NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

(Name of the Subject/Lab Course): WATER RESOURCE ENGINEERING - 1

(COURSE CODE: (C313) **Programme: UG/PG**

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Verified by: 1) Name : 2) Sign : 3) Design : 4) Date :	***For Q.C only** 1) Name : 2) Sign : 3) Design : 4) Date :
Approved by (HOD) : 1) Name: Prof SYED FARRUKH ANWAR 2) Sign : 3) Date :	

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1.1 Vision of Institute

To be a leading institute of world class quality technical education with strong ethical values, preparing students for leadership in their fields for the dynamic and global careers, developing breakthrough environment for professional education and research.

Mission of Institute

M1: To enable the students to develop into outstanding professionals with high ethical standards capable of creating developing and managing local and global engineering enterprises.

M2: To ensure quality assurance by fulfilling expectations of the society and industry with state of the art technology.

M3: To attract and retain knowledgeable, creative, motivated, and highly skilled individuals whose leadership and contributions uphold the college tenets of education through student–centric learning methodologies.

M4: To provide opportunities for deserving students of all communities.

M5: To promote all round personality development of the students through interactions with alumni and academia.

1.1 Availability of statements of the Department

Vision of the Civil Engineering Department

To develop technically strong civil engineers having ethics and human values by providing quality education, enabling them to be competent in facing any challenges that may arise during their service in particular to the society and in general to the nation.

Mission of the Civil Engineering Department

M1: To provide conceptually strong technical knowledge relating to all fields of civil engineering braced with professional ethics.

M2: To adopt the latest developments in civil engineering to provide conducive environment for better teaching learning process.

M3: To provide adequate soft skills and make the students prepare for industry ready to grab the opportunities in this field.

M4: To encourage students to participate in various technical events at research institutes, institutes of higher learning so that they develop the capabilities to serve the nation effectively

1.2 PEO's of Civil Engineering Department

PEO1: Graduates will be capable of handling the Civil Engineering projects independently in their future assignments

PEO2: Graduates will be able to apply technical skills in their chosen fields in an ethical manner.

PEO3: Graduates will be able to implement their core concept to obtain solution for real time problems.

PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES (CE)

Program Outcomes	
PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering Problems.
PO2	**Problem analysis**: Identify, formulate, review research literature, and analyze Complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and Environmental considerations.
PO4	**Conduct investigations of complex problems**: User search-based knowledge and research methods including design of experiments, analysis and interpretation of data, and Synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and Modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities Relevant to the professional engineering practice.

PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and Need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and Write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply the set one's own work, as a member And leader in a team, to manage projects and in multi-disciplinary environments.
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological Change.
Program Specific Outcomes	
PSO1	**Professional Skills:** To plan, perform analysis, design, and estimate and execute all kinds of Civil Engineering Projects.
PSO2	**Problem Solving Skills:** To adopt latest technologies and use modern techniques, so as to execute projects efficiently and effectively.

6. Course Objectives

1. To Make the Students Excellent Civil Engineers and Respectable Human Beings Who Are Asset To The Country
2. To. Know the application of hydrology.
3. Development of hydraulic structure, canal, utilizing irrigation water effectively. Navigation system.
4. Development power plant, IMD rainfall record throughout India.
5. Prediction of rainfall, recording the rainfall data.

2. SYLLABUS

UNIT - I:

Introduction to engineering hydrology and its applications, Hydrologic cycle, types and forms of precipitation, rainfall measurement, types of rain gauges, computation of average rainfall over a basin, processing of rainfall data - Adjustment of record - Rainfall Double Mass Curve. Runoff- Factors affecting Runoff - Runoff over a Catchment - Empirical and Rational Formulae.

Abstraction from rainfall-evaporation, factors affecting evaporation, measurement of evaporation- Evapotranspiration- Penman and Blaney & Criddle Methods - Infiltration, factors affecting infiltration, measurement of infiltration, infiltration indices.

UNIT - II:

Distribution of Runoff - Hydrograph Analysis Flood Hydrography - Effective Rainfall - Base Flow - Base Flow Separation - Direct Runoff Hydrograph - Unit Hydrograph, definition, and limitations of applications of Unit hydrograph, derivation of Unit Hydrograph from Direct Runoff Hydrograph and vice versa - S-hydrograph, Synthetic Unit Hydrograph.

UNIT - III:

Ground water Occurrence, types of aquifers, aquifer parameters, porosity, specific yield, permeability, transmissivity and storage coefficient, Darcy's law, radial flow to wells in confined and unconfined aquifers. Types of well's, Well Construction - Well Development.

UNIT - IV:

Necessity and Importance of Irrigation, advantages and ill effects of irrigation, types of Irrigation, methods of application of Irrigation water, Indian agricultural soils, methods of improving soil fertility - Crop Roation, preparation of land for Irrigation, standards of quality for Irrigation water.

Soil-water-plant relationship, vertical distribution of soil moisture, soil moisture constants, soil moisture tension, consumptive use, Duty and delta, factors affecting duty- Design discharge for a water course. Depth and frequency of Irrigation, irrigation Efficiencies-Water Logging.

UNIT - V:

Classification of canals, Design of Irrigation canals by Kennedy's and Lacey's theories, balancing depth of cutting, IS standard for a canal design canal lining.

Design Discharge over a catchment, Computation of design discharge rational formula, SCS curve number method, flood frequency analysis- Introductory Part Only. Stream Gauging - measurement and estimation of stream flow.

TEXT BOOKS

- Engineering hydrology by Jayram Reddy, Laxmi publications pvt. Ltd., New Delhi.
- Irrigation and water power engineering by Punmia & Lal, Laxmi publications pvt. Ltd., New Delhi.

REFERENCES

- Elementary hydrology by V. P. Singh, PHI publications.
- Irrigation and Water Resources & Water Power by P. N. Modi, Standard Book House.
- Water Resources Engineering – I by Dr. G. Venkata Ramana, Acadamic Publishing Company.
- Irrigation Water Management by D. K. Manjundar, Printice Hall of India.
- Irrigation and Hydraulic structures by S. K. Grag.
- Applied hydrology by Ven Te Chow, David R. Maidment larry W. Mays Tata Mc. Graw Hill.
- Introduction to hydrology by Warren Viessvann, Jr, Garyl. Lewis, PHI.

NAWAB SHAH ALAM KHAN COLEEG OF ENGINEERING & TECHNOLOGY

Department of civil Engineering

Course Outcomes & CO-PO Mapping

Course Name: Hydrology & Water resource-Engineering -1

AY: 2020-21

Course Code: C-321 **YEAR:** 3-2

Name of the faculty: MOHD ABDUL AQUIL

Course Outcomes

After completing this course the student will be able to:

CO No.	Course Outcome	Taxonomy Level
CO1	**Understand** the basic concept of hydrological cycle and analyze hydro-metrological data based on different precipitation methods	**L2:Understand** **L4:Analyze**
CO2	**Define** and illustrate flood hydrograph and evaluate various types of runoff with respect to effective rainfall.	**L1:Remember** **L4:Understad** **L:5Evaluate**
CO3	**Classification** of irrigation, based on irrigation standards and applying controlled method for improvement of soil-water-plant relationship	**L2:understand** **L3:Apply**
CO4	**Classify** and solve a canal irrigation by using IS-Standard and design an unlined and lined irrigation canals based on theorem's	**L2:understand** **L3:Apply** **L6:Create**

Hydrology & Water Resources Engineering-1 (C-321)

A.Y:2020-21

CO-PO/PSO mapping Justification

CO1: **Understand** the basic concept of hydrological cycle and analyze hydro-metrological data based on different precipitation methods **(L2: Understand, L4: Analyze)**

	Mapping Level	Justification
PO1	3	Requires strong knowledge of environmental engineering for problem solving
PO2	3	directly relates to problem analysis, as students need to understand the basic principle and methods for solving a problem
PO3	2	To provide basic solution of engineering problems based on analysis of hydro-metrological data
PO4	2	To apply basic knowledge of engineering for understanding hydrological cycle
PSO1	3	To perform analyze of metrological data by using different rain gauge stations

CO2: **Define** and illustrate flood hydrograph and evaluate various types of runoff with respect to effective rainfall. **(L1: Remember, L4: Understand, L: 5Evaluate)**

	Mapping Level	Justification
PO1	3	Requires strong knowledge of water resource engineering for problem solving and also fundamentals of mathematics
PO2	3	problem analysis, is done for analyzing flood hydrograph to calculate maximum runoff
PO3	2	To provide solution for engineering problems based on effective rainfall
PO4	2	To solve complex problem based maximum probable flood by using flood hydrograph
PSO1	3	Design of runoff is done by using method of direct runoff

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY

NEW MALAKPET, HYDERABAD - 500024.

TIME TABLE FOR B.TECH III YEAR II SEMESTER 2020 - 2021 (ONLINE/OFFLINE MODE)

DEPARTMENT OF CIVIL ENGINEERING — wef:31-8-2020

Branch	Civil III-A							
Days	9:30 TO 10:20	10:20 TO 11:10	11:10 TO 12:00	12:00 TO 12:50	12:50 TO 1:30	1:30 TO 2:20	2:20 TO 3:10	3:10 TO 4:00
MON	SE-II		EE		LUNCH BREAK	FE		FOME
TUE	EE		SE-II			FE		FOME
WED	H&WRE		FOME			PSC		TUTORIALS
THUR	H&WRE		TUTORIALS			PSC		TUTORIALS
FRI	LABS SLOT					LAB SLOT		
SAT	PSC					TUTORIALS		

THEORY:

SE-II : MR SHAZEB
EE : MR USAMA
FE : MR USAMA
H&WRE : MR AQUIL
FOME : MR SAMEER
PSC : MR ZAKER
PSC:MR MUNEER UDDIN (VISITING FACULTY ON SAT)

HOD

HEAD
Department of Civil Engineering
NAWAB SHAH ALAM KHAN COLLEGE
OF ENGINEERING & TECHNOLOGY
16-4-1/A, New Malakpet, Hyderabad - 500 024.

PRINCIPAL

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NAWAB SHAH ALAM KHAN COLLEGE
OF ENGINEERING & TECHNOLOGY
16-4-1/A, New Malakpet, Hyderabad-500024
College Code:1610

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY								
NEW MALAKPET, HYDERABAD - 500024.								
TIME TABLE FOR B.TECH III YEAR II SEMESTER 2020 - 2021 (ONLINE/OFFLINE MODE)								
DEPARTMENT OF CIVIL ENGINEERING								wef:31-8-2020
Branch	Civil III-B							
Days	9:30 TO 10:20	10:20 TO 11:10	11:10 TO 12:00	12:00 TO 12:50	12:50 TO 1:30	1:30 TO 2:20	2:20 TO 3:10	3:10 TO 4:00
MON	SE-II		EE		LUNCH BREAK	FE		H&WRE
TUE	SE-II		EE			FE		H&WRE
WED	H&WRE		PSC			TUTORIALS		
THUR	FOME		FOME			LABS SLOT		
FRI	PSC		TUTORIALS			LABS SLOT		
SAT	PSC					TUTORIALS		

THEORY:

SE-II : MR SHAKEEB
EE : MS MANGA
FE : MR AMEER
H&WRE : MR AQUIL
FOME : MR SAMEER
PSC : MR TOUFEEQ
PSC:MR MUNEER UDDIN (VISITING FACULTY ON SAT)

HOD
Department of Civil Engineering
NAWAB SHAH ALAM KHAN COLLEGE
OF ENGINEERING & TECHNOLOGY
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NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY

NEW MALAKPET, HYDERABAD - 500024.

TIME TABLE FOR B.TECH III YEAR II SEMESTER 2020 - 2021 (ONLINE/OFFLINE MODE)

DEPARTMENT OF CIVIL ENGINEERING

wef:31-8-2020

Branch	Civil III-C							
Days	9:30 TO 10:20	10:20 TO 11:10	11:10 TO 12:00	12:00 TO 12:50	12:50 TO 1:30	1:30 TO 2:20	2:20 TO 3:10	3:10 TO 4:00
MON	FE		H&WRE		LUNCH BREAK	FOME		PSC
TUE	FE		H&WRE			FOME		PSC
WED	SE-II		EE			TUTORIALS		
THUR	EE		SE-II			LABS SLOT		
FRI	TUTORIALS		PSC			LABS SLOT		
SAT	PSC					TUTORIALS		

THEORY:

SE-II : MR JAVED
EE : MS MOHEMMEDI
FE : MR AHMED
H&WRE : MR ISMAIL
FOME : MR SAMEER
PSC : MR AHMED
PSC:MR MUNEER UDDIN (VISITING FACULTY ON SAT)

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Department of Civil Engineering
NAWAB SHAH ALAM KHAN COLLEGE
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16-4-1/A, New Malakpet, Hyderabad - 500 024

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OF ENGINEERING & TECHNOLOGY

11. Lecture schedule with methodology being used/adopted Lessonplan

Branch Civil III-A

S. No.	Period No.	Topic	Regular/ Additional	Teaching aids used PPT/ OHP/ BB	Remarks
		UNIT-1			
1	2	Introduction to engineering hydrology Its applications. Hydrologic cycle,	Regular	BB	
2	4	types and forms of precipitation rainfall measurement, types of rain gauges	Regular	BB	
3	6	computation of average rainfall over a basin Geometric Design of Railway Tracks	Regular	BB, PPT	
4	8	processing of rainfall data Adjustment of record– Rainfall Double Mass Curve	Regular	BB	
5	10	Runoff- Factors affecting Runoff - Runoff over a Catchment - Empirical and Rational Formulae	Regular	BB, PPT	
6	12	Abstraction from rainfall- evaporation, factors affecting evaporation, measurement of evaporation	Regular	BB	
7	14	Evapotranspiration- Penman and Blaney & Criddle Methods	Regular	BB	
8	16	Infiltration, factors affecting infiltration, Measurement of infiltration, infiltration indices.	Regular	BB	
		UNIT-II			
9	18	Distribution of Runoff Hydrograph Analysis Flood Hydrograph - Effective Rainfall - Base Flow	Regular	BB, PPT	
10	20	Direct Runoff Hydrograph - Unit Hydrograph	Regular	BB	
11	22	definition, and limitations of applications of Unit	Regular	BB, PPT	

		hydrograph			
12	24	Derivation of Unit Hydrograph from Direct Runoff Hydrograph and vice versa.	Regular	BB	
13	26	S-hydrograph Synthetic Unit Hydrograph	Regular	BB	
		UNIT-III			
14	28	Ground water Occurrence types of aquifers, aquifer parameters,	Regular	BB	
15	30	porosity, specific yield, permeability transmissivity and storage coefficient Darcy's law	Regular	BB	
16	32	radial flow to wells in confined and unconfined aquifers	Regular	BB	
17	34	Types of well's, Well Construction Well Development	Regular	BB, PPT	
		UNIT-IV			
18	36	Necessity and Importance of Irrigation, advantages and ill effects of irrigation, types of Irrigation,	Regular	BB	
19	38	methods of application of Irrigation water, Indian agricultural soils, methods of improving soil fertility - Crop Rotation, preparation of land for Irrigation	Regular	BB	
20	40	Standards of quality for Irrigation water. Soil-water-plant relationship, vertical distribution of soil moisture,	Regular	BB	

21	42	soil moisture constants, soil moisture tension, consumptive use, Duty and delta,	Regular	BB	
22	44	Factors affecting duty- Design discharge for a water course.	Regular	BB	
23	46	. Depth and frequency of Irrigation, irrigation Efficiencies-Water Logging.	Regular	BB	
		UNIT-V			
24	48	Classification of canals Design of Irrigation canals by Kennedy's and Lacey's theories,	Regular	BB	
25	50	Balancing depth of cutting, IS standard for a canal design canal lining.	Regular	BB	
26	52	Design Discharge over a catchment	Regular	BB	
27	54	Computation of design discharge rational formula, SCS curve number method	Regular	BB	
28	56	flood frequency analysis-Introductory Part Only	Regular	BB	
29	58	Stream Gauging	Regular	BB	
30	60	Measurement and estimation of stream flow.	Regular	BB	

12. Lesson schedule

Branch Civil III-A

NAWAB SHAH ALAM KHAN COLLEGE OF ENGG & TECH			
NEW MALAKPET HYDERABAD-24			
Department of CIVIL Engineering			
B.Tech(CIVIL) IIInd Year II Semester 2020-2021			
TEACHING PLAN			
Subject: WRE-1			Faculty Name: Mohd Abdul Aquil
S. No.	Date	Topic	Total No. of Periods
		UNIT-I	
1	24/3/2021	Introduction to engineering hydrology Its applications. Hydrologic cycle,	2
2	25/3/2021	types and forms of precipitation rainfall measurement, types of rain gauges	2
3	31/3/2021	computation of average rainfall over a basin Geometric Design of Railway Tracks	2
4	1/4/2021	processing of rainfall data - Adjustment of record– Rainfall Double Mass Curve	2
5	7/4/2021	Runoff- Factors affecting Runoff - Runoff over a Catchment - Empirical and Rational Formulae	2
6	8/4/2021	Abstraction from rainfall-evaporation, factors affecting evaporation, measurement of evaporation	2
7	14/4/2021	Evapotranspiration- Penman and Blaney & Criddle Methods	2
8	15/4/2021	Infiltration, factors affecting infiltration, Measurement of infiltration, infiltration indices.	2
		UNIT-II	
9	22/4/2021	Distribution of Runoff Hydrograph Analysis Flood Hydrograph - Effective Rainfall - Base Flow	2
10	28/4/2021	Direct Runoff Hydrograph - Unit Hydrograph	2
11	29/4/2021	definition, and limitations of applications of Unit hydrograph	2
12	5/5/2021	Derivation of Unit Hydrograph from Direct Runoff Hydrograph and vice versa.	2
13	6/5/2021	S-hydrograph Synthetic Unit Hydrograph	2
		UNIT-III	

14	12/5/2021	Ground water Occurrence types of aquifers, aquifer parameters,	2
15	13/5/2021	porosity, specific yield, permeability transmissivity and storage coefficient Darcy's law	2
16	19/5/2021	radial flow to wells in confined and unconfined aquifers	2
17	20/5/2021	Types of well's, Well Construction Well Development	2
		UNIT-IV	
18	26/5/2021	Necessity and Importance of Irrigation, advantages and ill effects of irrigation, types of Irrigation,	2
19	27/5/2021	methods of application of Irrigation water, Indian agricultural soils, methods of improving soil fertility - Crop Rotation, preparation of land for Irrigation	2
20	2/6/2021	Standards of quality for Irrigation water. Soil-water-plant relationship, vertical distribution of soil moisture,	2
21	3/6/2021	soil moisture constants, soil moisture tension, consumptive use, Duty and delta,	2
22	9/6/2021	Factors affecting duty- Design discharge for a water course.	2
23	10/6/2021	. Depth and frequency of Irrigation, irrigation Efficiencies-Water Logging.	2
		UNIT-V	
24	16/6/2021	Classification of canals Design of Irrigation canals by Kennedy's and Lacey's theories,	2
25	17/6/2021	Balancing depth of cutting, IS standard for a canal design canal lining. Design Discharge over a catchment	2
26	23/6/2021	Design Discharge over a catchment	2
27	24/6/2021	Computation of design discharge rational formula, SCS curve number method	2
28	30/6/2021	Flood frequency analysis- Introductory Part Only.	2
29	1/7/2021	, Stream Gauging	2
30	7/7/2021	Measurement and estimation of stream flow.	2

11. Lecture schedule with methodology being used/adopted Lesson plan

Branch Civil III-B

S. No.	Period No.	Topic	Regular/ Additional	Teaching aids used PPT/ OHP/ BB	Remarks
		UNIT-1			
1	1	Introduction to engineering hydrology Its applications. Hydrologic cycle,	Regular	BB	
2	2	types and forms of precipitation rainfall measurement, types of rain gauges	Regular	BB	
3	4	computation of average rainfall over a basin Geometric Design of Railway Tracks	Regular	BB, PPT	
4	5	processing of rainfall data Adjustment of record– Rainfall Double Mass Curve	Regular	BB	
5	7	Runoff- Factors affecting Runoff - Runoff over a Catchment - Empirical and Rational Formulae	Regular	BB, PPT	
6	8	Abstraction from rainfall- evaporation, factors affecting evaporation, measurement of evaporation	Regular	BB	
7	9	Evapotranspiration- Penman and Blaney & Criddle Methods	Regular	BB	
8	11	Infiltration, factors affecting infiltration, Measurement of infiltration, infiltration indices.	Regular	BB	
		UNIT-II			
9	12	Distribution of Runoff Hydrograph Analysis Flood Hydrograph - Effective Rainfall - Base Flow	Regular	BB, PPT	
10	13	Direct Runoff Hydrograph - Unit Hydrograph	Regular	BB	
11	15	definition, and limitations of applications of Unit	Regular	BB, PPT	

		hydrograph			
12	16	Derivation of Unit Hydrograph from Direct Runoff Hydrograph and vice versa.	Regular	BB	
13	17	S-hydrograph Synthetic Unit Hydrograph	Regular	BB	
		UNIT-III			
14	19	Ground water Occurrence types of aquifers, aquifer parameters,	Regular	BB	
15	20	porosity, specific yield, permeability transmissivity and storage coefficient Darcy's law	Regular	BB	
16	21	radial flow to wells in confined and unconfined aquifers	Regular	BB	
17	23	Types of well's, Well Construction Well Development	Regular	BB, PPT	
		UNIT-IV			
18	24	Necessity and Importance of Irrigation, advantages and ill effects of irrigation, types of Irrigation,	Regular	BB	
19	25	methods of application of Irrigation water, Indian agricultural soils, methods of improving soil fertility - Crop Rotation, preparation of land for Irrigation	Regular	BB	
20	27	Standards of quality for Irrigation watcr. Soil-water-plant relationship, vertical distribution of soil moisture,	Regular	BB	

21	28	soil moisture constants, soil moisture tension, consumptive use, Duty and delta,	Regular	BB	
22	30	Factors affecting duty- Design discharge for a water course.	Regular	BB	
23	31	. Depth and frequency of Irrigation, irrigation Efficiencies-Water Logging.	Regular	BB	
		UNIT-V			
24	32	Classification of canals Design of Irrigation canals by Kennedy's and Lacey's theories,	Regular	BB	
25	34	Balancing depth of cutting, IS standard for a canal design canal lining.	Regular	BB	
26	35	Design Discharge over a catchment	Regular	BB	
27	36	Computation of design discharge rational formula, SCS curve number method	Regular	BB	
28	38	flood frequency analysis-Introductory Part Only	Regular	BB	
29	39	Stream Gauging	Regular	BB	
30	40	Measurement and estimation of stream flow.	Regular	BB	

12. Lesson schedule

Branch Civil III-B

NAWAB SHAH ALAM KHAN COLLEGE OF ENGG & TECH			
NEW MALAKPET HYDERABAD-24			
Department of CIVIL Engineering			
B.Tech(CIVIL) IIInd Year Semester-II 2020-2021			
TEACHING PLAN			
Subject: WRE-1		Faculty Name: Abdul Aquil	
S. No.	Date	Topic	Total No. of Periods
		UNIT-I	
1	22/3/2021	Introduction to engineering hydrology Its applications. Hydrologic cycle,	1
2	23/3/2021	types and forms of precipitation rainfall measurement, types of rain gauges	1
3	24/3/2021	computation of average rainfall over a basin Geometric Design of Railway Tracks	2
4	30/3/2021	processing of rainfall data - Adjustment of record– Rainfall Double Mass Curve	1
5	31/3/2021	Runoff- Factors affecting Runoff - Runoff over a Catchment - Empirical and Rational Formulae	2
6	5/4/2021	Abstraction from rainfall-evaporation, factors affecting evaporation, measurement of evaporation	1
7	6/4/2021	Evapotranspiration- Penman and Blaney & Criddle Methods	1
8	7/4/2021	Infiltration, factors affecting infiltration, Measurement of infiltration, infiltration indices.	2
		UNIT-II	
9	12/4/2021	Distribution of Runoff Hydrograph Analysis Flood Hydrograph - Effective Rainfall - Base Flow	1
10	19/4/2021	Direct Runoff Hydrograph - Unit Hydrograph	1
11	20/4/2021	definition, and limitations of applications of Unit hydrograph	2
12	25/4/2021	Derivation of Unit Hydrograph from Direct Runoff Hydrograph and vice versa.	1
13	26/4/2021	S-hydrograph Synthetic Unit Hydrograph	1
		UNIT-III	

14	27/4/2021	Ground water Occurrence types of aquifers, aquifer parameters,	2
15	2/5/2021	porosity, specific yield, permeability transmissivity and storage coefficient Darcy's law	1
16	3/5/2021	radial flow to wells in confined and unconfined aquifers	1
17	4/5/2021	Types of well's, Well Construction Well Development	2
		UNIT-IV	
18	9/5/2021	Necessity and Importance of Irrigation, advantages and ill effects of irrigation, types of Irrigation,	1
19	10/5/2021	methods of application of Irrigation water, Indian agricultural soils, methods of improving soil fertility - Crop Rotation, preparation of land for Irrigation	1
20	11/5/2021	Standards of quality for Irrigation water. Soil-water-plant relationship, vertical distribution of soil moisture,	2
21	17/5/2021	soil moisture constants, soil moisture tension, consumptive use, Duty and delta,	1
22	18/5/2021	Factors affecting duty- Design discharge for a water course.	2
23	23/5/2021	. Depth and frequency of Irrigation, irrigation Efficiencies-Water Logging.	1
		UNIT-V	
24	24/5/2021	Classification of canals Design of Irrigation canals by Kennedy's and Lacey's theories,	1
25	25/5/2021	Balancing depth of cutting, IS standard for a canal design canal lining. Design Discharge over a catchment	2
26	30/5/2021	Design Discharge over a catchment	1
27	31/5/2021	Computation of design discharge rational formula, SCS curve number method	1
28	1/6/2021	Flood frequency analysis- Introductory Part Only.	2
29	6/6/2021	, Stream Gauging	1
30	7/6/2021	Measurement and estimation of stream flow.	1

11. Lecture schedule with methodology being used/adopted Lesson plan

Branch Civil III-C

S. No.	Period No.	Topic	Regular/ Additional	Teaching aids used PPT/ OHP/ BB	Remarks
		UNIT-1			
1	2	Introduction to engineering hydrology Its applications. Hydrologic cycle,	Regular	BB	
2	4	types and forms of precipitation rainfall measurement, types of rain gauges	Regular	BB	
3	6	computation of average rainfall over a basin Geometric Design of Railway Tracks	Regular	BB, PPT	
4	8	processing of rainfall data Adjustment of record– Rainfall Double Mass Curve	Regular	BB	
5	10	Runoff- Factors affecting Runoff - Runoff over a Catchment - Empirical and Rational Formulae	Regular	BB, PPT	
6	12	Abstraction from rainfall- evaporation, factors affecting evaporation, measurement of evaporation	Regular	BB	
7	14	Evapotranspiration- Penman and Blaney & Criddle Methods	Regular	BB	
8	16	Infiltration, factors affecting infiltration, Measurement of infiltration, infiltration indices.	Regular	BB	
		UNIT-II			
9	18	Distribution of Runoff Hydrograph Analysis Flood Hydrograph - Effective Rainfall - Base Flow	Regular	BB, PPT	
10	20	Direct Runoff Hydrograph - Unit Hydrograph	Regular	BB	
11	22	definition, and limitations of applications of Unit	Regular	BB, PPT	

		hydrograph			
12	24	Derivation of Unit Hydrograph from Direct Runoff Hydrograph and vice versa.	Regular	BB	
13	26	S-hydrograph Synthetic Unit Hydrograph	Regular	BB	
		UNIT-III			
14	28	Ground water Occurrence types of aquifers, aquifer parameters,	Regular	BB	
15	30	porosity, specific yield, permeability transmissivity and storage coefficient Darcy's law	Regular	BB	
16	32	radial flow to wells in confined and unconfined aquifers	Regular	BB	
17	34	Types of well's, Well Construction Well Development	Regular	BB, PPT	
		UNIT-IV			
18	36	Necessity and Importance of Irrigation, advantages and ill effects of irrigation, types of Irrigation,	Regular	BB	
19	38	methods of application of Irrigation water, Indian agricultural soils, methods of improving soil fertility - Crop Rotation, preparation of land for Irrigation	Regular	BB	
20	40	Standards of quality for Irrigation water. Soil-water-plant relationship, vertical distribution of soil moisture,	Regular	BB	

21	42	soil moisture constants, soil moisture tension, consumptive use, Duty and delta,	Regular	BB	
22	44	Factors affecting duty-Design discharge for a water course.	Regular	BB	
23	46	. Depth and frequency of Irrigation, irrigation Efficiencies-Water Logging.	Regular	BB	
		UNIT-V			
24	48	Classification of canals Design of Irrigation canals by Kennedy's and Lacey's theories,	Regular	BB	
25	50	Balancing depth of cutting, IS standard for a canal design canal lining.	Regular	BB	
26	52	Design Discharge over a catchment	Regular	BB	
27	54	Computation of design discharge rational formula, SCS curve number method	Regular	BB	
28	56	flood frequency analysis-Introductory Part Only	Regular	BB	
29	58	Stream Gauging	Regular	BB	
30	60	Measurement and estimation of stream flow.	Regular	BB	

12. Lesson schedule

Branch Civil III-C

NAWAB SHAH ALAM KHAN COLLEGE OF ENGG & TECH			
NEW MALAKPET HYDERABAD-24			
Department of CIVIL Engineering			
B.Tech(CIVIL) IIInd Year Semester-II 2020-2021			
TEACHING PLAN			
Subject: WRE-1		Faculty Name: Abdul Aquil	
S. No.	Date	Topic	Total No. of Periods
		UNIT-I	
1	21/3/2021	Introduction to engineering hydrology Its applications. Hydrologic cycle,	2
2	22/3/2021	types and forms of precipitation rainfall measurement, types of rain gauges	2
3	28/3/2021	computation of average rainfall over a basin Geometric Design of Railway Tracks	2
4	29/3/2021	processing of rainfall data - Adjustment of record– Rainfall Double Mass Curve	2
5	4/4/2021	Runoff- Factors affecting Runoff - Runoff over a Catchment - Empirical and Rational Formulae	2
6	11/4/2021	Abstraction from rainfall-evaporation, factors affecting evaporation, measurement of evaporation	2
7	12/4/2021	Evapotranspiration- Penman and Blaney & Criddle Methods	2
8	18/4/2021	Infiltration, factors affecting infiltration, Measurement of infiltration, infiltration indices.	2
		UNIT-II	
9	19/4/2021	Distribution of Runoff Hydrograph Analysis Flood Hydrograph - Effective Rainfall - Base Flow	2
10	25/4/2021	Direct Runoff Hydrograph - Unit Hydrograph	2
11	26/4/2021	definition, and limitations of applications of Unit hydrograph	2
12	2/5/2021	Derivation of Unit Hydrograph from Direct Runoff Hydrograph and vice versa.	2
13	9/5/2021	S-hydrograph Synthetic Unit Hydrograph	2
		UNIT-III	

14	10/5/2021	Ground water Occurrence types of aquifers, aquifer parameters,	2
15	16/5/2021	porosity, specific yield, permeability transmissivity and storage coefficient Darcy's law	2
16	17/5/2021	radial flow to wells in confined and unconfined aquifers	2
17	23/5/2021	Types of well's, Well Construction Well Development	2
		UNIT-IV	
18	24/5/2021	Necessity and Importance of Irrigation, advantages and ill effects of irrigation, types of Irrigation,	2
19	30/5/2021	methods of application of Irrigation water, Indian agricultural soils, methods of improving soil fertility - Crop Rotation, preparation of land for Irrigation	2
20	31/5/2021	Standards of quality for Irrigation water. Soil-water-plant relationship, vertical distribution of soil moisture,	2
21	6/6/2021	soil moisture constants, soil moisture tension, consumptive use, Duty and delta,	2
22	7/6/2021	Factors affecting duty- Design discharge for a water course.	2
23	13/6/2021	. Depth and frequency of Irrigation, irrigation Efficiencies-Water Logging.	2
		UNIT-V	
24	14/6/2021	Classification of canals Design of Irrigation canals by Kennedy's and Lacey's theories,	2
25	20/6/2021	Balancing depth of cutting, IS standard for a canal design canal lining. Design Discharge over a catchment	2
26	21/6/2021	Design Discharge over a catchment	2
27	27/6/2021	Computation of design discharge rational formula, SCS curve number method	
28	28/6/2021	Flood frequency analysis- Introductory Part Only.	2
29	4/7/2021	, Stream Gauging	2
30	5/7/2021	Measurement and estimation of stream flow.	2

14.Detailed Notes

UNIT-I

HYDROLOGY

Introduction

The amount of precipitation flowing over the land surface and the evapotranspiration losses from land and water bodies were discussed in Lesson 2.1. This water ultimately is returned to the sea through various routes either overland or below ground. Evaporation from the ocean, which is actually a large water body, contributes to the bulk of water vapour to the atmosphere, driven by the energy of the sun. This process completes the ***hydrologic cycle*** (Figure 1), which keeps the water content of the Earth in a continuous dynamic state.

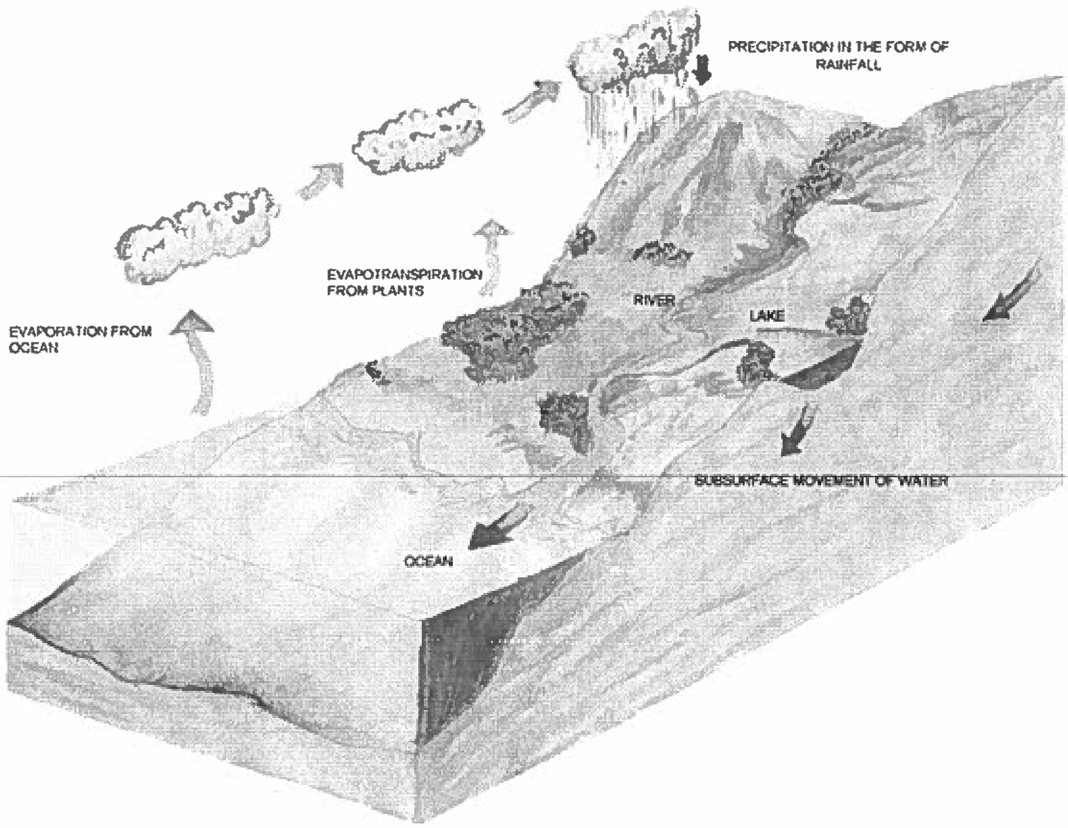


FIGURE 1. HYDROLOGIC CYCLE

In this lesson, we would study the fate of the raindrops as they fall on the earth and flow down the land surface to meet streams and rivers. Part of the water, as it flows down the land surface, infiltrates into the soil and ultimately contributes to the ground water reserve.

Overland flow and inter flow

During a precipitation event, some of the rainfall is intercepted by vegetation before it reaches the ground and this phenomenon is known as ***interception***. At places without any vegetation, the rain directly touches the land surface. This water can infiltrate into the soils, form puddles called the ***depression storage***, or flow as a thin sheet of water across the land surface. The water trapped in puddles ultimately evaporates or infiltrates. If the soil is initially quite dry, then most of the water infiltrates into the ground. The amount of rainfall in excess of the infiltrated quantity flows over the ground surface following the land slope. This is the ***overland flow***. The portion that infiltrates moves through an unsaturated portion of the soil in a vertical direction for some depth till it meets the water table, which is the free surface of a fully saturated region with water (the ground water reserve). Part of the water in the ***unsaturated zone*** of the soil (also called the ***vadose zone***) moves in a lateral direction, especially if the ***hydraulic conductivity*** in the horizontal direction is more than that in vertical direction and emerges at the soil surface at some location away from the point of entry into the soil. This phenomenon is known as ***interflow***. Figure 2 illustrates the flow components schematically.

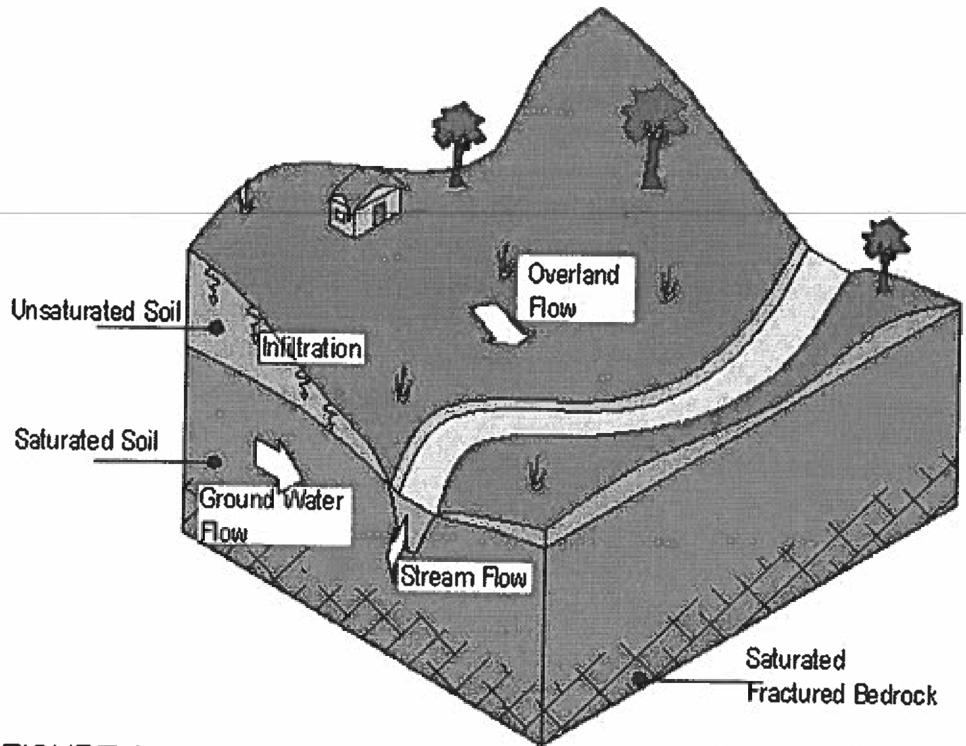


FIGURE 1. Surface and sub-surface flow components of hydrologic cycle

Hydraulic conductivity is a measure of the ability of a fluid to flow through a porous medium and is determined by the size and shape of the pore spaces in the medium and their degree of interconnection and also by the viscosity of the fluid. Hydraulic conductivity can be expressed as the volume of fluid that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Stream flow and groundwater flow

If the unsaturated zone of the soil is uniformly permeable, most of the infiltrated water percolates vertically. Infiltrated water that reaches the ground water reserve raises the water table. This creates a difference in potential and the inclination of the water table defines the variation of the ***piezo metric head*** in horizontal direction. This difference in energy drives the ground water from the higher to the lower head and some of it ultimately reaches the stream flowing through the valley. This contribution of the stream flow is known as Base flow, which usually is the source of dry-weather flow in perennial streams.

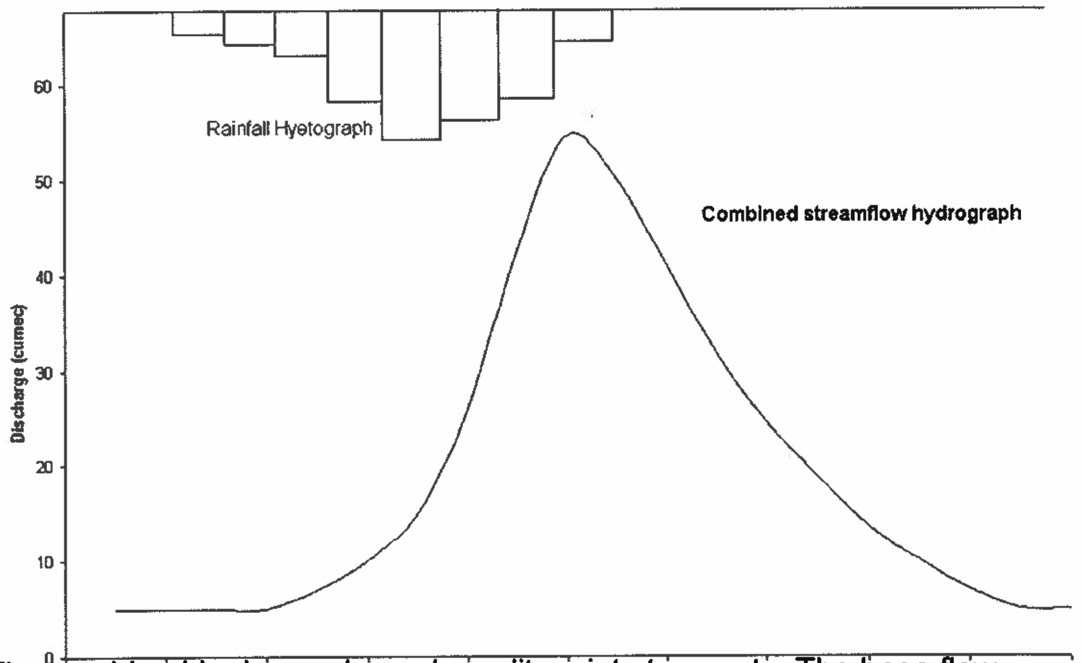
During a storm event, the overland flow contributes most of the immediate flow of the stream. The total flow of the stream, however, is the sum of overland flow, interflow and ***base flow***. It must be remembered that the rates at which these three components of runoff move varies widely. Stream flow moves fastest, followed by interflow and then ground water flow, which may take months and sometimes even years to reach the stream.

Note that for some streams, the water table lies quite some distance below the bottom of the stream. For these streams, there is a loss of water from the river bed percolating into the ground ultimately reaching the water table. The reason for a low water table could possibly be due to natural geographic conditions, or a dry climate, or due to heavy pumping of water in a nearby area.

The hydrograph and hyetograph

As the name implies, Hydrograph is the plot of the stream flow at a particular location as a function of time. Although the flow comprises of the contributions from overland flow, interflow and groundwater flow, it is useful to separate only the groundwater flow (the base flow) for hydrograph analysis, which is discussed in Lesson 2.3.

In Lesson 2.1, precipitation was discussed. The hyetograph is the graphical plot of the rainfall plotted against time. Traditionally, the hyetograph is plotted upside down as shown in Figure 3, which also shows a typical hydrograph and its components. Splitting up of a complete stream flow hydrograph into its components requires the knowledge of the geology of the area and of the factors like surface slope, etc. Nevertheless, some of the simpler methods to separate base flow are described subsequently.



The combined hydrograph can be split up into two parts: The base flow (Figure 4) and the overland flow added to interflow (Figure 5)

FIGURE 2. Rainfall hyetograph and corresponding flow hydrograph

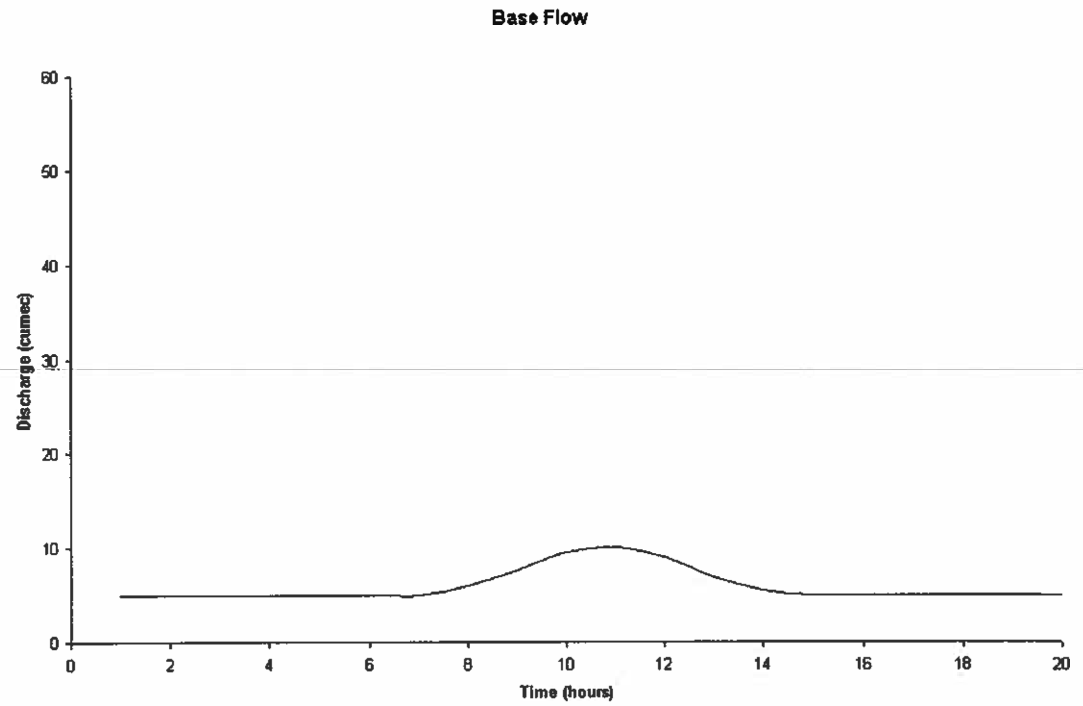


FIGURE 3. Typical baseflow discharge hydrograph

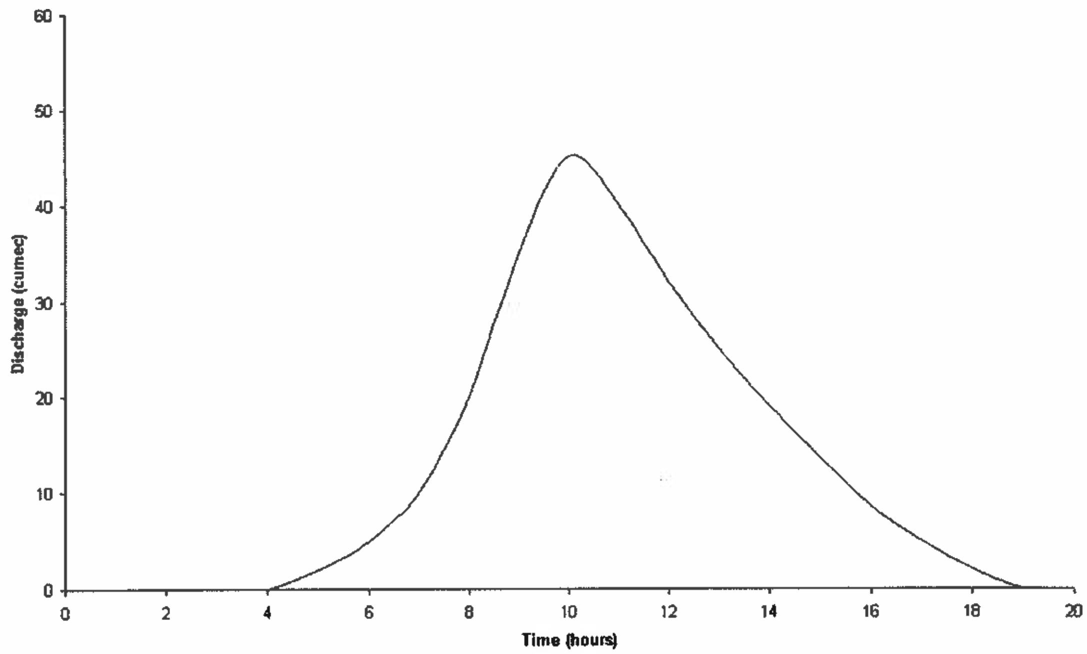


FIGURE 5. Overland flow and interlfow combined hydrogrph

Effective rainfall

A part of the rainfall reaching the earth's surface infiltrates into the ground and finally joins the ground water reservoirs or moves laterally as interflow. Of the interflow, only the quick response or prompt interflow contributes to the immediate rise of the stream flow hydrograph. Hence, the rainfall component causing perceptible change in the stream flow is only a portion of the total rainfall recorded over the catchment. This rainfall is called the effective rainfall.

The infiltration capacity varies from soil to soil and is also different for the same soil in its moist and dry states. If a soil is initially dry, the infiltration rate (Or the infiltration capacity of the soil) is high. If the precipitation is lower than the infiltration capacity of the soil, there will be no overland flow, though interflow may still occur. As the rainfall persists, the soil become moist and infiltration rate decreases, causing the balance precipitation to produce surface runoff. Mathematical representation of the infiltration capacity and the methods to deduct infiltration for finding effective rainfall is described later in this lesson.

Methods of base flow separation

Consider the total runoff hydrograph shown in Figure 3, for which the corresponding effective rainfall hyetograph over the catchment is known. In this example, the flow in the stream starts rising at about 4 hours, and the peak is seen to reach at about 10.5 hours. The direct runoff is presumed to end at about 19.5 hours. Though we have separately shown the base flow and the direct runoff in Figures 4 and 5, it is only a guess, as what is observed flowing in the stream is the total discharge. A couple of procedures are explained in the following sub-sections to separate the two flows. For this, we consider another hydrograph (Figure 6), where the total flow is seen to be reducing initially, and then a sudden rise takes place, probably due to a sudden burst of rainfall.

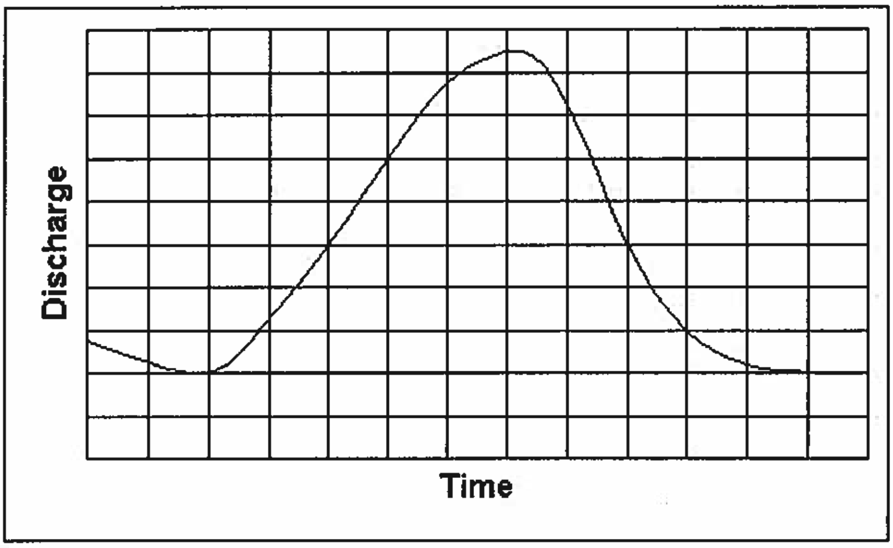


FIGURE 6. A typical hydrograph requiring base flow separation

Method 1

One method to separate the base flow from the total runoff hydrograph is to join points X and Z as shown in Figure 7. This method is considered not very accurate, though.

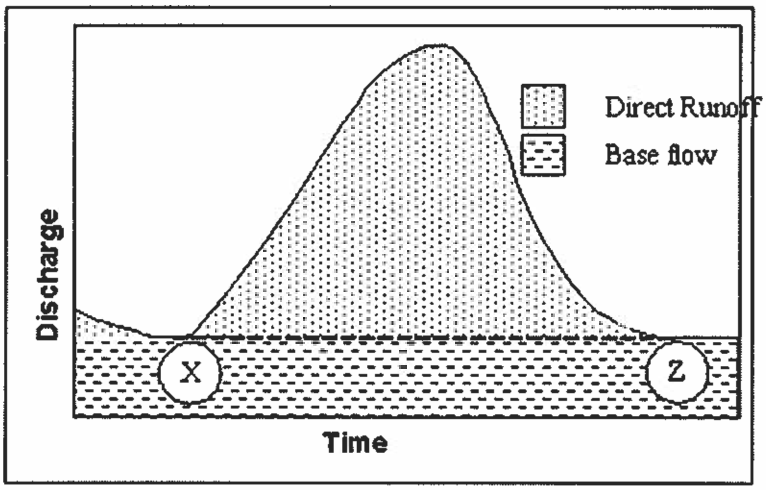


FIGURE 7. Method 1 to separate base flow

Method 2

This method suggests the extension of the base flow graph (Figure 8) along its general trend before the rise of the hydrograph up to a point P directly below the runoff hydrograph peak. From P, a straight line PQ is drawn to meet the hydrograph at point Q, which as separated from P in the time scale by an empirical relation given as:

$$N \text{ (in days)} = 0.862\, A^{0.2} \quad (1)$$

Where, A is the area of the drainage basin in square kilometers.

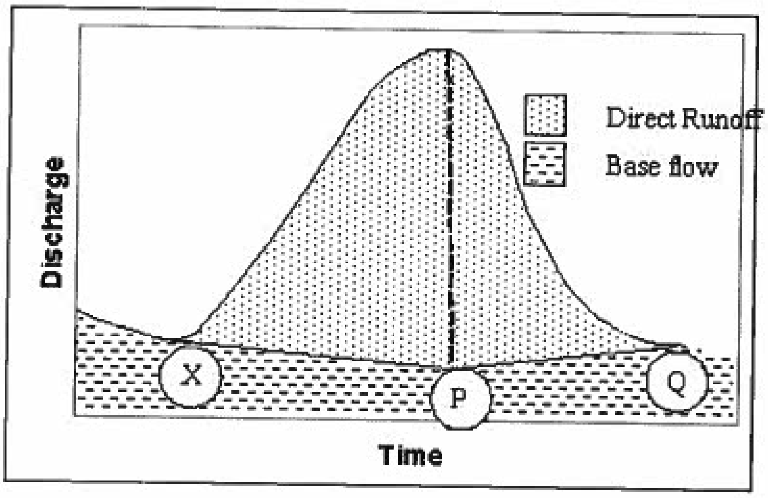


FIGURE 8. Method 2 to separate base flow

Method 3

The third method makes use of composite base flow recession curve, as shown in Figure 9. The following points are to be kept in mind:

X – A follows the trend of the initial base flow recession curve prior to the start of the direct runoff hydrograph

B – Q follows the trend of the later stage base flow recession curve.

B is chosen to lie below the point of inflection (C) of the hydrograph.

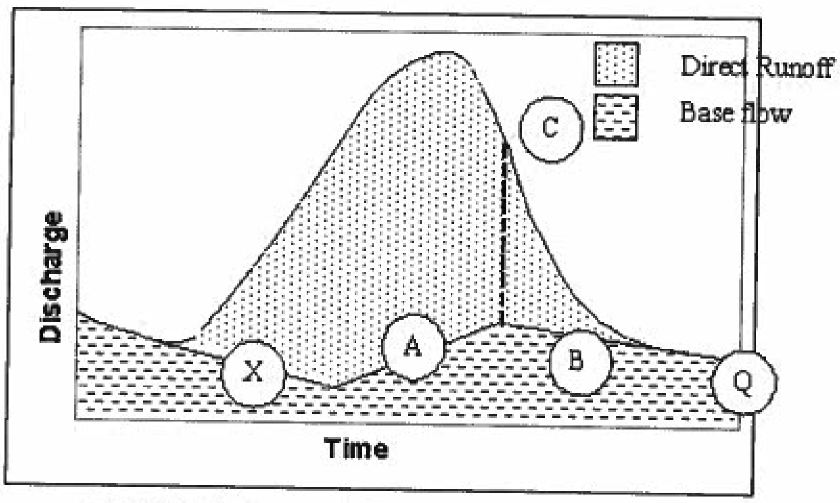


FIGURE 9. Method 3 for base flow separation

2.2.6 Estimation of infiltration

The rate at which water infiltrates into a ground is called the ***infiltration capacity.*** When a soil is dry, the infiltration rate is usually high compared to when the soil is moist. For an initially dry soil subjected to rain, the infiltration capacity curve shows an exponentially decaying trend as shown in Figure 10. The observed trend is due to the fact that when the soil is initially dry, the rate of infiltration is high but soon decreases, as most of the soil gets moist. The rate of infiltration reaches a uniform rate after some time.

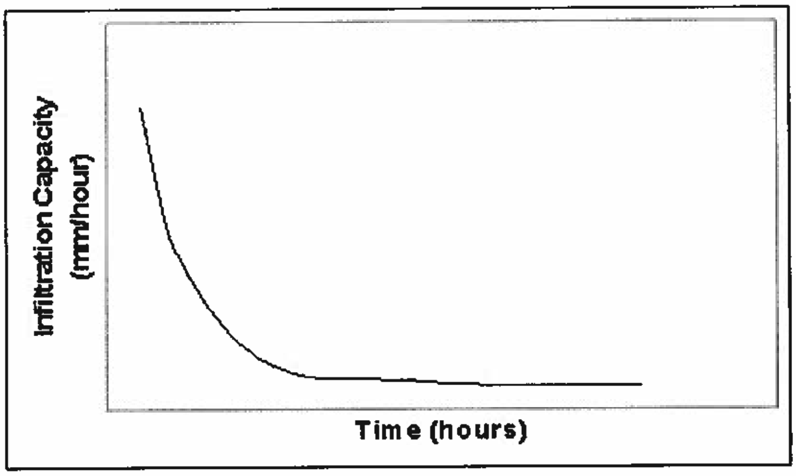


FIGURE 10. Infiltration rate decreasing as more water infiltrates

Interestingly, if the supply of continuous water from the surface is cutoff, then the infiltration capacity starts rising from the point of discontinuity as shown in below.

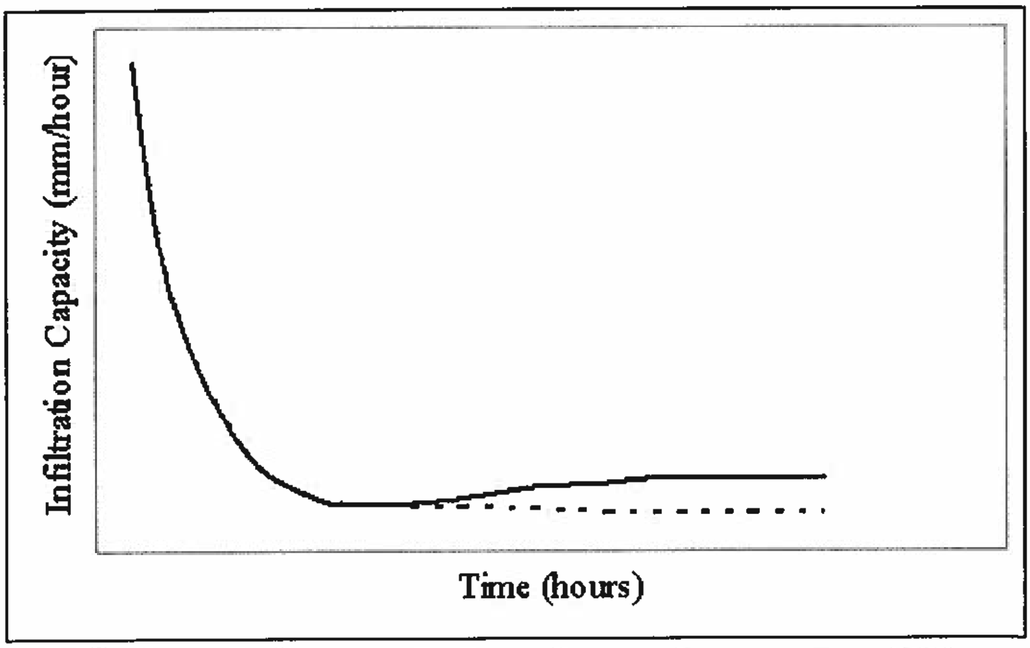


FIGURE 11. Infiltration capacity rising after supply from top is cut off

For consistency in hydrological calculations, a constant value of infiltration rate for the entire storm duration is adopted. The average infiltration rate is called the Infiltration Index and the two types of indices commonly used are explained in the next section.

2.2.7 Infiltration indices

The two commonly used infiltration indices are the following:

φ – index W

– index

2.2.7.1 The φ - index

This is defined as the rate of infiltration above which the rainfall volume equals runoff volume, as shown in Figure12.

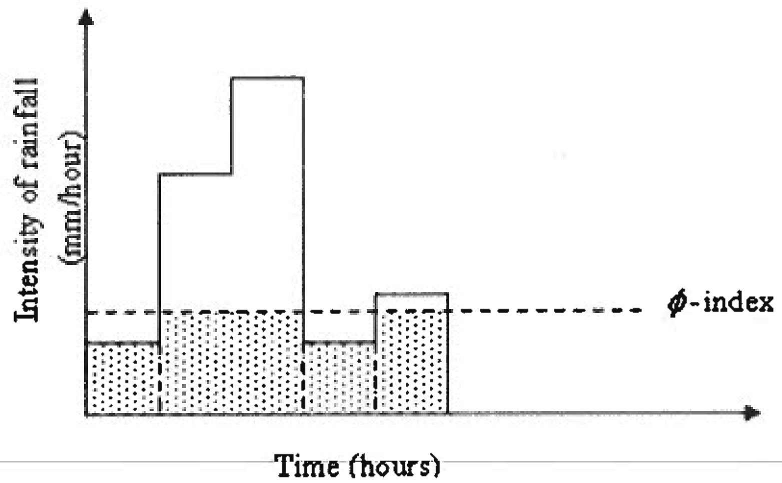


FIGURE 12. Illustrating the ϕ- index

The method to determine the - index would usually involve some trial. Since the infiltration capacity decreases with a prolonged storm, the use of an average loss rate in the form of - index is best suited for design storms occurring on wet soils in which case the loss rate reaches a final constant rate prior to or early in the storm. Although the - index is sometimes criticized as being too simple a measure for infiltration, the concept is quite meaningful in the study of storm runoff from large watersheds. The evaluation of the infiltration process is less precise for large watersheds. The data is never sufficient to derive an infiltration curve. Under the circumstances, the - index is the only feasible alternative to predict the infiltration from the storm.

2.2.7.2 The W –index

This is the average infiltration rate during the time when the rainfall intensity exceeds the infiltration rate.

Thus, ***W*** may be mathematically calculated by dividing the total infiltration

Expressed as a depth of water) divided by the time during which the rainfall intensity exceeds the infiltration rate. Total infiltration may be fund out as under:

Total infiltration = Total precipitation – Surface runoff – Effective storm retention

UNIT-II

UNIT HYDROGPH

Introduction

It was explained what a hydrograph is and that it indicates the response of water flow of a given catchment to a rainfall input. It consists of flow from different phases of runoff, like the overland flow, interflow and base flow. Methods to separate base flow from the total stream flow hydrograph to obtain the direct runoff hydrograph as well as infiltration loss from the total rainfall hyetograph to determine the effective rainfall have been discussed. In this lesson, a relationship between the direct runoff hydrograph of a catchment observed at a location (the catchment outlet) and the effective rainfall over the catchment causing the runoff are proposed to be dealt with.

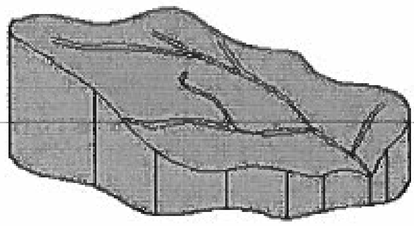
We start with discussing how the various aspects of a catchment's characteristics affect the shape of the hydrograph.

Hydrograph and the catchment's characteristics

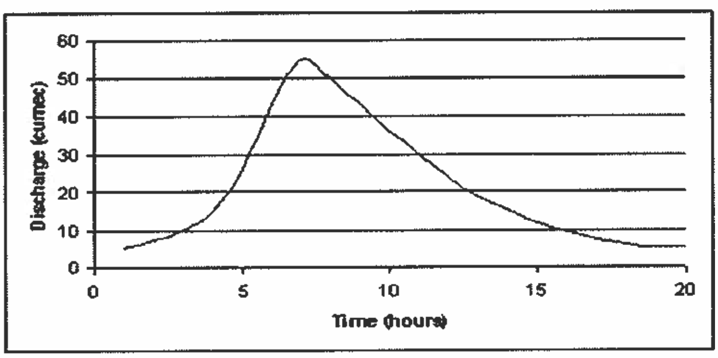
The shape of the hydrograph depends on the characteristics of the catchment. The major factors are listed below.

Shape of the catchment

A catchment that is shaped in the form of a pear, with the narrow end towards the upstream and the broader end nearer the catchment outlet (Figure 1a) shall have a hydrograph that is fast rising and has a rather concentrated high peak



(a)

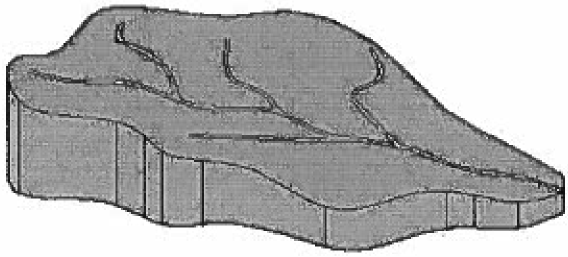


(b)

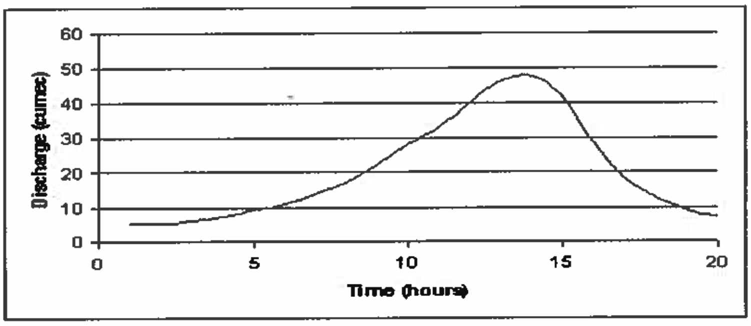
Figure 1. (a) Pear shaped catchment with narrow end towards upstream and blunt end towards outlet
(b) Corresponding hydrograph for a hypothetical rainfall

(Figure 1b).

A catchment with the same area as in Figure 1 but shaped with its narrow end towards the outlet has a hydrograph that is slow rising and with a somewhat lower peak (Figure 2) for the same amount of rainfall.



(a)



(b)

FIGURE 2. (a) Catchment with narrow end towards outlet
(b) Corresponding hydrograph for a hypothetical rainfall

Though the volume of water that passes through the outlets of both the catchments is same (as areas and effective rainfall have been assumed same for both), the peak in case of the latter is ***attenuated.***

Size of the catchment

Naturally, the volume of runoff expected for a given rainfall input would be proportional to the size of the catchment. But this apart, the response characteristics of large catchment (say, a large river basin) is found to be significantly different from a small catchment (like agricultural plot) due to the relative importance of the different phases of runoff (overland flow, inter flow, base flow, etc.) for these two catchments. Further, it can be shown from the mathematical calculations of surface runoff on two impervious catchments (Like urban areas, where infiltration becomes negligible), that the non-linearity between rainfall and runoff becomes perceptible for smaller catchments.

Slope

Slope of the main stream cutting across the catchment and that of the valley sides or general land slope affects the shape of the hydrograph. Larger slopes generate more velocity than smaller slopes and hence can dispose of runoff faster. Hence, for smaller slopes, the balance between rainfall input and the runoff rate gets stored temporally over the area and is able to drain out gradually over time. Hence, for the same rainfall input to two catchments of the same area but with with different slopes, the one with a steeper slope would generate a hydrograph with steeper rising and falling limits.

Here, two catchments are presented, both with the same area, but with different slopes. A similar amount of rainfall over the flatter catchment (Figure 3) Produces a slow-rising moderated hydrograph than that produced by the steeper catchment (Figure 4).

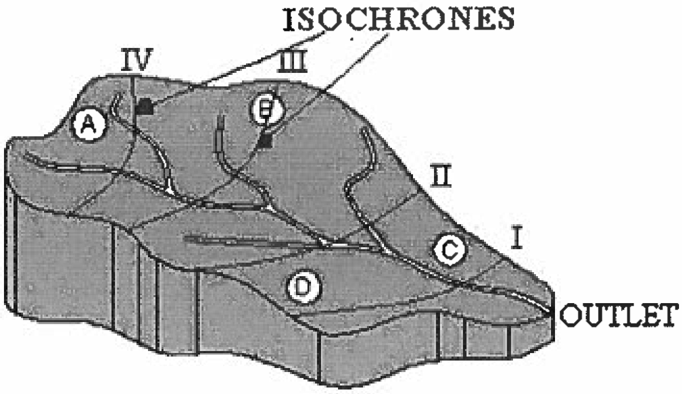


FIGURE 5. Typical isochrones over a catchment

Effect of rainfall intensity and duration on hydrograph

If the rainfall intensity is constant, then the rainfall duration determines in part the peak flow and time period of the surface runoff.

The concept of ***Isochrones*** might be helpful for explaining the effective of the duration of a uniform rainfall on the shape of hydrograph. Isochrones are imaginary lines across the catchment (see Figure 5) from where water particles traveling downward take the same time to reach the catchment outlet.

If the rainfall event starts at time zero, then the hydrograph at the catchment outlet will go on rising and after a time't', the flow from the isochrones ***I*** would have reached the catchment outlet. Thus, after a gap of time t, all the area A_1 contributes to the outflow hydrograph.

Continuing in this fashion, it can be concluded that after a lapse of time '4 t', all the catchment area would be contributing to the catchment outflow, provided the rain continues to fall for at least up to a time 4 t. If rainfall continues further, then the hydrograph would not increase further and thus would reach a plateau.

Effect of spatial distribution of rainfall on hydrograph

The effect of spatial distribution of rainfall, that is, the distribution in space, may be explained with the catchment image showing the isochrones as in Figure 6. Assume that the regions between the isochrones receive different amounts of rainfall (shown by the different shades of blue in the figure).

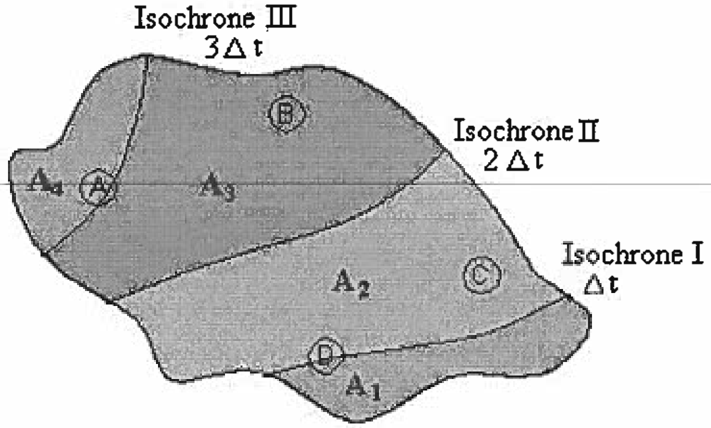


FIGURE 6. Areas of catchment subjected to different amounts of rainfall

If it is assumed now that only area A_1 receives rainfall but the other areas do not, then since this region is nearest to the catchment outlet, the resulting hydrograph immediately rises. If the rainfall continues for a time more than 't', then the hydrograph would reach a saturation equal to $r_e.A_1$, where r_e is the intensity of the effective rainfall.

Assume now that a rainfall of constant intensity is falling only within area A_4, which Is farthest from the catchment outlet. Since the lower boundary of A_4 is the Isochrones III, there would be no resulting hydrograph till time '3 t'.

If the rain continues beyond a time '4 t', then the hydrograph would reach a saturation level equal to $r_e A_4$ where r_e is the effective rainfall intensity.

Direction of storm movement

The direction of the storm movement with respect to the orientation of the catchments drainage network affects both the magnitude of peak flow and the duration of the hydrograph. The storm direction has the greatest effect on elongated catchments, where storms moving upstream tend to produce lower peaks and broader time base of surface runoff than storms that move downstream towards the catchment outlet. This is due to the fact that for an upstream moving storm, by the time the contribution from the upper catchment reaches the outlet, there is almost no contribution from the lower watershed.

Rainfall intensity

Increase in rainfall intensity increases the peak discharge and volume of runoff for a given infiltration rate. In the initial phases of the storm, when the soil is dry, a rainfall intensity less than infiltration rate produces no surface runoff. Gradually, as the rain progresses, the soil saturates and the infiltration rate reduces to a steady rate.

The relation between rainfall intensity and the discharge, strictly speaking, is not linear, which means that doubling the rainfall intensity does not produce a doubling of the hydrograph peak value. However, this phenomenon is more pronounced for small watersheds, such as an urban area. However, in the catchment scale, due to the uncertainty of all the hydrological parameters, it might be assumed that the rainfall runoff relation follows a linear relationship. This assumption is made use of in the unit hydrograph concept, which is explained in the next section.

The Unit Hydrograph

The Unit Hydrograph (abbreviated as UH) of a drainage basin is defined as a hydrograph of direct runoff resulting from one unit of effective rainfall which is uniformly distributed over the basin at a uniform rate during the specified period of time known as unit time or unit duration. The unit quantity of effective rainfall is generally taken as 1mm or 1cm and the outflow hydrograph is expressed by the discharge ordinates. The unit duration may be 1 hour, 2 hour, 3 hours or so depending upon the size of the catchment and storm characteristics. However, the unit duration cannot be more than the time of concentration, which is the time that is taken by the water from the furthest point of the catchment to reach the outlet.

Figure 7 shows a typical unit hydrograph.

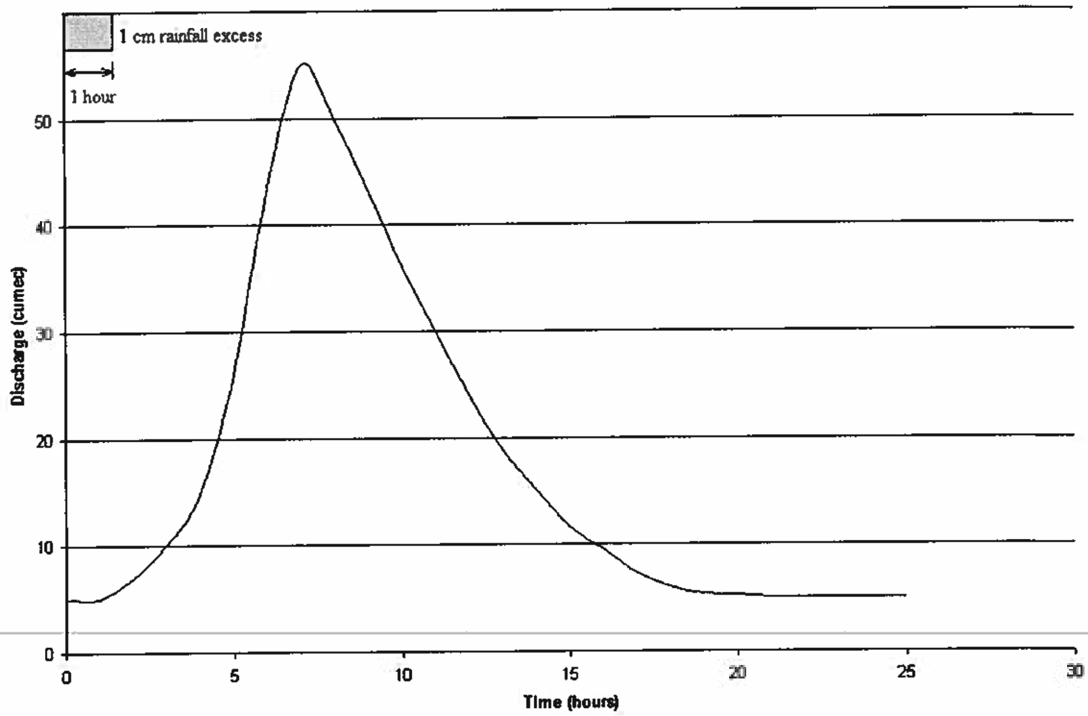


FIGURE 7. A typical unit hydrograph

Unit hydrograph assumptions

The following assumptions are made while using the unit hydrograph principle:

1. Effective rainfall should be uniformly distributed over the basin, that is, if there are 'N' rain gauges spread uniformly over the basin, then all the gauges should record almost same amount of rainfall during the specified time.

2. Effective rainfall is constant over the catchment during the unit time.

3. The direct runoff hydrograph for a given effective rainfall for a catchment is always the same irrespective of when it occurs. Hence, any previous rainfall event is not considered. This antecedent precipitation is otherwise important because of its effect on soil-infiltration rate, depression and detention storage, and hence, on the resultant hydrograph.

4. The ordinates of the unit hydrograph are directly proportional to the effective rainfall hyetograph ordinate. Hence, if a 6-h unit hydrograph due to 1 cm rainfall is given, then a 6-h hydrograph due to 2 cm rainfall would just mean doubling the unit hydrograph ordinates. Hence, the base of the resulting hydrograph (from the start or rise up to the time when discharge becomes zero) also remains the same.

Unit hydrograph limitations

Under the natural conditions of rainfall over drainage basins, the assumptions of the unit hydrograph cannot be satisfied perfectly. However, when the hydrologic data used in the unit hydrograph analysis are carefully selected so that they meet the assumptions closely, the results obtained by the unit hydrograph theory have been found acceptable for all practical purposes.

In theory, the principle of unit hydrograph is applicable to a basin of any size. However, in practice, to meet the basic assumption in the derivation of the unit hydrograph as closely as possible, it is essential to use storms which are uniformly distributed over the basin and producing rainfall excess at uniform rate. Such storms rarely occur over large areas. The size of the catchment is, therefore, limited although detention, valley storage, and infiltration all tend to minimize the effect of rainfall variability. The limit is generally considered to be about 5000 sq. km. beyond which the reliability of the unit hydrograph method diminishes. When the basin area exceeds this limit, it has to be divided into sub-basins and the unit hydrograph is developed for each sub-basin. The flood discharge at the basin outlet is then estimated by combining the sub-basin floods, using ***flood routing*** procedures.

Note:
Flood Routing: This term is used to denote the computation principles for estimating the values of flood discharge with time and in space, that is, along the length of a river. Details about flood routing procedures may be had from the following book:
M H Chaudhry (1993) Open channel hydraulics, Prentice Hall of India

Application of the unit hydrograph

Calculations of direct runoff hydrograph in catchment due to a given rainfall event (with recorded rainfall values), is easy if a unit hydrograph is readily available. Remember that a unit hydrograph is constructed for a unit rainfall falling for a certain T-hours, where T may be any conveniently chosen time duration. The effective rainfall hyetograph, for which the runoff is to be calculated using the unit hydrograph, is obtained by deducting initial and

Infiltration losses from the recorded rainfall. This effective rainfall hyetograph is divided into blocks of T-hour duration. The runoff generated by the effective rainfall for each T-hour duration is then obtained and summed up to produce the runoff due to the total duration.

Direct runoff calculations using unit hydrograph

Assume that a 6-hour unit hydrograph (UH) of a catchment has been derived, whose ordinates are given in the following table and a corresponding graphical representation is shown in Figure8.

Time (hours)	Discharge (m^3/s)
0	0
6	5
12	15
18	50
24	120
30	201
36	173
42	130
48	97
54	66
60	40
66	21
72	9
78	3.5
84	2

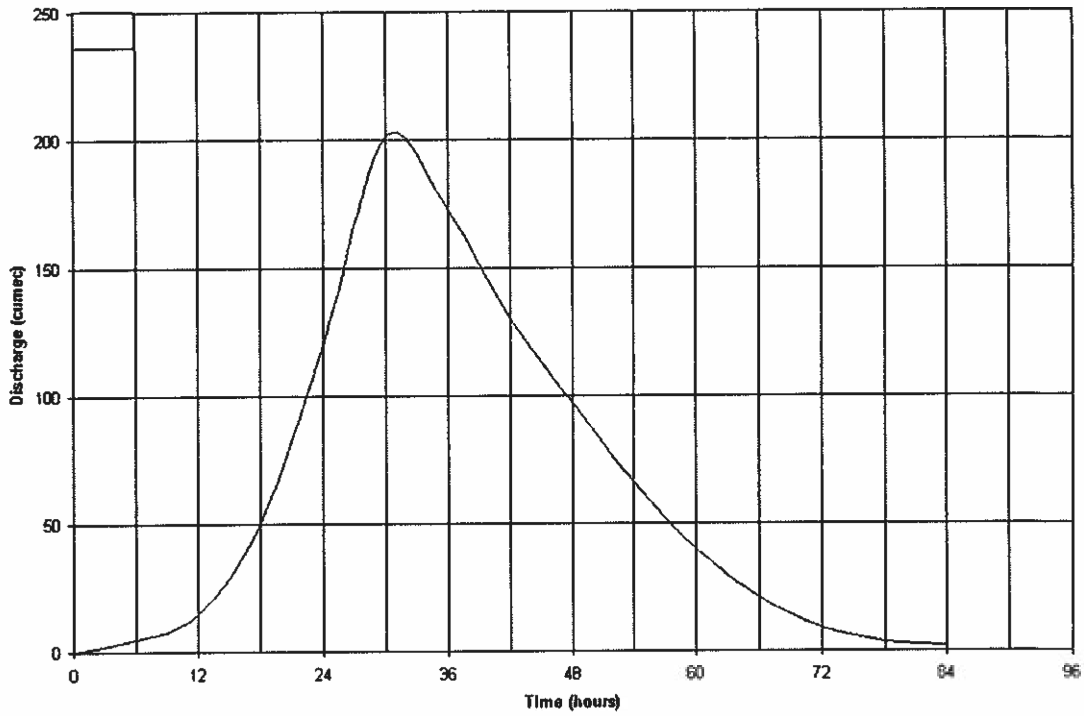


FIGURE 8. A 6-hour unit hydrograph

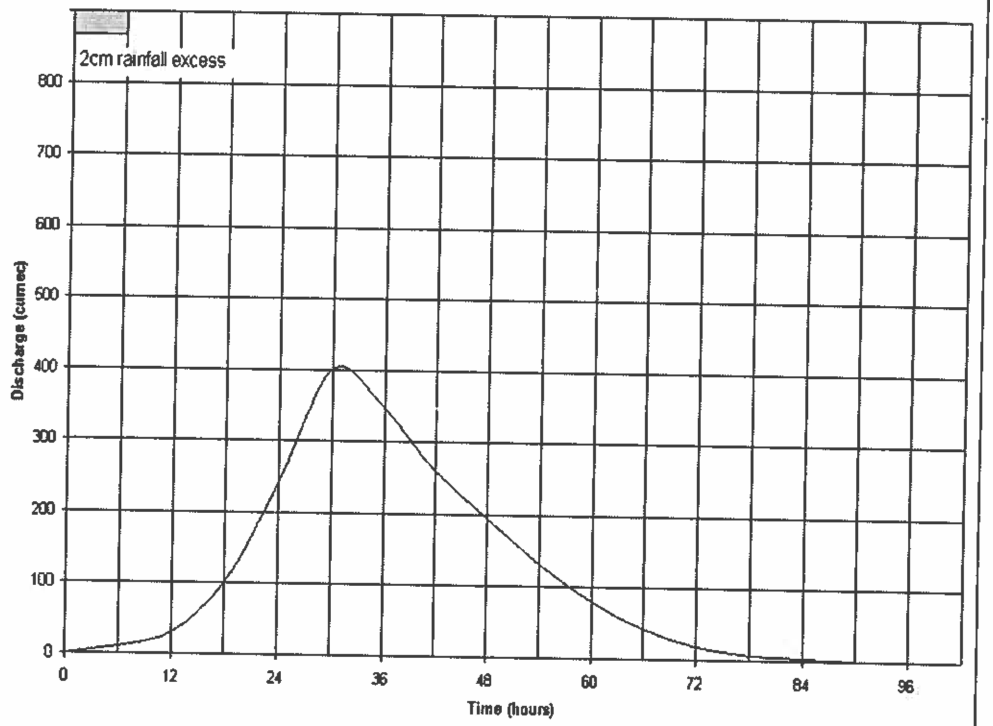
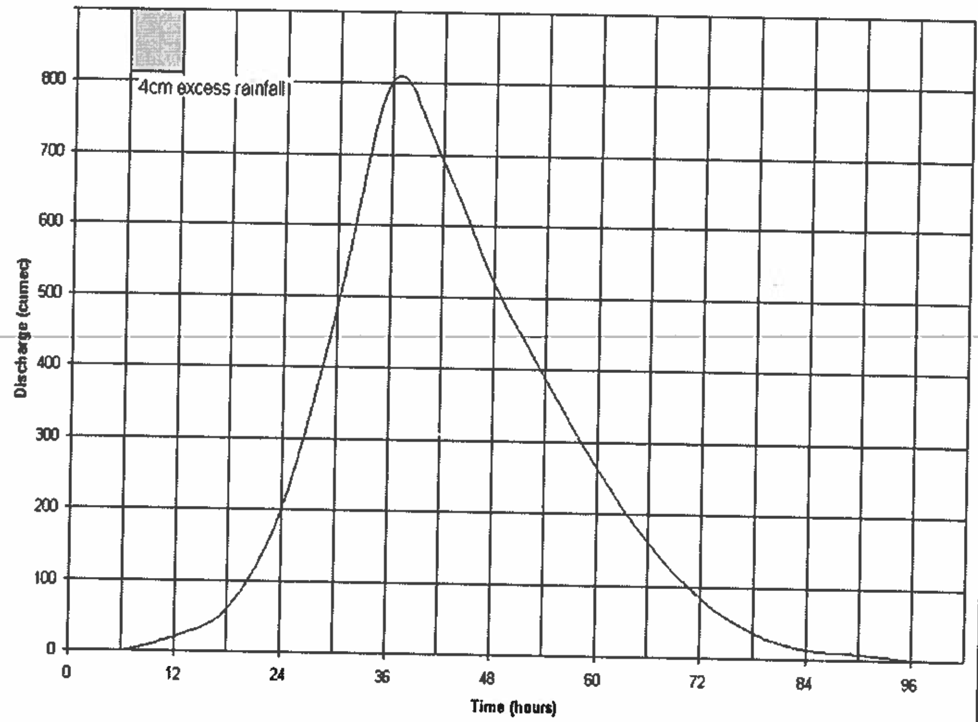
Assume further that the effective rainfall hyetograph (ERH) for a given storm on the region has been given as in the following table:

Time (hours)	Effective Rainfall (cm)
0	0
6	2
12	4
18	3

This means that in the first 6 hours, 2cm excess rainfall has been recorded, 4cm in the next 6 hours, and 3cm in the next.

The direct runoff hydrograph can then be calculated by the three separate hyetographs for the three excess rainfalls by multiplying the ordinates of the hydrograph by the corresponding rainfall amounts. Since the rainfalls of 2cm, 4cm and 3cm occur in successive 6-hour intervals, the derived DRH corresponding to each rainfall is delayed by 6 hours appropriately.

These have been shown in the figures indicated.

DRH for 2cm excess rainfall in 0-6 hours	 FIGURE 9. DRH corresponding to 2cm excess rainfall in 0 - 6 hours
DRH for 4cm excess rainfall in 6-12hours	 FIGURE 10. DRH corresponding to 4cm excess rainfall during 6 - 12 hours

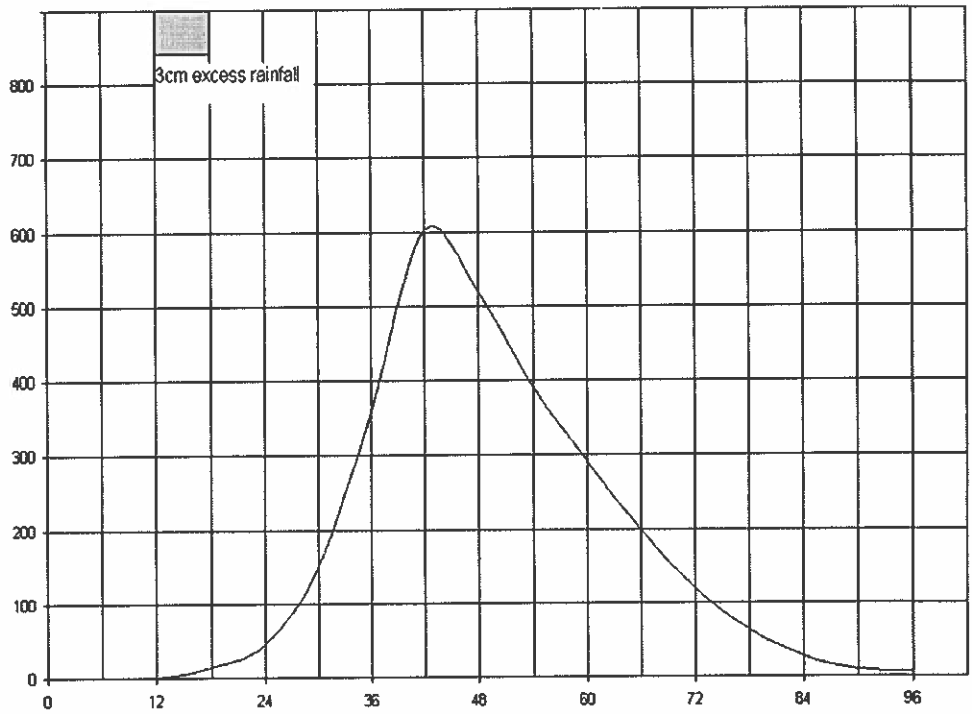
DRH for 3cm excess rainfall in 12-18 hours	

FIGURE 11. DRH corresponding to 3cm excess rainfall during 12 - 18 hours

The final hydrograph is found out by adding the three individual hydrographs, as shown in Figure 12.

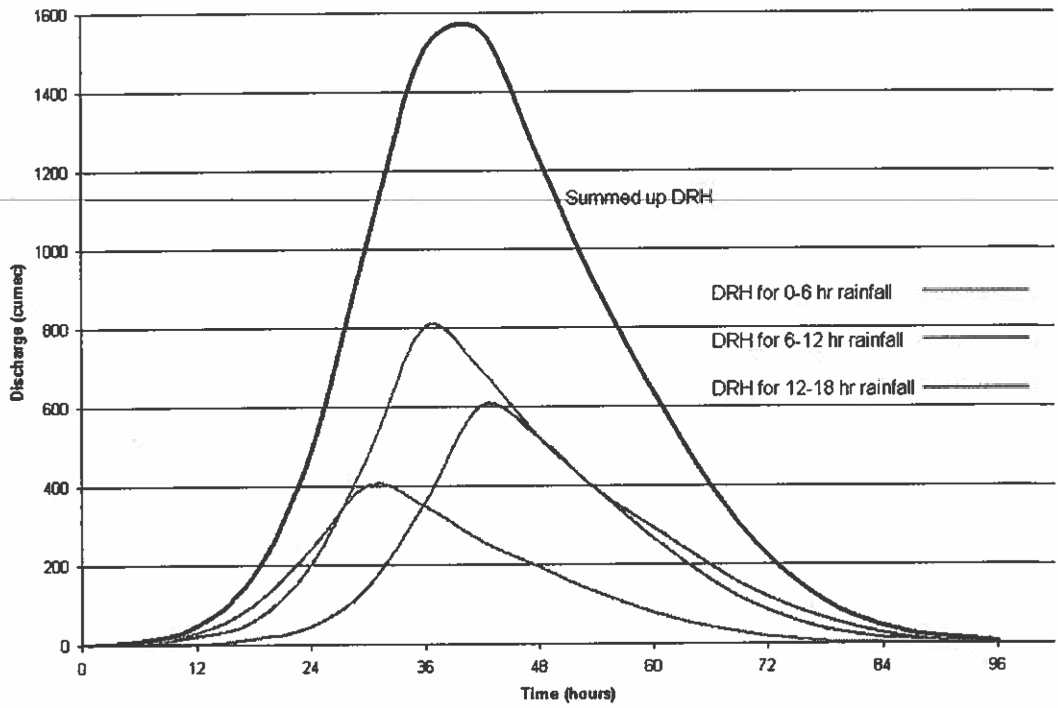


FIGURE 12. Final direct runoff hydrograph derived from summation of individual DRHs

The calculations to generate the direct runoff hydrograph (DRH) from a given UH and ERH can be conveniently done using a spreadsheet program, like the Microsoft XL.

A sample calculation for the example solved graphically is given in the following table. Note the 6 hour shift of the DRHs in the second and subsequent hours.

Time (hours)	Unit Hydrograph ordinates (m^3/s)	Direct runoff due to 2 cm excess rainfall in first 6 hours (m^3/s) (I)	Direct runoff due to 4 cm excess rainfall in second 6 hours (m^3/s) (II)	Direct runoff due to 3 cm excess rainfall in third 6 hours (m^3/s) (III)	Direct runoff Hydrograph (m^3/s) (I)+(II)+(III)
0	0	0	0	0	0
6	5	10	0	0	10
12	15	30	20	0	50
18	50	100	60	15	175
24	120	240	200	45	485
30	201	402	480	150	1032
36	173	346	804	360	1510
42	130	260	692	603	1555
48	97	194	520	519	1233
54	66	132	388	390	910
60	40	80	264	291	635
66	21	42	160	198	400
72	9	18	84	120	222
78	3.5	7	36	63	106
84	2	4	14	27	45
90		0	8	10.5	18.5
96		0	0	6	6

The last column in the above table gives the ordinates of the DRH produced by the ERH. If the base flow is known or estimated (Lesson 2.2), then this should be added to the DRH to obtain the 6-houly ordinates of the flood hydrograph.

The S – curve

This is a concept of the application of a hypothetical storm of 1 cm ERH of infinite duration spread over the entire catchment uniformly. This may be done by shifting the UH by the T-duration for a large number of periods. The

The average intensity of the effective rainfall producing the S – curve is 1/T

(mm/h) and the equilibrium discharge is given as $X10^4) \; m3 / H$ where, A is (T

The area of the catchment in Km^2 and T is the unit hydrograph duration in hours.

Application of the S – curve

Though the ***S – curve*** is a theoretical concept, it is an effective tool to derive a ***t – hour*** UH from a ***T – hour*** UH, when ***it*** is smaller than T or ***t*** is larger than T but not an exact multiple of T. In case ***it*** is a multiple of T, the corresponding UH can be obtained without the aid of an S – hydrograph by summing up the required number of UH, lagged behind by consecutive T – hours.

For all other cases shift the original S – hydrograph as derived for the T – hour UH by ***t*** hours to obtain a lagged S- hydrograph. Subtract the ordinates of the second curve from the first to obtain the ***t*** – hour graph. Next, scale the ordinates of the discharge hydrograph by a factor ***t/T***, to obtain the actual ***t*** – hour UH which would result due to a total 1 cm of rainfall over the catchment. This is illustrated by the S-curve derived in the previous section.

Recall that the S-curve was obtained from a 6-hour UH. Let us derive the UH for a 3- hour duration. Since we do not know the ordinates of the S-curve at every 3-hour interval, we interpolate and write them in a tabular form as given in the table below:

Time	S-curve ordinates as derived from 6-hr UH (I)	S-curve ordinates as derived from 6-hr UH but with inter-polated values (II)	S-curve ordinates as derived from 6-hr UH lagged By 3 hrs. (III)	Difference of the two S-curves (II) – (III) (IV)	3-hr UH ordinates Col. (IV) divided by (3hr/6hr) = (IV)*2
(hours)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
0	0	0		0	
3		2.5	0	2.5	
6	5	5	2.5	2.5	
9		12.5	5	7.5	
12	20	20	12.5	7.5	
15		45	20	25	
18	70	70	45	25	
21		130	70	60	
24	190	190	130	60	
27		290.5	190	100.5	
30	391	391	290.5	100.5	

33		477.5	391	86.5	
36	564	564	477.5	86.5	
39		629	564	65	
42	694	694	629	65	
45		742.5	694	48.5	
48	791	791	742.5	48.5	
51		824	791	33	
54	857	857	824	33	
57		877	857	20	
60	897	897	877	20	
63		907.5	897	10.5	
66	918	918	907.5	10.5	
69		922.5	918	4.5	
72	927	927	922.5	4.5	
75		928.75	927	1.75	
78	930.5	930.5	928.75	1.75	
81		931.35	930.5	0.85	
84	932.5	932.5	931.35	1.15	
87		932.5	932.5	0	
90	932.5	932.5	932.5	0	
93		932.5	932.5	0	
96	932.5	932.5	932.5	0	

Derivation of unit hydrograph

An observed flood hydrograph at a stream flow gauging station could be a hydrograph resulting from an isolated intense short – duration storm of nearly uniform distribution in time and space, or it could be due to a complex rainfall event of varying intensities. In the former case, the observed hydrograph would mostly be single peaked whereas for the latter, the hydrograph could be multi peaked depending on the variation in the rainfall intensities. For the purpose of this course, we shall only consider rainfall to be more or less uniformly distributed in time and space for the purpose of demonstrating the derivation of unit hydrograph. The procedure may be broadly divided into the following steps:

1. Obtain as many rainfall records as possible for the study area to ensure that the amount and distribution of rainfall over the watershed is accurately known. Only those storms which are isolated events and with uniform spatial and temporal distribution are selected along with the observed hydrograph at the watershed outlet point.
2. Storms meeting the following criteria are generally preferred and selected out of the uniform storms data collected in Step 1.
3. Storms with rainfall duration of around 20 to 30 % of ***basin lag***,
4. Storms having rainfall excess between 1 cm and 4.5cm.

5. From the observed total flood hydrograph for each storm separate the base flow and plot the direct runoff hydrograph.

6. Measure the total volume of water that has passed the flow measuring point by finding the area under the DRH curve. Since area of the watershed under consideration is known, calculate the average uniform rainfall depth that produced the DRH by dividing the volume of flow (Step 3) by the catchment area. This gives the effective rainfall (ER) corresponding to the storm. This procedure has to be repeated for each selected storm to obtain the respective ERs.

7. Express the hydrograph ordinate for each storm at T – hour is the duration of rainfall even. Divide each ordinate of the hydrograph by the respective storm ER to obtain the UH corresponding to each storm.

8. All UHs obtained from different storm events should be brought to the same duration by the S – curve method.

9. The final UH of specific duration is obtained by averaging the ordinates of the different UH obtained from step6.

Unit hydrograph for ungauged catchments

For catchments with insufficient rainfall or corresponding concurrent runoff data, it is necessary to develop synthetic unit hydrograph. These are unit hydrographs constructed form basin characteristics. A number of methods like that of Snyder's had been used for the derivation of the Synthetic hydrographs. However, the present recommendations of the Central Water Commission discourage the use of the Snyder's method.

Instead, the Commission recommends the use of the Flood Estimation Reports brought out for the various ***sub–zones*** in deriving the unit hydrograph for the region. These sub–zones have been demarcated on the basis of similar hydro – meteorological conditions and a list of the basins may be found. The design flood is estimated by application of the design storm rainfall to the synthetic hydrograph developed by the methods outlined in the reports.

Catchment modelling

With the availability of personal computer high processing speed within easy reach of all, it is natural that efforts have been directed towards numerical modeling the catchment dynamics and its simulation. It is not possible to outline each model in detail, but the general concept followed is to represent each physical process by a conceptual mathematical model which can be represented by an equivalent differential or ordinary equation. These

Equations are solved by changing the equations to solvable form and writing algorithms in suitable computer language. However, the user of the programs generally input data through a ***Graphical User Interface*** (GUI) since there is a lot of spatial information to be included like land-use, land-cover, soil property, etc. Now a day, this information interaction between the user and the computer is through ***Geographic Information System*** (GIS) software.
Once the information is processed, the output results are also displayed graphically. A list of notable conceptual models may be found in the following websites:

- http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6656/cr6656.pdf
- www.hydrocomp.com/simoverview.html
- http://www.ems- i.com/gmshelp/numerical

Examples of catchment models

Though many of these models are sold commercially, there are quite a few developed by academic institutions and government agencies worldwide which are free and can be downloaded for non – commercial purposes through the internet. A few examples are given below.

- US Army corps of Engineers' ***HEC-HMS*** and ***HEC-GeoHMS***
- US Army corps of Engineers ***'GRASS***
- US Army corps of Engineers'***TOPMODEL***

Water resources section of the Department of Civil Engineering, IIT Kharagpur has developed a watershed simulation model based on deterministic theory. A copy of the same may be made available on request for educational purposes.

Important terms

1. ***Linearity***: A linear relation between rainfall and runoff form a catchment suggests that variations in rainfall over a catchment is related to the variations in runoff from the outlet of the catchment by a linear function.

2. ***Basin lag***: Basin lag is the time between the peak flow and the centroid of rainfall.

3. ***Graphical User Interface*** **(GUI)**: An interface that represents programs, files, and options with graphical images is called GUI. These images can include icons, menus, and dialog boxes. The user selects and activates these options by pointing and clicking with a mouse or with the keyboard. A

Unit-III
Introduction

Ground WATER

In the earlier lesson, qualitative assessment of subsurface water whether in the unsaturated or in the saturated ground was made. Movement of water stored in the saturated soil or fractured bed rock, also called aquifer, was seen to depend upon the hydraulic gradient. Other relationships between the water storage and the portion of that which can be withdrawn from an aquifer were also discussed.
In this lesson, we derive the mathematical description of saturated ground water flow and its exact and approximate relations to the hydraulic gradient.

Although ground water flow is three – dimensional phenomenon, it is easier to analyse flows in two – dimension. Also, as far as interaction between surface water body and ground water is concerned, it is similar for lakes, river and any such body. Here we qualitatively discuss the flow

Of ground water through a few examples which show the relative interaction between the flow and the geological properties of the porous medium. Here, the two – dimensional plane is assumed to be vertical.

1. Example of a gaining lake and river.

Figure 11 shows an example of a lake perched on a hill that is receiving water from the adjacent hill masses. It also shows a river down in a valley, which is also receiving water.

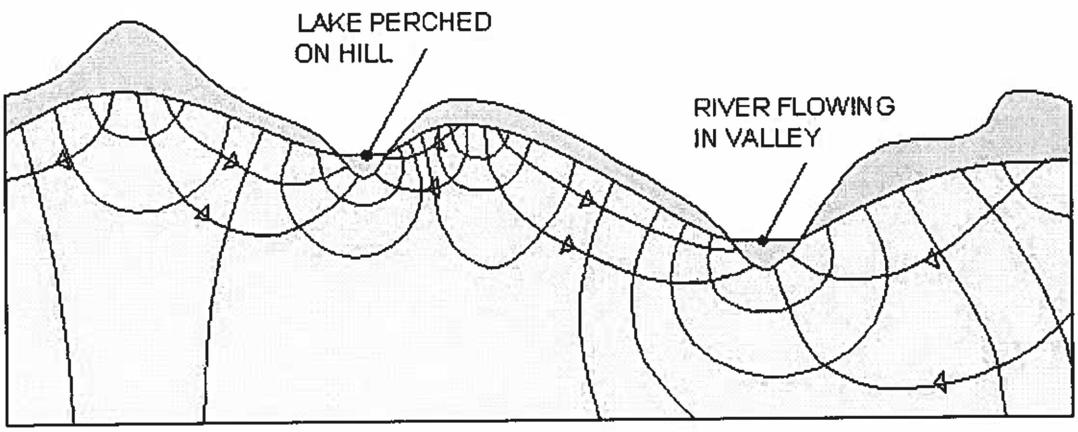


FIGURE 11. Example of a lake and a river, both of which are receiving warer from the adjoining soils.

2. Example of a partially losing lake, a disconnected losing lake, and a gaining river.

Figure 12 illustrates this example modifies the situation of example 1 slightly.

3. Example of flow through a heterogeneous media, casein.

This case (Figure 13) illustrates the possible flow through a sub-soil material of low hydraulic conductivity sandwiched between materials of relatively higher hydraulic conductivities.

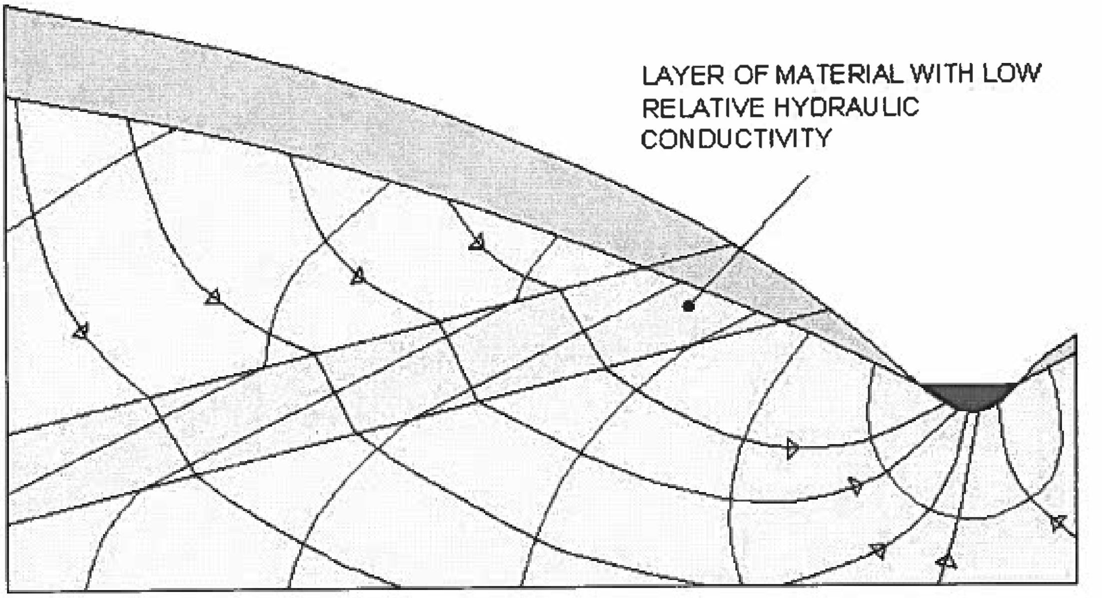


FIGURE 13. Example of sub-soil flow through heterogeneous media - Case I

This case (Figure 14) is just opposite to that shown in example 3. Here, the flow is through a sub-soil material of high hydraulic conductivity sandwiched between materials of relatively low hydraulic conductivities.

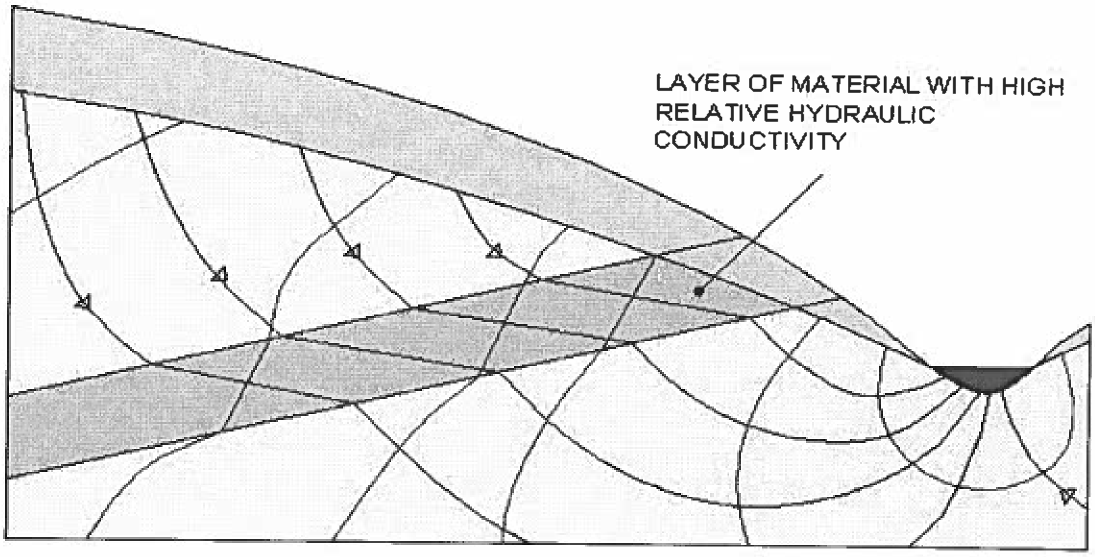


FIGURE 14. Example of sub-soil flow throuhg heterogenous media - Case II

Water table contours and regional flow

For a region, like a watershed, if we plot (in a horizontal plane) contours of equal hydraulic head of the ground water, then we can analyse the movement of ground water in a regional scale. Figure 15 illustrates the concept, assuming homogeneous porous media in the region for varying degrees of hydraulic conductivity (which is but natural for a real setting).

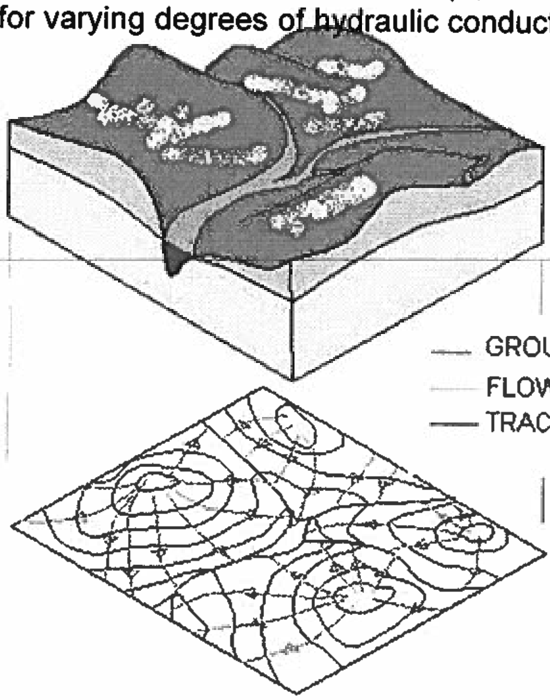


FIGURE 15. Movement of ground water in a regional scale

Aquifer properties and ground water flow

Porosity

Ground water is stored only within the pore spaces of soils or in the joints and fractures of rock which act as an aquifers. The porosity of an earth material is the percentage of the rock or soil that is void of material. It is defined mathematically by the equation

$$n = \frac{100 v_v}{v} \qquad (2)$$

Where n is the porosity, expressed as percentage; v_v is the volume of void space in a unit volume of earth material; and v is the unit volume of earth material, including both voids and solid.

Specific Yield

While porosity is a measure of the water bearing capacity of the formation, all this water cannot be drained by gravity or by pumping from wells, as a portion of the water is held in the void spaces by molecular and surface tension forces. If gravity exerts a stress on a film of water surrounding a mineral grain (forming the soil), some of the film will pull away and drip downward. The remaining film will be thinner, with a greater surface tension so that, eventually, the stress of gravity will be exactly balanced by the surface tension (Hygroscopic water is the moisture clinging to the soil particles because of Surface tension). Considering the above phenomena, the Specific Yield (S_y) is the ratio of the volume of water that drains from a saturated soil or rock owing to the attraction of gravity to the total volume of the aquifer.

If two samples are equivalent with regard to porosity, but the average grain size of one is much smaller than the other, the surface area of the finer sample will be larger. As a result, more water can be held as hygroscopic moisture by the finer grains.

The volume of water retained by molecular and surface tension forces, against the force of gravity, expressed as a percentage of the volume of the saturated sample of the aquifer, is called Specific Retention S_r, and corresponds to what is called the Field Capacity.

Hence, the following relation holds good:

$$n = S_y + S_r \qquad (3)$$

Specific storage (s_s)

Specific storage (s_s), also sometimes called the Elastic Storage Coefficient, is the amount of water per unit volume of a saturated formation that is stored or expelled from storage owing to compressibility of the mineral skeleton and the pore water per unit change in potentiometric head. Specific Storage is given by the expression

The porosity; β is the compressibility of water.

Specific storage has the dimensions of length^{-1}

The storability (S) of a confined aquifer is the product of the specific storage (S_S) and the aquifer thickness (b).

$$S \square\, bS_s \tag{5}$$

All of the water released is accounted for by the compressibility of the mineral skeleton and pore water. The water comes from the entire thickness of the aquifer.

In an unconfined aquifer, the level of saturation rises or falls with changes in the amount of water in storage. As water level falls, water drains out from the pore spaces. This storage or release due to the specific yield (Sy) of the aquifer. For an unconfined aquifer, therefore, the storativity is found by the formula.

$$S \quad S_y \quad hS_s \tag{6}$$

Where h is the thickness of the saturated zone.

Since the value of S_Y is several orders of magnitude greater than hS_S for an unconfined aquifer, the storativity is usually taken to be equal to the specific yield.

Aquifers and confining layers

It is natural to find the natural geologic formation of a region with varying degrees of hydraulic conductivities. The permeable materials have resulted usually due to weathering, fracturing and solution effects from the parent bed rock. Hence, the physical size of the soil grains or the pre sizes of fractured rock affect the movement of ground water flow to a great degree. Based on these, certain terms that have been used frequently in studying hydrogeology, are discussed here.

- **Aquifer:** This is a geologic unit that can store and transmit water at rates fast enough to supply reasonable amount to wells.
- **Confining layers:** This is a geologic unit having very little hydraulic conductivity.
  Confining layers are further subdivided as follows:
  - o Aquifuge: an absolutely impermeable layer that will not transmit any water.
  - o Aquitard: A layer of low permeability that can store ground water and also transmit slowly from one aquifer to another. Also termed as "leaky aquifer'.
  - 5. Aquiclude: A unit of low permeability, but is located so that it forms an upper or lower boundary to a ground water flow system.

Aquifers which occur below land surface extending up to a depth are known as unconfined. Some aquifers are located much below the land surface, overlain by a confining layer. Such aquifers are called confined or artesian aquifers. In these aquifers, the water is under pressure and there is no free water surface like the water table of unconfined aquifer.

Continuity equation and Darcy's law under steady state conditions

Consider the flow of ground water taking place within a small cube (of lengths Δx, Δy and Δz respectively the direction of the three areas which may also be called the elementary control volume) of a saturated aquifer as shown in Figure1.

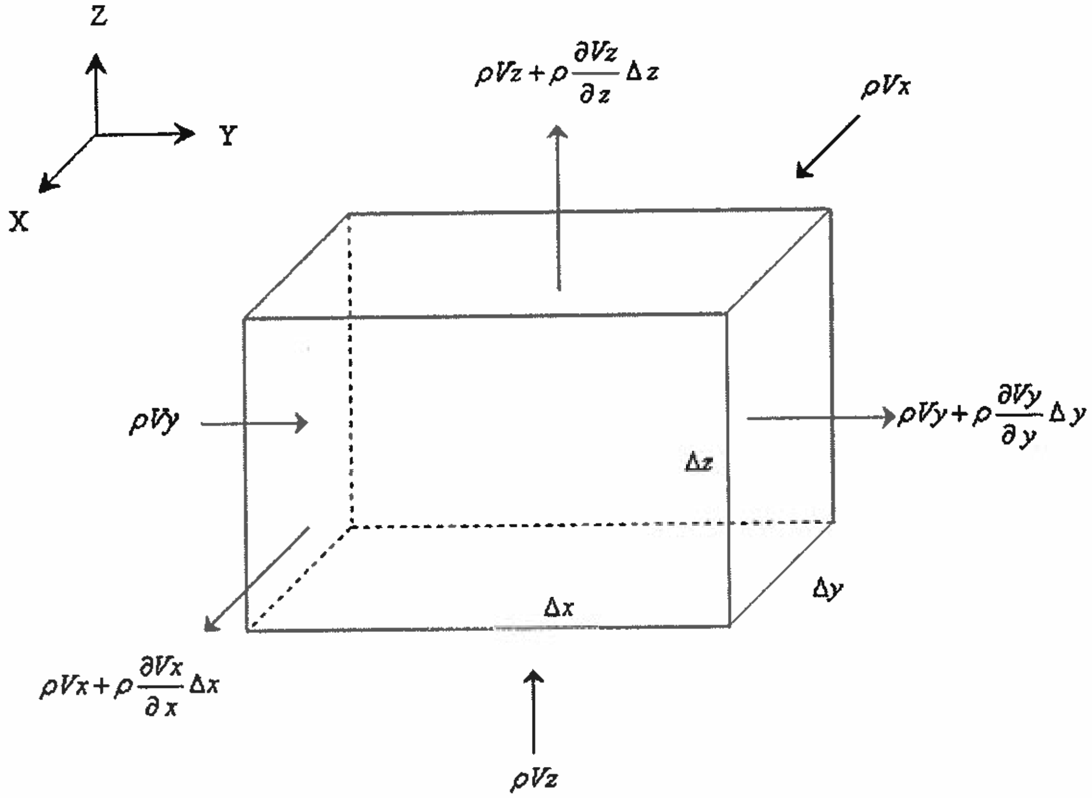


FIGURE 1. Infinitesimal cube for deriving the equation of continuity of flow of ground water

It is assumed that the density of water (ρ) does not change in space along the three directions which implies that water is considered incompressible. The velocity components in the x, y and z directions

Have been denoted as v_x, v_y, v_z respectively.

Since water has been considered incompressible, the total incoming water in the cuboidal volume should be equal to that going out. Defining inflows and outflows as:

Inflows:

In x-direction: $\rho \; v_x \; (\Delta y.\Delta x)$ In y-direction: $\rho \; v_y \; (\Delta x.\Delta z)$ In z-direction: $\rho \; v_z \; (\Delta x.\Delta y)$

Outflows:

In X-direction: $\rho \left(v_x + \frac{\partial v_x}{\partial x} \Delta x\right) (\Delta y.\Delta z)$

In Y-direction: $\rho \left(v_y + \frac{\partial v_y}{\partial y} y\right) (\Delta x.\Delta z)$

In Z-direction: $\rho \left(v_z + \frac{\partial v_z}{\partial z} . \Delta z\right) (\Delta y.\Delta x)$

The net mass flow per unit time through the cube works out to:

$$\left(\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}\right) (\Delta x.\Delta y.\Delta z)$$

Or

$$\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} = 0 \qquad (2)$$

This is continuity equation for flow. But this water flow, as we learnt in the previous lesson, is due to a difference in potentiometric head per unit length in the direction of flow. A relation between the velocity and potentiometric gradient was first suggested by Henry Darcy, a French Engineer, in the mid nineteenth century. He found experimentally (see figure below) that the discharge 'Q' passing through a tube of cross sectional area 'A' filled with a porous material is proportional to the difference of the hydraulic head 'h' between the two end points and inversely proportional to the flow length 'L'.

It may be noted that the total energy (also called head, h) at any point in the ground water flow per unit weight is given as

$$h = Z + \frac{p}{\gamma} + \frac{v^2}{2g} \tag{3}$$

Where

Z is the elevation of the point above a chosen datum;

$\frac{p}{\gamma}$ is the pressure head, and

$\frac{v^2}{2g}$ is the velocity head

Since the ground water flow velocities are usually very small, $\frac{v^2}{2g}$ is neglected and

$h = Z + \frac{p}{\gamma}$ is termed as the potentiometric head (or piezo metric head in some texts)

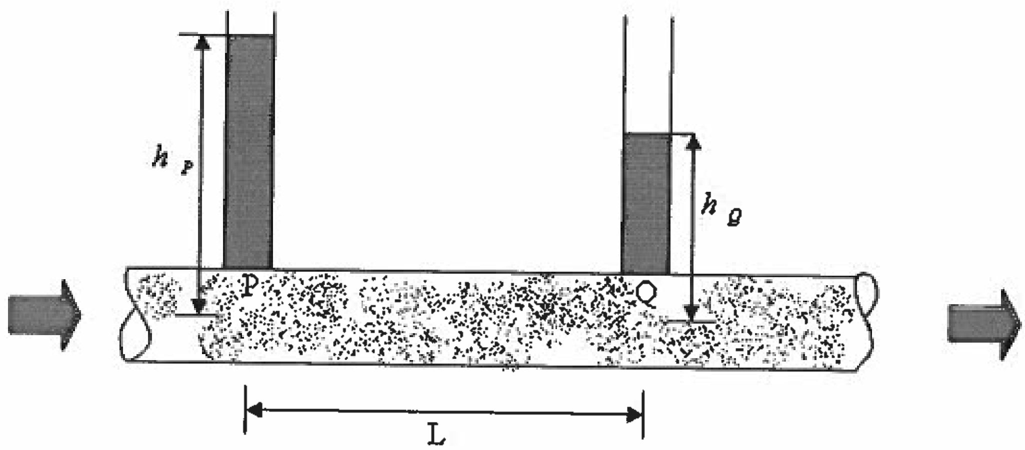


FIGURE 2. Flow through a saturated porous medium

Thus

$$Q \alpha A \cdot \frac{h_P - h_Q}{L} \qquad (4)$$

Introducing proportionality constant K, the expression becomes

$$Q = K.A. \frac{h_P - h_Q}{L} \qquad (5)$$

Since the hydraulic head decreases in the direction of flow, a corresponding differential equation would be written as

$$Q = -K.A. \frac{dh}{dl} \qquad (6)$$

Where (dh/dl) is known as hydraulic gradient.

The coefficient 'K' has dimensions of L/T, or velocity, and as seen in the last lesson this is termed as the hydraulic conductivity.

Thus the velocity of fluid flow would be:

$$v = \frac{Q}{A} = -K\left(\frac{dh}{dl}\right) \qquad (7)$$

It may be noted that this velocity is not quite the same as the velocity of water flowing through an open pipe. In an open pipe, the entire cross section of the pipe conveys water. On the other hand, if the pipe is filed with a porous material, say sand, then the water can only flow through the pores of the sand particles.
Hence, the velocity obtained by the above expression is only an apparent velocity, with the actual velocity of the fluid particles through the voids of the porous material is many time more. But for our analysis of substituting the expression for velocity in the three directions x, y and z in the continuity relation, equation (2) and considering each velocity term to be proportional to the hydraulic gradient in the corresponding direction, one obtains the following relation

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial x}\left(K_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right) = 0 \qquad (8)$$

Here, the hydraulic conductivities in the three directions (K_X, K_Y and K_Z) have been assumed to be different as for a general anisotropic medium. Considering isotropic medium with a constant hydraulic conductivity in all directions, the continuity equation simplifies to the following expression:

$$\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{\partial^2 h}{\partial z^2}=0 \qquad (9)$$

In the above equation, it is assumed that the hydraulic head is not changing with time, that is, a steady state is prevailing.

If now it is assumed that the potentiometric head changes with time at the location of the control volume, then there would be a corresponding change in the ***porosity*** of the aquifer even if the fluid density is assumed to be unchanged.

What happens to the continuity relation is discussed in the next section.

Important term:

Porosity: It is ratio of volume of voids to the total volume of the soil and is generally expressed as percentage.

Steady one dimensional flow in aquifers

Some simplified cases of ground water flow, usually in the vertical plane, can be approximated by one dimensional equation which can then be solved analytically. We consider the confined and unconfined aquifers separately, in the following sections.

Confined aquifers

If there is a steady movement of ground water in a confined aquifer, there will be a gradient or slope to the potentiometric surface of the aquifer. The gradient, again, would be decreasing in the direction of flow. For flow of this type, Darcy's law may be used directly.

Aquifer with constant thickness

This situation may be shown as in Figure 6.

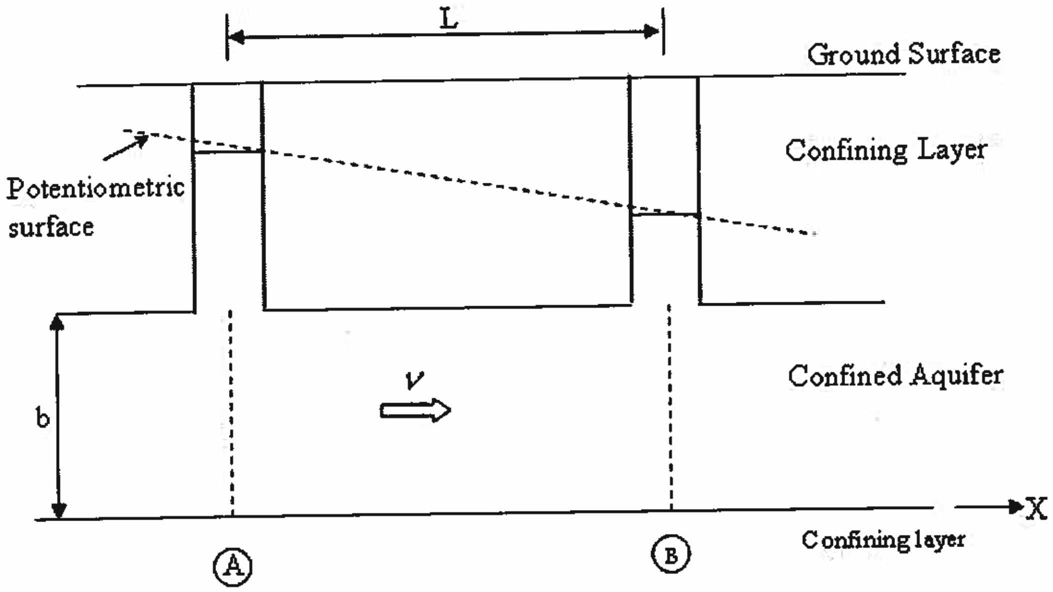


FIGURE 6. Flow through an aquifer of constant thckness

Assuming unit thickness in the direction perpendicular to the plane of the paper, the flow rate 'q' (per unit width) would be expressed for an aquifer of thickness"

$$q = b * 1 * v \tag{43}$$

According to Darcy's law, the velocity 'v' is given by

$$v = -K \frac{\partial h}{\partial x} \tag{44}$$

Where h, the potentiometric head, is measured above a convenient datum. Note that the Actual value of 'h' is not required, but only its gradient $\frac{\partial h}{\partial x}$ in the direction of flow, Is what matters. Here is K is the hydraulic conductivity

hence,

$$q = bK \frac{\partial h}{\partial x} \tag{45}$$

The partial derivative of 'h' with respect to 'x' may be written as normal derivative since we are assuming no variation of 'h' in the direction normal to the paper. Thus

$$q = - b K \frac{dh}{dx} \tag{46}$$

For steady flow, q should not vary with time, t, or spatial coordinate, x. hence,

$$\frac{dq}{dx} = -bK\frac{d^2h}{dx^2} = 0 \qquad (47)$$

Since the width, b, and hydraulic conductivity, K, of the aquifer are assumed to be constants, the above equation simplifies to:

$$\frac{d^2h}{dx^2} = 0 \qquad (48)$$

Which may be analytically solved as

$$h = C_1 x + C_2 \qquad (49)$$

Selecting the origin of coordinate x at the location of well A (as shown in Figure 6), and having a hydraulic head, h_A and also assuming a hydraulic head of well B, located at a distance L from well A in the x-direction and having a hydraulic head h_B, we have:

$h_A = C_1.0+C_2$ and

$h_B = C_1.L+C_2$

Giving

$$C_1 = h - h_A/L \text{ and } C_2 = h_A \qquad (50)$$

Thus the analytical solution for the hydraulic head 'h' becomes:

$$H = \frac{h_B - h_A}{L}x + h_A \qquad (51)$$

Aquifer with variable thickness

Consider a situation of one- dimensional flow in a confined aquifer whose thickness, b, varies in the direction of flow, x, in a linear fashion as shown in Figure 7.

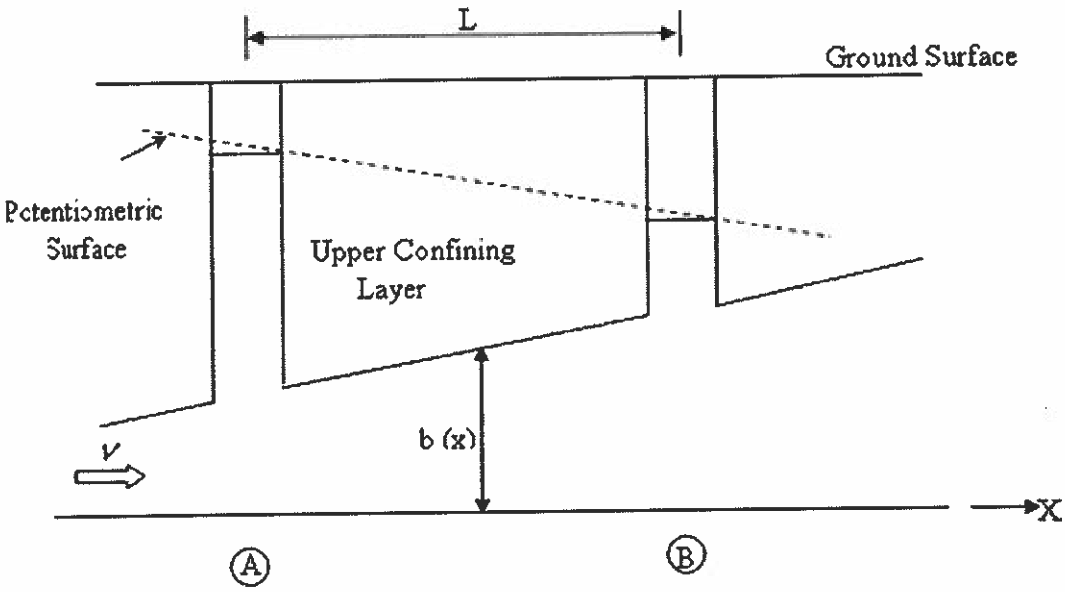


FIGURE 7. Flow through an aquifer with variable thickness

The unit discharge, q, is now given as

$$q = -\,b\,(x)\,K\,\frac{dh}{dx} \qquad (52)$$

Where K is the hydraulic conductivity and dh/dx is the gradient of the potentiometric surface in the direction of flow,x.

For steady flow, we have,

$$\frac{dq}{dx} = -K\left(\frac{db}{dx}\frac{dh}{dx} + b\,\frac{d^2h}{dx^2}\right) = 0 \qquad (53)$$

Which may be simplified, denoting $\frac{db}{dx}$ as b'

$$b\frac{d^2h}{dx^2} + b'\frac{dh}{dx} = 0 \qquad (54)$$

A solution of the above differential equation may be found out which may be substituted For known values of the potentiometric heads h_A and h_B in the two observation wells A and B respectively in order to find out the constants of integration.

Unconfined aquifers

In an unconfined aquifer, the saturated flow thickness, h is the same as the hydraulic head at any location, as seen from Figure8:

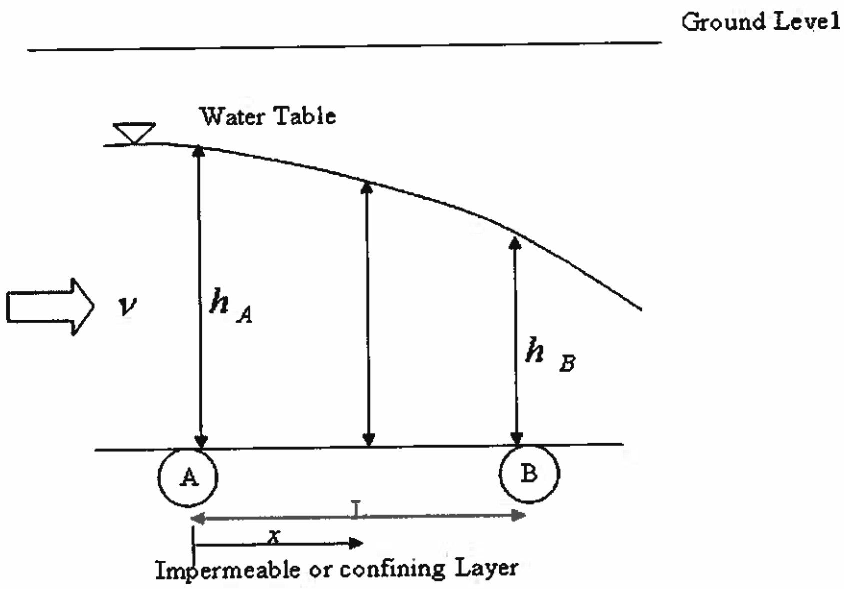


FIGURE 8. Flow through an unconfined aquifer

Considering no recharge of water from top, the flow takes place in the direction of fall of the hydraulic head, h, which is a function of the coordinate, x taken in the flow direction. The flow velocity, v, would be lesser at location A and higher at B since the saturated flow thickness decreases. Hence v is also a function of x and increases in the direction of flow. Since, v, according to Darcy's law is shown to be

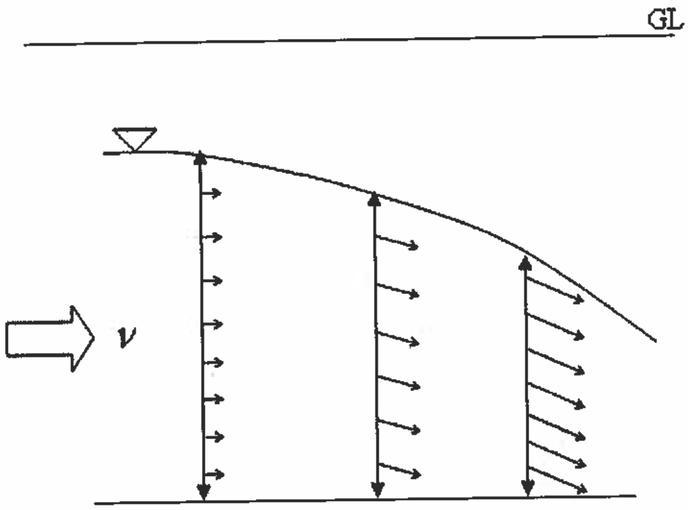
$$v = K\frac{dh}{dx} \qquad (55)$$

The gradient of potentiometric surface, dh/dx, would (in proportion to the velocities) be smaller at location A and steeper at location B. Hence the gradient of water table in unconfined flow is not constant, it increases in the direction of flow.

This problem was solved by J.Dupuit, a French hydraulician, and published in 1863 and his assumptions for a flow in an unconfined aquifer is used to approximate the flow situation called Dupuit flow. The assumptions made by Dupuit are:

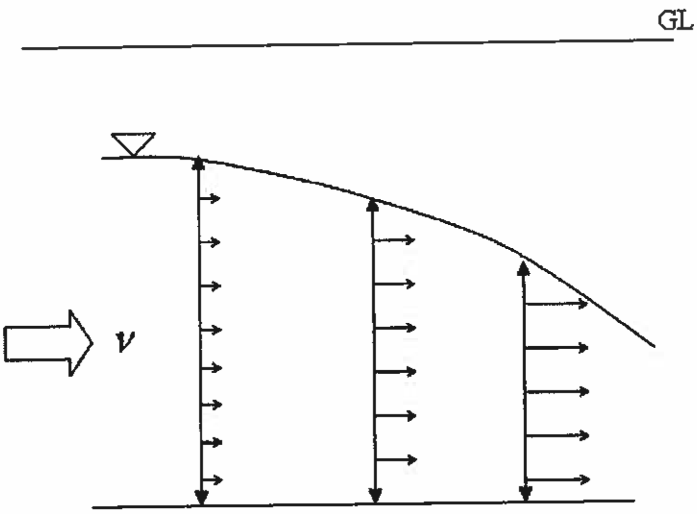
6. The hydraulic gradient is equal to the slope of the water table, and
5. For small water table gradients, the flow-lines are horizontal and the equipotential lines are vertical.

The second assumption is illustrated in Figure 9.



Actual Velocity pattern

(a)



Velocity pattern after Dupuit's assumptions

(b)

FIGURE 9. (a) Actual velocity pattern in ground water flow and
(b) Assumption of Dupuit regarding ground water flow

Solutions based on the Dupuit's assumptions have proved to be very useful in many practical purposes. However, the Dupuit assumption do not allow for a ***seepage face*** above an outflow side.

An analytical solution to the flow would be obtained by using the Darcy equation to

Express the velocity, v, at any point, x, with a corresponding hydraulic gradient as $\frac{dh}{dx}$,

$$v = -K\frac{dh}{dx} \tag{56}$$

Thus, the unit discharge, q, is calculated to be

$$q = -Kh\frac{dh}{dx} \tag{57}$$

Considering the origin of the coordinate x at location A where the hydraulic head us h_A and knowing the hydraulic head h_B at a location B, situated at a distance L from A, we may integrate the above differential equation as:

$$\int_0^L q\,dx = -K\int_{h_A}^{h_B} h\,dh \tag{58}$$

Which, on integration, leads to

$$q \cdot x\Big|_0^L = -K \cdot \frac{h^2}{2}\Big|_{h_A}^{h_B} \tag{59}$$

Or,

$$q \cdot L = K\left(\frac{h_B^2}{2} - \frac{h_A^2}{2}\right) \tag{60}$$

Rearrangement of above terms leads to, what is known as the Dupuit equation:

$$q = \frac{1}{2}K\frac{h_B^2 - h_A^2}{L} \tag{61}$$

An example of the application of the above equation may be for the ground water flow in a strip of land located between two water bodies with different water surface elevations, as in Figure 10.

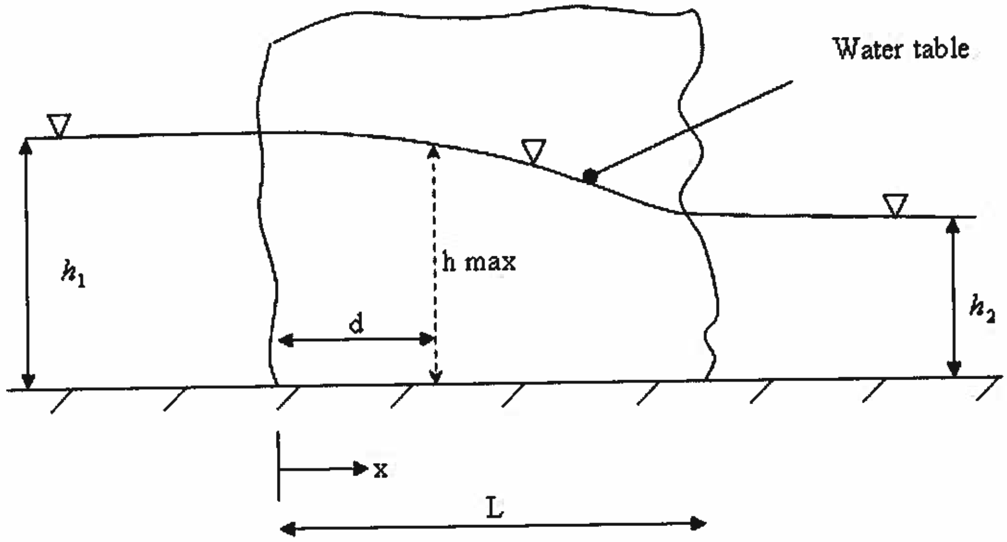


FIGURE 10. Ground water flow through a strip of land with difference in water surface elevation on either side.

The equation for the water table, also called the phreatic surface may be derived from Equation (61) as follows:

$$h = \sqrt{h_1^2 - \frac{(h_1^2 - h_2^2)x}{L}} \qquad (62)$$

In case of recharge due to a constant infiltration of water from above the water table rises to a many as shown in Figure11:

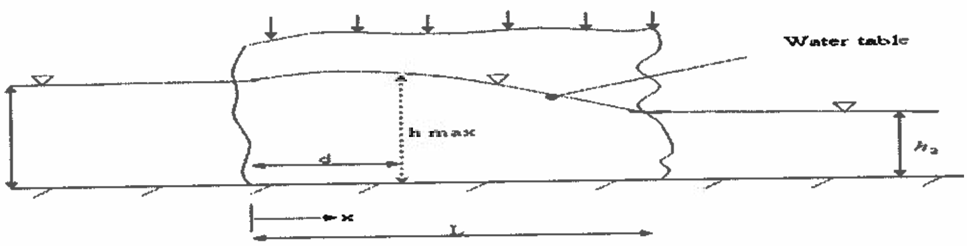


FIGURE 11. Ground water flow through a strip of land with infiltration from above

There is a difference with the earlier cases, as the flow per unit width, q, would be increasing in the direction of flow due to addition of water from above. The flow may be analyzed by considering a small portion of flow domain as shown in Figure 12.

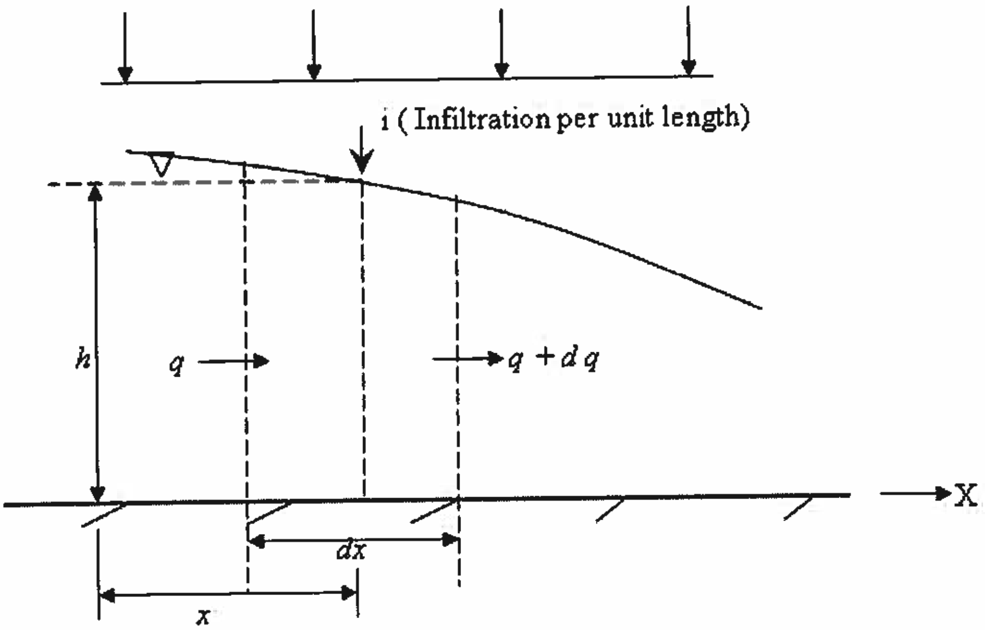


FIGURE 12. Definition of terms for flow analysis for the case shown in Figure 11

Considering the infiltration of water from above at a rate *i* per unit length in the direction of ground water flow, the change in unit discharge d_q is seen to be

$$d_q = i\,.dx \qquad (63)$$

Or,

$$\frac{dq}{dx} = i \qquad (64)$$

From Darcy's law,

$$q = -K.h.\frac{dh}{dx} = -\frac{1}{2}K\frac{d(h^2)}{dx} \qquad (65)$$

$$\frac{dq}{dx} = -\frac{1}{2}K\frac{d^2(h^2)}{dx^2} \qquad (66)$$

Or,

$$-\frac{1}{2}K\frac{d^2}{dx^2}(h^2) = i$$

$$\frac{d^2(h^2)}{dx^2} = \frac{2.i}{k}$$

The solution for this equation is of the form

$$Kh^2 + 2x^2 = C_1x + C_2$$

If, now, the boundary condition is applied as, At $x = 0$, $h = h_1$, and
At $x = L$, $h = h_2$

The equation for the water table would be:

$$h = \sqrt{h_1^2 - \frac{(h_1^2 - h_1^2)x}{L} + \frac{i}{K}(L - x)x}$$

$$_x = q_0 + 2x \tag{71}$$

Where q_0 is the unit discharge at the left boundary, x = 0, and may be found out to be

$$q_0 = \frac{(h_1^2 - h_1^2)}{2L} - \frac{iL}{2} \tag{72}$$

Which gives an expression for unit discharge $q_x$at any point x from the origin as

$$q_x = K\frac{(h^2 - h^2)}{2L} - i \quad \frac{L}{2} \quad -x \tag{73}$$

For no recharge due to infiltration, I = 0 and the expression for q_x is then seen to become independent of x, hence constant, which is expected.

WELLS

A well is an intake structure dug on the ground to draw water from the reservoirs of water stored within. The water from the well could be used to meet domestic, agricultural, industrial, or other uses. The structure may be an open dug well, or as is common these days, may be tube-wells. The well may be shallow, tapping an unconfined reservoir or could be deep, penetrating further inside the ground to tap a confined aquifer located within aquicludes. In this lesson, we shall discuss the design of tube wells, a typical installation of which is given in Figure11.

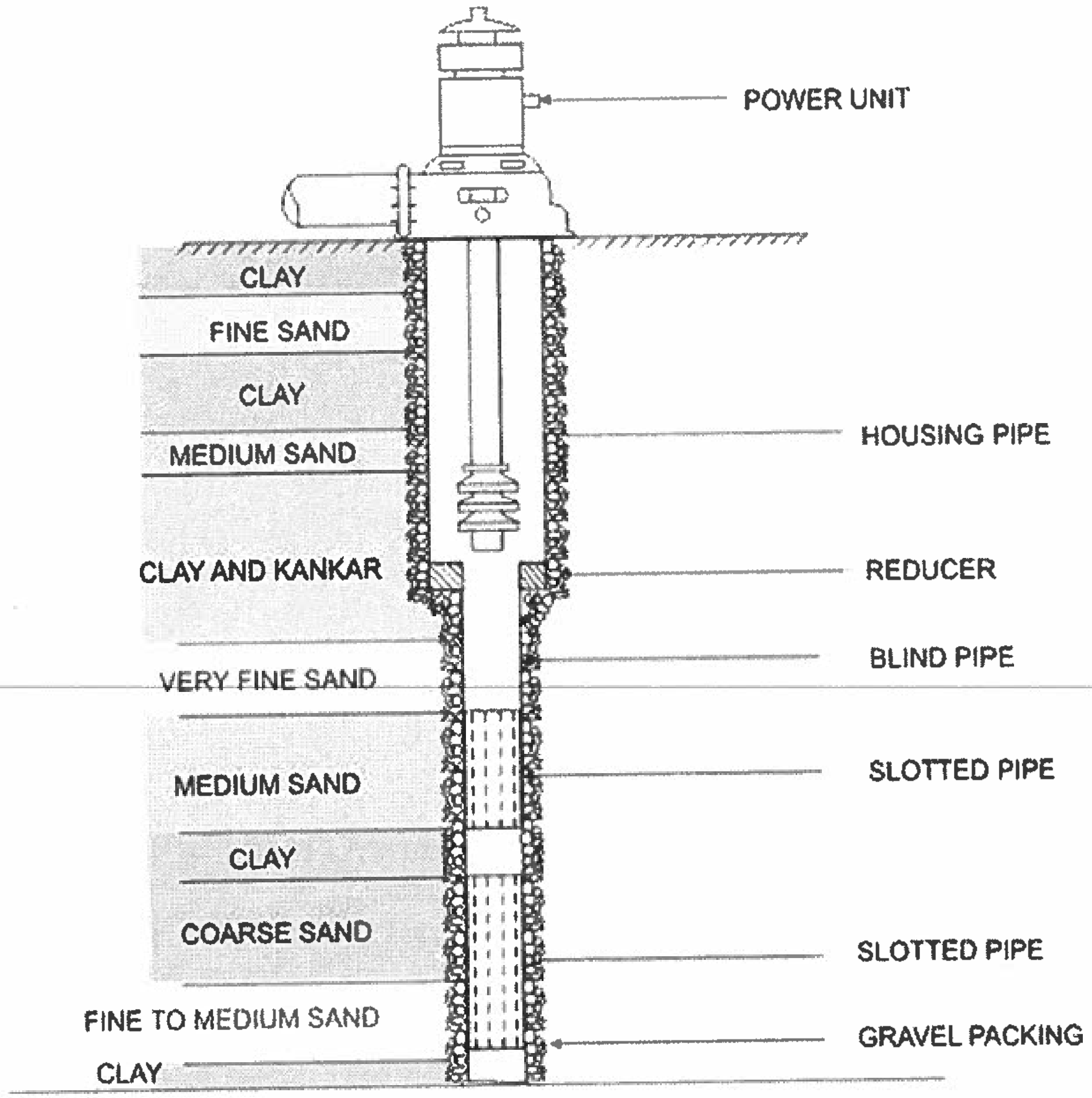


FIGURE . 11 TYPICAL INSTALLATION OF TUBE WELl

Design of a well involves selecting appropriate dimensions of various components and choosing

Proper materials to be used for its construction. A good design of tube well should aim at efficient utilization of the aquifer, which it is supposed to tap, have a long and useful life, should have a low initial cost, and low maintenance and operation cost.
The parameters that need to be designed for a well include the following:

3. diameter
   The diameter of the well must be chosen to give the desired percentage of open area in the screen (15 to 18 percent) so that the entrance velocities near the screen do no exceed 3 to 6 cm/s so as to reduce the well losses and hence, the draw down. The velocity should be reasonably low as indicated, such that the five particles within the sand should not migrate towards the well strainer slots.

4. Well depth

5. Selection of strata to be tapped
   The samples during drilling are collected from various depths and a bore log is prepared. This log describes the soil material type, size distribution, uniformity coefficient etc. for the material available at different depths.

6. Well screen design
   This includes fixing the following parameters for a well:
   o Well screen length
   o Well-screen slot size o
   Well-screen diameter o
   Well-screen material

In case of unconfined aquifers, where too thick and homogeneous aquifer is met, it is desirable to provide screen in the lower one third thickness. In case of confined aquifers where thick and nearly homogeneous aquifer is met, about 80 to 90 percent of the depth at the center of the aquifer is advised to be screened. Where too thick and homogeneous aquifers are encountered it is common practice to place screen opposite the more permeable beds leaving about 0.3m depth both at the top and bottom of the aquifer, so that finer material in the transition zone does not move into the well.

The size of the well screen slots depends upon the gradation, and size of the formation material, so that there is no migration of fines near the slots. In case of naturally developed wells the slot size is taken as around 40 to 70 percent of the size of the formation material. If the slot size selected on this basis comes to less than 0.75 mm, then an artificial ground pack is used. An artificial gravel pack is required when the aquifer material is homogeneous with a uniformity coefficient less than 3 and effective grain size less than 0.25 mm.

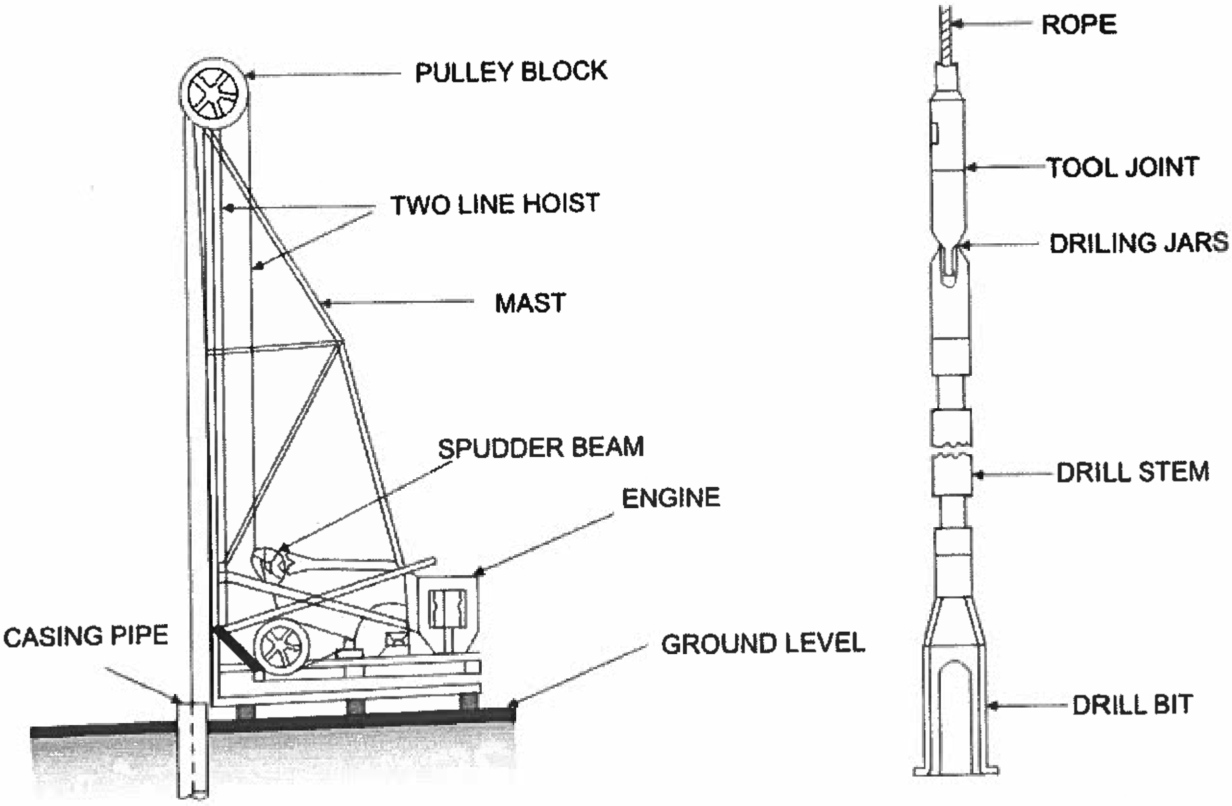
The screen diameter is determined so that the entrance velocity near the well screen does not exceed 3 to 6 cm/sec.

The screen material should be resistant to incrustation and corrosion and should have the strength to withstand the weight of the well pipe. The selection of the screen material also depends on the quality of ground water, diameter and depth of the well and type of strata encountered.

Installation of wells

The entire process of installation of tube wells include drilling of a hole, installing the screen and housing pipes, gravel packing and development of the well to insure sand free water. Depending on the size of the tube well, depth and formation to be drilled, available facility and technical know-how, different methods are used for the construction of tube wells. Two methods that are commonly used are explained below.

- *Cable-tool percussion drilling*
  A rig consists of a mast, lines of hoist for operating the drilling tool and a sand pump (Figure 12).



(a) Drill machine

(b)Drill assembly

FIGURE .12 CABLE TOOL PERCUSSION DRILLING

The cutting tool is suspended from a cable and the drilling is accomplished by up and down movement (percussion) of the tool. A full string of drilling tool consists of four components:

p Drill bit
q Drill stem
r Drilling jars
s Rope
socket

The drill bit is used to loosen the formation material and its reciprocating action breaks it down to smaller particles or muck. Water injected from the top converts the muck into slurry. For this purpose water is added as long as drilling continues in dry formations. The slurry flows up due to the pressure of water. The drill stem fixed just above the bit provides additional tools in order to maintain a straight line. The drilling jars consist of a pair of linked steel bars and can be moved in a vertical direction relative to each other. The rope socket connects the string of tools to the cable.

7. *Rotary Drilling method*

There are two main types of rotary drilling methods: Direct rotary methods, and Reverse rotary method

In either case, a rotating bit is used as a drilling bit. The major difference is in the direction of the flowing fluid (Figure 13).

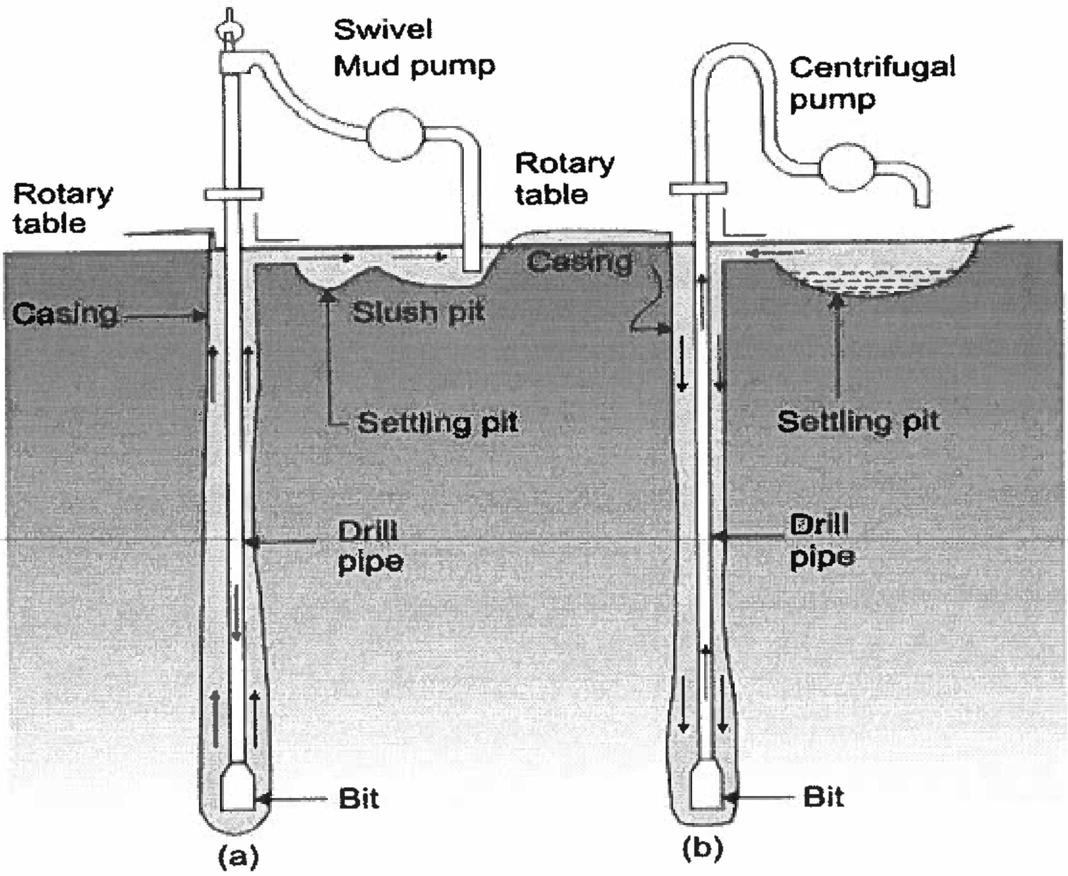


FIGURE . 13 ROTARY DRILLING (a) Hydraulic rotary (b) Reverse rotary

Well screens

For installation of well screens, different methods are used depending upon the design of the well, the type of well, locally available facility and the type of problems encountered in drilling operation. The Pull-back method is generally used with the cable-tool percussion method of well drilling. After the casing pipe has reached to the depth where the bottom of the screen is to be located, the sand that might have flowed into the pipe is removed. The well assembly consisting of screen and blind pipe lengths is lowered into the well. A heavy plate bail handle is provided at the bottom of the screen. The lowering of the assembly may be accomplished by suspending it by the bail handle using a flat hook attached to the sand line to engage the bail. After lowering the complete well screen assembly inside the casing pipe, the casing rip is pulled back.

For rotary drilled wells generally the Open-Hole method of screen installation used, though Method, after drilling the hole below the well caring, the drill stem is withdrawn and a telescope–size screen is lowered into the hole by any suitable method. The depth of the hole should be checked such that when the screen rests on the bottom of the hole, the lead packer should remain inside the lower end of the casing.

Gravel packing

Well can either manually ground packed or artificially ground packed. Natural ground packed condition is created by removing the fine sand from the formation either by pumping or by surging. An artificially gravel packed well has a envelop of especially grand sand or gravel placed around the well screen. Ground pack is designed on the basis of sieve analysis of the aquifer materials obtained during drilling. Aquifer consisting of coarse materials of less uniform sizes may not require any gravel pack.

Well Development

This process is used to remove sand, silt and other fine materials from a zone immediately surrounding the well screen. This is done by flow reversal through the screen openings so as to rearrange the formation particles in a naturally developed well and form a graded filter with materials of increasing porosity and permeability towards the well in an artificially gravel packed well, so that ultimately the well will yield clear sand free water.

UNIT-IV

IRRIGATION

Both soil and water are essential for plant growth. The soil provides a structural base to the plants and allows the root system (the foundation of the plant) to spread and get a strong hold. The pores of the soil within the ***root zone*** hold moisture which clings to the soil particles by surface tension in the driest state or may fill up the pores partially or fully saturating with it useful nutrients dissolved in water, essential for the growth of the plants. The roots of most plants also require oxygen for respiration. Hence, full saturation of the soil pores leads to restricted root growth for these plants. (There are exceptions, though, like the rice plant, in which the supply of oxygen to the roots is made from the leaves through aerenchyma cells which are continuous from the leaves to the roots).

Since irrigation practice is essentially, an adequate and timely supply of water to the plant root zone for optimum crop yield, the study of the inter relationship between soil pores, its water- holding capacity and plant water absorption rate is fundamentally important. Though a study in detail would mostly be of importance to an agricultural scientist, in this lesson we discuss the essentials which are important to a water resources engineer contemplating the development of a command area through scientifically designed irrigation system.

Soil-water system

Soil is a heterogeneous mass consisting of a three phase system of solid, liquid and gas. Mineral matter, consisting of sand, silt and clay and organic matter form the largest fraction of soil and serves as a framework (matrix) with numerous pores of various proportions. The void space within the solid particles is called the soil pore space. Decayed organic matter derived from the plant and animal remains are dispersed within the pore space. The soil air is totally expelled from soil when water is present in excess amount than can be stored.

On the other extreme, when the total soil is dry as in a hot region without any supply of water either naturally by rain or artificially by irrigation, the water molecules surround the soil particles as a thin film. In such a case, pressure lower than atmospheric thus results due to surface tension capillarity and it is not possible to drain out the water by gravity. The salts present in soil water further add to these forces by way of osmotic pressure. The roots of the plants in such a soil state need to exert at least an equal amount of force for extracting water from the soil mass for their growth.

In the following sections, we discuss certain important terms and concepts related to the soil- water relations. First, we start with a discussion on soil properties and types of soils.

Soil properties

Soil is a complex mass of mineral and organic particles. The important properties that classify soil according to its relevance to making crop production (which in turn affects the decision making process of irrigation engineering) are:

7. Soil structure

Soil texture:

This refers to the relative sizes of soil particles in a given soil. According to their sizes, soil particles are grouped into gravel, sand, silt and day. The relative proportions of sand, silt and clay is a soil mass determines the soil texture. Figure 1 presents the textural classification of 12 main classes as identified by the US department of agriculture, which is also followed by the soil survey organizations of India.

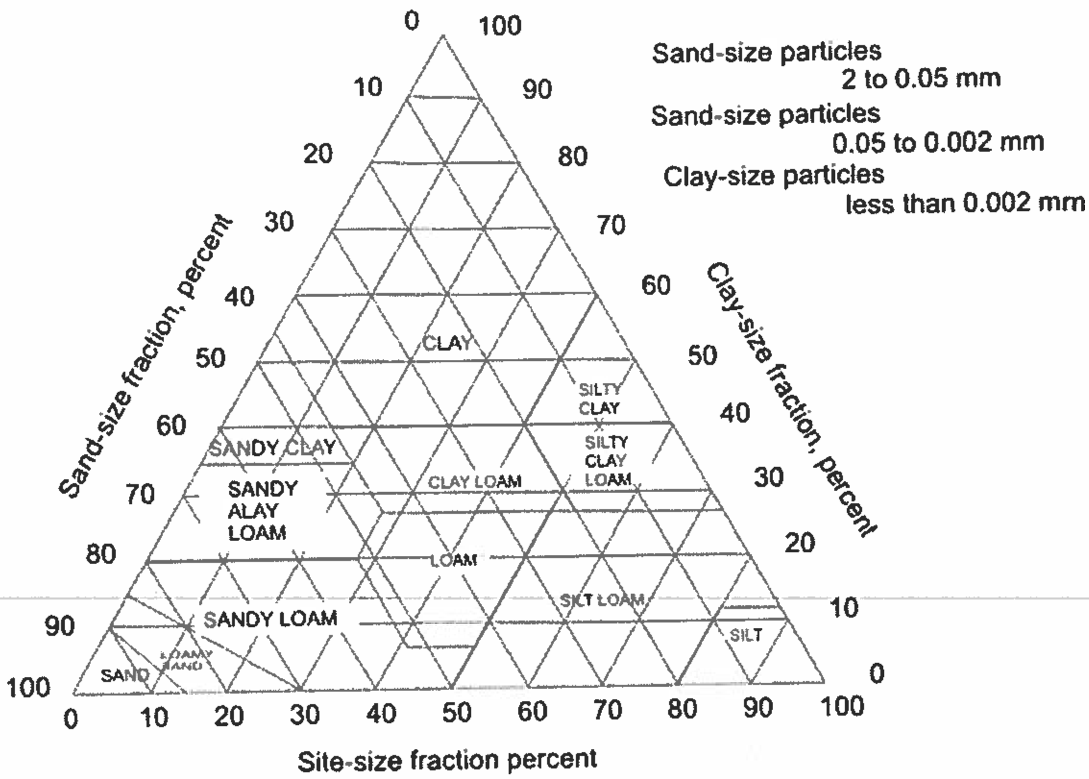


FIGURE 1. USDA textural classification chart

According to textural gradations a soil may be broadly classified as:

8. Open or light textural soils: these are mainly coarse or sandy with low content of silt and clay.
9. Medium textured soils: these contain sand, silt and clay in sizeable proportions, like loamy soil.
10. Tight or heavy textured soils: these contain high proportion of clay.

Soil structure:

This refers to the arrangement of soil particles and aggregates with respect to each other. Aggregates are groups of individual soil particles adhering together. Soil structure is recognized as one of the most important properties of soil mass, since it influences aeration, permeability, water holding capacity, etc. The classification of soil structure is done according to three indicators as:-

6. ***Type:*** there are four types of primary structures-platy, prism-like, block like and spheroidal.
7. ***Class:*** there are five recognized classes in each of the primary types. These are very fine, fine, medium, coarse and very coarse.
8. ***Grade:*** this represents the degree of aggradation that is the proportion between aggregate and aggregated material that results when the aggregates are displaced or gently crushed. Grades are termed as structure less, weak, moderate, strong and very strong depending on the stability of the aggregates when disturbed.

Soil classification

Soils vary widely in their characteristics and properties. In order to establish the interrelation ship between their characteristics, they need to be classified. In India, the soils may be grouped into the following types:

10. **Alluvial soils:** These soils are formed by successive deposition of silt transported by rivers during floods, in the flood plains and along the coastal belts. This group is by for the largest and most important soil group of India contributing the greatest share to its agricultural wealth. Though a great deal of variation exists in the type of alluvial soil available throughout India, the main features of the soils are derived from the deposition laid by the numerous tributaries of the Indus, the Ganges and the Brahmaputra river systems. These streams, draining the Himalayas, bring with them the products of weathering rocks constituting the mountains, in various degrees of fineness and deposit them as they traverse the plains. Alluvial soils textures vary from clayey loam to sandy loam. The water holding capacity of these soils is fairly good and is good for irrigation.

11. **Black soils:** This type of soil has evolved from the weathering of rocks such as basalts, traps, granites and gneisses. Black soils are derived from the Deccan trap and are found in Maharashtra, western parts of Madhya Pradesh, parts of Andhra Pradesh, parts of Gujarat and some parts of Tamilnadu. These soils are heavy textured with the clay content varying from 40 to 60 percent. The soils possess high water holding capacity but are poor in drainage.

12. **Red soils:** These soils are formed by the weathering of igneous and metamorphic rock comprising gneisses and schist's. They comprise of vast areas of Tamil nadu, Karnataka, Goa, Daman & Diu, south-eastern Maharashtra, Eastern Andhra Pradesh, Orissa and Jharkhand. They also are in the Birbhum district of West Bengal and Mirzapur, Jhansi and Hamirpur districts of Uttar pradesh. The red soils have low water holding capacity and hence well drained.

- **Laterites and Lateritic soils:** Laterite is a formation peculiar to India and some other tropical countries, with an intermittently moist climate. Laterite soils are derived from the weathering of the laterite rocks and are well developed on the summits of the hills of the Karnataka, Kerala, Madhya Pradesh, and The eastern ghats of Orissa, Maharashtra, West Bengal, Tamilnadu and Assam. These soils have low clay content and hence possess good drainage characteristics.

- **Desert soils:** A large part of the arid region, belonging to western Rajasthan, Haryana, Punjab, lying between the Indus River and the Aravalli range is affected by the desert conditions of the geologically recent origin. This part is covered by a mantle of blown sand which, combined with the arid climate, results in poor soil development. They are light textured sandy soils and react well to the application of irrigation water.

- **Problem soils:** The problem soils are those, which owing to land or soil characteristics cannot be used for the cultivation of crops without adopting proper reclamation measures. Highly eroded soils, ravine lands, soils on steeply sloping lands etc. constitute one set of problem soils. Acid, saline and alkaline soils constitute another set of problem soil.

Some of the major soil groups of the country are listed in the following table:

Zone	Name	Climate	Regions	Major soil group
1	Western Himalayan Region	Humid	Jammu & Kashmir, Himachal pradesh, Uttaranchal	Submontane soils, Hill and terai soils
2	Bengal-Assam Basin	Humid	West Bengal, Assam	Riverine alluvium, terai soils, lateritic soils, red-yellow loams
			Andaman & Nicobar	
	Eastern Himalayan Region and bay islands	Humid	Islands, Arunachal Pradesh, Nagaland, Manipur, Tripura, Meghalaya	Red loamy soils, lateritic soils, red yellow soils, alluvial soils
			Punjab, Uttar	Calcareous alluvial soils, riverine

4	Sutlej-Ganga Plains	Sub-Humid	Pradesh, Bihar, Delhi, Uttaranchal	alluvium alkaline soils, red yellow loams, mix red and black soils
5	Eastern and south eastern uplands	Sub-Humid to Humid	Orissa, Jharkhand, Chattisgarh, Andhra Pradesh	Lateritic soils, red yellow loams, mixed red and black soils, red loamy soils, coastal alluvium alluvial soils, red yellow soils, medium to deep black soils
6	Western plains	Arid	Harayana, Rajasthan, Dadra & Nagar Haveli	Lateritic soils, red yellow loams, mixed red and black soils, red loamy soils, coastal alluvium alluvial soils, red yellow soils, medium to deep black soils
7	Lava plateau and central highlands	Semi-arid	Maharashtra, Goa, Madhya Pradesh, Daman & Diu	Riverine alluvium, coastal alluvium, mixed red and black soils,

				skeletal soils, shallow deep black soils and red sandy soils
8	Western Ghats and Karnataka Plateau	Humid to semi arid	Karnataka, tamil Nadu, Kerala, Pondicherry, Lakshadweep islands	Lateritic soils, red sandy soils, deltaic coastal alluvium and red loamy Soils.

Classification of soil water

As stated earlier, water may occur in the soil pores in varying proportions. Some of the definitions related to the water held in the soil pores are as follows:

- **Gravitational water:** A soil sample saturated with water and left to drain the excess out by gravity holds on to a certain amount of water. The volume of water that could easily drain off is termed as the gravitational water. This water is not available for plants use as it drains off rapidly from the root zone.

- **Capillary water:** the water content retained in the soil after the gravitational water has drained off from the soil is known as the capillary water. This water is held in the soil by surface tension. Plant roots gradually absorb the capillary water and thus constitute the principle source of water for plant growth.

- **Hygroscopic water:** the water that an oven dry sample of soil absorbs when exposed to moist air is termed as hygroscopic water. It is held as a very thin film over the surface of the soil particles and is under tremendous negative (gauge) pressure. This water is not available to plants.

The above definitions of the soil water are based on physical factors. Some properties of soil water are not directly related to the above significance to plant growth. These are discussed next.

Soil water constants

For a particular soil, certain soil water proportions are defined which dictate whether the water is available or not for plant growth. These are called the soil water constants, which are described below.

1 **Saturation capacity:** this is the total water content of the soil when all the pores

Soil. At saturation capacity, the ***soil moisture tension*** is almost equal to zero.

2 **Field capacity:** this is the water retained by an initially saturated soil against the force of gravity. Hence, as the gravitational water gets drained off from the soil, it is said to reach the field capacity. At field capacity, the macro-pores of the soil Are drained off, but water is retained in the micro pores. Though the soil moisture tension at field capacity varies from soil to soil, it is normally between 1/10 (for clayey soils) to 1/3 (for sandy soils) atmospheres.

3. **Permanent wilting point:** plant roots are able to extract water from a soil matrix, which is saturated up to field capacity. However, as the water extraction proceeds, the moisture content diminishes and the negative (gauge) pressure increases. At one point, the plant cannot extract any further water and thus ***wilts.***

Two stages of wilting points are recognized and they are:

Temporary wilting point: this denotes the soil water content at which the plant wilts at day time, but recovers during right or when water is added to the soil.

Ultimate wilting point: at such a soil water content, the plant wilts and fails to regain life even after addition of water to soil.

It must be noted that the above water contents are expressed as percentage of water held in the soil pores, compared to a fully saturated soil. Figure 2 explains graphically, the various soil constants; the full pie represents the volume of voids in soil.

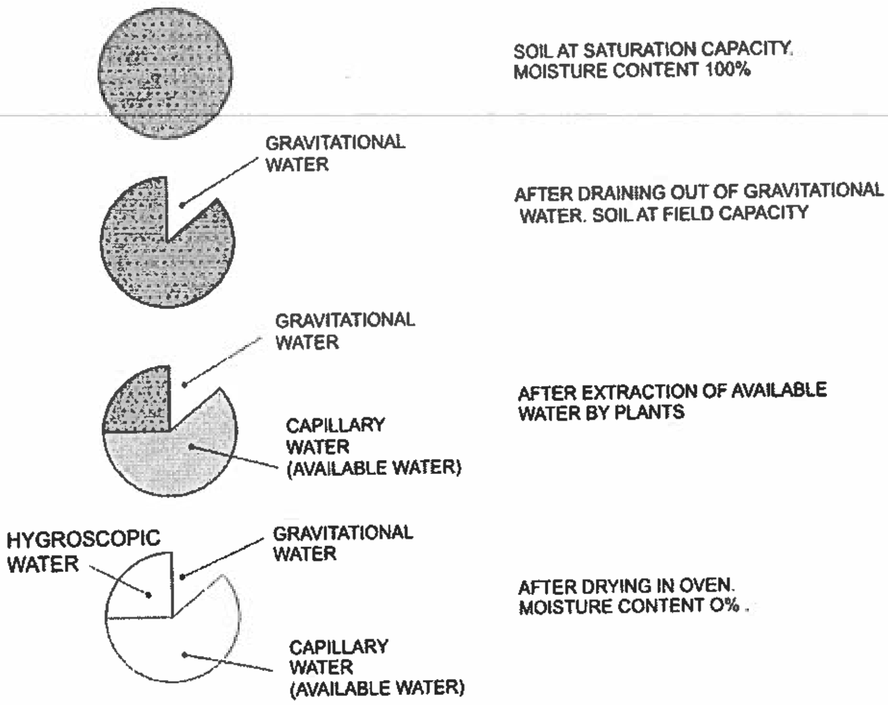


FIGURE 2. Classification of soil water

As shown in Figure 2, the available water for plants is defined as the difference in moisture content of the soil between field capacity and permanent wilting point.

Field capacity and Permanent wilting point: Although the pie diagrams in Figure 2 demonstrate the drying up of saturated soil pores, all the soil constants are expressed as a percentage by weight of the moisture available at that point compared to the weight of the dried soil sand sample.

Soil water constants expressed in depth units:

In the last section, the soil water constants were mentioned as being expressed as weight percentages of the moisture content (that is amount of water) held by the water at a certain state with respect to the weight of the dried soil sample. The same may also be expressed as volume of water stored in the root zone of a field per unit area. This would consequently express the soil water constants as units of depths. The conversion from one form to the other is presented below:

Assume the following:

- Root zone depth = D(m)
- Specific weight of soil = $\gamma_s(kg/m^3)$
- Specific weight of water = $\gamma_w(kg/m^3)$
- Area of plot considered = 1m x1m

Hence, the weight of soil per unit area would be: γ_s x 1 x D (kg)

The weight of water held by the soil per unit area would be equal to: γ x 1 x d

Where d is equivalent depth of water that is actually distributed within the soil pores. Hence the following constants may be expressed as:

$$\text{Field capacity} = \frac{\text{Weight of water held by soil per unit area}}{\text{Weight of soil per unit area}}$$

$$= \frac{\gamma_w * 1 * d}{\gamma_s * 1 * D} \qquad (1)$$

Thus, depth of water (***d** $_{Fc}$*) held by soil at field capacity (***FC***)

$$= \frac{\gamma_s}{\gamma_w} * D * FC \qquad (2)$$

Similarly, depth of water (***d** $_{wp}$*) held by soil at permanent wilting point (***PWP***)

$$= \frac{\gamma_s}{\gamma_w} * D * PWP \qquad (3)$$

Hence, depth of water (d_{Aw}) available to plants

$$= \frac{\gamma_s}{\gamma_w} * D * [FC - PWP] \qquad (4)$$

Therefore, the depth of water available to plants per meter depth of soil

$$= \frac{\gamma_s}{\gamma_w} [FC - PWP] \qquad (5)$$

It may be noted that plants cannot extract the full available water with the same efficiency. About 75 percent of the amount is rather easily extracted, and it is called the readily available water. The available water holding capacity for a few typical soil types are given as in the following table:

Soil Texture	Field Capacity (FC) percent	Permanent Wilting Point (PWP) percent	Bulk Density(γ_s) Kg/m^3	Available water per meter depth of soil profile(m)
Sandy	5 to 10	2 to 6	1500 to 1800	0.05 to 0.1
Sandy loam	10 to 18	4 to 10	1400 to 1600	0.09 to 0.16
Loam	18 to 25	8 to 14	1300 to 1500	0.14 to 0.22
Clay loam	24 to 32	11 to 16	1300 to 1400	0.17 to 0.29
Clay	32 to 40	15 to 22	1200 to 1400	0.20 to 0.21

Water absorption by plants

Water is absorbed mostly through the roots of plants, though an insignificant absorption is also done through the leaves. Plants normally have a higher concentration of roots close to the soil surface and the density decreases with depth as shown in Figure 3.

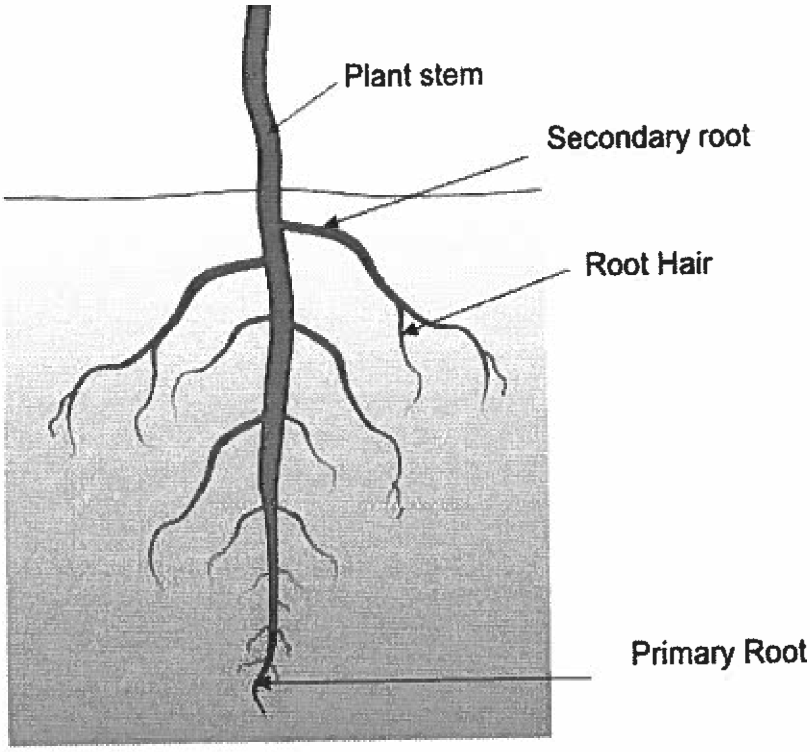


FIGURE 3. Typical root density variation of a plant with depth.

In a normal soil with good aeration, a greater portion of the roots of most plants remain within 0.45m to 0.60m of surface soil layers and most of the water needs of plants are met from this zone. As the available water from this zone decreases, plants extract more water from lower depths. When the water content of the upper soil layers reach wilting point, all the water needs of plants are met from lower layers. Since there exists few roots in lower layers, the water extract from lower layers may not be adequate to prevent wilting, although sufficient water may be available there.

When the top layers of the root zone are kept moist by frequent application of water through irrigation, plants extract most of the water (about 40 percent) from the upper quarter of their root zone. In the lower quarter of root zone the water extracted by the

Plant meets about 30 percent of its water needs. Further below, the third quarter of the root zone extracts about 20 percent and the lowermost quarter of root zone extracts the remaining about 10 percent of the plants water. It may be noted that the water extracted from the soil by the roots of a plant moves upwards and essentially is lost to the atmosphere as water vapors mainly through the leaves. This process, called transpiration, results in losing almost 95percent of water sucked up. Only about5percent of water pumped up by the root system is used by the plant for metabolic purpose and increasing the plant body weight.

Watering interval for crops

A plot of land growing a crop has to be applied with water from time to time for its healthy growth. The water may come naturally from rainfall or may supplemented by artificially applying water through irrigation. A crop should be irrigated before it receives a setback in its growth and development. Hence the interval between two irrigations depends primarily on the rate of soil moisture depletion. Normally, a crop has to be irrigated before soil moisture is depleted below a certain portion of its availability in the root zone depending on the type pf plant. The intervals are shorter during summer than in winter. Similarly, the intervals are shorter for sandy soils than heavy soils. When the water supply is very limited, then the interval may be prolonged which means that the soil moisture is allowed to deplete below 50percent of available moisture before the next irrigation is applied. The optimum rates of soil moisture for a few typical crops are given below (Reference: Majumdar, D K, 2000)

- Maize : Field capacity to 60 percent of availability
- Wheat : Field capacity to 50 percent of availability
- Sugarcane: Field capacity to 50 percent of availability
- Barley : Field capacity to 40 percent of availability
- Cotton : Field capacity to 20 percent of availability

As for rice, the water requirement is slightly different than the rest. This is because it requires a constant standing depth of water of about 5cm throughout its growing period. This means that there is a constant percolation of water during this time and it has estimated that about 50 to 70 percent of water applied to the crop is lost in this way.

For most of the crops, except rice, the amount of water applied after each interval should be such that the moisture content of the soil is raised to its field capacity. The soil moisture depletes gradually due to the water lost through evaporation from the soil surface and due to the absorption of water from the plant roots, called transpiration more of which has been discussed in the next session. The combined effect of evaporation and transpiration, called evapo- transpiration (ET) decides the soil water depletion rate for a known value of ET (which depends on various factors, mainly climate); it is possible to find out the irrigation interval.

Some of the operational soil moisture ranges of some common crops are given below:

Rice:

This crop is grown both in lowland and upland conditions and throughout the year in some parts of the country. For lowland rice, the practice of keeping the soil saturated or up to shallow submergence of about 50mm throughout the growing period has been found to be the most beneficial practice for obtaining maximum yields. When water resources are limited, the land must be submerged at least during critical stages of growth. The major portion of the water applied to the rice crop, about 50-75% is lost through deep percolation which varies with the texture of the soil. Since the soil is kept constantly submerged for rice growth, all the pores are completely filled with water through it is in a state of continuous downward movement. The total water required by the rice plant is about 1.0 to 1.5m for heavy soils and soils with high water table; 1.5 to
2.0m for medium soils and 2.0 to 2.5 for light soils with deep water table.

Wheat:

The optimum soil moisture range for tall wheats is from the field capacity to 50% of availability. The dwarf wheats need more wetness, and the optimum moisture range is from 100 to 60 percent availability. The active root zone of the crops varies from 0.5 to 0.75m depending upon the soil type. The total water requirement for wheat plants vary from 0.25m to 0.4 m in northern India to about 0.5m to 0.6m in Central India.

Barley:

This crop is similar to wheat in its growing habits, but can withstand more droughts because of the deeper and well spread root system. The active root zone of Barley extends between 0.6m to 0.75m on different soil types. The optimum soil moisture ranges from the field capacity to 40% of availability.

Maize:

The crop is grown almost all over the country. The optimum soil moisture range is from 100 to 60% of availability in the maximum root zone depth which extends from 0.4 to 0.6 on different soil types. The actual irrigation requirement of the crop varies with the amount of rainfall. In north India, 0.1m and 0.15m is required to establish the crop before the onset of monsoon. In the south, it is found that normal rain fall is sufficient to grow the crop in the monsoon season whereas 0.3m of water is required during water.

Cotton:

The optimum range of soil moisture for cotton crop is from the field capacity to 20% of available water. He root zone varies up to about 0.75m. The total water requirement is about 0.4m to 0.5m.

Sugarcane:

The optimum soil moisture for sugarcane is about 100 to 50 percent of water availability in the maximum root zone, which extends to about 0.5m to 0.75m in depth. The total water depth requirement for sugarcane varies from about 1.4m to 1.5m in Bihar; 2.2m – 2.4 M in Karnataka; and 2.0 – 2.3m in Madhya Pradesh.

Importance of water in plant growth

During the life cycle of a plant water, among other essential elements like air and fertilizers, plays a vital role, some of the important ones being:

- Water maintains the turgidity of the plant cells, thus keeping the plant erect. Water accounts for the largest part of the body weight of an actively growing plant and it constitutes 85 to 90 percent of the body weight of young plants and 20 to 50 percent of older or mature plants.
- Water provides both oxygen and hydrogen required for carbohydrate synthesis during the photos thesis process.
- Water acts as a solvent of plant nutrients and helps in the uptake of nutrients from soil.
- Food manufactured in the green parts of a plant gets distributed throughout the plant body as a solution in water.
- Transpiration is a vital process in plants and does so at a maximum rate (called the potential evapo transpiration rate) when water is available in adequate amount. If soil moisture is not sufficient, then the transpiration rate is curtailed, seriously affecting plant growth and yield.
- Leaves get heated up with solar radiation and plants help to dissipate the heat by transpiration, which itself uses plant water.

Irrigation water quality

In irrigation agriculture, the quality of water used for irrigation should receive adequate attention. Irrigation water, regardless of its source, always contains some soluble salts in it. Apart from the total concentration of the dissolved salts, the concentration of some of the individual salts, and especially those which are most harmful to crops, is important in determining the suitability of water for irrigation. The constituents usually determined by analyzing irrigation water are the electrical conductivity for the total dissolved salts, soluble sodium percentage, sodium absorption ratio, boron content, PH, cations such as calcium, magnesium, sodium, potassium and anions such as carbonates, bicarbonates, sulphates, chlorides and nitrates.

Water from rivers which flow over salt effected areas or in the deltaic regions has a greater concentration of salts sometimes as high as 7500 ppm or even more. The quality of tank or lake water depends mainly on the soil salinity in the water shed areas and the aridity of the region. The quality of ground water resources, that is, from shallow or deep wells, is generally poor under the situations of

- high aridity
- high water table and water logged conditions
- in the vicinity of seawater

On the basis of suitability of water for irrigation, the water may be classified under three categories, which are shown in the following table:

Class	Electrical Conductivity (micro-ohm/cm)	Total Dissolved Solids (ppm)	Exchangeable sodium (percentage)	Chloride (ppm)	Sulphates (ppm)	Boron (ppm)	Remarks
I	0-1000	0-700	0-60	0-142	0-192	0-0.5	Excellent to good for irrigation
II	1000-3000	700-2000	60-75	142-355	192-480	0.5-2.0	Good to injurious; suitable only with permeable soils and moderate Teaching. Harmful to more Sensitive crops.
III	>3000	>2000	>75	>355	>480	>2.0	Unfit for irrigation

Important Definitions

1. **Root Zone:** The soil root zone is the area of the soil around the plant that comes in contact with the plant root (Figure4).

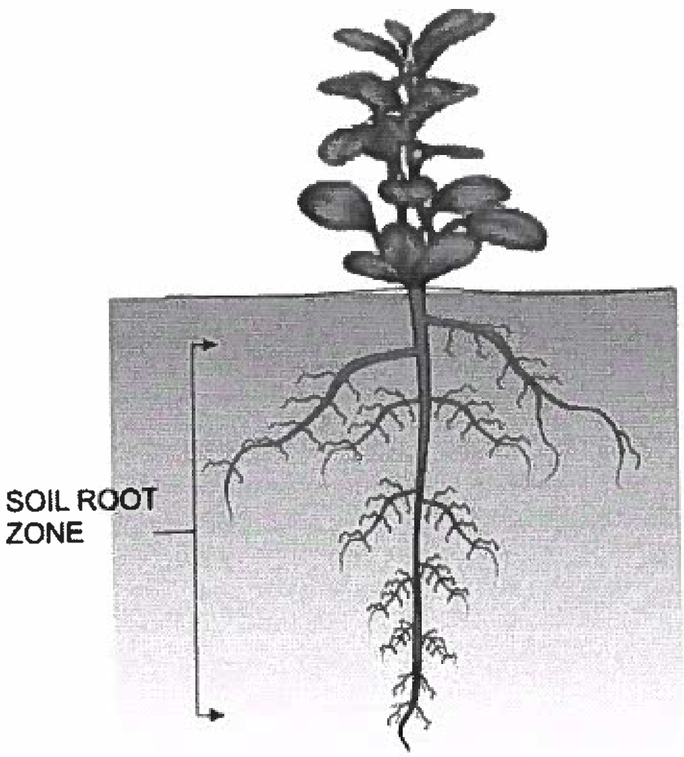


FIGURE 4 **Definition of soil root zone**

2. **Soil Moisture tension:** In soils partially saturated with water there is moisture tension, which is equal in magnitude but opposite in sign to the soil water pressure. Moisture tension is equal to the pressure that must be applied to the soil water to bring it to a hydraulic equilibrium, through a porous permeable wall or membrane, with a pool of water of the same composition.

3. **Wilts:** Wilting is drooping of plants. Plants bend or hang downwards through tiredness or weakness due to lack of water.

Introduction

A plot of land growing a certain crop or a combination of crops has to be supplied with water from time to time. Primarily, the plot or field is expected to receive water from rain falling on the land surface. But, as we know, the distribution of rain is rather uncertain both in time and space. Also some of the rain as in a light shower does not reach the ground as it may be intercepted by the leaves of the plant during

Falling rain may be effective in raising the soil moisture that is actually useful for plant growth. Hence, for proper crop growth, the effective rain has to be supplemented by artificially applying water to the field by irrigation.

If the area of the field is small, water may be supplied from the local ground water source. If the field is large, supplemented irrigation water may be obtained from a local surface water source, like a river, if one is available nearby. The work of a water resources engineer therefore would be to design a suitable source for irrigation after knowing the demand of water from field data. In this lesson, we proceed on to find out the methods by which estimation may be made for irrigation water demand.

Crop water requirement

It is essential to know the water requirement of a crop which is the total quantity of water required from its sowing time up to harvest. Naturally different crops may have different water requirements at different places of the same country, depending upon the climate, type of soil, method of cultivation, effective rain etc.

The total water required for crop growth is not uniformly distributed over its entire life span which is also called crop period. Actually, the watering stops same time before harvest and the time duration from the first irrigation during sowing up to the last before harvest is called base period. Though crop period is slightly more than the base period, they do not differ from practical purposes. Figure 1 Indicates the relative usage of water for a typical crop during its entire growth period.

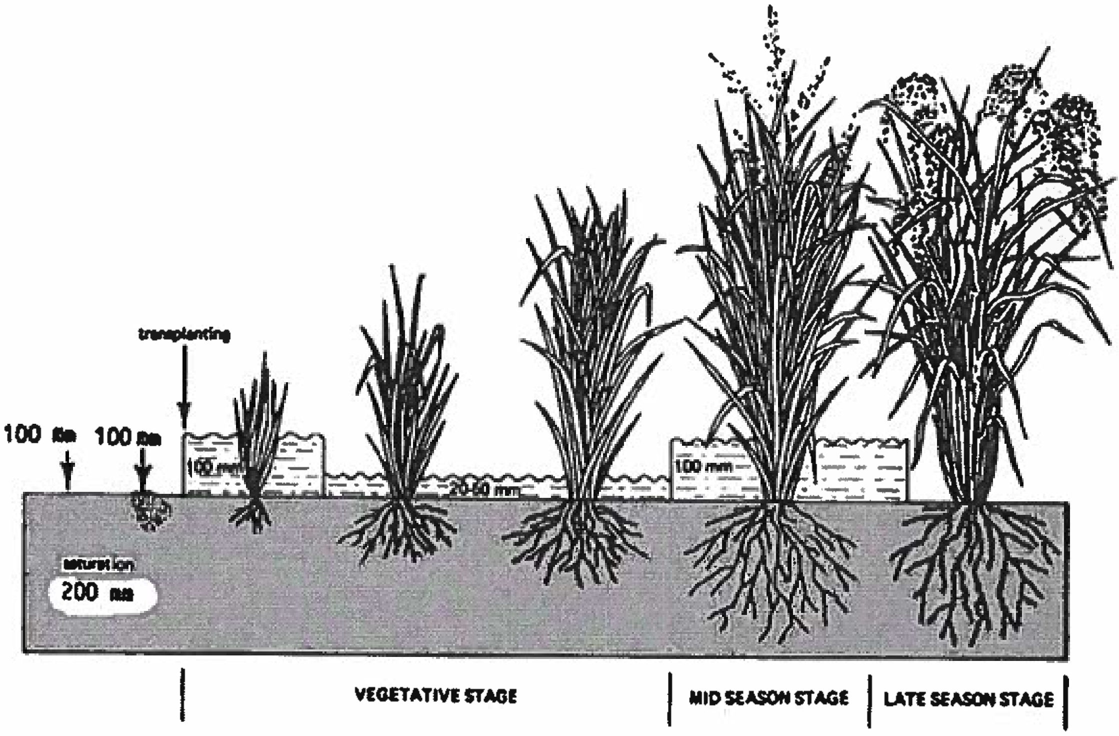


FIGURE 1. Variation in the requirement of water for paddy with stage of growth
(Image courtesy: Food and Agriculture Organisation, FAO)

When the plants are still young. It is usually the maximum single watering required, and other watering are done at usual intervals.

The total depth of water required to raise a crop over a unit area of land is usually called ***Delta***. Some typical values of delta for common crops in some regions of India are as follows:

Rice

9. 1000mm to 1500mm for heavy soils or high water table
10. 1500mm to 2000mm for medium soils
11. 2000 to 2500 for light soils or deep water table
12. 1600mm for upland conditions

Wheat

11. 250mm to 400mm in northern India
9. 500mm to 600mm in Central India
10. Barley:450mm

Maize

13. 100mm during rainy season
14. 500mm during winter season
15. 900mm during summer season
16. Cotton: 400 –500mm

Sugarcane

- 1400mm to 1500mm in Bihar
- 1600mm to 1700mm in Andhra Pradesh
- 1700mm to 1800mm in Punjab
- 2200mm to 2400mm in Madhya Pradesh
- 2800mm to 3000mm in Maharashtra

Duty of water

The term ***duty*** means the area of land that can be irrigated with unit volume of irrigation water. Quantitatively, duty is defined as the area of land expressed in hectares that can be irrigated with unit discharge, that is, 1 cumec flowing throughout the base period, expressed in days.

Imagine a field growing a single crop having a base period B days and a Delta Δ mm which is being supplied by a source located at the head (uppermost point) of the field, as shown in Figures 2 and 3.

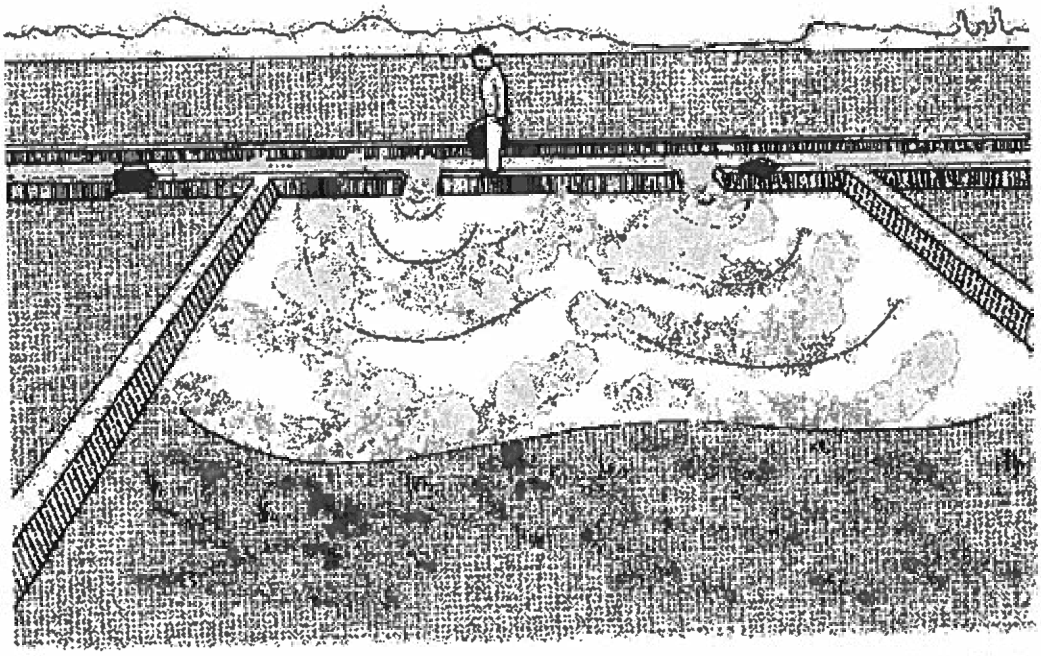


FIGURE 2. Border irrigation method of applying water at the head of a field
(Image courtesy: Food and Agriculture Organisation, FAO)

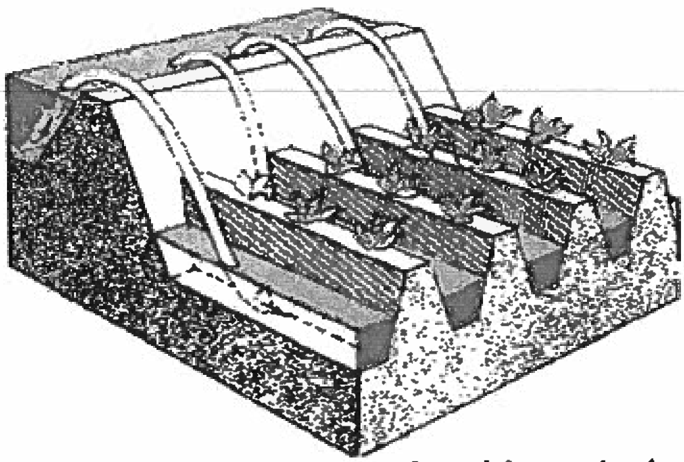


FIGURE 3. Furow irrigation method of applying water to a field

(Image courtesy: Food and Agriculture Organisation, FAO)

The water being supplied may be through the diversion of river water through a canal, or it could be using ground water by pumping (Figure 4).

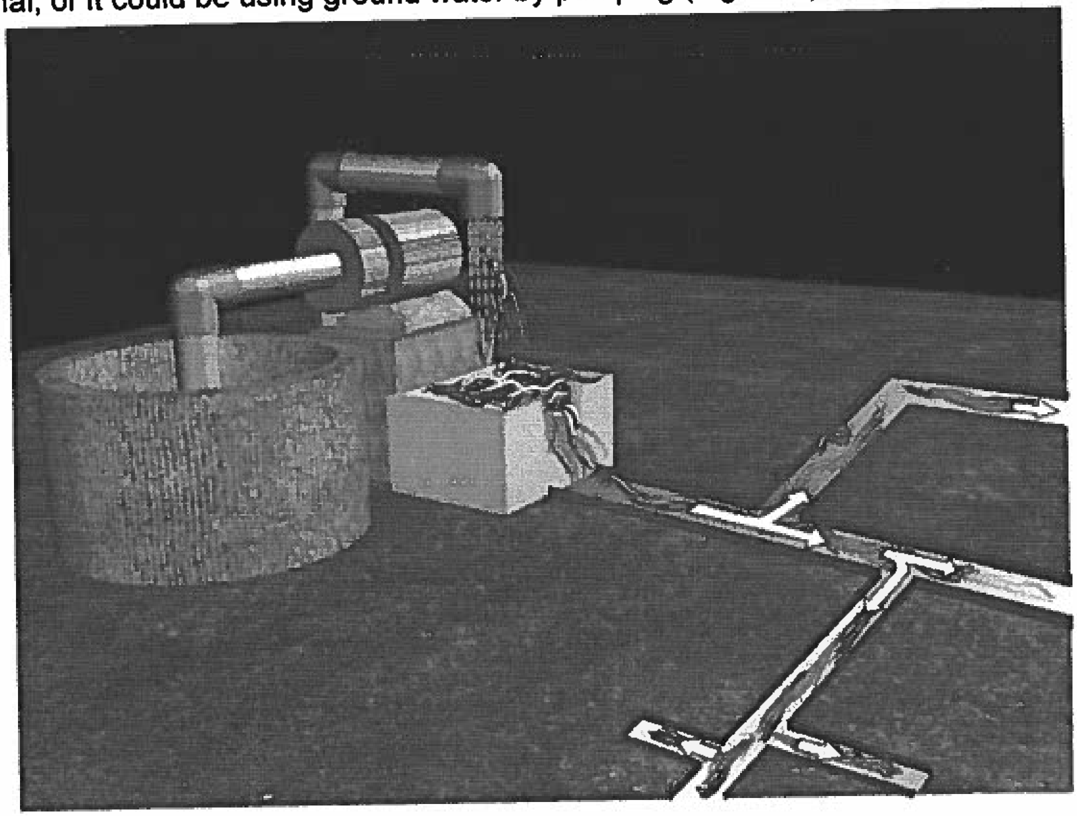


FIGURE 4. Water applied to field by pumping ground water

The water supplied is just enough to raise the crop within D hectares of the field, then a relationship may be found out amongst all the variables as:

Volume of water supplied = B*60*60*24

m^3 Area of crop irrigated = D*10^4 m^2

Volume of water supplied per unit area = $\frac{86400}{D}$ = $\frac{8.64 B}{D}$

10000

Hence, knowing two of the three variables B, D and The third party may be Δfound out.

The duty of irrigation water depends upon a number of factors; some of the important ones are as follows:

- **Type of crop:** As different crops require different amount of water for maturity, duties are also required. The duty would vary inversely as the water requirement of crop.

- **Climate season and type of soil:** Some water applied to the field is expected to be lost through evaporation and deep percolation.

  Evaporation loss has a direct bearing on the prevalent climate and percolation may be during drier seasons when the water table is low and soil is also dry. Percolation loss would be more for sandy soils than silty or clayey soils.

6. **Efficiency of cultivation methods:** If the tillage and methods of water application are faulty and less efficient, then the amount of water actually reaching the plant roots would be less. Hence, for proper crop growth more water would be required than an equivalent efficient system. Also, if the water is conveyed over long distances through field channels before being finally applied to the field, then also the duty will rise due to the losses taking place in the channels.

Crop growing seasons in India

Each crop has its own sowing and harvesting seasons and it is important to have a knowledge of this which may help to decide the total water demand in a field having mixed crops.

In India, the northern and north eastern regions have two distinct cropping

Cropping patterns

Planning of an irrigation project requires estimation of water demand of a cultivated area. Naturally, this would depend upon the type of crop grown. Since irrigation water may have to be supplied to one field growing a combination of crops or to many fields growing different crops, it is important to understand certain cropping practices which would be helpful in estimating the irrigation demand. Some of the prevalent practices are as follows:

1. Crops grown solely or mixed: Mixed cropping
2. Crops grown in a definite sequence: Rotational cropping
3. Land occupied by one crop during one season: Mono-cropping
4. Land occupied by two crops: double cropping
5. Land sowed with more than one crop in a year: multiple cropping

Irrigation water need

For raising a field crop effectively, it is essential to supply water through artificial irrigation supplementing the rain falling over the plot of land and raising the soil moisture. Irrigation requirement for a typical crop and an assumed rainfall pattern may be illustrated as in Figure5.

Hence, it may be seen that irrigation water requirement is rather a dynamic one. Also, the crop water requirement is shown with slight variation, it actually shows more variation, depending on the type of crop and the prevalent climate. Though farmers may be tempted to allow more water to the plants through supplemental irrigation, it must be remembered that there is an optimum water requirement schedule of each crop depending upon its stage of growth. It has been proved that at times application of more water may cause reduction in yield.

Variation of crop water requirement

The total water need for various plants, known as delta, has been discussed earlier. However, in planning the supply of irrigation water to a field crop, it is essential to estimate the water requirement of each plot of land growing a crop or crops at any point of time. This may be done by studying the dynamic interaction between a crop and the prevalent climate and the consequent water requirement. The demand would, naturally be also dependent on the type of crop and its stage of growth.

Plant roots extract water from the soil. Most of this water doesn't remain in the plant, but escapes to the atmosphere as vapor through the plants leaves and

Stems, a process which is called ***transpiration*** and occurs mostly during daytime. The water on the soil surface as well as the water attaching to the leaves and stem of a plant during a rainfall also is lost to the atmosphere by evaporation. Hence, the water need of a crop consists of transpiration plus evaporation, together called ***evapotranspiration***.

The effect of the major climatic factors on crop water needs may be summarized as follows:

- Sunshine
- Temperature
- Humidity
- Wind speed

The variation of evapotranspiration upon these factors is illustrated in Figure 6.

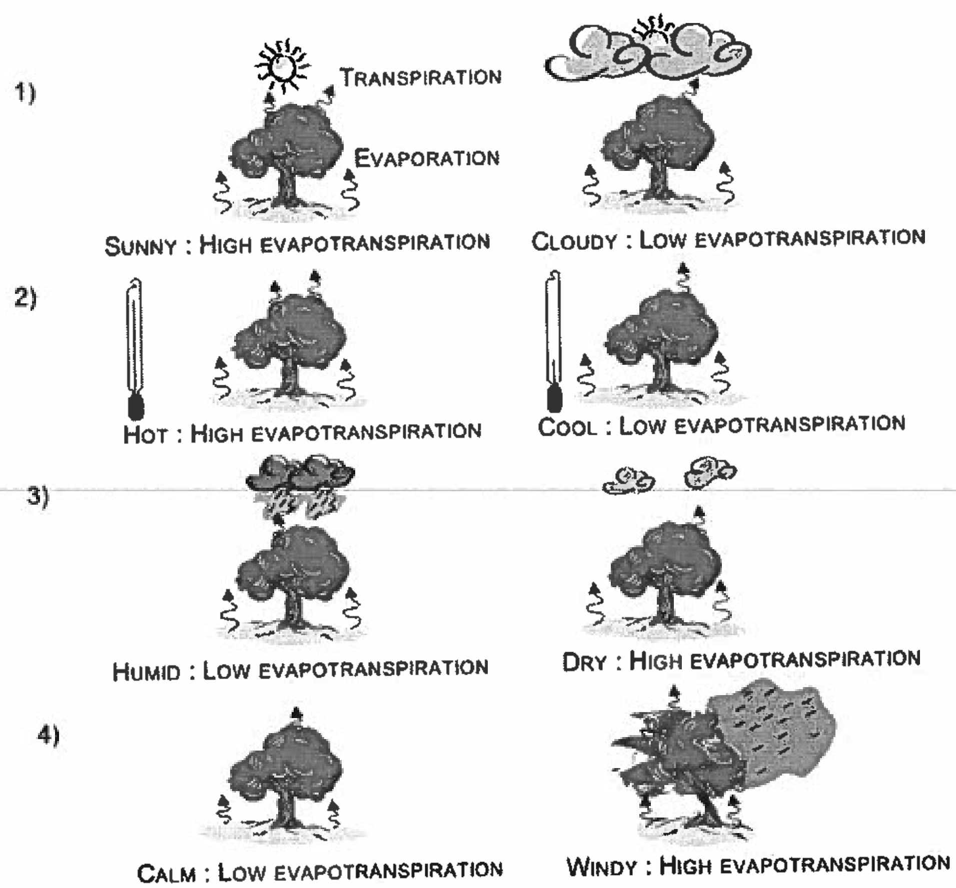


FIGURE 6. Dependence of evapotranspiration upon different climatological factors

Since the same crop grown in different climatic variations have different water needs, it has been accepted to evaluate the evapotranspiration rate for a standard or reference crop and find out that of all other crops in terms of this reference. Grass has been chosen as standardreferenceforthispurpose.Theevapotranspirationrateofthisstandardgrassis

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Therefore, called the ***reference crop evapotranspiration*** and is denoted as ***ET_O***, which is of course, the function of the climatic variables. Training Manual 3: Irrigation Water Needs published by the Food and Agricultural Organization, (FAO) and available on-linethrough the under-mentioned web-site gives an idea about the variation of ET_O under different climatic conditions and is reproduced in the table below.

http://www.fao.org/ag/agL/public.stm#iwmtm

Table showing the daily variation of water needs of standard grass (in mm) under different climatic patterns (ET_O)

Climatic Zone	Mean daily Temperature		
	Low (<15°C)	Medium (15°- 25°C)	High (>25°C)
Desert/Arid	4-6	7-8	9-10
Semi-arid	4-5	6-7	8-9
Sub-humid	3-4	5-6	7-8
humid	1-2	3-4	5-6

Other methods have been devised to calculate ET_O for given values of climatic parameters. These are discussed in the next section. In this section, we proceed on to

Discuss, how to find crop water need, if ET_O is known.

Agricultural scientists have evaluated a factor called ***crop factor*** and denoted it by K_C, to evaluate specific crop water needs. Naturally, Kc would be different for different crops and would not be the same throughout the growth season of one type of crop. Thus, the

Crop evapotranspiration, denoted by ET_C is to be evaluated as under:

$$ET_O = K_C * ET_C \qquad (1)$$

Both ET_O and ET_C should be in the same units and generally, mm/day is used as a standard all over the world.

In order to simply the calculations, the factor K_C has been evaluated for 4 stages of a crop growth usually denoted as

1. Initial stage
2. Crop development stage
3. Mid-season stage
4. Late season stage

The FAO Training Manual 3 gives the growth stage periods and the corresponding K_C values for some typical crops. In the table below, that for rice is presented.

Rice	Climate			
	Little wind		Strong wind	
Growth stage	Dry	Humid	Dry	Humid
0-60 days	1.1	1.1	1.1	1.1
Mid-season	1.2	1.05	1.35	1.3
Last 30 days before harvest	1.0	1.0	1.0	1.0

It may be mentioned that any crop doesn't have a fixed total growth period, which is the summation of growth stage periods given above. There is usually a range, depending upon the variety of the crop and the condition in which it is cultivated.

The values of K_C also depend upon the climate and particularly on humidity and wind Speed, as shown for rice in the above table. In general, the values of K_C should be reduced by 0.05 if the relative humidity is high (>80%) and the wind speed is low (<2m/s). Likewise, the values should be increased by 0.05 if the relative humidity is low (<50%) and the wind speed is high (>5m/s).

For full details, the FAO training manual 3 may be consulted as K_C values for other crops are evaluated in different manners. For some of the crops, the following table provides information:

Crop	Variety	Crop growth stage				Total growth period
Cabbage/Carrot	Short duration	20 days	25 days	60 days	15 days	120 days
	Long duration	25 days	30 days	65 days	20 days	140 days
	Kc	0.45	0.75	1.05	0.9	
Cotton/Fiax	Short duration	30 days	50 days	55 days	45 days	180
	Long duration	30 days	50 days	65 days	50 days	195
	Kc	0.45	0.75	1.15	0.75	
Lentil/Pulses	Short duration	20 days	30 days	60 days	40 days	150
	Long duration	25 days	35 days	70 days	40 days	170
	Kc	0.45	0.75	1.1	0.5	
	Short	20	25	25	10	80

Maize	duration					
	Long duration	20	30	50	10	110
	K_C	0.4	0.8	1.15	1.0	
Onion (dry)	Short duration	15	25	70	40	150
	Long duration	20	35	110	45	210
	K_C	0.5	0.75	1.05	0.85	
Potato	Short duration	25	30	30	20	105
	Long duration	30	35	50	30	145
	K_C	0.45	0.75	1.15	0.85	

Estimation of reference crop ET_O

Of the many methods available, the commonly used ones are two:

i. Experimental methods, using the experimentation data from evaporation pan.
ii. Theoretical methods using empirical formulae, that take into account, climatic parameters.

Experimental method

Estimation of ET_O can be made using the formula

$$ET_O = K\ pan \times E\ pan \qquad (2)$$

Where ET_O is the ***reference crop evapotranspiration*** in mm/day, K pan is a coefficient called ***pan coefficient*** and Epan is the ***evaporation*** in mm/day from the pan.

The factor K pan varies with the position of the equipment (say, whether placed in a fallow area or a cropped area), humidity and wind speed. Generally, the details are supplied by the manufacturers of the pan. For the ***US Class A evaporation pan***, which is also used in India, K pan varies between 0.35 and 0.85, with an average value of0.7.

It may be noticed that finding out ET_C would involve the following expression

The important methods that have been proposed over the years take into account, various climatic parameters. Of these, only the following would be discussed, as they are the most commonly used.

Blanney-Criddle formula:

This formula gives an estimate of the mean monthly values of ET_O, which is stated as

$$ET_O = p\,(0.46\,T_{mean} + 8.13) \qquad (5)$$

Where p is the mean daily percentage of annual day time hours and has been estimated according to latitude; T mean is the mean monthly temperature in degrees Centigrade and may be taken as ½ x (T max + T min) for a particular month. Thus using the Equation (1),

One may evaluate ET_C for each month of the growing season, from which the total water need for the full growing season of the crop may be found out.

Penman-Monteith method:

This method suggests that the value of ET_O may be evaluated by the following formula:

$$ET_O = \frac{0.408\,(R_n - G) + \gamma \frac{900}{T+273} u_2 \,(e_s - e_a)}{+\gamma\,(1 + 0.34u_2)} \qquad (6)$$

Unit-V

21.1 Design of Canals

Many procedures have been developed over the years for the hydraulic design of open channel sections. The complexity of these procedures vary according to flow conditions as well as the level of assumption implied while developing the given equation. The Chezy equation is one of the procedures that was developed by a French engineer in the solution for any unknown related to the cross-sectional area of flow and wetted perimeter involves the implementation of an implicit recursive solution procedure which cannot be achieved analytically. Many implicit solution procedures such as the Newton-Raphson, Regula-Falsi (false position), secant, and the Van Wijngaarden-Dekker-Brent Methods (Press et al., 1992).

One of the important topics in the area of free surface flows is the design of channels capable of transporting water between two locations in a safe, cost - effective manner. Even though economics, safety, and aesthetics must always be considered, in this unit thrust is given only to the hydraulic aspects of channel design. For that discussion is confined to the design of channels for uniform flow. The two types of channels considered are

1. lined or none erodible;
2. Unlined, earthen, or erodible.

There are some basic issues common to both the types and are presented in the following paragraphs.

1. Shape of cross-section

From the Manning and Chezy equation, it is obvious that the conveyance of a channel increases as the hydraulic radius increases or as the wetted perimeter decreases. Thus, there is among all channel cross sections of a specified geometric shape and areas an optimum set of dimensions for that shape from the viewpoint of. Among all possible channel cross sections, the hydraulically efficient section is a semicircle since, for a given area, it has the minimum wetted perimeter. The proportions of the hydraulically efficient section of a specified geometric shape can be easily_derived. The geometric elements of these sections are summarized in Table. It should be noted that, the hydraulically efficient section is not necessarily the most economic section.

In practice the following factors are to be kept in mind:

a. The hydraulically efficient section minimizes the area required to convey a specified discharge. However, the area which required to be excavated to achieve the flow area required by the hydraulically efficient section may be much larger if one considers the removal of the over burden.

b. It may not be possible to construct a hydraulically efficient stable section in the available natural condition. If the channel is to be lined, the cost of the lining may be comparable with the cost of excavation.

c. The cost of excavation depends on the amount of material that is to removed, in addition to. Further Topography of the land access to the site also influence the cost of disposal of the material removed.

d. The slope of the channel bed must be considered also as a variable since it is not necessarily completely defined by topographic consideration. For example, reduced

Channel slope may require a larger flow area to convey the flow, on the other hand the cost of excavation of the overburden may be reduced.

2. Side slopes

The side slopes of a channel depend primarily on the engineering properties of the material through which the channel is excavated. From a practical viewpoint, the Side slopes should be suitable for preliminary purposes. However, in deep cuts, side slopes are often steeper above the water surface than they would be in an irrigation canal excavated in the same material. In many cases, side slopes are determined by the economics of construction. In this regard following observations are made:

a. In many unlined earthen canals, side slopes are usually 1.5 : 1;However,
Side slopes as steep as 1:1 have been used when the channel runs through cohesive materials.

b. In lined canals, the side slopes are generally steeper than in an unlined canal. If concrete is the lining material, side slopes greater than 1: 1 usually require the use of forms, and with side slopes greater than 0 .75: 1 the linings must be designed to withstand earth pressures. Some types of lining require side slopes as flat as those used for unlined channels.

c. Side slopes through cuts in rock can be vertical if this is desirable.

Table: Suitable side slopes for channels built in various types of materials (chow, 1959)

Material	Side slope
Rock	Nearly vertical
Muck and peat soils	1 / 4 : 1
Stiff clay or earth with concrete lining	1 / 2 : 1 to 1 : 1
Earth with stone lining or each for large channels	1 : 1
Firm clay or earth for small ditches	1 1/2 : 1
Loose, sandy earth	2 : 1
Sandy loam or porous clay	3 : 1

Indian standards for canal in cutting and embankment

Material (soil)	Side slope (Horizontal to Vertical m:1)	
	Cutting	Embankment
Hard clay or gravel	0.75 : 1	1.5 to 1.0
Soft Clay and alluvial soils	1.0 to 1.0	2.0 to 1.0
Sandy loam	1.5 to 1.0	2.0 to 1.0
Light sand	2.0 to 1.0	2.0 to 1.0 to 3.0 to 1.0
Soft rock	0.25 to 1.0 to 0.5 to 1.0	-
Hard rock	0.125 to 1 to 0.25 to 1.0	-

3. Longitudinal slope

The longitudinal slope of the channel is influenced by topography, the head required to carry the design flow, and the purpose of the channel. For example, in a hydroelectric power canal, a high head at the point of delivery is desirable, and a minimum longitudinal channel slope should be used. The slopes adopted in the irrigation channel should be as minimum as possible in order to achieve the highest command. Generally, the slopes vary from 1: 4000 to 1: 20000 in canal. However, the longitudinal slopes in the natural river may be very steep (1/10).

Slope of the channels in Western Ghats

Gentle slope	10 m / km	$S_0 = 0.01$
Moderate slope	10 to 20 m / km	$S_0 = 0.01$to 0.02
Steep slope	≥20 m / km	$S_0 \geq 0.02$

4. Permissible Velocities: Minimum and Maximum

It may be noted that canals carrying water with higher velocities may scour the bed and the sides of the channel leading to the collapse of the canal. On the other hand the weeds and plants grow in the channel when the nutrients are available in the water. Therefore, the minimum permissible velocity should not allow the growth of vegetation such as weed, hycinth as well you should not be permitting the settlement of suspended material (non silting velocity). The designer should look into these aspects before finalizing the minimum permissible velocity.

"Minimum permissible velocity" refers to the smallest velocity which will prevent both sedimentation and vegetative growth in general. An average velocity of (0.60 to 0.90 m/s) will prevent sedimentation when the silt load of the flow is low.

A velocity of 0.75 m /s is usually sufficient to prevent the growth of vegetation which significantly affects the conveyance of the channel. It should be noted that these values

Are only general guidelines. Maximum permissible velocities entirely depend on the material that is used and the bed slope of the channel. For example: in case of chutes, spillways the velocity may reach as high as 25 m/s. As the dam heights are increasing the expected velocities of the flows are also increasing and it can reach as high as 70 m/s in exceptional cases. Thus, when one refers to maximum permissible velocity, it is for the normal canals built for irrigation purposes and Power canals in which the energy loss must be minimized. Hence, following table gives the maximum permissible velocity for some selected materials.

Maximum permissible velocities and n values for different materials

material	V (m / s)	n
Fine sand	0.5	0.020
vertical Sandy loam	0.58	0.020
Silt loam	0.67	0.020
Firm loam	0.83	0.020
Stiff clay	1.25	0.025
Fine gravel	0.83	0.020
Coarse gravel	1.33	0.025
Gravel	1.2	
Disintegrated Rock	1.5	
Hard Rock	4.0	
Brick masonry with cement pointing	2.5	
Brick masonry with cement plaster	4.0	
Concrete	6.0	
Steel lining	10.0	

5. Resistance to the flow

In a given channel the rate of flow is inversely proportional to the surface roughness. The recommended values for a different types of lining are given below: Manning roughness for the design of several types of linings is as follows

Surface Characteristics	Value of n
Concrete with surface as indicated below	
(a) Trowel finish	0.012 - 0.014
(b) Flat finish	0.013 - 0.015
(c) Float finish some gravel on bottom	0.015 - 0.017
(d) Gunite, good section	0.016 - 0.017
Concrete bottom float finished sides	as indicated below
(a) Dressed stone in mortar	0.015 - 0.017
(b) Random stone in mortar	0.017 - 0.020
(c) Cement rubble masonry plastered	0.016 - 0.020
Brick lining	0.014 - 0.017

Asphalt lining	
(a) Smooth	0.01 3
(b) Rough	0.01 6
Concrete lined excavated rock with	
(a) Good section	0.017 - 0.020
(b) Irregular section	0.022 - 0.027

These values should, however, be adopted only where the channel has flushing velocity. In case the channel has non-flushing velocity the value of n may increase due to deposition of silt in coarse of time and should in such cases be taken as that for earthen channel. The actual value of n in Manning formula evaluated on the basis of observations taken on Yamuna Power Channeling November 1971 ranged between

0.0175 And 0.0229 at km 0.60 and between 0.0164 and 0.0175 at km 2.05. The higher value of n evaluated at km 0.60 could be attributed to the deposition of silt in head reaches of the channel.

Table: Manning Roughness Coefficients

Lining Category	Lining Type	n-value different depth ranges		
		Depth ranges		
		0 – 15 cm	15 – 60 cm	> 60 cm
Rigid	Concrete	0.015	0.013	0.013
	Grouted Riprap	0.040	0.030	0.028
	Stone Masonry	0.042	0.032	0.030
	Soil Cement	0.025	0.022	0.020
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.023	0.020	0.020
	Rock Cut	0.045	0.035	0.025
Temporary	Woven Paper Net	0.016	0.015	0.015
	Jute Net	0.028	0.022	0.019
	Fiberglass Roving	0.028	0.021	0.019
	Straw with Net	0.065	0.033	0.025
	Cured Wood Mat	0.066	0.035	0.028
	Synthetic Mat	0.036	0.025	0.021
Gravel Riprap	2.5-cm (d_{50})	0.044	0.033	0.030
	5 -cm (d_{50})	0.066	0.041	0.034
Rock Riprap	15-cm (d_{50})	0.104	0.069	0.035
	30-cm (d_{50})	-	0.078	0.040

The free board recommended by USBR for channels are given below

Q m^3/s	Free board F_B in m
< 0.75	0.45
0.75 - 1.5	0.60
1.5 - 85.0	0.75
> 85	0.90

The free board (measured from full supply level to the top of lining) depends upon the size of canal, velocity of water, curvature of alignment, wind and wave action and method of operation. The normal free board is 15 cm for small canals and may range up to 1.0 m for large canals. The

U.S.B.R. practice for the minimum permissible free board for various sizes of canal is given in Figure. Indian Standard IS : 4745 recommends a free board of 0.75 m for canal carrying a discharge of more than 10 m^3/sec.

Free board as per Indian Standards (IS 4745 - 1968), (IS 7112 - 1973)

Discharge Q (m^3/s)	Free board (m)	
	Unlined	Lined
< 10.0	0.50	0.60
> 10.0	0.75	0.75

21.1.1 Hydraulically Efficient Channel

It is well known that the conveyance of a channel section increases with increases in the hydraulic radius or with decrease in the wetted perimeter. Therefore, from the point of hydraulic aspects, the channel section having the least wetted perimeter for a given area has the maximum conveyance; such a section is known as the hydraulically efficient channel. But this is popularly referred as Best Hydraulic section. The semicircle has the least perimeter among all sections with the same area; hence it is the most hydraulically efficient of all sections.

The geometric elements of six best hydraulic section are given in Table. It may be noted that it may not be possible to implement in the field due to difficulties in construction and use of different materials. In general, a channel section should be designed for the best hydraulic efficiency but should be modified for practicability. From a practical point of view, it should be noted that a best hydraulic section is the section that gives the minimum area of flow for a given discharge but it need not be the minimum excavation. The section of minimum excavation is possible only if the water surface is at the level of +the top of the bank. When the water surface is below the bank top of the bank (which is

Very common in practice), channels smaller than those of the best hydraulic section will give minimum excavation. If the water surface overtops the banks and these are even with the ground level, wider channels will provide minimum excavation. Generally, hydraulically efficient channel is adopted for lined canals. It may also be noted that hydraulically efficient channel need not be economical channel (least cost).

Geometric elements of best hydraulically efficient section (figures)

Cross Section	A	P	R	T	D	Z = AD
Rectangular	$2y^2$	4y	0.5 y	2y	y	$2y^{2.5}$
Trapezoidal	$3y^2$ $(1.732\ y^2)$	2 3y (3.464y)	0.5 y	$\frac{4\ 3}{3}\ y$ (2.3094y)	$\frac{3}{4}y$ (0.75y)	$\frac{3}{2}y^{2.5}$ $(1.5y^{2.5})$
Triangular	y^2	2 2 y 2.828y	$\frac{2}{4}\ y$ 0.3535y	2y	$\frac{y}{2}$ 0.5y	$\frac{2}{2}\ y^{2.5}$ $0.707\ y^{2.5}$
Semi Circular	$\frac{\pi}{2}y^2$	πy	0 .5y	2y	$\frac{\pi}{4}y$	$\frac{\pi}{4}y^{2.5}$ $0.25\pi\ y^{2.5}$
Parabola $\frac{4}{\ }$ 2	$\frac{4}{3}\ 2\ y^2$ 1.89 [illegible]	$\frac{8}{3}\ 2\ y$	y/2 0.5y	2 2 y 2.83y	3	$\frac{8}{9}\ 3\ y^{2.5}$ 1.5396 [illegible]

** Hydrostatic Caternary (Linteria)

Flexible sheet: Filled with water up to rim, and held firmly at the top ends without any effect of fixation on shape. Shape assumed under self-height of water is called Hydrostatic Catenary.

21.1.2 Selection of Lining

Introduction

The need for lining channels in alluvium has long been identified to conserve every bit of water for more and more utilization. Lining of an irrigation channel is restored to achieve all or some of the following objectives keeping in view the overall economy of the project. The major advantages of rigid impermeable linings are as follows:

. education of seepage losses resulting in a saving of water which can be utilized for additional irrigation.

Prevention of water logging by reducing seepage to water-table.

Reduction in area of cross-section (and thereby saving in land) due to increase in permissible velocity by reduction in the value of rigidity and availing of steeper slope, where available. Minimize excavation costs

Improvement of discharging capacity of existing channels.

Improvement of operational efficiency.

Prevention of weed growth.

Reduction of maintenance cost.

Long economic life

ı.Insure Cross section stability from scour, low flow conditioned.

Canal Lining

ıe lining commonly adopted for irrigation channels can be classified into three groups

Rigid-impermeable Lining,

Flexible and Permeable Permanent Liningsand

Flexible TemporaryLinings.

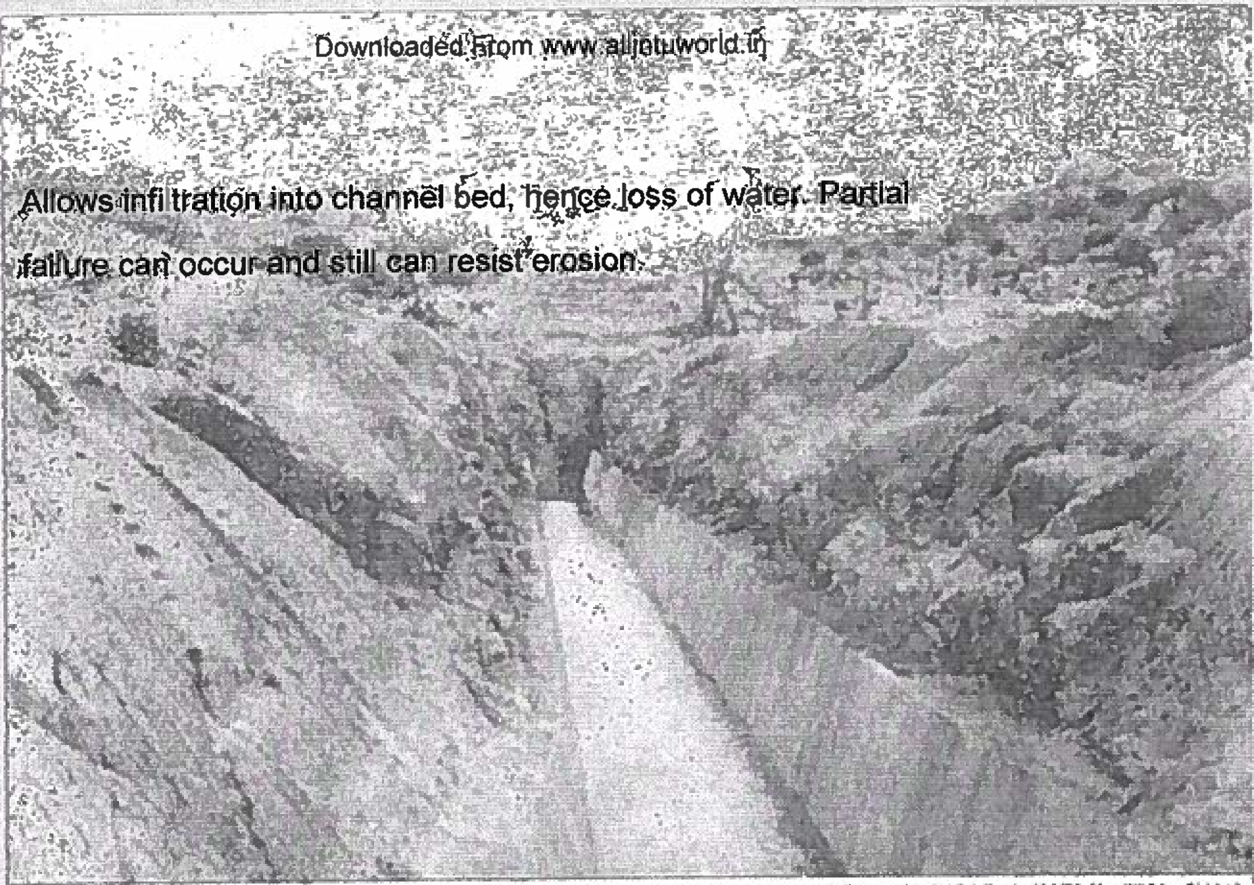
ҁample for the same are indicated in the box.

Canal Lining

Rigid Impermeable Linings	Flexible and Permeable Permanent Linings	Flexible Temporary
Rubble Masonry Cast-in-place Concrete Grouted Rip-rap or Grouted Pre-cast Concrete Soil Cement	Rip-rap or Stone Blocks Gabions Interlocking Pre-cast Concrete Interlocking Synthetic Units Vegetation and Grasses	Bare Soil Straw with Netting Hemp or Jute Mats Synthetic Matting

ıere are different types of lining like Cement Concrete, Shotcrete, Soil cement, ṣphaltic Concrete, etc.

ɬvantages of Flexible and Permeable Linings: Lining easily fits to cross section shape.



Canal piercing through a hill range by a tunnel, Tungabhadra Project

17. University Question papers of previous years

15 AG1A0139

R15

Code No: 125AC

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech III Year I Semester Examinations, November/December - 2017

WATER RESOURCES ENGINEERING-I

(Common to CE, CEE)

Time: 3 hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART - A

(25 Marks)

1.a) Define the terms interception loss and base flow. [2]
b) What is hydrograph? Draw a single peaked hydrograph and explain its components? [3]
c) What are the different types of aquifers? [2]
d) Write a short note on sprinkler method of irrigation. [3]
e) Describe with the help of a diagram, various forms of a soil moisture. What do you understand by the available moisture? [2]
f) Explain various types of canals, according to various classification systems. [3]
g) Differentiate between ground water flows and inter flow. [2]
h) Write short notes on infiltration indices. [3]
i) Define S-Curve hydrograph. What are its uses? [2]
j) Distinguish between influent stream and effluent stream. [3]

PART - B

(50 Marks)

2.a) What do you understand by precipitation? Explain various types of precipitation.
b) Find out the ordinates of a storm hydrograph resulting from a 3hr storm with rainfall of 3, 4.5 and 1.5cm during subsequent 3 hours intervals. The ordinates of unit hydrograph are given in the table below. Assume an initial loss of 5mm, infiltration index of 5mm/hour and base flow of 20cumecs. [5+5]

Hours	0	03	06	09	12	15	18	21	24	03	6	09	12
Ordinates of unit hydrograph (cumecs)	0	90	200	350	450	350	260	190	130	80	45	20	0

OR

3.a) What are the factors affecting infiltration? Discuss their effect in producing variation in infiltration rate during a storm, and also in producing seasonal and spatial variations in infiltration rate.
b) Describe the ISI standard evaporation pan with a neat sketch. In what way it is different from USWB class A land pan? [5+5]

4.a) What are the various components of runoff? Describe how each component is derived in the runoff process?

b) The hourly ordinates of a two hour unit hydrograph are given below. Derive a 6-hour unit hydrograph for the same catchment. [5+5]

Time (Hours)	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Discharge (cumecs)	0.0	1.0	2.7	5.0	8.0	9.8	9.0	7.5	6.3	5.0	4.0	2.9	2.1	1.3	0.5	0.0

OR

5. What do you understand by unit hydrograph? How is it derived? Explain its use in construction of flood hydrograph resulting from two or more periods of rainfall? [10]

6.a) Explain the terms
i) Porosity
ii) Specific yield
iii) Permeability

b) Explain Darcy's law. List out the assumptions made in the analysis of steady radial flow into well. [5+5]

OR

7.a) Explain the terms
i) Cone of depression
ii) Radius of influence
iii) Drawdow

b) When 3.68 million m^3 of water was pumped out from an unconfined aquifer of $6.2km^2$ areal extent, the water table was observed to go down by 2.6m. What is the specific yield of the aquifer? During a monsoon season if the water table of the same aquifer goes up by 10.8m. what is the volume of recharge? [5+5]

8.a) Write a short notes on the following:
i) Saturation capacity
ii) Field capacity
iii) Wilting point
iv) Optimum water.

b) What are the factors affecting duty? How can duty be improved? [5+5]

OR

9.a) Discuss in brief various methods of surface irrigation.

b) Explain consumptive use and water logging. What are irrigation efficiencies? [5+5]

10.a) For a channel, the discharge Q, rugosity coefficient N, critical velocity ratio m, and the bed width-depth ratio B/D are given. Explain how would you design the channel using Kennedy's theory?

b) How do you measure and estimate stream flow? [5+5]

OR

11.a) Using Lacey's theory, design an irrigation channel for the following data:
Discharge Q=50cumecs
Silt facor f=1
Side slopes=$\frac{1}{2}$: 1

b) What is flood frequency analysis? How do you compute design discharge over a catchment? [5+5]

---ooOoo---

ode No:

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
***B.*Tech IH Year I Semester Examinations, May - 2018 WATER RESQVRCES ENGINEERING-I**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries Ifi marks and may.have a, .b, c as sub questions.

PART — A

(25 Marks)

[2]

1.a) List the factors that affect the runoff from catchment area.

b) Describe various types of precipitation. [2s

c) What is.Effective rainfa1U 3I'

d) Write down the nsumptions of unit hydrograph. (2)

e) . Define aquicludé. ' ' [3]

f) Draw the divisions of sub-surface water. (2)

g) List the importance of irrigation. [3]

h) What are the ill effects of irrigation? [2]

i) How do you classify the canal, based on the functions of the canal? {3]

j) What are the disadvantages of canal lining?

[5+5]

2.a) Explain tipping bucket type rain gauge with a neat sketch.

b) Describe the factors affecting infiltration.

OR

3.a) Explain any one method of estimation pf evaporatio.n in detail. [5+5]

b) Déscribe any two method8 ofcomputiiig average rainfall over the basin. I

[5+5]

4.a) What is unit hydrograph? How do you construct it?

b) Describe the two methods of separating base flow from the total runoff.

OR

5. The ordinates of a 4h unit hydrograph of a basin area 300km² measured at Ih internals are 6,36.,66,91; 106,93,79. 68,58;49,.41,34,27,23,17,13,9,6,3. And 1.5 m /s...respectively.
;Obtaln the ordinates of a.3h unit hydrograph for the basin using the S,-curve techni u0$

6. a) Explain the types of aquifer.

b) How do you determine the yield of the open well from recuperation test? [5+5]

OR

7. Explain in detail the types of tube wells along with their construction details.

8) Explain in detail the factors affecting duty. [10]

OR

9) After how many days will you supply water to soil in order to ensure efficient irrigation of, the given crop„•i
10a} field capacity. Fif'soi1"27%
A) Permanent wilting point = 14%
b) Dry density of soil = 15kN/x'
c) Effective depth of root zone =75 cm
D) Daily consumptive use of water for the given crop =11mm. [10]

11. A) Explain the balancing depth of cutting
b) Explain the flood frequency analysis method.[5+5]

NAWAB SHAH ALAM KHAN COLEEG OF ENGINEERING & TECHNOLOGY

Hydrology Water Resources Engineering - I
B.TECH 3RD YEAR SEM-II CIVIL MID-1 EXAM
31-5-2021

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*Required

EMAIL ID *

Your answer

NAME *

Your answer

ROLLNUMBER *

Your answer

SECTION *

Your answer

4. In filtration occurs of capacity rate * 1 point

- A. Due to watershed leakage
- B. If there had been antecedent rain fall
- C. If the intensity of the rain fall is lower than the capacity
- D. during a first flash storm fallowing summer

5. Unit hydro graph method for flood estimation is usually applied to * 1 point

- A. Large basins
- B. hilly areas
- C. Small and medium sized basins
- D. Oceans

6. Darcy's law of flow through soil assumes that the flow is de * 1 point

- A. steady and laminar
- B. non uniform
- C. turbulent
- D. transition

10. Evapotranspiration depends on 1 point
*

- A. hours of bright sum shine
- B. type of crop
- C. method of irrigation
- D. all of the above

11.Water contains * 1 point

- A. one hydrogen atom and one oxygen atom
- B.two hydrogen atoms and one oxygen atom
- C.one hydrogen atom and two oxygen atoms
- D. three hydrogen atoms and two oxygen atoms

12.Unit Hydrograph theory was enunciated by * 1 point

- A. Merril Bernard
- B. W.W. Horner
- C.Le-Roy K. Shermen
- D. Robert E. Horten.

16. The surface Run-off is the quantity of water * 1 point

- A. absorbed by soil
- B. intercepted by buildings and vegetative cover
- C. required to fill surface depressions
- D. that reaches the stream channels

17. Pick up the correct statement from the following : * 1 point

- A. Rain which is intercepted by buildings, vegetation's and other objects, is generally known as rainfall interception
- B. The difference between the total rainfall and intercepted rainfall, is generally called ground rainfall
- C. When rainfall exceeds the interception rainfall, water reaches the ground and infiltration starts
- D. all the above

20. Pick up the correct statement from the following : * 1 point

- A. When rainfall rate exceeds the infiltration capacity, the water enters the soil at full capacity rate
- B. When rainfall rate is less than the infiltration capacity, the infiltration rate is approximately equal to the rainfall rate
- C. The actual infiltration rate at any time may be equal to or less than the infiltration capacity
- D. all the above

21. According to Robert E. Horton, the equation of infiltration capacity curve, is (where letters carry their usual meanings) * 1 point

- A. f = fc (fo - fc) ekt
- B. f = ft - (fo - fc) e-kt
- C. f = ft + (fo - fc) e-kt
- D. f = f + (fo - fc) ekt

25. In India, rain fall is generally recorded at * 1 point

- A. 8 A.M.
- B. 12 Noon
- C. 4 P.M.
- D. 8 P.M.

26. Precipitation caused by lifting of an air mass due to the pressure difference, is called * 1 point

- A. cyclonic precipitation
- B. convective precipitation
- C. orographic precipitation
- D. none of these.

27.A recording type rain gauge * 1 point

- A. produces a mass curve of rain fall
- B. records the cumulative rain
- C. is sometimes called integrating rain gauge or continuous rain gauge
- D. all the above.

30. If a gauge is installed perpendicular to the slope, its measurement is reduced by multiplying * 1 point

- A. sine of the angle of inclination with vertical
- B.cosine of the angle of inclination with vertical
- C. tangent of the angle of inclination with vertical
- D. Calibration coefficient of the gauge.

31.For determination of average annual precipitation in a catchment basin, the best method is * 1 point

- A. Arithmetical method
- B.Thiessen's mean method
- C. Isohyetal method
- D. None of these.

35. Prof. Running suggested the method for extending the discharge curve. It is known as * 1 point

- A. Logarithmic method
- B.y method
- C.General method
- D. None of these.

36. If y is the depth of water at any section, then the mean velocity is * 1 point

- A.0.1 y
- B.0.2 y
- C.0.3 y
- D.0.6 y

37. The run off is affected by * 1 point

- A.type of precipitation
- B.rain intensity and duration of rainfall
- C.rain distribution and soil moisture deficiency
- D.all the above.

40. From the Survey of India map, the distance of the critical point is 20 km and difference in elevation is 193 m. The over land flow time, is * 1 point

- A. 2 hours
- B. 3 hours
- C. 2 hours and 30 minutes
- D. 4 hours

Submit

Clear form

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING AND TECHNOLOGY

New Malakpet , Hyderabad-500024

III-II-B.TECH MID-II EXAMINATION 2021

SUBJECT: HYDROLOGY & WATER RESOURCE ENGINEERING

BRANCH: CIVIL ENGINEERING **DATE:**

TIME: 1HOUR **MARKS: 10**

Q.NO	Question	Blooms level
1	Define well? What are the various types of well with neat sketch?	L4 CO3
2	What is irrigation? What are the types of irrigation method with neat sketch?	L4 CO3
3	What is delta and duty? What are the factor affecting duty? Determine the Relation between them?	L5 CO4
4	What is canal? Various canals according to classification systems? Design of canal?	L6 CO4

17.QUESTION BANK

UNIT – I

S. No	Questions	Blooms Taxonomy Level	course Outcome
1	A basin has the area in the form of a pentagon with each side of length 20Km. The five raingauges loc ted at the corners A, B, C, D and E have recorded 60, 81, 73, 59 and 45 mm of rainfall respectively. Compute average depth of rainfall over the basin using arithmetic mean and Theissen polygon methods.	evaluate	CO1
2	The annual rainfalls at 7 raingauge stations in a basin are 58, 94, 60, 45, 20, 88 and 68cm respectively. What is the percentage accuracy of the existing network in the estimation of average depth of rainfall over the basin. How many addit ional gauges are required, if it is desired to limit the error to only 10%.	evaluate	CO1
3	(a)Define water equivalent of snow and explain how you estimate snow melt? (b) Discuss the analysis of rainfall data with respect to time, space, frequency and intensity.	Remembering Understanding	CO1
4	(a)Explain the balanced equation for precipitation and describe the terms i. Interception and ii. Depression storage. (b)Describe with the help of neat sketches any three methods of separation of base flow from the hydrograph of runoff (i.e. stream flow hydrograph) indicating the situation under which you advocate them.	Analyse	CO1
5	(a) Describe with the help of sketch various forms of soil moisture. Which of these soil moistures is mainly available for utilization by the plants? (b)Write short notes on: (i) Double-mass curve (ii) Cold and warm fronts (iii) Cyclones and anticyclones.	Analyse	CO1
6	(a)Write short notes on: (i) Pan Co-efficient (ii) ϕ-index (iii) Evaporation opportunity. (b) Evaporation is indirectly a cooling process. Justify the statement. Discuss the factors affecting evaporation.	Creating	CO1
7	a)Bring out the difference between evaporation, transpiration, evapotranspiration and consumptive use. (b) Discuss the various factors affecting evapotranspiration. (c) Distinguish between the potential evapotranspiration and the actual evapo-transpiration.	Creating	CO1
8	(a) Discuss the various factors affecting evapotranspiration. (b)Write notes on the following: (i). Permanent Wilting point (ii). Temporary Wilting point (iii). Readily available soil moisture	Analyze	CO1
9	(a) Explain energy budget method of computing lake evaporation. What are its limitations? (b) What factors are considered while locating a gauge-discharge site?	Remembering Understanding	CO1
10	(a) Different iate between: infiltration rate and infiltration capacity (b) Write short notes on: (i)Isochrones (ii)Time of concentration	Analyse	CO1

UNIT – II

S.No	Questions	Blooms Taxonomy Level	course Outcome
1	Define unit hydrograph. What are the assumptions underlying the unit hydrogr aph theory. How do they limit the applicability of unit hydrograph?	Understanding	CO2
2	(a) What does the word unit refer to in the unit hydrograph? Explain with sketches what do you understand by the principle of linearity and principle of time invariance in the unit hydrograph theory? (b) Describe how recession constants of direct runoff and base flow curves are obtained from a semi log arithmetic plot.	evaluate	CO2
3	Explain the terms: (i)Annual series (ii). Partial duration series (iii). Recurrence interval (iv). Probable maximum precipitation.	Understanding Remembering	CO2
4	Describe how unit hydrograph can be used to predict the runoff from a storm. What are the uses of unit hydrograph.	Understanding Remembering	CO2
5	Describe the method of estimating a Tr -year flood using Gumbel's distr ibution.	analyze	CO2
6	(a) What are the various components of runoff? Describe how each component is derived in the runoff process (b) How is runoff estimated using Strange's tables and Barlow's tables	apply	CO2
7	State the significance of inflection point on recession side of the hydrograph. Also explain the different factors that effect the shape of the hydrograph	analyze	CO2
8	(a) Describe the method of deriving unit hydrograph from complex storms . (b) Describe SCS method in detail.	analyze	CO2
9	Discuss a method to obtain UH from complex storms. What do you under stand by the principle of linearity and time invariance in unit hydrograph?	evaluate	CO2
10	(a) What do you mean by Antecedent precipitation index? Explain. (b) List out and explain various physiographic factors affecting runoff.	Understanding Remembering	CO2

UNIT –III

S. No	Questions	Blooms Taxonomy Level	course Outcome
1	Write short notes on: (a) Specific capacity of a well and specific yield of an aquifer (b) Aquifer and acuiclude (c) Open wells and tube wells (d) Water table and artesian aquifers	Understanding Remembering	CO3
2	Distinguish between (a) Aquifer and Aquifuge (b) Confined aquifer and water table aquifer (c) Aquiclude and Aquitard (d) Groundwater and Perched groundwater	Evaluate	CO3
3	Write notes on the following: i. well losses, ii. Specific capacity of a well, iii. Spherical flow in a well, iv. Interference among wells	Understanding Remembering	CO3
4	Distinguish between i. Aquifer s and aquicludes ii. Non- ar tesian and artesian wells iii. Perched aquif ers and water table aquifier iv. Permeability and transmissibility.	Analyze	CO3
5	Differentiate between shallow dug wells and deep dug wells. How the dug well is constructed? Enumerate the methods which are used for determining the yield of dug wells. Discuss briefly any one of these methods.	Evaluate	CO3
6	(a) Distinguish with sketches if necessary, the difference between unconfined and confined aquifer (b) Derive a formula for discharge of a well in a homogeneous unconfined aquifer assuming equilibrium flow condition. State the	Evaluate	CO3
	assumptions on which the for mula is based.		CO3
7	(a) Distinguish between. i. Vadose zone and phreatic zone ii. Aquiclude and Aquitard iii. Transmissivity and storativity	Understanding Remembering	CO3
8	Define and explain the following terms as used in connection with ground water i. Capillary fringe, ii. Specific yeild, iii. Pellecular water, iv. Field capacity	Remembering &Evaluate	CO3
9	Write notes on the following: i. Capillary water , ii. Hygroscopic water iii. Gravitational water	Understanding	CO3
10	Define outlet factor, capacity factor, full supply coefficient and root zone depth.	Understanding	CO3

UNIT – IV

S. No	Questions	Blooms Taxonomy Level	course Outcome
1	Discuss various methods of irrigation and state the advantages of each method.	Understanding	CO4
2	(a) Discuss in brief, various methods of surface irrigation (b) Describe the step by step procedure for preparation of land for irrigation	Understanding Remembering	CO4
3	(a) What is meant by C2-S2 water?. Discuss its usefulness for irrigating fine textured soils. (b) Write short notes on: i. Applicability of lift irrigation ii. Mixed cropping iii. Il-effects of irrigation	Evaluate	CO4
4	(a) What is meant by Furrow irrigation and Sprinkler irrigation? Which one is preferred in India and Why. (b) What is meant by 'Border flooding' How does it differ from 'Check flooding' and 'free flooding'?	Understanding Remembering	CO4
5	(a) Define Irrigation. What is the necessity of irrigation? (b) Describe in brief some of the important irrigation projects and multipurpose river valley projects under taken or completed after independence of our countr y.	Evaluate	CO4
6	(a) What is meant by flow duty and quantity duty? (b)Ex plain as how the following factors effect the duty of a crop. i. soil and sub soil condition ii. Stage of growth iii. Temperature iv. Rainfall	Understanding	CO4
7	(a) Define the terms Duty, Delta and base period and also derive the relation between them. (b) Explain the following terms:	Understanding	CO4
	i. Field capacity ii. Moisture equivalent iii. Available moisture.		CO4
8	(a) Define irrigation efficiency. List out different types of irrigation efficiencies. Explain any two of them (b) Define Consumptive use of water? List out various methods used for the assessment of consumptive use of water? Explain any one method in detail for the estimation of consumptive use	Understanding	CO4
9	(a) Why soil is necessary for plant life . Explain the classification of soils based on geological process of formation. b) Write down the classification of irrigation water based on sodium absorption ratio and its suitability for irrigation.	Understanding	CO4
10	What is meant by duty and delta of canal water? Derive a relation between duty and delta for a given base period.	Analyze	CO4

UNIT – V			
S. No	Questions	Blooms Taxonomy Level	course Outcome
1	(a) Write short notes on the following : i. free boarding in canals ii. Permanent land width iii. Inspection road iv. Berm (b) Write down the classification of canals. Explain canal alignment.	Analyze	CO4
2	(a) Why is Lacey's conception is superior to that of Kennedy's? (b) What do you understand by i. regime channels ii. Initial and final regime of channels?	Evaluate	CO4
3	(a) When do you classify the channel as having attained regime condition? (b) Describe briefly the observations of Lacey on the regime of river.	Evaluate	CO4
4	(a) Discuss critically the statement "The bank s of an unlined channel are more Susceptible to erosion than its bed, and hence the stability of the bank s and not of its bed is the governing factor in unlined canal designs". (b) Explain the following terms in detail. i. Ridge canal ii. Side slope canal	Evaluate	CO4
5	(a) What is the necessity of drainage below the lining? Discuss the various drainage and pressure release arrangements. (b) Using Lacey's basic regime equations derive an expression for Lacey's scour depth.	Analyze	CO4
6	What is meant by scour? What precautions do you take against it during the design of weirs?	Analyze	CO4
7	Explain the mid-section method of computing the discharge in a stream. Show in a neat sketch, the positions of velocity measurements over the cross sectional area of the stream.	Analyze	CO4
8	Draw a typical cross section of a barrage founded on pervious foundations and ex plain its salient features.	Analyze	CO4
9	(a) What do you understand by critical gradient. What will happen if the critical gradient is exceeded? What is Khosla s safe exit gradient? (b) Explain how Khoslas theory is modification over Bligh's theory.	Analyze	CO4
10	Distinguish between: i. Overland flow and interflow ii. Influent and effluent streams iii. Detention storage and depression storage iv. Drainage density and drainage divide.	Remembering	CO4

18.ASSIGNMENT QUESTION

UNIT – I

S. No	Questions	Blooms Taxonomy Level	course Outcome
1	Draw the hydrological cycle?	Understanding	CO1
2	What are the types of precipitation?	Understanding	CO1
3	Define Readily available soil moisture?	Understanding	CO1
4	How can we reduce the water usage?	Understanding Remembering	CO1
5	Difference between the rainfall and run off?	Evaluate	CO1
6	What are the factors affecting evaporation?	Understanding	CO1
7	How can you measure the infiltration?	Evaluate	CO1
8	What are the types of infiltration indices?	Remembering	CO1
9	Define permanent wilting point?	Understanding	CO1
10	Define rainfall double mass curve?	Understanding Remembering	CO1

UNIT- II

S. No	Questions	Blooms Taxonomy Level	course Outcome
1	Explain hydrograph analysis?	Understanding	C02
2	What do you mean by base flow?	Understanding	CO2
3	What do you understand about flood hydrograph?	Understanding	CO2
4	Define return period and exceedence probability?	Understanding	CO2
5	Define Unit hydrograph?	Understanding , remembering	CO2
6	Define S- hydrograph?	Evaluate	CO2
7	Define Maximum probable flood?	Evaluate	CO2
8	Define Design flood?	Understanding , remembering	CO2
9	Define Annual series?	Remembering	CO2
10	Define Partial series?	Understanding remembering	CO2

UNIT – III

S. No	Questions	Blooms Taxonomy Level	course Outcome
1	Define aquifer?	understanding	CO3
2	What are the different types of aquifers?	understanding	CO3
3	Define porosity?	understanding	CO3
4	Define Specific yield?	understanding	CO3
5	Define specific retention?	Evaluate	CO3
6	Define Permeability?	understanding	CO3
7	Define transmissibility?	understanding	CO3
8	Define Storage coefficient?	Understanding ,remembering	CO3
9	What are the types of wells?	Understanding , remembering	CO3
10	Ground water and surface water, Which water is more pure?	Evaluate	CO3

UNIT-IV

S. No	Questions	Blooms Taxonomy Level	course Outcome
1	Define Irrigation?	understanding	CO4
2	What are the different types of soils?	understanding	CO4
3	What do you understand about full supply coefficient?	understanding	CO4
4	What are the ill effects of irrigation?	understanding	CO4
5	What standards required for Irrigation water?	understanding	CO4
6	Define Duty and Delta?	understanding	CO4
7	What do you know about the water conveyance efficiency?	understanding	CO4
8	What do you understand about vertical distribution of soil moisture?	Evaluate	CO4
9	Define water logging?	Evaluate	CO4
10	Define field capacity?	Evaluate	CO4

UNIT-V

S. No	Questions	Blooms Taxonomy Level	course Outcome
1	What is the difference between the lake and a canal?	Understanding	CO4
2	Name the two different types of silt theories?	Remembering	CO4
3	What do you meant by initial and final regime of channels?	Remembering Understanding	CO4
4	What are the merits of Lacey's theory?	Remembering Understanding	CO4
5	Why do we need to provide side slopes for canals?	Understanding	CO4
6	What do you understand about SCS curve?	Understanding Remembering	CO4
7	What is meant by detention storage and depression storage?	Remembering	CO4
8	What do you know about Gumbels method of flood frequency anaylasis?	Remembering Understanding	CO4
9	What is the difference between the silt and scour?	Remembering Understanding	CO4
10	Which rational formula gives the best results for flood frequency analysis?	Evaluate	CO4

20. Unit wise Quiz Questions and long Key

UNIT -I

I. Choose the correct alternative:

1. The depth of rice root zone is [ ]

a)50cm b) 60cm c) 70cm d)90cm

2.The field capacity of a soil depends upon [ ]
a) Capillary tension in soil b) Porosity of a soil
c)Both 1&2 d) Neither 1&2
3. Effective rainfall for a crop may be define as [ ]
a) The portion of the rainfall which utilized by crop b) The total rainfall
c) The total rainfall minus the total runoff d) none
4. The time factor of a canal is define as [ ]
a) The number of days of irrigation period to the number of days
b) The number of days the canal has run at it capacity
c) the hectare of irrigation d) none
5.Which of the following has maximum water application efficiency [ ]
a) surface irrigation b) Lift irrigation c)Sprinkler irrigation d) All the above
6.Irrigation canal are generally aligned along [ ]
a) Rigid line b) Contour line c) valley line d) Straight line
7. Canals constructed for draining off water from water logged area known as[ ]
a) Drains b)Inundation canals c)valley canal d) contour canals
8. For diversion of flood water of rivers the type of canal is constructed is [ ]
a) Rigid canal b) Perennial canal c) Inundation canal d) canal
9.Canal taken off ice-fed perennial rivers are known as [ ]
a) Permanent canal b) Rigid canal c) Perennial canal d) Inundation canals
10. Which type of crop is sugar cane [ ]
a) Kharif b) Rabi c) Hot weather d) Perennial

II Fill in the Blanks:

11. When the water table is within the root zone depth & deter mental to plant life is said to be ________

12. the most commonly adopted method of irrigation for cereal crop is________

13. The top soil of a waterlogged field becomes more alkaline & infertile if PH value is ___________

14. The duty of water at the outlet is also known as_________

15. An irrigation canal which is designed to irrigate all round year called as _________

16. The kharif crop is sown in which season ______________

17. A climatic region lacking enough water for agriculture without artificial irrigation is called_________

18. The moisture useful for plant growth is _________

19. IMD stand for ___________.

20. The strange's table gives the relation between_________

UNIT -I KEYS

I choose the correct alternative

1. D
2. C
3. A
4. A
5. C
6. A
7. A
8. C
9. C
10. A

II Fill in the blanks

11. SCOT PINE
12. CHECK METHOD
13. 11
14. OUT LET PIPE
15. ARTIFICAL WATER WAYS
16. MONSOON SEASON
17. ARID ZONE
18. CAPPILARY WATER
19. INDIAN METROLOGICAL DEPARTMENT
20. RAINFALL RUNOFF

UNIT -II

I. Choose the correct alternative:

1. in filtration occurs of capacity rate [ ]
a).Due to watershed leakage b) If there had been antecedent rain fall
c) If the intensity of the rain fall is lower than the capacity
d) During a first flash storm fallowing summer

2. Unit hydro graph method for flood estimation is usually applied to [ ]
a)Large basins b)hilly areas c.)Small and medium sized basins d) oceans

3. Darcy's law of flow through soil assumes that the flow is [ ]
a) Steady and laminar b) non uniform c) turbulent d) transition

4. In a tube well strainers are used to [ ]
a) Reduce the area of percolation b)prevent average soil particles from entering the bored hole
c) Improve the quality of the water d) lift the stored water

5. An aquifer that is confined at the bottom but not at the top is known as [ ]
a) Partially confined aquifer b) aquiclude c) semi confined aquifer d) Unconfined aquifer

6. Unit hydrograph method is usually adopted for estimating floods when the catchment [ ]
a)100 sq.km only b)less than 5000 sq.km c)more than 7500 sq.km d)more than 10000 sq.km

7. Evapotranspiration depends on [ ]
a)hours of bright sun shine b)type of crop c)method of irrigation d)all of the above

8. The diameter of the standard Symon's type rain guess [ ]
a) 12.7 cm b) 7.5cm c) 5cm d) 15 cm

9. Maximum surface run off is favored due to [ ]
a) Leaf shaped catchment b) A flash storm
c) Improved land management d) presence of forest area

10. Isohyets are [ ]
a) Areas of equal precipitation b) lines of equal Precipitation
c) Lines of equal temperature on maps d) lines of equal barometric pressure on maps

II Fill in the Blanks:

11. A Permeable stratum which is capable to yield appreciable quantity of ground water under gravity is Known as __________

12. Double mass curve method is employed in extrapolation of __________

13. A hydrograph is a plot of ________________

14. Rainfall is measured in __________

15. A tube well is suitable when the sub soil formation is made up of __________

16. ____________formula is widely used in ground water problems.

17. Delayed ground water flow reaching a stream is known as __________

18. Run off volumes are generally computed for large areas by using _________

19. The instrument used for the measurement of wind speed is _________

20. Precipitation falling during the growing period of crop that is available to meet the evaporation needs of the crop is called ____________rain fall

UNIT -II KEYS

I choose the correct alternative

1. A
2. D
3. A
4. A
5. B
6. A
7. B
8. C
9. C
10. C

II Fill in the blanks

11. RAINFALL DATA
12. RUNOFF
13. CHECK METHOD
14. INDIAN METROLOGICAL DEPARTMENT
15. CAPPILARY WATER
16. PRECIPITATION
17OUT LET PIPE
18. ARTIFICAL WATER WAYS
19. MONSOON SEASON
20. ARID ZONE

UNIT-III

I. Choose the correct alternative:

1. Darcy's law of flow through soil assumes that the flow is de [ ]
a) Steady and laminar b) non uniform c) turbulent d) transition

2. In a tube well strainers are used to [ ]
a) Reduce the area of percolation b)prevent average soil particles from entering the bored hole
c) Improve the quality of the water d) lift the stored water

3. An aquifer that is confined at the bottom but not at the top is known as [ ]
a) Partially confined aquifer b) aquiclude c) semi confined aquifer d) Unconfined aquifer

4. Unit hydrograph method is usually adopted for estimating floods when the catchment area is [ ]
a)100 sq.km only b)less than 5000 sq.km c)more than 7500 sq.km d)more than 10000 sq.km

5. Evapotranspiration depends on [ ]
a)hours of bright sun shine b)type of crop c)method of irrigation d)all of the above

6. The diameter of the standard Symon's type rain guess [ ]
a) 12.7 cm b) 7.5cm c) 5cm d) 15 cm

7. Maximum surface run off is favored due to [ ]
a) Leaf shaped catchment b) A flash storm
c) Improved land management d) presence of forest area

8. Isohyets are [ ]
a) Areas of equal precipitation b) lines of equal Precipitation
c) Lines of equal temperature on maps d) lines of equal barometric pressure on maps

9. in filtration occurs of capacity rate [ ]
a) Due to watershed leakage b) If there had been antecedent rain fall
c) If the intensity of the rain fall is lower than the capacity
d) During a first flash storm fallowing summer

10. Unit hydro graph method for flood estimation is usually applied to [ ]
a) Large basins b) hilly areas
c) Small and medium sized basins d) oceans

II Fill in the Blanks:

11. A hydrograph is a plot of _______________

12. Rainfall is measured in _________

13. A tube well is suitable when the sub soil formation is made up of _________

14. ___________formula is widely used in ground water problems.

15. Delayed ground water flow reaching a stream is known as _________

16. Run off volumes are generally computed for large areas by using _________

17. The instrument used for the measurement of wind speed is _________

18. Precipitation falling during the growing period of crop that is available to meet the evaporation needs of the crop is called ___________rain fall.

19. A Permeable stratum which is capable to yield appreciable quantity of ground water under gravity is Known as _________

20. Double mass curve method is employed in extrapolation of _________

UNIT -III KEYS

I choose the correct alternative

1. B
2. A
3. B
4. C
5. B
6. A
7. A
8. C
9. A
10. B

II Fill in the blanks

1. CONFIED AQUIFER
2. PORISITY
3. CHECK METHOD
4. SPECIFIC YIELD
5. CAPPILARY WATER
6. AQUIFER
7. OUT LET
8. ARTIFICAL WATER WAYS
9. DARCY'S LAW
10. PERMIABILITY

Unit IV

I. Choose the correct alternative:

1. An aquifer that is confined at the bottom but not at the top is known as [ ]
a) Partially confined aquifer b) aquiclude c) semiconfined aquifer d) Unconfined aquifer

2. Unit hydrograph method is usually adopted for estimating floods when the catchment area is [ ]
a)100 sq.km only b)less than 5000 sq.km c)more than 7500 sq.km d)more than 10000 sq.km

3. Evapotranspiration depends on [ ]
a) Hours of bright sun shine b) type of crop c) method of irrigation d) all of the above

4. The diameter of the standard Symon's type rain guess [ ]
a) 12.7 cm b) 7.5cm c) 5cm d) 15 cm

5. Maximum surface run off is favored due to [ ]
a) Leaf shaped catchment b) A flash storm
c) Improved land management d) presence of forest area

6. Isohyets are [ ]
a) Areas of equal precipitation b) lines of equal Precipitation
c) Lines of equal temperature on maps d) lines of equal barometric pressure on maps

7. In filtration occurs of capacity rate [ ]
a) Due to watershed leakage b) If there had been antecedent rain fall
c) If the intensity of the rain fall is lower than the capacity
d) During a first flash storm fallowing summer

8. Unit hydro graph method for flood estimation is usually applied to [ ]
a)Large basins b)hilly areas
c) Small and medium sized basins d) oceans

9. Darcy's law of flow through soil assumes that the flow is de [ ]
a) Steady and laminar b) non uniform c) turbulent d) transition

10. In a tube well strainers are used to [ ]
a) Reduce the area of percolation b)prevent average soil particles from entering the bored hole
c) Improve the quality of the water d) lift the stored water

II Fill in the Blanks:

11. A tube well is suitable when the sub soil formation is made up of __________

12. ____________formula is widely used in ground water problems.

13. Delayed ground water flow reaching a stream is known as __________

14. Run off volumes are generally computed for large areas by using _________

15. The instrument used for the measurement of wind speed is _________

16. Precipitation falling during the growing period of crop that is available to meet the evaporation needs of the crop is called ____________rain fall.

17. A Permeable stratum which is capable to yield appreciable quantity of ground water under gravity is
Known as __________

18. Double mass curve method is employed in extrapolation of __________

19. A hydrograph is a plot of ________________

20. Rainfall is measured in __________

UNIT -IV KEYS

I choose the correct alternative

1. C
2. B
3. A
4. D
5. B
6. A
7. A
8. C
9. A
10. D

II Fill in the blanks

11. TUBE WELL
12. RUNOFF
13. CAVITY WELL
14. OPEN WELL
15. CAPPILARY WATER
16. PRECIPITATION
17. OUT LET PIPE
18. WELL DEVELOPMENT
19. MONSOON SEASON
20. WELL CONSTRUCTION

UNIT -V

Choose the correct alternative:

1. in filtration occurs of capacity rate [ ]
a).Due to watershed leakage b) If there had been antecedent rain fall
c) If the intensity of the rain fall is lower than the capacity
d) During a first flash storm fallowing summer

2. Unit hydro graph method for flood estimation is usually applied to [ ]
a)Large basins b)hilly areas c.)Small and medium sized basins d) oceans

3. Darcy's law of flow through soil assumes that the flow is [ ]
a) Steady and laminar b) non uniform c) turbulent d) transition

4. In a tube well strainers are used to [ ]
a) Reduce the area of percolation b)prevent average soil particles from entering the bored hole
c) Improve the quality of the water d) lift the stored water

5. An aquifer that is confined at the bottom but not at the top is known as [ ]
a) Partially confined aquifer b) aquiclude c) semi confined aquifer d) Unconfined aquifer

6. Unit hydrograph method is usually adopted for estimating floods when the catchment [ ]
a)100 sq.km only b)less than 5000 sq.km c)more than 7500 sq.km d)more than 10000 sq.km

7. Evapotranspiration depends on [ ]
a)hours of bright sun shine b)type of crop c)method of irrigation d)all of the above

8. The diameter of the standard Symon's type rain guess [ ]
a) 12.7 cm b) 7.5cm c) 5cm d) 15 cm

9. Maximum surface run off is favored due to [ ]
a) Leaf shaped catchment b) A flash storm
c) Improved land management d) presence of forest area

10. Isohyets are [ ]
a) Areas of equal precipitation b) lines of equal Precipitation
c) Lines of equal temperature on maps d) lines of equal barometric pressure on maps

II Fill in the Blanks:

11. A Permeable stratum which is capable to yield appreciable quantity of ground water under gravity is
Known as __________

12. Double mass curve method is employed in extrapolation of __________

13. A hydrograph is a plot of ________________

14. Rainfall is measured in __________

15. A tube well is suitable when the sub soil formation is made up of __________

16. ____________formula is widely used in ground water problems.

17. Delayed ground water flow reaching a stream is known as __________

18. Run off volumes are generally computed for large areas by using _________

19. The instrument used for the measurement of wind speed is _________

20. Precipitation falling during the growing period of crop that is available to meet the evaporation needs of the crop is called ____________rain fall

UNIT -V KEYS

I choose the correct alternative

1. C
2. D
3. A
4. A
5. B
6. A
7. B
8. A
9 .B
10. B

II Fill in the blanks

11KENEDDYS THEORY
13CHECK METHOD
14RIGID
15LACEY'S THEORY
16PRECIPITATION
17PERMENANT CANAL
18ARTIFICAL WATER WAYS
19PENMAN
20CANALS

21 Tutorial problems

1. A basin has the area in the form of a pentagon with each side of length 20Km. The five rain gauges located at the corners A, B, C, D and E have recorded 60, 81, 73, 59 and 45 mm of rainfall respectively. Compute average depth of rainfall over the basin using arithmetic mean and Theissen polygon methods

2. The annual rainfalls at 7 rain gauge stations in a basin are 58, 94, 60, 45, 20, 88 and 68cm respectively. What is the percentage accuracy of the existing network in the estimation of average depth of rainfall over the basin? How many additional gauges are required, if it is desired to limit the error to only 10%.

3. The following information is available at a gauging site

River	Data (m3/sec)	Mean of the Flood (m3/sec)	Standard deviation Length
A	80 Years	6200	2850.0
B	50 Years	5400	3210.0

Estimate 200 year and 500 year floods for the two rivers using Gumbel's method

4. An outlet is to be designed for a town covering 25 km2, of which road area is 30%, residential area 40% and rest industrial area. The slope of the catchment is 0.004 and maximum length of the town measured in map is 3 km. From depth duration analysis the following information is obtained.

Rainfall Duration (min)	30	45	60
Rainfall Depth (mm)	15	20	30

Calculate the peak discharge. The coefficients for road is 0.80, residential area 0.40 and industrial area is 0.20

5. The ordinates of a 4-hour unit hydrograph are given below. Derive the ordinates of a 8-hour unit hydrograph by the S-curve method.

	Time (hr) (Cumec)	4-hr UGO (hr)	Time (cumec)	4-hr UGO
0	0	24	103	
	4	24	28	64
	8	82	32	36
	12	159	36	17
	16	184	40	6
	20	151	44	0

6. What are the factors which affect infiltration? Explain any one Method of determining the infiltration capacity of soil surface.

Dates	Consumptive use in mm	Effective rain fall in mm
October 16-31	37	20.8
November 1-30	94.2	10.4
December 1-31	124.9	6.7
January 1-31	168.1	2.4
February 1-2	13.3	1.0

7.

The average rainfall over 45 ha of watershed for a particular storm was as follows: The volume of runoff from this storm was determined
As 2.25 ha-m. Establish the ϕ-index.

Time (hr.) :	0	1	2	3	4	5	6	7
Rainfall(cm) :	0	0.5	1.0	3.25	2.5	1.5	0.5	0

8. The average rainfall over 45 ha of water shed for a particular storm was as follows:

Time (hr.):	0	1	2	3	4	5	6	7
Rainfall (cm) :	0	0.5	1.0	3.25	2.5	1.5	0.5	0

The volume of runoff from this storm was determined as 2.25 ha -m. Establish the φ-index

9. Cumulative rainfall during a storm are: Time (h)

0	1	2	3	4	5	6	7	8

Rainfall (mm)

0	7	16	22	32	40	52	68	70

Assume an initial abstraction loss of 10 mm and a constant infiltration loss rate of 5.0 mm/ h. Calculate the storm runoff volume from the catchment of 122 sq. km.

10. The rate of rainfall for the successive 30 min period of a 3-hour storm is: 1.6, 3.6, 5.0, 2.8, 2.2, 1.0 cm/hr. The corresponding surface runoff is estimated to be 3.6 cm. Establish the φ-index. Also determine the W –index

11. A well with a radius of 0.5m penetrates completely a confined aquifer of thickness 40 m and permeability 30m /day. The well is pumped so that the water level in the well remains at 7.5m below the original piezo metric surface. Assuming that the radius of influence is 500m
Compute the steady state discharge from the well?

12. A 20 cm well penetrates 30 m below static water level. After a long period of pumping at a rate of 1800 lpm, the drawdowns in the observation wells at 12 m and 36 m from the pumped well are 1.2 m and 0.5 m respectively. Determine the

i. Transmissibility of the aquifer
ii Drawdown in the pumped well assuming radius of influence as 300 m
iii. Specific capacity of the well.

13. A tube well of 30m diameter penetrates fully in an artesian aquifer. The strainer length is 15 m. calculate the yield from the well under a drawdown of 3 m. The aquifer consists of sand of effective size of 0.2mm having coefficient of permeability equal to 50 m/day. Assume radius of influence is equal to 150 meters?

14 What is the classification of irrigation water having the following characteristics? Concentration of Na, Ca and Mg are 22, 3 and 2.5 milli-equivalents per liter respectively and the electrical conductivity is 200 micro mhos percm at 250C? What problems may rise in using this water on fine textured soils? What remedies do you suggest to overcome this trouble?

15 watercourse has a cultural command area of 1200 ha. The intensity of irrigation for crop A is 40% and for B is 35%, both the crops being Rabi crops. Crop A has a kor period of 20 days and crop has a kor period of 15 days. Calculate the discharge of the watercourse if the depth for crop A is 10 cm and for B is 16 cm?

16. An outlet has 600 ha, out of which only 75% is cultivable. The intensity of irrigation for Rabi and Kharief seasons are 70% and 30% respectively. Assuming losses in conveyance system as 10% of the outlet discharge, determine the discharge at the head of the irrigation Channel. Take outlet discharge factor for Rabi season as 1500 ha/cumecs and for Kharief season as 750 ha/cumecs?

17. After how many days the farmer should apply water to his field to ensure efficient use of irrigation water, if the field capacity is 27%, permanent wilting point is 14%, density of soil is 1500 kg/m3, effective root zone depth 0.75 m and daily consumptive use of water is 11 mm
18. In a certain area paddy crop requires 14 cm of depth of water at an interval of 10 days for a base period of 110 days; whereas wheat crop requires 9.0 cm of depth of water after 35 days with a base period of 140 days. Determine the delta of paddy crop and duty of wheat crop of that area.
19. The base period of Paddy is 120 days. If the duty for this is 900 Hectares/cumecs. find the value of delta.

20. Design a trapezoidal shaped concrete lined channel to carry a discharge of 100 cumecs at a slope of 25 cm/ km. The side slopes of the channel are 1.5:1. The value of N may be taken as 0.016. Assume the limiting velocity as 1.5 m/sec

22 Known gaps, if any a

NO

23Discussion topics, if any

24 References, Journals, websites and E-links if any

REFERENCES

- Elementary hydrology by V. P. Singh, PHI publications.
- Irrigation and Water Resources & Water Power by P. N. Modi, Standard Book House.
- Water Resources Engineering – I by Dr. G. Venkata Ramana, Acadamic Publishing Company.
- Irrigation Water Management by D. K. Manjundar, Printice Hall of India.
- Irrigation and Hydraulic structures by S. K. Grag.

Journals

1.http://www.nrc.gov/reading-rm/doc-
2.www.hydrocomp.com/simoverview.html
3.NPTEL Resources

TEXT BOOKS

- Engineering hydrology by Jayram Reddy, Laxmi publications pvt. Ltd., New Delhi.
- Irrigation and water power engineering by Punmia & Lal, Laxmi publications pvt. Ltd., New Delhi.
- Irrigation Water Management by D. K. Manjundar, Printice Hall of India.
- Irrigation and Hydraulic structures by S. K. Grag.

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY

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B.TECH STUDENT LIST OF III YEAR I SEMESTER (A.Y. 2021 - 2022)

BRANCH: CIVIL-A H-WRG

S.NO	H.T. NO	NAME OF STUDENT
1	14RT1A0113	SYED SHOAIB ULLAH
2	14RT1A0114	MOHAMMED SALMAN
3	14RT1A0126	SYED SAMEER
4	14RT1A0128	MIR MOHAMMED ALI
5	14RT1A0132	MOHD AZAM UDDIN ASIM
6	14RT1A0133	MIR ABID ALI
7	14RT1A0163	SYED ABDUL JUNAID
8	14RT1A0164	SYED MUNEEB UDDIN
9	14RT1A0166	MOHAMMED SALMAN FAIZAN
10	14RT1A0171	NAJEEB ULLAH KHAN
11	14RT1A0172	MOHAMMED MUTEE UR RAHMAN
12	14RT1A0173	SYED SHOEB BAHRI
13	14RT1A0174	MOHD IMTIYAZ AHMED
14	14RT1A0175	SYED RUHULLAH NADEEM
15	14RT1A0177	MOHAMMED BASEER ULLAH
16	14RT1A0183	SYED OWAIS KALEEM
17	15RT1A0109	ATHER HUSSAIN
18	15RT1A0122	MA SHAHABAZ HASEEB KHAN
19	15RT1A0131	MD MUNAWAR KHAN
20	15RT1A0132	MD NASEER
21	15RT1A0136	MD SARTAJ
22	15RT1A0149	MOHAMMED ABDUL MUJEEB
23	15RT1A0193	MOHD FARAAZ UR RAHMAN
24	15RT1A01D5	SHAIK ASIM BIN IBRAHIM
25	15RT1A01E6	SYED ASLAM HUSSAIN
26	15RT1A01F7	SYED NABEEL UDDIN
27	16H11A0189	SYED OBAID UZZAMA
28	16RT1A0123	MD AMAIR FAISAL
29	16RT1A0130	MD ILYAS
30	16RT1A0131	MD KALEEMULLA SHAREEF
31	16RT1A0151	MOHAMMED ATIF MOHIUDDIN
32	16RT1A0189	MOHD ABDUL ARBAAZ
33	16RT1A01A8	MOHD RASHAD ALI
34	16RT1A01B7	MOHD ANASUDDIN
35	16RT1A01E4	SYED ABDUL QUADEER UDDIN
36	16RT1A01F1	SYED FAIZAN HUSSAIN
37	16RT5A0101	AAMER AHMED
38	16RT5A0104	AHMED FAIZ

39	16RT5A0105	SHAIK SIDDIQ
40	16RT5A0114	MOHAMMED GULAM HUSSAIN SIDDIQUI
41	16RT5A0128	DARAVATH AKHIL KUMAR
42	17RT1A0115	HABEEB AHMED
43	17RT1A0123	KHAJA SAIFUDDIN
44	17RT1A0136	MIR MUKARRAMUDDIN ALI KHAN
45	17RT1A0147	MOHAMMED ABDUL SAYEED
46	17RT1A0155	MOHAMMED BASHARATH BARI
47	17RT1A0161	MOHAMMED JASSIM
48	17RT1A0162	MOHAMMED KALEEM UDDIN
49	17RT1A0166	MOHAMMED MOHSIN
50	17RT1A0167	MOHAMMED MULTAZIM QURESHI

HOD PRINCIPAL

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New Malakpet, Hyderabad-500 024

B.TECH STUDENT LIST OF III YEAR I SEMESTER (A.Y. 2021 - 2022)

BRANCH: CIVIL-B

S.NO	H.T. NO	NAME OF STUDENT
1	17RT1A0188	MOHD ASIF
2	17RT1A01B1	MOHD SIRAJUDDIN
3	17RT1A01D9	SYED ASGHER HASAN ABEDI
4	17RT1A01F2	SYED OMER YAMEEN
5	17RT1A01F4	SYED UMAIR ASHFAQ
6	17RT5A0118	MOHAMMAD AMIR
7	17RT5A0126	MOHD MUDASSIR UDDIN
8	17RT5A0130	SAIF ALI KHAN
9	18RT1A0105	ABDUL WASAY
10	18RT1A0108	ARBAAZ KHAN
11	18RT1A0109	ARFATH SIDDIQUE
12	18RT1A0111	FAHEEM ULLAH KHAN
13	18RT1A0112	ZAINUDDIN MOHAMMED ABDULLAH
14	18RT1A0113	GULAM MAOZZAM
15	18RT1A0125	MIRZA MURTAZA HUSSAIN
16	18RT1A0128	MOHD ABDUL MUQTADIR
17	18RT1A0129	MOHD IMRAN
18	18RT1A0130	MOHAMMAD NASER HUSSAIN KHAN
19	18RT1A0137	MOHD ABDUL FURQAN
20	18RT1A0138	MOHD ABDUL QAYYUM
21	18RT1A0145	MOHD ABDUL ZAHIR
22	18RT1A0150	MOHAMMED AHMED RAZA
23	18RT1A0153	MOHD AIYAZ JUNAID
24	18RT1A0155	MOHAMMED ARBAZ
25	18RT1A0156	MOHAMMED ASIM UZ ZAMA
26	18RT1A0162	MOHD IMRAN ALI
27	18RT1A0163	MD INZEMAM UR RAHMAN
28	18RT1A0166	MOHAMMED KHAJA AKRAM MOHIUDDIN
29	18RT1A0168	MOHD MAAZ UDDIN
30	18RT1A0177	MD SHOAIB MOHIUDDIN
31	18RT1A0178	MOHD SHOEB ADNAN
32	18RT1A0181	MOHD ZAIYAD MAHMOOD
33	18RT1A0185	SAIF ALI KHAN
34	18RT1A0186	SAMEER AHMED MOHAMMED
35	18RT1A0188	SHAIK AJAZ
36	18RT1A0190	SHAIK FAYAZ SHAREEF
37	18RT1A0193	SHAIK MOHD MUJAHED
38	18RT1A0196	ARQAM

39	18RT1A0198	SYED AHMED AIZAZ
40	18RT1A01A2	SYED ISMAIL
41	18RT1A01A3	SYED KAZIM HYDER ZAIDI
42	18RT1A01A8	SYED MUSHTAQ AHMED
43	18RT1A01B0	SYED YASIR ALI

HOD PRINCIPAL

Department of Civil Engineering

Advanced & Slow Learners (2020-2021)

YEAR: III , SEM: II SUBJECT: WRE-I

Section: A FACULTY NAME: MOHD ABDUL AQUIL

Student List Advance Learner

S.no	Roll Number	Marks
1	18RT1A0101	21
2	18RT1A0103	22
3	18RT1A0106	22
4	18RT1A0107	21
5	18RT1A0110	21
6	18RT1A0116	22
7	18RT1A0117	17
8	18RT1A0118	19
9	18RT1A0120	23
10	18RT1A0121	23
11	18RT1A0122	23
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13	18RT1A0131	23
14	18RT1A0132	19
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52	18RT1A01A5	22
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54	18RT1A01A7	19
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56	18RT1A01B4	19
57	19RT5A0101	24
58	19RT5A0102	24
59	19RT5A0103	24
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63	19RT5A0107	17
64	19RT5A0108	24
65	19RT5A0109	22
66	19RT5A0110	19
67	19RT5A0111	23
68	19RT5A0112	20
69	19RT5A0113	17
70	19RT5A0114	23
71	19RT5A0115	24
72	19RT5A0116	24
73	19RT5A0117	22
74	19RT5A0118	22
75	19RT5A0119	23
76	19RT5A0120	21
77	19RT5A0121	19
78	19RT5A0122	23
79	19RT5A0123	19
80	19RT5A0124	17
81	19RT5A0125	22
82	19RT5A0126	22
83	19RT5A0127	23
84	19RT5A0128	23
85	19RT5A0129	23
86	19RT5A0130	20
87	19RT5A0131	24
88	19RT5A0132	21
89	19RT5A0133	23
90	19RT5A0134	24
91	19RT5A0135	23
92	19RT5A0136	21

Student List Slow Learner

S.no	Roll Number	Marks
1	18RT1A0115	5

93	19RT5A0137	23
94	19RT5A0138	22
95	19RT5A0139	23
96	19RT5A0140	24
97	19RT5A0141	24
98	19RT5A0142	21
99	19RT5A0143	24
100	19RT5A0144	19
101	19RT5A0145	20
102	19RT5A0148	23
103	19RT5A0149	24
104	19RT5A0150	22
105	19RT5A0151	19
106	19RT5A0152	23
107	19RT5A0153	23
108	19RT5A0154	24
109	19RT5A0155	23
110	19RT5A0156	23
111	19RT5A0157	23
112	19RT5A0158	19
113	19RT5A0159	23
114	19RT5A0160	23
115	19RT5A0161	19
116	19RT5A0162	23
117	19RT5A0163	23

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING AND TECHNOLOGY, OSMANIA UNIVERSITY, Hyderabad
DEPARTMENT OF CIVIL ENGINEERING

B.E. I YEAR, I/II SEM - ATTAINMENT CALCULATIONS - Academic Year: 2020-21

Subject: HWRE-1 **Subject Code:** 156BF **Faculty:** MOHD ABDUL AQUIL

		MID-1					MID-2											MID		SEE
S.No.	Hall Ticket No.	ASG-1 (2.5M)	ASG-2 (2.5 M)	Quiz-1 (20 M)		Mid-1 TOTAL (25 M)	ASG-3 (2.5M)	ASG-4 (2.5 M)	Quiz-2 (10 M)		Q 1 (5 M)	Q 2 (5 M)	BEST OF Q1&Q2	Q 3 (5 M)	Q 4 (5 M)	BEST OF Q3&Q4	Mid-2 TOTAL (25 M)	Average MID	TOTAL Marks	End Exam
		C01	C02	C01	C02		C03	C04	C03	C04	CO3	CO3	C03	CO4	CO4	C04		(25 M)	(100 M)	(75 M)
1	18RT1A0101	2.5	2.5	8	8	21	2.5	2.5	3	3		5	5	5		5	21	21	23	2
2	18RT1A0103	2.5	2.5	8	9	22	2.5	2.5	3	4		5	5		5	5	22	22	33	11
3	18RT1A0106	2.5	2.5	8	9	22	2.5	2.5	3	4		5	5		5	5	22	22	48	26
4	18RT1A0107	2.5	2.5	8	8	21	2.5	2.5	3	3		5	5	5		5	21	21	36	15
5	18RT1A0110	2.5	2.5	8	8	21	2.5	2.5	3	3		5	5	5		5	21	21	24	3
6	18RT1A0115	2.5	2.5	0	0	5	2.5	2.5					0			0	5	5	49	44
7	18RT1A0116	2.5	2.5	8	9	22	2.5	2.5	3	4		5	5		5	5	22	22	27	5
8	18RT1A0117	2.5	2.5	6	6	17	2.5	2.5	3	2	4		4		3	3	17	17	24	7
9	18RT1A0118	2.5	2.5	7	7	19	2.5	2.5	3	2	4		4	5		5	19	19	21	2
10	18RT1A0120	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
11	18RT1A0121	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	29	6
12	18RT1A0122	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	35	12
13	18RT1A0127	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	25	2
14	18RT1A0131	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	40	17
15	18RT1A0132	2.5	2.5	7	7	19	2.5	2.5	3	2	4		4	5		5	19	19	53	34
16	18RT1A0133	2.5	2.5	8	8	21	2.5	2.5	3	3		5	5	5		5	21	21	31	10
17	18RT1A0134	2.5	2.5	8	9	22	2.5	2.5	3	4		5	5		5	5	22	22	56	34
18	18RT1A0135	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	59	36
19	18RT1A0136	2.5	2.5	8	8	21	2.5	2.5	3	3		5	5	5		5	21	21	21	0
20	18RT1A0139	2.5	2.5	7	7	19	2.5	2.5	3	2	4		4	5		5	19	19	19	0
21	18RT1A0140	2.5	2.5	10	9	24	2.5	2.5	4	5		5	5	5		5	24	24	34	10
22	18RT1A0141	2.5	2.5	7	7	19	2.5	2.5	3	2	4		4	5		5	19	19	25	6
23	18RT1A0142	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	29	6
24	18RT1A0143	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	28	5
25	18RT1A0144	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	39	16
26	18RT1A0146	2.5	2.5	8	9	22	2.5	2.5	3	4		5	5		5	5	22	22	34	12
27	18RT1A0147	2.5	2.5	8	9	22	2.5	2.5	3	4		5	5		5	5	22	22	33	11
28	18RT1A0148	2.5	2.5	10	9	24	2.5	2.5	4	5		5	5	5		5	24	24	37	13
29	18RT1A0149	2.5	2.5	8	9	22	2.5	2.5	3	4		5	5		5	5	22	22	30	8
30	18RT1A0151	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
31	18RT1A0152	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	53	30
32	18RT1A0154	2.5	2.5	10	9	24	2.5	2.5	4	5		5	5	5		5	24	24	53	29
33	18RT1A0158	2.5	2.5	7	7	19	2.5	2.5	3	2	4		4	5		5	19	19	48	29
34	18RT1A0159	2.5	2.5	10	9	24	2.5	2.5	4	5		5	5	5		5	24	24	41	17
35	18RT1A0161	2.5	2.5	6	7	18	2.5	2.5	3	2	4		4		4	4	18	18	44	26
36	18RT1A0164	2.5	2.5	10	9	24	2.5	2.5	4	5		5	5	5		5	24	24	50	26
37	18RT1A0169	2.5	2.5	9	9	23	2.5	2.5	3	5		5	5	5		5	23	23	39	16

38	18RT1A0170	2.5	2.5	8	7							20	2.5	2.5	3	3	4		4		5	5	20	20	55	35
39	18RT1A0171	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
40	18RT1A0172	2.5	2.5	8	7							20	2.5	2.5	3	3	4		4		5	5	20	20	30	10
41	18RT1A0174	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	51	32
42	18RT1A0175	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	57	34
43	18RT1A0176	2.5	2.5	8	7							20	2.5	2.5	3	3	4		4		5	5	20	20	33	13
44	18RT1A0179	2.5	2.5	8	9							22	2.5	2.5	3	4		5	5		5	5	22	22	48	26
45	18RT1A0180	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	61	38
46	18RT1A0182	2.5	2.5	8	9							22	2.5	2.5	3	4		5	5		5	5	22	22	34	12
47	18RT1A0183	2.5	2.5	8	9							22	2.5	2.5	3	4		5	5		5	5	22	22	50	28
48	18RT1A0184	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	45	26
49	18RT1A0192	2.5	2.5	8	8							21	2.5	2.5	3	3		5	5	5		5	21	21	47	26
50	18RT1A0194	2.5	2.5	8	8							21	2.5	2.5	3	3		5	5	5		5	21	21	47	26
51	18RT1A0195	2.5	2.5	6	6							17	2.5	2.5	3	2	4		4		3	3	17	17	34	17
52	18RT1A01A4	2.5	2.5	8	9							22	2.5	2.5	3	4		5	5		5	5	22	22	48	26
53	18RT1A01A5	2.5	2.5	8	9							22	2.5	2.5	3	4		5	5		5	5	22	22	26	4
54	18RT1A01A6	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	19	0
55	18RT1A01A7	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	22	3
56	18RT1A01B3	2.5	2.5	6	7							18	2.5	2.5	3	2	4		4		4	4	18	18	18	0
57	18RT1A01B4	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	19	0
58	19RT5A0101	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	50	26
59	19RT5A0102	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	50	26
60	19RT5A0103	2.5	2.5	10	9							24	2.5	2.5	3	5		5	5	5		5	23	24	49	26
61	19RT5A0104	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	37	14
62	19RT5A0105	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	33	9
63	19RT5A0106	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	52	28
64	19RT5A0107	2.5	2.5	6	6							17	2.5	2.5	3	2	4		4		3	3	17	17	22	5
65	19RT5A0108	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	52	28
66	19RT5A0109	2.5	2.5	8	9							22	2.5	2.5	3	4		5	5		5	5	22	22	56	34
67	19RT5A0110	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	19	0
68	19RT5A0111	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	36	13
69	19RT5A0112	2.5	2.5	7	8							20	2.5	2.5	3	3	4		4		5	5	20	20	32	12
70	19RT5A0113	2.5	2.5	6	6							17	2.5	2.5	3	2	4		4		3	3	17	17	52	35
71	19RT5A0114	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
72	19RT5A0115	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	39	15
73	19RT5A0116	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	40	16
74	19RT5A0117	2.5	2.5	8	9							22	2.5	2.5	3	4		5	5		5	5	22	22	48	26
75	19RT5A0118	2.5	2.5	8	9							22	2.5	2.5	3	4		5	5		5	5	22	22	48	26
76	19RT5A0119	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	55	32
77	19RT5A0120	2.5	2.5	8	8							21	2.5	2.5	3	3		5	5	5		5	21	21	47	26
78	19RT5A0121	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	45	26
79	19RT5A0122	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
80	19RT5A0123	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	30	11
81	19RT5A0124	2.5	2.5	6	6							17	2.5	2.5	3	2	4		4		3	3	17	17	17	0
82	19RT5A0125	2.5	2.5	9	8							22	2.5	2.5	3	4		5	5		5	5	22	22	38	16
83	19RT5A0126	2.5	2.5	9	8							22	2.5	2.5	3	4		5	5		5	5	22	22	48	26
84	19RT5A0127	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	58	35
85	19RT5A0128	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26

CO ATTAINMENT	Internal Marks %	Internal Attainment	External Marks %	External Attainment	DIRECT ATTAINMENT LEVEL
CO1	87	3	53.39	2	2.25
CO2	86	3	53.39	2	2.25
CO3	83	3	53.39	2	2.25
CO4	90	3	53.39	2	2.25
Average					2.25

INTERNAL EXAM ATTAINMENT LEVEL SCALE

Attainment Levels	0	<=49
	1	50-64
	2	65-79
	3	>=80

EXTERNAL EXAM / FINAL ATTAINMENT LEVEL SCALE

Attainment Levels	0	<=39
	1	40-49
	2	50-59
	3	>=60

Direct Attainment %
CO1=(CO1IntAtn*0.25+CO1ExtAtn*0.75)
CO2=(CO2IntAtn*0.25+CO2ExtAtn*0.75)
CO3=(CO3IntAtn*0.25+CO3ExtAtn*0.75)
CO4=(CO4IntAtn*0.25+CO4ExtAtn*0.75)

CO-PO Matrix

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2		Attainment
CO1	3	3	2	2	-	-	-	-	-	-	-	-	3	-		2.25
CO2	3	3	2	2	-	-	-	-	-	-	-	-	3	-		2.25
CO3	2	3	2	2	-	-	-	-	-	-	-	-	2	-		2.25
CO4	3	3	3	2	-	-	-	-	-	-	-	-	3	-		2.25
Average	2.75	3	2.25	2	0	0	0	0	0	0	0	0	2.75	0		2.25

Final Attainment %
CO1 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
CO2 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
CO3 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
CO4 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)

Course PO Attainments

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Direct Attainment	2.0625	2.25	1.6875	1.5	0	0	0	0	0	0	0	0	2.0625	0	0

PO ATTAINMENTS
DIRECT ATTAINMENT (PO1)= (Average of PO1*Average of CO Direct Attainment)/3
Similar for PO2 TO PO12 & PSO1 TO PSO3

86	19RT5A0129	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
87	19RT5A0130	2.5	2.5	7	8							20	2.5	2.5	3	3	4		4		5	5	20	20	37	17
88	19RT5A0131	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	40	16
89	19RT5A0132	2.5	2.5	8	8							21	2.5	2.5	3	3		5	5	5		5	21	21	54	33
90	19RT5A0133	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	53	30
91	19RT5A0134	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	25	1
92	19RT5A0135	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
93	19RT5A0136	2.5	2.5	8	8							21	2.5	2.5	3	3		5	5	5		5	21	21	47	26
94	19RT5A0137	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
95	19RT5A0138	2.5	2.5	9	8							22	2.5	2.5	3	4		5	5		5	5	22	22	22	0
96	19RT5A0139	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	51	28
97	19RT5A0140	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	50	26
98	19RT5A0141	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	50	26
99	19RT5A0142	2.5	2.5	8	8							21	2.5	2.5	3	3		5	5	5		5	21	21	47	26
100	19RT5A0143	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	50	26
101	19RT5A0144	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	45	26
102	19RT5A0145	2.5	2.5	8	7							20	2.5	2.5	3	3	4		4		5	5	20	20	27	7
103	19RT5A0148	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	50	27
104	19RT5A0149	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	50	26
105	19RT5A0150	2.5	2.5	9	8							22	2.5	2.5	3	4		5	5		5	5	22	22	48	26
106	19RT5A0151	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	50	31
107	19RT5A0152	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	51	28
108	19RT5A0153	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
109	19RT5A0154	2.5	2.5	10	9							24	2.5	2.5	4	5		5	5	5		5	24	24	38	14
110	19RT5A0155	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	33	10
111	19RT5A0156	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	50	27
112	19RT5A0157	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
113	19RT5A0158	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	34	15
114	19RT5A0159	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	52	29
115	19RT5A0160	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	53	30
116	19RT5A0161	2.5	2.5	7	7							19	2.5	2.5	3	2	4		4	5		5	19	19	19	0
117	19RT5A0162	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
118	19RT5A0163	2.5	2.5	9	9							23	2.5	2.5	3	5		5	5	5		5	23	23	49	26
Average Marks		2.50	2.50	8.34	8.26							21.60	2.50	2.50	3.16	3.93	4.00	5.00	4.70	5.00	4.63	4.86	21.59	21.60	40.93	25.78

CIE (Mid Exam) CO Wise Percentage		
COURSE OUTCOME	CO Wise Sum	CO Wise Percentage %
C01	10.84	86.71
C02	10.76	86.10
C03	10.37	82.93
C04	11.29	90.30
Average	10.81	86.51

CIE - CO Wise Sum Formula
C01 = ASG(C01) + Q1(C01) + BestOfQ2&Q3(C01)
C02 = ASG(C02) + Q1(C02) + BestOfQ4&Q5(C02)
C03 = ASG(C03) + Q1(C03) + BestOfQ2&Q3(C03)
C04 = ASG(C04) + Q1(C04) + BestOfQ4&Q5(C04)

CIE - CO Wise Percentage
C01 % = (C01 SUM/total C01 Marks(12.5))*100
C02 % = (C02 SUM/total C02 Marks(12.5))*100
C03 % = (C03 SUM/total C03 Marks(12.5))*100
C04 % = (C04 SUM/total C04 Marks(12.5))*100

Average Marks	25.78
Student Count >Avg	63
Total Students	118
Percentage	53.3898

SEE (End Exam) CO Wise Percentage		
C01-C04	25.78	53.39

SEE - CO Wise Percentage
C01-C04 = End Exam Avg Marks

SEE - CO Wise Percentage
C01-C04 % = (End Exam Avg Marks/75)*100

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING AND TECHNOLOGY						
DEPARTMENT OF CIVIL ENGINEERING						
CO Feedback form						
Academic Year 2020-2021						
Course Name with Code	H&WRE & C321					
Class	B.TECH III YEAR II SEM					
Faculty Name	MOHD ABDUL AQUIL					
CO Attainment	**Internal Attainment**	**External Attainment**	**DIRECT ATTAINMENT LEVEL**	**Indirect Attainment**	**Overall Attainment**	**COPO MAPPING**
CO 1	3	2	2.25	2.01	2.7	2.52
CO 2	3	2	2.25	2.01	2.7	2.52
CO 3	3	2	2.25	1.87	2.7	2.24
CO 4	3	2	2.25	2.13	2.7	2.76
Overall Course Attainment			2.25	2.01	**2.70**	**2.51**
Set Target for the course						
Course Attainment						
Status(Yes/No)						**YES**

Percentage of students attained CO	**CO attainment rubric**
%CO ≥ 80	3
65 ≤ %CO < 80	2
%CO < 65	1

Rawal

H.O.D

Action taken for course outcome attainment feedback:

- Student performance can be enhanced further by involving them to prepare a model for innovation in teaching and learning programme under the institute.
- Taking much longer time than the usual for the assessment and evaluation, for about three to five years roughly.