Applied Geomorphology Lecture 9: Groundwater

Water on Planet Earth

Most of the Fresh Water is in Glacial Ice

SALT WATER 95.96%. Oceans and seas (1.40 x 10 ⁹ km ³)	FRESH WATER 4.04%
	Glaciers and polar ice 2.97% ($4.34 \times 10^7 \text{ km}^3$)
	Atmosphere 0.001% (1.5 × 10 ⁴ km ⁵)
	Lakes and rivers 0.009% (1.27 × 10^5 km ³)
	Underground waters 1.05% ($1.54 \times 10^7 \text{ km}^3$)
	Biosphere 0.0001 % $(2 \times 10^3 \text{ km}^3)$

Hydrologic Cycle



Orographic Lifting

Rain Shadow Desert results



Average Annual Precipitation

- Used to measure climate
- More accurate to use precipitation/evaporation



Runoff

 Precipitation that is collected by streams and rivers

 Runoff is transported to the oceans in a matter of several days (Short residence time)

River	Water Flow (m ³ /s)
Amazon, South America	175,000
La Plata, South America	79,300
Congo, Africa	39,600
Yangtze, Asia	21,800
Brahmaputra, Asia	19,800
Ganges, Asia	18,700
Mississippi, North America	17,500

Wetlands

- Wetlands tend to store fresh water
- Wetlands also act as barriers to storm surge
- Wetlands are also one of the most productive biological environments



In dry periods, streams bring in small amounts of water

....and carry away small amounts.



WET PERIOD: HIGH RUNOFI



... which is

In wet periods, streams bring in large amounts of water stored

... and slowly released during dry periods.



Groundwater

Groundwater is water that infiltrates below the erosional surface Porosity: percent void space in a material Permeability: ability of a material to transmit a fluid Common permeable geological material includes sandstone, limestone, marble, fault breccia

Examples of Porosity & Permeability



Well-sorted sandstone



Fractured shale

Impermeable Small amounts rock. of pore space along cracks.



12.

Poorly sorted sandstone



Unfractured shale

Clay grains. Very small amounts of pore space between clays and silt grains

Silt

Water Table

Saturated Zone: all void space is filled with water



Water Table Morphology

- The water table is a subdued replica of the overlying topographic surface
- Where the water table intersects the surface there will be a water discharge (spring, pond, lake or stream)
- The recharge area is where the precipitation enters the groundwater system
- Clay layers may generate a perched water table

Perched Water Table

Impermeable clay layer generates a localized water table



Figure 17.11 A perched water table forms in geologically complex situations—in this case, where a shale aquiclude is located above the main water table in a sandstone aquifer. The dynamics of the perched water table's recharge and discharge may be different from those of the main water table. The main water table in this example can be recharged only from its lower outcrop slopes.

Anthropogenic Effects

Excessive pumping lowers the elevation of the local water table (Drawdown)



Effects of Drought on Water Table

During drought water lowers throughout area



Aquifer

- Aquifer: a geological unit that contains water (porous and permeable)
- Confined Aquifer: bracketed by aquicludes (impermeable)
- Potentiometric Surface: elevation to which the pressurized water in a confined aquifer will rise
- Artesian Well: water rises to an elevation above the aquifer
- Flowing Artesian Well: potentiometric surface is above the ground surface

Example of Confined Aquifer

 Confined aquifers may contain pressurized water (hydraulic head)

 A confined aquifer is situated between two aquicludes (beds of low permeability).

Upland recharge area

2 An artesian well flows in response to the difference in natural pressure between the height of the water table in the recharge area and the bottom of the well.

Water¹ table Difference

Average height of water table in recharge area

> Aquiclude Confined aquifer Aquiclude

Flowing artesian well

4 If the well were as high as the water table in the recharge area, there would be no pressure difference and thus no flow. 3 The actual pressure difference that governs the flow from the top of the well is the difference between the elevation of the water table and that of the top of the well.

Height of entry of water into well

Groundwater Issues

Drawdown



Sinkholes



Saltwater Intrusion

Salt water is more dense than fresh water



Groundwater Flow

- Darcy's Law: governs the volume of groundwater produced at a well head
- Q = A(K)(h/I)
 - Q is volume
 - A is cross sectional area of aquifer
 - K is permeability
 - h is hydraulic head
 - I is map distance



Water Resources

Potable groundwater is a rapidly diminishing resource



Erosional Work of Groundwater

Natural groundwater is acidic (pH=6.5)
 Carbonates are susceptible to dissolution
 Sinkhole Formation
 Stalagtite
 Stalagtite





Stages of Landform Erosion in Karst Regions

Landforms dominated by solution of bedrock are termed Karst landforms



Solution Valley

Water Quality

Contamination of groundwater supply



Contamination Issues

Lead (Pb): sources include atmospheric pollution and older lead pipes • Radioactive Waste: natural and anthropogenic sources Microorganisms: sewage and waste water, flooding and storm surge Other chemical contaminants (solvents, gasoline, nitrates, road salt, etc.)

Hydrothermal Systems

Groundwater heated by magmatic sources



3 Hot springs occur where heated groundwater is discharged at the surface.

4 The water in a geyser follows an irregular network of pores and cracks, which slows down and complicates the flow of water. Steam and boiling water are released to the surface under pressure, resulting in intermittent eruptions.

