

STANDARD
HANDBOOK of
ENVIRONMENTAL
ENGINEERING



Robert A. Corbitt

CONTENTS

Contributors xv

Preface xix

Chapter 1. Environmental Engineering 1.1

The Environmental Engineer 1.1

Consulting 1.1 / Industry 1.2 / Government 1.2 / Academics 1.6 /
Professional Societies 1.6 / Engineering Registration 1.7

Contracting for Consultant Services 1.15

Consultant Services 1.15 / Consultant Selection 1.16 / Teaming
Agreements 1.16 / Contract Types 1.17 / Fixed Price 1.17 / Percent of
Construction Cost 1.17 / Time and Expense 1.18 / Cost-Plus-Fixed Fee 1.18 /
Basic Agreements 1.18 / Contract Provisions 1.18

Project Management 1.19

The Project Manager 1.19 / Planning the Project 1.20 / The Work Plan 1.20 /
The Task Outline 1.20 / Scheduling 1.23 / Budgeting 1.25 / Monitoring
Schedules and Budgets 1.28 / Estimating Individual Task Progress 1.29 /
Computing Total Project Progress 1.30 / Estimating Project Expenditures 1.30 /
Schedule and Budget Status 1.30 / Task Schedule Status 1.34 / Task Budget
Status 1.34 / Analyzing Trends 1.34

Project Economics 1.39

Capital Costs 1.39 / Direct Costs 1.40 / Indirect Costs 1.41 / Cost
Factors 1.41 / Cost Indices 1.41 / Operation and Maintenance Costs 1.41 /
Project Cost Analyses 1.43 / Annual Cost Analysis 1.45 / Present Worth Cost
Analysis 1.46 / Cost Effective Analysis 1.48 / Cost Sensitivity Analysis 1.48 /
Project Financing 1.50

Studies and Designs 1.50

Policy Studies 1.50 / Federal Studies 1.50 / Community Planning 1.51 /
Environmental Audits 1.51 / Feasibility Studies 1.55 / Design
Development 1.55 / Conceptual Design 1.55 / Preliminary Design 1.55 /
Detailed Design 1.59 / Value Engineering 1.59 / Information Phase 1.60 /
Functional Phase 1.60 / Creative Phase 1.63 / Judgment Phase 1.63 /
Development Phase 1.64 / Presentation Phase 1.64 / Implementation
Phase 1.69 / Follow-Up Phase 1.69

Construction 1.70

Contract Administration 1.71 / Resident Representation 1.71 / Resident
Engineering 1.71 / Construction Management 1.75 / Turnkey: Design-
Construction 1.75

Start-Up and Training 1.76

Equipment Check Out 1.77 / Process Start-Up 1.78 / Steady-State
Operation 1.78 / Operator Training 1.79 / Operation and Maintenance
Manual 1.79 / Periodic Operations Review 1.84

Computer Utilization 1.84

Computer Equipment and Services 1.85 / Computer Equipment 1.85 /
Timesharing and Remote Computing Services 1.85 / Programming and Logic
Languages 1.86 / Programming Logic 1.86 / Program Languages 1.88 /
Computer Program Development 1.89 / Computer Applications in
Environmental Engineering 1.91 / Project Management 1.91 / Air
Quality 1.91 / Water Supply 1.92 / Storm and Sanitary Sewer Systems 1.92 /
Wastewater Treatment and Disposal 1.92 / Water Quality Modeling 1.93 /
Surface Water Hydrology 1.93 / Solid and Hazardous Waste Management 1.93

References 1.94**Chapter 2. Environmental Legislation and Regulations 2.1**

Rationale for Environmental Legislation and Regulations 2.1

Concerns Regarding Environmental Legislation and Regulations 2.2

Legislative Data Systems 2.3

Federal Legal Information Through Electronics (FLITE) 2.3 / Justice Retrieval
and Inquiry System (JURIS) 2.3 / Computer-Aided Environmental Legislative
Data System (CELDS) 2.3 / LEXIS 2.4 / WESTLAW 2.4

Overview Federal Environmental Legislation 2.4

Clean Air Act 2.5 / Noise Control Act 2.7 / Safe Drinking Water Act 2.9 /
Clean Water Act 2.10 / Resource Conservation and Recovery Act 2.14 /
Comprehensive Environmental Response, Compensation and Liability Act 2.16 /
Superfund Amendments and Reauthorization Act 2.18 / Federal Insecticide,
Fungicide, and Rodenticide Act 2.19 / Marine Protection, Research and
Sanctuaries Act 2.20 / Toxic Substances Control Act 2.21 / National
Environmental Policy Act 2.23 / National Historic Preservation Act 2.23 / Wild
and Scenic River Act 2.24 / Coastal Zone Management Act 2.25 / Endangered
Species Act 2.26 / Fish and Wildlife Coordination Act 2.27

Trends in Environmental Legislation and Regulations 2.28

New Legislation 2.28 / Balancing Federal and Non-Federal Roles 2.29 /
Balancing Economic and Environmental Costs 2.30

References 2.31

Chapter 3. Air and Water Quality Standards 3.1

Air Quality Objectives 3.2

Ambient Air Quality Standards 3.2 / Air Quality Regions 3.3

Emission Standards 3.4

New Source Performance Standards 3.4 / Hazardous Air Pollutant
Standards 3.4

Water Quality Objectives 3.4

Water Quality Standards 3.7 / Water Quality Protection Programs 3.8

Effluent Standards 3.8

Secondary Treatment 3.10 / Industrial Effluents 3.11 / Toxic Pollutants 3.13

References 3.14

Chapter 4. Air Quality Control 4.1**Air Pollutants: Source and Effects 4.1**

Sources of Air Contaminants 4.2 / Carbon Monoxide 4.2 / Hydrocarbons 4.2 / Lead 4.3 / Nitrogen Oxides 4.3 / Ozone 4.3 / Particulate Matter 4.3 / Sulfur Oxides 4.3 / Effects of Air Contaminants 4.3 / Carbon Monoxide 4.4 / Hydrocarbons 4.4 / Lead 4.4 / Nitrogen Oxides 4.4 / Ozone 4.4 / Particulate Matter 4.4 / Sulfur Oxides 4.4

Characterization 4.5

Emission Survey 4.5 / Source Identification 4.5 / Emission Qualifications 4.6 / Emission Measurements 4.6 / Emission Testing 4.8 / Emission Measurements 4.9 / Ambient Air Monitoring 4.9 / Site Selection 4.9 / Monitoring Equipment 4.11

Particulate Controls 4.17

Source Controls 4.17 / Fuel Substitution 4.18 / Process Modifications 4.18 / Settling Chambers 4.19 / Inertial Separators 4.21 / Cyclone Separators 4.21 / Mechanical Separators 4.25 / Impingement Separators 4.25 / Wet Scrubbers 4.26 / Preformed Spray Scrubbers 4.29 / Packed-Bed Scrubbers 4.29 / Plate Scrubbers 4.30 / Venturi Scrubbers 4.30 / Orifice Scrubbers 4.35 / Mechanical Scrubbers 4.35 / Fabric Filters 4.35 / Fabric Filter Systems 4.37 / Mechanical Shakers 4.37 / Reverse Air 4.37 / Pulse Jet 4.38 / Fabric Filter Design 4.38 / Fabric 4.38 / Air-To-Cloth Ratio 4.39 / Operating Condition 4.39 / Differential Pressure 4.40 / Safety 4.40 / Electrostatic Precipitators 4.42 / Electrostatic Precipitation Systems 4.42 / Dry Systems 4.43 / Wet Systems 4.43 / Single-Stage Systems 4.43 / Two-Stage Systems 4.43 / Component Characteristics 4.43 / Housing Materials 4.43 / Discharge Electrode 4.44 / Collection Electrode 4.44 / Transformer-Rectifier 4.46 / Cleaning Mechanism 4.46 / Solids Handling 4.46 / Design Considerations 4.47 / Particle Size 4.47 / Gas Flow 4.47 / Resistivity 4.47 / Temperature 4.48 / Collection Area 4.48

Gas Controls 4.49

Source Controls 4.50 / Fuel Substitution 4.50 / Fuel Cleaning 4.50 / Process Modifications 4.50 / Absorption 4.51 / Absorber Systems 4.52 / Absorber Design 4.60 / Adsorption 4.61 / Adsorber systems 4.63 / Adsorber Design 4.64 / Condensation 4.65 / Condenser Systems 4.65 / Condenser Design 4.65 / Flaring 4.66 / Flare Systems 4.66 / Flare Design 4.67 / Incineration 4.69 / Incinerator Systems 4.69 / Incinerator Design 4.72

Fugitive Emissions 4.72

Fugitive Industrial Particulate Emissions 4.72 / Fugitive Particulate Sources 4.72 / Emission Controls 4.72 / Fugitive Industrial Chemical Emissions 4.76 / Fugitive Chemical Sources 4.76 / Source Controls 4.77 / Fugitive Dust 4.81 / Fugitive Dust Sources 4.83 / Dust Controls 4.83

Odor Control 4.86

Odor: Source and Effect 4.86 / Characterization 4.86 / Odor Control Methods 4.88 / Source Control 4.88 / Absorption 4.88 / Adsorption 4.88 / Biological 4.88 / Chemical Treatment 4.88 / Condensation 4.88 / Containment 4.88 / Counteraction 4.88 / Dilution 4.88 / Incineration 4.88 / Masking 4.90

Indoor Air Quality 4.90

Radon: Source and Effect 4.91 / Residential Radon Reduction Techniques 4.91 / Preventing Radon Entry 4.93 / Ventilating for Radon Reduction 4.93

Noise Pollution 4.97

Noise: Source and Effect 4.97 / Sources of Noise 4.98 / Effects of Noise 4.100 / Characterization 4.103 / Noise Survey 4.103 / Sound Characteristics 4.104 / Noise Control 4.106 / Isolation 4.107 / Suppression 4.108 / Shielding 4.109

References 4.110

Chapter 5. Water Supply**5.1**

Water Demand 5.1

Domestic Use 5.1 / Peak Demands 5.4 / Lawn Sprinkling 5.4 / Fire Protection 5.5 / Manufacturing Use 5.6 / Agricultural Use 5.6 / Energy Production 5.6 / Minerals Industry 5.7 / Water Conservation 5.7 / Urban Water Conservation 5.7 / Industrial Water Savings 5.8 / Agricultural Water Savings 5.8 / Pricing 5.8 / Metering 5.10

Water Quality 5.10

Raw Water Supply 5.10 / Drinking Water Quality 5.11 / Physical Characteristics 5.12 / Chemical Characteristics 5.13 / Biological Characteristics 5.16 / Radiological Characteristics 5.17 / Potable Reuse 5.17 / Nonpotable Water Quality 5.18 / Industrial Process Requirements 5.18 / Cooling Waters 5.21 / Steam Generation 5.22 / Heating Waters 5.24 / Recycle and Reuse 5.24

Water Supply Source 5.26

Water Budget 5.26 / Groundwater 5.29 / Wells 5.32 / Springs 5.32 / Surface Water 5.32 / Snow 5.32 / Saline Waters 5.33 / Seawater 5.33 / Brackish Water 5.33

Groundwater Production 5.34

Aquifers 5.34 / Level Fluctuations 5.36 / Hydraulic Characteristics 5.36 / Safe Yield 5.38 / Source Contamination 5.40 / Groundwater Development 5.40 / Wells 5.40 / Springs 5.41 / Flow 5.42 / Safeguards 5.42 / Well Development 5.42 / Yield 5.43 / Site Preparation 5.47 / Well Construction 5.47 / Well Pumps 5.54 / Individual and Small Systems 5.57 / Pump Capacity 5.64 / Pipe and Fittings 5.64 / Pipe Flow 5.65

Surface Water Collection 5.67

Intakes 5.68 / Intake Locations 5.68 / Intake Types 5.68 / Intake Design 5.68 / Transmission Systems 5.69 / Supply Conduits 5.69

Water Treatment 5.76

Rapid Mix 5.77 / Coagulation 5.79 / Flocculation 5.83 / Sedimentation 5.84 / Number of Basins 5.90 / Size and Shape of Basins 5.90 / Inlet Arrangements 5.91 / Short-Circuiting 5.92 / Outlet Arrangements 5.92 / Detention Time 5.92 / Velocity 5.93 / Sludge Storage 5.93 / Surface Loading Rate 5.93 / Solids Loading Rate 5.94 / Sludge Handling 5.94 / Sludge Collection 5.94 / Sludge Disposal 5.96 / Filtration 5.96 / Filter Types 5.96 / Filtration Process 5.100 / Filter Design 5.101 / Filter Backwashing 5.103 / Chemical Feed and Handling 5.104 / Capacity and Reserve Provisions 5.104 / Storage Provisions 5.105 / Chemical Handling 5.105 / Disinfection 5.106 / Chemistry of Chlorination 5.116 / Chlorine Residuals 5.119 / Points of Application 5.122 / Softening 5.123 / Lime-Soda Processes 5.124 / Ion Exchange Softening 5.133 / Sludge Disposal 5.137 / Land Application 5.138 / Vacuum Filters 5.138 / Filter Presses 5.138 / Centrifuges 5.138 / Drying

Beds 5.139 / Ion Exchange 5.139 / Adsorption 5.140 / Powdered Activated Carbon 5.142 / Granular Activated Carbon 5.143 / Reverse Osmosis 5.146 / Aeration 5.149 / Design Considerations 5.152 / Physical Chemistry of Aeration 5.153 / Aeration Systems 5.156

Other Water Sources 5.160

Water Reuse 5.160 / Desalinization 5.161 / Distillation 5.161 / Electrodialysis 5.164 / Freezing 5.166 / Ion Exchange 5.166

Distribution 5.167

Storage 5.167 / Service Lines 5.167 / Water Mains 5.173 / Ductile Iron Pipe 5.173 / Prestressed Concrete Cylinder Pipe 5.173 / Polyvinyl Chloride Pipe 5.173 / Reinforced Plastic Pipe 5.181 / Steel Pipe 5.181 / Asbestos-Cement Pipe 5.181 / Fittings 5.181 / Installation 5.181 / Repair and Maintenance 5.185 / Pipe Rehabilitation 5.186 / Pipe Cleaning 5.188 / Cement Mortar Lining 5.192 / Valves 5.192 / Gate Valves 5.192 / Butterfly Valves 5.195 / Ball Valves and Cone Valves 5.195 / Altitude Valves 5.195 / Air Release Valves 5.198 / Air/Vacuum Release Valves 5.198 / Installation 5.198 / Operation and Maintenance 5.198 / Fire Hydrants 5.200 / Dry-Barrel Hydrants 5.200 / Wet-Barrel Hydrants 5.200 / Installation 5.202 / Inspection and Maintenance 5.202 / Distribution System Configuration 5.212 / Branch Systems 5.212 / Loop Systems 5.212 / System Pressures 5.213 / Valve Spacing and Sizing 5.213 / Cross-Connections and System Contamination 5.213 / Leaks 5.213 / Storage Tanks 5.214 / Construction 5.214 / Cross-Connections 5.214

References 5.220

Chapter 6. Wastewater Disposal

6.1

Wastewater Pollutants: Source and Effect 6.1

Nature of Wastewater 6.1 / Suspended Solids 6.2 / Biodegradable Organics 6.2 / Pathogens 6.3 / Nutrients 6.3 / Refractory Organics 6.8 / Heavy Metals 6.8 / Dissolved Inorganic Solids 6.9 / Toxic Organic Compounds 6.9 / Sources of Wastewater Contaminants 6.9 / Effects of Wastewater Contaminants 6.12

Wastewater Characterization 6.16

Domestic Wastewater 6.17 / Composition 6.17 / Flow Characteristics 6.19 / Industrial Wastewater 6.25 / Plant Wastewater Survey 6.27

Collection 6.49

Hydraulic Design 6.49 / Gravity Sewer 6.50 / Force Main 6.50 / System Components 6.54 / Service Connections 6.55 / Manholes 6.55 / Pump Stations 6.56 / Stream Crossings 6.56 / Aerial Crossings 6.58 / Depressed Sewers 6.59 / Drinking Water Protection 6.60 / Sewer Materials 6.60 / Pipe Materials 6.60 / Joints 6.61 / Corrosion Protection 6.62 / Infiltration/Inflow 6.62 / Infiltration/Inflow Analysis 6.62 / Evaluation Survey 6.64 / Rehabilitation 6.69 / Infiltration Correction 6.69 / Inflow Correction 6.71

Suspended Solids Treatment 6.71

Screens 6.74 / Coarse Screens 6.74 / Fine Screens 6.77 / Grit Chambers 6.77 / Gravity Grit Chambers 6.79 / Aerated Grit Chambers 6.80 / Sedimentation 6.80 / Sedimentation Processes 6.80 / Design Considerations 6.86 / Plain Sedimentation 6.87 / Chemical Sedimentation 6.92 / Flotation 6.93 / Dissolved Air Flotation 6.96 / Air Flotation 6.96 / Vacuum Flotation 6.96 / Centrifugation 6.97 / Filtration 6.97

Aerobic Biological Treatment 6.99

Activated Sludge 6.99 / Activated Sludge Processes 6.100 / Aeration System 6.106 / Aerobic Pond Systems 6.110 / Aerobic Ponds 6.113 / Facultative Ponds 6.113 / Aerated Ponds 6.114 / Trickling Filter 6.115 / Low-Rate Trickling Filter 6.121 / High-Rate Trickling Filter 6.121 / Roughing Filter 6.123 / Rotating Biological Contactor 6.123

Anaerobic Treatment 6.125

Biochemistry and Microbiology 6.125 / pH and Alkalinity Requirements 6.126 / Nutrient Requirements 6.127 / Temperature 6.127 / Toxicity 6.127 / Reactor Type 6.128 / Suspended-Growth Systems 6.128 / Fixed-Growth Systems 6.129 / Combination System 6.132 / Design Considerations 6.133

Land Treatment 6.135

Slow-Rate Systems 6.135 / Rapid Infiltration 6.143 / Overland Flow 6.146

Physical and Chemical Treatment 6.148

Equilization 6.149 / Flow Balance 6.149 / Composition Balance 6.149 / Flow and Composition Balance 6.152 / Mixing 6.152 / Spill Control 6.153 / Neutralization 6.154 / Temperature Control 6.157 / Oil and Grease Removal 6.160 / Free Oil 6.160 / Emulsions 6.165 / Heavy Metals Removal 6.170 / Post Aeration 6.172 / Diffused Aeration 6.172 / Mechanical Aeration 6.173 / Cascade Aeration 6.174 / U-Tube Aeration 6.174 / Disinfection 6.174 / Chlorination 6.174 / Dechlorination 6.177 / Ozonation 6.179 / Ultraviolet Irradiation 6.179

Advanced Treatment 6.180

Nitrogen Control 6.180 / Nitrification 6.181 / Denitrification 6.184 / Air Stripping 6.186 / Breakpoint Chlorination 6.186 / Ion Exchange 6.187 / Phosphorus Control 6.187 / Phosphorus Limitations 6.187 / Characterizations 6.188 / Influent Controls 6.188 / Treatment Process Controls 6.188 / Plant Operations 6.190 / Granular Media Filtration 6.191 / Design Considerations 6.191 / Filter Backwashing 6.192 / Carbon Adsorption 6.195 / Adsorption 6.195 / Regeneration 6.196 / Granular Activated Carbon 6.197 / Powdered Activated Carbon 6.201 / Ion Exchange 6.202 / Ion Exchange Resins 6.202 / Regeneration 6.204 / Operating Modes 6.205 / Design Considerations 6.205 / Reverse Osmosis 6.209 / Deep-Well Disposal 6.209

Sludge Handling 6.209

Stabilization 6.210 / Aerobic Digestion 6.210 / Anaerobic Digestion 6.214 / Chemical Stabilization 6.216 / Composting 6.216 / Heat Treatment 6.218 / Irradiation 6.218 / Lagooning 6.218 / Conditioning 6.218 / Chemical Conditioning 6.219 / Elutriation 6.219 / Heat Treatment 6.220 / Concentration 6.220 / Gravity Settling 6.221 / Dissolved Air Flotation 6.223 / Centrifugation 6.223 / Dewatering 6.224 / Centrifugation 6.224 / Drying Beds 6.228 / Drying Lagoons 6.232 / Vacuum Filters 6.232 / Pressure Filters 6.233 / Belt Filter Presses 6.236 / Drying 6.236 / Heat Treatment 6.239 / Incineration 6.241 / Pyrolysis 6.245 / Starved Air Combustion 6.247 / Wet-Air Oxidation 6.248 / Residual Disposal 6.248 / Landfill 6.250 / Land Application 6.257 / Chemical Fixation 6.264 / Deep-Well Injection 6.264

Treatment Facilities 6.264

Engineering Documents 6.264 / Engineering Report 6.264 / Plans and Specifications 6.265 / Process Design 6.265 / Physical Design 6.266 / Site Conditions 6.267 / Plant Layout 6.267 / Plant Hydraulics 6.267 /

Aesthetics 6.268 / Plant Utilities 6.268 / Operational Design 6.268 /
Reliability 6.269 / Safety 6.269 / Laboratory 6.269

References 6.270

Chapter 7. Stormwater Management 7.1

Rainfall 7.1

Occurrence and Distribution of Rainfall 7.1 / Convective Precipitation 7.2 /
Orographic Precipitation 7.3 / Cyclonic Precipitation 7.3 / Rainfall Data
Sources 7.3 / Raw Rainfall Data 7.3 / Rainfall Frequency Data 7.3 / Design
Storms 7.5 / Design Rainfall Frequency 7.9 / Intensity-Duration-Frequency
Relationships 7.9 / Design Hyetographs 7.11

Surface Runoff 7.13

Runoff Processes 7.14 / Hortonian Overland Flow 7.15 / Saturation Overland
Flow 7.15 / Subsurface Storm Flow 7.15 / Drainage Basin Parameters 7.15 /
Time of Concentration and Basin Lag 7.16 / Overland Flow Travel Time 7.16 /
Channel Travel Time 7.17 / Rational Method 7.18 / Hydrograph
Procedures 7.21 / SCS Curve Number Method 7.24 / Watershed Routing 7.31

River and Reservoir Routing 7.42

Channel Routing 7.43 / Muskingum Method 7.43 / Convex Method 7.44 /
Reservoir Routing 7.46

Nonpoint Source Pollution 7.50

Point versus Nonpoint Sources 7.50 / Types of Nonpoint Sources 7.50 /
Magnitude of Pollutant Sources 7.51 / Description of Nonpoint Sources 7.51 /
Urban Sources 7.52 / Rural Sources 7.54 / Atmospheric Deposition 7.54 /
Other Sources 7.54 / Water Quality Impacts 7.56 / Conservative Systems 7.56
/ Nonconservative Systems 7.56 / Design of Field Monitoring Programs 7.58 /
Manual versus Automatic Sampling 7.59 / Number and Location of
Stations 7.60 / Flow Measurement 7.60 / Water Sampling Methods 7.61 /
Other Monitoring 7.63 / Analysis of Monitoring Data 7.63 / Event Mean
Concentration 7.64 / Statistical Analysis 7.64 / Storm Loads 7.65 / Annual
Loads 7.65 / Nonpoint Source Models 7.65 / Loading Functions 7.65 /
Desktop Models 7.66 / Computer Models 7.71

Combined Sewer Overflows 7.81

Water Quality Characteristics 7.83 / Water Quality Control 7.86 /
Treatment 7.87

Stormwater Management Systems 7.88

Philosophy and Goals of Stormwater Management 7.88 / Common Drainage
Systems and Their Alternatives 7.89 / Curb-and-Gutter Storm Sewer
System 7.89 / Culverts and Swales 7.92 / Alternative Drainage Systems
7.94 / Infiltration 7.98 / Detention 7.110 / Sedimentation 7.115 /
Permanent Ponds and Wetlands 7.119

Legal, Institutional and Financial Implications 7.122

Legal Concepts 7.122 / Common Enemy Doctrine 7.123 / Civil Law
Doctrine 7.123 / Reasonable Use Doctrine 7.123 / Federal Role in Stormwater
Management 7.124 / State Role in Stormwater Management 7.125 / Municipal
Role in Stormwater Management 7.125 / Financing of Stormwater Management
Programs 7.126 / Authority to Establish Drainage Control Programs 7.127 /
Cost Apportionment Methods 7.128 / Allocating Costs between Present and
Future Residents 7.129 / Stormwater Drainage Utilities 7.129 / Stormwater

Drainage Ordinances 7.130 / New Development 7.130 / Existing Development 7.130

References 7.130

Chapter 8. Solid Waste

8.1

Solid Waste—Source and Effect 8.1

Source 8.1 / Residential Waste Generation 8.1 / Nonresidential Waste Generation 8.2 / Effect 8.2

Solid Waste Characterization 8.4

Solid Waste Constituents 8.7 / Sampling Methodology 8.8 / Truckload Sampling 8.9 / Planning the Sorting Program 8.9 / Sorting Methodology 8.12 / Compositing Samples 8.14 / Data Summaries 8.17 / Constituent Makeup 8.17 / Laboratory Analysis 8.20 / Spot Sampling 8.25 / Curbside Weighing Program 8.31 / Characterization Program Perspective 8.33

Collection and Transfer Operations 8.36

Collection Practices 8.36 / Service Arrangements 8.37 / Collection System Administration 8.38 / Service Level 8.43 / Residential Collection 8.43 / Commercial Collection 8.51 / Storage Containers 8.52 / Containers for Manual Collection 8.52 / Containers for Mechanized Collection 8.52 / Unacceptable Containers 8.54 / Collection Equipment 8.54 / Residential Collection Vehicles 8.54 / Commercial Collection Vehicles 8.57 / Routing 8.58 / Collection Area 8.59 / Disposal Area 8.59 / Collection Zones 8.59 / Daily Vehicle Assignment 8.60 / Service Stops 8.60 / District Routes 8.61 / Heuristic Routing 8.61 / Source Separation 8.62 / Collection Practices 8.64 / Separation Volumes 8.64 / Antiscavenging Ordinance 8.64 / Rural Collections 8.64 / Transfer Operations 8.65 / Transfer Station Economics 8.65 / Transfer Station Locations 8.66 / Transfer Station Design 8.66 / Transfer Techniques 8.69 / Transfer Station Equipment 8.70 / Mobile Equipment 8.71 / Backup Equipment 8.73 / Transfer Station Staffing 8.73

Processing 8.73

Shredding 8.74 / Types of Shredders 8.74 / Design Considerations 8.75 / Shredder Selection 8.76 / Shredder Rating 8.79 / Special Design Aspects 8.79 / Trommel Screens 8.81 / Design Considerations 8.81 / Trommel Selection 8.82 / Magnetic Ferrous Separation 8.83 / Types of Magnetic Separators 8.84 / Design Considerations 8.85 / Air Classification 8.86 / Design Considerations 8.87 / Air Classifier Performance 8.87 / Baling 8.87 / Baler Operation 8.87 / Baler Selection 8.89 / Bale Stability 8.90 / Balefill 8.90

Recovery and Reuse 8.92

Energy from Solid Waste 8.92 / Heating Values 8.92 / Energy Recovery Technologies 8.94 / Refuse-Derived Fuels 8.100 / Fuel Product Classification 8.100 / Heating Value 8.101 / Ferrous Metals 8.102 / Magnetic Separation 8.104 / Markets 8.105 / Nonferrous Metals 8.106 / Mechanical Separation 8.107 / Product Quality 8.111 / Glass Products 8.111 / Froth Flotation Separation 8.112 / Optical Separation 8.114 / Paper and Plastics 8.115

Treatment and Disposal 8.117

Sanitary Landfill 8.117 / Preliminary Determination of Landfill Requirements 8.117 / Site Selection 8.119 / Hydrogeologic and Soils Investigation of Selected Site 8.120 / Preliminary Design 8.121 / Final Design 8.134 / Land Reclamation 8.137 / Composting 8.137 / Public Health

Issues 8.137 / Biological Processes 8.138 / Process Flow 8.139 / Design Considerations 8.140 / Methods of Composting 8.141 / Economics 8.143 / Utilization and Marketing 8.144 / Incineration 8.145 / Nature of the Fuel 8.146 / Plant Design 8.148 / Residue Handling 8.152 / Furnace Design 8.153 / Boilers 8.163 / Air Pollution Control 8.165 / Operational Experience 8.172 / Pyrolysis and Gasification Processes 8.173 / Energy/Fuel Recovery 8.175 / Reactor Systems 8.178 / Advantages over Direct Incineration 8.187 / Wet Oxidation 8.189

References 8.189

Chapter 9. Hazardous Waste

9.1

Hazardous Waste—Source and Effect 9.1

Sources of Hazardous Wastes 9.2 / Generation 9.2 / Transportation 9.3 / Treatment and Disposal 9.4 / Effects of Hazardous Wastes 9.4 / Health 9.4 / Safety 9.4 / Property 9.4 / Environment 9.5

Characterization 9.6

Characteristics 9.6 / Properties 9.6 / Delisting 9.9 / Sampling, Preservation, and Handling 9.10 / Analysis 9.13 / Compatibility 9.16 / Manifest 9.18

Waste Treatment 9.18

Liquid Waste Treatment 9.19 / Activated Carbon 9.20 / Air Stripping 9.20 / Biological Processes 9.24 / Chemical Precipitation 9.25 / Filtration 9.25 / Ion Exchange 9.27 / Neutralization 9.27 / Oxidation-Reduction 9.27 / Reverse Osmosis 9.28 / Sorptive Resins 9.28 / Gaseous Waste Treatment 9.29 / Absorption 9.29 / Adsorption 9.29 / Flaring 9.29 / Solid Waste Treatment 9.29 / Solids Separation 9.29 / Dewatering 9.31 / Land Disposal 9.34 / Landfills 9.34 / Surface Impoundments 9.35 / Land Application 9.35 / Deep-Well Injection 9.36 / Solidification and Stabilization 9.36 / Cement Processes 9.40 / Pozzolanic Processes 9.40 / Thermoplastic Processes 9.40 / Organic Polymer Processes 9.40 / Thermal Destruction 9.40 / Combustion 9.41 / Gasification 9.41 / Liquefaction 9.41 / Wet Oxidation 9.41

Remedial Action 9.43

Surface Water Control 9.43 / Capping 9.43 / Floating Covers 9.50 / Grading 9.50 / Revegetation 9.50 / Diversion and Collection 9.52 / Groundwater Control 9.52 / Groundwater Pumping 9.52 / Subsurface Drains 9.53 / Subsurface Barriers 9.54 / Air Pollution Control 9.55 / Gas Emission Control 9.55 / Fugitive Dust Control 9.58 / Gas Control 9.60 / Passive Gas Collection 9.60 / Active Gas Collection 9.60 / In Situ Treatment 9.63 / Biological Treatment 9.63 / Chemical Treatment 9.63 / Physical Treatment 9.65 / Waste and Soil Disposal 9.67 / Sediment Disposal 9.67

Underground Storage Tanks 9.69

Underground Tank Design 9.69 / Leak Detection 9.71 / Tank Monitoring 9.73 / Containment Migration 9.73 / Corrective Actions 9.76 / Corrective Action Technologies 9.76 / Initial Response Actions 9.76 / Permanent Response Actions 9.83

Low-Level Radioactive Waste 9.83

Principles of Radiation Protection 9.87 / Radiation: Source and Effect 9.87 / Radiation Protection Guidelines 9.96 / Radiation Protection Methods 9.98 / Nuclide Characteristics 9.100 / Low-Level Waste Regulations 9.111 / Waste

Classification 9.111 / Waste Package Requirements 9.111 / Transportation Regulations 9.112 / Treatment and Processing Methods 9.112

References 9.119

Chapter 10. Environmental Assessment

10.1

Legislative Requirements 10.1

National Environmental Policy Act 10.1 / Purpose 10.6 / Title I 10.6 / Title II 10.7

CEQ Regulations and Environmental Documents 10.8

Environmental Documents 10.8 / Notice of Intent 10.9 / Environmental Assessment 10.9 / Draft Environmental Impact Statement 10.9 / Final Environmental Impact Statement 10.9 / Finding of No Significant Impact 10.9 / Record of Decision 10.10 / EIS Format and Content 10.11 / Cover Sheet 10.11 / Summary 10.11 / Table of Contents 10.11 / Purpose and Need 10.11 / Alternatives, Including the Proposed Action 10.11 / Affected Environment 10.14 / Environmental Consequences 10.14 / List of Preparers 10.14 / Agencies, Organizations and Persons to Whom Copies Are Sent 10.14 / Index 10.14 / Appendix 10.15 / Processing Environmental Documents 10.15 / Notice of Intent 10.15 / Environmental Assessment 10.15 / Draft EIS 10.15 / Final EIS 10.16 / Finding of No Significant Impact 10.17 / Record of Decision 10.17 / Timing of Agency Action 10.17

Public Participation 10.18

Effective Public Participation 10.18 / Public Information and Public Involvement 10.18 / Participation as a Group Member 10.20 / Benefits from an Effective Public Participation Program 10.20

Environmental Impacts 10.20

Impact Types 10.21 / Direct Impacts 10.21 / Indirect Impacts 10.21 / Cumulative Impacts 10.21 / Identification of Impacts 10.21 / Measurement of Impact 10.22 / Aggregation 10.22

Resource Factors 10.22

Categories of Environmental Resource Factors 10.23 / Atmosphere 10.23 / Water 10.24 / Land 10.26 / Biological Environment 10.26 / Sound 10.27 / Human Aspects 10.27 / Economic Aspects 10.28 / Environmentally Sensitive Areas 10.28 / Human Health and Safety 10.29 / Threatened Species 10.29 / Nonrenewable Resources 10.29 / Aesthetics 10.29 / Cultural Resources 10.29

Alternatives 10.29

Types of Alternatives 10.30 / No Action 10.30 / Reasonable Alternatives 10.30 / Preferred Alternatives 10.30 / Mitigation Measures 10.30 / Alternative Analysis 10.30

Assessment Preparation and Review 10.31

The Interdisciplinary Team 10.32 / Baseline Studies 10.32 / Conditions Prior to the Activity 10.32 / Geographic Characteristics 10.32 / Temporal Characteristics 10.33 / Scoping 10.33 / Assessment Methodologies 10.34 / Ad Hoc 10.34 / Overlays 10.34 / Checklists 10.34 / Matrices 10.34 / Networks 10.34 / Combination Computer-Aided Methods 10.34 / Document Preparation 10.35 / Document Review 10.36 / Review Situations 10.36 / Types of Review 10.36

References 10.37

Index I.1