UNIT – I

Ground Water Occurrence

1. Introduction to Groundwater

Groundwater is the water present beneath the earth's surface in the pores and fractures of soil and rocks. It is one of the most important natural resources and is widely used for drinking, irrigation, and industrial purposes.

Importance of Groundwater

- Provides drinking water supply
- Supports irrigation and agriculture
- Maintains river base flow during dry periods
- Used for industrial and domestic purposes
- Acts as a natural underground storage system

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2. Hydrologic Cycle

The hydrologic cycle describes the continuous movement of water between atmosphere, land, and oceans.

Stages of Hydrologic Cycle

1. Evaporation
2. Condensation
3. Precipitation
4. Infiltration
5. Percolation
6. Runoff
7. Groundwater Flow

Groundwater in Hydrologic Cycle

Part of rainfall infiltrates into the soil and moves downward due to gravity. This water reaches the saturated zone and becomes groundwater.

3. Origin of Groundwater

a) Meteoric Water

- Derived from rainfall and snow
- Major source of groundwater

b) Connate Water

- Water trapped within sedimentary rocks during rock formation

c) Juvenile Water

- Water released from magma deep inside the earth

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4. Rock Properties Affecting Groundwater

The occurrence and movement of groundwater depend on the properties of rocks and soils.

4.1 Porosity

Porosity is the percentage of void spaces present in soil or rock.

Formula

$$n = \frac{V_v}{V_t} \times 100$$

Where:

- n = Porosity
- V_v = Volume of voids
- V_t = Total volume

Types of Porosity

- Primary porosity
- Secondary porosity

Factors Affecting Porosity

- Grain size
- Shape of particles
- Compaction
- Cementation

4.2 Permeability

Permeability is the property of soil or rock that permits water to flow through it.

Factors Affecting Permeability

- Size of pores
- Interconnection of pores
- Viscosity of fluid
- Degree of saturation

4.3 Specific Yield

Specific yield is the ratio of volume of water drained by gravity to the total volume of material.

Formula

$$S_y = \frac{V_d}{V_t} \times 100$$

Where:

- S_y = Specific yield
- V_d = Volume drained
- V_t = Total volume

4.4 Specific Retention

Specific retention is the amount of water retained by soil after drainage.

Formula

$$S_r = \frac{V_r}{V_t} \times 100$$

Where:

- S_r = Specific retention
- V_r = Volume retained

Relation

$$n = S_y + S_r$$

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5. Vertical Distribution of Groundwater

The subsurface water is divided into different zones.

5.1 Zone of Aeration (Vadose Zone)

- Located above water table

- Contains both air and water

Subdivisions

1. Soil water zone
2. Intermediate zone
3. Capillary fringe

5.2 Zone of Saturation

- All pores completely filled with water
- Upper surface is called water table

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6. Geological Formations as Aquifers

Aquifer

A geological formation capable of storing and transmitting water in sufficient quantity.

Types of Aquifers

a) Unconfined Aquifer

- Upper surface open to atmosphere
- Water table present

b) Confined Aquifer

- Sandwiched between impermeable layers
- Water under pressure

c) Semi-confined Aquifer

- Partially confined by semi-pervious layer

d) Perched Aquifer

- Localized saturated zone above main water table

Aquitard

Semi-pervious formation allowing slow movement of water.

Aquiclude

Porous but impermeable formation.

Aquifuge

Neither porous nor permeable.

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7. Darcy’s Law

Darcy’s law states that discharge through porous media is proportional to hydraulic gradient.

Darcy's Equation

$$Q = KIA$$

Where:

- Q = Discharge
- K = Coefficient of permeability
- I = Hydraulic gradient
- A = Cross-sectional area

Hydraulic Gradient

$$I = \frac{h}{L}$$

Where:

- h = Head loss
- L = Length of flow path

Assumptions of Darcy's Law

- Flow is laminar
- Soil is homogeneous
- Water is incompressible

Applications of Darcy's Law

- Seepage analysis
- Groundwater flow studies
- Filter design

Limitations

- Not valid for turbulent flow
- Not suitable for coarse gravels

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8. Storage Coefficient

Storage coefficient is the volume of water released from storage per unit decline in hydraulic head.

Formula

$$S = \frac{V_w}{A\Delta h}$$

Where:

- S = Storage coefficient
- V_w = Volume of water released
- A = Area
- Δh = Change in head

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9. Transmissivity

Transmissivity is the rate at which groundwater flows through unit width of aquifer.

Formula

$$T = Kb$$

Where:

- T = Transmissivity
- K = Hydraulic conductivity
- b = Thickness of aquifer

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10. Groundwater Flow Equation

The differential equation governing groundwater flow in three dimensions is:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right) = S_s \frac{\partial h}{\partial t}$$

Where:

- h = Hydraulic head
- K_x, K_y, K_z = Hydraulic conductivity
- S_s = Specific storage

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11. Groundwater Flow in Polar Coordinates

For radial flow towards wells:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial h}{\partial r}\right) = \frac{S}{T}\frac{\partial h}{\partial t}$$

Applications

- Pumping tests
- Well hydraulics

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12. Groundwater Contours

Groundwater contour maps show equal hydraulic head lines.

Uses

- Determine groundwater flow direction
- Estimate hydraulic gradient
- Identify recharge and discharge zones
- Locate wells
