Kansas Geological Survey

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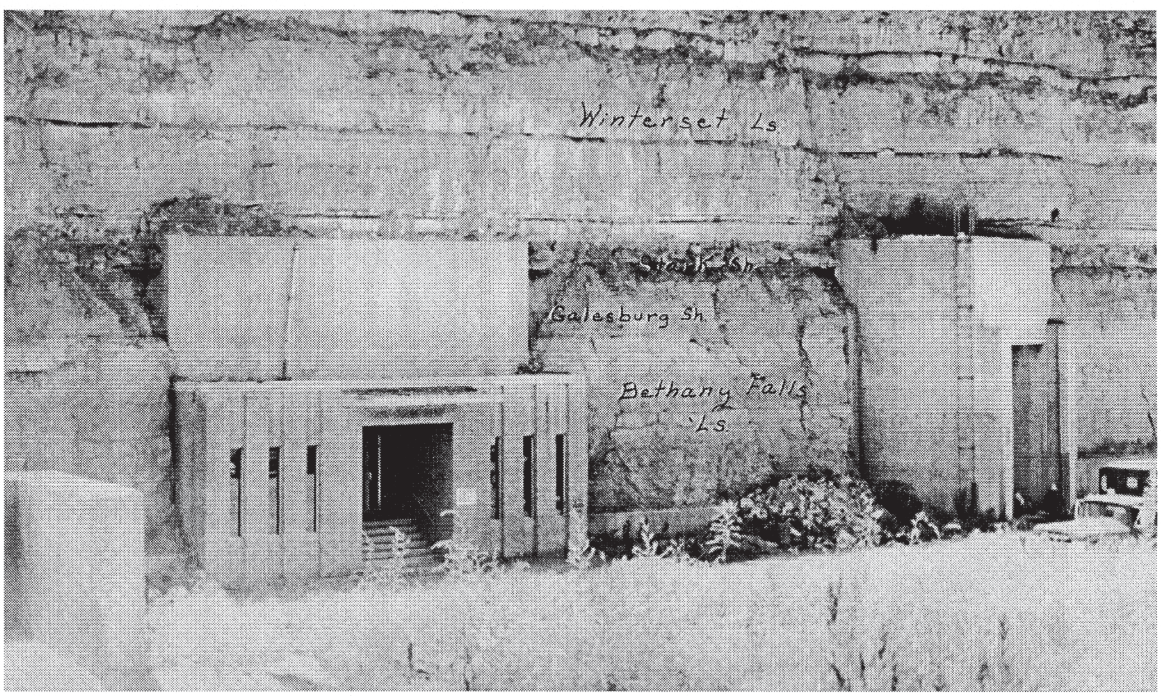
By

Gregory C. Ohlmacher



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Introduction

On February 2, 1999, the Unified Government of Kansas City, Kansas and AmeriCold Logistics held a public meeting to address concerns related to the closure of the cold-storage facility and warehouse in Turner, Kansas. Mr. Joel Smith, Sr. Vice-President of AmeriCold Logistics and Mr. Paul Niewald also representing AmeriCold Logistics presented a brief history of the mine and warehouse facility, the economics that led to the proposed closure of the warehouse, and possible surface problems related to the closure. The surface problems are (1) the potential for damage to surface structures associated with the shut down and abandonment of the cold storage facility and warehouse and (2) the potential for damage to Holliday Drive where it passes over the area of the old mine.

Brief History of Site

The following is based on information provided by AmeriCold Logistics at the public meeting, from various articles on the site (Fredericksen and Gentile, 1972; Gentile, 1997; Jewett, Hornbaker, and Press, 1967; Woodward-Clyde International-Americas, 1999) and a telephone conversation with Mr. Paul Niewald. Mining at the site began about the turn of the century. One report places the beginning of mining in 1912 (Jewett, Hornbaker, and Press, 1967). In about 1952, a decision was made to develop portions of the mined out area as an underground storage facility. The first cold storage room was opened in 1953. In December 1991 a fire occurred in one of the cold storage rooms. As a result of the fire, the fire-damaged room and room 28, located between the fire damaged room and the entrance to the mine, were closed. Several years after the fire-damaged room was sealed, it was opened twice within a two-week period for inspection. On both occasions, it was reported that rock from the ceiling had fallen to the floor, roof collapse. One area of collapse occurred in the two-week interval between the inspections. No subsidence of the ground surface has been reported in the area above the fire-damaged room.

As a result of the fire, the refrigeration units in room 28 were shut down. Since the shut down, the room has experienced roof collapse and "dome outs." Dome outs are dome-shaped areas in the ceiling that develop when blocks of rock break out of the ceiling creating a dome-shaped void. Mr. Niewald also reported subsidence of the ground surface over room 28; however, no damage to surface structures was reported.

Site Geology and Mining Practices

The AmeriCold Logistics warehouse and mine are excavated into the Bethany Falls Limestone (Figure 1). The Bethany Falls Limestone averages 6-meters (20-feet) thick in the greater Kansas City area and can be subdivided into three zones (Gentile, 1997). The lower zone is 4 meters (13 feet) of thin, wavy-bedded limestone with a high concentration of calcium carbonate. This portion is mined for concrete aggregate, railroad ballast, agricultural lime, and other products. The middle zone is up to 2 meters (7 feet) of thick even-bedded limestone. The bottom of the zone is straight and nearly horizontal; however, the upper surface is irregular. This zone forms the roof of the mines in the Bethany Falls Limestone throughout the Kansas City area. Where this zone is thick and remains intact, it forms a stable roof. However, roof problems have occurred where this zone is thin or fractured (Gentile, 1997). Unfortunately, the locations of thin portions of the middle zone are almost impossible to detect. Additional thin areas of the middle zone are found under stream valleys where erosion and weathering have removed the overburden. Weathering is the disintegration of rock by physical and chemical processes. Overburden is the rock between the ceiling of the mine and the ground surface. The upper zone of the Bethany Falls Limestone is weak, shaly limestone containing rounded fragments, nodules, of hard limestone. The thickness of this zone ranges from centimeters (inches) to just over a meter (3-feet) thick. It is thickest where the middle zone is thin.

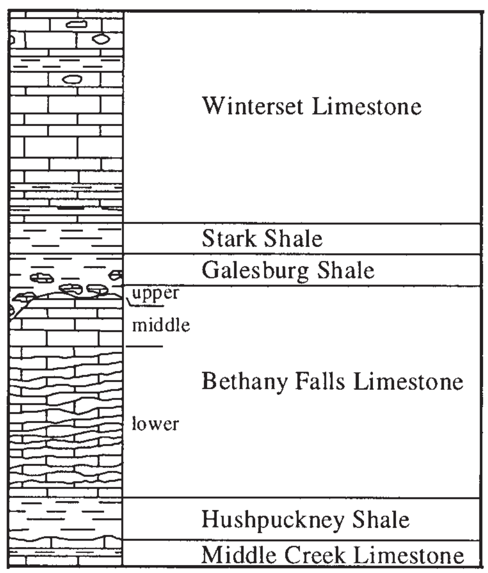

Figure 1—*Stratigraphic section of rocks near the AmeriCold Logistics facility after Gentile (1997).*

Approximately 2 meters (7 feet) of shale overlie the Bethany Falls Limestone. These clay-rich rocks have a low permeability and help prevent ground water from entering the mine. The Winterset Limestone overlies the shale. This unit consists of alternating layers of limestone up to 2.3-meters-thick (8-feet-thick) and thin shales. The limestone layers are strong and provide some strength to the roof.

Fractures are breaks or cracks in the rock. Natural fracturing can result from regional stresses associated with plate tectonics and local stresses caused by valley incision and freezing of water near the ground surface. In the Bethany Falls Limestone the fractures are vertical, are up to 7.5 m (25 feet) long, and have an average spacing of 16.5 m (54 feet) (Jewett, Hornbaker, and Press, 1967). The spacing between fractures is lowest and the length of fractures is greatest near the valley walls and outcrops (Parizek, 1982).

Fractures form natural conduits for ground-water flow through limestones. Additionally, as ground water migrates, it can dissolve the limestone in the fracture walls enlarging the opening. In general, ground water is not a problem in the Bethany Falls Limestone at the AmeriCold Logistics facility because shale layers above and below the Winterset Limestone prevent the flow of ground water into the Bethany Falls Limestone (Jewett, Hornbaker, and Press, 1967). However, where the shales have been removed by erosion or are fractured, ground water can reach the Bethany Falls Limestone.

Room and pillar mining is used in the AmeriCold Logistics mine. This method leaves behind columns of intact rock (pillars) that support the roof. Prior to the development of the warehouse facility, the columns were of variable size and arranged in a nonsystematic (random) pattern. The size and arrangement were controlled by the experience of the miners and company policy. After development of the warehouse, a systematic grid pattern of pillars was adopted. Standard practice for mines in the Kansas City area is to have square pillars that are 5.5-7.5 meters (18-25 feet) on a side and spaced in a grid pattern 12-20 meters (40-65 feet) on centers. This creates rooms that have openings that are 6-12 meters (20-40 feet) wide. The practice used by AmeriCold Logistics is 6.1-meter (20-foot) pillars on 19.8-meter (65-foot) spacing creating 13.7-meter-wide (45-foot-wide) rooms (Fredericksen and Gentile, 1972).

Potential Modes of Failure

The modes of failure associated with underground mining that can lead to subsidence at the ground surface can be subdivided into failures of the roof, pillar, and floor. The following discussion covers the general modes of failure and does not cover all potential situations. Additionally, some of these modes of failure may not apply to the AmeriCold Logistics facility.

Roof failures include spalling and roof fall. Spalling occurs when chips and slabs break off from the roof or pillars. Roof fall involves larger blocks of rock that fall from the ceiling of the mine. If not corrected, the damage from roof failure can propagate through the overburden and cause subsidence of the ground surface. Some causes of roof failure include natural thin areas in the middle zone of the Bethany Falls limestone, natural fractures, weathered roof rock, thin overburden under stream valleys, overbreak during blasting, and scalping. Overbreak is rock broken outside of the intended limits of the blast and can be minimized by proper blasting techniques. Scalping is the intentional removal of some of the roof to increase the amount of limestone extracted. It is unknown whether scalping has occurred at the AmeriCold Logistics site.

The roof of a mine can be strengthened by rock bolting (Figure 2). A rock bolt is a metal rod that is placed in a drill hole and anchored in a strong layer of rock, like limestone. The rod is threaded at the end where it extends below the ceiling. A large metal plate and a washer are placed over the rod and a large nut is tightened on the end. Rock bolts strengthen loose ceiling rocks by (1) transferring the weight to higher layers of rock and (2) allowing many thin layers to behave like a thick layer. Two lengths of rock bolts are used in the AmeriCold Logistics mine. Short rock bolts are used to strengthen the middle zone of the Bethany Falls Limestone. In older areas of the mine or where the middle zone of the Bethany Falls Limestone is thin, the practice is to use long rock bolt into the Winterset Limestone. Since these longer bolts extend through the impermeable shale above the Bethany Falls Limestone, the drill holes will allow ground water to enter the mine (Jewett, Hornbaker, and Press, 1967). This ground water could weaken the rock bolts by enhancing corrosion (Woodward-Clyde International-Americas, 1999).

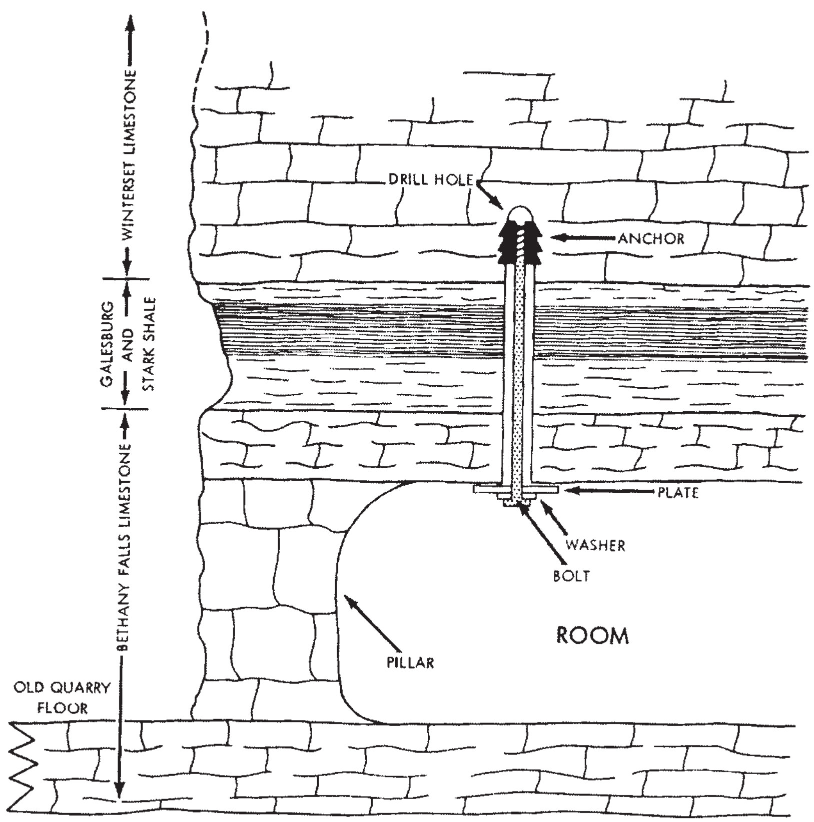

Figure 2—*Schematic of a rock bolt at the AmeriCold Logistics mine from Jewet, Hornbaker, and Press (1967).*

Mr. Niewald (personal communication, 1999) reported that when small loose rocks are observed in the ceiling, they are removed. Larger loose rocks and other problem areas in the AmeriCold Logistics mine are stabilized with rock bolts.

Pillar failure can occur by spalling or when the stress from the overburden exceeds the bearing capacity of the pillar. Natural fractures, insufficient pillar size, and overbreak can cause pillar failure. Information on pillar failures at the AmeriCold Logistics facility was not available.

Upward arching of the floor between pillars is observed in many mines in the Kansas City area. Arching can result from (1) expansion of the Hushpuckney Shale after the Bethany Falls Limestone is removed, (2) growth of gypsum crystals in the Hushpuckney Shale due to the weathering of pyrite, (3) expansion of the Hushpuckney Shale due to water absorption, and (4) pillar punching (Coveney and Parizek, 1977). Pillar punching is when a pillar sinks into the shale below the floor of the mine. The shale is squeezed out from below the pillar into the room. Pillar punching leads to subsidence of the overburden and ground surface, for example, the subsidence at the American Rock Crusher Mine in Wyandotte County (Walters, 1984).

Closing the Warehouse

One of the issues at the AmeriCold Logistics facility is the effect of shutting down the freezer rooms and allowing them to return to ambient temperatures. AmeriCold Logistics at the February 2nd public meeting reported that shutting down the refrigeration units in the cold storage portion of the warehouse has the potential of creating roof collapse and ground-surface subsidence. Two surface structures that can potentially be impacted by subsidence are the Board of Public Utilities (BPU) power substation and Holliday Drive. AmeriCold Logistics bases the potential for subsidence on the performance of room 28 after the 1991 fire (Niewald, personal communication, 1999) and the opinions of Mr. Jack Parker (1998). As was mentioned previously, room 28 suffered roof collapse and ground-surface subsidence after the fire. It is unclear whether the roof problems in room 28 are the result of the shut down of the refrigeration units, the lack of inspection and maintenance after the fire, or secondary damages related to the fire. AmeriCold Logistics emphasizes that there was no fire in room 28.

The environmental impact statement (Woodward-Clyde International-Americas, 1999) reported that AmeriCold Logistics had contacted an expert in mine safety, Mr. Jack Parker, about the effect of the shut down on roof stability. The Kansas Geological Survey was unable to obtain a copy of the letter written by Mr. Parker to AmeriCold Logistics (Parker, 1998) or the information that is the basis for Mr. Parker's opinions. The environmental impact (Woodward-Clyde International-Americas, 1999) statement highlights four of Mr. Parker's opinions. (1) Ice formation has damaged the rock adjacent to the freezer room. (2) Seasonal freeze-thaw cycles have deteriorated the rock above the mine. (3) Defrosting the room will lead to roof fall. (4) Roof fall will result in subsidence of the ground.

When the freezer units were turned on ground water in the pores and fractures of the rock began to freeze and expand. This can lead to further fracturing of the rock mass. At the same time the mineral grains that make up the rock are contracting. Whether the rock mass (mineral grains and pores) expands or contracts is a function of the amount of water present in the pores. In areas where the rock has lots of pores filled with water, the rock mass will expand during freezing. This will create horizontal compression in the ceiling and the potential for horizontal fracturing, spalling, and possible roof falls. In areas where the rock is dry the rock mass will contract during freezing creating horizontal tension in the ceiling (Figure 3) and conditions would be favorable for vertical fracturing of the rock mass.

Damage to the rocks due to water freezing most likely continued during the operation of the freezer room. Moisture can enter the freezer room from the mine entrance, ventilation system, and from animals and humans. This moisture can collect in the fractures and expand causing the fractures to grow. Groundwater from above the mine will freeze as it enters the frozen rocks surrounding the freezer rooms further deteriorating the roof rocks.

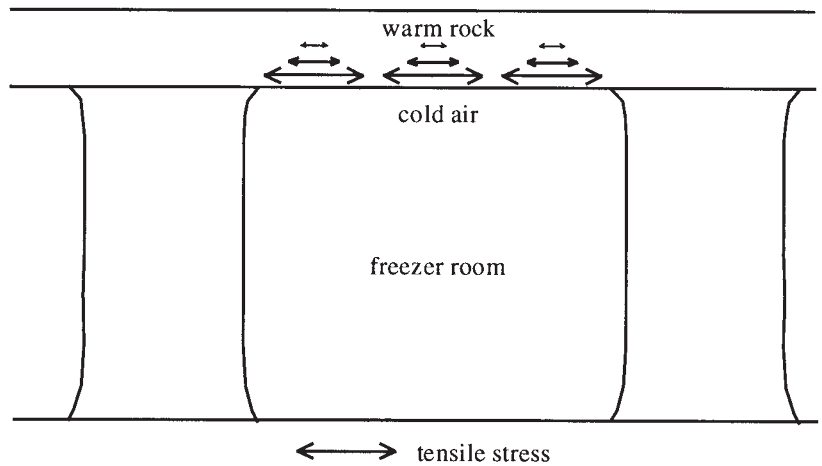

Figure 3—*Schematic sketch of the tension that develops in the rocks mass as the freezer room cools.*

Seasonal and daily temperature variations especially during cold months lead to freeze/thaw cycles of groundwater in the soil and rock. Normally, this affects only the rock and soil near the ground surface. However, it is possible that in areas where the overburden above the freezer rooms is thin or near air intakes and shafts, these freeze/thaw cycles could penetrate to a greater depth and deteriorate the rock above the mine. This should not be a problem in areas where the overburden is thick.

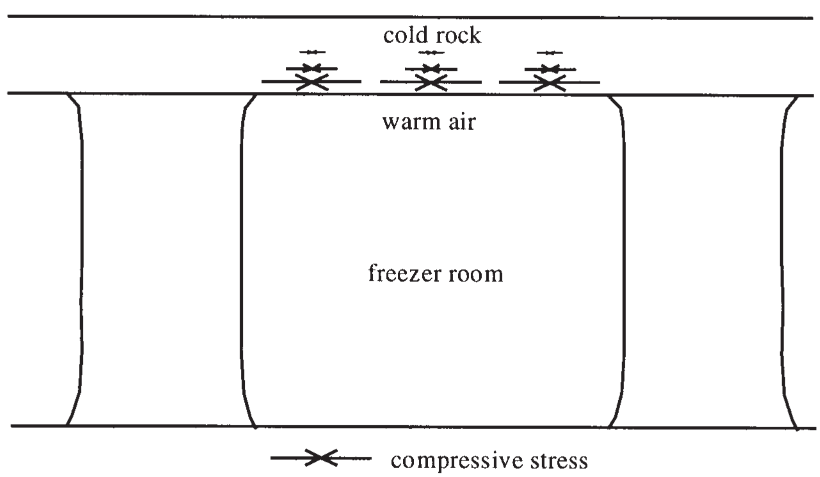

Figure 4—*Schematic sketch of the compression that develops in the rock mass after shut down of the refrigeration units.*

When the refrigeration units are shut off, the ice in the rocks will begin to melt. Currently, the ice provides some strength to the fractured rock mass. As the ice melts, this strength will be lost and areas of the roof and pillars deteriorated during the operation of the warehouse will begin to fail. Additionally, in areas where the roof mass was initially dry and contraction occurred, the warming of the rocks would cause the rock surface adjacent to the room to expand while the rocks further into the rock mass are frozen and contracted. This leads to horizontal compression (Figure 4) and a chance for spalling and large rock failures. Both rapid heating and melting of ice may have contributed to problems during and after the 1991 fire.

The extent to which any of the above problems will occur when AmeriCold Logistics shuts down the refrigeration units is unknown because the required data is lacking. Currently, AmeriCold Logistics is planing to shut down the refrigeration units and for safety reasons to discontinue inspection and maintenance of the warehouse facility. Using the behavior of room 28 as a guide, it would be prudent to expect roof collapse in the warehouse area and the potential for ground-surface subsidence.

Old Mine Operations

AmeriCold Logistics reported at the February 2nd public meeting that a potential for subsidence exists over the old mine area along Holliday Drive between 65th Street and Inland Drive. AmeriCold Logistics bases this on their annual mine surveys. As reported above, the old mine has nonsystematic pillars and variable sized rooms. Although the details of the mining practices in the old mine were not discussed, AmeriCold Logistics reported dome outs in the old mine area. Their concern is that these dome outs could coalesce and break through to the surface. Additionally, during the question and answer period following AmeriCold Logistics presentation, it was mentioned that a sinkhole (surface manifestation of subsidence) developed near the corner of 65th Street and Holliday Drive. This sinkhole highlights the need for concern in the area along Holliday Drive.

Current Mine Operations

AmeriCold Logistics also reported at the February 2nd meeting that they are continuing mining operations at the site. They offered to monitor blast vibrations wherever property owners were concerned; however, AmeriCold Logistics claimed that no surface structures would be affected by the mining. During the question and answer period following AmeriCold Logistics presentation the local citizens expressed the following concerns related to future mining. Some homeowners complained of blast damages (from vibrations) to their homes. AmeriCold again offered to set up seismometers to monitor vibrations, but claimed that the damages to the homes were unrelated to blasting. Another topic of concern was subsidence. This concern has two aspects: subsidence while the mining is active and financial responsibility for subsidence after the mine closes. During the discussion local citizens reported two sinkholes associated with the AmeriCold Logistics site. The first sinkhole along 65th Street near Holliday Drive was discussed above. The second sinkhole opened up near Pierson Park.

This is over an area of grid-pattern mining where the overburden is thin. No surface structures were involved.

No matter how careful the mining practices, the potential still exists for roof collapse and ground-surface subsidence. Proper mining practices can minimize the risk, but not eliminate it.

Remediation methods

The following is a brief discussion of potential methods for remediation or stabilization of the potential subsidence problem. It is recommended that a qualified engineer do the selection and design of a remediation method with input from a geologist.

Avoidance: This would involve removing all existing structures, rerouting transportation routes, and leaving the area as woodland or open area. Subsidence would be expected, and the potential exists for injury to people or animals in this area if they came upon a depression unexpectedly.

Backfill: This involves filling the mine rooms with select materials in order to minimize the amount of subsidence. Materials might include gravel, crushed stone, concrete, or soil. Trash, hazardous materials, materials that can deteriorate and loose strength, and materials that could cause ground-water pollution must be avoided.

Roof support: Man-made pillars could be used to support the roof. These pillars should be constructed of materials that will not be affected by the moisture conditions in the mine after closure. Concrete pillars are preferred and steel should be avoided because of long term corrosion damage (Hasan, 1996). Pillars can either be constructed in the mine before closure or from the surface after the mine is closed.

Pillar extraction: This involves blasting the pillars after the mine is closed causing the entire ground surface above the mine to subside. Existing surface structures could be damaged by the subsidence. The fracturing caused by the subsidence following pillar extraction would allow ground water into the mine. This ground water could dissolve the remaining limestone and create small sinkholes in the future.

Grouting overburden: Cement (grout) can be pumped into the fractures in the rock mass above the mine (Lin, Peng, and Tsang, 1990). This will strengthen the overburden by gluing the fractures and provide temporary protection from subsidence. However, the mine opening remains and in the future the grout and rock will weaken leading to subsidence.

Spanning the mined out area: Reinforced concrete slabs can be constructed over the areas where subsidence is expected provided that the anticipated sinkholes are small. The slabs span the areas of potential mine collapse, such that the length of the slab is much greater than the size of the potential sinkhole. This method was used over an abandoned coal mine with subsidence problems south of Denver, Colorado (Noe, Soule, and others, 1999). It may be impractical in Kansas City area since the room sizes in the limestone mines are much larger than those in coal mines.

Conclusion

Based on the information reported by AmeriCold Logistics and other information, there is a potential for roof collapse and subsidence associated with the closure of the warehouse and within the area of the old mining practices. In order to assess the degree of risk and to increase public safety, an engineering study covering all the remedial options for Holliday Drive is recommended.

Later Developments

In the summer of 1999 the Unified Government of Kansas City, Kansas and AmeriCold Logistics were close to reaching an agreement on the remediation activities for Holliday Drive (Tom Burroughs, personal communication, 1999). Representative Burroughs told me that a portion of Holliday Drive would be relocated and sections of the mine under the road would be backfilled.

On Monday, February 14, 2000, a section of the mine collapsed causing a sinkhole to develop at the corner of Holliday Drive and 65th Street (Nicely, 2000). The failure occurred while the road was closed for reconstruction associated with the remediation. The 1-acre sinkhole was over a section of the old mining practices thought to present a hazard. This failure highlights that the concern for public safety expressed by AmeriCold Logistics and the Unified Government's response was warranted.

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