4.3.7 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 Essex County.

2020 HMP Update Changes

- All subsections have been updated using best available data.
- Previous occurrences were updated with events that occurred between 2014 and 2019.
- Updated New Jersey Geological Survey and Water landslide susceptibility data (2016) was utilized for the risk assessment.

4.3.7.1 Profile

Hazard Description

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).

Although gravity acting on an over-steepened slope is the primary reason for a landslide, there are other contributing factors that include:

- Erosion by rivers, glaciers, or ocean waves create over-steepened slopes
- Rock and soil slopes are weakened through saturation by snowmelt or heavy rains
- Earthquakes create stresses that make weak slopes fail
- Earthquakes of magnitude 4.0 and greater have been known to trigger landslides
- Volcanic eruptions produce loose ash deposits, heavy rain, and debris flows
- Excess weight from accumulation of rain or snow or stockpiling of rock or ore, from waste piles or man-made structures may stress weak slopes to failure (USGS 2016).

Landslides may be triggered by both natural and human-caused changes in the environment. Warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavement, or sidewalk
- Soil moving away from foundations
- Ancillary structures, such as decks and patios, tilting and moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls, or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity
- Sudden increase in creek water levels while rain is still falling or just recently ended
- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together (USGS 2013).

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 (NJOEM 2019).

Sinkholes, the type of subsidence most frequently seen in the New Jersey, are a natural and common geologic feature in areas with underlying limestone, carbonate rock, salt beds, or other rocks that are soluble in water. Over periods of time, measured in thousands of years, the carbonate bedrock can be dissolved through acidic rain water moving in fractures or cracks in the bedrock. This creates larger openings in the rock through which water and overlying soil materials will travel. Over time the voids will enlarge until the roof over the void is unable to support the land above will collapse forming a sinkhole. In this example the sinkhole occurs naturally, but in other cases the root causes of a sinkhole are anthropogenic. These anthropogenic causes can include those that involve changes to the water balance of an area such as: over-withdrawal of groundwater; diverting surface water from a large area and concentrating it in a single point; artificially creating ponds of surface water; and drilling new water wells. These actions can serve to accelerate the natural processes of creation of soil voids, which can have a direct impact on sinkhole creation (NJOEM 2019).

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 (NJOEM 2019).

Expansive Soils

Expansive soil is usually comprised of a fine-grained clay that occurs naturally and is generally found in areas that historically were a flood plain or lake area, but can occur in hillside areas also. Expansive soil is subject to swelling and shrinkage, varying in proportion to the amount of moisture present in the soil (Essex County HMP 2007).

Other than soil moisture, the most important property affecting the degree of volume change in a soil is mineralogy. Clay minerals are the most common cause of expansive soils, although calcium sulfates (gypsum and anhydrite) and iron sulfides can also experience volume changes. Generally speaking, expansive soils often appear sticky when wet, and have surface cracks when dry (Essex County HMP 2007).

Structures built on this type soil tend to subside. Expansive movement can easily crack foundations, slabs, walls, stucco and fences. Because soils dry from the surface down, this type of soil can successfully host structures if foundations and/or footings are placed deep enough into the soil. If the surface receives enough moisture so that the soil column never dries to the bottom of the footing, the structure should not settle or lift (Essex County HMP 2007).

Location

Within Essex County, the highest elevations of approximately 660 feet above sea level are found at four areas along the Second Watchung Mountain within Verona, North Caldwell and Essex Fells. Areas along the First Watchung Mountain near Eagle Rock Reservation and Mills Reservation reach elevations of approximately 600 feet. Elevations decrease eastward of the first Watchung; ranging between 500 and 600 feet approximately eight miles outside central Newark and decreasing to around 200 feet five miles from the city. Elevations are near sea level at Newark Bay (Essex County Environmental Resource Inventory 2007).

Essex County contains a number of steep slope areas, particularly along the Watchung Ridges. "Steep" slopes are those slopes typically at a 15% gradient or greater. S lopes included in the mapping are between 15% and 60% gradients. Essex County steep slope areas exist primarily along the second Watchung Mountain Ridge in Cedar Grove, Verona, and south through portions of the Second and along the First Watchung Mountain Ridge in West Orange and through Maplewood. NJDEP mapping identifies steep slopes extending along the eastern edge of the First Watchung Mountain from South Mountain in Montclair southwest through West Orange and South Orange. Many additional small areas of steep slopes are mapped in central Essex County. In east Essex County, pockets of steep slope areas are mapped around portions of Weequahic Lake in Newark and near Yantacaw Park in Nutley (Essex County Environmental Resource Inventory 2007).

Landslides

Landslides are common in New Jersey, primarily in the northern region of the State. 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). 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 4.3.7-1 shows landslide susceptibility in Essex County. A majority of the County is not susceptible to landslides. There are small areas in the central portion of the County that are susceptible to landslide events (Class AI, AII, AIV, AVI, BIII, and BIV). Table 4.3.7-1 summarizes the area within each class. According to the figure and table, the Townships of Fairfield and Millburn have the largest areas landslide susceptible areas. Overall, approximately 1.4 square miles of Essex County are located in landslide hazard areas; 0.42 square miles in Class A and 0.94 square miles in Class B.

Figure 4.3.7-1. Landslide Susceptibility in Essex County

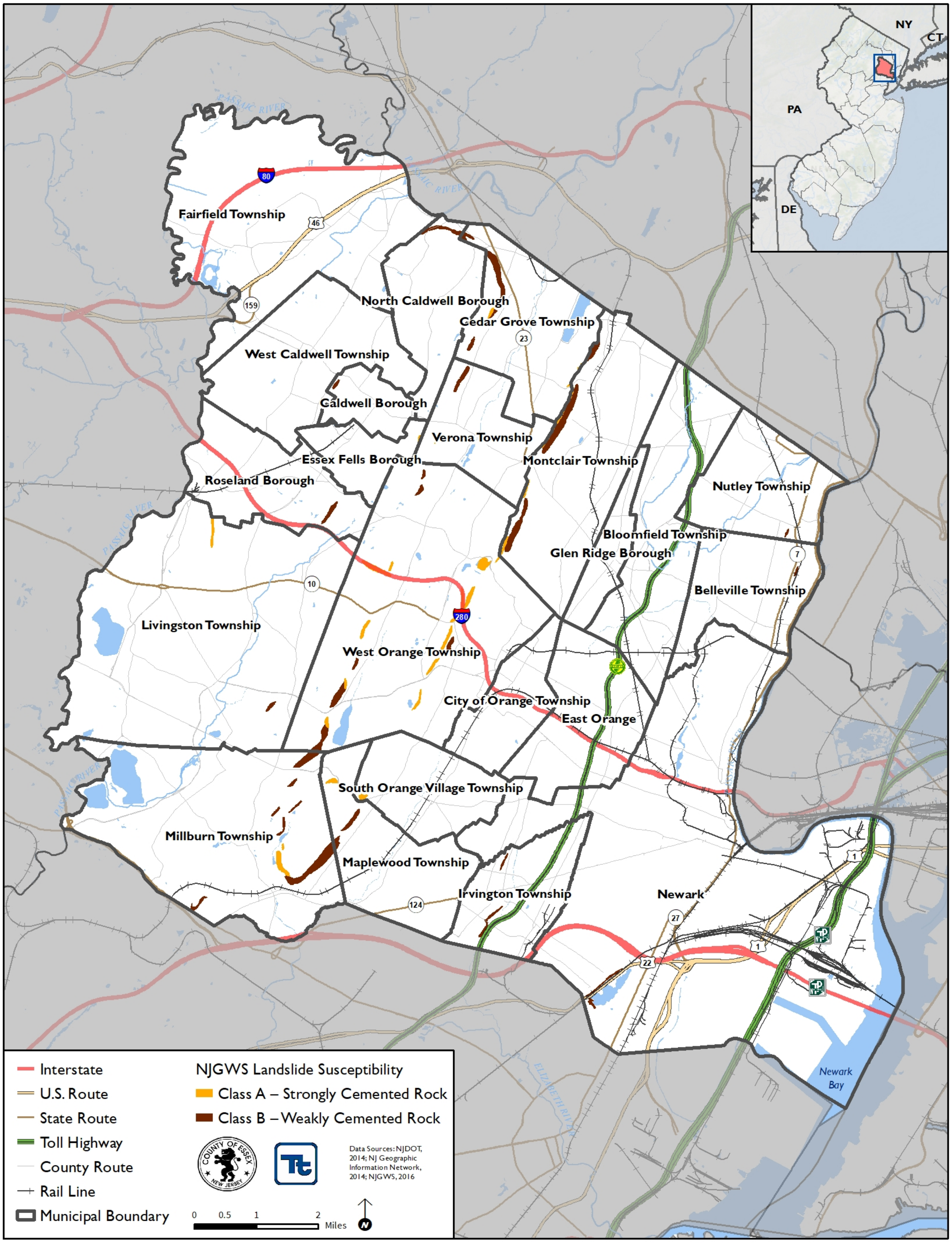


Table 4.3.7-1. Total Land Area Located in the Landslide Susceptible Areas

Municipality	Total Area (acres)	NJGWS-Defined Landslide Susceptible Areas	
		Class A and B (sq mi)	% Total
Township of Belleville	2,156	4	0.2%
Township of Bloomfield	3,434	0	0.0%
Borough of Caldwell	759	5	0.7%
Township of Cedar Grove	2,791	103	3.7%
City of East Orange	2,514	0	0.0%
Borough of Essex Fells	906	3	0.3%
Township of Fairfield	6,618	0	0.0%
Borough of Glen Ridge	818	3	0.4%
Township of Irvington	1,866	22	1.2%
Township of Livingston	9,040	20	0.2%
Township of Maplewood	2,480	37	1.5%
Township of Millburn	6,324	166	2.6%
Township of Montclair	3,995	179	4.5%
City of Newark	16,778	21	0.1%
Borough of North Caldwell	1,968	26	1.3%
Township of Nutley	2,186	3	0.1%
City of Orange Township	1,418	0	0.0%
Borough of Roseland	2,361	16	0.7%
Township of South Orange Village	1,822	9	0.5%
Township of Verona	1,796	24	1.3%
Township of West Caldwell	3,239	0	0.0%
Township of West Orange	7,756	230	3.0%
Essex County (Total)	**83,023**	**870**	1.0%

Source: NJGWS 2016

Notes: 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 types were identified in Essex County. Total area includes land and water.

% percent

sq mi square miles

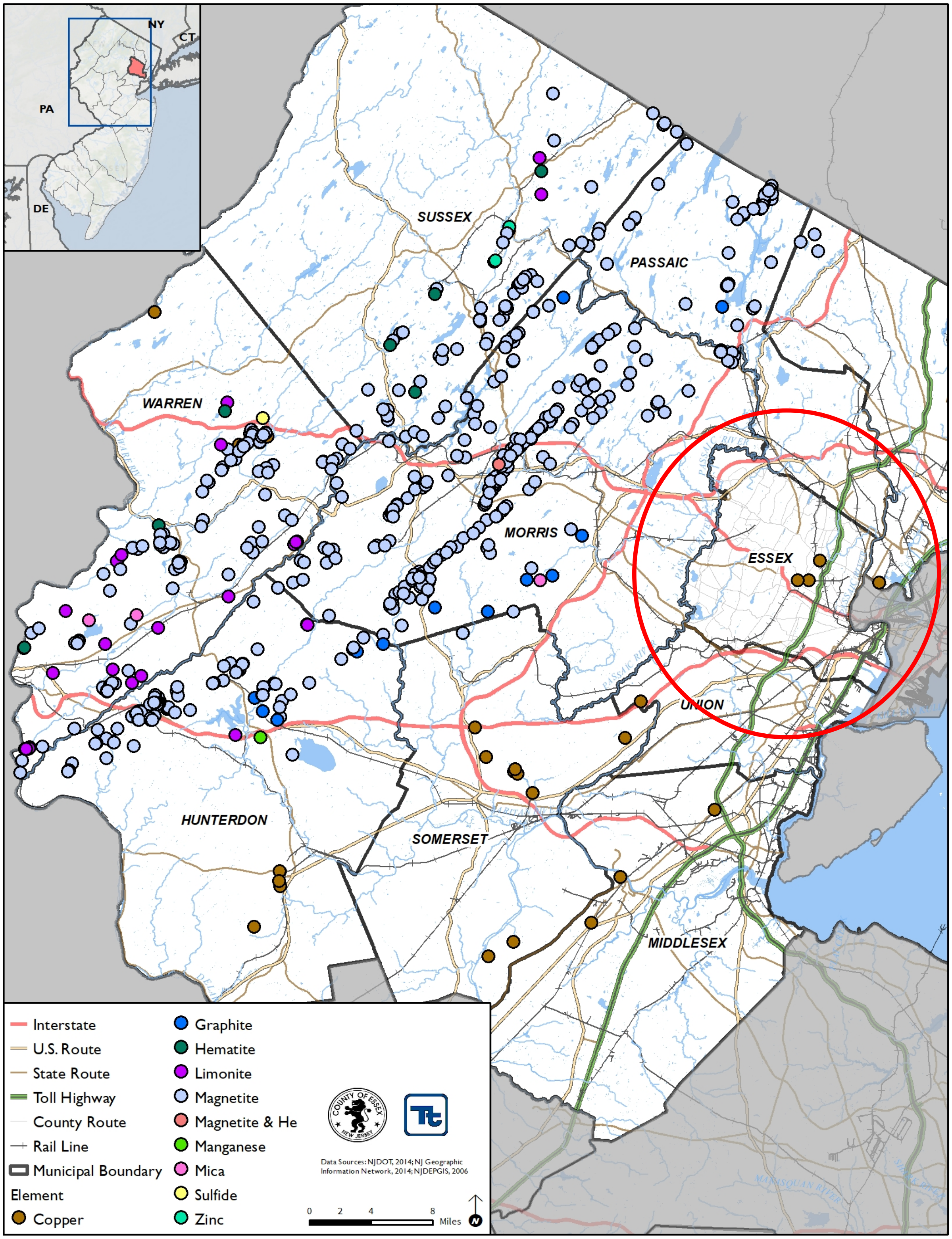
Subsidence/Sinkholes

New Jersey is susceptible to the effects of subsidence and sinkholes, primarily in the northern region of the State. The State's susceptibility to subsidence is due in part to the number of abandoned mines throughout New Jersey. The State historically was an iron-producing state and the first mines in New Jersey were drilled in the early

1700s, with operations continuing until 1986 when the last active mine was closed. 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.

Figure 4.3.7-2 shows the location of the mapped abandoned mines in New Jersey. The data from NJGWS and the figure indicate that Essex County has three abandoned mines. All three mines in Essex County were copper mines: located in East Orange, Orange, and Glen Ridge (NJGWS 2006).

Figure 4.3.7-2. Abandoned Mines in New Jersey



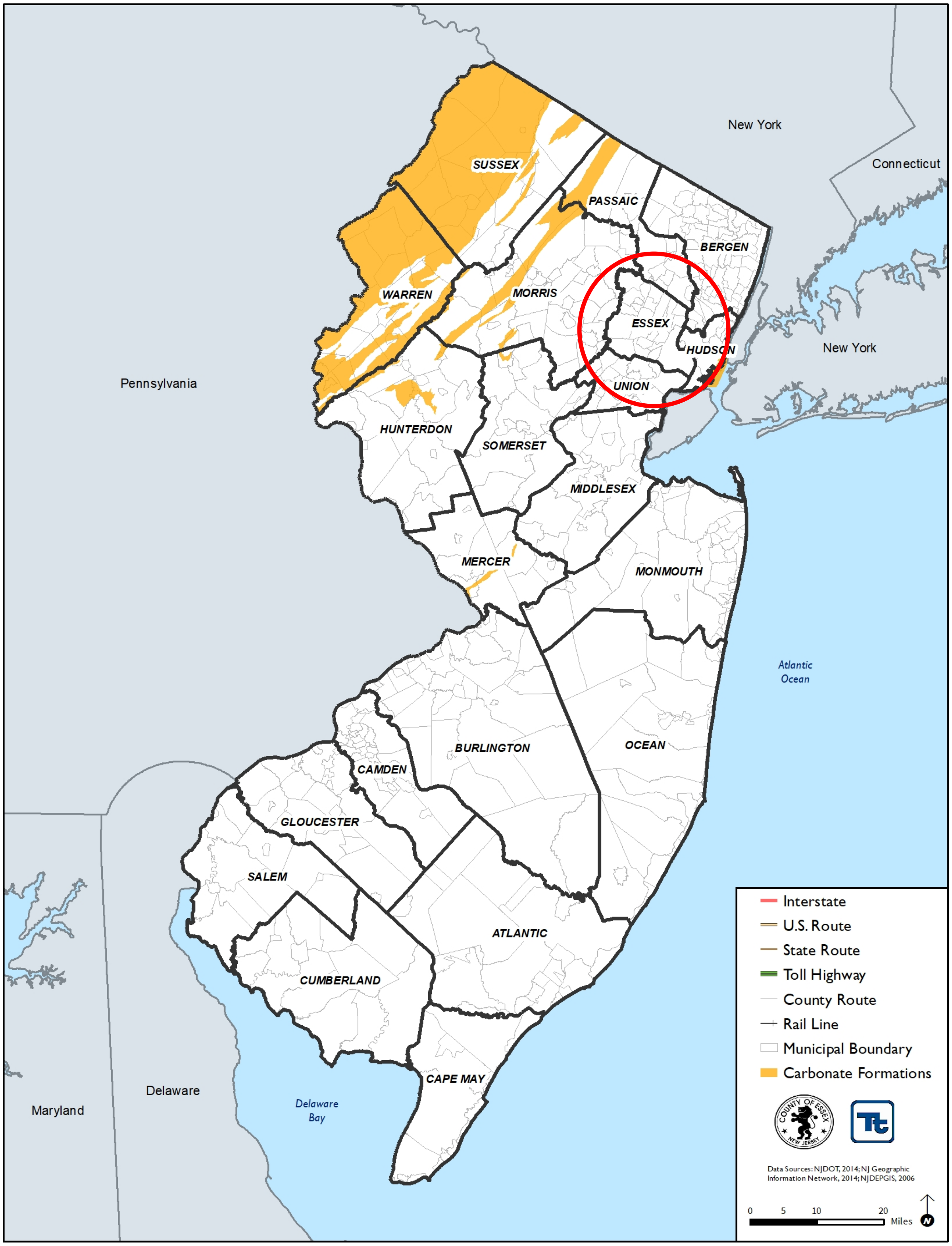
Note: The red circle indicates the location of Essex County.

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. No collapse sinkholes have been identified; however, there are some features which could be either very shallow solution depressions or wind blowout features. Sinkholes in New Jersey are generally concentrated in the northwestern part.

Areas underlain by carbonate rock may contain surface depressions and open drainage passages making such areas unstable and susceptible to subsidence and surface collapse. As a result, the alteration of drainage patterns, placement of impervious coverage, grade changes or increased loads can result in land subsidence and sinkhole formation (Piefer 2006).

Figure 4.3.7-3 illustrates the locations of carbonate-bearing geologic formations of New Jersey. These formations are areas of potential natural subsidence. These geologic units contain a high enough percentage of carbonate minerals such as calcite and/or dolomite for karst features such as sinkholes to form. Some of these units are more prone to sinkhole development than others due to a greater carbonate content in the rock. Although not every unit listed has documented sinkholes, all are susceptible to dissolution by groundwater so various karst features, including sinkholes, may be found on any of these units. According to this figure, Essex County does not contain carbonate rock formations.

Figure 4.3.7-3. Carbonate Rock Regions of New Jersey



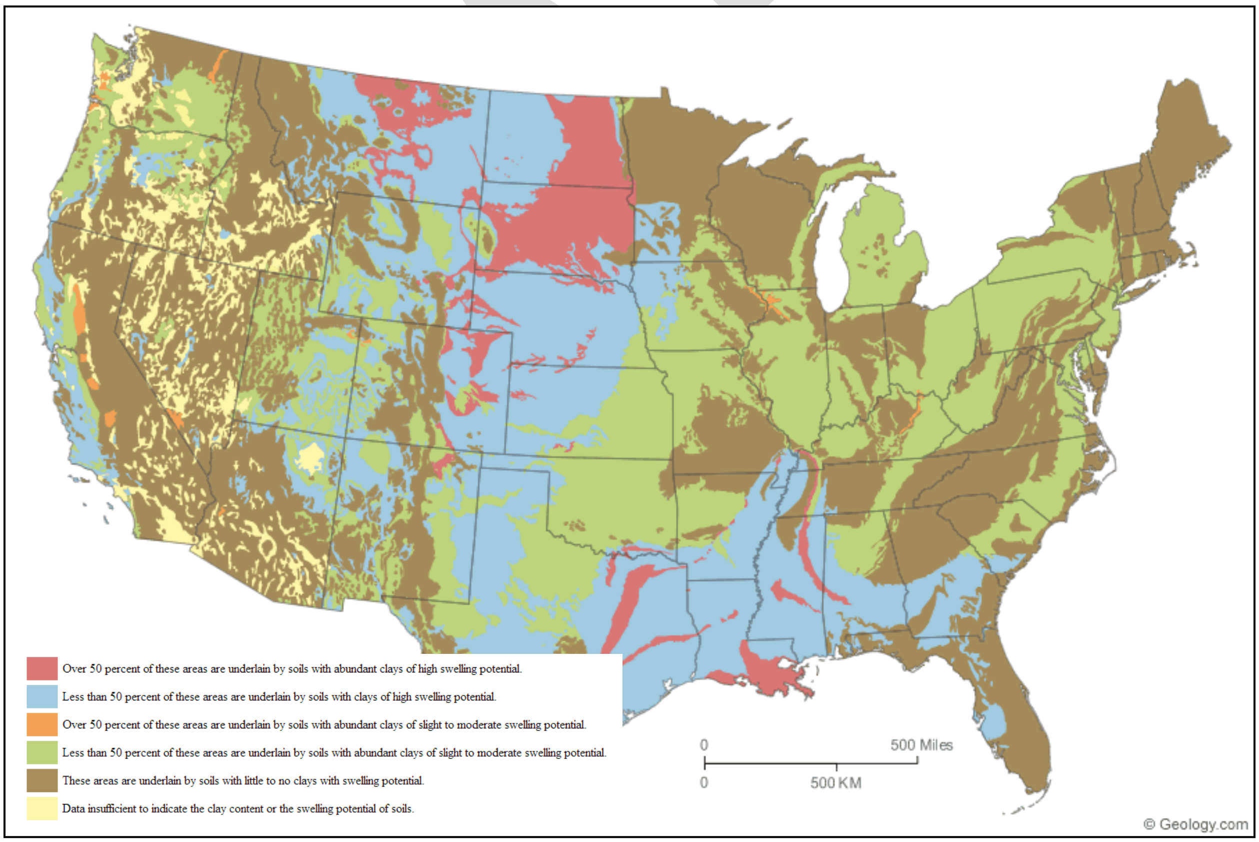
Note: The red circle indicates the location of Essex County. The County does not have carbonate formations.

While fewer karst features have been mapped in existing urban areas, human activity can often be the cause of a subsidence or sinkhole event. Furthermore, the lack of karst features exhibited in maps of urban areas is likely a result of development activities that disguise, cover, or fill existing features rather than an absence of the features themselves. Leaking water pipes or structures that convey stormwater runoff may also result in areas of subsidence as the water dissolves substantial amounts of rock over time. In some cases, construction, land grading, or earthmoving activities that cause changes in stormwater flow can trigger sinkhole events. Subsidence or sinkhole events may occur in the presence of mining activity, especially in areas where the cover of a mine is thin, even in areas where bedrock is not necessarily conducive to their formation. Piggott and Eynon (1978) indicated that sinkhole development normally occurs where the interval to the ground surface is less than three to five times the thickness of the extracted seam, and the maximum interval is up to ten times the thickness of the extracted seam. Sub-surface (i.e. underground) extraction of materials such as oil, gas, coal, metal ores (copper, iron, and zinc), clay, shale, limestone, or water may result in slow-moving or abrupt shifts in the ground surface.

Expansive Soils

Portions of New Jersey are underlain by soils with little to no clays with swelling potential. Essex County has less than 50 percent of the area underlain by soils with abundant clays of slight to moderate swelling potential (Figure 4.3.7-4).

Figure 4.3.7-4. Expansive Soils of the United States



Source: Geology.com 2014

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 (Geological Hazards Program 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 (Geological Hazards Program Date Unknown, OAS 1991).

Subsidence/Sinkhole

Subsidence and sinkholes occur 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 2014).

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 2014).

Expansive Soils

The plasticity index (PI) is expressed as the numerical difference between the plastic limit (the percent moisture content at which clay passes from the solid to the plastic state) and the liquid limit (the percent moisture content at which clay passes from the plastic to liquid state). The PI bears a direct relation to the amount and type of clay minerals present and to the orientation and size of clay particles. Other factors remain constant, the PI increases with amount of clay minerals, decreases with degree of parallel orientation of the clay minerals, and decreases with clay particle size (FEMA 1996).

The PI is generally a good indicator of swelling potential. Scientists have found the PI to be one of the most useful indicators of swelling potential. Expansive soils can be recognized either by visual inspection in the field or by conducting laboratory analyses (FEMA 1996).

Previous Occurrences and Losses

Between 1954 and 2019, FEMA issued a disaster (DR) or emergency (EM) declaration for the State of New Jersey for one geological hazard-related event, classified as a mudslide. Of those events, Essex County has not been included any declarations (EM and DR) (FEMA 2014).

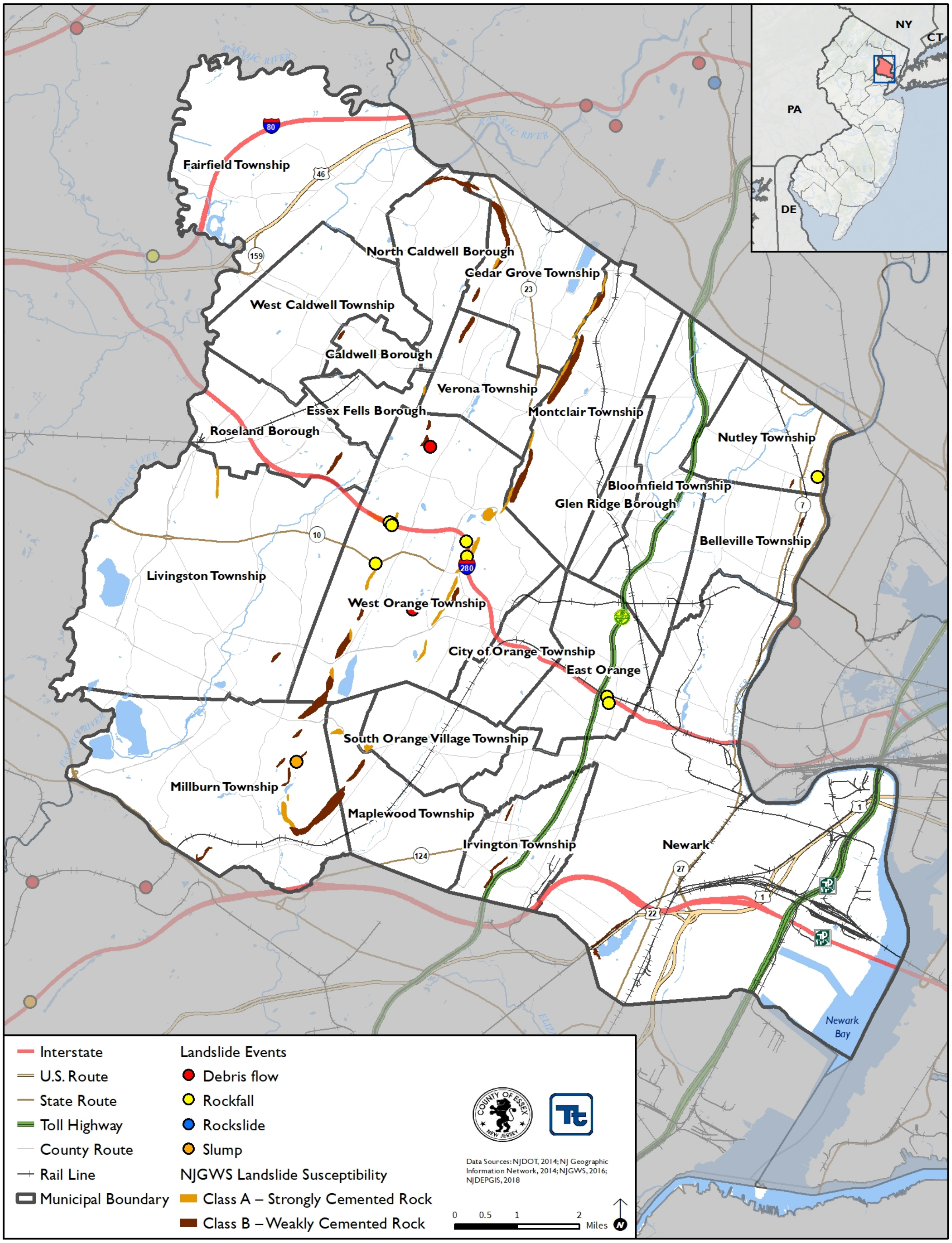
Geological hazard events that have impacted Essex County between 2014 and 2019 are identified in Table 4.3.7-2. With geological hazard documentation for New Jersey and Essex County being so extensive, not all sources have been identified or researched. Therefore, Table 4.3.7-2 may not include all events that have occurred in the County.

Table 4.3.7-2. Geological Hazard Events in Essex County, 2014 to 2019

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Essex County Designated?	Description
April 2014	Weathering	N/A	N/A	Rockfall along Rt. 280 in East Orange off ramp leading to Garden State Parkway, estimated location.
December 6, 2014	Rockfall	N/A	N/A	A 3,000-4,000 lb. boulder rolled down a hill and crashed into a car. The rockfall was attributed to prior heavy rains earlier in the month. The boulder caused about $8,000 worth of damage to a Subaru Forrester.

Source: NJGWS 2017 NOAA-NCEI 2019
N/A Not applicable
NCDC National Climatic Data Center
NJDEP New Jersey Department of Environmental Protection
NOAA National Oceanic and Atmospheric Administration

Figure 4.3.7-5. Landslide Susceptibility Areas and Historic Landslide Events



Probability of Future Occurrences

Based upon risk factors for and past occurrences, it is likely that geological hazards will occur in Essex County in the future. It is estimated that Essex County will continue to experience 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 4.1, the identified hazards of concern for Essex 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 'occasional'.

Climate Change Impacts

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

Both northern and southern New Jersey have become wetter over the past century. Northern New Jersey's 1971-2000 precipitation average was over five inches (12%) greater than the average from 1895-1970 (Office of New Jersey State Climatologist). Annual precipitation in New Jersey has been 8-percent above average during the last 10 years; and has experienced an upward trend of 4.1 inches in precipitation in 100-years (NJDEP 2019).

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, 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.

Expansive Soils

As the climate changes and temperatures increase, soils have the potential to dry out, resulting in expansive soils shrinking and failing. This could lead to a big problem in residential areas where buildings have shallow foundations; the soils will be unable to support the weights of a building. When expansive soils get dry, they begin to repel moisture instead of soaking it up. The water is more likely to run off, creating flash floods. It takes a slow and steady rain, over an extended period of time, to restore expansive clay soils (Gehr 2014).

4.3.7.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed and/or vulnerable to the identified hazard. For geological hazards, NJGWS landslide susceptibility areas have been identified as the hazard area; due the lack of spatially delineated subsidence hazard areas in the County, a spatial analysis was not conducted. The following text summarizes the potential impact of geological hazards on the County. Refer to Section 4.2 (Methodology and Tools) for additional details on the methodology used to assess geological hazard risk.

Impact on Life, Health and Safety

Generally, a landslide or subsidence event would be an isolated incidence and impact the populations within the immediate area of the incident. Specifically, the population located downslope of the landslide hazard areas are particularly vulnerable to this hazard. In addition to causing damages to residential buildings and displacing residents, landslides and subsidence events can block off or damage major roadways and inhibit travel for emergency responders or populations trying to evacuate the area.

Table 4.3.7-3 summarizes the population located in Class A and Class B landslide susceptible areas. The Township of West Orange has the greatest number of populations located in Class A areas with 256 people (less than 1-percent of its total), while the Township of Irvington has the greatest number of populations located in Class B areas with 838 peoples (1.5-percent of its total).

Table 4.3.7-3. Estimated Population Located in the Landslide Hazard Areas

Municipalities	American Community Survey (2013-2017) Population	NJGWS-Defined Landslide Susceptible Areas			
		Class A	% Total	Class B	% Total
Township of Belleville	36,383	0	0.0%	5	0.0%
Township of Bloomfield	48,892	0	0.0%	0	0.0%
Borough of Caldwell	8,032	0	0.0%	43	<1%
Township of Cedar Grove	12,638	25	<1%	114	<1%
City of East Orange	65,151	0	0.0%	0	0.0%
Borough of Essex Fells	2,095	8	0.4%	0	0.0%
Township of Fairfield	7,671	0	0.0%	0	0.0%
Borough of Glen Ridge	7,668	0	0.0%	3	0.0%
Township of Irvington	54,715	0	0.0%	838	1.5%
Township of Livingston	29,955	12	<1%	25	<1%
Township of Maplewood	24,706	0	0.0%	117	0.5%
Township of Millburn	20,387	0	0.0%	314	1.5%
Township of Montclair	38,572	41	<1%	497	1.3%
City of Newark	282,803	0	0.0%	0	0.0%
Borough of North Caldwell	6,637	0	0.0%	57	<1%
Township of Nutley	28,829	0	0.0%	76	<1%
City of Orange Township	30,731	0	0.0%	0	0.0%
Borough of Roseland	5,907	0	0.0%	13	<1%
Township of South Orange Village	16,503	18	<1%	0	0.0%

Municipalities	American Community Survey (2013-2017) Population	NJGWS-Defined Landslide Susceptible Areas			
		Class A	% Total	Class B	% Total
Township of Verona	13,585	3	0.0%	0	0.0%
Township of West Caldwell	10,932	0	0.0%	0	0.0%
Township of West Orange	47,609	256	<1%	186	<1%
Essex County (Total)	**800,401**	**364**	**<1%**	**2,288**	**<1%**

Sources: American Community Survey 5-year Estimate, 2017; NJGWS, 2016
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 Essex County.
NJGWS New Jersey Geological Water Survey

Socially vulnerable populations (e.g. the elderly and low-income populations) are particularly vulnerable to a hazard event. Within Class A areas, there are approximately 78 people over the age of 65 and 16 people below the poverty level. As for populations within Class B areas, there are approximately 334 people over the age 65 and 219 people considered low income populations.

Impact on General Building Stock

In general, the built environment located in the high landslide susceptibility area and the population, structures and infrastructure located downslope are vulnerable to this hazard. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary losses to businesses and residents. There are 612 buildings with a replacement cost value of $404 million located in these areas countywide. The Township of West Orange has the greatest number of buildings located in Class A areas with 62 buildings (less than 1-percent of its total) with an estimated replacement cost of $52 million, while the Township of Montclair has the greatest number of buildings located in Class B areas with 140 buildings (1.5-percent of its total) with an estimated replacement cost of $91 million. Table 4.3.7-4 summarizes the exposed building stock located in Class A and Class B landslide susceptibility areas by municipality.

Table 4.3.7-4. Number of Buildings in the Landslide Hazard Area by Municipality

Municipality	Total Number of Buildings	Total Replacement Cost Value (RCV)	Class A				Class B			
			Number of Buildings - Class A	% of Total	RCV - Class A	% of Total	Number of Buildings - Class B	% of Total	RCV - Class B	% of Total
Township of Belleville	7,910	$4,483,250,138	0	0.0%	$0	0.0%	1	<1%	$359,884	<1%
Township of Bloomfield	11,720	$6,021,089,887	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
Borough of Caldwell	1,738	$1,183,204,981	0	0.0%	$0	0.0%	8	<1%	$4,937,770	<1%
Township of Cedar Grove	3,944	$3,008,045,785	8	<1%	$9,889,827	<1%	35	<1%	$31,804,607	<1%
City of East Orange	7,908	$6,090,766,912	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
Borough of Essex Fells	766	$527,629,662	3	<1%	$1,745,705	<1%	0	0.0%	$0	0.0%
Township of Fairfield	3,121	$6,082,819,367	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
Borough of Glen Ridge	2,256	$1,095,474,263	0	0.0%	$0	0.0%	1	<1%	$593,925	<1%
Township of Irvington	7,934	$5,384,838,816	0	0.0%	$0	0.0%	120	1.5%	$40,533,104	<1%
Township of Livingston	9,795	$7,691,376,811	4	<1%	$2,322,170	<1%	9	<1%	$7,155,578	<1%
Township of Maplewood	6,738	$3,575,395,600	0	0.0%	$0	0.0%	33	<1%	$17,862,543	<1%
Township of Millburn	6,437	$5,241,567,136	0	0.0%	$0	0.0%	92	1.4%	$56,360,432	1.1%
Township of Montclair	9,436	$5,845,976,130	12	<1%	$10,037,037	<1%	140	1.5%	$91,235,148	1.6%
City of Newark	43,085	$40,970,549,425	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
Borough of North Caldwell	2,095	$1,727,767,442	0	0.0%	$0	0.0%	18	<1%	$22,907,921	1.3%
Township of Nutley	7,945	$3,841,553,722	0	0.0%	$0	0.0%	13	<1%	$4,901,120	<1%
City of Orange Township	3,890	$3,520,865,708	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
Borough of Roseland	1,794	$1,955,487,279	0	0.0%	$0	0.0%	4	<1%	$2,150,840	<1%
Township of South Orange Village	4,188	$2,877,374,186	6	<1%	$15,365,495	<1%	0	0.0%	$0	0.0%
Township of Verona	4,113	$2,213,338,613	1	<1%	$501,935	0.0%	0	0.0%	$0	0.0%
Township of West Caldwell	3,730	$3,533,044,820	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
Township of West Orange	11,845	$8,358,783,858	62	<1%	$52,442,928	<1%	42	<1%	$30,403,393	<1%
Essex County (Total)	**162,388**	**$125,230,200,542**	**96**	**<1%**	**$92,305,098**	**<1%**	**516**	**0.3%**	**$311,206,265**	**0.2%**

Sources: Microsoft, 2018, Open Street Map, 2019; NJOIT, 2018; NJGWS, 2016

Note: NJGWS New Jersey Geological Water Survey
RCV Replacement Cost Value
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 Essex County.

Impact on Critical Facilities

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 Philadelphia and 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. Overall, there are 2 critical facilities located in landslide susceptible areas – both facilities are in the Township of Montclair (1 communication facility and 1 water tank).

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 2005). 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.

Most of the areas that are potentially at risk to the landslide hazard are located along the ridges of the Watchung Mountains in areas that have steep slopes. Many of these areas remain undeveloped. Interstate 280 runs through the center of the County from the northwest corner of the County to the southeastern corner of the County and traverses both the western and eastern ridges of this mountain range. There is risk to potential landslides along this road in these areas; however, engineering standards would have likely mitigated landslide potential.

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. There are 612 buildings located on steep slopes and account for $404 million, or less than 1-percent of the County's total building replacement cost. These losses would impact Essex County's tax base and the local economy.

I-280 and US-22 are major roadways that are used every day by commuters and provide access to major urban areas within and outside the County. I-280 runs west to east across the County and through some of the most densely populated areas in eastern Essex County, and provides access to major areas of both Morris and Hudson Counties. US-22 provides access to populations from Union County and other western New Jersey communities to the US-1&9 corridor in the City of Newark. Both of these roads traverse the landslide susceptible areas, and a landslide impacting these roadways would cause cascading impacts to populations throughout the region.

Future Changes that May Impact Vulnerability

Understanding future changes that effect vulnerability in the County can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. The County considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of climate change

Projected Development

Any areas of growth could be potentially impacted by the geologic hazard if located within the identified hazard areas or downslope. In general, development of slopes is not recommended due to the increased risk of erosion, stormwater runoff and flooding potential. The additional runoff results in sedimentation of down slope surface waters, which damages habitat and has the potential to damage property. The sloping land increases the rate of runoff, which reduces the rate of groundwater infiltration. This effect is exacerbated when vegetation is unnecessarily stripped from the slope (Essex County Environmental Resource Inventory 2007). Several municipalities within the County have steep slope ordinances to restrict development in these areas.

Each municipality identified areas of recent development and proposed development in their community. Developments that could be located using an address or Parcel ID were geocoded and overlain with the landslide hazard areas to determine vulnerability to flooding. No identified new development is located in a landslide susceptible area. Refer to Section 3 (County Profile), and Volume II Section 9 (Jurisdictional Annexes) for potential new development and landslide hazard areas in Essex County and Figure 4.3.7-6 which illustrates the proposed new development and the landslide hazard areas in Essex County.

Projected Changes in Population

According to population projections from the State of New Jersey Department of Labor and Workforce Development, Essex County will experience an increase in population through 2034 (approximately 40,000 people between 2017 and 2034). Population change is not expected to have a measurable effect on the overall vulnerability of the county's population over time. As discussed above, I-280 and US-22 are exposed to the landslide hazard areas, and an increasing population will result in a greater vulnerability as more people are using these roadways on a daily basis. Refer to Section 4.3.1, Population Trends in the County Profile, includes a discussion on population trends for the county.

Climate Change

A direct impact of climate change on landslides is difficult to determine. Multiple secondary effects of climate change have the potential to increase the likelihood of landslides. Warming temperatures resulting in wildfires would reduce vegetative cover along steep slopes and destabilize the soils due to destruction of the root system; increased intensity of rainfall events would increase saturation of soils on steep slopes. Under these future conditions, the County's assets located on or at the base of these steep slopes will have an increased risk to landslides. Roadways and other transportation infrastructure located in these areas will also be at an increased risk of closure, which would impact the County's risk as described above .

Higher temperatures and the possibility of more intense, less frequent summer rainfall may lead to changes in water resource availability. The projection in the increase of average temperatures may lead to an increase in the frequency of droughts. Sinkhole activity intensifies in some karst areas increases during periods of drought. With an increase in drought periods, the number of sinkholes can increase (Linares et al. 2016). Additionally, changes to the water balance of an area including over-withdrawal of groundwater, diverting surface water from a large area and concentrating it in a single point, artificially creating ponds of surface water, and drilling new water wells will cause sinkholes. These actions can also serve to accelerate the natural processes of bedrock degradation, which can have a direct impact on sinkhole creation.

Change of Vulnerability Since 2015 HMP

The entire County continues to be vulnerable to the landslide hazard. Several differences exist between the 2015 HMP and this update including updated hazard data and asset inventory data. As discussed in Section 4.2 (Methodology and Tools), an updated general building stock based upon replacement cost value from MODIV tax assessment data and 2019 RS Means, and an updated critical facility inventory were used to assess the County's risk to the identified hazards of concern. In addition, the 2017 American Community Survey population estimates were used and estimated at a structural level in place of the 2010 U.S. Census blocks. Updated hazard areas were used as well; since the 2015 HMP, the NJGWS has released updated landslide susceptibility data. The updated data was used for the exposure analysis and to update HAZUS-MH's default earthquake data. Overall, the hazard area delineations remained unchanged, so any signification increase in vulnerability would be attributed to population growth and new development.

Figure 4.3.7-6. Potential New Development and Landslide Hazard Areas