4.8 GEOLOGICAL HAZARDS

SECTION 4.8 GEOLOGICAL HAZARDS

4.8-1 HAZARD OVERVIEW

For the 2024 NJ State Hazard Mitigation Plan, Geological Hazards refers to landslides, land subsidence/sinkholes, radon exposure, and saltwater intrusion.

Hazard Definitions

Landslides

According to the United States Geological Survey (USGS), the term landslide is defined as the movement of a mass of rock, debris, or earth down a slope. Landslides are a type of "mass wasting," which denotes any down-slope movement of soil and rock under the direct influence of gravity. (USGS, 2022). 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).

Almost every landslide has multiple causes. Slope movement occurs when forces acting down-slope (mainly due to gravity) exceed the strength of the earth materials that compose the slope. Causes include factors that increase the effects of down-slope forces and factors that contribute to low or reduced strength. Landslides can be initiated in slopes already on the verge of movement by rainfall, snowmelt, changes in water level, stream erosion, changes in ground water, earthquakes, volcanic activity, disturbance by human activities, or any combination of these factors. Earthquake shaking and other factors can also induce landslides underwater. These landslides are called submarine landslides. (USGS, 2022).

Sinkholes/ Subsidence

A sinkhole is a depression in the ground that has no natural external surface drainage. Basically, this means that when it rains, all of the water stays inside the sinkhole and typically drains into the subsurface. There are three types of sinkholes: *geologic, solid waste*, and *excavation*.

- *Geologic sinkholes* are most common in what geologists call, “karst terrain.” These are regions where the types of rock below the land surface can naturally be dissolved by groundwater circulating through them. Soluble rocks include salt beds and domes, gypsum, limestone, and other carbonate rock. (USGS, 2022).
- *Solid waste sinkholes* form when material, such as wood, is buried and then decays, leaving a subsurface void.
- *Excavation sinkholes* occur when fill material that was placed during an excavation erodes away or compacts. These types of sinkholes may form after a water or sewer pipe breaks, or when underground tanks (septic and/or oil) collapse.

Subsidence is the sinking of the ground because of underground material movement that is most often caused by the removal of water, oil, natural gas, or mineral resources out of the ground by pumping, fracking, or mining activities (NOAA, 2022). Subsidence can also be caused by natural events such as earthquakes, soil compaction, glacial isostatic adjustment, erosion, sinkhole formation, and adding water to fine soils deposited by wind (a natural process known as loess deposits). Subsidence can happen over very large areas like whole states or provinces, or very small areas like the corner of a property (NOAA, 2022).

Radon Exposure
Radon is an invisible, odorless, and tasteless radioactive gas that comes from uranium breaking down in soil and rock. It is the second leading cause of lung cancer in the United States, behind smoking. Radon enters homes through openings in contact with the ground, such as small openings around pipes or cracks in building foundations and can only be detected by specialized tests. Radon produces new, solid, radioactive materials that can attach to other particles in homes like dust and cigarette smoke (NJDEP, 2019).

The concentration of radon in homes is dependent on several factors. Radon moves more easily through permeable soils and fractures in rock can allow for easier movement. Homes in areas with drier, highly permeable soils and bedrock are more likely to have high indoor radon levels. Also, houses with low indoor air pressure, poorly sealed foundations, and several entry points in soil draw more air from the ground than is typical, potentially increasing the concentration of radon in the home. In addition to radon exposure through the air, radon can also be contained in water. The use of private wells can transport radon into the home and allow it to be released through showers, laundry, washing dishes, or other household activities that use water (USGS, 1992).

Saltwater Intrusion
Saltwater Intrusion occurs when saline water moves into freshwater aquifers. This naturally occurring process is an increasingly common hazard with impacts to agriculture, water supply, and implications for increased flood risk. Fresh groundwater and saline groundwater mix at a line referred to as the freshwater/saltwater interface. If freshwater is removed too quickly or without recharging at a similar rate, it can create an opportunity for saline groundwater to move inland. Additionally, it has been identified that as sea-levels rise, the pressure created is moving the freshwater/saltwater interface further inland and raising groundwater tables (USDA 2020).

Secondary Hazards
Flooding can increase the potential risk of landslides and subsidence occurring by eroding soils in susceptible areas. Additionally, droughts increase the potential for saltwater intrusion by limiting the fresh water available to flush salts out of soil and groundwater (USDA, 2020).None of the geological hazards in this plan increase the potential for secondary hazards to occur.

4.8-2 LOCATION, EXTENT AND MAGNITUDE
For this chapter, location, extent, and magnitude are discussed for each hazard contained under Geological Hazards. This is due to the interdependence between magnitude/extent and the potential location of the hazards.

Location
Landslide
The areas that are susceptible to landslide are located in the northeastern portion of the state, located in Passaic, Bergen, Morris, Essex, Somerset, Union, Middlesex, and Monmouth Counties. The only counties with High Susceptibility areas are Middlesex, Monmouth, and Somerset Counties. Figure 4.8-1 below showcases these areas.

Subsidence/Sinkholes
New Jersey may be susceptible to the effects of subsidence and sinkholes, primarily in the northern region of the State. 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. 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 that 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. Figure 4.8-2 below showcases the locations (in black) across the state where soluble carbonate rocks can be found, which may contain karst.

Figure 4.8-1 Landslide Susceptibility in New Jersey

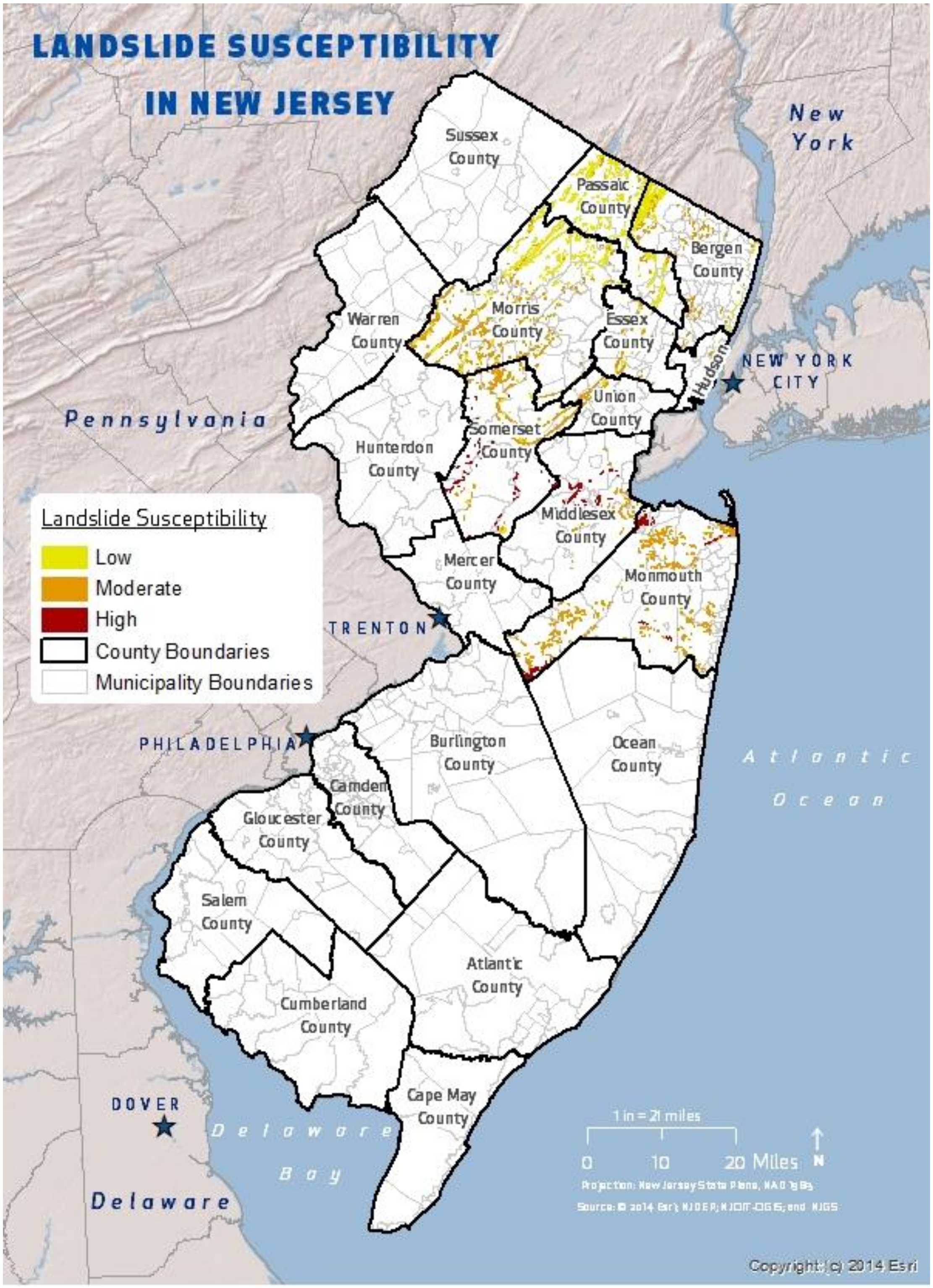
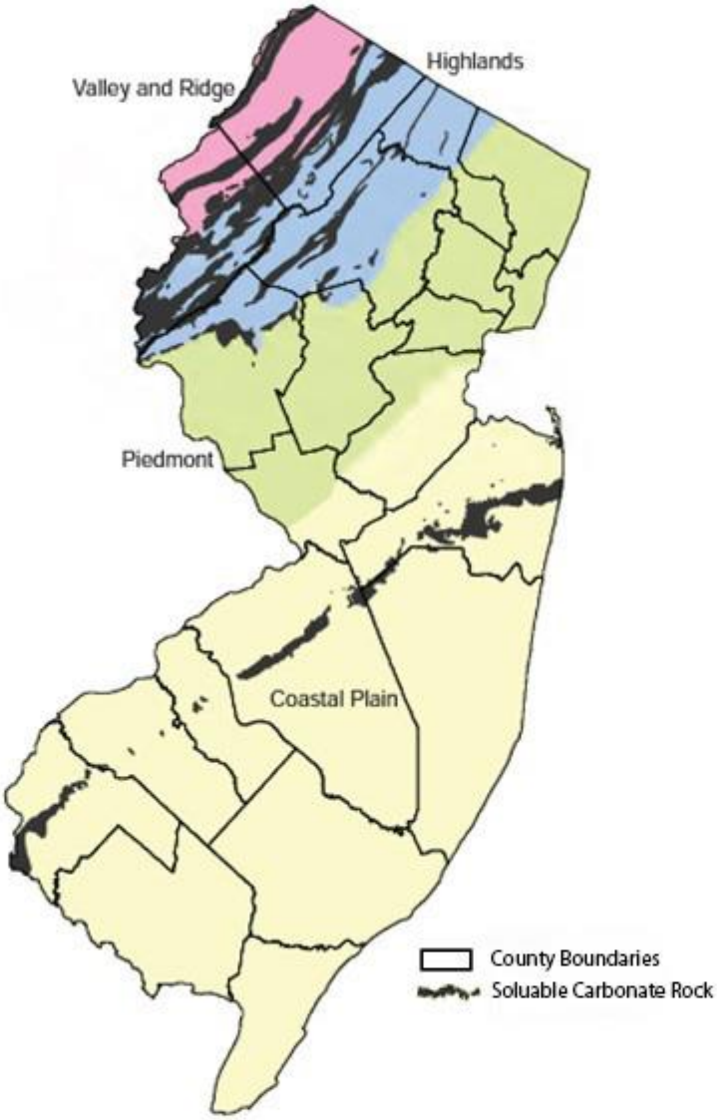


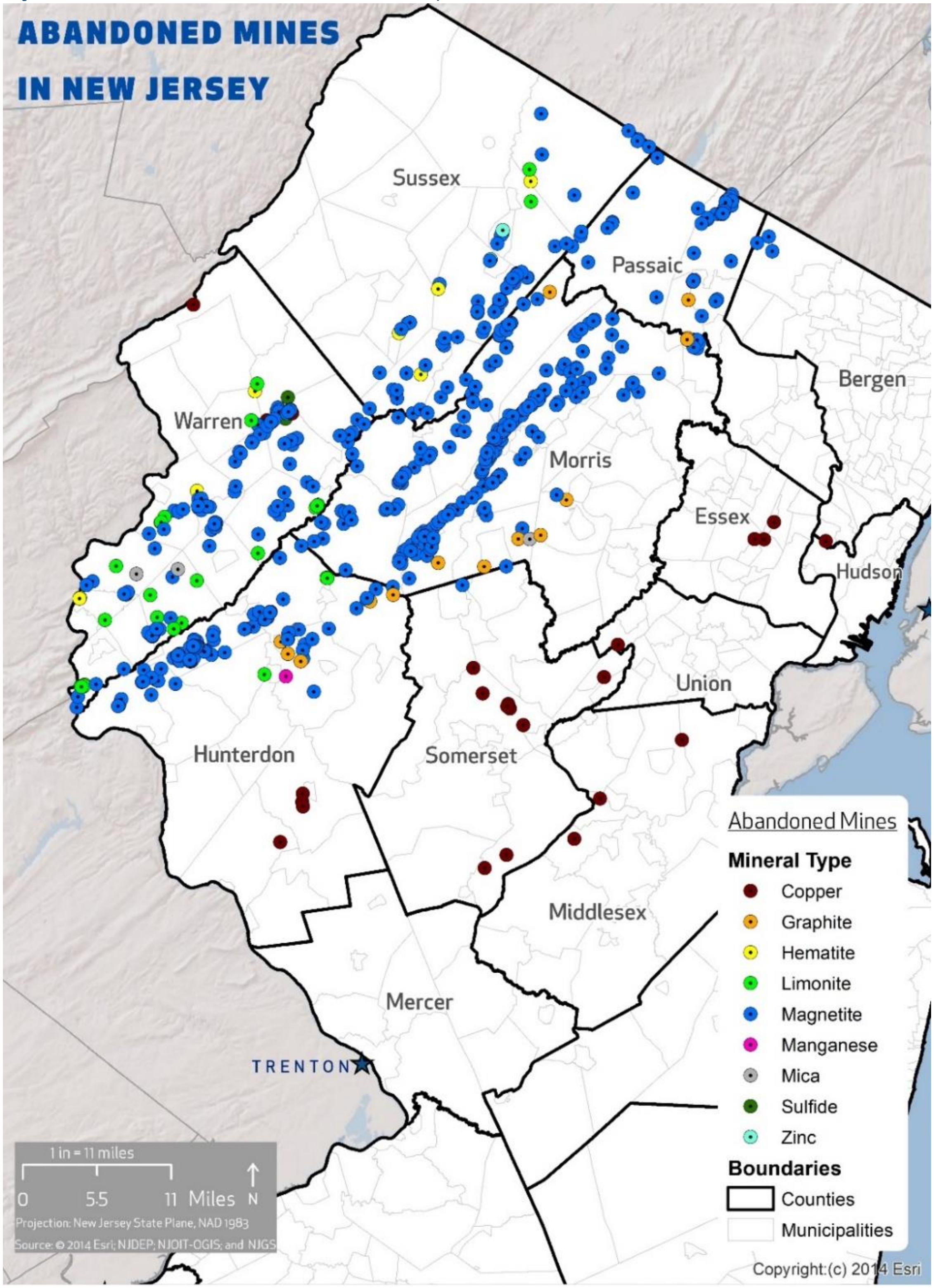
Figure 4.8-2 Physiographic Provinces and Areas Underlain By Soluble Carbonate Rock



Source: NJGWS, 2014

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 could prove 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 4.8-3 showcases their locations and a table listing of all the documented abandoned mines in New Jersey can be found in Appendix B: Risk Assessment Supplement.

Figure 4.8-3 Abandoned Mines in New Jersey



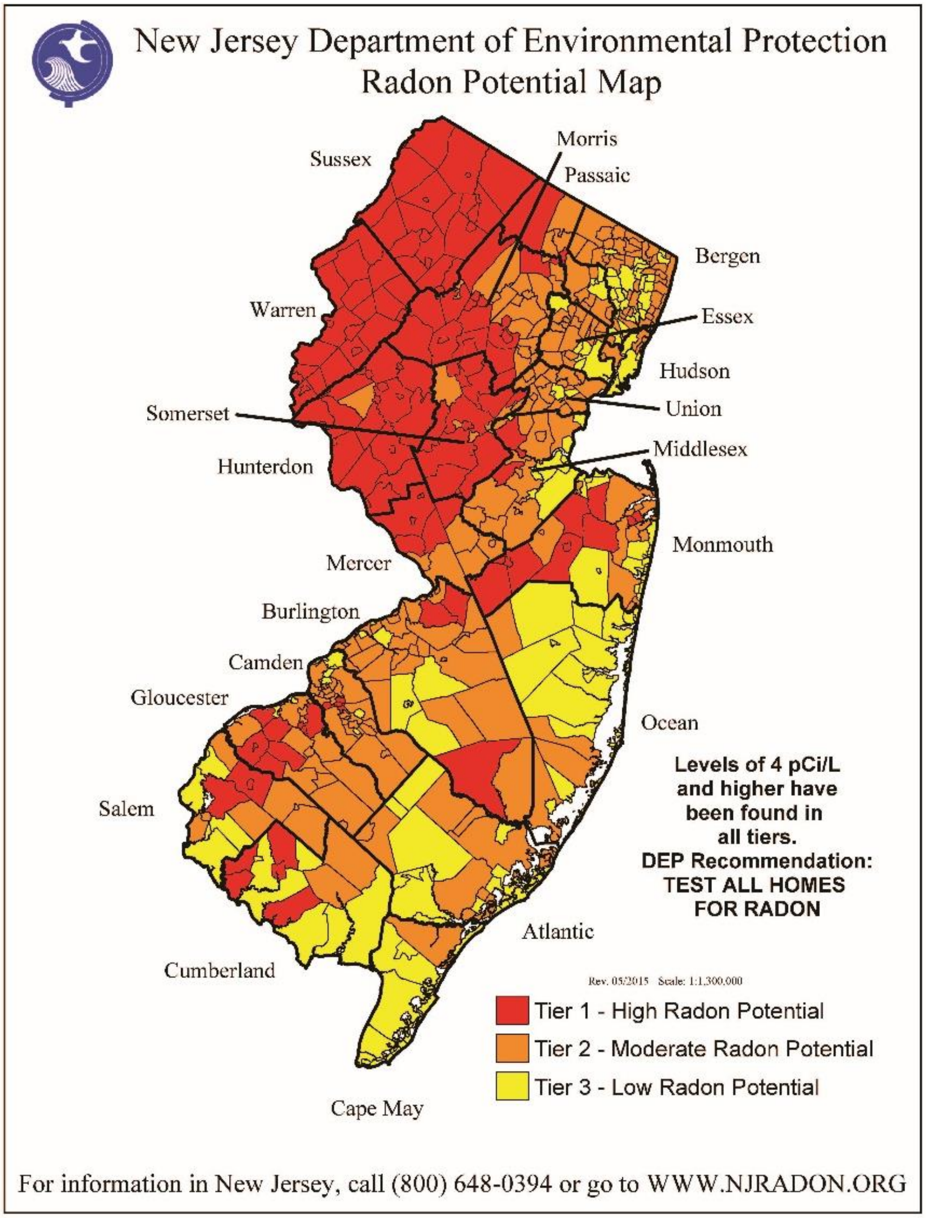
Source: NJDEP, 2014

Radon Exposure

Areas with high radon potential are scattered around New Jersey, but the majority are in the Northwest portion of the state as shown in Figure 4.8-4. All of the communities in both Sussex and Warren Counties are considered high potential, while counties such as Hunterdon, Morris, and Somerset are majority high potential areas. Coastal areas are more likely to have lower radon potentials. The following are the definitions for the different radon potentials:

- Tier 1: High potential – at least 25 homes tested with 25 percent or more having radon concentrations greater than or equal to 4 pCi/L
- Tier 2: Moderate potential – at least 25 homes tested with 5 to 24 percent having radon concentrations greater than or equal to 4 pCi/L
- Tier 3: Low potential – at least 25 homes tested with less than 5 percent having radon concentrations greater than or equal to 4 pCi/L

Figure 4.8-4 Radon Potential Across New Jersey



Saltwater Intrusion

Saltwater Intrusion occurs when saline water moves into freshwater aquifers. The aquifers most likely to be subject to saltwater intrusion are those located in the Coastal Plain, due to their proximity to saltwater and their elevation. Steadily increasing use also places these aquifers at greater risk as saltwater may enter as the freshwater is removed and the pressure resisting saltwater intrusion is lessened. In Figure 4.8-5 below, those aquifers are located below the green swath that ranges from Bergen County to Mercer County. Some of the most susceptible aquifers are in the Kirkwood-Cohansey aquifer system, which makes up most of Southern New Jersey and the entire Atlantic Coast from Ocean County to Cape May County. NJ DEP's New Jersey Water Supply Plan (2017-2022) does report that saltwater intrusion has compromised several aquifers in several places, including Raritan Bay, the Delaware River valley, the New Jersey Pine Barrens of Gloucester County, and Cape May County. Aquifers with measured saltwater intrusion include the Semi-Confined Cohansey aquifer, Lower PRM aquifer, Piney Point aquifer, and the Atlantic City 800-foot sand aquifer (NJ DEP, 2017).

Figure 4.8-5 Aquifers in New Jersey

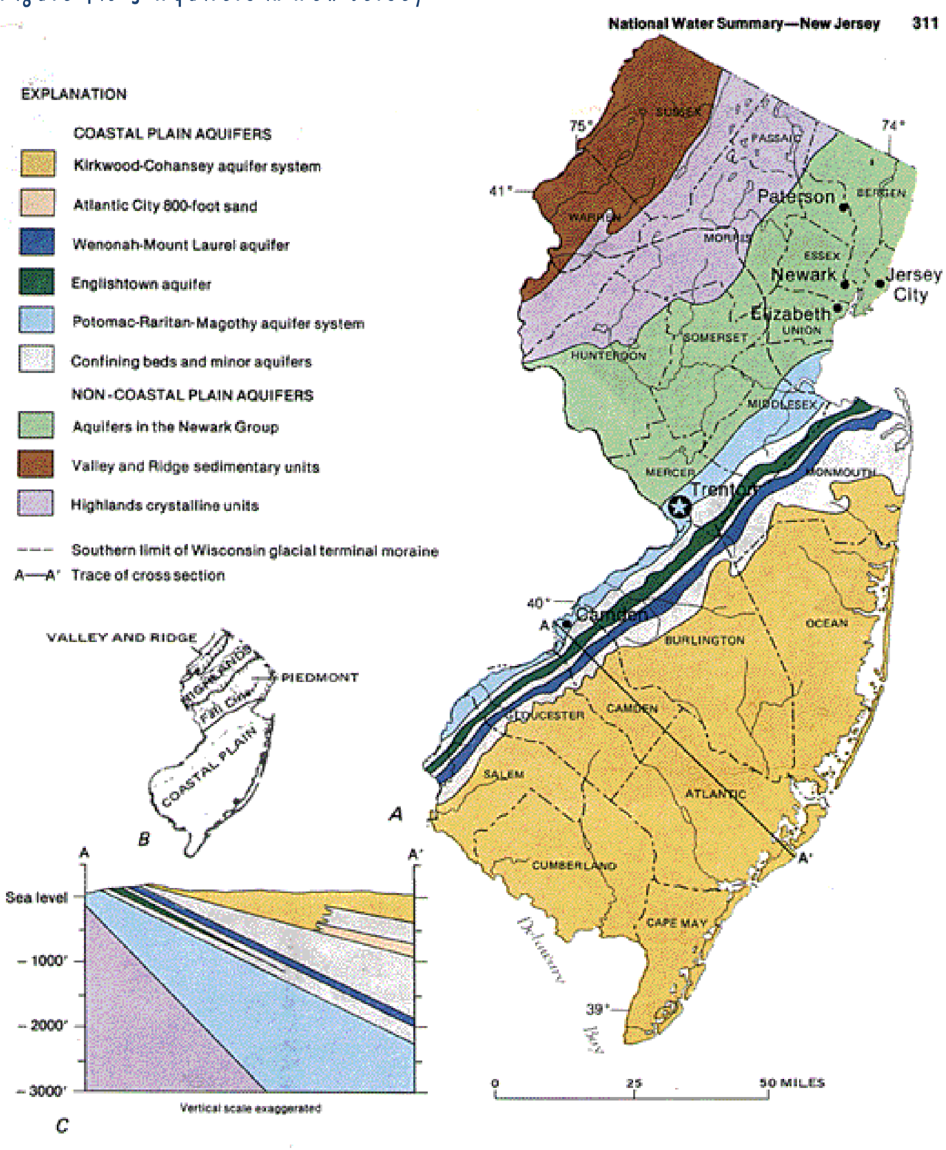


Figure 1. Principal aquifers in New Jersey. *A*, Geographic distribution. *B*, Physiographic diagram and divisions. *C*, Generalized cross section (A-A') of the Coastal Plain. (See table 2 for more detailed description of the aquifers. Sources: *A*, *C*, Compiled by O. S. Zapecza from U.S. Geological Survey files. *B*, Owens and Sohl, 1969; Ralsz, 1954.)

Extent and Magnitude

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 Geological Survey of Alabama indicates that 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 landslide; 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.
- **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 landslide.

Subsidence/Sinkhole

Subsidence and sinkholes can occur due to either natural processes (karst sinkholes in areas underlain by soluble bedrock) or because of human activities such as the Hoboken, New Jersey sinkhole outbreak in 2013 caused by two watermain breaks. Similar to landslides, 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 area include soil properties, topographic position and slope, and historical incidence.

Radon Exposure

NJDEP classifies radon potential into three separate tiers, which are covered above in Figure 4.8-4. Radon exposure is the second leading cause of lung cancer after smoking, and the concentrations of exposure play a large role in the risks associated. Smoking is an additional risk factor for radon exposure. Table 4.8-1 below showcases the exposure impacts at different radon levels, measured in pCi/L.

Table 4.8-1 Radon Risk for Smokers and Non-Smokers

Radon Level (pCi/L)	If 1,000 People Were Exposed to This Level Over A Lifetime… *	Risk Of Cancer from Radon Exposure Compares To… **	Action Threshold
SMOKERS			
20	About 260 people could get lung cancer	250 times the risk of drowning	Fix structure
10	About 150 people could get lung cancer	200 times the risk of dying in a home fire	Fix structure
8	About 120 people could get lung cancer	30 times the risk of dying in a fall	Fix structure
4	About 62 people could get lung cancer	5 times the risk of dying in a car crash	Fix structure
2	About 32 people could get lung cancer	6 times the risk of dying from poison	Consider fixing between 2 and 4 pCi/L
1.3	About 20 people could get lung cancer	(Average indoor radon level)	Reducing radon levels below 2 pCi/L is difficult
0.4	About 3 people could get lung cancer	(Average outdoor radon level)	
NON-SMOKERS			
20	About 36 people could get lung cancer	35 times the risk of drowning	Fix structure

Radon Level (pCi/L)	If 1,000 People Were Exposed to This Level Over A Lifetime… *	Risk Of Cancer from Radon Exposure Compares To… **	Action Threshold
10	About 18 people could get lung cancer	20 times the risk of dying in a home fire	Fix structure
8	About 15 people could get lung cancer	4 times the risk of dying in a fall	Fix structure
4	About 7 people could get lung cancer	The risk of dying in a car crash	Fix structure
2	About 4 people could get lung cancer	The risk of dying from poison	Consider fixing between 2 and 4 pCi/L
1.3	About 2 people could get lung cancer	(Average indoor radon level)	Reducing radon levels below 2 pCi/L is difficult
0.4		(Average outdoor radon level)	

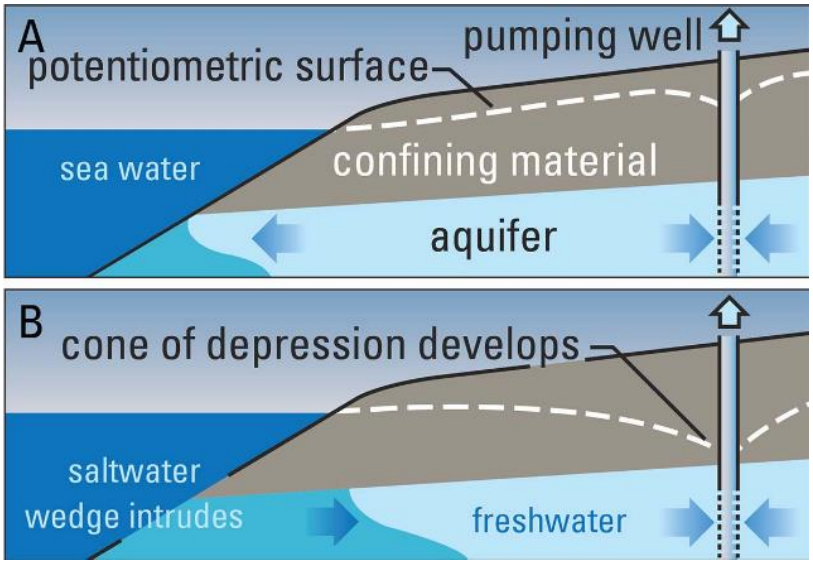
NOTE: Risk may be lower for former smokers.
* Lifetime risk of lung cancer deaths from EPA Assessment of Risks from Radon in Homes (EPA 402-R-03-003).
** Comparison data calculated using the Centers for Disease Control and Prevention's 1999-2001 National Center for Injury Prevention and Control Reports.

Source: EPA, 2016

Saltwater Intrusion

The extent of saltwater intrusion for aquifers depends on many factors. These include the rate of groundwater withdrawal, the freshwater recharge, the distance between recharge locations and saltwater sources, and both the geologic structure and hydraulic properties of the aquifer. High rates of withdrawal can create more favorable conditions for intrusion as the hydraulic pressure resisting saltwater is decreased and saltwater is drawn toward the freshwater storage areas (USGS, n.d.). Figure 4.8-6 below demonstrates this phenomenon.

Figure 4.8-6 Conceptual Figures of Saltwater Intrusion



Source: USGS, n.d.

4.8-3 PREVIOUS OCCURRENCES AND LOSSES

FEMA Disaster Declarations

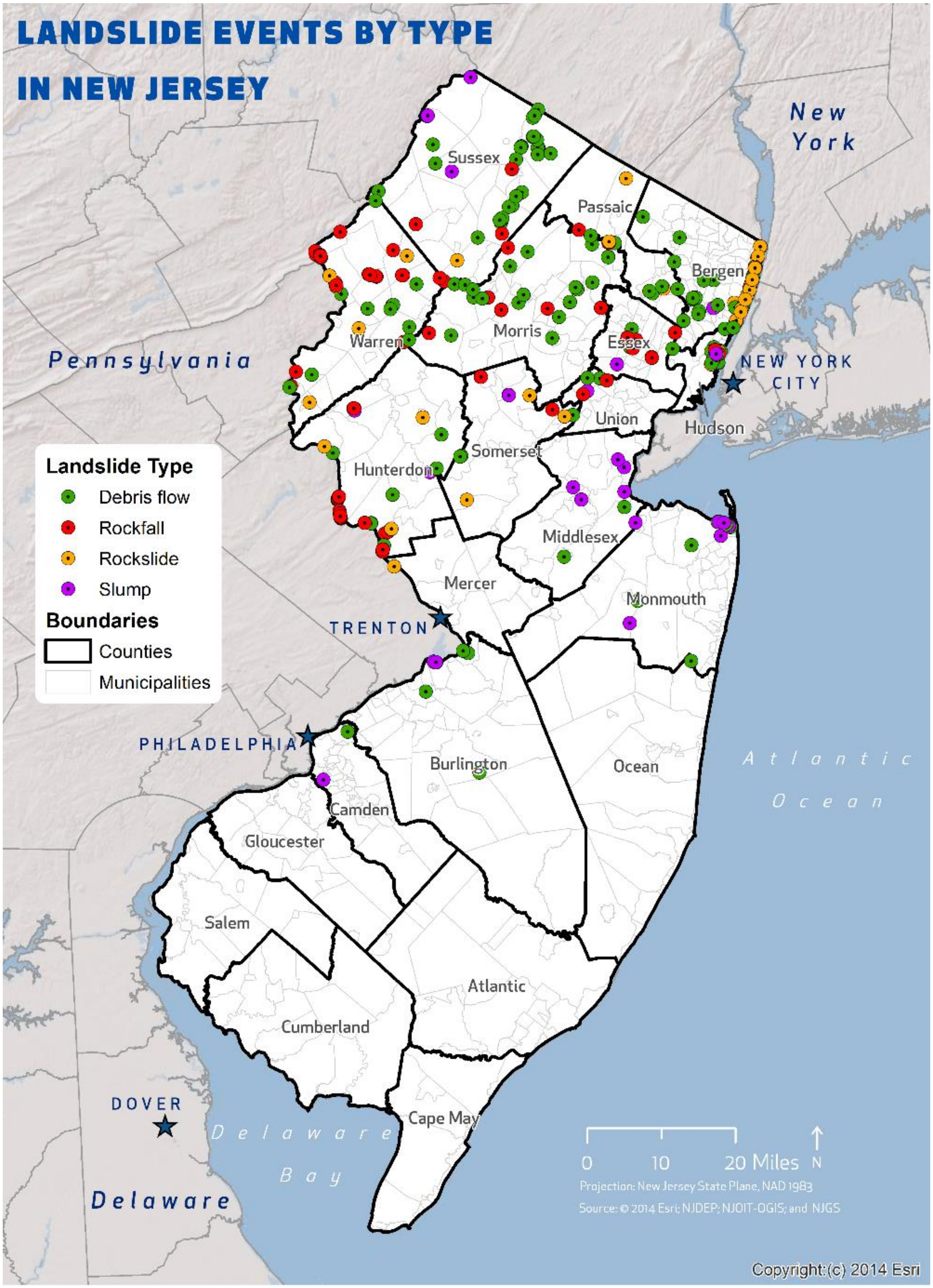
New Jersey has never had a disaster declaration or emergency management declaration specifically for landslides, subsidence/sinkhole, radon, or saltwater intrusion. Though debris flows have occurred during storm events that were subsequently issued disaster declarations. Hurricane Irene in 2011 triggered 38 debris flow events in northwestern New Jersey, while Bergen, Essex, Hunterdon, and Somerset Counties experienced 11 landslide events during Hurricane Ida in 2021.

Historical Events Summary

Landslides

Since 2010, 153 landslide events have been documented in NJ. There have been 67 Debris Flow events, 59 rockfalls, 11 rockslides, and 15 slumping events. 54 percent of these events were triggered by heavy rain, while 44 percent were associated with weathering. Of the 153 events, nine had documented damage. The cost of the damage was not recorded in the state's landslide database. Hunterdon County has experienced the highest number of landslide events, based on the number of reports rather than individual days on which landslides occurred. There have been no fatalities reported due to landslides in this period and a March 2014 rockslide in Somerset caused the only injury. Figure 4.8-7 shows the locations of all landslide events across the State in recorded history.

Figure 4.8-7 Landslide Events in New Jersey



Source: NJDEP, 2022

Subsidence/Sinkholes

Sinkhole and subsidence activities occur primarily in Warren, Sussex, Passaic, Morris, Somerset, and Hunterdon Counties (NJGWS). While there is a limited amount data available for natural (karst) sinkholes, the New Jersey Geological and Water Survey did compile data for Warren County between 1961 and 1999. Warren County had 1,251 sinkholes in that time, with 66 of them over 40,000 square feet in area. Some significant sinkhole events that have occurred since the last plan are provided below.

- In May 2021, a sinkhole opened in Morris County that required the fire department and gas company to arrive at the scene. A broken sewer pipe caused a sinkhole that placed a nearby high pressure main in danger (TAPinto, 2021).
- In October 2022, a sinkhole opened on the beach in Monmouth County after an outflow pipe malfunctioned. The pipe had done the same multiple times in the past but been repaired each time. Officials were hopeful that a more permanent repair would prevent future leaks and additional sinkholes forming (News12 New Jersey, 2022).
- In August 2022, a 72-inch water main break in Essex County caused excess water to flood a roadway and resulted in a massive sinkhole. The water was flowing at 25,000 gallons per minute. A driver and her car were caught in the sinkhole, but the driver was able to swim to safety. The vehicle was later towed out of the sinkhole (Stunson, 2022).
- In May 2023, a sinkhole opened on Route 37 in Ocean County on a Monday morning, impacting commuting times for travelers in the area. The sinkhole closed two westbound lanes, but there were no reports of damaged vehicles or injuries. An investigation of the site revealed that a potential cause was a damaged stormwater pipe that needed to be replaced. The repair work was complicated by a natural gas line that crossed the area of the sinkhole (Wall, 2023).

Radon Exposure

There is no inventory or database of radon exposure events across the state. However, radon testing occurs continuously and is tracked. As of 2019, 36.9 percent of homes in New Jersey have been tested and around 10% of these tests have revealed radon levels at or above the action level recommended by the EPA (NJSHAD, 2020; American Lung Association, 2022). The positive test rate is the 8th lowest in the country.

Saltwater Intrusion

There is no inventory or database of saltwater intrusion events across the state. However, NJ DEP's New Jersey Water Supply Plan (2017-2022) does report that saltwater intrusion has compromised aquifers in several places, including Raritan Bay, the Delaware River valley, the New Jersey Pine Barrens of Gloucester County, and Cape May County. Supply wells in Wildwood, Cape May City, and Lower Township were abandoned due to saltwater intrusion. Aquifers with measured saltwater intrusion include the Semi-Confined Cohansey aquifer, Lower PRM aquifer, Piney Point aquifer, and the Atlantic City 800-foot sand aquifer (NJ DEP, 2017).

Salinity intrusion, resulting from sea level rise and drought conditions, can be an issue for water users with intakes in the upper Delaware River Estuary, also known as the tidal Delaware River. In that part of the Estuary, the salinity of the water is still suitable for use as source water for public water supplies with treatment, thermoelectric power generation, manufacturing, and industrial purposes. The last major salinity intrusion event here was in the 1960s. The current drought management program for the main stem Delaware River established by the Delaware River Basin Commission (DRBC) in 1983, was designed to protect both the aquifers near and upstream of Camden and drinking water utilities with reservoir releases to add freshwater to the Estuary for salinity repulsion. Currently studies are underway or planned to assess the ability of the drought management program to balance interests, continue to repel salinity, and manage flood risk, considering the threats of sea level rise and climate change, which may affect freshwater inflows to the estuary.

4.8-4 PROBABILITY OF FUTURE OCCURRENCES

Each of the four hazards covered in the chapter are highly likely to occur in New Jersey in the future. Given changes in precipitation, sea-level rise, and changes in development, it is possible that the potential for the magnitude/extent of the risk and frequency may also change. However, the location of susceptibility for landslide, radon, subsidence, and saltwater intrusion events is expected to remain relatively static as the driving factors for the potential location of occurrence is underlying bedrock and soil formation.

Potential Effects of Climate Change

Many different phenomena influence the stability of slopes and cause landslides, subsidence, and sinkholes. It is not well understood exactly how climate and geophysical processes interact; however, it is predicted that climate change will increase the frequency of geohazards through changes in precipitation, temperature, and sea level rise (Univ of Washington, 2015).

Landslide

New Jersey is becoming hotter and wetter. Rainfall in the state is expected to become more intense and frequent, with overall precipitation projected to increase by 4% to 11% by 2050 (NJDEP, 2020). Intense rainfall can saturate and destabilize soil creating landslide conditions. Additionally, warming temperatures and changing precipitation patterns could increase the occurrence and duration of droughts, which could increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. Although less of a concern given the geography of New Jersey's coast, sea level rise could increase landslide probability for unprotected beaches and bluffs.

Subsidence/Sinkholes

A significant trigger for subsidence and sinkholes is an abundance of moisture which has the potential to permeate the bedrock causing an event. The projected increase in precipitation levels in the state will coincide with an increased potential risk in subsidence and sinkholes in vulnerable areas. Subsidence and sinkholes can also be caused through groundwater depletion. Extended drought periods can result in high levels of groundwater withdrawal for personal and agricultural uses. As precipitation patterns change due to climate change, periods of intense drought are expected to increase. This can create conditions favorable for sinkholes to form.

Radon Exposure

Radon exposure in New Jersey could increase in the future due to indirect effects of climate change. Summers in the state are becoming hotter and heat waves becoming longer and more frequent (NJDEP, 2020) . Increased air conditioning and fan usage, necessitated by increasing temperatures and more frequent heat waves, leads to decreased air exchange rates particularly in tightly sealed homes and could potentially lead to higher radon concentration and exposure (EPA, 2010).

Saltwater Intrusion

Water resources along the coasts face risks from saltwater intrusion due to climate change. Rising sea levels, and changes in water demand and availability due to factors like drought can increase the risk of saltwater intrusion into both groundwater and surface water. Sea levels in the state could rise between 1.4 feet and 2.1 feet by 2050 (NJDEP, 2020). This could result in saltwater intrusion in groundwater aquifers or encroachment further upstream into surface waters. Extended periods of drought forecasted as a result of climate change can lead to increased groundwater pumping which exacerbates intrusion.

4.8-5 VULNERABILITY ASSESSMENT

Method and Data Sources

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 potential impact of geological hazards to and the built environment (including state facilities), population and economy, and ecosystems and natural assets in New Jersey. Spatial analysis was performed for landslide vulnerable areas.

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). This dataset uses HAZUS landslide classification categories, based on the angle of the slope, the type of geologic material forming the slope, and groundwater level.

- Class AI-Strongly cemented rock, slope angle 15-20 degrees (HAZUS number 1)
- Class AII-Strongly cemented rock, slope angle 20-30 degrees (HAZUS number 2)
- Class AIV-Strongly cemented rock, slope angle 30-40 degrees (HAZUS number 5)

- Class AVI-Strongly cemented rock, slope angle >40 degrees (HAZUS number 7)
- Class BIII-Weakly cemented rock and sandy soil, slope angle 10-15 degrees (HAZUS number 3)
- Class BIV-Weakly cemented rock and sandy soil, slope angle 15-20 degrees (HAZUS number 4)
- Class BV- Weakly cemented rock and sandy soil, slope angle 20-30 degrees (HAZUS number 7)
- Class CVI-Shales and clayey soil, slope angle 10-15 degrees (HAZUS number 8)
- Class CVII-Shales and clayey soil, slope angle 15-20 degrees (HAZUS number 9)
- Class CIX-Shales and clayey soil, slope angle 20-40 degrees if dry, 10-15 degrees if groundwater at surface (HAZUS number 9)
- Class CX-Shales and clayey soil, groundwater at surface, slope angle >15 degrees (HAZUS number 10)

Vulnerable Jurisdictions

Susceptibility to geohazards varies by county in New Jersey due to geologic conditions. Some counties do not identify geohazards as a hazard of concern. In addition to the rankings created by the counties, Table 4.8-2 below includes the Hazard Risk Rating data from the National Risk Index. The ratings are relative to other jurisdictions and based on an equation that accounts for expected annual loss, social vulnerability, and community resilience. For more information on the NRI, see Section 4.1 Risk Assessment Overview. Organization of hazards does not align perfectly between the NRI and County HMPs or among the counties themselves. The only geohazard included within the NRI is landslide whereas County HMP sections may group geohazards or discuss them separately depending on local context.

Table 4.8-2 Geohazard Risk Rankings

County	Landslide		Geohazard	Land Subsidence
	NRI Hazard Risk Rating	Ranking by County HMP	Ranking by County HMP	Ranking by County HMP
Atlantic	Relatively Low	Not Profiled	Not Profiled	Not Profiled
Bergen	Relatively Moderate	Profiled, Not Ranked	Profiled, Not Ranked	Profiled, Not Ranked
Burlington	Relatively Low	High	Not Profiled	Not Profiled
Camden	Relatively Low	Medium	Medium	Medium
Cape May	Very Low	Not Profiled	Not Profiled	Not Profiled
Cumberland	Relatively Low	Not Profiled	Low	Not Profiled
Essex	Relatively Moderate	Not Profiled	Medium	Not Profiled
Gloucester	Relatively Low	Low	Low	Low
Hudson	Relatively Moderate	Medium	Medium	Medium
Hunterdon	Relatively Moderate	Medium	Medium	Medium
Mercer	Relatively Moderate	Medium	Medium	Medium
Middlesex	Relatively Moderate	Low	Low	Low
Monmouth	Relatively Moderate	Medium	Not Profiled	Not Profiled
Morris	Relatively Moderate	Medium	Medium	Medium
Ocean	Relatively Low	Not Profiled	Not Profiled	Low
Passaic	Relatively Moderate	Medium	Medium	Medium
Salem	Relatively Low	Not Profiled	Low	Not Profiled
Somerset	Relatively Moderate	Not Profiled	Not Profiled	Not Profiled
Sussex	Relatively Moderate	Medium	Medium	Medium
Union	Relatively Moderate	Low	Low	Not Profiled
Warren	Relatively Moderate	High	High	High

Source: FEMA NRI (accessed June 2023), County Hazard Mitigation Plans (accessed June 2023)

Table 4.8-3 below shows the total land area located in each seismic soil class (Class A, Class B, Class C) calculated for each county. Based upon the analysis using NJGWS data, Bergen, Passaic, Morris, and Hudson Counties have the greatest area delineated with landslide susceptible soils.

Table 4.8-3 Total Land Located in the Landslide Areas

County	Total Area (sq. mi)	NJGWS-Defined Landslide Susceptible Areas					
		Class A (sq. mi.)	% Total	Class B (sq. mi)	% Total	Class C (sq. mi)	% Total
Atlantic	610.7	-	-	-	-	-	-
Bergen	239.8	5.1	2.1%	1.5	0.6%	0	0.0%
Burlington	820.3	-	-	-	-	-	-
Camden	227.6	-	-	-	-	-	-
Cape May	286.1	-	-	-	-	-	-
Cumberland	501.8	-	-	-	-	-	-
Essex	129.7	0.4	0.3%	0.9	0.7%	0	0.0%
Gloucester	336.2	-	-	-	-	-	-
Hudson	51.5	0.4	0.7%	0	0.0%	0	0.0%
Hunterdon	437.3	-	-	-	-	-	-
Mercer	228.8	-	-	-	-	-	-
Middlesex	317	0	0.0%	0.6	0.2%	0.7	0.2%
Monmouth	485.7	0	0.0%	4.2	0.9%	0	0.0%
Morris	481.4	4.7	1.0%	6.9	1.4%	1	0.2%
Ocean	757.9	-	-	-	-	-	-
Passaic	198.3	6.3	3.2%	0.6	0.3%	0	0.0%
Salem	347.1	-	-	-	-	-	-
Somerset	304.9	1.4	0.5%	3.1	1.0%	0.6	0.2%
Sussex	535.5	-	-	-	-	-	-
Union	105.4	0.2	0.2%	0.8	0.8%	0	0.0%
Warren	362.6	-	-	-	-	-	-

Source: NJGWS 2005; USGS 2001

Built Environment

Table 4.8-4 shows estimated potential annual losses (EAL) for geohazards by county in the state of New Jersey. Total building EAL was derived from FEMA's National Risk Index while EAL for state owned assets was calculated using Replacement Cost Value for state owned facilities per county derived from LBAM data and Expected Annual Loss Rate for Buildings by county provided by the NRI. Of the hazards contained in this chapter, the NRI only includes estimates for landslides.

Table 4.8-4 Estimated Potential Annual Losses for Geologic Hazards

County	Landslides	
	Total Buildings	State-Owned Assets
Atlantic	$4,500.00	$30.73
Bergen	$147,013.64	$131.98
Burlington	$5,395.72	$34.68
Camden	$4,500.00	$22.18
Cape May	$1,759.14	$5.29
Cumberland	$4,500.00	$96.63

County	Landslides	
	Total Buildings	State-Owned Assets
Essex	$144,278.19	$920.52
Gloucester	$4,500.00	$7.94
Hudson	$163,438.78	$548.22
Hunterdon	$105,000.00	$685.42
Mercer	$ 105,000.00	$3,481.27
Middlesex	$ 105,000.00	$345.38
Monmouth	$ 119,078.30	$340.53
Morris	$ 184,516.21	$575.83
Ocean	$4,500.00	$12.91
Passaic	$ 106,460.38	$315.77
Salem	$4,500.00	$22.24
Somerset	$ 128,768.59	$331.15
Sussex	$ 213,019.90	$580.40
Union	$ 105,000.00	$186.20
Warren	$ 135,484.84	$376.45

Source: FEMA NRI, NJOMB, 2023

Impacts to Community Lifelines

FEMA created the eight Community Lifelines to contextualize information from incidents, communicate impacts in plain language, and promote a more unified effort across a community that focuses on stabilizes these lifelines during response. More information on these lifelines can be found in Section 4.1. Risk Assessment Overview. Table 4.8-5 showcases the most likely lifelines to be impacted by geological hazards, including a short description of anticipated impacts.

Table 4.8-5 Lifelines Most Likely Impacted by Geologic Hazards

Lifeline Categories	Notable Impacts
Safety and Security	Community safety may be threatened due to potential direct harm from geohazards and compounding effects on administration of services. Transportation infrastructure issues may directly impact the abilities of law enforcement, fire service, search and rescue, and other government services to respond to a flooding hazard.
Food, Hydration, Shelter	Food, Water, and Shelter lifelines may be impacted by geological hazards. Landslides may damage water lines. Water supplies may be threatened by saltwater intrusion affecting access to water for human consumption and agricultural uses potentially leading to consequences in the food supply chain. Radon exposure can impact shelter lifelines.
Health and Medical	Medical facilities can be impacted due to damage to structures from geohazards such as landslides, while patient movement and medical supply chains can be impacted by effects on transportation infrastructure. Radon exposure can impact any structure including a medical facility.
Transportation	Geohazards may impact Transportation lifelines when hazards such as landslide or sinkhole/land subsidence occur near a road or other modes of transportation infrastructure. This can lead to cascading impacts on other lifelines.
Water Systems	Geohazards could pose a threat to the Water System lifeline. Landslides can result in broken water lines. Saltwater intrusion can increase the cost of water treatment for facilities and cause drinking water utilities to have issues with taste and odor in treated water and corrosion in equipment and the distribution system.

Critical Facilities

Critical facilities are important for ensuing the day-to-day functioning of a society. These facilities include utilities, hospitals, and schools, among others similar in nature. They are also important in emergency response; thus, it is vital that in the event of a disaster they continue to operate. Table 4.8-6 illustrates the number of critical facilities which are in landslide susceptible areas by county and seismic soil classification. This analysis is only for the nine counties in New Jersey that the New Jersey Geologic Survey determined landslide susceptibility. Analysis shows that there are nine Communications facilities, nine Safety and Security facilities, 30 Hazardous Material facilities, two Food, Water, and Shelter facilities, one Energy facility, two Transportation facilities, and 235 Historic and Cultural facilities which are vulnerable to landslide. No Financial or Health assets intersected with landslide susceptibility. Of the facilities identified as susceptible, two Safety and Security facilities, four Hazardous Material facilities, one Food, Water, and Shelter facility, and 23 Historic and Cultural facilities are considered highly vulnerable.

Table 4.8-6 Critical Facilities Susceptible to Landslide

County	Landslide Class	Communi-cations	Safety and Security	Hazardous Materials	Food, Water, Shelter	Energy	Transport-ation	Cultural
Bergen	A		1	2			1	10
	B		3		1			41
Essex	A			1				10
	B			5				75
Hudson	A	4	1	9			1	27
Middlesex	B	1	2	1		1		1
	C		1					1
Monmouth	B	2						15
	C			2	1			14
Morris	A	1						1
	B		1	2				15
Passaic	A	1		5				11
	B							6
Somerset	A		1	2				
	B			1				
	C							3
Union	B							7
Total		**9**	**9**	**30**	**2**	**1**	**2**	**235**

Source: HIFLD, 2006, 2007, 2012, 2014, 2017, 2018, 2019, 2020, 2021, 2022; NJOGIS, 2019, 2020; NJ TRANSIT, 2021; PANYNJ, 2023; USDOT, 2022; NJGWS, 2005

Bridges

Bridges are a critical node in our transportation infrastructure. Landslide has the potential to cause damage to bridges, possibly even resulting in collapse. Table 4.8-7 below shows the number of bridges in each county that are susceptible to landslide. A total of 33 bridges are located within these areas in the nine counties for which landslide susceptibility data is available. Nine of these bridges, those located within CVI, CVII, and CIX landslide class areas, are considered highly vulnerable.

Table 4.8-7 Number of Landslide Susceptible Bridges by County

County	Landslide Class	Number of Bridges
Bergen	A	6
Hudson	A	4
Middlesex	B	3
	C	2
Monmouth	B	4
	C	7
Morris	B	1
Passaic	B	1
Somerset	A	3
	C	1
Union	B	1
Total		**33**

Source: USDOT, 2022; NJGWS, 2005

To assess the vulnerability of the state-owned and leased facilities provided by the New Jersey Office of Management and Budget (NJOMB), an analysis was conducted with the landslide susceptible areas. Using GIS, these hazard areas were overlaid with the state facility data to determine the number of vulnerable state facilities. Table 4.8-8 summarizes the state-owned and -leased facilities vulnerable to the landslide by county. Table 4.8-9 summarizes the facilities vulnerable by state agency.

Table 4.8-8 State-Owned and -Leased Buildings in the Landslide Area by County

County	Landslide Class	Total Buildings
Morris	A	1
	B	1
Passaic	A	3
Total		**5**

Table 4.8-9 State-Owned and -Leased Buildings in the Landslide Area by Agency

County	Landslide Class	Total Buildings
Environmental Protection	A	4
Treasury	B	1
Total		**5**

The vulnerability of each individual state building and critical facility will differ based on the topography and underlying geology. The limitations of this analysis are recognized because this figure assumes 100% loss to each structure. This potential loss estimate is considered high given it is not likely that the geologic hazard events discussed would occur across the entire hazard area at the same time from one event. As more current replacement cost data becomes available at the structure level, and standardized methodologies for the landslide hazards become available to estimate potential losses, this section of the plan will be updated with new information and the potential loss estimates will be further refined.

Population and Economy

Economic Impacts

Saltwater intrusion poses a threat to water supply. Water resources along the coasts face risks from saltwater intrusion. Rising sea levels, drought, and changes in water demand and availability can increase the salinity of both groundwater and surface water sources of drinking water (EPA, 2023). Saltwater intrusion into groundwater aquifers can increase treatment costs for drinking water facilities or render groundwater wells unusable. As sea levels risk, the location of the freshwater-saltwater line may progress further upstream. This encroachment can result in the need for water utilities to increase treatment, relocate water intakes, or develop alternate sources of freshwater (EPA, 2023).

Saltwater intrusion also poses an economic threat to the agricultural industry in southern New Jersey. Groundwater pumping can reduce freshwater flow toward coastal areas and cause saltwater to be drawn toward the freshwater zones of the aquifer (USGS, 2023). Excessive groundwater pumping can also lead to subsidence and fissures on the landscape (USGS, 2018), potentially putting the 700,000 acres of farmland in New Jersey further at risk. Other water users also may experience corrosion in their equipment and interference with manufacturing and chemical and other processes used in manufacturing and industry. Increased salinity water may also affect the health and food quality for oysters, potentially impacted the commercial oyster beds in the Delaware Bay. Oysters become more susceptible to predators and diseases at higher salinity. Both the size and taste of the oysters can also be adversely affected.

Population Impacts and Changes in Development

The population within the landslide and sinkhole/subsidence areas may be vulnerable. Specifically, the population located downslope of the landslide hazard areas are particularly vulnerable to this hazard. According to the CDC, every year, landslides and debris flows result in 25 to 50 deaths in the United States. The health hazards associated with landslides and mudflows include rapidly moving water and debris that can lead to trauma; broken electrical, water, gas, and sewage lines that can result in injury or illness; and disrupted roadways and railways that can endanger motorists and disrupt transport and access to health care (CDC, 2018).

The more radon you are exposed to, and the longer the exposure, the greater the risk of eventually developing lung cancer. Radon is the second leading cause of lung cancer in the United States, and the leading cause among non-smokers (NJDOH, 2023). Saltwater intrusion can adversely impact salt sensitive individuals and those with other health issues.

As New Jersey's population continues to grow, so will the number of individuals potentially impacted by geological hazards. However, recent changes in land use, development, and infrastructure in New Jersey have no measurable impact to the location or magnitude New Jersey faces from geological hazards such as sinkholes, landslides, radon exposure, and saltwater intrusion.

Socially Vulnerable and Underserved Communities

There is limited research indicating a relationship between socially vulnerable populations and unique/increased risk from geological hazards in New Jersey. However, it is important to note that the cost for mitigating geological hazards such as sinkholes, landslides, radon exposure, and saltwater intrusion will fall to the individual property owner on the site where the event occurs. Therefore, individual homeowners without significant disposable income may face hardship from the financial burden of mitigating the potential of and/or recovering from a geological hazard event.

To better understand whether socially vulnerable or underserved communities are more likely to live in proximity to high-risk areas for geological hazards, census tracts identified as underserved or socially vulnerable were intersected with landslide susceptibility and the locations of known abandoned mines. For radon exposure, municipalities with the high radon potential were intersected with underserved and socially vulnerable population data to determine which municipalities may have the highest number of households facing potential financial hardship to test/mitigate the risk to radon exposure. The results of this analysis are included in Table 4.8-10 below. Given the lack of geographic extent for the potential of saltwater intrusion, a similar analysis was not performed for this hazard.

Table 4.8-10 New Jersey Disadvantaged Communities within the Landslide Susceptibility Area

County	Total Countywide Population	Disadvantaged Communities Identified by the White House Climate and Economic Justice Screening Tool		Socially Vulnerable Communities Identified by the CDC/ATSDR Social Vulnerability Index		Overburdened Communities Identified by the NJDEP Overburdened Communities under the Environmental Justice Rule	
		Total Disadvantaged Population in Landslide Area	% of Population that is Disadvantaged and in Landslide Area	Total Socially Vulnerable Population in Landslide Area	% of Population that is Socially Vulnerable and in Landslide Area	Total Overburdened Population in Landslide Area	% of Population that is Overburdened and in Landslide Area
Atlantic	274,534	0	0.00%	0	0.0%	0	0.0%
Bergen	955,732	1,748	0.18%	3,651	0.4%	8,265	0.9%
Burlington	461,860	0	0.00%	0	0.0%	0	0.0%
Camden	523,485	0	0.00%	0	0.0%	0	0.0%
Cape May	95,263	0	0.00%	0	0.0%	0	0.0%
Cumberland	154,152	0	0.00%	0	0.0%	0	0.0%
Essex	863,728	727	0.08%	1,357	0.2%	1,895	0.2%
Gloucester	302,294	0	0.00%	0	0.0%	0	0.0%
Hudson	724,854	1,814	0.25%	5,254	0.7%	6,771	0.9%
Hunterdon	128,947	0	0.00%	0	0.0%	3	0.0%
Mercer	387,340	0	0.00%	0	0.0%	0	0.0%
Middlesex	863,162	1,299	0.15%	1,565	0.2%	2,848	0.3%
Monmouth	643,615	36	0.01%	172	0.0%	929	0.1%
Morris	509,285	694	0.14%	1,325	0.3%	1,652	0.3%
Ocean	637,229	0	0.00%	0	0.0%	0	0.0%

County	Total Countywide Population	Disadvantaged Communities Identified by the White House Climate and Economic Justice Screening Tool		Socially Vulnerable Communities Identified by the CDC/ATSDR Social Vulnerability Index		Overburdened Communities Identified by the NJDEP Overburdened Communities under the Environmental Justice Rule	
		Total Disadvantaged Population in Landslide Area	% of Population that is Disadvantaged and in Landslide Area	Total Socially Vulnerable Population in Landslide Area	% of Population that is Socially Vulnerable and in Landslide Area	Total Overburdened Population in Landslide Area	% of Population that is Overburdened and in Landslide Area
Passaic	524,118	2,499	0.48%	4,133	0.8%	4,234	0.8%
Salem	64,837	0	0.00%	0	0.0%	0	0.0%
Somerset	345,361	0	0.00%	391	0.1%	1,618	0.5%
Sussex	144,221	0	0.00%	0	0.0%	0	0.0%
Union	575,345	71	0.01%	58	0.0%	1,075	0.2%
Warren	109,632	0	0.00%	0	0.0%	0	0.0%
Total	**9,288,994**	**8,888**	**0.10%**	**17,906**	**0.2%**	**29,290**	**0.3%**

Sources: United States 2020 Census; White House Climate and Economic Justice Screening Tool; CDC/ATSDR Social Vulnerability Index; NJDEP Overburdened Communities under the Environmental Justice Rule; NJGWS, 2005

Ecosystems & Natural Assets

Beaches and Dunes

Climate change and groundwater withdrawal are resulting in an accelerated rate of land subsidence along the Jersey shore causing an increase in sea level rise compared to the global average. As sea level rises from subsidence, beach and dune erosion can leave inland areas exposed to flooding and storm damage. In developed areas, subsidence can cause property damage, disruption of utilities and transportation, or loss of life.

Water Resources

Sinkhole formation near coastal areas may result in saltwater intrusion of freshwater aquifers where groundwater withdrawals are causing a decline in water levels. Sinkholes may also result in radon exposure to groundwater in areas with karst terrain. Landslides can result in degradation of surface water quality by increasing turbidity or the release of contaminants. Both sinkholes and landslides can also cause the loss of surface water resources. Salinity can only be removed from salt water intruded waters through desalinization, a high-cost energy intensive form of treatment, with environmental issues related to disposal of the leftover, highly concentrated residual brine.

Freshwater and Coastal Wetlands

Freshwater and coastal wetlands located near dunes can be filled in by slumps covering vegetation resulting in full or partial loss of wetland functions. Sinkholes can also consume wetland vegetation resulting in significant damage to these resources.

Forests and Vegetated Lands

Forests and vegetated lands including agricultural lands located near slopes can experience rapid loss from landslides by vegetation being completely covered or trees knocked down. Sinkholes can consume trees and vegetation also resulting in significant damage to these resources.