LANDSLIDES
in New Jersey

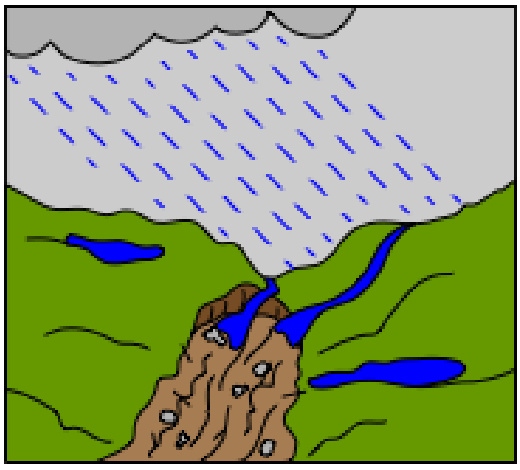
Landslides are geological processes that change the landscape and often have an impact on humans. The scientific study of landslides helps determine when and where they may occur and how humans can be protected. New Jersey has multiple landslides every year, but you will probably never see or rarely hear about one, as steps are taken to minimize and prevent landslides. In this lesson, you will learn what landslides are, the types that occur in New Jersey, how science handles them, and how that knowledge keeps people and places protected.

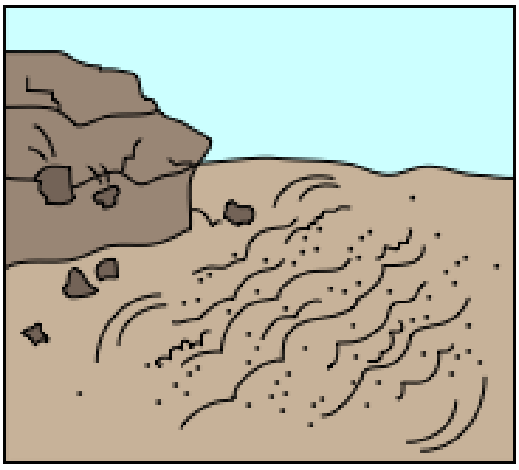
What is a landslide? What causes one to happen?

A landslide is a process in which soil, rock, debris (leaf litter, sticks, gravel, and other material from Earth's surface), or a combination of these is moved downhill. A landslide can pick up more material as it flows, becoming stronger and more destructive. It can be slowed by obstacles, friction, and a change of slope. Landslides can go down steep or gentle slopes. Some landslides are fast while others are slow.

Landslides are caused by many factors. Most are natural causes, but others are due to the actions of man. The most common causes are:

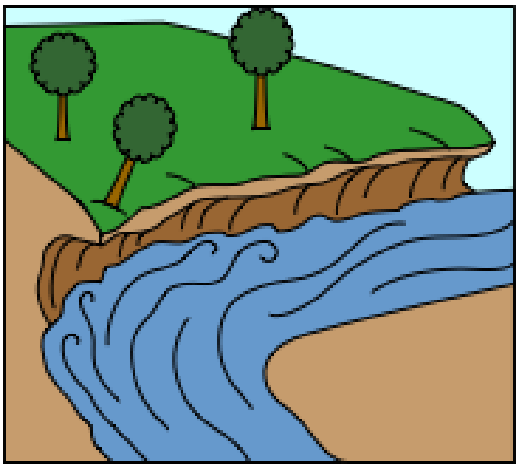
- ***heavy rain*** — excessive water soaks, weakens, loosens, and carries or pushes earth and rock over other surfaces.
- ***earthquakes*** — shaking, vibrating, weakening, and separating earth causes it to collapse, crumble, and even "liquify" (behave like a fluid even though it is made of solid materials).

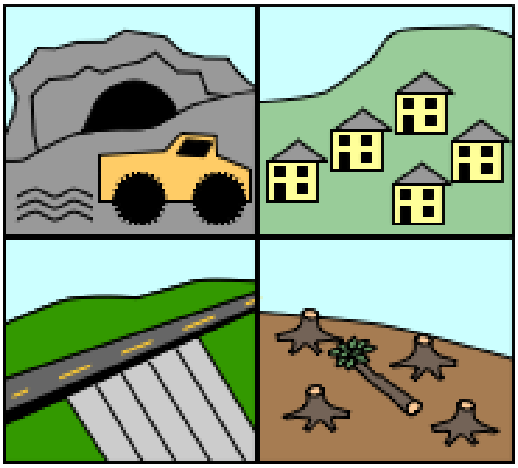




- ***undercutting water*** — ocean waves, rivers, and streams that carve into the lower part of a wall of soil or rock cause overhangs to form; when this material becomes too heavy and weak, it falls.

- ***human activity*** — excavation, mining, development (building upon land), building roadways and slopes, deforestation (removing trees from a large area), and changing water flow and drainage can cause landslides. Disturbing an old landslide can also set it off again!





In New Jersey, landslides have mainly occurred in areas of road construction, deforestation (removing trees and vegetation on slopes), mining and quarrying, undercutting by ocean waves, and development (building houses). Landslides are most likely to occur where there are steep to moderate slopes, though they can occur on gently sloped land, too. Further along in this lesson, you will see in more detail where landslides occur in New Jersey.

Thinking Point 1:
What natural cause might mining and quarrying mimic? (Hint: blasting with explosives is used to break rock.) What effect does deforestation have on soil?

Mining and quarrying produce effects like an earthquake: explosives shake, separate, and weaken rock; huge, heavy machinery vibrates the land.

Deforestation removes trees and plants that would normally take up water from the soil, plant roots hold soil, rock, and other plants in place. Without these, rainfall can easily wash the soil away and cause a landslide.

How big are landslides?
Landslides come in all sizes. A small landslide might contain only a few feet of material that moves only a few feet. The largest landslide recorded by man occurred because of the eruption of Mount St. ("Saint") Helens in Washington state. An incredible amount of material was moved — multiply the 2-meter deep Olympic-sized swimming pool below times *one million*! (Illustration is not to scale.)

Scientists know that even bigger landslides, miles wide and long, occurred in prehistoric times. Evidence left on Earth's surface shows that these gargantuan slides occurred. New Jersey does not have evidence of a landslide of such immense size.

Are there different kinds of landslides?
Yes, many different types of landslides exist. Initially, landslides are classified as **subaerial** ("below air") or **submarine** ("below water"). Most are subaerial — the ones you see on the surface of the Earth. But submarine landslides do occur where sediments build up and collapse underwater. This is especially true in large bodies of water like oceans.

Thinking Point 2:

Giant submarine landslides in the ocean have occurred and are still a threat. What major natural disaster can they produce? (Hint: Surf's up!)

A tsunami. The movement of tons of ocean sediment displaces huge volumes of water, which becomes a tsunami.

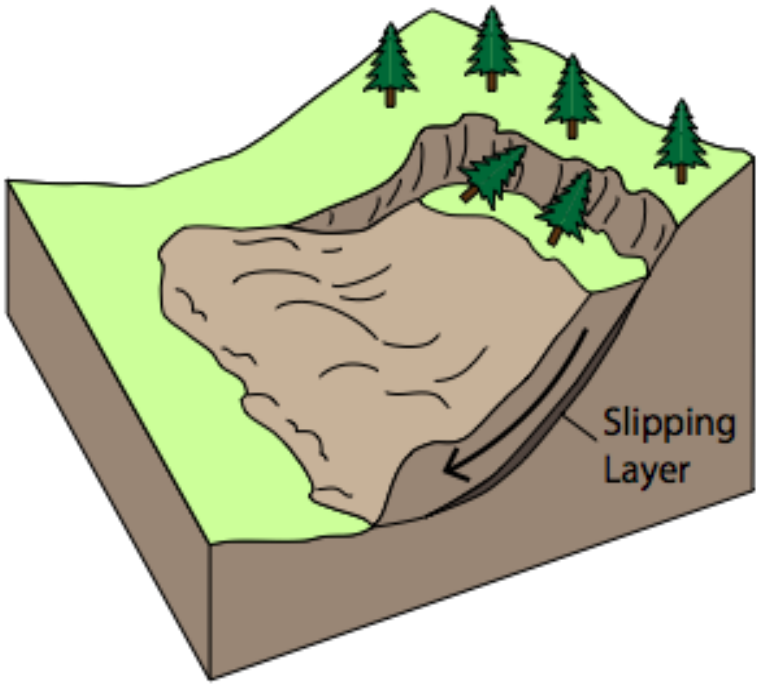
Landslides also differ by **material** and **mode**. The **material** in a landslide is rock, debris, earth, or a combination of those. The **mode**, or way, in which the material moved is either a fall, topple, slide, spread, or flow. Both material and mode are used to create a two-part name for a landslide. For example, debris that flowed down a slope is known as a debris flow; rock that fell off the face of a cliff is called a rockfall.

New Jersey has recorded four types of landslides:

1. Slump
2. Debris Flow
3. Rockfall
4. Rockslide

1. Slump

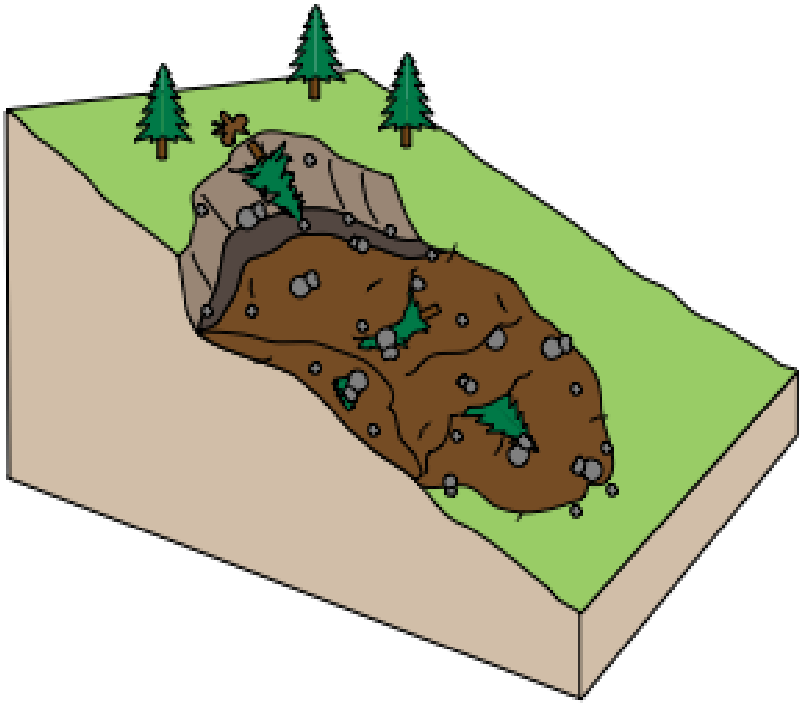
A slump is an area of land that moves downhill because of a layer of earth under it is slipping. The piece of land on top is carried by the moving layer beneath. The land can move along a flat plane or in a sort of scooped shape. "Slump" is a special name — it has only to do with the way the material moved; it does not matter what material was in it, so a mix of anything can be in a slump.



Below is an image of a slump that destroyed a road in Hunterdon County in 1989.

2. Debris Flow

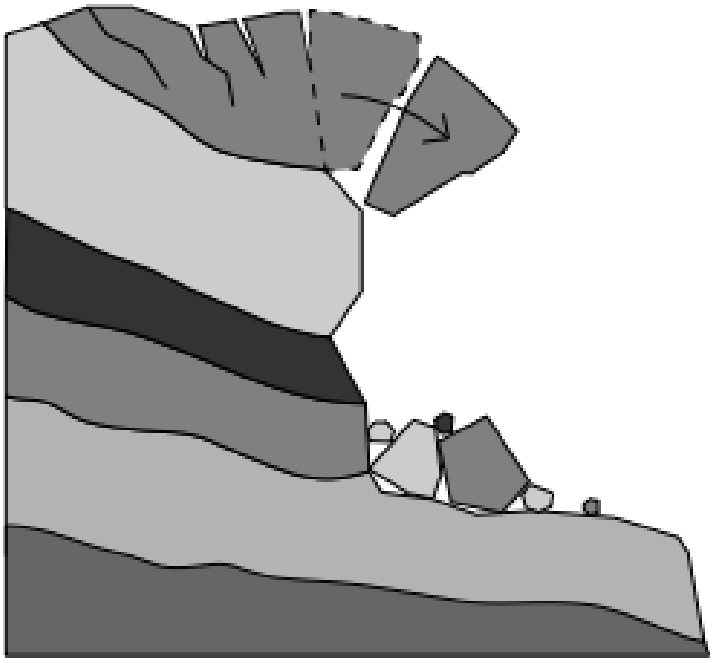
A debris flow is also known as a mudflow or mudslide. Debris flow is the technically correct name for it. These landslides do look and can be very muddy, but they are usually a mixture of loose soil, rock, air, water, and plant material (whole trees are included!). Debris flows often occur after heavy rains or snowmelt. The “slushy” mix moves quickly downhill and is quite destructive.



At right is a photograph of a debris flow that occurred in Bergen County in 2007.

3. Rockfall

A rockfall is the sudden drop of rocks and boulders that have come apart and fallen away from steep slopes or cliffs.

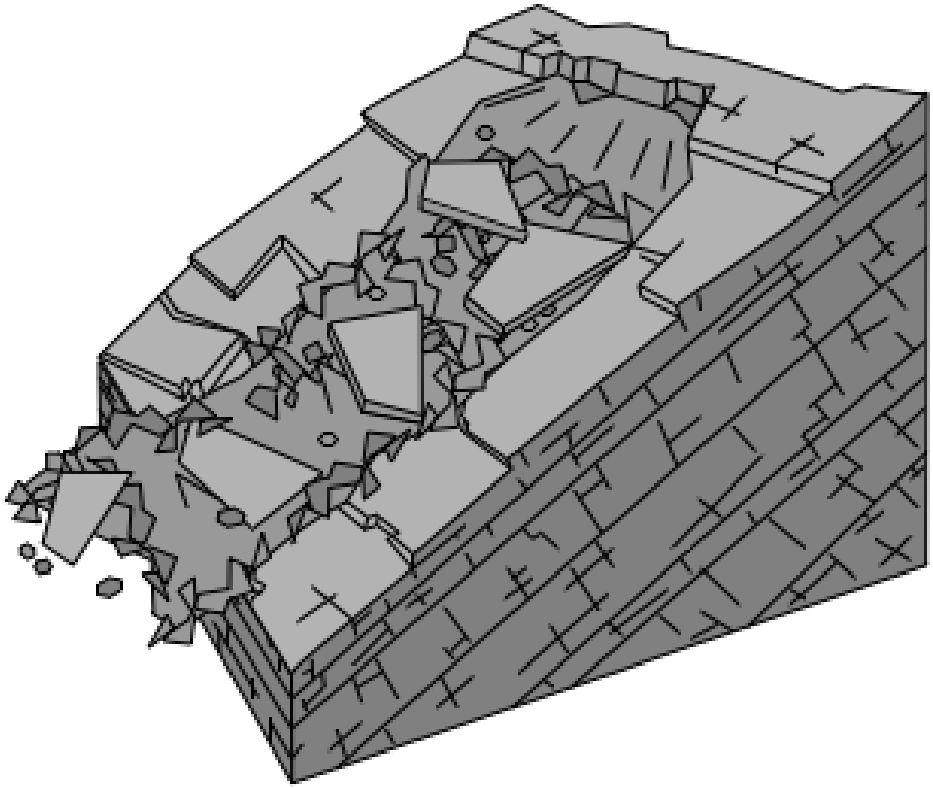


The photograph below shows the huge pieces of rock that fell onto a New Jersey roadway during a rockfall in 1933.

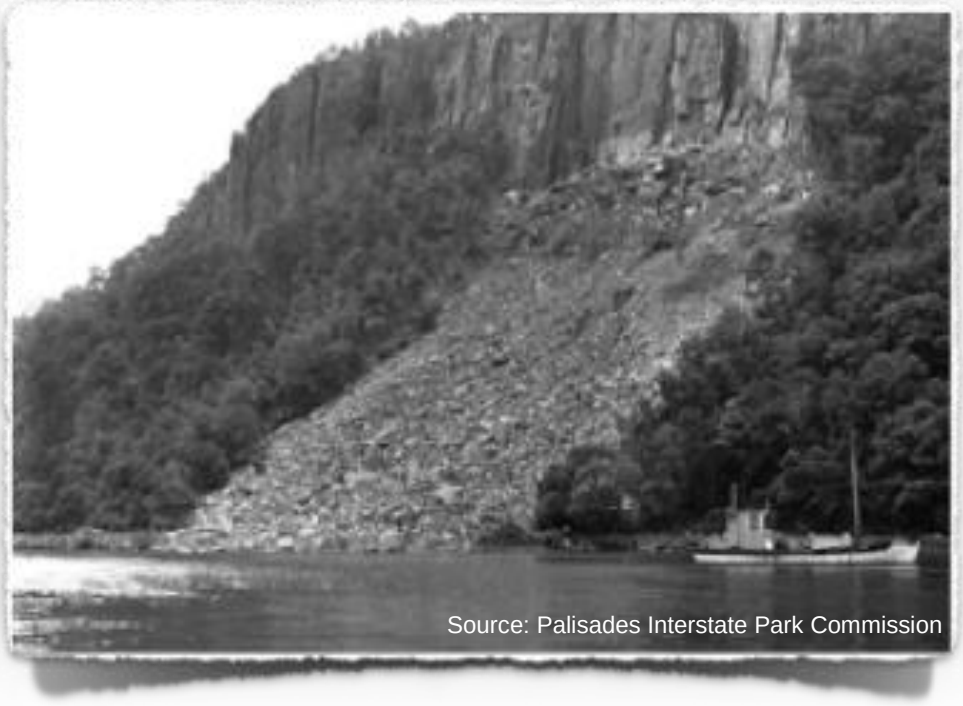
Source: Palisades Interstate Park Commission

4. Rockslide

Rockslides occur when layers of rock break and slip away from the main body of the rock. Enormous pieces or large areas of broken rock can be moved this way.



The rockslide in the photograph below came off the vertical Palisades cliffs in 1938.



Landslides do not stop there! They can even be made up of two or more types. For example, it is possible for both a slump and a rockfall to happen in one event. They are counted as one landslide. In that case, the official name of the entire landslide comes from the event that was bigger. So, if the slump was bigger than the rockfall, then the whole event will be known as "a slump with a rockfall".

Activity – Create your own landslide. Using the two lists below, create two or more types of landslides by combining a material with a mode. Try to use different terms for each landslide. (*You can also have a Slump.) Jot down the names in the blank space to the right of the word lists. Circle the landslide that you wish to be the biggest — that will be the official name of your landslide. Next, choose the secondary event. Then fill in the sentence. Use the space at the bottom of the page to sketch one of your landslide types (or the whole event if you are able!).

Material	+	**Mode**	**=**
mud		fall	
debris		topple	
rock		slide	
		spread	
*Slump		flow	

Example: "This landslide is a rock fall with a debris flow."

"This landslide is a _____ with a _____."

Where do landslides occur in New Jersey?

New Jersey has 21 counties. Most of them have recorded at least one landslide. The landslide location map to the right shows the counties, the approximate locations of where landslides have occurred, and what types of landslides were recorded.

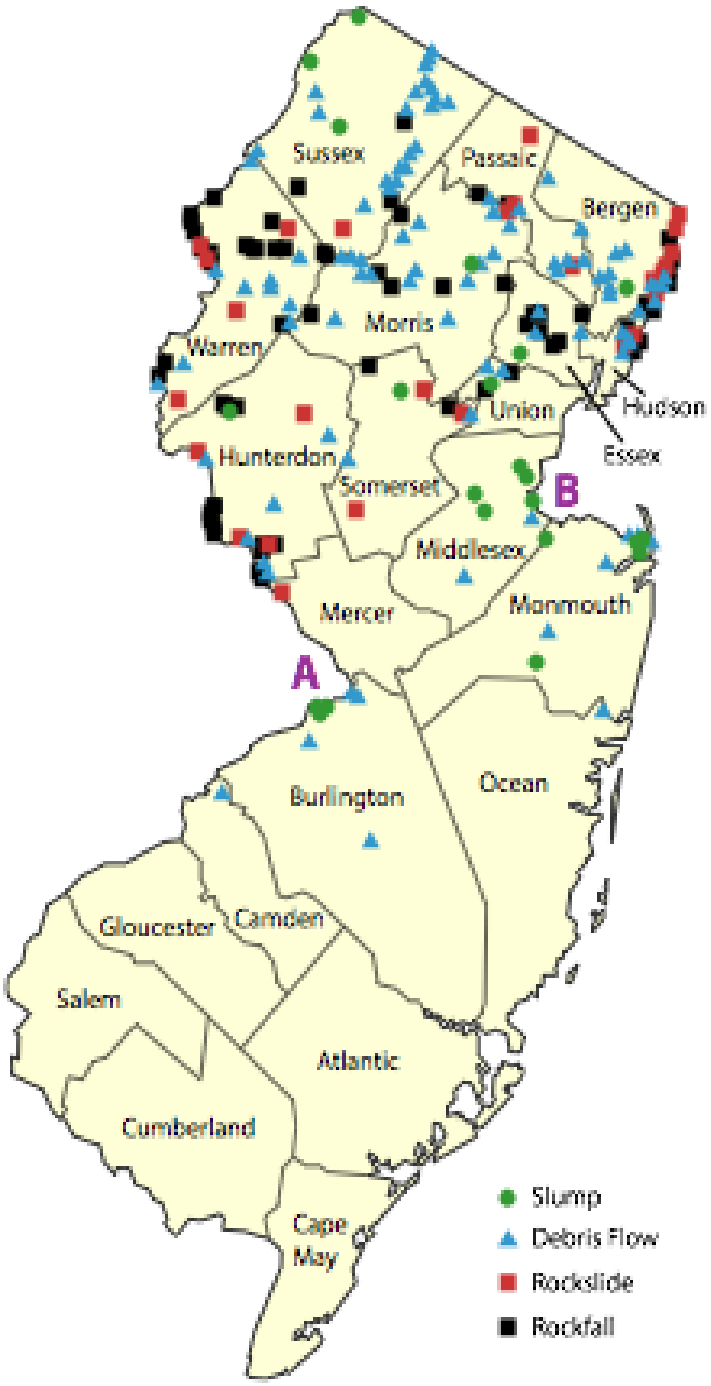
Not every landslide that has been recorded (there are 345) is marked with a symbol because of the small scale of the map.

Answer the following questions:

1. Which counties do not have a landslide on record, and how many counties does that total?

2. There are three counties with only 1 recorded landslide — which are they? Look carefully!

3. Draw a line across the state from A to B. You now have north and south regions of the state. What can you say about where landslides usually occur in New Jersey?

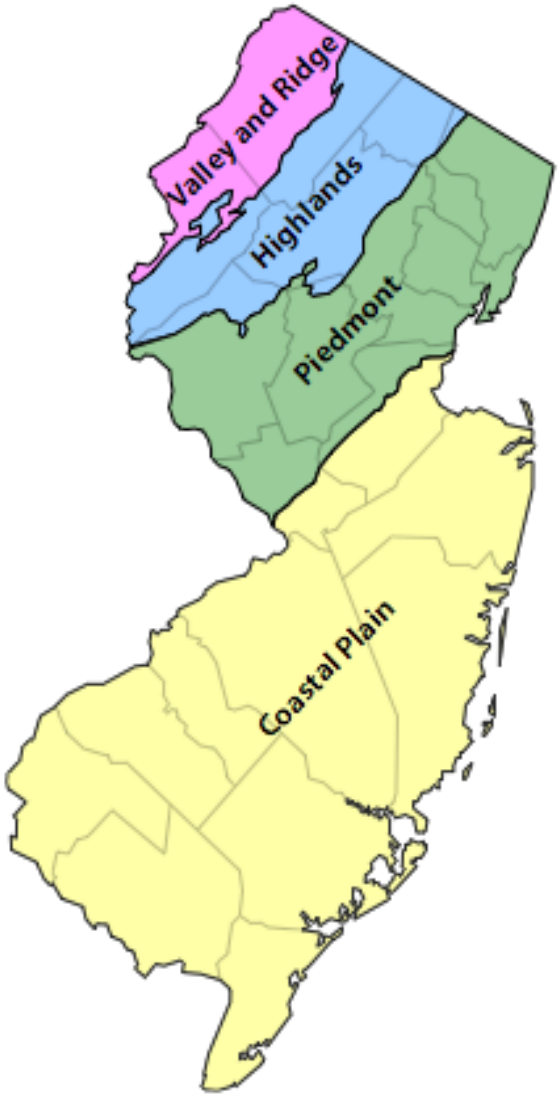


Answers:
1. Atlantic, Cape May, Cumberland, Gloucester, and Salem — 5 counties.
2. Camden, Mercer, and Ocean
3. Landslides tend to occur in the northern part of the state.

The geology of New Jersey has a lot to do with landslides. The condition of rock — its strength, fractures, layers, water content, and slope — affect the chances of a landslide happening. The movement of softer or broken rock, soil, sand, and fine sediments are dependent on these factors as well.

Rocky areas are prone to rockfalls, rockslides, and debris flows. Regions with softer rock might have rockslides, debris flows, and slumps. Sandy areas may have debris flows and slumps.

As it happens, New Jersey is easily divided into different areas based on different geology. There are four geological areas, or **provinces:**



Valley and Ridge - the Valley and Ridge province is composed of solid rock in steep mountain ridges and includes the highest land in New Jersey.

Highlands - the Highlands are rocky like the Valley and Ridge, but its ridges and hills are lower.

Piedmont - the Piedmont province has hard and soft rocks. There are some high and low areas, but the land is lower than both the Valley and Ridge and Highlands provinces.

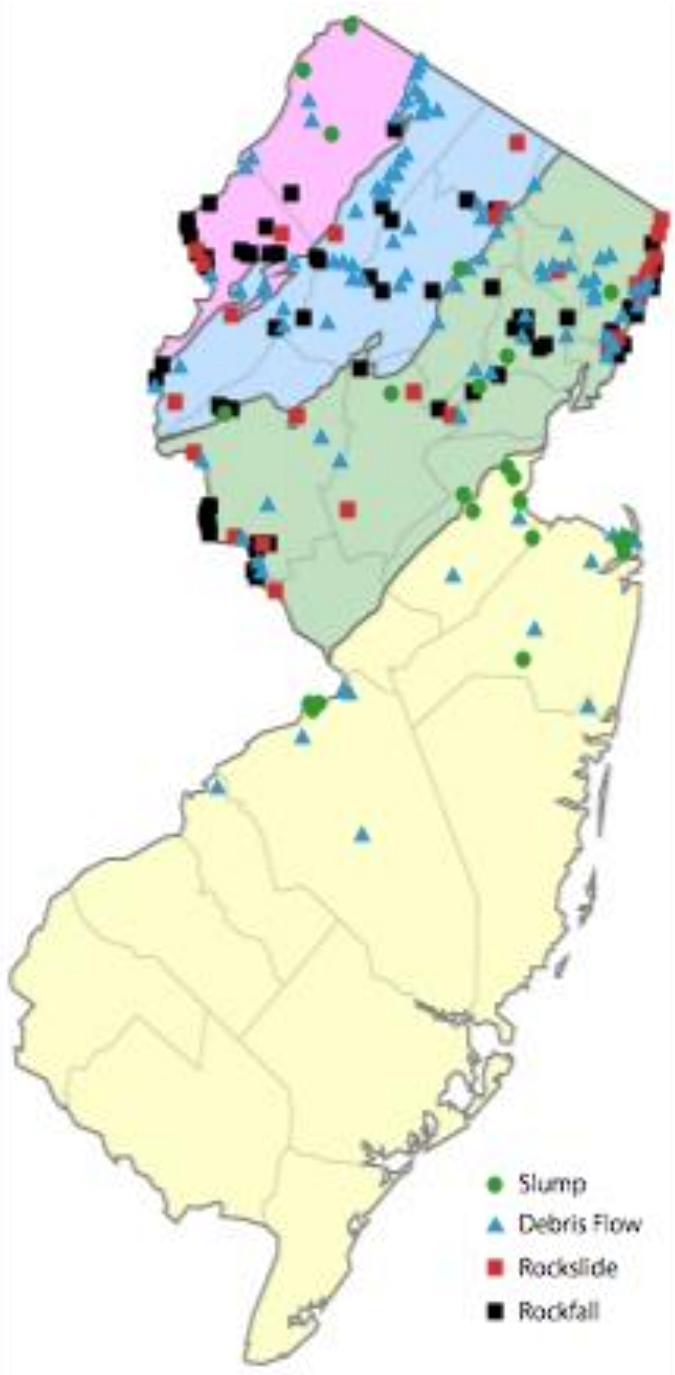
Coastal Plain - the Coastal Plain is mostly sand and fine sediment. The land here is the lowest and flattest in the state.

All these regions have areas where soil and sediment have built up, including at the edges of the Delaware River and along the coast.

Thinking Point 3:

Similar to the line A-B that you drew across the landslide location map, a line on this map divides not just two provinces but two main regions of the state. It is a major dividing line in New Jersey geology. Between which two provinces does the line lay? What does it divide?

The line is between the Coastal Plain and Piedmont provinces. It divides geology of the Coastal Plain, which contains no native rock but is mainly sand, from that of the three provinces that do contain rock and are not sandy.



In this map, the geologic province map has been combined with the landslide location map. Use this map to answer the following questions:

1. What are the names of the provinces with the most landslides?

2. Why are landslides more likely to occur in those provinces?

Answers:
1. Valley and Ridge, Highlands, and Piedmont
2. The land is rockier, hillier, and steeper; the Coastal Plain is mainly flat and without as many of the materials that make up most landslides.

Do landslides cause damage? How much damage?

Landslides can change or destroy anything in their path: forests, rivers, roads, towns, buildings, back yards… the list goes on. The ground or rock they originate from is changed, and anything in their path is also at risk for change or destruction.


Source: Hunterdon County, New Jersey

Landslides can affect things that we use every day. Utilities are one example. Utilities are the services (and equipment) for electric, natural gas, water, sewer, and cable, for example. When utilities are damaged or destroyed, humans suffer some hardship and sometimes unsafe conditions.

Roads can be blocked or destroyed by landslides — this might make travel or escape from a dangerous area impossible. An added complication of landslides is flooding. Waterways can be blocked by landslide material, which is like a dam. If a pond or lake is filled with landslide debris, the water is displaced. Rivers can be cut and form lakes or new waterways where they did not exist before.

The picture at left shows what one landslide can do – power lines, trees, soil, and water are all blocking a road. This event occurred in Hunterdon County in 2005.

Can we see where landslides have happened?

Before 20th century technology, landslides were seen from the ground only and were explored on foot. Then, airplanes made aerial photography of the land possible. With the advent of satellites, more images were captured more often and with better clarity. In the later 20th century, additional spatial technology was developed. Scientists can now view land at any scale to see landslides. Both past and present images of landslides are useful in studies. Scientists can see how landslides spread, as well as measure how large the areas are without having to go to the actual location, although this is also done as a matter of thorough geologic study.

Aerial, satellite, and **LIDAR** are three types of imagery used in the study of landslides.

Aerial imagery is simply photography from the air. Photographs of the land are taken at a certain constant altitude, as from an airplane. Each image covers only so much area, so the photographs must overlap and be pieced together to create a bigger image. For most of the 20th century, aerial photographs were taken on film by cameras on airplanes. These images are in the form of large, physical photographs, and the earliest pictures were only in black and white. Later, color prints were used; after this, digital photography was employed. Aerial photography is still done today. Airplanes, helicopters, balloons, and remote-controlled devices like drones are used to collect digital images.

Satellite images are snapshots of Earth's surface taken from space by satellites and put together in sequence to form one continuous land image. The images are similar to those of aerial photography, except that they are always digital and they can be taken from much higher altitudes. You are familiar with satellite imagery if you have used Google Maps or Google Earth. Satellite imagery is sometimes cheaper to obtain than aerial imagery and it can be done more often, and so

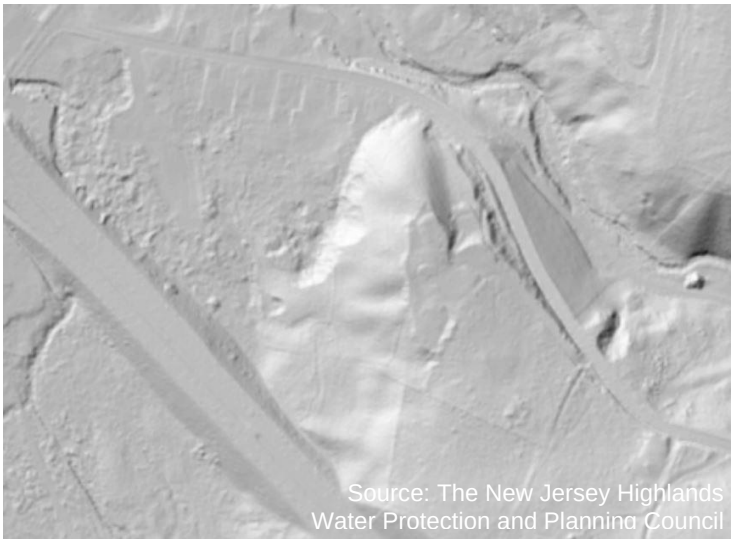
a wider range of data is available. Images from different times of just one year, or images from many different years, can easily be compared to each other to identify changes on the land surface.


Source: U.S. Department of Agriculture (USDA), Farm Service Agency (FSA), Aerial Photography Field Office (APFO), NJ Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS)

Aerial and satellite images help scientists identify the location, size, and impact of landslides (as well as other events like volcanic eruptions, earthquakes, and tsunamis). The disadvantage of these images is that hills and mountains are not easy to tell apart from flat land, and waterways (amongst many other features) are often obscured by tree cover. Following, left, is an example of an aerial image (no landslide, however). Roads, trees, grass, and man-made structures are visible in aerial as well as satellite images.

You have probably heard of RADAR… but have you heard of **LIDAR**?

LIDAR stands for **LI**ght **D**etection **A**nd **R**anging or **L**aser **I**maging, **D**etection, **A**nd **R**anging. Special equipment on aircraft sends laser pulses down to the ground that bounce back to the equipment. The time it takes for the pulses to travel down and back is used to calculate the height of Earth's features. When the data is put together, it forms a somewhat strange, bumpy, gray image of the surface of the Earth, as in the image to the right.


Source: The New Jersey Highlands Water Protection and Planning Council

LIDAR imagery is useful because an area that shows new features where they did not exist before may alert scientists to a landslide or other change that happened there. This kind of imagery removes trees, houses, and other features that usually block the shape of the land in satellite images. LIDAR makes it easy to see the actual form of the land.

***Thinking Point 4*:** Why is satellite and LIDAR imagery a good resource for observing and analyzing landslides versus humans exploring them on foot?

Exploring a landslide could be dangerous and even life-threatening; it is safer to let technology do the work for us while we stay safe! Additionally, scientists can "see" more from the air than on foot.

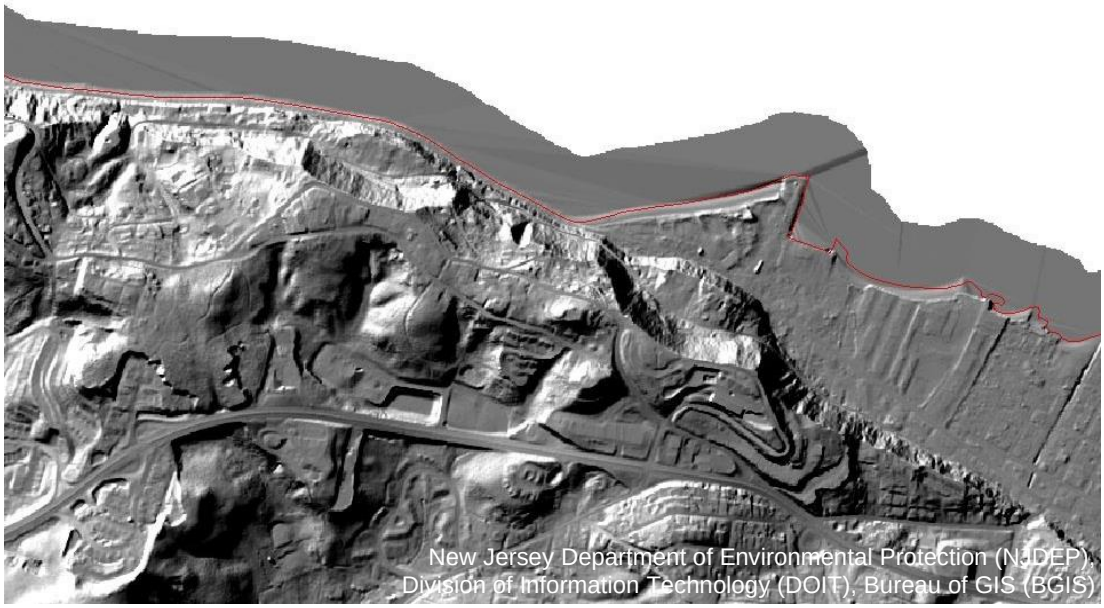
Exercise — Using aerial and LIDAR imagery from New Jersey to locate landslides

Part 1.

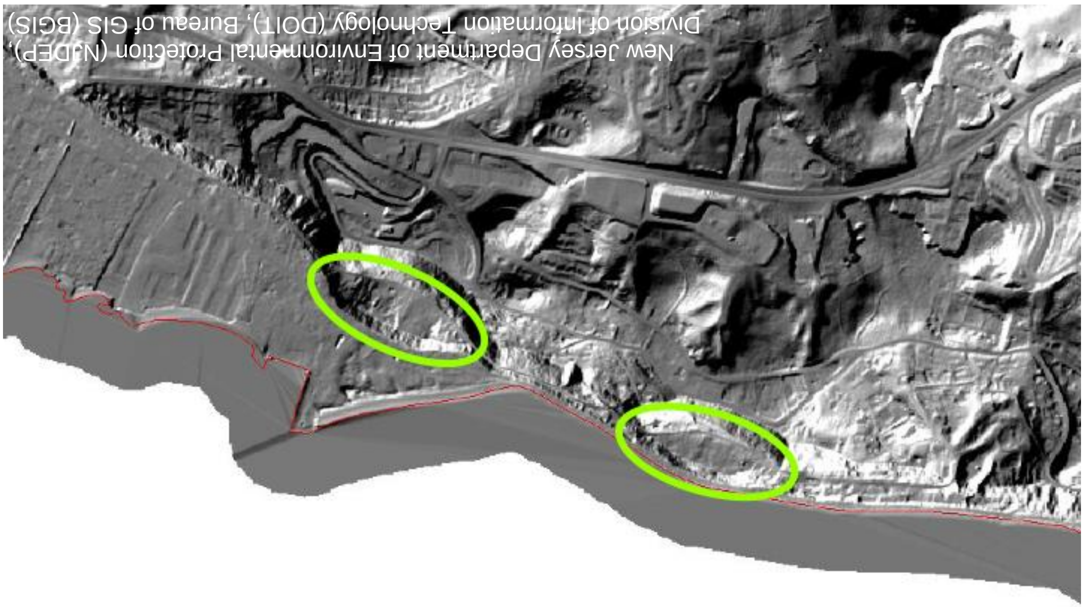
Below is an aerial image of Atlantic Highlands on the north coast of Monmouth County, New Jersey. There are *two* slumps in this area. Try to determine where they are; then circle them.

It is not easy, so do not be discouraged. Perhaps you can accomplish this another way. How about trying different imagery?

Try looking at a LIDAR image of the same area, below. *Now* can you tell where the two slumps are located? Circle them.



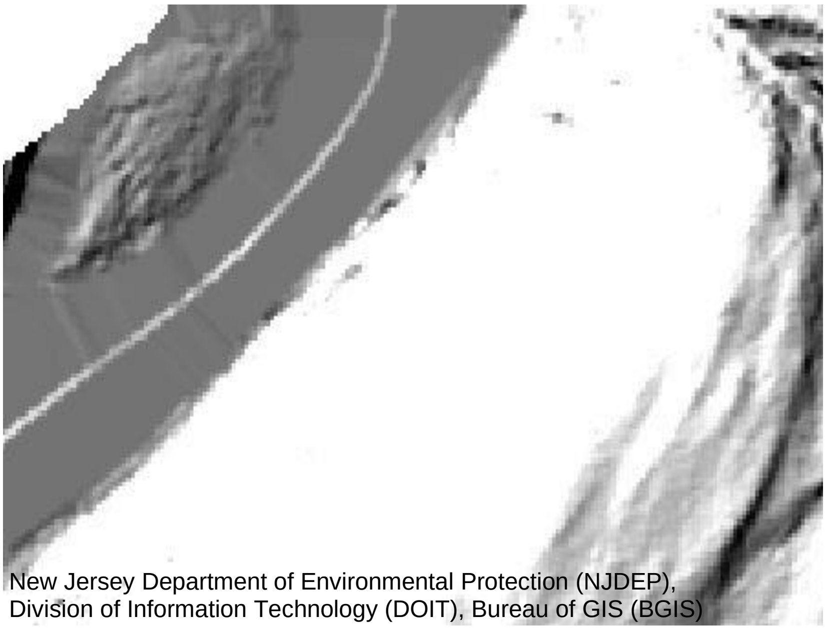
Do the areas you circled match from one image to the other? Was it easier to find a landslide using aerial or LIDAR imagery? Which type of imagery do you think would be more useful and reliable for scientists to find where landslides have occurred?



Here are the locations of the two slumps:

Part 2.

Here is a LIDAR image at the Delaware Water Gap on the Delaware River, at the northern tip of Warren County, New Jersey. There is a debris flow that occurred by the river. Try to locate it; then circle it.



You should be realizing that the LIDAR image was not helpful.

Now try viewing the aerial image of the same area:

What happened? The aerial imagery clearly shows where the landslide occurred, but the LIDAR does not. This is the opposite result of the imagery from Atlantic Highlands.

Here is the location of the debris flow:

Quick Questions:

- Have you changed your opinion about a type of imagery that is more useful in identifying landslides?

- What is your conclusion?

Comparing aerial or satellite images to LIDAR images is only one way of finding landslides and other features. Scientists must also look at imagery of one type from different *years* to get the best picture of the land and determine the changes that occurred over time. For example, a satellite image from one year might not be the same or as good as an image from another year. Perhaps a landslide is seen in images from three different years and all show a change in the area. That is important data! It takes a lot of going back and forth between images to get all the information possible.

Do we have historic data on New Jersey landslides?

The earliest known recorded landslide in New Jersey is from 1782 — shortly after the American Revolution! However, landslides that happened long ago were not well documented. There are 345 recorded landslides in New Jersey, from the 1782 event through December 2019. You can see a large difference in the numbers of landslides recorded each century in this table:

Landslides Recorded in New Jersey

Century	Number of Landslides
18th (1700s)	1
19th (1800s)	4
20th (1900s)	91
21st (2000 through 2019 only)	225
Unknown Date	24
Total	345

In the 20th century, scientists began keeping better notes on natural events like landslides. Technology — like databases, digital imagery, mapping, and modeling — has helped make gathering, keeping, and analyzing data on landslide events much easier and quickly shareable amongst many people.

Quick Activity: On the following page is a table with information about two landslides that occurred in Warren County, New Jersey approximately 100 years apart. Compare the information and answer the following questions:

1. Which landslide was better documented?

2. Which landslide was better and more scientifically analyzed for its cause?

Two Landslides in Warren County, NJ		
Date	July 1887	October 1995
Location	Manunka Chunk	Wallpack Bend
Causes	Three days of rain; presumed that poor drainage behind railroad track loosened soil	Heavy rain; thin, saturated soil; undercut slope at bend in river; soil slid on polished bedrock beneath
Materials	Mud and water	Soil, water, plant material
Landslide Type	- *not specified* -	Debris flow
Results	House and a quarter mile of railroad track demolished	Cut bank collapsed, slope cleared of trees, plants; debris 60 feet into river
Deaths	2	0
Width	- *not specified* -	40-50 feet
Length	- *not specified* -	660 feet
Volume displaced	- *not specified* -	48,000 cubic feet

The 1887 event was written in the newspaper as a dramatic tale about the persons involved, and it included information that was irrelevant to the actual event! The lesson here is that it is important to perform a strong scientific study, gather facts, and present those facts for future use.

Can science prevent landslides?

Absolutely! In New Jersey and throughout the world, scientists study locations where landslides have already happened to predict future events. They analyze data about factors like rainfall, slope, vegetation, roads, and geology. Digital imagery helps to identify landslides (although they are still investigated on foot), maps are drawn, and data is compiled to create models and statistics on landslide chances and impact. Scientists can then predict:

- where and when will landslides occur
- how big will the landslides be
- how fast and how far will they move
- what areas the landslides will affect or damage
- how frequently landslides occur in a location

Landslides and their effects can be prevented or minimized by managing forests, carefully engineering roads and slopes, designing homes and businesses away from landslide-prone areas, and better controlling the way land is used.

There have been deaths from New Jersey landslides — about 65 over a long period of time. However, in the last half century, New Jersey citizens have been safely evacuated from landslide areas before the events occurred. Technology, mapping, and sharing data with emergency agencies for disaster planning has greatly helped save lives. If you see or learn of a landslide in New Jersey, please contact the New Jersey Geological and Water Survey at njgsweb@dep.nj.gov. This way you can help geologists keep track of landslides in New Jersey and help protect others.

References

United States Geological Survey. Frequently Asked Questions, Natural Disasters, Landslides. https://www.usgs.gov/faq/natural-hazards

NJDEP Bureau of GIS. Landslides in New Jersey. https://gisdata-njdep.opendata.arcgis.com/datasets/landslides-in-new-jersey

New Jersey Geological and Water Survey. Landslides In New Jersey, Series DGS06-3, Edition July 2018. https://www.state.nj.us/dep/njgs/geodata/dgs06-3.htm

Suggested External Websites and Activities

Landslide Lesson Plan – Australian Institute for Disaster Resilience
https://www.schools.aidr.org.au/media/4643/00_lessonplan_landslide_231017.pdf

Erosion and Landslides Lesson Plan – NASA
https://gpm.nasa.gov/education/lesson-plans/landslides-erosion

Beautiful Earth: Floods and Landslides – NASA
https://gpm.nasa.gov/education/videos/beautiful-earth-floods-and-landslides

Lesson: All About Landslides: Land on the Run – Teach Engineering
https://www.teachengineering.org/lessons/view/cub_natdis_lesson05

Hands-on Activity: Mini-Landslide – Teach Engineering
https://www.teachengineering.org/activities/view/cub_natdis_lesson05_activity1

Experiment with Erosion and Landslides Lesson Plan – Discovery Education
https://streaming.discoveryeducation.com/teacherCenter/lessonPlans/pdfs/6-8_Science_ExperimentWithErosionAndLandslides.pdf

Erosion and Landslides Lesson Plan – Discovery Education
https://streaming.discoveryeducation.com/teacherCenter/lessonPlans/pdfs/6-8_Science_ErosionAndLandslides.pdf

Do-It-Yourself Experiments - Landslide
https://www.youtube.com/watch?v=6tSnA9I6uL4

Correlations to the 2020 New Jersey Student Learning Standards (NJSLS)

The following ***Disciplinary Core Ideas*** can be correlated to the activities within this bulletin:

Disciplinary Core Ideas in Physical Science
PS1: Matter and Its Interactions
- PS1.A: Structure and Properties of Matter

PS2: M K-2-ETS1-Motion and Stability: Forces and Interactions
- PS2.A: Forces and Motion
- PS2.B: Types of Interactions
- PS2.C: Stability and Instability in Physical Systems

PS3: Energy
- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer
- PS3.C: Relationship Between Energy and Forces

Disciplinary Core Ideas in Earth and Space Science

ESS2: Earth's Systems

- ESS2.C: The Roles of Water in Earth's Surface Processes

ESS3: Earth and Human Activity

- ESS3.B: Natural Hazards
- ESS3.C: Human Impacts on Earth Systems

Disciplinary Core Ideas in Engineering, Technology, and the Application of Science

ETS1: Engineering Design

- ETS1.A: Defining and Delimiting an Engineering Problem
- ETS1.B: Developing Possible Solutions
- ETS1.C: Optimizing the Design Solution

ETS2: Links Among Engineering, Technology, Science, and Society

- ETS2.A: Interdependence of Science, Engineering, and Technology
- ETS2.B: Influence of Engineering, Technology, and Science on Society & the Natural World

See pages 5 and 6 of https://www.nj.gov/education/cccs/2020/NJSLS-Science.pdf.

All ***Crosscutting Concepts*** found on page 7 of https://www.nj.gov/education/cccs/2020/NJSLS-Science.pdf can be correlated to the activities within this bulletin.

Disciplinary Core Ideas in Computer Science and Design Thinking

8.2 Design Thinking

- Engineering Design
- Interaction of Technology and Humans
- Effects of Technology on the Natural World

Disciplinary Concepts in Social Studies

Geography, People and the Environment: Human Population Patterns