

Table of Contents

PART I	INTRODUCTION	1
1	LAND DRAINAGE FOR AGRICULTURE	1
1.1	Drainage Objectives; Scope of the Book	3
1.2	Waterlogging Control	5
1.3	Agro Hydrological Regimes	10
1.4	Drainage Systems.....	13
1.5	Bio-drainage.....	14
1.6	Environmental Impacts	15
1.7	Global Drainage Zones	22
1.8	Drainage Development Considerations	25
2	PLANNING AND DESIGN.....	29
2.1	Field Investigations	29
2.2	Stages of Project Preparation	30
2.3	Basic Design Criteria	31
2.4	Design Rainfall	34
2.5	Design of Field Drainage Systems.....	37
2.6	Determination of Design Criteria.....	38
3	WATER IN THE SOIL	41
3.1	Forms and Nature of Occurrence of Water in the Soil.....	41
3.2	Pressures in the Soil Water	42
3.3	Soil Moisture Characteristics	44
3.4	Soil Water Potential and Soil Water Movement.....	46
3.5	Hydraulic Conductivity.....	48
3.6	Unsaturated Zone; Soil Moisture Constants	49
3.7	Infiltration and Percolation	52
3.8	Groundwater Flow; Laplace Equation	54
PART II	SYSTEMS AND TECHNOLOGY	57
4	SUBSURFACE DRAINAGE SYSTEMS.....	59
4.1	Pipe Drain Systems	60
4.2	Deep Ditch Systems	63
4.3	Drain Pipes	64
4.4	Envelopes	69
4.5	Envelope Design Guidelines and Criteria.....	75
4.6	Structures in Pipe Drain Systems.....	83
4.7	Construction of Pipe Drain Systems	88
5	SURFACE/SHALLOW DRAINAGE SYSTEMS.....	103
5.1	Bedding Systems.....	104
5.2	Shallow Ditch Systems	106
5.3	Mole Drainage Systems	113
5.4	Pipe Drainage Systems.....	115
5.5	Complementary Measures.....	118

6	MAIN DRAINAGE SYSTEMS.....	121
6.1	Main Features.....	121
6.2	Low Land and Upland Drainage.....	128
PART III	PLANNING AND DESIGN.....	135
7	DESIGN OF PIPE DRAINAGE SYSTEMS.....	137
7.1	Flow Patterns.....	137
7.2	Drain Spacing Formulae	140
7.3	Hooghoudt Formula	142
7.4	Non-Steady State Drainage Formulae.....	146
7.5	Basic Design Criteria	153
7.6	Drain Depth.....	160
7.7	Pipe Diameter.....	162
8	DESIGN DISCHARGES.....	169
8.1	Discharge Transformation.....	169
8.2	Approaches	172
8.3	Statistical Analysis of Observed Discharges	174
8.4	Flat basins	175
8.5	Sloping Basins.....	181
8.6	Area Reduction Formulae	189
8.7	Discharge Reduction through Storage	191
9	HYDRAULIC DESIGN OF DRAINAGE CANALS AND STRUCTURES	201
9.1	Drainage Canals	201
9.2	Structures in Drainage Canals.....	210
9.3	Tidal Outlets.....	216
9.4	Pumps.....	220
PART IV	SALINITY CONTROL	229
10	SOIL SALINITY	231
10.1	Forms of Occurrence and Distribution of Salts in the Soil	232
10.2	Agricultural Impacts; Diagnosis and Assessment.....	237
10.3	Classification.....	245
10.4	Conventional Mapping and Sampling.....	248
10.5	New Salinity Measurement and Mapping Techniques	252
11	IRRIGATION INDUCED SALINISATION	257
11.1	Salinisation by the Applied Irrigation Water	257
11.2	Salinisation from the Groundwater (Capillary Salinisation).....	257
11.3	Sodification	260
11.4	Salt Balance of Irrigated Land	261
11.5	Irrigation Water Quality.....	266
12	DRAINAGE OF IRRIGATED LAND.....	273
12.1	Waterlogging and Salinity	273
12.2	Surface Drainage.....	274
12.3	Pipe Drainage Systems.....	276
12.4	Well or Vertical Drainage	285
12.5	Main Drainage.....	288

PART V	SPECIAL TOPICS.....	293
13	SEEPAGE AND INTERCEPTION.....	295
13.1	Drainage Systems for Sloping Land.....	295
13.2	Interception.....	298
13.3	Natural Drainage of River Valleys.....	301
13.4	Seepage into a Polder.....	302
13.5	Seep Zones and Springs.....	305
14	RECLAMATION AND DRAINAGE OF UNRIPENED SOILS.....	307
14.1	The Soil Ripening Processes.....	307
14.2	Reclamation and Drainage Methods.....	309
14.3	Acid Sulphate Soils.....	311
14.4	Subsidence Prediction.....	314
15	DRAINAGE OF RICE LANDS.....	319
15.1	Surface Drainage.....	320
15.2	Subsurface Drainage.....	324
15.3	Crop Diversification.....	325
15.4	Flood Control.....	326
16	CONTROLLED DRAINAGE.....	329
16.1	Current Issues and Developments.....	329
16.2	Design Considerations.....	330
16.3	Operation and Maintenance by Farmers.....	338
16.4	Controlled Drainage at the Regional Level.....	341
17	COMPUTER APPLICATIONS.....	345
17.1	Drainage Design Applications.....	345
17.2	Rainfall Discharge Models.....	348
17.3	Ground Water Flow Models.....	351
17.4	Agrohydrological Models.....	352
17.5	Salinity Prediction Models.....	356
PART VI	FIELD INVESTIGATIONS AND COST EVALUATION.....	359
18	FIELD SURVEYS AND INVESTIGATIONS.....	361
18.1	Climate.....	361
18.2	Topography.....	364
18.3	Soil and Land Conditions.....	365
18.4	Soil Parameters and Properties.....	367
18.5	Watertable and Groundwater.....	371
18.6	Hydrology and Geohydrology.....	374
18.7	Agriculture and Irrigation.....	375
18.8	Pilot Areas and other Field Tests.....	376
18.9	Environment.....	377
18.10	Miscellaneous Investigations.....	379
19	HYDRAULIC CONDUCTIVITY.....	381
19.1	Laboratory Measurement.....	381
19.2	Field Measurements below the Watertable.....	382
19.3	Field Measurements above the Watertable.....	390

19.4	Composed K-Values	392
19.5	Surveys and Data Processing	394
20	COST EVALUATION	399
20.1	Required Information	399
20.2	Discounting	400
20.3	Evaluation Indices	401
20.4	Examples of Cost Evaluation of Drainage Projects	402
20.5	Cost Calculations for Pipe Drainage Systems	403
PART VII	MANAGEMENT	407
21	INSTITUTIONAL, ORGANISATIONAL AND FINANCIAL ARRANGEMENTS	409
21.1	Drainage Laws	409
21.2	Development and Management Models	409
21.3	Public Drainage Organisation	412
21.4	Financing	414
22	MAINTENANCE	419
22.1	Classification	419
22.2	Organisation, Planning and Execution	419
22.3	Maintenance of Open Canals	420
22.4	Maintenance of Pipe Drains	426
22.5	Developing Countries	430
23	PERFORMANCE ASSESSMENT AND BENCHMARKING	433
23.1	Drainage Design and Performance	433
23.2	Indicators	434
23.3	Performance Assessment Procedure	434
23.4	Performance Checking of Pipe Systems	437
23.5	Causes of Under-Performance of Drainage Systems	438
INDEX	441
ABOUT THE AUTHORS	447