

Module 5: Ground Water and Well Hydrology

1. Forms of Subsurface Water

Subsurface water occurs below the earth's surface and can be classified into:

- **Zone of Aeration (Unsaturated Zone):**
 - *Soil Water Zone:* Near-surface, vital for plants.
 - *Intermediate/Vadose Zone:* Transitional area, temporarily holds water.
 - *Capillary Fringe:* Thin layer where groundwater is drawn above the water table by capillary action^[1].
- **Zone of Saturation (Saturated Zone):**
 - All soil pores are filled with water, forming the groundwater reservoir.

Groundwater flow happens below the water table, replenishing springs, wells, and water bodies^{[2] [3]}.

2. Saturated Formation and Geologic Formations of Aquifers

Aquifers

An **aquifer** is a saturated, permeable geologic formation that produces significant water to wells and springs^{[3] [4] [5]}.

Types of Aquifers:

Type	Structure	Characteristics
Unconfined	Open to surface	Water table at upper boundary
Confined	Bounded by impermeable layers	Under pressure, may form artesian wells
Perched	Localized, perched above main water table by lens of impermeable rock	Limited size and depth, seasonal ^{[6] [5]}

Geologic Formations in India

- **Unconsolidated Sediments:** Alluvium (Indo-Gangetic plains)—high-yielding aquifers^{[7] [8]}.
- **Consolidated Rocks:** Sandstones, limestones—porous/fracture flow; Deccan basalt—fractured and vesicular flow.
- **Metamorphic/Igneous Rocks:** Granites, gneisses—generally have low primary porosity but may transmit water through cracks, fractures, and weathered zones^{[7] [8]}.

3. Aquifer Properties

Property	Description	Unit
Porosity	% of rock/soil volume that is pore space	Dimensionless (%)
Specific Yield	Draining portion of water by gravity	Dimensionless
Permeability	Ease of water movement through pores ^[4]	m ²
Hydraulic Conductivity	Rate of flow through aquifer material	m/day
Transmissivity	Rate of water transmitted across aquifer thickness	m ² /day
Storage Coefficient	Volume of water released from storage per area per unit drop in head	Dimensionless

4. Well Hydraulics: Steady State Flow in Wells

- **Steady-State Flow:** Achieved when pumping a well at a constant rate and piezometric heads stabilize throughout the aquifer ^[9].
- **Cone of Depression:** The drawdown curve that forms around a well when pumping begins.

Equilibrium Equations

(A) Confined Aquifers (Theim Equation):

$$Q = \frac{2\pi T(h_1 - h_2)}{\ln(r_2/r_1)}$$

Where:

- \$ Q \$: Pumping rate (m³/s)
- \$ T \$: Transmissivity (m²/s)
- \$ h_1, h_2 \$: Piezometric heads at radii \$ r_1, r_2 \$ ^[10]
- ln: Natural logarithm

(B) Unconfined Aquifers:

$$Q = \frac{\pi K(h_1^2 - h_2^2)}{\ln(r_2/r_1)}$$

Where:

- \$ K \$: Hydraulic conductivity (m/s)
- \$ h_1, h_2 \$: Water table elevations above base at \$ r_1, r_2 \$
- Used for water table (unconfined) aquifers ^[10]

5. Aquifer Tests

Aquifer tests determine hydraulic properties like transmissivity and storage.

Methods:

- **Pumping test:** Water is pumped at constant rate, and drawdown is measured over time and distance in observation wells.
- **Slug test:** Water level is quickly raised or lowered in a well; recovery is monitored to estimate hydraulic conductivity.
- **Constant-head test:** Head is held steady, and discharge is observed.

Purpose:

- Estimation of aquifer capacity.
- Determination of sustainable yield.
- Analysis of well performance and drawdown.

Parameters evaluated:

- **Transmissivity (T):** Rate of water flow through aquifer thickness.
- **Storativity (S):** Water released per unit area per unit drop in head ^[11] ^[10] ^[12].

Summary Table

Topic	Key Points
Subsurface Water	Zone of aeration (soil, vadose, capillary); zone of saturation (groundwater) ^[1]
Aquifers	Unconfined, confined, perched; found in unconsolidated sediments, sedimentary, igneous or metamorphic rocks ^[4] ^[5] ^[8]
Aquifer Properties	Porosity, specific yield, permeability, hydraulic conductivity, transmissivity, storativity
Well Hydraulics	Steady flow equations: Theim (confined), equilibrium (unconfined) ^[9] ^[10]
Aquifer Tests	Pumping, slug, constant-head—estimate T, S, sustainable yield ^[11] ^[12]

A strong grasp of these fundamentals is essential for managing groundwater resources and designing effective well systems.



1. <https://www.geographynotes.com/hydrogeology/classification-of-subsurface-water-hydrogeology/1516>
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