# 5.4.6 Geological Hazards

The following section provides the hazard profile (hazard description, location, extent, previous occurrences and losses, probability of future occurrences, and impact of climate change) and vulnerability assessment for the geological hazards in Morris County.

## 2015 Plan Update Changes

- The hazard profile has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, probability of future occurrence, and potential change in climate and its impacts on the geological hazards is discussed. The geological hazards is now located in Section 5 of the plan update.
- New and updated figures from federal and state agencies are incorporated.
- Previous occurrences were updated with events that occurred between 2010 and 2014.
- A vulnerability assessment was conducted for the geological hazards and it now directly follows the hazard profile.

## 5.4.6.1 Profile

### Hazard Description

Geological hazards are any geological or hydrological process that poses a threat to humans and natural properties. Every year, severe natural events destroy infrastructure and cause injuries and deaths. Geologic hazards may include volcanic eruptions and other geothermal related features, earthquakes, landslides and other slope failures, mudflows, sinkhole collapses, snow avalanches, flooding, glacial surges and outburst floods, tsunamis, and shoreline movements. For the purpose of this HMP Update, only landslides and land subsidence/sinkholes will be discussed in the Geological Hazard profile. Morris County has only expressed their concern for potential landslide susceptibility and land subsidence within the County.

#### Landslides

According to the U.S. Geological Survey (USGS), the term landslide includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors (USGS 2013). Among the contributing factors are: (1) erosion by rivers, glaciers, or ocean waves which create over-steepened slopes; (2) rock and soil slopes weakened through saturation by snowmelt or heavy rains; (3) earthquakes which create stresses making weak slopes fail; and (4) excess weight from rain/snow accumulation, rock/ore stockpiling, waste piles, or man-made structures. Scientists from the USGS also monitor stream flow, noting changes in sediment load in rivers and streams that may result from landslides. All of these types of landslides are considered aggregately in USGS landslide mapping.

In New Jersey, there are four main types of landslides: slumps, debris flows, rockfalls, and rockslides. Slumps are coherent masses that move downslope by rotational slip on surfaces that underlie and penetrate the landslide deposit (Briggs et al 1975). A debris flow, also known as a mudslide, is a form of rapid mass movement in which loose soil, rock, organic matter, air, and water mobilize as slurry that flows downslope. Debris flows are often caused by intense surface water from heavy precipitation or rapid snow melt. This precipitation loosens surface matter, thus triggering the slide. Rockfalls are common on roadway cuts and steep cliffs. These landslides are abrupt movements of geological material such as rocks and boulders. Rockfalls happen when these materials become detached. Rockslides are the movement of newly detached segments of bedrock sliding on bedrock, joint, or fault surfaces (Delano and Wilshusen 2001).

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public, and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures. Vegetation or poles on slopes can be knocked over, resulting in possible losses to power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary loss for residents. They also can damage rivers or streams, potentially harming water quality, fisheries, and spawning habitat.

### Subsidence/Sinkholes

Land subsidence can be defined as the sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion, owing to the subsurface movement of earth materials (USGS 2000). Subsidence often occurs through the loss of subsurface support in karst terrain, which may result from a number of natural- and human-caused occurrences. Karst describes a distinctive topography that indicates dissolution of underlying carbonate rocks (limestone and dolomite) by surface water or groundwater over time. The dissolution process causes surface depressions and the development of sinkholes, sinking stream, enlarged bedrock fractures, caves, and underground streams (New Jersey State HMP 2014). There are areas of karst in northwestern New Jersey, including parts of Morris County (USGS 2014).

The State's susceptibility to subsidence is also due in part to the number of abandoned mines throughout New Jersey. The mining industry in New Jersey dates back to the early 1600s when cooper was first mined by Dutch settlers along the Delaware River in Warren County. One of the first iron mines in the U.S. was located in the Mount Hope section of Rockaway Township (Morris County) around 1710. There are approximately 450 underground mines in New Jersey, all of which are now abandoned. Although mines have closed in New Jersey, continued development in the northern part of the State has been problematic because of the extensive mining there which has caused widespread subsidence. One problem is that the mapped locations of some of the abandoned mines are not accurate. Another issue is that many of the surface openings were improperly filled in, and roads and structures have been built adjacent to or on top of these former mine sites.

According to the USGS, sinkholes are common where the rock below the land surface is limestone, carbonate rock, salt beds, or rocks that can naturally be dissolved by groundwater circulating through them. As the rock dissolves, spaces and caverns develop underground. A sinkhole is an area of ground that has no natural external surface draining, so when it rains, all of the water stays inside the sinkhole and typically drains into the subsurface (USGS 2014). Sinkholes are the most frequently seen type of subsidence in New Jersey (New Jersey State HMP 2014).

Both natural and man-made sinkholes can occur without warning. Slumping or falling fence posts, trees, or foundations, sudden formation of small ponds, wilting vegetation, discolored well water, and/or structural cracks in walls and floors, are all specific signs that a sinkhole is forming. Sinkholes can range in form from steep-walled holes, to bowl, or cone-shaped depressions. When sinkholes occur in developed areas they can cause severe property damage, disruption of utilities, damage to roadways, injury, and loss of life (New Jersey State HMP 2014).

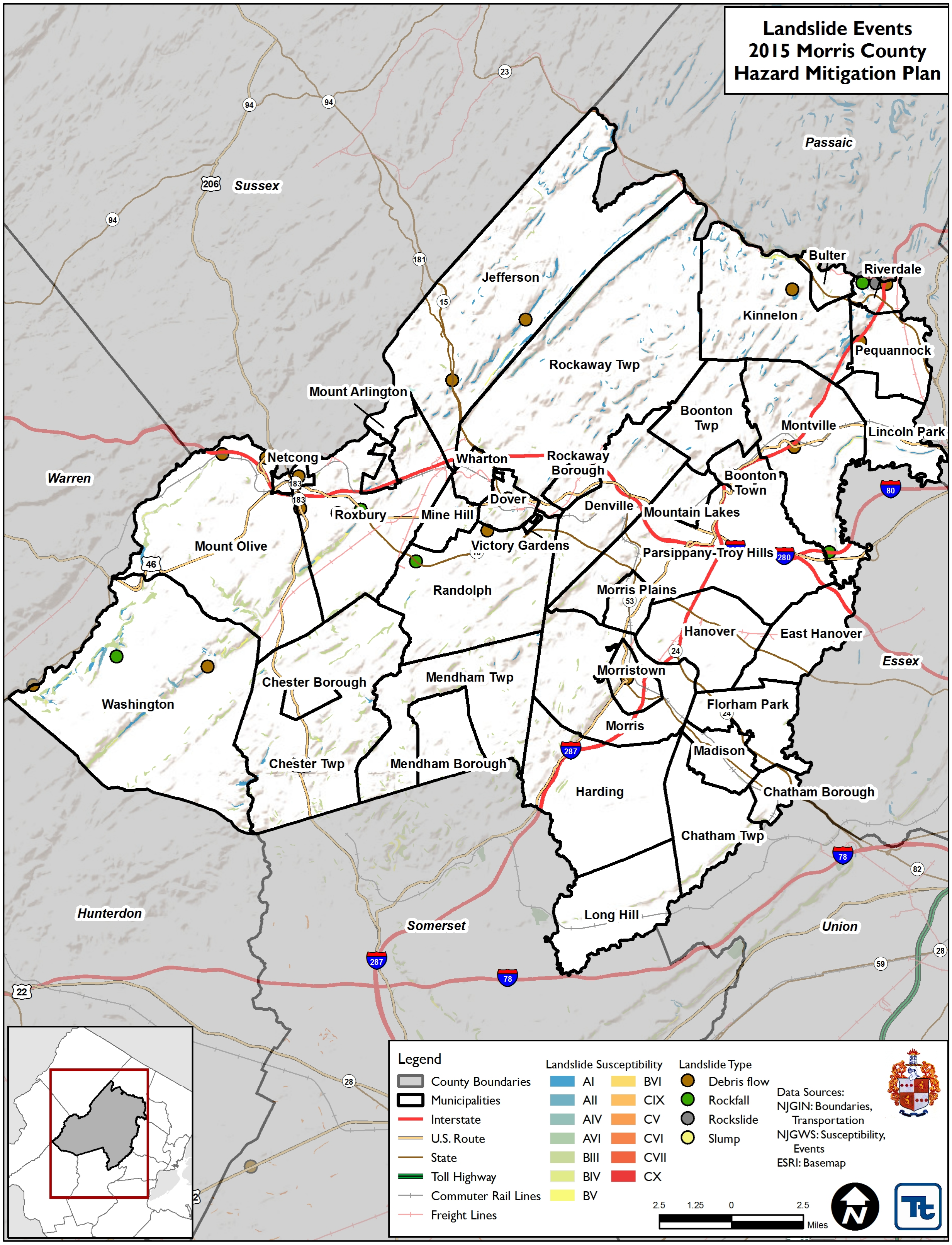
## Location

### Landslides

The entire U.S. experiences landslides, with 36 states having moderate to highly severe landslide hazards. Expansion of urban and recreational developments into hillside areas exposes more people to the threat of landslides each year. According to the USGS, parts of Morris County have moderate landslide potential. For a figure displaying the landslide potential of the conterminous United States, please refer to http://pubs.usgs.gov/fs/2005/3156/2005-3156.pdf.

Landslides are common in New Jersey, primarily in the northern region of the State. As noted in the previous occurrences section, New Jersey has an extensive history of landslides, and the landslides occur for a variety of reasons. In Morris County, the area most susceptible to landslides is western and northeastern portions of the County. Figure 5.4.6-1 illustrates the historic landslide locations in Morris County. According to the figure, landslides have occurred throughout Morris County.

## Figure 5.4.6-1. Historic Landslide Locations in Morris County, 1869 –2014

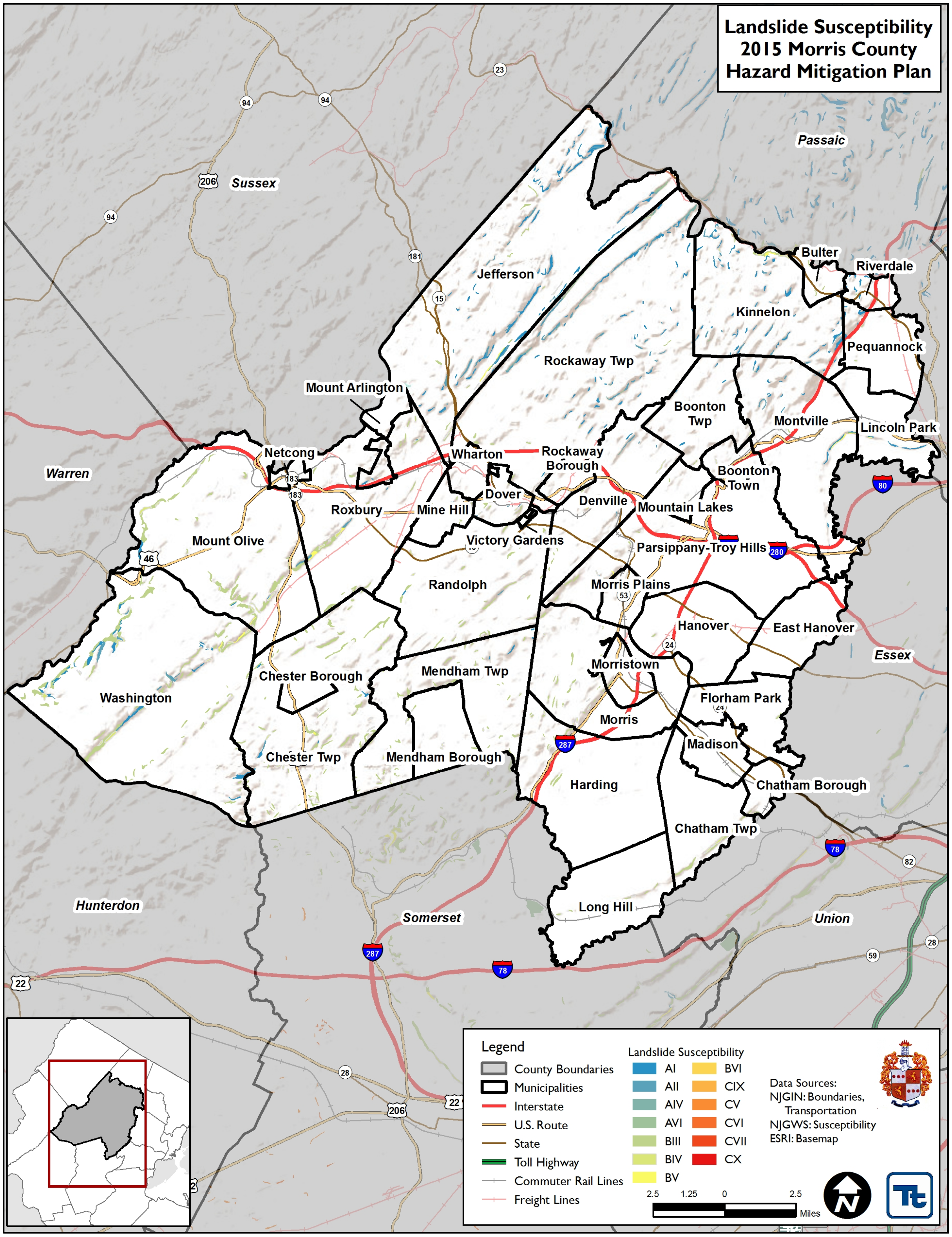



*Source:* *NJGWS 2014*
*NJGWS* *New Jersey Geological Water Survey*

The New Jersey Geological and Water Survey (NJGWS) (formally known as the New Jersey Geological Survey) determined landslide susceptibility for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union). Areas within these counties are classified into Class A, B, and C landslide susceptible classes, and several subclasses within the main classifications. These classes are consistent with HAZUS User Manual Table 9.2. Class A areas in New Jersey include classes AII, AIV, AVI which is strongly cemented rock at varying slope angles; Class B includes classes BIII, BIV, BV, and BVI which includes weakly cemented rock and soil at varying slope angles; and Class C includes classes CV, CVI, CVII, CIX, and CX which includes shale and clayey soil at varying slope angles.

Figure 5.4.6-2 shows the landslide susceptibility in Morris County. Nearly all of the County does not have landslide susceptibility. There are small areas throughout that are susceptible to landslides (Class AI, AII, AIV, BIII, BIV, and BV), with a majority of the susceptibility in the northwestern and southwestern portions of the County. Table 5.4.6-1 summarizes the area within each class. According to the figure and table, the Townships of Jefferson and Rockaway have the greatest total area of landslide susceptibility with 1.5 and 1.2 square miles, respectively.

## Figure 5.4.6-2. Landslide Susceptibility in Morris County




*Source:* *NJGWS 2014*

*NJGWS* *New Jersey Geological Water Survey*

**Table 5.4.6-1. Total Land Area Located in the Landslide Susceptible Areas**

| Municipality | Total Area (sq. mi) | NJGWS-Defined Landslide Susceptible Areas | | | |
|---|---|---|---|---|---|
| | | Class A (sq. mi) | % Total | Class B (sq. mi) | % Total |
| Town of Boonton | 2.5 | 0 | 0% | 0.03 | 1.2% |
| Township of Boonton | 8.5 | 0.03 | 0.3% | 0.03 | 0.3% |
| Borough of Butler | 2.1 | 0.003 | 0.1% | 0.02 | 1.2% |
| Chatham Borough | 2.4 | 0 | 0% | 0.02 | 0.9% |
| Chatham Township | 9.3 | 0 | 0% | 0.2 | 2.4% |
| Chester Borough | 1.6 | 0 | 0% | 0 | 0% |
| Chester Township | 29.1 | 0.1 | 0.4% | 1.0 | 3.4% |
| Denville Township | 12.7 | 0.1 | 0.4% | 0.1 | 0.5% |
| Town of Dover | 2.7 | 0.0 | 0.4% | 0.1 | 2.2% |
| Township of East Hanover | 8.1 | 0 | 0% | 0 | 0 |
| Borough of Florham Park | 7.5 | 0 | 0% | 0.01 | 0.2% |
| Township of Hanover | 10.7 | 0 | 0% | 0.01 | 0.1% |
| Township of Harding | 20.6 | 0 | 0% | 0.1 | 0.7% |
| Township of Jefferson | 41.9 | 1.3 | 3.2% | 0.2 | 0.5% |
| Borough of Kinnelon | 19.2 | 0.7 | 3.4% | 0.1 | 0.7% |
| Borough of Lincoln Park | 6.9 | 0.1 | 0.8% | 0.01 | 0.2% |
| Township of Long Hill | 12.0 | 0.01 | 0.1% | 0.1 | 0.9% |
| Borough of Madison | 4.3 | 0.0 | 0% | 0.01 | 0.3% |
| Borough of Mendham | 6.0 | 0.0 | 0% | 0.04 | 0.7% |
| Township of Mendham | 18.0 | 0.1 | 0.4% | 0.5 | 2.6% |
| Township of Mine Hill | 3.0 | 0.02 | 0.6% | 0.04 | 1.2% |
| Township of Montville | 19.1 | 0.2 | 0.9% | 0.1 | 0.3% |
| Borough of Morris Plains | 2.6 | 0.0 | 0% | 0.01 | 0.4% |
| Township of Morris | 15.8 | 0.003 | 0.02% | 0.2 | 1.3% |
| Town of Morristown | 3.0 | 0.0 | 0% | 0.04 | 1.2% |
| Borough of Mount Arlington | 2.8 | 0.02 | 0.8% | 0.01 | 0.2% |
| Township of Mount Olive | 31.2 | 0.1 | 0.5% | 1.1 | 3.6% |
| Borough of Mountain Lakes | 2.9 | 0.0 | 0% | 0.01 | 0.2% |
| Netcong Borough | 0.9 | 0.0 | 0% | 0.01 | 0.9% |
| Township of Parsippany-Troy Hills | 25.3 | 0.01 | 0.02% | 0.1 | 0.4% |
| Township of Pequannock | 7.1 | 0.1 | 1.1% | 0.03 | 0.4% |
| Township of Randolph | 21.2 | 0.02 | 0.1% | 0.4 | 1.7% |
| Borough of Riverdale | 2.1 | 0.1 | 2.9% | 0.02 | 0.9% |
| Borough of Rockaway | 2.1 | 0.0 | 0.0% | 0.01 | 0.3% |
| Township of Rockaway | 45.8 | 1.1 | 2.4% | 0.1 | 0.2% |
| Township of Roxbury | 21.9 | 0.1 | 0.2% | 0.4 | 1.9% |
| Borough of Victory Gardens | 0.1 | 0.0 | 0% | 0 | 0% |
| Township of Washington | 44.6 | 0.7 | 1.5% | 1.8 | 3.9% |
| Borough of Wharton | 2.1 | 0.0 | 0% | 0.01 | 0.3% |
| **Morris County (Total)** | **479.8** | **4.7** | **1.0%** | **6.9** | **1.4%** |

*Source: NJGWS 2014*
*NJGWS New Jersey Geological Water Survey*

Surficial materials in Morris County include postglacial, glacial, and hillslope deposits, weathered bedrock, and exposed bedrock with thin or no soil cover. For detailed information regarding the surficial materials found in Morris County, refer to the November 2005 *Geological Component of the Earthquake Loss Estimation Study for Morris County, New Jersey* (http://www.njgeology.org/enviroed/freedwn/morris_hazus.pdf).

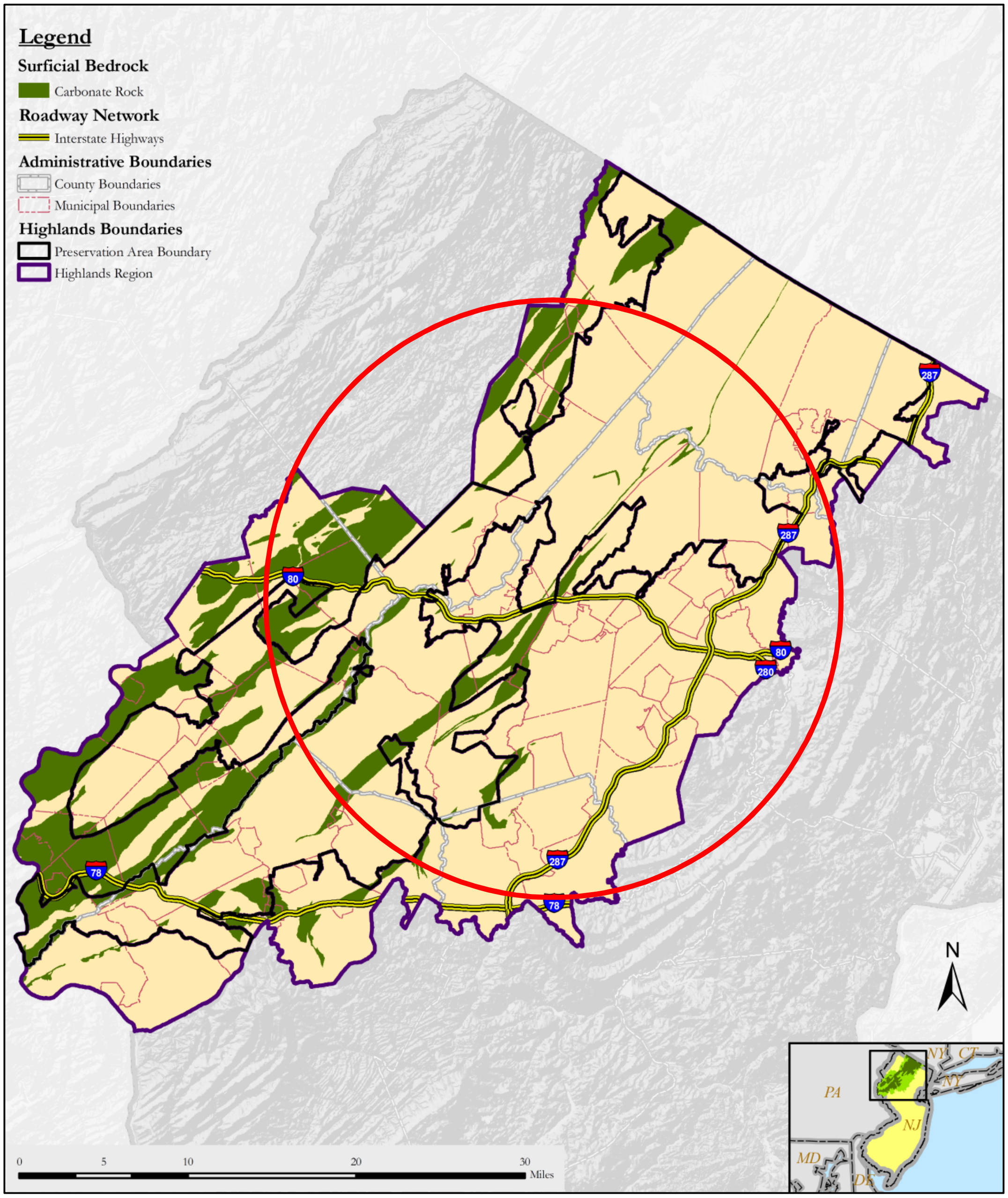
## Subsidence/Sinkholes

New Jersey is susceptible to the effects of subsidence and sinkholes, primarily in the northwestern section of the State, which includes Morris County. Land subsidence and sinkholes have been known to occur as a result of natural geologic phenomenon or as a result of human alteration of surface and underground geology.

Naturally occurring subsidence and sinkholes in New Jersey occur within bands of carbonate bedrock. In northern New Jersey, there are more than 225 square miles that are underlain by limestone, dolomite, and marble. In some areas, no sinkholes have appeared, while in others, sinkholes are common. In southern New Jersey, there are approximately 100 miles which are locally underlain by a lime sand with thin limestone layers. No collapse sinkholes have been identified; however, there are some features which could be either very shallow solution depressions or wind blowout features. Morris County has a large band of carbonate rock in the western half of the County and smaller areas throughout (NJGWS 2004).

Substantial areas of the New Jersey Highlands are underlain by carbonate rocks, including portions of Morris County (Figure 5.4.6-3). These rock formations, consisting primarily of limestone, dolomite, and marble, have unique characteristics that require responses to both the policy level and in specific technical guidance to municipalities. According to the NJDEP, 59 of the 88 municipalities within the Highlands region contain carbonate rocks. Eleven of these municipalities are in Hunterdon County. Fourteen municipalities are in Morris County. Four municipalities are in Passaic County, three are in Somerset. Eight municipalities are in Sussex and 19 are in Warren. Far from being an isolated geologic condition, the widespread presence of carbonate rocks in the regulated area indicates that their presence is a matter of regional concern. As seen in Figure 5.4.6-3, the Highlands Region has several large areas of carbonate rock formations and karst features exist in some, but not all, of these areas (Highlands Regional Master Plan 2008).

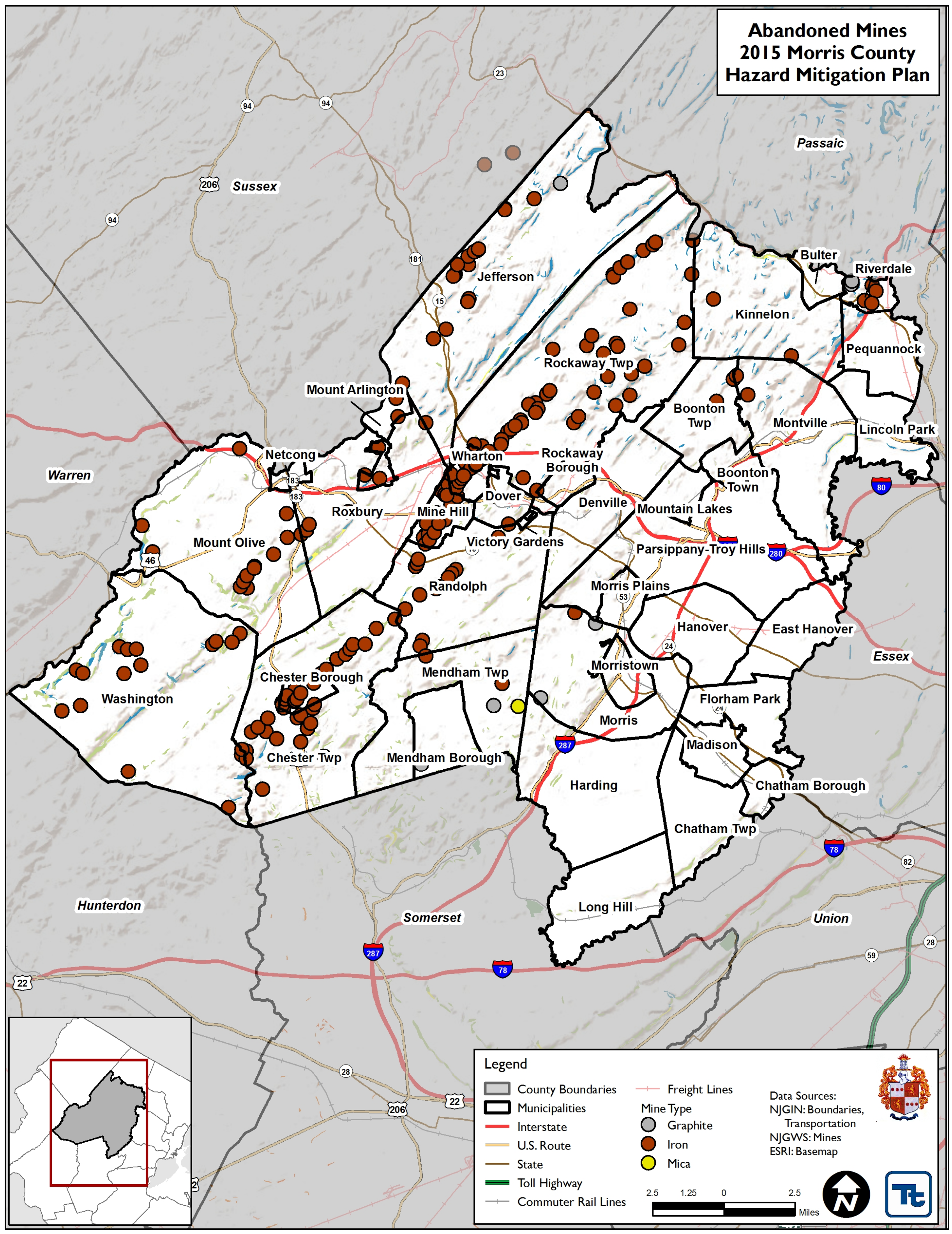
**Figure 5.4.6-3. Carbonate Rock in the New Jersey Highlands**




*Source: New Jersey Highlands Council 2007*
*Note: The red circle indicates the approximate location of Morris County.*

As previously stated, abandoned mines are a source for sinkholes and subsidence in New Jersey. Mines create voids under the earth's surface, making areas above mines more susceptible to land subsidence. Sinkholes and subsidence occur from the collapse of the mine roof into a mine opening. Areas most vulnerable to sinkholes are those where mining occurred 20 to 30 feet below the surface. Figure 5.4.6-4 shows the location of the mapped abandoned mines in New Jersey. The data from NJGWS and the figure indicate that Morris County has numerous abandoned mines, mainly iron mines with a couple graphite and mica mines, located mainly in the western half of the County (NJGWS 2006)).

### Figure 5.4.6-4. Abandoned Mines in Morris County




*Source: NJGWS 2006*

## Extent

### Landslide

To determine the extent of a landslide hazard, the affected areas need to be identified and the probability of the landslide occurring within some time period needs to be assessed. Natural variables that contribute to the overall extent of potential landslide activity in any particular area include soil properties, topographic position and slope, and historical incidence. Predicting a landslide is difficult, even under ideal conditions and with reliable information. As a result, the landslide hazard is often represented by landslide incidence and/or susceptibility, as defined below:

- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15% of a given area has been involved in landsliding; medium incidence means that 1.5 to 15% of an area has been involved; and low incidence means that less than 1.5% of an area has been involved (State of Alabama Date Unknown).
- Landslide susceptibility is defined as the probable degree of response of geologic formations to natural or artificial cutting, to loading of slopes, or to unusually high precipitation. It can be assumed that unusually high precipitation or changes in existing conditions can initiate landslide movement in areas where rocks and soils have experienced numerous landslides in the past. Landslide susceptibility depends on slope angle and the geologic material underlying the slope. Landslide susceptibility only identifies areas potentially affected and does not imply a time frame when a landslide might occur. High, medium, and low susceptibility are delimited by the same percentages used for classifying the incidence of landsliding (State of Alabama Date Unknown).

### Subsidence/Sinkhole

Landslide subsidence occurs slowly and continuously over time or abruptly for various reasons. Subsidence and sinkholes can occur due to either natural processes (karst sinkholes in areas underlain by soluble bedrock) or as a result of human activities. Subsidence in the U.S. has directly affected more than 17,000 square miles in 45 states, and associated annual costs are estimated to be approximately $125 million. The principal causes of subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost (Galloway et al. 2000). There are several methods used to measure land subsidence. Global Positioning System (GPS) is a method used to monitor subsidence on a regional scale. Benchmarks (geodetic stations) are commonly space around four miles apart (State of California 2009).

Another method which is becoming increasingly popular is Interferometric Synthetic Aperture Radar (InSAR). InSAR is a remote sensing technique that uses radar signals to interpolate land surface elevation changes. It is a cost-effective solution for measuring land surface deformation for a region while offering a high degree of spatial detail and resolution (State of California 2009).

## Previous Occurrences and Losses

Numerous sources provided historical information regarding previous occurrences and losses associated with geological hazard events throughout Morris County. Many sources were reviewed for the purpose of this HMP and loss and impact information could vary depending on the source. Therefore, the accuracy of monetary figures, if any, is based only on the available information identified during research for this HMP.

Between 1954 and 2014, FEMA issued a disaster (DR) or emergency (EM) declaration for the State of New Jersey for one geological hazard-related event, classified as severe storms, flooding and mudslide. This declaration included Morris County (FEMA 2014).

For this 2015 Plan Update, known geological hazard events that have impacted Morris County between 2008 and 2014 are identified in Appendix G. According to the NJGWS, between 1869 and 2014, Morris County has had 31 landslide events, with 15 of them occurring between 2008 and 2014. Events prior to 2008 can be found in the 2010 Morris County HMP. With geological hazard documentation being so extensive, not all sources have been identified or researched. Therefore, Appendix G may not include all events that have occurred in Morris County.

## Probability of Future Occurrences

Based upon risk factors for and past occurrences, it is likely that geological hazards will occur in Morris County in the future. Landslide probabilities are largely a function of surface geology, but are also influenced by both weather and human activities. Based on NJGWS data, Morris County can experience 0.2 landslide events each year. On average, the County has experienced one landslide event every four years. However, there are presumably other smaller landslides that have occurred in the County that have not been reported to the NJGWS and not included in these calculations. The probability of future landslides having a significant impact on life and property in Morris County is relatively low. The County will continue to experience the direct and indirect impacts of geological hazards and its impacts on occasion, with the secondary effects causing potential disruption or damage to communities.

In Section 5.3, the identified hazards of concern for Morris County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for geological hazards in the County is considered ‘frequent’ (likely to occur within 25 years, as presented in Table 5.3-3).

## Climate Change Impacts

Providing projections of future climate change for a specific region is challenging. Shorter term projections are more closely tied to existing trends making longer term projections even more challenging. The further out a prediction reaches the more subject to changing dynamics it becomes.

Temperatures in the Northeast United States have increased 1.5 degrees Fahrenheit (°F) on average since 1900. Most of this warming has occurred since 1970. The State of New Jersey, for example, has observed an increase in average annual temperatures of 1.2°F between the period of 1971-2000 and the most recent decade of 2001-2010 (ONJSC, 2011). Winter temperatures across the Northeast have seen an increase in average temperature of 4°F since 1970 (Northeast Climate Impacts Assessment [NECIA] 2007). By the 2020s, the average annual temperature in New Jersey is projected to increase by 1.5°F to 3°F above the statewide baseline (1971 to 2000), which was 52.7°F. By 2050, the temperature is projected to increase 3°F to 5°F (Sustainable Jersey Climate Change Adaptation Task Force 2013). Both northern and southern New Jersey have become wetter over the past century. Northern New Jersey’s 1971-2000 precipitation average was over 5” (12%) greater than the average from 1895-1970. Southern New Jersey became 2” (5%) wetter late in the 20th century (Office of New Jersey State Climatologist).

Future climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Increase in global temperature could affect the snowpack and its ability to hold and store water. Warming temperatures also could increase the occurrence and duration of droughts, which could increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors could increase the probability for landslide occurrences.

## Landslides

Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Increase in global temperature could affect the snowpack and its ability to hold and store water. Warming temperatures also could increase the occurrence and duration of droughts, which would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors would increase the probability for landslide occurrences.

## Subsidence/Sinkholes

Similar to landslides, climate change will affect subsidence and sinkholes in New Jersey. As discussed throughout this profile, one of the triggers for subsidence and sinkholes is an abundance of moisture which has the potential to permeate the bedrock causing an event. Climatologists expect an increase in annual precipitation amounts. This increase will coincide with an increased risk in subsidence and sinkholes in vulnerable areas.

More recently, sinkholes have been correlated to land use practices, especially from groundwater pumping and from construction and development practices. Sinkholes may also form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The substantial weight of the new material can trigger an underground collapse of supporting material, thus causing a sinkhole. Additionally, the overburden sediments that cover buried cavities in the aquifer systems are delicately balanced by groundwater fluid pressure. Groundwater is helping keep the surface soil in place. Pumping groundwater for urban water supply and for irrigation can produce new sinkholes in sinkhole-prone areas. If pumping results in a lowering of groundwater levels, then underground structural failure, sinkholes may occur as well (USGS 2014).

## 5.4.6.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For geological hazards, the known landslide and subsidence/sinkhole vulnerable areas as identified by the New Jersey Geologic and Water Survey have been identified as the hazard area. The following text evaluates and estimates the potential impact of geologic hazards on the County including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (2) general building stock, (3) critical facilities, (4) economy, and (5) future growth and development
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2010 Morris County Hazard Mitigation Plan
- Further data collections that will assist understanding this hazard over time

### Overview of Vulnerability

Vulnerability to ground failure hazards is a function of location, soil type, geology, type of human activity, use, and frequency of events. The effects of ground failure on people and structures can be lessened by total avoidance of hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce ground failure effects by educating themselves on past hazard history of the site and by making inquiries to planning and engineering departments of local governments (National Atlas, 2007).

To determine vulnerability, a spatial analysis was conducted in GIS using the landslide susceptibility datasets discussed below. When the analysis determined the hazard area would impact the area in a jurisdiction, or the location of critical facilities, these locations were deemed vulnerable to the hazard.

### Data and Methodology

The New Jersey Geologic Survey (currently known as the New Jersey Geological and Water Survey) determined landslide susceptibility for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union). Figure 5.4.6-2 earlier in this section illustrates the classifications in Morris County. Based upon the analysis using NJGWS data, the areas of landslide susceptibility and karst are specific to hilly or mountainous areas with steep slopes and erodible soils.

The limitations of this analysis are recognized and are only used to provide a general estimate of exposure and vulnerability. Over time additional data will be collected to allow better analysis for this hazard. Available information and a preliminary assessment are provided below.

### Impact on Life, Health and Safety

To estimate the population located within the hazard areas, the hazard area boundaries were overlaid upon the 2010 Census population data (U.S. Census, 2010). The Census blocks with their center (centroid) within the boundary of the landslide incidence hazard areas were used to calculate the estimated population considered exposed to this hazard. Please note the Census blocks do not align exactly with the hazard areas and, therefore, these estimates should be considered for planning purposes only. Table 5.4.6-2 summarizes the population within each identified landslide-susceptible area by municipality (U.S. Census 2010). Specifically, the population located downslope of the landslide hazard areas are particularly vulnerable to this hazard. Due to the nature of Census block data, it is difficult to determine demographics of populations vulnerable to mass movements of geological material.

As discussed earlier, naturally occurring subsidence and sinkholes in New Jersey occur within bands of carbonate bedrock. According to the NJGWS dataset, there is carbonate rock in areas of the northern half of the County.

**Table 5.4.6-2. Estimated Population Located in the Landslide Hazard Areas**

| Municipalities | Total Population (2010 U.S. Census) | NJGWS-Defined Landslide Susceptible Areas | | | | NJGWS-Karst Area | |
|---|---|---|---|---|---|---|---|
| | | Class A | % Total | Class B | % Total | Population Exposed | % Total |
| Town of Boonton | 8,347 | 0 | 0% | 73 | 0.9% | 0 | 0% |
| Township of Boonton | 4,263 | 0 | 0% | 2 | 0.0% | 0 | 0% |
| Borough of Butler | 7,539 | 0 | 0% | 0 | 0% | 0 | 0% |
| Chatham Borough | 8,962 | 0 | 0% | 100 | 1.1% | 0 | 0% |
| Chatham Township | 10,452 | 0 | 0% | 1,044 | 10.0% | 0 | 0% |
| Chester Borough | 1,649 | 0 | 0% | 0 | 0% | 0 | 0% |
| Chester Township | 7,838 | 0 | 0% | 152 | 1.9% | 457 | 5.8% |
| Denville Township | 16,635 | 0 | 0% | 0 | 0% | 0 | 0% |
| Town of Dover | 18,157 | 0 | 0% | 23 | 0.1% | 0 | 0% |
| Township of East Hanover | 11,157 | 0 | 0% | 0 | 0% | 0 | 0% |
| Borough of Florham Park | 11,696 | 0 | 0% | 0 | 0% | 0 | 0% |
| Township of Hanover | 13,712 | 0 | 0% | 42 | 0.3% | 0 | 0% |
| Township of Harding | 3,838 | 0 | 0% | 24 | 0.6% | 0 | 0% |
| Township of Jefferson | 21,314 | 0 | 0% | 39 | 0.2% | 496 | 2.3% |
| Borough of Kinnelon | 10,248 | 0 | 0% | 0 | 0% | 0 | 0% |
| Borough of Lincoln Park | 10,521 | 51 | 0.5% | 0 | 0% | 0 | 0% |
| Township of Long Hill | 8,702 | 0 | 0% | 2 | 0.02% | 0 | 0% |
| Borough of Madison | 15,845 | 0 | 0% | 142 | 0.9% | 0 | 0% |
| Borough of Mendham | 4,981 | 0 | 0% | 0 | 0% | 12 | 0.2% |
| Township of Mendham | 5,869 | 0 | 0% | 0 | 0% | 148 | 2.5% |
| Township of Mine Hill | 3,651 | 0 | 0% | 0 | 0% | 202 | 5.5% |
| Township of Montville | 21,528 | 39 | 0.2% | 0 | 0% | 0 | 0% |
| Borough of Morris Plains | 5,532 | 0 | 0% | 0 | 0% | 0 | 0% |
| Township of Morris | 22,306 | 0 | 0% | 261 | 1.2% | 32 | 0.1% |
| Town of Morristown | 18,411 | 0 | 0% | 0 | 0% | 0 | 0% |
| Borough of Mount Arlington | 5,050 | 0 | 0% | 0 | 0% | 0 | 0% |
| Township of Mount Olive | 28,117 | 0 | 0% | 1,004 | 3.6% | 4,830 | 17.2% |
| Borough of Mountain Lakes | 4,160 | 0 | 0% | 0 | 0% | 0 | 0% |
| Netcong Borough | 3,232 | 0 | 0% | 0 | 0% | 0 | 0% |
| Township of Parsippany-Troy Hills | 53,238 | 0 | 0% | 312 | 0.6% | 0 | 0% |
| Township of Pequannock | 15,540 | 0 | 0% | 0 | 0% | 0 | 0% |

| Municipalities | Total Population (2010 U.S. Census) | NJGWS-Defined Landslide Susceptible Areas | | | | NJGWS-Karst Area | |
|---|---|---|---|---|---|---|---|
| | | Class A | % Total | Class B | % Total | Population Exposed | % Total |
| Township of Randolph | 25,736 | 0 | 0% | 26 | 0.1% | 339 | 1.3% |
| Borough of Riverdale | 3,559 | 0 | 0% | 0 | 0% | 0 | 0% |
| Borough of Rockaway | 6,438 | 0 | 0% | 800 | 12.4% | 0 | 0% |
| Township of Rockaway | 24,156 | 135 | 0.6% | 449 | 1.9% | 200 | 0.8% |
| Township of Roxbury | 23,324 | 0 | 0% | 0 | 0% | 8,053 | 34.5% |
| Borough of Victory Gardens | 1,520 | 0 | 0% | 0 | 0% | 0 | 0% |
| Township of Washington | 18,533 | 0 | 0% | 514 | 2.8% | 3,343 | 18.0% |
| Borough of Wharton | 6,522 | 0 | 0% | 0 | 0% | 0 | 0% |
| **Morris County (Total)** | **492,276** | **225** | **0.05%** | **5,009** | **1.0%** | **18,112** | **3.7%** |

*Source: United States Census 2010; NJGWS, 2014*

*Note: Class A includes classes AII, AIV, AVI which is strongly cemented rock at varying slope angles. Class B includes classes BIII, BIV, BV, and BVI which includes weakly cemented rock and soil at varying slope angles. No Class C soils were identified in Morris County*

*% percent*

*NJGWS New Jersey Geological and Water Survey*

## Impact on General Building Stock

In general, the built environment located in the high susceptibility zones and the population, structures and infrastructure located downslope are vulnerable to this hazard. In an attempt to estimate the general building stock vulnerable to this hazard, the building improvement values (buildings and contents) were determined for the buildings with their centroids within the approximate landslide hazard areas. Table 5.4.6-3 and Table 5.4.6-4 summarize the exposed building stock in the landslide susceptibility and subsidence hazard areas by municipality.

**Table 5.4.6-3. Number of Buildings in the Landslide Hazard Area by Municipality**

| Municipality | Total Number of Buildings | Total Replacement Value | Class A | | | | Class B | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | # Buildings | % Total | Replacement Value | % Total | # Buildings | % Total | Replacement Value | % Total |
| Town of Boonton | 3,210 | $2,359,806,704 | 0 | 0% | $0 | 0% | 16 | 0.5% | $8,329,392 | 0.4% |
| Township of Boonton | 1,853 | $1,657,854,494 | 0 | 0% | $0 | 0% | 14 | 0.8% | $18,102,921 | 1.1% |
| Borough of Butler | 2,725 | $1,818,159,072 | 0 | 0% | $0 | 0% | 2 | 0.1% | $1,158,582 | 0.1% |
| Chatham Borough | 3,245 | $2,112,769,732 | 0 | 0% | $0 | 0% | 11 | 0.3% | $10,463,810 | 0.5% |
| Chatham Township | 3,998 | $3,234,872,840 | 0 | 0% | $0 | 0% | 75 | 1.9% | $79,875,922 | 2.5% |
| Chester Borough | 859 | $798,032,736 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Chester Township | 3,587 | $3,763,335,644 | 1 | 0.03% | $855,158 | 0.02% | 30 | 0.8% | $22,471,326 | 0.6% |
| Denville Township | 7,032 | $5,687,212,965 | 7 | 0.1% | $2,919,517 | 0.1% | 21 | 0.3% | $25,018,938 | 0.4% |
| Town of Dover | 4,385 | $3,075,745,326 | 0 | 0% | $0 | 0% | 14 | 0.3% | $7,494,276 | 0.2% |
| Township of East Hanover | 4,776 | $5,401,896,233 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Borough of Florham Park | 3,722 | $3,991,843,257 | 0 | 0% | $0 | 0% | 17 | 0.5% | $24,224,731 | 0.6% |
| Township of Hanover | 7,045 | $6,582,774,313 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Township of Harding | 2,050 | $2,344,644,664 | 0 | 0% | $0 | 0% | 43 | 2.1% | $27,400,919 | 1.2% |
| Township of Jefferson | 9,281 | $5,074,333,318 | 14 | 0.2% | $4,799,963 | 0.1% | 13 | 0.1% | $5,427,524 | 0.1% |
| Borough of Kinnelon | 4,078 | $3,942,612,191 | 31 | 0.8% | $31,532,548 | 0.8% | 0 | 0% | $0 | 0% |
| Borough of Lincoln Park | 4,184 | $2,521,331,492 | 30 | 0.7% | $23,447,978 | 0.9% | 4 | 0.1% | $2,469,059 | 0.1% |
| Township of Long Hill | 3,515 | $2,686,329,094 | 0 | 0% | $0 | 0% | 50 | 1.4% | $31,022,574 | 1.2% |
| Borough of Madison | 6,235 | $4,038,218,735 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Borough of Mendham | 2,054 | $1,938,234,052 | 0 | 0% | $0 | 0% | 5 | 0.2% | $9,256,823 | 0.5% |
| Township of Mendham | 2,545 | $2,900,551,737 | 5 | 0.2% | $2,766,520 | 0.1% | 34 | 1.3% | $45,414,158 | 1.6% |
| Township of Mine Hill | 1,555 | $968,302,365 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Township of Montville | 8,066 | $7,935,508,932 | 19 | 0.2% | $11,350,120 | 0.1% | 12 | 0.1% | $9,083,208 | 0.1% |
| Borough of Morris Plains | 2,361 | $2,353,504,441 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Township of Morris | 9,488 | $8,423,230,635 | 0 | 0% | $0 | 0% | 34 | 0.4% | $32,746,787 | 0.4% |
| Town of Morristown | 4,935 | $4,131,251,475 | 0 | 0% | $0 | 0% | 39 | 0.8% | $39,800,114 | 1.0% |
| Borough of Mount Arlington | 2,303 | $1,698,506,114 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |

| Municipality | Total Number of Buildings | Total Replacement Value | Class A | | | | Class B | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | # Buildings | % Total | Replacement Value | % Total | # Buildings | % Total | Replacement Value | % Total |
| Township of Mount Olive | 8,525 | $7,726,519,709 | 0 | 0% | $0 | 0% | 61 | 0.7% | $47,991,925 | 0.6% |
| Borough of Mountain Lakes | 1,589 | $1,470,833,586 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Netcong Borough | 1,075 | $936,477,404 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Township of Parsippany-Troy Hills | 17,033 | $14,262,637,338 | 0 | 0% | $0 | 0% | 8 | 0.0% | $4,516,082 | 0.0% |
| Township of Pequannock | 5,586 | $4,903,988,440 | 0 | 0% | $0 | 0% | 6 | 0.1% | $3,775,593 | 0.1% |
| Township of Randolph | 8,375 | $8,283,021,151 | 1 | 0.01% | $1,761,883 | 0.02% | 58 | 0.7% | $52,739,141 | 0.6% |
| Borough of Riverdale | 1,155 | $1,246,580,332 | 3 | 0.3% | $2,407,167 | 0.2% | 1 | 0.1% | $859,880 | 0.1% |
| Borough of Rockaway | 2,580 | $1,804,154,071 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Township of Rockaway | 11,215 | $7,782,228,135 | 9 | 0.1% | $4,128,577 | 0.1% | 10 | 0.1% | $7,191,556 | 0.1% |
| Township of Roxbury | 9,408 | $6,601,093,651 | 2 | 0.02% | $2,702,401 | 0.04% | 9 | 0.1% | $5,326,848 | 0.1% |
| Borough of Victory Gardens | 338 | $138,840,857 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| Township of Washington | 7,793 | $6,580,308,267 | 5 | 0.1% | $3,742,589 | 0.1% | 107 | 1.4% | $77,811,620 | 1.2% |
| Borough of Wharton | 2,040 | $1,699,397,922 | 0 | 0% | $0 | 0% | 0 | 0% | $0 | 0% |
| **Morris County (Total)** | **185,799** | **$154,876,943,422** | **127** | **0.1%** | **$92,414,420** | **0.1%** | **695** | **0.4%** | **$602,523,640** | **0.4%** |

*Source: Morris County, NJGWS*

**Table 5.4.6-4. Number of Buildings in the Subsidence and Sinkhole Hazard Area by Municipality**

| Municipality | Total Number of Buildings | Total Replacement Value | Karst Hazard Area | | | |
|---|---|---|---|---|---|---|
| | | | # Buildings | % Total | Replacement Value | % Total |
| Town of Boonton | 3,210 | $2,359,806,704 | 0 | 0% | $0 | 0% |
| Township of Boonton | 1,853 | $1,657,854,494 | 0 | 0% | $0 | 0% |
| Borough of Butler | 2,725 | $1,818,159,072 | 0 | 0% | $0 | 0% |
| Chatham Borough | 3,245 | $2,112,769,732 | 0 | 0% | $0 | 0% |
| Chatham Township | 3,998 | $3,234,872,840 | 0 | 0% | $0 | 0% |
| Chester Borough | 859 | $798,032,736 | 0 | 0% | $0 | 0% |
| Chester Township | 3,587 | $3,763,335,644 | 219 | 6.1% | $225,062,959 | 6.0% |
| Denville Township | 7,032 | $5,687,212,965 | 0 | 0% | $0 | 0% |
| Town of Dover | 4,385 | $3,075,745,326 | 0 | 0% | $0 | 0% |
| Township of East Hanover | 4,776 | $5,401,896,233 | 0 | 0% | $0 | 0% |
| Borough of Florham Park | 3,722 | $3,991,843,257 | 0 | 0% | $0 | 0% |
| Township of Hanover | 7,045 | $6,582,774,313 | 0 | 0% | $0 | 0% |
| Township of Harding | 2,050 | $2,344,644,664 | 0 | 0% | $0 | 0% |
| Township of Jefferson | 9,281 | $5,074,333,318 | 384 | 4.1% | $180,662,863 | 3.6% |
| Borough of Kinnelon | 4,078 | $3,942,612,191 | 0 | 0% | $0 | 0% |
| Borough of Lincoln Park | 4,184 | $2,521,331,492 | 0 | 0% | $0 | 0% |
| Township of Long Hill | 3,515 | $2,686,329,094 | 0 | 0% | $0 | 0% |
| Borough of Madison | 6,235 | $4,038,218,735 | 0 | 0% | $0 | 0% |
| Borough of Mendham | 2,054 | $1,938,234,052 | 6 | 0.3% | $1,555,585 | 0.1% |
| Township of Mendham | 2,545 | $2,900,551,737 | 144 | 5.7% | $186,233,388 | 6.4% |
| Township of Mine Hill | 1,555 | $968,302,365 | 134 | 8.6% | $50,167,577 | 5.2% |
| Township of Montville | 8,066 | $7,935,508,932 | 0 | 0% | $0 | 0% |
| Borough of Morris Plains | 2,361 | $2,353,504,441 | 0 | 0% | $0 | 0% |
| Township of Morris | 9,488 | $8,423,230,635 | 34 | 0.4% | $35,430,155 | 0.4% |
| Town of Morristown | 4,935 | $4,131,251,475 | 0 | 0% | $0 | 0% |
| Borough of Mount Arlington | 2,303 | $1,698,506,114 | 0 | 0% | $0 | 0% |
| Township of Mount Olive | 8,525 | $7,726,519,709 | 1,649 | 19.3% | $1,807,771,413 | 23.4% |
| Borough of Mountain Lakes | 1,589 | $1,470,833,586 | 0 | 0% | $0 | 0% |
| Netcong Borough | 1,075 | $936,477,404 | 0 | 0% | $0 | 0% |
| Township of Parsippany-Troy Hills | 17,033 | $14,262,637,338 | 0 | 0% | $0 | 0% |
| Township of Pequannock | 5,586 | $4,903,988,440 | 0 | 0% | $0 | 0% |
| Township of Randolph | 8,375 | $8,283,021,151 | 114 | 1.4% | $267,108,522 | 3.2% |
| Borough of Riverdale | 1,155 | $1,246,580,332 | 0 | 0% | $0 | 0% |
| Borough of Rockaway | 2,580 | $1,804,154,071 | 0 | 0% | $0 | 0% |
| Township of Rockaway | 11,215 | $7,782,228,135 | 189 | 1.7% | $425,023,494 | 5.5% |
| Township of Roxbury | 9,408 | $6,601,093,651 | 3,520 | 37.4% | $2,649,966,193 | 40.1% |

| Municipality | Total Number of Buildings | Total Replacement Value | Karst Hazard Area | | | |
|---|---|---|---|---|---|---|
| | | | # Buildings | % Total | Replacement Value | % Total |
| Borough of Victory Gardens | 338 | $138,840,857 | 0 | 0% | $0 | 0% |
| Township of Washington | 7,793 | $6,580,308,267 | 1,717 | 22.0% | $1,478,527,493 | 22.5% |
| Borough of Wharton | 2,040 | $1,699,397,922 | 0 | 0% | $0 | 0% |
| **Morris County (Total)** | **185,799** | **$154,876,943,422** | **8,110** | **4.4%** | **$7,307,509,641** | **4.7%** |

*Source: Morris County, NJGWS*

## Impact on Critical Facilities

To estimate exposure, the approximate landslide hazard areas were overlaid upon the essential and municipal facilities. There is one critical facility (potable pump station) located in a landslide susceptibility hazard area, and one critical facility (air) located on carbonate bedrock.

In addition to critical facilities, a significant amount of infrastructure can be exposed to mass movements of geological material:

- *Roads*—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems, and delays for public and private transportation. This can result in economic losses for businesses.
- *Bridges*—Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.
- *Power Lines*—Power lines are generally elevated above steep slopes; but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.
- *Rail Lines* – Similar to roads, rail lines are important for response and recovery operations after a disaster. Landslides can block travel along the rail lines, which would become especially troublesome, because it would not be as easy to detour a rail line as it is on a local road or highway. Many residents rely on public transport to get to work around the County and into New York City, and a landslide event could prevent travel to and from work.

Several other types of infrastructure may also be exposed to landslides, including water and sewer infrastructure. At this time all critical facilities, infrastructure, and transportation corridors located within the hazard areas are considered vulnerable until more information becomes available.

### Table 5.4.6-5. Critical Facilities Exposed to the Landslide Hazard Areas (Classes A through B)

| Municipality | Facility Types |
|---|---|
| | Dam |
| Township of Randolph | 1 |

*Source: Morris County, HAZUS-MH, NJGWS*
*Note: Only 1 facility in the County is located in the hazard area*

## Table 5.4.6-6. Critical Facilities in the Subsidence and Sinkhole Hazard Area by Municipality

| Municipality | Facility Types | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dam | DPW | Electric Substation | EMS | Emergency Operation Center | Fire Station | Hazardous Material | Municipal Hall | Natural Gas | School | Senior | Wastewater Facility |
| Town of Boonton | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Boonton | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Butler | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chatham Borough | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chatham Township | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chester Borough | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chester Township | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Denville Township | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Town of Dover | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of East Hanover | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Florham Park | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Hanover | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Harding | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Jefferson | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Kinnelon | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Lincoln Park | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Long Hill | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Madison | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Mendham | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Mendham | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Mine Hill | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Montville | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Morris Plains | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Morris | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Town of Morristown | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Mount Arlington | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Mount Olive | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| Borough of Mountain Lakes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Netcong Borough | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Parsippany-Troy Hills | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Pequannock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Randolph | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Borough of Riverdale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Municipality | Facility Types | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dam | DPW | Electric Substation | EMS | Emergency Operation Center | Fire Station | Hazardous Material | Municipal Hall | Natural Gas | School | Senior | Wastewater Facility |
| Borough of Rockaway | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Rockaway | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Roxbury | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 0 | 1 |
| Borough of Victory Gardens | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Township of Washington | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 3 | 1 | 2 |
| Borough of Wharton | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Morris County (Total)** | **4** | **2** | **1** | **3** | **1** | **5** | **2** | **1** | **1** | **10** | **1** | **4** |

*Source: Morris County, HAZUS-MH, NJGWS*
*Note: DPW – Department of Public Works*
*EMS – Emergency Medical Services*

## Impact on the Economy

Geologic hazards can impose direct and indirect impacts on society. Direct costs include the actual damage sustained by buildings, property and infrastructure. Indirect costs, such as clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity are difficult to measure. Additionally, ground failure threatens transportation corridors, fuel and energy conduits, and communication lines (USGS 2003). Estimated potential damages to general building stock can be quantified as discussed above. For the purposes of this analysis, general building stock damages are discussed further.

Direct building losses are the estimated costs to repair or replace the damage caused to the building. There are 127 buildings located in the Class A Landslide Susceptibility zones, which accounts for approximately $92 million, or 0.1% of the County's total building cost. 695 buildings are located in the Class B Landslide Susceptibility zones and account for approximately $603 million, or 0.4% of the County's total. These dollar value losses to Morris County's total building inventory replacement value would impact Morris County's tax base and the local economy.

Many of the major transportation routes in the County would be affected by a landslide in the designated susceptible areas. These include NJ-15, US-46, -202, -206, and I-80 and -287. In addition, many of the rail lines would be affected. These include the Morris & Essex Line and Montclair-Boonton Line.

A landslide or sinkhole/subsidence event will alter the landscape. In addition to changes in topography, vegetation and wildlife habitats may be damaged or destroyed, and soil and sediment runoff will accumulate downslope potentially blocking waterways and roadways and impacting quality of streams and other water bodies. Additional environmental impacts include loss of forest productivity. Sinkhole and subsidence events can cause major damage to buildings if they occur on the property. There are 8,110 buildings located within karst areas and account for $7.3 billion, or 4.7% of the County's total building cost.

## Future Growth and Development

As discussed in Section 4 and Volume II, Section 9, areas targeted for future growth and development have been identified across Morris County. It is anticipated that new development within the identified hazard area will be exposed to such risks.

## Change of Vulnerability

Morris County and all plan participants continue to be vulnerable to the geological hazards. However, there are differences between the potential loss estimates between this plan update to the results in the original 2010 HMP. Their differences are due to the use of updated population data and an updated general building stock based upon improvement value from MODIV tax assessment data.

## Effect of Climate Change on Vulnerability

Providing projections of future climate change for a specific region is challenging. Some scientists feel that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the Earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. National Aeronautics and Space Administration (NASA) and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes.

Secondary impacts of earthquakes could be magnified by future climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity because of the increased saturation. Dams storing increased volumes of water from changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

## Additional Data and Next Steps

Obtaining historic damages to buildings and infrastructure incurred due to ground failure will help with loss estimates and future modeling efforts, given a margin of uncertainty. More detailed landslide susceptibility zones can be generated so that communities can more specifically identify high hazard areas. Further, research on rainfall thresholds for forecasting landslide potential may also be an option for Morris County.