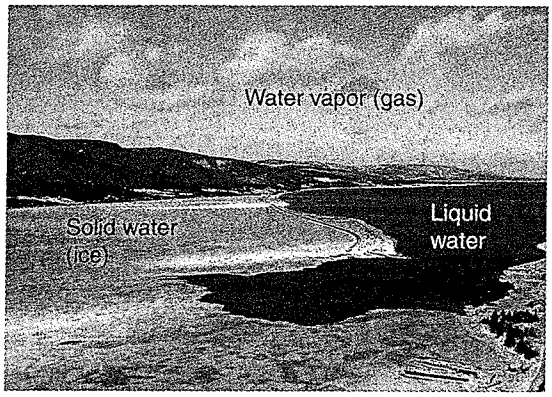
82 The Hydrologic Cycle

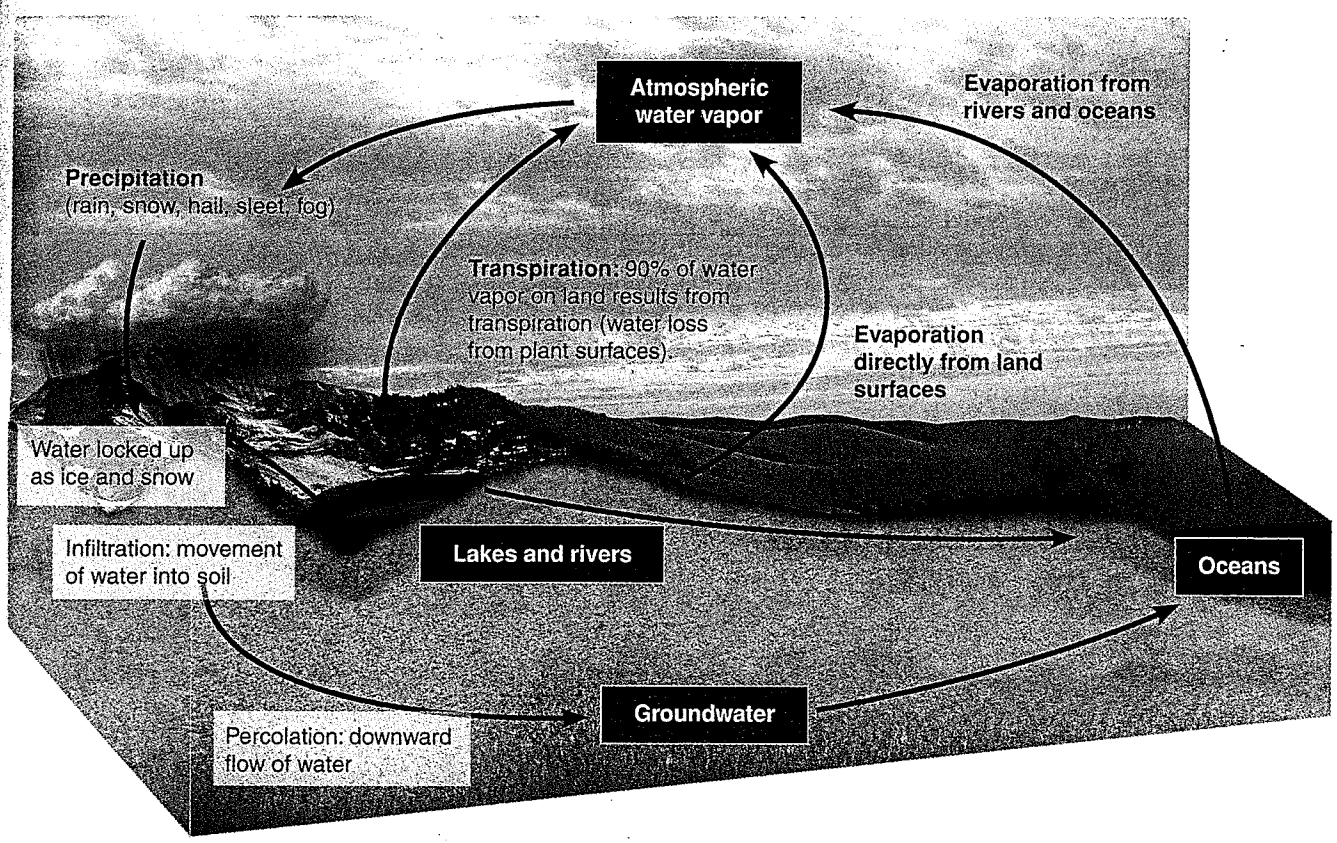
Key Idea: The hydrologic cycle is the cycling of water from the oceans to the land and back.

Earth's water

- About 97% of Earth's water is stored in the oceans, which contain more than 1.3 billion km^3 of water. Less than 1% of Earth's water is freely available fresh water (in lakes, rivers, and streams).
- Water evaporates from the oceans and lakes into the atmosphere and falls as precipitation (e.g. rain, snow, or hail). Precipitation falling on the land is transported back to the oceans by rivers and streams or is returned to the atmosphere by evaporation or transpiration (evaporation from plant surfaces).
- Water can cycle very quickly if it remains near the Earth's surface, but it can also remain locked away for hundreds or even thousands of years, e.g. if trapped in deep ice layers at the poles or in groundwater storage (aquifers).
- Humans intervene in the water cycle by using water for their own needs. Withdrawing water from rivers and lakes for irrigation changes evaporation patterns, lowers lake levels, and reduces river flows.



Water is the only substance on Earth that is found naturally as a solid, liquid, or gas. It has an unexpectedly high boiling point compared to other similar molecules and requires a lot of energy to change state. This means it acts as a buffer against extreme temperature fluctuations in the environment.



1. What is the main storage reservoir for water on Earth? _____

2. Describe the feature of water that allows it cycle as described above: _____

_____

_____

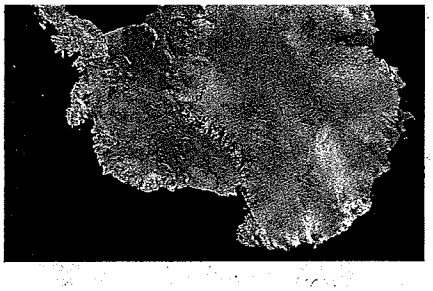
3. Identify the two processes by which water moves from the land or oceans to the atmosphere: _____

_____

_____

The water cycle is important in the transport of energy about the globe. Energy (from the Sun) is absorbed by the oceans. Water evaporates from the oceans, cooling them. This energy is released again when water vapor condenses.

Water can be held inside the Earth itself. The largest reservoir of water on Earth is in fact in the mantle, bound with minerals. Some estimates put the amount of water in the mantle at ten times the volume in the Earth's oceans.



Water can be locked up in ice for tens of thousands of years. The ice in the ice sheet of Greenland is about 100,000 years old, while ice cores from Antarctica have dated some ice to at least 800,000 years old.

4. Explain how the hydrologic cycle helps to move energy around the globe: _____

_____

_____

_____

_____

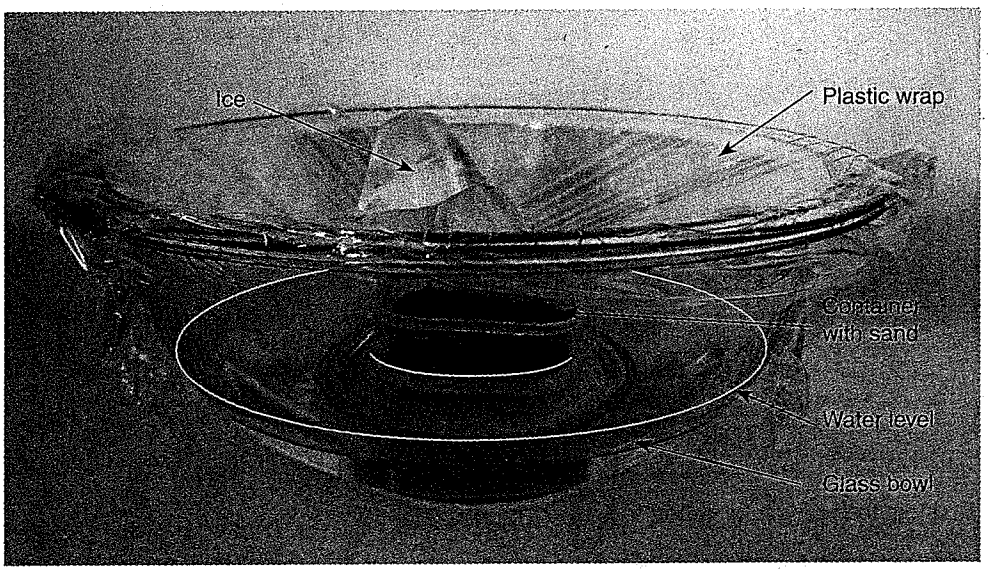
5. How do humans intervene in the water cycle and how might this affect bodies of water such as lakes?

_____

_____

_____

6. (a) The photograph below shows a set up for modeling the water cycle in the classroom. Use the following labels to label the model: *Clouds, oceans, rain, evaporation, land*



(b) i. What represents the clouds in the model?

ii. Explain how the "clouds" model this part of the actual water cycle: _____

_____

_____

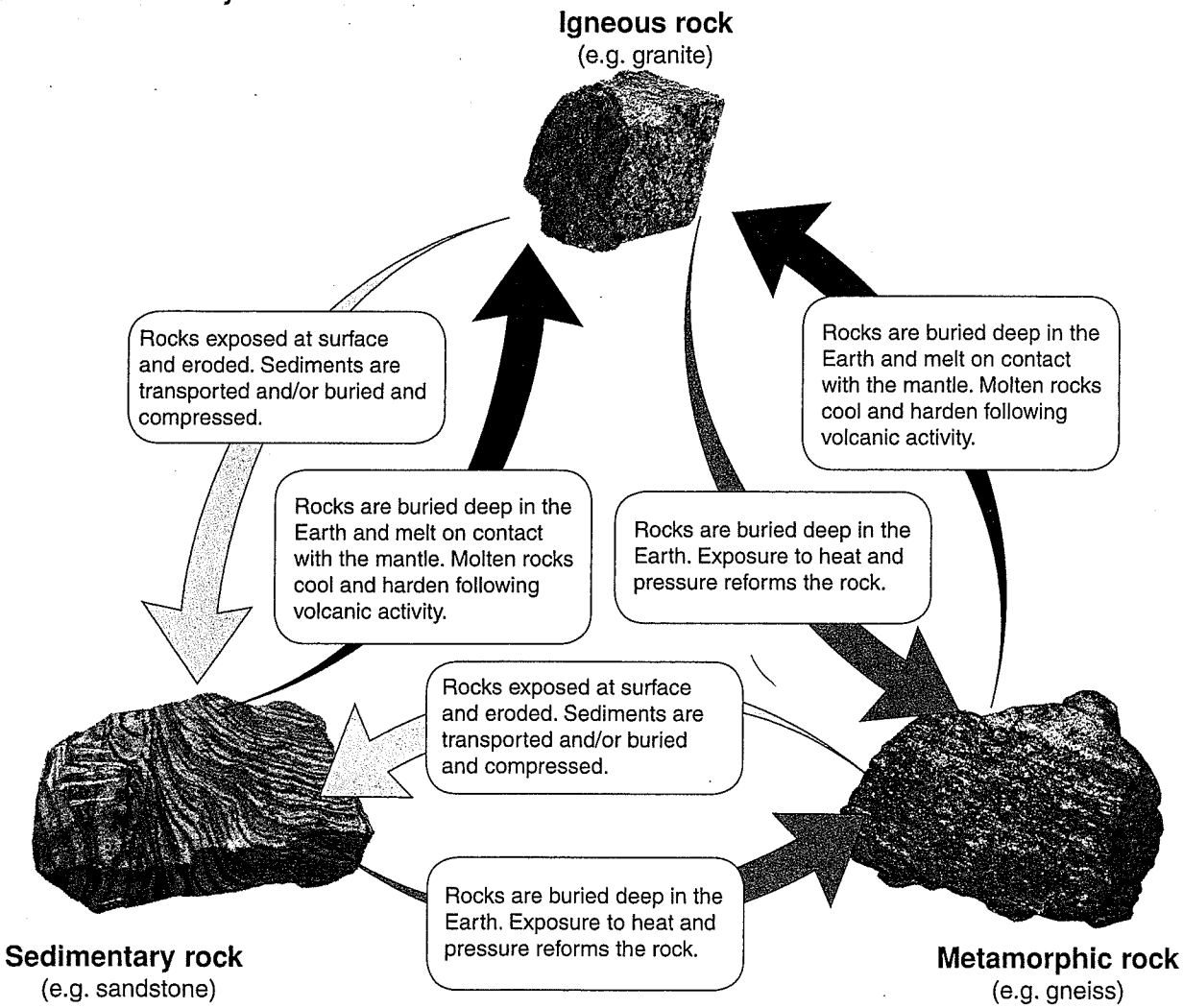
_____

ISBN: 978-1-927309-37-7

83 The Rock Cycle

Key Idea: The continual erosion, burial, melting, and reforming of the Earth's rocks forms a continuous cycle.

- The Earth's many rock types can be grouped as **igneous**, **metamorphic**, and **sedimentary rocks**.
- These rocks form in a continuous cycle. Erosion of surface rocks produces sediments. Burial of these transforms them into sedimentary rocks. Heat and pressure within the Earth can then transform pre-existing rocks to form metamorphic rocks such as slate and schist. Contact with magma may melt the rock which may then form as volcanic extrusions or plutonic intrusions (rocks formed underground e.g. cooling magma).
- When rocks are exposed at the surface, they are then subjected to the physical, chemical, and biological processes collectively known as **weathering**. This cycle of rock formation, exposure, weathering, erosion, and deposition is known as the **rock cycle**.



1. Identify the three rock types formed on Earth: _____

_____

2. Explain how the following rocks are formed:

   (a) Gneiss forms from granite: _____

   _____

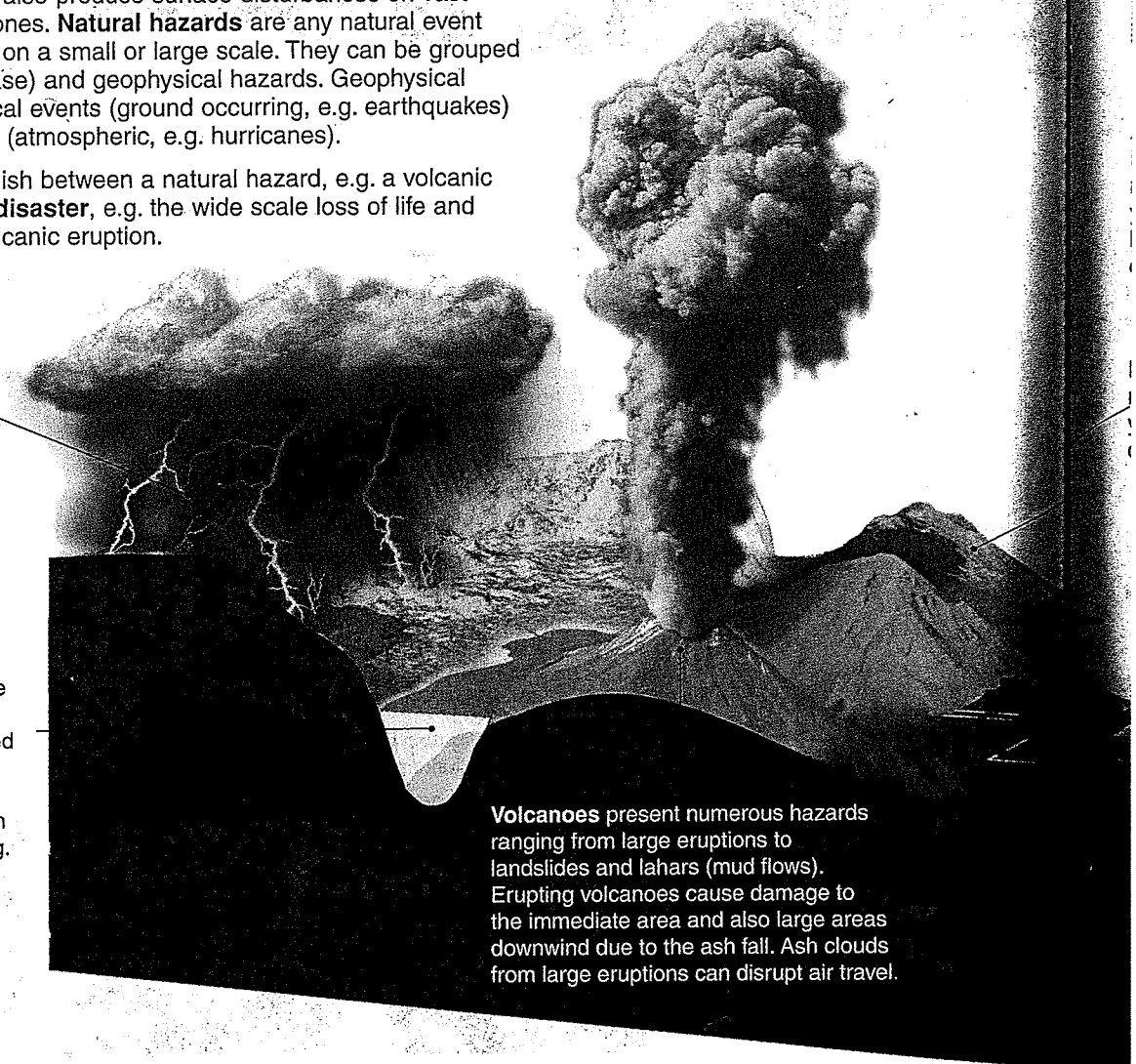
   _____

   (b) Mudstone is formed from sediment: _____

   _____

Key Idea: Natural hazards are environmental events that could potentially cause damage or threaten human lives and property.

- The Earth can be a hazardous place. The processes that shape the surface of the Earth can also produce surface disturbances on vast scales, e.g. tropical cyclones. **Natural hazards** are any natural event that may cause damage on a small or large scale. They can be grouped into biological (e.g. disease) and geophysical hazards. Geophysical hazards include geological events (ground occurring, e.g. earthquakes) or meteorological events (atmospheric, e.g. hurricanes).
- It is important to distinguish between a natural hazard, e.g. a volcanic eruption, and a **natural disaster**, e.g. the wide scale loss of life and property caused by a volcanic eruption.



Storms can produce large scale effects. Hazards include lightning strikes, wind and water damage, flooding, and landslides due to water -logged soil.

Rivers and **lakes** present possible flood hazards. People living on the floodplains of large rivers are often inundated when rivers burst their banks. Many rivers near towns have levees or stopbanks to contain the water and prevent flooding.

Volcanoes present numerous hazards ranging from large eruptions to landslides and lahars (mud flows). Erupting volcanoes cause damage to the immediate area and also large areas downwind due to the ash fall. Ash clouds from large eruptions can disrupt air travel.

1. Identify the natural hazards associated with each of the following phenomena:

   (a) Storm: _____

   (b) Volcano: _____

   (c) High mountains: _____

2. Identify ways to reduce the risk of damage from each of the following hazards:

   (a) Drought: _____

   _____

   (b) River: _____

   _____

   (c) Seaside: _____

   _____

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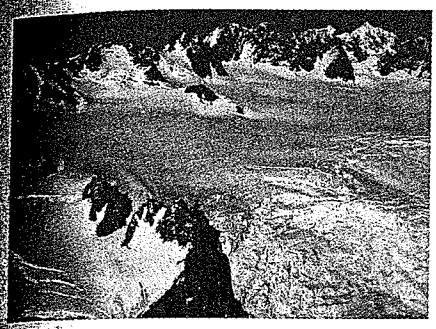
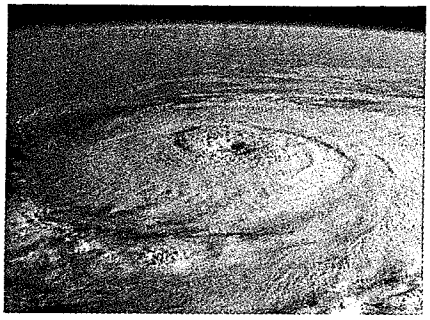


Hazards in high mountains include rock falls, blizzards, and avalanches. Avalanches occur when the snowpack loses adhesion and slides down the mountain face. More than 100 people a year are killed in avalanches despite the large effort that is put into reducing the damage they cause.



Tropical cyclones, typhoons, and hurricanes present hazards around the tropical regions of the world. Damage may occur due to 200 $km\,h^{-1}$ winds and flooding from rainfall and storm surges. Large cyclones can cause damage up to 40 km from the coast. Climate change may increase the frequency of cyclones.

Many areas of land used for grazing or cropping are prone to drought. Drought causes enormous economic damage as it seriously reduces farm productivity. Efforts to reduce drought damage include building dams to store water and planting drought tolerant crops. Climate change may increase the occurrences of drought.

Landslides are common on mountains and steep terrain. Every year, many thousands of homes are destroyed by landslides.

Tsunamis result from movements of the sea floor caused by earthquakes or subsea landslides. Waves may reach more than 10 m high when they reach the shore. Many high risk areas (such as Japan) have high sea walls to reduce tsunami damage.

Earthquakes result from the sudden movement of the ground along fault lines. They present a hazard with the potential to cause enormous damage. Billions of dollars a year is put into recovery from earthquakes or planning and building to minimize damage risk.

3. (a) Identify one significant natural hazard in your local area: _____

_____

(b) How does your local area prepare for or reduce the risks posed by this natural hazard? _____

_____

_____

_____

(c) Why do you think people might have settled in the area despite the presence of this hazard? _____

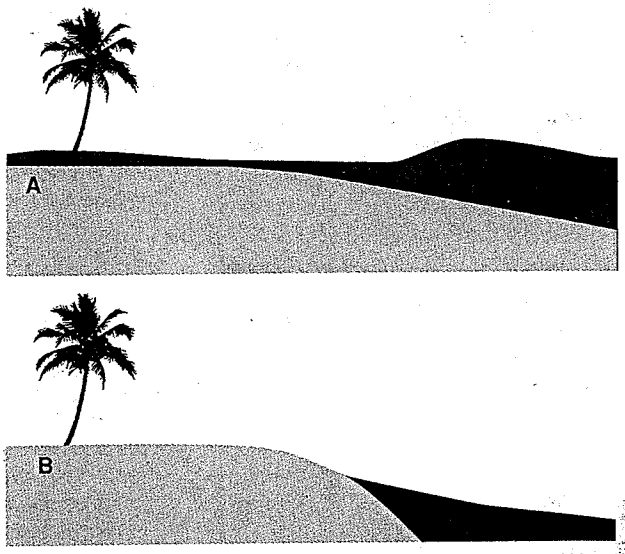
_____

Key Idea: The impact a natural hazard has depends on the features of the natural hazard itself, the natural features of the land affected, and a region's economic development.

- Natural hazards are not recent phenomena. They have been (and will continue to be) caused by the same processes that have always occurred (e.g. movement along a fault line produces earthquakes). However, some natural hazards have been made more common through human activity (e.g. forest fires, or flood events caused by changing the course of a river).

Many factors influence the impact of a natural hazard

- **Natural features**
  Natural features of the Earth and the environment can have a significant influence on how much damage a natural hazard can cause. For example, the angle of the coastline (steep or gentle incline) will influence how much damage will be caused by a storm surge (right).
- **Magnitude**
  The size (or magnitude) of the event has a significant impact on the damage that the natural hazard causes. For example a 2.5 magnitude earthquake is not usually felt, but a 7.0 magnitude earthquake in the same location can cause serious damage.
- **Frequency**
  The frequency of a hazard (how often it occurs) will directly affect how a particular area responds and recovers from the most recent event. For example, areas prone to frequent flood events may be severely damaged with each event and also do not have time to recover between floods.



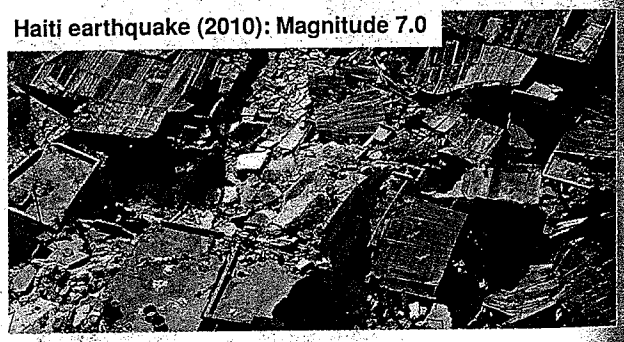
The effect of storm surge on a gently sloping coastline (A) and a steep coastline (B) is shown above. The storm surge travels much further inland when the coastline has a gentle slope, potentially damaging more land and property. A steeper slope at the coastline prevents or limits inundation, and acts as a natural protective barrier.

Many factors influence the impact of a natural disaster

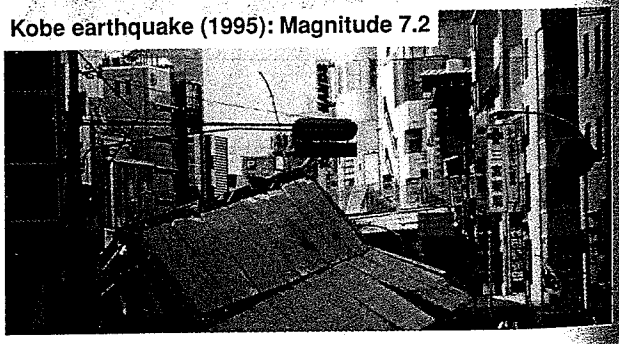
When a natural hazard event affects human life or property, the event is called a **natural disaster**. The extent of the natural disaster depends not only on the features of the natural hazard, but social factors too.

- **Level of development**
  The level of development (e.g. infrastructure and money) of an area will contribute to how well that region can respond to a natural disaster. Better economically developed regions will have the resources to respond more quickly and more efficiently than lesser economically developed regions.
- **Preparedness**
  How ready the population is to respond to a natural disaster will influence how well they cope immediately after the event. Factors include constructing buildings to withstand earthquakes in vulnerable areas (e.g. San Francisco) or having resources ready to be distributed after the event. Early warning systems, such as the tsunami warning system, are designed to give coastal residents time to evacuate to higher ground.
- **Accessibility**
  Remote or severely damaged areas can be difficult for disaster teams to access. If support cannot be provided to the affected population, death rates may rise. For example, if the water supply has been contaminated, disease may spread through the population. Without access to clean water and medical supplies, people may die from causes secondary to the disaster event itself.

Haiti earthquake (2010): Magnitude 7.0



Kobe earthquake (1995): Magnitude 7.2

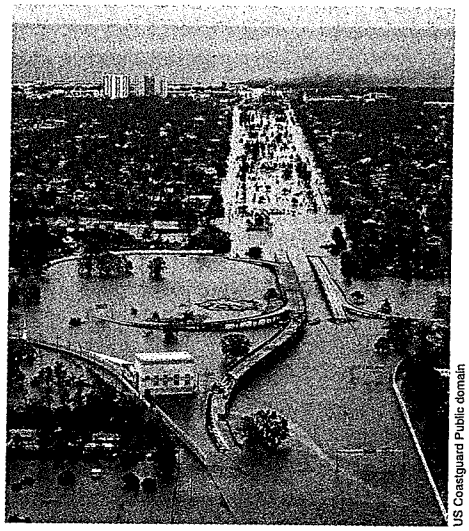


Kobe (1995) and Haiti (2010) were both struck by similar sized earthquakes. The damage was less severe in Kobe because Japan's strict building codes reduced the number of collapsed buildings. Regular earthquake drills meant the population were well rehearsed for an earthquake and emergency services were able to deliver supplies quickly. The death toll was much lower in Kobe and recovery was much faster because Japan has a higher level of economic development and preparedness than Haiti.

ISBN: 978-1-927309-37-7

Natural hazards can cause natural disasters

The Atlantic hurricane season refers to a period (June to November) when hurricanes usually form in the Atlantic Ocean. During this period, the East Coast of the US can expect a number of hurricanes ranging in intensity from category 1-5. Anything above category 3 is a major hurricane. An average of 6 hurricanes develop during the Atlantic season, with 2-3 of these developing into category 3 or greater hurricanes.

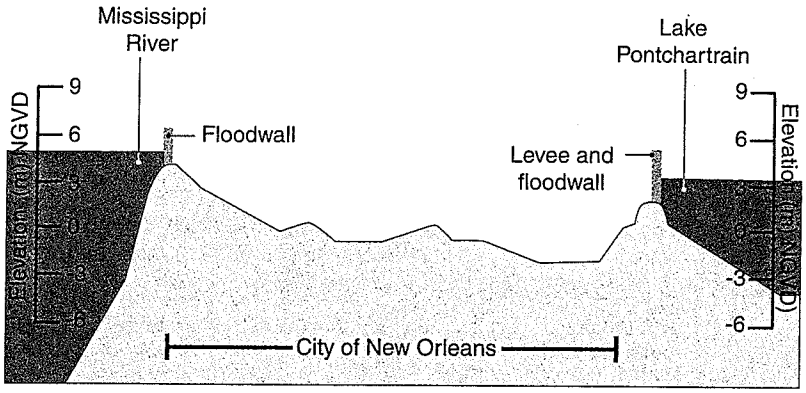


US Coastguard Public domain

Hurricanes are a regular natural hazard, but some have greater impact than others. The devastation caused in New Orleans by Hurricane Katrina in 2005 was due to a combination of the intensity of the hurricane and the physical land features of New Orleans. Hurricane Katrina varied in intensity reaching category 5 before reducing in intensity to category 1-2 when it reached New Orleans. The prolonged heavy rain and storm surge (up to 9 meters) meant that many of the levees and floodwalls failed, resulting in flooding of up to 80% of the city (right). Many of the 1464 deaths associated with Hurricane Katrina were a result of levee failure.

A history of flooding in New Orleans

New Orleans was originally built on natural levees along the Mississippi River. New Orleans is completely surrounded by water, the Mississippi River on one side and Lake Pontchartrain on the other. As the city grew and demand for land increased, people settled the lower lying land, which was more prone to flooding. Houses were built elevated above ground to cope with the frequent flood events. Over time, a series of drains, levees and floodwalls were developed to help protect New Orleans from flooding. Today, much of the city lies below sea level (right), relying on the levees and floodwalls to protect it. During Hurricane Katrina, the strong storm surges and prolonged rain caused most of the levees to fail, resulting in widespread flooding and destruction. (NGVD is the National Geodetic Vertical Datum, a reference point for elevation).



1. Describe some features of natural hazards that can increase their impact: _____

2. Using an example, explain how a country's level of economic development can affect the impact of a natural disaster?

3. What factors contributed to Hurricane Katrina significantly damaging New Orleans? _____