

# Water Resources Engineering

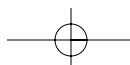
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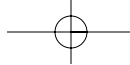
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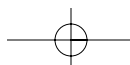
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# Acknowledgments

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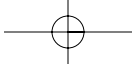
*Water Resources Engineering* is the result of teaching classes over the past 24 years at the University of Texas at Austin and Arizona State University. So first and foremost, I would like to thank the many students that I have taught over the years. Several of my past Ph.D. students have helped me in many ways through their review of the material and help in development of the solutions manual. These former students include Drs. Aihua Tang, Guihua Li, John Nicklow, Burcu Sakarya, Kaan Tuncok, Carlos Carriaga, Bing Zhao, and Messele Ejeta. I would like to acknowledge Arizona State University, especially the time afforded me to pursue this book.

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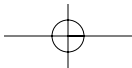
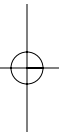
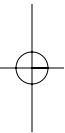
During my academic career as a professor I have received help and encouragement from so many people that it is not possible to name them all. These people represent a wide range of universities, research institutions, government agencies, and professions. To all of you I express my deepest thanks.

*Water Resources Engineering* has been a part of a personal journey that began years ago when I was a young boy with a love of water. This love of water resources has continued throughout my life, even in my spare time, being an avid snow skier and fly-fisherman. Books are companions along the journey of learning and I hope that you will be able to use this book in your own exploration of the field of water resources. Have a wonderful journey.

*Larry W. Mays*  
Scottsdale, Arizona



I would like to dedicate this book to humanity and human welfare.



# Preface

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*Water Resources Engineering* can be used for the first undergraduate courses in hydraulics, hydrology, or water resources engineering and for upper level undergraduate and graduate courses in water resources engineering design. This book is also intended as a reference for practicing hydraulic engineers, civil engineers, mechanical engineers, environmental engineers, and hydrologists.

Water resources engineering, as defined for the purposes of this book, includes both water use and water excess management. The fundamental water resources engineering processes are the hydrologic processes and the hydraulic processes. The common threads that relate to the explanation of these processes are the fundamentals of fluid mechanics using the control volume approach. The hydraulic processes include pressurized pipe flow, open-channel flow, and groundwater flow. Each of these in turn can be subdivided into various processes and types of flow. The hydrologic processes include rainfall, evaporation, infiltration, rainfall-runoff, and routing, all of which can be further subdivided into other processes. Knowledge of the hydrologic and hydraulic processes is extended to the design and analysis aspects. This book, however, does not cover the water quality management aspects of water resources engineering.

Water resources development has had a long history, basically beginning when humans changed from being hunters and food gatherers to developing of agriculture and settlements. This change resulted in humans harnessing water for irrigation. As humans developed, they began to invent and develop technologies, and to transport and manage water for irrigation. The first successful efforts to control the flow of water were in Egypt and Mesopotamia. Since that time humans have continuously built on the knowledge of water resources engineering. This book builds on that knowledge to present state-of-the-art concepts and practices in water resources engineering.

*Water Resources Engineering* is divided into four parts: Part I – Hydraulics; Part II – Hydrology; Part III – Engineering Analysis and Design for Water Use; and Part IV – Engineering Analysis and Design for Water Excess Management. Part I consists of six chapters that introduce the basic processes of hydraulics. Chapter 1 is a very brief introduction to water resources. Chapter 2 is a review of basic fluid mechanics principles. Chapter 3 presents the control volume approach for continuity, energy, and momentum. Chapters 4, 5, and 6 cover pressurized pipe flow, open-channel flow, and groundwater flow. Part II presents four chapters that cover the basics of hydrology: Chapter 7 on hydrologic processes; Chapter 8 on rainfall-runoff analysis; Chapter 9 on routing and Chapter 10 on and probability and frequency analysis. Part III, on engineering analysis and design for water use, consists of three chapters: Chapter 11 on water withdrawals and uses; Chapter 12 on water distribution systems; and Chapter 13 on water for hydroelectric generation. Part IV, on engineering analysis and design for water excess management, includes four chapters: Chapter 14 on water excess management; Chapter 15 on stormwater control: storm sewers and detention; Chapter 16 on stormwater control: street and highway drainage and culverts; and Chapter 17 on the design of hydraulic structures for flood control storage systems.

Several first courses could be taught from this book: a first course on hydraulics, a first course on hydrology, a first course on water resources engineering analysis and design, and a first course on hydraulic design. The flowcharts on the following pages illustrate the topics and chapters that could be covered in these courses.

This is a comprehensive book covering a large number of topics that would be impossible to cover in any single course. This was done purposely because of the wide variation in the manner in which faculty teach these courses or variations of these courses. Also, to make this book more valuable to the practicing engineer or hydrologist, the selection of these topics and the extent of

**vi** Preface

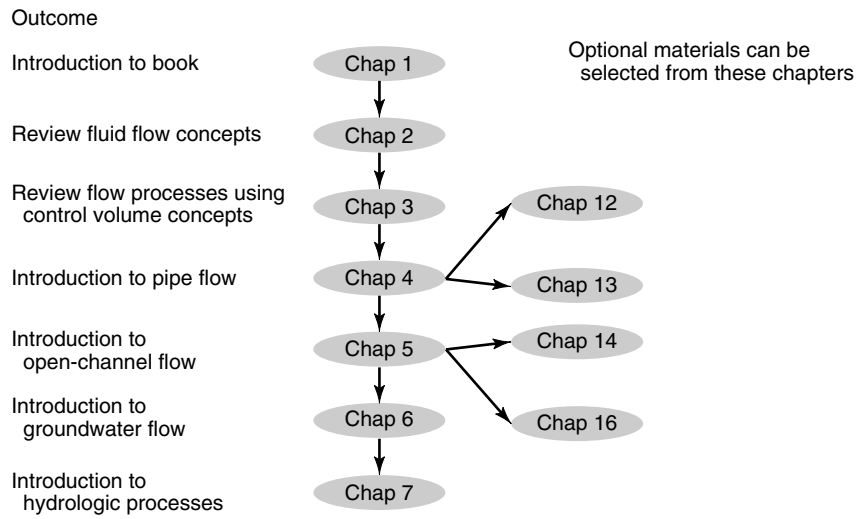
coverage in each chapter were considered carefully. I have attempted to include enough example problems to make the theory more applicable, more understandable, and most of all more enjoyable to the student and engineer.

Students using this book will most likely have had an introductory fluid mechanics course based on the control volume approach. Chapter 2 should serve as a review of basic fluid concepts and Chapter 3 should serve as a review of the control volume concepts. Control volume concepts are then used in the succeeding chapters to introduce the hydrologic and hydraulic processes. Even if the student or engineer has not had an introductory course in fluid mechanics, this book can still be used, because the concepts of fluid mechanics and the control volume approach are covered.

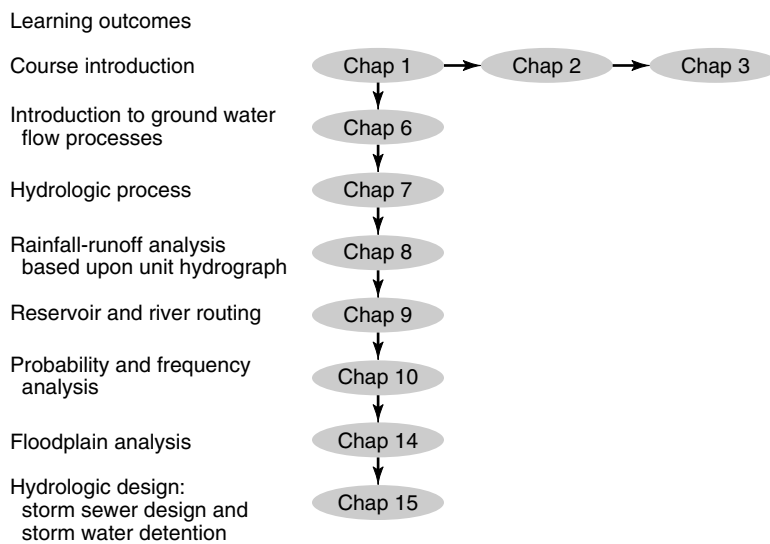
I sincerely hope that this book will be a contribution toward the goal of better engineering in the field of water resources. I constantly remind myself of the following quote from Baba Diodum: “In the end we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught.”

This book has been another part of a personal journey of mine that began as a young boy with an inquisitive interest and love of water, in the streams, creeks, ponds, lakes, rivers, and oceans, and water as rain and snow. Coming from a small Illinois town situated between the Mississippi and Illinois Rivers near Mark Twain’s country, I began to see and appreciate at an early age the beauty, the useful power, and the extreme destructiveness that rivers can create. I hope that this book will be of value in your journey of learning about water resources.

First Undergraduate Hydraulics Course

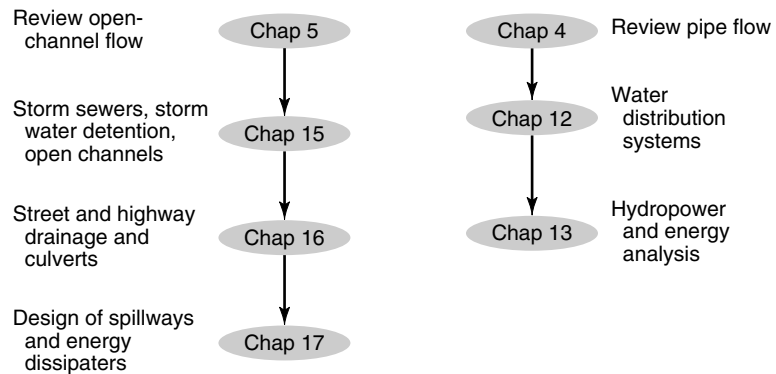


First Undergraduate Hydrology Course

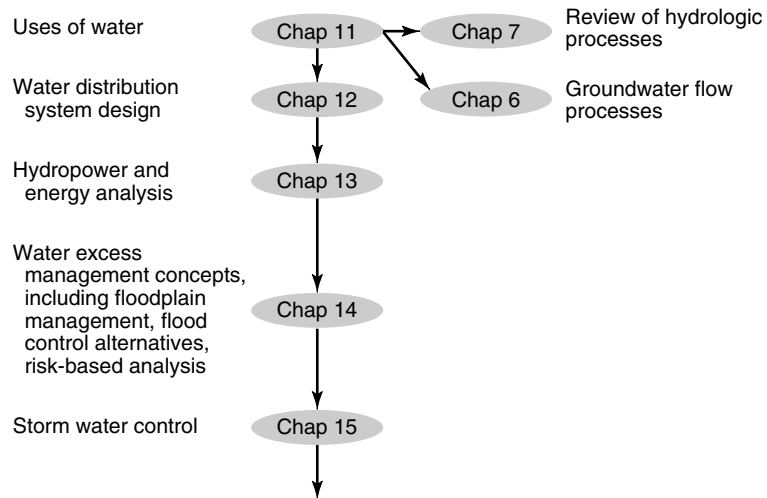


viii Preface

Undergraduate Hydraulic Design Course



Water Resources Engineering



# Contents

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<b>Chapter 1</b>	<b>Introduction</b>	<b>1</b>
1.1	Background	1
1.2	The World's FreshWater Resources	4
1.3	Water Use in the United States	6
1.4	Systems of Units	8
1.5	What Is Water?	10
1.6	The Future of Water Resources	12
<b>Chapter 2</b>	<b>Principles of Flow in Hydrosystems</b>	<b>15</b>
2.1	Properties Involving Mass or Weight of Water	15
2.2	Viscosity	17
2.3	Elasticity	18
2.4	Pressure and Pressure Variation	19
2.5	Surface Tension	21
2.6	Flow Visualization	23
2.7	Laminar and Turbulent Flow	24
2.8	Discharge	25
<b>Chapter 3</b>	<b>Flow Processes and Hydrostatic Forces</b>	<b>29</b>
3.1	Control Volume Approach for Hydrosystems	29
3.2	Continuity	32
3.3	Energy	34
3.4	Momentum	38
3.5	Pressure and Pressure Forces in Static Fluids	39
3.5.1	Hydrostatic Forces	39
3.5.2	Buoyancy	43
3.6	Velocity Distribution	44
<b>Chapter 4</b>	<b>Hydraulic Processes: Pressurized Pipe Flow</b>	<b>49</b>
4.1	Classification of Flow	49
4.2	Pressurized (Pipe) Flow	52
4.2.1	Energy Equation	52
4.2.2	Hydraulic and Energy Grade Lines	56
4.3	Headlosses	56
4.3.1	Shear-Stress Distribution of Flow in Pipes	56
4.3.2	Velocity Distribution of Flow in Pipes	58
4.3.3	Headlosses from Pipe Friction	61
4.3.4	Form (Minor) Losses	63
4.4	Forces in Pipe Flow	70
4.5	Pipe Flow in Simple Networks	73
4.5.1	Series Pipe Systems	73
4.5.2	Parallel Pipe Systems	75
4.5.3	Branching Pipe Flow	78
		<b>ix</b>

## x Table of Contents

4.6	Measurement of Flowing Fluids in Pressure Conduits	79
4.6.1	Measurement of Static Pressure	79
4.6.2	Measurement of Velocity	80
4.6.3	Measurement of Discharge	81
<b>Chapter 5</b>	<b>Hydraulic Processes: Open-Channel Flow</b>	<b>85</b>
5.1	Steady Uniform Flow	85
5.1.1	Energy	85
5.1.2	Momentum	88
5.1.3	Best Hydraulic Sections for Uniform Flow in Nonerodible Channels	94
5.2	Specific Energy, Momentum, and Specific Force	95
5.2.1	Specific Energy	95
5.2.2	Momentum	101
5.2.3	Specific Force	102
5.3	Steady, Gradually Varied Flow	105
5.3.1	Gradually Varied Flow Equations	105
5.3.2	Water Surface Profile Classification	108
5.4	Gradually Varied Flow for Natural Channels	111
5.4.1	Development of Equations	111
5.4.2	Energy Correction Factor	114
5.4.3	Application for Water Surface Profile	118
5.5	Rapidly Varied Flow	123
5.6	Discharge Measurement	128
5.6.1	Weir	128
5.6.2	Flumes	132
5.6.3	Stream Flow Measurement: Velocity-Area-Integration Method	135
<b>Chapter 6</b>	<b>Hydraulic Processes: Groundwater Flow</b>	<b>141</b>
6.1	Groundwater Concepts	141
6.2	Saturated Flow	150
6.2.1	Governing Equations	150
6.2.2	Flow Nets	152
6.3	Steady-State One-Dimensional Flow	154
6.4	Steady-State Well Hydraulics	157
6.4.1	Flow to Wells	157
6.4.2	Confined Aquifers	158
6.4.3	Unconfined Aquifers	161
6.5	Transient Well Hydraulics—Confined Conditions	162
6.5.1	Nonequilibrium Well Pumping Equation	162
6.5.2	Graphical Solution	165
6.5.3	Cooper–Jacob Method of Solution	167
6.6	Transient Well Hydraulics—Unconfined Conditions	172
6.7	Transient Well Hydraulics—Leaky Aquifer Conditions	173
6.8	Boundary Effects: Image Well Theory	174
6.8.1	Barrier Boundary	175
6.8.2	Recharge Boundary	178
6.8.3	Multiple Boundary Systems	179
6.9	Simulation of Groundwater Systems	181
6.9.1	Governing Equations	181
6.9.2	Finite Difference Equations	182
6.9.3	MODFLOW	186

<b>Chapter 7</b>	<b>Hydrologic Processes</b>	<b>191</b>
7.1	Introduction to Hydrology	191
7.1.1	What Is Hydrology?	191
7.1.2	The Hydrologic Cycle	191
7.1.3	Hydrologic Systems	193
7.1.4	Atmospheric and Ocean Circulation	199
7.2	Precipitation (Rainfall)	202
7.2.1	Precipitation Formation and Types	202
7.2.2	Rainfall Variability	204
7.2.3	Disposal of Rainfall on a Watershed	212
7.2.4	Design Storms	212
7.2.5	Estimated Limiting Storms	224
7.3	Evaporation	227
7.3.1	Energy Balance Method	228
7.3.2	Aerodynamic Method	231
7.3.3	Combined Method	232
7.4	Infiltration	233
7.4.1	Unsaturated Flow	233
7.4.2	Green-Ampt Method	237
7.4.3	Other Infiltration Methods	243
<b>Chapter 8</b>	<b>Surface Runoff</b>	<b>247</b>
8.1	Drainage Basins	247
8.2	Hydrologic Losses and Rainfall Excess	251
8.3	Rainfall-Runoff Analysis Using Unit Hydrograph Approach	253
8.4	Synthetic Unit Hydrographs	256
8.5	S-Hydrographs	259
8.6	SCS Rainfall-Runoff Relation	262
8.7	Curve Number Estimation and Abstractions	263
8.7.1	Antecedent Moisture Conditions	263
8.7.2	Soil Group Classification	264
8.7.3	Curve Numbers	267
8.8	SCS Unit Hydrograph Procedure	270
8.8.1	Time of Concentration	271
8.8.2	Time to Peak	273
8.8.3	Peak Discharge	273
8.9	Kinematic-Wave Overland Flow Runoff Model	274
8.10	Computer Models for Rainfall-Runoff Analysis	280
<b>Chapter 9</b>	<b>Reservoir and Stream Flow Routing</b>	<b>283</b>
9.1	Routing	283
9.2	Hydrologic Reservoir Routing	284
9.3	Hydrologic River Routing	288
9.4	Hydraulic (Distributed) Routing	292
9.4.1	Unsteady Flow Equations: Continuity Equation	293
9.4.2	Momentum Equation	295
9.5	Kinematic Wave Model for Channels	298
9.5.1	Kinematic Wave Equations	298
9.5.2	U.S. Army Corps of Engineers HEC-1 Kinematic Wave Model for Overland Flow and Channel Routing	300

## xii Table of Contents

9.5.3	KINEROS Channel Flow Routing Model	302
9.5.4	Kinematic Wave Celerity	302
9.6	Muskingum-Cunge Model	303
9.7	Implicit Dynamic Wave Model	304
<b>Chapter 10</b>	<b>Probability, Risk, and Uncertainty Analysis for Hydrologic and Hydraulic Design</b>	<b>309</b>
10.1	Probability Concepts	309
10.2	Commonly Used Probability Distributions	312
10.2.1	Normal Distribution	312
10.2.2	Log-Normal Distribution	312
10.3	Hydrologic Design for Water Excess Management	315
10.3.1	Hydrologic Design Scale	315
10.3.2	Hydrologic Design Level (Return Period)	317
10.3.3	Hydrologic Risk	317
10.3.4	Hydrologic Data Series	318
10.4	Hydrologic Frequency Analysis	320
10.5	U.S Water Resources Council Guidelines for Flood Flow Frequency Analysis	326
10.5.1	Procedure	326
10.5.2	Testing for Outliers	328
10.6	Analysis of Uncertainties	330
10.7	Risk Analysis: Composite Hydrologic and Hydraulic Risk	334
10.7.1	Reliability Computation by Direct Integration	335
10.7.2	Reliability Computation Using Safety Margin/Safety Factor	337
10.8	Computer Models for Floodflow Frequency Analysis	340
<b>Chapter 11</b>	<b>Water Withdrawals and Uses</b>	<b>343</b>
11.1	Water-Use Data—Classification of Uses	343
11.2	Water for Energy Production	348
11.3	Water for Agriculture	356
11.3.1	Irrigation Trends and Needs	356
11.3.2	Irrigation Infrastructure	357
11.3.3	Irrigation System Selection and Performance	365
11.3.4	Water Requirements for Irrigation	368
11.3.5	Impacts of Irrigation	370
11.4	Water Supply/Withdrawals	372
11.4.1	Withdrawals	372
11.4.2	Examples of Regional Water Supply Systems	378
11.5	Water Demand and Price Elasticity	383
11.5.1	Price Elasticity of Water Demand	383
11.5.2	Demand Models	385
11.6	Drought Management	386
11.6.1	Drought Management Options	386
11.6.2	Drought Severity	388
11.6.3	Economic Aspects of Water Shortage	390
11.7	Analysis of Surface Water Supply	394
11.7.1	Surface-Water Reservoir Systems	394
11.7.2	Storage—Firm Yield Analysis for Water Supply	394
11.7.3	Reservoir Simulation	403

<b>Chapter 12</b>	<b>Water Distribution</b>	<b>409</b>
12.1	Introduction	409
12.1.1	Description, Purpose, and Components of Water Distribution Systems	409
12.1.2	Pipe Flow Equations	419
12.2	System Components	421
12.2.1	Pumps	421
12.2.2	Pipes and Fittings	433
12.2.3	Valves	436
12.3	System Configuration and Operation	438
12.4	Hydraulics of Simple Networks	440
12.4.1	Series and Parallel Pipe Flow	440
12.4.2	Branching Pipe Flow	443
12.5	Pump Systems Analysis	444
12.5.1	System Head Curves	444
12.5.2	Pump Operating Point	447
12.5.3	System Design for Water Pumping	449
12.6	Network Simulation	459
12.6.1	Conservation Laws	459
12.6.2	Network Equations	460
12.6.3	Network Simulation: Hardy–Cross Method	461
12.6.4	Network Simulation: Linear Theory Method	467
12.6.5	Extended-Period Simulation	468
12.7	Modeling Water Distribution Systems	469
12.7.1	Computer Models	469
12.7.2	Calibration	469
12.7.3	Application of Models	470
12.7.4	Water Quality Modeling	470
12.8	Hydraulic Transients	472
12.8.1	Hydraulic Transients in Distribution Systems	472
12.8.2	Fundamentals of Hydraulic Transients	472
12.8.3	Control of Hydraulic Transients	482
<b>Chapter 13</b>	<b>Water for Hydroelectric Generation</b>	<b>491</b>
13.1	Role of Hydropower	491
13.2	Components of Hydroelectric Plants	497
13.2.1	Elements to Generate Electricity	497
13.2.2	Hydraulics of Turbines	504
13.2.3	Power System Terms and Definitions	506
13.3	Determining Energy Potential	507
13.3.1	Hydrologic Data	507
13.3.2	Water Power Equations	508
13.3.3	Turbine Characteristics and Selection	510
13.3.4	Flow Duration Method	513
13.3.5	Sequential Streamflow-Routing Method	519
13.3.6	Power Rule Curve	520
13.3.7	Multipurpose Storage Operation	521

## xiv Table of Contents

<b>Chapter 14</b>	<b>Flood Control</b>	<b>523</b>
14.1	Introduction	523
14.2	Floodplain Management	527
14.2.1	Floodplain Definition	527
14.2.2	Hydrologic and Hydraulic Analysis of Floods	527
14.2.3	Floodways and Floodway Fringes	530
14.2.4	Floodplain Management and Floodplain Regulations	531
14.2.5	National Flood Insurance Program	532
14.2.6	Stormwater Management and Floodplain Management	533
14.3	Flood-Control Alternatives	534
14.3.1	Structural Alternatives	535
14.3.2	Nonstructural Measures	542
14.4	Flood Damage and Net Benefit Estimation	544
14.4.1	Damage Relationships	544
14.4.2	Expected Damages	545
14.4.3	Risk-Based Analysis	548
14.5	U.S. Army Corps of Engineers Risk-Based Analysis for Flood-Damage Reduction Studies	549
14.5.1	Terminology	549
14.5.2	Benefit Evaluation	550
14.5.3	Uncertainty of Stage-Damage Function	552
14.6	Operation of Reservoir Systems for Flood Control	554
14.6.1	Flood-Control Operation Rules	554
14.6.2	Tennessee Valley Authority (TVA) Reservoir System Operation	554
<b>Chapter 15</b>	<b>Stormwater Control: Storm Sewers and Detention</b>	<b>561</b>
15.1	Stormwater Management	561
15.2	Storm Systems	562
15.2.1	Information Needs and Design Criteria	562
15.2.2	Rational Method Design	564
15.2.3	Hydraulic Analysis of Designs	571
15.2.4	Storm Sewer Appurtenances	586
15.2.5	Risk-Based Design of Storm Sewers	586
15.3	Stormwater Drainage Channels	590
15.3.1	Rigid-Lined Channels	590
15.3.2	Flexible-Lined Channels	596
15.4	Stormwater Detention	599
15.4.1	Why Detention? Effects of Urbanization	599
15.4.2	Types of Surface Detention	601
15.4.3	Sizing Detention	604
15.4.4	Detention Basin Routing	613
15.4.5	Subsurface Disposal of Stormwater	615
<b>Chapter 16</b>	<b>Stormwater Control: Street and Highway Drainage and Culverts</b>	<b>627</b>
16.1	Drainage of Street and Highway Pavements	627
16.1.1	Design Considerations	627
16.1.2	Flow in Gutters	629
16.1.3	Pavement Drainage Inlets	633
16.1.4	Interception Capacity and Efficiency of Inlets on Grade	634
16.1.5	Interception Capacity and Efficiency of Inlets in Sag Locations	642

16.1.6	Inlet Locations	646
16.1.7	Median, Embankment, and Bridge Inlets	649
16.2	Hydraulic Design of Culverts	651
16.2.1	Culvert Hydraulics	652
16.2.2	Culvert Design	664
<b>Chapter 17</b>	<b>Design of Spillways and Energy Dissipation for Flood Control Storage and Conveyance Systems</b>	<b>671</b>
17.1	Hydrologic Considerations	671
17.2	Dams	672
17.2.1	Type of Dams	672
17.2.2	Hazard Classification of Dams	676
17.2.3	Spillway Capacity Criteria	677
17.2.4	Safety of Existing Dams	678
17.2.5	Hydraulic Analysis of Dam Failures	681
17.2.6	Examples of Dams and Spillways	683
17.3	Spillways	694
17.3.1	Functions of Spillways	694
17.3.2	Overflow and Free-Overfall (Straight Drop ) Spillways	695
17.3.3	Ogee (Overflow) Spillways	697
17.3.4	Side Channel Spillways	704
17.3.5	Drop Inlet (Shaft or Morning Glory) Spillways	706
17.3.6	Baffled Chute Spillways	714
17.3.7	Culvert Spillways	716
17.4	Hydraulic-Jump Type Stilling Basins and Energy Dissipators	718
17.4.1	Types of Hydraulic Jump Basins	718
17.4.2	Basin I	720
17.4.3	Basin II	721
17.4.4	Basin III	722
17.4.5	Basin IV	723
17.4.6	Basin V	724
17.4.7	Tailwater Considerations for Stilling Basin Design	727
17.5	Other Types of Stilling Basins	736
17.6	Gates and Valves	740
17.6.1	Spillway Crest Gates	740
17.6.2	Gates for Outlet Works	742
17.6.3	Valves for Outlet Works	742
17.7	Outlet Works	744
<b>Appendix A</b>	<b>Newton–Raphson Method</b>	<b>749</b>
	Finding the root for a single nonlinear equation	749
	Application to Solve Manning’s Equation for Normal Depth	750
	Finding the roots of a system of nonlinear equations	751
<b>Index</b>		<b>753</b>

