When Leah was getting ready for school, it began to rain. “Oh no, there goes our basketball practice again,” she thought. “I hope it stops raining by tomorrow.”

She ate her breakfast while her mother read the newspaper. “It says here it’s going to rain all day today,” said her mother. “This is the fourth day in a row. I’ll give you a ride to school, but let’s leave early. There might be traffic problems because of the rain.”

“Thanks, Mom,” said Leah, as she grabbed her rain jacket. “Yesterday I walked to school, and I was wet and cold all day.”

As they drove along North Street, they had to slow down several times where water had flooded the road. Leah noticed that there was a lot of mud along the curb near the park.

“Where did that mud come from?” she asked.

“I don’t know,” said her mother, “but it wasn’t there before all this heavy rain. It sure has made a mess.”

Where did the mud come from? How was it transported to the road?

In this unit, you will explore the earth processes that move rocks and soil from one place to another. You will learn how they shape the land around you.
Over the last 20 years, the population of Boomtown has been growing steadily. People have built houses and stores on most of the available land. Now, the Boomtown City Council is trying to decide where to build a new development of apartment buildings and houses. Three possible locations for the new homes are being considered.

Where should Boomtown construct the new buildings?

**MATERIALS**

For each group of four students

PROCEDURE

1. Each set of photographs on the next page shows a different location, before and after the construction of buildings. In your science notebook, make a table like the one below.

<table>
<thead>
<tr>
<th></th>
<th>Appearance Before Construction</th>
<th>Appearance After Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hillside</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cliff</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Carefully examine the photographs, one location at a time. Observe changes before and after the construction in
   - the land
   - the plants and animals
   - the water

3. Discuss these changes with your partner. Then record your observations in your table.

4. After observing the photographs of all three locations, discuss your ideas with the other pair in your group of four. Review your table together and then add any new observations of the three building sites.

5. Examine the map of Boomtown on Student Sheet 24.1, “Street Map of Boomtown Today.” Find each of the three sites being considered for the new homes:
   - Delta Marsh
   - Green Hill
   - Seaside Cliff
Activity 24 • Where Shall We Build?

BUILDING SITES BEFORE AND AFTER CONSTRUCTION

Marsh before

Marsh after

Hillside before

Hillside after

Cliff before

Cliff after
1. Marshes, hills, and cliffs are three kinds of landforms. A landform is any characteristic physical shape of the earth’s surface. Make a list of some other familiar landforms that you can think of that aren’t mentioned in this activity.

2. Explain how each of the following places was either changed or not changed by the construction of buildings:
   a. marsh
   b. hillside
   c. cliff

3. Based on what you know so far, on which site do you think Boomtown should build houses? Explain, using the observations that formed your opinion.

4. Explain how the following information about the Delta Marsh, Green Hill, and Seaside Cliffs could help the council make the decision about where to build the new housing.
   a. weather
   b. animals
   c. plants
   d. housing prices
   e. shape of the land

5. Reflection: Compare Boomtown to where you live now. How is it similar or different?
A collection of landforms in an area is called its **topography** (ta-PAH-gruh-fee). In Boomtown, there are many different kinds of landforms that make its topography interesting. For example, the street map of Boomtown shows that it has a hill, river, marsh, cliff, and beach. These landforms can be identified because they are labeled on the street map.

For places that are not clearly named, or where more information about the landform is needed, a **topographical map** is useful. A topographical map uses a series of lines to represent the three-dimensional shape of the land surface. Each line represents a specific elevation (el-a-VAY-shun) above sea level. For example, one line on a topographical map might represent an elevation of 100 meters. Topographical maps can be confusing for those not familiar with them. This activity will help you understand how lines on a topographical map represent the shape of the land.

**CHALLENGE**

What do the lines on a topographical map show?

*This topographical map shows roads, trails, creeks, and lakes in addition to elevation.*
MATERIALS

For each group of four students

1. landform model
2. transparent plastic lid
3. dry erase marker
4. 15-mL bottle of blue food coloring
5. large container of cold water

PROCEDURE

1. Place 20 drops of food coloring in your container of water.

2. Place the lid on the box of the landform model and look down at the landform. Use the marker to draw a dashed line on the lid that outlines the edge of the landform.

   **Hint:** It may help to close one eye when you’re viewing the box from above. Make sure to keep your head in one place while you’re drawing the line.

3. Being careful not to smudge your line, remove the lid and fill the box with water until it reaches the first step on the side of the box.

4. Place the lid on the box and then use the marker to draw at least one line that shows where the water reaches the sides of the landform.

5. Label any line you draw with a “1.”

6. Add water until it reaches the next step, and repeat Steps 2–4. Label the line(s) drawn with water filled to the second step with a “2.”

7. Add water to the levels of the third, fourth, and fifth steps of the box, repeating Steps 2–4 each time. Label the lines “3,” “4,” and “5.”

8. Watch carefully as you add just enough water to cover the top of the landform. Use your observations to place an “X” on the lid above the highest point.
ANALYSIS

1. A contour interval is the change in elevation between adjacent lines. If each water line in your landform model represents 25 meters, what is
   a. the contour interval for your topographical map?
   b. an estimated height of the top of the hill?

2. a. What does your topographical map show you about the land?
   b. What does your topographical map not show you about the land?

3. Compare the following diagrams that were each drawn with the same contour interval and scale.
   a. Which one shows a fairly flat area?
   b. Which one shows a hill or a valley with a gentle slope?
   c. Which one shows a steep hillside?

4. Look at the diagram below and answer the following questions.
   a. What kind of landform is this?
   b. Which of the locations marked on the map is the steepest?
   c. Which of the locations marked on the map is the flattest?
An important part of evaluating a building site is determining the stability of the land. Stable areas have landforms that have not changed much over a long time. One way to learn about recent changes to the land surface is to compare the present day topography with past topography.

*Although Boomtown has grown quickly in the last twenty years, it was only a small town one hundred years ago. The Boomtown Library has maps that can show you how the area looked in the past.*

**What can topographical maps tell you about the stability of a building site?**

**MATERIALS**

For each pair of students
- 1 Student Sheet 26.1, “Maps of Boomtown 100 Years Ago”
- 1 Student Sheet 26.2, “Maps of Boomtown 20 Years Ago”
- 1 Student Sheet 26.3, “Maps of Boomtown Today”
**PROCEDURE**

1. Each student sheet shows a street map and a topographical map of Boomtown at different times: 100 years ago, 20 years ago, and today.

2. In your science notebook, make a table like the one below.

3. Carefully examine the maps and compare one location at a time.

<table>
<thead>
<tr>
<th>Location</th>
<th>100 years ago</th>
<th>20 years ago</th>
<th>Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hillside</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cliff</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observe changes in
- roads and buildings
- waterways
- landforms

4. Discuss any changes you see in the maps with your partner. Record your observations in your table.

5. After observing all the maps, discuss your ideas with the other pair in your group of four. Review your table together and add any new observations of the three building sites.
ANALYSIS

1. What is the contour interval in the topographical maps of Boomtown?

2. a. What major changes did you observe between 100 years ago and 20 years ago?

   b. What major changes did you observe between 20 years ago and today?

3. Look at the maps of the three locations in Boomtown.

   a. Which of the three locations is the most stable?

   b. Which of the three locations is the least stable?

   c. Explain the evidence that supports your answers to 3a and 3b above.

4. Do the maps indicate possible problems for building at any of the possible locations?
The shapes of landforms are affected by flowing water. Water comes from several sources, including rain, river flow from mountains, and ocean waves hitting the beach.

One hundred years ago, the Boomtown historian wrote about the Rolling River flooding from heavy rain. The area had 30 centimeters (12 inches) of rain in one month, most of which fell during one week. Main Street was covered with water! The base of Green Hill was flooded, Delta Marsh was full of water, and Seaside Cliff had streams running off its edge.

Flooding from such storms could create problems for housing built at these locations. Looking at the history of Boomtown’s average rainfall will help you determine the risk of future flooding.

Is Boomtown’s rainfall likely to cause flooding?
PROCEDURE

1. Use the data in Table 1 below to make the following calculations.

   a. Calculate the mean annual rainfall for this 10-year period.
      
      Hint: Calculate the mean by adding up all of the values and dividing by the total number of values.

   b. Calculate the mode for annual rainfall for this 10-year period.
      
      Hint: The mode is the value that appears most often.

   c. Calculate the median annual rainfall for this 10-year period.
      
      Hint: The median is the middle value after the data has been listed from smallest to largest OR largest to smallest. If the data has an even number of values, then the median is the average (the mean) of the two middle values.

2. Use the data in Table 1 to make a bar graph of Boomtown’s annual rainfall in centimeters.

3. Draw a horizontal line across your graph to show the mean annual rainfall. Label the line, “Mean: annual.”

Table 1: Annual Rainfall in Boomtown: 2002–2011

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (centimeters)</td>
<td>92</td>
<td>99</td>
<td>89</td>
<td>94</td>
<td>94</td>
<td>84</td>
<td>97</td>
<td>85</td>
<td>94</td>
<td>72</td>
</tr>
<tr>
<td>Rainfall (inches)</td>
<td>36</td>
<td>39</td>
<td>35</td>
<td>37</td>
<td>37</td>
<td>33</td>
<td>38</td>
<td>33</td>
<td>37</td>
<td>28</td>
</tr>
</tbody>
</table>

Data provided by Boomtown Weather Service
4. Use the data in Table 2 above to make the following calculations.
   a. Calculate the mean monthly rainfall.
   b. Calculate the mode monthly rainfall.
   c. Calculate the median monthly rainfall.

5. Use the data in Table 2 to make a bar graph of Boomtown’s average monthly rainfall in centimeters.

6. Draw a horizontal line across your graph to show the mean monthly rainfall. Label the line, “Mean: monthly.”

**ANALYSIS**

1. Look at the graphs of annual and monthly rainfall in Boomtown. Describe any patterns that you see in the rainfall.

2. a. Is there anything unusual about Boomtown’s annual rainfall? Explain.
   b. Is there anything unusual about Boomtown’s monthly rainfall? Explain.

3. During the same year, a town in California and a city in Maryland both received about 99 cm (39 inches) of rain. In August, the town in California had less than one centimeter of rain while the city in Maryland had 7 cm (3 inches). Explain how these two places could have the same annual rainfall.

4. Which location—Delta Marsh, Green Hill, or Seaside Cliff—would be most affected by
   a. a year of typical rainfall in Boomtown? Explain.
   b. another flood in Boomtown? Explain.

5. **Reflection:** How does Boomtown’s rainfall pattern compare to that of your community?
EXTENSION

Use the data in Table 3 below to make a bar graph of Boomtown’s monthly rainfall in 2001, in centimeters. Compare it to the graphs you made in this activity.

a. How was the annual rainfall in 2001 both similar to and different from Boomtown’s annual rainfall from 2002 through 2011?

b. How was the monthly rainfall pattern in 2001 both similar to and different from Boomtown’s average monthly rainfall from 2002 through 2011?

Table 3: Monthly Rainfall in Boomtown in 2001

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (centimeters)</td>
<td>0</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Rainfall (inches)</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

Data provided by Boomtown Weather Service
Rivers carry water that is flowing from a higher elevation to a lower elevation. While it travels, water breaks apart and carries away small pieces of rocks and soil. The flowing water carries these sediments downhill until the water can’t carry them anymore and they are dropped to the ground again. The water drops these sediments in places where they pile up and create new land.

How can moving sediments create problems for construction?
PROCEDURE

1. Set up the river model as shown below.

2. Use Student Sheet 28.1, “River Model Drawings,” to predict what will happen to the sand and water when water is allowed to flow down the river model. Draw your ideas on the left-hand diagram labeled “Prediction.”

3. Using the 30-mL graduated cup, put 3 full cups of sand into the river model between Point A and Point B.

4. Use your fingers or the spoon to pack the sand into a uniform layer that covers the bottom of the river model between Point A and Point B.
5. Place the rainmaker over Point A of the river model, as shown below.

![Rainmaker over Point A](image)

6. Add 50 mL of water to the rainmaker.

7. Observe the effect of the water on the sand. Make sure to watch not only what happens in the river model, but also what happens in the catch basin.

8. Repeat Steps 6 and 7 two more times.

9. On Student Sheet 28.1, draw the water and shape of the sand on the diagram labeled “Observations.” Label the diagram as completely as you can.

**ANALYSIS**

1. **a.** How is your river model like a real river?
   
   **b.** How is it not like a real river?

2. Describe the biggest changes that you observed during the river model investigation.

3. Observe the photograph at right. It shows a river at the bottom of a canyon with hard rock walls.
   
   **a.** Explain how the water flowing down the river created the canyon.
   
   **b.** Explain what happened to the rock that once filled up the canyon.
4. How did the movement of sediments help make each of the following landforms?
   a. marsh
   b. hillside
   c. cliff

5. How could the movement of sediments cause a problem if someone builds on:
   a. Delta Marsh
   b. Green Hill
   c. Seaside Cliff

EXTENSION

Investigate how the steepness of the land affects the movement of sediments in the river model. Model a steeper hill by placing a book or books under the base of the river model and then repeat the investigation. Compare your results from the steeper slope with those from the less steep slope.
Earth processes are dynamic actions that occur both on the earth’s surface and inside the earth. Any process that breaks down earth material, such as water eroding the side of a hill, is called a destructive process. Processes that build up earth material, such as the deposition of sediments that create landforms such as deltas, are called constructive processes.

Destructive forces are not always harmful and constructive forces are not always helpful. The effect of natural earth processes depends on the situation. Before building, it helps to understand how certain earth processes affect the land you plan to build on.

What happens when soil and rocks are moved from one place to another?

**MATERIALS**

*For each student*


Destructive earth processes helped form these towers of rock, called hoodoos, in Arches National Park.

In Alaska, where this river meets a lake, constructive earth forces built up a delta.
READING

Use Student Sheet 29.1, “Three-Level Reading Guide: Weathering, Erosion, and Deposition,” to guide you as you complete the following reading.

The Process of Weathering

One earth process that breaks down rocks into smaller pieces is called weathering. Over time, rocks crack, crumble, and are broken apart by water and wind. Drops of water on a rock may repeatedly freeze and melt, causing the rock to crack. Water may react with some of the chemicals in a rock and cause part of the rock to break down. Rocks sometimes fall from higher places, breaking as they fall. Small animals and the roots of plants also contribute to the weathering of rock when they burrow into the ground. Weathering forms sediments that can be moved by wind and water.

The Process of Erosion

The movement of sediments from one place to another by water, wind, or ice is called erosion (e-ROW-shun). When water erodes the earth’s surface, it cuts into the ground, forming surface channels. These channels can range from tiny depressions in the earth to huge canyons, such as the Grand Canyon. Slow and steady water erosion over long periods of time has created valuable features of the earth’s landscape such as lakes, rivers, hills, canyons, and fertile plains.

Natural events, such as the floods from storms and tsunamis, often cause more dramatic erosion. Shorelines have shifted and rivers have changed their courses as a result of these events. Glaciers—large sheets of snow and ice—also bring erosion. The glacier’s weight causes it to move slowly, scraping away the surface of land.
Results of Erosion

Erosion forms important landforms, but it can also be damaging. Serious problems occur when land quickly collapses or slides near buildings or roads, as shown at left. Slower erosion can also cause damage to roads and buildings. A hillside that erodes over many years can cause buildings on it to shift or be in danger of toppling over. Erosion near a road can cause rocks and sediments to suddenly move onto the road. Even worse, the road itself could eventually erode.

Erosion also creates caves. Ocean waves that crash into sandstone or limestone wear pockets of the rock away. Other caves are caused by rainwater that seeps into the earth. Rainwater picks up carbon dioxide from decaying plants and animals, forming a weak acid. This acid dissolves limestone, forming a cave. As the carbon dioxide evaporates, calcium carbonate leaves cone-shaped structures that hang from the roof (stalactites) or project from the floor (stalagmites) of the cave.

Glaciers caused these landforms in Yosemite National Park.

The projections from the roof (stalactites) and floor (stalagmites) in this cave formed from calcium carbonate left behind when carbon dioxide evaporated from the cave.
Weathering, Erosion, and Deposition • Activity 29

The Process of Deposition

When erosion carries sediments from one place to another, the sediments are left, or deposited somewhere else. This earth process is called deposition (de-puh-ZI-shun). It occurs when pieces of rock or soil settle out of flowing water, ice, or wind as they slow down. The rocks and earth materials that a glacier picks up are often deposited far away from their source. The processes of erosion and deposition are closely related because erosion moves the sediments that are eventually deposited. A delta at the mouth of a river is an example of a landform formed by deposition.

In some cases, deposited sediments can be helpful. For example, sediments add important nutrients to the soil. The Mississippi and Nile River valleys have large fertile floodplains that are excellent for growing crops. These plains have been formed by the deposition of sediments that occurs when the rivers flood. After very long periods of time, deposited sediments can even form rocks such as sandstone. Deposition also builds landforms in new places. Figure 1 below shows the amount of sediment at the mouths of rivers in different areas of the U.S. Notice the large amount of sediment where the Mississippi River empties into the Gulf of Mexico.

![Figure 1: Sediment Deposition in the United States](image)

The size of each brown semicircle indicates the amount of sediment deposited by a river when it empties into the ocean. Darker colors on the land indicate eroded sediments that will be moved by rivers.
In other cases, deposited sediments can be harmful. Sediments can build up and fill in rivers, lakes, wetlands, bays, and even parts of the ocean. Sediments can cover the habitat areas needed by fish and other animals. For people, deposition in the wrong place can make the water too shallow for boats and clog the pipes that provide water to towns and cities.

**People and Earth Processes**

The processes of weathering, erosion, and deposition have been occurring for billions of years. Many natural factors affect the rate of these processes. In addition, human activities can accelerate them. For example, the photos below show that clearing plants from the land can result in erosion or deposition. Construction and farming are the two human activities that cause the most erosion. These activities break apart the rocks, soil, and plant roots that hold the land in place. This makes it easier for water or wind to erode the exposed land. In time, the effects of such erosion can make such areas less suitable for building or farming.

Once sediments have been eroded as a result of human actions, they can cause problems when they are deposited. Many rivers, lakes, and ocean areas have been filled in by heavy deposition. In addition, sediments can carry pollution when they are deposited. These sediments can carry toxic materials, such as pesticides used in farming or chemicals that are already present in the soil.
ANALYSIS

1. Why is weathering important to the process of erosion?

2. Why does erosion always lead to deposition? Explain and provide an example.

3. Prepare a concept map for weathering, erosion and deposition. Be sure to use the following terms:

   - earth processes
   - weathering
   - erosion
   - deposition
   - sediments
   - wind
   - water
   - ice
   - floodplains
   - lakes
   - toxic materials
   - environment
   - delta
   - water
   - positive effects
   - negative effects
   - farming
   - construction

4. Look back at the topographical maps on the student sheets from Activity 26, “Boomtown’s Topography.” Choose one major topographical change in Boomtown. Describe the change and the earth process(es) that may have caused the change.

5. At which of the three building sites—Delta Marsh, Green Hill, and Seaside Cliff—would you expect:
   a. erosion to have the most effect on the land?
   b. deposition to have the most effect on the land?

EXTENSION

Earth processes such as weathering, erosion, and deposition help make the landforms that are all around you. Some landforms are formed quickly, while others take millions of years. Visit the Issues and Earth Science page of the SEPUP website to find more information about specific landforms found in the United States.
A delta is formed when a river slows down and deposits sediment as it flows into a lake or ocean. The largest delta in the United States is at the mouth of the Mississippi River. The Mississippi River Delta has an area of 3 million km² and the river continues to deposit over 300 metric tons of sediment per year.

The Mississippi Delta wasn’t always so large. Over a period of millions of years, the Mississippi River carried and deposited sediment that eventually built up a huge fan-shaped delta. This ancient delta made up the land from southern Illinois to Louisiana and Mississippi, as shown below.

The city of New Orleans is built on land deposited by the Mississippi River and this location has resulted in many problems for the city. In 2005, the city was affected by a severe hurricane and flood that took over 1,800 lives. Although New Orleans has rebuilt a lot of its downtown area, there is still a lot of damage. The future of the city continues to be uncertain because of the earth processes that shape the area.

CHALLENGE

How has the Mississippi River Delta challenged the people of New Orleans?
PROCEDURE

1. Assign one of the following roles to each person in your group.
   - Teresa Corelli, interviewer for the Student Science Hour
   - Natalie Ludlow, ecologist
   - Dr. K.C. Sandoval, geologist at Boomtown University
   - Ethan Porter, engineer from Builders, Inc.

2. In your group, read the role-play aloud. As you read, think about what each character is saying.

3. Discuss what you think the people of New Orleans can do about the problems they face due to their location.

4. Mark whether you agree or disagree with the statements on Student Sheet 30.1, “Intra-act Discussion: Challenges of the Mississippi Delta.” Predict what you think other members of your group will say.

5. Discuss the statements with your group. Have each person share his or her opinion about each statement and explain why he or she agreed or disagreed.

NEW ORLEANS: AN UNCERTAIN FUTURE

Teresa: Welcome to the Student Science Hour. Today we have brought together a panel of experts who will help us explore some of the challenges facing New Orleans because of its location. What can be done to prevent another disaster? Panelists, please introduce yourselves and describe your background.

Dr. Sandoval: Hello, my name is K.C. Sandoval. I am a geology professor at Boomtown University. I study earth processes, such as erosion and deposition, in the Mississippi River Delta.

Ms. Ludlow: My name is Natalie Ludlow. I studied ecology when I was in college. Ecology looks at the relationships between organisms (including humans), and our environment. Some ecologists, like me, are interested in understanding the relationship between the natural world and human activities. I use my ecology background to help politicians preserve the environment for the future.
Mr. Porter: And I’m Ethan Porter. I’m an engineer for a large construction company. My company works with the cities along the Mississippi River, building many of the large buildings, roads, and bridges in the area. My expertise is in flood control and in constructing safe structures on soft, wet ground.

Teresa: I’m glad that you could take the time to join us today. Now let’s talk about New Orleans and the Mississippi Delta. Dr. Sandoval, I understand that even before Hurricane Katrina, many scientists had warned that New Orleans was in danger.

Dr. Sandoval: Yes, that’s right. Its location puts it at great risk. To understand this, you must first understand how the land in southern Louisiana was formed. The powerful Mississippi River erodes many tons of soil every year. When the rapidly flowing river hits the Gulf of Mexico, it slows down and deposits the small bits of dirt and soil that it has been carrying at the mouth of the river. Over thousands of years, these sediments built up until they rose slightly above the level of the water. New Orleans was built on the loose soil of the delta.

Teresa: Mr. Porter, why was the city built on such an unstable place?

Mr. Porter: New Orleans was built on the banks of the Mississippi River because the river was used to ship products between the central United States and the Gulf of Mexico. It has not always been located below sea level. Until one hundred years ago, construction was limited to a more stable area on the naturally higher ground along the river. Much of the rest of the delta at that time was a marshy floodplain that was wet and frequently flooded.
Teresa: How can parts of New Orleans be located below sea level, but not be under water?

Mr. Porter: As New Orleans expanded, a system made up of levees, canals, and pumps was built to control the water. This system was built to hold back the river and drain the surrounding marsh, so New Orleans could grow. Because of this engineering, parts of the city were built 1 to 6 meters below sea level. The system keeps the land dry by controlling the path of the Mississippi and by removing extra water.

Teresa: Is that why Hurricane Katrina caused such a severe flood in 2005?

Mr. Porter: That is part of it. The levees that held the water back failed in the storm. Very quickly afterwards, water flooded the city and destroyed houses, roads and the pump system itself. Unfortunately, about 1,000 people lost their lives, while many more New Orleans residents lost their homes or jobs.

Teresa: Ms. Ludlow, can you tell us how building a city on the delta can affect the environment?

Ms. Ludlow: When New Orleans expanded onto the delta, the surrounding marsh was drained. It may be good for the city in the short term, but removing a marsh, which is a kind of wetlands, can be a disaster for the environment. It damages plants and animals that can only live in that kind of environment, or habitat. Wetlands might not be attractive to people, but they provide food and homes for fish, shellfish, and birds.

Teresa: How was the ecology affected by the events from Hurricane Katrina?

Ms. Ludlow: It harmed the wildlife in the area, and, even now, we do not know how long it will take to recover. We estimate 150,000 acres of coastal wetlands and bottomland forests were damaged on national wildlife refuges alone. The debris and silt left from the storm damaged habitats and reduced the fish and shellfish populations. This in turn harmed the birds that depended on the fish and shellfish for food. Many endangered animals lived in this area. We know that 50 sea turtle nests were lost, as were 70% of the trees that were home to endangered red-cockaded woodpeckers.
Teresa: Dr Sandoval, New Orleans decided to rebuild and has been successful, at least economically. What are the problems the city will face in the future?

Dr. Sandoval: Of course, there is always the threat that they will be hit with another large hurricane. But in addition, there are problems that are the result of efforts to control the Mississippi River.

Teresa: You mean there is more to the story than just removing the water?

Dr. Sandoval: That’s right. The natural processes in the area are disrupted by the city. This is because the sediments that would usually be deposited in the New Orleans area are not allowed to be deposited there. Instead, the river is controlled and the sediments are carried farther downstream to the mouth of the river. So, the land in the New Orleans area is not built back up with fresh sediments.

Teresa: This must be related to the sinking land in New Orleans.

Dr. Sandoval: Exactly. The land under the city has been sinking for quite a while. The land compresses as the water is removed, which causes it to slowly sink as the water is pumped away. Even before the flood, it was not uncommon to see large gaps and cracks under buildings in New Orleans.

Teresa: Mr. Porter, is the water control system in New Orleans making the Delta smaller?

Mr. Porter: Yes, it is. An unfortunate result of the water control system that moves water away from the city is that it prevents the water from depositing sediments. It’s successful in keeping the city dry, but Dr. Sandoval is right in that controlling the river flow disrupts the natural balance of erosion and deposition in the area. All of the sediments are sent downstream to another location, while erosion continues to wash away the delta.

Teresa: Ms. Ludlow, is the area near New Orleans the only place where the Mississippi Delta is shrinking?

Ms. Ludlow: No, the entire state of Louisiana is losing its wetlands at an incredible rate. In the southern section of the Mississippi River, the delta is sinking and being washed away faster than it is being replaced.
Teresa: Dr. Sandoval, I heard that the Mississippi River is trying to change its course. Is this true?

Dr. Sandoval: Yes, that is true. When people built New Orleans and the surrounding area, they created buildings and roads around the natural channel of the river. But over time, the channel of any river will change as erosion and deposition continue. The Mississippi River is no exception. For the last 50 years, the river has been trying to travel a shorter path to the sea. This would take it away from New Orleans.

Teresa: Dr. Porter, it seems like letting the Mississippi River change its channel would reduce the risk to the people of New Orleans. Isn’t it a good idea to let nature win this battle?

Mr. Porter: You’re right that a change in the river channel would reduce the risk of flooding in the city of New Orleans. But it would destroy homes, roads, and other structures in its new channel. It would also be the end of the port of New Orleans. The economic impact of closing this port is tremendous, since it is one of the largest in the United States.

Teresa: I have one last question for each of you. During Hurricane Katrina, the people of New Orleans suffered terribly. As the city is rebuilt, what do you think could be done to prevent another catastrophe like this?

Ms. Ludlow: I believe as much of the wetlands habitat as possible should be restored to the area. Not only will this help protect the wildlife, but it will also protect the area from flooding. Wetlands can protect an area from floods during storms by absorbing large amounts of water before it reaches the city. Without the wetlands located between New Orleans and the Mississippi River, the city is more likely to flood again.

Mr. Porter: In the future we must focus on maintaining the safety of the large population of New Orleans. We have the technology to protect ourselves from even the worst disasters. It is a question of having enough money to build what we need to keep people safe. I believe that the answer is to do a better job of controlling the water in the future.

Dr. Sandoval: Flooding will be an ongoing problem in the future of the Mississippi Delta region. Having studied the effects of natural processes over a long period of time, I do not believe that controlling the river is good for the people of New Orleans in the long run. I believe that we should allow the river to change its course and that people should learn to work around nature, instead of bending nature to our needs. In the end, I think that nature will win anyway.

Teresa: Unfortunately we have run out of time for the Student Science Hour. Thank you all for joining us today.
ANALYSIS

1. Name three problems that the city of New Orleans faces as a result of its location on the banks of the Mississippi River.

2. How are erosion and deposition related to the problems that New Orleans has experienced?

3. Compare the situation of the Mississippi River in New Orleans to the Rolling River in Boomtown.
   a. List the similarities.
   b. List the differences.

EXTENSION

Investigate careers in ecology, engineering, and geology. Start at the Issues and Earth Science page of the SEPUP website.
The amount of erosion that occurs, whether on the banks of the Mississippi River or on Green Hill in Boomtown, depends on two major factors. The first factor is the strength of the force causing the erosion. For example, a fast-flowing river has more force than a trickle of water. Water flowing down a steep slope will erode the land more quickly than the same amount of water flowing down a flatter portion of the same hill, because the water travels faster on the steep slope. The second factor that determines the effect of erosion is the resistance of the material that is being eroded. For example, if granite and sandstone are both undergoing the same erosional force, the sandstone will erode faster because it is “softer,” or less resistant to erosion.

In and around Boomtown, there are different kinds of soils and rocks. Green Hill has loose and relatively soft soil. Seaside Cliff has more erosion-resistant, compact soil that is also sticky. In this activity you will investigate the resistance of earth materials to erosion under similar forces.

Do all kinds of earth materials erode in the same way?

The rock layers shown above are made of limestone and shale. Notice how the two kinds of rock erode differently.
Activity 31 • Resistance to Erosion

MATERIALS

For each group of four students
3 plastic basins
1 rainmaker
1 50-mL graduated cylinder
1 30-mL graduated cup
1 plastic spoon
supply of Earth Material A
supply of Earth Material B
supply of Earth Material C
supply of water
paper towels
masking tape

PROCEDURE

1. In your science notebook, make a table like the one below.

   Observations of Erosion Resistance

<table>
<thead>
<tr>
<th>Basin</th>
<th>Observations Ranking</th>
<th>Erosion Runoff</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Place the three plastic basins next to each other on the table. Use the masking tape to label them A, B, and C.
3. Using the spoon, pack the 30-mL graduated cup with Earth Material A.
4. Make a small “hill” by flipping the cup over in the center of Basin A. Remove the 30-mL cup, but leave the material standing in the basin as shown.

5. Repeat Steps 3 and 4 using Earth Materials B and C and their labeled basins.

6. Place the empty rainmaker over the basin that contains Earth Material A.

7. Add 50 mL of water to the rainmaker.

8. Observe any changes that take place as a result of the water on the hill. Pay close attention to how much erosion occurs and how much water runs off the hill. Record your observations in your table.

9. Repeat Steps 3–8 for Earth Materials B and C.

10. Compare the three model hills. In your table, rank how much erosion occurred on each hill with 1 indicating the most erosion and 3 indicating the least erosion. Then rank how much water ran off the hills with 1 indicating the most runoff and 3 indicating the least runoff.
ANALYSIS

1. How are the models you used:
   a. like a real landform?
   b. not like real landform?

2. In this investigation, what variables were:
   a. kept the same?
   b. tested?
   c. not kept the same?

3. In your model, which earth material showed the least erosion? Using evidence from this investigation, explain why this material may have eroded less than the other two.

4. The hills made in this activity model the three kinds of earth materials listed below. Copy the list and then, next to each description, write whether it describes Earth Material A, B, or C. For each one, give the evidence from this activity that helped you make your choice.
   a. loose soil
   b. sticky soil
   c. loose soil with vegetation

5. Would you expect more erosion to be observed at Green Hill or Seaside Cliff?
In the previous activities you investigated erosion and deposition caused by rivers, streams, and rain. But erosion can take place anywhere that water, ice, or the wind carries pieces of rock or soil from one place to another. The shores of oceans, seas, and lakes are other sites where erosion and deposition play a role in shaping the land. In this activity you will model the role of ocean waves at Seaside Cliff and examine their effect on the rate of erosion.

**Challenge**

How do ocean waves affect the shape of the land?

These photographs show the same cliff in California in 1987 and 2002. Notice how much of the cliff has eroded away from the columns that support the houses.
**Activity 32 • Modeling Erosion**

**PROCEDURE**

Part A: Modeling Cliff Erosion

1. Place the plastic retaining wall in the plastic box at the line marked on the box. Hold the wall vertically in the box.

2. Use the 30-mL graduated cup to fill the smaller portion of the box with 150 mL of moist earth material. Level the top of the material with the spoon.

3. Place the sand-filled end of the box on the catch basin from the river model. This will create a gentle slope.

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**MATERIALS**

For each group of four students

1. plastic box
2. plastic retaining wall
3. wavemaker (2 pieces)
4. river model catch basin
5. 30-mL graduated cup
6. spoon
   - supply of moist earth material
   - supply of water
7. 2 mesh sleeves of small rocks
8. 2 rectangular blocks, long
9. 2 rectangular blocks, short
4. While holding the retaining wall in place, gently pour water into the edge of the box opposite the earth material until it just touches the bottom of the cliff.

![Image of water being poured into a box to simulate erosion]

5. Complete the cliff model by carefully removing the retaining wall. Do this by slowly lifting the wall straight up out of the box.

6. Place the slotted part of the wavemaker on the side opposite the model cliff. Insert the other piece of the wavemaker into the slot, as shown at right.

![Image of the wavemaker being placed into the cliff model]

7. At the rate of 1 wave per 3 seconds, move the wavemaker back and forth along the bottom of the box 5 times. Record your observations in your science notebook.

8. Make 5 more waves and record your observations in your science notebook. Make 2 more sets of 5 waves and record your observations.

9. Observe the bottom of the container and record any additional observations in your science notebook.

10. Place the retaining wall back in the plastic box and use it to push the earth material back into the end of the box. Carefully drain out any remaining water in the box.

Part B: Preventing Cliff Erosion

11. Rebuild the cliff as in Steps 1–2. If the earth material is too wet to form the cliff, mix a little dry earth material into it until it is the right consistency.

12. Place two long rectangular blocks up against the base of the cliff. These blocks represent a retaining wall.

14. With your class, compare the results of the investigation with and without the retaining wall.

Part C: Modeling and Slowing Down Beach Erosion

15. Make a model of a beach by flattening the sand out where you built the cliff. Use the spoon to make an even slope to the water.

![Beach model](image)

16. Based on what you learned in Part A, design and build a structure to reduce erosion on the model beach. Work with the materials provided. The best design will involve as little material as possible to protect the beach. The structure you design should not prevent people from playing on the beach or swimming.

As you develop your design, make sure to:
- decide on a standardized way of testing your design, recording what happens, and explaining your design to others.
- predict what will happen when you make the waves.
- obtain your teacher's approval of your design, and conduct your investigation.
- construct diagrams that show the beach before and after you use the wave maker. Include any measurements you take.
- discuss ways in which the model might be improved, based on the evidence from your investigation.
- redesign the structure(s), and conduct the investigation again.

17. Present your final design to the class.

18. With the class, discuss the limitations of your design.
ANALYSIS

1. What did the waves do to the cliff model? Explain in terms of erosion and deposition.

2. What was the effect of the retaining rocks on the model cliff?

3. a. What kind of landform was created at the bottom of the model cliff?
   b. What earth process was involved?

4. Granite on a mountaintop is likely to erode differently than granite found on a sea cliff. Why do you think this is true?

5. Review your results and your response to Analysis Question 5 in Activity 31. This activity has provided you with more evidence about the erosion of cliffs. Where would you expect to see more erosion, at Green Hill or at Seaside Cliff? Be sure to explain your evidence.

6. What did all the designs for reducing erosion on a shoreline have in common? Explain how they reduce erosion at a cliff and a beach.

7. What are some of the advantages and disadvantages of building a structure to protect a cliff or beach?

EXTENSION

Design and conduct an investigation of the model cliff that compares the erosion in an area that has high and powerful waves to the erosion in a calmer area with less powerful waves.
Although a beach is not one of the possible building sites, Boomtown is a coastal community and the beach is important to the area. The Town Beach is a landform that is directly related to the three possible sites. Rain and sediments run down Green Hill to the Rolling River. The river then transports the water and sediments to the ocean at the Delta Wetlands, where they become a part of the beach. Likewise, eroded material from Seaside Cliff adds material to the beach.

Some geologists are interested by beaches because beaches are subject to repeated weathering, erosion, and deposition. Beaches are always changing because they are a part of a larger, dynamic system of earth processes.

How is a beach part of a coastal system?
Beach Formation

There are many kinds of beaches, with different shapes, types of sand, and waves of various sizes. The appearance of a beach depends on many factors, such as the wave energy of the ocean, the sediment supply from the river, the earth material in the area, the tides and the seasons, and the weather. Of these factors, the most important ones are the amount of sediment moved to the coast by the river and the amount of wave energy hitting the shore.

Beaches are most commonly found near the mouth of a river where sediments are deposited. A beach will form when the amount of sediment supplied by the river is in balance with the erosion energy of the ocean waves. In other words, a beach has equal and opposite forces: the constructive force of sediment deposition is roughly the same as the destructive force of the waves eroding the sediments.

A Naturally Changing Coastline

When the sediment supply from the river is much more than the ocean waves can erode, a delta will form. This happens at a coastline when the constructive force of deposition dominates over the destructive force of erosion. Deltas are typically formed on coastlines with large rivers. In fact, almost every major river builds a delta at its mouth. If the delta continues to form, it will extend the beach, or coastline, towards the ocean.

When the force of the ocean waves is much greater than the amount of sediment deposited by the river, the destructive force of erosion dominates the force of deposition. The result is a coastline that erodes and retreats inland. A beach can be washed away in this situation, or a cliff can form from any nearby high land. When a shore or coast is actively eroded, the effect can be dramatic because of the large force of ocean waves.

Longshore Current

Every time an ocean wave hits the beach, it picks up millions of sand grains and moves them. Sand is continually moved off shore and then back again. But sand doesn’t just move in and out from the beach. Because waves hit the shoreline at an angle, sand is pushed across the shore as well as in and out. The longshore current, which is a result of waves hitting the beach at an angle, is a stream of water in the ocean that runs parallel to the shore and moves sand across the face of the beach. (See Figure 1 on the next page.) The longshore current lengthens a beach by transporting sand and sediments away from the mouth of a river.
When humans build near the beach, there can be a large environmental impact because of the high activity of the earth processes there. One problem that is created when buildings, bridges, or harbors are placed on the shore is the interruption of the longshore current. When water in the longshore current travels around a structure, it slows down, causing sand and sediments to settle out of the water. This results in excessive deposition of sand near the structure.

Managing Earth Processes

One way to protect the beach from the problem of unwanted deposition is to dig up the sand and move it to another location. Dredging is often successful, but it’s a lot of work. It can also expose contaminated sediments, and can make the land less stable. A jetty—a rock structure built perpendicular to the shore—can help avoid the problem of unwanted deposition by collecting the sand on one side of it before it reaches the structure. Jetties are often used in harbors to prevent the harbor from filling in with sediment. (See Figure 2 on the next page.) Although a jetty will increase deposition on the upstream side of the jetty, the other side of the barrier will erode and narrow the beach there.

Another common problem associated with building on the shore is erosion caused by the force of ocean waves, which may make the land beneath the buildings unstable. One way to slow down this erosion is to reduce the energy of the waves. A breakwater—a rock structure that is built parallel to the shore—may slow erosion by reducing the wave energy that hits the shore. (See Figure 3.) However, the breakwater also slows down the longshore current, so that sediments in the longshore current are deposited in between the breakwater and the beach.
Sometimes piles of rock (called *riprap*) or *seawalls* are built right up against the cliff or shoreline. Ocean waves hit the structure instead of the cliff, reducing the wave energy and the amount of erosion. The erosion around the seawall, however, is often increased because waves are redirected there.

Dredging and building jetties, breakwaters, and seawalls are only some of the ways communities attempt to protect their coastlines. All of these approaches are effective, but have undesirable consequences. These structures can be effective for a while, but the protection is temporary. Eventually, the waves and longshore current will destroy any attempts to hold back the sea.

**ANALYSIS**

1. Describe how each of the landforms below contribute sediments to the Town Beach in Boomtown.
   a. Seaside Cliff
   b. Delta Wetlands
   c. Green Hills
   d. Rolling River

2. Look at the topographical maps of Boomtown over the last 100 years on Student Sheet 26.1, “Maps of Boomtown 100 Years Ago,” Student Sheet 26.2, “Maps of Boomtown 20 Years Ago,” and Student Sheet 26.3, “Maps of Boomtown Today.” At the Delta Wetlands, is the constructive force of deposition greater, less than, or equal to the destructive force of erosion? Explain your answer using evidence from the maps.
3. Prepare a concept map for beaches and coastal systems. Be sure to use the following terms:

- coastal system
- beach
- dredging
- erosion
- delta
- jetty
- deposition
- cliff
- breakwater
- balanced
- hill
- seawall
- longshore current
- river

4. Choose a method that helps control either erosion or deposition on the coastline. For the method you choose, describe both an advantage and a disadvantage of its use.

EXTENSION

Visit the Issues and Earth Science page on the SEPUP website for more information and dramatic photographs of beach and cliff erosion.
In Boomtown, all the land that is best for building has already been developed. The only options are to build on Green Hill, the Delta Wetlands, or the top of Seaside Cliff.

To help decide where to build new housing, the Boomtown City Council has asked local experts to visit the three possible building sites and report on their findings. In this activity, you will help prepare the Geologist’s Report. The City Council will discuss your report at their next meeting.

What is the geology of the three building sites?
Activity 34 • Preparing the Geologist’s Report

PROCEDURE

1. Read the Geologist’s Report on Green Hill on the next page.

2. With your group, review the report by identifying the following information:
   - the description and location of the landform
   - the role of earth processes in the area
   - the topographical changes and land stability over time
   - the potential geological problems for construction

3. To prepare for writing your own report, do each of the following steps with your group members.
   a. Gather information about the geology at the Delta Wetlands and/or Seaside Cliff. Use what you have learned from other activities in the unit.
   b. Complete Student Sheet 34.1, “Evidence for the Geologist’s Report,” by filling in the columns for your location(s). As an example, the Green Hill column is filled in already.

ANALYSIS

1. Prepare for the City Council meeting by writing a report stating what you know about the geology of the site(s) you investigated in Procedure Step 3.

In your report, include a summary of the relevant information on Student Sheet 34.1. An example of a report for Green Hill is on the next page.
Geologist’s Report: Green Hill

Green Hill is a 150-meter-high hill located next to the Rolling River in the western part of Boomtown. The land is steep on the west and south sides of the hill but it has a gentler slope on the east and north side. The east and south sides are covered with roads and homes. Green Hill is made up of loose, soft soil.

Erosion is the main earth process that affects this landform. The hill is eroded by the rainfall that runs down it. Eventually the sediments removed from Green Hill are carried down the Rolling River and deposited in the Delta Wetlands. Since the hill is at a higher elevation, there is little risk of flood on Green Hill.

The topographical maps of Boomtown show that the hill has been stable over the last 100 years, except for the area with houses. On that slope of the hill, there has been erosion in the twenty years since the houses and roads were built. The erosion may have been caused when the land was dug up to build the houses.

The biggest potential geological problem at Green Hill is erosion due to more building. Although the hill is eroded by rain instead of powerful ocean waves, the composition of the hill is less resistant to erosion than other places in Boomtown, so it may become a problem in the future.
It is time for the Boomtown City Council meeting to decide where to build the new housing. Participants will discuss the ecology and needs of the Boomtown community at each site. You will play the role of a builder, and present your plans for one of the building sites to the City Council for approval.

Where should Boomtown build its new apartments and houses?

**MATERIALS**

- For each group of four students:
  - 1 poster board
  - assorted colored poster pens

- For each student:
  - 1 completed set of Geologist’s Reports from Activity 34
  - 1 Student Sheet 35.1, “Discussion Web: Our Building Site”
  - 1 Student Sheet 35.2, “Evidence from the City Council Meeting”
PROCEDURE

1. Your teacher will assign your group one of the building sites. Your group will develop a building plan for this location.

2. Read all the reports for your location. The reports are found on the following pages.

3. With your group members, complete Student Sheet 35.1, “Discussion Web: Our Building Site.” This will help you to identify the advantages and disadvantages of your location.

   Remember to listen to and consider the ideas of the other members of your group. If you disagree with others in your group, explain why you disagree.

4. Work with your group to prepare a presentation and poster that will describe your building plans. Be sure you present information from the geologist, engineer, ecologist, and City Council Member, as well as from the various activities in the unit. Your poster should include:

   • the advantages of your chosen building site, based on evidence from this activity and from earlier activities in this unit.
   • the main disadvantages or risks of your proposed building site.
   • how your plan will succeed despite the disadvantages of your building site.

5. Make your presentation to the class and listen to those of the other groups. As you listen to each presentation, record the information on Student Sheet 35.2, “Evidence from the City Council Meeting.”

ANALYSIS

1. Where do you think Boomtown should build new housing—on Green Hill, the Delta Wetlands, or Seaside Cliff? Describe the evidence that you used to make your decision and how you weighed the advantages and disadvantages of each location.

2. Reflection: Look in your science notebook to see how you answered Question 3 in Activity 24, “Where Shall We Build?”

   a. Have you changed your mind since then?
   b. What new information did you use in making your decision this time?
Reports from the Field

Delta Wetlands

ENGINEER’S REPORT
The biggest challenge for building on wetlands is managing all the water. First, pumps are needed to remove the water from the marsh and dry the area. Next, soil will have to be brought in and added to the current, loose soil of the wetlands. This will make the ground solid and stable enough for building. However, once the wetlands are filled in and covered with buildings and roads, the water from heavy rains will no longer be absorbed by the wetlands. This means that the water can build up at the lower elevations and flood the area. A system of canals can be used to collect excess water from rains and help prevent floods. Walls can also be built to protect the buildings from water overflow or surges from the ocean during storms.

ECOLOGIST’S REPORT
Delta Wetlands is a unique habitat for shellfish, fish, and birds. These animals will no longer have a home if the wetlands are destroyed. The wetlands also help filter water before sending it to the ocean. If the sediments from the river are not deposited in the delta as nature intended, they will be carried directly to the ocean. Once there, the sediments could cloud the water near the beaches. This may lead to a loss of ocean fish and, as a result, a loss of the birds that eat the fish.

CITY COUNCIL REPORT
The city next to Boomtown filled in a wetland area 20 years ago and has not yet experienced any disasters, such as flooding. If Boomtown decides to fill in the wetlands, the plans must be evaluated by the Wetlands Protection Agency in order to determine the impact on the habitat. Their evaluation will take at least 12 months. It is likely that Boomtown will be required to preserve part of the wetlands.
ENGINEER’S REPORT
When we cut into the side of the hill to put up a building, it makes that part of the hill steeper and more likely to erode when it rains. When we cut down vegetation and cover the land with buildings and roads, the water runs off in channels down the hill because it can no longer sink into the soil. To fix this problem, drainage pipes can be built so that the water can flow down without eroding the hill. Then, the water in the drainage pipes can be directed to the Rolling River. We also can plant a lot of vegetation on the slopes, wherever there are no buildings, to help the hill become more resistant to erosion.

ECOLOGIST’S REPORT
Green Hill has an environment similar to that of other hills in the area. Where there are no houses and roads, the hill area is covered in thick forest. There are trees, grasses, and small bushes. Common wildlife on the hill includes deer, raccoons, rabbits, and foxes. Green Hill provides homes for these animals, as well as space for the animals to move between Pine Forest, Rolling River, and Riverside Forest. Building here will not only directly reduce the wildlife population by destroying their homes, but it will also stress the animals by preventing them from moving between areas with food and water.

CITY COUNCIL REPORT
People who already own houses on the hill are concerned about the new buildings. Some are upset that the habitat of the animals on the hill will be disturbed. Others think that large buildings will create bad traffic and congestion in the area. The Green Hill Neighborhood Organization is sending around a petition trying to block any new buildings on their hill. People in town are concerned that the water running off the hill could cause flooding or landslides that would affect the neighborhoods below the hill.
**Seaside Cliff**

![Seaside Cliff illustration](image)

**ENGINEER’S REPORT**

Structures built on cliffs suffer some of the same erosion problems due to heavy rain as do structures built on a hillside. Because of this, the problem is handled in a similar way—by improving drainage and planting vegetation that can absorb water. However, Seaside Cliff is also affected by the strong erosion force of the ocean waves that pound its base. This could cause the cliff to be undercut and, eventually, cause it to collapse. To prevent this, barriers should be placed at the bottom of the cliff to protect it from the waves. This could be in the form of retaining walls. Another way to slow down the erosion at the base of the cliff is to build a stone breakwater. This breakwater should be built in the water about 15 meters from the cliff. These additions will reduce the impact of the waves on the cliff and slow down the process of erosion.

**ECOLOGIST’S REPORT**

Seaside Cliff has some wildlife, although not as much as Green Hill. The cliff top is covered with vines, bushes, and a few small trees. The roots of these plants help to hold the soil in place. In order to build housing, these plants would have to be cleared, making the cliff erode more easily. Even if the vegetation is replanted after the building is finished, it will take a while for the plants to grow. In addition, there are also rabbits, gophers, deer, and other animals in the area. They would lose their homes because of the building.
CITY COUNCIL REPORT
Homes built on cliffs in other towns have been damaged when severe erosion causes the cliffs to collapse. Because of this, home insurance at Seaside Cliff will cost twice as much as in other areas of Boomtown. The buildings would have a great view of the ocean, though, and would be worth more than houses on the hillside. People from Boomtown have expressed concern that the houses will take away from the natural environment of the beach, since they will be so close to the water. The citizens of Boomtown are also worried that the seawalls or breakwaters will have negative effects on the beach and other places along the coast.