3.14 - Land Subsidence Hazard Profile

Contents of this section result from research and outreach including but not limited to the following sources:

- *United States Geological Survey (USGS* – research and review information located on the web site, http://water.usgs.gov/ogw/pubs/fs00165/, including the following;
  - U.S. Geological Survey Subsidence Interest Group Conference, Edwards Air Force Base, Antelope Valley, California, November 18-19, 1992:
- Abstracts and Summary edited by Keith R. Prince, Devin L. Galloway, and S.A. Leake, U.S. Geological Survey Open-File Report 94-532
- U.S. Geological Survey Open-File Report 94-532, SUMMARY OF TALKS, DISCUSSIONS, FIELD TRIP, AND OUTSTANDING ISSUES, Keith R. Prince (U.S. Geological Survey, Menlo Park, California)
- U.S. Geological Survey Open-File Report 94-532, MUDBOILS IN THE TULLY VALLEY, ONONDAGA COUNTY, NEW YORK, William M. Kappel (U. S. Geological Survey, Ithaca, New York)
- U.S. Geological Survey Subsidence Interest Group Conference, Proceedings of the Technical Meeting, Las Vegas, Nevada, February 4-16, 1995, edited by Keith R. Prince and S.A. Leake, U.S. Geological Survey Open-File Report 97-47
  - U.S. Geological Survey Subsidence Interest Group Conference, Proceedings of the Technical Meeting, Las Vegas, Nevada, February 14–16, 1995, HISTORY OF THE SUBSIDENCE INTEREST GROUP, By Keith R. Prince
  - Hydrogeologic effects of flooding in the partially collapsed Retsof Salt Mine, Livingston County, New York, by Dorothy H. Tepper, William M. Kappel, Todd S. Miller, and John H. Williams
- *New York State Emergency Management Office* situation report archives for historical events.

The following table provides the definition of Land Subsidence

Term	Definition
Land Subsidence	The sudden sinking or gradual downward settling of land with little or no horizontal motion, caused by a loss of subsurface support which may result from a number of natural and human caused occurrences including subsurface mining or the pumping of oil or ground water. Land Subsidence events, depending on where they occur, can pose significant risks to health and safety or interruption to transportation and other services

The Concept of Land Subsidence

It is estimated that land subsidence and resulting flooding and structural damage costs $125 million annually and an additional $400 million is spent nationwide in attempts to control subsidence (Prince, U.S. Geological Survey). **Figure 3-211** and **3-212** identify underlying rock and mineral types some of which lend to the potential of land subsidence. In the absence of a formal land subsidence hazard map this plan presents information present **Figure 3-211** and **3-212** indicating land subsidence susceptible areas in the State based on the characteristic of underlying rock type.

Geographic Location/Extent/Severity of Land Subsidence:

The potential for land subsidence exists across New York State, in fact, according to the USGS it is a National problem affecting an estimated 17,000 square miles in 45 States. Scientific and historical land subsidence event data, although sparse, does exists which indicates those areas of the state having a higher land subsidence risk. As a general rule of thumb *land subsidence occurrence can be expected where it has occurred in the past*. **Figure 3-211** from the U.S. Geological Survey web site http://water.usgs.gov/ogw/pubs/fs00165/, indicates the location of Karst from evaporative and carbonate rock.

Figure: 3-211

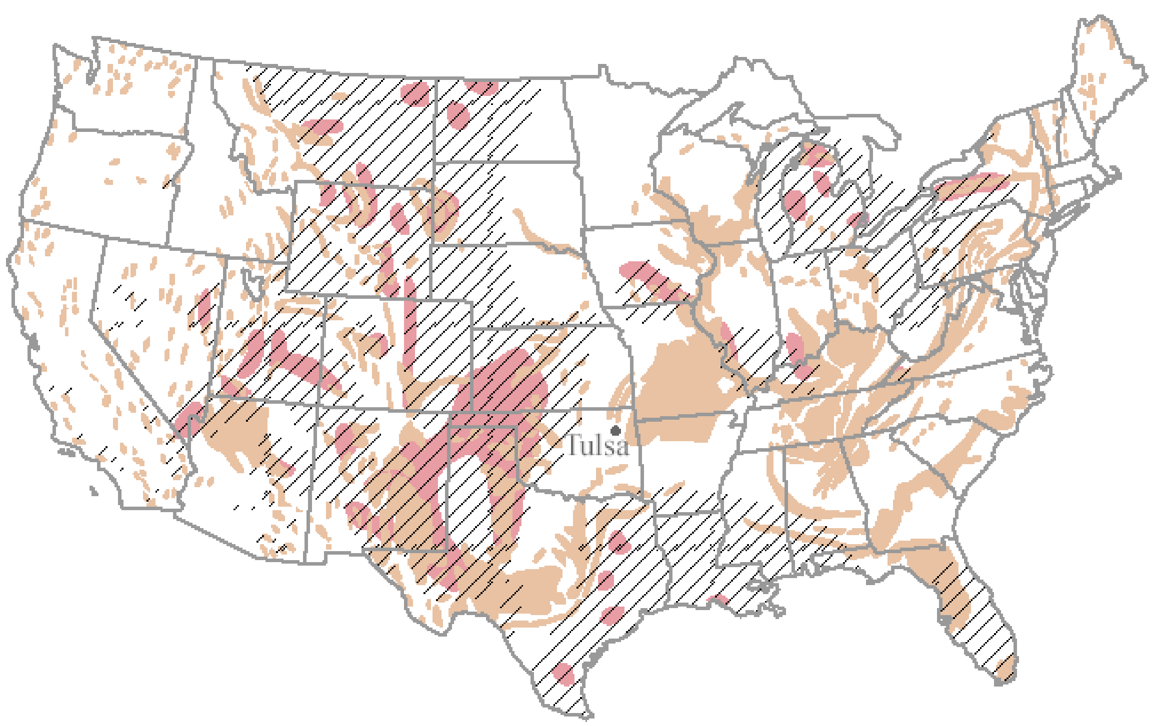


Figure 9. Salt and gypsum underlie about 40 percent of the contiguous United States. Carbonate karst landscapes constitute about 40 percent of the United States east of Tulsa, Oklahoma (White and others, 1995).

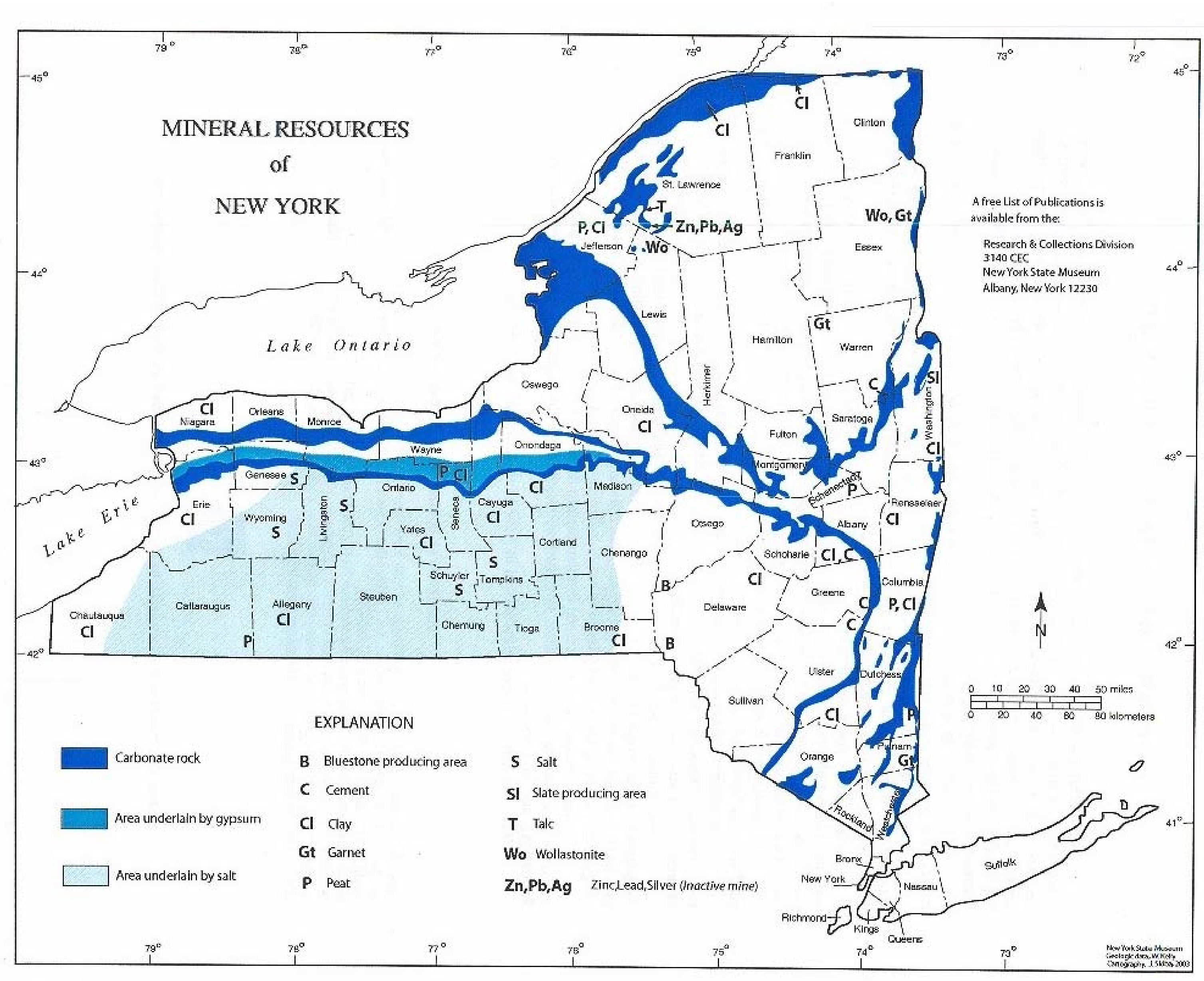
Source: USGS Fact Sheet-165-00**,** December 2000, Land Subsidence in the United States.

Karst is distinctive topography in which the landscape is largely shaped by the dissolving action of water on carbonate bedrock (usually limestone, dolomite, or marble). Karst landscape by definition implies the existence of land subsidence. Karst topography includes land subsidence in the form of sink holes which is brought on by sinking soils resulting from caves or simply cavities below. In NY, we have karst topography which is nicely developed in a narrow band along the Helderberg Escarpment in Schoharie and Albany counties. These areas are underlain by highly soluble Silurian and Devonian rocks including the upper part of the Rondout Formation and stratigraphically upward to the Onondaga formation. However, the best expression of karst is in the intervening Coeymans and Manlius formations. The configuration of the geological formations results in a band around the edge of the Escarpment from roughly Clarksville to the Village of Sharon Springs (Schoharie County), or perhaps a little south and west of those towns. These same rocks continue westward and south but the karst is not prevalent. (It is reported by miners and drillers that there are caverns in the Onondaga Formation as far west as Rochester but as this unit is two to three hundred feet below the surface, no karst topography is present.) For instance, the Helderberg mountain formations of Albany and Schoharie Counties are karst landscapes which include typical karst characteristics such as caves and sinkhole lakes.

Figure 3-211 also indicates the existence of evaporate rock (salt and gypsum) from western to central New York. According to NYS Geological Survey staff, cavity collapse land subsidence, better known as sink holes, have a tendency to occur more often than not due to man-made influences, (i.e., a mine), and more often in ground that is made up of evaporite rock, which includes salt and gypsum. Evaporative rock (salt and gypsum) are soluble in water and large cavity formations can occur. Sink holes or cavity collapses occur when these underground voids are created naturally, or artificially, and collapse due to natural or human induced forces.

Carbonate rock (limestone and dolomite) is also prone to void formation but is less soluble and therefore take much more time (centuries to millennia) for cavities to form all things remaining constant. The glacial till also seems to prevent Florida- or Pennsylvania-style sudden collapses in carbonate rock. The till is sufficiently stable to support itself and to subside slowly over carbonate sinks. Collapses, sudden or otherwise, are relatively rare in the regions of karst topography in New York. The last occurred about fifteen years ago in the Cobleskill area. No structural damage has been reported to date. The New York State Geological Survey staff concurs with the USGS information that identifies Evaporative rock and existing Karst typography as a causal factor of land subsidence incidence and the indications of the (USGS) map presenting locations of these underground rock types. In fact, the NYGS has produced a similar higher resolution map titled “Mineral Resources of NY”, which we include below as **figure 3-212**. This map of NY mineral resources although it does not indicate karst landscape (cavity formation lending to subsidence characteristics), as the USGS map indicates, it does emulate the USGS map showing the location of rock type and minerals (those areas shaded in blue) that are generally susceptible to natural land subsidence. The NY mineral resources map indirectly indicates those areas where the potential exists for human caused land subsidence due to mining collapse. Most land subsidence information source material mentions mining operations (and potential mine collapse) as one of the causal elements of land subsidence. Salt and Gypsum are abundant across western and central NY. A number of underground salt and gypsum mines exist in this part of the State as indicated by the two (2) lighter shades of blue. Other areas of significant underground mining include the cement mines in the Catskill plateau of Southeastern NY and the iron mines in the Adirondacks of Northeast NY.

Figure 3-212


MINERAL RESOURCES
of
NEW YORK
Lake Ontario
Lake Erie
A free List of Publications is available from the:
Research & Collections Division
3140 CEC
New York State Museum
Albany, New York 12230
EXPLANATION
Carbonate rock
Area underlain by gypsum
Area underlain by salt
B Bluestone producing area
C Cement
Cl Clay
Gt Garnet
P Peat
S Salt
Sl Slate producing area
T Talc
Wo Wollastonite
Zn,Pb,Ag Zinc,Lead,Silver (Inactive mine)
0 10 20 30 40 50 miles
0 20 40 60 80 kilometers
N

Affecting Conditions Land Subsidence:

The predominant conditions that lend to the overall risk of land subsidence occurrence includes, as mentioned previously, underlying soil and rock type, natural and human impact on ground water, and occurrence of underground mining (natural and human caused). Following is the description of these conditions as identified under two (2) classifications, underlying rock and triggers.

Underlying Rock: As **Figure 3-211** indicates, evaporite rocks (salt and gypsum) underlie about 40 percent of the contiguous United States. (Martinez and others, 1998), and Carbonate Karst landscapes constitute about 40% of the U.S. east of Tulsa, Oklahoma (White and others, 1995). New York State is no exception, in fact it appears that **figure 3-212** indicates a similar percentage for the State.

Triggers: According to the NYS Geological Survey in areas of karst development, the triggering event for subsidence is often during a period of heavy precipitation and/or rapid snowmelt. Caverns have formed over the last 100,000 years and streams flow through these most of the year. During periods of flooding, either within the cavern or in sinking streams entering the caverns, both chemical and physical erosion are particularly aggressive. Dissolution of carbonate rock or removal of supporting in-filled sediments triggers new collapses. In mining areas, subsidence may be initiated by weakness in the roof rocks due to previous ore removal. Some subsidence has been triggered by the process of active mining. Unexpected geological conditions, such as a fault or water-filled cavity in the mine roof, may lead to failure. Collapse of the mine void may propagate to the surface, creating a sink hole. Other significant factors in land subsidence occurrence include; aquifer-system compaction, drainage of organic soils, underground mining, hydro-compaction, natural compaction, sink holes, and thawing of permafrost. The USGS estimates that 80% of the identified subsidence in the U.S. is a consequence of human impact on subsurface water. Three distinct processes account for most of the water-related subsidence, compaction of aquifer systems, drainage and subsequent oxidation of organic soils, and dissolution and collapse of susceptible rock (limestone aquifers).

Previous Occurrences of Land Subsidence:

According to NYS Geological Survey staff, historical records including scientific study data for land subsidence in New York State is sparse, not readily available, and does not exist in summary form. The following narrative is a description of previous occurrence including reference to two historical land subsidence events in New York State. The two historical subsidence events demonstrate the natural conditions that lend to land subsidence as well a human caused element of land subsidence. The narrative is an excerpt from the abstracts presented at U.S. Geological Survey Subsidence Interest Group Conference Proceedings.

More recently, the bank of the Claverack Creek in the town of Greenport in Columbia County subsided. A State of Emergency was declared.

SEMO and other State agencies worked together to assess the damage and stabilize the area. Damage was minimal and the site declared stable the day following the incident.

Figure 3-213 Claverack Creek in February 2006

New sinkhole formations in the karst areas are rare, the last being in 1989 in a farmer's field. Although, unofficial reports indicate small collapses that expand existing sink holes are relatively common, occurring every few years. An iron ore mine collapse in Mineville, NY (approximately 100 miles north of Albany) in April of 2004 is one of an indeterminate number of similar occurrences reported in the last few years. Similarly, unofficial reports also indicate minor incidents of subsidence over the gypsum mines in western to central part of NY State.

Greenport Subsidence – 2006

On February 2, 2006, SEMO Region II was notified by Columbia County Emergency Management Office that an approximate 675-foot section of the bank of Claverack Creek has subsided into the creek in the area of the Italian American Center in the Town of Greenport. The erosion was estimated to be approximately 30 feet deep. No physical structures were damaged, but a quarter-mile of road, Bridge Street, was closed due to the subsidence.

A State of Emergency was declared in the Town of Greenport in response to the collapse. The Town of Greenport surrounds the city of Hudson. The Columbia County EOC was activated to deal with the emergency. Representatives from Department of Public Works (DPW), power, water, emergency management, and law enforcement were called in, as were representatives from the NYS Departments of Transportation (DOT) and Environmental Conservation (DEC).

The DEC reported that the subsidence resulted in a damming of the creek which threatened the Route 66 bridge, county jail, and water and sewer systems. The DEC thought the jail would have to be evacuated. Columbia County EMO reported that the jail could remain functional for up to 12 hours if the water was shut off.

This never came to pass. Within 24 hours, the agencies at the scene declared the situation stable, even though the accident site received over an inch of rain since the collapse. The agencies declared there was no threat to adjacent properties. The only damages were to two Bocce courts belonging to the Sons of Italy and the collapse of a 20-foot area of the wall near the 'Sons and Daughters of Italy' the only area flooded is a farm where the water has ponded. The creek has taken a new natural flow and is presently flowing freely.

The present agencies' solution to the problem is to let the creek flow in its new course and remove any trees that are in the way. The county jail continued to function normally.

Hydrogeologic Effects of Flooding in the Partially Collapsed Retsof Salt Mine, Livingston County, New York

By Dorothy H. Tepper, William M. Kappel, Todd S. Miller, *and* John H. Williams
U.S. Geological Survey Subsidence Interest Group Conference, Las Vegas, Nevada, February 14–16, 1995

The Retsof Salt Mine is in Livingston County, New York, about 25 mi (40 km) southwest of Rochester (fig. 1). This mine which has been in operation for 110 years and is about 1,100 ft (335 m) below land surface, supplies road salt to 14 States in the Northeast. Retsof Salt Mine is the largest salt mine in the Western Hemisphere and includes an underground area that is roughly the size of Manhattan (6,500 acres or about 2,630 hectares). An underground room near the southern end of the mine near Cuylerville collapsed on March 12, 1994, and an adjacent room collapsed in early April. Two large, circular collapse features that are several hundred feet apart have developed at land surface above the two collapsed mine rooms. The northernmost feature, which is about 700 ft (213 m) in diameter, includes a central area about 200 ft (60 m) wide that has subsided about 20 to 30 ft (6 to 9 m). The southernmost feature, which is about 900 ft (274 m) in diameter, includes a central area that is about 700 ft (213 m) wide that has subsided about 70 ft (21 m). The subsidence in the collapse area has forced the closure of a section of State Route 20A as a result of the partial collapse of a New York State Department of Transportation bridge. During the formation of these collapse features, hydraulic connections formed between aquifers and the mine that had been previously isolated from each other by confining units. These new connections have provided routes for rapid migration of ground water downward to the mine level. Since March 12, ground water draining from overlying aquifer systems has been progressively flooding the mine at inflow rates averaging about 18,000 gal/min (1,135 L/s). This aquifer drainage has caused inadequate water supplies in a number of local wells, and some wells actually have gone dry. The U.S. Geological Survey (USGS) has been working with the Livingston County Department of Health since March 1994 to provide technical expertise in dealing with this situation.

Figure 3-214

U.S. Geological Survey Open-File Report 97-47

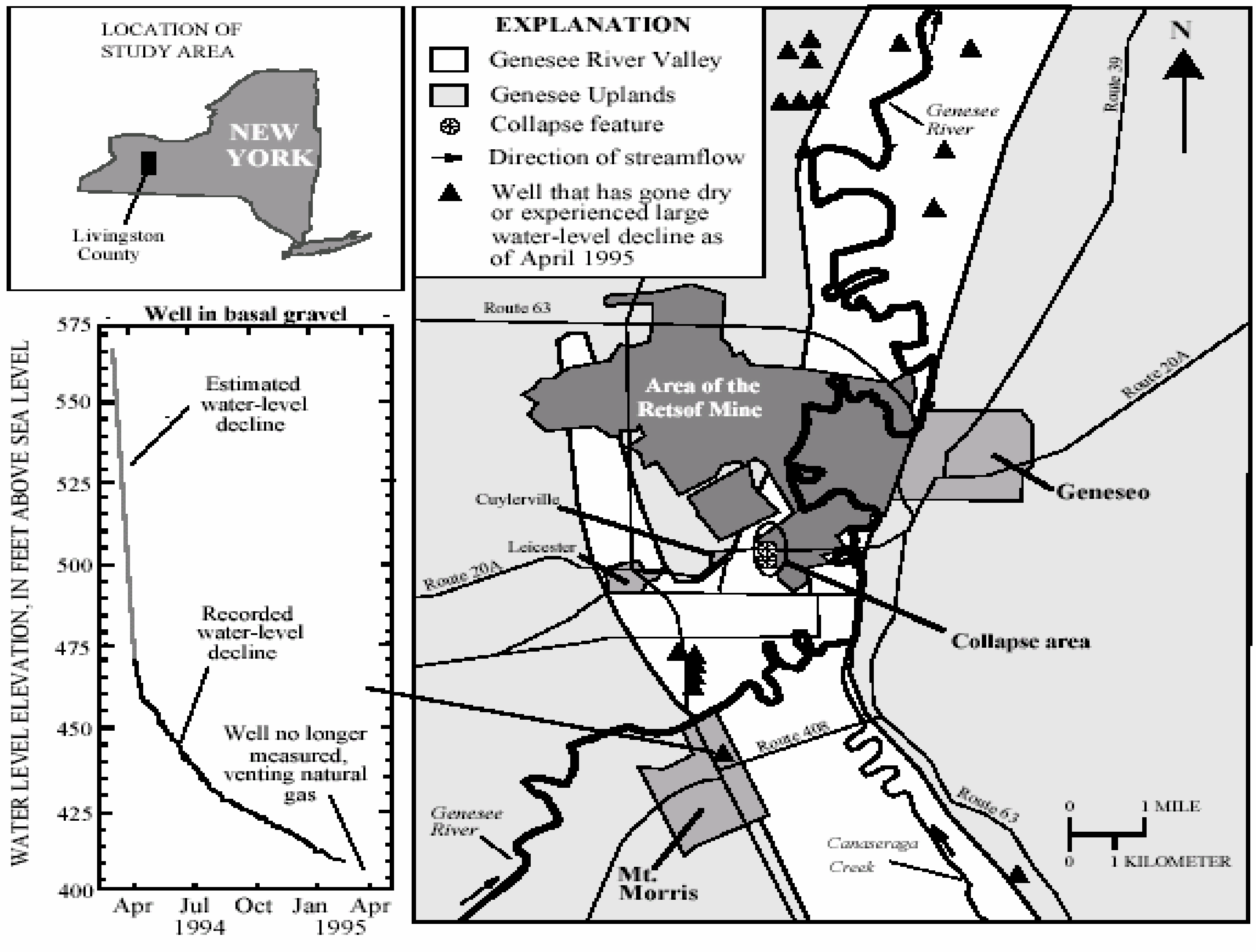


Figure 1. Location of Retsof Salt Mine, area of collapse, and hydrograph of water-level decline in a well 3.5 miles from the mine.

USGS Abstract - Historical Land Subsidence Event #2 -

MUDBOILS IN THE TULLY VALLEY, ONONDAGA COUNTY, NEW YORK
William M. Kappel (U. S. Geological Survey, Ithaca, New York)

USGS Subsidence Interest Group Conference, Edwards AFB, Antelope Valley, Nov. 18-19, 1992: Abstracts and Summary - U.S. Geological Survey Open-File Report 94-532

The discharge of turbid ground water and fine sand to the land surface in the Tully Valley, approximately 20 miles south of Syracuse, New York, has formed a series of mudboils (fig. 1). The volcano-like cone of a mudboil can be several inches to several feet high and from 1 ft to more than 30 ft in diameter. Where mudboil activity is persistent, the removal of sediment at depth has caused land subsidence. Depending on the depth of the source zone, individual mudboils discharge fresh or brackish ground water. The temperature of freshwater discharges ranges between 45 and 55 degrees farenheit; the temperature of brackish water discharge is nearly constant at 51 degrees Fahrenheit. Mudboil activity may be natural or may be associated with a large solution salt-mining operation that began in the southern part of the valley in the late 1800's and ceased in 1988. The mined salt beds range from 1,000 to 1,400 ft below land surface (fig. 2)**.** The northern extent of the brining operation is one (1) mile south of the mudboil area; the northern limit of its effect is unknown. Dissolution of the salt beds initially utilized injected surface water but since the late 1950's dissolution has occurred only under natural conditions, involving ground-water infiltration to the salt beds from the surrounding fractured bedrock and possibly from the more permeable unconsolidated glacial deposits in the Tully Valley.

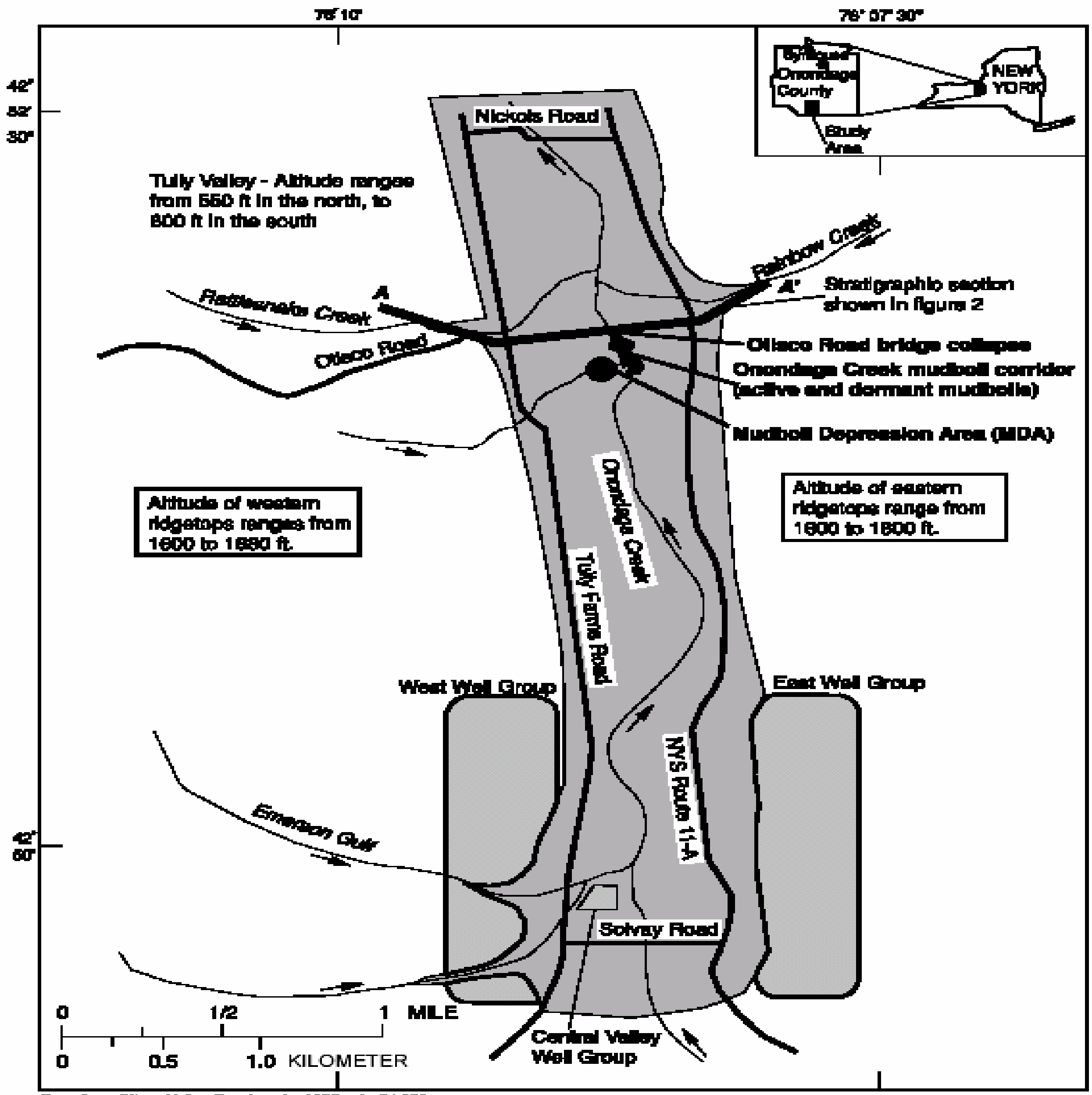
The earliest known mudboil in Tully Valley, reported in the Syracuse Post Standard on October 19, 1899, was apparently localized and short-lived. From 1899 to the 1970's, the mudboils within the Onondaga Creek mudboil corridor (fig. 1) appeared and dissipated over a span of several weeks to a few months but had no long-term effect on the water quality of Onondaga Creek and Onondaga Lake, 20 mi downstream. Active mudboils became increasingly persistent during the mid-1970's, causing turbid discharges that degraded the quality of Onondaga Creek. Before the mid-1980's, relatively fresh ground water was discharged from what is now called the main 'mudboil depression area' (MDA), located 1,500 ft south of Otisco Road (fig. 1). Since then, however, the discharge has been more brackish, and land subsidence (locally as much as 15 ft) has progressed outward. In June 1991, a new mudboil appeared in Onondaga Creek just upstream of the Otisco Road bridge (fig. 1), and within 2 months the bridge collapsed. Subsidence around the 150-ft radius of this collapse area ranges from several inches at the perimeter to more than 5 ft at the bridge.

Cessation of pumping: The cessation of the solution salt-mining field's annual pumping of approximately one (1) billion gal of brine in the late 1980's caused the hydraulic head in the deep sand and gravel zone to increase by 70 ft or more, and this increased head coincided with the onset of increased mudboil activity and changes in the quality of water discharged from the MDA. Subsidence of the land surface in the Tully Valley has occurred over the past 100 years, but the causes of this subsidence are varied. In the brine fields, uncontrolled solution mining of the deep salt beds has resulted in the collapse of large unsupported spans of rock materials immediately above the salt (Fernandez, 1991). In some cases the subsidence is gradual and occurs over a large area (tens of acres) as the upper bedrock units sag into the lower collapse area. In other cases the subsidence is confined to a small area (hundreds of square feet) due to the development of a "chimney" through the rock formations above the collapse area, which creates a sinkhole at the land surface (Fernandez, 1991). Along Onondaga Creek and in the main MDA, land-surface subsidence is related to the discharge of ground water and fine-grained materials from the subsurface to the land surface where stream erosion moves the discharged mudboil sediments downstream. Continued discharge of subsurface materials and subsequent removal leads to land subsidence (see Helm abstract for discussion of related physical mechanisms in the formation of earth fissures). This process is gradual but perceptible, as noted in the collapse of the Otisco Road bridge**.** A third type of subsidence is suspected but is currently undocumented—subsidence due to the compaction of fine-grained materials resulting from the aggressive pumping of ground water during the last 20 years of solution mining in the Tully Valley brine fields. The cessation of pumping resulted in a 70-to 100-ft recovery of water levels in the deep sand and gravel and probably brought this type of subsidence to a halt. Although the following information is circumstantial, it may indicate that this form of subsidence has occurred in the Tully Valley.

1. Structural damage: Large-building foundations are reported to have separated, cracked, or subsided in all parts of the Tully Valley, both in and outside of the solution mining area. Study of the Tully Valley mudboils will continue through 1993. Subsidence will be monitored at the main MDA to determine if any planned remedial actions will affect rates of subsidence. A deep well will be drilled to determine if there is a collapse feature in the bedrock beneath the MDA or if the saltbeds have been solutioned-out in this area. Ground-water samples from selected water-bearing zones in the bedrock, the basal sand and gravel unit, and the shallow mudboil source zone will be collected and compared with samples collected from fresh and brackish water mudboils to determine possible source zone(s) feeding the mudboils.

Figure 3-215

U.S. Geological Survey Open-File Report 94-532



Base from Otisco Valley Quadrangle, 1955 1 : 24,000

Figure 1. Geographic features in the Tully Valley, Onondaga County, New York. Tully Valley is about 20 miles south of Syracuse, New York.

Probability of Future Land Subsidence Events:

Given that land subsidence is a documented occurrence in New York State, it is certain that future land subsidence will occur. However, the sparse historical record of occurrences and the lack of comprehensive summarized, and readily available scientific studies make it difficult to predict probability of future occurrence, only that it is likely.

According to the NYS Geological Survey (regarding the likelihood of subsidence); "…new sink hole formation in the karst areas is **rare**, the last being 1989 (15 years ago) in a farmer's field….", and "…subsidence occurring in areas that are already subsiding (expanding existing sink holes) are relatively common, occurring every few years…."

Additionally, the NYS Geological Survey staff explains that subsidence induced by mine collapse is a different story. Mine collapse and resulting subsidence can be sudden and unpredictable. An iron mine collapse in Mineville, NY (approximately 100 miles north of Albany) April of 2004 is one of an indeterminate number of similar occurrences reported in the last few years. Similarly, NYS Geologist report there have been minor incidents of subsidence over the gypsum mines in western and central NY. Again, these occur largely in agricultural fields and are reportedly of the magnitude that can be filled with a couple of truckloads of dirt. Certainly, the subsidence at the Retsof salt mine collapse, as described in the abstract above, was a surprise but it demonstrates that a collapse of eleven or twelve feet, 1000 feet below the surface, can in fact "chimney" (propagate) all the way to the surface. However, this was the first such incident in 110 years of operation for that mine.

In summary, it appears that the nature of all forms of land subsidence in New York makes it difficult to determine probability of future events (frequency). The fact that moderate to low land subsidence susceptibility exists (based on land area at risk), as shown on the USGA map figure 3-38, and land subsidence has occurred in the past, suggests that, although very infrequent, land subsidence will occur sooner or later. The question remains, to what degree are people and property at significant risk from damaging land subsidence events in New York State?

Vulnerability Assessment and Loss Estimation

Although our research indicates a certain amount of land subsidence hazard in New York State, it also indicates very low risk to population and property. Additionally, the extremely localized and virtually unpredictable nature of land subsidence makes it nearly impossible to estimate potential loss. This said, with the exception of continuing to document land subsidence occurrence, this Plan will not include the land subsidence hazard in further analysis or mitigation strategy development.