hazard identification data were queried from SHARPP to evaluate each hazard and its frequency. Land subsidence ranked 11th for frequency when compared to all 15 hazards evaluated in this plan (Chart 2.2.a), and it ranked very low for all other factors as well. Overall, this hazard ranked 15th out of 15 hazards evaluated, which indicates a very low priority at the local level for land subsidence. This ranking correlates with the limited number of occurrences and overall effects throughout east and southeast Ohio. These and additional HIRA data queried from SHARPP can be found in Appendix J.


State of Ohio
Abandon Mine Locations
Insurance Availability
1
2
2
3
Legend
Region Boundaries
Known Mine Locations
Suspected Mine Locations
County
Insurability
Insurance Not Available
Insurance Optional
Insurance Mandatory
Produced by the Ohio EMA
Disclaimer: The information presented on this map has been compiled through various sources. The Ohio EMA doesn not guarantee its accuracy.
Source: Ohio Geological Survey
N
0 15 30 60
Miles

Map 2.14.a

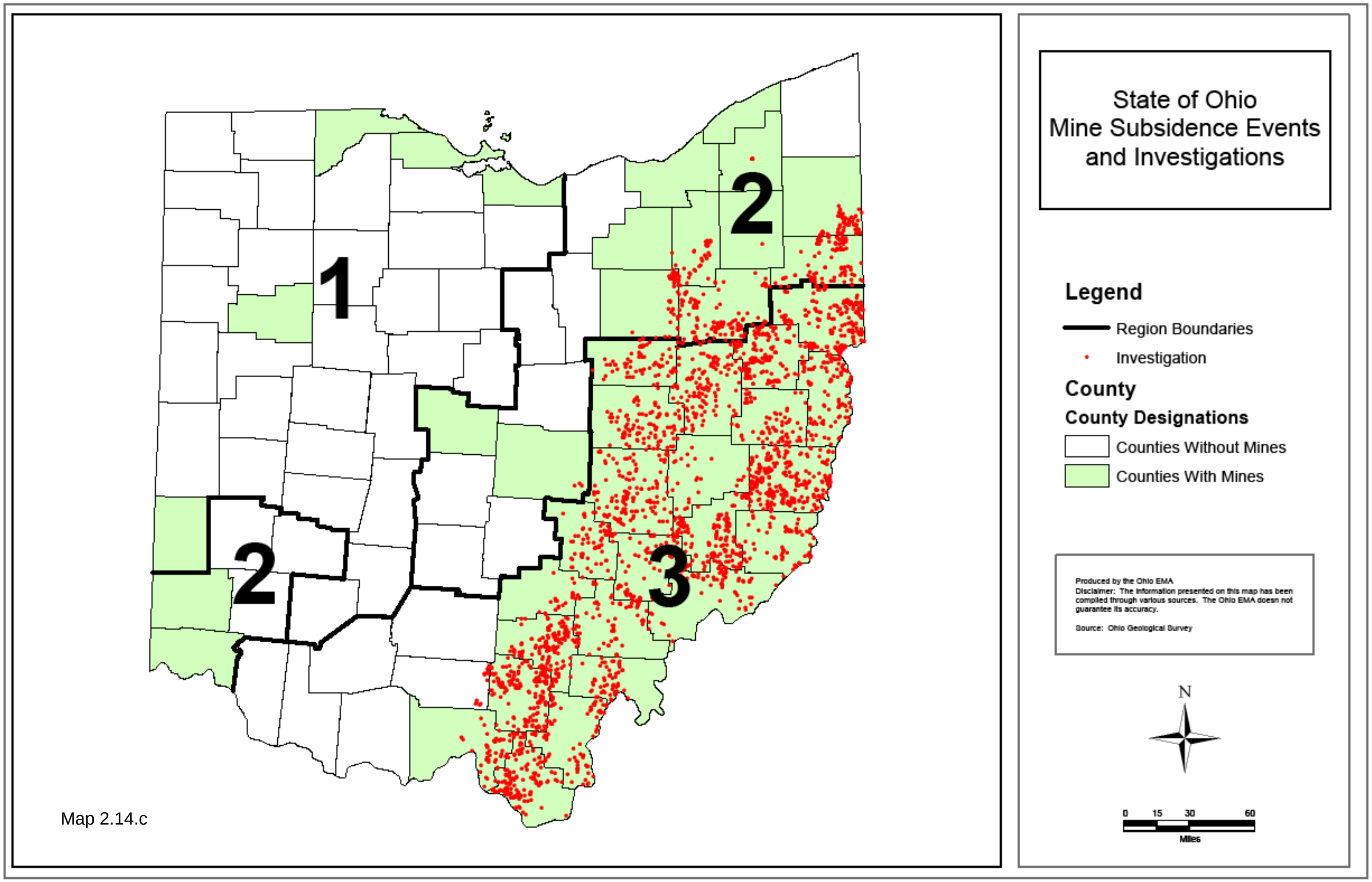

State of Ohio
Karst Geology Impacted Area by Bedrock and Glacial Drift Overlay
Legend
County
Region Boundaries
Karst Probable
Karst Geology
Bedrock & Drift Overlay
Carbonate < 20 Feet
Carbonate > 20 Feet
Limestone/Shale < 20 Feet
Limestone/Shale > 20 Feet
Produced by the Ohio EMA
Disclaimer: The information presented on this map has been compiled through various sources. The Ohio EMA doesn not guarantee its accuracy.
Source: Ohio Geological Survey
N
0 15 30 60
Miles
1
2
2
3
Map 2.14.b

Past Occurrences

Abandoned underground mines in Ohio are monitored by the Ohio Department of Natural Resources, Division of Mineral Resources Management, which is primarily federally funded. Within the division, two programs exist to address mine subsidence: one for emergencies and a second for non-emergencies. Inspectors institute an investigation for every reported occurrence. The inspector uses several criteria to classify the emergency status of the event by determining first if it is mine related, second if there is an imminent and substantial threat to the public or the environment and finally if the onset was sudden and not part of a prolonged event. The emergency program gives priority to events which are directly affecting a structure (within 300 feet) or transportation route. Each year between 50 and 60 investigations are completed generating 25 to 30 projects. Of those investigations, approximately five or six represent damage to a structure (see Map 2.14.c). When an event is classified as an emergency, federal concurrence is requested followed by a streamlined engineering evaluation and hiring of a contractor. The time between the event and response is often within one week. Projects are undertaken to protect lives and property and can range from simple precautions to filling the void with cement to stabilize the area affected.

Subsidence events that do not qualify as emergencies (where people and infrastructure are not directly involved) must follow the standard state project development and bid process. Repeated emergency incidents can lead to larger non-emergency response. The City of North Canton (Region 2), Village of Cadiz (Region 3) and Village of New Lexington (Region 3) each experienced repeated emergency events culminating in area-wide engineering studies to address the problems. In each case comprehensive mitigation activities, including the installation of in-mine support columns and the filling of voids, stabilized large areas which were subsidence-prone.

The ODOT has inventoried over 1,200 sites where abandoned underground mines underlie state highways, U.S. routes, and interstate highways. Since 1998, ODOT has been actively inventorying these geologic hazards and conducting risk assessments to determine the potential impact on the state's transportation infrastructure. The statewide inventory and risk assessment of these mine sites continues. However, there are an estimated 7,000+ underground mines across Ohio. As of 2005, only 50% of these mines had been recorded in the state's (ODNR) database. Approximately 2,700 of the 7,000 underground mines are unmapped. Both mapped and unmapped underground mines pose a continuing threat of subsidence to Ohio's transportation system.


State of Ohio
Mine Subsidence Events
and Investigations
1
2
2
3
Legend
Region Boundaries
Investigation
County
County Designations
Counties Without Mines
Counties With Mines
Produced by the Ohio EMA
Disclaimer: The information presented on this map has been compiled through various sources. The Ohio EMA doesn not guarantee its accuracy.
Source: Ohio Geological Survey
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0 15 30 60
Miles
Map 2.14.c

Whenever an event affecting transportation infrastructure occurs, an initial site investigation is launched. The first step in the process involves the collection of basic information on the location, type of event, geologic setting, mining information for the area, impact on the roadway, and how it was discovered. The next step involves a site reconnaissance and the completion of a series of data collection forms starting with the Initial Site Evaluation. Compiled information is then used by the geologist or engineer to complete the risk assessment rating form. Each inventoried site receives a matrix score based on standardized criteria and scoring methods. Some examples of key scoring criteria are: number of surface deformation features, number of mine openings, thickness of unconsolidated material over the mine, thickness of rock overburden, height of the mine void(s), average daily traffic volume, hydrology, and secondary mining evidence. The overall rating provides ODOT a planning tool to prioritize sites across the state for remediation. With limited resources and the large number of mine subsidence problems, the abandoned underground mine inventory and risk assessment provides ODOT the means to direct expenditure of funds in a cost-effective and logical manner.

The most notable event occurred in 1986 when an abandoned mine located in Guernsey County collapsed underneath Interstate 70 resulting in the closure of the entire interstate. Remediation included stabilizing the void and repairing the damaged roadway costing over $10 million dollars.

Underground salt mining under Lake Erie has not generated any known subsidence to date; however, solution mining in Lake, Summit and Medina Counties has. The most dramatic case in Ohio is in the Lake County community of Painesville where an abandoned mine is responsible for a six foot surface depression. Due to the proximity of the impacted area to Lake Erie, it is now filled with water. Other solution mines in Summit and Medina counties have experienced minor surface impacts. The potential effect of salt mining is epitomized in the failure of the Retsof mine in New York. The event was first misinterpreted as an earthquake. The collapse of the mine roof resulted in several 50-foot deep sinkholes, which closed roadways, produced changes in the aquifer, and caused the release of methane and hydrogen sulfide gases.

Until recently, Karst events in Ohio had very little direct impact from a subsidence perspective on the built environment; however, they have been very costly in terms of pollution and flooding. Two well documented karst related events deal with contamination of aquifers. The oldest researched event in Ohio is associated with the Village of Bellevue straddling the Huron / Sandusky County border. The 1961 study documents how from 1919 to 1946 the community permitted untreated wastewater injection wells and unimpeded groundwater runoff into sink holes as an acceptable water management program. In 1946 after the groundwater was determined unfit for human consumption, the Village abandoned its last well and has since spent millions of dollars to develop a potable system based on piping water from safe sources. In February 2008, more than 200 homes experienced flooding in Bellevue when runoff from heavy snows and spring rains flooded underground karst chambers. Experts believed building pressure caused the pent-up water to surge up existing sinkholes and cracks, flooding homes and yards. A section of State Route 269 was swamped from February through June 2008.

The Village of Put-In-Bay, located on South Bass Island in Lake Erie, was the site of an extensive gastrointestinal illness outbreak in 2004. The island is a popular warm-weather tourist destination and, at the height of the season, over 1,000 cases of digestive related maladies were documented in people who had recently vacationed there. The investigation began with the municipal systems and quickly shifted to a number of transient non-community public water systems used for geothermal cooling, flushing toilets and outdoor cleaning. These systems were found interconnected to the main water system. The karst topography allowed groundwater to travel quickly between locations and is easily affected by seasonal precipitation.

The only known karst-related subsidence impact to the built environment is roadway damage. In 2007 State Route 19 was closed in Crawford County when an adjacent karst feature expanded destabilizing the road bed. Engineering studies including sonar and LIDAR analyses of the associated void are underway to determine the extent of the developing cavity and to determine a long-term solution. Although this is the first documented event where damage to the built environment can be directly attributed to karst formations, there is an effort underway thought the ODOT to collect detailed historical data of karst-related roadway impacts to better understand and address future events.

During the construction of U.S. Route 33 near East Liberty, karst was encountered. Construction crews had to perform considerable back-filling and reinforcing, creating a land-bridge to make sure the highway was secure.

Another example of the impact of karst was the construction of tunnels for sewage pipelines by the City of Dublin (Franklin County). Sinkholes, filled with clayey overburden caused the expensive rock-boring machinery to clog and break, resulting in tremendous cost overruns.

Finally, one housing development in the City of Westerville (Franklin County) contains homes which have been dislodged and damaged by the effects of soils which dramatically expand when wet and contract when dry. Since 2000 the Ohio EMA has purchased 6 damaged homes; however, this is the only known impact from this form of land subsidence.

Probability of Future Events

Mine-related land subsidence is an annual event impacting an average of five homes or roadways. Approximately 20 additional events occur each year that do not impact the built environment, yet may require remediation.

Unlike mine-related events, karst events historically have manifested their impact in the form of groundwater contamination. Based on past exposure, a significant event occurs approximately each decade. As the ODOT begins to collect detailed data regarding the impact of karst events on federal highways, both the profile of the hazard and frequency of occurrence may experience significant change.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

Methodology

The only predictable impact which can be quantified for analysis is damage to Ohio's roadways. The Ohio Department of Transportation, Office of Geotechnical Engineering has a comprehensive inventory of the federal and state routes which intersect with known and estimated abandoned mines. The location, length of each segment, potential for failure, along with a host of other data is maintained in a database. The failure potential is broken into three categories: high, with failure expected within 50 years; medium, with failure expected within 100 years; and low, with failure expected beyond 100 years. The segments are reported by length of the segment, with a 500-foot buffer, and the number of road lanes. The final and key piece of information supplied is the proven cost of $1,000,000 per lane mile to replace roadways impacted by mine subsidence. For loss estimates that full cost per-mile is used, with 50% and 25% used for medium and low, respectively.

STATE-OWNED AND STATE-LEASED CRITICAL FACILITIES VULNERABILITY ANALYSIS & LOSS ESTIMATION

Land subsidence is a spatial hazard, but is spatial-specific in that it would only affect very small areas given an occurrence. Therefore, this hazard has a very limited potential of affecting any state-owned or state-leased facilities. However, it should be noted that such events could impact lifelines, which could have significant effects on the functionality of various state facilities.