

AGRICULTURAL ENGINEERING



UPSC

INDIAN FOREST SERVICE

2026 - 27

Linkage of
Concepts with
PYQs

+

Infused with
Infographics &
Maps

Paper - 1

Section - A

Quick Revision

MPPSC STATE FOREST SERVICE 2023



Rank – 1

Shashank Jain

Comprehensive Forestry
Course + CIGP



Rank – 3

Jyoti Thakur

Comprehensive Forestry
Course + CIGP



Rank – 4

Shivam Gautam

Comprehensive Interview
Guidance Programme



Rank – 5

Nitin Patel

Comprehensive Forestry
Course + CIGP



Rank – 6

Ravi Kumar

Comprehensive Interview
Guidance Programme + Test Series



Rank – 7

Ankur Gupta

Comprehensive Forestry
Course



Rank – 8

Deependra Lodhi

Comprehensive Interview
Guidance Programme



Rank – 9

Kapil Chauhan

Comprehensive Forestry
Course



Rank – 10

Alok Kumar Jhariya

Comprehensive Forestry
Course + CIGP



Rank – 11

Tarun Chouhan

Comprehensive Interview
Guidance Programme + Test Series



Rank – 12

Raghvendra Thakur

Comprehensive Forestry
Course + Test S. + CIGP

11 Out of 12 Total Selections in

Assistant Conservator of Forest (ACF) 2023

108 Out of 126 Total Selections in

Range Forest Officer (RFO) 2023



Rank – 1

Arvind Ahirwar

Comprehensive Interview
Guidance Programme + Test Series



Rank – 2

Pushpendra Singh Ahirwar

Comprehensive Forestry
Course + CIGP



Rank – 3

Narendra Gunare

Comprehensive Interview
Guidance Programme + Test Series



Rank – 4

Jitendra Kumar Verma

Comprehensive Forestry
Course + CIGP



Rank – 5

Jaishrish Barethiya

Comprehensive Forestry
Course + CIGP



Rank – 6

Bhavna Sehariya

Comprehensive Forestry
Course + CIGP



Rank – 7

Pradeep Ahirwar

Comprehensive Forestry
Course + CIGP



Rank – 8

Anil Kumar Gour

Comprehensive Forestry
Course + CIGP



Rank – 9

Aakash Kumar Malviya

Comprehensive Forestry
Course + CIGP



Rank – 11

Rajesh Kumar Jatav

Comprehensive Forestry
Course + CIGP



Rank – 12

Veerendra Prajapati

Comprehensive Interview
Guidance Programme + Test Series



Rank – 13

Dinesh Kumar

Test Series



Rank – 14

Niranjana Dehariya

Comprehensive Forestry
Course + CIGP



Rank – 15

Abhinay Chouhan

Test Series



Rank – 18

Sher Singh Ahirwar

Comprehensive Interview
Guidance Programme + Test Series



Rank – 19

Pradeep Jatav

Comprehensive Forestry
Course + CIGP



Rank – 21

Amit Sisodiya

Comprehensive Interview
Guidance Programme



Rank – 22

Abhishek Barodiya

Comprehensive Interview
Guidance Programme



Rank – 24

Golu Goyal

Comprehensive Interview
Guidance Programme + Test Series



Rank – 25

Pawan Raj

Comprehensive Interview
Guidance Programme + Test Series

SOIL & WATER CONSERVATION
+
AERIAL PHOTOGRAPHY & REMOTE SENSING

Paper – 1 | Section – A



EDITION : 2026

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SYLLABUS

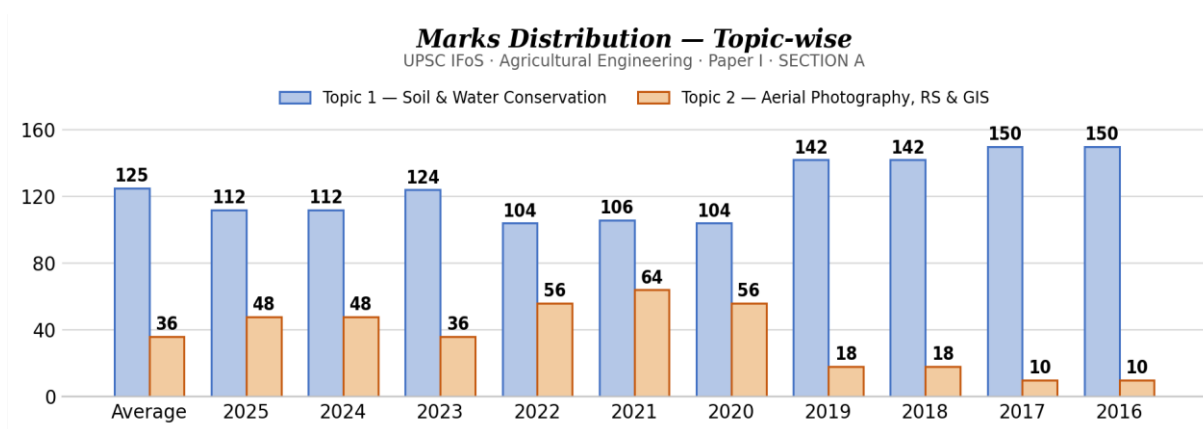
Indian Forest Service (IFoS) [Paper 1 Section A]	Soil and Water Conservation : Scope of soil and water conservation. Mechanics and types of erosion, their causes. Rainfall, runoff and sedimentation relationships and their measurement. Soil erosion control measures — biological and engineering including stream bank protection — vegetative barriers, contour bunds, contour trenches, contour stone walls, contour ditches, terraces, outlets and grassed waterways. Gully control structures — temporary and permanent — design of permanent soil conservation structures such as chute, drop and drop inlet spillways. Design of farm ponds and percolation ponds. Principles of flood control — flood routing. Watershed Management — investigation, planning and implementation — selection of priority areas and watershed work plan, water harvesting and moisture conservation. Land development — leveling, estimation of earth volumes and costing. Wind Erosion process — design for shelter belts and wind brakes and their management. Forest (Conservation) Act. Aerial Photography and Remote Sensing : Basic characteristics of photographic images, interpretation keys, equipment for interpretation, imagery interpretation for land use, geology, soil and forestry. Remote sensing — merits and demerits of conventional and remote sensing approaches. Types of satellite images, fundamentals of satellite image interpretation, techniques of visual and digital interpretations for soil, water and land use management. Use of GIS in planning and development of watersheds, forests including forest cover, water resources etc.
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Module - 1

CONTENTS



SN	Chapter	Page No
1.	Soil erosion fundamentals	1 – 19
2.	Soil conservation	
3.	Gully control permanent structure	
4.	Flood control watershed management, land development	
5.	Aerial photography and remote sensing	
6.	GIS application	



INDIAN FOREST SERVICE (IFoS) PYQs | 2010 – 2024

SECTION A – UPSC IFoS Previous-Year Questions		35 questions • 2016 – 2025
2025	- Discuss the major types of precipitation storm. [P1/1(a) 8M] - Discuss the impacts of soil erosion on water quality. [P1/1(b) 8M] - Discuss the basic assumptions and steps involved in the development of unit hydrograph. [P1/1(c) 8M] - Explain the functional relationship of length of slope and degree of slope in the process of soil loss by water erosion. Discuss the methods of estimation of erosivity from rainfall data. [P1/2(a) 10M] - What are the factors that influence soil erodibility by wind? Discuss the impacts of different types of water erosion. [P1/2(b) 15M]	
2024	Write a short note on the salient characteristics of precipitation on India. [P1/1(a) 8M]	
2023	- Explain the different processes involved in the development of gullies. [P1/1(b) 8M] - Determine the peak rate of runoff for a 10-year frequency from a watershed of 250 hectares, having weighted value of runoff coefficient (C) as 0.47. The distance from the remotest point in the watershed to the outlet is 3000 m and the elevation difference between the highest and outlet points of the watershed is 25 m. The maximum intensity-duration-frequency relationship of the watershed is given by $i = (6.3117 \times T^{0.1523}) / (D + 0.50)^{0.945}$ where i = intensity in cm/h, T = return period in years and D = duration of rainfall in hours. [P1/2(b) 10M] - Explain the terms 'erodibility index' and 'roughness factor' used for prediction of wind erosion. [P1/3(a) 10M]	
2022	- Describe isohyetal method of estimating average rainfall depth over an area. Also write the advantages of it over arithmetic mean method. [P1/1(c) 8M] - What is a unit hydrograph? Write the uses and limitations of unit hydrograph. Explain the method for development of unit hydrographs of different durations by S-curve. [P1/2(b) 15M]	
2021	- Discuss in brief: (i) Sediment delivery ratio (ii) Stream channel erosion. [P1/1(b) 8M] - Define synthetic unit hydrograph and describe its derivation method. [P1/2(c) 20M] - Differentiate between the approaches of USLE and MUSLE models for soil loss and comment on their ranges of utility. [P1/3(a) 10M]	
2020	- Define drainage density and derive the relationship between drainage density and ruggedness number. [P1/1(c) 8M] - Determine the depth of runoff and peak rate of runoff for 25 years recurrence interval for antecedent moisture condition II from a 150-ha watershed. The curve number to apply for three 50 ha sub-watersheds for antecedent moisture condition II are respectively 85, 65 and 75. Six hours, 25 years frequency rainfall for the given location is 120 mm. The time of concentration and time to peak of runoff are 30 min and 60	

	min respectively. [P1/2(c) 15M] - The normal annual rainfall at Stations A, B, C, and D in the basin are 80.97, 67.59, 76.28 and 92.01 cm, respectively. In the year 1985, the Station D was inoperative and the Stations A, B and C recorded annual precipitation of 91.11, 72.33 and 79.89 cm, respectively. Estimate the rainfall at Station D in that year. [P1/3(b) 10M] - Discuss the methods of separation of base flow from a runoff hydrograph. [P1/3(c) 20M]
2019	- Name different soil conservation regions of India with salient soil conservation problems in these regions. [P1/1(a) 8M] - What is universal soil loss equation? Explain in detail various parameters involved in the computation of soil loss using this equation. [P1/2(a) 10M] - Explain different methods for measurement of soil losses from agricultural watersheds (use diagrams wherever required). [P1/3(b) 10M] - Construct a hyetograph from the rainfall data provided in the table. [P1/4(c) 10M] - Compute the peak runoff rate of 15 years return period from a watershed area of 150 ha to design the field diversion. The sub-watersheds of 50 ha, 75 ha and 25 ha are kept under cultivation ($c = 0.5$), forest cover ($c = 0.3$) and grassland ($c = 0.3$), respectively. The other details are as follows: maximum length of watercourse = 2500 m; relief = 50 m; slope of watershed = 2.5%; watershed soil is clay; values of a, b, k and n are 0.1483, 0.50, 7.176 and 0.9459, respectively. [P1/4(d) 10M]
2018	- What are the different types of runoff? Explain the factors that affect the runoff in a watershed. [P1/1(a) 8M] - Discuss the Rational method of predicting design peak runoff rate. In a watershed the most remote point is 600 m away from the outlet point. The outlet point is 3.0 m below the most remote point. Calculate the time of concentration of watershed. [P1/2(b) 10M] - Explain a procedure for checking rainfall data of a station for consistency. [P1/2(c) 10M] - The ordinates of the 2-h unit hydrograph of a watershed are given for hours 0 to 22. Determine the ordinates of S-curve hydrograph and using S-curve determine the ordinates of the 4-h unit hydrograph of watershed. [P1/3(a) 10M] - What are the factors which affect soil erosion by water? Discuss. If the degree of slope is increased 4 times, what will be the relative increase in erosion caused by water? [P1/3(b) 10M]
2017	- Describe briefly, the SCS-CN method of runoff estimation. A watershed has 100 ha area. The watershed has 20 ha pasture in silty clay soil of 2% slope ($CN = 65$), 30 ha of pasture on silty loam soil of 0.5% slope ($CN = 70$) and remaining 50 ha of wheat crop on loam soil of 1% slope ($CN = 85$). Estimate the weighted curve number for the watershed. [P1/1(e) 8M] - What are rainfall Depth-Area-Duration (DAD) curves? Write down the step-by-step procedure for drawing Depth-Area-Duration curves. [P1/2(a) 10M] - Explain in brief, different types of erosion and their causes. [P1/2(b) 10M]

2016	- What are the main causes of soil erosion in India? Explain the agronomic practices adopted for controlling the soil erosion. [P1/1(a) 10M] - Let $P_1, P_2, P_3, \dots, P_n$ be the depths of rainfall recorded in n rain gauges enclosed by polygon having areas $A_1, A_2, A_3, \dots, A_n$ within the watershed. Calculate the average depth of rainfall ($\bar{P}$) in the watershed of area A. [P1/1(c) 10M] - Define rational formula for estimating peak runoff rate. Why is it called rational? What are the limitations of rational formula? [P1/3(b) 10M] - What is water-stage recorder? Discuss the current meter as a water flow measuring device. [P1/4(b) 10M]
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SECTION B : State PSC Previous-Year Questions	40 questions • All states • year-descending
What do you understand by soil erosion? Explain various types of water erosion. UK-PSC ACF/RFO/Logging Officer (Mains) 2025 Agri. Engineering Q.1(I) 10M	
Factors affecting water erosion. MH-PSC Forest Services (Mains) 2024 Agri. Engineering Q.1(a) 8M	
Biological measures to control soil erosion. MH-PSC Forest Services (Mains) 2024 Agri. Engineering Q.1(e) 8M	
What is universal soil loss equation? How different factors in this equation are determined? MH-PSC Forest Services (Mains) 2024 Agri. Engineering Q.3(c) 10M	
The ordinates of a 4-h unit hydrograph are given below. If there is 4 cm and 6 cm of effective rainfall occurring uniformly for two consecutive 4-h intervals, calculate the direct runoff hydrograph. OPSC-CSE CSE (Main) 2024–25 Agri. Engineering Paper-I, Q.7 15M	
What are the methods of estimation of rainfall erosivity factor? OPSC-CSE CSE (Main) 2023–24 Agri. Engineering Paper-I, Q.14(a) 20M	
Explain the components of the Universal Soil Loss Equation (USLE) in estimating soil loss. What are the limitations of using the USLE in watershed management? OPSC-CSE CSE (Main) 2023–24 Agri. Engineering Paper-I, Q.14(b) 20M	
Explain the SCS Curve Number (CN) method for estimating runoff in a watershed. What factors influence the CN value and runoff estimation? OPSC-CSE CSE (Main) 2023–24 Agri. Engineering Paper-I, Q.17(b) 20M	
How the soil erosion affects the agricultural land. Explain the different methods of soil erosion control measures. OPSC-Forest Forest Service (Main) 2023–24 Agri. Engineering Paper-I, Q.1(b) 10M	
Explain about various runoff estimation methods. OPSC-CSE CSE (Main) 2022–23 Agri. Engineering Paper-I, Q.13(b) 12M	
What is soil loss? Discuss about the estimation of soil loss using USLE equation.	

OPSC-CSE CSE (Main) 2022–23 Agri. Engineering Paper-I, Q.15(b) 12M
✎ What is the purpose of estimating peak runoff rate? Describe the rational formula and its limitations for estimating peak runoff rate. UK-PSC RFO (Mains) 2021 Agri. Engineering Q.1(i) 10M
✎ Classify the factors influencing soil erosion by wind. Briefly describe the wind break and shelter belts practices for controlling wind erosion. UK-PSC RFO (Mains) 2021 Agri. Engineering Q.1(iv) 10M
✎ Following are the ordinates of direct runoff of 2.5 cm effective rainfall of 3-h duration. Determine the ordinates of 3- h unit hydrograph:. OPSC-CSE CSE (Main) 2020–21 Agri. Engineering Paper-I, Q.5(c),(ii) 12M
✎ Calculate the soil erodibility factor (K) for use in universal soil loss equation, using the following information :. OPSC-CSE CSE (Main) 2020–21 Agri. Engineering Paper-I, Q.6(c),(ii) 12M
✎ Explain the universal soil loss equation. OPSC-CSE CSE (Main) 2020–21 Agri. Engineering Paper-I, Q.7(d) 12M
✎ Flow Chart - Multimedia - Hardware and Software - Computer Networks - Applications of Computer - Enumerate how soil erosion affects agriculture. Explain different types of soil erosion. How soil loss is estimated by Universal Soil Loss Equation? What is its revised form?. OPSC-Forest Forest Service (Main) 2019–20 Agri. Engineering Paper-I, Q.1(a) 20M
✎ Describe the on-site and off-site impacts of soil erosion. AP-PSC RFO (Mains) 2018 Agri. Engineering Q.1(a) 4M
✎ Compare the differences between water and wind erosion in terms of sediment transport. AP-PSC RFO (Mains) 2018 Agri. Engineering Q.1(b) 6M
✎ Discuss the main reasons for the high rates of soil erosion in some regions and low in others. AP-PSC RFO (Mains) 2018 Agri. Engineering Q.1(c) 6M
✎ Describe factors affecting soil erodibility. AP-PSC RFO (Mains) 2018 Agri. Engineering Q.1(d) 4M
✎ Describe in brief about stream bank erosion. AP-PSC RFO (Mains) 2018 Agri. Engineering Q.2(c) 5M
✎ What would be the impacts of corn monocropping for biofuel production on soil erosion and long-term soil productivity?. AP-PSC RFO (Mains) 2018 Agri. Engineering Q.3(b) 6M
✎ Describe the mechanisms responsible for the reduction of soil erosion by adding animal manure to the soil surface. AP-PSC RFO (Mains) 2018 Agri. Engineering Q.3(c) 4M
✎ How will you select a site for a raingauge station?. OPSC-CSE CSE (Main) 2018–19 Agri. Engineering Paper-I, Q.5(a),(iii) 5M
✎ Write on the characteristics of the raindrops that are important from soil erosion point of view. OPSC-CSE CSE (Main) 2018–19 Agri. Engineering Paper-I, Q.6(b) 10M
✎ Present the critique of the vegetative and mechanical measures to control soil erosion.

OPSC-CSE CSE (Main) 2016–17 Agri. Engineering Paper-I, Q.7(a) 15M
✎ Explain, in brief, the SCS curve number technique (Hydrological Soil Cover Complex Method) of estimation of surface runoff from small agricultural watersheds. OPSC-CSE CSE (Main) 2016–17 Agri. Engineering Paper-I, Q.8(a) 15M
✎ Coefficient of storage - Area of influence - Give the procedure for estimation of runoff volume by curve number method. OPSC-CSE CSE (Main) 2015–16 Agri. Engineering Paper-I, Q.5(b),(i) 10M
✎ Discuss on the various factors affecting runoff. OPSC-CSE CSE (Main) 2015–16 Agri. Engineering Paper-I, Q.5(b),(ii) 10M
✎ Discuss briefly on the different types of water erosion. OPSC-CSE CSE (Main) 2015–16 Agri. Engineering Paper-I, Q.5(c),(i) 10M
✎ Describe, with the help of neat sketch, any three methods of separation of base flow from the hydrograph of runoff indicating the situations under which the methods are suitable. OPSC-CSE CSE (Main) 2015–16 Agri. Engineering Paper-I, Q.1(c) 20M
✎ Draw a single peaked hydrograph and indicate its various components. OPSC-CSE CSE (Main) 2015–16 Agri. Engineering Paper-I, Q.4(b) 10M
✎ Define Runoff and explain the rational method of computing the peak discharge of small catchment. OPSC-Forest Forest Service (Main) 2015–16 Agri. Engineering Paper-I, Q.2(c) 10M
✎ Tabulated are the data derived from a drainage basin. Determine the average depth of rainfall using Thiessen polygon method:. OPSC-Forest Forest Service (Main) 2015–16 Agri. Engineering Paper-I, Q.3(b) 10M
✎ What are the ill effects of water erosion? Describe, in brief, the various forms of water erosion. OPSC-Forest Forest Service (Main) 2015–16 Agri. Engineering Paper-I, Q.3(c) 10M
✎ A 3 hour storm occurred at a place and the precipitations in the neighboring rain-gauge stations P, Q and R were measured as 3.8, 4.1 and 4.5 cm, respectively. The precipitation in the neighboring station S could not be measured since the rain gauge bottle was broken. The normal precipitations in the four stations P, Q, R and S as per IMD Bulletin were 45, 48, 53 and 50 cm, respectively. Estimate the storm precipitation at station S. OPSC-Forest Forest Service (Main) 2015–16 Agri. Engineering Paper-I, Q.4(a) 10M
✎ Derive the Hooghoudts equation for constant ground water table at uniform rate of irrigation or rainfall. Enlist the required assumptions for the derivation. OPSC-Forest Forest Service (Main) 2015–16 Agri. Engineering Paper-I, Q.5(a) 20M
✎ Derive the curve number equation used for the determination of excess runoff from its basic principle? Also discuss its limitation. AP-PSC RFO (Mains) 2012 Agri. Engineering Q.7 40M
✎ Explain various phases of wind erosion process, and different factors involved in estimation of soil loss by wind. UK-PSC RFO (Mains) 2012 Agri. Engineering Q.1(i) 10M

SECTION C — Year × Source Heatmap												Dark = high frequency · Light = low frequency								
SOURCE YEAR \	25	24- 25	24	23- 24	23	22- 23	22	21	20- 21	20	19- 20	19	18- 19	18	17	16- 17	16	15- 16	12	TOTAL
IFoS	5	·	1	·	3	·	2	3	·	4	·	5	·	5	3	·	4	·	·	35
OPSC-CSE	·	1	·	3	·	2	·	·	3	·	·	·	2	·	·	2	·	5	·	18
OPSC-Forest	·	·	·	1	·	·	·	·	·	·	1	·	·	·	·	·	·	5	·	7
MH-PSC	·	·	3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3
UK-PSC	1	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·	·	·	1	4
HP-PSC	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0
AP-PSC	·	·	·	·	·	·	·	·	·	·	·	·	·	7	·	·	·	·	1	8

Reference resources

- **Soil and Water Conservation Engineering** by R. Suresh, Standard Publishers Distributors, New Delhi.
- **Soil and Water Conservation Engineering** by Glenn O. Schwab, D. D. Fangmeier and W. J. Elliot, John Wiley & Sons, New York.
- **Principles of Agricultural Engineering, Vol. II** by A. M. Michael and T. P. Ojha, Jain Brothers, New Delhi.
- **Land and Water Management Engineering** by V. V. N. Murty and Madan K. Jha, Kalyani Publishers, Ludhiana.
- **Engineering Hydrology** by K. Subramanya, McGraw Hill Education, New Delhi.
- **Soil Conservation** by Norman Hudson, Iowa State University Press / Batsford Academic.
- **Textbook of Remote Sensing and Geographical Information Systems** by M. Anji Reddy, BS Publications, Hyderabad.
- **Remote Sensing and Image Interpretation** by T. M. Lillesand, R. W. Kiefer and J. W. Chipman, John Wiley & Sons, New York.
- **Fundamentals of Remote Sensing** by George Joseph, Universities Press, Hyderabad.
- **Concepts and Techniques of Geographic Information Systems** by C. P. Lo and Albert K. W. Yeung, PHI Learning, New Delhi.
- ICAR-IISWC, Dehradun bulletins; NRSC/ISRO Remote Sensing Applications and Bhuvan geoportal; Forest (Conservation) Act, 1980 bare Act.
- Many other National/Internet magazines, news cuttings, MoEF&CC, ICAR & NRSC websites for data, pictures, graphs and concept clarity.

1

SOIL EROSION - FUNDAMENTALS

Mechanics of erosion / Rainfall & runoff / Hydrograph analysis / USLE / RUSLE / MUSLE

SYLLABUS (Paper I | Soil & Water Conservation): Mechanics and types of erosion (water & wind), their causes; rainfall, runoff and sedimentation; rainfall erosivity & soil erodibility; wind erosion process. Foundational hydrology — precipitation analysis, runoff & peak-flow, hydrographs & unit hydrographs, and the USLE/MUSLE soil-loss models —

Chapter Outline

1. **Scope & Basics of Soil Erosion**
2. **Mechanics of Water Erosion**
3. **Forms / Types of Water Erosion**
4. **Gully & Ravine Development**
5. **Wind Erosion**
6. **Soil Erodibility & Rainfall Erosivity**
7. **Soil-Loss Models — USLE / RUSLE / MUSLE**
8. **Sediment — Delivery Ratio, Yield, Channel Erosion**
9. **Measurement of Soil Loss**
10. **Precipitation & Rainfall Analysis**
11. **Runoff & Peak-Flow Estimation**
12. **Hydrographs & Unit Hydrograph**
13. **Streamflow / Runoff Measurement**

1

SCOPE & BASICS OF SOIL EROSION

Soil and water conservation (SWC) is the planned use, development and protection of soil and water resources so as to obtain optimum, sustained production while preventing the degradation of these resources. Controlling soil erosion is its central concern. In India, of the **328 million ha** of geographical area, about **68 M-ha are critically degraded and 107 M-ha severely eroded**, and roughly **144.12 M-ha** are affected by water and wind erosion — of which ~69 M-ha is critical and needs immediate attention.

Soil erosion : the process of detachment, transportation and deposition of soil particles (sediment) from the land surface by the agents of erosion — chiefly water and wind, and locally gravity and ice. The word derives from the Latin erodere, 'to eat away'.

Erosion is thus a **three-phase process**: (i) *detachment* of particles from the soil mass, (ii) *transportation* by the erosive agent, and (iii) *deposition* when the transporting energy falls below that needed to carry the load. *Sediment* is the end-product. Finer particles (silt) are detached and carried more easily than coarse sand.

Geological vs accelerated erosion: Geological (normal) erosion is the slow, natural wearing of the land, broadly in balance with soil formation. Accelerated erosion is the rapid, man-induced loss (deforestation, overgrazing, faulty cultivation) that far outpaces soil formation — it is the real problem SWC addresses.

1.1 Causes of Soil Erosion in India
PREVIOUS YEAR QUESTIONS

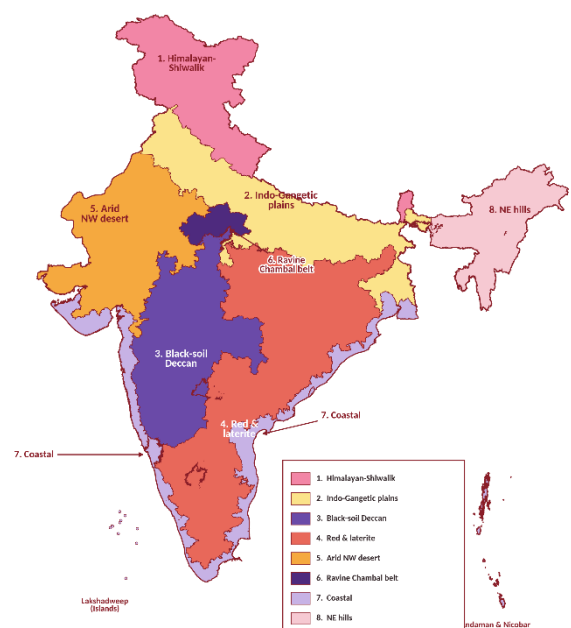
- 🌿 Main causes of soil erosion in India; agronomic practices for control. *** [IFoS 2016 | P1/1(a) | 10M]
- 🌿 Why erosion is high in some regions and low in others. [AP-PSC 2018 | Q.1(c) | 6M]

The rate of erosion at a place is governed by the balance between erosivity (the eroding power of rain and wind) and erodibility (the susceptibility of the soil), modified by slope, vegetal cover and land use. The principal causes in India are:

- **Deforestation** : removal of natural vegetal cover exposes bare soil to raindrop impact and wind.
- **Overgrazing** : large livestock populations destroy ground cover and compact the surface.
- **Faulty cultivation** : up-and-down (vertical) ploughing, clean tillage, cultivation of steep slopes and fallowing.
- **Shifting (jhum) cultivation** : on steep North-Eastern hill slopes.
- **High-intensity monsoon rainfall** : large erosive energy delivered in a few months.
- **Topography & erodible soils** : steep slopes, loose alluvium and ravine soils.
- **Land disturbance** : mining, road-building and construction.

Erosion is high where intense rain, steep bare slopes and erodible soils coincide (Shiwaliks, ravines, NE hills) and low on flat, well-vegetated or cohesive-soil terrain. (*Agronomic / engineering control practices are treated in the Erosion-Control chapter.*)

SOIL-CONSERVATION REGIONS OF INDIA



1.2 Soil-Conservation Regions of India

PREVIOUS YEAR QUESTIONS

- ✿ Name the soil-conservation regions of India with salient problems. *** [IFoS 2019 | P1/1(a) | 8M]

Region	Salient soil-conservation problem
Northern Himalayan & Shiwalik	Landslides, steep-slope & terrace erosion, torrential hill streams, heavy run-off
Indo-Gangetic alluvial plains	Sheet erosion, water-logging, riverbank erosion; some wind erosion in the NW
Black-soil (Deccan / regur)	Sheet & gully erosion on cracking clays; deep gullies along streams
Red & laterite (peninsular)	Sheet & rill erosion, low fertility, surface sealing/crusting
Arid & semi-arid (NW desert)	Severe wind erosion, sand-dune movement, sparse cover
Ravine & gully (Chambal/Yamuna/Mahi)	Deep ravines & gully erosion of alluvial banks — the most spectacular erosion
Coastal region	Sheet erosion, coastal sand & wind action, salinity
North-eastern hills	Jhum (shifting-cultivation) erosion on steep, high-rainfall slopes

1.3 Impacts of Soil Erosion

PREVIOUS YEAR QUESTIONS

- ✿ Impacts of soil erosion on water quality. [IFoS 2025 | P1/1(b) | 8M]
 ✿ On-site and off-site impacts of soil erosion. [AP-PSC 2018 | Q.1(a) | 4M]
 ✿ How soil erosion affects agriculture. [OPSC-CSE 2019 | 20M]

On-site impacts (where erosion occurs)

- Loss of fertile topsoil and plant nutrients (N, P, K, organic matter) → falling fertility and yield.
- Reduced rooting depth, water-holding capacity and infiltration; structural deterioration and crusting.
- Rills, gullies and ravines that fragment and remove land from cultivation.
- Exposure of less-fertile subsoil and loss of soil organic carbon, reducing microbial activity and long-term soil health.
- Lower input-use efficiency and higher cultivation costs as more fertiliser, water and tillage are needed to sustain yields.
- Breakdown of soil structure and surface sealing that lowers seed germination and emergence, thinning the crop stand.
- Progressive land degradation and abandonment, lowering land value and threatening farm livelihoods and food security.

Off-site impacts (downstream / downwind)

- Sedimentation of reservoirs, tanks and canals — loss of storage capacity and project life.
- Aggradation of river beds → higher flood frequency; siltation of drainage and harbours.
- Dust storms and sand deposition (wind erosion).
- Eutrophication and pollution of water bodies as eroded sediment carries nutrients (N, P), pesticides and other agrochemicals.
- Damage to roads, bridges, culverts and other infrastructure, with increased dredging and maintenance costs.

- Reduced hydropower generation and shorter turbine life as silt-laden water abrades machinery and cuts reservoir head.
- Burial of fertile downstream farmland and standing crops under coarse, infertile sand and debris during floods.

Impact on water quality

- Increased turbidity & suspended-sediment load less light penetration, harm to aquatic life, higher treatment cost.
- Eutrophication — adsorbed N & P carried with sediment enrich water bodies → algal blooms and oxygen depletion.
- Transport of adsorbed pesticides, heavy metals and pathogens with eroded particles.
- Raised salinity and siltation reduce usefulness of water for irrigation and drinking.
- Smothering of fish spawning beds and benthic habitats by deposited sediment, reducing aquatic biodiversity and fishery yields.
- Higher water temperature as turbid, sediment-laden water absorbs more solar radiation, lowering dissolved-oxygen levels.
- Clogging of water-supply intakes, filters and irrigation channels, raising pumping, cleaning and maintenance costs.
- Acidification and contamination of water from sediment-bound mine spoil and acid-forming materials in degraded catchments.

MODEL Q Niche pointers : Corn mono-cropping for biofuel (AP 2018) raises erosion (low residue cover, intensive tillage, bare row inter-spaces) and depletes long-term productivity. Animal manure on the surface (AP 2018) reduces erosion by improving aggregation, infiltration and providing a protective cover that absorbs raindrop impact. ***

2

MECHANICS OF WATER EROSION

PREVIOUS YEAR QUESTIONS

- ✿ Factors affecting water erosion. [MH-PSC 2024 | Q.1(a) | 8M]
- ✿ Factors affecting soil erosion by water; if slope is increased 4×, relative increase in erosion. ***
[IFoS 2018 | P1/3(b) | 10M]
- ✿ Raindrop characteristics important from the soil-erosion point of view. [OPSC-CSE 2018 | 10M]

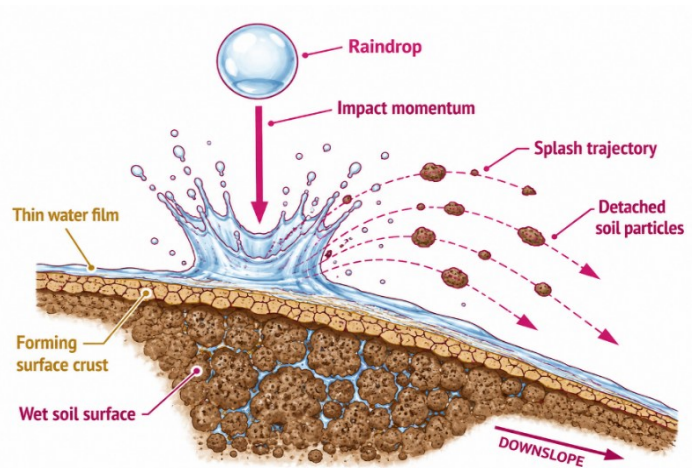
Water erosion proceeds in the same three linked phases as erosion in general: **detachment**, **transportation** and **deposition**. Detachment is achieved mainly by *raindrop impact (splash)* and by the shearing drag of flowing water; transport is by splash and by overland/channel flow; deposition occurs where the transporting capacity of the flow falls below the sediment load.

Limiting principle: Erosion at a point is limited either by the detachment capacity or by the transport capacity, whichever is smaller. Detachment needs energy; transport needs velocity. This is the conceptual basis of all soil-loss modelling.

2.1 Raindrop Characteristics that Govern Detachment

The kinetic energy of falling rain — not its mere amount — is the true eroding agent. The relevant raindrop properties are:

- **Drop size & size distribution** : larger drops (up to ~6 mm) carry more mass and energy; median drop size rises with rainfall intensity.
- **Terminal velocity** : the impact speed (up to ~9 m s⁻¹); governs the momentum delivered.
- **Kinetic energy ($\frac{1}{2}mv^2$)** : the actual detaching agent; KE increases with intensity, the basis of the **rainfall-erosivity index EI_{30}** .
- **Rainfall intensity & momentum** : high-intensity storms detach and transport far more soil.
- **Drop shape & angle of impact** : affect the direction of splash, especially on slopes.



Raindrop impact / splash mechanics

2.2 Factors Affecting Water Erosion

Factor group	How it controls erosion
Climate (rainfall)	Amount, intensity, duration, drop-size and frequency fix the erosivity; intense monsoon storms dominate in India.
Soil (erodibility)	Texture, organic matter, structure and permeability fix the soil's susceptibility (the K-factor).
Topography	Slope length and steepness — soil loss rises with both (see §6, LS-factor).
Vegetation / cover	Canopy intercepts rain, roots bind soil, residue absorbs impact and slows runoff — the C-factor.
Land use & management	Tillage direction, cropping system and conservation practices — the P-factor.

MODEL Q Slope : relation pointer (IFoS 2018): soil loss varies roughly as a power of slope steepness. Taking soil loss $\propto S^n$ with $n \approx 1.4$ (RUSLE) or the older squared form, a 4× increase in slope gives a relative increase of $41.4 \approx 7$ times (≈ 16 times if the squared relation is used). The full LS derivation and worked example are in §6.***

3

FORMS / TYPES OF WATER EROSION

PREVIOUS YEAR QUESTIONS

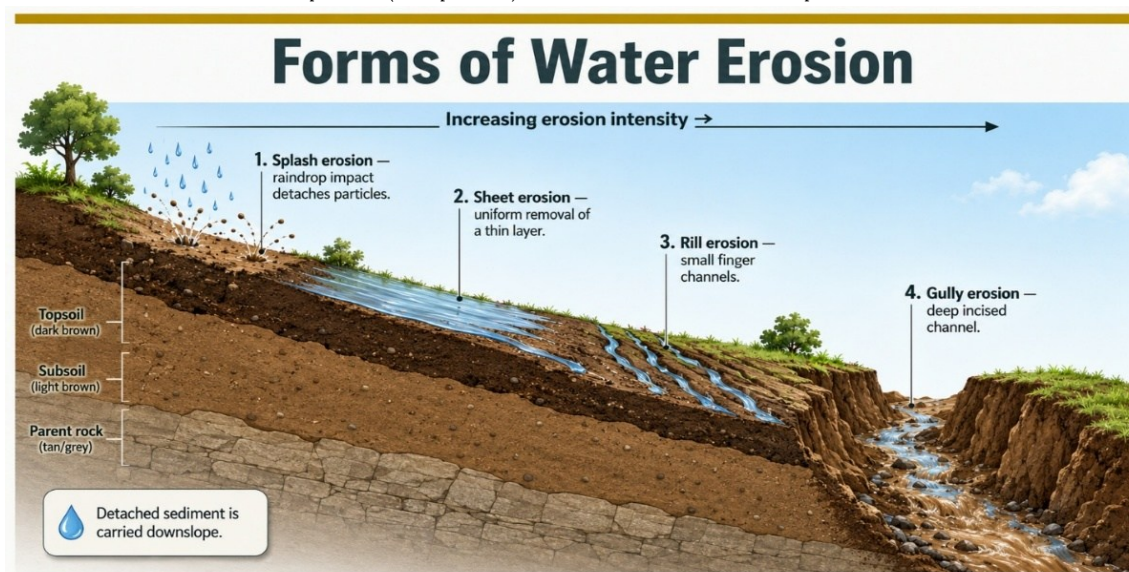
- Different types of erosion and their causes. *** [IFoS 2017 | P1/2(b) | 10M]
- What is soil erosion? Explain various types of water erosion. [UK-PSC 2025 | Q.1(i) | 10M]
- Different types of water erosion. [OPSC-CSE 2015 | 10M]
- Compare water vs wind erosion in terms of sediment transport. [AP-PSC 2018 | Q.1(b) | 6M]

Water erosion is classified by the way runoff concentrates, forming a natural progression of increasing severity:

1. **Splash (raindrop) erosion** : the first stage; raindrop impact detaches and throws soil particles, seals the surface and reduces infiltration.

2. **Sheet erosion** : near-uniform removal of a thin soil layer over the whole surface by shallow overland flow; insidious because it goes unnoticed until topsoil is lost.
3. **Rill erosion** : flow concentrates into many small finger-like channels (rills) that can still be smoothed out by tillage; the transition between sheet and gully erosion.
4. **Gully erosion** : rills enlarge into deep channels that cannot be crossed by farm machinery; the most advanced and conspicuous stage (see §4).
5. **Stream-bank / channel erosion** : scour and undercutting of banks and beds by flowing water in established channels.

Source: Kumar et al., Ch.3, p.16–20 (PDF p.16–20); Mishra & Bal, Lesson 3 & 12, p.20–25, 84–90.



3.1 Stream-bank vs Sheet/Rill — and Water vs Wind transport

In water erosion, sediment moves in *suspension*, *saltation* and *bed-load* (rolling/sliding) within the flow, sorted by particle size and flow velocity, and is delivered downstream to channels and reservoirs. In wind erosion (see 5) the analogous modes are *suspension*, *saltation* and *surface creep*, but the carrying fluid is air, so finer particles travel much farther and the deposition pattern is dust and dune rather than channel silt.

4

GULLY & RAVINE DEVELOPMENT

PREVIOUS YEAR QUESTIONS

- ✿ Different processes involved in the development of gullies. *** [IFoS 2024 | P1/1(b) | 8M]
- ✿ Stream-channel erosion (with sediment delivery ratio). [IFoS 2021 | P1/1(b) | 8M]

Gully - a deep, steep-sided channel cut by concentrated runoff that cannot be obliterated by normal tillage. When gullies coalesce into vast networks on deep alluvium (Chambal, Yamuna, Mahi) they form ravines — India's most spectacular erosion (~4 M-ha).

4.1 Stages / Processes of Gully Development

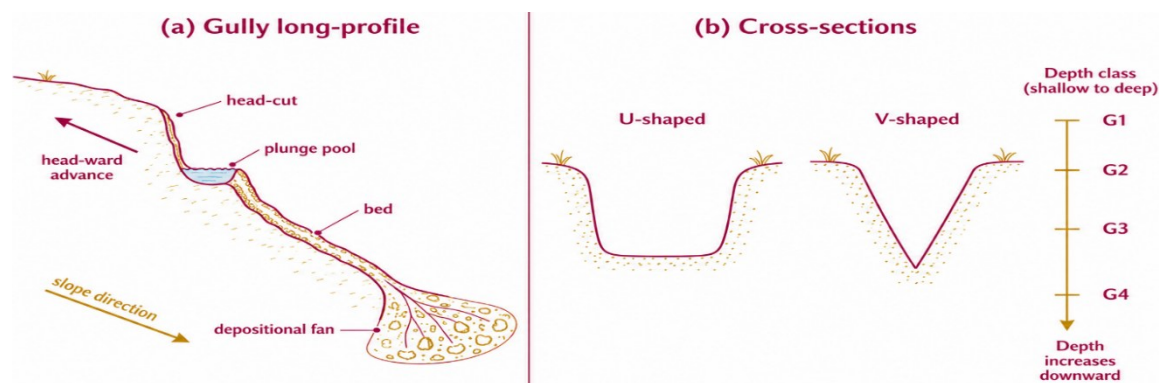
1. **Formation (channel erosion)** : concentrated overland flow scours a small channel as rill erosion deepens; flow energy exceeds soil resistance.
2. **Development (head-ward cutting)** : the gully head advances up-slope by waterfall/plunge-pool action; cross-section deepens and widens rapidly.

3. **Healing** : vegetation begins to establish on the gully floor and sides as gradient flattens; erosion slows.
4. **Stabilisation** : the gully reaches a stable gradient and cross-section; bed and banks attain a vegetal cover and erosion ceases. vegetation cover becomes complete and erosion effectively stops.

✦ Source: Mishra & Bal, Lesson 7 (Gully Erosion), p.46–57 (PDF p.46–57); Kumar et al., Ch.4, p.21–33.

4.2 Classification of Gullies

Basis	Classes
Size / depth (continuous system)	Very small (G1, <1 m deep), small (G2, 1–3 m), medium/deep (G3, 3–9 m), very deep/large (G4, >9 m)
Shape of cross-section	U-shaped (uniform, easily eroded subsoil) vs V-shaped (resistant subsoil)
Activity	Active (advancing) vs inactive/stabilised (vegetated, stable gradient)



Gully cross-section & stages

5 WIND EROSION

PREVIOUS YEAR QUESTIONS

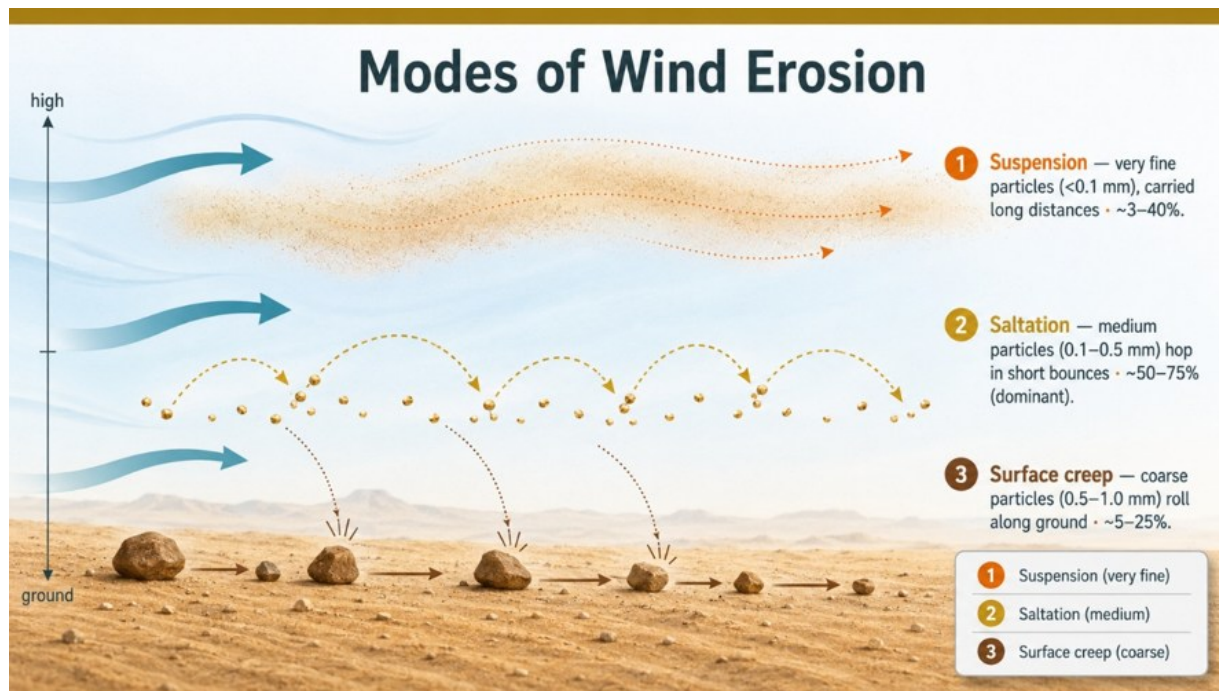
- ✦ Factors influencing soil erodibility by wind; impacts of types of water erosion. *** [IFoS 2025 | P1/2(b) | 15M]
- ✦ 'Erodibility index' and 'roughness factor' used for prediction of wind erosion. [IFoS 2023 | P1/3(a) | 10M]
- ✦ Phases of wind-erosion process; factors in estimation of soil loss by wind. [UK-PSC 2012 | Q.1(i) | 10M]

Wind erosion dominates the **arid and semi-arid NW (Rajasthan, Gujarat, Haryana)**, and its severity is *inversely related to rainfall* — the less the rain, the more the wind erosion. Like water erosion it involves detachment, transport and deposition, but air is the carrying fluid.

5.1 Phases / Modes of Soil Movement

Mode	Particle size	Description & share of moved soil
Suspension	< 0.1 mm	Fine dust lifted into the air, carried very high and over long distances; the most visible mode — about 3–40% of moved soil.
Saltation	0.1–0.5 mm	The major fraction — a series of bounces/jumps; travels ~4× longer in distance than in height; carries 50–75% of the moved soil.
Surface creep	0.5–2 mm	Large particles too heavy to lift are rolled along the surface by impacting saltating grains; 5–25% of the moved soil.

Over 93% of wind-borne soil moves at or within 1 m of the surface, and saltation is the engine that drives the other two modes.



5.2 Factors Affecting Wind Erosion (Erodibility by Wind)

- **Soil factors** : texture and particle size (loose, fine, dry sands most erodible), aggregate stability, non-erodible clods > 0.84 mm resist movement.
- **Soil moisture** : dry soil is far more erodible; moisture binds particles.
- **Surface roughness** : ridges/clods reduce wind velocity at the surface — the roughness factor.
- **Wind velocity & turbulence** : erosion increases sharply above the threshold velocity.
- **Climate** : wind velocity, turbulence and the temperature/evaporation regime (aridity).
- **Field length (unsheltered distance)** : longer bare fields along the wind direction lose more soil.
- **Vegetative cover** : standing residue and crops shelter the surface and trap moving soil.

5.3 Wind-Erosion Equation (WEQ) — Woodruff & Siddoway (1965)

The potential annual soil loss by wind, E, is expressed as a functional relationship of five groups of variables:

$E = f(I, K', C, L', V)$	
Term	Meaning
I	Soil-erodibility index — potential erosion from a wide, bare, smooth, unsheltered field (depends on % non-erodible clods > 0.84 mm).
K'	Soil-ridge-roughness factor — the sheltering effect of surface ridges/clods.
C	Climatic factor — combines wind velocity and surface-soil moisture ($\propto V^3 / (P-E \text{ index})^2$).
L'	Unsheltered field-length along the prevailing wind direction.
V	Equivalent vegetative cover (quantity, kind and orientation of residue).

MODEL Q Direct answer to IFoS 2023: the 'erodibility index' (I) and the 'roughness factor' (K') are simply the first two terms of the WEQ — I is the field's inherent susceptibility (governed by non-erodible aggregate %), and K' is the reduction in that loss produced by surface ridge roughness.

6

SOIL ERODIBILITY & RAINFALL EROSIVITY

PREVIOUS YEAR QUESTIONS

- ✿ Methods of estimation of erosivity from rainfall data. *** [IFoS 2025 | P1/2(a) | 10M]
- ✿ Methods of estimation of rainfall-erosivity factor. [OPSC-CSE 2023 | 20M]
- ✿ Factors affecting soil erodibility. [AP-PSC 2018 | Q.1(d) | 4M]
- ✿ Calculate the soil-erodibility factor (K) for use in USLE. *** [OPSC-CSE 2020 | 12M]

Soil loss is the product of two opposing tendencies: the **erosivity** of the rain (its power to detach and transport) and the **erodibility** of the soil (its susceptibility). When erosivity exceeds the soil's resistance, erosion occurs.

6.1 Soil Erodibility (K-factor)

Soil erodibility is the inherent susceptibility (vulnerability) of a soil to detachment and transport by the agents of erosion. It is the soil's *own* contribution, independent of rainfall, slope or cover. The soil-loss rate per unit of rainfall erosivity from a standard unit plot (22.13 m long, 9% slope, continuous bare fallow, up-and-down tillage). It is the reciprocal of the soil's resistance to erosion; high for silts and fine sands, low for clays and well-aggregated soils.

Factors that raise erodibility

- (i) **Texture** : silt and very fine sand are most erodible; clays resist detachment, sands resist transport.
- (ii) **Organic matter** : binds aggregates, raises infiltration, lowers K.
- (iii) **Soil structure & aggregate stability** : stable granular structure lowers K.
- (iv) **Permeability** : rapid permeability lowers runoff and K.

Wischmeier nomograph equation (the working derivation)

$$100 K = 2.1 \times 10^{-4} | M^{1.14} (12 - a) + 3.25 (b - 2) + 2.5 (c - 3)$$

where $M = (\% \text{ silt} + \% \text{ very-fine sand}) \times (100 - \% \text{ clay})$; $a = \% \text{ organic matter}$; $b = \text{soil-structure code (1-4)}$; $c = \text{permeability code (1-6)}$. K emerges in US units (t·ac·h per hundred·ac·ft·tonf·in); divide by 7.59 for SI (t·ha·h ha⁻¹ MJ⁻¹ mm⁻¹).

WORKED NUMERICAL — Soil-erodibility factor K (nomograph)

Problem (OPSC-CSE 2020; data illustrative) : Calculate the soil erodibility factor (K) for use in the Universal Soil Loss Equation, using the given information. (The original exam data table is not reproduced; representative values are used below.)

Given (illustrative soil)

Silt = 40%, very-fine sand = 25%, clay = 15%, organic matter $a = 2.0\%$, structure code $b = 2$ (fine granular), permeability code $c = 3$ (moderate).

Step 1 : particle term M

$$M = (40 + 25) (100 - 15) = 65 \times 85 = 5525$$

Step 2 : substitute in the nomograph equation

$$100K = 2.1 \times 10^{-4} (5525)^{1.14} (12 - 2) + 3.25(2 - 2) + 2.5 (3 - 3)$$

$$(5525)^{1.14} \approx 20\,700; \quad 100K = 2.1 \times 10^{-4} \times 20\,700 \times 10 + 0 + 0 = 43.5$$

$$K \approx 0.435 \text{ (US units)} = 0.435 / 7.59 \approx 0.057 \text{ t ha h ha}^{-1} \text{ MJ}^{-1} \text{ mm}^{-1} \text{ (SI)}$$

Result

$K \approx 0.44$ (US) ≈ 0.057 (SI) — a moderately erodible silty soil. (Structure & permeability terms vanish here as $b=2$, $c=3$.)

6.2 Rainfall Erosivity (R-factor) and EI_{30}

Rainfall erosivity R - the potential of rainfall to cause erosion, measured as the number of erosion-index (EI_{30}) units. For a storm, the erosion index is the product of the storm's total kinetic energy (E) and its maximum 30-minute intensity (I_{30}).

Methods of estimating erosivity

1. **EI_{30} index (Wischmeier & Smith) : the standard method:** for each storm, erosivity = (total storm kinetic energy E) $\times$ (maximum 30-minute intensity I_{30}). The **R-factor** = ΣEI_{30} of all storms in a year, averaged over years. Requires recording-raingauge (intensity) data.
2. **Kinetic-energy computation** : E for each intensity increment from $e = 0.119 + 0.0873 \log_{10}(i)$ (MJ/ha-mm), summed over the storm; multiplied by I_{30} .
3. **KE > 25 index (Hudson)** : for tropical rains, only the energy of rainfall at intensity > 25 mm/h is counted (suited to high-intensity tropical storms).
4. **Fournier index / modified Fournier index** : uses monthly and annual rainfall (p^2/P) where intensity data are unavailable.
5. **Regional regression equations** : relate R to readily available annual/seasonal rainfall for Indian conditions.

Kinetic-energy–intensity relation

Erosivity rests on the fact that a storm's kinetic energy increases with its intensity. The unit-energy relations are:

$$KE = 916 + 331 \log_{10} I \quad (\text{US: ft}\cdot\text{tonf per acre}\cdot\text{inch, } I \text{ in in h}^{-1})$$

$$KE = 210.3 + 89 \log_{10} I \quad (\text{metric: tonne}\cdot\text{m per ha}\cdot\text{cm, } I \text{ in cm h}^{-1})$$

Storm and annual erosion index

$$EI_{30} = (\Sigma KE \text{ over storm increments}) \times I_{30}$$

Each storm's E is found by summing (unit-energy $\times$ rainfall depth) over its intensity increments, then multiplying by I_{30} (the greatest 30-min intensity). Summing storm EI_{30} over the year gives the annual R. Lines joining equal annual EI_{30} — **iso-erodent maps** — are drawn for ready use in the USLE.

WORKED NUMERICAL — Storm erosion index EI_{30}

P Problem (illustrative) : A storm occurs in three successive intensity blocks (data below) with a maximum 30-minute intensity of 6 cm/h. Compute the storm erosion index EI_{30} . (Illustrative problem on the IFoS 2025 / OPSC 2023 theme — estimation of rainfall erosivity from rainfall data.)

Given a storm in three intensity blocks

Block 1: $I = 2 \text{ cm h}^{-1}$, depth 1.0 cm. Block 2: $I = 6 \text{ cm h}^{-1}$, depth 3.0 cm. Block 3: $I = 4 \text{ cm h}^{-1}$, depth 1.0 cm. Maximum 30-min intensity $I_{30} = 6 \text{ cm h}^{-1}$.

Step 1 : unit energy of each block (metric, $KE = 210.3 + 89 \log_{10} I$)

Block 1: $210.3 + 89 \log_{10} 2 = 210.3 + 26.8 = 237.1$; Block 2: $210.3 + 89 \log_{10} 6 = 210.3 + 69.2 = 279.5$; Block 3: $210.3 + 89 \log_{10} 4 = 210.3 + 53.6 = 263.9$ (tonne-m/ha-cm).

Step 2 : energy of each block (unit energy $\times$ depth)

$$E = 237.1(1.0) + 279.5(3.0) + 263.9(1.0) = 1339.5 \text{ tonne}\cdot\text{m ha}^{-1}$$

Step 3 : storm erosion index

$$EI_{30} = 1339.5 \times 6 = 8037 \text{ (tonne}\cdot\text{m ha}^{-1}) \text{ (cm h}^{-1})$$

Result

Storm $EI_{30} \approx 8.0 \times 10^3$ metric units; the annual R is the sum of all storm EI_{30} in the year.

7

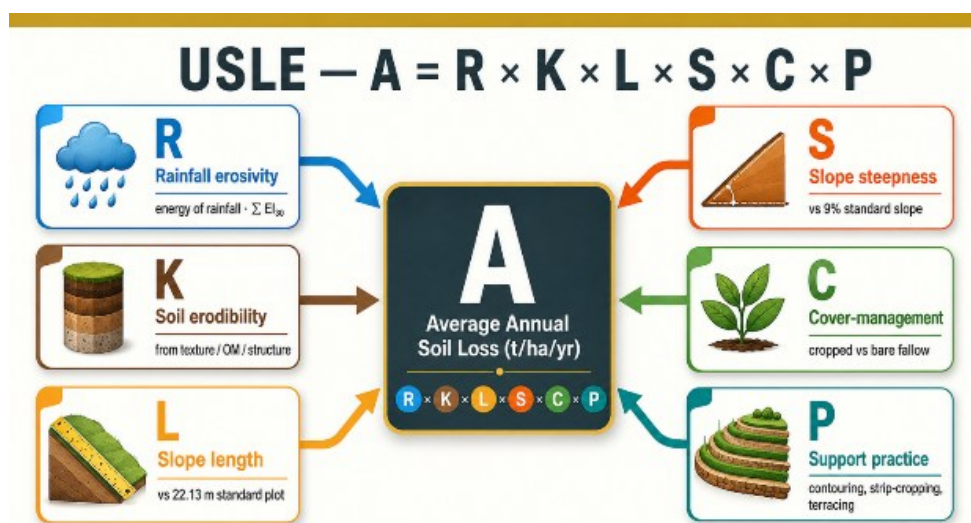
SOIL-LOSS MODELS — USLE / RUSLE / MUSLE

PREVIOUS YEAR QUESTIONS

- USLE — explain in detail the parameters in computing soil loss *** [IFoS 2019 | P1/2(a) | 10M]
- Differentiate USLE and MUSLE approaches; comment on utility ranges. *** [IFoS 2021 | P1/3(a) | 10M]
- USLE and how each factor is determined. [MH-PSC 2024 | Q.3(c) | 10M]
- Components of USLE; limitations in watershed management. [OPSC-CSE 2023 | 20M]
- How soil loss is estimated by USLE; what is its revised form? [OPSC-Forest 2019 | 20M]

7.1 Universal Soil Loss Equation (USLE)

Developed by **Wischmeier & Smith (USDA, 1965, revised 1978)** from over 10 000 plot-years of runoff-plot data, the USLE estimates the long-term *average annual* soil loss from sheet and rill erosion on arable land:



$$A = R | K | LS | C | P$$

Factor	Meaning & how it is determined
A	Computed soil loss per unit area per unit time ($t\ ha^{-1}\ yr^{-1}$).
R	Rainfall-erosivity factor = annual ΣEI_{30} (from iso-erodent maps) — §6.2.
K	Soil-erodibility factor (nomograph / unit-plot) — §6.1.
L	Slope-length factor = ratio of soil loss from the field length to that from a 22.13 m plot.
S	Slope-steepness factor = ratio of soil loss at field slope to that at the standard 9% slope.
C	Cover-management factor = ratio of loss under given cover to that from continuous bare fallow (≤ 1).
P	Support-practice factor = ratio of loss with a practice (contouring, strip-cropping, terracing) to that with up-and-down tillage (≤ 1).

Topographic factor LS — the slope derivation (IFoS 2018, 2025)

Slope length and slope loss combine in the LS factor. Wischmeier & Smith (metric) give:

$$LS = (\lambda / 22.13)^m | (65.41 \sin^2\theta + 4.56 \sin\theta + 0.065)$$

where λ = field slope length (m), θ = slope angle, and $m = 0.5$ for slopes $\geq 5\%$, 0.4 for $3-5\%$, 0.3 for $1-3\%$ and 0.2 for $<1\%$. Since $L \propto \lambda^m$ and the steepness term rises with $\sin^2\theta$, soil loss climbs steeply with both length and gradient.

WORKED NUMERICAL — Effect of slope steepness (IFoS 2018 — slope $\times 4$)
P Question (IFoS 2018)

What are the factors which affect soil erosion by water? Discuss. If the degree of slope is increased 4 times, what will be the relative increase in erosion caused by water? (The factors are covered in §2; the slope part is worked here.)

Using the steepness term $S \propto \sin^2\theta$ (small-angle: $\sin\theta \approx \tan\theta \approx \text{slope}$)

$$S \propto (\text{slope})^2 \Rightarrow S_2/S_1 = (4)^2 = 16$$

Using the RUSLE empirical exponent $S \propto (\text{slope})^{1.4}$

$$S_2/S_1 = 4^{1.4} \approx 7$$

Answer

Erosion increases about 16-fold on the classical squared relation, or ~ 7 -fold on the RUSLE exponent — i.e. roughly an order of magnitude. State the assumption you use.

WORKED NUMERICAL — Average annual soil loss by USLE

Problem (illustrative) : Using the Universal Soil Loss Equation, estimate the average annual soil loss from a maize field for which the rainfall-erosivity (R), soil-erodibility (K), slope length, slope steepness, cover-management (C) and support-practice (P) factors are given below.

Given

R = 600 (MJ mm ha⁻¹ h⁻¹ yr⁻¹), K = 0.30, slope length λ = 100 m, slope = 9% (so the steepness ratio = 1), C = 0.25 (maize), P = 0.6 (contouring).

Step 1 : LS factor ($\lambda=100$ m, $m=0.5$; 9% slope $\Rightarrow$ steepness term ≈ 1.0)

$$L = (100/22.13)^{0.5} = (4.52)^{0.5} = 2.13; \text{LS} \approx 2.13 \times 1.0 = 2.13$$

Step 2 : apply USLE

$$A = R \cdot K \cdot \text{LS} \cdot C \cdot P = 600 \times 0.30 \times 2.13 \times 0.25 \times 0.6$$

$$A \approx 57.5 \text{ t ha}^{-1} \text{ yr}^{-1}$$

Result

$\approx 57.5 \text{ t ha}^{-1} \text{ yr}^{-1}$ — far above the tolerable limit ($\sim 5\text{--}12 \text{ t ha}^{-1} \text{ yr}^{-1}$), so a conservation practice (lower C or P) is needed.

7.2 RUSLE — the Revised USLE (full treatment)

RUSLE (Renard *et al.*, 1997) keeps the form $A = R \cdot K \cdot \text{LS} \cdot C \cdot P$ but re-derives every factor on a stronger process basis:

Factor	RUSLE refinement vs USLE
R	Same EI ₃₀ basis, but with much denser iso-erodent data and an equivalent-R for flat/snow regions; sub-monthly distribution used.
K	Time-varying (seasonal) K reflecting freeze–thaw, antecedent moisture and consolidation, not a single annual value.
LS	Re-derived for rill vs inter rill erosion. McCool slope-length exponent $m = \beta/(1+\beta)$, $\beta = (\sin\theta/0.0896)/(3 \sin^{0.8}\theta + 0.56)$; and $S = 10.8 \sin\theta + 0.03$ (slope <9%) or $S = 16.8 \sin\theta - 0.50$ (slope $\geq 9\%$).
C	Replaced by a continuous sub-factor product $\text{SLR} = \text{PLU} \mid \text{CC} \mid \text{SC} \mid \text{SR} \mid \text{SM}$ (prior-land-use, canopy-cover, surface-cover, surface-roughness, soil-moisture) weighted over the year.
P	Expanded for contouring, strip-cropping, terracing and sub-surface drainage with improved values.

MODEL Q USLE $\rightarrow$ RUSLE in one line: same five factors, but K becomes seasonal, LS uses the McCool rill/inter rill formulation, and C becomes a continuous sub-factor product instead of a crop-stage table — giving better accuracy on complex slopes and rotations.

7.3 MUSLE — the Modified USLE (Williams, 1975)

Williams (1975) modified the USLE by replacing the rainfall-energy factor R with a **runoff-energy factor**, because runoff (not rainfall alone) carries the sediment off a watershed:

$$Y = 11.8 (Q | q_p)^{0.56} | K | LS | C | P$$

where Y = sediment yield from a single storm (tonnes), Q = storm runoff volume (m^3) and q_p = peak runoff rate ($m^3 s^{-1}$). The factors K , LS , C , P keep their USLE meaning. Because the runoff term embodies the transport process, MUSLE predicts **sediment yield directly per storm** and needs *no separate sediment-delivery ratio*.

WORKED NUMERICAL — Sediment yield by MUSLE

Problem (illustrative) : Using the Modified Universal Soil Loss Equation (MUSLE), estimate the sediment yield from a single storm for a watershed whose storm runoff volume (Q), peak runoff rate (q_p) and K , LS , C and P factors are given below.

Given (single storm)

$Q = 30\,000\,m^3$, $q_p = 6\,m^3\,s^{-1}$, $K = 0.30$, $LS = 2.13$, $C = 0.25$, $P = 0.60$.

Step 1 : runoff-energy term

$$(Q \cdot q_p)^{0.56} = (30\,000 \times 6)^{0.56} = (180\,000)^{0.56} \approx 1064$$

Step 2 : apply MUSLE

$$Y = 11.8 \times 1064 \times 0.30 \times 2.13 \times 0.25 \times 0.60$$

$$Y \approx 1203 \text{ tonnes (sediment yield from this storm)}$$

Result

$\approx 1.2 \times 10^3\,t$ for the event — a per-storm sediment yield, delivered to the outlet without any delivery-ratio adjustment.

7.4 USLE vs MUSLE — comparison & limitations (IFoS 2021 banker)

Aspect	USLE	MUSLE
Driving factor	Rainfall erosivity R (EI_{30})	Runoff-energy factor $11.8(Q \cdot q_p)^{0.56}$
Output	Average annual gross soil loss	Sediment yield per individual storm
Delivery ratio	Needed separately to get yield at outlet	Not needed — yield is direct
Time scale	Long-term average (annual)	Single storm event
Best for	Field/plot sheet & rill erosion	Small watershed sediment yield ($\approx 2\text{--}40$ ha)
Process basis	Detachment by rain	Detachment + transport by runoff

Limitations common to the family

- Applies to sheet and rill erosion only — gully, stream-bank and mass erosion are not predicted.
- USLE gives gross soil loss, not the sediment actually delivered downstream (needs a delivery ratio).
- Empirical, factor values are region-specific; Indian values must be used for Indian conditions.
- Does not model deposition within the field, nor single-storm variability (USLE).

8

SEDIMENT — DELIVERY RATIO, YIELD & CHANNEL EROSION

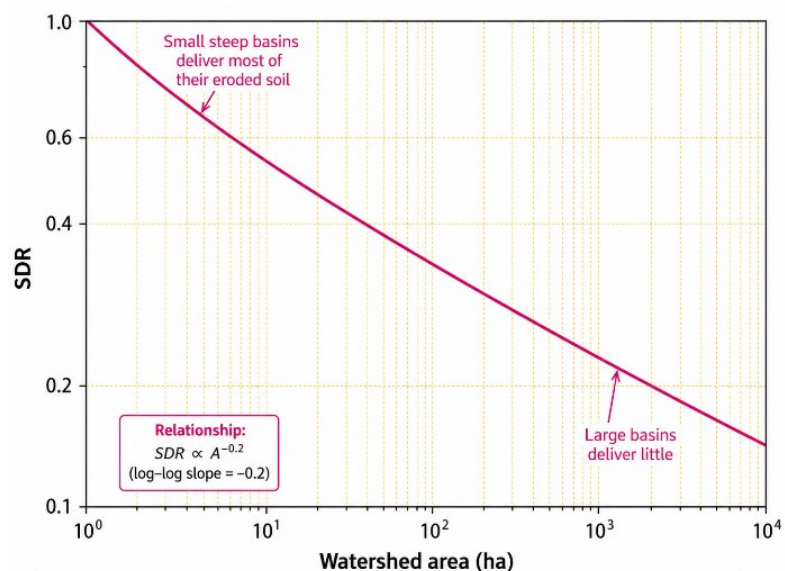
PREVIOUS YEAR QUESTIONS

- 🌿 Sediment delivery ratio; stream-channel erosion [IFoS 2021 | P1/1(b) | 8M]
- 🌿 Stream-bank erosion. [AP-PSC 2018 | Q.2(c) | 5M]

Sediment yield — the total sediment that actually leaves a watershed past a given point in a given time (t yr^{-1} or $\text{t ha}^{-1} \text{yr}^{-1}$). It is less than the gross erosion in the watershed, because much eroded soil is re-deposited on slopes, in channels and in flood-plains before reaching the outlet.

8.1 Sediment Delivery Ratio (SDR)

SDR is always ≤ 1 and **decreases as watershed area increases** (more opportunity for deposition en route) — empirically $\text{SDR} \propto A^{-0.2}$ for many basins. It also rises with steeper, well-connected channels and falls with flatter, vegetated, storage-rich catchments. SDR converts USLE gross soil loss into the sediment delivered downstream.



8.2 Stream-Bank & Channel Erosion

Once runoff is concentrated in defined channels, the flow itself erodes the **bed (degradation)** and **banks (lateral scour/undercutting)**. Bank erosion is driven by flow velocity and shear, bank height and saturation, freeze–thaw and the loss of riparian vegetation; it supplies a large part of the sediment in alluvial rivers and threatens land, bridges and embankments. It is the channel-stage counterpart of the upland sheet–rill–gully sequence.

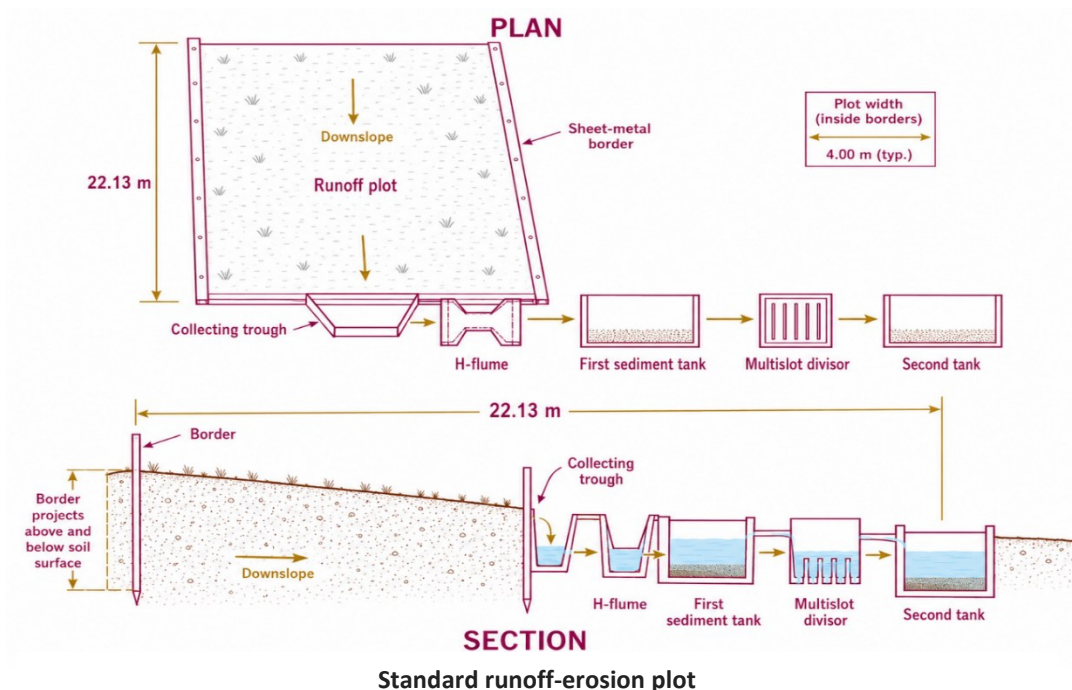
9 MEASUREMENT OF SOIL LOSS

📋 PREVIOUS YEAR QUESTIONS

- 🌿 Different methods for measurement of soil losses from agricultural watersheds (use diagrams). *** [IFoS 2019 | P1/3(b) | 10M]

Soil loss is measured directly in the field by trapping the runoff and sediment from a defined area, or estimated from channel/reservoir surveys. The principal methods:

- **Runoff / erosion plots** : bounded plots (the standard USLE plot is 22.13 m long on 9% slope) with a border, a collection trough at the lower end leading to sediment tanks; runoff and sediment are weighed/sampled after each storm.
- **Multislot (Geib) divisors** : aliquot samplers that split large runoff volumes so only a known fraction is stored — used where tanks would otherwise overflow.
- **Small unit-source & large mixed watersheds** : gauged outlets with stage recorders and sediment samplers give watershed-scale sediment yield (links to §13).
- **Reservoir / tank sedimentation survey** : periodic capacity surveys give long-term average sediment yield of the catchment.
- **Profile / pin meters & tracers** : surface-lowering and radio-tracer methods for spatial patterns of loss.



Standard runoff-erosion plot

10 PRECIPITATION & RAINFALL ANALYSIS

PREVIOUS YEAR QUESTIONS

- Major types of precipitation storm. [IFoS 2025 | P1/1(a) | 8M]
- Salient characteristics of precipitation in India. [IFoS 2024 | P1/1(a) | 8M]
- Isohyetal method + advantages over arithmetic mean. *** [IFoS 2022 | P1/1(c) | 8M]
- Estimate missing rainfall at Station D (normal-ratio). *** [IFoS 2020 | P1/3(b) | 10M]
- Checking rainfall data of a station for consistency (double-mass). [IFoS 2018 | P1/2(c) | 10M]
- Depth-Area-Duration (DAD) curves + procedure. [IFoS 2017 | P1/2(a) | 10M]

10.1 Forms & Types of Precipitation

By the lifting mechanism, storms are **convective** (local heating, intense short showers/thunderstorms), **orographic** (air forced up mountains — the dominant Indian monsoon type, e.g. Western Ghats, NE hills), **cyclonic/frontal** (warm–cold air-mass interaction, depressions), and **monsoonal** (seasonal land–sea pressure reversal). Indian rainfall is *highly seasonal* ($\approx 75\%$ in the SW monsoon, June–Sept), *spatially variable* (from <100 mm in the NW desert to $>11\,000$ mm at Mawsynram), and *high-intensity* — hence its great erosive power.

10.2 Mean Areal Rainfall over a Watershed

Point gauge values are converted to an average depth over the area by three methods of rising accuracy:

(a) Arithmetic-mean method

$$\bar{P} = (1/n) \sum P_i$$

Simple average of all gauges; adequate only for flat areas with uniformly distributed gauges and little spatial variation.

(b) Thiessen-polygon method (area-weighted)

$$\bar{P} = (\sum A_i P_i) / (\sum A_i)$$

Each gauge is weighted by the polygon area it represents (polygons formed by perpendicular bisectors of lines joining gauges). It accounts for non-uniform gauge spacing but assumes linear variation and fixed weights.

(c) Isohyetal method

$$\bar{P} = [\Sigma ((P_1+P_2)/2 \mid a)] / A$$

Isohyets (equal-rainfall contours) are drawn; the area between successive isohyets is multiplied by their mean depth and summed. **Advantages over the arithmetic mean** (IFoS 2022): it uses the analyst's knowledge of orography and storm pattern, represents the true spatial distribution, and is the most accurate — whereas the arithmetic mean ignores spatial variation and gauge weighting.

WORKED NUMERICAL — Mean areal rainfall — Thiessen polygon

Problem (OPSC-Forest 2015) : Tabulated are the data derived from a drainage basin. Determine the average depth of rainfall using the Thiessen polygon method.

Given (4 gauges)

$P = 26.9, 15.4, 28.2, 19.2$ mm with Thiessen areas $A = 108, 35, 18, 110$ km² respectively.

Step 1 : $\Sigma A_i P_i$

$$= 26.9(108) + 15.4(35) + 28.2(18) + 19.2(110) = 2905.2 + 539 + 507.6 + 2112 = 6063.8$$

Step 2 : ΣA_i and weighted mean

$$\Sigma A = 271 \text{ km}^2; \bar{P} = 6063.8 / 271 = 22.4 \text{ mm}$$

Result

Area-weighted mean rainfall $\bar{P} \approx 22.4$ mm — note it differs from the plain arithmetic mean (22.4 vs 22.4 here; the gap widens when areas are very unequal).

10.3 Estimation of Missing Rainfall — Normal-Ratio Method

If the normal annual rainfalls of the gauges differ by more than 10%, the missing value P_x at a station is weighted by the ratio of normals:

$$P_x = (1/n) \Sigma (N_x / N_i) \mid P_i$$

where N_x is the normal annual rainfall at the missing station, N_i and P_i the normals and observed values at the n index stations.

WORKED NUMERICAL — Missing rainfall — normal-ratio (IFoS 2020)

Problem (IFoS 2020) : The normal annual rainfall at Stations A, B, C and D in the basin are 80.97, 67.59, 76.28 and 92.01 cm, respectively. In the year 1985, Station D was inoperative and Stations A, B and C recorded annual precipitation of 91.11, 72.33 and 79.89 cm, respectively. Estimate the rainfall at Station D in that year.

Given

Normals: $N_A=80.97, N_B=67.59, N_C=76.28, N_D=92.01$ cm. In 1985, D was inoperative; A, B, C recorded $P_A=91.11, P_B=72.33, P_C=79.89$ cm. Find P_D .

Normals differ >10% $\Rightarrow$ use normal-ratio method ($n = 3$)

$$P_D = (N_D/3) [P_A/N_A + P_B/N_B + P_C/N_C]$$

Step 1 : ratios

$$= (92.01/3) [91.11/80.97 + 72.33/67.59 + 79.89/76.28]$$

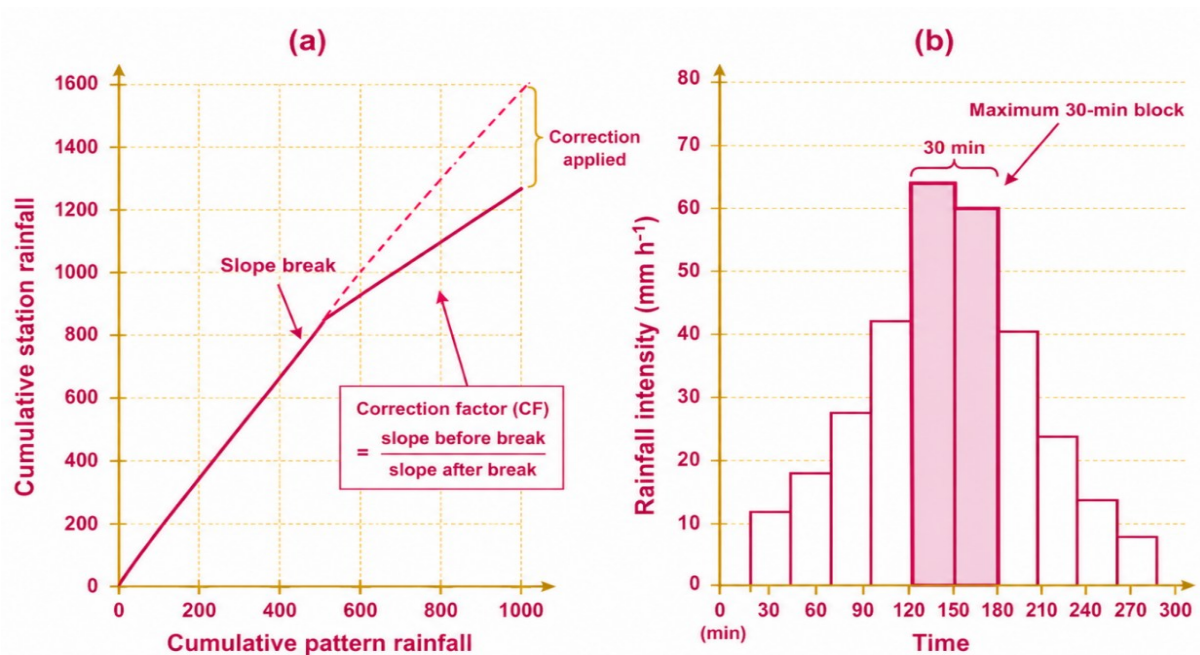
$$= 30.67 [1.1252 + 1.0701 + 1.0473] = 30.67 \times 3.2426$$

Result

$$P_D \approx 99.4 \text{ cm}$$

10.4 Consistency of Records (Double-Mass Curve) & DAD

A station's record may become **inconsistent** if its exposure changes (gauge shifted, trees grown). The **double-mass curve** plots the station's cumulative annual rainfall against the cumulative mean of surrounding stations; a *change in slope* marks the year of inconsistency, and the older record is corrected by the slope ratio. **Depth-Area-Duration (DAD)** curves give the maximum average depth over an area for a given duration built from isohyetal maps and storm mass curves — and are used in design-storm and flood studies.



Double-mass curve & hyetograph

11 RUNOFF & PEAK-FLOW ESTIMATION

PREVIOUS YEAR QUESTIONS

- Peak runoff, 10-yr, 250 ha, C=0.47, IDF given (numerical). *** [IFoS 2023 | P1/2(b) | 10M]
- Rational method; time of concentration (numerical). *** [IFoS 2018 | P1/2(b) | 10M]
- Rational formula; why 'rational'; limitations. *** [IFoS 2016 | P1/3(b) | 10M]
- Types of runoff; factors affecting runoff. [IFoS 2018 | P1/1(a) | 8M]
- SCS-CN method; factors influencing CN. [OPSC-CSE 2023 | 20M]

11.1 Runoff — Types & Factors

Runoff is the part of precipitation that flows over the land to a stream. **Surface runoff** reaches the channel quickly over the surface; **interflow (subsurface)** moves laterally through the soil; **base flow** is the delayed groundwater contribution. Runoff depends on *rainfall (amount, intensity, duration)*, *catchment (size, shape, slope, orientation)*, *soil & land use (infiltration, cover)*, and *storage (lakes, dams)* — fan-shaped catchments give sharper peaks than fern-leaf ones.

11.2 Rational Method (peak flow)

For a uniform-intensity storm of duration $\geq$ the time of concentration, runoff at the outlet reaches a steady peak. The **rational formula** is:

$$Q_p = C | i | A \quad (\text{consistent units}) ; Q_p = C i A / 360 \quad (Q \text{ in } m^3 s^{-1}, i \text{ in } mm h^{-1}, A \text{ in } ha)$$

where C = runoff coefficient (runoff/rainfall, 0–1), i = rainfall intensity for duration = t_c at the design frequency, A = catchment area. It is called 'rational' because it rests on the rational premise that the peak occurs when the whole catchment contributes simultaneously (at $t = t_c$).

Time of concentration — Kirpich (1940)

$$t_c = 0.0195 | L^{0.77} | S^{-0.385} \quad (t_c \text{ in min, } L \text{ in m, } S = \text{bed slope})$$

Limitations of the rational formula

- Assumes constant uniform rainfall intensity over the whole catchment for the full t_c — valid only for small areas (typically < 50 km²).
- C is assumed constant, though it varies with storm depth and antecedent moisture.
- Gives only the peak, not the hydrograph shape or runoff volume.

WORKED NUMERICAL — Peak runoff by rational method (IFoS 2023)

Problem (IFoS 2023) : Determine the peak rate of runoff for a 10-year frequency from a watershed of 250 hectares, having a weighted value of runoff coefficient (C) as 0.47. The distance from the remotest point in the watershed to the outlet is 3000 m and the elevation difference between the highest and outlet points of the watershed is 25 m. The maximum intensity-duration-frequency relationship of the watershed is given by $i = (6.3117 \times T^{0.1523}) / (D + 0.50)^{0.945}$, where i = intensity in cm/h, T = return period in years and D = duration of rainfall in hours.

Given

$A = 250$ ha, 10-yr frequency, $C = 0.47$, $L = 3000$ m, elevation diff $H = 25$ m. IDF: $i = (6.3117 T^{0.1523}) / (D + 0.50)^{0.945}$ cm h⁻¹ (T yr, D h).

Step 1 : slope and time of concentration (Kirpich)

$$S = H/L = 25/3000 = 0.00833$$

$$t_c = 0.0195 (3000)^{0.77} (0.00833)^{-0.385} = 0.0195 \times 552 \times 5.62 \approx 60.5 \text{ min} \approx 1.01 \text{ h}$$

Step 2 : design intensity at $D = t_c$, $T = 10$ yr

$$i = 6.3117(10)^{0.1523} / (1.01 + 0.50)^{0.945} = 6.3117 \times 1.420 / (1.51)^{0.945} \\ = 8.96 / 1.475 = 6.08 \text{ cm h}^{-1} = 60.8 \text{ mm h}^{-1}$$

Step 3 : rational formula ($Q = C i A / 360$)

$$Q_p = 0.47 \times 60.8 \times 250 / 360 \approx 19.8 \text{ m}^3 \text{ s}^{-1}$$

Result

Design peak runoff $\approx 19.8 \text{ m}^3 \text{ s}^{-1}$ ($\approx 20 \text{ m}^3 \text{ s}^{-1}$).

11.3 SCS Curve-Number (CN) Method

The US-SCS method estimates runoff depth Q from storm rainfall P using a single parameter, the **curve number CN**, which embodies soil type (hydrologic groups A–D), land use/cover and antecedent moisture (AMC I/II/III). It derives from the continuity premise $P = I_a + F + Q$ with the proportionality $F/S = Q/(P - I_a)$ and the standard initial abstraction $I_a = 0.2S$:

$$Q = (P - 0.2S)^2 / (P + 0.8S) \quad ; \quad S = (25400/CN) - 254 \quad (\text{mm})$$

For a watershed of several cover types, an area-weighted CN is used. AMC-II is the average condition; AMC-I (dry) and AMC-III (wet) are obtained from conversion tables.

WORKED NUMERICAL — Weighted CN & runoff (IFoS 2017 / 2020)

Problem (IFoS 2017) : Describe briefly the SCS-CN method of runoff estimation. A watershed has 100 ha area. The watershed has 20 ha pasture in silty clay soil of 2% slope (CN = 65), 30 ha of pasture on silty loam soil of 0.5% slope (CN = 70) and remaining 50 ha of wheat crop on loam soil of 1% slope (CN = 85). Estimate the weighted curve number for the watershed. (The direct runoff for a 120 mm storm is also worked below as an extension.)

Given (weighted CN, IFoS 2017)

100 ha = 20 ha (CN 65) + 30 ha (CN 70) + 50 ha (CN 85), all AMC-II.

Step 1 : area-weighted CN

$$CN = [20(65) + 30(70) + 50(85)] / 100 = (1300 + 2100 + 4250)/100 = 76.5$$

Step 2 : potential retention S

$$S = 25400/76.5 - 254 = 332.0 - 254 = 78.0 \text{ mm}$$

Step 3 : runoff for, say, P = 120 mm

$$Q = (120 - 0.2 \times 78)^2 / (120 + 0.8 \times 78) = (104.4)^2 / (182.4) = 10\,899 / 182.4$$

$$Q \approx 59.8 \text{ mm}$$

Result

Weighted CN = 76.5; for a 120 mm storm the direct runoff depth $\approx$ 60 mm ($\approx$ 50% of rainfall).

12

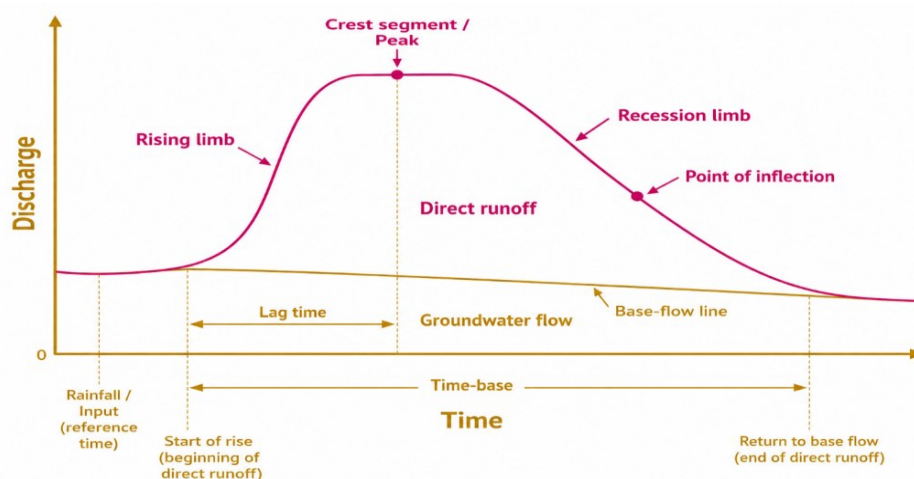
HYDROGRAPHS & UNIT HYDROGRAPH

PREVIOUS YEAR QUESTIONS

- Assumptions and steps in development of the unit hydrograph. *** [IFoS 2025 | P1/1(c) | 8M]
- UH; uses & limitations; S-curve method for other durations. *** [IFoS 2022 | P1/2(b) | 15M]
- Synthetic unit hydrograph & its derivation. *** [IFoS 2021 | P1/2(c) | 20M]
- Methods of base-flow separation from a runoff hydrograph. *** [IFoS 2020 | P1/3(c) | 20M]
- Drainage density; relation between drainage density and ruggedness number. [IFoS 2020 | P1/1(c) | 8M]

12.1 Hydrograph & its Components

Hydrograph — a plot of discharge against time at a stream section in response to a storm. A single-peaked hydrograph has a rising limb (concentration), a crest/peak, and a falling (recession) limb, sitting on the base flow; the area under the direct-runoff part equals the storm runoff volume.



Single-peaked hydrograph with components

PRINCIPAL MEASURES

- **Vegetative barriers / live hedges** : close-planted rows of stiff, deep-rooted grass (e.g. vetiver/khus) or shrubs along the contour that slow runoff and trap sediment, forming a living, self-repairing barrier.
- **Grassed / vegetated cover** : permanent grass established on waterways, bund tops, terrace risers and gullied land to resist scour (designed as channels in §10).
- **Wattling** : a bio-engineering measure in which live cuttings or brushwood are bundled and staked in shallow trenches along the contour (or across gully beds) to form a 'wattle' fence; the stakes sprout, bind the soil and check downslope movement, giving permanent cover on unstable slopes and gully sides.
- **Afforestation / pasture establishment** : on Class VI–VIII land unsuited to cultivation, to provide permanent protective cover and stabilise degraded and steep ground.



When to recommend biological measures (AP-PSC 2012) : wherever the slope is gentle-to-moderate and rainfall and soil allow vegetation to establish; as the protective component of every watershed plan; and as the living cover on the engineering works themselves. On steep slopes or under high runoff they are used to support structures, not as the sole defence.

✦ **Source** — *Gully & Ravine Control Structures*, L22, p.177–183; *Mishra & Bal*, L4, p.26–30.

5. CONTOUR BUNDS — DESIGN

PREVIOUS YEAR QUESTIONS

- ✦ Contour and graded bunds — how they differ in design and function. *** [IFoS 2016 | P1/1(b) | 10M]
- ✦ Engineering measures of erosion control; design criteria of contour bund. [IFoS 2021 | P1/1(b) | 8M]
- ✦ Principles of bund spacing; calculate bund height (L, V, W, S; rain 15 cm). *** [IFoS 2025 | P1/3(c) | 15M]
- ✦ Methods of bunds; design criteria & specification of contour bund. [OPSC-Forest 2023 | Q.1(c) | 10M]
- ✦ When do you recommend a contour vs a graded bund? [AP-PSC 2012 | Q.1(H) | 4M]

A bund is a small earthen embankment built across the slope to intercept runoff, reduce its velocity and impound or divert it, thereby breaking the slope into shorter lengths and trapping sediment. Built exactly on the contour it is a contour bund, which stores water for in-situ moisture; given a slight longitudinal grade it becomes a graded bund (§6), which safely leads excess water away. Bunding is the cheapest mechanical measure and the single biggest source of design numericals in this paper, so the geometry below must be mastered.

Basis	Contour bund	Graded bund
Alignment	Exactly on the contour (level)	On a slight grade, 0.2–0.4%
Function	Impounds & stores runoff for infiltration / in-situ moisture	Safely disposes of excess runoff to a protected outlet

Step 1 : VI by Cox's formula. High rainfall (120 cm) with high intake $\Rightarrow X \approx 0.8$; low cover $\Rightarrow Y \approx 1.0$ (ICAR table). $S = 4\%$.

$$\text{Cox: } VI = 0.3 (X \cdot S/3 + Y) \text{ m}$$

$$VI = 0.3(0.8 \times 4/3 + 1.0) = 0.3(1.067 + 1.0) = 0.3 \times 2.067 = 0.62 \text{ m.}$$

Step 2 : Horizontal interval.

$$HI = 100 \times 0.62/4 = 15.5 \text{ m.}$$

Step 3 : Water depth to store.

$$d = \sqrt{2 \cdot Pe \cdot VI}$$

$$Pe = 0.10 \text{ m; } d = \sqrt{2 \times 0.10 \times 0.62} = \sqrt{0.124} = 0.35 \text{ m.}$$

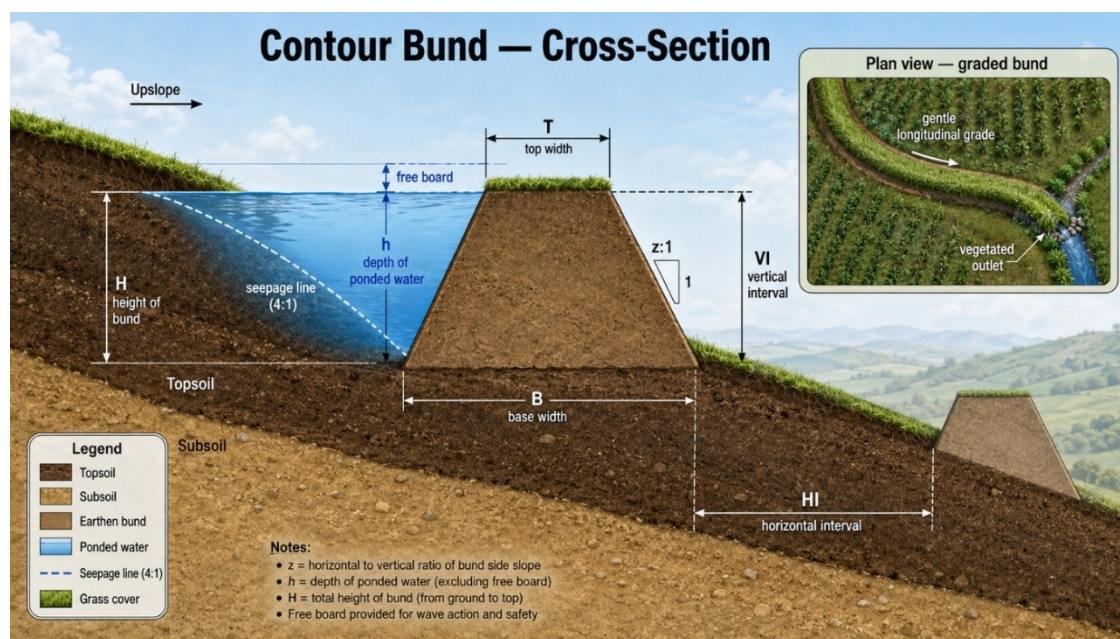
Step 4 : Bund height & cross-section (10% free board, top width 0.3 m, side slope 1.5:1).

$$H = d/0.9 \approx 0.39 \text{ m;}$$

$$\text{base } B = 0.3 + 2(1.5)(0.39) = 1.47 \text{ m.}$$

Answer. $VI \approx 0.62 \text{ m}$, $HI \approx 15.5 \text{ m}$, water depth $\approx 0.35 \text{ m}$, bund height $\approx 0.39 \text{ m}$, base width $\approx 1.47 \text{ m}$.

► *X and Y are read from the ICAR table for the stated rainfall and cover — state this assumption in the answer.*



✂ Design dimensions of a contour bund

Full question. Calculate the design dimensions of a contour bund in a medium-deep soil of average slope 3%. The maximum expected rainfall for a 10-year recurrence is 20 cm. The soil's infiltration capacity is such that 30% of the rain infiltrates. The horizontal interval between bunds is 60 m. Take the seepage-line slope as 4:1 and the bund side slope as 1.5:1. [IFoS 2022 | P1/2(c) | 10M]

Given:

- Average slope, $S = 3\%$ (medium-deep soil)
- Maximum expected rainfall (10-yr recurrence) = 20 cm
- Infiltration = 30% of rainfall
- Horizontal interval, $HI = 60 \text{ m}$
- Seepage-line slope = 4:1
- Bund side slope = 1.5:1

Step 1 : Excess rainfall to store. 30% infiltrates $\Rightarrow$

$$\text{runoff} = 70\% \text{ of } 20 \text{ cm} = 14 \text{ cm} \Rightarrow Pe = 0.14 \text{ m.}$$

Step 2 : VI from the given HI.

$$VI = HI \cdot S / 100$$

$$VI = 60 \times 3 / 100 = 1.8 \text{ m.}$$

Step 3 : Water depth.

$$d = \sqrt{(2 \cdot Pe \cdot VI)}$$

$$d = \sqrt{(2 \times 0.14 \times 1.8)} = \sqrt{0.504} = 0.71 \text{ m.}$$

Step 4 : Bund height & cross-section (10% free board, top 0.3 m, side 1.5:1).

$$H = 0.71 / 0.9 \approx 0.79 \text{ m;}$$

$$\text{base } B = 0.3 + 2(1.5)(0.79) = 2.67 \text{ m.}$$

Answer. VI = 1.8 m, water depth $\approx$ 0.71 m, bund height $\approx$ 0.79 m, base width $\approx$ 2.67 m; % area lost = $2.67/60 \approx 4.4\%$.

🔗 Bund design and % area lost (30-mark)

Full question. A contour bund is to be constructed on land of 2.5% slope. The vertical interval is 1.5 m and the area receives a maximum rainfall of 10 cm for a 10-year recurrence. One-fourth of the rainfall is lost as surface runoff. The bund side slope is 1.5:1; a free board of 10% of bund height is provided. Design the bund size and determine the percentage area lost to bunds. Take the seepage-line slope as 4:1. [OPSC-CSE 2018 | Q.7(a) | 30M]

Given:

- Land slope, $S = 2.5\%$
- Vertical interval, $VI = 1.5 \text{ m}$
- Maximum rainfall (10-yr recurrence) = 10 cm
- Runoff = $1/4$ of the rainfall
- Bund side slope = 1.5:1
- Free board = 10% of bund height
- Seepage-line slope = 4:1

Step 1 : Excess rainfall (runoff).

$$\text{One-fourth runs off} \Rightarrow Pe = 0.25 \times 10 \text{ cm} = 2.5 \text{ cm} = 0.025 \text{ m.}$$

Step 2 : Horizontal interval.

$$HI = 100 \cdot VI / S$$

$$HI = 100 \times 1.5 / 2.5 = 60 \text{ m.}$$

Step 3 : Water depth.

$$d = \sqrt{(2 \cdot Pe \cdot VI)}$$

$$d = \sqrt{(2 \times 0.025 \times 1.5)} = \sqrt{0.075} = 0.274 \text{ m.}$$

Step 4 : Bund height (free board 10% of H).

$$H = d / (1 - 0.10) = 0.274 / 0.9 = 0.304 \text{ m.}$$

Step 5 : Cross-section & % area lost (top 0.3 m, side 1.5:1).

$$\text{base} = 0.3 + 2(1.5)(0.304) = 1.21 \text{ m;}$$

$$\% \text{ area lost} = \text{base} / HI$$

$$HI = 1.21/60 = 2.0\%$$

Answer. HI = 60 m, water depth $\approx$ 0.27 m, bund height $\approx$ 0.30 m, base width $\approx$ 1.21 m, area lost $\approx$ 2.0%.

⌘ Spacing & length of contour bund

Full question. Calculate the spacing and length of contour bund for a medium-rainfall area on 4 ha, if the land has a 5% slope. [OPSC-CSE 2020 | Q.6(b)(iii) | 12M]

Given:

- Area = 4 ha
- Land slope, $S = 5\%$
- Rainfall category = medium ($\Rightarrow X \approx 0.4, Y \approx 1.0$ from ICAR table)
- Method to use: Cox's formula for VI

Step 1 : VI by Cox's formula (medium rainfall $\Rightarrow X \approx 0.4, Y \approx 1.0$).

$$\text{Cox: } VI = 0.3 (X \cdot S/3 + Y) \text{ m}$$

$$VI = 0.3 (0.4 \times 5/3 + 1.0) = 0.3(0.667 + 1.0) = 0.50 \text{ m.}$$

Step 2 : Spacing (horizontal interval).

$$HI = 100 \times 0.50/5 = 10 \text{ m.}$$

Step 3 : Total length of bund for 4 ha (= 40 000 m²).

$$\text{Length} = \text{Area}/HI = 40\,000/10 = 4\,000 \text{ m.}$$

Answer. Spacing (HI) $\approx$ 10 m; total length of contour bund $\approx$ 4 000 m (4 km) for the 4-ha field.

► *X and Y read from the ICAR table for medium rainfall.*

⌘ Height of contour bund

Full question. Calculate the height of a contour bund on a land slope of 5%. Assume: (i) rainfall excess for 24 h = 80 cm; (ii) horizontal interval = 15 m; (iii) depth of water flow over the weir = 30 cm. [IFoS 2019 | P1/2(d) | 10M]

Given:

- Land slope, $S = 5\%$
- Rainfall excess for 24 h = 8 cm
- Horizontal interval, HI = 15 m
- Depth of water flow over the weir = 30 cm

Step 1 : VI from the given HI.

$$VI = HI \cdot S/100 = 15 \times 5/100 = 0.75 \text{ m.}$$

Step 2 : Water depth to store the excess.

$$Pe = 0.08 \text{ m}$$

$$d = \sqrt{2 \cdot Pe \cdot VI}$$

$$d = \sqrt{2 \times 0.08 \times 0.75} = \sqrt{0.12} = 0.35 \text{ m.}$$

Step 3 : Bund height = storage depth + weir-flow depth + free board.

$$H = d + \text{weir depth} = 0.35 + 0.30 = 0.65 \text{ m (+ ~10\% free board } \approx 0.72 \text{ m).}$$

Answer. Bund height $\approx$ 0.65–0.72 m.

⌘ Bund-height expression & principles of spacing

- **Manning's $n = 0.04$**

Step 1 : Permissible velocity for dub grass $\approx 2.5 \text{ m/s} \Rightarrow$

$$A = Q/v$$

$$= 3/2.5 = 1.20 \text{ m}^2.$$

Step 2 : Hydraulic radius.

$$R = (v \cdot n / \sqrt{S})^{1.5}$$

$$R = (2.5 \times 0.04 / \sqrt{0.04})^{1.5} = (0.50)^{1.5} = 0.354 \text{ m}.$$

Step 3 : Depth & top width. $D = 3R/2 = 0.53 \text{ m}$; $T = 3A/(2D) = 3.39 \text{ m}$.

Answer. Identical to the 2021 problem (same Q , S , n , grass): top width $\approx 3.39 \text{ m}$, depth $\approx 0.53 \text{ m}$ (+ free board). Velocity $2.5 \text{ m/s} \leq$ permissible for dub grass.

⌘ Trapezoidal grassed waterway

Full question. Design a trapezoidal grassed waterway: peak runoff $Q = 4.0 \text{ m}^3/\text{s}$, grade 0.3% , $n = 0.04$, side slope $Z = 2:1$ (H:V). Assume other necessary data. [IFoS 2023 | P1/3(b) | 15M]

Given:

- **Design discharge, $Q = 4.0 \text{ m}^3/\text{s}$**
- **Channel grade, $S = 0.3\%$**
- **Manning's $n = 0.04$**
- **Side slope, $Z = 2:1$ (H:V)**
- **Bottom width not given – assumed in the solution**

Step 1 : Assume a bottom width and solve Manning for depth. With $b = 3 \text{ m}$, $Z = 2$, $n = 0.04$, $S = 0.003$, solving $Q = (1/n) \cdot A \cdot R^{2/3} \cdot S^{1/2} = 4.0$ gives $d \approx 0.87 \text{ m}$.

$$A = bd + Zd^2 = 3(0.87) + 2(0.87)^2 = 4.11 \text{ m}^2;$$

$$\text{Wetted Perimeter } P = b + 2d\sqrt{1+Z^2} = 3 + 2(0.87)\sqrt{5} = 6.89 \text{ m};$$

$$\text{Hydraulic Radius } R = A/P = 0.597 \text{ m}.$$

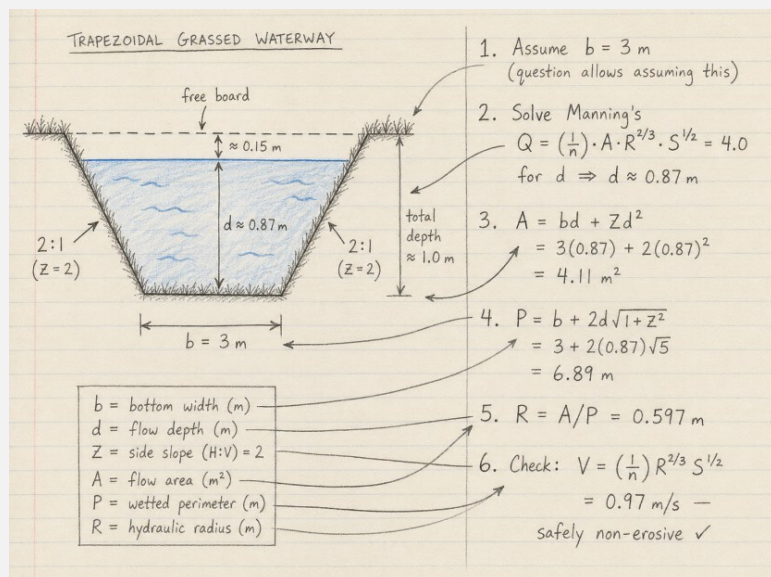
Step 2 : Check velocity.

$$v = (1/n) \cdot R^{2/3} \cdot S^{1/2}$$

$$V = (1/0.04) (0.597)^{2/3} (0.003)^{1/2} = 25 \times 0.709 \times 0.0548 = 0.97 \text{ m/s};$$

$$Q = A \cdot V \approx 4.0 \text{ m}^3/\text{s} \checkmark.$$

Answer. Trapezoidal waterway: bottom width 3 m , flow depth $\approx 0.87 \text{ m}$ (+ $\sim 0.15 \text{ m}$ free board $\Rightarrow \approx 1.0 \text{ m}$), side slope $2:1$. Velocity $\approx 0.97 \text{ m/s}$ is safely non-erosive. (Bottom width assumed, as the question permits.)



⌘ Parabolic waterway (State PSC)

Full question. Design a parabolic grassed waterway to carry a peak flow of $6 \text{ m}^3/\text{s}$ on a 1% slope on erodible sandy soil; good grass cover allows a permissible velocity of 1.5 m/s . Take $n = 0.034$. [OPSC-CSE 2023 | Q.15(b) | 20M]

Given:

- **Design discharge, $Q = 6 \text{ m}^3/\text{s}$**
- **Channel slope, $S = 1\%$**

- **Soil type** = erodible sandy soil
- **Grass cover** = good, permissible velocity $v = 1.5 \text{ m/s}$
- **Manning's n** = 0.034

Step 1 : Area.

$$A = Q/v = 6/1.5 = 4.0 \text{ m}^2.$$

Step 2 : Hydraulic radius ($n = 0.034$, $S = 0.01$).

$$R = (v \cdot n / \sqrt{S})^{1.5}$$

$$R = (1.5 \times 0.034 / \sqrt{0.01})^{1.5} = (0.51)^{1.5} = 0.364 \text{ m}.$$

Step 3 : Depth & top width.

$$D = 3R/2 = 0.546 \text{ m};$$

$$T = 3A/(2D) = 3 \times 4.0 / (2 \times 0.546) = 11.0 \text{ m}.$$

Answer. Parabolic waterway: top width $\approx 11 \text{ m}$, depth $\approx 0.55 \text{ m}$ (+ free board). Velocity 1.5 m/s suits erodible sandy soil under good grass.

11.

WIND BREAKS & SHELTER BELTS

PREVIOUS YEAR QUESTIONS

- ✿ Design factors and layout to install a shelter-belt against wind erosion. *** [IFoS 2019 | P1/3(a) | 10M]
- ✿ Calculate the spacing between shelter-belts ($H=15 \text{ m}$, $V_a=18$, $V_t=9 \text{ kmph}$, deviation 10°). *** [IFoS 2021 | P1/2(b-i) | 10M]
- ✿ Wind-erosion factors; wind-break and shelter-belt practices. [UK-PSC 2021 | Q.1(iv) | 10M]

Wind breaks and shelter belts are barriers of trees and shrubs (often with a grass understorey) planted across the prevailing wind to reduce its velocity near the ground and so control wind erosion, evaporation and crop damage. A wind break is a narrow barrier of one or two rows protecting a farmstead or a small field; a shelter belt is a wider, multi-row belt protecting a large area of cropland. Both reduce wind velocity, trap drifting soil and conserve soil moisture on the leeward side.

DESIGN FACTORS & LAYOUT (IFOS 2019)

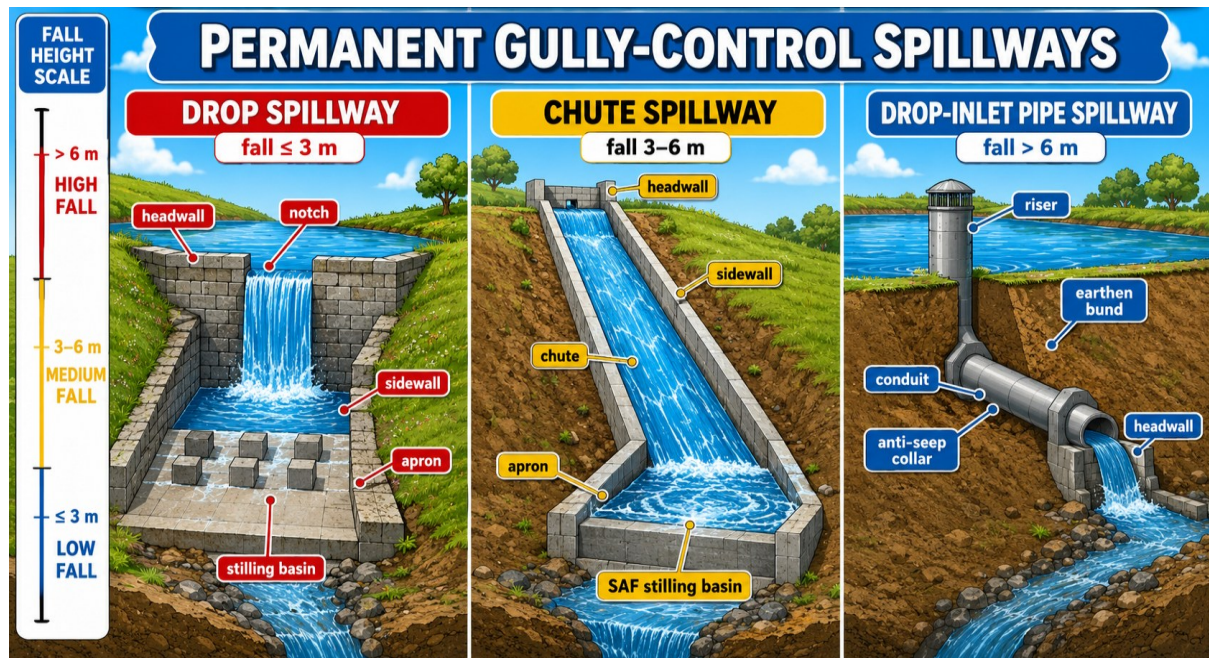
- **Height (H)** : the key parameter; the protected leeward distance scales with barrier height, about 10–20 times the height ($\approx 17 H$).
- **Orientation** : the belt is aligned perpendicular (at right angles) to the prevailing wind for maximum effect; a deviation angle reduces the protected distance.
- **Density / permeability** : a semi-permeable belt ($\approx 40\text{--}60\%$ density) is best — it diffuses the wind and protects a longer leeward distance, whereas a solid barrier creates sharp eddies and a short shelter.
- **Width & composition** : several rows — tall trees in the centre flanked by shrubs — giving a graded, triangular, durable profile of hardy, deep-rooted, fast-growing species.
- **Length & layout** : long ($> \sim 12 H$) and continuous to avoid funnelling at gaps; main belts across the wind at the design spacing, with subsidiary belts at right angles.

SPACING OF SHELTER BELTS

The spacing (protected distance) between successive belts follows from the height, the prevailing and threshold wind velocities and the angle of deviation:

$$D = 17 \cdot H \mid (V_t / V_a) \mid \cos \theta$$

dissipation		toe	
Storage used?	No	No (optional)	Yes — temporary storage reduces peak
Debris / clogging	Not a problem	Not a problem	Riser can clog
Relative cost	Low at small drops	Economical at 3–6 m	Least material at high heads
Design method	Rational (peak rate)	Rational (peak rate)	Flood routing (inflow–storage–outflow)



✦ **Source** — Soil & Water Conservation Structures, L13–14 (design requirements & procedure), p.119–130; Soil & Water Conservation Engineering, L8 (PGCS), p.58–60.

4. DROP SPILLWAY — THEORY, DESIGN & STRUCTURAL STABILITY

PREVIOUS YEAR QUESTIONS

- ✦ Objectives of a drop spillway; advantages and limitations; procedure for its design. ***
[IFoS 2021 | P1/3(c) | 20M]
- ✦ Design a drop spillway in a gully (width 5 m, area 58 ha, net drop 2 m; $i=120$ mm/h, $T=25$ yr, $C=0.3$, stone masonry). ***
[IFoS 2019 | P1/3(c) | 10M]
- ✦ Determine the height of the wing wall of a drop structure ($F=2.5$ m, $h=1.5$ m, $S=0.5$ m). ***
[IFoS 2023 | P1/3(c) | 15M]
- ✦ Adaptability and functions of a drop spillway. *** [IFoS 2020 | P1/1(a) | 8M]
- ✦ Size of each side of a square box inlet for a drop spillway ($Q=3.2$ cumec, fall 1.5 m, energy-head/fall ratio ≤ 0.6). ***
[IFoS 2025 | P1/2(c)(ii) | 5M]
- ✦ Purpose of the structural components of a drop spillway (with sketch). *** [UK-PSC 2015 | Q1(iii) | 10M]
- ✦ Functions, advantages and limitations of a drop spillway; label a straight-inlet drop spillway. ***
[UK-PSC 2012 | Q2(i) | 10M]

12.3 RETARDS

A **retard** is a **permeable bank-protection device** — permeable spurs / groynes, timber or wire-and-pile fences, tree / brush screens — projecting from or laid along an eroding bank.

Adaptability & functions. used on alluvial river bends and eroding banks where full armour is costly. By offering resistance they **reduce the flow velocity next to the bank and induce silt deposition**, so the bank line is protected and gradually rebuilt. They are cheaper and more flexible than solid revetment but give slower, partial protection — contrast with impermeable spurs / groynes that deflect the current away.

13. STABILITY ANALYSIS — RETAINING WALLS & GRAVITY DAMS

PREVIOUS YEAR QUESTIONS

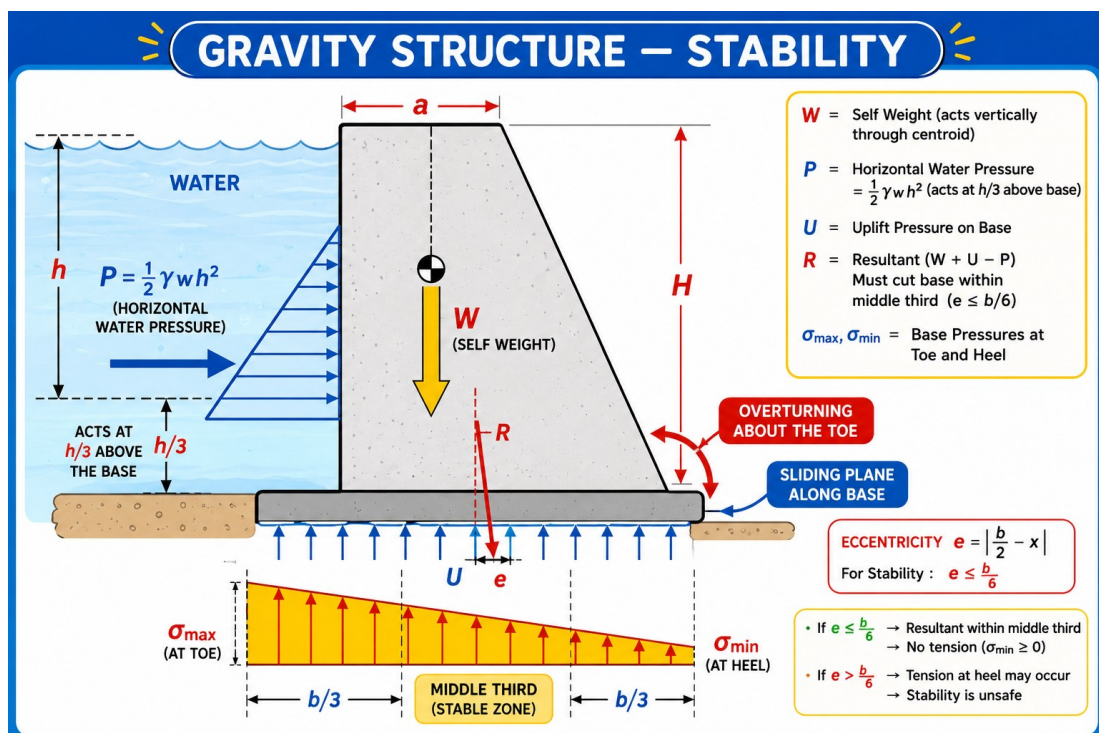
- ✿ Explain the stability analysis of retention walls and dams. *** [IFoS 2019 | P1/1(d) | 8M]
- ✿ Test the structural stability of a straight gravity masonry dam (top 1.6 m, base 3.2 m, height 6.2 m, water 5.6 m, $\mu=0.5$, bearing capacity 25000 kg/m^2). ***

[OPSC-CSE 2016-17 | Q7(c) | 30M]

Retaining walls and gravity dams are **gravity structures**: they hold back the horizontal thrust of water / earth by sheer self-weight. Both are checked against the same four modes of failure **overturning, sliding, tension (no-tension / middle-third), and crushing (compression)**; dams add a piping / uplift check. The governing idea is that the resultant of all forces must stay within the **middle third** of the base so that no tension develops.

13.1 FORCES

- **Self-weight W** : acts vertically through the centroid of the section (the stabilising force).
- **Horizontal thrust ΣH** : water pressure $P = \frac{1}{2}\gamma_w h^2$ (at $h/3$ above base) for a dam; active earth pressure $P = \frac{1}{2}K_a \gamma H^2$ for a retaining wall.
- **Uplift U** : (dams) hydrostatic pressure on the base, reducing the effective weight.



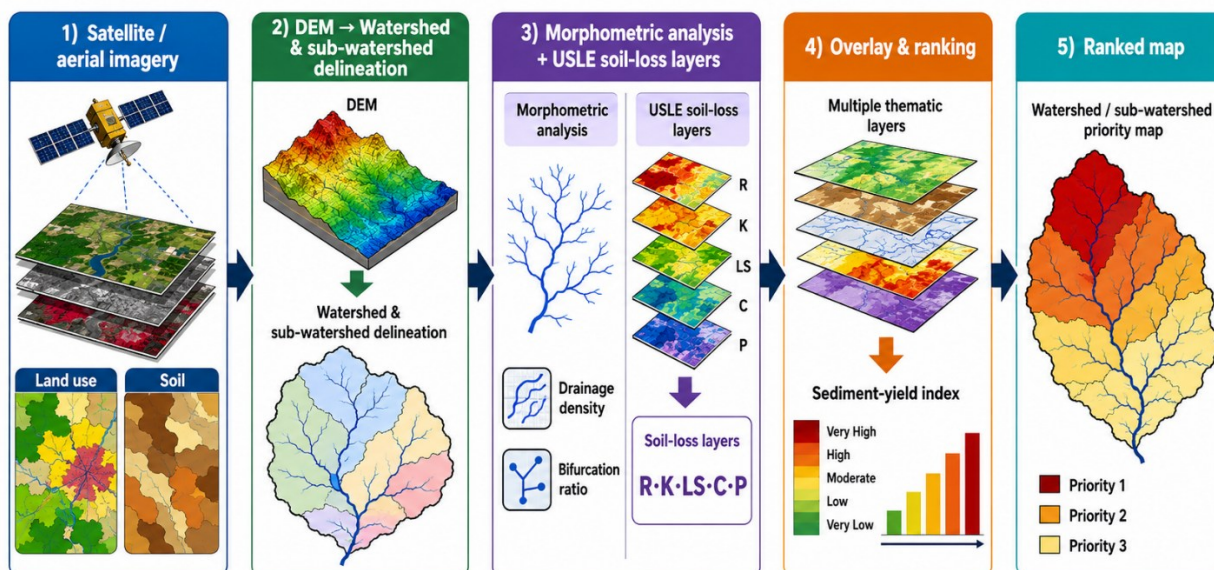
Compound-parameter prioritization (textbook-type)

Three sub-watersheds have morphometric ranks — **SW-A:** (Dd 2, Rb 1, Fs 2); **SW-B:** (3,3,3); **SW-C:** (1,2,1). Order them for treatment.

Compound value = **mean rank:** **A** = $(2+1+2)/3 = 1.67$; **B** = $(3+3+3)/3 = 3.0$; **C** = $(1+2+1)/3 = 1.33$.

Lowest compound value = highest erodibility = first priority → C → A → B.

Watershed Prioritization using RS & GIS



5. WATERSHED DEVELOPMENT PROGRAMMES, PEOPLE'S PARTICIPATION & M&E

PREVIOUS YEAR QUESTIONS

- Differentiate 'WARASA – Jan Sahbhagita' and 'Hariyali' watershed development programmes.***
[IFoS 2024 | P1 Q2(a) | 10M]
- Guiding principles for watershed development projects as stipulated in the Common Guidelines.***
[IFoS 2022 | P1 Q1(a) | 8M]
- Role of people's participation in watershed development.*** [IFoS 2017 | P1 Q1(a) | 8M]
- Gaps between planning and implementation of watershed programmes.*** [OPSC 2017 | 7(d)]

5.1 EVOLUTION OF WATERSHED PROGRAMMES IN INDIA (BRIEF)

From the Soil Conservation Research, Demonstration & Training Centres of the 1950s → NWDPR (National Watershed Development Project for Rainfed Areas, 1990-91) and IWDP (Integrated Wastelands Development Programme, 1995) → WARASA–Jan Sahbhagita (2000, the revised NWDPR guidelines making implementation community-led) → Hariyali guidelines (2003) → NRAA (National Rainfed Area Authority, 2006) → the unifying Common Guidelines (2008) → IWMP (Integrated Watershed Management Programme, 2009-10) → WDC-PMKSY (Watershed Development Component–Pradhan Mantri Krishi Sinchayee Yojana, 2015-16), now WDC-PMKSY 2.0 (2021-26).

☞ Plane method — formation level & cut/fill (textbook-type)

A field is levelled to a single down-field slope. Four grid points along a line at 30 m spacing read RLs 100.60, 100.30, 100.10, 99.80 m. Design to the plane of best fit (cross slope = 0).

x (from first peg) = 0, 30, 60, 90 m $\rightarrow \bar{x} = 45$ m;

$\bar{h} = (100.60 + 100.30 + 100.10 + 99.80)/4 = 100.20$ m.

$\Sigma(x - \bar{x})(h - \bar{h})$: $(-45)(0.40) + (-15)(0.10) + (15)(-0.10) + (45)(-0.40) = -18 - 1.5 - 1.5 - 18 = -39$.

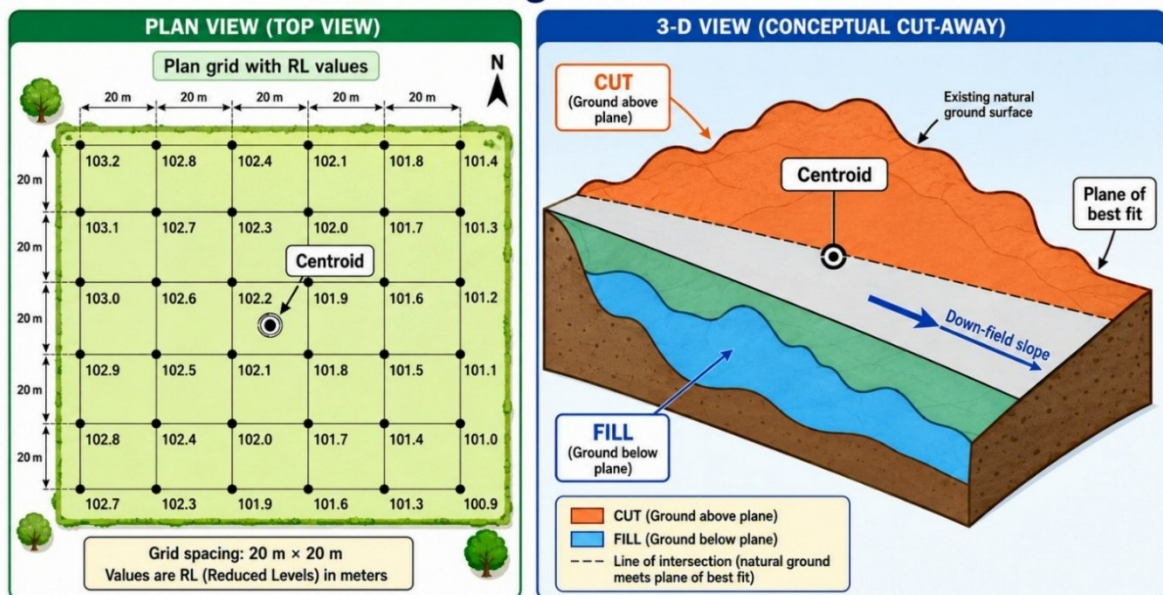
$\Sigma(x - \bar{x})^2 = 45^2 + 15^2 + 15^2 + 45^2 = 2025 + 225 + 225 + 2025 = 4500$.

$S_x = -39/4500 = -0.00867$ (i.e. a fall of 0.87 m per 100 m).

Formation RL at peg 1 ($x=0$): $100.20 + (-0.00867)(0-45) = 100.20 + 0.39 = 100.59 \rightarrow \text{cut} = 100.60 - 100.59 = 0.01$ m.

At peg 4 ($x=90$): $100.20 + (-0.00867)(45) = 100.20 - 0.39 = 99.81 \rightarrow \text{fill} = 99.80 - 99.81 = -0.01$ m. (Cut $\approx$ fill, balanced $\checkmark$)

Land Grading — Plane Method



13. LAND DEVELOPMENT II - EARTHWORK COMPUTATION, COSTING & MACHINERY

📄 PREVIOUS YEAR QUESTIONS

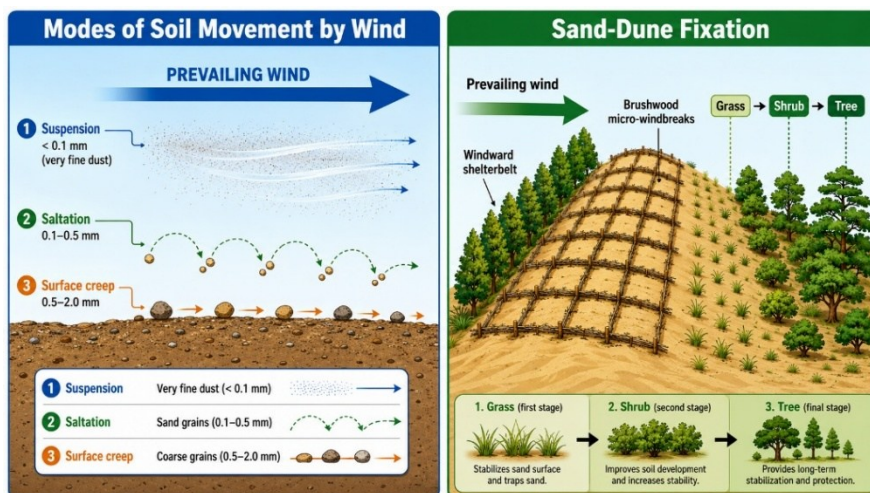
- Methods for computation of earthwork; machinery/equipment used for land grading.***
[IFoS 2019 | P1 Q4(a) | 10M]
- Different methods of calculating earth and soil volumes. ** [IFoS 2017 | P1 Q1(c) | 8M]
- Volume of earthwork for a trapezoidal canal by trapezoidal and prismoidal formulae. **
[OPSC 2024 | Q2 | 15M]

13.1 METHODS OF EARTHWORK COMPUTATION (Answers IFoS 2019 | 4(A) & 2017 | 1(C))

- Cross-section methods** (roads/canals) : Mid-section, average end-area (trapezoidal), and prismoidal formulae.

14.5 SAND DUNES & THEIR FIXATION (Answers IFoS 2022 | 1(B))

Sand dunes are mounds/ridges of wind-deposited sand formed in arid regions where saltating sand accumulates around an obstruction; live (mobile) dunes bury cropland, roads and canals. Types include barchan (crescentic), transverse, longitudinal (seif) and parabolic. Fixation procedure:



- Protect the dune from grazing and traffic (fencing) to stop fresh disturbance.
- Erect micro-windbreaks — brushwood/checkerboard fences (parallel & perpendicular) on the dune to break wind velocity and trap sand.
- Mulch / spray the surface with a stabiliser (bitumen emulsion) to hold the sand temporarily.
- Establish vegetation in stages — hardy drought-resistant grasses first, then shrubs, then trees (Prosopis, Acacia, Calligonum, Tamarix) in the sheltered pockets for permanent cover.
- Raise shelterbelts on the windward side for long-term protection.

QUICK-REVISION FORMULA SHEET

Topic	Key formula / value
Bifurcation ratio	$R_b = N_w / N(w+1)$ (3–5)
Drainage density	$D_d = L / A$
Length of overland flow	$L_o = 1 / (2 D_d)$
Form / shape factor	A/L^2 ; L^2/A
Elongation / compactness	$1.128VA/L$; $0.2821 P/VA$
Muskingum storage	$S = K[xI + (1-x)Q]$, $0 \leq x \leq 0.5$
Muskingum routing	$Q_2 = C_0I_2 + C_1I_1 + C_2Q_1$; $C_0+C_1+C_2 = 1$
Routing coefficients	$C_0=(0.5\Delta t-Kx)/D$, $C_1=(0.5\Delta t+Kx)/D$, $C_2=(K-Kx-0.5\Delta t)/D$; $D=K-Kx+0.5\Delta t$
Routing interval	$K > \Delta t > 2Kx$
Continuity (routing)	$I - Q = dS/dt$
Prismoidal volume	$V = (L/3)[A_1+A_n + 4(\text{even}) + 2(\text{odd interior})]$
Average end-area	$V = L[(A_1+A_n)/2 + A_2+\dots+A_{n-1}]$
Four-point earthwork	$V = (A/4) \Sigma(\text{corner cut or fill depths})$
Trapezoidal-canal area	$A = (b + s \cdot d) \cdot d$
Plane of best fit — slope	$S_x = \Sigma[(x-\bar{x})(h-\bar{h})]/\Sigma(x-\bar{x})^2$
Formation level	$h_f = \bar{h} + S_x(x-\bar{x}) + S_y(y-\bar{y})$
Cut / fill	= ground RL – formation RL ; design cut $\approx 1.2-1.5 \times$ fill
Farm-pond capacity	prismoidal / average-end-area of contour areas

Radiometric correction rectifies errors in the **brightness (DN) values** of pixels caused by sensor response variations, atmospheric scattering/absorption and illumination (sun-angle) differences. It restores the true radiance/reflectance of features. Operations include sensor calibration, striping/line-drop correction, atmospheric correction (haze removal) and sun-angle/topographic correction.

10.5 GEOMETRIC CORRECTION

PYQ IFoS 2024 3(c) & 2023 1(d): *geometric correction*.

Geometric correction removes **positional/geometric distortions** so that image pixels correspond to true ground coordinates (a map projection). Distortions arise from Earth curvature and rotation, platform altitude/altitude variations, sensor scanning and relief. Steps:

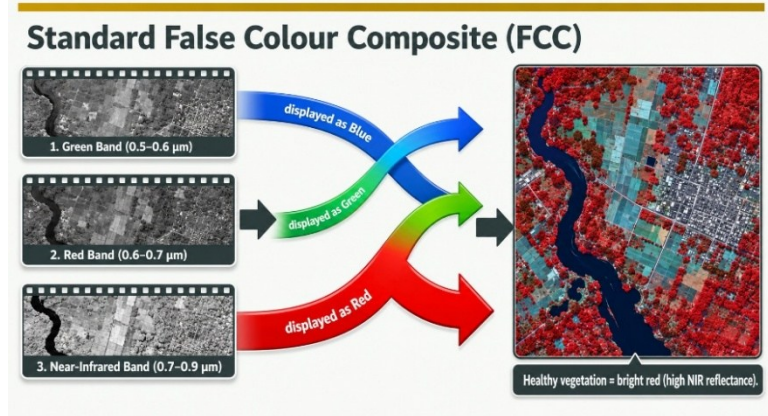
1. Select **Ground Control Points (GCPs)** — features identifiable on both image and map/reference.
2. Fit a **coordinate transformation** (polynomial) relating image to map coordinates.
3. **Resampling** (nearest-neighbour, bilinear, cubic convolution) to assign DN values to the corrected grid.

Radiometric vs Geometric — Radiometric correction fixes the pixel's value (brightness); geometric correction fixes the pixel's position (location). Restoration encompasses both, plus noise removal.

10.6 IMAGE ENHANCEMENT & FALSE COLOUR COMPOSITE

PYQ IFoS 2023 1(e): *what is false colour composite?*

- **Contrast stretching, density slicing, spatial filtering and band ratioing** improve the visual separability of features.
- **False Colour Composite (FCC):** a colour image created by assigning the three additive primaries (Blue, Green, Red display channels) to bands **other** than their natural ones — classically the **green band** →



blue, red band → **green**, and **near-infrared band** → **red**. Because healthy vegetation reflects strongly in NIR, it appears in **bright red** on a standard FCC, making vegetation mapping and vigour assessment easy. (A 'true colour composite' instead assigns each band to its natural colour.)

10.7 IMAGE CLASSIFICATION

PYQ IFoS 2023 4(b): *how is classification done in DIP?* | IFoS 2020 4(b): *methods of DIP, discuss one.*

Classification assigns every pixel to a thematic class (e.g., water, forest, crop, built-up) based on its spectral (DN) values, converting a multispectral image into a thematic map. Two approaches:

Supervised Classification	Unsupervised Classification
Analyst defines 'training sites' of known classes	Algorithm groups pixels with no prior training
Software computes class signatures from training data	Pixels clustered by natural spectral groupings
Pixels assigned by rules — Minimum-Distance, Parallelepiped, Maximum-Likelihood	Clustering algorithms — ISODATA, K-means

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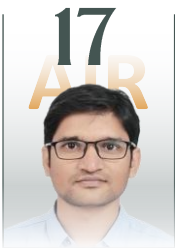
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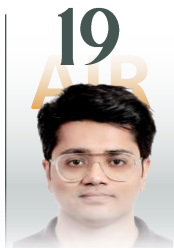
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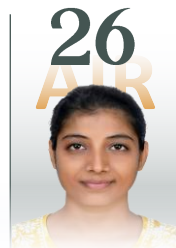
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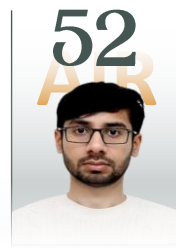
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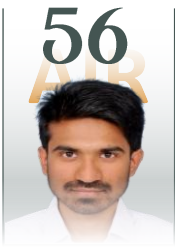
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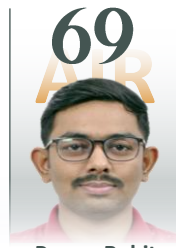
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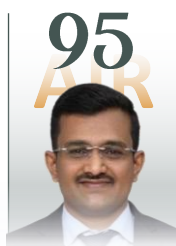
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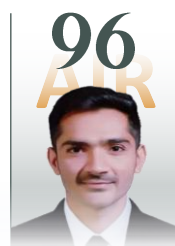
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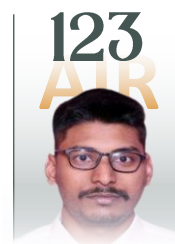
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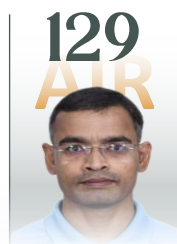
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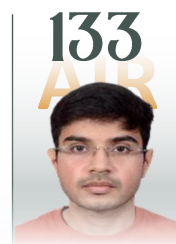
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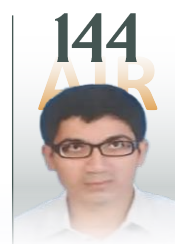
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