

Foreword

The Water Resources Management Division of the Department of Environment and Conservation considers the Guidelines for the Design, Construction and Operation of Water and Sewerage Systems as an integral part of its regulatory program directed at ensuring public health and environmental protection.

This document supersedes April 1980 version of the “Guidelines for the Design, Construction and Operation of Water and Sewerage Systems”. During the preparation of the current document, the main objectives were: (i) to keep pace with the new development in water and sewer industry and provide appropriate guidance and (ii) to ensure the consistency between the content of guidelines document and the master specifications document. The document provides general guidance on good engineering practices for design, construction, operation and maintenance aspects of water and sewerage systems.

As a part of the review process, the Water Resources Management Division referred and reviewed: the Nova Scotia Department of Environment Standards and Guidelines Manual For The Collection, Treatment and Disposal of Sanitary Sewage; the Alberta Environmental Protection Standards and Guidelines For Municipal Waterworks, Wastewater and Storm Drainage Systems; the Atlantic Canada Standards and Guidelines Manual For The Collection, Treatment and Disposal of Sanitary Sewage; the Great Lakes-Upper Mississippi River Board of State Public Health & Environmental Managers Recommended Standards For Water Works and the Recommended Standards For Wastewater Facilities; the Government of Newfoundland and Labrador Municipal Water, Sewer and Road Specifications, and et al. We also provided the earlier draft of the document to appropriate government departments, municipal staff, builders and contractors, and consultants, for their review and comments. The review comments have improved the quality of the document and reviewer’s contribution is very much appreciated.

I would like to extend special thanks to Deneen Spracklin for coordinating the overall completion of this project. I would also like to take this opportunity to acknowledge the work of Ron Goulding, Herbert Card, Erik Neilson and Chris Blanchard in revising and re-writing the various sections of this document, and thank them for the excellent contribution during numerous project meetings.

The previous version of this document was shared with the Water Resources Management Division, Department of Municipal Affairs, Department of Government Services, and Consulting Engineers. The staff of these agencies provided valuable comments which have been incorporated in this version.

Haseen Khan, P.Eng.
Manager

Table of Contents

1.0	Approval by Regulatory Authority	1-1
1.1	Submission	1-1
1.2	Review Period	1-1
1.3	Permits	1-1
1.4	Payment	1-1
1.5	Limits of Review and Approval	1-2
 2.0	 Project Reports.....	 2-1
2.1	Preliminary Engineering Report.....	2-1
2.2	Technical Report.....	2-1
2.2.1	Population	2-2
2.2.2	General Considerations	2-2
2.1.1	Ocean Outfalls	2-3
2.1.2	Industrial, Institutional or Commercial Wastes	2-3
2.1.3	Regulations	2-3
 3.0	 Water Works	 3-1
3.1	General.....	3-1
3.1.1	Plant Layout	3-1
3.1.2	Building Layout	3-1
3.1.3	Location of Structures	3-1
3.1.4	Electrical Controls	3-2
3.1.5	Standby Power	3-2
3.1.6	Shop Space and Storage	3-2
3.1.7	Laboratory Equipment	3-2
3.1.8	Monitoring Equipment	3-2
3.1.9	Sample Taps	3-3
3.1.10	Facility Water Supply	3-3
3.1.11	Wall Castings	3-3
3.1.12	Meters	3-3
3.1.13	Piping Colour Code.....	3-3
3.1.13.1	Water Lines	3-3
3.1.13.2	Chemical Lines	3-4
3.1.13.3	Waste Lines	3-4
3.1.13.4	Other	3-4
3.1.14	Disinfection	3-5

3.1.15	Operation and Maintenance Manuals and Parts Lists.....	3-5
3.1.16	Operator Instruction.....	3-5
3.1.17	Other Considerations	3-5
3.2	Source Development	3-5
3.2.1	Environmental Assessment Process for Source Development	3-6
3.2.2	Control of Organic Contamination for Public Water Supplies.....	3-6
3.2.3	Surface Water.....	3-8
3.2.3.1	Surface Water Quantity Assessment.....	3-8
3.2.3.2	Quality.....	3-9
3.2.3.3	Minimum Treatment	3-9
3.2.3.4	Design of Intake Structures.....	3-9
3.2.3.5	Wet Wells.....	3-10
3.2.3.6	Upground Reservoir	3-11
3.2.3.7	Impoundments and Reservoirs	3-11
3.2.3.7.1	Site Preparation.....	3-11
3.2.3.7.2	Construction.....	3-11
3.2.4	Groundwater	3-11
3.2.4.1	Quantity.....	3-11
3.2.4.2	Auxiliary Power	3-12
3.2.4.3	Quality.....	3-12
3.2.4.3.1	Microbiological Quality.....	3-12
3.2.4.3.2	Physical and Chemical Quality.....	3-12
3.2.4.4	Protection Management	3-12
3.2.4.4.1	Well Location.....	3-12
3.2.4.4.2	Continued Sanitary Protection	3-12
3.2.4.4.3	Wellhead Protection.....	3-13
3.2.4.5	Testing and Records.....	3-13
3.2.4.5.1	Yield and Drawdown Tests.....	3-13
3.2.4.5.2	Plumbness and Alignment Requirements	3-13
3.2.4.5.3	Geological Data	3-13
3.2.4.6	General Well Construction	3-14
3.2.4.6.1	Drilling Fluids and Additives.....	3-14
3.2.4.6.2	Minimum Protected Depths	3-14
3.2.4.6.3	Temporary Steel Casing.....	3-14
3.2.4.6.4	Permanent Steel Casing	3-14
3.2.4.6.5	Nonferrous Casing Materials	3-15
3.2.4.6.6	Packers	3-15
3.2.4.6.7	Screens	3-15
3.2.4.6.8	Grouting Requirements.....	3-16
3.2.4.6.9	Upper Terminal Well Construction	3-17
3.2.4.6.10	Development.....	3-17

3.2.4.6.11	Disinfection of New, Modified or Reconditioned Groundwater Sources.....	3-18
3.2.4.6.12	Capping Requirements.....	3-18
3.2.4.6.13	Well Abandonment.....	3-18
3.2.4.7	Aquifer Types and Construction Methods – Special Conditions.....	3-18
3.2.4.7.1	Sand or Gravel Wells.....	3-18
3.2.4.7.2	Gravel Pack Wells.....	3-19
3.2.4.7.3	Radial Water Collector.....	3-19
3.2.4.7.4	Infiltration Lines.....	3-19
3.2.4.7.5	Dug Wells.....	3-20
3.2.4.7.6	Limestone or Sandstone Wells.....	3-20
3.2.4.7.7	Naturally Flowing Wells.....	3-20
3.2.4.8	Well Pumps, Discharge Piping and Appurtenances.....	3-20
3.2.4.8.1	Line Shaft Pumps.....	3-20
3.2.4.8.2	Submersible Pumps.....	3-20
3.2.4.8.3	Discharge Piping.....	3-21
3.2.4.8.4	Pitless Well Units.....	3-21
3.2.4.8.5	Casing Vent.....	3-22
3.2.4.8.6	Water Level Measurement.....	3-22
3.2.4.8.7	Observation Wells.....	3-22
3.2.5	Langelier Index.....	3-23
3.2.6	pH Adjustment.....	3-23
3.2.7	Source Protection.....	3-23
3.3	Water Treatment.....	3-24
3.3.1	Clarification.....	3-24
3.3.1.1	Presedimentation.....	3-24
3.3.1.2	Rapid Mix.....	3-25
3.3.1.3	Flocculation.....	3-25
3.3.1.3.1	Detention.....	3-25
3.3.1.3.2	Equipment.....	3-25
3.3.1.3.3	Piping.....	3-25
3.3.1.3.4	Alternate Design.....	3-25
3.3.1.3.5	Superstructure.....	3-26
3.3.1.4	Sedimentation.....	3-26
3.3.1.4.1	Detention.....	3-26
3.3.1.4.2	Inlet.....	3-26
3.3.1.4.3	Outlet.....	3-26
3.3.1.4.4	Velocity.....	3-26
3.3.1.4.5	Overflow.....	3-26
3.3.1.4.6	Drainage.....	3-27

3.3.1.4.7	Superstructure	3-27
3.3.1.4.8	Sludge Collection.....	3-27
3.3.1.4.9	Flushing Lines.....	3-27
3.3.1.4.10	Safety	3-27
3.3.1.4.11	Sludge Removal.....	3-27
3.3.1.4.12	Sludge Disposal	3-27
3.3.1.5	Solids Contact Unit.....	3-27
3.3.1.5.1	Installation of Equipment.....	3-28
3.3.1.5.2	Operating Equipment.....	3-28
3.3.1.5.3	Chemical Feed	3-28
3.3.1.5.4	Mixing.....	3-28
3.3.1.5.5	Flocculation.....	3-28
3.3.1.5.6	Sludge Concentrators	3-28
3.3.1.5.7	Sludge Removal	3-28
3.3.1.5.8	Cross-connections.....	3-28
3.3.1.5.9	Detention Period	3-29
3.3.1.5.10	Suspended Slurry Concentrate.....	3-29
3.3.1.5.11	Water Losses.....	3-29
3.3.1.5.12	Weirs or Orifices.....	3-29
3.3.1.5.13	Upflow Rates	3-29
3.3.1.6	Tube or Plate Settlers.....	3-30
3.3.2	Filtration.....	3-30
3.3.2.1	Rapid Rate or Gravity Filters.....	3-31
3.3.2.1.1	Pretreatment	3-31
3.3.2.1.2	Rate of Filtration.....	3-31
3.3.2.1.3	Number of Units	3-31
3.3.2.1.4	Structural Details and Hydraulics	3-31
3.3.2.1.5	Washwater Troughs	3-32
3.3.2.1.6	Filter Material	3-32
3.3.2.1.7	Filter Bottoms and Strainer Systems.....	3-34
3.3.2.1.8	Surface Wash or Subsurface Wash.....	3-34
3.3.2.1.9	Air Scouring.....	3-35
3.3.2.1.10	Appurtenances.....	3-35
3.3.2.1.11	Backwash	3-36
3.3.2.1.12	Miscellaneous	3-37
3.3.2.2	Rapid Rate Pressure Filters.....	3-37
3.3.2.2.1	Rate of Filtration.....	3-37
3.3.2.2.2	Details of Design.....	3-37
3.3.2.3	Diatomaceous Earth Filtration	3-38
3.3.2.3.1	Conditions of Use	3-38
3.3.2.3.2	Pilot Plant Study	3-38

3.3.2.3.3	Types of Filters	3-38
3.3.2.3.4	Treated Water Storage	3-38
3.3.2.3.5	Number of Units	3-39
3.3.2.3.6	Pre-coat	3-39
3.3.2.3.7	Body Feed	3-39
3.3.2.3.8	Filtration.....	3-39
3.3.2.3.9	Backwash	3-40
3.3.2.3.10	Appurtenances.....	3-40
3.3.2.3.11	Monitoring	3-40
3.3.2.4	Slow Sand Filters	3-40
3.3.2.4.1	Quality of Raw Water	3-40
3.3.2.4.2	Number of Units	3-40
3.3.2.4.3	Structural Details and Hydraulics	3-40
3.3.2.4.4	Rates of Filtration	3-41
3.3.2.4.5	Underdrains.....	3-41
3.3.2.4.6	Filtering Material	3-41
3.3.2.4.7	Filter Gravel.....	3-41
3.3.2.4.8	Depth of Water on Filter Beds	3-41
3.3.2.4.9	Control Appurtenances	3-42
3.3.2.4.10	Ripening.....	3-42
3.3.2.5	Direct Filtration.....	3-42
3.3.2.5.1	Technical Report.....	3-42
3.3.2.5.2	Pilot Plant Studies.....	3-42
3.3.2.5.3	Pretreatment – Rapid Mix and Flocculation	3-43
3.3.2.5.4	Filtration.....	3-43
3.3.2.5.5	Siting Requirements.....	3-43
3.3.2.6	Deep Bed Rapid Rate Gravity Filters	3-43
3.3.2.7	Biologically Active Filters.....	3-44
3.3.2.8	Membrane Filtration for Treating Surface Sources	3-44
3.3.2.8.1	Characteristics.....	3-44
3.3.2.8.2	Selection and Design Considerations.....	3-45
3.3.2.9	Reverse Osmosis.....	3-46
3.3.2.10	Bag and Cartridge Filters.....	3-47
3.3.2.10.1	Pre-design/Design	3-48
3.3.2.10.1	Operations.....	3-50
3.3.3	Softening.....	3-50
3.3.3.1	Lime or Lime-Soda Process.....	3-50
3.3.3.1.1	Chemicals.....	3-51
3.3.3.1.2	Reaction Basin	3-51
3.3.3.1.3	Hydraulics.....	3-51
3.3.3.1.4	Aeration.....	3-51

3.3.3.1.5	Stabilization	3-51
3.3.3.1.6	Sludge Collection and Disposal	3-52
3.3.3.1.7	Disinfection.....	3-52
3.3.3.1.8	Plant Start-up	3-52
3.3.3.2	Cation Exchange Program	3-52
3.3.3.2.1	Design	3-52
3.3.3.2.2	Capacity	3-52
3.3.3.2.3	Depth of Resin	3-53
3.3.3.2.4	Rate of Flow.....	3-53
3.3.3.2.5	Freeboard	3-53
3.3.3.2.6	Underdrains and Supporting Gravel	3-53
3.3.3.2.7	Distribution of Brine.....	3-53
3.3.3.2.8	Cross-connection Control	3-53
3.3.3.2.9	Bypass.....	3-53
3.3.3.2.10	Additional Limitations.....	3-53
3.3.3.2.11	Wet Salt Storage Tanks and Brine Tanks	3-53
3.3.3.2.12	Stabilization	3-54
3.3.3.2.13	Sampling Taps	3-54
3.3.3.2.14	Waste Disposal.....	3-54
3.3.3.2.15	Construction Materials.....	3-54
3.3.3.2.16	Housing.....	3-54
3.3.3.3	Water Quality Test Equipment	3-54
3.3.4	Aeration.....	3-55
3.3.4.1	Natural Draft Aeration	3-55
3.3.4.2	Forced or Induced Draft.....	3-55
3.3.4.3	Spray Aeration	3-56
3.3.4.4	Pressure Aeration.....	3-56
3.3.4.5	Packed Tower Aeration.....	3-56
3.3.4.5.1	Process Design.....	3-57
3.3.4.5.2	Materials of Construction	3-57
3.3.4.5.3	Water Flow System.....	3-57
3.3.4.5.4	Air Flow System	3-58
3.3.4.5.5	Other Features.....	3-59
3.3.4.5.6	Environmental Factors.....	3-59
3.3.4.6	Other Methods of Aeration	3-59
3.3.4.7	Protection of Aerators	3-60
3.3.4.8	General Design.....	3-60
3.3.4.8.1	Wind Protection	3-60
3.3.4.8.2	Disinfection.....	3-60
3.3.4.8.3	Bypass.....	3-60
3.3.4.8.4	Contamination.....	3-60
3.3.4.8.5	Corrosion Control	3-60

3.3.4.8.6	Quality Control	3-62
3.3.5	Iron and Manganese Removal	3-62
3.3.5.1	Removal by Oxidation, Detention and Filtration.....	3-62
3.3.5.1.1	Oxidation.....	3-62
3.3.5.1.2	Detention.....	3-62
3.3.5.1.3	Filtration.....	3-62
3.3.5.2	Removal by Lime-Soda Softening Process.....	3-63
3.3.5.3	Removal by Manganese Coated Media Filtration	3-63
3.3.5.4	Removal by Units Regenerated with Potassium Permanganate.....	3-63
3.3.5.5	Removal by Ion Exchange.....	3-63
3.3.5.6	Sequestration by Polyphosphates.....	3-63
3.3.5.7	Sequestration by Sodium Silicates.....	3-64
3.3.5.8	Sampling Taps	3-64
3.3.5.9	Testing Equipment.....	3-64
3.3.6	Nitrate Removal Using Sulphate Selective Anion Exchange Resin.....	3-65
3.3.6.1	Special Caution	3-65
3.3.6.2	Pretreatment Requirement	3-65
3.3.6.3	Design	3-65
3.3.6.4	Exchange Capacity.....	3-65
3.3.6.5	Flow Rates	3-66
3.3.6.6	Freeboard	3-66
3.3.6.7	Miscellaneous Appurtenances	3-66
3.3.6.8	Monitoring	3-66
3.3.6.9	Waste Disposal.....	3-66
3.3.6.10	Additional Limitations	3-66
3.3.7	Taste and Odour Control.....	3-66
3.3.7.1	Flexibility.....	3-66
3.3.7.2	Chlorination	3-66
3.3.7.3	Chlorine Dioxide.....	3-67
3.3.7.4	Powdered Activated Carbon	3-67
3.3.7.5	Granular Activated Carbon.....	3-67
3.3.7.6	Copper Sulphate and Other Copper Compounds.....	3-67
3.3.7.7	Aeration.....	3-68
3.3.7.8	Potassium Permanganate	3-68
3.3.7.9	Ozone	3-68
3.3.7.10	Other Methods for Taste and Odour Control.....	3-68
3.3.8	Fluoridation.....	3-68
3.3.8.1	Approval of Fluoridation Program.....	3-68
3.3.8.2	Fluoride Compounds.....	3-69
3.3.8.3	Fluoride Storage Facilities	3-69

3.3.8.4	Chemical Feeders.....	3-69
3.3.8.5	Protective Equipment.....	3-70
3.3.8.6	Dust Control.....	3-70
3.3.8.6.1	Dry Conveyors.....	3-70
3.3.8.6.2	Dust Control Procedures.....	3-71
3.3.8.6.3	Approval.....	3-71
3.3.8.7	Testing Equipment.....	3-71
3.3.9	Chemical Application.....	3-72
3.3.9.1	Choice of Chemicals.....	3-72
3.3.9.2	Chemical Feed Devices.....	3-72
3.3.9.3	Mixing Chamber.....	3-72
3.3.10	Pre-engineered Water Treatment Plants.....	3-73
3.3.11	Automated/Unattended Operation of Surface Water Treatment Plants.....	3-74
3.3.12	Waste Handling and Disposal.....	3-76
3.3.12.1	Specific Wastes.....	3-76
3.3.12.1.1	Sanitary Waste.....	3-76
3.3.12.1.2	Brine Waste.....	3-76
3.3.12.1.3	Sludge.....	3-76
3.3.12.1.4	Red Water Waste.....	3-78
3.3.12.1.5	Filter Wash Water.....	3-78
3.3.12.2	Waste Disposal.....	3-78
3.3.12.2.1	Sand Filters.....	3-78
3.3.12.2.2	Wastewater Treatment Ponds (Lagoons).....	3-79
3.3.12.2.3	Recycling Waste Filtrates.....	3-80
3.4	Chemical Application.....	3-80
3.4.1	Approval.....	3-80
3.4.2	General Equipment Design.....	3-81
3.4.3	Facility Design.....	3-81
3.4.3.1	Number of Feeders.....	3-81
3.4.3.2	Control of Facility.....	3-81
3.4.3.3	Dry Chemical Feeders.....	3-82
3.4.3.4	Positive Displacement Solution Pumps.....	3-82
3.4.3.5	Liquid Chemical Feeders – Siphon Control.....	3-82
3.4.3.6	Cross-connection Control.....	3-83
3.4.3.7	Chemical Feed Equipment Location.....	3-83
3.4.3.8	In-plant Water Supply.....	3-83
3.4.3.9	Storage of Chemicals.....	3-83
3.4.3.10	Solution Tanks.....	3-84
3.4.3.11	Day Tanks.....	3-85
3.4.3.12	Feed Lines.....	3-85

3.4.3.13	Handling.....	3-86
3.4.3.14	Housing.....	3-86
3.4.4	Chemicals.....	3-86
3.4.4.1	Shipping Containers.....	3-86
3.4.4.2	Specifications.....	3-86
3.4.4.3	Assay.....	3-86
3.4.5	Operator Safety.....	3-87
3.4.5.1	Ventilation.....	3-87
3.4.5.2	Protective Equipment.....	3-87
3.4.6	Specific Chemicals.....	3-87
3.4.6.1	Acids and Caustics.....	3-87
3.4.6.2	Sodium Chlorite for Chlorine Dioxide Generation.....	3-87
3.5	Pumping Facilities.....	3-88
3.5.1	Location.....	3-88
3.5.2	Pumping Stations.....	3-89
3.5.2.1	Suction Well.....	3-89
3.5.2.2	Equipment Servicing.....	3-89
3.5.2.3	Stairways and Ladders.....	3-89
3.5.2.4	Heating.....	3-90
3.5.2.5	Ventilation.....	3-90
3.5.2.6	Dehumidification.....	3-90
3.5.2.7	Lighting.....	3-90
3.5.2.8	Sanitary and Other Conveniences.....	3-90
3.5.3	Pumps.....	3-91
3.5.3.1	Suction Lift.....	3-91
3.5.3.2	Priming.....	3-91
3.5.4	Booster Pumps.....	3-91
3.5.4.1	Duplicate Pumps.....	3-91
3.5.4.2	Metering.....	3-91
3.5.4.3	Inline Booster Pumps.....	3-92
3.5.4.4	Individual Home Booster Pumps.....	3-92
3.5.5	Automatic and Remote Controlled Pumping Stations.....	3-92
3.5.6	Appurtenances.....	3-92
3.5.6.1	Valves.....	3-92
3.5.6.2	Piping.....	3-92
3.5.6.3	Gauges and Meters.....	3-92
3.5.6.4	Water Seals.....	3-93
3.5.6.5	Controls.....	3-93
3.5.6.6	Standby Power.....	3-93

3.5.6.7	Water Pre-lubrication.....	3-93
3.6	Finished Water Storage.....	3-94
3.6.1	Definitions.....	3-94
3.6.2	Hydropneumatic Systems	3-94
3.6.3	Materials of Construction	3-95
3.6.3.1	Standards and Materials Selection.....	3-95
3.6.3.2	Steel Construction.....	3-95
3.6.3.3	Concrete Construction	3-95
3.6.4	Design Criteria.....	3-95
3.6.4.1	Demand Equalization (Peak Balancing Storage).....	3-96
3.6.4.2	System Operation (Convenience).....	3-96
3.6.4.3	Smoothing Pumping Requirements	3-96
3.6.4.4	Reducing Power Costs.....	3-96
3.6.4.5	Emergency Storage.....	3-96
3.6.4.6	Fire Storage.....	3-96
3.6.4.7	Pressure Surge Relief.....	3-96
3.6.4.8	Detention Time	3-97
3.6.4.9	Blending of water Sources.....	3-97
3.6.5	Sizing of Water Storage Facilities	3-97
3.6.5.1	Fire Flow Storage Requirements	3-98
3.6.5.2	Peak Balancing Storage Requirements.....	3-98
3.6.5.3	Emergency Storage.....	3-98
3.6.5.4	Dead Storage.....	3-98
3.6.5.5	Turnover and Water Quality.....	3-99
3.6.5.6	Plant Storage.....	3-99
3.6.5.6.1	Clearwell Storage.....	3-99
3.6.6	Location of Distribution Storage	3-99
3.6.6.1	Elevated Storage	3-99
3.6.6.2	Above Ground and In-Ground Storage Reservoirs.....	3-100
3.6.7	Facility Requirements.....	3-100
3.6.7.1	Inlet/Outlet and Baffle Wall.....	3-100
3.6.7.2	Level Control	3-100
3.6.7.3	Overflow	3-100
3.6.7.4	Drainage of Storage Structures.....	3-101
3.6.7.5	Roof Drainage.....	3-101
3.6.7.6	Roof and Sidewall.....	3-101
3.6.7.7	Vents	3-102
3.6.7.8	Frost Protection.....	3-102
3.6.7.9	Internal Catwalk.....	3-102
3.6.7.10	Silt Stop.....	3-102
3.6.7.11	Grading	3-102
3.6.7.12	Corrosion Prevention/Reduction.....	3-103

3.6.7.13	Disinfection.....	3-103
3.6.7.14	Provisions for Sampling.....	3-103
3.6.7.15	Adjacent Compartments.....	3-103
3.6.7.16	Basins and Wet-wells.....	3-103
3.6.7.17	Standby Power	3-104
3.6.8	Water Treatment Plant Storage.....	3-104
3.6.8.1	Backwash Tanks	3-104
3.6.8.2	Clearwell.....	3-104
3.6.8.3	Adjacent Compartments.....	3-104
3.6.8.4	Wet-wells	3-104
3.6.9	Hydropneumatic Tanks.....	3-104
3.6.9.1	Location	3-105
3.6.9.2	Sizing	3-105
3.6.9.3	Piping.....	3-105
3.6.9.4	Appurtenances.....	3-105
3.6.10	Security/Safety.....	3-105
3.6.10.1	Access	3-105
3.6.10.2	Safety	3-106
3.6.10.3	Protection	3-106
3.7	Watermains	3-106
3.7.1	Definitions.....	3-106
3.7.2	Materials	3-107
3.7.2.1	Standards, Materials Selection.....	3-107
3.7.2.2	Used Materials	3-108
3.7.2.3	Joints	3-108
3.7.2.4	Corrosion Prevention/Reduction.....	3-108
3.7.3	Design Criteria – Transmission and Distribution Systems	3-108
3.7.3.1	Transmission and Distribution Pipelines	3-108
3.7.3.2	Water Demands.....	3-109
3.7.3.3	Pressure.....	3-110
3.7.3.4	Diameter.....	3-110
3.7.3.5	Small Mains for Domestic Services.....	3-111
3.7.3.6	Velocity.....	3-111
3.7.3.7	Dead Ends/Looping Requirements	3-111
3.7.3.8	Fire Protection.....	3-111
3.7.3.9	Fire Pumps	3-111
3.7.3.10	Drain/Flushing Devices	3-112
3.7.3.11	Valves	3-112
3.7.3.12	Valve Location.....	3-112
3.7.3.13	Air Relief and Vacuum Valves.....	3-112
3.7.3.14	Flow Monitoring.....	3-113

3.7.3.15	Crossing Obstacles.....	3-113
3.7.3.15.1	Road Crossings	3-113
3.7.3.15.2	Sewers	3-113
3.7.3.15.3	Surface Water Crossings.....	3-113
3.7.3.15.4	Horizontal Drillings	3-113
3.7.3.16	Bedding.....	3-114
3.7.3.17	Cover.....	3-114
3.7.3.18	Warning/marker and Detection Tape.....	3-114
3.7.3.19	Thrust Restraint.....	3-114
3.7.3.20	Pressure and Leakage Testing.....	3-114
3.7.3.21	Disinfection.....	3-114
3.7.3.22	Commissioning	3-114
3.7.4	Hydrants.....	3-115
3.7.4.1	Location and Spacing.....	3-115
3.7.4.2	Valves and Nozzles.....	3-115
3.7.4.3	Hydrant Leads.....	3-115
3.7.4.4	Drainage.....	3-115
3.7.4.5	Frost Protection.....	3-116
3.7.5	Valve and Metering Chambers	3-116
3.7.5.1	Chamber Construction	3-116
3.7.5.2	Air Relief and Vacuum Valve Chambers	3-116
3.7.5.3	Flow Measurement and Meter Chamber.....	3-116
3.7.5.4	Pressure Reducing Valve Chambers.....	3-116
3.7.5.5	Chamber Drainage	3-116
3.7.6	Separation Distances to Sanitary and Storm Sewers	3-117
3.7.6.1	Parallel Installation	3-117
3.7.6.2	Crossings.....	3-117
3.7.6.3	Forcemains.....	3-117
3.7.6.4	Manholes.....	3-118
3.7.6.5	Other Sources of Contamination.....	3-118
3.7.6.6	Water Only Servicing	3-118
3.7.6.7	Exceptions.....	3-118
3.7.7	Cross-connection Control	3-118
3.7.7.1	Cross-connection Control Programs	3-118
3.7.7.2	Interconnections.....	3-119
3.7.7.3	Backflow Prevention.....	3-119
3.7.8	Water Services and Plumbing.....	3-119
3.7.8.1	Plumbing.....	3-119
3.7.8.2	Consumer Connections (Laterals and Curb-Stops).....	3-119
3.7.8.3	Booster Pumps	3-119

3.7.8.4 Service Meters	3-119
3.7.8.5 Water Loading Stations.....	3-120
3.7.8.6 Sampling Stations	3-120
4.0 Disinfection of Drinking Water	4-1
4.1 Forms of Disinfection.....	4-1
4.2 Chlorination.....	4-1
4.2.1 Contact Time and Point of Application	4-1
4.2.2 CT Factor and Log Inactivation	4-2
4.2.2.1 CT Factor	4-2
4.2.2.2 Log Inactivation or Removal	4-6
4.2.3 Residual Chlorine and Testing.....	4-7
4.2.4 Chlorine Gas – Facility Design.....	4-7
4.2.4.1 Capacity	4-7
4.2.4.2 Standby Equipment.....	4-7
4.2.4.3 Automatic Switchover	4-8
4.2.4.4 Automatic Proportioning and Residual Analyzer.....	4-8
4.2.4.5 Chlorination Room.....	4-8
4.2.4.6 Separate Storage Room.....	4-9
4.2.4.7 Floor Drains	4-9
4.2.4.8 Construction Materials.....	4-9
4.2.4.9 Weigh Scales.....	4-9
4.2.4.10 Lighting.....	4-10
4.2.4.11 Emergency Ventilation	4-10
4.2.4.12 Warning Devices.....	4-10
4.2.4.13 Temperature Control.....	4-11
4.2.4.14 Cross-connection Protection	4-11
4.2.4.15 Chlorine Piping	4-11
4.2.4.16 Injector	4-12
4.2.4.17 Methods of Dosage Control.....	4-12
4.2.4.17.1 Open Loop Flow Proportional Control.....	4-12
4.2.4.17.2 Closed-Loop Flow Proportional Control (Compound- Loop Arrangement with One Chlorine Analyzer) ..	4-12
4.2.4.17.3 Closed-Loop Flow Proportional Control (Compound- Loop Arrangement with Two Chlorine Analyzers)	4-12
4.2.4.17.4 Required Chlorine Control Systems	4-13
4.2.4.18 Gas Protection and Safety Equipment	4-13
4.2.4.19 Eye Wash Stations and Showers.....	4-14
4.2.4.20 Other Protection.....	4-14
4.2.4.21 Operation.....	4-14
4.2.4.22 Fencing.....	4-15

4.2.4.23	System Design and Installation.....	4-15
4.2.4.24	Deviation from these Guidelines	4-15
4.2.5	Hypochlorination – Facility Design.....	4-15
4.2.5.1	Capacity	4-15
4.2.5.2	Standby Equipment.....	4-15
4.2.5.3	Application of Chlorine	4-15
4.2.5.4	Automatic Proportioning	4-15
4.2.5.5	Storage Requirements	4-16
4.2.5.6	Floor Drains	4-16
4.2.5.7	Hose Bibbs and Cross-Connection Control	4-16
4.2.5.8	Lighting.....	4-16
4.2.5.9	Ventilation.....	4-16
4.2.5.10	Temperature Control.....	4-16
4.2.5.11	Chlorine Solution Tank and Piping.....	4-17
4.2.5.12	Point of Application.....	4-17
4.2.5.13	Methods of Dosage	4-17
4.2.5.14	Eye Wash Stations	4-17
4.2.5.15	Other Protection.....	4-17
4.2.5.16	Operation.....	4-17
4.2.5.17	Fencing.....	4-18
4.2.5.18	System Design and Installation.....	4-18
4.2.5.19	Deviation from these Guidelines	4-18
4.3	Ozone.....	4-18
4.3.1	Ozone Generator	4-19
4.3.1.1	Capacity	4-19
4.3.1.2	Electrical	4-19
4.3.1.3	Cooling.....	4-20
4.3.1.4	Materials	4-20
4.3.2	Ozone Contactors.....	4-20
4.3.3	Ozone Destruction Unit	4-21
4.3.4	Piping Materials.....	4-21
4.3.5	Joints and Connections	4-22
4.3.6	Instrumentation	4-22
4.3.7	Alarms.....	4-23
4.3.8	Safety	4-23
4.3.9	Construction Considerations.....	4-24
4.3.10	Ozone Feed Gas Preparation.....	4-24
4.3.10.1	Air Compression	4-24
4.3.10.2	Air Drying.....	4-24
4.3.10.3	Air Filters.....	4-25
4.3.10.4	Air Preparation Piping	4-25

4.4	UV	4-25
4.4.1	UV Reactor Design.....	4-26
	4.4.1.1 Hydraulic Design Considerations.....	4-27
4.4.2	Pathogen Inactivation.....	4-27
	4.4.2.1 Bacteria and Virus Inactivation.....	4-28
	4.4.2.2 Protozoa Inactivation.....	4-28
4.4.3	Disinfection Efficiency.....	4-28
	4.4.3.1 Chemical Films and Dissolved Organics and Inorganics.....	4-29
	4.4.3.2 Microorganism Clumping and Turbidity.....	4-29
	4.4.3.3 Reactor Geometry and Short Circuiting.....	4-29
4.4.4	Operational Considerations.....	4-29
	4.4.4.1 Equipment Operation.....	4-30
	4.4.4.1.1 UV Lamp Aging.....	4-30
	4.4.4.1.2 Quartz Sleeve Fouling.....	4-30
	4.4.4.2 Equipment Maintenance.....	4-30
	4.4.4.2.1 UV lamp Replacement.....	4-30
	4.4.4.2.2 Quartz Sleeve Cleaning.....	4-31
	4.4.4.2.3 Miscellaneous.....	4-31
4.5	Chlorine Dioxide	4-31
4.5.1	Safety Issues.....	4-32
4.5.2	Disinfection.....	4-32
4.5.3	Taste and Odour Control.....	4-33
4.5.4	Oxidation of Iron and Manganese.....	4-33
4.5.5	Dosage Requirements.....	4-33
4.5.6	CT Value Enhancement.....	4-33
4.5.7	On-site Generation.....	4-34
4.5.8	Disinfection By-products.....	4-34
4.6	Chloramines	4-35
4.6.1	Advantages and Disadvantages.....	4-35
4.6.2	Converting Treatment Plants to Chloramines.....	4-36
4.6.3	Potential Operational Impacts of Chloramination.....	4-37
	4.6.3.1 Pre-treatment.....	4-37
	4.6.3.2 Nitrification.....	4-37
	4.6.3.3 Taste and Odour.....	4-37
4.6.4	Special Considerations for Chloramination Facilities.....	4-37
	4.6.4.1 Organic Nitrogen.....	4-37
	4.6.4.2 Mixing.....	4-38
	4.6.4.3 Blending Waters.....	4-38

4.6.4.4	Corrosion.....	4-38
4.6.4.5	Formation of Nitrogen Trichloride	4-38
4.6.4.6	Human Health and the Environment.....	4-39
4.6.5	Ammonia Feed Facilities	4-39
4.6.5.1	Anhydrous Ammonia.....	4-39
4.6.5.2	Aqueous Ammonia	4-39
4.6.5.3	Piping and Valving	4-39
4.6.6	Safety Provisions for Chloramine Generation Facilities	4-40
4.6.7	Points of Application	4-40
4.6.8	Impact on Other Treatment Processes	4-40
4.6.9	Environmental Effects	4-41
4.6.10	DBP Formation.....	4-41
5.0	Sewerage Works.....	5-1
5.1	Regulations	5-1
5.2	Sewers and Appurtenances	5-1
5.2.1	Types of Sewers.....	5-1
5.2.2	Capacity of Sewers	5-2
5.2.3	Sewage Flows	5-2
5.2.3.1	Extraneous Sewage Flows	5-2
5.2.3.1.1	Inflow.....	5-2
5.2.3.1.2	Infiltration.....	5-2
5.2.3.2	Design Criteria	5-3
5.2.3.2.1	Development with Separate Storm and Sanitary Sewer Systems	5-3
5.2.3.2.2	Development with Combined Sewer Systems – Estimating Wastewater Flows.....	5-3
5.2.3.2.2.1	Residential (Population Generated)	5-3
5.2.3.2.2.2	Commercial/Institutional and Industrial	5-4
5.2.3.2.2.3	Peak Factor.....	5-5
5.2.3.2.2.4	Industrial Sewage Flows.....	5-5
5.2.3.2.2.5	Flow Variation	5-5
5.2.3.2.2.6	Flow Rate.....	5-5
5.2.3.2.2.7	Average Flow Generation Estimates for Planning	5-5
5.2.3.2.2.8	Extraneous Flow Allowance – All Land Uses.....	5-6
5.2.3.2.2.9	Total Peak Design Flow Rates.....	5-7

5.2.4	Sewer Size.....	5-7
5.2.5	Sewer Grade.....	5-7
	5.2.5.1 Hydraulic Design.....	5-7
	5.2.5.2 Minimum and Maximum Velocities.....	5-7
	5.2.5.3 Sewers on Steep Slopes.....	5-8
	5.2.5.4 Sewers in Tidal Zones.....	5-9
5.2.6	Sewer Location.....	5-9
	5.2.6.1 Cross-connection Prohibited.....	5-9
	5.2.6.2 Relation to Water Works Structures.....	5-9
	5.2.6.3 Relation to Watermains.....	5-9
	5.2.6.3.1 Horizontal and Vertical Separation.....	5-9
	5.2.6.3.2 Crossings.....	5-9
	5.2.6.4 Stream Crossings.....	5-9
	5.2.6.4.1 Cover Depth.....	5-9
	5.2.6.4.2 Horizontal Location.....	5-10
	5.2.6.4.3 Structures.....	5-10
	5.2.6.4.4 Alignment.....	5-10
	5.2.6.4.5 Materials.....	5-10
	5.2.6.4.6 Siltation and Erosion.....	5-10
5.2.7	Sewer Alignment.....	5-10
5.2.8	Depth of Sewers.....	5-11
5.2.9	Sewer Material.....	5-11
	5.2.9.1 Warning/marker and Detection Tape.....	5-11
5.2.10	Overflow Structures and Bypasses.....	5-12
5.2.11	Sewer Testing and Inspection.....	5-12
	5.2.11.1 Exfiltration Test.....	5-12
	5.2.11.2 Infiltration Test.....	5-12
	5.2.11.3 Allowable Leakage.....	5-13
	5.2.11.4 Low Pressure Air Testing.....	5-13
	5.2.11.5 Allowable Time for Air Pressure Decrease.....	5-13
	5.2.11.6 Sewer Inspection.....	5-14
5.2.12	Sanitary Sewer Service Connections.....	5-14
5.2.13	Manholes.....	5-14
	5.2.13.1 Minimum Diameter.....	5-14
	5.2.13.2 Manhole Covers.....	5-15
	5.2.13.3 Location.....	5-15
	5.2.13.4 Drop Manholes.....	5-15
	5.2.13.5 Channel and Benching.....	5-15
	5.2.13.6 Manhole Steps.....	5-16
	5.2.13.7 Watertightness.....	5-16
	5.2.13.8 Frost Lugs.....	5-16
	5.2.13.9 Safety Chains.....	5-16

5.2.13.10	Inverted Siphons	5-16
5.2.14	Alternative Wastewater Collection Systems.....	5-17
5.2.14.1	Applications	5-17
5.2.14.2	Population Density.....	5-17
5.2.14.3	Ground Slopes.....	5-17
5.2.14.4	Subsurface Obstacles	5-17
5.2.14.5	Low Pressure Collection Systems.....	5-18
5.2.14.5.1	Definition	5-18
5.2.14.5.2	Design	5-18
5.2.14.5.2.1	Grinder Pump.....	5-18
5.2.14.5.2.2	Storage Tank	5-18
5.2.14.5.2.3	Collection Pipe.....	5-18
5.2.14.5.2.4	Frost Protection.....	5-18
5.2.14.5.2.5	Common Trench Construction.....	5-19
5.2.14.5.3	Applications for Approval	5-19
5.2.14.6	Vacuum Sewer Systems.....	5-19
5.2.14.6.1	Services.....	5-19
5.2.14.6.2	Collection Piping	5-20
5.2.14.6.3	Vacuum Station.....	5-20
5.2.14.7	Small Diameter Gravity Sewers.....	5-21
5.2.14.7.1	House Connections	5-21
5.2.14.7.2	Interceptor Tanks	5-21
5.2.14.7.3	Service Laterals.....	5-21
5.2.14.7.4	Collector Mains.....	5-21
5.2.14.7.5	Cleanouts, Manholes and Vents.....	5-21
5.2.14.7.6	Lift Stations.....	5-22
5.2.15	Outfall Sewers.....	5-22
5.2.15.1	Approval	5-22
5.2.15.2	Design	5-22
5.2.15.2.1	Length and Depth.....	5-22
5.2.15.2.2	First Point of Discharge	5-22
5.2.15.2.3	Protection and Maintenance.....	5-22
5.2.15.2.4	Signage.....	5-23
5.2.15.2.5	Offset from Bottom.....	5-23
5.2.15.2.6	Sampling Provisions	5-23
5.2.15.3	Receiving Water Quality Objectives	5-23
5.2.15.3.1	Assimilation Study Procedures.....	5-23
5.2.15.3.2	Assimilation Capacity of Receiving Water	5-25
5.2.15.3.2.1	Dilution Ratio.....	5-25

5.2.15.3.2.2	Mixing Zone.....	5-25
5.2.15.3.2.2.1	Calculating the Mixing Zone	5-27
5.2.15.3.3	Waste Assimilation Study Field Procedures for Coastal Waters	5-27
5.2.15.3.3.1	General Strategies	5-27
5.2.15.3.3.2	Pre-Design Survey vs. Monitoring Survey	5-28
5.2.15.3.3.3	Pre-Design Waste Assimilation Studies.....	5-28
5.2.15.3.3.3.1	General Objectives.....	5-28
5.2.15.3.3.3.2	Measurement of Parameters.....	5-28
5.2.15.3.3.3.3	Survey Procedure	5-30
5.2.15.3.3.3.4	Equipment.....	5-31
5.2.15.3.4	Waste Assimilation Study Field Procedures for Estuaries.....	5-31
5.2.15.3.5	Waste Load Allocation Modelling.....	5-33
5.2.15.3.5.1	Model Selection	5-33
5.2.15.3.5.2	Model Selection Guidelines.....	5-34
5.2.15.3.5.3	Modelling Procedures	5-36
5.2.15.4	Registration Under the Environmental Assessment Regulations	5-37
5.3	Wastewater Pumping Stations.....	5-37
5.3.1	Energy Requirements.....	5-37
5.3.2	Flooding	5-37
5.3.3	Accessibility and Security.....	5-37
5.3.4	Grit	5-37
5.3.5	Safety	5-37
5.3.6	Design	5-38
5.3.6.1	Type	5-38
5.3.6.2	Access and Safety Landings	5-38
5.3.6.3	Buoyancy	5-38
5.3.6.4	Construction Materials.....	5-38
5.3.6.5	Separation	5-38
5.3.6.6	Equipment Removal.....	5-38
5.3.6.7	Dry Space.....	5-38
5.3.7	Pumps.....	5-39
5.3.7.1	Number of Pumps	5-39
5.3.7.2	Type of Pumps	5-39
5.3.7.3	Pump Capacities.....	5-39

5.3.7.4	Pumping Rates	5-39
5.3.7.5	Pump Connections	5-39
5.3.7.6	Pump Openings.....	5-39
5.3.7.7	Dry Well Dewatering.....	5-40
5.3.7.8	Electrical Equipment.....	5-40
5.3.7.9	Intake.....	5-40
5.3.7.10	Controls.....	5-40
5.3.8	Piping and Valves	5-40
5.3.8.1	Piping.....	5-40
5.3.8.2	Suction Lines	5-40
5.3.8.3	Discharge Line.....	5-41
5.3.9	Wet Wells.....	5-41
5.3.9.1	Divided Wells	5-41
5.3.9.2	Size.....	5-41
5.3.9.3	Floor Slope.....	5-41
5.3.9.4	Hazardous Area.....	5-42
5.3.9.5	Air Displacement	5-42
5.3.10	Safety Ventilation	5-42
5.3.10.1	Air Inlets and Outlets.....	5-42
5.3.10.2	Electrical Controls	5-42
5.3.10.3	Fans, Heating and Dehumidification	5-42
5.3.10.4	Wet Wells.....	5-42
5.3.10.5	Dry Wells.....	5-43
5.3.11	Flow Measurement.....	5-43
5.3.12	Potable Water Supplies.....	5-43
5.3.13	Suction-Lift Pump Stations.....	5-43
5.3.13.1	Pump Priming and Lift Requirements	5-43
5.3.13.2	Equipment, Wet Well Access, and Valving Location	5-44
5.3.14	Submersible Pump Stations	5-44
5.3.14.1	Construction.....	5-44
5.3.14.2	Pump Removal.....	5-44
5.3.14.3	Electrical Equipment.....	5-44
5.3.14.3.1	Power Supply and Control Circuitry.....	5-44
5.3.14.3.2	Controls.....	5-44
5.3.14.3.3	Power Cord	5-45
5.3.14.4	Valves	5-45
5.3.15	Alarm Systems.....	5-45
5.3.16	Emergency Operations.....	5-45
5.3.16.1	Overflow Prevention Methods.....	5-46
5.3.16.2	Overflows.....	5-46

5.3.17	Equipment Requirements.....	5-46
5.3.17.1	General.....	5-46
5.3.17.1.1	Engine Protection.....	5-46
5.3.17.1.2	Size.....	5-46
5.3.17.1.3	Fuel Type.....	5-46
5.3.17.1.4	Engine Ventilation.....	5-46
5.3.17.1.5	Routine Start-up.....	5-46
5.3.17.1.6	Protection of Equipment.....	5-47
5.3.17.2	Engine-Driven Pumping Equipment.....	5-47
5.3.17.2.1	Pumping Capacity.....	5-47
5.3.17.2.2	Operation.....	5-47
5.3.17.2.3	Portable Pumping Equipment.....	5-47
5.3.17.3	Engine-Driven Generating Equipment.....	5-47
5.3.17.3.1	Generating Capacity.....	5-47
5.3.17.3.2	Operation.....	5-47
5.3.17.3.3	Portable Generating Equipment.....	5-48
5.3.17.4	Independent Utility Substations.....	5-48
5.3.18	Instructions and Equipment.....	5-48
5.3.19	Safety and Housekeeping.....	5-48
5.3.20	Forcemains.....	5-48
5.3.20.1	Diameter and Velocity.....	5-48
5.3.20.2	Termination.....	5-48
5.3.20.3	Design Friction Losses.....	5-49
5.3.20.3.1	Friction Coefficient.....	5-49
5.3.20.3.2	Maximum Power Requirements.....	5-49
5.3.20.4	Air and Vacuum Relief Valves.....	5-49
5.3.20.5	Pipe and Design Pressure.....	5-49
5.3.20.6	Separation.....	5-49
5.3.20.7	Slope and Depth.....	5-49
5.3.20.8	Identification.....	5-49
5.3.20.9	Testing.....	5-50
5.4	Wastewater Treatment.....	5-50
5.4.1	Plant Location.....	5-50
5.4.1.1	Flood Protection.....	5-50
5.4.2	Quality of Effluent.....	5-50
5.4.3	Design.....	5-51
5.4.3.1	Type of Treatment.....	5-51
5.4.3.2	Required Engineering Data for New Process and Application Evaluation.....	5-51

5.4.3.3	Design Loads	5-52
5.4.3.3.1	Hydraulic Design	5-52
5.4.3.3.2	Organic Design	5-52
5.4.3.3.3	Minimum Parameters.....	5-52
5.4.3.4	Shock Effects	5-52
5.4.3.5	Design by Analogy	5-52
5.4.3.6	Conduits and Piping.....	5-53
5.4.3.7	Arrangement of Units	5-53
5.4.3.8	Flow Division Control	5-53
5.4.4	Plant Details	5-53
5.4.4.1	Installation and Inspection of Mechanical Equipment.....	5-53
5.4.4.2	Unit Dewatering, Flotation Protection and Plugging.....	5-53
5.4.4.3	Unit Bypasses.....	5-53
5.4.4.3.1	Removal from Service	5-53
5.4.4.3.2	Unit Bypass During Construction.....	5-54
5.4.4.4	Construction Materials.....	5-54
5.4.4.5	Painting	5-54
5.4.4.6	Operating Equipment	5-55
5.4.4.7	Grading and Landscaping	5-55
5.4.4.8	Erosion Control During Construction.....	5-55
5.4.5	Plant Outfalls	5-55
5.4.6	Essential Facilities	5-55
5.4.6.1	Emergency Power Facilities	5-55
5.4.6.1.1	Power for Aeration.....	5-56
5.4.6.1.2	Power for Disinfection.....	5-56
5.4.6.2	Measurement of Flow	5-56
5.4.6.2.1	Facilities.....	5-56
5.4.6.2.2	Location	5-56
5.4.6.2.3	Hydraulic Conditions	5-57
5.4.6.3	Septicity	5-57
5.4.6.4	Water Supply	5-57
5.4.6.4.1	Direct Connections.....	5-57
5.4.6.4.2	Indirect Connections	5-58
5.4.6.4.3	Separate Potable Water Supply.....	5-58
5.4.6.4.4	Separate Non-potable Water Supply.....	5-58
5.4.6.5	Sanitary Facilities.....	5-58
5.4.6.6	Stairways.....	5-58
5.4.6.7	Instrumentation and Control	5-58
5.4.6.8	Laboratory Facilities	5-58

5.4.7	Safety	5-59
5.5	Screening and Grit Removal.....	5-60
5.5.1	Bar Racks and Screens.....	5-60
5.5.1.1	Selection Considerations.....	5-60
5.5.1.2	Access	5-60
5.5.1.3	Ventilation.....	5-60
5.5.1.4	Design	5-60
5.5.1.4.1	Velocity.....	5-60
5.5.1.4.2	Bar Spacing.....	5-60
5.5.1.4.3	Slope	5-60
5.5.1.4.4	Channels.....	5-61
5.5.1.4.5	Materials	5-61
5.5.1.4.6	Lighting.....	5-61
5.5.1.5	Safety	5-61
5.5.1.5.1	Railings and Gratings.....	5-61
5.5.1.5.2	Mechanical Devices	5-61
5.5.1.5.3	Drainage.....	5-61
5.5.1.6	Control Systems	5-61
5.5.1.6.1	Timing Devices.....	5-61
5.5.1.6.2	Electrical Systems and Components.....	5-61
5.5.1.6.3	Manual Override	5-61
5.5.1.7	Screenings Removal and Disposal.....	5-62
5.5.1.8	Auxiliary Screens.....	5-62
5.5.1.9	Fine Screens	5-62
5.5.2	Comminutors.....	5-62
5.5.2.1	Location	5-62
5.5.2.2	Size.....	5-62
5.5.2.3	Installation.....	5-62
5.5.2.4	Servicing	5-63
5.5.2.5	Electrical Control and Motors.....	5-63
5.5.3	Grit Removal Facilities	5-63
5.5.3.1	Location	5-63
5.5.3.2	Accessibility.....	5-63
5.5.3.3	Ventilation.....	5-63
5.5.3.4	Electrical	5-63
5.5.3.5	Outside Facilities	5-64
5.5.3.6	Design Factors	5-64
5.5.3.6.1	Inlet	5-64
5.5.3.6.2	Type and Number of Units	5-64

5.5.3.6.3	Grit Channels	5-64
5.5.3.6.3.1	Velocity	5-64
5.5.3.6.3.2	Control Sections	5-64
5.5.3.6.3.3	Channel Dimensions	5-64
5.5.3.6.4	Grit Storage	5-64
5.5.3.6.5	Detritus Tanks	5-64
5.5.3.6.6	Aerated Grit Tanks	5-65
5.5.3.6.6.1	Detention Time	5-65
5.5.3.6.6.2	Air Supply	5-65
5.5.3.6.6.3	Inlet Conditions	5-65
5.5.3.6.6.4	Baffling	5-65
5.5.3.6.6.5	Outlet Conditions	5-65
5.5.3.6.6.6	Tank Dimensions	5-65
5.5.3.6.6.7	Velocity	5-65
5.5.3.6.6.8	Tank Geometry	5-66
5.5.3.6.6.9	Multiple Units	5-66
5.5.3.6.7	Mechanical Grit Chambers	5-66
5.5.3.6.8	Grit Washing	5-66
5.5.3.6.9	Dewatering	5-66
5.5.3.6.10	Water	5-66
5.5.3.7	Grit Removal	5-66
5.5.3.8	Grit Handling	5-66
5.5.3.9	Grit Disposal	5-66
5.5.4	Pre-aeration and Flocculation	5-67
5.5.4.1	Arrangement	5-67
5.5.4.2	Pre-aeration	5-67
5.5.4.3	Flocculation	5-67
5.5.4.3.1	Detention Period	5-67
5.5.4.3.2	Stirring Devices	5-67
5.5.4.3.2.1	Paddles	5-67
5.5.4.3.2.2	Aerators	5-67
5.5.4.3.3	Details	5-68
5.5.4.3.4	Rapid Mix	5-68
5.5.5	Flow Equalization	5-69
5.5.5.1	Location	5-69
5.5.5.2	Type	5-69
5.5.5.3	Size	5-69
5.5.5.4	Operation	5-69
5.5.5.4.1	Mixing	5-69
5.5.5.4.2	Aeration	5-69

5.5.5.4.3	Controls.....	5-70
5.5.5.5	Electrical.....	5-70
5.5.5.6	Access.....	5-70
5.6	Clarification.....	5-70
5.6.1	Sedimentation Tanks.....	5-70
5.6.1.1	Design Requirements.....	5-70
5.6.1.1.1	Number of Units.....	5-70
5.6.1.1.2	Arrangement of Units.....	5-70
5.6.1.1.3	Interaction with Other Processes.....	5-70
5.6.1.1.4	Flow Distribution and Control.....	5-71
5.6.1.1.5	Tank Configuration and Proportions.....	5-71
5.6.1.1.6	Site Constraints.....	5-71
5.6.1.1.7	Size Limitations.....	5-71
5.6.1.1.8	Inlet Structures.....	5-71
5.6.1.1.9	Outlet Arrangements.....	5-71
5.6.1.1.9.1	Location.....	5-71
5.6.1.1.9.2	Weir Troughs.....	5-72
5.6.1.1.10	Submerged Surfaces.....	5-72
5.6.1.1.11	Unit Dewatering.....	5-72
5.6.1.1.12	Freeboard.....	5-72
5.6.1.1.13	Clarifier Covers.....	5-72
5.6.1.1.14	Surface Settling Rates.....	5-72
5.6.1.1.14.1	Primary Settling Tanks.....	5-72
5.6.1.1.14.2	Intermediate Settling Tanks.....	5-72
5.6.1.1.14.3	Final Settling Tanks.....	5-73
5.6.1.2	Types of Settling.....	5-73
5.6.1.2.1	Type I Settling (Discrete Settling).....	5-73
5.6.1.2.2	Type II Settling (Flocculant Settling).....	5-73
5.6.1.2.3	Type III Settling (Hindered or Zone Settling).....	5-73
5.6.1.2.4	Settling Type Design Criteria.....	5-73
5.6.1.3	Scum and Sludge Removal.....	5-74
5.6.1.3.1	Scum Removal.....	5-74
5.6.1.3.2	Sludge Removal.....	5-74
5.6.1.3.2.1	Sludge Collection.....	5-75
5.6.1.3.2.2	Sludge Hopper.....	5-75
5.6.1.3.2.3	Cross-Collectors.....	5-75
5.6.1.3.2.4	Sludge Removal Piping.....	5-75
5.6.1.3.2.5	Sludge Removal Control.....	5-75
5.6.2	Enhanced Primary Clarification.....	5-75
5.6.2.1	Chemical Enhancement.....	5-75

5.6.2.1.1	Chemical Coagulants	5-76
5.6.2.1.2	Rapid Mix	5-76
5.6.2.1.3	Flocculation.....	5-77
5.6.2.1.4	Coagulant Addition.....	5-77
5.6.2.2	Plate and Tube Settlers.....	5-77
5.6.2.2.1	Calculation of Settling Area.....	5-77
5.6.2.2.2	Configuration	5-78
5.6.2.3	Ballasted Flocc Clarifiers	5-78
5.6.3	Dissolved Air Flotation.....	5-79
5.6.3.1	Process Design Considerations and Criteria.....	5-79
5.6.3.1.1	Types of Solids	5-80
5.6.3.1.2	Hydraulic-Loading Rate.....	5-80
5.6.3.1.3	Solids-Loading Rate.....	5-80
5.6.3.1.4	Feed-Solids Concentration.....	5-80
5.6.3.1.5	Air-to-Solids Ratio.....	5-81
5.6.3.1.6	Float-Blanket Depth.....	5-81
5.6.3.1.7	Polymer Addition.....	5-81
5.6.4	Protective and Service Facilities.....	5-82
5.6.4.1	Operator Protection.....	5-82
5.6.4.2	Mechanical Maintenance Access.....	5-82
5.6.4.3	Electrical Fixtures and Controls.....	5-82
5.7	Sludge Handling and Disposal.....	5-83
5.7.1	Process Selection	5-83
5.7.2	Sludge Conditioning	5-83
5.7.2.1	Chemical Conditioning.....	5-83
5.7.2.1.1	Chemical Requirements.....	5-83
5.7.2.1.2	Laboratory Testing.....	5-84
5.7.2.1.3	Conditioning Chemicals.....	5-84
5.7.2.1.3.1	Iron or Aluminum Salts	5-84
5.7.2.1.3.2	Lime	5-84
5.7.2.1.3.3	Polymers	5-84
5.7.2.1.3.4	Chemical Feed System.....	5-84
5.7.2.2	Heat Conditioning.....	5-85
5.7.2.2.1	Operating Temperatures and Pressures.....	5-85
5.7.2.2.2	Increase in Aeration Tank Organic Loading.....	5-85
5.7.2.2.3	Design Considerations	5-85
5.7.2.2.3.1	Materials	5-85
5.7.2.2.3.2	Sludge Grinding.....	5-85
5.7.2.2.3.3	Feed Pumps.....	5-85
5.7.2.2.3.4	Heat Exchangers	5-85

5.7.2.2.3.5	Reaction Vessel.....	5-85
5.7.2.2.3.6	Hot Water Re-circulation Pump.....	5-85
5.7.2.2.3.7	Odour Control.....	5-86
5.7.2.2.3.8	Solvent Cleaning.....	5-86
5.7.2.2.3.9	Piping.....	5-86
5.7.2.2.3.10	Decant Tank.....	5-86
5.7.2.2.4	Laboratory Testing.....	5-86
5.7.2.3	Addition of Admixtures.....	5-86
5.7.3	Sludge Thickening.....	5-87
5.7.3.1	Applicability.....	5-87
5.7.3.2	Multiple Units.....	5-87
5.7.3.3	Thickener Location.....	5-87
5.7.3.4	Thickening Methods and Performance with Various Sludge Types.....	5-87
5.7.3.5	Sludge Pretreatment.....	5-88
5.7.3.6	Gravity Thickening.....	5-88
5.7.3.6.1	Process Application.....	5-88
5.7.3.6.2	Design Criteria.....	5-88
5.7.3.6.2.1	Tank Shape.....	5-88
5.7.3.6.2.2	Tank Dimensions.....	5-88
5.7.3.6.2.3	Floor Slope.....	5-89
5.7.3.6.2.4	Solids Loading.....	5-89
5.7.3.6.2.5	Dilution.....	5-89
5.7.3.6.2.6	Hydraulic Overflow Rate.....	5-89
5.7.3.6.2.7	Sludge Volume Ratio.....	5-89
5.7.3.6.2.8	Hydraulic Retention Time.....	5-90
5.7.3.6.2.9	Sludge Underflow Piping.....	5-90
5.7.3.6.2.10	Chemical Conditioning.....	5-90
5.7.3.6.2.11	Mechanical Rake.....	5-90
5.7.3.6.2.12	Overflow Handling.....	5-90
5.7.3.7	Air Flotation.....	5-90
5.7.3.7.1	Applicability.....	5-90
5.7.3.7.2	Pilot Scale Testing.....	5-90
5.7.3.7.3	Design Parameters.....	5-91
5.7.3.7.3.1	Recycle Ratio.....	5-91
5.7.3.7.3.2	Air to Solids Weight Ratio.....	5-91
5.7.3.7.3.3	Feed Concentration.....	5-91
5.7.3.7.3.4	Hydraulic Feed Rate.....	5-91
5.7.3.7.3.5	Solids Loading.....	5-91
5.7.3.7.3.6	Chemical Conditioning.....	5-91
5.7.3.7.3.7	Detention Time.....	5-91

5.7.3.7.4	Thickened Sludge Withdrawal.....	5-91
5.7.3.7.5	Bottom Sludge	5-91
5.7.3.8	Centrifugation	5-92
5.7.3.8.1	Types of Centrifuges.....	5-92
5.7.3.8.2	Applicability	5-92
5.7.3.8.3	Solids Recovery	5-92
5.7.3.8.4	Polymer Feed Range.....	5-92
5.7.4	Anaerobic Sludge Digestion	5-92
5.7.4.1	Applicability	5-92
5.7.4.1.1	Advantages.....	5-93
5.7.4.1.2	Disadvantages	5-93
5.7.4.2	Digestion Tanks and Number of Stages.....	5-94
5.7.4.3	Access Manholes	5-94
5.7.4.4	Safety	5-94
5.7.4.5	Field Data.....	5-94
5.7.4.6	Typical Sludge Qualities and Generation Rates for Different Unit Processes.....	5-94
5.7.4.7	Solids Retention Time.....	5-95
5.7.4.8	Design of Tank Elements.....	5-95
5.7.4.8.1	Digester Shape	5-95
5.7.4.8.2	Floor Slope.....	5-96
5.7.4.8.3	Depth and Freeboard.....	5-96
5.7.4.8.4	Scum Control	5-96
5.7.4.8.5	Grit and Sand Control	5-96
5.7.4.8.6	Alkalinity and pH Control	5-97
5.7.4.8.7	Mixing.....	5-97
5.7.4.8.8	Sludge Inlets, Outlets, Re-circulation, and High Level Overflow	5-97
5.7.4.8.8.1	Multiple Inlets and Draw-Offs.....	5-97
5.7.4.8.8.2	Inlet Configurations	5-97
5.7.4.8.8.3	Inlet Discharge Location.....	5-97
5.7.4.8.8.4	Sludge Withdrawal.....	5-98
5.7.4.8.8.5	Emergency Overflow	5-98
5.7.4.8.9	Primary Tank Capacity	5-98
5.7.4.8.9.1	High Rate Digester.....	5-98
5.7.4.8.9.2	Low Rate Digester	5-98
5.7.4.8.10	Secondary Digester Sizing.....	5-98
5.7.4.8.11	Digester Covers.....	5-99
5.7.4.8.12	Sludge Piping	5-99
5.7.4.8.13	Overflows.....	5-99

5.7.4.9 Gas Collection, Piping and Appurtenances	5-99
5.7.4.9.1 Safety Equipment.....	5-99
5.7.4.9.2 Gas Piping and Condensate	5-100
5.7.4.9.3 Gas Utilization Equipment.....	5-100
5.7.4.9.4 Electrical Systems.....	5-100
5.7.4.9.5 Waste Gas	5-100
5.7.4.9.6 Ventilation.....	5-101
5.7.4.9.7 Meter.....	5-101
5.7.4.10 Digestion Tank Heating.....	5-101
5.7.4.10.1 Heating Capacity.....	5-101
5.7.4.10.2 Insulation.....	5-101
5.7.4.10.3 Heating Facilities	5-101
5.7.4.10.3.1 External Heating	5-101
5.7.4.10.3.2 Other Heating Methods.....	5-101
5.7.4.10.4 Hot Water Internal Heating Controls.....	5-102
5.7.4.10.4.1 Mixing Valves.....	5-102
5.7.4.10.4.2 Boiler Controls.....	5-102
5.7.4.10.4.3 Boiler Water Pumps.....	5-102
5.7.4.10.4.4 Thermometers	5-102
5.7.4.10.4.5 Water Supply	5-102
5.7.4.10.5 External Heater Operating Controls.....	5-102
5.7.4.11 Supernatant Withdrawal.....	5-102
5.7.4.11.1 Piping Size	5-102
5.7.4.11.2 Withdrawal Arrangement.....	5-103
5.7.4.11.2.1 Withdrawal Levels.....	5-103
5.7.4.11.2.2 Supernatant Selector	5-103
5.7.4.11.2.3 Withdrawal Selection.....	5-103
5.7.4.11.3 Sampling	5-103
5.7.4.11.4 Alternate Supernatant Disposal.....	5-103
5.7.4.12 Sludge Sampling Requirements.....	5-103
5.7.5 Aerobic Sludge Digestion.....	5-104
5.7.5.1 Applicability	5-104
5.7.5.2 Field Data.....	5-104
5.7.5.3 Multiple Units	5-104
5.7.5.4 Pretreatment	5-104
5.7.5.5 Design Considerations	5-105
5.7.5.6 Solids Retention Time.....	5-105
5.7.5.7 Hydraulic Retention Time.....	5-105
5.7.5.8 Tank Design.....	5-105

5.7.5.8.1	Tank Capacity	5-105
5.7.5.8.2	Air and Mixing Requirements	5-105
5.7.5.8.3	Tank Configuration	5-106
5.7.5.8.4	Supernatant Separation and Scum and Grease Removal	5-106
5.7.5.9	High Level Emergency Overflow	5-106
5.7.5.10	Mixing Tanks and Equipment	5-107
5.7.5.11	Chemical Feed and Storage Equipment	5-107
5.7.5.11.1	Feed and Slaking Equipment	5-107
5.7.5.11.2	Chemical Storage Facilities	5-107
5.7.5.12	Sludge Storage	5-108
5.7.5.12.1	Liquid Sludge	5-108
5.7.5.12.2	Dewatered Sludge	5-108
5.7.5.12.3	Off-Site Storage	5-108
5.7.5.13	Sludge Disposal	5-108
5.7.6	Sludge Dewatering	5-108
5.7.6.1	Dewatering Process Compatibility with Subsequent Treatment or Disposal Techniques	5-109
5.7.6.2	Sludge Drying Beds	5-110
5.7.6.2.1	Pretreatment	5-110
5.7.6.2.2	Chemical Conditioning	5-110
5.7.6.2.3	Design Criteria	5-110
5.7.6.2.3.1	Factors Influencing Design	5-110
5.7.6.2.3.2	Bed Area	5-110
5.7.6.2.3.3	Percolation Type Beds	5-111
5.7.6.2.3.4	Impervious Type Beds	5-112
5.7.6.2.3.5	Location	5-112
5.7.6.2.3.6	Winter Storage	5-112
5.7.6.2.3.7	Dimensions	5-112
5.7.6.2.3.8	Depth of Sludge	5-112
5.7.6.2.3.9	Number of Beds	5-112
5.7.6.2.3.10	Walls	5-112
5.7.6.2.3.11	Sludge Influent	5-112
5.7.6.2.3.12	Sludge Removal	5-112
5.7.6.2.3.13	Covered Beds	5-113
5.7.6.3	Sludge Lagoons	5-113
5.7.6.3.1	Design Considerations	5-113
5.7.6.3.2	Pretreatment	5-113
5.7.6.3.3	Soil and Groundwater Conditions	5-114
5.7.6.3.4	Depth	5-114

5.7.6.3.5	Seal.....	5-114
5.7.6.3.6	Area.....	5-114
5.7.6.3.7	Location	5-114
5.7.6.3.8	Cycle Time and Sludge Removal	5-114
5.7.6.4	Mechanical Dewatering Facilities.....	5-114
5.7.6.4.1	Performance of Mechanical Dewatering Methods.....	5-114
5.7.6.4.2	Number of Units	5-115
5.7.6.4.3	Ventilation.....	5-115
5.7.6.4.4	Chemical Handling Enclosures.....	5-115
5.7.6.4.5	Drainage and Filtrate Disposal.....	5-115
5.7.6.4.6	Other Dewatering Facilities	5-115
5.7.6.4.7	Vacuum Filters.....	5-116
5.7.6.4.8	Filter Presses	5-117
5.7.6.4.9	Solid Bowl Centrifuges.....	5-117
5.7.6.4.10	Bed Filter Presses.....	5-118
5.7.7	Sludge Pumps and Piping	5-118
5.7.7.1	Sludge Pumps.....	5-118
5.7.7.1.1	General Sludge Pumping Requirements	5-118
5.7.7.1.2	Capacity	5-119
5.7.7.1.3	Duplicate Units	5-119
5.7.7.1.4	Type	5-119
5.7.7.1.5	Minimum Head	5-119
5.7.7.1.6	Head Loss.....	5-120
5.7.7.1.7	Sampling Facilities.....	5-121
5.7.7.2	Sludge Piping.....	5-121
5.7.7.2.1	Size and Head	5-121
5.7.7.2.2	Slope	5-121
5.7.7.2.3	Supports	5-121
5.8	Biological Treatment	5-121
5.8.1	Activated Sludge.....	5-121
5.8.1.1	Applicability	5-121
5.8.1.2	Process Selection	5-121
5.8.1.3	Energy Requirements.....	5-122
5.8.1.4	Winter Protection	5-122
5.8.1.5	Pretreatment	5-122
5.8.1.6	Aeration.....	5-122
5.8.1.6.1	Capacities and Permissible Loadings.....	5-122
5.8.1.6.2	Arrangement of Aeration Tanks	5-123
5.8.1.6.2.1	Number of Units	5-123
5.8.1.6.2.2	Inlets, Outlets and Conduits.....	5-123
5.8.1.6.2.3	Freeboard	5-124

5.8.1.6.3	Aeration Equipment.....	5-124
5.8.1.6.3.1	Aeration Equipment Selection	5-124
5.8.1.6.3.2	Diffused Air Systems.....	5-125
5.8.1.6.3.3	Mechanical Aeration Systems.....	5-126
5.8.1.6.3.3.1	Oxygen Transfer Performance.....	5-126
5.8.1.6.3.3.2	Design Requirements	5-126
5.8.1.6.3.3.3	Winter Protection.....	5-127
5.8.1.7	Process Definitions	5-127
5.8.1.7.1	Conventional Activated Sludge	5-127
5.8.1.7.2	Complete Mix Activated Sludge.....	5-127
5.8.1.7.3	Step Aeration	5-127
5.8.1.7.4	Contact Stabilization.....	5-127
5.8.1.7.5	Extended Aeration	5-128
5.8.1.7.6	Oxidation Ditch.....	5-128
5.8.1.7.7	High Rate Aeration.....	5-128
5.8.1.7.8	High Purity Oxygen	5-128
5.8.1.8	Return Sludge Equipment.....	5-128
5.8.1.8.1	Return Sludge Rate	5-128
5.8.1.8.2	Return Sludge Pumps.....	5-129
5.8.1.8.3	Return Sludge Piping.....	5-129
5.8.1.8.4	Waste Sludge Facilities.....	5-129
5.8.1.8.5	Froth Control Units.....	5-130
5.8.1.9	Measuring Devices.....	5-130
5.8.2	Rotating Biological Contactors.....	5-130
5.8.2.1	Applicability	5-130
5.8.2.2	Winter Protection	5-130
5.8.2.3	Flow Equalization	5-131
5.8.2.4	Operating Temperature	5-131
5.8.2.5	Design Flexibility.....	5-131
5.8.2.6	Hydrogen Sulphide	5-131
5.8.2.7	Pretreatment	5-131
5.8.2.8	Unit Sizing	5-131
5.8.2.9	Hydraulic Loading	5-132
5.8.2.10	Organic Loading	5-132
5.8.2.11	Tank Volume	5-132
5.8.2.12	Detention Time	5-132
5.8.2.13	Media Submergence and Clearance.....	5-133
5.8.2.14	Design Considerations	5-133
5.8.2.14.1	Unit Staging	5-133
5.8.2.14.2	Tankage.....	5-133
5.8.2.14.3	High Density Media.....	5-133

5.8.2.14.4	Shaft Rotational Velocity.....	5-134
5.8.2.14.5	Biomass Removal	5-134
5.8.2.14.6	Dissolved Oxygen Monitoring.....	5-134
5.8.2.14.7	Supplemental Air	5-134
5.8.2.14.8	Side Stream Inflows	5-134
5.8.2.14.9	Re-circulation.....	5-134
5.8.2.14.10	Load Cells	5-135
5.8.2.14.11	Shaft Access.....	5-135
5.8.2.14.12	Structural Design	5-135
5.8.2.14.13	Energy Requirements.....	5-135
5.8.2.14.14	Nitrification Consideration	5-136
5.8.3	Sequencing Batch Reactor (SBR).....	5-136
5.8.3.1	Process Configurations	5-136
5.8.3.2	Continuous Influent Systems	5-136
5.8.3.3	Intermittent Influent Systems.....	5-137
5.8.3.4	Sequencing Batch Reactor Equipment.....	5-138
5.8.3.4.1	Process Control	5-138
5.8.3.4.2	Reactors.....	5-139
5.8.3.4.3	Decanters.....	5-139
5.8.3.4.4	Solids Wasting	5-139
5.8.3.4.5	Aeration/Mixing Systems	5-139
5.9	Wastewater Treatment Ponds (Lagoons)	5-140
5.9.1	Supplement to the Pre-design Report	5-140
5.9.1.1	Supplementary Field Survey Data	5-140
5.9.1.1.1	Location of Nearby Facilities.....	5-140
5.9.1.1.2	Land Use Zoning.....	5-140
5.9.1.1.3	Site Description.....	5-140
5.9.1.1.4	Location of Field Tile	5-140
5.9.1.1.5	Soil Borings	5-140
5.9.1.1.6	Sulphate Content of Water Supply	5-140
5.9.1.1.7	Percolation Rates	5-141
5.9.1.1.8	Well Survey	5-141
5.9.2	Location	5-141
5.9.2.1	Distance from Habitation.....	5-141
5.9.2.2	Prevailing Winds.....	5-141
5.9.2.3	Surface Runoff.....	5-141
5.9.2.4	Groundwater Pollution.....	5-141
5.9.2.5	Protection of Surface Water Supplies	5-141
5.9.2.6	Geology.....	5-142
5.9.2.7	Floodplains.....	5-142
5.9.3	Definitions.....	5-142
5.9.4	Application, Advantages and Disadvantages of Different Lagoon	

Types.....	5-143
5.9.5 Basis of Design	5-143
5.9.5.1 Lagoons.....	5-143
5.9.5.1.1 Holding Capacity Requirements.....	5-143
5.9.5.1.2 Area and Loadings	5-144
5.9.5.1.3 Flow Distribution.....	5-144
5.9.5.1.4 Typical Performance Potentials.....	5-144
5.9.5.1.5 Controlled-Discharge Lagoons.....	5-144
5.9.5.1.6 Flow-Through Lagoons	5-144
5.9.5.1.7 Tertiary Lagoons.....	5-145
5.9.5.2 Aerated Lagoons.....	5-145
5.9.5.2.1 Aerated Aerobic Lagoons	5-145
5.9.5.2.2 Aerated Facultative Lagoons	5-145
5.9.5.2.3 Design Parameters	5-146
5.9.5.2.3.1 Detention Time	5-146
5.9.5.2.3.2 Oxygen Requirement.....	5-146
5.9.5.3 Industrial Wastes.....	5-147
5.9.5.4 Multiple Units.....	5-147
5.9.5.5 Design Depth	5-147
5.9.5.5.1 Controlled-Discharge Lagoons.....	5-147
5.9.5.5.2 Flow-Through Lagoons	5-147
5.9.5.5.3 Aerated Lagoon Systems	5-147
5.9.5.6 Lagoon Shape.....	5-147
5.9.5.7 Additional Treatment.....	5-148
5.9.6 Lagoon Construction Details	5-148
5.9.6.1 Embankments and Dykes.....	5-148
5.9.6.1.1 Materials	5-148
5.9.6.1.2 Top Width.....	5-148
5.9.6.1.3 Maximum Slopes	5-148
5.9.6.1.4 Minimum Slopes.....	5-148
5.9.6.1.5 Freeboard	5-148
5.9.6.1.6 Erosion Control.....	5-148
5.9.6.2 Lagoon Bottom and Liners	5-149
5.9.6.2.1 Location	5-149
5.9.6.2.2 Uniformity.....	5-149
5.9.6.2.3 Vegetation.....	5-149
5.9.6.2.4 Soil.....	5-149
5.9.6.2.5 Liner.....	5-150
5.9.6.2.6 Seepage Control Criterion for Clay Liners.....	5-150
5.9.6.2.7 Seepage Control Criterion for Synthetic Liners.....	5-150
5.9.6.2.8 Site Drainage.....	5-150

5.9.6.3	Design and Construction Procedures for Clay Liners.....	5-151
5.9.6.3.1	Delineation of Borrow Deposit.....	5-151
5.9.6.3.2	Liner Thickness.....	5-151
5.9.6.3.3	Hydraulic Conductivity of Compacted Clay.....	5-151
5.9.6.3.4	Subgrade Preparation.....	5-152
5.9.6.3.5	Liner Material Placement and Compaction.....	5-152
5.9.6.3.6	Construction Control.....	5-152
5.9.6.3.7	Planning.....	5-153
5.9.6.4	Prefilling.....	5-153
5.9.6.5	Influent Lines.....	5-154
5.9.6.5.1	Material.....	5-154
5.9.6.5.2	Manhole.....	5-154
5.9.6.5.3	Surcharging.....	5-154
5.9.6.5.4	Forcemains.....	5-154
5.9.6.5.5	Flow Distribution.....	5-154
5.9.6.5.6	Location.....	5-154
5.9.6.5.7	Point of Discharge.....	5-154
5.9.6.5.8	Influent Discharge Apron.....	5-155
5.9.6.5.9	Pipe Size.....	5-155
5.9.6.6	Control Structures and Interconnecting Piping.....	5-155
5.9.6.6.1	Structure.....	5-155
5.9.6.6.2	Piping.....	5-155
5.9.6.6.3	Hydraulic Capacity.....	5-156
5.9.6.6.4	Interconnecting Piping.....	5-156
5.9.6.6.5	Location.....	5-156
5.9.7	Miscellaneous.....	5-156
5.9.7.1	Fencing.....	5-156
5.9.7.2	Access.....	5-157
5.9.7.3	Warning Signs.....	5-157
5.9.7.4	Flow Measurement.....	5-157
5.9.7.5	Groundwater Monitoring.....	5-157
5.9.7.6	Pond Level Gauges.....	5-157
5.9.7.7	Service Building.....	5-157
5.9.7.8	Liquid Depth Operation.....	5-157
5.9.7.9	Pretreatment and Post-Treatment.....	5-157
5.10	Kikuth Bioreactor (Phytoklare).....	5-158
5.11	BMS “Blivet”.....	5-158
5.12	Biogreen.....	5-158

5.13	Other Biological Systems.....	5-159
5.13.1	Biological Aerated Filters	5-159
5.13.1.1	Design Features.....	5-159
5.13.1.2	Configurations.....	5-160
5.13.1.3	Performance	5-160
5.13.2	Moving Bed Biofilm Reactors	5-161
5.13.3	Membrane Bioreactors.....	5-161
5.13.3.1	Configuration	5-161
5.13.3.2	Process Description.....	5-162
5.13.4	Small Treatment Plants	5-163
5.13.4.1	Flows.....	5-163
5.14	Nutrient Removal and Tertiary Treatment.....	5-163
5.14.1	Phosphorous Removal	5-163
5.14.1.1	Applicability	5-163
5.14.1.2	Phosphorous Removal Criteria	5-164
5.14.1.3	Method of Removal	5-164
5.14.1.4	Design Basis.....	5-164
5.14.1.4.1	Preliminary Testing.....	5-164
5.14.1.4.2	System Flexibility	5-164
5.14.1.5	Effluent Requirements	5-164
5.14.1.6	Process Requirements	5-164
5.14.1.6.1	Dosage.....	5-164
5.14.1.6.2	Chemical Selection	5-165
5.14.1.6.3	Chemical Feed System.....	5-165
5.14.1.6.4	Chemical Feed Points	5-166
5.14.1.6.5	Flash Mixing.....	5-166
5.14.1.6.6	Flocculation.....	5-166
5.14.1.6.7	Liquid-Solids Separation	5-166
5.14.1.6.8	Filtration.....	5-167
5.14.1.7	Feed Systems	5-167
5.14.1.7.1	Location	5-167
5.14.1.7.2	Liquid Chemical Feed System.....	5-167
5.14.1.7.3	Dry Chemical Feed System	5-167
5.14.1.8	Storage Facilities.....	5-167
5.14.1.8.1	Size.....	5-167
5.14.1.8.2	Location	5-168
5.14.1.8.3	Accessories	5-168

5.14.1.9 Other Requirements	5-168
5.14.1.9.1 Materials	5-168
5.14.1.9.2 Temperature, Humidity and Dust Control	5-168
5.14.1.9.3 Cleaning	5-168
5.14.1.9.4 Drains and Drawoff.....	5-168
5.14.1.10 Hazardous Chemical Handling	5-169
5.14.1.11 Sludge Handling and Dewatering	5-169
5.14.2 Ammonia Removal	5-169
5.14.2.1 Breakpoint Chlorination.....	5-169
5.14.2.1.1 Applicability	5-169
5.14.2.1.2 Design Considerations	5-169
5.14.2.1.2.1 Mixing.....	5-169
5.14.2.1.2.2 Dosage.....	5-169
5.14.2.1.2.3 Monitoring	5-169
5.14.2.1.2.4 Standby Equipment.....	5-170
5.14.2.1.2.5 pH Adjustment.....	5-170
5.14.2.2 Air Stripping	5-170
5.14.2.2.1 Applicability	5-170
5.14.2.2.2 Design Considerations	5-171
5.14.2.2.2.1 Tower Packing	5-171
5.14.2.2.2.2 Hydraulic Loadings.....	5-171
5.14.2.2.2.3 Air Requirements	5-171
5.14.2.2.2.4 Temperature	5-171
5.14.2.2.2.5 General Construction Features.....	5-171
5.14.2.2.2.6 Process Control	5-171
5.14.3 Biological Nutrient Removal	5-172
5.14.3.1 Biological Phosphorus Removal.....	5-172
5.14.3.1.1 Mainstream Phosphorus Removal (A/O Process).....	5-172
5.14.3.1.2 Sidestream Phosphorus Removal (PhoStrip Process).....	5-172
5.14.3.1.3 Design Criteria	5-172
5.14.3.2 Biological Nitrogen Removal	5-173
5.14.3.2.1 Nitrification.....	5-173
5.14.3.2.2 Combined Nitrification/Denitrification	5-174
5.14.3.2.2.1 Bardenpho Process (Four-Stage)	5-174
5.14.3.2.2.2 Oxidation Ditch.....	5-174
5.14.3.3 Combined Biological Nitrogen and Phosphorous Removal .	5-175
5.14.3.3.1 A ² /O Process	5-175
5.14.3.3.2 Bardenpho Process (Five-Stage).....	5-175

5.14.3.3.3	UCT Process	5-175
5.14.3.3.4	Design Criteria	5-175
5.14.3.4	Sequencing Batch Reactor (SBR)	5-176
5.14.4	Effluent Filtration	5-176
5.14.4.1	Applicability	5-176
5.14.4.2	Design Considerations	5-177
5.14.4.3	Location of Filter System	5-177
5.14.4.4	Number of Units	5-177
5.14.4.5	Filter Types	5-177
5.14.4.6	Filtration Rates	5-177
5.14.4.6.1	Hydraulic Loading Rate	5-177
5.14.4.6.2	Organic Loading Rate	5-178
5.14.4.7	Backwash	5-178
5.14.4.7.1	Backwash Rate	5-178
5.14.4.8	Filter Media	5-178
5.14.4.9	Filter Appurtenances	5-179
5.14.4.10	Reliability	5-179
5.14.4.11	Backwash Surge Control	5-179
5.14.4.12	Backwash Water Storage	5-180
5.14.4.13	Proprietary Equipment	5-180
5.14.5	Microscreening	5-180
5.14.5.1	Applicability	5-180
5.14.5.2	Design Considerations	5-180
5.14.5.3	Screen Material	5-180
5.14.5.4	Screening Rate	5-180
5.14.5.5	Backwash	5-181
5.14.5.6	Appurtenances	5-181
5.14.5.7	Reliability	5-181
5.14.6	Activated Carbon Adsorption	5-181
5.14.6.1	Applicability	5-181
5.14.6.2	Design Considerations	5-181
5.14.6.3	Unit Sizing	5-182
5.14.6.3.1	Contact Time	5-182
5.14.6.3.2	Hydraulic Loading Rate	5-182
5.14.6.3.3	Depth of Bed	5-182
5.14.6.3.4	Number of Units	5-183
5.14.6.4	Backwashing	5-183
5.14.6.5	Valve and Pipe Requirements	5-183
5.14.6.6	Instrumentation	5-183

5.14.6.7	Hydrogen Sulphide Control	5-183
5.14.6.8	Carbon Transport	5-184
5.14.6.9	Carbon Regeneration	5-184
5.14.6.9.1	Quantities of Spent Carbon	5-184
5.14.6.9.2	Carbon Dewatering	5-184
5.14.6.9.3	Regeneration Furnace	5-185
5.14.7	Constructed Wetlands	5-185
5.14.7.1	Types	5-185
5.14.7.2	Site Evaluation	5-186
5.14.7.3	Preapplication Treatment	5-186
5.14.7.4	Vegetation Selection and Management	5-187
5.14.7.5	Design Parameters	5-187
5.14.7.5.1	Detention Time	5-187
5.14.7.5.2	Water Depth	5-188
5.14.7.5.3	Aspect Ratio	5-188
5.14.7.5.4	Loading Rates	5-189
5.14.7.5.5	Nutrient Removal	5-189
5.14.7.6	Vector Control	5-190
5.14.7.7	Vegetation Harvesting	5-190
5.14.7.8	Monitoring	5-190
5.14.8	Floating Aquatic Plant Treatment Systems	5-190
5.14.8.1	Plant Selection	5-191
5.14.8.1.1	Water Hyacinths	5-191
5.14.8.1.2	Duckweed	5-191
5.14.8.1.3	Pennywort	5-191
5.14.8.2	Types of Systems	5-192
5.14.8.2.1	Water Hyacinth Systems	5-192
5.14.8.2.2	Duckweed Systems	5-192
5.14.8.3	Climatic Constraints	5-192
5.14.8.4	Preapplication Treatment	5-193
5.14.8.5	Design Parameters	5-193
5.14.8.6	Pond Configuration	5-193
5.14.8.6.1	Water Hyacinth Systems	5-193
5.14.8.6.2	Duckweed Systems	5-194
5.14.8.7	Plant Harvesting and Processing	5-194
5.15	Septic Tank Systems	5-194
5.15.1	Definitions	5-194
5.15.2	Septic Tank	5-195
5.15.2.1	Location	5-195
5.15.2.2	Capacity	5-195

5.15.2.3	Tank Proportions.....	5-195
5.15.2.4	Detention Time	5-195
5.15.2.5	Design Flow	5-195
5.15.2.6	Liquid Depth	5-195
5.15.2.7	Inlets and Outlets	5-195
5.15.2.8	Top of Tank.....	5-197
5.15.2.9	Tank Installation	5-197
5.15.2.10	Manholes.....	5-197
5.15.2.11	Material of Construction.....	5-197
5.15.2.12	Dosing Devices.....	5-197
5.15.3	Distribution Boxes	5-197
5.15.4	Tile Field.....	5-198
5.15.4.1	Location	5-198
5.15.4.2	Design	5-198
5.15.4.3	Construction.....	5-199
5.15.4.4	Site Appraisal and Soil Percolation Tests.....	5-201
5.15.5	Other Distribution Methods	5-202
5.16	Holding Tanks	5-202
5.16.1	Policy	5-202
5.16.2	Tank Construction and Installation.....	5-202
5.17	Communal Septic Tank Systems.....	5-204
5.17.1	Location	5-204
5.17.2	Capacity	5-205
5.17.3	Solids Retention – Inlets and Outlets.....	5-205
5.17.4	Maintenance Requirements.....	5-205
5.17.5	Material of Construction.....	5-205
5.17.6	Top of Tank.....	5-205
5.17.7	Bedding.....	5-206
5.17.8	Access	5-206
5.17.9	Scum Capacity	5-206
5.17.10	Effluent Disposal Options.....	5-206
5.17.10.1	Ocean/Marine Discharge	5-206
5.17.10.2	Exfiltration Beds.....	5-206
5.17.10.3	Communal Disposal Beds.....	5-206
5.17.10.4	Distribution Systems.....	5-206
5.17.10.5	Other Innovative Means of Disposal	5-206
5.18	Travel Trailer Dumping Stations	5-207
5.19	Disinfection of Sewerage.....	5-207
5.19.1	Forms of Disinfection	5-207
5.19.2	Chlorination	5-207

5.19.2.1	Design Guidelines	5-207
5.19.2.1.1	Mixing	5-207
5.19.2.1.2	Diffusers	5-207
5.19.2.1.3	Contact Time and Residual	5-208
5.19.2.1.4	Coliform Levels	5-208
5.19.2.1.5	Contact Tank	5-208
5.19.2.2	Chlorination Facilities Design	5-208
5.19.2.2.1	Feed Equipment	5-208
5.19.2.2.2	Odour Control	5-209
5.19.2.3	Other	5-209
5.19.3	Dechlorination	5-209
5.19.3.1	Dosage	5-210
5.19.3.2	Containers	5-210
5.19.3.3	Feed Equipment, Mixing, and Contact Requirements	5-210
5.19.3.4	Housing Requirements	5-211
5.19.3.4.1	Feed and Storage Rooms	5-211
5.19.3.4.2	Protective and Respiratory Gear	5-211
5.19.3.5	Sampling and Control	5-211
5.19.3.6	Activated Carbon	5-212
5.19.4	UV Disinfection	5-212
5.19.4.1	UV Transmission	5-212
5.19.4.2	Wastewater Suspended Solids	5-212
5.19.4.3	Design Flowrate and Hydraulics	5-212
5.19.4.4	Level Control	5-213
5.19.4.5	Iron Content	5-213
5.19.4.6	Wastewater Hardness	5-213
5.19.4.7	Wastewater Sources	5-213
5.19.4.8	UV Lamp Life	5-214
5.19.4.9	UV System Configuration and Redundancy	5-214
5.19.5	Ozone	5-214
5.19.5.1	Dosage	5-214
5.19.5.2	Design Considerations	5-215
5.19.5.2.1	Feed Equipment	5-215
5.19.5.2.2	Air Cleaning	5-215
5.19.5.2.3	Compression	5-215
5.19.5.2.4	Cooling and Drying	5-215
5.19.5.2.5	Injection, Mixing, and Contact	5-215
5.19.5.2.6	Controls	5-215
5.19.5.2.7	Piping and Connections	5-216

6.0	Instrumentation and Controls	6-1
6.1	Water Works	6-1
6.1.1	Measurement List.....	6-1
6.1.2	Degree of Automation in Plant Control.....	6-2
6.1.3	Alarms and Status Indication.....	6-3
6.1.4	Control Equipment (Automatic Systems).....	6-4
6.1.5	Field Instruments	6-5
6.1.5.1	Level Instruments.....	6-5
6.1.5.1.1	Ultrasonic Level Measurement.....	6-5
6.1.5.1.2	Pressure-Sensing Level Transmitter	6-5
6.1.5.2	Flow Instruments	6-6
6.1.5.2.1	Turbine Flow Meters.....	6-6
6.1.5.2.2	Magnetic Flow Meters	6-7
6.1.5.2.3	Ultrasonic Flow Meters.....	6-7
6.1.5.3	Water Quality Instruments.....	6-8
6.1.5.3.1	Turbidity Instruments.....	6-8
6.1.5.3.2	pH Instruments.....	6-9
6.1.5.3.3	Chlorine Residual Instruments.....	6-9
6.1.5.4	Pressure Instruments	6-10
6.1.5.4.1	Pressure Gauges.....	6-10
6.1.5.4.2	Pressure Transmitters.....	6-11
6.1.6	Process Controls.....	6-11
6.1.6.1	Pumping Systems.....	6-11
6.1.6.1.1	Raw Water Pumping.....	6-11
6.1.6.1.2	Finished Water Pumping.....	6-12
6.1.6.2	Treatment Processes.....	6-13
6.1.6.2.1	Travelling Screens	6-13
6.1.6.2.2	Chemical Feed Systems	6-14
6.1.6.2.2.1	Liquid Chemical Feed.....	6-14
6.1.6.2.2.2	Dry Chemical Feed	6-14
6.1.6.2.3	Rapid Mixing	6-15
6.1.6.2.4	Flocculation.....	6-15
6.1.6.2.5	Clarification	6-16
6.1.6.2.5.1	Sedimentation	6-16
6.1.6.2.5.2	Dissolved Air Flotation.....	6-17
6.1.6.2.6	Filtration.....	6-18
6.1.6.2.6.1	Rapid Gravity Filtration.....	6-18
6.1.6.2.6.1.1	Constant Rate	6-18

	6.1.6.2.6.1.2 Declining Rate	6-19
	6.1.6.2.6.1.3 Backwashing	6-20
	6.1.6.2.6.2 Slow Sand Filtration	6-22
	6.1.6.2.7 Disinfection	6-22
6.1.7	Design Documents	6-23
6.1.8	Control System Documentation	6-23
6.1.9	Training	6-24
6.2	Sewage Works (Wastewater)	6-24
6.2.1	Types of Instruments	6-25
6.2.1.1	Flow Measurement	6-25
6.2.1.1.1	Magnetic Flowmeters (Mag Meters)	6-25
6.2.1.1.2	Ultrasonic Flowmeters	6-25
6.2.1.1.3	Turbine Flowmeters	6-26
6.2.1.1.4	Flumes and Weirs (Parshall Flume)	6-26
6.2.1.2	Suspended Solids Measurement (Turbidity)	6-26
6.2.1.3	Suspended Solids Measurement (Optical)	6-27
6.2.1.4	Dissolved Oxygen Measurement (Galvanic)	6-27
6.2.1.5	Level Measurement	6-27
6.2.1.5.1	Sonic Ultrasonic	6-27
6.2.1.5.2	Float	6-27
6.2.1.5.3	Capacitance	6-27
6.2.1.6	Pressure Measurement	6-28
6.2.1.6.1	Bourdon Tubes	6-28
6.2.1.6.2	Bellows	6-28
6.2.1.6.3	Diaphragms	6-28
6.2.1.7	Temperature Measurement	6-28
6.2.1.7.1	Thermocouples	6-28
6.2.1.7.2	Resistance Temperature Detector	6-28
6.2.1.7.3	Thermistor	6-29
6.2.1.7.4	Thermal Bulb	6-29
6.2.2	Process Controls	6-29
6.2.2.1	Lift Stations	6-29
6.2.2.1.1	Level Control	6-29
6.2.2.1.2	Flow Monitoring	6-30
6.2.2.1.3	Pressure Monitoring	6-30
6.2.2.1.4	Pumps and Motors	6-30
6.2.2.1.5	Alarms	6-30

6.2.2.2	Mechanical Bar Screens.....	6-30
6.2.2.3	Primary Treatment	6-31
6.2.2.3.1	Raw Sludge Pumping.....	6-31
6.2.2.3.2	Scum Pumping.....	6-31
6.2.2.4	Secondary Treatment	6-32
6.2.2.4.1	Dissolved Oxygen (DO) Control	6-32
6.2.2.4.2	Return Activated Sludge Control.....	6-32
6.2.2.4.3	Waste Activated Sludge Control.....	6-32
6.2.2.4.4	Chemical Control System	6-32
6.2.2.4.5	Disinfection Control Systems (Ultra Violet)	6-33
6.2.2.5	Control and Monitoring Systems	6-33
6.2.2.5.1	Conventional Relay Control Systems	6-33
6.2.2.5.2	PLC Control Systems (Programmable Logic Controllers).....	6-33
6.2.3	Design Documents	6-34
6.2.4	Control Systems Documentation	6-34
6.2.5	Training.....	6-34
7.0	Operator Training	7-1
7.1	Training Programs and Operator Qualification	7-2
7.2	Operating Manual	7-3
8.0	Occupational Health and Safety	8-1
8.1	Fencing.....	8-1
8.2	Stairways and Handrails	8-1
8.3	Working Area.....	8-1
8.4	Grating	8-1
8.5	Piping.....	8-1
8.6	Non-Potable Water.....	8-1

List of Tables

Table 3.1 – Piping Colour Code for Water Lines	3-3
Table 3.2 – Piping Colour Code for Chemical Lines.....	3-4
Table 3.3 – Piping Colour Code for Waste Lines.....	3-4
Table 3.4 – Piping Colour Code for Other Types of Lines.....	3-4
Table 3.5 – Permanent Steel Casing Pipe Minimum Weight and Thickness	3-15
Table 3.6 – Size and Depth Distribution.....	3-34
Table 3.7 – Peaking Factors for Municipal Water Supply Systems	3-110
Table 4.1 – CT Values for 3.0 log (99.9%) Inactivation of <i>Giardia</i> Cysts by Free Chlorine (Water Temperature of 15°C)	4-4
Table 4.2 – CT Values for Inactivation of Viruses by Free Chlorine.....	4-5
Table 4.3 – CT Values for Inactivation of <i>Giardia</i> Cysts by Chloramine Within the pH Range 6 to 9	4-5
Table 4.4 – CT Values for Inactivation of Viruses by Chloramine	4-5
Table 4.5 – Log Inactivation and Percent Inactivation.....	4-6
Table 4.6 – Chlorine Control Guidelines.....	4-13
Table 5.1 – Estimated Sewage Flows	5-4
Table 5.2 – Minimum Sewer Slopes.....	5-8
Table 5.3 – Minimum Times Allowed for Pressure Drop	5-14
Table 5.4 – Depth and Length Requirements for Marine Outfalls	5-23
Table 5.5 – Paint Colour Code for Sewage Systems	5-54
Table 5.6 – Sedimentation Basins Design Parameters.....	5-74
Table 5.7 – Chemical Conditioning Requirements.....	5-83
Table 5.8 - Sludge Thickening Methods and Performance With Various Sludge Types.....	5-88
Table 5.9 – Solids Loading on Gravity Thickeners for Various Sludge Types.....	5-89
Table 5.10 – Typical Sludge Qualities and Generation Rates	5-95
Table 5.11 – Advantages and Disadvantages of Aerobic Sludge Digestion.....	5-104
Table 5.12 – Minimum HRT	5-105
Table 5.13 – Relationship of Dewatering to Other Sludge Treatment Processes for Typical Municipal Sludge.....	5-109
Table 5.14 – Sludge Drying Bed Areas	5-111
Table 5.15 – Sludge Dewatering Methods and Performance With Various Sludge Types.....	5-115
Table 5.16 – Sludge Pumping Requirements for Various Sludge Types	5-119
Table 5.17 – Allowable Aeration Tank Capacity and Loading	5-123
Table 5.18 – Percentage of Average Design Flow	5-129
Table 5.19 – Minimum Distance Criteria	5-142
Table 5.20 – Application, Advantages and Disadvantages of the Different Lagoon Types....	5-143
Table 5.21 – Membrane Bioreactor Effluent Quality	5-162
Table 5.22 – Typical Chemical Dosage Requirements for Phosphorous Removal.....	5-165
Table 5.23 – Quantities of Chlorine Required for Three Wastewater Sources	5-170

Table 5.24 – Design Criteria for Biological Phosphorus Removal	5-173
Table 5.25 – Design Criteria for Nitrification	5-174
Table 5.26 – Design Criteria for Combined Biological Nitrogen and Phosphorus Removal..	5-176
Table 5.27 – Media Depths and Sizes.....	5-179
Table 5.28 – Typical Carbon Dosages for Different Column Wastewater Influent.....	5-184
Table 5.29 – Loading Rates for Constructed Wetlands	5-189
Table 5.30 – Floating Aquatic Plant System Design Criteria.....	5-193
Table 5.31 – Commonly Used Fill Material and their Design Infiltration Rates	5-199
Table 5.32 – Required Absorptive Area	5-201
Table 5.33 – Chlorine Dosage Requirements	5-209
Table 5.34 – Dechlorination Chemicals and Required Amounts	5-210

List of Figures

Figure 3.1 – Above Ground Storage 3-95

Figure 5.1 – Air Flow Required for Different Periods of Preaeration 5-68

Figure 5.2 – Approximate Friction Head Loss for Laminar Flow of Sludge 5-120

Figure 5.3 – Typical Septic Tank Detail 5-196

Figure 5.4 – Distribution Box Detail 5-198

Figure 5.5 – Tile Field Details 5-200

Figure 5.6 – Percolation Test Arrangement 5-202