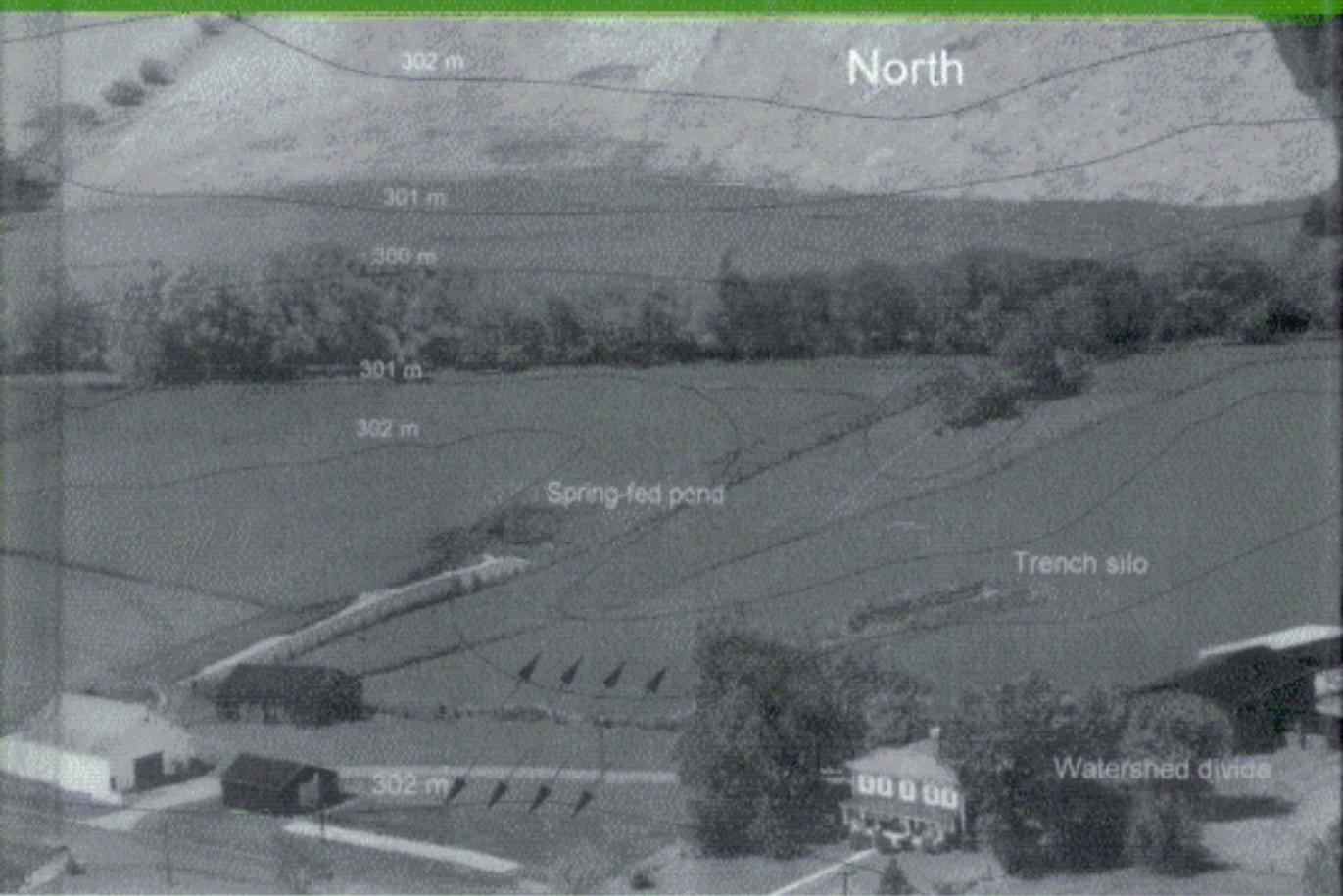
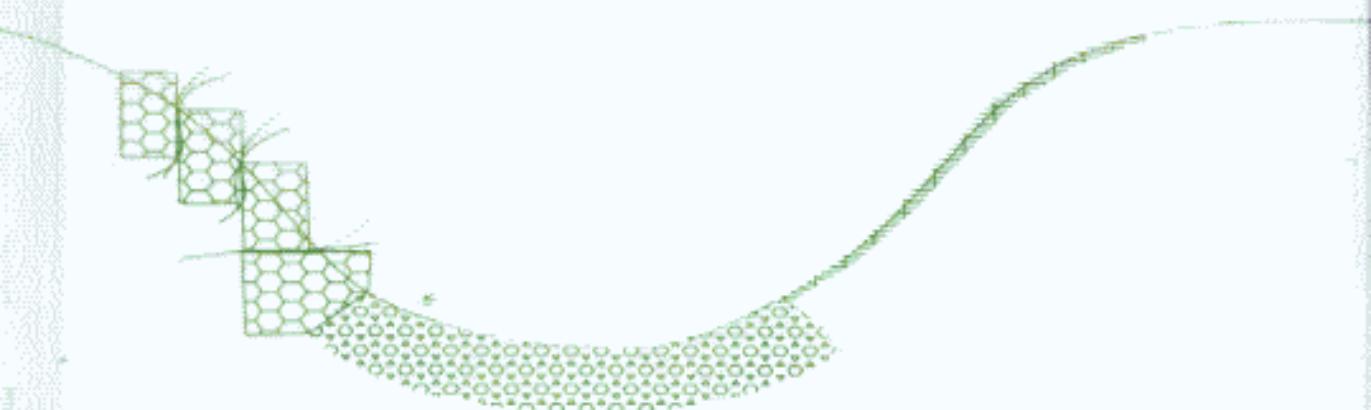


Natural Resources Engineering



Ernest W. Tollner



Contents

Acknowledgments xiii

Preface xv

Chapter 1 Natural Resources Engineering Opportunities 1

Defining Natural Resources Engineering and Related Terms 2
The Hydrologic Cycle 3
Changing Land Uses Due to Societal Forces 4
The Scope of Natural Resources Engineering 6
Outlook 15
Problems and Questions 17
References 18

Chapter 2 Precipitation 20

Precipitation Defined 20
Raindrop Characteristics 21
Precipitation Mechanisms 21
Precipitation Types and Seasonal Effects 22
Precipitation Measurement 23
Precipitation Analyses 25
Introduction to Hydrologic Frequency Analyses:
 Return Period Analysis 27
Calculating Storm Magnitudes for Design Purposes 33
Local-Scale Precipitation Analyses 43
Pollution Transport by Precipitation 46
Outlook 46
Problems and Questions 47
Notes 49
References 49

Chapter 3 Infiltration 51

Infiltration, Percolation, and Subsurface Flow Defined	51
Factors Affecting Infiltration	51
Darcy's Law	52
Infiltration and Percolation Prediction	57
Infiltration Measurement	62
Pollutant Transport by Subsurface Flow	64
Outlook	65
Problems and Questions	66
Notes	68
References	68

Chapter 4 Evapotranspiration 69

Factors Affecting Evaporation	70
Evaporation Prediction Approaches	70
Evaporation from Water Surfaces Based Solely on Aerodynamic Effects or Mass Balance	71
Evaporation Prediction from the Energy Balance: The Bowen Ratio Method	73
Evaporation (E_p) Prediction Accounting for Aerodynamic Effects and Energy Balance: The Penman-Monteith Combination Equation Method	74
Empirical and Approximate Methods for E Prediction	82
Physical Analog: The Standard Evaporation Pan	87
Evaporation and Evapotranspiration Measurement	89
Pollutants and Evaporation	90
Outlook	90
Problems and Questions	91
References	92

Chapter 5 Runoff 94

Background	94
Watershed or Catchment Delineation	96
Runoff Volume for a Compact Watershed	98
Peak Runoff Rate with Compact Watersheds	105
Runoff Hydrograph Development	123
Impact of Errors on Runoff Assessment	132
Outlook	133
Problems and Questions	133
Notes	135
References	136

Chapter 6 Erosion by Water 137

Factors Affecting Erosion by Water	138
Soil Erosion versus Sediment Yield	140
Soil Loss Tolerance	140
Types of Water Erosion	140
Erosion Mechanics	142
Predicting Soil Detachment and Upland Erosion	144
The Weighted $R_{rf}C_{prac}$ Factor for Average Annual Erosion Computation	154
Note on Units	158
Prediction of Sediment Yield	159
Modeling Approaches for Sediment Yield Prediction	162
Erosion Control Practices in Agriculture	165
Sediment Control Practices in Construction	168
Erosion and Pollution	168
Future Directions of Water Erosion Prediction	169
Outlook	169
Going from Engineering Science to Engineering Design: Why Some Approaches Are Empirical	170
Problems and Questions	171
Notes	174
References	174

Chapter 7 Water Quality and Upland Nonpoint Pollution 177

Important Concepts and Selected Pollution Measurement Techniques	179
Water Quality Background	183
Scale Effects	186
Some Best Management Practices for Nonpoint Pollution Abatement	189
Quantitative Removal and Renovation of Selected Pollution Constituents	197
Outlook	199
Problems and Questions	201
References	203

Chapter 8 Open Channel Hydraulics 205

Fundamentals of Hydraulics	205
Fluid Statics Review	208
Channel Design and Construction	215
Outlook	231
Problems and Questions	233
Notes	236
References	236

Chapter 9 Vegetated Waterways 238

Background	239
Channel Planning	240
Design Procedures	245
Other Design Approaches	253
Construction and Maintenance	253
Outlook	253
Problems and Questions	255
References	256

Chapter 10 Terraces and Diversions 257

Background	257
Terrace Definitions and Types	259
Function of Terraces	261
Erosion Terrace Spacing for Erosion Prevention	261
Terrace Channel Length, Cross Section, Maximum Grade, and Capacity	264
Broadbase and Bench Erosion Terrace Design Summary	269
Diversion Terraces and Diversions in Agricultural and Urban Applications	270
Diversion Terraces for Construction Site Erosion Control	274
Terrace Outlet Selection	276
Calculations for Tile Outlet Terrace or Sedimentation Pond	276
Parallel Terrace System Planning and Design	281
Outlook	283
Problems and Questions	287
Notes	289
References	290

Chapter 11 Hydraulics of Water Management Structures 291

Structure Types	292
Hydraulic Concepts	294
Stage-Discharge Relationships of Weir Inlets and Flumes	297
Discharge Relations of Orifices and Sluice Gate Inlet Devices	304
Stage-Discharge Curves for Culverts and Spillways	316
Closed Conduit Systems for Urban Storm Water Collection	321
Water Measurement Structures for Irrigation and Aquaculture	322
Outlook	323
Problems and Questions	325
References	327

Chapter 12 Impoundments and Embankments 329

Soil Fundamentals for Embankment Construction	330
Flood Routing through Reservoirs and Related Structures	335
General Pond Design	342
Spillway Design	352
Embankment Safety: Selection of Design Storm	354
Applications	355
Construction and Safety Issues	362
Outlook	363
Problems and Questions	366
Notes	369
References	369

Chapter 13 Shallow Groundwater Management with Drains and Wells 371

Surface Drainage	371
Introduction to Subsurface Flow	375
Pipe Drainage	376
Shallow Wells	390
Uniform Infiltration and Drainage to a Nearby Stream	396
Outlook	398
Problems and Questions	398
References	400

Chapter 14 Introduction to Irrigation Design 402

Irrigation Systems Overview	403
Soil-Water-Plant Relations	406
Soil Intake Rate	413
Water Quality Issues and Leaching Requirement for Crop Production	414
Irrigation Efficiency	416
Irrigation Scheduling	419
Computing <i>ET</i> Requirements: Peak <i>ET</i>	420
Effective Rainfall for Agricultural Irrigation	420
Computing <i>ET</i> Requirements: Seasonal Water Use	421
Irrigation Pumping Rate for Meeting <i>ET</i> Requirements	423
Water Rights	423
Sprinkler Lateral Design for Agricultural Applications	426
Center Pivot System Specification	436
Design for Nonagricultural Applications	439

Microirrigation System Design with Pressure-Compensated Emitters	442
Safety and Maintainability	445
Outlook	447
Problems and Questions	447
Notes	449
References	449

Chapter 15 Streamflow Processes and Lake Dynamics 452

Background	452
How Waters Are Biologically Impaired	454
Predominant Physical Processes	454
Biological Processes	474
Predominant Nutrient and Chemical Processes	482
Outlook	487
Problems and Questions	488
Notes	490
References	490

Appendix A Ethics, Biotic Relationships, and Resource Economics 493

Review of Values and Ethics	493
Ethical Concepts and the Environment	497
Principles of Ecological Engineering or Design	498
Resource Economics: Social Traps	500
What Defines a Well-Designed Project?	501
Case Study 1: Pitcher Plant Community Viability	502
Case Study 2: Clean Water Act Compliance, a Hypothetical Case	505
Ethics, Ecological Knowledge, and Natural Resources Problem Solution	506
Notes	507
References	507

Appendix B Solutions for Trapezoidal Channels with Constrained Velocity 509

Appendix C Structure Installation and Soil-Imposed Forces 511

Impoundment and Embankment Volume Calculations	511
Setting Slope Stakes for Cuts and Fills	515
Techniques for Installation of Channels and Other Structures	516
Materials Specifications for Channels and Structures	521

Rural Road Construction 524

Buried Pipe Loading 525

References 529

Appendix D Land-Forming Computations for Surface Drainage 530

References 533

Appendix E Centrifugal Pumps and Pumping System Design 534

Pump Fundamentals 534

Centrifugal Pump Type Selection 536

Centrifugal Pump Performance Curves 537

Friction Losses in Pipes 537

Suction Line Design Considerations 539

Total Dynamic Head and Power 540

Determination of the System Head-Flow Curve 542

Selecting and Matching Pumps to a System 543

Pumps in Series and Parallel 545

Storage Requirements at Pumping Plants 545

Pump and Power Plant Fittings and Protection 546

Problems and Questions 547

Notes 548

References 548

Appendix F Plant Water Potential 550

References 552

Appendix G Unit Conversions 553

Index 555