Table of Contents

Chapter I	1.9 Additional Resources 33
Introduction to Water Distribution	
1.1 Water as a Limited Resource 2	Chapter Review 34
1.1 Walet as a milited Researce 2	
1.2 The Water Supply System 3	Chapter 2
I.2.1 Sources of Water 4	Water Storage Facilities 37
1.2.1.1 Ocean Water 4	2.1 Purpose of Storage Facilities 38
1.2.1.2 Surface Water 6	
1.2.1.3 Groundwater 7	2.2 Types of Storage Facilities 40
1.2.1.4 Reclaimed Water 8	2.2.1. Cl. W/ II /2
1.2.2 Storage Facilities 9	2.2.1 Clear Wells 42 2.2.1.1 Elevated Tanks 42
1.2.3 Treatment Facilities 9	2.2.1.2 Standpipes 42
1.2.3.1 Water Treatment 10	2.2.1.3 Ground-Level Reservoirs 43
1.2.4 Distribution Systems 10	2.2.2 Hydro-Pneumatic or Pressure Tanks 43
1.3 Water Quality Standards 12	2.2.3 Surge Tanks 43
	2.2.4 Surge Protection 44
1.4 Water Quality in Distribution Systems 15	
I.4.1 Water Quality Complaints 16	2.3 Selection and Location of Storage Facilities 45
1.5 Contaminants and Their Sources 18	2.4 Storago Tonk Operation 44
I.5.1 Supplied Water Quality 19	2.4 Storage Tank Operation 46
	2.4. Storage Levels 48
1.5.2 Water Quality Degradation 20	2.4.2 Storage Level Controls 51
1.5.2.1 Water Mains 24 1.5.2.2 Storage Facilities 26	2.4.3 Pumps 52
	2.4.4 Sampling 54
1.5.3 Water Quality Monitoring 27	2.4.5 Troubleshooting 54
1.6 Protecting Water Quality Through O&M 28	2.5 Maintenance 56
1.7 Distribution System Operators 29	2.5 Wantenance 50
1.7 Distribution System Operators 29	2.5.1 Inspection 56
1.7.1 Operation and Maintenance 30	2.5.2 Cleaning 58
1.7.2 Supervision and Administration 30	2.5.3 Painting 58
1.7.3 Public Relations 31	2.5.4 Corrosion Control 61
1.7.4 Safety 32	2.5.5 Disinfection 64
1.8 Math Assignment 33	2.5.6 Concrete Storage Facilities 68
1.0 Maiii 1155igiiiiciii 00	2.5.7 Frozen Distribution Reservoirs 68

2.6 Booster Pumps, Regulator Stations, and	3.7.4.10 Safety 130
Gauges 70	3.7.5 Pipe Extensions 131
2.7 Records 74	3.7.6 Appurtenances 132
Z./ Records / I	3.7.6.1 Valves 132
2.8 Safety 74	3.7.6.2 Fittings 142
	3.7.6.3 Hydrants 143
2.9 Math Assignment 75	3.8 Meters 146
2.10 Additional Resources 75	3.8. Displacement Meters 147
	3.8.2 Velocity-Type Meters 149
Chapter Review 76	3.8.3 Compound Meters 150
	3.8.4 Electronic Meters 151
Chapter 3	3.8.5 Proportional Meters 151
Distribution System Facilities 79	3.9 Service Connections 152
3.1 Delivering Water 80	
	3.9.1 Installation 153
3.2 Hydraulics 81	3.9.2 Backflow Prevention Devices 155
2.2 Deviews and Considerations 94	3.10 Moth Assignment 162
3.3 Performance Considerations 86	1/2
3.4 Water Transmission Systems 90	3.11 Additional Resources 163
	Chapter Review 164
3.5 Distribution Storage 90	
3.5.1 Location 91	Chapter 4
3.5.2 Types of Storage 91	Operation and Maintenance 167
3.5.3 Preventing Contamination 93	•
3.6 Storage and Booster Pumping 93	4.1 Need for System Operation and Maintenance 168
3.0 Storage and booster Fulliping 75	1/10/11/01/01/05
3.7 Water Mains and Appurtenances 94	4.2 System Surveillance 169
3.7.1 Pipe Types 97	4.2. Treated Water Storage Facilities 169
3.7.1.1 Types of Service Pipe 101	4.2.2 Mains 171
	4.2.2 Mains 1/1
3.7.2 Joints 102	4.2.3 Valves and Blowoffs 171
3.7.2 Joints 102 3.7.3 Pipe Protection 107	
	4.2.3 Valves and Blowoffs 171
3.7.3 Pipe Protection 107	4.2.3 Valves and Blowoffs 1714.2.4 Meters and Curb Boxes 171
3.7.3 Pipe Protection 107 3.7.4 Pipe Installation 108 3.7.4.1 Locating Nearby Utility Lines 109 3.7.4.2 Water and Sewer Line Separation 109	4.2.3 Valves and Blowoffs 1714.2.4 Meters and Curb Boxes 1714.2.5 Preventing Vandalism 172
3.7.3 Pipe Protection 107 3.7.4 Pipe Installation 108 3.7.4.1 Locating Nearby Utility Lines 109 3.7.4.2 Water and Sewer Line Separation 109 3.7.4.3 Storage and Handling 109	 4.2.3 Valves and Blowoffs 171 4.2.4 Meters and Curb Boxes 171 4.2.5 Preventing Vandalism 172 4.2.6 Telemetering 173 4.2.7 Other Surveillance 173
3.7.3 Pipe Protection 107 3.7.4 Pipe Installation 108 3.7.4.1 Locating Nearby Utility Lines 109 3.7.4.2 Water and Sewer Line Separation 109 3.7.4.3 Storage and Handling 109 3.7.4.4 Excavation and Shoring 111	 4.2.3 Valves and Blowoffs 171 4.2.4 Meters and Curb Boxes 171 4.2.5 Preventing Vandalism 172 4.2.6 Telemetering 173
3.7.3 Pipe Protection 107 3.7.4 Pipe Installation 108 3.7.4.1 Locating Nearby Utility Lines 109 3.7.4.2 Water and Sewer Line Separation 109 3.7.4.3 Storage and Handling 109 3.7.4.4 Excavation and Shoring 111 3.7.4.5 Pipe Laying and Jointing 120	 4.2.3 Valves and Blowoffs 171 4.2.4 Meters and Curb Boxes 171 4.2.5 Preventing Vandalism 172 4.2.6 Telemetering 173 4.2.7 Other Surveillance 173
3.7.4 Pipe Installation 108 3.7.4.1 Locating Nearby Utility Lines 109 3.7.4.2 Water and Sewer Line Separation 109 3.7.4.3 Storage and Handling 109 3.7.4.4 Excavation and Shoring 111 3.7.4.5 Pipe Laying and Jointing 120 3.7.4.6 Thrust Blocks 123	 4.2.3 Valves and Blowoffs 171 4.2.4 Meters and Curb Boxes 171 4.2.5 Preventing Vandalism 172 4.2.6 Telemetering 173 4.2.7 Other Surveillance 173 4.3 Water Quality Monitoring 173
3.7.3 Pipe Protection 107 3.7.4 Pipe Installation 108 3.7.4.1 Locating Nearby Utility Lines 109 3.7.4.2 Water and Sewer Line Separation 109 3.7.4.3 Storage and Handling 109 3.7.4.4 Excavation and Shoring 111 3.7.4.5 Pipe Laying and Jointing 120 3.7.4.6 Thrust Blocks 123 3.7.4.7 Backfilling 124	 4.2.3 Valves and Blowoffs 171 4.2.4 Meters and Curb Boxes 171 4.2.5 Preventing Vandalism 172 4.2.6 Telemetering 173 4.2.7 Other Surveillance 173 4.3 Water Quality Monitoring 173 4.3.1 Monitoring Program 174
3.7.4 Pipe Installation 108 3.7.4.1 Locating Nearby Utility Lines 109 3.7.4.2 Water and Sewer Line Separation 109 3.7.4.3 Storage and Handling 109 3.7.4.4 Excavation and Shoring 111 3.7.4.5 Pipe Laying and Jointing 120 3.7.4.6 Thrust Blocks 123	 4.2.3 Valves and Blowoffs 171 4.2.4 Meters and Curb Boxes 171 4.2.5 Preventing Vandalism 172 4.2.6 Telemetering 173 4.2.7 Other Surveillance 173 4.3 Water Quality Monitoring 173 4.3.1 Monitoring Program 174 4.3.2 Sampling Location 178

4.3.5 Lead and Copper Monitoring and Sampling Procedures 180	4.8.13.4 Maintenance 247 4.8.13.5 Meter Reading 248
4.4 Cross-Connection Control 181	4.8.14 Corrosion Control 249
4.4.1 Program Responsibilities 182	4.9 Field Disinfection 251
4.4.2 Water Supplier Program 184	4.9.1 Disinfection of Mains 252
4.4.3 Typical Cross-Connection Hazards 186	4.9.2 Disinfection of Storage Facilities 256
4.4.3.1 Hazardous Chemicals Used by Consumers 186	4.10 Records 259
4.4.3.2 Industries with Cross-Connection	
Potential 188	4.10.1 Maps 260
4.4.3.3 Maintenance and Testing	4.11 SCADA Systems 264
Procedures 193	4 10 Familian and Stones Off
4.5 System Pressures 194	4.12 Equipment and Stores 265
4.6 Distribution Storage 195	4.13 Emergency Planning 266
4.0 Distribution storage 175	
4.7 Pumps 195	4.14 Public Relations 268
	4.15 Parallilar Lamada camin ar and Carafaga Markay
4.8 Water Main and Appurtenance Maintenance 201	4.15 Facility Landscaping and Surface Water Drainage 270
4.8.1 Locating Leaks 201	4.16 Distribution System Math 274
	4.10 Distribution System Main 2/4
4.8.2 Locating Pipes 2064.8.3 Repairing Leaks and Pulled Services 207	4.17 Math Assignment 279
4.8.4 Making Pipe and Service Connections 208	
4.8.5 Detecting Service Deficiencies 209	4.18 Additional Resources 280
4.8.6 Pipe Flushing 212	Chapter Review 281
4.8.7 Pipe Cleaning 216	Onapier Review 201
4.8.8 Cement-Mortar Lining 222	Chapter 5
4.8.9 Thawing 223 4.8.9.1 Hot Water Thawing of Frozen Service	Disinfection 285
Lines 224	
4.8.9.2 Steam Thawing of Frozen Service Valves,	5.1 Drinking Water Safety 286
Main Valves, and Hydrants 225	5.1.1 Safe Drinking Water Laws 286
4.8.9.3 Electrical Thawing of Frozen Service Lines 226	5.2 Factors Influencing Disinfection 289
4.8.9.4 Flushing the Water Mains to Prevent Freezing 228	5.2.1 pH 289
4.8.10 Main Breaks 232	5.2.2 Temperature 289
4.8.11 Valves 232	5.2.3 Turbidity 289
4.8.12 Fire Hydrants 239	5.2.3.1 Organic Matter 290
4.8.13 Meters 242	5.2.3.2 Inorganic Matter 290
4.8.13.1 Test Procedures 242	5.2.4 Reducing Agents 290
4.8.13.2 Accuracy Testing Requirements 245	5.2.5 Microorganisms 290
4.8.13.3 Meter Registers and Readouts 246	5.2.6 Disinfection Considerations 291

5.3	Disinfection Process 292	5.5 Operation of Chlorination Equipment 324
5.3.1	Physical Means of Disinfection 292	5.5.1 Hypochlorinators 324
5.3.2	Chemical Disinfectants (Other Than Chlorine) 293	5.5.2 Chlorinators 325
5.3.3	Chlorine 294	5.5.2.1 Chlorinator Flow Path 327
	5.3.3.1 Chlorine Disinfection Action 294	5.5.2.2 Chlorinator Parts and Their
	5.3.3.2 Reactions with Water 295	Purposes 328
	5.3.3.3 Reactions with Impurities in Water 295	5.5.3 Chlorine Containers 332
5.3.4	Hypochlorite 297	5.5.3.1 Plastic 332
	5.3.4.1 Reactions with Water 297	5.5.3.2 Steel Cylinders 332
	5.3.4.2 Chlorine Gas Reactions vs. Hypochlorite	5.5.3.3 Ton Tanks 332
	Compound Reactions 298	5.5.4 Chlorine Room Ventilation 333
	5.3.4.3 Onsite Chlorine Generation 298	5.5.5 Chlorine Storage and Handling 334
5.3.5	Chlorine Dioxide 298	5.5.6 Removing Chlorine from Containers 335
	5.3.5.1 Reaction in Water 299	5.5.6.1 Connections 335
	5.3.5.2 Reactions with Impurities in Water 299	5.5.6.2 Valves 336
5.3.6	Breakpoint Chlorination 299	5.5.6.3 Ton Tanks 336
5.3.7	Chloramination 301	5.5.7 Performance of Chlorination Units 336
	5.3.7.1 Methods for Producing Chloramines 302	5.5.7.1 Hypochlorinators 337
	5.3.7.2 Chlorine-to-Ammonia-Nitrogen	5.5.7.2 Chlorinators 342
	Ratios 302	5.5.8 Normal and Abnormal Operation 346
	5.3.7.3 Special Water Users 303	5.5.8.1 Container Storage Area 346
	5.3.7.4 Blending Chloraminated Waters 303	5.5.8.2 Evaporators 347
	5.3.7.5 Chloramine Residuals 303	5.5.8.3 Chlorinators, Including Injectors 350
5.3.8	Nitrification 304	5.5.8.4 Daily Operations 354
	5.3.8.1 Nitrification Prevention and Control 305	5.5.8.5 Laboratory Tests 356
5.3.9	Chlorine Residual Testing 306	5.5.9 Gas Chlorinator System Troubleshooting 357
	5.3.9.1 Chlorine Residual Curve 306	5.5.10 Disinfection Troubleshooting 358
	5.3.9.2 Critical Factors 307	5.5.11 Managing Chlorination System Failure 358
5.3.1	0 CT Values 308	
5.3. I	Chlorination Process Calculations 309	5.6 Maintenance of Chlorination Equipment 358
5.4	Points of Chlorine Application 311	Equipment 550
011		5.6.1 Chlorine Leaks 358
5.4.1	Wells and Pumps 311	5.6.2 Chlorine Facilities Installation Considerations 362
	5.4.1.1 Procedures 315	5.7 Measuring Chlorine Residual 364
	5.4.1.2 Continuous Disinfecting of Wells 315	o., measaning omornie kestadar oo i
5.4.2	Mains 315	5.7.1 Amperometric Titration for Free Chlorine
	5.4.2.1 Disinfection Alternatives 317	Residual 364
	5.4.2.2 Flushing After Disinfection 320	5.7.2 DPD Colorimetric Method for Free Chlorine Residual 364
	5.4.2.3 Testing After Disinfection 320	Residual 364
	5.4.2.4 Emergency or Maintenance Disinfection 320	5.8 Chlorine Safety Program 365
	5.4.2.5 Disinfection Specifications 321	5.8.1 Chlorine Hazards 366
	5.4.2.6 Disinfection Problems 321	5.8.2 Why Chlorine Must Be Handled
54?	Tanks 322	with Care 366
~ · T · J	INIII	

5.8.3 Chlorine Safety for Operators 367	6.4.2 New Wells 401
5.8.3.1 First-Aid Measures 368	6.4.3 Sanitary Seal 401
5.8.4 Hypochlorite Safety 369	6.4.4 Surface Portion of Well 401
5.8.5 Operator Safety Training 369	6.4.5 Tank Coatings 402
5.9 Chlorination Math 370	6.4.6 Well Chemicals 402
	6.4.7 Working Around Electrical Units 404
5.9.1 Disinfection of Facilities 371	6.4.8 Abandoning and Plugging Wells 405
5.9.1.1 Wells and Pumps 371 5.9.1.2 Mains 372	6.4.9 Safety Inspection 405
5.9.1.3 Tanks 373	6.5 Pump Safety 406
5.9.2 Disinfection of Water from Wells 374	6.5 Pump Safety 406
5.9.2.1 Chlorine Dose 374	6.5.1 Guards Over Moving Parts 406
5.9.2.2 Chlorinator 374	6.5.2 Maintenance and Repair 408
5.9.2.3 Hypochlorinator 377	6.5.3 Lockout/Tagout Procedure 410
5.10 Math Assignment 381	6.5.4 Storage of Lubricants and Fuel 411
5.10 Math Assignment 361	6.6 Working in Streets 411
5.11 Additional Resources 381	410
	6.6.1 Fundamental Principles 412
Chapter Review 382	6.6.2 Definitions 413
	6.6.3 Major Temporary Traffic Control Considerations 417
Chapter 6	6.6.4 Individuals Qualified to Control Traffic 418
Safety 385	6.6.5 Permission to Work Within the Right-of-Way 418
6.1 Safety Program 386	6.6.6 General Responsibilities of Utility Agencies 419
	6.6.7 Street or Highway Work Regulations 419
5.1.1 Tailgate Safety Sessions 387	6.6.8 Temporary Traffic Control Zones 420
6.1.1.1 Tailgate Safety Sample Script 387	6.6.8.1 Roadway Tapers 425
5.1.2 Employee Right-To-Know Laws 388	6.6.9 Pedestrian Safety 428
6.2 Vehicle Safety 389	6.6.10 Worker Safety 431
5.2.1 Towing a Trailer 389	6.6.10.1 Speed Limits in Work Zones 432
5.2.2 How to Charge a Battery 390	6.6.10.2 Flagger Control 433
5.2.3 Boat Safety 391	6.6.11 Using Temporary Traffic Control Zone Devices 436
·	6.6.12 Excavations in Streets 451
6.3 Personal Safety 392	6.6.12.1 Trenches 451
6.3.1 Monitoring Equipment 392	6.6.12.2 Cave-Ins 452
6.3.2 Personal Protective Equipment 397	6.6.12.3 Using Ladders 453 6.6.12.4 Locating Underground Utilities Before
6.3.3 Avoiding Slips and Falls 398	You Dig 454
6.3.4 Handling and Lifting 398	6.7 Safety Around Water Storage Facilities 456
6.3.5 Electrical Safety 399	6.7 Safety Around Water Storage Pacifiles 430
6.3.6 Handling Corrosive Chemicals 399	6.7.1 Avoiding Slips and Falls 456
	6.7.2 Using Ladders 456
6.4 Safety Around Wells 400	6.7.3 Applying Interior Coatings 458

6.8 Noise Exposure 463	7.7.6 Telephone Contacts 508
4.0 Carlota Inguicariona 444	7.7.7 Consumer Inquiries 509
6.9 Safety Inspections 466	7.7.8 Plant Tours 510
6.10 Additional Resources 466	7.8 Planning for Financial Stability 511
Chapter Review 468	7.8.1 Measuring Stability 511
	7.8.2 Budgeting 512
Chapter 7	7.8.3 Equipment Repair/Replacement Fund 514
Management 473	7.8.4 Water Rates 515
	7.8.5 Capital Improvement Program 515
7.1 Managing Utilities 474	7.8.6 Financial Assistance 517
7.2 Planning 476	7.9 Operation and Maintenance 518
7.3 Organizing 476	7.9.1 Using Geographic Information Systems 518
7.00.94	7.9.2 Types of Maintenance 519
7.4 Staffing 480	7.9.3 Benefits of Managing Maintenance 521
7.4. Workforce Analysis 481	7.9.4 SCADA Systems 521
7.4.2 Qualifications Profile 481	7.9.5 Cross-Connection Control Program 525
7.4.3 Applications and the Selection Process 483	7.9.5.1 Program Responsibilities 526
7.4.4 New Employee Orientation 487	7.9.5.2 Water Supplier Program 527
7.4.5 Employment Policies and Procedures 487	7.10 Emergency Response 528
7.4.5.1 Probationary Period 487	7.10.1 Federal Requirements 528
7.4.5.2 Compensation 488	7.10.2 Security 531
7.4.5.3 Training and Certification 488	7.10.2.1 Guarding Against Unplanned Physical
7.4.5.4 Performance Evaluation 489	Intrusion 532
7.4.5.5 Dealing with Disciplinary Problems 490 7.4.5.6 Example Policy: Harassment 495	7.10.2.2 Making Security a Priority for Employees 532
7.4.5.7 Labor Laws Governing Employer/ Employee Relations 499	7.10.2.3 Coordinating Actions for Effective Emergency Response 533
7.4.5.8 Personnel Records 500 7.4.6 Unions 500	7.10.2.4 Investing in Security and Infrastructure Improvements 533
	7.10.3 Managing Contamination Threats 535
7.5 Communication 501	7.10.3.1 Evaluating and Responding to Threats 536
7.5.1 Oral Communication 5027.5.2 Written Communication 503	7.10.3.2 Cryptosporidium in water systems 538
	7.11 Safety Program 539
7.6 Conducting Meetings 505	7 III I Bassata and Associate 540
7.7 Public Relations 506	7.11.1 Regulatory Agencies 540
	7.11.2 Managers 540 7.11.3 Supervisors 541
7.7.1 Establish Objectives 506	7.11.3 Supervisors 541 7.11.4 Operators 5/3
7.7.2 Utility Operations 507	7.11.4 Operators 543
7.7.3 The Mass Media 507	7.11.5 First Aid 543 7.11.6 Hazard Communication Standard and Worker
7.7.4 Being Interviewed 508	7.11.6 Hazard Communication Standard and Worker Right-To-Know Laws 544
7.7.5 Public Speaking 508	

A.6 Metric System 620

A.6.1 SI Base Units 620

7.11.7 Confined Space Entry Procedures 556	Basic Concepts (Sections A.1-A.4) 587
7.11.8 Reporting 558	•
7.11.9 Training 561	A.1 Numbers and Operations 587
7.11.10 Measuring Program Effectiveness 563	A.I.I Addition 587
7.11.11 Human Factors 567	A.1.2 Subtraction 587
7.12 Recordkeeping 568	A.I.3 Multiplication 588
7.12.1 Plant Operations Data 569	A.I.4 Division 588
7.12.2 Maintenance 569	A.2 Order of Operations 588
7.12.3 Procurement 569	A.2.1 More on Exponents 592
7.12.4 Inventory 571	
7.12.5 Equipment 571	A.3 Basic Algebra (Solving Equations) 592
7.12.6 Computer Recordkeeping Systems 571	A.4 Percentages 595
7.12.7 Retaining Utility Records 572	
7.13 Water and Energy Conservation 572	Intermediate Concepts (Sections A.5–A.6) 598
7.13.1 Elements of Conservation Programs 573	A.5 Units 598
7.13.1.1 Residential Water Surveys 574	A.5.1 Distance or Length 598
7.13.1.2 Residential Plumbing Retrofits 574	A.5.2 Area 599
7.13.1.3 System Water Audits, Leak Detection,	A.5.2.1 Surface Area of a Rectangle 599
and Repair 575	A.5.2.2 Surface Area of a Triangle 600
7.13.1.4 Metering with Commodity Rates 575 7.13.1.5 Large Landscape Conservation	A.5.2.3 Surface Area of a Trapezoid 601
Programs 575	A.5.2.4 Surface Area of a Circle 601
7.13.1.6 Public Information Programs 576	A.5.2.5 Surface Area of a Cylinder 602
7.13.1.7 Commercial, Industrial, and Institutional	A.5.2.6 Surface Area of a Cone 603
Sector Programs 577	A.5.2.7 Surface Area of a Sphere 604
7.13.1.8 Wholesale Agency Assistance Programs 577	A.5.3 Volume 604
7.13.1.9 Conservation Pricing 578	A.5.3.1 Cube 605
7.13.1.10 Conservation Coordinator 579	A.5.3.2 Rectangular Prism 605 A.5.3.3 Triangular Prism 606
7.13.1.11 Water Waste Prohibition 579	A.5.3.4 Cylinder 606
7.13.1.12 Residential ULFT Replacement	A.5.3.5 Cone 606
Programs 579	A.5.3.6 Sphere 607
7.13.1.13 Potential Best Management Practices 579	A.5.4 Mass and Weight 607
7.14 Additional Resources 580	A.5.5 Density, Specific Weight, and Specific Gravity 608
	A.5.6 Concentration 608
Chapter Review 581	A.5.7 Velocity and Flow Rate 610
A 1. A	A.5.8 Force and Pressure 612
Appendix A	A.5.9 Work, Head, and Power 617
Introduction to Basic Math for	work, ficau, and rower of/

Operators 585

Introduction 586

A.6.2 Measures of Length 622	A.8.4 Moving Averages 659
A.6.3 Measures of Capacity or Volume 622	A.8.5 More Applications of Graphs 661
A.6.4 Measures of Weight 622	A.8.5.1 Volume of Sludge in a Digester 661
A.6.5 Temperature 623	A.8.5.2 Tracking BOD Loading 664
Advanced Concepts (Sections A.7–A.8) 624	A.8.6 Regression Analysis (Prediction Equations, Trends, and Correlations) 666A.8.6.1 Correlations 671
A.7 Pumps 624	
A.7.1 Pressure 624	A.9 Typical Water Distribution System Problems (English System) 672
A.7.2 Work 625	A.9.1 Flows 672
A.7.3 Power 626	A.9.2 Chemical Doses 672
A.7.4 Horsepower 626	A.9.3 Distribution System Facilities 674
A.7.5 Head 630	A.9.4 Operation and Maintenance 678
A.7.6 Pump Characteristics 632	A.9.5 Disinfection 684
A.7.7 Evaluation of Pump Performance 634	A.9.6 Laboratory Procedures 686
A.7.7.1 Capacity 634	
A.7.7.2 Efficiency 635	A.10 Typical Water Distribution System Problems (Metric System) 686
A.7.8 Pump Speed–Performance Relationships 638	
A.7.9 Friction or Energy Losses 639	A.10.1 Flows 686
A.8 Analysis and Presentation of Data 643	A.10.2 Chemical Doses 687
A.8.1 Causes of Variations in Results 643	A.10.3 Distribution System Facilities 688
A.8.1.1 Water or Material Being	A.10.4 Operation and Maintenance 691
Examined 644	A.10.5 Disinfection 697
A.8.1.2 Sampling 644	A.10.6 Laboratory Procedures 699
A.8.1.3 Testing 644	A.11 Calculation of Log Removals 699
A.8.2 Controlling Variation 644 A.8.2.1 Reading Charts 646	A
A.8.3 Describing Data or Results 646	Answer Key 701
A.8.3.1 Graphs and Charts 647	Glossary 705
A.8.3.2 Numerical Representation of Data 652	Index 735
•	

A	operations and maintenance (O&M),	Ammonia, test for leaks, 343, 359
	518–528	Ammonia-oxidizing bacteria (AOB), 304
AADT (annual average daily traffic), 413	operator duties, 30	Amperometric titration, 364
Abandoning wells, 405	oral communication, 502	Anaerobic, 24
ABC (Association of Boards of	orientation, new employee, 487	Annual average daily traffic (AADT), 413
Certification), 489	performance evaluation, 489	Annual report, 505, 514
Abnormal conditions, chlorination, 324,	personnel records, 500	Annual running TTHM average, 175–177
341, 346, 352	planning, 476	Anode, 62
Accident reports, 558, 559, 560	plant tours, 510	Applications, job, 483
Accidents, 386, 387, 392, 453	policies and procedures, 487	Appurtenance, 80
Accuracy, meters, 147, 245	probationary period, 487–488	Aquifers, 8
Acid rain, 2	procurement of materials, 569–571	Arrow boards, traffic, 446
Acids, safety practices, 399, 402	public relations, 506	Arsenic, 13
ADA (Americans with Disabilities Act of	public speaking, 508	Artesian wells, 7
1990), 499	qualifications profile, 481–482	Asbestos-cement pipe, 100, 104, 107
Additional resources	rates, water, 515	As-built plans (record drawings), 31, 109,
disinfection, 381	recordkeeping, 568–572	262
distribution system facilities, 163	records, personnel, 480, 500	Assessment of system vulnerability, 529
introduction to water distribution, 33	repair/replacement fund for equipment,	Association of Boards of Certification
management, 580	514–515	(ABC), 489
operation and maintenance, 280	safety program, 539–567	Atmospheric vacuum breaker, 155
water distribution system operator, 466	SCADA (supervisory control and data	Audience, communications, 502, 503, 506
water storage facilities, 75	acquisition) systems, 521-525	Audiovisuals, 502
Administration	selection process, 483	Audits, water, 204, 575
advertising positions, 483	sexual harassment, 495	Authority, 476
applications, 483	staffing, 480–501	Available chlorine, 64
backflow prevention program, 526-527	supervisor, training, 489	Available chlorine residual, 294, 299
certification, 488	telephone contacts, 508–509	Average measurements, water quality, 175
communication, 501	tours, plant, 510	Average water demand, 38
compensation, 483, 488	training, 488–489	Awareness, safety, 386
conducting meetings, 505–506	unions, 500	
consumer inquiries, 509	water rates, 515	
contaminated water supply, 535	written communication, 503	В
contingency planning, 528	Advertising, job openings, 483	_
continuing education, 489	Aesthetics, water quality, 12	Backfilling, laying pipe, 124
cross-connection control program,	Affirmative action, 483	Backflow, 20, 67, 81, 181, 182
181–193	Agents, disinfection, 252	Backflow prevention, 140, 152, 155-162,
discipline problems, 490	Agricultural runoff, 2, 6	181–193, 525–526
disposing of plant records, 572	Air gap, 55, 155–157, 181	Back pressure, 20, 156, 181
emergency response, 528–539	Air gap, chlorination equipment, 342	Backsiphonage, 20, 47, 55, 155, 181, 183
employee complaints, 490	Air release valves, 136, 138	Bacteria, pathogenic, 18
equipment repair/replacement fund,	Air shores, 116, 119	Bacterial cells, 294
514	Algal blooms, 7	Bacteriological analyses, 261
evaluation, performance, 489	Allocations, water shortage, 578	Bacteriological sampling, 178
financial assistance, 517	Alternative disinfection process, 301	Ball valves, 132
first aid, 543-544	Altitude control valves, 49, 70, 139	Barium, 13
functions of a manager, 474	Aluminum shoring, 117	Barricades, traffic control, 448, 450

Ambient temperature, 363

(ADA), 499

Ammonia, 296, 299, 304, 359

Americans with Disabilities Act of 1990

hazard communication, 544-556

meetings, conducting, 505-506

interviews, media, 507

interviewing job applicants, 483-487

Battery, charging, 390-391

Below-ground reservoirs, 26

Bell and spigot coupling, 105, 106

Bedding, pipe, 108

Certification, 29, 30, 488

Benefits, employee, 483, 487 C Factor, 81, 85, 211 ejector, 325 injector, 325 Best management practice (BMP), Channelizing devices, traffic, 446 installation, 325, 362 conservation, 573, 579 Check valves, 94, 140, 159 Billing inserts, 576 Chemical leaks, 367 analyses, 261 location, 362 Biofilm, 21-22 Biological, water quality, 15 safety, 252, 402 maintenance, 341, 358, 367 Biological growth, 21-22 water quality, 16 manifold, 331, 363 Bitter tastes in water, 293 Chemical disinfectants, 293-301 metering, 327, 331 Block rate structure, 578 Chemical solution tank, 324 operation, 337-354 Blowoff valves, 140, 171 CHEMTREC, 370, 531 parts, 328 Chloramination pigtail tubing, 335 Boats, safety, 391 Bonds, 516 blending, 303 plans and specifications review, 362 Booster pumps, 70, 93 chloramine production, 302 poppet valves, 338 Boxes for valves, 140 chlorine to ammonia-nitrogen ratios, residual analyzer, 350, 351 Branching systems, 95, 96 302-303 rotameter, 327 Breakpoint chlorination, 55, 299, 355 contact time, 308 safety, 342, 365-370 Breaks, mains, 232 critical factors, 307 self-contained breathing apparatus, nitrification, 302, 304 335, 366, 367 Bromine, 293 Budgets, 31, 512 postammoniation, 302 shutdown, 337 preammoniation, 302 Buffer capacity of water, 298 solution feeders, 324, 326, 337 Butterfly valves, 132, 133 prechlorination, 302 startup, 337, 342 storage, containers, 362 Byproducts, disinfection, 14, 292 residuals, 303-304 system failure, 358 Byproducts Rule, Disinfectants and special water users, 303 Disinfection, 288 Chloramines, 22, 297, 299-305 ton tanks, 332 Chloride, 14 troubleshooting, 357, 358 Chlorination vacuum-controlled chlorinators, Also see Chlorinators, Disinfection, and 325-332, 350 valves, 335, 336, 338, 341, 342, 349 Hypochlorinators CAD (computer-aided design) system, 519 abnormal operation, 324, 341, 346, 352 water supply system, 342 Cadmium, 13 ammonia test for leaks, 343, 359 wrenches, chlorine container valve, 336 Calcium carbonate equilibrium, 62 amperometric titration, 364 yoke-type connectors, 335 Calcium hypochlorite, 297 breakpoint, 299, 355 evaporator, 343, 347 CHEMTREC, 370, 531 first aid, 368 Calculations C Factor, 85 chloramination, 301 formulas, 339, 355 chloramines, 297, 299-305 free available residual chlorine, 299 disinfection, 64, 66, 254-255, 258-259, 309-310, 311-314, 316-317, 370-381 chlorinator, 325-332, 342, 350-358 hazards, 366 chlorine, 294 flushing, 215 hypochlorinator, 324, 326, 337 leakage, 125-129 chlorine dioxide, 298 hypochlorite, 297 mains, testing, 125-129 chlorine residual tests, 364 injection point, 307 chlorophenol, 301 injector, 325, 330, 350, 357 meters, 242-249 pressure, 81, 82, 85 contact time, 308 injector water supply, 342 storage facilities, 50, 64, 66 containers, 332, 334 laboratory tests, 356 testing of mains, 125-129 container storage, 362 leaks, 335, 342, 352, 357, 358-362, 367 water quality monitoring, 174, 175 corrosion, 331, 343, 348, 366 maintenance, equipment, 341, 358, 367 California hydrant (wet-barrel hydrants), 145 critical factors, 307-308 mixing, 307 monitoring, 287 Call Before You Dig program (811), 454 CT values, 308 Capital improvement program, 515 monochloramine, 301 cylinders, 332, 334 demand, 294, 309, 310 nitrification, 302, 304 Carbon monoxide, safety, 392 Carcinogen, 19, 292 dew point, 343 operation of equipment, 336-354 diaphragm pump, 326 organic matter, 290, 299 Cardiopulmonary resuscitation (CPR), 544 Cast-iron pipe, 97 dichloramine, 301 pathogen removal, 290 Cathode, 62 distribution system, 354 performance, 336 pH, 289, 296, 307 dosage, 294 Cathodic protection, 61, 63, 95, 348 Causes of work injuries, 387 DPD test, 356, 364 phenol, 301 Cave-ins, 452-453 emergency repair kits, 359, 360 population served, 288 equipment postchlorination, 307, 354 Cavitation, 234 Cement-mortar lining, 222-223 prechlorination, 297, 302, 307, 354 air gap, 342 Centrifugal pumps cathodic protection, 348 process calculations, 309 priming, 52, 53 chemical solution tank, 325 reducing agents, 290, 296, 307 startup, 53 chlorinator, 350-354 removing chlorine, 335 troubleshooting, 72, 73 connections to chlorine containers, 325 residual chlorine, 179, 291, 292, 294,

eductor, 367

299, 301, 302, 306, 307, 350, 364

residual chlorine test, 364	Chlorine dioxide	Connections, chlorine containers, 335
safety, 365-369	disinfection uses, 291	Connections, equipment, 335
sampling, 288	iron and manganese, 299	Connections, pipe, 152, 153, 208
self-contained breathing apparatus, 335,	microbial control, 22	Connectors, yoke-type, 335, 351
365, 367	phenolic tastes and odors, 298	Conservation
storage, 334	reaction in water, 299	audits, water, 575
storage of containers, 346, 362	reactions with impurities, 299	best management practice (BMP), 573,
system failure, 358	taste and odor control, 301	579
tanks, 332, 360	trihalomethanes, 299	commercial, industrial, and institutiona
tastes and odors, 301, 355	Chlorine facilties, 362	(CII), 577
temperature, 305, 307	Chlorine neutralization, 67, 257	commodity rates, 575
THMs (trihalomethanes), 290, 291	Chlorine residual testing, 179, 363	coordinator, 579
training, safety, 369	Chlorophenol, 301	elements of programs, 573–580
trichloramine, 301	Chlororganic, 299	energy, 572
trihalomethanes (THMs), 290, 291	Chromium, 13	large landscape, 575
troubleshooting equipment, 357, 358	Cistern, water storage, 6	leak detection, 575
turbidity, 289, 307	Cleaning	metering, 575
variables, 289	mains, 216–221	need, 572
ventilation, 363	tanks, 58	pricing, 578
viruses, 19, 290	Clear wells	public information programs, 576
waterborne diseases, 286	description, 9	public relations, 506
weighing chlorine containers, 363	storage facilities, 38, 40, 42	residential plumbing retrofits, 574
Chlorinators, 325–332, 342–346,	Clothing, safety, 397–398	residential water surveys, 574
350–358	CMMS (computer-based maintenance	school education programs, 576
Chlorine	management system), 519	water audits, 575
ammonia, 296, 299, 301, 304, 359	Coagulation removal process, pathogens,	WaterSense, EPA partnership program,
	290	580
ammonia test for leaks, 343, 359		
available residual, 295, 299	Coaliform hastoria 43, 388, 311	water waste prohibition, 579
CHEMTREC, 370	Color 14	wholesale agency assistance programs,
chloramines, 297, 299–305	Color, 14	577
concentrations, effects, 366	Color, water quality problem, 55	Constituents, drinking water, 14
containers, 334	Colorimeter, 365	Construction, distribution systems, 24, 25
cylinders, 334	Combustible gases, 392	26, 27
demand, 294, 309, 310	Commercial, industrial, and institutional	Consumer
detection, leaks, 352, 357, 358–362, 367	(CII) conservation programs, 577	complaints, 259, 269–271, 509
detention rate curve, 307	Commercial divers and wet inspections, 57	demands for water, 10
disinfection, 252–257, 294	Commodity rates, 575	inquiries, 509
dose, 295, 310	Communication, 267, 501–505	Contact time, chlorine, 308
first aid, 368	Compensation, 488	Containers, chlorine, 332, 334, 346, 362
frozen, 350	Competent person	Container valve wrenches, chlorine, 336
handling, 334	confined spaces, 461	Contaminated water supply
hazards, 366	defined by OSHA, 431	countermeasures, 536
HTH (High Test Hypochlorite), 297, 314	excavation inspection, 451	cross-connections, 181, 525
hydrogen sulfide, 296	hazard assessment of work site, 431	Cryptosporidium, 538
hypochlorite, 297	shoring safety, 116, 451	emergency treatment, 537
hypochlorous acid, 295, 296, 298, 300	Complaints	incident commander, 536
ice, 350	consumer, 259, 269–271	source of supply, 18
leaks, 335, 342, 352, 357, 358–362, 367	customer, 509	sources, 18
maximum removal rate, 335, 362	employee, 490	threats, managing, 535–539
on-site generation, 298	handling, 16, 32	Contingency planning, 528
рН, 289, 296, 307	procedure, 490	Continuing education, 489
physiological response, 366	Compound meters, 146, 150	Contract negotiations, 500
prechlorination, 297, 302, 307, 354	Computer-aided design (CAD) system, 519	Control devices and zones. See Traffic
properties, 366	Computer-based maintenance management	control
rate of withdrawal, 335, 362	system (CMMS), 519	Control of
reactions, 295	Computerized recordkeeping systems, 571	corrosion, 61, 95, 100, 108, 249
residual, 179, 291, 292, 294, 299, 301,	Concrete pipe, 99, 103	cross-connections, 181
302, 306, 307, 350, 364	Concrete storage facilities, 68	water quality, 12
safety, 366, 403	Conducting meetings, 505	Controls, instruments, 51, 69, 74
uses, 252–257	Confined space, 392, 393, 396, 459,	Coordinator, conservation, 579
ventilation, 333	556–558	Copper, 13, 14

Confined space entry permit, 459, 460, 557 Corey hydrant, 145

withdrawal rate, 335, 362

Cysts, 290

Corporation stop, 125, 152, 153 discharge of chlorinated water, 257 D diseases, 286 Corrective maintenance, 168, 519 Daily log or diary, 260 distribution system, 251 Corrosion chemical treatment, 249 Dangerous air contamination, 392, 394, dosage, 295 461 emergency, 320 control, 61, 95, 100, 108, 249 distribution systems, 21 Dead ends, 24, 89, 95 enzymes, 294 inhibitors, 250 Decibel, noise exposure, 464, 465 formulas, 339, 355 polyphosphate, 62 Decision sight distance, 417 Giardia, 13, 19, 308 problems, chlorination, 348, 366 Deficiencies in service, 209, 211 giardiasis, 19 storage facilities, 61 heat method, 293 Degradation, water quality, 23 valves, 238 Demand, chlorine, 294, 309, 310 hepatitis, 19 Corrosive chemicals, 399 Demand, storage, 46 hypochlorite, 252-259, 295 Demand, water, 10, 38, 46 inorganic matter, 290 Corrosivity, 14 Demand-initiated regenerating (DIR) water iodine, 293 operation and maintenance, 10 softeners, 579 mains, 129, 252, 315-322 treatment, 3, 10 Detecting service deficiencies, 209-212 maintenance, 320-321 Detection, chlorine leaks, 352, 357, 358-Couplings, pipe, 102, 104, 106, 107, 143 math assignment, 381 362, 367 membrane filter, 254 Coupons, 171, 249 Coverage ratio, 511 Detention rate curve, chlorine, 307 membrane filter (MF) test, 257 methods, 315, 318 Covers on reservoirs, 26 Detention time CPR (cardiopulmonary resuscitation), chlorine, 306 microbial standards, 287 microorganisms, 290 544 curves, 306 monitoring, 287 Crenothrix, 21 nitrification, 305 Cross-connection control Deterioration of monochloramine, 291 multiple-tube fermentation (MTF) test, air gap separation, 155, 181 distribution systems, 168 atmospheric vacuum breaker, 155 water quality, 15-18, 20-27 257 backflow, 181, 525-527 Dew point, 343 neutralizing chemicals, 257 back pressure, 181 organic matter, 290, 299 Diaphragm pump, 326 backsiphonage, 181 Diaphragm valves, 136 ozone, 291, 293 Diatoms, 302 distribution storage, 55, 93 parasites, 19 distribution systems, 20, 183, 526 Dichloramine, 301 pathogen removal, 290 double check valve, 155 Direct runoff, 6 pH, 289, 296, 307 Dirty water, 25, 269 physical means, 292 hazards, 186-193 industrial settings, 188-193 Disasters, 266 points of application, 311 Discharge of chlorinated waters, 257 population served, 288 maintenance (device) record form, Disciplinary problems, 490 postchlorination, 307, 354 187 ordinance, 184, 527 Discriminatory hiring, 481 prechlorination, 297, 302, 307, 354 Diseases, 19, 286 preventive measures, 316 pressure vacuum breaker, 155, 526 program responsibilities, 182 Disinfectants and Disinfection Byproducts problems, 321 surveillance, 173 Rule (DBPR), 288 procedures, 315, 322 survey form, 185 Disinfection process calculations, 309 water supplier, 184 Also see Chlorination processes, 292 Cryptosporidiosis, 6 reducing agents, 257, 289, 290, 296, 307 action, 294 Cryptosporidium, 288, 538 additional resources, 381 removal processes, pathogens, 290 CT values, 308 agents, 252, 291 residual chlorine, 179, 291, 292, 294, Curb boxes and meters, 171 bacterial cells, 290 299, 301, 302, 306, 307, 350, 364 Curb stop, 152 bitter taste, 293 safety, 403 sampling, 288 Customer breakpoint chlorination, 55, 299, 355 complaints, 259, 269-271, 509 bromine, 293 selection of disinfectant, 292 inquiries, 509 byproducts, 14, 292 specifications, 321 calculations, 64, 66, 254-255, 258-259, Customer service spore-forming bacteria, 290 backflow prevention devices, 155 standards, microbial, 287 309-310, 311-314, 316-317, 370-381 sterilization, 286 complaint form, 269, 271 chemical disinfectants, 293 corporation stop, 153 chlorination, 294 storage facilities, 64-68, 256 installation of service line, 152 chlorine, 252-257, 294 tablets, 252 chlorine dioxide, 291, 298 tanks, 322 meters, 152 coliforms, 288, 311 tastes and odors, 291 meter size, 152 shutoff valve, 152 temperature, 289, 307 contact time, 308 survey form, 272 critical factors, 307 trihalomethanes (THMs), 290, 291 Cylinders, chlorine, 332, 334 Cryptosporidium, 288 troubleshooting equipment, 357, 358 Cylinder shoring, 120, 121 CT values, 308 turbidity, 289, 307

cysts, 290

ultrasonic waves, 293

ultraviolet (UV) systems, 291, 292	flushing, 212-216	repair, 25
variables, 289	hydrants, 239	reservoirs, 26–28
viruses, 18, 290	inspections, wet, 57	safety, 130
waterborne diseases, 286	landscaping, 270	sampling, 178
wells, 311, 374	leaks, 125, 201–206	sources of contaminants, 18
Disinfection byproducts (DBPs), 14, 292	locating pipes, 206	storage facilities, 26, 90, 195
Displacement meters, 147	main breaks, 232	temperature, 23
Disposing of plant records, 572	maintenance, 168	time in system, 23
Distribution storage	math, 279	trihalomethanes (THMs), 18
Also see Storage facilities (water)	meters, 242	troubleshooting, 28
cross-connections, 93	monitoring, 173	uncovered reservoirs, 26, 27
health, 93	objective, 168	water quality, 15–28
location, 91, 92	pressures, 46, 81, 86, 194	water quality degradation, 15, 20–27
pumping, 93	pressure tests, 125–129, 211	water supply, 15, 19
purpose, 91	preventive maintenance, 168	wet inspections, 57
types, 91	public relations, 268	Divers, tank inspection and cleaning,
water quality, 91	pumps, 194, 195	57
Distribution system facilities	records, 259	Documentation, administration, 480
Also see Distribution system O&M and	repairs, 25, 168	Dose, chlorine, 295, 310
Distribution systems	reservoirs, 68	Double check valves, 155, 156, 157, 158
appurtenances, 80, 94, 132	safety, 130	DPD test, 304, 356, 364
booster pumping, 93	shoring, 111, 207	Drainage, landscape, 270
check valves, 94	storage facilities, 169, 195	Draining tanks, 59
corporation stop, 125	surveillance, 169	Drain valves, 140
dead ends, 24, 89, 95	Also see Surveillance of distribution	Drinking water
fire demand, 89	systems	laws, 286
grid system, 89, 95, 96	systems system pressures, 194	regulations, 13, 174
hydrants, 123, 143	tapping, 209	safety, 286
hydraulics, 81–86	thawing, 223, 226–228	turbidity removal, 14
layout, 95, 96	valves, 232	Driving, safety, 389
looped system, 89, 95, 96	Also see Valves	Drums, traffic control, 449
mains, 87, 95	water audits, 204	Dry-barrel hydrants, 145
Also see Mains, water	water quality monitoring, 173	Dry tapping, 131
meters, 146	water quality problems, 212	Ductile-iron pipe, 97, 98, 102
Also see Meters	Distribution systems	Duties of operators, 29, 30
performance, 86	Also see Distribution system facilities	Dysentery, contamination of water
physical characteristics, 80	and Distribution system O&M	supply, 6
	aging facilities, 23	suppry, o
pressure-reducing valves, 88 pressures, 80, 86	backflow, 20	
purpose, 80	back pressure, 20	-
safety, 130	back pressure, 20 backsiphonage, 20	E
	below-ground reservoirs, 26	Eductor 225
storage, 90 surge chambers, 84	biological growth, 21–23	Eductor, 325 Efficiency program, water, 580
thrust blocks, 83, 108, 123, 124	construction, 24, 25, 26, 27	
transmission systems, 90		Ejector, 325
	contamination sources, 18	Electrical, safety, 399, 404
valves, 88, 132, 232	corrosion, 21	Electrical thawing, 223, 226
Also see Valves	covers on reservoirs, 26	Electrochemical reaction, 21
Distribution system O&M	Crenothrix, 21	Electrolysis, 100
audits, water, 204	cross-connections, 20, 183, 525	Electromotive force, 62
breaks, mains, 232	dead ends, 24	Electronic water meters, 151
cement-mortar lining, 222–223	description, 10	Elements of conservation programs
cleaning mains, 216–221	deterioration of water quality, 15, 20–27	audits, water, 575
connections, 154, 155, 208	dirty water, 25, 27	best management practice (BMP), 573,
corrective maintenance, 168	disinfection, 355	579
corrosion control, 249	flow, 23	commercial, industrial, and institutional
cross-connection control, 181	hazardous facilities, 25	(CII), 577
detecting service deficiencies, 209	mains, 24	commodity rates, 575
disinfection, 252	milky water, 23, 25	coordinator, 579
emergency procedures, 56, 168, 266	operation, 23–25	large landscape, 575
equipment and stores, 265	pipe material, 24–25	leak detection, 575
fire demand, 87, 89		
flow tests, 211	pressures, 44, 46 red water, 21	metering, 575 pricing, 578

Elements of conservation	Evaporator, chlorine, 343, 34/	Friction losses, 81
programs (continued)	Evapotranspiration, 575	Frozen chlorine, 350
public information programs, 576	Excavation	Frozen distribution reservoirs, 68
residential plumbing retrofits, 574	hazardous wastes, 111	Frozen hydrants, 242
residential water surveys, 574	locating underground utilities, 109	Frozen pipes
school education programs, 576	mains, 112	See Thawing pipes
system water audits, 575	shoring, 112	Fuel storage, safety considerations, 411
water waste prohibition, 579	Excavations in streets	Fund, repair/replacement, 514
wholesale agency assistance programs,	cave-ins, 452	rund, repair/replacement, 911
	*	
577	ladders, 453	
Elevated tanks, 39, 56, 58, 92	safety rules, 453	G
Emergency	shoring, 451	
chlorine repair kits, 359, 360	spoil, 453	Galvanized steel pipe, 99
contaminated water supply,	trenches, 451	Gases, combustible, 393
535–538	underground utilities, 454–456	Gases, safety considerations, 394
disinfection, 320	Exercising valves, 234	Gate valves, 132, 133
maintenance, 56, 519	Explosive conditions, safety, 393	Gauges, 71
preparation for, 476, 528-539	Explosive limits, 393, 395	Geographic information system (GIS), 263,
procedures, 168, 267, 536	Extensions, mains, 372	518-519
response plan, 476, 528–539		Giardia, 13, 19, 308
traffic control situations, 267		Giardiasis, 6, 19
treatment, 537	F	GIS (geographic information system), 263,
Emergency planning	Г	518–519
	Failure ablasination exetem 250	
disasters, 266	Failure, chlorination system, 358	Globe valves, 134, 135
mutual aid agreements, 267	Falls, avoiding, 398	Goals, utility, 476
organization, 268	Family and Medical Leave Act of 1993	Graywater use, 579
preparation, 266	(FMLA), 499	Grid systems, 89, 95, 96
procedures, 267	Filling tanks, 65	Grievances, employee, 490, 501
public relations, 48	Filtration, pathogen removal, 291	Ground-level storage tanks, 40, 41, 43
responsibilities, 267	Financial	Grounds (yard), maintenance, 56
staffing, 267	assistance, 517	Groundwater
training, 266	stability, 511	contamination, 2
vulnerability assessment, 267	Fire demands, 47, 87, 89	recharge, 9
Employee	Fire hydrants	source, 8, 11
benefits, 488	See Hydrants	Groups, protected by employment laws, 486
evaluation, 489–491	Fires, thawing pipes, 224	Guards, safety equipment, 406–408
grievances, 493, 501	First aid	7 · 1 · 1
orientation, 487	chlorine, 368	
problems, 493, 501	safety program, 543	н
Right-To-Know laws, 388	First-draw samples, 180	п
		1141:
Employee-management relationship, 500	Fittings, mains, 142, 143	Handling and lifting, safety practices,
Employer policies, 487, 495	Flagging, traffic control, 433, 437	398–399
Encroachment, 169	Flag tree warning devices, traffic control, 447	Handling chlorine, safety considerations,
Endrin, 13	Flammable conditions, 393	334–335
Energy conservation	Flanged joint, 102, 106	Handling pipe, 95, 108, 109–111
see Conservation	Flexible joint, 102	Harassment, 495
Entrain, 23	Float on system, 68	Hazard communication, 544–556
Entry permit, confined space, 460	Flow, distribution systems, 23	Hazardous
Environmental Protection Agency (EPA)	Flow calculation, 279	excavation, wastes, 111
monitoring programs, 174	Flow regulation, valves, 132	facilities, 25
WaterSense partnership program, 580	Flow tests, mains, 211	wastes, 3
Enzymes, 294	Fluoride, 13, 14	Hazards
Equal Employment Opportunity	Flushing, unidirectional, 213	chlorine gas, 334
Commission (EEOC), 499	Flushing mains, 212–216	labeling, 551
Equipment	FMLA (Family and Medical Leave Act of	safety, 386
chlorination, 327		
	1993), 499 Foaming agents (MRAS), 14	Head loss, pipes, 87
records, 260, 571	Foat valve 52	Health, water quality, 15, 92
repair/replacement fund, 514	Foot valve, 52	Health hazards
safety, 392–396, 541	Formulas	disease, 6
safety guards, 406–409	chlorination, 339, 355	groundwater recharge, 9
Equipment and stores, 265	disinfection, 339, 355	Hearing protection, 464
Evaluation, performance, 489–492	Free available residual chlorine 300	Heat method of disinfection 293

Hepatitis, 6, 19	Injection point, chlorine, 307	Landscaping, surface water drainage, 273
Heterotrophic bacteria, 13, 301	Injector, chlorine, 325, 330, 350, 357	Land subsidence, 8
High-level flag tree warning devices, traffic	Injuries, prevention, 386	Large landscape conservation, 575
control, 446, 447	Injuries, safety, 386	Laws, drinking water, 286
High-risk homes, Lead and Copper Rule,	Inorganic chemicals, 13	Laying pipe, 120
178	Inorganic matter, 290	Layout
High Test Hypochlorite (HTH), 297, 314	Inquiries, pre-employment, 483, 484–485	distribution systems, 80, 89, 95, 96
Hiring procedures, 480–487	Inspection	utility lines, 110
Homeland Security Advisory System, 533,	hydrants, 239	valves, 141
534	ladders, 458	Lead, 13
Hot tapping, 209	reservoirs, 56	Lead and Copper Rule, 23, 174, 178, 180
HTH (High Test Hypochlorite), 297, 314	safety, 405, 466–467	Leaks
Human factors, safety, 567	safety report form, 466–467	chlorine, 335, 343, 352, 357, 358–362, 367
Hydrants	storage facilities, 57, 58, 59, 68	detecting, 575
components, 144	tanks, 56	rate, 126
distribution systems, 87, 123, 239	Installation	water, 125, 171, 201–208, 260
frozen, 239	chlorination equipment, 325, 362	Legal liability, water system, 259
inspection, 239	meters, 151, 152	LEL (lower explosive limit), 393, 395
mains, 143, 242	pipe, 95, 98, 108, 111, 120, 451	Levels of water, tanks, 49, 51
maintenance, 239	service line, 152	Lifeline rates, 578
maps, 260, 262	Instrumentation, storage facilities, 46–52	Lifting, safety considerations, 398
operation, 239	Intake structures, reservoirs, 7	Lighting devices, traffic control, 450
painting, 242	Interface of pipe and water, 24	Limits on water, 2
record form, 239, 240-241	Interim Enhanced Surface Water Treatment	Lindane, 13
types, 144, 145	Rule (IESWTR), 288	Listening skills, 502
vandalism, 242	Internal parasites, 18	Locating pipes, 206
Hydraulic grade line, 81–83	Interview	Location
Hydraulic gradient, 211	job, 483–487	chlorination equipment, 362
Hydraulics, distribution systems, 81-86	media, 507	sampling, 178
Hydraulic shoring, 116, 117	Inventory, supplies, 571	storage facilities, 45, 91, 92
Hydrogen sulfide, 394	Iodine, disinfection, 293	Lockout/tagout procedure, 410
chlorine reaction with, 296	Ion, 62	Long Term 2 Enhanced Surface Water
Hydro-pneumatic tanks, 40, 41, 43	Iron, 14	Treatment Rule (LT2ESWTR), 288
Hypochlorinators	Iron and manganese control	Looped distribution system, 89, 95, 96
feed system, 326	chlorine dioxide, 299	Lower explosive limit (LEL), 393, 395
operation, 324	secondary maximum contaminant level	LT2ESWTR (Long Term 2 Enhanced
performance, 336	(SMCL), 14	Surface Water Treatment Rule), 288
Hypochlorite	Irrigation	Lubricants, safety considerations, 411
calcium hypochlorite, 297	reclaimed water, 8	•
disinfection, 297	runoff, 3, 6	
forms, 252	, - ,	M
HTH (High Test Hypochlorite), 297		**
hypochlorous acid, 295, 296, 298, 300	1	Macroscopic organisms, 18
ion, 295	,	Magnetic meters, 151
reactions with water, 297	Job	Mains, water
safety, 369	duties, 474	appurtenances, 132
sodium hypochlorite, 297	interview, 483–487	asbestos-cement pipe, 100, 104, 107
Hypochlorous acid, 295, 296, 298, 300	knowledge and skills needed, 29	backfilling, 124
11, poemorous usia, 2, 3, 2, 6, 2, 6, 366	Jointing, mains, 123	bedding, 108, 120
	Joints, 102–106	bell and spigot coupling, 105, 106
I .	Johns, 10 2 100	branching systems, 95, 96
1		breaks, 232
Ice, chlorine, 350	The second secon	cast-iron pipe, 97
IDLH (Immediately Dangerous to Life or	L	cathodic protection, 95
Health), 333, 363	Labeling hazards 551	cement-mortar lining, 222–223
IESWTR (Interim Enhanced Surface Water	Labeling hazards, 551 Laboratory	cleaning, 216–221
Treatment Rule), 288	chlorination tests, 356	concrete pipe, 99, 104
		connections, 152, 153, 208
Impermeable surfaces, 6 Improving system management, 474	chlorine residual tests, 363 colorimeter, 365	corporation stop, 125, 152, 153
Incident commander for emergency	Ladders, safety considerations, 456,	corrosion control, 95, 98, 108, 249
response, 535	457–458	couplings, 102, 104, 106, 107, 143
1001130, 707	17/-170	coupings, 102, 101, 100, 10/, 11/

Lakes, sources of water, 6

coupons, 171, 249

Inhibitors, corrosion, 250

Mains, water (continued)	corrosion control, 61	revenue loss, 242
dead ends, 89, 95	cross-connection control, 182, 525	selection, 146
disinfection, 129, 251, 315-322	distribution system, 168	size, 154
distribution systems, 23	emergency, 56, 519	sonic, 151
Also see Distribution systems	hydrants, 239	testing, 242
dry tapping, 131	meters, 146, 152, 247	turbine, 149–150
ductile-iron pipe, 97, 98, 101	painting, 58–61	types, 146
excavation, 111	predictive, 519	velocity, 149
extensions, 131	preventive, 519	Venturi, 149
failure report, 233	pumps, 195	Meters and curb boxes, surveillance, 171
fittings, 142, 143	record form, 187	Methoxychlor, 13
flanged joint, 102, 106	recordkeeping, 569	Microbial standards, 13, 287
flexible joint, 102	records, 259	Microorganisms, 290
flow tests, 211	safety, 408	Milky water, 23, 25
flushing, 212–215	storage facilities, 56, 58	Mixing, chlorine, 307
grid, 89, 95	types, 519	Monitoring
handling, 95, 108, 109, 111	valves, 236	chlorination, 287
hydrants, 143, 239	Management	disinfection, 287
installation, 95, 98, 108, 112, 120	See Administration	Monitoring, water quality
joints, 102–106, 120	Management, safety, 386	annual running TTHM average, 175–177
laying, 120	Managerial functions, 475	average measurements, 175
layout, 95, 96	Manager's responsibilities, 474, 480, 518	bacteriological sampling, 178
	Also see Administration	calculations, 175, 176
leaks, 125, 170, 201–208		chlorine residual, 179, 364
loop systems, 95, 96	Manganese, 14	
meters, 146, 152, 242	Manufold, 331, 363	Lead and Copper Rule, 180
Also see Meters	Manual on Uniform Traffic Control Devices	location of sampling, 178
pigs, 216–221	(MUTCD), 412	maximum contaminant levels, 174
pipe, 94, 95	Maps, 232, 236, 260–264	program, 27, 173
pipe extensions, 131	Material safety data sheet (MSDS), 549	running TTHM average, 175–177
pipe laying and jointing, 120	Math assignment, 33, 75, 162, 279, 381	sampling, 178, 180
plastic pipe, 100, 104, 111	Also see Calculations	sanitary survey, 175, 261
pressure tests, 125–129, 211	Maximum contaminant level (MCL), 13, 174	Monitoring equipment, safety, 392, 396
pulled services, 207	MBAS (foaming agents), 14	Monochloramine, 291, 301
recordkeeping, 233, 260	MCL (maximum contaminant level), 13, 174	Moving parts, safety, 406–408
repairs, 207–209	Measurement, safety, 563	MSDS (material safety data sheet), 549
saddles, 131	Media, news, 507	Multiple-tube fermentation (MTF) test, 257
safety, 130	Meetings, conducting, 505	MUTCD (Manual on Uniform Traffic
service deficiencies, 209	Membrane filter (MF) test, 169, 254, 257	Control Devices), 412
service pipe, 97, 101, 152	Mercury, 13	
services, 209	Metering	
sewer location, 109	chlorine, 325, 331	N
shoring, 111, 207	conservation, 574	
Also see Shoring	Meters	Nameplate, 74
steel pipe, 99, 103, 108	accuracy, 147, 245	National drinking water regulations, 174
stringing, 120	calculations, 242–246	National Labor Relations Act, 501
surveillance, 170	compound, 147, 150	National Primary Drinking Water
swabs, 216–221	displacement, 147	Regulations (NPDWRs), 12, 174
tapping, 131, 209	electronic, 151	National Secondary Drinking Water
testing, 125–129	installation, 152, 153	Regulations (NSDWRs), 174
thawing, 223, 226–232	magnetic, 151	Negligence, safety, 387
thrust blocks, 83, 108, 123, 124	maintenance, 247	Negotiations, contract, 500
tree distribution systems, 95, 96	nutating disc, 147, 247	Neutralization of chlorine, 67, 257
valves, 132, 140, 231	orifice, 149	New employee orientation, 487
Also see Valves	piston, 147	News media, 507
Victaulic coupling, 102	Pitotmeter, 205, 206	Nitrate, MCL (maximum contaminant
water quality problems, 95, 212	propeller, 149	level), 13
welded joints, 105	proportional, 151	Nitrification, 302, 304
wet tapping, 131	purpose, 146	Nitrite-oxidizing bacteria, 304
Maintenance	reading, 246, 247	Noise exposure, safety, 463, 465
administration, 519–527	readouts, 246, 249	Non-permit-required confined space, 461
chlorination equipment, 342, 358, 367	registers, 246	Normal conditions, chlorination, 324, 336,
corrective, 519	requirements, 153	345
, ,	,	

North American Industry Classification	Overturn, lake, 6	plastic, 100, 101, 104, 111
System (NAICS) code, 577	Oxidizing agent, 299	prestressed, 99
NPDWRs (National Primary Drinking	Oxygen deficiency/enrichment, 392, 461	protection, 108
Water Regulations), 12, 174	Ozone	pushers, 265
NSDWRs (National Secondary Drinking	disinfection, 293	repairs, 207–209
Water Regulations), 174	mixed oxidants, 291	steel, 97, 105, 108
Nutating-disc meter, 147, 247		storage, 109–111
		types, 97
	P	Piston meters, 147, 149
0	D : 4	Pitotmeter, 205, 206
Objection	Painting	Pitot tube, 205
Objective, water treatment, 10	hydrants, 242 safety considerations, 60, 61	Plan, organizational, 476, 477
Occupational Safety and Health Act of 1970 (OSH Act of 1970), 114, 431, 540	· · · · · · · · · · · · · · · · · · ·	Plan and profile map, 263 Planning
Occupational Safety and Health	tanks, 58–61 Palatable, water quality, 15	administration, 475, 476
Administration (OSHA), 396	Paper screening, 483	emergencies, 476
Odor threshold, 14	Parallel, pumps, 94	Plan review, chlorine facilities, 362
On-site chlorine generation, 298	Parasites, 18, 19	Plant
Operating ratio, 511	Pathogenic organisms, 18, 19	operations data, 569
Operation Operation	Pathogen removal, 290	records, 568–572
chlorination, 336–354	Patrolling storage facilities, 169	tours, 510
disinfection, 336–354	Pay, operator, 29	Plastic pipe
Operation and maintenance (O&M)	Payback time calculation, 513	characteristics, 100
administration, 518–528	PCBs (polychlorinated biphenyls), 60	joints, 104
distribution systems	PCMS (portable changeable message sign),	service lines, 101
See Distribution system O&M	444	storage on site, 109
hydrants, 239	Peak water demand, 38	Plugging, wells, 405
operator's duties, 30	Pedestrian safety, traffic control, 130, 412,	Plug valves, 132
storage facilities, 48, 68	428, 452	Policies and procedures, administration, 487
valves, 140	Performance evaluation, 489–492	Policy, safety, 386
Operator	Permit-required confined space, 460, 461	Policy, thawing pipes, 228
certification, 29, 30, 488	Permits, confined space entry, 557	Policy statement, safety, 540
complaint handling, 32	Personal safety, 130, 392	Polychlorinated biphenyls (PCBs), 60
duties, 29, 30	Personnel records, 480, 500	Polyphosphates
operation and maintenance, 30	рН	corrosion control, 62
protection	chlorination efficiency, 289, 296, 308	safety, 62
first-aid equipment, 543	SMCL (secondary maximum contaminant	storage facilities, 62
safety program, 539-567	level), 14	Poppet valves, 338
public relations, 31	Phenol, 301	Population decline, 492
qualifications, 29	Phenolic tastes and odors, 298	Population served, 288
recordkeeping, 30	Phosphate corrosion inhibitors, 250	Portable changeable message sign (PCMS)
requirements, 10	Physical	444
safety, 32, 365, 369	characteristics of water, 18	Positive coliform results, 54, 55
salary, 29 staffing needs, 29	disinfection, 292	Postammoniation, 302 Postchlorination, 307, 354
supervision and administration, 30	water quality, 13 Physiological response, chlorine, 366	Powered valve operators, 234, 235
training courses, 33	Pigs, 216–221	Preammoniation, 302
Oral communication, 502	Pigtail tubing, 335	Prechlorination, 297, 307, 318, 354
Ordinance, cross-connection control, 184, 527	Pipe	Predictive maintenance, 519
Organics	bedding, 108	Pre-employment inquiries, 483, 484–485
chlorine demand, 290, 299	characteristics, 95	Preparing for emergencies, 528
MCL (maximum contaminant level), 13	cleaning, 216–221	Present worth, capital improvements, 516
Organizational plan, 476, 477	couplings, 102, 104, 106, 107, 143	Pressure
Organizing, administration, 475, 476	extensions, 131	distribution system, 45, 80, 86
Orientation, new employee, 487	fittings, 142, 143	head, 81
Orifice plate meter, 149	flushing, 212–214	reducing valves, 88, 136
Orthophosphate corrosion inhibitors, 250	handling, 95, 107, 109–111	regulation valves, 137
OSHA (Occupational Safety and Health	installation, 108	relief valves, 139
Administration), 396	laying and jointing, 120-123	sustaining valves, 136
OSH Act of 1970 (Occupational Safety and	lining, 222–223	tanks, 38, 41, 43
Health Act of 1970), 114, 431, 540	locating (buried), 206	tests, 125–129, 211
Overflows, tanks, 68, 69	materials, 95, 97–101	vacuum breaker, 155, 526

Prestressed pipe, 99	Readouts, meters, 249	chlorine, 335
Preventing accidents, 386	Reclaimed water, 9	pathogenic organisms, 292
Preventive maintenance, 168, 519	Recognition, employee, 488, 489	Repair/replacement fund, 514
Also see Maintenance	Record drawings (as-built plans), 31, 109, 262	Repairs
Pricing, conservation, 578	Recordkeeping	distribution systems, 25, 168
Primary drinking water regulations,	accident reports, 558	mains, 25, 207–209
174	as-builts (record drawings), 31, 109, 262	safety, 408
Prime, pumps, 52, 53, 196	bacteriological analyses, 261	valves, 238
Priorities, emergencies, 267	chemical analyses, 261	Replacement cost, 514 Reporting, safety, 558
Probationary period, 487 Problem employees, 490	computerized, 571 consumer complaints, 259	Report preparation, 259
Process, disinfection, 292	daily log, 260	Report writing, 503–505
Procurement of materials, 569, 570	disposing of records, 572	Requisition, 513
Procurement records, 569	distribution system, 260	Requisition system, 570
Productive meetings, 505	equipment, 260, 571	Reservoirs
Profile, qualifications, 481	hydrants, 239, 240–241	covers, 26
Program, safety, 32, 386	inventory, 571	distribution system, 26–27, 38, 68, 169
Propeller meters, 149	litigation and legal liability, 259	stratification, 6
Proportional meters, 151	mains, water, 233, 261	Residential
Protected groups, employment laws, 486	maintenance, 259, 569	plumbing retrofits, 574
Protection from chlorine, 334	maps	water surveys, 574
Protective clothing, 397, 398	hydrant, 261, 262	Residual analyzer, chlorine, 350, 351
Public health, 6, 9, 10, 536–537	leak survey, 262	Residual chlorine, 179, 291, 292, 294, 299
Public information programs, conservation,	plan and profile, 263	301, 302, 306, 307, 350, 364
576	symbols, 262	Responsibilities
Public relations	valve, 261	managers, 474, 480
campaigns, 506–511	nameplate, 74	operator
communication, 268	operations data, 569	cross-connection control, 526
consumer complaints, 269–271	operator's responsibility, 30	emergencies, 266
distribution system O&M, 268	personnel, 480, 500	safety, 32, 386
forms, 271, 272	planning, 259	shoring, 116
operator's duties, 30	plant, 568–572	organizational structure, 478
Public safety, 403, 428–431, 452 Public speaking, 508	procurement, 569 purchase order, 570	Retention time, records, 261 Retrofits, residential plumbing, 574
Pulled services, 207	purpose, 568	Revenue loss, 242
Pump failure, 194	record drawings (as-builts), 32, 109, 262	Right-To-Know (RTK) laws, 388,
Pumping, distribution storage, 93	report preparation, 259	544–556
Pumps, unbalanced current, 199–201	requisition, 570	Rivers, sources of water, 6
Pumps, wells	retention of records, 261, 572	Rotameter, 327
booster, 71	safety, 556	Routing traffic, 411–451
distribution system, 195	sanitary survey, 175, 261	RTK (Right-To-Know) laws, 388, 544-556
maintenance, 195	sectional plat, 260, 261	Running TTHM average, 175–177
parallel, 94	storage facilities, 74	
safety, 406–411	types, 260	
Purchase order, 512, 570	valves, 236, 237	S
	work orders, 260	
	Records	Sacrificial anode, 62
Q	See Recordkeeping	Saddles, mains, 131, 209
	Reduced-pressure (RP) devices, 156, 157,	Safe Drinking Water Act (SDWA), 31, 286
Qualifications for operator jobs, 29	159	Safe drinking water laws, 31, 286
Qualifications profile, 481	Reducing agents, 257, 289, 290, 296, 307	Safe procedures
Quality degradation, 15, 20–28	Red water, 21, 269	emergency traffic control situations, 420
	Registers, meters, 246	hazard communication, 544–556
B	Regulations	high-visibility clothing, 432
R	monitoring programs, 174	noise exposure, 464
Radioactivity MCI (maximum contaminant	OSH Act of 1970, 540 SDWA (Safe Drinking Water Act) 31, 286	portable changeable message sign (PCMS), 444
Radioactivity, MCL (maximum contaminant level), 14	SDWA (Safe Drinking Water Act), 31, 286 street work, 419	regulations, street work, 419
Radiological water quality, 13	Regulator stations, valves, 70	Right-To-Know laws, 544–556
Rate of chlorine withdrawal, 335, 362	Regulatory agencies, safety, 540	speed limits in work zones, 432
Rates, water, 2, 515	Remote reading, meters, 246	street work regulations, 419
Reading meters, 248	Removal processes	traffic control, 417, 420, 436–451

Safety	lifting, 398	training, 386, 459, 487, 561
accident	lockout/tagout procedure, 410	trenches, 116, 451
causes, 387, 539	lower explosive limit (LEL), 393, 395	underground utilities, 109, 454-455
excavations, 453	lubricants, 411	unsafe acts, 386, 387, 398, 543
prevention, 386, 387	mains, 254	upper explosive limit (UEL), 393, 395
reports, 558, 559, 560	maintenance, 408	valves, 139
types, 392	management, 386	ventilation, 333, 393, 404, 461
acids, 400, 403	measuring, 563	water storage facilities, 62, 64,
additional resources, 466–467	monitoring equipment, 392, 396	74, 456
awareness, 386	moving parts, 406–408	wells, 400, 402, 403
battery charging, 390-391	negligence, 387	working in streets, 411-455
boats, 391	noise exposure, 463	Also see Traffic control
Call Before You Dig program (811),	non-permit-required confined space, 461	Safety data sheet (SDS), 388
454	OSH Act of 1970 (Occupational Safety	Safety program, small plants, 386
carbon monoxide, 392	and Health Act of 1970), 114	Salary, operator, 29
causes of work injuries, 387	objectives, 386	Sampling
cave-ins, 452	operator, 32, 543	chlorination, 287
chemicals, 252, 402	OSHA (Occupational Safety and Health	disinfection, 287
chlorination, 365–370	Administration), 396	first-draw samples, 180
chlorine, 404	oxygen deficiency/enrichment, 392, 461	Lead and Copper Rule, 178, 180
clothing, 397–398	painting, 60, 61	storage facilities, 54, 60
coatings, 402, 459	pedestrian traffic control, 130, 412,	water quality, 178, 180
combustible gases, 392	428, 452	Sandblasting, 59
competent person, 461	permit, confined space, 557	Sanitary hazards, 169
confined space, 392, 393, 396, 459,	permit-required confined space, 460, 461	Sanitary landfills, 3
556–558	personal, 130, 392	Sanitary survey, 175, 261
confined space entry permit, 460	policy, 386	records, 261, 275
corrosive chemicals, 399	policy statement, 540	water quality, 175
costs, 564	polyphosphate, 62	Saturation zone, 7
dangerous air contamination, 392,	preventing accidents, 386	SCADA (supervisory control and data
394–395, 461	preventing accidents, 386	acquisition) systems
definition, 386	program, 32, 386, 539–567	communications, 522
disinfection, 403	protective clothing, 397, 398	description, 264, 522
		distribution systems, 521–525
distribution systems, 130	public, 428–431, 452	•
drinking water, 286	pumps, 406–411	treatment plants, 521–525
driving, 389	regulatory agencies, 540	Screw jack, 116, 118 SDS (safety data sheet), 388
education, 561	repair, 409	
electrical, 399, 404	reporting, 558, 559, 560	SDWA (Safe Drinking Water Act), 31, 286
emergencies, 543	responsibilities, 32, 386	Seawater intrusion, 3, 8
equipment, 392–393, 396	Right-To-Know laws, 388	Secondary drinking water regulations, 12
excavations, 451	safety data sheet (SDS), 388	14, 174
explosive conditions, 393	security, facilities, 531–535	Sectional plat, 261
explosive limits, 393, 395	shoring, 114, 451, 452	Security, facilities, 531–535
falls, avoiding, 398, 456	sling, 409	Sedimentation (settling), pathogen
first aid, 543–544	slips, 398, 456	removal, 290
flammable conditions, 393	standard operating procedures (SOPs),	Selection, employees, 483
fuel, 411	544	Selenium, 13
gases, 394	statistics, 563	Self-contained breathing apparatus, 335,
guards on equipment, 406–408	storage facilities, water, 62, 64,	359, 365, 367
handling and lifting, 398	74, 456	Septic tank leaching systems, 3
hazards, 386, 398–399	storage of fuel, 411	Service cost recovery, 578
hearing protection, 464	street work, 411–455	Service deficiencies, 209
human factors, 567	supervisors, 539, 541, 559, 561	Service lines, 97, 101, 152
hydrogen sulfide, 392	tailgate	Sewers, location from mains, 109
hypochlorite, 369	safety sessions, 116, 387	Sexual harassment, 495
injuries, 386	training, 562	Shield shoring, 120, 121
injury rate, 564	tanks, 402, 459	Shop steward, 500
inspection, 405, 466–467	threat levels, security advisory, 533	Shoring
inspection by competent person, 116,	toxic gases, 392	air shores, 116, 119
451	traffic control	aluminum, 117
ladders, 453, 456, 457–458	See Traffic control	cave-ins, 453
laying pipe, 130	trailers, towing, 389	cylinder, 120, 121

Shoring (continued) orientation, 487 coatings, 58-60 problems, 490, 501 color, water quality problem, 55 distribution system, 207 concrete storage facilities, 68 equipment, 113 employee-management relationship, 500 excavation, 111 employer policies, 487, 495 controls, instruments, 51, 69, 74 evaluation, performance, 489-492 corrosion control, 61 hydraulic, 116, 117 mains, water, 112, 209 groups, protected, 486 cross-connections, 93 need, 112 harassment, 495 demand, meeting, 38, 46 OSHA (Occupational Safety and Health hiring procedures, 480-487 description, 9 Administration), 114 interviewing, 483-487 disinfection, 64-68, 256 distribution system pressures, 44, 45 regulations, 114 manager's responsibilities, 474, 479 requirements, 114 managing employees, 480 distribution systems, 26, 90, 195 responsibility, 116 National Labor Relations Act, 501 draining, 59 safety, 114, 451, 543 needs, 29 elevated tanks, 39, 40, 42, 92 screw jacks, 116, 118 orientation, new employees, 487 emergency plans, 47 shield, 120, 121 paper screening, 483 filling, 65 solid sheeting, 117, 119 performance evaluation, 489-490 fire demands, 47 types, 112, 116 personnel records, 500 frozen distribution reservoirs, 68 Shortage, water, 2 policies, employer, 487, 495 gauges, 70 Shutdown, chlorination, 337 probationary period, 487 ground-level storage tanks, 40, 41, 43 problem employees, 490 grounds (yard), 56 Shutoff valves, 132, 152 Signal transmitters, 521 protected groups, 486 health, 191 qualifications profile, 481 Signs, traffic control, 416, 445, 447 hydropneumatic tanks, 40, 41, 43 inspection, 56, 58, 59, 68 Also see Traffic control retaliation, 498 Silt, source, 6 selection process, 486 inspections, wet, 57 sexual harassment, 495 instrumentation, 47-52 Silver, 14 Slide valve, 132 training, 488 levels of water, 48, 51 Sling, safety, 409 unions, 500 location, 45, 91, 92 Slips, safety, 398, 456 Stage 2 Disinfection Byproducts (Stage 2 maintenance, 56, 58 Slope, pipe, 81 D/DBP), 288 neutralization of chlorine, 67 Sodium hypochlorite, 297 Stale water, 47 operation, 46, 48, 68 Standard Industrial Classifications (SIC) Solid sheeting, 117, 119 operator responsibility, 74 Solution feeders, 325, 326, 337 code, 577 overflows, 43, 69 painting, 58-60 Standard operating procedures (SOPs), Sonic meters, 151 Sources of contaminants, 19 polyphosphate, 62 Standards positive coliform results, 54, 55 Sources of water description, 4 microbial, 13, 286 pressures, 45, 46 water quality, 12 direct runoff, 6 pressure tanks, 40, 41, 43 Standby facilities, 47 pumps, 48, 52, 93 groundwater, 7, 11 lakes, 6 Standpipes, 40, 42, 92 purpose, 38, 90 ocean, 4 Startup recordkeeping, 74 reclaimed water, 8 chlorination, 337, 342 regulator stations, 71 disinfection, 337, 342 related equipment, 74 reservoirs, 6 Static head, 86 requirements, 38, 47 rivers, 6 Steam thawing, 225 reservoirs, 68 springs, 8 streams, 6 Steel pipe sacrificial anode, 62 surface water, 6, 11 characteristics, 98 safety, 62, 64, 74, 456 wells, 8 corrosion control, 108 sampling, 54, 59 sandblasting, 59 Specifications joints, 105 disinfection, 321 Sterilization, 286 stale water, 47 standby facilities, 47-48 review, chlorine facilities, 362 Steward, shop, 500 Speed limits in work zones, 432 Stopping distance, vehicle, 416 standpipes, 40, 42, 92 Storage, chlorine surge tanks, 40, 43-44 Spoil, 451 containers, 346, 362 system pressures, 45, 47, 194 Spore-forming bacteria, 290 Staffing procedures, 334 tastes and odors, 47, 55, 60 advertising positions, 483 Storage facilities (water) thawing frozen reservoirs, 70 applications, job, 483 advantages, 38 troubleshooting, 54, 55, 72, 73 certification, 488 altitude control valves, 49, 70 turbidity, 55 compensation, 483, 488 booster pumps, 70 types, 38, 91-92 disciplinary problems, 490 calculations, 50, 64, 66 valves, regulator stations, 70 emergencies, 266 cathodic protection, 61, 63 vents, 43, 68, 69 employee chlorine, neutralization, 67 water quality problems, 54, 55, 93 grievances, 490, 501 clear wells, 40, 42 wet inspections, 57

Storing fuel, 411	Tailgate training, 562	Tours, plant, 510
Stratification, reservoirs, 6	Tanks	Toxic gases, 392, 393
Street work	chlorine, 332, 360	Traffic control
Also see Traffic control	cleaning, 57	barricades, 448, 450
regulations, 419	disinfection, 322	devices, 415, 436-451
safety, 411–455	inspection, 56	drums, 449
Stringing pipe, 120	painting, 58-60	flagging, 437
Subsidence, land, 8	safety, 402, 459	high-level flag tree warning devices,
Suction lift, 196	Tapers, traffic control, 424, 427	446, 447
Sulfate, SMCL (secondary maximum	Tapping, pipe, 131, 209	pedestrian safety, 428, 430, 452
contaminant level), 14	Target audience, communications, 502,	signs, 416, 445, 447
Supervising inquiries, pre-employment,	503, 506	stopping distances, 417
484–485	Taste and odor control	street closure, 420
Supervision, 30, 489	bitter tastes, 293	tapers, 424, 427
Supervisors, safety, 539, 541,	chlorine, 301, 355	temporary traffic control (TTC) zones,
559, 561	chlorine dioxide, 301	411–451
Supervisory control and data acquisition	odor, secondary maximum contaminant	trenches, safety considerations,
(SCADA) systems	level (SMCL), 12	451–452
communications, 522	Tastes and odors	visibility, clothing for worker safety,
description, 264, 521	causes, 47, 55, 60	432
distribution systems, 521–524	protective coatings, 55, 60	Trailers, towing, 389
treatment plants, 521–524	stale water, 47	Training
Surface water, 6	troubleshooting, 55	administration, 487
Surface water drainage, managing, 270	TCE (trichloroethylene), 2	collection system operators, 466
Surface Water Treatment Rule (SWTR),	TDS (total dissolved solids), 14	course, 33
286, 308	Telemetering	emergencies, 266
Surge chambers, 84	instrumentation, 522	flaggers, 433
Surges, 43–44, 47	surveillance, 173	safety, 369, 386, 459, 488, 561
Surge tanks, 40, 41, 43–44	Telephone contacts, 508–509	Transmission systems, 90
Surveillance of distribution systems	Temperature	Transpiration, 7
blowoffs, 171	chlorination, 289, 307	Treatment, emergency, 537
cross-connection control, 173, 181	disinfection, 289, 307	Treatment facilities, purpose, 9
deterioration, 169	distribution system, 23	Treatment processes
encroachment, 169	water quality, 23	by source water, 11
leaks, 170	Temporary traffic control (TTC) zones,	reclaimed water, 9
mains, 171	411-451	Tree distribution systems, 159, 160
meters and curb boxes, 171	Also see Traffic control	Trenches, safety, 116, 451–452
monitoring, 173	Testing, mains, water, 125–129	Trichloramine, 301
patrolling facilities, 169	Thawing frozen reservoirs, 70	Trichloroethylene (TCE), 2
sanitary hazards, 169	Thawing pipes	Trihalomethanes (THMs), 14, 18, 174, 175,
storage facilities, 169, 195	dangers, 224	290, 291, 299
telemetering, 173	electrical thawing, 224, 226	Troubleshooting
valves, 173	fires, 224	chlorination equipment, 357, 358
vandalism, 169, 172	flushing, 228–231	disinfection equipment, 357, 358
water quality, 169, 173	hot water, 224	distribution systems, 27–28
Survey form	mains, 224, 226–231	storage facilities, 54, 55, 72, 73
complaint, 271	policy, 228	water quality, 27–28, 54, 55
cross-connection control, 185	steam, 225	TTC (temporary traffic control)
customer service, 272	THMs (trihalomethanes), 14, 18, 174, 175,	zones. See Temporary traffic
Swabs, 218–221	290, 291, 299	control (TTC)
SWTR (Surface Water Treatment Rule),	Threat response, contaminated water	Tubercle, 22
286, 308	supply, 536	Tuberculation, 97, 171
Symbols, maps, 261, 262	Threshold odor, 14	Tubing, pigtail, 335
System pressures, 45, 47, 194	Thrust blocks, 83, 108, 123–124	Turbidity
System vulnerability, 529	Time, detention	chlorination, 289, 307
System water audits, 575	chlorine, 308	disinfection, 289, 307
,	curves, 308	storage tanks, 55
	Time in distribution system, 23	Turbidity units, 54
Т	Time-weighted average (TWA), 465	Turbine meters, 149–150
•	Ton tanks, chlorine, 332	Turnover, lake, 5
Tablets, chlorine, 252	Topography, 8	TWA (time-weighted average), 465
Tailgate safety meeting, 116, 387	Total dissolved solids (TDS), 14	Typhoid, contamination of water supply, 5

U	pressure reducing, 88, 136	water quality
	pressure relief, 139	aesthetics, 12
UEL (upper explosive limit), 393, 395	pressure sustaining, 136	biological, 18, 54
Ultra-low-flush [flow] toilet (ULFT), 574,	protection, 139	chemical, 18, 54
578, 579	record form, 236, 237	consumer demands, 10
Ultrasonic waves, 293	regulator stations, 70	contaminants, 18
Ultraviolet (UV) systems, disinfection, 291,	repairs, 238	control, 18
292	safety, 139	degradation, 23
Unaccounted-for water (UFW), 204, 474	shutoff, 132	distribution systems, 15-28
Unbalanced voltage, 197-201	slide, 132	health, 15, 93
Uncovered reservoirs, 26, 27	surveillance, 171	internal parasites, 18
Underground service alert (USA), 109	types, 132	monitoring, 27, 173
Underground utilities	vacuum relief, 136	Also see Monitoring, water quality
Call Before You Dig program (811),	vaults for valves, 140	parasites, 18
454	water hammer, 234	pathogenic organisms, 19
excavations, 451–455	Vandalism, 169, 172, 242	physical, 14, 18, 54
locating, 109	Vaults for valves, 140	primary regulations, 12
Unidirectional flushing, 212	Velocity meters, 146, 149	problems, 11, 15, 54, 55, 93, 212
Unions, 500	Ventilation	radiological, 14
Unity of command, 476	chlorine rooms, 333	secondary drinking water
Unsafe acts, 386, 387, 398, 543	safety, 333, 393, 402, 459	regulations, 12
Upper explosive limit (UEL), 393, 395	Vents, storage facilities, 43, 68, 69	standards, 12
USA (underground service alert), 109	Venturi meters, 149	surveillance, 169, 173
	Vertical traffic control panels, 446	
Utility lines, locating, 109, 110 Utility management, 474	Also see Traffic control	temperature, 23 trihalomethanes (THMs), 11
Utinty management, 4/4		
	Victaulic coupling, 102	troubleshooting, 27–28, 54, 55
**	Violence in the workplace, 494	Water rates, 2, 515
V	Viruses, 19, 290	WaterSense, EPA partnership program,
	Visibility, clothing for worker safety,	580
Vacuum-controlled chlorinator, 327–332,	432	Water shortage allocations, 578
350	Voltage imbalance, 197–201	Water supply systems
Valves	Volume-related charges, 578	chlorination equipment, 358
air release, 136, 138	Vortex, 27	description, 3–9
altitude control, 49, 70, 139	Vulnerability assessment, 267, 530	distribution systems, 9, 15, 19
backflow prevention, 140, 152,		sources, 4
155–156		storage facilities, 9
ball, 132	W	threat response, contamination, 536
blowoff, 140, 171		treatment facilities, 9
boxes for valves, 140	Wastewater facilities, 7	Water table, 7
butterfly, 132, 133	Water	Water treatment plants
cavitation, 234	acid rain, 2	costs, 3, 10
check, 94, 140, 159	audits, 204, 575	objectives, 10
chlorination, 335, 338, 341, 342, 349	conservation	purpose, 29
corporation stop, 125, 152, 153	See Conservation	water quality problems, 2
corrosion, 238	contamination, 2	Water waste prohibition, 579
couplings, 143	costs, 2	Weighing, chlorine containers, 363
curb stop, 152	cycle, 4	Welded joints, 105
diaphragm, 135	efficiency program, 579	Wells
distribution systems, 88, 132, 232	evaporation, 4	abandoning, 405
double-check type, 155	groundwater, 7, 11	disinfection, 311, 374
drain, 140	irrigation runoff, 2	plugging, 405
	seawater intrusion, 3, 8	safety, 400, 402, 403
exercising, 234		
flow regulation, 132	shortages, 2	yield, 8
gate, 132, 133	sources, 11	Wet-barrel hydrants, 145
globe, 134, 135	surface, 6, 11	Wet inspection, 57
layout, 141	table, 7	Wet tapping, 131
mains, water, 132, 141, 232	treatment, 10, 11	Wholesale agency assistance programs,
maintenance, 238	water quality problems, 11	577
map, 234, 236, 260	Waterborne diseases, 286	Withdrawal rate, chlorine, 335, 362
operation, 141	Water hammer, 44, 47, 83, 207, 234	Worker Right-To-Know (RTK) laws,
plug, 132	Water mains	544–556
powered operation, 234, 235	See Mains, water	Worker visibility, clothing for safety, 431

Working conditions, 485 Working in streets, safety, 411–455 Work injuries, causes, 387 Work orders, 260 Wrench, chlorine container valve, 336 Written communication, 503–505



Yield, wells, 8 Yoke-type connectors, 335

Z

Zinc, SMCL (secondary maximum contaminant level), 14
Zinc orthophosphate, 251
Zone of saturation, 7

