

Hydrology and Water Resources Engineering



Alpha
Science

K.C. PATRA

1. Introduction	1
1.1 General	1
1.2 History of Hydrology	1
1.3 Meteorology	3
Lapse Rate	4
Pressure	5
Water Vapour	5
Precipitable Water	7
Latent Heat	9
Humidity	10
1.4 Cloud and Raindrop Formation	10
1.5 Hydrologic Cycle	11
1.6 Availability of Water on Earth	14
1.7 Importance of Hydrology and its Applications in Engineering	16
Problems	17
2. Statistics and Probabilities in Hydrology	19
2.1 Introduction	19
2.2 Statistical Parameters	20
Central Tendency Parameters	20
Dispersion Characteristics	25
Skewness	26
Kurtosis	27
2.3 Theoretical Probability Distribution	30
Discrete Distribution	31
Continuous Distribution	33
2.4 Frequency Analysis	38
Gumbel's Distribution	40
Pearson Type III Distribution	41
Log Pearson Type III Distribution	41
Normal Distribution	42
Log Normal Distribution	43
2.5 Graphical Method Using Probability Paper	50
Construction of Probability Paper	51
Selection of Type of Distribution	51
2.6 Confidence Limits	52
2.7 Regression and Correlation	56
Graphical Method	56
Analytical Method	56
Correlation	58
Significance of Parameters	60
Standard Forms of Bivariate Equations	61

2.8	Multivariate Linear Regression and Correlation	64
	Multiple Correlation Coefficient	65
2.9	Analysis of Time Series	68
	Trend Analysis	70
	Oscillation	73
	Jump	74
	Periodicity or Seasonality	74
	Serial Correlation	76
	Stochastic Component	78
2.10	Dependenc Models	78
	Thomas-Fiering Model	79
2.11	Chi-square Test of Goodness of Fit	82
	<i>Problems</i>	90

3. Precipitation

94

3.1	Introduction	94
3.2	Forms of Precipitation	95
3.3	Types of Precipitation	96
3.4	Rainfall in India	99
3.5	Measurement of Rainfall	101
	Non-Recording Rain Gauge	102
	Recording Type Rain Gauges	103
	Weather Radar	106
	Totalisers	107
3.6	Network Design	107
	Optimum Number of Rain Gauge Stations	108
	Ideal Location for a Rain Gauge Station	109
3.7	Consistency of Rainfall Data	111
3.8	Estimating Missing Data	114
	Arithmetic Mean Method	114
	Normal Ratio Method	114
	Regression Method	115
	Inverse Distance Method	115
3.9	Presentation of Precipitation Data	118
	Moving Average Curve	119
	Mass Curve	119
	Rainfall Hyetograph	119
	Intensity-Duration-Frequency Curves	121
3.10	Mean Aerial Rainfall	122
	Arithmetic Mean Method	123
	Thiessen Polygon Method	123
	Isohyetal Method	125
	Grid Point Method	126
	Orographic Method	127
	Isopercental Method	127
3.11	Depth-Area-Duration Curve	129
3.12	Design Storm	131
	Statistical Storm	132
	Probable Maximum Precipitation	140
	Standard Project Storm	145
	<i>Problems</i>	146

4. Losses from Precipitation**149**

- 4.1 Introduction 149
- 4.2 Evaporation and its Estimation 149
 - Measurement Using Evaporation Pans 151
 - Empirical Equations 154
 - Water Balance Method 156
 - Energy Budget Method 157
 - Mass Transfer Method 161
- 4.3 Methods to Reduce Reservoir Evaporation 161
- 4.4 Evapotranspiration (Consumptive Use) and its Estimation 163
 - Experimental Measurement 164
 - Climatic Approaches 165
- 4.5 Interception 176
- 4.6 Depression Storage 178
- 4.7 Infiltration and its Estimation 178
 - Factors Affecting Infiltration 179
 - Field Measurement Using Infiltrometers 182
 - Rainfall-Runoff Analysis 184
 - Infiltration Indices 185
 - Mass Curve Method 190
 - Analytical Models 191
- 4.8 Watershed Leakage 191
 - Problems 192

5. Ground Water**195**

- 5.1 Introduction 195
- 5.2 Zoning of Subsurface 195
 - Aeration Zone 195
 - Saturated Zone 197
- 5.3 Water Bearing Materials 197
- 5.4 Aquifer Properties Affecting Ground Water 199
 - Aquifer Material Properties 200
 - Ground Water Flow Parameters 202
 - Stratification of Layers 207
 - Calculation of Flow from Flownet 209
- 5.5 Steady Flow Equation 211
- 5.6 Unsteady Flow Equation 214
- 5.7 Ground Water Flow Problems 215
 - Steady Flow in Unconfined Aquifer 215
 - Steady Flow in Confined Aquifer of Constant Thickness 217
 - Steady Flow in a Confined Aquifer of Variable Thickness 219
 - Unconfined Flow with Recharge from Rainfall 220
 - Drainage Using Tiles 222
 - Flow Through Leaky Aquifer 224
 - Flow into Infiltration Galleries 226
- 5.8 Well Hydraulics 227
 - Steady Radial Flow into a Well 228
 - Partially Penetrated Well 233
- 5.9 Unsteady Flow into a Well 235
 - Confined Aquifer 235
 - Unsteady Radial Flow into a Well in Unconfined Aquifer 242

5.10	Spacing of Wells	243
5.11	Well Loss	245
5.12	Well Adjacent to a Stream (Method of Images)	246
5.13	Sea Water Intrusion	248
5.14	Methods of Ground Water Investigation	250
	Hydro-Geologic Investigation	250
	At Surface	252
	Sub-Surface Geophysical Methods	253
	Model Study	255
	Hydrologic Investigation	255
	<i>Problems</i>	256
6.	Stream Flow	258
6.1	Introduction	258
6.2	Terms Used	258
6.3	Factors Affecting Runoff	261
6.4	Stage Measurement	266
	Non-Recording Stage Recorders	266
	Automatic Gauge Recorders	268
6.5	Discharge Measurement	270
	Discharge Measuring Structures	270
	Approximate Area-Slope Method	270
	Slope Method	273
	Area Velocity Method	276
	Radio Tracer Method	286
	Dilution Technique	286
	Electromagnetic Induction Method	287
6.6	Stage Discharge Relationship	287
	Extension of Stage Discharge Relation	290
6.7	Requirement of a Good Gauge-Discharge Site	295
	Network Design	296
6.8	Runoff Computation	297
	Extension of Runoff Records	297
6.9	Runoff From Rainfall Records	305
	Use of Rainfall-Runoff Data at a Site	305
	Use of Rainfall-Runoff Relation of Neighbouring Sites	308
	Empirical Relations	310
6.10	Runoff Simulation Models	315
	Steps in Modelling	316
	HEC Model	317
	<i>Problems</i>	321
7.	Hydrograph	324
7.1	Introduction	324
7.2	Hydrograph Concept	325
7.3	Components of Hydrograph	326
7.4	Unit Hydrograph	334
	Assumptions and Conditions in Unit Hydrograph	335
	Limitations of Unit Hydrograph	336
	Uses of Unit Hydrograph	336
7.5	Derivation of Unit Hydrograph	337
	From Simple Storm Hydrograph	337
	From Complex Storms	341

- 7.6 S-Hydrograph 346
- 7.7 Change of Unit Duration of Unit Hydrograph 349
 - Required Duration is an Integer Multiple of D-hour 349
 - Required Duration is a Real Multiple of D-hour 350
- 7.8 Instantaneous Unit Hydrograph (IUH) 350
 - Derivation of UH from IUH 352
- 7.9 Derivation of Instantaneous Unit Hydrograph 353
 - From S-hydrograph 353
 - From Conceptual Models 353
- 7.10 Synthetic Unit Hydrograph 379
 - Snyder's Approach 379
 - Synthetic Unit Hydrograph for Indian Catchment 381
 - Goel et al. Method 382
- 7.11 Dimensionless Unit Hydrograph 384
- 7.12 Distribution Graph 386
 - Problems* 388

8. Design Flood 392

- 8.1 Introduction 392
- 8.2 Design Flood 392
- 8.3 Flood Peak Estimations for Ungauged Catchments 395
 - Rational Method 395
 - Empirical Equations 399
 - Envelope Curves 408
- 8.4 Flood Estimation for Gauged Catchment 410
 - Flood Frequency Analysis 411
 - Unit Hydrograph Approach 420
- 8.5 Regional Flood Frequency Analysis 427
- 8.6 Analysis of Partial Duration Series 430
 - Problems* 432

9. Flood Routing 434

- 9.1 Introduction 434
- 9.2 Routing Methods 435
- 9.3 Hydrologic Channel Routing 437
 - Muskingum Equation 439
 - Working Value Method 447
- 9.4 Hydraulic Channel Routing 449
 - Finite Difference Method 450
 - Numerical Methods in Routing 452
- 9.5 Hydrologic Reservoir Routing 453
 - Analytical (Trial and Error) Method 454
 - Modified Puls Method 455
 - Inflow-Storage-Discharge Method 461
 - Goodrich Method 466
- 9.6 Flood Routing Machines 469
 - Mechanical Flood Routers 469
 - Electric Analog Routing Machine 469
 - Digital Computers 470
- 9.7 Flood Forecasting 470
- 9.8 Flood Control Measures 482
 - Problems* 485

10. Reservoir and Sedimentation

488

- 10.1 Introduction 488
- 10.2 Fixation of Reservoir Capacity 488
 - Ripples Mass Curve 489
 - Sequent Peak Algorithm 490
- 10.3 Determination of Spillway Size 494
- 10.4 Allocation of Storage Space for Various Uses 496
 - Reservoir Elevation-Area-Capacity Curve 497
 - Reservoir Operation 497
 - Reservoir Working Table 498
- 10.5 Reservoir Sedimentation 501
- 10.6 Determination of Sediment Yield at a River Site 502
 - Sheet Erosion 502
 - Sediment Measurement by Sample Recorder 504
 - Bed Load Estimation 507
 - Empirical Relations for Total Sediment Load 509
- 10.7 Reservoir Sedimentation 513
 - Reservoir Classification 514
 - Distribution of Sediment in Reservoirs 515
- 10.8 Reservoir Sediment Control 521
- 10.9 Reservoir Economics 524
 - Cost-Benefit Ratio 524
 - Optimisation of Benefits 528
 - Linear Programming in Multipurpose Water Resource Projects 530
 - Problems 532

OBJECTIVE QUESTIONS

534

REFERENCES

547

CONVERSION FACTORS

549

INDEX

553