

Contents

<i>Preface</i>	xv
1. Introduction	1
<i>Learning Objectives</i>	1
1.1 Engineering Hydrology	1
1.2 Importance of Engineering Hydrology	2
1.3 Hydrologic Cycle	5
1.3.1 Atmospheric Moisture	6
1.3.2 Precipitation	6
1.3.3 Infiltration	7
1.3.4 Groundwater	8
1.3.5 Surface Runoff	9
1.3.6 Evaporation and Transpiration	9
1.3.7 General Discussion of the Hydrologic Cycle	10
<i>Summary</i>	11
<i>Exercises</i>	12
<i>Objective-Type Questions</i>	12
<i>Descriptive Questions</i>	15
<i>Numerical Questions</i>	15
<i>Useful Links</i>	16
<i>Glossary</i>	16
2. Precipitation	18
<i>Learning Objectives</i>	18
2.1 Introduction	18
2.2 Occurrence – Mechanism of Formation, Various Forms, Distribution	19
2.2.1 Mechanism	19
2.2.2 Forms	20
2.2.3 Intensity	21
2.2.4 Distribution	21

- 2.3 Measurement – Rain Gauges, Remote Sensing 22
- 2.4 Analysis of Data – Missing Data, Consistency Check, Averaging 22
 - 2.4.1 Completeness Check 26
 - 2.4.2 Estimation of Missing Data 26
 - 2.4.3 Consistency Check 29
 - 2.4.4 Averaging of Data 33
- 2.5 Storm Averaging 38
- Summary 44
- Exercises 45
 - Objective-Type Questions 45
 - Descriptive Questions 47
 - Numerical Questions 48

3. Abstractions from Precipitation

51

- Learning Objectives 51
- 3.1 Introduction 51
- 3.2 Abstraction Processes 51
 - 3.2.1 Interception 52
 - 3.2.2 Depression Storage 52
 - 3.2.3 Evaporation 53
 - 3.2.4 Transpiration 53
 - 3.2.5 Infiltration 53
- 3.3 Initial Abstraction 53
- 3.4 Evaporation 55
 - 3.4.1 Factors Affecting Evaporation 58
 - 3.4.2 Estimation of Evaporation 59
- 3.5 Evapotranspiration 75
 - 3.5.1 Empirical Equations 75
 - 3.5.2 Theoretical Equations 78
- 3.6 Infiltration 79
 - 3.6.1 Infiltration Process 80
 - 3.6.2 Factors Affecting Infiltration 81
 - 3.6.3 Estimation of Infiltration Capacity 82
 - 3.6.4 Actual Infiltration 90
- Summary 95
- Exercises 96
 - Objective-Type Questions 96
 - Descriptive Questions 99
 - Numerical Questions 99

4. Runoff **101**

Learning Objectives 101

- 4.1 Runoff Generation 101
- 4.2 Measurement of Streamflow 102
 - 4.2.1 Area 103
 - 4.2.2 Velocity 103
- 4.3 Annual and Storm Hydrographs 104
 - 4.3.1 Annual Hydrograph 105
 - 4.3.2 Storm Hydrograph 105
- 4.4 Factors Affecting Runoff 107
 - 4.4.1 Catchment Characteristics 107
 - 4.4.2 Storm Characteristics 108
- 4.5 Rainfall-Runoff Relationships 109
 - 4.5.1 Analytical Models 109
 - 4.5.2 Empirical Models 110
- 4.6 Rational Formula 115
 - 4.6.1 Runoff Coefficient 115
 - 4.6.2 Intensity of Rainfall 117
 - 4.6.3 Time of Concentration 118
- 4.7 SCS Method 119
- 4.8 Flow Duration Curve 126
- 4.9 Flow Mass Curve 130

Summary 135

Exercises 136

Objective-Type Questions 136

Descriptive Questions 141

Numerical Questions 142

5. Hydrograph Analysis **145**

Learning Objectives 145

- 5.1 Introduction 145
- 5.2 Unit Hydrograph 146
 - 5.2.1 Definition 146
 - 5.2.2 Theory and Assumptions 147
 - 5.2.3 Application of UH 148
- 5.3 Derivation of Unit Hydrograph 150
 - 5.3.1 Baseflow Separation 150
 - 5.3.2 Effective Rainfall and Direct Runoff Hydrograph 152
 - 5.3.3 Derivation of UH from an Isolated Storm 152
 - 5.3.4 Derivation of UH from a Complex Storm 154
- 5.4 S-Hydrograph 156
- 5.5 Unit Hydrograph of Different Durations 158

- 5.5.1 UH of Different Durations by Method of Superposition 159
- 5.5.2 UH of Different Durations by S-Hydrograph Method 161
- 5.6 Synthetic Unit Hydrograph 163
 - 5.6.1 Snyder's Synthetic Unit Hydrograph 163
 - 5.6.2 SCS Dimensionless Synthetic Unit Hydrograph 167
- 5.7 Instantaneous Unit Hydrograph 170
- 5.8 Relationships among UH, IUH, and S-Hydrograph 171
- Summary 174
- Exercises 175
 - Objective-Type Questions 175
 - Descriptive Questions 182
 - Numerical Questions 183

6. Hydrograph Routing

187

- Learning Objectives 187
- 6.1 Introduction 187
- 6.2 Hydrologic and Hydraulic Routing 188
 - 6.2.1 Hydrologic Routing 188
 - 6.2.2 Hydraulic Routing 189
- 6.3 Hydrologic Routing through a Reservoir 190
 - 6.3.1 Modified Puls Method 191
 - 6.3.2 Goodrich's Method 195
 - 6.3.3 Standard Runge–Kutta (SRK) Method 195
 - 6.3.4 Changes in Inflow Hydrograph Characteristics 200
- 6.4 Hydrologic Routing through a Channel 200
 - 6.4.1 Muskingum Method 202
 - 6.4.2 Estimation of Parameters of Muskingum Equation 205
- 6.5 IUH Development 207
 - 6.5.1 Clark's Method 208
 - 6.5.2 Nash's Method 211
- Summary 217
- Exercises 218
 - Objective-Type Questions 218
 - Descriptive Questions 226
 - Numerical Questions 226
 - Useful Links 229

7. Groundwater

230

- Learning Objectives 230
- 7.1 Introduction 230
- 7.2 Occurrence of Groundwater 231
 - 7.2.1 Unsaturated Zone 232

7.2.2	Saturated Zone	235
7.3	Movement of Groundwater	236
7.3.1	Basic Equations	239
7.4	Flow through a Confined Aquifer	245
7.4.1	Steady One-Dimensional Flow	246
7.4.2	Steady Flow Towards a Well	248
7.4.3	Transient One-Dimensional Flow	250
7.4.4	Transient Flow Towards a Well	252
7.5	Flow through Unconfined Aquifers	257
7.5.1	Steady One-Dimensional Flow	257
7.5.2	Steady Flow Towards a Well	260
7.5.3	Transient One-Dimensional Flow	262
7.5.4	Transient Flow Towards a Well	263
7.6	Non Ideal Conditions	265
7.6.1	Well Loss and Specific Capacity	265
7.6.2	Flow through a Layered Porous Medium	267
7.6.3	Flow through Leaky Aquifers	269
7.6.4	Flow through Unsaturated Zone	271
7.6.5	Flow Near Boundaries	271
7.7	Parameter Estimation	272
7.7.1	Estimation of Flow Direction	272
7.7.2	Estimation of Recharge	273
7.7.3	Estimation of Hydraulic Conductivity	274
7.7.4	Estimation of Transmissivity and Storage Coefficient	275
	<i>Summary</i>	281
	<i>Exercises</i>	282
	<i>Objective-Type Questions</i>	282
	<i>Descriptive Questions</i>	284
	<i>Numerical Questions</i>	285
	<i>Useful Links</i>	287

8. Irrigation and Water Resource Management

288

	<i>Learning Objectives</i>	288
8.1	Introduction	288
8.2	Water Requirement of Crops	289
8.3	Canal Irrigation	292
8.4	Irrigation Methods	294
8.4.1	Basin Irrigation	296
8.4.2	Furrow Irrigation	296
8.4.3	Border Irrigation	296
8.4.4	Ring Irrigation	297
8.4.5	Sprinkler Irrigation	297

- 8.4.6 Subsurface Irrigation 297
- 8.4.7 Drip Irrigation 297
- 8.5 Single-purpose and Multipurpose Projects 298
- Summary 301
- Exercises 302
 - Objective-Type Questions 302
 - Descriptive Questions 304
 - Numerical Questions 304

9. Statistical Methods in Hydrology

305

- Learning Objectives 305
- 9.1 Introduction 305
- 9.2 Basic Probabilistic and Statistical Concepts 306
 - 9.2.1 Sample and Population 306
 - 9.2.2 Random Variable 307
 - 9.2.3 Probability 307
 - 9.2.4 Probability of Discrete Random Variables 309
 - 9.2.5 Probability of Continuous Random Variables 312
- 9.3 Moments and Basic Descriptive Statistics 315
 - 9.3.1 Measures of Central Tendency 316
 - 9.3.2 Measures of Variation 319
 - 9.3.3 Measure of Skewness 322
 - 9.3.4 Measures of Peakedness 323
- 9.4 Some Important Probability Distributions 326
 - 9.4.1 Binomial Distribution 326
 - 9.4.2 Normal Probability Distribution 329
 - 9.4.3 Gumbel's Probability Distribution 332
- 9.5 Frequency Analysis 334
 - 9.5.1 Probability Plotting Method 335
 - 9.5.2 Frequency Factor Method 338
- 9.6 Risk and Reliability of Water Resources Projects 349
 - 9.6.1 Risk 350
 - 9.6.2 Reliability 350
 - 9.6.3 Factor of Safety 350
- Summary 351
- Exercises 352
 - Objective-Type Questions 352
 - Descriptive Questions 357
 - Numerical Questions 358

10. Measurement of Hydrologic Variables	361
<i>Learning Objectives</i>	361
10.1 Introduction	361
10.2 Measurements – General	362
10.3 Selection of Site and Instruments	363
10.3.1 Site-selection	363
10.3.2 Instrument-selection	364
10.4 Measurement Techniques	364
10.4.1 Precipitation	364
10.4.2 Evaporation and Transpiration	370
10.4.3 Infiltration	374
10.4.4 Soil Moisture	377
10.4.5 Streamflow	379
10.4.6 Groundwater	383
10.4.7 Temperature, Pressure, Humidity, Wind, Radiation	384
10.5 Databases	385
<i>Summary</i>	386
<i>Exercises</i>	387
<i>Objective-Type Questions</i>	387
<i>Descriptive Questions</i>	389
<i>Numerical Questions</i>	390
<i>Answers to Objective-Type Questions</i>	392
<i>References</i>	395
<i>Index</i>	400