Chapter 34: Aquifers – Types

Introduction

Aquifers form a crucial component of groundwater hydrology and are vital for sustaining agricultural, industrial, and domestic water supplies. They act as natural underground reservoirs, storing and transmitting water through the pore spaces and fractures in soil and rock. Understanding aquifers, their properties, and classifications is essential for the efficient design and management of water resources engineering systems, including wells, pumps, and recharge mechanisms.

This chapter focuses on defining aquifers, exploring their properties, and discussing their different types based on geological and hydraulic characteristics.

34.1 Definition of Aquifer

An **aquifer** is a geological formation that can store and transmit significant quantities of groundwater. These formations are composed of permeable materials such as sand, gravel, fractured rock, or sandstone, which allow water to move through them under natural hydraulic gradients.

Aquifers must possess two essential properties:

- **Porosity**: The capacity to store water.
- **Permeability**: The capacity to transmit water.

34.2 Aquicludes, Aquitards, and Aquifuges

In understanding aquifers, it's important to differentiate between related terms:

34.2.1 Aquiclude

- A geological formation that **can store water** but **cannot transmit** it significantly.
- Made up of clay or shale.
- Example: A layer of clay beneath a sand aquifer.

34.2.2 Aquitard

- A semi-permeable layer that **transmits water at a slower rate**.
- Lies between an aquifer and an aquiclude.
- Important in **confined aquifer systems**.

34.2.3 Aquifuge

- A completely **impervious** formation.
- **Neither stores nor transmits** water.
- Example: Massive granite without any fractures.

34.3 Classification of Aquifers

Aquifers are classified based on their structure, water-holding characteristics, and pressure conditions.

34.3.1 Unconfined Aquifer (Water Table Aquifer)

- **Definition**: An aquifer that is directly open to the atmosphere through the porous material above it.
- **Water table** forms the **upper surface**.
- **Recharge** occurs directly from precipitation and surface water.
- **Features**:
  - Water level in wells corresponds to the water table.
  - Susceptible to contamination.
  - Fluctuates seasonally.
- **Examples**: Alluvial sands along riverbanks.

34.3.2 Confined Aquifer (Artesian Aquifer)

- **Definition**: An aquifer that is sandwiched between two **impermeable layers** (aquicludes).
- Water is under **pressure**; when tapped, water rises above the top of the aquifer and may even flow without pumping.
- **Piezometric surface** replaces water table in these aquifers.
- **Features**:
  - High yields.
  - Pressure-dependent discharge.
  - Recharge occurs from remote areas where aquifer outcrops.
- **Examples**: Deep sandstone layers confined between clay layers.

34.3.3 Semi-Confined Aquifer (Leaky Aquifer)

- Bounded by aquitards on one or both sides.
- Allows **slow leakage** of water through the bounding layers.
- **Intermediate behavior** between confined and unconfined aquifers.

- Important in regional groundwater flow studies.

34.3.4 Perched Aquifer

- Occurs **above the main water table** due to a **localized impermeable layer**.
- Temporary and often small-scale.
- Found above clay lenses in a sandy formation.
- **Features**:
  - Creates false water tables.
  - Not reliable for large-scale water supply.

34.4 Classification Based on Rock Types

Aquifers can also be classified based on the **geological material** that composes them:

34.4.1 Alluvial Aquifers

- Composed of sand, gravel, and silt deposited by rivers.
- Highly porous and permeable.
- Common in river plains and basins.

34.4.2 Sandstone Aquifers

- Consist of cemented sand particles.
- Moderate porosity and permeability.
- Good storage capacity.

34.4.3 Limestone Aquifers (Karst Aquifers)

- Characterized by **solution channels and caverns**.
- Very high transmissivity due to dissolution features.
- Susceptible to rapid contamination spread.

34.4.4 Basaltic (Volcanic) Aquifers

- Composed of lava flows and fractured basalt.
- Water stored in fractures and vesicles.
- Variable yield depending on the degree of fracturing.

34.4.5 Fractured Rock Aquifers

- Found in crystalline rocks like granite and gneiss.
- Water stored and transmitted through **joints and fractures**.
- Limited porosity; permeability depends on fracture network.

34.5 Storage Properties of Aquifers

Two key properties define the storage capacity of aquifers:

34.5.1 Specific Yield

- The volume of water that drains from the aquifer due to gravity, expressed as a percentage of total volume.

34.5.2 Specific Retention

- The volume of water retained against gravity, due to capillary and surface tension forces.

The **porosity (n)** is the sum of specific yield and specific retention.

34.6 Transmissivity and Hydraulic Conductivity

These properties define the ability of aquifers to transmit water:

34.6.1 Hydraulic Conductivity (K)

- The rate at which water moves through a unit cross-section under a unit hydraulic gradient.
- Depends on:
  - Pore size.
  - Pore connectivity.
  - Viscosity of water.

34.6.2 Transmissivity (T)

- The rate at which water is transmitted through the full saturated thickness of the aquifer.
- $T = K \times b$, where b is the saturated thickness.

34.7 Yield of Wells in Different Aquifers

- **Unconfined Aquifers**: Drawdown is greater; recharge is quick.
- **Confined Aquifers**: Yield depends on pressure head; limited recharge.
- **Leaky Aquifers**: Yield increases due to leakage from aquitards.
- **Fractured Aquifers**: Highly variable yield; dependent on fracture characteristics.

34.8 Artificial and Natural Recharge

- **Natural Recharge**: Through precipitation, river seepage, etc.
- **Artificial Recharge Methods**:
  - Spreading basins.
  - Recharge wells.
  - Percolation tanks.
  - Induced recharge by pumping.

Aquifer recharge is essential for **sustainable groundwater development**, especially in overexploited regions.

34.9 Summary of Aquifer Characteristics (Tabulated)

Type of Aquifer	Water Table	Pressure Condition	Boundaries	Water Movement	Contamination Risk
Unconfined	Present	Atmospheric	Permeable top	Rapid	High
Confined	Absent	Under pressure	Impermeable top/bottom	Slow	Low (remote recharge)
Semi-Confined	Variable	Partial pressure	Leaky aquitards	Moderate	Moderate
Perched	Localized	Local pressure	Local impervious lens	Isolated	Variable

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