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Section 1 Water Beneath the Surface

Section 2 Groundwater and Chemical Weathering

Objectives

- **Identify** properties of aquifers that affect the flow of groundwater.
- **Describe** the water table and its relationship to the land surface.
- **Compare** wells, springs, and artesian formations.
- **Describe** two land feature formed by hot groundwater.

End Of Slide

Properties of Aquifers

groundwater the water that is beneath Earth's surface

aquifer a body of rock or sediment that stores groundwater and allows the flow of groundwater

- Groundwater is an important source of freshwater in the United States.
- The ease with which water flows through an aquifer is affected by many factors, including porosity and permeability.

End Of Slide

Properties of Aquifers, *continued*

Porosity

porosity the percentage of the total volume of a rock or sediment that consists of open spaces

- One factor that affects porosity is sorting. *Sorting* is the amount of uniformity in the size of the rock or sediment particles.
- Particle packing also affects porosity. Grain shape also affects porosity.

End Of Slide

Properties of Aquifers, *continued*

Permeability

permeability the ability of a rock or sediment to let fluids pass through its open spaces, or pores

- For a rock to be permeable, the open spaces must be connected.
- Permeability is also affected by the size and sorting of the particles that make up a rock or sediment. The larger and better sorted the particles are, the more permeable the rock or sediment tends to be.

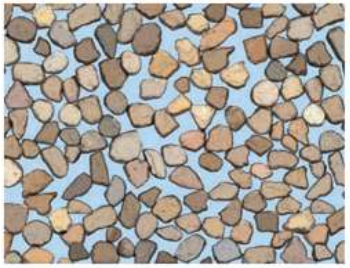
End Of Slide

Properties of Aquifers, *continued*

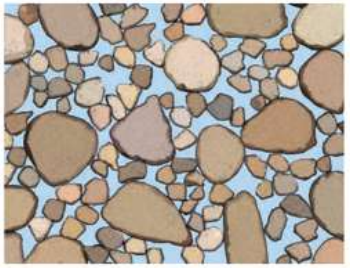
The image below shows the differences in porosity.

Porosity

Well-sorted, coarse-grained sediment has high porosity.

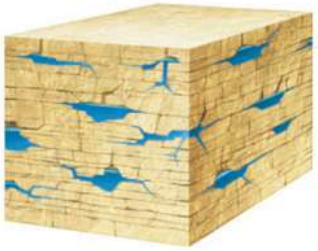


Well-sorted, fine-grained sediment has high porosity equal to the porosity of coarse-grained sediment.



Poorly sorted sediment that contains grains of many sizes has low porosity.

Permeability



Rock is considered porous if it has many empty spaces that can fill with water.

Rock is considered permeable if its empty spaces are connected so that water may flow from one space to the next.

End Of Slide

Zones of Aquifers

- Gravity pulls water down through soil and rock layers until the water reaches impermeable rock.
- Water then begins to fill, or saturate, the spaces in the rock above the impermeable layer.
- As more water soaks into the ground, the water level rises underground and forms two distinct zones of groundwater.

End Of Slide

Zones of Aquifers, *continued*

Zone of Saturation

water table the upper surface of underground water; the upper boundary of the zone of saturation

- The layer of an aquifer in which the pore space is completely filled with water is the *zone of saturation*.
- The term *saturated* means "filled to capacity."
- The zone of saturation is the lower of the two zones of groundwater.

End Of Slide

Zones of Aquifers, *continued*

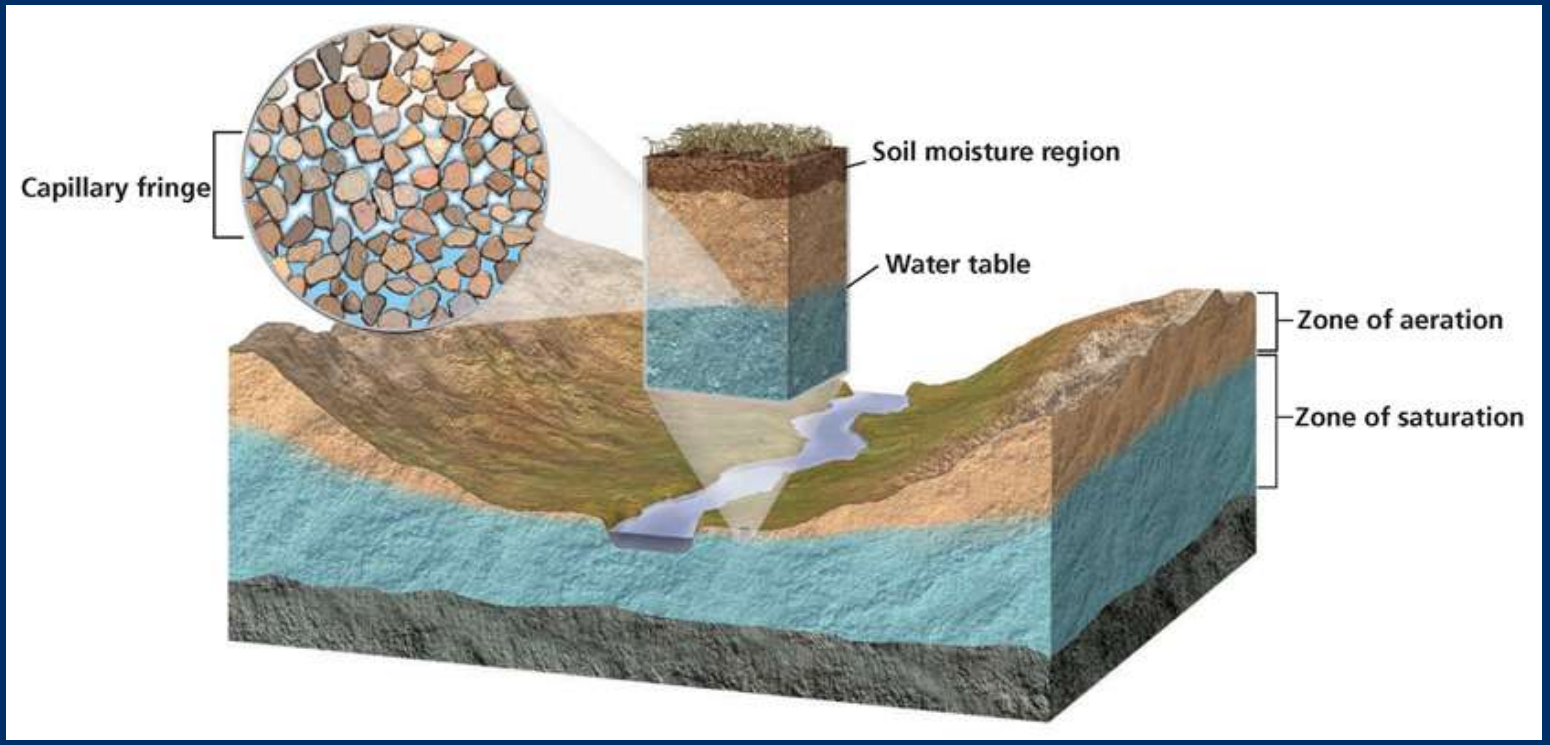
Zone of Aeration

- The zone that lies between the water table and Earth's surface is called the *zone of aeration*.
- The zone of aeration is composed of three regions.
- Water is drawn up from the zone of saturation into the capillary fringe by capillary action. *Capillary action* is caused by the attraction of water molecules to other materials, such as soil.

End Of Slide

Zones of Aquifers, *continued*

The image below shows the two zones aquifers.



End Of Slide

Reading Check

What are the two zones of groundwater?

End Of Slide

Reading Check

What are the two zones of groundwater?

The two zones of groundwater are the zone of saturation and the zone of aeration.

Movement of Groundwater

- Water passes quickly through highly permeable rock and slowly through rock that is less permeable.
- The rate at which groundwater flows horizontally depends on both the permeability of the aquifer and the gradient of the water table.
- *Gradient* is the steepness of a slope.
- The velocity of groundwater increases as the water table's gradient increases.

End Of Slide

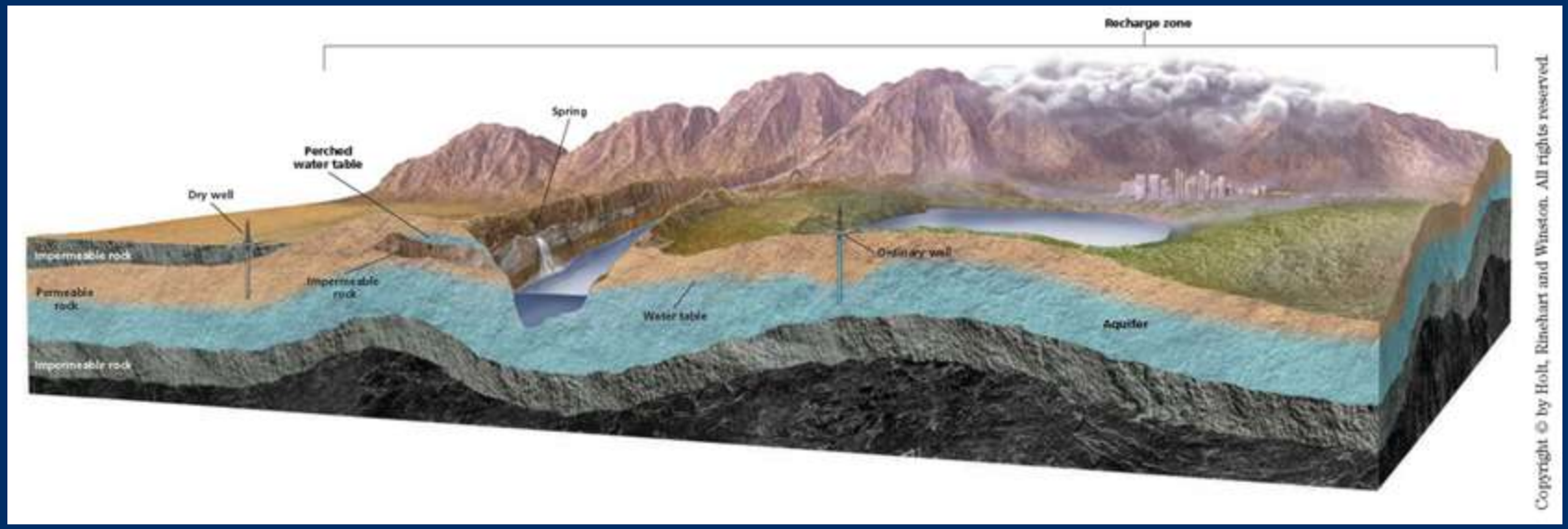
Topography and the Water Table

- The depth of the water table below the ground surface depends on surface topography, the permeability of the aquifer, the amount of rainfall, and the rate at which humans use water.
- Only one water table exists in most areas.
- In some areas, however, a layer of impermeable rock lies above the main water table. Water collects on top of this upper layer and creates a second water table, which is called a *perched water table*.

End Of Slide

Topography and the Water Table, *continued*

The image below shows the water table and a surface topography.



End Of Slide

Reading Check

What four factors affect the depth of a water table?

End Of Slide

Reading Check

What four factors affect the depth of a water table?

The depth of a water table depends on topography, aquifer permeability, the amount of rainfall, and the rate at which humans use the groundwater.

Conserving Groundwater

- Although groundwater is renewable, its long renewal time limits its supply. Groundwater collects and moves slowly, and the water taken from aquifers may not be replenished for hundreds or thousands of years.
- Communities often regulate the use of groundwater to help conserve this valuable resource.
- Some communities recycle used water. This water is purified and may be used to replenish the groundwater supply.

End Of Slide

Conserving Groundwater, *continued*

- Surface water enters an aquifer through an area called a recharge zone.
- A *recharge zone* is anywhere that water from the surface can travel through permeable rock to reach an aquifer.
- Recharge zones are environmentally sensitive areas because pollution in the recharge zone can enter the aquifer.

End Of Slide

Wells and Springs

- Groundwater reaches Earth's surface through wells and springs.
- A *well* is a hole that is dug to below the level of the water table and through which groundwater is brought to Earth's surface.
- A *spring* is a natural flow of groundwater to Earth's surface in places where the ground surface dips below the water table.

End Of Slide

Wells and Springs, *continued*

Ordinary Wells and Springs

- *Ordinary wells* work only if they penetrate highly permeable sediment or rock below the water table.
- If the rock is not permeable enough, groundwater cannot flow into the well quickly enough to replace the water that is withdrawn.
- Pumping water from a well lowers the water table around the well and forms a *cone of depression*.

End Of Slide

Wells and Springs, *continued*

Ordinary Wells and Springs, *continued*

- *Ordinary springs* are usually found in rugged terrain where the ground surface drops below the water table.
- These springs may not flow continuously if the water table in the area has an irregular depth as a result of variable rainfall.

Wells and Springs, *continued*

Artesian Wells and Springs

artesian formation a sloping layer of permeable rock sandwiched between two layers of impermeable rock and exposed at the surface

- Water in some wells may come from as far away as hundreds of kilometers.
- The permeable rock is the aquifer, and the top layer of impermeable rock is called the *caprock*.

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Wells and Springs, *continued*

Artesian Wells and Springs

- Because the water is under pressure, when a well is drilled through the caprock, the water quickly flows up through the well and may even spout from the surface.
- An *artesian well* is a well through which water flows freely without being pumped
- When cracks occur naturally in the caprock, water from the aquifer flows through the cracks. This flow forms *artesian springs*.

End Of Slide

Reading Check

What is the difference between ordinary springs and artesian springs?

End Of Slide

Reading Check

What is the difference between ordinary springs and artesian springs?

Ordinary springs occur where the ground surface drops below the water table. An artesian spring occurs where groundwater flows to the surface through natural cracks in the overlying caprock.

Hot Springs

- Groundwater is heated when it passes through rock that has been heated by magma.
- Hot groundwater that is at least 37°C and that rises to the surface before cooling produces a *hot spring*.
- When water in a hot spring cools, the water deposits minerals around the spring's edges.
- The deposits form steplike terraces of calcite called *travertine*.

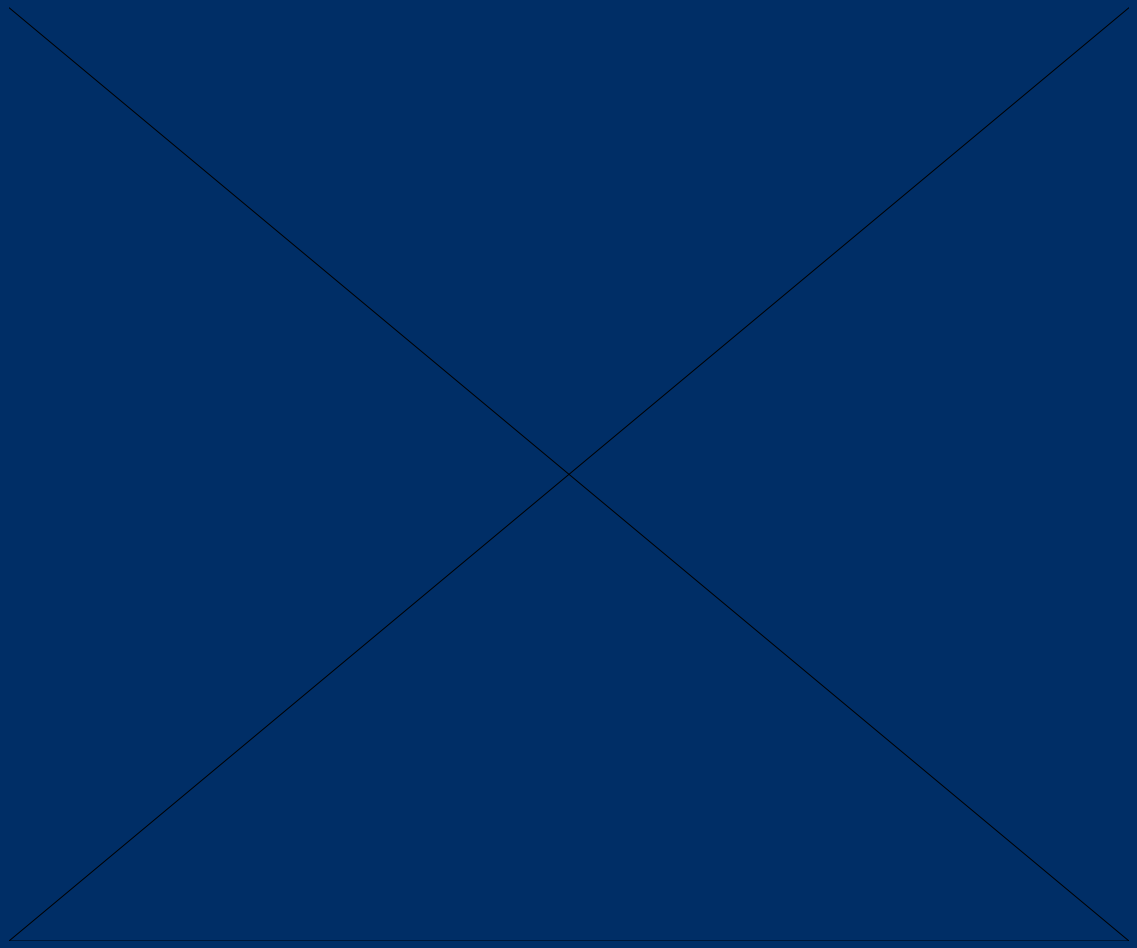
End Of Slide

Geysers

- Hot springs that periodically erupt from surface pools or through small vents are called *geysers*.
- A geyser consists of a narrow vent that connects one or more underground chambers with the surface.
- Release of the water near the top of the vent relieves the pressure on the superheated water farther down.
- The eruption continues until most of the water and steam are emptied from the vent and chambers.

End Of Slide

Aquifers and Artesian Springs



Objectives

- **Describe** how water chemically weathers rock.
- **Explain** how caverns and sinkholes form.
- **Identify** two features of karst topography.

End Of Slide

Groundwater and Chemical Weathering

- As groundwater passes through permeable rock, minerals in the rock dissolve. The warmer the rock is and the longer it is in contact with water, the greater the amount of dissolved minerals in the water.
- Water that contains relatively high concentrations of dissolved minerals, especially minerals rich in calcium, magnesium, and iron, is called *hard water*.
- Water that contains relatively low concentrations of dissolved minerals is called *soft water*.

End Of Slide

Results of Weathering by Groundwater

- One way that minerals become dissolved in groundwater is through chemical weathering.
- As water moves through soil and other organic materials, the water combines with carbon dioxide to form carbonic acid.
- This weak acid chemically weathers the rock that the acid passes through by breaking down and dissolving the minerals in the rock.

End Of Slide

Results of Weathering by Groundwater, *continued*

Caverns

cavern a natural cavity that forms in rocks as a result of the dissolution of minerals; also a large cave that commonly contains many smaller, connecting chambers

- Rocks that are rich in the mineral calcite, such as limestone, are especially vulnerable to chemical weathering.

End Of Slide
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Results of Weathering by Groundwater, *continued*

Caverns, *continued*

- Although limestone is not porous, vertical and horizontal cracks commonly occur through limestone layers.
- As groundwater flows through these cracks, carbonic acid slowly dissolves the limestone and enlarges the cracks.
- Eventually, a cavern may form.

End Of Slide
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Results of Weathering by Groundwater, *continued*

Stalactites and Stalagmites

- When water containing dissolved calcite drips from the ceiling of a limestone cavern, some of the calcite is deposited on the ceiling.
- As this calcite builds up, it forms a suspended, cone-shaped deposit called a *stalactite*.
- When drops of water fall on the cavern floor, calcite builds up to form an upward-pointing cone called a *stalagmite*.

End Of Slide
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Results of Weathering by Groundwater, *continued*

Sinkholes

sinkhole a circular depression that forms when rock dissolves, when overlying sediment fills an existing cavity, or when the roof of an underground cavern or mine collapses

- *Subsidence sinkholes* form by a similar process except that as rock dissolves, overlying sediments settle into cracks in the rock and a depression forms.

End Of Slide

Chapter menu

Resources

Results of Weathering by Groundwater, *continued*

Sinkholes, *continued*

- *Collapse sinkholes* may form when sediment below the surface is removed and an empty space forms within the sediment layer.
- Collapse sinkholes may also form during dry periods, when the water table is low and caverns are not completely filled with water.
- Collapse sinkholes may develop abruptly and cause extensive damage.

End Of Slide

Results of Weathering by Groundwater, *continued*

Natural Bridges

- When the roof of a cavern collapses in several places, a relatively straight line of sinkholes forms.
- The uncollapsed rock between each pair of sinkholes forms an arch of rock called a *natural bridge.*
- When a natural bridge first forms, it is thick, but erosion causes the bridge to become thinner.

End Of Slide

Reading Check

How are sinkholes related to natural bridges?

End Of Slide

Reading Check

How are sinkholes related to natural bridges?

A natural bridge may form when two sinkholes form close to each other. The bridge is the uncollapsed rock between the sinkholes.

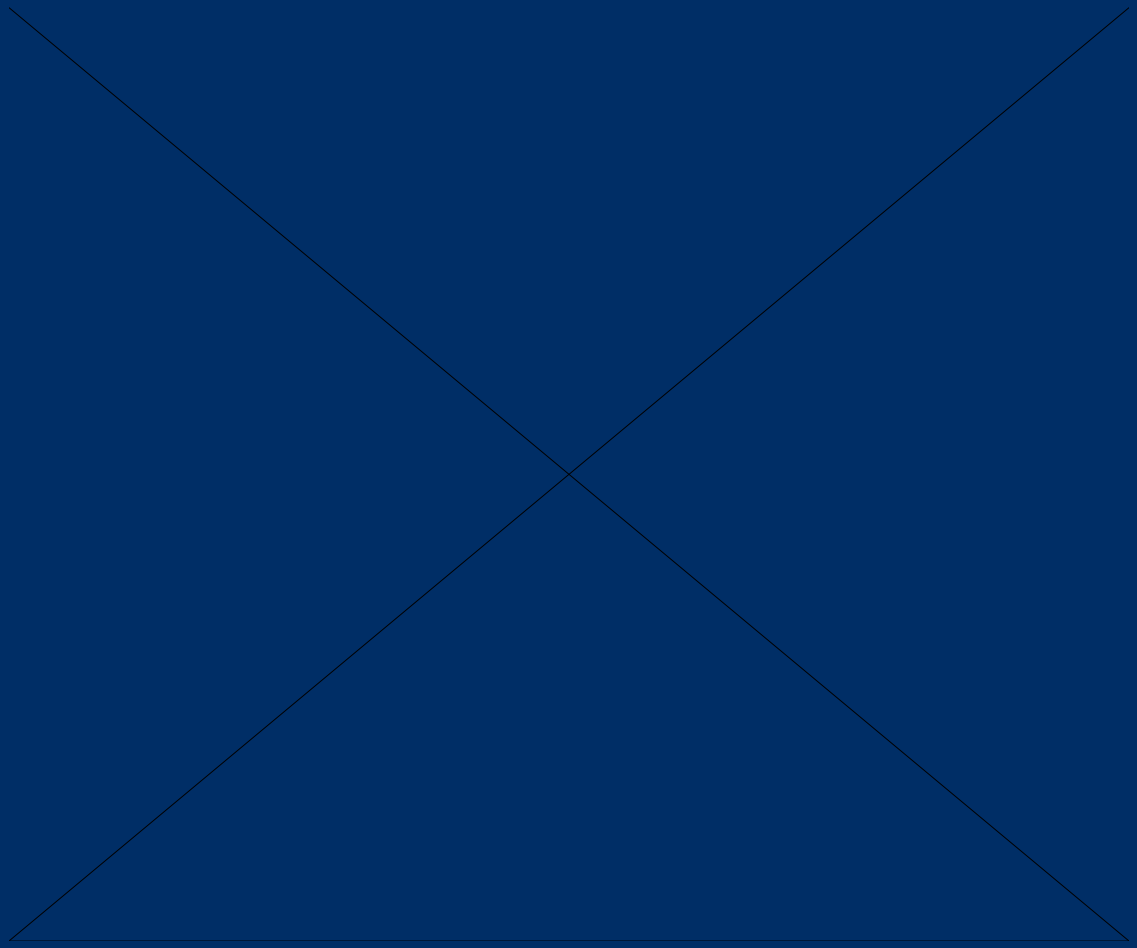
Karst Topography

karst topography a type of irregular topography that is characterized by caverns, sinkholes, and underground drainage and that forms on limestone or other soluble rock

- Common features of karst topography include many closely spaced sinkholes and caverns.
- Generally, karst topography forms in regions where the climate is humid and where limestone formations exist at or near the surface.

End Of Slide

Chemical Weathering



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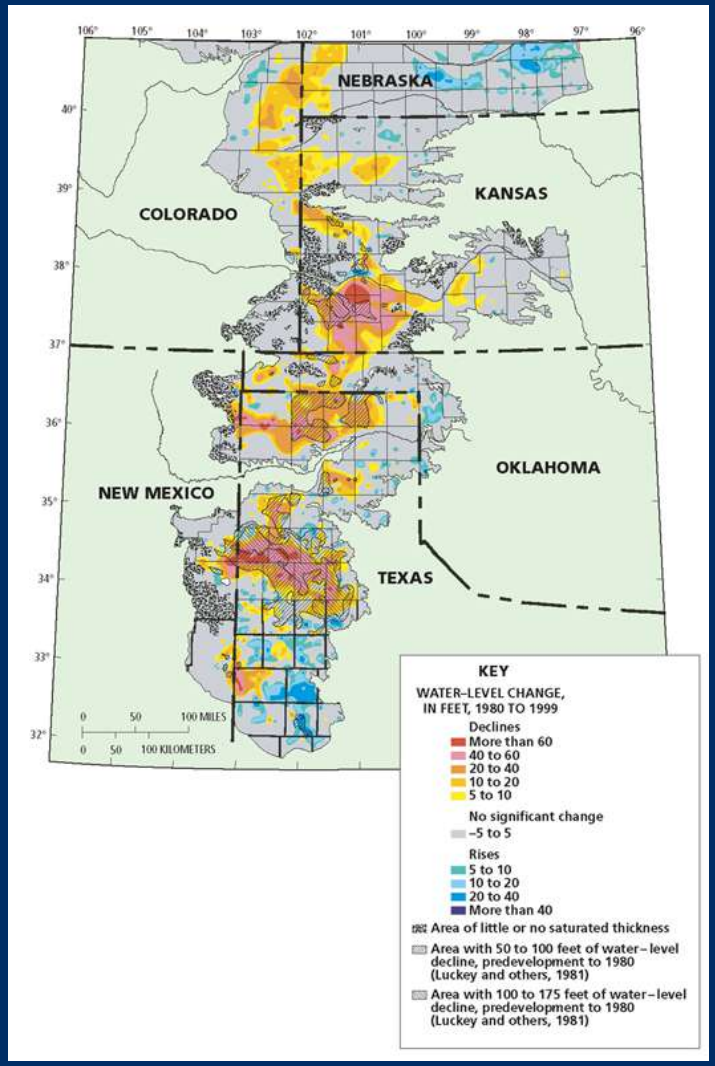
Brain Food Video Quiz

End Of Slide

Maps in Action

Water Level in the Southern Ogallala



End Of Slide

Multiple Choice

1. Which of the following statements is false?

A. Permeability affects flow through an aquifer.

B. Groundwater can be stored in an aquifer.

C. An aquifer is composed of a single rock layer.

D. Well-sorted sediment holds the most water.

Multiple Choice

1.Which of the following statements is false?

A.Permeability affects flow through an aquifer.

B.Groundwater can be stored in an aquifer.

C.An aquifer is composed of a single rock layer.

D.Well-sorted sediment holds the most water.

Multiple Choice, *continued*

2. The amount of surface water that seeps into the pores between rock particles is influenced by which of the following factors?

F. rock type, land slope, and climate

G. rock type, land slope, and capillary fringe

H. rock type, land slope, and sea level

I. rock type, land slope, and recharging

Multiple Choice, *continued*

2. The amount of surface water that seeps into the pores between rock particles is influenced by which of the following factors?

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I. rock type, land slope, and recharging

Multiple Choice, *continued*

3. Shanghai removed 96.03 million cubic meters of groundwater in 2002 but replaced only 13.75 million cubic meters. What was the rate of groundwater depletion in Shanghai that year?

A. 109.78 million cubic meters per year.

B. 1,320.41 million cubic meters per year.

C. 6.98 million cubic meters per year.

D. 82.28 million cubic meters per year.

Multiple Choice, *continued*

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A. 109.78 million cubic meters per year.

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Multiple Choice, *continued*

4.How does karst topography form in dry regions?

F.Limestone dissolves, and caves form.

G.Sinkholes form close together.

H.Soluble rock is chemically weathered.

I.Soluble rock is physically weathered.

Multiple Choice, *continued*

4.How does karst topography form in dry regions?

F.Limestone dissolves, and caves form.

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Multiple Choice, *continued*

5. What quality distinguishes an ordinary well from an artesian well?

A. Water flows freely from an ordinary well.

B. Water is pressurized in an ordinary well.

C. Water must be pumped from an ordinary well.

D. Water comes from rainfall in an ordinary well.

Multiple Choice, *continued*

5. What quality distinguishes an ordinary well from an artesian well?

A. Water flows freely from an ordinary well.

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D. Water comes from rainfall in an ordinary well.

Short Response, *continued*

6.What is a watershed?

Short Response, *continued*

6.What is a watershed?

an area of land that is drained by a river

Short Response, *continued*

7. What is the term for a local lowering of the water table caused by the pumping water from a well?

Short Response, *continued*

7. What is the term for a local lowering of the water table caused by the pumping water from a well?

a cone of depression

Reading Skills

Read the passage below. Then, answer questions 8–10.

Land Subsidence

Land subsidence is the settling or sinking of earth in response to the movement of materials under its surface. The greatest contributor to land subsidence is aquifer depletion. As groundwater is removed, the surface above may sink. Rocks may settle and pores may close, which leaves less area for water to be stored. In areas where aquifers are replenished, the surface of Earth may subside and then return almost to its previous level. However, in areas where water is not pumped back into aquifers, subsidence is substantial and whole regions may sink. Human activities can contribute to land subsidence. These activities include the pumping of water, gas, and oil from underground reservoirs and the collapse of mine tunnels.

Reading Skills, *continued*

8. According to the passage, which of the following statements is not true?

A. Land subsidence is the settling or sinking of earth.

B. As groundwater is removed, the earth above may sink.

C. The greatest contributor to land subsidence is aquifer depletion.

D. Rocks settle and pores close, which leaves more area for water to be stored.

Reading Skills, *continued*

8. According to the passage, which of the following statements is not true?

A. Land subsidence is the settling or sinking of earth.

B. As groundwater is removed, the earth above may sink.

C. The greatest contributor to land subsidence is aquifer depletion.

D. Rocks settle and pores close, which leaves more area for water to be stored.

Reading Skills, *continued*

9. Which of the following statements can be inferred from the information in the passage?

F. Subsidence sinkholes occur most often in rural areas.

G. The majority of all subsidence sinkholes are formed through natural processes.

H. Subsidence sinkholes form both naturally and because of the activities of humans.

I. Older sinkholes are easily recovered by refilling the area with water.

Reading Skills, *continued*

9. Which of the following statements can be inferred from the information in the passage?

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H. Subsidence sinkholes form both naturally and because of the activities of humans.

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Reading Skills, *continued*

10. Subsidence due to groundwater depletion may occur slowly or very abruptly. Which type of subsidence presents a greater chance for recovery? Why?

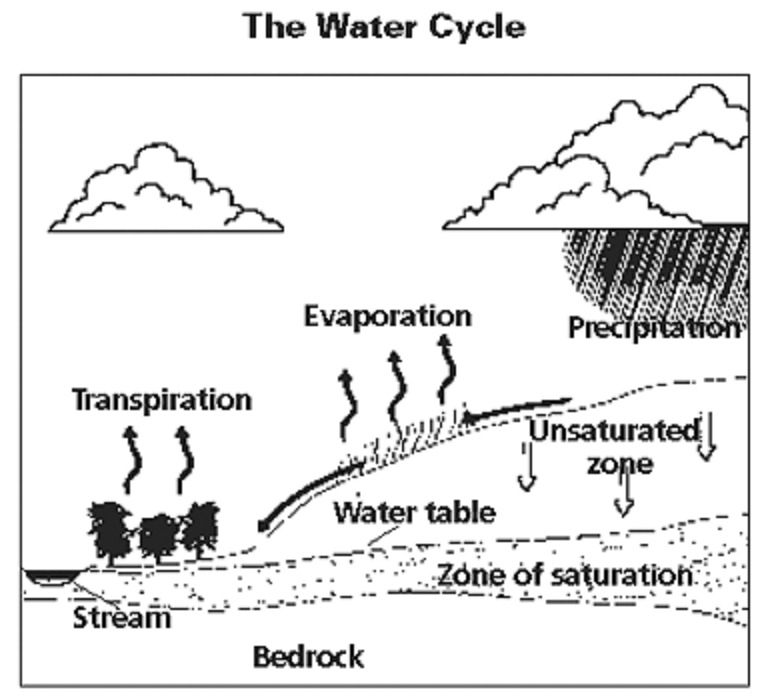
Reading Skills, *continued*

10. Subsidence due to groundwater depletion may occur slowly or very abruptly. Which type of subsidence presents a greater chance for recovery? Why?

Abrupt subsidence may involve greater compression of pore space and leave less chance for recovery.

Interpreting Graphics

Use the figure below to answer question 11. The figure shows an example of the water cycle.



Interpreting Graphics, *continued*

11. Which process occurs where the water table intersects the surface.

A. stream formation

B. runoff

C. groundwater movement

D. saturation

Interpreting Graphics, *continued*

11. Which process occurs where the water table intersects the surface.

A. stream formation

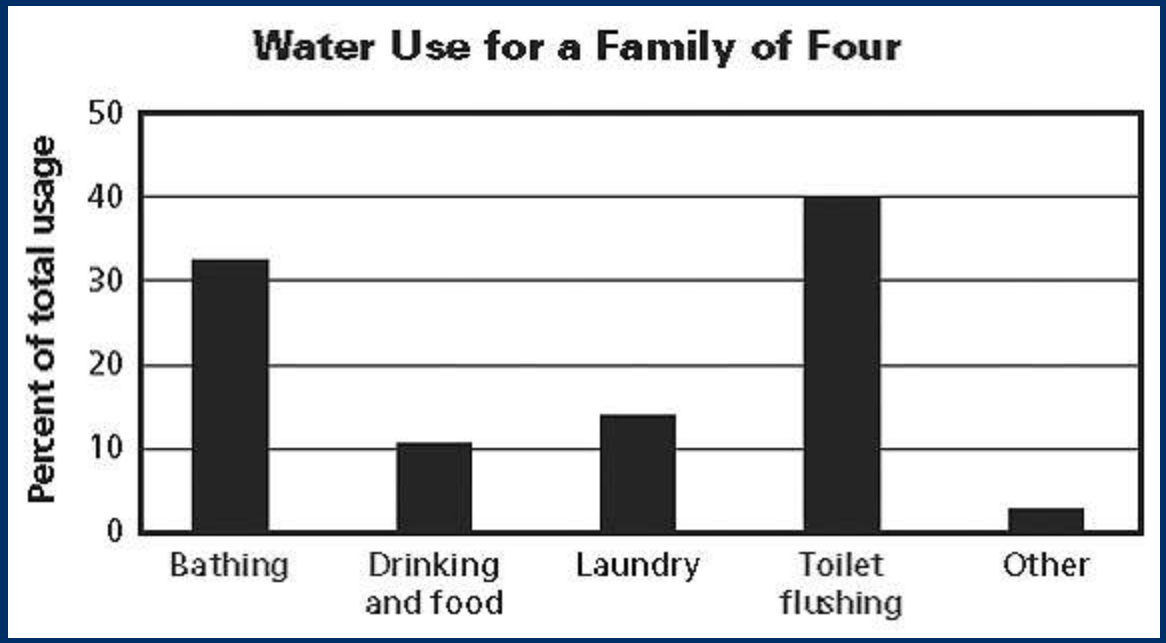
B. runoff

C. groundwater movement

D. saturation

Interpreting Graphics, *continued*

Use the figure below to answer questions 12-13. The figure shows indoor water use for a typical family.



Interpreting Graphics, *continued*

12. According to the graph, what is the largest use of indoor water for a family in the United States? Name some ways that people can reduce the amount of water consumed by this task.

Interpreting Graphics, *continued*

12. According to the graph, what is the largest use of indoor water for a family in the United States? Name some ways that people can reduce the amount of water consumed by this task.

Answers should include: toilet flushing is the largest use of indoor water; an understanding that toilets are a necessity, but may be made more water-efficient; suggested solutions may include using low-flow toilets, not flushing items such as tissue unnecessarily, and keeping toilets in good working order to help reduce the need for water.

Interpreting Graphics, *continued*

13. What total percentage of household indoor water is consumed by the two largest uses of indoor water? Round your answer to the nearest 10. How could this knowledge be used to help people reduce water usage?

Interpreting Graphics, *continued*

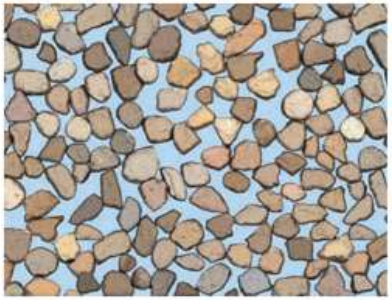
13. What total percentage of household indoor water is consumed by the two largest uses of indoor water? Round your answer to the nearest 10. How could this knowledge be used to help people reduce water usage?

Answers should include: estimate the percentage of water used for the two largest uses of indoor water, toilet flushing (40%) and bathing (32%). Rounded to the nearest 10, these uses account for 70% of water usage; proposed suggestions for conservation that target the largest uses of water first; students may connect ecological benefits of water conservation to the economic benefits of water conservation; students may suggest that people may be more easily convinced to reduce water usage if they are shown how much that usage costs them.

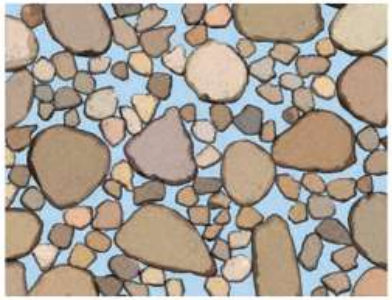
Porosity and Permeability

Porosity

Well-sorted, coarse-grained sediment has high porosity.

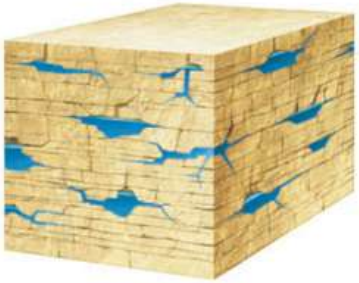


Well-sorted, fine-grained sediment has high porosity equal to the porosity of coarse-grained sediment.



Poorly sorted sediment that contains grains of many sizes has low porosity.

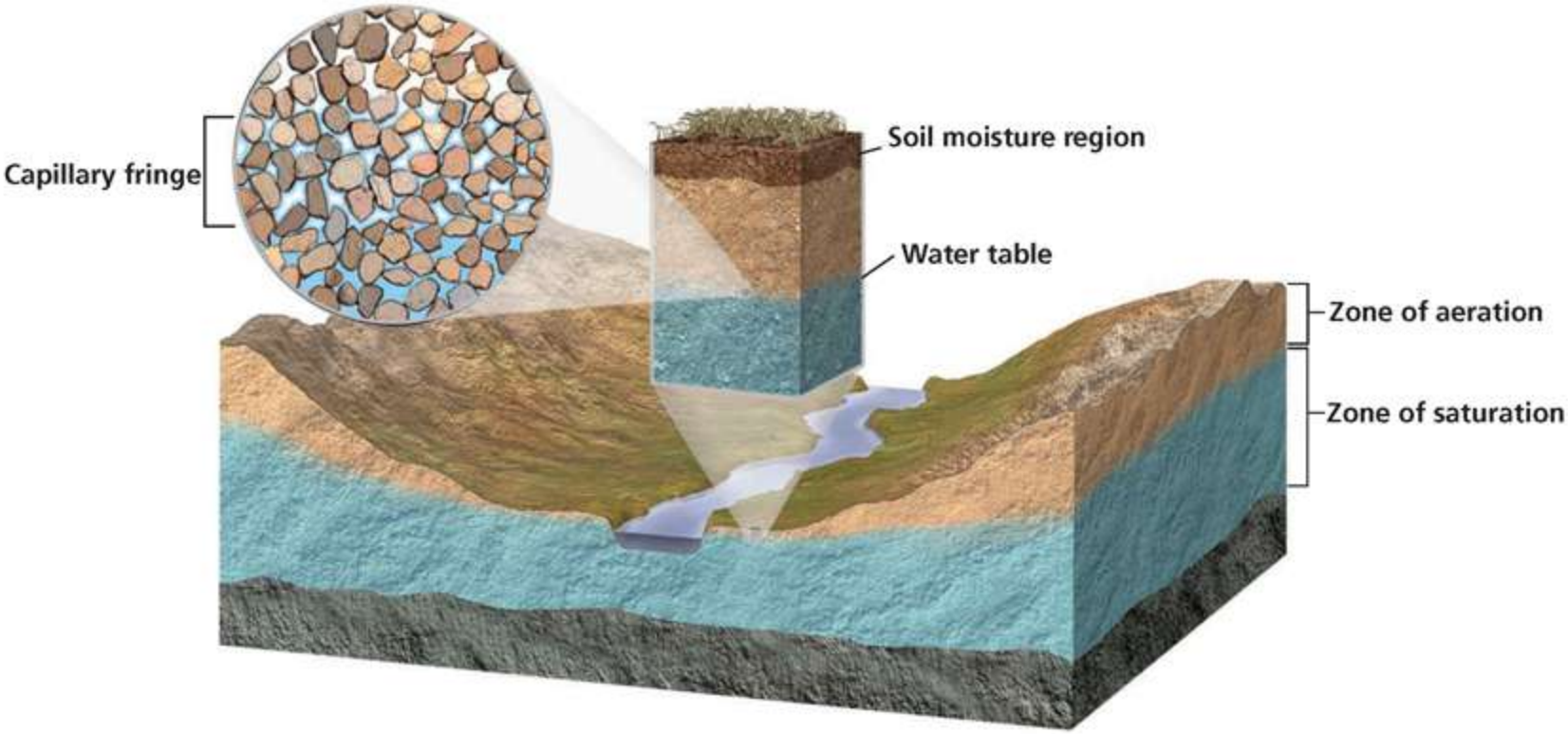
Permeability



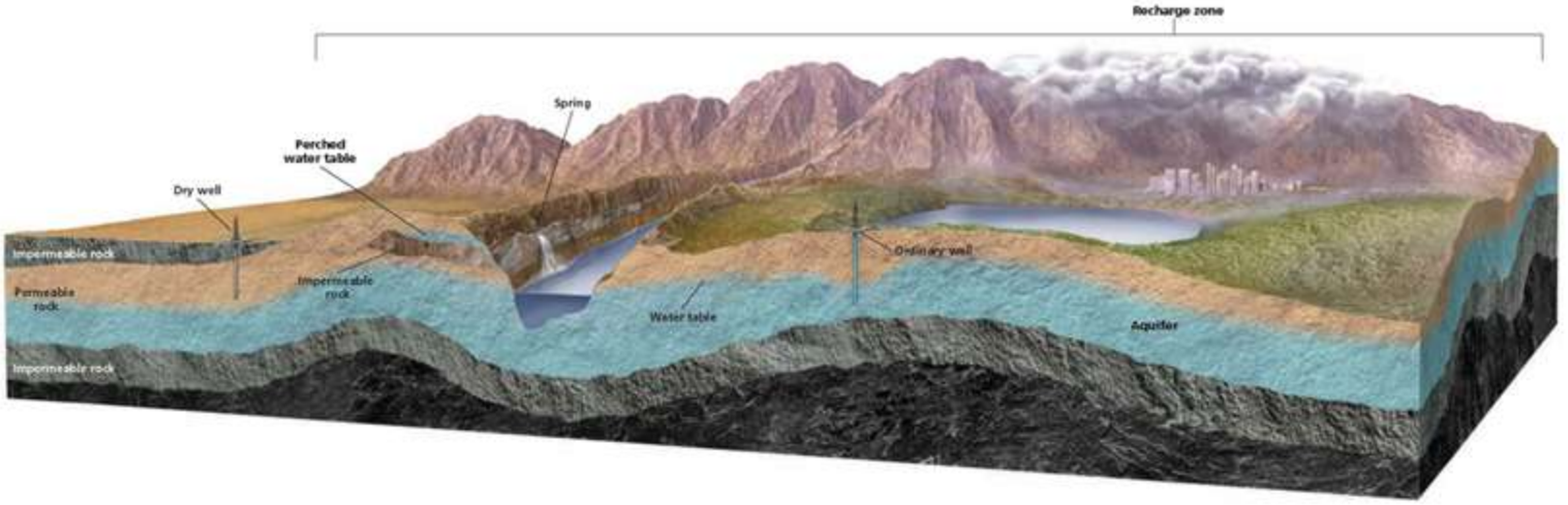
Rock is considered porous if it has many empty spaces that can fill with water.

Rock is considered permeable if its empty spaces are connected so that water may flow from one space to the next.

Zones of Aquifers



Topography and the Water Table



Water Level in the Southern Ogallala