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Water Sources & Characteristics

Developing the Water Supply

AWWA WSO: Water Sources

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Learning Objectives

- Hydrologic Cycle
- Characteristics of Groundwater and Surface Water
- Sources of Groundwater and Surface Water
- Water Rights
- Source Development and Protection
- Wells Operation and Maintenance
- Regulatory Publications and Rules

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Water Supply Hydrology and the Hydrologic Cycle

- Hydrologic Water Cycle
  - movement of water from the surface of the earth to the atmosphere and back
- Process of evaporation and transpiration
- Condensation forms water vapor droplets
- Precipitation returns water to earth
- Water penetrates ground via infiltration, percolation, and runoff
  - Surface runoff occurs when ground is saturated

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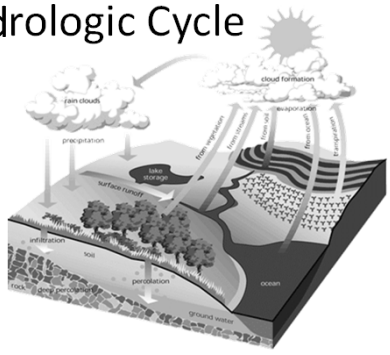
Hydrologic Cycle



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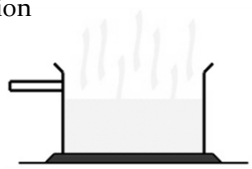
Hydrologic Cycle

- Evaporation and Transpiration
  - Evaporation
    - the changing of liquid to gas (water to water vapor)
  - Water is constantly evaporating from the earth
  - Transpiration
    - the process in which water from the earth is absorbed by plants and transferred to the air through the leaves



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Hydrologic Cycle

- Condensation and Precipitation
  - Condensation
    - occurs when water vapor condenses as it cools and forms tiny droplets of water or clouds
  - Precipitation
    - occurs when the droplets become too heavy to stay airborne
    - these droplets fall back to earth as rain, snow, sleet or hail

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Hydrologic Cycle

- Infiltration and Percolation
  - As precipitation falls, it soaks into the ground
  - Infiltration
    - the movement of water through the soil
  - Some of the water goes back to the surface due to *capillary action*
    - the movement of water above a water surface
  - The rest percolates (continues downward) to the water table

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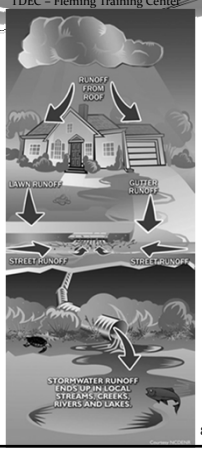
Hydrologic Cycle

- Surface Runoff
  - When the soil can hold no more water, it flows downward over the ground surface
  - It flows into streams or lakes or, eventually, the ocean



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Groundwater

- Water below the surface
- Hidden resource
- Provides 20% of water used in the US
- Has few contaminants
- Resultant of infiltration and percolation
- Relatively free from micro contamination
- Characterized by:
  - high TDS
    - Fe & Mn
  - high dissolved gases
    - radon, CH_4, H_2S
  - low dissolved oxygen
  - low color
  - high hardness
- Can be influenced by natural and human activities

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Groundwater

- Sources
  - Aquifers
    - confined and unconfined
  - Springs
- Half of the world's groundwater resource is located within one mile of the ground surface
- Other half is found in deep aquifers

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Aquifers

Unconfined Aquifers

- Upper surface is free to rise and fall
- Water table wells
  - wells constructed to reach an unconfined aquifer
- Amount of water produced varies widely as water table rises and falls in relation to rainfall
- Indicates water table level of surrounding aquifer

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Aquifers

Confined Aquifers

- Also known as Artesian Aquifer
- Permeable layer confined by an upper level and lower level of low permeability material
- Water recharge area usually higher than main part of aquifer
- Water is usually under pressure
- Flowing artesian well
  - pressure causes water to rise above ground surface
- Non-flowing artesian well
  - water doesn't rise to the surface
- Piezometric surface
  - height that water rises

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Aquifers

- Characteristics
  - Underground layer of gravel, sand, sandstone, shattered rock, or limestone
  - Impermeable layer of rock, clay or granite keeps water from sinking downward
  - Water table is upper surface of an aquifer
  - Classified as water table or artesian and confined or unconfined

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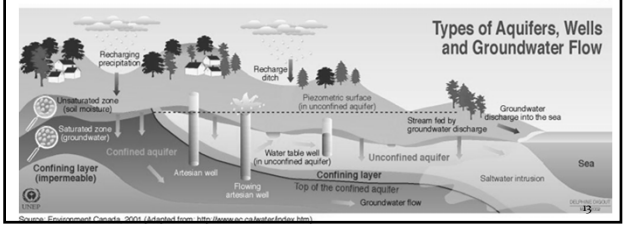

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Source: Environment Canada, 2001 (Adapted from: http://www.ec.ca/water/index.htm)

Aquifers Terms & Materials

- Porosity
  - amount of water the material will hold
- Hydraulic conductivity
  - how easily the water will flow thought the aquifer material
- Both determine how much the aquifer will yield
- Pumping rates are higher in coarser material and cost less
  - less pumping head loss
- Consolidated aquifer formations consist of limestone and fractured rock and produce large quantities of water

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Groundwater Movement Characteristics

- Movement of water is naturally downhill
- Rainfall percolates down to the water table
- Water moves slowly through soil which removes suspended particles
- Soil acts as a natural filtration process
  - Dissolved pollutants cannot be removed
  - Contaminants can be picked up
- Water table is never completely level

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Springs

- Occur if water table intersects the ground surface
- Difficult to determine source of springs
- They should be considered contaminated until sanitary survey is conducted
- Flows vary considerably and are influenced by artesian pressures
- Enclose intake in a concrete spring box

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Surface Water Characteristics

- Higher turbidity
- Suspended solids
- More color
- Microbial contamination
- Impurities in snow and rain
- Impurities from runoff
  - soluble formations such as limestone, gypsum, & rock salt affect characteristics
- Precipitation dissolves gases in atmosphere
- Dust and solids from industrial processes
- Usually soft, low in solids and alkalinity, and pH slightly below 7
- Usually corrosive
- Seasonal changes

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Surface Water Supply and Operating Problems

- Contamination
- Loss of water source by evaporation & seepage
- Weather (rain and snowfall)
- Exposure to environmental changes
- Icing
- Rainfall intensity and droughts
- Soil composition
- Human influences
- More and varied treatment processes

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Wells

You surface water people stay awake!

This is a GROUNDWATER people session.

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Wells

- Advantages
  - Provide 20% of water used in US
  - Facilities cost less to operate
  - Water is less turbid
  - Contains fewer bacteriological and viral contaminants
    - require less treatment
  - Maintain uniform temperature

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Parts of a Well

- **Sanitary seal**
  - prevents contamination
  - seal has openings for discharge pipe, pump controls, and air vent
- **Well casing**
  - liner to prevent walls from caving in
  - protects water quality
- **Well casing vent**
  - prevents pump vacuum and contamination from entering

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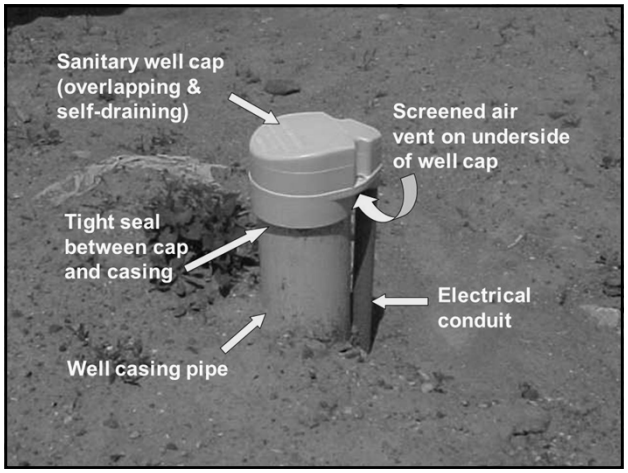
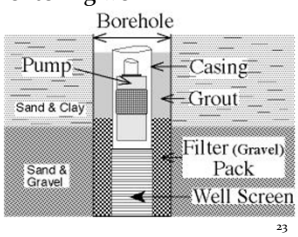


Parts of a Well

- **Grout**
  - cement or other material that prevents water from the surface from entering well
- **Intake screen**
  - prevents sand or other material from entering the well and allows water to flow freely



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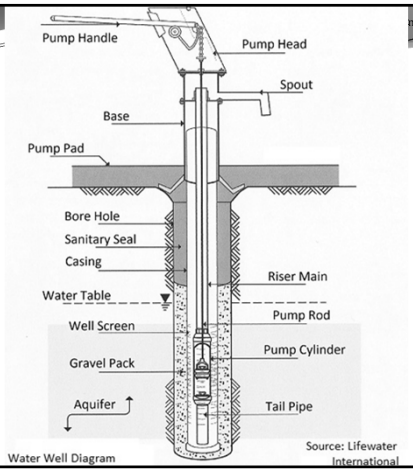

Water Well Diagram

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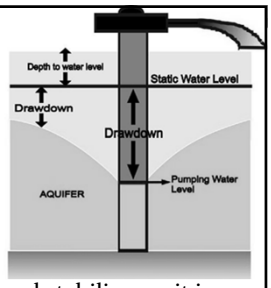
Well Terms



- **Static water level**
  - water surface level when no water is being drawn
- **Pumping water level**
  - level at which water drops and stabilizes as it is pumped
- **Drawdown**
  - drop between static and pumping level

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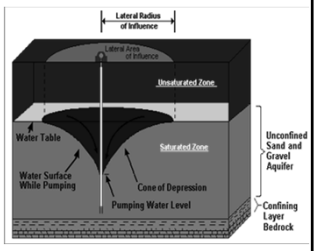
Well Terms

- **Cone of depression**
  - depression in the water level around a well during pumping
- **Zone of influence**
  - length and depth of Radius of Influence
  - determined by Cone of Depression



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Well Terms

- **Residual drawdown**
  - difference between the original water level and water level after pumping has stopped
- **Well yield**
  - rate of water withdrawal that a well can supply over a long period of time
- **Safe yield**
  - maximum amount of water that can be withdrawn continuously during the driest periods
- **Specific capacity**
  - yield per unit of drawdown (can indicate problems)

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Well Location and Sanitary Considerations

- Located to produce max yield while being protected
- Deep as possible to prevent contamination from the surface
- If shallow groundwater source, ensure casing and hole grouted
- Prefer a 2 foot deep layer of clay within a 50 foot radius around the well

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Well Operation and Maintenance

- Record Keeping
  - Static water level after pump has been idle for a period of time
  - Pumping water level
  - Drawdown
  - Well production
  - Well yield
  - Time required for recovery after pumping
  - Specific capacity

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Well Operation and Maintenance

- Regular Maintenance
  - Plugging of screen most common problem
    - encrustation of biological growth
    - precipitates of Fe, Mn, and hardness
  - Can be cleaned using hydrochloric acid (muriatic acid)
    - refer to AWWA manual M21
  - Well can fail if screen collapses or corrodes
  - Bacteriological samples should be periodically
  - Disinfection may be needed sometimes

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Procedures for Well Abandonment

- Eliminate any physical hazards
- Take measures to prevent groundwater contamination and protect other nearby wells
- Conservation of the aquifer
- Return to geological conditions present before well was constructed
- Private wells must be properly abandoned and plugged
  - can be a cross connection if home is connected to both a well and public water supply
  - it should be permanently disconnected
- **Must be done properly**

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Surface Water Source Development

- Includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake

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Surface Water Source Development

- Factors
  - Quantity
  - Quality
  - Structures
  - Impoundments and reservoirs
    - Site preparation
    - Construction
- Tennessee Public Water System Design Criteria part 3

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Groundwater Source Development

- Includes all water obtained from drilled wells or springs
- General Well Construction Requirements
- Tennessee Public Water System Design Criteria part 3.3

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Safe Drinking Water Act

- SDWA
  - Establishes primary drinking water standards
  - Secondary standards
  - Public notification procedures and requirements
  - Federal Enforcement
  - Established a cooperative program among local, state, and federal agencies
  - EPA executive agency
  - Established MCL's (Maximum Contaminate Level)
  - Established sampling and testing requirements

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Tennessee Water Program

- Governing agency
  - Department of Environment and Conservation Bureau of Environment Division of Water Resources
  - Rules/Regulations
    - Chapter 0400-45-1 Public Water Systems
  - Sanitary surveys
  - Wellhead Protection Plan
  - Technical assistance
  - Laboratory services
  - Enforcement
  - Environmental Field Offices(EFOs)
  - Design criteria

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Physical Characteristics of Water

- Relates to sensory qualities of water
- Temperature
  - most familiar characteristic
  - effects lake turnovers, dissolving of chemicals and palatability
  - most desirable drinking water is considered cool
- Turbidity
  - cloudiness of water
  - indicator of health significance
  - operational considerations
  - aesthetics
- Color
  - indicates contamination, dissolved organics, and humic substances that could form THMs
- Taste & odor
  - degradation aesthetic quality

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Chemical Characteristics of Water

- Inorganic
  - pH
    - indicator of acidity or alkalinity
  - Hardness
  - Dissolved oxygen
    - measured in mg/L
  - Dissolved solids
    - toxic minerals include
      - chromium
      - arsenic
      - lead
      - barium
      - mercury
      - fluoride
      - silver
      - nitrate
- Organic
  - Includes
    - pesticides
    - herbicides
    - domestic wastes
    - industrial wastes
    - watershed runoff
  - Can cause taste, odor, and toxicity problems

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Biological Characteristics of Water

- Aquatic life (algae)
- Bacteria
- Coliforms
- Viruses
- Protozoa
- Spores
- Cysts
- Many originate with fecal discharges
- Not easily identified and isolated

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Radiological Factors in Water

- Development of atomic energy and mining of radioactive materials made it necessary to examine safe limits
- Divided into two categories:
  - Natural and Man-made
- Sources are
  - Natural deposits and Man-made deposits

If someone is glowing, Be Suspicious! ☺

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Water Source Protection

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Fundamental Principles

- The quality of source water is influenced by natural and human activities
- It is the responsibility of the operators to minimize harm from both of these
- Surface waters are more influenced by human activities
- Groundwater can also be influenced

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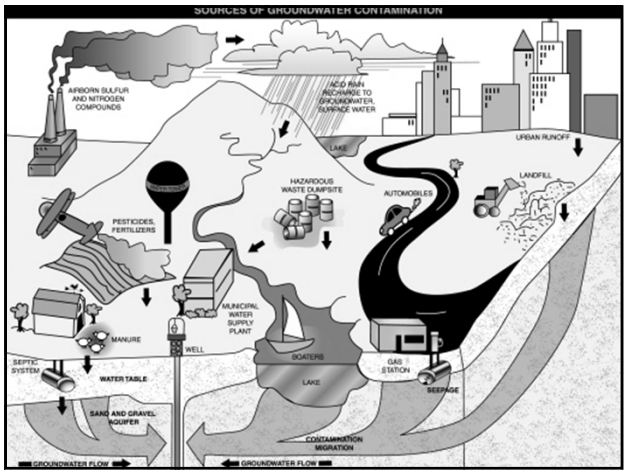

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Benefits of Source Water Protection Program

- Source control is the first barrier in a multiple-barrier treatment plan
- Water treatment methods are not 100% effective in removing contaminants
  - The risks of residual contaminants can be too high
- As the quality of source water deteriorates, the cost of treatment goes up and can become prohibitive

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Benefits of Source Water Protection Program

- Increase in public confidence
- Decrease in public health risks
- Due to difficulty to analyze, remove, and/or disinfect pathogens with conventional methods, keeping pathogens out of the source water may be the only way of providing protection

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Developing a Source Water Protection Program

- Inventory and characterize the water source
- Identify pollutant sources and relative impact
- Assess vulnerability of intake to contaminants
- Establish source water protection goals

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Developing a Source Water Protection Program

- Develop source water protection strategies
- Implement the program
- Monitor and evaluate program effectiveness

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Developing a Source Water Protection Program

- Identify area that needs protection and who has an interest in protecting it
  - For wellhead protection
    - aquifer delineation
  - For surface water sources
    - watershed mapping

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Developing a Groundwater Source Protection Program

- Aquifer Delineation (**Wellhead Protection Area**)
  - Define the land area over the portion of the aquifer that influences the quality of the water
  - Should be identified and inventoried for potential of contamination
  - For microbiological contaminants, a small area is suitable

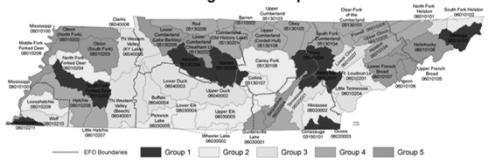
Developing a Groundwater Source Protection Program

- Aquifer Delineation (Wellhead Protection Area)
  - Chemical contaminants can travel from several thousand feet for relatively deep wells
  - USGS maps are a good place to start
  - 1986 SDWA amendments require each state to develop a Wellhead Protection Program
  - Limit activities in area to protect well and aquifer from contamination

Developing a Groundwater Source Protection Program

- Watershed Mapping
  - Surface water sources
  - Watershed is area sloped toward water source that drains to it
  - Watershed should be identified and inventoried for potential sources of contaminantion
  - USGS (United States Geological Survey)

Tennessee Watershed Management Groups



Developing a Source Water Protection Program

- Regulations
  - Tennessee Regulations for Wellhead Protection
    - Section 0400-45-1-.34

Developing a Surface Water Source Protection Program

- Watershed Mapping
  - If utility can purchase lands in the watershed, it can limit activities that could affect water quality
  - If land cannot be bought, buffer zones for logging and agriculture operations should be implemented
  - Promote community activities that emphasize protection of watershed

Developing a Source Water Protection Program

- Identify Pollutant Sources and Relative Impact
  - Sewage disposal
  - Urban, industrial, agricultural and mine runoff
  - Animal population
  - Forestry/soil disturbance runoff
  - Recreation

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Developing a Source Water Protection Program

- Assess Vulnerability of Intake to Contaminants
  - Purpose
    - identify contaminant
    - identify amount of contaminant
    - correlate land use to contaminant level
  - Assessment methods
    - water quality monitoring
    - modeling
    - onsite assessment

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Developing a Source Water Protection Program

- Strategies
  - Land use controls
    - buffer zones
    - land acquisition
    - comprehensive planning
    - watershed/recharge area inspections

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Developing a Source Water Protection Program

- Vandalism and Terrorism
  - Before 9/11/01, no serious threat
  - Protect intakes
  - Safeguard area around source, if possible
  - Monitoring and surveillance may be required if threat is serious
  - Be alert of suspicious events

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Developing a Source Water Protection Program

- Title IV Drinking Water Security and Safety
  - Must have assessment of system
  - Dateline is dependent on size of system
  - ERPs (Emergency Response Plans) are due 6 months after assessment
  - Plans include actions, procedures, and identification of equipment which can prevent or lessen the impact of a terrorist act

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Developing a Source Water Protection Program

- Source of Contamination
  - After WHPA or watershed boundary for a water source has been determined, inventory of potential contaminant sources is to be performed
  - Community volunteer effort along with utility personnel is encouraged
    - volunteer fire dept., citizen group, etc.

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Water Sources and Characteristics Review Questions

1. Draw the basic hydrologic cycle.

2. What is the water table?

3. Define the term aquifer.

4. What two things determine the amount of water an aquifer will yield?
   - ➢
   - ➢

5. Describe the differences in water characteristics of groundwater and surface water.

6. Define the term watershed.

7. List six factors that influence the amount of surface runoff.
   - ➢
   - ➢
   - ➢
   - ➢
   - ➢
   - ➢

8. What is the purpose of an impoundment?

Water Sources & Treatment Vocabulary

A. Acid rain
B. Appropriative
C. Aquifer
D. Artesian
E. Capillary fringe
F. Contamination
G. Cross connection
H. Detention Time
I. Direct runoff
J. Drawdown
K. Evaporation
L. Evapotranspiration
M. Hydrologic cycle
N. Impermeable
O. Infiltration
P. Microorganisms
Q. Nonpotable
R. Pathogenic organisms
S. Percolation
T. Potable water
U. Precipitation
V. Raw water
W. Safe Drinking Water Act
X. Safe yield
Y. Stratification
Z. Transpiration
AA. Trihalomethanes
BB. Turbidity
CC. Water table

_____ 1. Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking.

_____ 2. The introduction into water of microorganisms, chemicals, toxic substances, wastes or wastewater in concentration that makes the water unfit for its next intended use.

_____ 3. Precipitation which has been rendered acidic by airborne pollutants.

_____ 4. The process of evaporation of water into the air and its return to earth by precipitation, including transpiration, groundwater movement, and runoff into rivers, streams and the ocean.

_____ 5. The upper surface of the zone of saturation of groundwater in an unconfined aquifer.

_____ 6. An act passed by the US Congress in 1974 that establishes a cooperative program among local, state and federal agencies to ensure safe drinking water for consumers.

_____ 7. Living organisms that can be seen individually only with the aid of a microscope.

_____ 8. Water rights to or ownership of a water supply which is acquired for the beneficial use of water by following a specific legal procedure.

_____ 9. The drop in the water table or level of water in the ground when water is being pumped from a well.

_____ 10. The process by which water vapor passes into the atmosphere from living plants.

_____ 11. Derivatives of methane in which three halogen atoms are substituted for three of the hydrogen atoms. Often formed by chlorination of organic matter.

_____ 12. Organisms capable of causing diseases in a host.

_____ 13. Water that may contain objectionable pollution, contamination, minerals or infective

_____ 14. A connection between a drinking water system and an unapproved water supply.

_____ 15. The annual quantity of water that can be taken from a source of supply over a period of years without depleting the source permanently.

_____ 16. The slow passage of water through a filter medium or the gradual penetration of soil & rocks by water.

_____ 17. Water flows over the ground surface or through the ground directly into streams, rivers, or lakes.

_____ 18. The process by which water vapor is released to the atmosphere by living plants.

_____ 19. The cloudy appearance of water caused by the presence of suspended and colloidal matter.

_____ 20. The process by which atmospheric moisture falls onto a land or water surface as rain, snow, hail, or other forms of moisture.

_____ 21. The formation of separate layers in lake or reservoir.

_____ 22. The process by which water or other liquid becomes a gas.

_____ 23. The porous material just above the water table which may hold water by capillarity in the smaller void spaces.

_____ 24. The seepage of groundwater into a sewer system, including service connections.

_____ 25. The theoretical time required for a small amount of water to pass through a tank at a given rate of flow.

_____ 26. Water in its natural state, prior to any treatment.

_____ 27. A natural underground layer of porous, water bearing materials usually capable of yielding a large amount or supply of water.

_____ 28. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water

_____ 29. Pertaining to groundwater, a well or underground basin where the water is under a pressure greater than atmospheric and will rise above the level of its upper confining surface if given an opportunity to do so.

Answers

1. T	7. P	13. Q	19. BB	25. H
2. F	8. B	14. G	20. U	26. V
3. A	9. J	15. X	21. Y	27. C
4. M	10. L	16. S	22. K	28. N
5. CC	11. AA	17. I	23. E	29. D
6. W	12. R	18. Z	24. O	

Parts of a Well – Matching

Draw a line from the term to its definition:

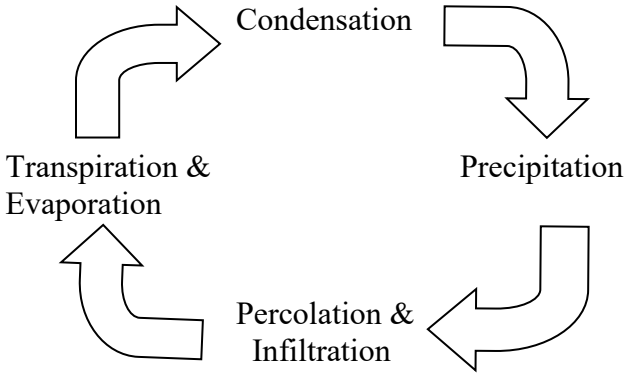
Sanitary Seal	Allows water to flow freely from an aquifer to a well; keeps sand out of a well.
Well Casing	Concrete area placed around the casing to support pumping equipment.
Intake Screen	A liner placed in the bore hole of a well to prevent the walls from caving in.
Grout	Prevents contamination from entering the well at the surface.
Well Slab	Seals the space between the casing and the bore hole.

Well Terms – Matching

Draw a line from the term to its definition:

Static Water Level	Inverted cone-shaped depression in water level while pump is operating.
Pumping Water Level	Water level when no water is being pumped from the aquifer.
Drawdown	Difference between original water level and the level after pumping has stopped.
Cone of Depression	Well yield ÷ drawdown.
Zone of Influence	Level to which water drops and stabilizes as it is pumped.
Residual Drawdown	Length and depth of radius of influence as determined by the cone of depression.
Well Yield	The drop between the static water level and the pumping water level.
Specific Capacity	The rate of water withdrawal that can be supplied over a period of time.

Answers to Water Sources and Characteristics Review Questions

1. 

2. The water table is the upper surface of an aquifer.

3. An aquifer is a porous, water-bearing geological formation.

4. The porosity and hydraulic conductivity determine the amount of water an aquifer will yield.

5. Groundwater:
   - High dissolved solids
   - Dissolved gasses
   - Low color
   - High hardness
   - Free from microbes

   Surface water:
   - Suspended solids
   - Higher turbidity
   - Higher color
   - Lower hardness
   - Microbial contamination

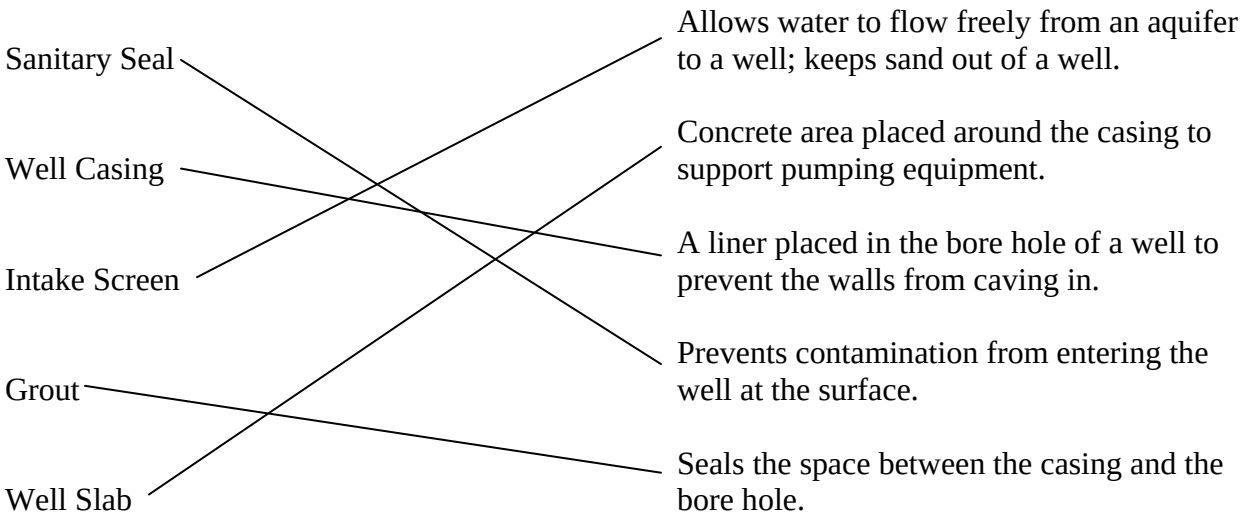
6. A watershed is the land area that is sloped toward a water source and drains into it.

7. Six factors influencing the amount of surface runoff are:
   rainfall intensity, rainfall duration, soil composition, soil moisture, ground slope, vegetation cover

8. An impoundment stores water for use during water deficiencies.

Parts of a Well – Matching

Draw a line from the term to its definition:



Well Terms – Matching

Draw a line from the term to its definition: