



Irrigation Engineering & Hydrology

Detailed notes + compact revision summary

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CHAPTER 01

Introduction and Methods of Irrigation

Need for irrigation, its benefits and ill-effects, types of irrigation systems, methods of applying water and the quality of irrigation water.

1.1 Definition, necessity and scope

Irrigation is the artificial application of water to soil to supply the moisture needed for plant growth when rainfall is insufficient, untimely or unevenly distributed. In India most rain falls in the four monsoon months, so assured crops in the remaining eight months depend on irrigation.

- **Less rainfall** — annual rainfall below crop needs (arid and semi-arid regions).
- **Non-uniform rainfall** — rain concentrated in a few months or erratic within a season.
- **Commercial / cash crops** (sugarcane, cotton, vegetables) need assured water at fixed stages.
- **Multiple cropping** — a second (rabi) or third (zaid) crop is possible only with irrigation.
- **High-yielding varieties** respond to fertiliser only when moisture is controlled.
- **Controlled supply** — water can be given exactly at the critical growth stages.

Exam tip: Irrigation engineering covers the whole chain: source (river, reservoir, groundwater) → headworks → canal network → field application → drainage of surplus water.

1.2 Benefits and ill-effects of irrigation

Benefits and ill-effects

Benefits	Ill-effects (if badly managed)
Higher and assured crop yield; protection against famine	Water logging of land due to seepage and over-irrigation
Multiple cropping and cash crops increase farm income	Salinity and alkalinity of soil (salts brought up by capillary rise)
Revenue to Government; growth of agro-industries	Breeding of mosquitoes — malaria; damp climate
Hydropower, domestic and industrial water supply from the same project	Loss of fertility where excess water leaches nutrients
Inland navigation, fisheries, recreation	Over-exploitation of groundwater lowers the water table
Recharge of groundwater; improved micro-climate	Displacement of people and submergence of land by reservoirs

Remember: Water logging and salinity are the two classic ill-effects of canal irrigation in north India; both are controlled by lining, drainage and economical water use (Chapter 8).

1.3 Types of irrigation systems

Irrigation systems are first divided by the way water reaches the field. In **flow irrigation** water flows to the land by gravity; in **lift irrigation** it is raised by pumps, wells or other devices.

Classification of irrigation systems

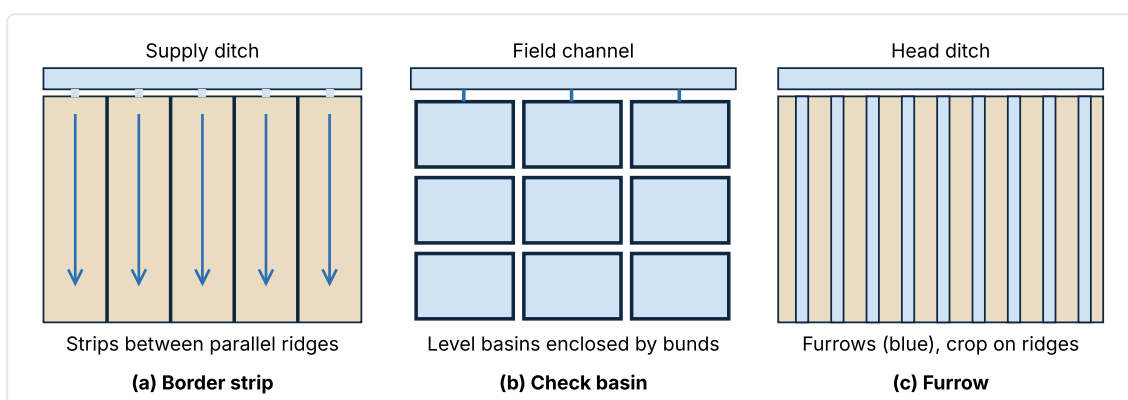
System	Main feature	Example
Perennial (flow)	Assured supply throughout the crop period from a storage or a weir on a perennial river	Canals from a barrage/weir with assured river flow
Inundation (flow)	Canals take water only when the river is in flood; no headworks to control level	Old inundation canals of Sind and Punjab
Lift irrigation	Water lifted by pumps from wells, tube wells, rivers or canals	Tube wells, river-lift schemes
Direct (diversion) irrigation	Water diverted from a river by a weir or barrage without storage	Diversion headworks on rivers
Storage irrigation	Dam stores monsoon flow in a reservoir; released in dry season	Bhakra, Hirakud, Nagarjuna Sagar
Tank irrigation	Small earthen bund stores local runoff	Tanks of south India
Conjunctive use	Canal water and groundwater used together in a planned way	Canal command with supplementary tube wells

- **Productive works** earn enough revenue to pay back cost with interest; **protective works** are built mainly to protect against famine, even if not remunerative.
- **Flow irrigation** can be **perennial** or **inundation**; storage-fed and weir-fed (direct) canals are both perennial when the supply is assured.

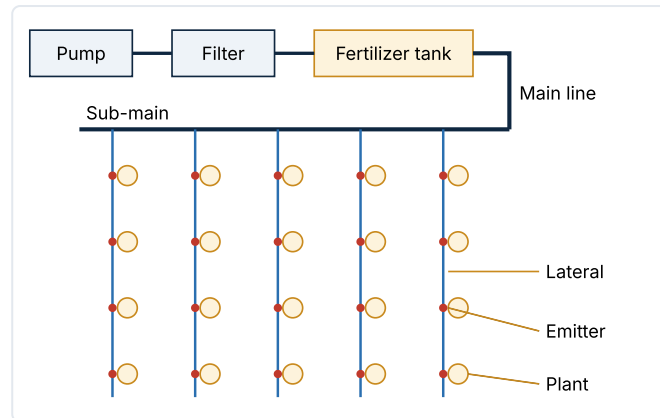
1.4 Methods of applying water

The method of application decides how uniformly water is spread and how much is lost by deep percolation and runoff. Choice depends on soil type, topography, crop, water availability and cost.

- **Free (wild) flooding** — water let loose from field ditches without any check; cheap but very wasteful; used on rolling land for pasture.
- **Border strip** — field divided into long strips by parallel low ridges; a sheet of water flows down each strip. Suits close-growing crops (wheat, fodder) on gentle slopes.
- **Check basin** — level plots enclosed by bunds are filled to the required depth. Suits rice, orchards and soils of both high and low permeability on flat land.
- **Basin (ring) method** — a small basin around each tree; used for orchards.
- **Furrow** — water runs in small channels between crop ridges; only 1/5 to 1/2 of the surface is wetted, so evaporation loss is low. Suits row crops (maize, cotton, potato, sugarcane).
- **Sub-surface irrigation** — water applied below the surface (natural high water table, or perforated pipes/tile lines) and reaches roots by capillarity.
- **Sprinkler** — water sprayed under pressure through nozzles like rain; suits undulating land, sandy soils and shallow soils.
- **Drip (trickle)** — water delivered drop by drop at the root zone through emitters on laterals; highest efficiency; ideal for orchards, vegetables, saline water and water-scarce areas.



Plan views of three surface irrigation methods. Arrows show the direction of flow down the field slope.



Layout of a drip (trickle) system: head unit, main, sub-main, laterals and emitters near each plant.

Comparison of irrigation methods (typical application efficiencies)

Method	Suitable crops / land	Efficiency	Remarks
Free flooding	Pasture, rolling land	Low	Cheapest; large losses
Border strip	Wheat, fodder; gentle uniform slopes	60–75 %	Needs land levelling
Check basin	Rice, orchards; flat land	60–75 %	Bunds occupy land
Furrow	Row crops	55–70 %	Less evaporation; risk of erosion on steep slopes
Sprinkler	Most crops; undulating, sandy land	70–85 %	Wind and high evaporation reduce efficiency; energy needed
Drip	Orchards, vegetables, cash crops	85–95 %	High initial cost; emitters may clog — filtration essential

Exam tip: Drip has the highest application efficiency and free flooding the lowest. Compared with sprinklers, drip wets only the root zone, works at low pressure, is unaffected by wind, limits weeds and allows efficient fertigation.

Exam trap: Sprinkler irrigation is **not** suited to fine clay soils with very low intake rate (ponding/runoff) or to areas of strong wind; drip is not economical for close-growing field crops like wheat.

1.5 Quality of irrigation water

Irrigation water is judged by its total salt content, the relative proportion of sodium, the concentration of toxic elements such as boron, and the bicarbonate content. Excess salts reduce water uptake by plants (osmotic effect); excess sodium disperses clay and destroys soil structure.

Sodium absorption ratio

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

concentrations in milli-equivalents per litre (meq/L)

meq/L = mg/L ÷ equivalent weight (Na 23, Ca 20, Mg 12)

Residual sodium carbonate

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

all in meq/L

CHAPTER 06

Groundwater and Wells

Aquifers and their properties, steady flow to wells, open wells and tube wells.

6.1 Occurrence of groundwater and aquifer properties

Water below the water table fills all pores (zone of saturation); above it lies the zone of aeration. A geological formation that stores and yields water in useful amounts is an **aquifer**.

Types of geological formations

Formation	Stores water?	Transmits water?	Example
Aquifer	Yes	Yes (freely)	Sand, gravel
Aquitard	Yes	Slowly (leaky)	Sandy clay
Aquiclude	Yes (porous)	No (practically)	Clay
Aquifuge	No	No	Massive granite

- **Unconfined (water-table) aquifer** — upper surface is the free water table at atmospheric pressure.
- **Confined (artesian) aquifer** — lies between two impervious layers; water is under pressure. If the piezometric surface is above ground, a well flows freely (**flowing artesian well**).
- **Perched aquifer** — small unconfined body held above the main water table by a local impervious lens.
- **Porosity** $n = S_y + S_r$. **Specific yield** S_y = volume drained by gravity / total volume; **specific retention** S_r = volume retained against gravity / total volume. Clay has high porosity but very low specific yield.
- **Storage coefficient (storativity) S** — volume of water released per unit surface area per unit decline of head: confined aquifers $\approx 5 \times 10^{-5}$ to 5×10^{-3} ; unconfined aquifers $S \approx S_y$ (≈ 0.01 – 0.30).

Darcy's law

$$v = K i, \quad Q = K i A$$

K = hydraulic conductivity (m/s); i = hydraulic gradient; v = discharge (Darcy) velocity

Transmissivity

$$T = K b$$

b = saturated thickness of aquifer; T in m^2/s or m^2/day

Exam trap: Actual (seepage) velocity = v/n , larger than the Darcy velocity. Storativity of a confined aquifer is hundreds of times smaller than the specific yield of an unconfined aquifer.

6.2 Steady flow to wells (Dupuit–Thiem)

Pumping lowers the water level around a well into a **cone of depression**; its horizontal extent is the **radius of influence R** and the fall at any point is the **drawdown s**. Steady-state equations assume a homogeneous isotropic aquifer of infinite extent, a fully penetrating well, horizontal radial flow and pumping long enough for equilibrium.

Confined aquifer (Thiem)

$$Q = \frac{2\pi K b (h_2 - h_1)}{\ln(r_2/r_1)} = \frac{2.72 T (s_1 - s_2)}{\log_{10}(r_2/r_1)}$$

h_1, h_2 = piezometric heads at radii r_1, r_2 ; s = drawdown

Unconfined aquifer (Dupuit)

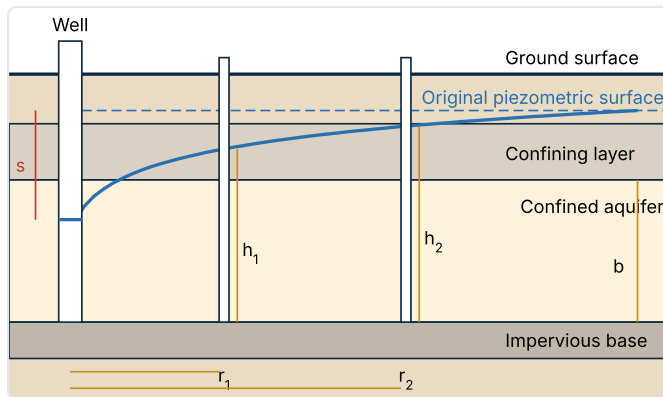
$$Q = \frac{\pi K (h_2^2 - h_1^2)}{\ln(r_2/r_1)} = \frac{1.36 K (H^2 - h_w^2)}{\log_{10}(R/r_w)}$$

H = original saturated thickness; h_w = depth of water in the well; r_w = well radius

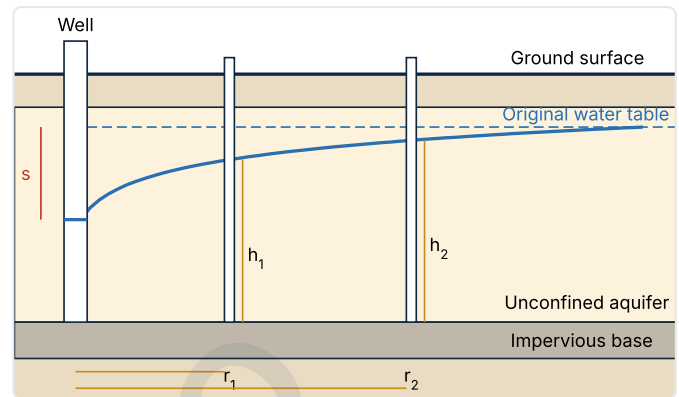
Sichardt's radius of influence

$$R = 3000 s_w \sqrt{K}$$

R and s_w in m; K in m/s



Steady flow to a well in a confined aquifer (Thiem): cone of depression in the piezometric surface.



Steady flow to a well in an unconfined aquifer (Dupuit): the water table itself is drawn down.

Worked example — Confined aquifer

A well fully penetrates a 20 m thick confined aquifer ($K = 40$ m/day). At steady pumping the drawdowns in observation wells 10 m and 50 m away are 3.0 m and 1.2 m. Find the discharge.

1. $h_2 - h_1 = s_1 - s_2 = 3.0 - 1.2 = 1.8$ m
2. $Q = 2\pi(40)(20)(1.8) / \ln(50/10) = 9047.8/1.609$
3. $Q = 5622$ m³/day

Answer: $Q \approx 5620$ m³/day (≈ 0.065 m³/s).

Worked example — Unconfined aquifer

A 0.30 m diameter well in an unconfined aquifer ($K = 5 \times 10^{-4}$ m/s, saturated thickness 25 m) is pumped with a drawdown of 4 m at the well. Find R (Sichardt) and the discharge.

1. $R = 3000 \times 4 \times \sqrt{5 \times 10^{-4}} = 268.3$ m
2. $h_w = 25 - 4 = 21$ m; $H^2 - h_w^2 = 625 - 441 = 184$ m²
3. $Q = \pi(5 \times 10^{-4})(184) / \ln(268.3/0.15) = 0.289/7.489 = 0.0386$ m³/s

Answer: $R \approx 268$ m; $Q \approx 0.039$ m³/s (≈ 39 L/s).

Exam tip: Discharge is not very sensitive to R because R appears inside a logarithm — a rough estimate of R is usually enough.

6.3 Open wells and tube wells

An **open well** (dug well) of large diameter (1–9 m) draws water mainly through its bottom; a **shallow** well rests in a water-bearing stratum, a **deep** well rests on an impervious (mota) layer and draws from a pervious stratum below it. A **tube well** is a small-diameter pipe sunk deep into the ground, drawing water through strainers or slots from several aquifers.

Yield of open well (recuperation test)

$$\frac{K}{A} = \frac{2.303}{T} \log_{10} \frac{s_1}{s_2}$$

K/A = specific yield of the well (m³/h per m² per m of depression head); s_1, s_2 = depressions at start and after time T (h)

Discharge of open well

$$Q = \frac{K}{A} A H$$

A = area of well bottom; H = safe (working) depression head
typical K/A (per h): clay 0.25, fine sand 0.5, coarse sand 1.0

PART B

Compact Summary Notes

Irrigation Engineering & Hydrology

Illustrated one-page-per-topic revision sheets — read these in the last days before the exam, after studying the detailed notes in Part A.

Summary notes

page 53

12 pages of summary notes

CIVIL ENGINEERING NOTES

IRRIGATION ENGINEERING

Topics Covered

- Irrigation & Methods of Irrigation
- Soil Moisture & Plant Relationships
- Water Requirements of Crops & Canal Irrigation
- Water Logging & Reclamation of Saline Soils
- Canal Design
- Canal Regulation Works
- Canal Head Works & Scour
- River Engineering
- Cross Drainage Works
- Dams and Reservoirs
- Spillways, Energy Dissipators & Spillw

*"Water is the driving force of all nature."
— Leonardo da Vinci*

1. IRRIGATION & METHODS OF IRRIGATION

1

1.1 Definition

Irrigation is the artificial application of water to the soil at regular intervals in the required quantity for normal growth of crops.

1.2 Need of Irrigation

- Rainfall is uncertain and unevenly distributed.
- Helps in proper growth and higher yield.
- Essential in areas of low rainfall.
- Helps in leaching of salts and controlling frost.

1.3 Methods of Irrigation

- (i) Surface Irrigation : Water is allowed to flow over the soil surface by gravity.
 - Types : Basin, Border strip, Check basin, Furrow, Wild flooding.
- (ii) Sprinkler Irrigation : Water is sprayed into the air and allowed to fall as rain over the crop.
 - Suitable for undulating land and sandy soils.
 - Uniform distribution of water.
- (iii) Drip Irrigation : Water is supplied slowly to the plant root zone drop by drop.
 - Saves water, increases efficiency,
 - Suitable for orchards and vegetable crops.

1.4 Field Water Requirement

Total water required = Field water requirement + Losses

Field water requirement = Area × Depth of water



End of the free preview

Irrigation Engineering & Hydrology

The full PDF has 64 pages:

Part A — detailed typed notes: 10 chapters, 48 pages

Part B — handwritten compact summary: 12 pages

Chapters in the full notes

- 01 Introduction and Methods of Irrigation
- 02 Soil-Water-Plant Relationship
- 03 Crop Water Requirement: Duty, Delta and Consumptive Use
- 04 Hydrology I: Precipitation, Evaporation and Infiltration
- 05 Hydrology II: Runoff, Hydrographs and Floods
- 06 Groundwater and Wells
- 07 Canals: Design, Losses, Lining and Water Logging
- 08 Canal Regulation and Cross-Drainage Works
- 09 Diversion Headworks and River Training
- 10 Dams, Spillways and Reservoirs

Formula boxes with every symbol explained · IS / IRC code values in tables · labelled sketches
Worked examples step by step · exam tips & traps · quick revision points after every chapter

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