DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Safe Drinking Water

DOCUMENT NUMBER:	394-2125-004
TITLE:	Public Water Supply Manual – Part II Community System Design Standards
EFFECTIVE DATE:	Upon publication of notice as final in the *Pennsylvania Bulletin*
AUTHORITY:	Pennsylvania's Safe Drinking Water Act (35 P.S. § 721.1 et seq.) and regulations at Title 25 Pa. Code Chapter 109
POLICY:	The design standards and procedures presented in this document the Department of Environmental Protection (DEP or Department) finds to be acceptable designs and procedures for community water systems (CWSs). Other designs may be approved by DEP if the applicant demonstrates the alternate design can provide an adequate and reliable quantity and quality of water to the public.
PURPOSE:	The purpose of this document is to set forth design standards for community water systems which DEP finds to be acceptable designs. This document serves as a guide in the design and preparation of plans and specifications and to establish uniformity of practice.
APPLICABILITY:	This guidance will apply to all CWSs.
DISCLAIMER:	The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The policies and procedures herein are not an adjudication or a regulation. DEP does not intend to give this guidance that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.
PAGE LENGTH:	250 pages
DEFINITIONS:	See Title 25 Pa. Code Chapter 109

Commonwealth of Pennsylvania

PUBLIC WATER SUPPLY MANUAL
PART II
COMMUNITY SYSTEM DESIGN STANDARDS

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USER'S GUIDE

The *Public Water Supply Manual* is a comprehensive publication designed to provide necessary, useful information to public water systems (PWSs) concerning Pennsylvania's Safe Drinking Water Program administered by DEP. The manual contains essential information PWSs will need to know about the Safe Drinking Water Program, including design and construction standards, water quality standards, operating requirements, emergency measures, and information on government agency programs and contacts.

In accordance with 25 Pa. Code § 109.602 of the Safe Drinking Water Regulations, a public water system must be designed to provide an adequate and reliable quantity and quality of water to the public that complies with the primary and secondary Maximum Containment Levels (MCLs), MRDLs and treatment techniques and conforms to accepted standards of engineering and design in the water supply industry. The standards outlined within this manual conform to accepted standards of engineering and design in the water supply industry and align with standards of the American Water Works Association and the Great Lakes – Upper Mississippi River Board Ten States Standards. An alternate design that does not meet the criteria identified in this manual may be approved by DEP if the water supplier can demonstrate the alternate design is capable of providing an adequate and reliable quantity and quality of water to the public.

The following technical guidance documents can be located at DEP's eLibrary under the "Technical Guidance Final Documents" folder and within the "Water Standards and Facility Regulations", "Water Supply Management", and "Water Supply and Wastewater Management" subfolders.

The following is a summary of the *Public Water Supply Manual* Parts. Following the summary is a Table of Contents for each part in the *Public Water Supply Manual*.

Part I - Summaries of Key Requirements

Part I is no longer published as a compilation of all the summaries of key requirements. The summaries of key requirements are available as individual documents. Additional summaries are added as new rules and regulations are adopted.

Part II - Community System Design Standards, DEP ID: 383-2125-108

Part II provides detailed design and construction standards for all CWSs except bottled water systems, bulk water haulers, vended water systems, and retail water facilities. Part II also contains instructions for submitting a PWS permit application.

Part III - Design Standards for Bottled Water, Bulk Water Hauling, Water Vending Machines, and Retail Water Facilities, DEP ID: 383-2126-303

Part III provides detailed design and construction standards for bottled water systems, bulk water haulers, vended water systems, and retail water facilities, including information on submitting a PWS permit application.

Part IV - Noncommunity System Design Standards, DEP ID: 394-2128-108

Part IV provides detailed design and construction standards for noncommunity water systems (NCWs), including information on the procedures to be followed to obtain DEP approval.

Part V - Operations and Maintenance, DEP ID: 383-3110-111

Part V provides the needed information to develop an Operations and Maintenance Plan as required under 25 Pa. Code § 109.702 of DEP's Safe Drinking Water Regulations. This is a comprehensive guidance document covering all aspects of PWS operations, including operation and maintenance standards.

Part V has been developed as two separate documents. Each is designed for specific type systems:

- Sections I and II are for surface water systems and the larger groundwater systems.
- Appendix A, Operations and Maintenance for Small Groundwater Systems, DEP ID: 383-3110-211, is a condensed version containing information needed by small groundwater systems having limited treatment (disinfection and corrosion control).

Part VI - Emergency Response, DEP ID: 383-5900-111

Part VI discusses the measures which a water supplier should take to prepare for emergency circumstances and explains how to prepare an emergency response plan.

Part VII - Cross-Connection Control/Backflow Prevention, DEP ID: 383-3100-111

Part VII provides the basic information needed by a PWS to establish an effective cross-connection control program.

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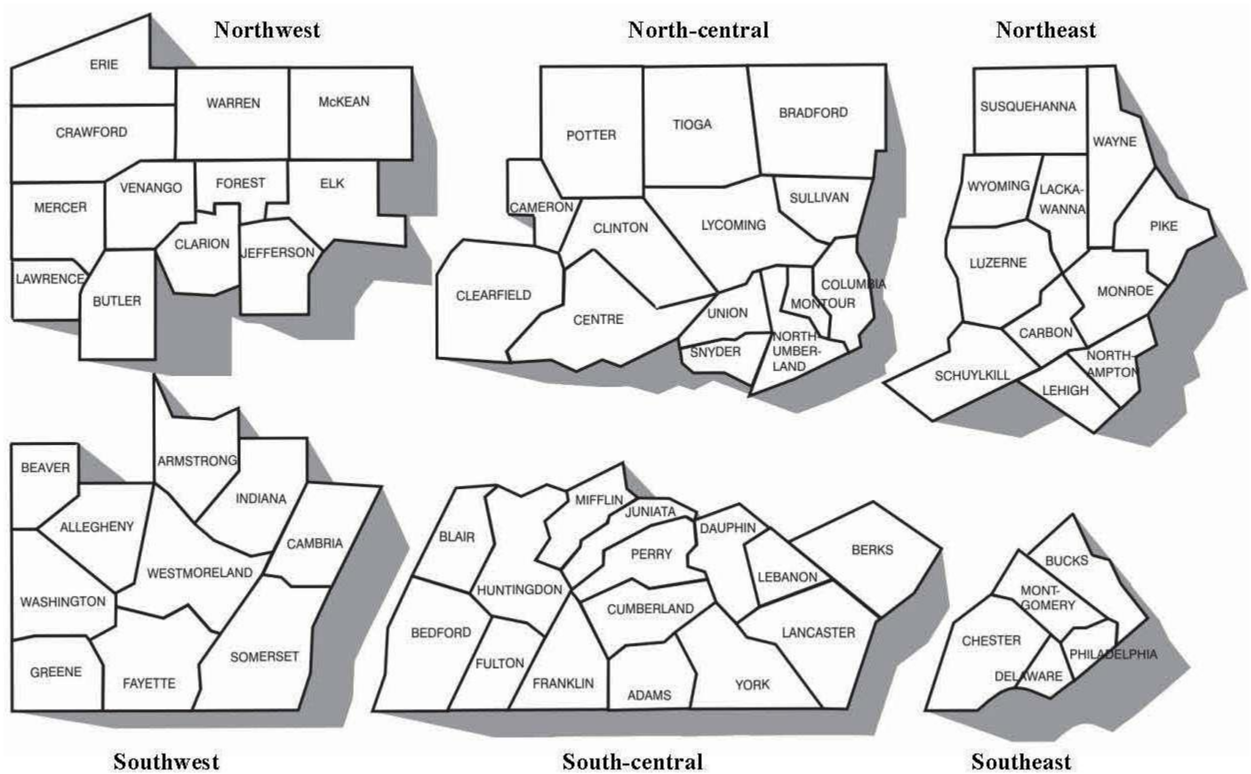

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230 Chestnut St.
Meadville, PA 16335-3481
Main Telephone: 814-332-6945
24-Hour Emergency: 1-800-373-3398

Counties: *Butler, Clarion, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, McKean, Mercer, Venango, and Warren*

North-central Region
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Williamsport, PA 17701
Main Telephone: 570-327-3636
24-Hour Emergency: 570-327-3636

Counties: *Bradford, Cameron, Clearfield, Centre, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga, and Union*

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1 APPLICATIONS FOR PERMITS

1.0 Permit Requirements

Under the provisions of Subchapter E, Permit Requirements, of DEP's Rules and Regulations at 25 Pa. Code § 109.501, no person may construct or operate a PWS without first obtaining a permit from DEP. Furthermore, no person may substantially modify a PWS operated under a PWS permit without first obtaining a permit amendment from DEP.

The purpose of this section is to provide guidelines on the procedures which must be followed when applying for a CWS permit.

1.0.1 Coverage

Pertaining to projects, the applicant shall submit for DEP approval:

1) Information on all facilities of any new system.

2) Information about any addition to, or modification of, an existing system which may affect the quality and/or quantity of the supply. Major modifications require the submission of a complete permit application as outlined in Section 1.1. Minor modifications must be discussed with the appropriate regional Safe Drinking Water engineer to determine the extent of the information which must be submitted to obtain the DEP's approval. The Department determines whether a modification is a substantial modification and requires the construction permit to be amended as per 25 Pa. Code § 109.503(b)(3).

Table 1.1
Modifications

MAJOR MODIFICATIONS	MINOR MODIFICATIONS
New sources (or relocation of source water intake) Increases in source or plant capacity	Deletion of sources
Addition, deletion, or modification of treatment techniques or processes	Changes in treatment chemicals, except where otherwise specified Moving chemical application points
Pumping stations (addition or modification)	New transmission mains
Storage reservoirs (addition or modification)	Construction of prefabricated storage tanks and standpipes to standard specifications Covering of reservoirs Replacement of storage tank or reservoir linings (or similar materials) in contact with the water supply Painting the interior of a storage tank
Installation of mixing or aeration systems to meet a Maximum Containment Level (MCL) (e.g., TTHM/HAAS MCL)	Installation of a mixing systems to minimize icing
Conversion or addition of disinfection practices	Conversion from gas to liquid (disinfection) Installation of chlorine contact piping
Any addition or modification to treat for an MCL	Addition of interconnections (permit required by receiving system or both systems if bi-directional flow)
	Installation of a bulk water loading stations
	Changes in legal status, such as transfers of ownership, incorporation, or mergers
	Water main extensions with the potential to adversely affect water quality (e.g., increase disinfection byproducts (DBPs), deplete disinfectant residuals) or quantity (e.g., cause diminution or pressure problems)

1.0.2 Application Fees

Applications must include the appropriate permit fee.

It is recommended that all applicants contact the appropriate Safe Drinking Water Program's regional office (Page xx) to determine the application fee that must accompany the permit application.

1.0.3 Construction and Operation Permits

In administering the permit requirements of DEP's Safe Drinking Water Regulations, the Bureau of Safe Drinking Water (BSDW) has implemented a two-part approval process. Upon approval of the plans, modules, and other design documents, a construction permit will be issued approving the construction or modification in accordance with the approved plans. This approval will be valid for a period of two years unless substantial work is initiated or the permit is renewed by DEP. Upon completion of construction/modification, the system is required to submit a Certificate of Construction/Modification Completion (3900-FM-BSDW0062) to DEP stating that construction or modification was completed in accordance with the approved plans and specifications. This statement must be signed by the professional engineer or other person responsible for the work. Upon receipt of the certificate, DEP will inspect the facility and issue an operation permit where the construction has been satisfactorily completed.

1.0.4 Revisions to Approved Plans

Any deviations from approved plans or specifications affecting capacity, hydraulic conditions, operating units, the functioning of water treatment processes, or the quality of water to be delivered must be approved by DEP before such changes are made.

1.0.5 DEP Review and Permit Coordination

In accordance with the Permit Decision Guarantee (PDG) Policy, DEP will approve or deny a permit within 120 business days of receipt of an administratively complete new or major permit application or within 60 business days of receipt of an administratively complete minor or transfer permit application. To comply with this requirement, DEP will not accept an application for review until the application is determined to be administratively complete. If the application is technically deficient, DEP will request the additional information in writing from the applicant within 60 business days of receipt of the administratively complete application. If an application is deemed administratively incomplete or technically deficient, the PDG is no longer applicable.

As other state or interstate environmental agencies may require approvals, applicants and their consultant engineers are advised to hold a preliminary engineering conference with the regional Safe Drinking Water staff to identify and coordinate these approvals. Failure to satisfy any permit coordination requirements could result in the refusal of an application or the denial of a permit.

1.1 Procedures for Obtaining a Permit

An application for a PWS permit shall be submitted in writing on forms provided by DEP and shall be accompanied by plans, specifications, engineer's and geologist's reports, water quality analyses, and other data, information, or documentation reasonably necessary to enable DEP to adequately evaluate the proposed design. Applications must be submitted to the appropriate regional office listed on Page xx. Unrelated projects require separate permit applications.

1.1.1 Licensed Professional Engineer and Geologist

The party desiring to construct, add to, or modify a water supply shall engage the services of a licensed professional engineer who is legally qualified to practice in Pennsylvania and who is competent in the design and construction of water supply facilities. When the proposed source is a groundwater source, the party shall also engage the services of a licensed professional geologist who is legally qualified to practice in Pennsylvania. The geologist shall be competent in groundwater source siting and hydrogeologic investigations.

1.1.2 Preliminary Conference

A preliminary conference with the regional Safe Drinking Water staff should be held for projects which include new sources of supply or treatment facilities. At such a conference, it will be helpful if the applicant's engineer and/or geologist is prepared to set forth the water supply problems and the proposed solutions in such a manner as to support their conclusions and recommendations.

1.1.2.1 Scope

Subjects appropriate to the project as covered in Section 1.1.3.1 Engineer's Report, and Section 2 - Preliminary Design Considerations, should be discussed in the preliminary conference.

1.1.2.2 Preliminary Plans

Location maps, layout sketches, and other illustrative material should be included.

1.1.2.3 Preliminary Report

A report presenting the proposed design plans should be included in the material presented in the preliminary conference. If a conference is not held, it is advisable to submit a preliminary report at least 30 days prior to preparation of final plans.

1.1.2.4 Preliminary Hydrogeologic Information

Prior to permitting a new source, a site survey (physical inspection) must be performed by the regional Safe Drinking Water hydrogeologist to determine if the proposed site is suitable. The supplier shall make reasonable efforts to obtain the highest quality sources available.

If the proposed source is a spring, infiltration gallery, Ranney well, or crib intake, the source water classification (groundwater/groundwater under the direct influence of surface water (GUDI)) shall be determined prior to submission of the permit application.

A pre-drilling plan is also necessary for proposed groundwater sources. The objective of this plan is to provide a preliminary characterization of the site-specific hydrogeologic setting, the proposed well construction, and identification and location of any potential sources of contamination. The pre-drilling plan must be submitted and approved prior to well construction and conducting an aquifer test. At a minimum, the pre-drilling plan must include preliminary results of the source water assessment, a hydrogeologic description, an aquifer test monitoring plan, and the proposed well construction design. A source water assessment is an evaluation documented in writing of the contamination potential of a drinking water source used by a public water system which includes identifying the contributing area to the water source, an inventory of potential contaminant sources, and a determination of the susceptibility of the water source to contamination.

Specific components of the plan are provided in DEP's Aquifer Testing Guidance for Public Water Systems, DEP ID: 394-2125-001. The pre-drilling plan must be signed and sealed by a licensed professional geologist.

1.1.3 Submission of Application

All applications, reports, final plans, and specifications shall be submitted in duplicate to the appropriate regional office (see Page xx). For some applications, a third copy of the application data may be necessary for submission to a county health department or river basin commission.

Documents submitted for approval of a major modification shall include, at a minimum:

1) Application
2) Modules
3) Engineer's Report
4) Geologist's Report (if applicable)
5) Detailed Plans
6) Specifications
7) New Source Sample Results and any required water quality results.
8) Permit Fee

The modules, specifications, and engineer's report shall bear the signature and imprint of the seal of the licensed engineer by, or under whom, it was prepared. In addition, each plan submitted shall bear an imprint or a legible facsimile of such seal. The cover of the geologist's report shall bear the signature and imprint of the seal of the licensed geologist by, or under whom, it was prepared.

1.1.3.1 Engineer's Report

As a minimum, the engineer's report shall consist of completed copies of the appropriate modules furnished by DEP. All modules pertaining to the project must be included.

A comprehensive engineer's report, covering the following items, shall be prepared when a construction or modification of a water system is proposed.

1.1.3.1.1 General Information

1) A description of the existing water works.

2) An identification of the municipality or area served.

1.1.3.1.2 Extent of Water Supply System

1) A description of the nature and extent of the area to be served.

2) Provisions for extending the water supply system to include additional areas.

3) An appraisal of the future requirements for service, including existing and potential industrial, commercial, institutional, and other water supply needs.

1.1.3.1.3 Justification of Project

Where two or more alternatives exist for providing PWS facilities, each of which is feasible and practicable, discuss the alternates. Give reasons for selecting the one recommended, including financial considerations, operational requirements, operator qualifications, reliability, and water quality considerations. Discuss any alternatives considered to prevent pollution, to utilize alternative energy sources, and to enhance energy efficiency.

1.1.3.1.4 Water Use Data

1) A description of the population trends as indicated by available records and the estimated population which will be served by the proposed water supply system or expanded system 20 years in the future in 5-year intervals or over the useful life of critical structures/equipment.

2) Present water consumption and the projected average and maximum daily demands, including fire flow demand where provided (see Table 2.2).

3) Present and/or estimated yield of the sources of supply.

4) Unusual occurrences.

1.1.3.1.5 Fire Flow Requirements

1) Requirements of the Insurance Services Office (or other similar agency) as to fire flows required or recommended in the service area involved.

2) Fire flows which will be made available by the proposed or enlarged system.

1.1.3.1.6 Sewage Facilities

Describe the existing treatment facilities (e.g., on lot) and/or municipal sewage treatment works, with special reference to their location to existing or proposed water sources or structures which may affect the operation of the water supply system or which may affect the quality of the sources.

1.1.3.1.7 Sources of Water

Describe the proposed source or sources of water supply to be developed, the reasons for their selection, and provide information as follows:

1.1.3.1.7.1 Surface Water Sources

1) Summarized data on the quality of the raw water with special reference to fluctuations in quality, changing meteorological conditions, stream flow, etc. (see Section 3.1).

2) Hydrological data, stream flow, and weather records.

3) Reliable yield, including all factors that may affect it.

4) Maximum flood flow, together with approval for safety features of the spillway and dam, from the Bureau of Waterways Engineering and Wetlands.

5) Description of the watershed, noting any existing or potential sources of contamination (e.g., sewerage treatment plants,

industrial facilities, etc.) which may affect water quality.

1.1.3.1.7.2 Groundwater Sources

1) A separate hydrogeologic report, signed and sealed by a licensed professional geologist, is required with the permit application, (see Section 3.2).

2) Documentation for proof of ownership, or substantial control, through a deed restriction or other methods acceptable to DEP, of the Zone I wellhead protection area that prohibits activities within Zone I that may have a potential adverse impact on source water quality or quantity.

1.1.3.1.8 Proposed Treatment Processes

Summarize and establish the adequacy of proposed processes and unit hydraulics for the treatment of the specific water under consideration. Alternative methods of water treatment and chemical use should be considered as a means of reducing waste handling and disposal problems. Bench scale tests, pilot studies, or other demonstrations may be required to establish adequacy for some water quality standards.

1.1.3.1.9 Project Sites

1) Discuss the various sites considered and advantages of the recommended ones.

2) Establish the proximity of residences, industries, and other establishments that may influence the quality of the supply or interfere with effective operation of the water supply system.

1.1.3.1.10 Automation

Provide supporting data justifying automatic equipment, including the servicing and operator training to be provided. Manual override must be provided for any automatic controls. Highly sophisticated automation may put proper maintenance beyond the capability of the plant operator, leading to equipment breakdowns or expensive servicing. Adequate funding must be assured for maintenance of automatic equipment.

1.1.3.1.11 Waste Disposal

Discuss the various wastes from the water treatment plant, their volume, proposed treatment, and points of discharge (see Section 9). If discharging to a sanitary sewerage system, verify that the system, including any lift stations, is hydraulically capable of handling the flow to the sewage treatment works, that the treatment works is capable of properly treating the wastewater, and that the wastewater treatment plant operator will accept the additional loading.

1.1.3.1.12 Soil, Groundwater Conditions, and Foundation Problems

Provide a description of:

1) The character of the soil through which water mains are to be laid.

2) Foundation conditions prevailing at sites of proposed structures.

3) The approximate elevation of groundwater in relation to subsurface structures.

1.1.3.1.13 Future Extensions

Capital improvements for future needs and services.

1.1.3.2 Detailed Plans

Plans shall be legible and shall be drawn to a scale which will permit all necessary information to be correctly shown. The size of the plans should not be larger than 36 inches by 50 inches. The plans shall include topographic maps, general layouts, plan views, elevations, sections, and supplementary views which, together with the specifications, provide the information for the contract and construction of the works. The topographic map shall include the location of the existing and potential sources of pollution listed in any reports.

1.1.3.2.1 The plans shall include:

1) The datum used.

2) The north point.

3) Boundaries of the municipalities, water districts, or specified areas to be served.

4) Land area owned and/or controlled by the water supplier, including the Zone I wellhead protection area.

5) Topography of the drainage area and site, including wells, springs, streams, lakes, dams, and reservoirs.

6) The location and outline form of equipment.

7) Water levels.

8) Flood levels.

9) The locations and logs of test borings and wells.

10) The diameter and depth of well casings and liners.

1.1.3.2.2 Each Plan Shall Bear a Suitable Title Showing:

1) The name of the municipality, authority, company, water district, or institution served.

2) The scale in feet.

3) A graphic scale.

4) The date.

5) The name, address, and seal of the design engineer.

1.1.3.3 Specifications

Complete, detailed technical specifications shall be supplied for the proposed project, including:

1) A program for keeping existing water works facilities in operation during construction of additional facilities to minimize interruption of service.

2) The type and design of chemical feed systems and grades of chemicals to be used.

3) All paints, coatings, or other materials which will come into contact with drinking water during and after construction.

4) All procedures for flushing, disinfecting, and testing (as needed), prior to placing the project in service. Disposal of disinfectant water shall be consistent with the requirements of the Clean Streams Law.

1.1.3.4 Water Quality Analysis

All bacteriological, chemical, and radiological laboratory analyses shall be performed by DEP accredited laboratories in accordance with the analytical techniques adopted by the United States Environmental Protection Agency (EPA) under the federal act or methods approved by DEP.

1.1.4 Simultaneous Compliance

Any change in source or treatment techniques may adversely impact compliance with other drinking water regulations. A simultaneous compliance analysis shall be submitted with every permit application.

This analysis shall include:

1) A detailed desktop analysis of any unintended consequences the project may cause that will adversely affect compliance with other drinking water regulations. American Water Works Association's Managing Change and Unintended Consequences: Lead and Copper

Rule Corrosion Control Treatment, EPA's Microbial and Disinfection Byproduct Rules Simultaneous Compliance Guidance Manual (EPA 815-R-99-015) and Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules (EPA 815-R-07-017) shall be referenced when preforming this analysis.

2) A detailed report on how these effects will be managed and the existing treatment, systems shall be evaluated to insure all systems are operating well in both quality and quantity and how the addition of the new treatment will affect this operation.

3) Before any new treatment can be added to the existing treatment, systems shall be analyzed to insure all systems are operating well in both quality and quantity and how the addition of the new treatment will affect this operation.

1.1.5 Consecutive Water Systems

Systems that provide water to consecutive systems shall provide proof of notification to all consecutive water systems of all proposed new sources or treatment additions or modifications. This notification shall include any potential effects these additions or modifications may cause to the consecutive system or it customers.

1.2 Innovative Treatment Permits

The risk incurred in experimentation with innovative treatment processes must rest upon the proponent of the method rather than the public. Recent developments or new equipment may be acceptable if they meet at least one of the following conditions:

1) The treatment process has been thoroughly tested in full-scale comparable installations under competent supervision.

2) The treatment process has been thoroughly tested in a pilot plant operation for a sufficient time to ensure the technology provides drinking water which meets DEP's drinking water standards under all conditions of raw water quality (see Section 1.2.1).

Permits for innovative treatment technologies may be limited in duration and may impose additional monitoring, reporting, or other requirements deemed necessary to protect the public health.

1.2.1 Pilot Plant Studies

Pilot plant studies which are to be conducted to determine the adequacy of new treatment technologies or the suitability of an unconventional treatment scheme must be discussed with the regional Safe Drinking Water engineer prior to initiating the tests. Readers should refer to DEP's Pilot Plant Filtration Studies for Surface Water Sources Guidance, DEP ID: 383-2000-208. In addition, the following procedures shall be followed:

1) A pilot study protocol outlining the purpose of the pilot study, the units to be tested, and the monitoring procedures to be followed must be submitted to DEP for approval prior to conducting the study. This report must include information on the water quality parameters of concern, seasonal water quality fluctuations, flow rates, chemicals to be used, or other information relevant to the specific proposal.

2) The operation, testing, and evaluation shall be conducted under the control of an engineer licensed to practice in the Commonwealth and experienced in the design and operation of drinking water treatment systems.

3) A record of all operating problems and the procedures used to correct them shall be maintained and submitted to DEP with the final report summarizing the performance of the system.

1.3 Conformance to Codes

All installations and operations shall meet or exceed the relevant requirements of the recognized national, state, local, or trade good practices codes, whichever has jurisdiction.

1.3.1 Electric Power

All electrical equipment and work shall conform to the relevant requirements of the National Fire Protection Association and to the pertinent state and/or local codes.

1.3.2 Air or Gas

When air or gas is used under pressure, equipment connected therewith shall conform to the current requirements for unfired pressure containers of the American Society of Mechanical Engineers and to other related provisions of that society's code.

1.3.3 Storage Tanks

Applicable facilities shall conform to the current requirements of American Water Works Association's (AWWA) Standards for Welded Steel Tanks for Water Storage, Factory-Coated Bolted Steel Tanks for Water Storage, Wire- and Strand-Wound Circular Prestressed Concrete Water Tanks, Circular

Prestressed Concrete Water Tanks with Circumferential Tendons, and Thermosetting Fiberglass-Reinforced Plastic Tanks.

1.3.4 Chemicals

Where chemicals are used, facilities for the safe storage and handling of chemicals shall be provided in accordance with Manual M3, "Safety Practice for Water Utilities," of the AWWA (see Section 5).

1.3.5 Disinfection

Facilities for conveying, treating, or storing water, which is not subsequently treated, shall be disinfected in accordance with the latest edition of the American National Standards Institute (ANSI) and AWWA Standards: C651 - Disinfecting Water Mains, C652 - Disinfection of Water Storage Facilities, C653 - Disinfection of Water Treatment Plants, and C654 - Disinfection of Wells.

1.3.6 Wells

All construction materials including, but not limited to, drilling fluids, casing, screens, gravel packs, grout, sealant, etc. shall conform to the current AWWA A100 Standard for Water Wells.

2 PRELIMINARY DESIGN CONSIDERATIONS

2.0 General

The design of a water supply system or treatment process encompasses a very broad area. Water supply systems must be designed to provide the best quality water for human consumption while giving due consideration to the future grouping or regionalization of water systems where this is feasible. All water treatment facilities should be designed so that they can be readily increased in capacity.

2.1 Sizing and Capacity

The quantity of water at the source(s), and the transmission, treatment, storage, and distribution facilities should be adequate to supply the water demand of the service area without major additions during the designated design period. For larger projects which require extensive planning, property acquisition, and financing (e.g., raw water storage reservoirs), the design period should be of adequate length (e.g., 50 years). For treatment works and distribution system components whose capacity can be increased without much difficulty, a shorter design period may be appropriate (e.g., 10 years).

2.1.1 Minimum Design Capacities

In general, water supply facilities should be designed per Table 2.1:

Table 2.1
Basics of Design

System Component	Minimum Design Capacity
Raw water pumping & transmission facilities	Maximum daily demand with consideration to finished water storage and fire flow demands
Treatment facilities system	Shall exceed the maximum 50 year projected daily demand of the system
Finished water storage	One day's storage with the ability to meet peak hourly demands and consideration for fire flow demands.
Distribution system piping, pump stations, and appurtenances	Provisions for maximum daily and peak hourly demand at a minimum pressure of 20 psig (pounds per square inch, gauge)

2.1.2 Water Demands

In calculating future average, maximum, and peak water demands, consideration should be given, but not limited to, the following:

1) History of past water usage and conservation practices.

2) Past and anticipated population growth.

3) Types of industry and anticipated growth.

4) Fire protection needs.

5) Increasing or decreasing trends in water use.

6) Water metering practices.

7) Availability of municipal sewerage.

8) Cost of water.

9) Unaccounted for water losses.

10) Minimum quantity of potable water. Data from similar uses may be utilized in the case of new systems; however, the designer must be able to clearly show DEP the similarities between the existing uses (whose data are being used) and the proposed facility. The designer should submit a narrative outlining the rationale for the data from similar uses.

11) Design by analogy. Systems should be designed to provide at least the minimum quantity of potable water as determined from Table 2.2.

Table 2.2
Recommended Water Demand Data to Meet Peak Daily Demand

User Category	Demand (gallons per day per capital unless otherwise noted)
Residential	
Manufactured housing spaces (per space)	150
Single family residences	75
Boarding house, per boarder	75
Apartments	65
Boarding house, per resident non-boarder	15
Commercial	
Department stores (per public toilet)	400
Shopping Center, per 1,000 ft^2	250
Beauty shops (per operator)	200
Laundromat (per washer)	200
Hotels (per room)	100
Motels (per room)	100
Offices (per employee)	15
Airports (per passenger)	3.5

Table 2.2 Recommended Water Demand Data to Meet Peak Daily Demand	
User Category	**Demand (gallons per day per capital unless otherwise noted)**
Service station (per vehicle)	10
Bar	
Per employee	15
Per customer	3
Restaurants	
Per patron	10
For bar and/or lounge, add	2
Bus service area (no food service)	5
Recreational and Seasonal	
Campgrounds, per site	
With water and sewer	100
With water, only	50
No water or sewer	30
Camps	
Hunting and summer residential	50
Day (no meals served)	15
Work or construction camps	50
Fairgrounds, Picnic Grounds and Parks	
For showers and bathhouses, add	25
Toilets only	10
Swimming Pools and Bath houses	10
Highway rest area	5
Theater	
Movie (per seat)	5
Drive-in (per space)	5
Institutional	
Hospitals (per bed)	150
Prisons (per inmate)	120
Other institutions (per bed)	100
Rest/Retirement homes	75
Schools	
Boarding	75
With cafeteria, gym and showers	30
With cafeteria, only	15
No cafeteria, gym or showers	10
Churches	
Per seat	3
Per meal served, add	3

Table 2.2 Recommended Water Demand Data to Meet Peak Daily Demand	
User Category	**Demand (gallons per day per capital unless otherwise noted)**
Industrial	
Factories	35
Warehouses	35

2.2 Facility Siting

Evaluations of all available sites should be made to determine the most favorable location for a facility. In addition to considering the following, design engineers are encouraged to consult with the regional water supply engineer and/or hydrogeologist in whose region the project is located.

- Facilities shall be located above the 100-year flood plain or protected to this level.

- Potential sources of raw water pollution (i.e., sewage, industrial waste, agricultural land, mining, surface water features that may contribute recharge to a groundwater source) should be evaluated prior to site selection.

2.2.1 Location and Protection

Minimum distances from a well to possible sources of pollution shall be great enough to provide assurances that subsurface flow of contaminated water will not reach the well. Each proposed well site should be field surveyed to evaluate the character and location of possible sources of contamination, distance to nearest surface water feature, types of geologic formations present, depth to the water bearing aquifer, direction of groundwater flow, and the effect on groundwater movement by well pumping.

2.2.1.1 Location

DEP shall be consulted during the well site selection process of a proposed well to determine the required separation between existing and potential sources of contamination. Poor well site selection can result in additional monitoring requirements and delay the issuance of a permit.

2.2.1.2 Source Protection

Water suppliers shall control all land within the Zone I wellhead protection area, which is a minimum 100 feet radius. Protection of the proposed groundwater source shall be provided through ownership, easements, deed restrictions, or zoning. Activities that may have a potential adverse impact on source quality or quantity shall be prohibited within the Zone I area. Prohibited activities shall include, but not be limited to, roads, pastures, buildings, farms, sewer or stormwater lines, etc. The storage, use, or disposal of potential contaminants within the Zone I area shall be discontinued unless the material is permitted in the production and/or treatment of drinking water.

2.3 Plant Layout and Design

2.3.1 Layout

The general layout of the plant should provide for security, functional efficiency, and convenience of operation.

1) Properly select and group units to facilitate operation and to permit effective supervision.

2) Centralize operations and control.

3) Eliminate operational irritants such as unnecessary steps and exposure of operators to adverse weather for routine tasks.

4) Provide adequate lighting, heating, ventilation, and drainage.

5) Provide for accessibility of equipment for operation, servicing, and removal.

6) Provide for future expansion.

7) Provide for expansion of the plant waste treatment and disposal facilities.

2.3.2 Design

Consideration shall be given to the following factors when designing a new or expanding an existing treatment facility:

1) Need for continuous monitoring and recording facilities for disinfectant residuals (see Section 4.1) and turbidity levels (see Section 4.3).

2) Operator safety (consider Occupational Safety and Health Administration (OSHA) requirements).

3) Flexibility of plant operations.

4) Simplified chemical handling, storage, and feeding.

5) Appropriate use of automation.

6) Economics of durable construction.

7) Simplification and centralization of equipment and operation.

8) Dehumidification equipment in damp areas.

9) Requirements for storage, shop, and laboratory space.

10) Need for sanitary facilities for operators and visitors.

11) Protection from oil tank or plant chemical spills.

12) Use of the piping color codes in Table 2.3:

Table 2.3 **Piping Color Codes**	
Water Lines	
Raw or Recycle	Olive Green
Settled or Clarified	Aqua
Finished or Potable	Dark Blue
Chemical Lines	
Alum or Primary Coagulant	Orange
Ammonia	White
Carbon Slurry	Black
Caustic	Yellow with Green Band
Chlorine (Gas & Solution)	Yellow
Chlorine Dioxide	Yellow with Violet Band
Fluoride	Light Blue with Red Band
Lime Slurry	Light Green
Ozone	Yellow with Orange Band
Phosphate Compounds	Light Green with Red Band
Polymer or Coagulant Aid	Orange with Green Band
Potassium Permanganate	Violet
Soda Ash	Light Green with Orange Band
Sulfuric Acid	Yellow with Red Band
Sulfur Dioxide	Light Green with Yellow Band
Waste Lines	
Backwash Waste	Light Brown
Sludge	Dark Brown
Sewer (Sanitary or Other)	Dark Gray
Other	
Compressed Gas	Dark Green
Gas	Red
Other Lines	Light Gray
Notes	
1. In situations where two colors do not have sufficient contrast to easily differentiate between them, a 6-inch band of contrasting color should be painted on one of the pipes at approximately 30-inch intervals.	
2. The name of the liquid or gas, with arrows indicating the direction of flow, also should be painted on the pipe.	

2.4 Laboratory Equipment

Each system shall have its own equipment and facilities for routine laboratory testing necessary to ensure proper operation. Laboratory equipment shall be based on the characteristics of the raw water source and the complexity of the treatment process involved. Laboratory test kits which simplify procedures are acceptable provided they comply with EPA-approved methods/standards specified in 40 CFR Part 141 and are acceptable to DEP.

2.4.1 Testing Equipment

As a minimum, the following laboratory equipment shall be provided:

1) Systems shall provide the necessary facilities for microbiological testing of water from both the treatment plant and the distribution system. DEP may allow deviations from this requirement where testing is conducted by DEP accredited laboratories.

2) Systems using surface water sources shall have a nephelometric turbidimeter meeting the requirements of the most current edition of "Standard Methods for the Examination of Water and Wastewater" jointly published by the American Public Health Association (APHA), AWWA, and the Water Environment Federation (WEF), or as approved by DEP.

3) Each surface water treatment plant utilizing flocculation and sedimentation, including those which lime soften, shall have a pH meter, jar test equipment, and titration equipment for both hardness and alkalinity.

4) Each ion-exchange softening plant, and lime softening plant treating only groundwater, shall have a pH meter and titration equipment for both hardness and alkalinity.

5) In addition to the equipment required above, those systems providing for the removal of iron and manganese shall have test equipment capable of accurately measuring iron to a minimum of 0.10 milligrams per liter (mg/L), and/or test equipment capable of accurately measuring manganese to a minimum of 0.05 mg/L.

6) Systems which chlorinate shall have test equipment for determining both free and total chlorine residual in water utilizing methods in the most current edition of "Standard Methods for the Examination of Water and Wastewater" jointly published by APHA, AWWA, and WEF, or as approved by DEP.

7) Systems which fluoridate shall have test equipment for measuring the quantity of fluoride in the water utilizing methods in the most current edition "Standard Methods for the Examination of Water and Wastewater" jointly published by APHA, AWWA, and WEF, or as approved by DEP.

8) Systems which feed polyphosphates shall have test equipment capable of accurately measuring phosphates from 0.1 to 2.0 mg/L.

9) Systems which provide treatment for removal of nitrate shall have test equipment for determining nitrate in the water utilizing methods in the most current edition "Standard Methods for the Examination of Water and Wastewater" jointly published by APHA, AWWA, and WEF, or as approved by DEP.

2.4.2 Monitoring Equipment

All water treatment plants should be provided with equipment to monitor and record water being discharged to the distribution system.

1) Plants treating surface water and/or GUDI shall have the capability to monitor and record turbidity, pH, temperature, and chlorine residual at locations necessary to determine CT disinfection and other important process control variables as determined by DEP. Turbidimeters shall continuous monitoring and recording and be equipped with alarms, shutdowns and the capacity to notify operators.

2) Ion exchange plants for nitrate removal shall monitor and record the treated water nitrate level daily.

2.5 Standby Power and Emergency Operation

2.5.1 Uninterrupted Operation

PWSs shall be designed for uninterrupted source water supply and operation of treatment and pumping facilities necessary to ensure that safe potable water is continuously supplied to users. Potential source contamination, transmission line failures, floods, and mechanical breakdowns should be considered for facility design.

2.5.2 Multiple Sources

Multiple water sources or interconnections with adjacent water systems shall be provided. Where pumping is necessary, multiple booster pumps which have sufficient capacity to meet peak demands plus fire demand with the largest pump out-of-service are required.

2.5.3 Resiliency

To ensure reliability under all circumstances, systems shall provide duplicate essential equipment and dual supply lines from different power sources or on-site power generation. Alternate fuel types and sources and duplicate substations should be considered.

System service from auxiliary power shall be provided through one or more of the following methods:

1) Connection to at least two independent power feeds from separate substation(s).

   - The power feeds shall not be in the same conduit or supported from the same utility pole.

   - If overhead power feeds are used, the power feeds shall not cross or be in an area where a single plausible occurrence (e.g., a fallen tree) could disrupt both the power feeds.

2) On-site auxiliary power sources (i.e., generators or engines).

   - Consideration shall be given to the minimum necessary power supply to operate all essential equipment. Carbon monoxide detectors are required where fuel-fired generators are housed.

The Department may approve alternate provisions, such as finished water storage capacity or interconnections with another public water system, to meet these requirements.

2.5.4 Siting

Plant access roads and power supply lines shall be located above the 100-year flood plain.

2.6 Disposal of Plant Wastes

Consideration shall be given to all the various wastes from the treatment plant, their volume, treatment, and ultimate method of disposal. The disposal of water treatment plant wastes, including sanitary wastes, shall conform to applicable local, state, and federal regulations (see Section 9). Design engineers should characterize the nature of their plant wastes as accurately as possible so that the necessary approvals required by other department agencies can be expedited.

2.7 Package Water Treatment Plants

Package water treatment plants are increasingly being considered for production of potable water. DEP individually evaluates proposals for package water treatment plants.

Generally, package plants are pre-engineered for treatment of raw water which is of relatively constant quality. However, many such plants are currently being considered for application on waters of variable quality. Accordingly, it will be necessary to demonstrate to DEP that the desired water quality can be produced under all raw water quality conditions and system flow demands.

Automated equipment and the small size usually associated with package treatment plants may lead the water supplier, plant operator, and consulting engineer to assume that these plants will operate themselves. Adequate funding and emphasis must be given for maintenance of all equipment to operate properly. Highly sophisticated automation may put proper maintenance beyond the plant operator's capability and lead to expensive servicing or equipment breakdown.

In addition, special consideration must be given to construction coordination, future budgeting, and the operation and maintenance requirements of these plants. Each water supplier and their consulting engineer must evaluate each of these items, prior to the submission of final plans and specifications.

Due to compressed treatment times, the operation of package treatment plants is even more critical than for conventional treatment plants. As with conventional water treatment plants, a qualified operator must be available at all times to make the necessary treatment adjustments.

2.8 New Technologies and Equipment

New technologies and equipment for the treatment of water are encouraged. However, any new developments must be thoroughly tested under competent supervision before approval is issued for a plant utilizing a new process or equipment. In addition to the development of satisfactory performance data, no new water treatment technology or material of construction will be accepted unless the designing engineer or manufacturer presents evidence that the process or material will:

1) Satisfy the design standards, treatment technique requirements, and drinking water standards established under Pennsylvania's Safe Drinking Water Act and Regulations.

2) Not impose undue problems of operation, maintenance, supervision, or laboratory control.

New or innovative treatment processes or unproven equipment may require the issuance of an Innovative Treatment Technology permit as outlined in Section 1.2.

2.9 Chemicals and Materials (American National Standards Institute (ANSI)/NSF International (NSF) Certification)

Incompatible chemicals shall not be stored together. Refer to Form 3940-FM-BSDW0559, Chemical Compatibility Table, for details and storage requirements.

Under the requirements of 25 Pa. Code § 109.606 of the Safe Drinking Water Regulations, all chemicals or materials (i.e., paints, coatings, liners, etc.) which may come in contact with the raw or finished drinking water must be acceptable to DEP.

2.9.1 ANSI/NSF 60 (Drinking Water Treatment Chemicals – Health Effects)

Chemicals which come in contact with or affect the quality of the water shall be certified for conformance with ANSI/NSF Standard 60 (Drinking Water Treatment Chemicals - Health Effects) or meet the food grade standards of the United States Pharmacopeia.

Chemicals that have been repackaged (transferred between containers) after leaving the manufacturing facility and before reaching the water supplier are not acceptable, unless the repackaging site has been certified for conformance with ANSI/NSF Standard 60.

2.9.2 ANSI/NSF 61 (Drinking Water System Components – Health Effects)

Materials or equipment used in construction or modification of a PWS which come in contact with the water or drinking water treatment chemicals shall meet the requirements of ANSI/NSF Standard 61 (Drinking Water System Components – Health Effects). PWS must ensure the leachate requirements for all contaminants (metals and non-metals), as well as the lead-free requirements of ANSI/NSF Standard 61 are met. Materials and equipment include but are not limited to:

- Pipes, fittings, and related products.
- Protective barrier materials (e.g., coatings, linings, liners, cement, cement ad-mixtures, etc.).
- Joining and sealing materials (e.g., adhesives, lubricants, elastomers, etc.).
- Process media (e.g., activated carbon, sand, ion exchange resin, regenerated media, etc.).

- Mechanical devices used in treatment and distribution (e.g., valves, pumps, filters, chlorinators, etc.).

If no product can be found that meets both the system requirements and is certified to ANSI/NSF Standard 61, it is the PWS's responsibility to provide evidence that the selected product meets the leachate requirements for all contaminants (metals and non-metals), as well as the lead-free requirements of ANSI/NSF Standard 61.

2.9.3 ANSI/NSF General

It is the responsibility of the PWS, the design engineer, contractor, or supplier to provide evidence of certification to ANSI/NSF Standard 60 and/or 61. The following ANSI accredited third-party certification bodies provide product certification to the new lead-free requirement for manufacturers of drinking water system and plumbing materials:

- Intertek Testing Services NA, Inc.
- NSF
- Truesdail Laboratories, Inc.
- Underwriters Laboratories (UL), LLC
- Water Quality Association (WQA)
- CSA Group
- ICC Evaluation Service (ICC-ES), LLC
- International Association of Plumbing and Mechanical Officials Research and Testing (IAPMO R&T)

Information on products and equipment that are certified by these organizations recorded on the organization's website.

2.10 Sample Taps

Sample taps shall be provided so that water samples can be obtained from each raw water source and from appropriate locations for each treatment unit and from the finished water. Taps shall be consistent with sampling needs and shall not be of the petcock type. Taps used for obtaining samples for bacteriological analysis shall be of the smooth-nosed type without interior or exterior threads, shall not be of the mixing type, and shall not have a screen, aerator, or other such appurtenance. Sample taps used for obtaining performance samples from a treatment process shall be located as close as practicable to the treatment process and not be influenced by subsequent treatment processes or appurtenances.

2.11 Safety

Consideration must be given to the safety of water plant personnel and visitors. The design must comply with all applicable safety codes and regulations. Items to be considered include noise arrestors, noise protection, confined space entry, protective equipment and clothing, gas masks, safety showers and eye washes, handrails and guards, warning signs, smoke detectors, toxic gas detectors, and fire extinguishers. A lockout/tag out system shall be utilized by plant personnel in connection with utility hazards that have been previously identified at the treatment facility.

2.12 Security

Security measures shall be installed and instituted. Appropriate design measures to help ensure the security of water system facilities shall be incorporated. Such measures, as a minimum, shall include means to lock all exterior doorways, windows, gates, and other entrances to source, treatment, and water storage facilities. Other measures may include fencing, signage, closed circuit monitoring, real-time water quality monitoring, and intrusion alarms.

3 SOURCE DEVELOPMENT AND CONSTRUCTION

3.0 General

Each system should maintain more than one source of supply. This may be accomplished by a combination of groundwater and/or surface water sources or through interconnections with other systems. 25 Pa. Code § 109.603 requires a PWS to take reasonable efforts to obtain the highest quality source(s) available and to make reasonable measures to protect these sources. In selecting the source(s) of water to be developed, the design engineer, and geologist where appropriate, must demonstrate to the satisfaction of DEP that an adequate quantity of water will be available and that the water which is to be delivered to the consumers will consistently meet the drinking water standards of DEP.

Actual source development, including water quality analyses, quantity testing, and construction is dependent on the source classification as surface water, groundwater, or GUDI. Each source classification type is defined below:

3.0.1 Surface Water

Surface water sources are defined as all water open to the atmosphere or subject to surface runoff, or, for treatment purposes, GUDI, which may include springs, infiltration galleries, cribs, or wells. The term excludes finished water.

3.0.2 Groundwater

Groundwater sources are defined as water that is located within the saturated zone below the water table, available to supply wells and springs, and not under the direct influence of surface water.

3.0.3 GUDI

GUDI Sources are defined as:

1) Water that experiences significant and relatively rapid shifts in characteristics such as turbidity, temperature, conductivity, and/or pH (which also may change in groundwater but at a much slower rate) which closely correlate to climatological or surface water conditions, or,

2) water that contains the presence of insects or other microorganisms, algae, organic debris, or large-diameter pathogens such as *Giardia lamblia* and *Cryptosporidium* as determined by a microscopic particulate analysis.

GUDI sources are determined on a case-by-case basis through a special evaluation and monitoring program (see Guidance for Surface Water Identification Protocol, DEP ID: 383-3500-106). Based on results of the evaluation, a source classification must be determined prior to submission of a permit application.

3.0.4 Finished Water

Finished water—Water that is introduced into the distribution system of a public water system and is intended for distribution and consumption without further treatment, except as necessary to maintain water quality in the distribution system (for example, booster disinfection or addition of corrosion control chemicals).

3.1 Source Water Quality

One of the prerequisites for achieving a sound water supply system is a representative water quality monitoring program. This includes collecting and analyzing enough raw water samples to characterize the source water quality under various hydrological and meteorological conditions.

The public water supplier, or its consultant, is responsible for collecting all New Source Samples. To ensure reliable laboratory results for all New Source Samples, the use of proper sample-collection methods and collecting equipment are critical. Water samples shall be collected by a person trained to sample for those specific parameters.

Laboratory analysis results should demonstrate that source water does not exceed DEP's MCLs. Applicants should contact the appropriate Safe Drinking Water regional office for the current list of MCLs. Other parameters which a sanitary survey may determine as having a potentially adverse impact on the quality of raw water shall so be included in the analyses.

All New Source sampling must be analyzed using EPA-approved/accepted methods. All analyses of the New Source Samples must be performed by a DEP accredited laboratory, except for those that may be performed by a person meeting the requirements of Title 25 Pa. Code § 109.704.

The minimum number of sample analyses to be performed for each water quality parameter depends on the source. Applicants, or their consultants, must notify the appropriate Safe Drinking Water regional office (see Page xx) prior to any new source sample collection. All new source samples are only valid for two years from the final collection date.

3.1.1 Surface Water Sources

The new source sampling requirements for surface water sources are provided in DEP's technical guidance, New Source Sampling Requirements for Surface Water Sources, DEP ID: 393-3130-108. Sample collection should be spaced such that high, average, and low stream flows will be evaluated. Samples shall be taken over a minimum time interval of 6 months and preferably over 1 year.

All surface water sources shall complete the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) source water monitoring bin determination requirements prior to a permit application (see Source Water Monitoring Guidance Manual for Public Water Systems, EPA ID: 815-R06-005). If the LT2ESWTR requirements are not completed the source shall be required to provide bin 4 treatment.

3.1.2 Groundwater Sources

For groundwater sources that are not under the direct influence of surface water, raw water quality sampling will include at least one set of samples collected toward the end of the constant-rate aquifer test. Laboratory analysis includes all parameters listed in DEP's technical guidance, New Source Sampling Requirements for Groundwater Sources for Community and Noncommunity Systems, DEP ID: 393-3130-208.

3.1.3 GUDI Sources

All GUDI sources shall conduct water quality testing in accordance with Section 3.1.1 and complete the LT2ESWTR source water monitoring bin determination requirements prior to a permit application. If the LT2ESWTR requirements are not completed, the source shall be required to provide bin 4 treatment.

3.1.4 Spring Sources, Infiltration Galleries, and Ranney Wells

For spring sources, infiltration galleries, and Ranney wells, a sampling plan shall be submitted to the DEP. The plan must be approved prior to data-collection efforts. Sampling and monitoring shall include the following, at a minimum:

1) Raw water quality sampling for all parameters for groundwater (see New Source Sampling Requirements for Groundwater Sources for Community and Noncommunity Systems, DEP ID: 393-3130-208); two-sets of samples shall be taken, and include both high flow and low flow periods.

2) The monitoring requirements provided in SWIP Guidance (see Guidance for Surface Water Identification Protocol, DEP ID: 383-3500-106).

3) If the source is determined to be GUDI, the LT2ESWTR source water monitoring bin determination requirements prior to a permit application. If the LT2ESWTR requirements are not completed the PWS shall be required to provide bin 4 treatment

3.1.5 Finished Water Sources

When a system proposes use of a finished water source, the applicant shall submit the most recent results of analyses for radionuclides, Volatile Organic Compounds (VOCs), Synthetic Organic Chemicals (SOCs), and Inorganic Compounds (IOCs) provided the analyses were conducted within the appropriate monitoring schedule and conducted by a DEP accredited laboratory. However, the applicant must provide data from their own sampling and analysis of turbidity, total coliforms, and total trihalomethanes.

If surface water is purchased as the finished water source, a subsidiary water allocation permit shall be obtained from the DEP.

3.2 Source Water Quantity

An evaluation of the quantity of raw water from each new source is required so that a reliable source of supply can be demonstrated to DEP. Information necessary for this evaluation is dependent on source type and classification.

The total developed source capacity should equal or exceed the design maximum day demand and equal or exceed the design average day demand with the largest producing source out-of-service.

3.2.1 Surface Water and Spring Sources

The quantity of water at the source shall provide a reasonable surplus for anticipated growth.

Where surface water sources are proposed to be used as a source of drinking water, a water allocation permit must be obtained from DEP. Applicants are advised to obtain the water allocation permit prior to preparation of plans and specifications.

3.2.2 Groundwater Sources

Testing and reporting requirements for conducting a constant-rate aquifer test shall be performed as per DEP's Aquifer Testing Guidance for Public Water Systems, DEP ID: 394-2125-001.

3.3 Source Water Assessment

The Source Water Assessment shall be submitted with the permit application. The assessment shall be an evaluation documented in writing of the contamination potential of a drinking water source used by a public water system which includes identifying the contributing area to the water source, an inventory of potential contaminant sources, and a determination of the susceptibility of the water source to contamination. The assessment shall entail:

1) Obtaining samples over an adequate period to assess the bacteriological, physical, chemical, and radiological characteristics of the water.

2) Determining future uses and effects of impoundments or reservoirs.

3) Determining the degree of control over the watershed that can be exercised by the owner.

4) Assessing the degree of hazard or vulnerability to the supply by agricultural, recreational, and residential activities in the watershed, and by accidental or deliberate spillage of materials that may be toxic, harmful, or detrimental to treatment processes.

3.4 Surface Water Source Construction and Design

3.4.1 Structures

3.4.1.1 Intakes

Intake structures shall:

1) Be able to withdraw water from more than one level if quality varies with depth.

2) Ports located above the bottom of the stream, lake, or impoundment, but at sufficient depth to be kept submerged at low water levels.

3) Be designed to handle the permitted capacity of the plant.

4) Be protected by at least two sets of removable, stationary screens or by a traveling screen. Screen slot size shall be small enough to exclude all matter which will cause clogging. The maximum screen slot size should not be greater than 1.0 mm.

5) Have protection against clogging by sediment, debris, or ice and against damage due to wave action and flotation.

6) Have a velocity of flow through the inlet structure not to exceed 0.5 feet per second in order to limit impact of frazil ice.

7) Have inspection manholes every 1,000 feet for pipes requiring visual inspections.

8) Be accessible during adverse weather conditions.

9) Provide for occasional cleaning of the inlet line.

3.4.1.2 Raw Water Wet Wells

Raw water wet well intakes shall:

1) Have motors and electrical controls located above grade and preferably above the 100-year flood level.

2) Be accessible during all adverse weather conditions.

3) Be designed against flotation.

4) Be equipped with removable or traveling screens before the pump suction well.

5) Provide for introduction of chlorine or other chemicals in the raw water transmission main if necessary for quality control.

6) Have intake valves and provisions for back-flushing or cleaning by a mechanical device and for testing for leaks where practical.

7) Have provisions for withstanding surges where necessary.

3.4.2 Impoundments and Reservoirs

3.4.2.1 Site Selection

Site selection shall consider:

1) Topography and geology.
2) Required storage capacity.

3) Safety.
4) Water rights.
5) Raw water characteristics.
6) Proximity to sources of pollution.
7) Accessibility during adverse weather conditions.

3.4.2.2 Site Preparation

Site preparation shall provide:

1) Removal of brush and trees to a level of 10 feet above the anticipated high-water elevation.

2) Protection from floods during construction.

3.4.2.3 Site Construction

Where earth disturbance will occur, an Erosion and Sediment Control Plan (E&S) *(*see Erosion and Sediment Pollution Control Program Manual, DEP ID: 363-2134-008*)* must be developed and retained at the construction site for the duration of the earth moving activities.

3.5 General Well Construction

3.5.1 Erosion and Sediment Control

Best Management Practices shall be utilized in developing and implementing E&S control plans for all well drilling construction sites. An E&S plan should be developed and submitted to DEP prior to well drilling. Consideration should be given to the terrain, vegetative cover, soil types, underlying geology, and proximity to waterways and wetlands.

3.5.2 Drilling Fluids and Additives

All fluids and additives used during drilling and well construction activities should not impart any toxic substances to the water or promote bacteriological contamination, be in accordance with AWWA's *Standard A100 Water Wells*, and approved by DEP prior to use. Water used during drilling and well construction shall be obtained from a PWS source permitted by DEP to assure water quality meets the standards established in the Safe Drinking Water Act.

3.5.3 Plumbness and Alignment

Every well shall be tested for plumbness and alignment in accordance with the latest version of AWWA's Standard *A100 Water Wells*. The test method and allowable tolerances shall be clearly stated in the specifications.

At a minimum, a 40-foot section of pipe or rigid dummy of the same length, having an outside diameter of not more than 0.5 inches less than the inside diameter of the well casing or hole being tested, should move freely throughout the length of the well casing or hole to the lowest anticipated pump setting.

3.5.4 Minimum Protected Depths

All drinking water supply wells and observation wells shall be constructed to be watertight to such depths as may be necessary to exclude pollution from surface runoff and from polluted aquifers above the aquifer being used as a source of supply.

In consolidated rock formations, if steel casing is used, the casing shall be equipped with a drive shoe and seated by driving it into the surface of the consolidated formation until a seal is obtained. If nonferrous casing is used, it must be seated into the rock for a length of at least 5 feet (1.5 meters) and must be cemented in place.

In unconsolidated formations, the permanent casing and grout shall extend at least 50 feet below original or final ground elevation, whichever is lower.

3.5.5 Temporary Casings

Temporary casings used for construction shall be capable of withstanding the structural load imposed during its installation and removal.

3.5.6 Well Casing Material

Protective casing of wrought iron or steel shall have minimum weights and thickness as specified in AWWA's Standard *A100 Water Wells*. Well casing material other than wrought iron or steel must be resistant to the corrosiveness of the water and to the stresses to which it will be subjected during installation, grouting, and operation. Casing and grouting materials must be compatible. In general, the criteria established in AWWA's Standard *A100 Water Wells* should be followed.

3.5.6.1 Ferrous Casings Shall:

1) Be new pipe meeting American Society for Testing and Materials (ASTM) or American Petroleum Institute (API) specifications for water well construction.

2) Have additional thickness and weight if minimum thickness is not considered sufficient to ensure reasonable life expectancy of the well.

3) Be capable of withstanding forces to which it is subjected.

4) Be equipped with a drive shoe when driven.

5) Have full circumferential welds or threaded pipe joints.

3.5.6.2 Polyvinyl Chloride Plastic (PVC) Well Casing is not Acceptable.

3.5.6.3 Other Nonferrous Casing

Other nonferrous casing shall meet appropriate ANSI/ASTM or NSF Standards for well casing applications as outlined in AWWA's Standard *A100 Water Wells*. Nonferrous casing materials shall not impart taste, odor, or toxic substances to the well water.

3.5.7 Packers

Packers shall be of materials that will not impart taste, odor, toxic substances, or bacterial contamination to the well water.

3.5.8 Screens

Well screens, when used, shall:

1) Be designed according to aquifer thickness and stratigraphic layering.

2) Provide the maximum amount of open area while still maintaining structural strength.

3) Have appropriate screen-aperture size based on a sieve analysis of the material contained in the surrounding geological formation or gravel pack.

4) Be constructed of materials resistant to damage by chemical action of groundwater or cleaning operations.

5) Have sufficient length and diameter to provide adequate specific capacity and low aperture velocity. Usually, the entrance velocity should not exceed 0.1 feet per second.

6) Be installed so that the pumping water level remains above the screen under all operating conditions.

7) Be designed and installed to permit removal or replacement without adversely affecting watertight construction of the well.

8) Be provided with a bottom plate or wash down bottom fitting of the same material as the screen.

3.5.9 Chemical Conditioning

Chemicals used during conditioning shall be acceptable to DEP. In general, specifications covering the chemical conditioning of wells shall be submitted to DEP for approval. Chemical conditioning procedures shall be included in the specifications and shall contain information concerning method, equipment, chemicals, testing for residuals, disposal of wastes, and inhibitors used. Chemicals certified under ANSI/NSF Standard 60 are deemed acceptable to DEP.

3.5.10 Grouting

All permanent well casings shall be surrounded by a minimum of 1.5 inches of grout for the entire length of casing, including couplings, unless prior approval is obtained from DEP. Grouting materials shall conform to AWWA Standards.

3.5.10.1 Application

1) All grouting shall be performed within 24-hours of the completion of the drilling by adding the mixture, from the bottom of the annular opening upward, in one continuous operation until the annular opening is filled.

2) Grout shall not be installed in the borehole until the annular space is completely cleared of all obstructions.

3) When the annular opening is less than 4 inches, grout shall be installed under pressure by means of a grout pump in one continuous operation.

4) After grouting is applied, work on the well shall be discontinued until the grout has properly set.

5) Alternate application methods may be approved by DEP on a case-by-case basis.

3.5.10.2 Guides

A protective casing must be provided with sufficient guides welded to the casing to permit unobstructed flow and uniform thickness of grout.

3.5.11 Gravel Packs

Gravel packs, when installed in the annular space between screen/casing and borehole for stabilizing the formation, shall:

1) Be properly sized well-rounded particles that are 95 percent siliceous, smooth and uniform, and free of foreign and carbonate materials.

2) Be protected from contamination prior to installation and be washed and disinfected immediately prior to or during placement.

3) Be installed in one uniform continuous operation.

4) Have a minimum thickness of 3 inches and a maximum thickness of 12 inches, depending on aquifer characteristics.

5) Extend to a minimum of 20 feet above the screen.

6) Have a minimum of 1.5 inches of grout surrounding all gravel refill pipes that are located in the grouted annular space.

7) Have protection from grout leakage into the gravel pack and well screen.

3.5.12 Upper Terminal Well Construction

1) Casing length shall extend 18 inches above final grade or well house floor, whichever is greater.

2) A pump discharge water meter is required to determine water production.

3) A sampling tap shall be provided for raw water sampling which discharges in a downward direction and away from the well casing.

4) Adequate support for the well pump and drop pipe shall be provided.

5) Where a well house is constructed, the floor shall:

- Be at least 6 inches thick.
- Extend at least 3 feet in all directions from the well.
- Be at least 6 inches above the final ground elevation.
- Slope 1/4 inch per foot towards a screened 4-inch floor drain to atmosphere.

6) The top of the well casing at sites subject to flooding shall be at least 3 feet above the highest known flood elevation or as directed by DEP.

7) Wells shall not be constructed in pits.

8) Drilled wells with the prime mover mounted on the casing shall:

- Have the casing extended 18 inches above the floor and be equipped with a flange or suitable sanitary seal.
- Have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least 1 inch into the base of the pump if a watertight connection is not provided.
- Have the base of the pump not less than 18 inches above the pump room floor or apron.
- Have the pump foundation and base designed to prevent water from coming into contact with the joint between the casing and the prime mover.

3.5.13 Well Development

Every well shall be developed to remove all fluids used during drilling activities, the native silts and clays, drilling mud, and/or the finer fraction of the gravel pack. Development should continue until the maximum specific capacity is obtained from the completed well.

3.5.14 Capping

A welded metal plate or bolted and locked cap shall be the minimum acceptable method of capping a well. The well shall also be equipped with a sanitary seal to prevent contamination.

3.5.15 Well Construction Log

Well construction logs shall be created for all wells. At a minimum, the well log(s) shall include:

1) The type, size, weight, and depth of all casing(s).

2) A description and location of all drive shoes and casing centralizers.

3) Amount, the material type, and depth of grout along with a description of the application process.

4) A description and location of all screened intervals and gravel pack.

5) The depth of production pump setting.

6) A list of all materials used, including quantities.

3.5.16 Well Decommissioning

Wells no longer being used, including but not limited to observation points and test wells, shall be sealed by such methods as necessary to restore the controlling hydrogeologic conditions which existed prior to construction and to eliminate potential pathways for the migration of contamination. Wells shall be sealed in accordance with the requirements outlined in the Department of Conservation and Natural Resources (DCNR) Water-Well Abandonment Guidelines. All forms submitted to DCNR, and their approval, should also be submitted to DEP.

3.6 Special Construction Methods

3.6.1 Radial Water Collectors

1) Locations of all caisson construction joints and porthole assemblies shall be indicated.

2) The caisson wall shall be reinforced to withstand the forces to which it will be subjected.

3) Provisions shall be made to assure that radial collectors are horizontal.

4) The top of the caisson shall be covered with a watertight floor.

5) All openings in the floor shall be curbed and protected from entrance of foreign material.

6) The pump discharge pipe shall not be placed through the caisson walls.

3.6.2 Infiltration Lines

1) Infiltration lines will be considered only where geological conditions preclude the possibility of developing an acceptable drilled well.

2) The area around infiltration lines, a peripheral 100 feet buffer distance around the outermost extent of the collection field, shall be under the control of the water supplier.

3) Flow in the lines shall be by gravity to the collecting well.

4) Water from infiltration lines shall be considered a GUDI source, unless demonstrated otherwise.

3.6.3 Sand and Gravel Wells

1) To prevent leakage, permanent casing and grout should extend through all clay or hard pan layers that are above the aquifer.

2) When permeable soils overlay the aquifer, with DEP approval, the casing and grout shall extend to a minimum of 25 feet below ground surface, but, when possible, extend greater than 50 feet below the ground surface.

3) If the use of temporary casing is needed during well-construction activities, the casing shall be removed from the borehole as grout is applied to the annular space.

3.6.4 Carbonate-Rock Wells

1) When the depth of unconsolidated formations above the water-bearing rock exceeds 50 feet, permanent well casing shall be seated at a minimum of 5 feet into competent rock that is not weathered.

2) When the depth of unconsolidated formations is less than 50 feet, depth of casing and grout shall be a minimum of 50 feet and seated into component rock that is not weathered.

3.6.5 Dug Wells

A dug well may not be used as a source of supply for a community system.

3.6.6 Naturally Flowing Artesian Wells

1) Flow from a naturally flowing artesian well shall be controlled to prevent discharge from around the casing by tightly sealing the juncture between the borehole wall and the well casing and stopping or reducing the discharge of water from within the well casing.

2) Casing shall be set in the impermeable (confining) layer.

3) The well shall be pressure grouted to ensure a proper seal around the casing.

4) Pitless adapters shall be welded or screwed onto the casing. Compression fittings shall not be used.

3.7 Well Pumps, Discharge Piping, and Appurtenances

3.7.1 Line Shaft Pumps

Wells equipped with line shaft pumps shall:

1) Have the pump structure effectively sealed to the well casing to prevent entrance of surface water.

2) Have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least 0.5 inches into the pump base.

3) Have the pump foundation and base designed to prevent water from coming into contact with the joint.

3.7.2 Submersible Pumps

Where a submersible pump is used:

1) The top of the casing shall be effectively sealed against the entrance of water under all conditions of vibration or movement of conductors or cables.

2) The electrical cable shall be firmly attached to the riser pipe at 20-foot intervals.

3.7.3 Discharge Piping

Discharge piping shall:

1) Have control valves and appurtenances located above the pump house floor when an aboveground discharge is provided.

2) Be protected against the entrance of contamination.

3) Be equipped with a check valve (in addition to any check valve within the well), a shutoff valve, a pressure gauge, a means of measuring flow, and a smooth nosed sampling tap located at a point where positive pressure is maintained.

4) Where applicable, be equipped with an air release-vacuum relief valve located upstream from the check valve, with exhaust/relief piping terminating in a downturned position at least 18 inches above the floor and covered with a 24-mesh corrosion resistant screen.

5) Be valved to permit test pumping and control of each well.

6) Have all exposed piping, valves, and appurtenances protected against physical damage and freezing.

7) Be properly anchored to prevent movement.

8) Be protected against surge or water hammer.

9) Be provided with a means of pumping to waste, but shall not be directly connected to a sewer. Piping and valves should be installed in a manner that allows pumping of the well to waste at the permitted rate while not affecting the status of other permitted sources.

3.7.4 Pitless Well Units

3.7.4.1 Design

A pitless well unit includes a section of casing, the pitless adapter, and the well cap or cover which extends the upper end of casing to above grade. The pitless well units shall:

1) Be shop-fabricated from the point of connection with the well casing to the unit cap or cover.

2) Be threaded or welded to the well casing or use compression fittings certified by the Water Systems

Council under Recommended Standards (PAS-1). Flexible couplings are not acceptable.

3) Be of watertight construction throughout.

4) Be of materials and weight at least equivalent and compatible to the casing.

5) Have field connection to the lateral discharge from the pitless unit of threaded, flanged, or mechanical joint connection.

6) Terminate at least 18 inches above final ground elevation or 3 feet above the highest known flood elevation, whichever is higher, or as DEP directs.

7) Provide access to disinfect the well.

8) Have a properly constructed casing vent that meets the requirements of Section 3.7.5.

9) Make provisions for facilities to measure water level in the well as per Section 3.7.6.

10) Be designed with a cover at the upper terminal of the well to prevent entrance of contaminants.

11) Have a contamination-proof entrance connection for electrical cable.

12) Have an inside diameter as great as that of the well casing, up to and including casing diameters of 12 inches, to facilitate work and repair on the well, pump, or well screen.

13) Have at least one check valve within the well casing.

3.7.4.2 Connection

If the connection to the casing is by field weld, the shop-assembled unit must be designed specifically for field welding to the casing. The only field welding permitted will be that which is needed to connect a pitless unit to the casing.

3.7.4.3 Grouting

The grouting of wells using pitless well units shall conform to the applicable criteria of Section 3.5.10, except that grout shall only be placed to a level immediately below the point where the adapter is connected to the well casing.

3.7.5 Casing Vent

Provisions shall be made for venting the well casing to the atmosphere. The vent shall terminate in a downturned position, at or above the top of the casing or pitless unit, no less than 18 inches above grade or floor or 3 feet above the highest known flood elevation, whichever is higher, or as DEP directs. The vent shall have a minimum 1.5-inch diameter opening covered with a 24-mesh corrosion resistant screen. The pipe connecting the casing to the vent shall be of adequate size to provide rapid venting of the casing. Where vertical turbine pumps are used, vents into the side of the casing may be necessary to provide adequate well venting. Installation of these vents shall be in accordance with the requirements of DEP.

3.7.6 Water Level Measurement

1) Provisions shall be made for periodic measurement of water levels in the completed well.

2) Installation of permanent water level measuring equipment shall be made using corrosion resistant materials attached firmly to the drop pipe or pump column and in such a manner as to prevent entrance of foreign materials.

3.7.7 Observation Points

Observation points shall be:

1) Constructed in accordance with the requirements for permanent sources if they are to remain in service after completion of a water supply source.

2) Protected at the upper terminal to preclude entrance of foreign materials.

3.7.8 Wellhead Security

All production and monitoring wells shall be constructed to deter vandals. At a minimum, all wellheads shall be protected by at least one of the following:

1) Installation of a locked cap.
2) Installation of security fencing.
3) Enclosure within a lockable building.

3.8 Interconnections.

3.8.1 Permit Application:

An interconnection between two public water systems (PWS) requires a PWS permit application.

The **purchaser** is defined as the PWS that is purchasing water from the interconnection.

The **seller** is defined as the PWS that is selling water through the interconnection.

An **emergency interconnection** is defined as an interconnection that is normally closed and is used 14 days or less per year.

A p**ermanent interconnection** is defined as an interconnection that is used more than 14 days per year.

If the interconnection can supply water to both the purchaser and the seller, then each PWS must submit a permit application for the interconnection. In addition to the requirements outlined in section 1.0 Permit Requirements (add link), the permit application for an interconnection between to PWS shall include at least:

1. Module 3C
2. The purchasing agreement between the PWSs
3. A description of the materials used
4. A quantity analysis
5. A simultaneous compliance analysis
6. An updated comprehensive monitoring plan
7. An inter-water system coordination plan

3.8.2 Purchasing Agreements:

The purchasing agreement between the seller and the purchaser shall include:

1. The maximum rate of water through the interconnection and the volume of water that can be purchased on a daily and month basis
2. All other conditions and limitations of the interconnection
3. The responsible parties for maintaining and controlling the interconnection
4. The purpose of the interconnection (emergency or standard)

3.8.3 Materials Requirements:

Interconnections shall contain:

1. All materials that are certified for conformance with ANSI/NSF Standard 61, including pipes, fittings, and valves
2. At least two valves to separate the two systems
3. Sample taps on both sides of the interconnection
4. For emergency interconnections, a riser with a small, protected outlet should be installed to signify operation of the emergency interconnection or failure of one of the valves
5. Piping designed and sized to provide the maximum flow rates, volumes, and pressures

3.8.4 Quantity Analysis:

The water quantity analysis shall include:

1. A demonstration of the source capacity and hydraulic capacity of the supplying and receiving systems at the designed flow rate through the interconnection
2. Calculations of each system's capacity, in regard to well rating, storage, pressure, service pumps and emergency power, to prove the seller provides enough production, treatment, and service pumping capacity to meet or exceed the combined maximum daily commitments specified in its various contractual obligations
3. A hydraulic analysis conducted to identify the potential impacts the interconnection will have upon each water system's quantity and pressures

3.8.5 Simultaneous Compliance Analysis:

The simultaneous compliance shall include:

1. A chemical analysis report that evaluates water quality parameter differences between the purchaser and seller and the potential impact the interconnection may have to water quality. DEP may require additional chemical parameters be analyzed. At a minimum, test parameters from

both the purchaser's interconnection point, and the seller's interconnection point are to include:

- pH
- Alkalinity (mg/L as $CaCO_3$)
- Orthophosphate (mg/L as P) (if used by either PWS)
- Hardness (mg/L as $CaCO_3$)
- Temperature (˚C)
- Calcium (mg/L as Ca)
- Total Dissolved Solids (mg/L)
- Conductivity (as µmho/cm @ 25 ˚C)
- Total Chlorine (mg/L as Cl_2)
- Free Chlorine (mg/L as Cl_2)
- Chloride (mg/L)
- Sulfate (mg/L)
- Iron (mg/L)
- Manganese (mg/L)
- Silica (mg/L as SiO_2) (if used by either PWS)
- Total Trihalomethanes (mg/L)
- Haloacetic Acids (mg/L)

2. A detailed evaluation of the potential effects interconnection may have in the distribution system do to differences in water chemistry between the two PWS.
3. A description of each system's corrosion control treatment
4. A description of the disinfection and disinfection systems used in both systems
5. A map showing predicted mixing zones (if different disinfectants are used)
6. A nitrification Control Plan that conforms to the requirements in American Water Works Association Manual M56 (if either system uses chloramines)

Updated Comprehensive Monitoring Plan:

An updated Comprehensive Monitoring Plan that includes the interconnection and meets the requirements in Chapter 107.718, of the Safe Drinking Water Regulations shall be provided.

An Inter-Water System Coordination Plan:

An inter-water system coordination plan should include:

1. A list of all interconnections with other water sellers and purchasers and whether the interconnection is permanent or emergency
2. All pertinent information, to include, at a minimum, the size, available capacity, disinfectants, and materials used for the interconnection
3. Contact information for the purchaser and seller (and any other PWS that could affect the quantity or quality of the water the flows through the interconnection), to include; names, titles, telephone numbers, and email addresses
4. The seller's notification plan that includes drinking water advisories and notifications for any changes to the seller's PWS that could affect the quality or quantity of water of the purchasing system. This plan shall include notifications for all the purchasing PWSs.

4 TREATMENT

4.0 General

The design of a water treatment plant must take into consideration the quality of the raw water, the desired quality of the finished water, simultaneous compliance, and worst-case conditions that may exist during the life of the facility. The following are accepted design criteria for treatment processes which, when properly sequenced and utilized, can be expected to meet DEP's drinking water standards. The ability to respond to more stringent water quality requirements also should be considered when designing a treatment plant.

4.1 Disinfection

Continuous disinfection of drinking water is required of all community systems. Chlorine and its compounds are the preferred disinfecting agents for the disinfection of drinking water.

Disinfecting agents other than chlorine can be used provided reliable application equipment is available and testing procedures for a residual are recognized in the latest edition of Standard Methods for the Examination of Water and Wastewater. These methods of disinfection will be considered on a case-by-case basis. Consideration must be given to the formation of disinfection byproducts (DBP) when selecting the disinfectant.

For equipment that is claimed to remove or reduce a specific contaminant, the name of the organization that meets the accreditation standards of the ANSI and that has certified the device to verify its inactivation, reduction, or removal performance for that contaminant, the name of the testing protocol or standard used to test the device, a statement from the testing laboratory giving the date of the test, a summary of the results, and the date, if any, by which the device must be retested for verification of the removal or reduction performance to remain effective.

Systems which use surface water or GUDI as a source of supply shall:

- Be designed in such a way that the combined total effect of the disinfection processes, by themselves, can achieve a 99.9 percent (3-log) inactivation of *Giardia* cysts.

- Provide at least 90 percent (1-log) inactivation of *Giardia* cysts and a 99.99 percent (4-log) inactivation of viruses post filtration.

This is to be determined by Concentration-Time (CT) factors and measurement methods established by EPA*.

*Refer to AWWA Research Foundation's publication Disinfectant Residual Measurement Methods, publication no. 90528, or EPA's Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

For systems, which use groundwater sources not subject to surface water influence or contamination shall provide at least 99.99 percent (4-log) inactivation of viruses.

4.1.1 Gas Chlorine and Sodium Hypochlorite

4.1.1.1 Feeding Equipment

Solution-feed gas type chlorinators or sodium hypochlorite feeders are preferred. For small supplies, sodium hypochlorite feeders of the positive displacement type should be used.

4.1.1.2 Capacity

The chlorinator effective capacity shall be such that a free chlorine residual of at least 3 mg/L can be attained in the water once all demands are met after the required CT are achieved. This condition must be attainable even when maximum flow rates coincide with anticipated maximum chlorine demands. The equipment shall be of such design that it will operate accurately at both minimum and maximum flow rates without the use of standby equipment.

Where chlorination is provided at more than one stage in the treatment process, separate regulators shall be provided at each stage and should not be injected at the same location as other chemicals.

4.1.1.3 Chlorine Residuals

4.1.1.3.1 Surface (or GUDI) Water Sources

The design of chlorination equipment shall be such that a chlorine residual, capable of achieving a minimum 99.9 percent (3-log) inactivation of *Giardia* cysts prior to the entry point and maintain a free chlorine residual of at least 0.2 mg/L throughout the distribution system.

4.1.1.3.2 Groundwater Sources

For systems utilizing groundwater sources not subject to surface water influence or contamination, the chlorination system shall be designed such that the minimum disinfectant residual entering the distribution system after a minimum of 20 minutes of effective chlorine contact time, shall not be less than 0.40 mg/L and maintain a free chlorine residual of at least 0.2 mg/L throughout the distribution system.

4.1.1.4 Standby Equipment and Spare Parts

Standby chlorination equipment of sufficient effective capacity shall be available to replace the largest unit during shutdown. Spare parts and tools should be available for emergency replacements, repairs, and preventive maintenance for each type of chlorinator in service, and shall be provided at any chlorination facility which is operated unattended. Automatic switchover devices for chlorine cylinders are recommended to ensure continuous disinfection.

4.1.1.5 Effective Contact Time and Point of Application

All contact basins used for disinfection shall be designed to minimize short-circuiting.

4.1.1.5.1 Surface (or GUDI) Water Sources

Provisions shall be made for applying chlorine to the raw water, in process water, filtered water, and water entering the distribution system. For systems utilizing surface water sources or GUDI, the design of the disinfection facilities shall provide enough chlorine application points to ensure the disinfection processes, by themselves, can achieve a 99.9 percent (3-log) inactivation of Giardia.

The design shall achieve a minimum 90 percent (1-log) inactivation of *Giardia* cysts and 99.99 percent (4-log) inactivation of viruses post filtration.

Minimum water level alarms must be provided on chlorine contact tanks to ensure minimum water levels, that are required to achieve a minimum of 1-log Giardia inactivation, are maintained, if water levels can vary. Alarms must have the capacity to shut down the plant and notify the operators

4.1.1.5.2 Groundwater Sources

For systems using chlorine as the primary disinfectant, a minimum of 20 minutes of effective chlorine contact time after the chlorine injection location and prior to the entry point monitoring location shall be provided.

4.1.1.6 Automatic Proportioning

Automatic proportioning chlorinators are required where the rate of flow or chlorine demand may vary significantly.

4.1.1.7 Automatic Switch-Over

Automatic switch-over of chlorine cylinders should be provided, where necessary, to assure continuous disinfection.

4.1.1.8 Injector

Each injector must be sized and located with attention given to the quantity of chlorine to be added, the maximum injector waterflow, the total discharge back pressure, the injector operating pressure, and the size of the chlorine solution line. Gauges for measuring water pressure and vacuum at the inlet and outlet of each injector should be provided.

4.1.1.9 Diffuser

Chlorine solution diffusers shall be compatible with the point of application to provide a rapid and thorough mix with all the water being treated. The center of a pipeline is the preferred application point.

4.1.1.10 Scales

Scales for weighing cylinders shall be provided at all water works using chlorine gas. At large water works, scales of the indicating and recording type are recommended. Where ton cylinders are used, the required number of trunnions shall be provided to allow for cylinder rotation. At small plants, at least a platform scale, including cylinder restraints, shall be provided. Scales shall be of corrosion-resistant material and have a dial accuracy of better than 1 percent.

4.1.1.11 Testing Equipment

1) Chlorine residual test equipment that utilizes an EPA approved method shall be provided and must be capable of measuring residuals to the nearest 0.02 mg/L in the range below 1.0 mg/L, to the nearest 0.1 mg/L between 1.0 mg/L and 2.5 mg/L, and to the nearest 0.2 mg/L above 2.5 mg/L. All systems shall use an instrument with a digital readout.

2) Continuous disinfectant residual monitoring and recording equipment should be provided where the chlorine demand varies appreciably over a short period of time.

3) Treatment plants which utilize surface water or GUDI source(s) shall be equipped with continuous disinfectant residual monitoring and recording equipment at the entry point monitoring location. The monitoring equipment shall have alarms,shutdowns and the capacity to notify the operators.

4) All systems that serve a population greater than 3,300 shall be equipped with continuous disinfectant residual monitoring and recording equipment at each entry point monitoring location. The monitoring equipment shall have alarms and shutdowns.

5) Systems that utilize chlorination for inactivation of bacteria or other microorganism outbreaks in source water or the distribution system shall have continuous disinfectant residual monitoring and recording equipment that automatically shuts down the facility when chlorine residuals are not met, unless otherwise approved by DEP. The monitoring equipment shall have alarms and shutdowns.

6) All continuously recording chlorine residual analyzers must be compatible with all requirements of EPA Method 334.0.

4.1.1.12 Water Supply for Chlorinators

An ample supply of water shall be available for operating the chlorinator. Where a booster pump is required, duplicate equipment shall be provided, and where power is subject to failure, standby power as well. Adequate protection against backflow shall be provided.

4.1.1.13 Chlorinator Piping

Piping arrangements should be as simple as possible and properly color-coded. Pressure gauges shall be installed on the piping to each chlorinator. The number of screwed or flanged joints should be held to a minimum. Piping systems should be well supported and adequately sloped to allow drainage; low spots should be avoided. Suitable allowance should be provided for pipe expansion due to changes in temperature. Liquid chlorine expansion chambers shall be installed where there is a danger of liquid chlorine becoming trapped in the supply lines. Spring-loaded relief valves discharging to the atmosphere shall not be used on liquid chlorine lines. Chlorine feed lines shall not carry pressurized chlorine gas beyond the chlorine room.

4.1.1.14 Pipe Material

Pipes carrying liquid chlorine or dry gaseous chlorine under pressure must be Schedule 80 seamless steel tubing or other materials recommended by the Chlorine Institute (never use PVC). For chlorine solution piping and fittings, rubber, PVC, polyethylene, or other materials recommended by the Chlorine Institute must be used. Nylon products are not acceptable for any part of the chlorine solution piping system.

4.1.1.15 Chlorine Containers

When the average daily consumption of gas chlorine exceeds 50 pounds, ton containers are to be considered. The containers of choice are

150-pound cylinders when the average daily consumption of chlorine does not exceed 50 pounds. Full and empty cylinders of chlorine gas should be:

1) Stored separately.
2) Isolated from operating areas.
3) Restrained in position.
4) Stored in rooms separated from ammonia storage.
5) Stored in areas not in direct sunlight or exposed to heat.
6) Marked with original NSF sticker.
7) Stored with hood secured.

Premanufactured chlorine cabinets may be used for retrofit situations only. These cabinets shall have an observation window, fan, air intake, ventilation, and light as required in Section 5 for normal chlorine gas rooms. These cabinets should not be placed on the sunny side of the building.

4.1.1.16 Housing for Gas Chlorinators

Separate rooms for cylinders and for equipment shall be provided at all installations. Rooms should be on the ground floor and provide sufficient space to allow easy access to all equipment. Chlorine feed and storage rooms shall meet the requirements of Section 5.4.3.

4.1.1.17 Safety Requirements for Gas Chlorination

4.1.1.17.1 Breathing Apparatus

Respiratory protection equipment, meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA), shall be available where chlorine gas is handled. This equipment shall be located in a readily accessible location, but not inside any room where chlorine is used or stored. The units shall use compressed air, have at least a 30-minute capacity, and be compatible with, or exactly the same as, the units used by the fire departments responsible for the plant.

4.1.1.17.2 Leak Detection and Repair Kits

A bottle of concentrated ammonium hydroxide shall be available for chlorine leak detection; where chlorine containers larger than 150 pounds are used, leak repair kits of the type approved by the Chlorine Institute shall be provided. The use of automatic chlorine detectors is highly recommended for all facilities using chlorine gas.

4.1.2 Chlorine Dioxide

Chlorine dioxide may be considered as a primary and residual disinfectant. It may also be used to control tastes and odors, to oxidize iron and manganese, and to control hydrogen sulfide and phenolic compounds. It has been shown to be a strong disinfectant which does not form trihalomethanes (THMs) or haloacetic acids (HAAs). When choosing chlorine dioxide, consideration must be given to formation of the regulated byproducts, chlorite and chlorate.

4.1.2.1 Chlorine Dioxide Generators

The preferred method for generating chlorine dioxide is the injection of a sodium chlorite solution into the discharge line of a solution-feed gas chlorinator with formation of the chlorine dioxide in a reaction chamber at a pH not over 4.0.

Chlorine dioxide generation equipment shall be factory assembled pre-engineered units with a minimum efficiency of 95 percent. The excess free chlorine shall not exceed 3 percent of the theoretical stoichiometric concentration required.

4.1.2.2 Feed and Storage Facilities

Chlorine gas and sodium chlorite storage facilities shall comply with Sections 5.4.3 and 5.4.4, respectively. Sodium hypochlorite feed and storage facilities shall comply with Section 5.4.5.

4.1.2.3 Other Design Requirements

1) The design shall comply with all applicable portions of Sections 4.1.1, 4.1.1.5., 4.1.1.11 and 4.1.13.

2) The chlorine dioxide system shall be designed to insure the maximum chlorine dioxide level is not exceed 0.8 mg/L as ClO2. The system shall be capable of maintaining a chlorine dioxide residual a minimum residual disinfectant level between 0.40 and 0.70 mg/L as ClO2 at the entry point monitoring location and a 0.2 mg/L as ClO2 throughout the distribution system. Higher residuals may be required depending on the pH, temperature, and other characteristics of the water.

4.1.2.4 Public Notification

The system shall provide public notification to advise of changes in its chlorine dioxide disinfection practices. Due to potential health hazards, it is especially important to notify hospitals and kidney dialysis facilities. Fish breeders should also be notified.

4.1.3 Chloramines

4.1.3.1 General

Chloramination is the application of ammonia to chlorinated water to create a combined chlorine disinfectant. Properly formed chloramines provide an effective secondary disinfectant that is more persistent than free chlorine, can reach the ends of larger distribution systems, is able to penetrate biofilms in distribution systems, forms less THMs and other DBPs than chlorine disinfection, and minimizes chlorine taste and odors.

Systems that chloraminate shall chloraminate at all hydraulically connected entry points.

Chloramination can have adverse effects on special water uses such as kidney dialysis, fish rearing, elastomeric materials used in distribution systems, and plumbing fixtures. Systems that chloraminate are also vulnerable to nitrification.

4.1.3.2 Secondary Disinfectant

Chloramines shall not be used as the primary disinfect, but rather as a secondary disinfectant. The ammonia injection location shall be located after all the primary disinfection requirements are achieved. The following shall be provided with the permit application:

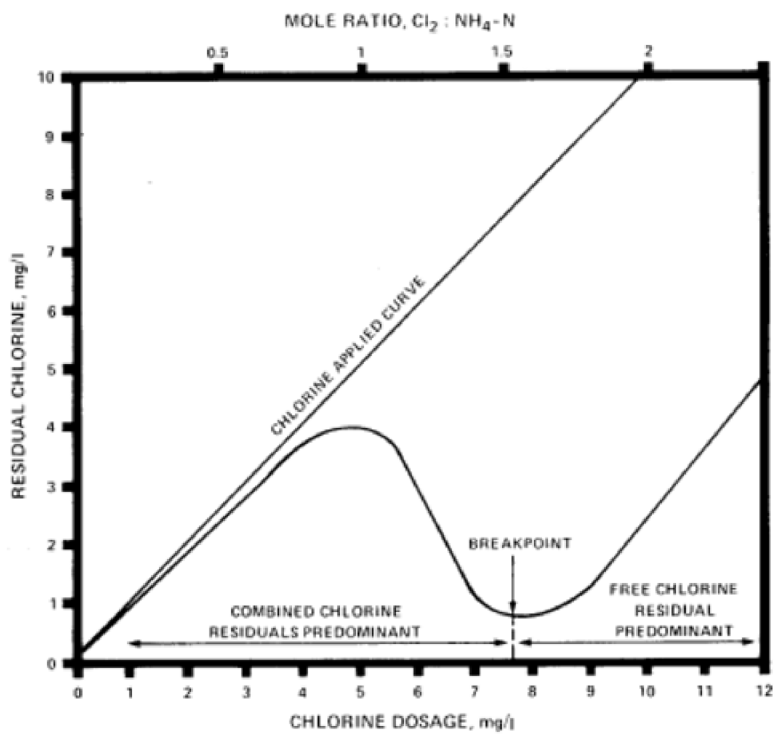
1) Calculations for all the primary log inactivation requirements achieved within disinfection segments prior to the point of chloramination.

2) Schematic showing all the disinfection segments (including dimensions and flow rates), all points of chlorine addition, the point of ammonia addition, chlorine sampling location, and the chloramine sampling location(s).

4.1.3.3 Chloramination Curve and Breakpoint Reaction

There are three main species of chloramines that can be produced; monochloramine (NH2Cl), dichloramine (NHCl2), and trichloramine (NCl3). Trichloramine is also known as nitrogen trichloride. Collectively, these are referred to as “combined chlorine.” The ratio at which chlorine and ammonia are combined determines the species of chloramines produced. Monochloramine is a more effective disinfectant than the other two species, and produces less taste and odor problems. When mixing ammonia and chlorine to form chloramines, the breakpoint reaction is the point at which the chlorine demand has been satisfied, most of the combined chlorine compounds have been destroyed, and as additional chlorine is added, free chlorine residual is produced (see Figure 4.1).

Figure 4.1: Chloramination Curve



4.1.3.4 Chlorine Storage and Use

Chlorine and chlorine compounds shall be stored in separate rooms from ammonia and ammonia compounds because potentially explosive or violent reactions could result in the event of a chlorine release. The chlorine feed system shall:

1) Be designed as per the requirements in Section 4.1.1.

2) Meet the chemical handling requirements in Section 5.4.

3) Have the capacity to produce at least an excess over that required to convert all the free ammonia present to chloramine, a mass ratio of roughly 5:1 (Cl2:NH3-N).

4.1.3.5 Ammonia Storage and Use

Ammonia and ammonia compounds shall be stored in separate rooms from chlorine and chlorine compounds because potentially explosive or violent reactions could result in the event of an ammonia release. Ammonia for chloramine formation may be added as a water solution of ammonium sulfate, aqua ammonia, or as anhydrous ammonia (purified 100% ammonia in liquid or gaseous form).

1) Ammonia feed systems shall meet the chemical handling requirements in Section 5.4.7.

2) The ammonia injection point shall be located after all disinfection requirements are achieved.

3) Ammonia feed systems shall have the capacity to produce a chloramine residual of at least 1 mg/L (total chlorine) throughout the distribution system.

4) Automatic proportioning ammoniators shall be provided where the rate of flow or chlorine demand may vary significantly.

5) Ammoniators shall be either vacuum-operated solution feed or pressure operated gas feed.

6) Ammoniators shall not be used as chlorinators and chlorinators shall not be used as ammoniators.

7) Automatic switchover devices for ammonia cylinders shall be provided to ensure continuous operation.

8) Make up feed water shall be soft (< 35 mg/L as $CaCO^3$) water.

9) A compound-loop control (control scheme in which both a flow signal (open-loop) and residual signal (closed-loop) are sent to the controller) should be provided.

10) Injectors should be located as close to diffusers as possible.

11) Gauges for measuring water pressure and vacuum at the inlet and outlet of each injector should be provided.

12) Duplicate diffusers should be provided to allow for cleaning.

13) Diffuser should be provided with fitting for flushing to dissolve scale.

14) Diffusers should be installed at the center of the pipeline.

15) Scales for weighing cylinders shall be provided at all water works using ammonia. Scales shall be of corrosion-resistant material, and have a data display accuracy within 1 percent.

16) Feed line piping should be well supported and adequately sloped to allow for drainage. The number of screwed or flanged joints should be held to a minimum.

17) Liquid ammonia expansion chambers shall be installed where there is a danger of liquid ammonia becoming trapped in the supply lines. Spring-loaded relief valves discharging to the atmosphere shall not be used on liquid ammonia lines.

18) Ammonia feed lines shall not carry pressurized ammonia gas beyond the ammonia room.

4.1.3.6 Testing Equipment

1) An entry point continuous chlorine residual analyzer with a continuous recording device and automated alarms capable of detecting low and high feed rates shall be provided and programmed in a manner that will prevent regulatory violations. Chloramines are measured as total chlorine. Monitoring equipment shall utilize an EPA approved method.

2) A hand-held analyzer(s) with the ability to analyze free chlorine, total chlorine, nitrate, nitrite, and free ammonia shall be provided.

3) All chlorine residual analyzers must be compatible with all EPA, DEP, and manufacturer recommended calibration requirements.

4.1.3.7 Standby Equipment and Spare Parts

Standby chloramination equipment of sufficient capacity shall be available to replace the largest unit(s) during shutdown. Spare parts and tools should be available for emergency replacements, repairs, and preventive maintenance for each type of chlorinator and ammoniator in service.

4.1.3.8 Nitrification

Distribution systems need to be routinely flushed or swabbed (line pigged) and regularly maintained to provide a consistent disinfectant residual and to minimize nitrifying bacterial activity and persistent coliform bacteria. Nitrifying activity needs to be checked by monitoring monochloramines, free ammonia, nitrite, and nitrate levels.

A nitrification control plan shall be submitted with the permit application. The plan must conform to the guidelines in industry standards such as the AWWA's M56 Manual on Nitrification. The plan shall include:

1) A plan to control chlorine:ammonia-nitrogen ratio. The ratio should be maintained between 4.5:1 and 5:1 to reduce free ammonia.

2) A plan to limit the excess ammonia (maintain between a detectable residual and 0.10 mg/L N).

3) A plan to maintain and ensure a consistent chloramine residual with the greatest percentage possible of monochloramine species and pH throughout the distribution system.

4) A monitoring plan (including locations and schedule) for pH, free ammonia, total chlorine, heterotrophic plate count (HPC), nitrite, and nitrate in the distribution system (particularly in areas of elevated water age such as storage tanks).

5) A response plan with expected water quality ranges and action levels.

6) A water storage operation and maintenance plan including operational strategies to minimize water age and schedule to routinely clean and inspect all storage tanks and reservoirs.

7) A flushing plan and schedule to ensure water quality and minimize water age.

8) A free chlorine burn plan

4.1.3.9 Chlorine Burn

Switching disinfectant types may cause undesirable effects such as change in the lead solubility, formation of THMs and HAAs, and taste and odor concerns. Therefore, a **free chlorine burn should only be implemented when other measures in the nitrification control plan prove ineffective**, as verified via routine monitoring for the triggering criteria parameters.

A free chlorine burn plan should include:

1) Triggering criteria.

2) Unidirectional flushing plan for expediting the switch from chloramines to free chlorine and back to chloramines.

3) Storage tank cycling plan estimating necessary time to fully transition tanks from chloraminated water to chlorinated water and then back to chloraminated water.

The system shall notify DEP, consecutive PWSs, and all customers in the affected area at least 30 days prior to the start of a free chlorine burn and provide an estimated schedule for completion of the burn and return to chloramination.

4.1.3.10 Chloramine Booster System

Systems that use chloramines as the residual disinfectant in the distribution system that require the residual to be boosted shall booster chloraminate with a targeted chlorine to ammonia feed ratio at the booster station. If chloramines are boosted incorrectly, a less effective disinfectant residual can be formed, providing the opposite effect of boosting.

Booster chloramination systems shall:

1) Meet the requirements in Section 4.1.3.

2) Continuously analyze and record the free ammonia and total chlorine residuals both before and after the booster system. Automated high-level residual alarms and shut downs shall be provided. Grab sampling capability for monochloramine residuals before and after booster chloramination shall also be provided.

4.1.3.11 PWS Interconnections

Blending chlorinated water with chloraminated water should be avoided when possible. When systems must be blended, interconnections between two PWS systems that do not have the same type of disinfection residual (free chlorine and chloramines) can lead to several different outcomes:

1) Free chlorine reacts with free ammonia to form chloramines.

2) Free chlorine reacts with the chloramines, destroying the chloramines resulting in a free chorine residual (breakpoint chlorination).

3) Free chlorine and chloramines react to form undesirable chlorine species (dichloramine, trichloramine).

The proportion and concentration of free chlorine and chloramines, the chlorine:ammonia-nitrogen ratio, the pH, and the temperature will all affect this outcome.

4.1.3.11.1 Blended Systems (Chlorine Reacts with Free Ammonia)

1) Sample results to ensure the chlorine:ammonia-nitrogen ratio can be maintained in a way that ensures formation of predominantly monochloramine.

2) A sampling plan that will ensure chlorine:ammonia-nitrogen ratio will remain acceptable in a blended distribution system.

3) Documentation showing how blending will occur.

4) Map showing the blending zones and evaluation of methods to reduce the size of the blending zones.

5) Documentation of the SOPs, sampling type, and frequency that the PWS will perform to ensure adequate disinfectant residual (1 mg/L chloramines measured as total chlorine throughout distribution system).

4.1.3.11.2 Blended Systems (Free Chlorine will React with the Chloramines)

This destroys the chloramines and results in a free chlorine residual (breakpoint chlorination):

1) Sample results from the pre-blended water that show the free chlorine to chloramine ratio will be high enough to ensure breakpoint chlorination (free chlorine will be measurable).

2) A sampling plan that will ensure free chlorine residual of at least 0.2 mg/L will be maintained throughout the blended distribution system.

3) Documentation showing how blending will occur.

4) Map showing the blending zones and evaluation of methods to reduce the size of the blending zones.

5) Documentation of the standard operating procedures (SOPs), sampling type, and frequency that the PWS will perform to ensure adequate chlorine residuals (0.2 mg/L throughout the distribution system).

4.1.3.12 Implementation Plan

An implementation plan shall be provided with the permit application. The plan shall include:

1) A notifications plan:

   - Provides public notification to all customers, consecutive PWS(s), and state and local health departments on the disinfection change.

   - Provides educational material that addresses possible effects and impacts to all customers and specialized needs for specific customers (dialysis centers and patients, laboratories, and aquariums are of concern). These customers may require capital investment (dechloramination equipment) which requires sufficient time to plan and budget for.

   - Is required from the parent system and all consecutive PWS(s).

2) Documentation showing compatibility with all other treatment processes.

3) A detailed analysis of the corrosion control treatment and possible side effects.

4) Distribution system pH evaluation that demonstrates the pH is within the control range for chloramination of 8.0 to 9.0 (optimum 8.3).

5) A detailed monitoring plan for chloramines.

Table 4.x Recommended Monitoring for Chloraminated Systems				
Parameter	**Raw Water**	**Pre-Ammonia**	**Post-Ammonia / EP**	**Distribution**
Free Chlorine		Continuous		
Temperature	Daily	Every 2 hours	Every 2 hours	At least monthly at each location[2,3]
pH	Daily	Every 2 hours	Every 2 hours	At least monthly at each location[2,3]
Free Ammonia	Daily until baseline is established[1]		Every 2 hours	At least monthly at each location[2,3]
Monochloramine			Every 2 hours	At least monthly at each location[2,3]
Total Chlorine			Continuous	At least monthly at each location[2,3]
Di- & Trichloramine			Every 2 hours	At least monthly at each location[2,3]
Nitrite			Daily until baseline is established	As needed to assess nitrification[4]
Nitrate			Daily until baseline is established	As needed to assess nitrification[4]
Other Parameters	Parameter specific, as determined by the utility			

[1] Seasonal baselines should be established due to changes in raw water quality.
[2] Distribution system parameters should be analyzed simultaneously.
[3] Frequency of distribution system monitoring should be increased at critical times and locations.
[4] Monitoring thresholds should be consistent with system's Nitrification Control Plan.

4.1.4 Ozonation

Ozonation is used for disinfection, microflocculation, and oxidation. These responses may occur together, but typically one will be the primary objective of the application with the other reactions becoming secondary benefits of the installation.

Effective disinfection from ozone is demonstrated through the CT values for inactivation of viruses and *Giardia* cysts. These are considerably lower than CT values using chlorine disinfectants. Microflocculation and enhanced filterability also have been demonstrated for many water supplies. Oxidation of organic compounds and inorganic compounds (i.e., iron, manganese, heavy metals, nitrite, arsenic, and hydrogen sulfide) has been documented and is helpful when treatment of HAA5's is required. The effectiveness of oxidation is varied, depending on pH and alkalinity of the water.

These parameters affect the formation of highly reactive hydroxyl radicals, or conversely, the scavenging of this oxidant. High levels of hydroxyl radicals cause lower levels of residual ozone. Depending on the desired oxidation reaction, it may be preferable to maximize ozone residual or maximize hydroxyl radical formation. For disinfection, residual ozone is necessary for development of CT.

Bench scale studies shall be conducted to determine minimum and maximum ozone dosages for disinfection CT compliance and oxidation reaction occurrences. More involved pilot plant studies should be conducted, when necessary, to document benefits and DBP precursor removal effectiveness. Consideration should be given to multiple points of ozone addition. Pilot studies should be conducted for all surface waters. Care must be taken during bench and pilot scale studies to ensure accurate results. Particularly sensitive measurements include gas flow rate, water flow rate, and ozone concentration.

Following the use of ozone, the application of a secondary disinfectant which maintains a measurable residual is required to ensure bacteriologically safe water throughout the distribution system. However, because ozone partially degrades natural organic matter that may be precursors to disinfection by-products, the addition of chlorine, chloramine, or chlorine dioxide should be withheld until after filtration. This will provide an opportunity to maximize biodegradation of the ozone-produced assimilable organic matter during the filtration process.

The ability to obtain qualified operators must be evaluated in the selection of the treatment process. The necessary operator training shall be provided prior to plant start-up.

The production of ozone is an energy intensive process. Substantial economies in electrical usage, reduction in equipment size, and waste heat removal requirements can be obtained by using oxygen enriched air or oxygen as feed, and by operating at increased electrical frequency.

Although ozone disinfection produces fewer DBPs than chlorine, ozone has been shown to oxidize bromide to form hypobromous acid/hypobromite, with hypobromite ion serving as an intermediate to bromate formation. The raw water must be adequately evaluated to insure Bromate formation is minimized.

4.1.4.1 Feed Gas Preparation

4.1.4.1.1 General

Feed gas can be air, high purity oxygen, or oxygen-enriched air. Sources of high purity oxygen include purchased liquid oxygen, on-site generation using cryogenic air separation, or pressure/vacuum swing (adsorptive separation) technology. For high purity oxygen-feed systems, dryers typically are not required.

Air handling equipment on conventional low-pressure air-feed systems shall consist of an air compressor, water/air separator, refrigerant dryer, heat reactivated desiccant dryer, and particulate filters. Some "package" ozonation systems for small plants may work effectively operating at high pressure without the refrigerant dryer and with a "heatless" desiccant dryer. In all cases the design engineer must ensure that the maximum dewpoint of minus 60°C (minus 76°F) will not be exceeded at any time. For high-purity oxygen-feed systems, dryers typically are not required.

4.1.4.1.2 Air Compression

1) Air compressors shall be of the liquid-ring or rotary lobe, oil less, positive displacement type for smaller systems, or dry rotary screw compressors for larger systems.

2) The air compressors must have the capacity to simultaneously provide for maximum ozone demand, provide the air flow required for purging the desiccant dryers (where required), and allow for standby capacity.

3) Air feed for the compressor should be drawn from a point protected from rain, condensation, mist, fog, and contaminated air sources to minimize moisture and hydrocarbon content of the air supply.

4) A compressed air filter-cooler and/or entrainment separator with automatic drain shall be provided prior to the dryers to reduce the water vapor.

5) A backup air compressor must be provided so that ozone generation is not interrupted in the event of a breakdown.

4.1.4.1.3 Air Dryer

1) Dry, dust-free, and oil-free feed gas must be provided to the ozone generator. Dry gas is essential to prevent formation of nitric acid, to increase the efficiency of ozone generation, and to prevent damage to the generator dielectrics. Sufficient drying to a maximum dew point of minus 60°C (minus 76°F) must be provided at the end of the drying cycle.

2) Drying for high pressure systems may be accomplished using heatless desiccant dryers only. For low pressure systems, a refrigeration air dryer in series with heat-reactivated desiccant dryers should be used.

3) A refrigeration dryer capable of reducing inlet air temperature to 4°C (40°F) shall be provided for low pressure air preparation systems. The dryer can be of the compressed refrigerant type or chilled water type.

4) For heat-reactivated desiccant dryers, the unit shall contain two desiccant-filled towers complete with pressure relief valves, two four way valves, and a heater. In addition, external type dryers shall have a cooler unit and blowers. The size of the unit shall be such that the specified dew point will be achieved during a minimum adsorption cycle time of 16 hours while operating at the maximum expected moisture loading conditions.

5) Multiple air dryers must be provided so that the ozone generation is not interrupted in the event of dryer breakdown.

6) Each dryer must be capable of venting dry gas to the atmosphere, prior to the ozone generator, to allow start-up when other dryers are on-line.

4.1.4.1.4 Air Filters

1) Air filters shall be provided on the suction side of the air compressors, between the air compressors and the

dryers, and between the dryers and the ozone generators.

2) The filter before the desiccant dryers shall be of the coalescing type and can remove aerosol and particulates larger than 0.3 microns in diameter. The filter after the desiccant dryers shall be of the particulate type and can remove all particulates greater than 0.1 microns in diameter, or smaller, if specified by the generator manufacturer.

4.1.4.1.5 Air Preparation Piping

Piping in the air preparation system can be common grade steel, seamless copper, stainless steel, or galvanized steel. The piping must be designed to withstand the maximum pressures in the air preparation system.

4.1.4.2 Ozone Generator

4.1.4.2.1 Capacity

1) The production rating of the ozone generators shall be stated in pounds per day and KWh per pound at a maximum cooling water temperature and maximum ozone concentration.

2) The design shall ensure that the maximum concentration of ozone in the generator exit gas will not be less than 1 percent (by weight).

3) Generators shall be sized to have sufficient reserve capacity so that the system does not operate at peak capacity for extended periods of time. This can result in premature breakdown of the dielectrics.

4) The production rate of ozone generators will decrease as the temperature of the coolant increases. If there is to be a variation in the supply temperature of the coolant throughout the year, then graphs or other means shall be used to determine production changes due to the temperature change of the supplied coolant. The design shall ensure that the generators can produce the required ozone at maximum coolant temperature.

5) Appropriate ozone generator backup equipment must be provided.

4.1.4.2.2 Electrical

The generators can be low, medium, or high frequency type. Specifications shall require that the transformers, electronic circuitry, and other electrical hardware be proven, high quality components designed for ozone service.

4.1.4.2.3 Cooling

Adequate cooling shall be provided. The required water flow to an ozone generator varies with the ozone production. Normally, unit design provides a maximum cooling water temperature rise of 2.8°C (5°F). However, in cases where it is advantageous to decrease the volume of water used for cooling, up to 10°F delta temperature has been successfully employed. The cooling water must be properly treated to minimize corrosion, scaling, and microbiological fouling of the water side of the tubes. A closed loop cooling water system is often used to ensure proper water conditions. Cooling water shall not be returned to the potable water supply.

4.1.4.2.4 Materials

To prevent corrosion, the ozone generator shell and tubes shall be constructed of Type 316L stainless steel.

4.1.4.3 Ozone Contactors

The selection or design of the contactor and method of ozone application depends on the purpose for which the ozone is being used.

4.1.4.3.1 Bubble Diffusers

1) Where disinfection is the primary application, a minimum of two contact chambers, each equipped with baffles to prevent short-circuiting and induce countercurrent flow, shall be provided. Ozone shall be applied using porous-tube or dome diffusers.

2) The minimum effective contact time (hydraulic detention time - HDT) shall be 10 minutes. A shorter effective contact time may be approved by DEP if justified by appropriate design and CT considerations.

3) For ozone applications in which precipitates are formed, such as with iron and/or manganese removal, porous diffusers should be used with caution.

4) Where taste and odor control is of concern, multiple application points and contactors shall be considered.

5) Contactors shall be separate closed vessels that have no common walls with adjacent rooms. The contactor must be kept under negative pressure and sufficient ozone-in-air monitors shall be provided to protect worker safety. Placement of the contactor where the entire roof is exposed to the open atmosphere is recommended.

6) Large contact vessels should be made of reinforced concrete. All reinforcement bars shall be covered with a minimum of 1.5 inches of concrete. Smaller contact vessels can be made of stainless steel, fiberglass, or other material which will be stable in the presence of residual ozone and ozone in the gas phase above the water level.

7) A system shall be provided between the contactor and the off-gas destruct unit to remove froth from the off-gas and return the froth to the contactor or other location acceptable to DEP. If foaming is expected to be excessive, then a potable water spray system shall be placed in the contactor head space.

8) All openings into the contactor for pipe connections, hatchways, etc. shall be properly sealed using welds or ozone resistant gaskets such as Teflon or Hypalon.

9) Multiple sampling ports shall be provided to enable sampling of each compartment's effluent water and to confirm CT calculations.

10) A pressure relief valve shall be provided in the contactor and piped to a location where there will be no damage to the destruction unit.

11) The diffusion system shall work on a countercurrent basis such that the ozone is fed at the bottom of the vessel and water is fed at the top of the vessel.

12) The depth of water in bubble diffuser contactors shall be a minimum of 18 feet. The contactor also shall

have a minimum of 3 feet of freeboard to allow for foaming.

13) All contactors shall have provisions for cleaning, maintenance, and drainage of the contactor. Each contactor compartment also shall be equipped with an access hatchway.

14) Aeration diffusers shall be fully serviceable by either cleaning or replacement.

4.1.4.3.2 Other Contactors

Other contactors, such as venturi or aspirating turbine mixer contactor, may be approved by DEP provided adequate ozone transfer is achieved and the required effective contact times and residuals can be met and verified. Injectors may be acceptable as ozone contactors subject to DEP approval.

4.1.4.4 Ozone Destruction Unit

1) A system for treating the final off-gas from each contactor must be provided to meet safety and air quality standards. Acceptable systems include thermal destruction and thermal/catalytic destruction units.

2) To reduce the risk of fires, the use of units that operate at lower temperatures is encouraged, especially where high purity oxygen is the feed gas.

3) The maximum allowable ozone concentration in the discharge is 0.1 ppm (by volume).

4) Enough units shall be provided so that the system can handle the entire gas flow with one unit out of service.

5) Exhaust blowers shall be provided to draw off-gas from the contactor into the destruct unit.

6) Catalysts must be protected from froth, moisture, and other impurities which may harm the catalyst.

7) The catalyst and the heating elements shall be located where they can be easily reached for maintenance.

4.1.4.5 Piping Materials

Only low carbon 304L and 316L stainless steels shall be used for ozone service, with the 316L preferred.

4.1.4.6 Joints and Connections

1) Connections on piping used for ozone service are to be welded where possible.

2) Connections with meters, valves, or other equipment are to be made with flanged joints with ozone resistant gaskets, such as Teflon or Hypalon. Screwed fittings shall not be used because of their tendency to leak.

3) A positive closing plug or butterfly valve plus a leak-proof check valve shall be provided in the piping between the generator and the contactor to prevent moisture from reaching the generator.

4.1.4.7 Instrumentation

1) Pressure gauges shall be provided at the discharge from the air compressor, at the inlet to the refrigeration dryers, at the inlet and outlet of the desiccant dryers, at the inlet to the ozone generators and contactors, and at the inlet to the ozone destruction unit.

2) Electric power meters shall be provided for measuring the electric power supplied to the ozone generators. Each generator shall have a trip which shuts down the generator when the wattage exceeds a maximum preset level.

3) Dew point monitors shall be provided for measuring the moisture of the feed gas from the desiccant dryers. Because it is critical to maintain the specified dew point, it is recommended that continuous recording charts be used for dew point monitoring which will allow the proper adjustment of the dryer cycles. Charts may not be necessary if a computer-based control system is in use. Where there is potential for moisture entering the ozone generator from downstream of the unit or where moisture accumulation can occur in the generator during shutdown, post-generator dew point monitors should be used.

4) Air flow meters shall be provided for measuring air flow from the desiccant dryers to each of the ozone generators, air flow to each contactor, and purge air flow to the desiccant dryers.

5) Temperature gauges shall be provided for the inlet and outlet of the ozone cooling water, the inlet and outlet of the ozone generator

feed gas, and, if necessary, for the inlet and outlet to the ozone power supply cooling water.

6) Water flow meters shall be installed to monitor the flow of cooling water to the ozone generators and, if necessary, to the ozone power supply.

7) Ozone monitors shall be installed to measure ozone concentration in both the feed-gas and off-gas from the contactor and in the off-gas from the destruct unit. For disinfection systems, monitors also shall be provided for monitoring ozone residuals in the water. The number and location of ozone residual monitors shall be such that the amount of time that the water is in contact with the ozone residual can be determined.

8) A minimum of one ambient ozone monitor shall be installed near the generator, and one adjacent to the first atmospherically vented process unit downstream of the contactor, if that unit is indoors. Ozone monitors also shall be installed in any areas where ozone gas might accumulate.

4.1.4.8 Alarms

The following alarm/shutdown systems shall be considered at each installation:

1) Dew Point Shutdown/Alarm - This system will shut down the generator in the event the system's dew point exceeds -60°C (-76°F).

2) Ozone Generator Cooling Water Flow Shutdown/Alarm - This system will shut down the generator if cooling water flow decreases to the point that generator damage could occur.

3) Ozone Power Supply Cooling Water Flow Shutdown/Alarm - This system shall shut down the power supply if cooling water flow decreases to the point that damage could occur to the power supply.

4) Ozone Generator Cooling Water Temperature Shutdown/Alarm - This system will shut down the generator if either the inlet or outlet cooling water exceeds a certain preset temperature.

5) Ozone Power Supply Cooling Water Temperature Shutdown/Alarm - This system will shut down the power supply if either the inlet or outlet cooling water exceeds a certain preset temperature.

6) Ozone Generator Inlet Feed-Gas Temperature Shutdown/Alarm - This system will shut down the generator if the feed-gas temperature is above a preset value.

7) Ambient Ozone Concentration Shutdown/Alarm - The alarm will sound when the ozone level in the ambient air exceeds 0.1 ppm or a lower value chosen by the water supplier. Ozone generator shutdown shall occur when ambient ozone levels exceed 0.3 ppm (or a lower value) in either the vicinity of the ozone generator or the contactor.

8) Ozone Destruction Temperature Alarm - The alarm will sound and the system will shut down when temperature exceeds a preset value.

4.1.4.9 Safety

1) The maximum allowable ozone concentration in the air to which workers may be exposed must not exceed 0.1 ppm (by volume).

2) Noise levels resulting from the operating equipment of the ozonation system should be reasonably controlled by special room construction and equipment isolation.

3) High voltage and high frequency electrical equipment must meet current applicable electrical and fire codes.

4) Emergency exhaust fans must be provided in the rooms containing the ozone generators to remove ozone gas if leakage occurs. The generating system must be shut down following detection of a leak.

5) A portable purge air blower that will remove residual ozone in the contactor prior to entry for repair or maintenance shall be provided.

6) A sign shall be posted indicating “No smoking, oxygen in use” at all entrances to the treatment plant. In addition, no flammable or combustible materials shall be stored within the oxygen generator areas.

4.1.4.10 Construction Considerations

1) Prior to connecting the piping from the desiccant dryers to the ozone generators, the air compressors should be used to blow the dust out of the desiccant.

2) The contactor should be tested for leakage after sealing the exterior. This can be done by pressurizing the contactor and checking for pressure losses.

3) Connections on the ozone service line should be tested for leakage using the soap-test method.

4) The feed gas and ozone piping must be properly cleaned prior to start-up.

4.1.5 Ultraviolet Light (UV) Disinfection

The following design standards are applicable to those public water systems intending to receive log-inactivation credits of *Cryptosporidium*, *Giardia*, or viruses through UV disinfection. In addition to this manual, the UV disinfection system shall comply with EPA's Ultraviolet Disinfection Guidance Manual (UVDGM) for the Final Long Term 2 Enhanced Surface Water Treatment Rule.

When implemented, UV disinfection must be used in conjunction with other accepted types of disinfection. As ultraviolet treatment does not provide a residual disinfectant, post-chlorination, or chloramination, is required to provide a disinfectant residual.

UV systems and/or components shall be designed and constructed so that their intended purposes shall be accomplished when installed and operated according to the manufacturer's instructions. Components shall not be adversely affected by the normal environment to which they are subjected. Normal environment shall include usual vibration, shock, climate condition, and/or cleaning procedures as prescribed by the manufacturer.

UV disinfection systems must undergo validation testing. The validation involves full-scale biodosimetric testing of the specific UV disinfection system that demonstrates inactivation of an appropriate challenge microorganism that is representative of the target microorganism. Chapter 5 of the UVDGM established acceptable UV validation protocols. The validation determines a range of operating conditions that must be monitored by a public water system to ensure that the UV dose required for a particular pathogen inactivation credit is delivered. These operating conditions must include flowrate, UV intensity (measured by a UV intensity sensor), transmissivity (UVT), and lamp status (i.e., power level).

4.1.5.1 Materials

1) All components shall be constructed of materials that are resistant to UV light. They shall not impart undesirable taste, odor, color, and/or toxic materials into the water because of the presence of toxic constituents in materials of construction or because of physical or chemical changes resulting from exposure to ultraviolet energy.

2) All components shall be constructed of materials suitable to withstand temperatures generated during normal operation.

3) All materials of construction that come in contact with water shall be certified for compliance with ANSI/NSF Standard 61.

4) The UV housing shall be stainless steel 304 or 316L.

5) The lamp sleeve shall be made of Type 214 clear fused quartz or another sleeve material as approved by DEP.

4.1.5.2 Design and Installation Criteria

To receive log inactivation credit, the specific make and model must have undergone validation testing. An acceptable third party off-site validation satisfies this requirement. On-site validation is not acceptable.

Reference Chapter 5 of US EPA Ultraviolet Disinfection Guidance Manual (UVDGM) for details on the validation test procedures. The following validation test procedures are acceptable:

1) UVDGM (Publication EPA 815-R-06-007) - Validation of UV Reactors

2) German Guideline DVGW W294

3) Austrian Standard ONORM M 5873-1, M 5873-2

(Note: These German and Austrian procedures specifically validate reactors for a reduction equivalent dose of 40 millijoules per square centimeter (mJ/cm^2)).

(Note: UV reactors validated per the German or Austrian procedures will only be granted 3-log *Cryptosporidium* and *Giardia* inactivation credit).

The minimum UV doses at 254 nm, in mJ/cm^2, needed to achieve the various Log inactivation levels of the target pathogens:

Table 4.x Minimum UV Doses (mJ/cm^2) to Achieve Log Inactivation Levels								
	Log Inactivation							
	0.5	1	1.5	2	2.5	3	3.5	4
Target Pathogens	**Doses (mJ/cm^2)**							
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

(Note: These dose values do not include safety/validation factors that would be incorporated into validation testing. The safety/validation factors are calculated on a site-specific basis to account for sources of uncertainty introduced from full-scale installation, site hydraulics, reactor equipment, and the dose monitoring approach.)

1) The permit application submission shall sufficiently address issues including: reactor installation location, desired inactivation credits, UVT data used to justify design UVT selection, and individual safety factors used in determining a recommended dose during operation.

2) The UV assemblies shall be accessible for visual observation, cleaning and replacement of lamps, lamp sleeves, and sensor window/lens.

3) The UV disinfection system must have the ability to automatically shut down flow and alarm equipment if treatment requirements/validated conditions are not being met. When power is not being supplied to the reactor, shutdown valves shall be in a closed (fail-safe) position.

4) No bypasses shall be installed. It is recommended that the system have the ability to send off-specification water to waste. At a minimum, the system shall have the capability to switch operation to the standby reactor on detection of an off-specification event.

5) Screens or other similar features should be installed upstream of the UV units to prevent objects from entering the reactor and possibly damaging reactor components.

6) At a minimum, the following equipment appurtenances must be provided:

- Flow control valves.
- Isolation valves.
- Sample taps upstream and downstream of the reactor.
- Flow meters.
- Air relief/vacuum relief valves.
- Alarms.
- Instrumentation for monitoring and controlling the system.
- On-line UV sensor(s) and, if required, an on-line UVT analyzer.

7) Headloss through the reactor and associated valves/piping must be evaluated to ensure headloss does not exceed the available head. Booster pumps may be required to maintain minimum water system pressure after the treatment devices.

8) Hydraulic distribution of flow significantly affects dose delivery. Reactor inlet and outlet configurations shall match the validation conditions or be more hydraulically conservative. This can be achieved by using one of these approaches:

(1) Providing a minimum of five pipe diameters of straight pipe upstream of each reactor.

(2) Inlet and outlet configurations at the treatment plant must match those used during validation for at least ten pipe diameters upstream and five pipe diameters downstream of the reactor.

9) UV units may be impacted by surge events produced by pumps located upstream or downstream. Maximum system pressures should be evaluated to ensure that they will not exceed the manufacturer’s specifications for the reactor. Alternatively, the design should have provisions (equipment or operational) for mitigating surges.

10) A flow or time delay mechanism wired in series with the well or service pump shall be provided to permit a sufficient time for lamp warm-up, per manufacturer recommendations, before water flows from the unit upon startup. Consideration should be given to unit shutdown between operating cycles to prevent heat build-up in the water due to the UV lamp. If cooling water is provided during warm-up, the design must allow for wasting this water since it will be inadequately treated.

11) Power conditioning equipment, such as an uninterruptable power supply, shall be included if power quality problems, such as frequent power interruptions/brownouts or remote location with unknown power quality, are anticipated.

12) The design shall ensure that the quartz sleeves containing the UV lamps will always be submerged in water under normal operating conditions unless the units are specifically designed with air cooling.

13) At least 2 in parallel reactors shall be provided. Where only 2 reactors are provided, each shall/can meet the plant's permitted capacity. Where more than 2 reactors are provided, the UV disinfection system shall/can meet the plant's permitted capacity with one reactor removed from service.

14) A wiper assembly or clean-in-place system should be provided to allow in-situ cleaning of lamp sleeves. The manufacturer's cleaning procedures, whether by off-line manual, in-line mechanical, or in-line mechanical-chemical methods, shall be followed. Adequate controls shall be in place to prevent contamination of the potable water with cleaning chemicals. Cleaning chemicals shall be certified for compliance with ANSI/NSF Standard 60.

    The cleaning methods may require chemical storage, delivery facilities, and provisions for dealing with chemical waste.

15) Drains shall be provided in the UV reactor or in piping between the reactor and isolation valves and floor drains shall be provided in the treatment plant design to allow draining of the reactor for maintenance and repair. Drainage design shall comply with cross connection control requirements.

16) Adequate space shall be provided around the UV reactors to allow access for maintenance activities.

4.1.5.3 Pretreatment

DEP will evaluate the need for pretreatment on a case-specific basis depending on raw water quality. Raw water quality shall be evaluated and pretreatment equipment shall be designed to handle water quality changes. Variable turbidity caused by rainfall events is of special concern. At a minimum, a 5-micron sediment filter, or equivalent, should be installed before the UV disinfection system for all UV installations used on unfiltered systems. Filtration, if provided, shall be performed prior to UV treatment.

The system shall gather sufficient water quality data in conjunction with facility design. Water samples shall be representative of the feed water to be treated by the UV reactor. Water entering the UV reactor shall meet the following parameters:

Table 4.x
Pre-UV Treatment Water Quality Parameters

Parameter	Maximum[1]
Dissolved Iron	0.3 mg/L
Dissolved Manganese	0.05 mg/L
Hardness	120 mg/L
Hydrogen Sulfide (if odor is present)	Non-Detectable
pH	6.5 – 9.5
Suspended Solids	10 mg/L
Turbidity	1.0 NTU
Total Coliform	1000/100 mL

[1] Higher values may be acceptable if experience with similar water quality and reactors shows that adequate treatment is provided and there are no treatment problems or excessive maintenance required or if the reactor was validated for values higher than these maximums.

UV transmissivity (UVT) measurements of the water to be treated, covering the range of UVTs expected for that water, shall be submitted to support selection of the design UVT.

4.1.5.4 Associated Instrumentation

1) Equipment must be provided to allow monitoring of parameters to ensure the system is operating within validated limits and delivering the required UV dose. Required parameters (e.g., flow, UV intensity, UVT, lamp status) will depend on the operating mode of the unit. Instrumentation must provide the data required to determine the volume of water produced that is not within the required specifications, known as off-specification water.

2) A minimum of two (2) reference UV sensors must be available to check calibration of the duty UV sensor(s). Sensor calibration is to be conducted as specified by DEP.

3) If an on-line UVT analyzer is required for UV system operation, a benchtop or hand-held UVT analyzer must be available to check calibration of the on-line meter. Analyzer calibration is to be conducted as specified by DEP.

4) Spare parts for the UV system need to be maintained at the treatment plant. These should include: UV lamps, lamp sleeves,

O-ring seals, ballasts, ballast cooling fan, duty UV sensor, reference UV sensor, and UVT analyzer (if required for dose monitoring).

4.1.5.5 Operation and Maintenance

1) A procedure for starting up and shutting down the UV treatment system shall be established for the site installation based upon manufacturer recommendations.

2) Ninety-five percent of the water treated by the UV system shall be within validated conditions. The percentage of off-specification water shall be calculated on a volume basis. The total off-specification volume for all UV reactors (indicated by the 5-minute alarm records) shall be divided by the total volume produced by the UV facility that month and multiplied by 100. Off-specification percentage shall be calculated at least daily.

3) UV water treatment devices operated on a seasonal basis shall be inspected and cleaned prior to use at the start of each operating season. The UV system including the filters shall be disinfected prior to placing the unit back into operation.

4) Each reactor shall be able to be isolated for maintenance.

5) An operation and maintenance (O&M) manual for the UV system shall be maintained and utilized at the treatment plant. O&M manual contents shall be based on manufacturer recommendations and UVDGM-specified guidelines, as applicable.

6) DEP shall have access to UV system records.

4.1.5.6 Monitoring and Reporting

1) Systems are required to submit applicable monthly operational reports to DEP. At a minimum, these reports shall contain the following information:

    - Percentage of off-specification water produced at the treatment plant.

    - UV intensity sensor calibration checks.

    - UVT analyzer calibration checks (only required if UVT is incorporated into the installation’s dose monitoring strategy).

- As applicable to the UV reactor site installation, a summary of the required validated operating parameters for each reactor that was in operation during the reporting month.

2) A UV system equipment use/maintenance logbook shall be maintained by personnel at the treatment plant.

4.2 Clarification

Clarification is generally considered to consist of any process or combination of processes which reduces the concentration of suspended matter in drinking water prior to filtration.

Plants designed to treat surface water, GUDI, or for the removal of a primary drinking water contaminant shall have a minimum of two units each for rapid mixing, coagulation, flocculation, and sedimentation. In addition, it is recommended that plants designed solely for aesthetic purposes also have a minimum of two units each.

Water treatment facilities designed to reduce suspended solids concentrations prior to filtration shall:

1) Provide for flexibility in operation.

2) Be constructed to permit units to be taken out of service without disrupting operation and with drains or pumps sized to allow dewatering in a reasonable period.

3) Provide multiple-stage treatment facilities when required by DEP.

4) Be started manually following shutdown.

5) Minimize hydraulic head losses between units to allow future changes in processes without the need for repumping.

6) Allow operation of the units either in series or parallel where softening is performed and should allow series or parallel operation in other circumstances where clarification is performed.

7) Provide a means of measuring and modifying the flow to each train or unit.

4.2.1 Pretreatment

4.2.1.1 Aeration

Aeration units shall be designed in accordance with Section 4.5.

4.2.1.2 Presedimentation

Water containing high turbidity may require pretreatment, usually sedimentation with the addition of coagulation chemicals.

1) Basin design - Presedimentation basins should have hopper bottoms or be equipped with continuous mechanical sludge removal apparatus and provide arrangements for dewatering.

2) Inlets - Incoming water shall be dispersed across the full width of the line of travel as quickly as possible. Short-circuiting shall be prevented.

3) Bypass - Provisions for bypassing presedimentation basins shall be included.

4) Detention Time - 2 hours detention time is the minimum recommended. Longer detention may be required where excessively high turbidities are encountered. Laboratory tests should be conducted to design presedimentation units with hydraulic properties best suited for the raw water to be treated.

4.2.2 Coagulation and Rapid Mixing

Coagulation is a process using coagulant chemicals and mixing by which colloidal and suspended material are destabilized and agglomerated into settleable or filterable flocs, or both. Designs shall be based on the velocity gradient (G value) selected, the chemicals to be added and water temperature, color, and other related water quality parameters. Consideration should be given to optimizing chemical feed point locations. For surface water plants using direct or conventional filtration, the use of a primary coagulant is required at all times.

4.2.2.1 Equipment

1) Basins should be equipped with devices capable of providing adequate mixing for all treatment flow rates. Static mixers should only be used where the flow is relatively constant and will be high enough to maintain the necessary turbulence for complete chemical reactions.

2) Streaming current detectors (SCDs) should be provided to continuously monitor the coagulation process.

4.2.2.2 Mixing

The detention period should not be more than 30 seconds with mixing equipment capable of imparting a minimum velocity gradient (G) of at least 750 fps/ft. The design engineer should determine the appropriate

G value and detention time through experimentation. The engineer shall submit the design basis for the G value selected, considering chemicals to be added, along with water temperature, color, and other related water quality parameters. Consideration should be given to optimizing chemical feed point locations. For surface water plants using direct or conventional filtration, the use of a primary coagulant is required at all times.

4.2.2.3 Location

The rapid mix and flocculation basin shall be as close together as possible.

4.2.2.4 Flow

If flow is split between basins, it is recommended that a means of measuring and modifying the flow to each train/unit be provided.

4.2.3 Flocculation

Flocculation shall mean a process to enhance agglomeration or collection of smaller floc particles into larger, more easily settleable or filterable particles through gentle stirring by hydraulic or mechanical means.

4.2.3.1 Basin Design

Inlet and outlet design shall minimize short-circuiting and destruction of floc. Series compartments are recommended to further minimize short-circuiting and to provide decreasing mixing energy with time. Basins should be designed so that individual basins may be isolated without disrupting plant operation. A drain and/or pumps shall be provided to facilitate dewatering and sludge removal.

4.2.3.2 Detention

The detention time for floc formation should be at least 30 minutes with consideration to using tapered (i.e., diminishing velocity gradient) flocculation. The flow-through velocity should be not less than 0.5 nor greater than 1.5 feet per minute. The design of flocculation units shall be based upon the value of GT (mean velocity gradient in seconds times the detention time in seconds) which is ordinarily in the range of 30,000 to 150,000. The engineer should establish the value of GT through experimentation.

4.2.3.3 Equipment

Agitators should be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 3.0 feet per second. External, nonsubmerged drive equipment is preferred.

4.2.3.4 Piping

Flocculation and sedimentation basins shall be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins shall not be less than 0.5 nor greater than 1.5 feet per second. Allowances must be made to minimize turbulence at bends and changes in direction.

4.2.3.5 Other Designs

Baffling may be used to provide for flocculation in small plants only after consultation with DEP. The design should be such that the velocities and flows noted above will be maintained.

A superstructure over the flocculation basins should be provided.

4.2.3.6 With Tube Settlers

Where tube settlers are proposed for the sedimentation units, flocculation facilities must be closely evaluated to ensure that proper coagulation occurs before application to the settling units.

4.2.3.7 Flow

If flow is split, it is recommended that a means of measuring and modifying the flow to each train/unit be provided.

4.2.3.8 Chemical Addition

Consideration should be given to the need for additional chemical feed in the future.

4.2.4 Sedimentation

Sedimentation shall follow flocculation unless otherwise approved by DEP. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to traditional gravity sedimentation basins.

4.2.4.1 Detention Time

Sedimentation basins should provide an average detention time of 2 to 4 hours based on an evaluation of the raw water, the character of the floc formed, and the design of the basin. Reduced sedimentation time also may be approved when equivalent, effective settling is demonstrated, or when the overflow rate is not more than 0.5 gpm per square foot (1.2 m/hr.). Detention times for tube and plate settlers varies (see Section 4.2.4.6).

4.2.4.2 Inlet Devices

Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. Where stilling walls are not provided, a baffle should be constructed across the basin close to the inlet end and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin.

4.2.4.3 Outlet Devices

Outlet devices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended to provide a volume above the orifices for storage when there are fluctuations in flow.

Outlet weirs and submerged orifices shall be designed as follows:

1) The rate of flow over the outlet weirs or through the submerged orifices shall not exceed 20,000 gallons per day per foot of the outlet launder or orifice circumference.

2) Submerged orifices should not be located lower than three feet below the flow line.

3) The entrance velocity through the submerged orifices shall not exceed 0.5 feet per second.

4.2.4.4 Overflow Rate

The rate of flow over the outlet weir shall not exceed 20,000 gallons per day (gpd) per foot of weir length, unless pilot studies or other performance data is submitted to justify higher rates. Where submerged orifices are used as an alternate for overflow weirs, they should not be lower than 3 feet below the flow line with flow rates equivalent to weir loadings.

4.2.4.5 Velocity

Flow velocity shall be reduced at the entrance to the settling basin by baffles or by directing the water into an enlarged section so that the velocity through the settling basin will not exceed 1 foot per minute. The basin must be designed to minimize short-circuiting. Fixed or adjustable baffles must be provided as necessary to achieve the maximum potential for clarification.

4.2.4.6 Tube or Plate Settlers

Proposals for tube settler clarification must be discussed with the regional Safe Drinking Water engineers prior to the preparation of final plans and specifications.

4.2.4.6.1 General Criteria

1) Inlet and outlet considerations - Design to maintain velocities suitable for settling in the basin and to minimize short-circuiting. Plate units shall be designed to minimize maldistribution across the units.

2) Drainage - Drain piping from the settler units must be sized to facilitate a quick flush of the settler units and to prevent flooding other portions of the plant.

3) Protection from freezing - Outdoor installations shall be covered to prevent freezing in the units.

4) Application rate for tubes - A maximum rate of 2 gpm per square foot of cross-sectional area for tube settlers, unless higher rates are successfully shown through pilot plant or in-plant demonstration studies.

5) Application rate for plates - A maximum plate loading rate of 0.5 gpm per square foot, based on 80 percent of the projected horizontal plate area.

6) Flushing lines - Flushing lines shall be provided to facilitate maintenance and must be properly protected against backflow or back siphonage.

7) Redundancy - If flows are split between multiple units, the units should be plumbed so they are not hydraulically connected so they can run independently.

4.2.4.6.2 Tube Placement

Tube modules shall be placed:

1) In zones of stable hydraulic conditions.

2) In areas nearest effluent launders in basins not completely covered by tubes.

3) So that the top of the tubes are 2 to 4 feet below the water surface.

4.2.4.6.3 Inlets and Outlets

Inlets and outlets shall conform with Sections 4.2.4.2 and 4.2.4.3.

4.2.4.6.4 Tube Support

The tube support system should be able to carry the weight of the tube modules when the basin is drained plus the weight of a workman standing on the tube modules. The minimum bearing surface width of a support member should be 1 inch and support members should be located about 6 inches from the module end.

4.2.4.6.5 Tube Cleaning

Provisions should be made to drop water level occasionally for tube cleaning or provide water or air jet cleaning system for top surface of tube modules.

4.2.4.6.6 Overflow

An overflow weir or pipe designed to establish the maximum water level desired on top of the filters should be provided. The overflow shall discharge by gravity with a free fall at a location where the discharge can be observed.

4.2.4.6.7 Superstructure

A superstructure over the sedimentation basins should be considered where extremes in cold temperature, winds, solar radiation, or other conditions may have an adverse effect on the settling process. If there is no mechanical equipment in the basins and if provisions are included for adequate monitoring under all expected weather conditions, a cover may be provided in lieu of a superstructure. Where covers are used, manholes with raised curbs and covers should be provided as well as drop-light connections, so observations of the floc can be made at several points to determine the efficiency of sedimentation.

4.2.4.6.8 Drainage

Basins must be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than 1 foot in

12 feet where mechanical sludge collection equipment is not used.

4.2.4.6.9 Flushing Lines

Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to DEP.

4.2.4.6.10 Safety

Permanent ladders or handholds should be provided for safety on the inside walls of the basins above the water level. Guidance rails are required when tanks are elevated above ground level or when walk areas are narrow. Compliance with other applicable safety requirements, such as OSHA, shall be required.

4.2.4.6.11 Turbidity Monitoring

Continuous on-line turbidity monitors and recorders should be installed on the settled water line.

4.2.4.6.12 Sludge Collection

Adequate sludge collection equipment that ensures proper basin coverage shall be provided.

4.2.4.6.13 Sludge Removal

Sludge removal design shall provide that:

1) Sludge pipes shall be not less than 3 inches in diameter and so arranged as to facilitate cleaning.

2) Entrance to sludge withdrawal piping shall prevent clogging.

3) Valves shall be located outside the tank for accessibility.

4) The operator may observe and sample sludge being withdrawn from the unit.

4.2.4.6.14 Sludge Disposal

Sludge disposal and any discharge of sludge basin supernatant must be approved by DEP.

4.2.4.6.15 Solids Contact Units

Units are acceptable for combined softening and clarification where water characteristics are not variable and flow rates are uniform. Before such units are considered as clarifiers without softening, specific approval from DEP shall be obtained. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flow which are less than the design rate and for changes in water characteristics. A minimum of 2 units is required. In addition, it is recommended that plants designed for the removal of a non-acute primary drinking water contaminant or for aesthetic purposes also have a minimum of two units.

4.2.4.7 Installation

A representative of the manufacturer shall supervise the installation and initial operation of each unit.

4.2.4.8 Operating Equipment

The following shall be provided for plant operation:

1) A complete outfit of tools and accessories. A tool shall be provided for operator use in monitoring solids depth and consistency.

2) Adequate piping with suitable sampling taps located to permit the collection of samples from various depths of the units shall be provided.

3) If flow is split, a means of measuring the flow to each unit shall be provided. If flow is split, it is recommended that a means of modifying the flow to each unit be provided.

4) A detailed operation and maintenance plan describing the theory of operation, the proper collection of samples, recommended operating parameters based on those sample results, and adjustments that should be made to achieve the recommended operating conditions.

4.2.4.9 Chemical Feed

Chemicals shall be applied at such points and by such means to ensure satisfactory mixing of the chemicals with the water.

4.2.4.10 Mixing

A rapid mix device or chamber ahead of solids contact units may be required by DEP to assure proper mixing of the chemicals applied. Mixing devices employed shall be constructed to:

1) Provide good mixing of the raw water with previously formed sludge particles.

2) Prevent deposition of solids in the mixing zone.

4.2.4.11 Flocculation

Flocculation equipment:

1) Shall be adjustable (speed and/or pitch).

2) Must provide for coagulation in a separate chamber or baffled zone within the unit.

3) Should provide a flocculation and mixing period of not less than 30 minutes.

4) Should be designed to allow for floc recirculation within the unit to aid in floc formation.

5) Should allow for chemical addition directly into the flocculation chamber.

4.2.4.12 Sludge Concentrators

1) The equipment should provide either internal or external concentrators to obtain a concentrated sludge with a minimum of wastewater.

2) Large basins should have at least two sumps for collecting sludge with one sump located in the central flocculation zone.

4.2.4.13 Sludge Removal

Sludge removal design shall provide that:

1) Sludge pipes shall be not less than 3 inches in diameter and so arranged to facilitate cleaning.

2) Entrance to sludge withdrawal piping shall prevent clogging.

3) Valves shall be located outside the tank for accessibility.

4) The operator may observe and sample sludge being withdrawn from the unit.

4.2.4.14 Cross-Connections

1) Blow-off outlets and drains must terminate and discharge at places satisfactory to DEP.

2) Cross-connection control must be included for the potable water lines used to backflush sludge lines.

4.2.4.15 Detention

The detention time shall be established based on the raw water characteristics and other local conditions that affect the operation of the unit. Based on design flows, the detention time should be:

1) 2 to 4 hours for suspended solids contact clarifiers and softeners treating surface water or groundwater under the direct influence of surface water.

2) 1 to 2 hours for the suspended solids contact softeners treating only groundwater.

DEP may alter detention time requirements.

4.2.4.16 Suspended Slurry Concentrate

Softening units should be designed so that continuous slurry concentrates of 1 percent or more, by weight, can be satisfactorily maintained.

4.2.4.17 Water Losses

1) Units shall be provided with controls to allow for adjusting the rate or frequency of sludge withdrawal.

2) Total water losses should not exceed:

(a) 5 percent for clarifiers.
(b) 3 percent for softening units.

3) Solids concentration of sludge bled to waste should be:

(a) 3 percent by weight for clarifiers.
(b) 5 percent by weight for softeners.

4.2.4.18 Weirs or Orifices

The units should be equipped with either overflow weirs or orifices constructed so that water at the surface of the unit does not travel over 10 feet horizontally to the collection trough.

1) Weirs shall be adjustable and at least equivalent in length to the perimeter of the tank.

2) Weir loading shall not exceed:

   (a) 10 gallons per minute (gpm) per foot of weir length for units used for clarifiers.

   (b) 20 gpm per foot of weir length for units used for softeners.

3) Where orifices are used, the loading per foot of launder rates should be equivalent to weir loadings. Either shall produce uniform rising rates over the entire area of the tank.

4.2.4.19 Upflow Rates

Unless supporting data is submitted to DEP to justify rates exceeding the following, the rates shall not exceed:

1) 1.0 gpm per square foot of area at the sludge separation line for units used for clarifiers.

2) 1.75 gpm per square foot of area at the slurry separation line, for units used for softeners.

4.2.5 High Rate Clarification Processes

High rate clarification processes may be approved upon demonstrating satisfactory performance under on-site pilot plant conditions. Reductions in detention times and/or increases in weir loading rates shall be justified. Examples of such processes may include dissolved air flotation, ballasted flocculation, contact flocculation/clarification, and helical upflow, solids contact units.

4.3 Filtration

The selection of any filters is to be supported by the submission of raw and finished water quality data representing a reasonable period to characterize filter performance under all variations in applied water quality.

The following are acceptable filters. Sufficient engineering data to justify their use is required and pilot plant studies may be required to demonstrate the applicability.

1) Rapid rate gravity filters.
2) Pressure filters.
3) Slow sand filters.
4) Diatomaceous earth filters.
5) Membrane filters.
6) Cartridge filters.

The application of any one type must be supported by water quality data representing a reasonable period to characterize the variations in water quality. Pilot studies may be required to demonstrate the applicability of the method of filtration proposed.

4.3.1 Rapid Rate Gravity Filters

4.3.1.1 Pretreatment

Pretreatment is required where rapid rate gravity filters are utilized. As a minimum, the use of a primary coagulant is required during all times that the treatment plant is in operation.

4.3.1.2 Number of Units

At least 2 units shall be provided. Where only 2 units are provided, each shall can meet the plant's permitted capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than 2 filter units are provided, the filters shall can meet the plant's permitted capacity at the approved filtration rate with one filter removed from service.

4.3.1.3 Rates of Filtration

The rates of filtration shall be determined through consideration of such factors as raw water quality, degree of pretreatment, filter media, and other factors as may be required by DEP. The maximum rate for a single media sand or anthracite filter is 2.0 gpm per square foot and for approved dual media or multimedia beds is 4.0 gpm per square foot of filter area.

4.3.1.4 Structural Details and Hydraulics

The filter structure shall be designed as to provide for:

1) Vertical walls within the filter.

2) No protrusion of the filter walls into the filter media.

3) Cover by superstructure.

4) Head room to permit normal inspection and operation.

5) Minimum depth of filter box of 8.5 feet.

6) Minimum water depth over the surface of the filter media of 3 feet.

7) Trapped effluent to prevent backflow of air to the bottom of the filters.

8) Prevention of floor drainage to the filter with a minimum 4-inch curb around the filters.

9) Prevention of flooding by providing overflow.

10) Maximum velocity of treated water in pipe and conduits to filters of 2 feet per second.

11) Cleanouts and straight alignment for influent pipes or conduits where solids loading is heavy or following lime-soda softening.

12) Washwater drain capacity to carry maximum flow.

13) Walkways around filters to be not less than 24 inches wide.

14) Safety handrails or walls around filter areas adjacent to normal walkways.

15) Construction to prevent cross-connections and common walls between potable and nonpotable water or filtered an unfiltered.

4.3.1.5 Washwater Troughs

Washwater troughs shall be designed to provide:

1) The bottom elevation above the maximum level of expanded media during washing.

2) A 2-inch freeboard at the maximum rate of wash.

3) The top edge to be level and all at the same elevation.

4) Spacing so that each trough serves the same number of square feet of filter area.

5) Maximum horizontal travel of suspended particles to reach the trough not to exceed 3 feet.

4.3.1.6 Filter Material

For rapid rate gravity filters, coarse-to-fine beds of mixed or dual media are preferred over fine-to-coarse single media beds.

All filter media shall comply with the criteria set forth in current AWWA's B100 Standard for Filtering Materials.

Water suppliers are strongly encouraged to require that the media supplier provide an affidavit of compliance which states that the media provided meets the specifications established for the installation.

Proper media installation procedures must be used to ensure that the filter will result in effective filtration. Before placement of any media, each filter cell should be thoroughly cleaned and inspected. All underdrain and backwash systems should be tested to the maximum extent possible.

Only clean, dry media, taken directly from its original shipping container, should be installed. Each gravel or media layer should be installed, washed, and scraped and its depth confirmed before placement of subsequent layers.

Installers must not be allowed to walk directly on gravel or media. Boards or plywood should be used to distribute their weight.

Installation procedures should comply with AWWA's B100 Standard for Filter Media.

Filter media shall be routinely measured to ensure minimum media depths are maintained.

Filter media shall be clean, free from clay, dust, micaceous material, organic matter, and detrimental chemical or bacterial contaminants, and have the following characteristics:

- The total media depth shall not be less than 24 inches and generally not more than 30 inches.
- A uniformity coefficient of the smallest material not greater than 1.65.
- A minimum of 12 inches of media with an effective size range no greater than 0.45 to 0.55 mm and a specific gravity greater than the other filtering materials within the filter.
- A ratio of filter depth (in inches) to media effective size (in millimeters) greater than 40 for single- and dual-media filters, and greater than 50 for multi-media filters. If dual- or multi-media

filters are used, the depth to effective size ratio shall be determined for each medium and summed to determine the ratio for the filter.

4.3.1.6.1 Types of Filter Media

1. **Anthracite** - Only clean crushed anthracite may be used and shall meet the following conditions:

   (a) When used alone, the effective size shall be in the range of 0.45 mm to 0.55 mm with a uniformity coefficient not greater than 1.65.

   (b) When used as a cap, the effective size shall be in the range of 0.8 mm to 1.2 mm with a uniformity coefficient not greater than 1.7.

   (c) Has a specific gravity greater than 1.4.

   (d) Has an acid solubility less than 5 percent.

   (e) Has an Mho's scale of hardness greater than 2.7.

   (f) When used for iron and manganese removal from groundwater, the effective size shall not exceed 0.8 mm unless on site pilot plant studies are conducted to justify larger sizes.

2. **Sand** - Sand shall consist of hard, durable, and dense grains of at least 85 percent siliceous material that will resist degradation during handling and use and shall have:

   (a) A minimum depth of 12 inches.

   (b) An effective size of 0.45 to 0.55 mm.

   (c) A uniformity coefficient of not greater than 1.65.

   (d) A specific gravity greater than 2.5.

   (e) An acid solubility less than 5 percent.

   Larger size media may be allowed by DEP where full-scale tests have demonstrated that treatment goals can be met under all conditions.

3. **High Density Sand** - High density sand shall consist of hard, durable, and dense grain garnet, ilmenite, hematite, magnetite, or associated minerals of those ores that will resist degradation during handling and use and shall:

(a) Contain at least 95 percent of the associated material with a specific gravity of 3.8 or higher.

(b) Have an effective size of 0.2 to 0.3 mm.

(c) Have a uniformity coefficient of not greater than 1.65.

(d) Have an acid solubility less than 5 percent.

4. **Granular Activated Carbon (GAC)** - Full bed or full depth GAC may be used, but only after consultation with DEP in addition to the following:

(a) The effective size shall be in the range of 0.45 mm to 0.75 mm with a uniformity coefficient not greater than 1.9.

(b) As a minimum, disinfection of the water from the GAC filters must be provided prior to distribution.

(c) Provisions must be made for replacement or regeneration where GAC is used for filtration and organics removal.

5. **Other Media** - Other media which meet AWWA's Standard for Filtering Material will be considered based on experimental data and operating experience.

4.3.1.6.2 Support Media

1) **Gravel** - Gravel, when used as a supporting media, shall consist of hard, rounded particles and shall not include flat or elongated particles. The coarsest gravel shall be 2.5 inches in size when the gravel rests directly on the strainer system and must extend above the top of the perforated laterals. Not less than four layers of gravel shall be provided in accordance with the following size and depth distribution when used with perforated laterals:

Table 4.X Gravel Size and Depth Distribution	
Size (in)	**Depth (in)**
3/16 to 3/32	2 to 3
1/2 to 3/16	2 to 3
3/4 to 1/2	3 to 5
1.5 to 3/4	3 to 5
2.5 to 1.5	5 to 8

2) **Torpedo Sand -** A 3-inch layer of torpedo sand shall be used as a supporting media for filter sand where supporting gravel is used and shall have:

(a) An effective size of 0.8 mm to 2.0 mm.

(b) A uniformity coefficient not greater than 1.7.

4.3.1.7 Filter Bottoms and Strainer Systems

Departures from these standards may be acceptable for high rate filters and for proprietary bottoms. Porous plate bottoms shall not be used where iron or manganese may clog them or with water softened by lime. The design of manifold-type collection systems shall be such as to:

1) Minimize loss of head in the manifold and laterals.

2) Ensure even distribution of washwater and even rate of filtration over the entire area of the filter.

3) Provide the ratio of the area of the final openings of the strainer system to the area of the filter at about 0.003.

4) Provide a total cross-sectional area of the laterals at about twice the total area of the final openings.

5) Provide the cross-sectional area of the manifold at 1.5 to 2 times the total area of the laterals.

6) Lateral perforations without strainers shall be directed downward.

4.3.1.8 Surface Wash or Subsurface Wash

Surface or subsurface wash facilities should be provided and may be accomplished by a system of fixed nozzles or a revolving-type apparatus. All devices shall be designed with:

1) Provisions for water pressures of at least 45 psi.

2) A properly installed vacuum breaker or other approved device to prevent back-siphonage if connected to the treated water system.

3) Rate of flow of 2 gpm per square foot of filter area with fixed nozzles or 0.5 gpm per square foot with revolving arms.

4) Simultaneous air and water wash may be used provided experimental data and operating experiences indicate media will not be lost. A fluidization wash at the end of the backwash cycle must be provided to re-stratify the media.

4.3.1.9 Air Scouring

Air scouring can be considered in place of surface wash.

1) Air flow for air scouring the filter must be 3-5 standard cubic feet per minute per square foot of filter area when the air is introduced in the underdrain; a lower air rate must be used when the air scour distribution system is placed above the underdrains.

2) A method for avoiding excessive loss of the filter media during backwashing must be provided.

3) Air scouring must be followed by a fluidization wash sufficient to re-stratify the media.

4) Air must be free from contamination.

5) Air scour distribution system should be placed below the media and supporting bed interface; if placed at the interface the air scour nozzles shall be designed to prevent media from clogging the nozzles or entering the air distribution system.

6) Piping for the air distribution system shall not be flexible hose which will collapse when not under air pressure and shall not be a relatively soft material which may erode at the orifice opening with the passage of air at high velocity.

7) Air delivery piping shall not pass down through the filter media nor shall there be any arrangement in the filter design which would

allow short-circuiting between the applied unfiltered water and the filtered water.

8) Consideration should be given to maintenance and replacement of air delivery piping.

9) The backwash water delivery system must be capable of 15 gpm per square foot of filter surface area; however, when air scour is provided the backwash water rate must be variable and should not exceed 8 gpm per square foot while air is being delivered unless operating experience shows that a higher rate is necessary to remove scoured particles from filter media surfaces.

10) The filter underdrains shall be designed to accommodate air scour piping when the piping is installed in the underdrain.

11) Duplicate blowers should be provided.

4.3.1.10 Turbidimeters

Continuous on-line turbidity monitors and recorders shall be installed on the raw water line, the effluent line from each filter, and the combined effluent line. All turbidimeters shall consistently determine and indicate the turbidity of the water in NTUs. Turbidimeters used to monitor individual filter effluent or combined filter effluent shall be designed to accurately measure low-range turbidities. Each turbidimeter shall report to a recorder that is designed and operated to allow the operator to accurately determine the turbidity at least once every 15 minutes. Turbidimeters on the effluent line from each filter shall be placed in a location that also allows measurement of turbidity during filter to waste.

1) Turbidimeters on individual filters shall have an alarm that will sound when the effluent turbidity level exceeds 0.3 NTU.

2) Plants that operate while unattended shall have an auto dialer or other mechanism to immediately alert operators to the alarm condition.

3) Plants that operate while unattended shall have a shut-off device that is capable of shutting down the flow of water from the plant when combined filter effluent turbidity exceeds 1 NTU.

4.3.1.11 Control Appurtenances

1) The following shall be provided for every filter:

(a) The necessary piping, valves, and control equipment needed to filter-to-waste or recycle the effluent water at actual/current and permitted production rates at the beginning of the filter cycle.

(b) A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

(c) Influent and effluent sampling taps.

(d) A head loss gauge.

(e) A meter indicating the instantaneous rate of flow.

(f) Provisions for draining the filter-to-waste with appropriate measures for backflow prevention.

(g) It is recommended that turbidimeters be placed in a location that also allows measurement of turbidity during filter to waste.

2) It is recommended the following be provided:

(a) Wall sleeves providing access to each filter interior at several locations for sampling or pressure sensing.

(b) A 1 to 1.5-inch pressure hose and storage rack at the operating floor for washing the filter.

(c) Access to particle counting equipment to enhance overall treatment operations.

4.3.1.12 Backwash

Provisions shall be made for washing filters as follows:

1) A minimum rate of 15 gpm per square foot, consistent with water temperatures and specific gravity of the filter media.

2) A rate of 20 gpm per square foot or a rate necessary to provide for a 50 percent expansion of the filter bed is recommended. A reduced rate of 10 gpm per square foot or a rate necessary to provide for a 50 percent expansion of the filter bed, whichever is larger, may be acceptable for full depth anthracite or granular activated carbon filters.

3) Filtered water provided at the required maximum rate by washwater tanks, a washwater pump from the high service main, or a combination of these.

4) Washwater pumps in duplicate unless an alternative means of obtaining washwater is available.

5) Not less than 15 minutes wash of one filter at the design rate of wash.

6) A washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with the washwater valves on the individual filters open wide.

7) A rate-of-flow indicator, preferably with a totalizer, on the main washwater line located so that it can be easily read by the operator during the washing process.

8) Design to prevent rapid changes in backwash water flow.

4.3.1.13 Miscellaneous

Roof drains shall not discharge into the filters or basins and conduits preceding the filters.

4.3.2 Pressure Filtration

The use of these filters may be considered for iron and manganese removal, but shall not be used in the filtration of surface waters or following lime-soda softening unless pilot plant testing demonstrates the system can meet drinking water standards at all times.

4.3.2.1 General

Minimum criteria relative to number of units, rate of filtration, use of a primary coagulant, structural details and hydraulics, filter media, etc., provided for rapid rate gravity filters also apply to pressure filters where appropriate.

4.3.2.2 Rate of Filtration

The rate shall not exceed 4 gpm per square foot of filter area except where in-plant testing as approved by DEP has demonstrated satisfactory results at higher rates.

4.3.2.3 Details of Design

Pressure filters shall be designed to provide for:

1) Filtration and backwashing of each filter individually with an arrangement of piping as simple as possible to accomplish these purposes.

2) Minimum side wall shell height of 5 feet. A corresponding reduction in side wall height is acceptable where proprietary bottoms permit reduction of the gravel depth.

3) The top of the washwater collectors to be at least 18 inches above the surface of the media.

4) The underdrain system to efficiently collect the filtered water and to uniformly distribute the backwash water at a rate not less than 15 gpm per square foot of filter area.

5) Backwash flow indicators and controls that are easily readable while operating the control valves.

6) An air release valve on the highest point of each filter.

7) An access manhole to facilitate inspection and repairs.

8) Means to observe the wastewater during backwashing.

9) Construction to prevent cross-connection.

4.3.2.4 Turbidimeters

Continuous on-line turbidity monitors and recorders shall be installed on the raw water line, the effluent line from each filter, and the combined effluent line. All turbidimeters shall consistently determine and indicate the turbidity of the water in NTUs. Turbidimeters used to monitor individual filter effluent or combined filter effluent shall be designed to accurately measure low-range turbidities. Each turbidimeter shall report to a recorder that is designed and operated to allow the operator to accurately determine the turbidity at least once every 15 minutes. Turbidimeters on the effluent line from each filter shall be placed in a location that also allows measurement of turbidity during filter to waste.

1) Turbidimeters on individual filters shall have an alarm that will sound when the effluent turbidity level exceeds 0.3 NTU.

2) Plants that operate while unattended shall have an auto dialer or other mechanism to immediately alert operators to the alarm condition.

3) Plants that operate while unattended shall have a shut-off device that is capable of shutting down the flow of water from the plant when combined filter effluent turbidity exceeds 1 NTU.

4.3.2.5 Control Appurtenances

1) The following shall be provided for every filter:

   (a) The necessary piping, valves, and control equipment needed to filter-to-waste or recycle the effluent water at actual/current and permitted production rates at the beginning of the filter cycle.

   (b) A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

   (c) Influent and effluent sampling taps.

   (d) An indicating loss of head gauge.

   (e) An indicating rate-of-flow meter.

   (f) A modified rate controller which limits the rate of filtration to a maximum rate may be used. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with DEP.

   (g) Provisions for draining the filter-to-waste with appropriate measures for backflow prevention.

2) It is recommended the following be provided:

   (a) A 1- to 1.5-inch pressure hose and storage rack at the operating floor for washing the filter.

   (b) Access to particle counting equipment to enhance overall treatment operations.

4.3.3 Diatomaceous Earth Filtration

Installation of diatomaceous earth filtration shall be limited to water having maximum turbidities of 10 NTU units, total coliform levels of 800 colonies per 100 mL, and a maximum color of 5 units; such turbidities must not be attributable to colloidal clay. Microscopic examination of the raw water must be made to determine the nature and extent of algae growths and their potential adverse impact on filter operations. A pilot plant study is required on the water to be treated.
T Diatomaceous earth filters may be used for iron removal from groundwater providing the pilot testing proves effective and the water is of satisfactory sanitary quality before treatment.

Only filter media certified for drinking water use under [ANSI/AWWA Standard No. 60]() or another DEP-approved third party shall be used.

4.3.3.1 Conditions of Use

Diatomaceous earth filters are expressly excluded from consideration for the following conditions:

1) Color removal.

2) Turbidity removal where either the gross quantity of turbidity is high or the turbidity exhibits poor filterability characteristics.

3) Filtration of waters with high algae levels.

4.3.3.2 Pilot Plant Study

Installation of a diatomaceous earth filtration system shall be preceded by a pilot plant study on the water to be treated.

1) Conditions of the study such as duration, filter rates, head loss, slurry feed rates, turbidity removal, bacteria removal, protozoan removal, etc. must be approved by DEP prior to the study.

2) Satisfactory pilot plant results must be obtained prior to preparation of final construction plans and specifications.

3) The pilot plant study must demonstrate the ability of the system to meet applicable drinking water standards at all times.

4.3.3.3 Types of Filters

Pressure or vacuum diatomaceous earth filtration units will be considered for approval. However, the vacuum type is preferred for its ability to accommodate a design which permits observation of the filter surfaces to determine proper cleaning, damage to a filter element, and adequate coating over the entire septum or filter area.

4.3.3.4 Treated Water Storage

Treated water storage capacity in excess of normal requirements shall be provided to:

1) Allow operation of the filters at a uniform rate during all conditions of system demand at or below the approved filtration rate.

2) Guarantee continuity of service during adverse raw water conditions without bypassing the system.

4.3.3.5 Number of Units

At least two units shall be provided. Where only two units are provided, each shall/can meet the plant's permitted capacity at the approved filtration rate. Where more than two filter units are provided, the filters shall/can meet the plant's permitted capacity at the approved filtration rate with one filter removed from service.

4.3.3.6 Pre-Coat

1) Application - A uniform pre-coat shall be applied hydraulically to each septum by introducing a slurry to the tank influent line and employing a filter-to-waste or recirculation system.

2) Quantity - Diatomaceous earth in the amount of 0.2 lbs. per square foot of filter area or an amount sufficient to apply a 1/8- to 1/5-inch coating should be used with recirculation.

4.3.3.7 Body Feed

A body feed system to apply additional amounts of diatomaceous earth slurry during the filter run is required to avoid short filter runs or excessive head losses. Diatomaceous earth filtration systems should make provisions for the addition of coagulant coating (alum or polymer) to the body feed.

1) Quantity - Rate of body feed is dependent on raw water quality and characteristics and must be determined in the pilot plant study.

2) Operation and maintenance can be simplified by providing accessibility to the feed system and slurry lines.

3) Continuous mixing of the body feed slurry is required.

4.3.3.8 Filtration

1) Rate of filtration - The rate shall not exceed 1.5 gpm per square foot of filter area with a recommended nominal rate is 1 gpm per square foot of filter area. The filtration rate shall be controlled by a positive means.

2) Head loss - The head loss shall not exceed 30 psi for pressure diatomaceous earth filters or a vacuum of 15 inches of mercury for a vacuum system.

3) Recirculation - A recirculation or holding pump shall be employed to maintain differential pressure across the filter when the unit is not in operation to prevent the filter cake from dropping off the filter elements. A minimum recirculation rate of 0.1 gpm per square foot of filter area shall be provided.

4) Septum or filter element - The filter elements shall be structurally capable of withstanding maximum pressure and velocity variations during filtration and backwash cycles and shall be spaced such that no less than 1 inch is provided between elements or between any element and a wall.

5) Inlet Design - The filter influent shall be designed to prevent scour of the diatomaceous earth from the filter element.

4.3.3.9 Backwash

A satisfactory method to thoroughly remove and dispose of spent filter cake shall be provided.

4.3.3.10 Control Appurtenances

1) The following shall be provided for every filter:

(a) The necessary piping, valves, and control equipment needed to filter-to-waste or recycle the effluent water at actual/current and permitted production rates at the beginning of the filter cycle.

(b) A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

(c) Influent and effluent sampling taps.

(d) An indicating loss of head gauge.

(e) An indicating rate-of-flow meter.

(f) A modified rate controller which limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow on to the filter is properly controlled. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with DEP.

(g) Provisions for draining the filter-to-waste with appropriate measures for backflow prevention

2) It is recommended the following be provided:

(a) A 1- to 1.5-inch pressure hose and storage rack at the operating floor for washing the filter.

(b) Access to particle counting equipment to enhance overall treatment operations.

(c) A throttling valve used to reduce rates below normal during adverse raw water conditions.

(d) Evaluation of the need for body feed, recirculation, and any other pumps, in accordance with Section 4.3.

4.3.3.11 Turbidimeters

Continuous on-line turbidity monitors and recorders shall be installed on the raw water line, the effluent line from each filter, and the combined effluent line. All turbidimeters shall consistently determine and indicate the turbidity of the water in NTUs. Turbidimeters used to monitor individual filter effluent or combined filter effluent shall be designed to accurately measure low-range turbidities. Each turbidimeter shall report to a recorder that is designed and operated to allow the operator to accurately determine the turbidity at least once every 15 minutes. Turbidimeters on the effluent line from each filter shall be placed in a location that also allows measurement of turbidity during filter to waste.

1) Turbidimeters on individual filters shall have an alarm that will sound when the effluent turbidity level exceeds 1.0 NTU.

2) Plants that operate while unattended shall have an auto dialer or other mechanism to immediately alert operators to the alarm condition.

3) Plants that operate while unattended shall have a shut-off device that is capable of shutting down the flow of water from the plant when combined filter effluent turbidity exceeds 2.0 NTU.

4.3.4 Slow Sand Filters

Proposals for slow sand filters will be approved after engineering studies have indicated the adequacy and suitability of these methods of filtration for a specific raw water quality.

4.3.4.1 Quality of Raw Water

Slow sand filtration shall be limited to water having maximum turbidities of 10 NTU, total coliform levels of 800 colonies per 100 mL, and a maximum color of 15 units; such turbidities must not be attributable to colloidal clay. Microscopic examination of the raw water must be made to determine the nature and extent of algae growths and their potential adverse impact on filter operations.

4.3.4.2 Number of Units

At least 2 units shall be provided. Where only 2 units are provided, each shall/can meet the plant's permitted capacity at the approved filtration rate. Where more than 2 filter units are provided, the filters shall/can meet the plant's permitted capacity at the approved filtration rate with one filter removed from service.

4.3.4.3 Structural Details

Slow rate gravity filters shall be designed to provide:

1) A cover for temperature control, exclusion of sunlight, or protection from intrusion.

2) Sufficient room to permit movement by operating personnel for scraping and sand removal. The structural strength of the underdrain system should take into consideration the possible use of heavy equipment for this purpose.

3) Adequate manholes and access ports for handling of sand and for ventilation.

4) An overflow at the maximum filter water level.

5) Protection from freezing.

4.3.4.4 Rates of Filtration

The permissible rates of filtration shall be determined by the quality of the raw water and shall be based on experimental data derived from the water to be treated. The nominal rate may be 45 to 150 gpd per square foot of sand area, with somewhat higher rates acceptable when demonstrated to the satisfaction of DEP.

4.3.4.5 Velocity

The maximum water velocity through the filter shall not exceed 1.2 ft./hr.

4.3.4.6 Underdrains

Each filter unit shall be equipped with a main drain and an adequate number of lateral underdrains to collect the filtered water. The underdrains shall be placed as close to the floor as possible and spaced so that the maximum velocity of the water flow in the lateral underdrain will not exceed 0.75 feet per second. The maximum spacing of the laterals shall not exceed 3 feet.

4.3.4.7 Filtering Material

Filtering materials should comply with the criteria set forth in AWWA's Standard for Filtering Material.

1) Filter sand shall be placed on graded gravel layers for a minimum depth of 30 inches.

2) The effective size shall be between 0.15 mm and 0.3 mm as the preferred range.

3) The uniformity coefficient shall not exceed 2.5.

4) The sand shall be clean and free from foreign matter.

5) The sand shall be rebedded when scraping has reduced the bed depth to less than 19 inches. Where sand is to be reused to provide biological seeding and shortening of the ripening process, rebidding shall utilize a throw-over technique, whereby new sand is placed on the support gravel and existing sand is replaced on top of the new sand.

4.3.4.8 Filter Gravel

Gravel, when used as a supporting media, shall consist of hard, rounded particles and shall not include flat or elongated particles. The coarsest gravel shall be 2.5 inches in size when the gravel rests directly on the strainer system and must extend above the top of the perforated laterals. Not less than four layers of gravel shall be provided in accordance with the following size and depth distribution when used with perforated laterals:

Table 4.X Gravel Size and Depth Distribution	
Size (in)	**Depth (in)**
3/16 to 3/32	2 to 3
1/2 to 3/16	2 to 3
3/4 to 1/2	3 to 5
1.5 to 3/4	3 to 5
2.5 to 1.5	5 to 8

4.3.4.9 Depth of Water on Filter Beds

Design shall provide a depth of at least 3 feet of water over the sand. Influent water shall not scour the sand surface.

4.3.4.10 Control Appurtenances

1) The following shall be provided for every filter:

   (a) The necessary piping, valves, and control equipment needed to filter-to-waste or recycle the effluent water at actual/current and permitted production rates at the beginning of the filter cycle.

   (b) A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

   (c) Influent and effluent sampling taps.

   (d) An indicating loss of head gauge or other means to measure head loss.

   (e) An indicating rate-of-flow meter.

   (f) A modified rate controller which limits the rate of filtration to a maximum rate may be used. Equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow on to the filter is properly controlled. An effluent pipe designed to maintain the water level above the top of the filter sand.

2) It is recommended the following be provided:

   (a) Wall sleeves providing access to each filter interior at several locations for sampling or pressure sensing.

   (b) A 1 to 1.5-inch pressure hose and storage rack at the operating floor for washing the filter.

(c) Access to particle counting equipment to enhance overall treatment operations.

4.3.4.11 Sand Cleaning Equipment

Slow rate sand filter plants should be equipped with portable sand ejectors operated by water under pressure, for removing dirty sand scraped from the filter. A sand-washing unit should be available to permit the washing of the sand so removed. The control building of a slow sand filtration plant shall have the necessary equipment to conduct a sieve analysis of the sand used in the filters.

4.3.4.12 Turbidimeters

Continuous on-line turbidity monitors and recorders shall be installed on the raw water line, the effluent line from each filter, and the combined effluent line. All turbidimeters shall consistently determine and indicate the turbidity of the water in NTUs. Turbidimeters used to monitor individual filter effluent or combined filter effluent shall be designed to accurately measure low-range turbidities. Each turbidimeter shall report to a recorder that is designed and operated to allow the operator to accurately determine the turbidity at least once every 15 minutes. Turbidimeters on the effluent line from each filter shall be placed in a location that also allows measurement of turbidity during filter to waste.

1) Turbidimeters on individual filters shall have an alarm that will sound when the effluent turbidity level exceeds 1.0 NTU.

2) Plants that operate while unattended shall have an auto dialer or other mechanism to immediately alert operators to the alarm condition.

3) Plants that operate while unattended shall have a shut-off device that shuts down the flow of water from the plant when combined filter effluent turbidity exceeds 2.0 NTU.

4.3.4.13 Laboratory Equipment

The control building of a slow sand filtration plant shall include the appropriate laboratory facilities for determining the turbidity and disinfectant residual of the water as outlined in Section 2.4.

4.3.5 Membrane Filtration: Ultrafiltration (UF) and Microfiltration (MF) Systems

4.3.5.1 Background

UF is a process that typically employs membranes with a pore size range of approximately 0.01 - 0.05 µm (nominally 0.01 µm). MF is a process that typically employs membranes with a pore size range of approximately 0.1 - 0.2 µm (nominally 0.1 µm).

UF and MF systems are designed and constructed in one or more discrete water production units, referred to as filter units. These consist of a number of cassettes, modules, or cartridges which could include membranes enclosed in their own housings or free-floating submerged membranes in a water-filled basin. Modules typically share feed and filtrate valving and each respective module can usually be isolated from the rest of the system for repair or cleaning purposes. A MF or UF system is composed of a number of identical filter units or skids that, in combination, generate the total production filtrate.

In this section the term "filter unit" refers to a group of pressure vessels that share common valving and which can be isolated as a group for testing, cleaning, or repair; synonymous with the terms train and rack; included under the term "unit, rack or skid". It term does not include a filtration train where a group of units, rack.

4.3.5.2 Design and Regulatory Framework

The United States Environmental Protection Agency Membrane Filtration Guidance Manual (MFGM) was developed in conjunction with LT2ESWTR to elaborate on the rule requirements associated with membrane filtration. Topics addressed in the MFGM include: membrane system design, challenge testing, direct/indirect integrity testing, pilot testing, implementation/operational considerations, and initial start-up. The contents of this section of the DEP PWSM are intended to complement information contained in the MFGM.

The MFGM provides a framework and guidance on what is needed regarding the use of membrane filtration to comply with LT2ESWTR requirements and ultimately receive *Cryptosporidium* log removal credits (LRC).

1) Membrane systems must comply with applicable requirements in the Safe Drinking Water Regulations (25 Pa. Code Chapter 109), MFGM, and the PWSM to receive *Cryptosporidium* LRC.

2) **DEP will NOT give virus removal credits for membrane filtration**.

4.3.5.3 Pilot Studies

DEP may require pilot studies for all proposed membrane filtration installations to evaluate and provide performance data on the specific system(s) under consideration.

The goals of a membrane pilot study are to obtain information used to design full scale facilities, and to provide operational experience to operators and designers contemplating use of membranes. Information used to design full scale facilities includes treated water quality (e.g., turbidity) and operating parameters (e.g., flux), which are necessary for the design of a membrane filtration facility.

The pilot study shall be conducted over a sufficient period (typically 3 chemical clean-in-place (CIP) cycles) to establish that the technology is appropriate for the source water and to determine appropriate design and operating parameters. The study shall evaluate pre-treatment requirements, membrane flux rates, transmembrane pressure (TMP), backwash parameters, and CIP procedures. The pilot study should be conducted during the time of year yielding the most difficult water quality to treat, so design parameters resulting from the study, such as flux and chemical cleaning frequency, are conservative for year-round operation. The study period shall include at least one raw water spike from a major rainfall event or an artificially induced event to mimic a major rainfall event.

1) The pilot study shall determine specifics such as:

    (a) Ability to meet all treatment objectives.
    (b) Pre-filtration treatment needs.
    (c) Post-filtration treatment needs.
    (d) Quantity of reject water.
    (e) Operation and maintenance needs.
    (f) Optimum system recovery and flux rate.
    (g) Process efficiency.
    (h) Organism removal efficiencies (LRC).
    (i) Fouling potential.
    (j) Transmembrane pressures.
    (k) Optimum cleaning procedures and frequency.
    (l) Other design and monitoring considerations.

2) Data collected during the pilot study shall include, at least:

    (a) Continuous monitoring of flow rate, run time, flux rate, filtrate pressures, TMP, raw water turbidity, feed water turbidity (following pre-filtration treatment), and individual filtrate turbidity (via laser turbidimeter).

(b) Daily (or more frequently if collected) monitoring of direct integrity parameters and results, pH, hardness, and temperature.

(c) Weekly monitoring of raw and membrane filtrate alkalinity, total hardness, calcium hardness, ammonia, silica, iron, sulfate, color, manganese, total suspended solids, and total dissolved solids.

(d) All backwash frequency, volumes, and rates.

(e) CIP procedures, frequency, and chemical usage.

3) The pilot study shall include at least one cut fiber test where a fiber is intentionally cut to demonstrate that the system can detect the broken fiber, how the fiber can be successfully repaired and passes the direct integrity test, and to familiarize operators with both aspects of operation.

4) The pilot study shall include at least three (3) CIP cycles (totaling at least 90 days) at normal anticipated frequency.

5) Water suppliers shall submit their proposed pilot study protocol to the appropriate DEP regional office and obtain approval prior to initiating the pilot study.

6) Certified operators and design engineers shall both be extensively involved in the operation of the pilot study for the proposed system to familiarize themselves with the operation, monitoring, cleaning, repairing, and other maintenance procedures for the membrane system.

7) The pilot unit shall be equipped with all the instrumentation, monitoring, controls, software, and hardware needed to establish stable operating conditions and satisfy the pilot study monitoring requirements.

8) The minimum performance goals of the membrane during the pilot study shall be:

(a) One hundred percent of regular daily direct integrity tests providing a log removal value (LRV) greater than or equal to 4.0 for a 3-micron defect.

(b) Ninety five percent of the individual filter effluent turbidity recorded every 15 minutes indicating less than or equal to 0.10 NTU.

Any deviations from the minimum performance goals should be documented and justified.

9) Upon study completion, the water supplier shall submit a report through the design engineer to DEP summarizing the procedures, all test results, and recommendations. The report should contain sufficient detail to establish design parameters for the full-scale plant.

10) A bench-scale study, which requires less time and expense, is considered a preliminary evaluation tool to verify process feasibility and to evaluate individual membrane elements. A bench-scale study can be used prior to a pilot study, but will not replace the requirement for a pilot study.

4.3.5.4 Permitting Support Documentation

For proposed membrane installations, project-specific information that shall be submitted to DEP as part of the Public Water Supply Permit Application is to include, at a minimum:

1) Treatment objectives.

2) Raw water quality information, including all new source sampling results and LT2ESWTR source water monitoring bin determination results.

3) An analysis of any pretreatment needs.

4) Maximum feed rate to each filter unit (Q_f).

5) Maximum production rate from each filter unit (Q_p).

6) Percent recovery (R).

7) Design flux rate (J).

8) Pertinent ANSI/NSF 61 certifications.

9) ANSI/NSF Standard 419 challenge test results.

10) Summary describing the pilot testing results and bench-scale study (if applicable) used to determine that the system will consistently produce treated water meeting regulatory requirements and the treatment objectives.

11) Direct integrity testing information, including method specifications, LRV calculations (include sample calculations), and

instrumentation specifications. The following information shall be provided to describe the direct integrity test:

- Minimum direct integrity test starting pressure (P_{test}).
- Pressure decay test result (ΔP_{test}).
- Minimum applicable log removal value (LRV).
- Air-to-liquid conversion ratio (ALCR).
- Volume of pressurized air in the membrane system during a pressure decay test (V_{sys}).
- Volumetric concentration factor (VCF).
- Maximum backpressure during pressure decay test (BP).
- Liquid-membrane contact angle (θ).
- Pore shape factor (Κ).
- Surface tension (σ).
- Transmembrane pressure (TMP).
- Water temperature (T).
- Time/Length of direct integrity test.

12) Indirect integrity testing information including laser turbidimeter make and model, data logging frequency, and alarm set points.

13) Additional system information, to include: process type (pressure/vacuum-driven), materials of construction, membrane surface area per filter unit (A_{sys}), effective pore size, minimum/maximum operating pressures, and manufacturer-recommended limitations to prevent equipment damage.

14) Specifications for all system equipment components, to include: pretreatment, the membrane filter unit, membrane modules, compressed air equipment, CIP system(s), reverse filtration/backwash system, air scrub/backwash system, tanks, heaters, pumps, drives, and associated equipment (i.e., piping, valves, wiring, supports, etc.), as applicable.

15) Information on the specific system being proposed for use shall also include:

(a) Dimensioned filter unit layout drawings.

(b) Process and instrumentation diagrams.

(c) Specifications for the respective production, backwash, CIP, and integrity test equipment.

(d) For cleaning process cross-connection control, description of a double block and bleed assembly or an equivalent assembly which is equally or more protective.

(e) Calculations adequately describing the establishment of critical operational control limits.

(f) Information on how redundancy requirements are being met.

(g) A description of the backwash process, to include: frequency for each backwash mode, duration of steps, impact to solids accumulation (expressed as VCF), and justification of the selected backwash process.

16) A plan for on-site training of the water system operator(s) on how to operate and maintain the membrane treatment system. The plan shall include: who will provide the training, the schedule of training, training forms, and operators who will be trained. The plan shall also include: collecting, recording, and interpreting data; startup and shutdown procedures; and all fiber testing and repair procedures.

4.3.5.5 Challenge Testing

To receive LT2ESWTR Log Removal Credit (LRC), the membrane filtration system shall be certified for conformance with ANSI/NSF Standard 419, Public Drinking Water Equipment Performance – Filtration. This standard addresses the performance evaluation test procedure for product-specific challenge testing of full-scale microfiltration/ultrafiltration membrane modules for determining the removal of microbial contaminants. The results shall include a minimum Log Removal Value (LRV) and a maximum filtrate flux rate.

4.3.5.6 Raw Water Quality

1) All LT2ESWTR source water monitoring bin determination requirements must be completed prior to submission of a permit application, otherwise, Bin 4 treatment (5.5-log treatment) must be supplied.

2) Weekly source water quality monitoring shall be conducted to include at least three (3) different seasons with a minimum of four (4) samples per season. Monitoring shall be conducted for:

(a) Turbidity
(b) Total Organic Carbon (TOC)
(c) Temperature
(d) pH

3) In addition to any new source sampling requirements, sample results for the following shall be submitted:

(a) Alkalinity
(b) Total Hardness
(c) Calcium Hardness
(d) Ammonia
(e) Iron
(f) Silica
(g) Sulfate
(h) Total Dissolved Solids (TDS)
(i) Color
(j) Manganese
(k) Dissolved Oxygen (DO)
(l) Algae
(m) Silt Density Index (SDI)

4.3.5.7 Pretreatment

Pretreatment needs shall be adequately evaluated. Pretreatment shall be employed for removing large particulate matter that could damage membranes and for material that could foul membranes. Acceptable feedwater characteristics are dependent on the type of membrane and system operational parameters. Without suitable pretreatment and/or acceptable feedwater quality, the membrane may become significantly fouled or physically damaged, likely resulting in a shortened useful life or premature membrane failure. Pretreatment shall be capable of lowering the turbidity to at least 1 NTU.

1) Coagulation, Flocculation, and Sedimentation

Coagulation, flocculation, and sedimentation processes shall be provided on all raw water originating from rivers, streams, creeks, lakes, and/or reservoirs that have maximum raw water turbidities exceeding 20 NTUs, unless a pilot study successfully demonstrates coagulation, flocculation, and sedimentation may not be necessary. However, even after a successful pilot study, DEP may require coagulation, flocculation, and sedimentation if it determines such treatment is necessary to ensure continuous delivery of high quality water at all times.

2) Prescreens and Strainers

A prescreen/strainer system shall be provided just prior to the membrane unit. Prescreens/strainers shall be of the same design basis and mesh size as specified by the membrane equipment manufacturer (typically 150 – 500 microns). Redundant strainers shall be installed, and those strainers shall be installed in a manner that allows operators to readily service and clean them. The permit application specifications shall include mesh size along with strainer cleaning and waste stream handling information.

3) Neither polymers or phosphates shall be used in advance of the membranes due to the potential for irreversible fouling.

4) Ability to pre-treat to waste should be considered.

4.3.5.8 Redundancy

1) At least two membrane filter units shall be provided. Where only two units are provided, each unit shall be capable of meeting the plant's permitted capacity at the approved flux rate. When more than two membrane units are provided, design must be able to meet the plant's permitted capacity, at the maximum approved flux rate, with one unit out of service.

2) Proposed water treatment facilities should include space or an additional membrane unit or additional modules/cassettes that may be needed for potential future increases in hydraulic capacity. Proposed facilities should also be constructed in a manner that facilitates insertion of additional membrane capacity with minimal need to change existing pipe, pump, and tank configurations.

4.3.5.9 Backwashing

Backwashing volumes can range from 5 - 15% of the permeate flow, depending upon the frequency of flushing/cleaning and the degree of fouling. This should be considered when sizing the treatment system and evaluating the capacity of the raw water source.

1) Backwash water supply shall be filtered water.

2) Adequate cross-connection control provisions shall be provided to protect the quality of the water used to backwash the membranes and the finished water. Refer to DEP's Public Water Supply Manual Part 7, Cross-Connection Control/Backflow Prevention.

3) Adequate backwash waste handling shall be provided. The design of backwash waste handling facilities should consider the volume of water produced on a daily basis, flow equalization requirements, and the concentration of suspended solids in the wastewater.

4.3.5.10 Cleaning

The membrane must be periodically cleaned with acid/bases, detergents, or disinfectants to control membrane fouling. Cleaning procedures, chemicals, and frequency must consider the information developed during the pilot study and should follow the membrane manufacturer's guidelines.

1) All cleaning chemicals shall be acceptable to the Department. Chemicals which are certified for conformance with ANSI/NSF Standard 60, or meet the food grade standards of the United States Pharmacopeia, are deemed acceptable to the Department.

2) Provisions for safe chemical storage, handling, and waste disposal shall be addressed.

3) Cross-connection control measures shall be provided to prevent contamination of both the feed and filtrate water systems from CIP cleaning chemicals using a double block and bleed valving arrangement or a removable spool.

4) A functional description of CIP procedures shall be provided, addressing the following:

   - A SOP for respective operator CIP activities, including frequency, triggers, automated/manual cleaning aspects, and post-CIP approach for the return to production mode.

   - Identification of the different chemicals to be utilized.

   - Methods to neutralize and dispose of the CIP chemical waste stream.

4.3.5.11 Direct Integrity Testing

Each filter unit shall be equipped with a direct integrity testing system that is consistent with Chapter 4, *Direct Integrity Testing*, of the MFGM. Operational parameters and critical control limits must ultimately be based upon the direct integrity test performed to achieve a minimum resolution of 3 microns. System-specific calculations shall be provided with the permit application and address: minimum test pressure, effective pressure, pressure decay rates, air-liquid conversion ratio (ALCR), and LRV.

Direct integrity test results comprise a component of the LRV determination. The actual *Cryptosporidium* removal credit that a low-pressure membrane filtration will receive is the lower of the following values: the removal efficiency demonstrated during challenge testing, or the maximum log removal that can be verified via the daily direct integrity testing required during operation. Any public water supply operating permit will stipulate the required LRV and the direct testing conditions that must be met to verify that the LRV is being achieved.

1) Each filter unit shall be equipped with an off-line pressure decay testing system. The system and protocol shall have a resolution of 3 microns or less.

2) Each filter unit shall be designed to perform a direct integrity test on a daily basis or more frequently as needed. The filter unit shall be designed to not return to production mode until the filter unit integrity has been confirmed by completion of a successful direct integrity test, having results within the established control limits.

3) At each location of a pressure transducer, a 1/4 inch diameter NPT pressure gauge connection shall be provided to facilitate the connection of a portable, pocket type test gauge.

4) A calibrated, portable pocket type pressure gauge of the correct range and accuracy for the application shall be provided to check each pressure transducer installed on the membrane filter unit.

5) The time for direct integrity test to determine the decay rate shall be at least five (5) minutes during any direct integrity test.

6) Each filter unit shall be equipped with alarms and shutdowns that will be triggered by exceedance of operational control limits. Failure to comply with the following limits shall cause the programmable logic controller (PLC) to initiate immediate shutdown of the affected filter unit:

   (a) Minimum initial direct integrity test starting pressure, after a stabilization period, is less than the required value (P_{test}).

   (b) The pressure decay rate (PSI per minute) exceeds the upper control limit value.

   (c) PLC-generated LRV is less than the required value.

4.3.5.12 Indirect Integrity Testing

1) An online laser turbidimeter shall be provided for each filter unit for continuous monitoring and recording of the membrane permeate (IFE). This shall include measurement and recording of permeate turbidity at least once every 15 minutes that the system is operated.

2) The PLC shall be designed to initiate immediate shutdown, alarm and contact the operator (autodialor) when the permeate turbidity exceeds 0.15 NTU and stays above 0.15 NTU for any fifteen-minute period based on continuous turbidity monitoring. If

a turbidity reading falls below this 0.15 NTU threshold for at least one minute during any fifteen-minute period, the timer resets.

4.3.5.13 Flux Rate

Permit applications shall include the rationale and a justification for the proposed maximum flux rate (gallons per square foot per day, GFD) to be used. The rationale associated with the recommended operational mode flux ranges shall be included. Any proposed pretreatment chemicals that could affect flux parameters need to be identified as well.

4.3.5.14 Transmembrane Pressure (TMP)

Large TMP differentials that require high influent pressures, increase operating costs, and shorten membrane life should be avoided. Membrane systems shall be designed to operate within the TMP range recommended by the manufacturer.

1) Pretreatment may be required to provide a low, practical range for operational TMP.

2) Permit applications shall identify acceptable operational TMP ranges, alarm, and shutdown conditions.

3) The PLC shall trigger an alarm at a prescribed TMP to notify the operator of rising pressure differential and unusual conditions.

4) The PLC shall trigger an automatic shutdown at a prescribed maximum TMP to protect the membrane from damage or failure.

4.3.5.15 Instrumentation/Appurtenances

At a minimum, the following equipment and instrumentation shall be provided:

1) Taps for sampling feed water, permeate, and concentrate.

2) Appropriate pressure gauges for TMP and for direct integrity testing. Include these devices on feed, permeate, and concentrate lines.

3) Flow meter for feed, permeate, and waste flow rate.

4) Flow rate controller to control the flux rate.

5) All required means of removing membrane modules and cartridges for replacement or repair, including cranes, lifts, adequate ceiling heights, and specialty tools, as applicable.

6) All fiber leak detection instrumentation and fiber repairing/pinning equipment, including test beds and pressurization systems, as applicable.

7) A dedicated work space within the plant large enough to perform all fiber repair/pinning and maintenance.

8) The feed water line shall include continuous monitors and recorders for turbidity, pH, conductivity, and temperature.

9) The permeate line on each individual filter unit shall include continuous monitors and records for turbidity (laser turbidimeter), pH, conductivity, and temperature. Turbidimeters shall be equipped with alarms, shutdowns the capacity to notify the operators.

10) The combined permeate line (CFE) shall be equipped with a laser turbidimeter continuously monitors and records and totalizing flow meter. Turbidimeters shall be equipped with alarms, shutdowns and the capacity to notify the operators.

4.3.5.16 Control Systems

1) A supervisory control and data acquisition (SCADA) system capable of monitoring, recording, and controlling all the treatment plant's critical operations shall be provided.

The SCADA system shall:

(a) Be programmed to automatically archive data to hard disk drives with removable media or to a secure off-site location.

(b) Provide adequate protection from power failures and spikes.

(c) Have the capability to resume full functionality utilizing all applicable site-specific control limits and parameters after power restoration.

(d) Be designed to ensure that site specific control limits and parameters are used in any replacement or restoration of SCADA programming.

(e) Be capable of meeting all the continuous recording requirements.

(f) Be capable of generating applicable reports for plant operators, such as results from direct integrity tests, parameter trending, and alarm histories.

(g) Be capable of trending at minimum the following parameters:

(1) Production from each filter unit (Q_p).
(2) Percent recovery (R).
(3) Flux rate (J).
(4) Permeate turbidity (NTU).
(5) Pressure decay test result (ΔP_{test}).
(6) Log removal value (LRV).
(7) Air liquid conversion ratio (ALCR).
(8) Transmembrane pressure (TMP).
(9) Permeability.

(h) Be designed to provide reliable and secure data. The automated monitoring and control systems shall be provided with back-up equipment consisting of the following:

(1) Dual running programmable logic controllers (PLCs) with synchronized programs and memory, or spare PLCs loaded with the most current program, which utilizes site specific control limits and parameters.

(2) Spare input/output (I/O) cards of each type.

(3) A minimum of two human machine interfaces (HMI).

(4) An uninterruptible power supply (UPS).

2) Control systems shall provide alarms, off site notices, and automatic shutdown processes. Notification alarms and shutdown alarms are to be utilized where appropriate. DEP shall approve the extent of operational control required. At a minimum, these alarms/shutdown parameters are to be provided:

(a) High turbidity (raw, membrane feed, individual filter unit, and combined permeate).

(b) Membrane failure (low pressure differentials).

(c) Pump failures.

(d) High pressure decay test result (ΔPtest).

(e) High transmembrane pressure (TMP).

(f) Low log removal value (LRV).

(g) PLC failure.

(h) Membrane equipment failure.

(i) Clearwell level (high and low).

(j) Entry point chlorine residual (high and low).

(k) Low chemical levels.

(l) Power failure.

(m) Building intrusion

4.3.5.17 PLC Programming

The membrane system's PLC shall be programmed to operate, and be able to demonstrate that it is programmed, in accordance with Department-approved site specific operational control limits and process parameters.

Applicable process parameters include the following:

1) Maximum production from each filter unit (Q_p).

2) Percent recovery (R).

3) Design flux rate (J).

4) Raw, membrane feed, and membrane permeate turbidity (NTU) setpoints.

5) Minimum direct integrity test starting pressure (P_{test}).

6) Minimum direct integrity end pressure (P_f).

7) Pressure decay test result (ΔP_{test}).

8) Minimum applicable log removal value (LRV).

9) Air liquid conversion ratio (ALCR).

10) Volume of pressurized air in a membrane system during a pressure decay test (V_{sys}).

11) Membrane surface area per filter unit (A_{sys}).

12) Volumetric concentration factor (VCF).

13) Maximum backpressure during pressure decay test (BP).

14) Liquid-membrane contact angle (θ).

15) Pore shape factor (Κ).

16) Surface tension (σ).

17) Transmembrane pressure (TMP).

18) Water temperature (T).

4.3.5.18 Operation and Maintenance

An O&M Manual shall be provided. The O&M manual shall include at a minimum:

1) SOPs for startup, shutdown, CIPs, direct integrity testing, membrane pinning and repairs, alarm conditions and responses, monthly reporting, and data trending.

2) The recommended or required maintenance requirements for each piece of equipment, including a maintenance and calibration schedule for turbidimeters, pressure sensors, and flow sensors.

3) Operational parameters of the membrane units and associated appurtenances, including software user instructions.

4) Trouble shooting guide for all equipment and procedures.

5) Assessment of potential equipment failure or damage and accompanying warranty documents. Guidance to determine when the membrane modules are approaching the end of their useful life (i.e., maximum number of fibers pinned, percent recovery, permeability, life span, total production, etc.).

4.3.6 Bag and Cartridge Filtration

4.3.6.1 General

Bag and cartridge filters are pressure-driven separation devices that remove particles, typically greater than 1 micron, using an engineered porous media. The particulate loading capacity of bag and cartridge filters is low, and once expended, the filters must be discarded.

1) Bag or cartridge filters that are integrated into the existing filtration system may be considered for LT2ESWR *Cryptosporidium* treatment credits for small systems.

2) Bag and cartridge filters as the primary filtration system shall only be considered for very small systems (< 100 persons served) and only on GUDI sources.

This technology is designed to meet the low flow requirement needs of small systems. They can effectively remove particles from water in the size range of *Giardia* cysts (5-10 microns) and *Cryptosporidium* (2-5 microns).

Operational and maintenance costs of bag/cartridge filter replacement must be considered when designing such a system. Their service life expectancy is dependent on many factors, including feed water quality and processed water volume.

Sufficient source water quality evaluation is needed to determine filter system and pretreatment equipment design needs. Seasonal variability of source water quality, along with impacts from heavy rainfall events, must be taken into consideration. Systems should also consider the affordability of frequent filter replacement due to rapid fouling during challenging water quality periods.

Applicable bag/cartridge filter and complete filter assembly specifications shall be included in the water supply permit application to be submitted to DEP.

4.3.6.2 Challenge Testing

All bag/cartridge filters being proposed for primary filtration or LT2ESWR treatment credits shall have been certified per ANSI/NSF Standard 419, Public Drinking Water Equipment Performance – Filtration. This standard addresses the performance evaluation test procedure for product-specific challenge testing of full scale products for the removal of microbial contaminants.

4.3.6.3 LT2ESWR Treatment Credit

DEP will issue removal credit for *Cryptosporidium* in accordance with EPA-established criteria. This removal credit is based on results of the product-specific challenge testing.

1) For challenge studies conducted on individual bag/cartridge filters, the removal credit for *Cryptosporidium* will be based on the corresponding study results minus a 1.0-log safety factor. Individual bag/cartridge filters would receive up to 2.0-log removal credit for filters showing a minimum of 3.0-log removal in challenge testing.

2) For challenge studies conducted on two bags/cartridges operated in series, the removal credit for *Cryptosporidium* will be based on the corresponding study results minus a 0.5-log safety factor. Bag/cartridge filters in series would receive up to 2.5-log removal credit for filters showing a minimum of 3.0-log removal in challenge testing.

4.3.6.4 Design Considerations

1) Cartridge/bag filters being proposed as the primary filtration system shall, at a minimum, have two ANSI/NSF Standard 419 certified bags/cartridges filters in series with a redundant set in parallel.

2) Cartridge/bag filter system-specific components shall be certified for performance with ANSI/NSF Standard 61. These components include the cartridge/bag, housing, O-rings, and gaskets. Additional testing may be required by DEP.

3) Pretreatment should follow manufacturer's recommendations. This is to provide a more consistent water quality to the filter and ultimately extend its service life. Pretreatment examples include: prefilters with a larger pore size, media filters, infiltration galleries, or beach wells.

4) The maximum turbidity applied to the cartridge/bag shall be less than 3.0 NTUs. Source waters with higher turbidity require pretreatment that reduces the turbidity to below 3.0 NTUs. Note: Lower NTUs may be required pending manufacturer's recommendation.

5) At least two filters shall be provided. Where only two filters are provided, each shall be capable of meeting the plant's permitted capacity. Where more than two filters are provided, the filter

system shall be capable of meeting the plant's permitted capacity with one filter removed from service.

6) The ability to filter-to-waste shall be provided.

7) Flow rate through the filter system shall be monitored with a flow valve and meter. The flow rate through the filter shall not exceed the maximum flow rate that was certified by ANSI/NSF Standard 419.

8) Individual (IFE), as well as combined (CFE), filter effluent turbidity shall be monitored and recorded continuously. All effluent turbidity must meet the DEP-established limit. Turbidimeters shall be equipped with alarms, shutdowns the capacity to notify the operators.

9) It is recommended that chlorine or another disinfectant be added before the cartridge/bag filters to reduce/eliminate the growth of algae, bacteria, etc. on filters. The impact on disinfectant byproduct formation should be considered.

10) A sampling tap shall be provided ahead of any plant treatment so that source water samples can be collected.

11) Pressure gauges and sampling taps shall be installed upstream and downstream of the cartridge/bag filtration system.

12) Wash water used for backwashes shall be finished water.

13) An automatic air release valve shall be installed on top of the filter housing.

14) A pressure relief valve should be incorporated into the filter housing.

15) Frequent start-and-stop operation should be avoided. To avoid this type of occurrence, these options are recommended:

   (a) Install a slow opening and closing valve ahead of the filter to reduce flow surges.

   (b) Reduce flow rate through the cartridge to as low as feasible to lengthen filter run times.

   (c) Install a recirculating pump that transfers treated water back to a point ahead of the cartridge/bag. Care must be taken to make sure there is no cross connection between the finished water and raw water.

4.3.6.5 Operation/Maintenance

1) At a minimum, one set of replacement cartridges/bags shall be maintained on sight and stored in a dry, cool area.

2) Filter system equipment shall be regularly inspected by treatment plant staff to assist with assessing anticipated service life. It should be noted that these filters typically do not load linearly. Additional observation of filter performance is recommended closer to the end of a filter run.

3) At a minimum, the following parameters shall be monitored: instantaneous flow rate, total flow rate, operating pressure, filter pressure differentials, and turbidity. The system shall be equipped with auto notification and shutdown alarms.

4) The filtration and backwash rates shall be monitored so that prefilters are being optimally used.

5) Cartridge filters must be replaced when either a pressure differential of 15 psi or the manufacturer-recommended maximum pressure differential is observed.

6) O-ring replacement shall be performed in accordance with the manufacturer's recommendations.

7) The filter system shall be properly disinfected and filter-to-waste shall be utilized each time the filter vessels are taken off-line and opened for maintenance.

8) An up-to-date version of an O&M manual shall be maintained at the treatment plant. This shall contain procedures describing the necessary filter cleaning and change-out activities. Records of corresponding filter maintenance activities are to be maintained by plant personnel.

4.4 Surface Water Treatment Processes

4.4.1 Conventional Treatment

Conventional treatment process is considered to be the best technology to meet the above requirements. The design shall consist of chemical coagulation, rapid mixing, flocculation, and sedimentation followed by filtration. These requirements are for systems to receive credits for 2-log removal of *Giardia* cysts and 3-log removal of *Cryptosporidium* oocysts for surface water (or GUDI) treatment.

4.4.1.1 Coagulation, Rapid Mix, Flocculation, and Sedimentation

Coagulation, Rapid Mix, Flocculation, and Sedimentation designs shall be based on:

4.2.2 - Coagulation and Rapid Mixing

4.2.3 - Flocculation

4.2.4 - Sedimentation

4.4.1.2 Filtration

Filters should be rapid rate gravity filters with dual- or multi-media designs shall be based on Section 4.3.1. Air Scour, surface wash, or subsurface wash shall be provided for the filters in accordance with Section 4.3.1.9.

Other filtration technology could be acceptable based on pilot studies. Pressure filters and single-media filters are not recommended.

4.4.2 Direct Filtration

Direct filtration process includes coagulation, flocculation, and filtration without sedimentation. These requirements are for systems to receive credits for 2-log removal of *Giardia* cysts and 2.5-log removal of *Cryptosporidium* oocysts for surface water (or GUDI) treatment. The nature of the treatment process will depend upon the raw water quality. Direct filtration process shall be limited to source water having maximum turbidities of 15 NTU, a maximum color of 40 units, and low concentrations of algae iron and manganese. Where direct filtration is proposed, a pilot study may be required. DEP, at its own discretion, may issue an innovative technology permit as outlined in Section 1.2 based on the data submitted.

4.4.2.1 Engineer's Report

In addition to the applicable items outlined in Section 1.1.3.1 - Engineer's Report, the report should include a historical summary of meteorological conditions and of raw water quality with special reference to seasonal fluctuations in quality, and possible sources of contamination. The following raw water parameters must be evaluated in the report:

1) Alkalinity.
2) Color.
3) Turbidity.
4) Bacterial concentration.
5) Microscopic biological organisms, including algae.
6) Temperature.
7) pH.

8) Total solids.
9) General inorganic chemical characteristics.
10) Additional parameters as determined by DEP which may be unique to the supply (DBPs, *Giardia*, etc.).

The report also should include a description of methods and work to be done during a pilot plant study or, where appropriate, an in-plant demonstration study.

4.4.2.2 Pilot Plant Studies

A pilot study or in-plant demonstration study may be required. The study should be conducted over a sufficient time to treat all expected raw water conditions throughout the year. This study shall be conducted as outlined in Section 1.2.1 and shall emphasize, but not be limited to, the following:

1) Chemical mixing conditions, including shear gradients and detention periods.

2) Chemical feed rates, especially under varying water quality conditions.

3) Use of various coagulant aids including polymers, the results of any jar tests performed on the various chemicals shall be tabulated.

4) Flocculation conditions.

5) Filtration rates.

6) Length of filter runs.

7) Filter gradation, types of media, and depth of media.

8) Length of backwash cycles.

9) Filter breakthrough conditions.

10) Quantities and make-up of the wastewater.

11) Adverse impact of recycling backwash water due to solids, algae, DBPs formation, and similar problems.

Prior to the initiation of design plans and specifications, a final report including the engineers' design recommendations shall be submitted to DEP.

4.4.2.3 Coagulation, Rapid Mix, and Flocculation designs shall be based on any pilot testing or in-plant demonstration studies and:

4.2.2 - Coagulation and Rapid Mixing

4.2.3 - Flocculation

4.4.2.4 Filtration

Filters should be rapid rate gravity filters with dual- or multi-media. The final filter design should be based on the pilot plant or in-plant demonstration studies augmented by applicable portions of Section 4.3.1. Air Scour, surface wash, or subsurface wash shall be provided for the filters in accordance with Section 4.3.1.9.

Other filtration technology could be acceptable based on the pilot studies. Pressure filters and single-media filters are not acceptable.

4.4.2.5 Siting Requirements

The plant design and land ownership surrounding the plant shall allow for the installation of conventional sedimentation basins should it be found that such are necessary.

4.5 Aeration

Aeration processes generally are used in two types of treatment applications. One is the transfer of a gas to water (i.e., adding oxygen to assist in iron and/or manganese removal) and is called gas absorption or aeration. The second is the removal of gas from water (reduce or remove objectionable amounts of carbon dioxide, hydrogen sulfide, etc.; reduce the concentration of taste and odor-causing substances; or removal of volatile organic compounds) and is classified as desorption or air stripping. The materials used in the construction of the aerator(s) shall meet ANSI/NSF Standard 61 or be approved by the DEP.

4.5.1 Natural Draft Aeration

The design shall provide:

1) Perforations in the distribution pan 3/16 to 1/2 inches in diameter, spaced 1 to 3 inches on centers to maintain a 6-inch water depth.

2) For distribution of water uniformly over the top tray.

3) Discharge through a series of three or more trays with separation of trays not less than 12 inches.

4) Loading at a rate of 1 to 5 gpm for each square foot of total tray area.

5) Trays with slotted, heavy wire (1/2-inch openings) mesh or perforated bottoms.

6) Construction of durable materials resistant to the aggressiveness of the water, dissolved gases, slime, and algae growths.

7) Eight to 12 inches of inert material, such as coke or limestone, that will not disintegrate due to freezing cycles, is used in trays.

8) Protection from loss of spray water by wind carriage by enclosure with louvers sloped to the inside at an angle of approximately 45 degrees.

9) Protection from insects by 24-mesh screen.

4.5.2 Forced or Induced Draft Aeration

Devices shall be designed to:

1) Include a blower with a weatherproof motor in a tight housing and screened enclosure.

2) Ensure adequate counter current of air through the enclosed aerator column.

3) Exhaust air directly to the outside atmosphere.

4) Include a downturned and 24-mesh screened air outlet and inlet.

5) Introduce air into the column that is as free from obnoxious fumes, dust, and dirt as possible.

6) Be such that sections of the aerator can be easily reached or removed for maintenance of the interior.

7) Provide loading at a rate of 1 to 5 gpm for each square foot of total tray area.

8) Ensure that the water outlet is adequately sealed to prevent unwarranted loss of air.

9) Discharge through a series of five or more trays with separation of trays not less than 6 inches or as approved by DEP.

10) Provide distribution of water uniformly over the top tray.

11) Be of durable material resistant to the aggressiveness of water and dissolved gases.

12) Provide provisions for continuous disinfection feed after aeration.

4.5.3 Spray Aeration

Design shall provide:

1) A hydraulic head of between 5 – 25 feet.

2) Nozzles, with the size, number, and spacing of the nozzles being dependent on the flowrate, space, and the amount of head available.

3) Nozzle diameters in the range of 1 to 1.5 inches to minimize clogging.

4) An enclosed basin to contain the spray. Any openings for ventilation, etc. must be protected with a 24-mesh screen.

4.5.4 Pressure Aeration

Pressure aeration may be used for oxidation purposes only if a pilot plant study indicates the method is applicable. It is not acceptable for removal of dissolved gases. Filters following pressure aeration must have adequate exhaust devices for release of air. Pressure aeration devices shall be designed to:

1) Give thorough mixing of compressed air with water being treated.

2) Provide screened and filtered air, free of obnoxious fumes, dust, dirt, and other contaminants.

4.5.5 Other Methods of Aeration

Other methods of aeration may be used if applicable to the treatment needs. Such methods include, but are not restricted to, spraying, diffused air, cascades, and mechanical aeration. The treatment process must be designed to meet the needs of the water to be treated and are subject to the approval of DEP.

4.5.6 Protection of Aerators

Aerators that are used for oxidation or removal of dissolved gases from waters that will be given no further treatment other than chlorination shall be protected from contamination from insects, birds, wind-borne debris, rainfall, and water draining off the exterior of the aerator.

4.5.7 Ventilation

Ventilation shall be provided to prevent the accumulation of released gases in the building that houses the treatment facilities.

4.5.8 Bypass

A bypass should be provided for all aeration units except those installed to comply with maximum contaminant levels.

4.5.9 Corrosion Control

The aggressiveness of the water after aeration should be determined and corrected by additional treatment if necessary (see Section 4.11).

4.5.10 Quality Control

Equipment should be provided to test for DO, pH, and temperature to determine proper functioning of the aeration device. Equipment to test for iron, manganese, and carbon dioxide should also be considered.

4.5.11 Redundancy

Redundant units shall be provided for all system treating to comply with a maximum contaminant levels.

4.6 Organic Contaminants Removal

Packed tower aeration (PTA) and granular activated carbon (GAC) are designated by the U.S. EPA as the best available technologies (BAT) for removing organic contaminants from drinking water. Properly designed PTA and GAC facilities can achieve a high removal rate (above 90 percent) of VOCs. GAC can remove most SOCs, but can be a costlier technique. PTA is the designated BAT for most VOCs. PTA also can remove dissolved gases such as radon and carbon dioxide.

The Henry's coefficient of a substance is an indicator of the ability to remove that substance from water. The Henry's coefficient of a substance is defined as that substance's vapor pressure divided by that substance's water solubility. The Henry's coefficient is highly temperature dependent. In general, vapor pressures increase with increasing temperature and water solubilities decrease with increasing temperature. Thus, an increase in temperature would lead to an increase in the Henry's coefficient. Henry's coefficients for most VOCs can be found in a variety of textbooks, technical articles, trade organization literature, and the EPA Risk Reduction Engineering Laboratory (RREL) Treatability Database.

A substance with a high Henry's coefficient is more easily removed from water, via volatilization, than a substance with a lower Henry's coefficient. Substances with Henry's coefficients greater than 100 atm*mol/mol can readily be removed via PTA. Substances with Henry's coefficients less than 10 atm*mol/mol may need to be removed via GAC. Substances between 10 and 100 atm*mol/mol might be removed via PTA, but should be verified through pilot study.

4.6.1 Packed Tower Aeration (PTA)

Generally, PTA is suitable for removing volatile organics with a Henry's Constant greater than 100 atm mol/mol at 12°C. Pilot testing also is recommended when the VOCs of concern have Henry's coefficients between 10 and 100 atm*mol/mol at about 12°C. PTA is not an acceptable treatment for VOCs with Henry's coefficients less than 10 atm*mol/mol.

PTA involves passing water down through a column of packing material while blowing air counter-currently up through the packing. PTA is used for the removal of VOCs and radon.

The use of mechanical aeration for organics removal may be approved by DEP on a case-by-case basis; however, the effectiveness of mechanical aeration should be verified by a pilot testing program acceptable to DEP. Other types of aeration techniques, which are covered in Section 4.5, also may be approved for volatile organics removal, but should be supported by adequate pilot testing.

4.6.1.1 Pilot Testing Considerations

Pilot plant testing is recommended to evaluate a variety of loading rates and air/water ratios at the peak contaminant concentration. Only when there is considerable past-performance data on a previous project that featured both <u>similar</u> source concentration(s) and a <u>similar</u> design, will DEP consider approving the process based on design calculations without pilot testing. Proposals of this type must be discussed with DEP's regional office staff prior to submission of any permit applications.

The following is a summary of the key items of a pilot test:

1) The proposed pilot test protocol must be submitted to the appropriate regional office for approval prior to pilot testing.

2) The VOC source water quality shall be determined for any design considerations. Monitoring data should be compared to this initial quality to determine contaminant trends.

3) Various operational parameters should be recorded with each test and submitted to the appropriate regional office for review and approval. These parameters include, but are not limited to:

   - Raw water VOCs concentrations.
   - Effluent VOCs concentrations.
   - Air flow rates.
   - Pressure drops of the air stream.
   - Water flow rates.
   - Test times.

4) Pilot test air flow rates should be converted to a standard pressure and temperature to account for test-to-test and test-to-full-scale fluctuations in these parameters.

4.6.1.2 Process Design Considerations

1) Process design methods for PTA involve the determination of several parameters, including the Henry's coefficient for the contaminant, the mass transfer coefficient, air pressure drop, air and water temperatures, influent and effluent concentrations, height and cross-sectional area of unit, air/water ratio, size and configuration of the packing, packing depth, and air/water loading rates.

2) Water loading rates should be in the range from 15 gpm/ft^2 to 30 gpm/ft^2, however the pilot test shall evaluate a variety of loading rates and air-to-water ratios at the peak contaminant concentration.

3) A safety factor of 3 shall be used for the VOC concentrations. With respect to influent (source) quality, the design method would be to design separately for various VOCs in the source quality, then choose the most stringent design. First, the VOC concentrations should be multiplied by a safety factor of 3.

4) The most stringent design should then be checked against all other VOC concentrations (scaled-up by 3) that have MCL, MUCC, or suggested criteria exceedances. This will ensure that all VOCs present will be successfully treated to their MCLs or MUCCs (for VOCs with MCLs or MUCCs), or to conservatively low levels (for VOCs without MCLs or MUCCs). Some features of the most stringent design may include the greatest tower height, lowest hydraulic loading, greatest packing surface area, and/or greatest air flow rate of all VOC designs.

5) An extensive database of VOC results for the source water may increase confidence in the data, thereby reducing the safety factor. Data confidence may reduce the safety factor anywhere from 3 down to a minimum of 1.5; the more confidence in the data, the closer a factor of 1.5 can be approached.

6) The air pressure drop across the packed tower should be no greater than 1.5 inches of water per foot of tower height. This pressure drop range provides the most flexible operation and helps to avoid flooding.

7) The ratio of the column diameter to packing diameter should be at least 7:1 for the pilot unit and at least 10:1 for the full-scale tower.

The type and size of the packing used in the full-scale unit shall be the same as that used in the pilot work.

8) The minimum volumetric air-to-water ratio at peak water flow should be 25:1. The maximum air-to-water ratio for which credit will be given is 80:1.

9) The design should consider potential fouling problems from calcium carbonate, iron, and manganese precipitation, as well as bacteria growth. The packing support plate(s) must be designed to hold the packing weight, water weight, and various fouling weights. It is recommended that the packing support plate(s) be designed to hold at least five times the original dry packing weight. In cases where lighter weight plastic packings are used, it may be necessary to use a packing support factor considerably higher than five. It may be necessary to provide softening, stabilization, sequestering, and/or disinfection facilities prior to and/or after PTA. Chemical cleaning access ports should be provided. Disposal of cleaning waste also should be considered in the design.

10) Due to an increase in DO, the effects of aeration on corrosion control shall be evaluated.

11) The effects of temperature should be considered since a change in air temperature can result in a change in contaminant removal efficiency.

12) The design should establish minimum and maximum hydraulic capacities. The maximum hydraulic capacity should be equal to or exceed the source capacity.

13) Redundant capacity may be required by DEP.

4.6.1.3 Materials of Construction

1) The tower can be constructed of stainless steel, concrete, aluminum, fiberglass, or plastic. Uncoated carbon steel is not acceptable because of corrosion.

2) Packing materials, column shell, and other internals shall be resistant to corrosion by the water, dissolved gases, and cleaning chemicals, and shall meet ANSI/NSF Standard 61. Plastic or ceramic packing materials are recommended.

3) All paints and coatings that are in direct contact with the water supply shall meet ANSI/NSF Standard 61.

4.6.1.4 Water Flow System

1) Water should be distributed uniformly at the top of the tower using spray nozzles or orifice-type distributor trays that prevent short circuiting. Systems with multi-point injection locations should have one injection point for every 30 square inches of column cross-sectional area.

2) A mist eliminator shall be provided above the water distribution system.

3) A side wiper redistribution ring shall be provided at least every 10 feet to prevent water channeling along the tower wall and short circuiting.

4) The packing support plate(s) should be either of the counter-current or the separate flow passage variety. Counter-current plates include wire mesh and welded rings. Separate flow passage plates include cap-type and beam-type plates. The packing support plate(s) should be strong enough to support deep packing heights, as well as water weight and fouling buildup through normal operation. It is recommended that the plate(s) be designed to support at least 5 times the original dry weight of the packing.

5) Sample taps shall be provided in the influent and effluent piping for each PTA treatment unit.

6) A butterfly valve shall be provided in the water effluent line to control flow, as well as minimize the potential for air entrainment in the finished water.

7) The tower bottom shall contain an effluent basin with a minimum depth of 8 inches. This depth is defined specifically as the depth between the bottom of the basin and the bottom of the effluent pipe. The basin water level shall inundate the effluent pipe during blower operation. The effluent basin will serve as both an air trap for the water effluent and a settling basin for any material sloughed off the packing material. In some cases, the effluent basin also may serve as a wet well and high service sump for repumping. The effluent basin should have easy access for cleaning and be equipped with a drain valve. The drain shall not be directly connected to any type of sewer. Either an approvable cross-connection control device or an air gap must be in place.

8) A blow-off line shall be provided to allow for discharge of water used to clean the tower.

9) The design shall have provisions to prevent freezing. Provisions could include a drainage feature during nonflow conditions or weather proofing (i.e., housing, insulation, heat tape).

10) The water flow to each tower shall be induvial metered.

11) Any overflow line shall be discharged 12 to 24 inches above a splash pad or drainage inlet. Overflow piping must be equipped with a 24-mesh screen.

12) Means shall be provided to prevent flooding of the both the air blower and the top of the tower.

13) Hydraulic loading rates (i.e., gpm per square foot) will vary between models and manufacturers. The manufacturer's specifications for hydraulic loading rates should be followed.

14) The water influent piping should be supported separately from the PTA structural support.

4.6.1.5 Air Flow System

1) The air inlet to the blower and the tower discharge vent shall be downturned and protected with a non-corrodible 24-mesh screen to prevent contamination from extraneous matter. It is recommended that a 4-mesh screen also be installed prior to the 24-mesh screen on the air inlet system.

2) The air inlet shall be in a protected location.

3) An air flow meter shall be provided on the influent airline or an alternative method to determine the air flow shall be provided.

4) A positive air flow sensing device and pressure gauge shall be provided on the air delivery line. The positive air flow sensing device shall be part of an automatic control system that will shut down water flow if no positive air flow is detected. The pressure gauge will serve as an indicator of fouling buildup.

5) The air blower shall be programmed to provide delayed air blowing after water shutdown. This could be accomplished by, but not limited to, an effluent sump control system or a predetermined time delay relay in the motor control circuitry.

6) This delayed blowing will ensure that all remaining water in the tower is adequately treated.

7) A backup motor, with spare parts, for the air blower shall be readily available.

4.6.1.6 Other Features that Shall be Provided

1) Enough access ports shall be provided in each section to allow inspection, media replacement, media cleaning, and maintenance of the interior. A minimum of two 24- to 36-inch bolted manways, one at the distributor plate and one at the support plate, should be provided. Hinged access doors of varying heights also are acceptable.

2) A method of cleaning the packing material shall be provided. This also includes the removal of the cleaning wastes before on-line service. Chemical cleaning ports shall be in place on both ends of the tower.

3) Provisions for extending the tower height, without major reconstruction, should be provided.

4) A second redundant PTA treatment system shall be provided unless the system has redundant source capacity capable of providing the maximum daily demand while the PTA source is out of service.

5) Operation of the blower, water pumps, controls, instrumentation, and all chemical feeder equipment must be maintained during power failures. This may be accomplished by an emergency generator or another alternative power source.

6) An access ladder and safety cage should be provided for inspection of the tower, exhaust port, and mist eliminator.

7) Adequate security for the facility shall be provided to prevent vandalism.

8) Fencing and locking gates to prevent vandalism shall be provided.

9) Noise and odor control features may be necessary for PTA systems located in residential areas.

10) No bypass around the PTA treatment system shall be provided.

4.6.2 Granular Activated Carbon (GAC)

GAC represents one-unit process with the ability to remove a broad spectrum of organic chemicals from water. GAC exhibits a wide range of effectiveness in adsorbing organic compounds and, therefore, should be evaluated on a site-specific basis. GAC is an effective adsorbent for SOCs, VOCs, DBP, and taste and odor causing organics.

4.6.2.1 Pretreatment and Post Treatment Requirements

Pretreatment may be required depending on the quality of the source water. Lower operation cost of GAC systems may be achieved by pretreating the feed water resulting in reduced organic loading. Examples of processes which can be used for pretreatment include conventional treatment, ozonation, and PTA.

Surface water sources which usually contain high amounts of natural organic matter should be pretreated by coagulation, flocculation, sedimentation, and filtration to increase the uptake capacity of the AC granules for the target contaminants.

For surface water sources, the use of powdered activated carbon (PAC) to remove organics and reduce the organic loading on the GAC during periods of high organic levels should be evaluated to extend the run time of the GAC contactors and/or reduce the loading on the GAC.

Ozone oxidation can affect adsorption behavior, as well as strongly influence the biodegradability of the substances present in the water. In general, preozonation immediately prior to carbon adsorption will decrease the absorbability of the organic constituents, and can cause a major increase in the immediate breakthrough point and a general reduction in the performance throughout the column run. The feed water should not contain any oxidizer (disinfectant) in substantial amounts.

Chlorine shall not be injected prior to GAC filters. Chlorine will break up the activated carbon granules and increases the concentration of chloro-organics, which reduces the absorbability of the activated carbon granules for the trace organic contaminants.

Effective disinfection shall be provided following GAC contactors to ensure inactivation of bacteria that may slough off from the GAC bed. The use of GAC prior to chlorination is the preferred mode of operation for several reasons. The chlorine demand will be greatly reduced and the formation of disinfection by-products also will be minimized. The potential to form precursors which will result in the formation of dioxin and furans during the reactivation of the GAC also can be significantly reduced.

Corrosion control, when necessary, shall be provided following GAC contactors. Treatment plants that currently increase the pH during pretreatment for corrosion control will need to switch to post-GAC pH adjustment. Optimum organic removal occurs at lower pH.

4.6.2.2 System Components

The major components of a typical GAC treatment system include:

1) Carbon Contactors - Either common wall concrete or lined steel vessels. In either case, provisions for underdrainage, backwash, and removal of spent carbon must be made.

2) Carbon Storage - Includes storage tanks for virgin and regenerated carbon. (May not be necessary for smaller systems).

3) Carbon Transport Facilities - Includes piping, valves, and pumps.

4.6.2.3 Bench and Pilot Studies

4.6.2.3.1 General

GAC has been used to remove toxic and nontoxic (taste and odor) organic chemicals in drinking water. However, GAC can be ineffective if it is not used properly. A bench scale and/or a pilot plant study on the water to be treated should be conducted.

During the bench and/or pilot plant studies, data should be collected for performance during typical conditions as well as during extremes of good and bad water quality. The primary result of these bench and/or pilot studies should be a determination of the type of GAC to be used, the size of the media, the design empty bed contact time (EBCT), and the expected regeneration frequency for the contaminant(s) of concern.

The influence of seasonal factors is often important and should be evaluated. Pilot plant studies may be influenced by temperature, growth of algae and diatoms, seasonal or unusual episodes of runoff and turbidity. Pilot operations also should include the variations of flow that normally exist and affect detention times and hydraulic loading rates.

4.6.2.3.2 Bench-Scale Studies

The bench-scale, rapid small-scale column test (RSSCT), uses small GAC particle sizes and requires less time and volume of water than pilot-scale tests.

A smaller than full-scale particle size should be selected for the RSSCT and, based on the ratio of the particle sizes, operating parameters such as EBCT, flow rate, and time to breakthrough can be scaled up to full-scale. Full-scale design variables, such as adsorbed operation (e.g., bed in-series or in-parallel operation), EBCT and usage rate, can be determined by conducting several RSSCTs that duplicate full-scale operation.

The following guidelines should be used in setting up an RSSCT:

1) The experimental apparatus should be constructed of glass, Teflon, or stainless steel to minimize adsorption of organics.

2) The experiments should be conducted in a temperature-controlled room at temperature ranges of 10°C to 14°C.

3) A minimum of 3 RSSCTs should be used when evaluating the effect of EBCT and absorber configuration, such as beds in series or in parallel, on GAC usage rate.

4) The minimum column diameter to avoid channeling should be 50 particle diameters. However, if large sample volumes are required, larger diameter columns can be used.

5) If the RSSCT is used in lieu of pilot-scale adsorption tests, the user should understand that the limitations of the test have not yet been clearly defined. However, two limitations which are known include:

    - The RSSCT is performed over a short period of time compared to that required for a pilot study. If the influent adsorbate concentration is not relatively constant, the RSSCT may not be able to produce a breakthrough profile comparable to a pilot-scale profile.

    - Selection of the appropriate equations for scaling-up the RSSCT depends upon the functional relationship between surface diffusivity and GAC particle size. Therefore, it is strongly recommended that this relationship be evaluated prior to performing the RSSCT.

4.6.2.3.3 Pilot Plant Studies

1) The pilot-scale adsorption studies should provide design information on adsorption of trace organics. Treatment efficiency varies with the organic character of the water. Because this differs between locations, experimentation must be done with the actual water, preferably on-site. Pilot testing should be conducted over a sufficient period to establish that the technology is appropriate for the source water and to determine appropriate design and operating parameters.

2) Pilot-scale columns are required to study adsorption. The general rule is to provide as many pilot columns as economically possible. A minimum of 3 columns is recommended. However, additional scale columns make test results easier to evaluate and compare since influent quality can vary from test to test.

3) The sizing of the column is based on empty bed contact time at the selected flow rate. A pilot-scale adsorption study should incorporate several EBCTs so that an optimum can be selected.

4) The columns should have an internal diameter of at least 1 inch (2.5 cm) to minimize sidewall effects, that is the slightly higher porosity of the medium next to the wall.

5) In studies in which water flow is less than 10 gpm (38 L/min), equipment should be constructed from stainless steel, plastic, or glass whenever possible to minimize contamination from structural materials.

6) Sampling taps shall be provided at various depths to allow effluent sampling corresponding to selected contact times. A minimum of 3 taps are recommended.

7) Pilot Plant Operation - GAC should be backwashed before it is put into service. Sufficient freeboard should exist to permit 30 to 50 percent bed expansion during backwash. The frequency of backwashing during the experimental study should vary depending upon factors such as head loss, turbidity, and floc carried over from settling. The following routine

schedule is recommended for pilot plant operation depending on the treatment objective:

- Test for the contaminant of concern.
- Flow adjustment (Q) should be performed at least daily.
- Temperature, pH, turbidity, threshold odor number, and color should be monitored at a frequency based on variability of applied water.
- Low-molecular-weight halogenated organic carbon compounds should be monitored weekly.
- Total organic carbon (TOC) should be monitored weekly.
- DBP formation potential or possibly organic halogen analysis (TOX) should be monitored twice a week especially if the feed water contains chlorine-containing disinfectants.

4.6.2.4 Process Design Considerations

4.6.2.4.1 Carbon Usage Rate

The carbon usage rate determines the rate at which carbon will be exhausted and how often carbon must be replaced/regenerated. Carbon treatment effectiveness improves with increasing contact times. Deeper beds will increase the percentage of carbon that is exhausted at breakthrough.

This basic design parameter, expressed as pounds/1,000 gallons, indicates the rate at which carbon will be exhausted or replaced. Carbon usage rates of organic compounds may be estimated from batch isotherm data and/or from dynamic pilot column or full-scale studies.

Freundlich isotherm constants are chemical-specific parameters that characterize the ability of certain concentrations of a substance to adsorb on to GAC. Thus, isotherm evaluations are batch tests which yield information about the maximum equilibrium organic loading on a particular carbon at a given organic concentration. Isotherms derived using high concentrations of VOCs and SOCs tend to overestimate GAC adsorption capabilities. Isotherms should be combined with pilot studies in the design process. Test results indicate that adsorption of any particular chemical by carbon is influenced by pH, temperature, and type of carbon used.

The carbon usage rate for the various contaminants depends on the type and the concentration of organic substances in the influent source water, the effect of preloading of natural organics on carbon, the contact time, and the maximum concentration of organics allowable in the effluent (i.e., levels at or below the MCL). If the source water contains several organics above the MCL, the design should consider the organics most difficult to remove by GAC.

4.6.2.4.2 Empty Bed Contact Time (EBCT)

EBCT is determined by dividing Volume (V) by Flow Rate (Q).

EBCT = V/Q

- **Volume (V)** carbon bed (including voids).
- **Flow rate (Q)** of the fluid stream through the absorber.

This design parameter provides an indication of the quantity of carbon which will be on-line at any one time, and thus reflect the capital cost for the system. The EBCT directly impacts the performance of the carbon for removing organic compounds.

- Pilot testing on organic removal may be conducted to determine the empty bed contact times sufficient to yield a reasonable carbon bed life.
- For preliminary design purposes, a 15-minute empty bed contact time should be used for optimum carbon bed life.

4.6.2.4.3 Contactor Configuration

The two basic modes of contactor operation are downflow and upflow. Downflow fixed bed contactors offer the simplest and most common contactor configuration for organic removal. Precautionary measures should be taken when using the contactor in an upflow mode to ensure that the GAC fines are not carried over into the treated water. The contactors may be operated either under pressure or by gravity. Pressure contactors may be more applicable to groundwater systems because of the nature of these systems. The use of gravity contactors for most groundwater systems would involve repumping the treated water to the distribution system.

The GAC absorbers (units) can be operated as either fixed bed absorbers or moving bed absorbers. In a fixed bed absorber, the carbon contained in the absorber remains stationary and operates in either a downflow or an upflow mode. Moving bed absorbers, on the other hand, always operate in an upflow mode.

4.6.2.4.4 Fixed Beds in Lead/Lag Series

When treating for a MCL or the unregulated contaminant health advisory exceedance, a lead/lag series configuration shall be used. Where only two units are provided, each unit shall be capable of meeting the plant permitted capacity. Where more than two units are provided, the units shall be capable of meeting the plant permitted capacity with one unit removed from service. A lead/lag series configuration shall be used. The lead unit/s shall be removing the contaminant of concern to below the MCL or MUCC level by itself. The lag unit or polisher unit shall act as a safeguard against premature leakage or exhaustion of the lead unit(s). In this configuration, the flow is downward through the carbon bed for each unit in the series. When carbon is removed for reactivation, the first absorber in the series is shut down with the next absorber in line becoming the lead unit. Larger systems should be built with an extra unit on standby to become the lag unit when the lead unit is taken out of service. Backwashing can be used on the lead unit(s) to remove suspended solids that accumulate in the carbon bed.

4.6.2.4.5 Fixed Beds in Parallel

In a parallel configuration, each unit receives the same quantity and quality of influent stream. Start-up of the individual units should be staggered so that exhaustion of the carbon occurs sequentially. This allows the removal of all carbon from each unit, one at a time, for reactivation. A spare unit shall be provided to be brought on-line when the exhausted absorber is taken out of service.

4.6.2.4.6 Pulsed Beds

A pulsed bed operates in an upflow counter-current to the carbon flow. Pulsed bed absorbers permit intermittent or continuous removal of spent carbon from the bottom of the bed, while fresh carbon is added at the top without system shutdown. The chief advantage of this system is better carbon utilization, because only thoroughly exhausted carbon will be removed.

4.6.2.4.7 Surface Loading Rate

Surface loading rate is the flow rate through the cross-sectional area of GAC unit and is expressed in units of gpm/ft^2. Once the required contact time is selected for a given performance objective, the cross-sectional area of the absorber is selected to ensure that hydraulic loadings are in the operating range of 2 to 10 gpm per square foot.

4.6.2.4.8 Type and Size of Carbon

It is recommended that virgin carbon be used for initial installation of the GAC unit and replacement of the carbon.

The choice of carbon should be based on head loss, backwash characteristics, water quality, and rate of adsorption. The head loss is less in the larger 8 x 30-mesh carbon, but the rate of adsorption is faster in the smaller 12 x 40-mesh carbon. The 8 x 30-mesh size may be effectively used in filter/absorbers or gravity absorbers while the 12 x 40-mesh size often is preferable in pressure vessels where the additional head loss is normally insignificant.

The uniformity coefficient (UC) shall not be greater than 1.9.

The particle density wetted in water is the mass of solid activated carbon plus the mass of water required to fill the internal pores per unit volume of particle. Typical values for GAC ranges from 90 to 105 pounds per cubic foot. This parameter determines the extent of fluidization and expansion of a given size particle during backwash.

4.6.2.4.9 Materials of Construction

To prevent corrosion, construction materials should be concrete, 316 stainless steel (304 stainless steel can corrode in the presence of activated carbon), or materials coated with paints or liners suitable for contact with wet carbon. If concrete is used, the reinforcing steel should be covered by at least 2 inches of concrete.

4.6.2.5 System Operation

4.6.2.5.1 Backwashing

1) Following the initial installation of the GAC unit, the system should be backwashed to provide filter effluent clear of activated carbon fines. Provisions should be made to completely exclude air from all contactor backwash piping to avoid air entrainment in the GAC. These provisions should include the installation of air relief valves at the backwash pump discharge connections, as well as at high points in the piping.

2) Frequency of backwashing usually depends on the rate of head loss buildup. The quantity of backwash water depends on the amount and characteristics of the accumulated solids. The frequency of backwash should be selected to ensure adequate solids removal and prevention of compaction of accumulated solids. A guide to selecting backwash frequency and duration is that no more than 1 percent of the treated clean water should be required for backwashing.

3) Filtering-to-waste for a few minutes after backwashing will prevent buildup of activated carbon fines in the distribution system and, thereby, lessen potential bacteriological or aesthetic problems.

4) Granular activated carbon is less dense than sand (1.4 grams per cubic centimeter versus 2.6 grams per cubic centimeter), so backwash water should be applied slowly initially, and then the rate gradually increased until the bed is expanded properly.

4.6.2.5.2 GAC Storage and Transport

Separate storage should be provided for the spent and regenerated or virgin make-up GAC. Storage facilities may not be required for smaller systems or where regeneration will be performed off-site. Storage capacity should be designed to ensure operational flexibility.

The selection of the type of storage tank to use and its location is a function of the quantity of carbon to be stored and the materials of construction. The tank can be sized to hold the entire contents of a carbon contactor or an amount equal to 1 or 2 days of furnace production capacity.

A conical bottom design is recommended to provide for complete removal of carbon from the tank. The angle of the cone should be adequate to ensure carbon removal, with 45 degrees as the minimum.

Since carbon, water and oxygen are corrosive to carbon steel, the materials of construction should be stainless steel or carbon steel with a 30 to 40 mil lining.

Facilities shall be provided to fluidize the GAC to permit the use of either recessed impeller slurry pumps or educator systems. Withdrawal ports should be provided in the support plate or the sidewall to facilitate removal of spent carbon. GAC should be transported as a water slurry at a concentration of 1 to 3 pounds of GAC per gallon of water.

4.6.2.5.3 Reactivation

Carbon Regeneration - Another basic consideration in evaluating the design of a GAC system for organics removal is the method of carbon regeneration (reactivation). The two basic approaches to regenerating the carbon are: 1) off-site disposal or regeneration; and 2) on-site regeneration. On-site regeneration generally is not feasible for systems where the carbon exhaustion rate is less than 1,000 to 2,000 pounds per day.

Three potential reactivation techniques are chemical, steam, and thermal. Thermal reactivation is the recommended procedure for on-site regeneration. Four different thermal reactivation systems are rotary kilns, hearth furnaces, fluid bed furnaces, and infrared furnaces. Multiple hearth is the traditional method of granular activated carbon reactivation, although fluidized bed and infrared furnaces are being used more frequently.

Reactivation (or regeneration) is the process of removing adsorbed organics and restoring the adsorptive characteristics of the adsorbent. It is recommended that only GAC used in drinking water treatment applications at a specific site be regenerated and reused in the same drinking water treatment facility. Thermal regeneration is recommended for facilities using on-site regeneration and should be carried out in the following scheme:

1) The exhausted granular carbon should be backwashed.

2) The washed granular carbon should be fed into a furnace and subjected to a controlled atmosphere of steam and oxygen at temperatures approaching 1,000°C. Air pollution devices, such as scrubbers and afterburners, shall be installed on the furnace to control off-gas pollutants.*

3) The reactivated carbon should be quenched with water and hydraulically transported back to the contactor (or storage).

4) Virgin activated carbon (make-up) should be added to replace the attrition losses.

* DEP's Bureau of Air Quality should be contacted for their regulatory requirements on air emissions.

4.6.2.5.4 Monitoring

Quarterly performance monitoring of the GAC effluent is required for VOCs for which treatment has been installed. More frequent monitoring may be necessary as the concentration of the contaminants to be removed approaches their respective MCLs. The GAC should be replaced or reactivated when the concentration of any organic contaminant reaches its MCL.

4.6.2.5.5 Waste Disposal

Where off-site disposal of the exhausted carbon is employed, it should be slurried by gravity to a draining bin where the free water is removed and returned and properly disposed to waste. The drained carbon should be drummed and shipped for landfilling or incineration. Approval for landfill disposal or incineration must be obtained from the Bureau of Waste Management and Bureau of Air Quality, respectively.

4.6.2.5.6 Safety

Oxygen may be consumed during chemical reactions such as in the absorption of oxygen by damp activated carbon in a filtration tank. This may pose a hazard to health unless appropriate oxygen measurements and ventilation are utilized.

4.7 Iron and Manganese Control

Iron and manganese control, as used herein, refers solely to treatment processes designed specifically for this purpose. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment processes must meet specific local conditions as determined by engineering investigations, including chemical analysis of representative samples of water to be treated. It may be necessary to conduct a pilot plant study to gather all information to be used as the basis of design. Consideration should be given to adjusting pH of the raw water to optimize the chemical reaction.

4.7.1 General

4.7.1.1 Sampling Taps

Smooth-nosed sampling taps shall be provided for control purposes. Taps shall be located on each raw water source, each treatment unit influent and each treatment unit effluent line.

4.7.1.2 Testing Equipment

1) Testing equipment shall be provided for all plants.

2) The equipment should have the capacity to accurately measure the iron content to a minimum of 0.1 mg/L and the manganese content to a minimum of 0.05 mg/L.

3) Where polyphosphate sequestration is practiced, appropriate phosphate testing equipment shall be provided.

4.7.2 Removal by Oxidation, Detention, and Filtration

4.7.2.1 Oxidation

Oxidation may be by aeration, as indicated in Section 4.5 or by chemical oxidation with chlorine, potassium permanganate, ozone, or chlorine dioxide.

4.7.2.2 Detention

1) Reaction - A minimum detention time of 30 minutes shall be provided following aeration to ensure that the oxidation reactions are as complete as possible. This minimum detention may be reduced only after pilot plant studies support a reduced detention time. The detention basin may be designed as a holding tank with no provisions for sludge collection, but with sufficient baffling to prevent short-circuiting. The reaction tank/detention basin shall be provided with an overflow, vent, and access hatch in accordance with Section 7.

2) Sedimentation - Sedimentation basins shall be provided when treating water with high iron and/or manganese content, or where chemical coagulation is used to reduce the load on the filters. Provisions for sludge removal shall be made.

4.7.2.3 Filtration

Duplicate filters shall be provided which conform to Section 4.3.

4.7.3 Removal by Lime-Soda Softening Process

See Section 4.8.1.

4.7.4 Removal by Manganese Coated Media Filtration

This process generally consists of the continuous or batch feed of potassium permanganate to the influent of a manganese greensand filter. Duplicate units shall be provided. Provisions should be made to apply the permanganate as far ahead of the filter as practical and to a point immediately before the filter.

1) Other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce chemical costs.

2) An anthracite media cap of at least 6 inches shall be provided over manganese greensand.

3) Normal filtration rate shall be 3 gpm per square foot except where in-plant testing can demonstrate satisfactory results at higher rates.

4) Minimum backwash rate should be 12 gpm per square foot at 60°F water temperature.

5) Air souring wash should be provided.

6) Sample taps shall be provided:

- Prior to addition of any oxidants.
- Immediately ahead of filtration.
- At the filter effluent.

4.7.5 Removal by Ion-Exchange

This process of iron and manganese removal should not be used for water containing more than 0.3 mg/L of iron, manganese, or a combination thereof. This process is not acceptable where either the raw water or washwater contains dissolved oxygen or other oxidants.

4.7.6 Sequestration by Polyphosphates

4.7.6.1 General

1) This process is not recommended when iron, manganese, or combination thereof exceeds 0.5 mg/L, and shall not be used when iron, manganese, or a combination thereof exceeds 1.0 mg/L.

2) Polyphosphate treatment may be less effective for sequestering manganese than for iron. Polyphosphate shall not be used when manganese exceeds 0.30 mg/L.

3) The total phosphate applied shall not exceed 10 mg/L as PO_4. The product feed rate shall not exceed the limit established under ANSI/NSF Standard No. 60, or as otherwise established by DEP.

4) Where phosphate treatment is used, satisfactory free chlorine residuals must be maintained in the distribution system.

4.7.6.2 Feeding Equipment

1) Feeding equipment shall conform to the requirements of Section 5.

2) Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L free chlorine residual, unless the phosphate is not able to support bacterial growth and the phosphate is being fed from the covered shipping container. Phosphate solutions having a pH of 2.0 or less may also be exempted from this requirement by DEP.

3) Polyphosphates shall not be applied ahead of iron and manganese removal treatment. The point of application shall be prior to any aeration, oxidation, or disinfection if no iron or manganese removal treatment is provided.

4) Phosphate chemicals must be acceptable to DEP. Chemicals certified under ANSI/NSF Standard 60 are deemed acceptable to DEP.

4.7.7 Sequestration by Sodium Silicates

Sodium silicate sequestration of iron and manganese is appropriate only to groundwater supplies prior to air contact. On-site pilot tests are required to determine the suitability of sodium silicate for the particular water and the minimum feed needed. Rapid oxidation of the metal ions (e.g., by chlorine or chlorine dioxide) must accompany or closely precede the sodium silicate addition. Injection of sodium silicate more than 15 seconds after oxidation may cause detectable loss of chemical efficiency. Dilution of feed solutions much below 5 percent silica as SiO_2 should be avoided for the same reason. Sodium silicate treatment may be less effective for sequestering manganese than for iron.

1) Sodium silicate addition is applicable to waters containing up to 2 mg/L of iron, manganese, or a combination thereof.

2) Chlorine residuals shall be maintained throughout the distribution system to prevent biological breakdown of the sequestered iron.

3) The amount of silicate added shall be limited to 20 mg/L as SiO2, but the amount of added and naturally occurring silicate shall not exceed 60 mg/L as SiO2. The product feed rate shall not exceed the limit established under ANSI/NSF Standard No. 60, or as otherwise established by DEP.

4) Feeding equipment shall conform to the requirements of Section 5.

5) Sodium silicate shall not be applied ahead of iron or manganese removal treatment.

4.8 Softening

The softening process selected must be based upon the mineral qualities of the raw water and the desired finished water quality in conjunction with requirements for disposal of sludge or brine waste, cost of plant, cost of chemicals, and plant location. Applicability of the process chosen shall be demonstrated.

4.8.1 Lime or Lime-Soda Process

Design standards for rapid mix, flocculation, and sedimentation are the same as for conventional water purification (see Section 4.2), except that the mixing and flocculation period should be at least 40 minutes. Additional consideration must be given to the following process elements.

4.8.1.1 Hydraulics

When split treatment is used, the bypass line should be sized to carry total plant flow, and an accurate means of measuring and splitting the flow must be provided.

4.8.1.2 Aeration

Determinations should be made for the carbon dioxide content of the raw water. When concentrations exceed 10 mg/L, the economics of removal by aeration as opposed to removal with lime should be considered if it has been determined that the DO level in the finished water will not cause corrosion problems in the distribution system. Aeration systems shall be designed in accordance with Section 4.5.

4.8.1.3 Chemical Feed Point

Lime and recycled sludge should be fed directly into the rapid mix basin.

4.8.1.4 Rapid Mix

Rapid mix basins must provide not more than 30 seconds detention time with adequate velocity gradients to keep the lime particles dispersed.

4.8.1.5 Stabilization

Equipment for stabilization of water softened by the lime or lime-soda process is required (see Section 4.11).

4.8.1.6 Sludge Collection

1) Mechanical sludge removal equipment shall be provided in the sedimentation tank.

2) Sludge recycling to the rapid mix should be provided. If it is to be recycled to a different location, DEP must approve the point of recycle.

4.8.1.7 Sludge Disposal

Provisions must be included for proper handling and disposal of softening sludges.

4.8.1.8 Disinfection

The use of excess lime shall not be considered an acceptable substitute for disinfection (see Section 4.1).

4.8.1.9 Plant Start-Up

The plant processes must be manually started following shut-down.

4.8.2 Cation Exchange Process

Alternative methods of hardness reduction should be investigated when the sodium content and dissolved solids concentration is of concern.

4.8.2.1 Pretreatment Requirements

Iron, manganese, or a combination of the two, should not exceed 0.3 mg/L in the water as applied to the ion exchange resin. Pretreatment for iron and manganese is required when the content of iron, manganese, or a combination of the two is 1 mg/L or more (see Section 4.7). Waters having 5 units or more turbidity should not be applied directly to the cation exchange softener.

4.8.2.2 Design

The units may be of pressure or gravity type of either an upflow or downflow design. Automatic regeneration based on volume of water softened should be used unless manual regeneration is justified and is approved by DEP. A manual override shall be provided on all automatic controls. Final sodium concentration and its health impact on the water system users must be a consideration if sodium chloride is used to regenerate the ion exchange beds.

4.8.2.3 Exchange Capacity

The design capacity for hardness removal should not exceed 20,000 grains per cubic foot when resin is regenerated with 0.3 pounds of salt per kilograin of hardness removed.

4.8.2.4 Depth of Resin

The depth of the exchange resin should not be less than 3 feet.

4.8.2.5 Flow Rates

The rate of softening should not exceed 7 gpm per square foot of bed area and the backwash rate should be 6 to 8 gpm per square foot of bed area. Rate-of-flow controllers or their equivalent must be installed on the backwash and rinse water lines.

4.8.2.6 Freeboard

The freeboard will depend upon the size and specific gravity of the resin and the direction of water flow. Generally, the washwater collector should be 24 inches above the top of the resin on downflow units.

4.8.2.7 Underdrains and Supporting Gravel

The bottoms, strainer systems, and support for the exchange resin shall conform to criteria provided for rapid rate gravity filters (see Section 4.3.1).

4.8.2.8 Brine Distribution

Facilities should be included for even distribution of the brine over the entire surface of both upflow and downflow units.

4.8.2.9 Cross-Connection Control

Backwash, rinse, and air relief discharge pipes shall be installed in such a manner as to prevent any possibility of back-siphonage. An air gap shall be provided at any connection to a sanitary sewer system.

4.8.2.10 Bypass Piping and Equipment

A bypass must be provided around softening units to produce a blended water of desirable hardness. Totalizing meters must be installed on the bypass line and on each softener unit. When treating for a MCL exceedance, an automatic proportioning or regulating device and shut-off valve shall be provided on the bypass line. In some installations, it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.

4.8.2.11 Additional Limitations

Silica gel resins should not be used for waters having a pH above 8.4 or containing less than 6 mg/L silica and should not be used when iron is present. When the applied water contains a chlorine residual, the cation exchange resin shall be a type that is not damaged by residual chlorine. Phenolic resins should not be used.

4.8.2.12 Sampling Taps

Smooth-nose sampling taps must be provided for the collection of representative samples. The taps shall be located to provide for sampling of the softener influent, effluent, and blended water. The sampling taps for the blended water shall be at least 20 feet downstream from the point of blending. Petcocks are not acceptable as sampling taps. Sampling taps should be provided on the brine tank discharge piping.

4.8.2.13 Brine and Salt Storage Tanks

1) Salt dissolving or brine tanks and wet salt storage tanks must be covered and must be corrosion-resistant.

2) All piping passing through the walls of the wet salt storage tanks shall be above the salt/brine wet line.

3) The make-up water inlet must be protected from back-siphonage. An air gap is the preferred method of protection. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank. The tanks should be provided with an automatic declining level control system on the make-up water line.

4) Wet salt storage basins must be equipped with manholes or hatchways for access and for direct dumping of salt from truck or rail car. Openings must be provided with raised curbs and watertight covers having overlapping edges similar to those required for finished water reservoirs. Each cover shall be hinged on one side and shall have locking device.

5) Overflows, where provided, must be turned down, have a proper free fall discharge, and be protected with corrosion-resistant screens or self-closing flap valves.

6) Two wet salt storage tanks or compartments designed to operate independently should be provided.

7) The salt shall be supported on graduated layers of gravel under which is a suitable means of collecting the brine.

8) Alternative designs which are conducive to frequent cleaning of the wet salt storage tank may be considered.

4.8.2.14 Brine and Salt Storage Capacity

Total salt storage should have sufficient capacity to store more than 1 1/2 carloads or truckloads of salt and provide for at least 30 days of operation. Brine storage should be adequate to regenerate the softeners for 24 hours of operation without being replenished.

4.8.2.15 Brine Pump or Eductor

An eductor may be used to transfer brine from the brine tank to the softeners. If a pump is used, a brine measuring tank or means of metering should be provided to obtain proper dilution.

4.8.2.16 Stabilization

The need for stabilization for corrosion control shall be evaluated. An alkali feeder shall be provided except when exempted by DEP (see Section 4.11).

4.8.2.17 Waste Disposal

Suitable disposal must be provided for brine waste (see Section 9). Where spent brine disposal must be reduced, consideration may be given to using a part of the spent brine for a subsequent regeneration.

4.8.2.18 Construction Materials

Pipes and contact materials must be resistant to the aggressiveness of salt. Plastic and red brass are acceptable piping materials. Steel and concrete must be coated with a non-leaching protective coating which is compatible with salt and brine.

4.8.2.19 Housing

Bagged salt and dry bulk salt storage shall be enclosed and separated from other operating areas to prevent damage to equipment.

4.8.2.20 Water Quality Testing Equipment

Test equipment for alkalinity, total hardness, carbon dioxide content, and pH should be provided to determine treatment effectiveness.

4.9 Anion Exchange Treatment

4.9.1 Pre-Treatment Requirements

Iron, manganese, or a combination of the two, should not exceed 0.3 mg/L in the water as applied to the ion exchange resin. Iron and manganese pre-treatment is required when a combination of iron and manganese exceeds 0.5 mg/L.

4.9.2 Design

1) Anion exchange units are typically of the pressure type, down flow design. Automatic regeneration based on volume of water treated should be used unless manual regeneration is justified and is approved by the reviewing authority. A manual override shall be provided on all automatic controls.

2) If a portion of the water is bypassed around the units and blended with treated water, the maximum blend ratio allowable shall be determined based on the highest anticipated raw water nitrate level. If bypassing is provided, a totalizing meter and a proportioning or regulating device or flow regulating valves shall be provided on the bypass line.

3) A stabilization system shall be provided for all systems utilizing anion-exchange treatment except when exempted by DEP.

4.9.3 Exchange capacity

The design capacity for nitrate removal should not exceed 10,000 grains per cubic foot when the resin is regenerated at 15 pounds of salt per cubic foot of resin.

4.9.4 Number of Units

At least two units shall be provided. The treatment capacity shall be capable of producing the permitted capacity of the plant at a level consistently below the MCL of concern, with one exchange unit out of service.

4.9.5 Type of Media

If the system is treating for nitrate or nitrite, the anion exchange media shall be of the nitrate selective type.

4.9.6 Flow Rates

The treatment flow rate should not exceed 5 gallons per minute per square foot of bed area. The backwash flow rate should be approximately 4.0 to 6.0 gpm per ft^2 of bed area. The regeneration rate should be approximately 1.0 gpm per ft^2 of bed area with a fast rinse approximately equal to the service flow rate.

4.9.7 Freeboard

Adequate freeboard must be provided to accommodate the backwash flow rate of the unit. The freeboard will depend on the size and specific gravity of the resin. The washwater collector should be 24 inches above the top of the resin on downflow units.

4.9.8 Miscellaneous Appurtenances

1) The system shall be designed to include an adequate under drain and supporting gravel system and brine distribution equipment.

2) Sample taps, brine and salt storage, salt and brine storage capacity, and brine pump or eductor shall be as required in Section 4.9.2.

4.9.9 Cross Connection Control

Backwash, rinse, and air relief discharge pipes shall be installed in such a manner as to prevent any possibility of back-siphonage.

4.9.10 Construction Materials

Pipes and contact materials shall be resistant to the aggressiveness of salt. Plastic and red brass is acceptable materials. Steel and concrete shall be coated with a non-leaching protective coating which is compatible with salt and brine.

4.9.11 Housing

Bagged salt and dry bulk salt storage shall be enclosed and separated from other operating areas to prevent damage to equipment.

4.9.12 Preconditioning of the Media

Prior to startup of the equipment, the media must be regenerated with no less than two bed volumes of water containing sodium chloride followed by an adequate rinse.

4.9.13 Waste Disposal

Suitable disposal must be provided for brine waste (see Section 9).

4.9.14 Water Quality Test Equipment

Test equipment must be provided for nitrates to determine treatment effectiveness.

4.10 Taste and Odor Control

Provisions shall be made for the addition of taste and odor control chemicals at all surface water treatment plants. Chemicals shall be added sufficiently ahead of other treatment processes to ensure adequate contact time for an effective and economical use of the chemicals. Where severe taste and odor problems are encountered, in-plant and/or pilot plant studies are required. In addition, a complete chemical and biological analysis of the raw water to identify the cause of the problem should be conducted.

4.10.1 Flexibility

Plants treating water that is known to have taste and odor problems should be provided with equipment that makes several of the control processes available so that the operator will have flexibility in operation.

4.10.2 Chlorination

Chlorination can be used for the removal of some objectionable odors. Adequate contact time must be provided to complete the chemical reactions involved. Excessive potential disinfection byproduct formation shall be investigated by bench-scale testing prior to design.

4.10.3 Chlorine Dioxide

Chlorine dioxide has been generally recognized as a treatment for tastes or odors caused by industrial wastes, such as phenols. However, chlorine dioxide can be used in the treatment of any taste or odor that is treatable by an oxidizing compound. Provisions shall be made for proper storing and handling of the sodium chlorite to eliminate any danger of explosion.

4.10.4 Powdered Activated Carbon (PAC)

1) PAC should be added as early as possible in the treatment process to provide maximum contact time. Flexibility to allow the addition of carbon at several

points is preferred. Activated carbon should not be applied near a point of chlorine or another oxidant application.

2) The carbon can be added as a pre-mixed slurry as by means of a dry-feed machine if the carbon is properly wetted.

3) Continuous agitation or resuspension equipment is necessary to keep the carbon from depositing in the slurry storage tank.

4) Provision shall be made for adequate dust control.

5) The required rate of feed of carbon in a water treatment plant depends upon the tastes and/or odors involved, but provision should be made for adding from 0.1 mg/L to at least 40 mg/L.

6) PAC shall be handled as a potentially combustible material. It should be stored in a building or compartment as fireproof as possible. Other chemicals should not be stored in the same compartment. A separate room should be provided for carbon feed installations. Carbon feeder rooms should be equipped with explosion-proof electrical outlets, lights, and motors.

4.10.5 Granular Activated Carbon Adsorption Units

Rates of flow must be consistent with the type and intensity of the problem. The rate used shall be supported by the results of pilot plant studies.

Replacement of anthracite with GAC may be considered as a control measure for geosmin and methyl isoborneol (MIB) taste and odors from algae blooms. Demonstration studies may be required by DEP.

4.10.6 Copper Sulfate and Other Copper Compounds

Continuous or periodic treatment of water with copper compounds to kill algae or other growths shall be controlled to prevent copper in excess of 1.0 mg/L (as copper) in the plant effluent or distribution system. Care shall be taken to ensure an even distribution within the treatment area to prevent excessive concentrations which may be toxic. Approval for the dose proposed must be obtained from DEP before applying copper compounds.

4.10.7 Aeration

See Section 4.5.

4.10.8 Potassium Permanganate

Application of potassium permanganate may be considered providing the treatment is designed so that the products of the reaction are not visible in the finished water.

4.10.9 Ozone

Ozonation can be used as a means of taste and odor control. Adequate contact time must be provided to complete the chemical reactions involved. Ozone is generally more desirable for treating water with high threshold odors. Ozone systems shall be designed in accordance with Section 4.1.4.

4.10.10 Other Methods

The decision to use any other method of taste and odor control should be made only after careful laboratory and/or pilot plant tests and on consultation with DEP.

4.11 Stabilization and Corrosion Control

All treated water that is considered unstable shall be stabilized.

Water may be unstable (i.e., change its chemical composition after treatment or after prolonged contact with water system components such as distribution or storage facilities) due to carbon dioxide, low pH, oversaturation with calcium or magnesium bicarbonates, and/or high levels of total dissolved solids. Subsequent corrosion may also be caused by galvanic or biochemical action.

Addition of new sources and certain chemicals or coagulants change the water characteristics (e.g., adjusting pH, alkalinity, chloride-to-sulfate mass ratio (CSMR), etc.) and may create corrosive water in the distribution system. Therefore:

- All treated water shall be evaluated to ensure that water quality parameters and characteristics are optimized to obtain the desired water stability throughout the distribution systems of a water supply.

The primary approaches to internal corrosion control in drinking water systems are to modify the water chemistry to make it less corrosive and to encourage formation of passivating films on the contacting surface. This is typically accomplished through pH and/or alkalinity adjustment or through the addition of a corrosion inhibitor. Most corrosion control treatment will be beneficial for reducing corrosion of lead, copper, iron, steel, and galvanized pipe.

Increasing the pH, alkalinity, and carbonate buffer content are the most consistent methods for reducing the rate of corrosion. Increasing the carbonate buffer level is particularly recommended for systems treating soft water.

Where adjustments to water quality parameters such as chlorine residual, pH, alkalinity, or carbonate buffer strength prove insufficient to control corrosion rates, the use of corrosion inhibitors should be considered. Orthophosphate is particularly effective for this purpose in most situations.

4.11.1 Corrosion Control Study

A corrosion control study is required for, construction of and changes to, corrosion control treatment systems. At a minimum, the corrosion control study shall include:

1) A sample site location plan for water quality parameter monitoring. Entry point samples shall be collected for water quality data and other system information pertinent to achieving optimum corrosion control. At a minimum, the water quality parameters shall include:

    - pH
    - Temperature
    - Alkalinity
    - Calcium
    - Sulfate
    - Chloride
    - Conductivity
    - Hardness
    - Iron
    - Manganese
    - Aluminum
    - Natural Organic Matter (NOM)

2) A summary of all water quality parameter monitoring results. These results should be evaluated considering the location of sample sites within the distribution system and used as the basis for considering corrosion control treatment options.

3) A desktop evaluation utilizing corrosion control computer modeling or an EPA screening tool. The evaluation shall recommend optimal corrosion control treatment and water quality parameter performance requirements for the selected treatment.

4) Identification of possible limitations and secondary impacts for treatment options.

4.11.2 Control

Monitoring equipment shall be provided for determining the effectiveness of stabilization treatment and the chemical residuals at the entry point and in the distribution system, including an acceptable pH probe that utilizes 3 standards for calibration.

4.11.3 Acid Addition

1) Chemical feed equipment shall conform to Section 5.

2) Adequate precautions shall be taken for safety, such as those outlined in Sections 5.4. and 5.5.

4.11.4 Phosphates

The feeding of phosphates may be applicable for sequestering calcium, corrosion control, and in conjunction with alkali feed.

4.11.4.1 Orthophosphate

Orthophosphate acts as a corrosion inhibitor by forming a protective film on the interior of pipes. This film protects the pipe material from the corrosive effects of water, which reduces or eliminates the potential for lead leaching into the water. Phosphates containing zinc will help protect cement and cement mortar-lined pipes at low alkalinity/hardness/pH conditions.

4.11.4.2 Blended Phosphates

Blended phosphates contain some proportion of orthophosphate and polyphosphate. The orthophosphate portion is beneficial for corrosion control while the polyphosphate sequesters hardness, iron, or manganese. It is possible that blended phosphates can provide both sequestration of metals and reduce metals release. The orthophosphate to polyphosphate ratio is very important to assure sufficient orthophosphate residual to control the lead or copper release.

4.11.4.3 Design

Phosphate systems shall:

1) Have chemical feed equipment that conforms to Section 5.

2) Have a chemical feed system that can maintain an orthophosphate residual of at least 1.0 mg/L as P (3.0 mg/L as PO_4) throughout the distribution system.

3) Have treated water within the phosphate manufacturer's pH recommendations (at least 7.2). When using orthophosphate for lead and copper control, the finished water alkalinity shall be at least 20 mg/L as $CaCO_3$.

4) Use the same phosphate chemical at each entry point that are hydraulically connected.

5) Follow manufacturer's specifications for handling, storage, and use.

6) Keep stock phosphate solution covered and disinfected by carrying approximately 10 mg/L free chlorine residual unless the phosphate is being fed from the covered shipping container. Phosphate solutions having a pH of 2.0 or less may also be exempted from this requirement by DEP.

7) Maintain satisfactory disinfectant residuals of at least 0.2 mg/L of free chlorine or 1.0 mg/L of total chlorine throughout the distribution system to ensure bacteriological safety of the water.

8) Have testing equipment that utilizes an EPA accepted method and is equipped with a digital display for monitoring the phosphate residual.

9) Consider a 6-month higher dose period to establish the desired residual.

10) Prior to beginning phosphate addition, the distribution system shall have been cleaned by flushing or with hydraulic pigs.

Phosphates can have secondary impacts that limit their use. Two factors that shall be evaluated prior to the installation of these corrosion control systems are (1) reactions with aluminum, and (2) impacts on wastewater treatment plants.

4.11.5 pH/Alkalinity Adjustment

pH/Alkalinity adjustment includes adding a base or similar chemical to the water to increase pH to a level where the practical lead or copper solubility lowers, acids are neutralized, and less soluble metal compounds are formed on the pipes.

4.11.5.1 Chemicals

4.11.5.1.1 Caustic Soda

Caustic soda (sodium or potassium hydroxide) will increase the pH with minimal effect on alkalinity and dissolved inorganic carbon (DIC). A stable pH is very difficult to provide when using caustic soda on water having low alkalinity. Caustic soda can cause severe burns and damage the eyes. Small systems (e.g., schools, churches, trailer parks) shall use a safer option such as soda ash, if possible.

4.11.5.1.2 Soda Ash

Soda ash (sodium or potassium carbonate) will increase the alkalinity, DIC, and moderately increase the pH. Soda ash is relatively safe to handle compared to caustic soda.

4.11.5.1.3 Lime

Lime (calcium hydroxide) will increase the pH, alkalinity, DIC, and hardness. A stable pH is very difficult to provide when using lime on water having low alkalinity. Some types of lime can cause an increase in turbidity.

4.11.5.1.4 Sodium Bicarbonate

Sodium bicarbonate substantially increases the alkalinity and DIC, while minimally increasing the pH. It will not increase the pH above 8.3.

4.11.6 Simultaneous Compliance

Alkalinity, pH, and DIC can have secondary impacts that limit their use. The following secondary impacts shall be evaluated:

1) Optimal pH for all other processes, particularly disinfection.
2) Calcium carbonate precipitation pH.
3) Oxidation of iron and manganese.
4) DBP formation (trihalomethanes).

4.11.7 Buffer Intensity

Buffer intensity is the water's ability to resist changes in pH. Low buffer intensity can mean wide pH changes in the distribution system.

Since buffer intensity minimum occurs between pHs 8 and 8.5, this range should be avoided for target distribution pH. Higher pHs may be required, especially for water with low DIC.

4.11.8 Alkalinity/pH Adjustments:

Systems:

1) Shall be capable of providing a stable pH.

2) Should have chemical feed injection points located after all the disinfection log inactivation requirements are achieved.

3) Shall have chemical feed equipment that conforms to Section 5.

4) Shall produce finished water with an alkalinity of at least 20 mg/L as $CaCO^3$.

A pH/alkalinity feed system shall be provided for all systems utilizing anion-exchange treatment except when exempted by DEP.

4.11.9 Aeration

Aeration can increase the pH and reduce excess DIC by removing carbon dioxide. Aeration is most effective when there is an adequate carbon dioxide concentration in the water (4 – 10 mg/L CO_2), and the pH is < 7.2.

Aeration devices shall conform to Sections 4.5 or 4.6.1.

4.11.10 Carbon Dioxide Addition

Recarbonation basin design should abide by the following guidelines:

1) Provide a total detention time of 20 minutes.

2) Be composed of two compartments, with a depth that will provide a diffuser submergence of not less than 7.5 feet nor greater than recommended by the manufacturer. The two compartments shall be as follows:

   - A mixing compartment having a detention time of at least 3 minutes.

   - A reaction compartment.

3) Discourage the practice of on-site generation of carbon dioxide.

4) Where liquid carbon dioxide is used, take adequate precautions to prevent carbon dioxide from entering the plant from the recarbonation process. In addition, consideration should be given to the installation of a carbon dioxide alarm system with light and audio warning, especially in lower areas.

5) House recarbonation tanks outside or seal and vent the tanks to the outside with adequate seals and adequate purge flow of air to ensure worker safety.

6) Make provisions for draining the recarbonation basin and removing sludge.

4.11.11 Water Unstable Due to Biochemical Action in Distribution System

Unstable water resulting from the bacterial decomposition of organic matter in water (especially in dead-end mains), the biochemical action within tubercles, and/or the reduction of sulfates to sulfides, should be prevented by the maintaining disinfectant residuals of at least 0.2 mg/L of free chlorine or 1.0 mg/L of total chlorine throughout the distribution system and by flushing all dead-ends on a regular basis.

4.11.12 Other Treatment

Other treatment for controlling corrosive waters by the use sodium silicate may be used where necessary. Any proprietary compounds must receive the specific approval from DEP before use. Chemical feeders shall be as required in Section 5.

4.11.13 Cathodic Protection

Cathodic protection should be considered to help prevent or minimize corrosion on the outer surfaces of metal conduits.

4.11.14 Blending

Blending is when a percentage of raw water is bypassed around softening systems to form a more stabilize treated water. Treatment plants designed to utilize blending also should contain facilities for further stabilization by other methods.

1) Blending is not permitted if softening is provided for any other reason than hardness reduction.

2) All surface water must be filtered. Diverting part of the flow from surface sources (e.g., bypassing softening systems) without complete surface water treatment will not be allowed.

3) All bypasses shall have flow meters and proportioning valves.

4.11.15 Chloride-to-Sulfate Mass Ratio (CSMR)

Using or changing to chloride-base coagulant, utilizing anion exchange treatment, and runoff from road salt can increase the lead solubility. The CSMR is calculated by the effluent chloride result divided by the effluent sulfate results. CSMR of 0.6 or greater can have a serious impact on the lead solubility.

Orthophosphate has shown to be ineffective at reducing the lead solubility when CSMR is higher than 0.6.

4.12 Microscreening

A microscreen is a mechanical supplement capable of removing suspended matter from the water by straining, usually prior to other treatment. It may be used to reduce nuisance organisms and organic loadings. Microscreening shall not be used in place of coagulation or filtration.

4.12.1 Design

Design shall give due consideration to:

1) Nature of the suspended matter to be removed.

2) Corrosiveness of the water.

3) Effect of chemicals used for pretreatment.

4) Automated back flushing operation.

5) A durable, corrosion-resistant screen.

6) Duplication of units for continuous operation during equipment maintenance or breakdown.

7) Protection against back-siphonage when potable water is used for washing.

8) Pressure differential gauges where backwash is based on pressure differential.

9) Proper disposal of washwater (see Section 9).

4.13 Arsenic Treatment

4.13.1 Blending

Blending involves mixing a source that exceeds the MCL with one or more sources that are below the MCL prior to the entry point to achieve a blended arsenic concentration below the MCL.

1) The maximum design blended entry point arsenic concentration shall be no greater than 0.008 mg/L.

2) At least two available sources with arsenic levels below the MCL are required for blending to be considered so that failure of one low arsenic source does not leave the system with only one high arsenic source of water in operation and no blending capabilities.

3) Each source in the blending process shall have a flow meter and a blending valve to ensure the streams are blended in a ratio that produces an arsenic concentration below the MCL.

4) A blending tank should be provided to ensure proper blending.

5) Flow restrictor shall be provided to ensure the arsenic laden source(s) does not exceed the blending ratio.

4.13.2 Treatment

The type of arsenic treatment selected should be from the EPA's BAT list.

1) If a treatment system is not on the EPA's BAT list, a pilot study may be required. The goals of the study are to determine if the treatment units meet the arsenic removal requirements, to assess any interference from competing ions or solids buildup within the media bed, to validate the design and operation parameters (including the empty bed contact times, media life

expectancy, and any backwash requirements). A minimum study period of 90 days is recommended. Pilot study water shall be discharged to waste.

Feed water to the treatment unit should meet the pertinent water quality limitations specified by the corresponding equipment and media manufacturers.

An Operations & Maintenance Manual for the treatment system shall be produced from this pilot study. This manual should include the manufacturer's data as well as operational guidelines, procedures, and waste disposal information.

2) The following raw water samples shall be taken to determine the treatment method:

- Arsenic, Total
- Arsenate [As(V)]
- Arsenite [As(III)]
- Orthophosphate
- pH
- Chloride
- Silica
- Fluoride
- Sulfate
- Iron
- Total Dissolved Solids (TDS)
- Manganese
- Total Organic Carbon (TOC)
- Nitrite
- Nitrate

3) The treatment shall be capable of reducing the maximum arsenic level in the water to one-half the MCL or less.

4) The treatment system shall be designed to treat the source(s) permitted capacity.

5) Instrumentation for measuring flowrate and total flow through the treatment unit and for measuring pressure upstream and downstream of each unit shall be provided.

6) Sample taps shall be provided before, between, and after the treatment units.

7) Treatment systems shall be protected from the elements by being placed within a treatment building. Access for media replacement shall be provided.

8) No bypasses shall be provided.

4.13.3 Adsorptive Media

These types of media remove arsenic from water by attaching the arsenic onto the surface of a porous solid. The media typically contains a metal oxide coating to facilitate removal of the arsenic. Iron-based sorbents, such as granular ferric oxide, have been demonstrated as very effective for arsenic removal via this process. Other products are available which use a different coating, such as aluminum, zirconium, or titanium. These technologies are one-time use application with subsequent media disposal and replacement.

1) Raw water with turbidities above 0.3 NTUs require prefiltration.

2) Chemical pre-oxidation shall be provided to ensure all arsenic is in the As (V) form.

3) At least two pressurized treatment units shall be provided, **piped in series**, and operated in a downflow mode. The system shall be designed for complete arsenic removal from the lead vessel(s) with a redundant lag unit(s). When the media is exhausted (when the sample result taken after the lead and before the lag units exceeds 10 µg/L for arsenic) in the lead unit, the media shall be replaced and the lag unit shall become the lead unit and the former lead unit with new media shall become the lag unit.

4) An upflow backwash should be provided.

5) The treatment vessel materials shall be constructed of fiberglass, stainless steel, or carbon steel. Carbon steel shall comply with American Society of Mechanical Engineers (ASME) Code Section VIII, Division 1. The interior shall be lined with abrasion-resistant vinyl ester or epoxy coating. Interior lining material shall be ANSI/NSF-61 certified and suitable for pH range 2.0-13.5. The vessel's pressure rating shall be at least 50 psig.

6) Refer to Clean Water Program guidance for waste water disposal.

4.13.3.1 Activated Alumina

Activated alumina adsorptive media for arsenic removal should not be used when the feed water has:

- Chloride > 250 mg/L
- Fluoride > 2.0 mg/L
- Silica > 30 mg/L
- Iron > 0.3 mg/L
- Manganese > 0.05 mg/L
- Dissolved Organic Carbon > 4 mg/L
- Sulfate > 720 mg/L
- TDS > 1,000 mg/L

1) Load rates should be between 2 to 8 gpm/ft^2, and shall not exceed 10 gpm/ft^2. The EBCT shall be at least 10 minutes.

2) Activated alumina may have 5 to 20 times longer bed runs under acidic pH (5.5 – 6.0) conditions. Pre- and post-adjustment of pH should be provided to enhance removal rates and reduce corrosivity. Where pH adjustment is provided, a pH analyzer shall be provided.

4.13.3.2 Iron Based Sorbents

1) Iron based sorbents for arsenic removal should not be used when the feed water has phosphate > 0.2 mg/L.

2) Load rates should be between 5 to 8 gpm/ft^2, and shall not exceed 10 gpm/ft^2.

3) The EBCT shall be at least 10 minutes. Manufacturer recommendations regarding design EBCT need to be taken into consideration.

4.13.4 Manganese Coated Media Filtration

This treatment method has historically been used for iron and manganese removal and can also be effective in removing 50 – 85 percent of the arsenic from the raw water.

1) Chemical pre-oxidation shall be provided to ensure all arsenic is in the As (V) form.

2) An iron to arsenic mass ratio in the raw water of 20:1 (or greater) is required. Raw water with less than a 20:1 ratio of iron to arsenic shall add additional iron in the form of ferric chloride or ferric sulfate to increase arsenic removal efficiencies.

3) Normal filtration rates shall not exceed 3 gpm/ft^2 and the maximum filtration rates shall not exceed 4 gpm/ft^2.

4) The system shall meet the design requirements from Section 4.7.4, removal by manganese coated media filtration.

5) Pre- and post-adjustment of pH should be provided to enhance removal rates and reduce corrosivity. Where pH adjustment is provided, a pH analyzer shall be provided.

4.13.5 Anion Exchange

Uses an anion exchange resin to remove arsenic by exchanging ions in the resin for arsenic ions in the raw water. Chloride-form resins are most often used in arsenic removal but sulfate or nitrate selective resins may also be used. This process works best if the arsenic is in the form of As (V).

1) Anion exchange for arsenic removal is only applicable for water with:

- pH between 6.5 - 9.0
- TDS < 500 mg/L
- Sulfate < 50 mg/L

2) Chemical pre-oxidation shall be provided to ensure all arsenic is in the As (V) form.

3) At least two treatment units shall be provided, piped in series, and operated in a downflow mode. The system shall be designed for complete arsenic removal from the lead vessel(s) with a redundant lag unit(s). When the volumetric setpoint in the lead unit is reached, the lead unit shall be regenerated and the lag unit shall become the lead unit and regenerated unit shall become the lag unit.

4) Cation exchange should be provided before the anion exchange system. Mixed beds are not permitted.

5) Loading rates should be between 8-12 gpm/ft^2.

6) EBCT shall be at least 5 minutes. 15 minutes is recommended.

7) Pre-filtration should be provided if the source water turbidity exceeds 0.3 NTU.

8) A volumetric setpoint shall be used to trigger regeneration. This setpoint shall be no greater than 80 percent of the calculated volume between regeneration.

9) Backwash/regeneration waste shall be properly disposed of in accordance with the Resource Conservation and Recovery Act (RCRA). Liquid waste streams that contain more than 5.0 mg/L of arsenic are hazardous waste based on toxicity characteristics listed in RCRA. Systems shall determine whether the waste will be hazardous.

10) The system shall meet the design requirements from Section 4.9, Anion exchange.

4.14 Nanofiltration (NF) and Reverse Osmosis (RO) Systems Membrane Treatment Processes

4.14.1 Regulatory

This section sets the minimum design criteria requirements for reverse osmosis (RO) and nanofiltration (NF) membrane systems for the removal of dissolved contaminants such as; total dissolved solids (TDS), hardness, nitrates, and disinfection byproduct precursors. The design criteria in this section are not meant to be used in the design of surface water filtration. Surface water membrane filtration is covered in Section 4.3.4, ultrafiltration (UF) and microfiltration (MF) Systems.

DEP will not award Surface Water Treatment Rule (SWTR) *giardia* or LT2ESWTR *cryptosporidium* removal credits for reverse (RO) and nanofiltration (NF) membranes systems.

4.14.2 Background

Reverse osmosis (RO) and nanofiltration (NF) are pressure-driven separation processes that utilize semi-permeable membranes which do not have definable pores. RO uses hydraulic pressure to oppose and exceed the liquid osmotic pressure across the semi-permeable membrane, forcing the water from the concentrated solution side to the dilute solution side. The result is that the RO membrane allows passage of the solvent (water), but not the solutes (dissolved solids).

RO units typically are equipped with a spiral wound type of membrane. Products equipped with a hollow fiber membrane are also available. An encased RO module is commonly referred to as an element. These membranes usually are constructed of a polyamide or cellulose acetate-based composite material. This process is particularly effective for treating water with high total dissolved solids (TDS) content and for desalting brackish water. Required operating pressure varies depending on the feed water TDS, membrane properties, and water temperature.

RO should not be used to treat waters having a TDS concentration exceeding 12,000 mg/L for low pressure (400 psi) membranes or 30,000 mg/L for high pressure (1,000 psi) membranes without specific justification. Detailed information shall be submitted to DEP concerning required feed water quality and anticipated equipment performance.

NF membranes are similar to RO membranes, though they usually require a lower operating pressure, and are less effective for removal of monovalent ions. This process is applied for purposes of softening or the removal of dissolved organic contaminants.

4.14.3 Process Evaluation Considerations

Since the amount of energy required to pump water through the membranes is directly related to the permeability of the membrane, the selection of the specific membrane process should be matched to the desired treatment objectives.

4.14.4 Pilot Studies

DEP may require pilot testing for all proposed installations to evaluate and provide performance data on each specific system under consideration.

The primary goal of a membrane pilot study is to obtain information such as treated water quality (e.g., turbidity) and operating parameters (e.g., flux) that are necessary for the design of a membrane filtration facility. The pilot study shall be conducted over a sufficient period (at least three (3) CIP cycles totaling at least 90 days) to establish that the technology is appropriate for the source water and to determine appropriate design and operating parameters. The study shall include all pre-treatment and membrane flux rates, TMP, backwash parameters, and chemical CIP procedures. Ideally, the pilot study should be conducted during the time of year yielding the most difficult water quality to treat, so that design parameters resulting from the study, such as flux and chemical cleaning frequency, would be conservative for year-round operation. The study period shall include at least one raw water spike from a major rainfall event using a turbidity spiking technique.

1) The pilot study shall determine specifics such as:

   (a) Most suitable membrane.
   (b) Ability to meet all treatment objectives.
   (c) Pretreatment needs.
   (d) Post-treatment needs.
   (e) Quantity of reject water.
   (f) Operation and maintenance needs.
   (g) Optimum system recovery and flux rate.
   (h) Process efficiency.
   (i) Cold and warm water flux rates.
   (j) Fouling potential.
   (k) Optimum membrane pressures.
   (l) Optimum cleaning procedures and frequency.
   (m) Other design and monitoring considerations.

2) The pilot study monitoring shall include:

   (a) Continuous flow rate, run time, flux rate, filtrate pressures, TMP, and raw, feed, and membrane effluent turbidities.

   (b) Daily nitrates (if applicable), pH, hardness, and temperature.

   (c) Weekly raw and membrane effluent alkalinity, total hardness, calcium hardness, ammonia, silica, iron, sulfate, color, manganese, total suspended solids, and total dissolved solids.

   (d) All backwash volumes, rates, and CIP chemical usage.

3) The pilot study shall include at least three (3) CIP cycles.

4) A pilot study protocol shall be submitted to the appropriate DEP regional office for approval prior to initiating the pilot study.

5) The pilot study should include heavy involvement with the Certified Operators for the proposed system, thus familiarizing plant personnel with the operation, cleaning, and other maintenance procedures for the membrane system. The pilot unit shall be equipped with all the instrumentation,

monitoring, and controls needed to establish hydraulic operation and satisfy the pilot study monitoring requirements.

6) The minimum performance goals of the membrane during the pilot study shall be:

   (a) Permeate samples are 50% or less of MCL for each contaminant of concern.

   (b) The target flux and recovery rates are maintained.

7) Upon study completion, a report shall be submitted to DEP summarizing the procedures and all test results. The report shall contain sufficient detail to establish design parameters for the full-scale plant.

8) A bench-scale study, which requires less time and expense, is considered a preliminary evaluation tool to verify process feasibility and to evaluate individual membrane elements. A bench-scale study can be used prior to a pilot study, but will not replace the requirement for a pilot study.

4.14.5 Permitting Support Documentation

For proposed membrane installations, project-specific information and calculations to be submitted to DEP as part of the Public Water Supply Permit Application shall include:

1) Treatment objectives.

2) Raw water quality information, including all new source sampling results.

3) An analysis of any pretreatment needs.

4) Predicted finished water qualities for the key operating parameters.

5) Maximum feed rate to each filter unit (Q_f).

6) Maximum production from each filter unit (Q_p).

7) Predicted net driving pressure (NDP).

8) Percent recovery (R).

9) Design flux rate (J).

10) Concentration Factor.

11) Pertinent ANSI/NSF Standard 61 certifications.

12) Summary describing any computer modeling or bench scale study used to determine that the system will produce treated water meeting the regulatory requirements and the treatment objectives.

13) Additional system information, to include: process type (pressure/vacuum-driven), materials of construction, membrane surface area per filter unit (Asys), minimum/maximum operating pressures, supporting media, and manufacturer-recommended limitations to prevent equipment damage.

14) Specifications for all system equipment components, to include: the membrane skid, membrane modules, compressed air equipment, CIP system(s), reverse filtration/backwash system, air scrub/backwash system, tanks, heaters, pumps, drives, and associated equipment (e.g., piping, valves, wiring, supports, etc.), as applicable.

15) Corresponding information on the specific system being proposed for use shall also include:

- Dimensioned filter unit layout drawings.
- Process and instrumentation diagrams.
- Descriptions of the respective production, backwash, and CIP modes.
- For cross-connection control, description of block and bleed assembly, or equivalent assembly which is equally or more protective.
- Calculations adequately describing the establishment of critical operational control limits.
- Information on how redundancy requirements are being met.
- A description of the backwash process, to include: frequency for each model-equipped backwash mode, duration of steps/events, and basis of approach for this process phase.

16) A plan for on-site training of the water system operator(s) to operate and maintain the membrane treatment system. The plan shall include: who will provide the training, the schedule of training, training forms, and operators who will be trained. The plan shall include collecting, recording, and interpreting data, startup, and shutdown procedures.

4.14.6 Raw Water Quality

Design considerations and membrane selection must also address target removal efficiencies and system recovery versus acceptable flux rates. Additionally, source water temperature can significantly impact the flux of the membrane(s) under consideration. At low water temperatures, the flux can be reduced appreciably, possibly impacting process economics associated with the number of membrane units to be required in the full-scale installation. Seasonal variation of design flow rates may be based on documented lower demand during colder weather periods.

In addition to any new source sampling requirements, sample results for the following shall be submitted:

- Turbidity
- Temperature
- Total Organic Carbon (TOC)
- Total Dissolved Solids (TDS)
- Alkalinity
- Total Hardness
- Aluminum
- Ammonia
- Barium
- Calcium
- Nitrite
- All VOCs included in EPA Method 524.2
- Nitrate
- Iron
- Manganese
- Magnesium
- Silica
- Sulfate
- Chloride
- Dissolved oxygen (DO)
- Diatoms
- Silt Density Index (SDI)

4.14.7 Pretreatment

Pretreatment needs shall be adequately evaluated. Pretreatment systems shall be capable of producing feed water of a quality recommended by the manufacturer of the RO/NF filter unit.

1) All pretreatment processes shall be compatible with the membrane system.

2) Pretreatment shall be provided for all raw water quality parameters that are outside of the manufactures requirements. Detailed information, including the manufacturer's feed water requirements, proposed pretreatment equipment, and evidence that this pretreatment system can produce the desired feed water quality, shall be included in the permit application. Maximum recommended values for selected water quality parameters include the following:

    - Turbidity: 0.5 NTU
    - TOC: 2 mg/L
    - Iron: 0.1 mg/L
    - Manganese: 0.05 mg/L
    - Oil & Grease: 0.1 mg/L
    - Silt Density Index (SDI): 3.0
    - VOCs: in µg/L range

3) A prefilter shall be provided immediately prior to each RO/NF filter unit. Typically, this is a disposable cartridge filter. Recommended prefilter pore size is less than or equal to 25 microns for a spiral-wound module.

4) Pretreatment for groundwater should include acid and antiscalants to inhibit the formation of scale precipitates.

5) Pretreatment for surface waters should include coagulation, flocculation, sedimentation, and filtration.

4.14.8 Design Considerations

1) At least two RO/NF filter units shall be provided. Where only two skids are provided, each shall be capable of meeting the plant's permitted capacity at the approved flux rate. Where more than two filter units are provided, the installed RO/NF system shall be capable of meeting the plant's permitted capacity with one filter unit removed from service.

2) A bypass shall be installed around the RO/NF unit to produce water with desired water quality characteristics. The maximum blend ratio allowable shall be determined based on the highest anticipated raw water contaminant. The bypassing shall include a totalizing meter and a proportioning or regulating device or flow regulating valves.

- When a primary contaminant is involved, the target blended water concentration shall be 50 percent of the corresponding MCL. For nitrate treatment, an online analyzer with auto-proportioning valves should be provided.

- For secondary contaminants, the target blended water concentration shall be 80 percent of the corresponding MCL.

3) A two-stage configuration may be utilized as appropriate. This arrangement refers to incorporating two, or more, stages of treatment in series, such that the concentrate, or reject from one stage becomes the feed for a subsequent stage. This option is appropriate for increasing a system's percent recovery, as well as for a system that has limitations on wastewater quantity being generated.

4) The ability to filter-to-waste should be provided.

5) Justification for the design flux rate being used shall be provided. The rationale associated with the recommended flux ranges shall be included. The maximum flux rate should be 2.5 gpd per square foot of membrane per 100 pounds per square inch applied pressure. Higher flux rates will be considered upon the presentation of satisfactory evidence of reliability and performance.

6) Backwash capability shall be provided. Backwash water supply shall be filtered water with adequate cross-connection control provisions.

4.14.9 Cleaning

The membrane must be periodically cleaned with acid, detergents, and possibly disinfection to control membrane fouling. Cleaning procedures, chemicals, and frequency should follow the membrane manufacturer’s guidelines.

1) All cleaning chemicals shall be ANSI/NSF Standard 60-certified.

2) Provisions for safe cleaning chemical storage, chemical handling, and resulting waste disposal shall be addressed.

3) Cross-connection control measures shall be provided to prevent contamination of both the raw and finished water system with CIP cleaning chemicals using a double block-and-bleed valving arrangement or a removable spool.

4) CIP procedures shall be provided, addressing the following:

   - A functional description of the CIP process, including, but not limited to: a SOP for respective operator CIP activities, frequency, triggers, automated/manual cleaning aspects, and post-CIP approach for the return to production mode.

   - Identification of the different chemicals to be utilized.

   - Methods to neutralize and dispose of the CIP chemical waste stream.

   - Cross-connection control provisions for chemical feeds and waste piping.

4.14.10 Instrumentation/Appurtenances

The following monitoring instrumentation and appurtenances, at a minimum, shall be provided:

1) Appropriate pressure gauges for TMP. Include these devices on feed, permeate, and concentrate lines.

2) Flow meter for feed, permeate, and waste flow rate.

3) Flow rate controller to control the flux rate.

4) All required means of removing membrane modules including cranes, lifts, required ceiling heights, and specialty tools, as applicable.

5) Sample taps for the following: feed, permeate from each stage (as applicable), combined permeate, combined concentrate, and blended (as applicable).

6) The feed water line and the permeate line from each filter unit shall include continuous monitors and recorders for, pH, conductivity, and temperature.

7) The combined permeate line shall be equipped with a continuous monitor and recorder for totalizing flow rate.

4.14.11 Control Systems

A supervisory control and data acquisition (SCADA) system capable of monitoring, recording, and controlling all the treatment plant's critical operations shall be provided.

The SCADA system shall:

1) Be programmed to automatically archive data to hard disk drives with removable media or to a secure off-site location.

2) Provide adequate protection from voltage and power spikes.

3) Have the capability to resume full functionality utilizing all applicable site-specific control limits and parameters after power restoration.

4) Be capable of meeting all the continuous recording requirements.

5) Be capable of generating applicable reports for plant operators, such as parameter trending and alarm histories.

6) Be capable of trending at minimum the following parameters:

   (a) Production flow rate from each filter unit (Qp).
   (b) Percent recovery (R).
   (c) Flux rate (J).
   (d) Transmembrane pressure.
   (e) Conductivity.

Systems shall provide alarms, communication systems, and automatic shutdown processes. Notification alarms and shutdown alarms are to be utilized where appropriate. DEP shall approve the extent of operational control required. At a minimum, these alarms are to be provided:

1) High turbidity (raw, membrane feed, individual filter unit, and combined permeate).

2) High pressure differentials.

3) Membrane failure (low pressure differentials).

4) Pump failures.

5) High transmembrane pressure (TMP).

6) PLC failure.

7) Membrane equipment failure.

8) Clearwell level (high or low).

9) Entry point chlorine residual (high or low).

10) Low chemical levels.

11) Power failure.

12) Building intrusion.

4.14.12 Operation and Maintenance

An O&M Manual shall be provided. The O&M manual shall include at a minimum:

1) SOPs for startup, shutdown, CIPs, alarm conditions responses, monthly reporting, and data trending.

2) The recommended or required maintenance requirements for each piece of equipment, including maintenance schedule for turbidimeters, pressure sensors, and flow sensors.

3) The proper operation parameters of the membrane units and associated appurtenances including software user instructions.

4) Trouble shooting guide for all equipment and procedures.

5) Assessment of potential equipment failure/damage and accompanying warranty documents. Guidance to determine when the membrane modules are approaching the end of useful life (i.e., percent recovery, permeability, life span, total production, etc.).

4.14.13 Post-Treatment

1) Due to the very corrosive characteristics of the permeate, post alkalinity, and pH adjustment shall be provided. A minimum of 20 mg/L as $CaCO^3$ of alkalinity and a pH of at least 7.0 shall be provided in the finished water.

2) Water treated using RO or NF typically includes aeration for degasification for carbon dioxide (if excessive) and hydrogen sulfide removal (if present).

5 CHEMICALS AND CHEMICAL HANDLING

5.0 General

No chemicals shall be applied to drinking waters unless specifically permitted by DEP. Chemicals which may come in contact with or affect the quality of the water and which are certified for conformance with ANSI/NSF Standard 60 (Drinking Water Treatment Chemicals-Health Effects) are deemed acceptable to DEP.

5.0.1 Plans and Specifications

Plans and specifications shall be submitted for review and approval, as stated in Section 1.1.3 and shall include:

1) Descriptions of feed equipment, including maximum and minimum feed ranges.

2) Location of feeders, piping layout, and points of application.

3) Storage and handling facilities.

4) Specifications for chemicals to be used.

5) Operating and control procedures including proposed application rates.

6) Descriptions of testing equipment and procedures.

7) All chemical holding tanks (with capacities), feeders, transfer pumps, connecting piping, valves, points of application, backflow prevention devices, air gaps, secondary containment, drains, overflows, vents, and safety eye washes and showers.

5.0.2 Chemical Application

Chemicals shall be applied to the water at such points and by such means as to:

1) Provide maximum efficiency of treatment.

2) Ensure maximum safety to consumer.

3) Provide maximum safety to operators.

4) Ensure satisfactory mixing of the chemicals with the water.

5) Provide maximum flexibility of operation through various points of application, when appropriate.

6) Prevent backflow or back-siphonage between multiple points of feed through common manifolds.

5.0.3 General Equipment Design

The design of chemical feed equipment shall be such that:

1) Feeders will be able to supply, at all times, the necessary amounts of chemicals at an accurate rate, throughout the range of feed, considering initial and ultimate treatment plant capacity.

2) Equipment surfaces and any appurtenances which contact chemicals are resistant to the aggressiveness of the chemical.

3) Corrosive chemicals are introduced in such a manner as to minimize potential for corrosion.

4) Chemicals that are incompatible shall not be stored or handled together.

5) All chemicals shall have separate feed lines.

6) Chemical feeders are as near as practical to the feed point.

7) Chemical feeders and pumps shall operate at no lower than 20% of the feed system's capacity unless the pump is equipped with two independent adjustment mechanisms, such as pump pulse rate and stroke length, in which case the pump shall operate at no lower than 10% of the feed system's capacity.

5.0.4 Chemical Information

The following information for each chemical shall be submitted:

1) Documentation that the chemical is NSF/ANSI Standard 60 or United States Pharmacopeia certified.

2) Specifications for the chemical.

3) Purpose of the chemical.

4) Proposed minimum non-zero, average and maximum dosages, solution strength or purity (as applicable), and specific gravity or bulk density.

5) Chemical feed calculations.

6) Chemical hazards class, if any, and regulatory workplace health/safety and chemical exposure standards listed in Safety Data Sheets (SDS).

5.1 Chemical Feed Equipment

5.1.1 Feeder Redundancy

1) Where a chemical feeder or booster pump is necessary for the protection of the supply, such as chlorination, coagulation, corrosion control, or other essential processes, a standby unit or a combination of units of sufficient size to meet capacity shall be provided to replace the largest unit when out of service, and the DEP may require that more than one be installed.

2) A separate feeder shall be used for each chemical applied.

3) Spare parts shall be available for all feeders to replace parts that are subject to wear and damage.

5.1.2 Control

1) Feeders may be manually or automatically controlled with automatic controls being designed to allow override by manual control.

2) Automatic chemical dosing controls or residual analyzers should provide:

   - Alarms for critical values.
   - Recording charts or a digital readout with computerized data recorder.

3) A means to measure water flow shall be provided to determine chemical feed rates.

4) Chemical feed rates shall be proportional to the rate of flow, especially where the water flow rate is not constant.

5) Provisions shall be made for measuring the quantities of chemicals used.

6) Weighing scales:

   - Shall be provided for weighing cylinders at all plants utilizing chlorine gas. The indicating and recording type are desirable.

   - Shall be required for fluoride solution fed from supply drums or carboys.

   - Should be provided for volumetric dry chemical feeders.

   - Shall be accurate to measure increments of 0.5 percent of load.

5.1.3 Dry Chemical Feed Systems

Dry chemical feed systems shall:

1) Completely enclose stored dry chemicals to prevent emission of dust to the operating room. Dry chemical storage silos and hoppers shall be designed to prevent chemical bridging and uncontrolled discharge. Hopper sidewall angle should be at least 60 degrees from the horizontal.

2) Measure chemicals volumetrically or gravimetrically.

    - Volumetric dry feeders - A vibrating bin with a screw-type conveyor shall not be used when dosing accuracy is a significant consideration.

    - Gravimetric dry feeders - Where ease of operation and accurate dosing are essential, gravimetric feeders shall be used.

3) Provide adequate solution water and agitation of the chemical in the solution pot.

    - When inorganic chemicals are used, the solubility of the chemical at lowest water temperature and at the maximum dosage rate should determine the size and water supply rate for a solution tank for a continuous dissolving system.

    - For dry polymers, the aging tank following the wetting tank and preceding the feed tank shall be sized to provide a 30-minute to 1-hour detention time.

5.1.4 Positive Displacement Solution Pumps

1) Positive displacement type solution feed pumps should be used to feed liquid chemicals, but shall not be used to feed chemical slurries.

2) Pumps must be capable of operating at the required maximum rate against the maximum head conditions found at the point of injection.

3) Calibration tubes or mass flow monitors which allow for direct physical measurement of actual feed rates should be provided.

4) A pressure relief valve should be provided on the pump discharge line.

5.1.5 Liquid Chemical Feed Systems

1) Liquid chemical feeders shall be such that chemical solutions cannot be siphoned or overfed into the water supply by ensuring discharge at a point of positive pressure or other suitable means or combinations as necessary.

2) A metering pump equipped with a calibration chamber shall be used in a liquid feeding system.

3) Chemical metering pumps should be equipped with a pulsation dampener (when pulsation-type pump is used), back pressure valve, pressure relief valve, and a pressure waterline to flush chemicals from the metering pump.

4) The pressure increase across the pump should be at least 10 to 20 psi.

5.1.6 Cross-Connection Control

Cross-connection control must be provided to ensure that:

1) The service water lines discharging to solution tanks shall be properly protected from backflow.

2) Liquid chemical solutions cannot be siphoned through solution feeders into the water supply.

3) No direct connection exists between any sewer and a drain or overflow from the feeder, solution chamber, or tank by providing that all drains terminate at least 6 inches or 2 pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit, or waste receptacle.

4) In the absence of other cross connection control measures, separate day tanks and feeders shall be provided for chemical feed systems that have feed points at both unfiltered and filtered water locations such that all unfiltered water feed points are fed from one-day tank and feeder, and that all filtered water feed points are fed from another day tank and feeder.

5.1.7 Chemical Feed Equipment Location

Chemical feed equipment shall:

1) Be located in a separate room to reduce hazards and dust problems.

2) Be conveniently located near points of application to minimize length of feed lines.

3) Be provided with protective curbings so that chemicals from equipment failure, spillage, or accidental drainage will not enter the water in conduits, treatment, or storage basins.

4) Be readily accessible for servicing, repair, and observation of operation.

5.1.8 Service Water Supply

1) In-plant water used for dissolving dry chemicals, diluting liquid chemicals, or operating chemical feeders shall be:

   - Only from finished water.
   - Protected from contamination by appropriate means.
   - Ample in supply and adequate in pressure.
   - Provided with means for measurement when preparing specific solution concentrations by dilution.
   - Properly treated for hardness when necessary.

2) Where a booster pump is required, duplicate equipment and, when necessary, standby power shall be provided. The standby power shall be capable of taking over with minimal delay in the event of a power outage in order to keep booster pumps in service.

3) Backflow prevention shall be achieved by appropriate means such as:

   - An air gap between fill pipe and maximum flow line of solution, or dissolving tank, equivalent to 2 pipe diameters but not less than 6 inches.
   - An approved reduced pressure zone backflow preventer, consistent with the degree of hazard, aggressiveness of chemical solution, back-pressure sustained, and available means for maintaining and testing the device.
   - A satisfactory vacuum release device.

5.1.9 Bulk Liquid Storage Tanks

1) A means which is consistent with the nature of the chemical solution shall be provided in a solution tank to maintain a uniform strength of solution. Continuous agitation shall be provided to maintain slurries in suspension.

2) Two solution tanks of adequate volume may be required for a chemical to ensure continuity of supply in servicing a solution tank.

3) Means shall be provided to measure the solution level in the tank.

4) Chemical solutions shall be kept covered. Large tanks with access openings shall have such openings curbed and fitted with overhanging covers.

5) Subsurface locations for solution tanks shall:

- Be free from sources of possible contamination.
- Ensure positive drainage for groundwater, accumulated water, chemical spills, and overflows.

6) Overflow pipes, when provided, shall:

- Be turned downward, with the end screened.
- Have a freefall discharge.
- Be located where noticeable.

7) Acid storage tanks must be vented to the outside atmosphere through separate dedicated vents.

8) Each tank shall be provided with a valved drain, protected against backflow in accordance with Sections 5.1.6 and 5.1.7.

9) Secondary containment volumes shall be provided and able to hold the volume of 110% of the largest storage tank.

10) Chemical feed piping shall be designed to minimize chemical spills in the event of pipe ruptures.

5.1.10 Day Tanks

1) Day tanks shall be provided where bulk storage of liquid chemical is provided.

2) Day tanks shall meet all the requirements of Section 5.1.9.

3) Day tanks should hold no more than a 30-hour supply based on average daily demand.

4) Day tanks shall be scale-mounted or have a calibrated gauge painted or mounted on the side if liquid level can be observed in a gauge tube or through translucent sidewalls of the tank. In opaque tanks, a gauge rod extending above a reference point at the top of the tank attached to a float may be used. The ratio of the area of the tank to its height must be such that unit readings are meaningful in relation to the total amount of chemical fed during a day.

5) Except for fluosilicic acid, hand pumps may be provided for transfer from a carboy or drum. A tip rack shall be used to permit withdrawal into a bucket from a spigot. Where motor-driven transfer pumps are provided, a liquid level limit switch and an overflow from the day tank must be provided.

6) A means which is consistent with the nature of the chemical solution shall be provided to maintain uniform strength of solution in a day tank. Continuous agitation shall be provided to maintain chemical slurries in suspension.

7) Tanks, and tank refilling line entry points, shall be properly labeled to designate the chemical contained.

8) Filling of day tanks shall not be automated, unless otherwise authorized by DEP.

9) Secondary containment volumes shall be provided and able to hold the volume of 110% of the largest storage tank.

5.1.11 Feed Lines

1) Feed lines shall be designed consistent with scale-forming or solids-depositing properties of the water, chemical, solution, or mixtures conveyed. Duplicate feed lines should be considered where blockages are likely.

2) Feed lines should be as short as possible and:

- Of durable, corrosion-resistant material.
- Easily accessible throughout the entire length.
- Protected against freezing.
- Readily cleanable.

3) Feed lines should slope upward from the chemical source to the feeder when conveying gases.

4) Feed lines shall be color coded (see Section 2.3.2).

5.2 Chemicals Storage and Handling

The handling, storage and use of chemicals requires careful attention (see Table 5.1). Consideration shall be given to methods of handling shipping containers, especially those containing compressed gases, oxidants, and corrosive materials. Height of ceilings for overhead hoists and floors of sufficient construction for ease in the handling of mechanical equipment should be provided. Storage and use areas shall be properly ventilated to minimize possible accidental reaction of chemicals involved based on their characteristics.

5.2.1 Chemical Storage and Handling Materials

Acceptable materials shall be used for storing/handling specific chemicals (see Table 5.x).

Table 5.x **Acceptable and Non-Acceptable Chemical Storage**		
Chemical	**Acceptable**	**Nonacceptable**
Calcium Hydroxide	Carbon Steel PVC 304 Stainless	Alumina Ceramic
Sodium Hydroxide 50% (Potassium Hydroxide)	Carbon Steel PVC 304 Stainless	Alumina Ceramic Viton
Sodium Carbonate	304 Stainless Hastelloy C Alumina Ceramic PVC	Carbon Steel
Sodium Bicarbonate	304 Stainless Hastelloy C Alumina Ceramic PVC	Carbon Steel
Sodium Silicate	304 Stainless Hastelloy C Alumina Ceramic PVC	Carbon Steel
Phosphoric Acid	Hastelloy C Alumina Ceramic PVC Kynar	Carbon Steel 304 and 316 Stainless Hypalon
Calcium Hypochlorite	Glass Rubber Stoneware Wood	All metals
Sodium Hypochlorite	Ceramics Glass Plastic Rubber	All metals

5.2.2 Quality

1) Chemical containers shall be fully labeled to include:

- Chemical name, purity, and concentration.
- Supplier’s name and address.
- Precautions in handling.

2) Chemicals shall meet AWWA specifications and/or ANSI/NSF Standard 60 where applicable, and all packaging shall be marked accordingly.

3) Provisions should be made to assay the chemicals delivered where the quality is in doubt.

4) Chemicals having a distinguishing color may be used, providing the coloring material is not toxic in concentrations used and will not impart taste, odor, or color to the finished water.

5.2.3 Storage

1) Space shall be provided for:

- A separate storage area for each chemical.
- At least 30 days of chemical supply.
- Convenient and efficient handling of chemicals.
- Dry storage conditions.
- A minimum storage volume of 1.5 truckloads where purchase is by truck load lots.

2) Storage tanks and pipelines for liquid chemicals shall be specific to the chemicals and not for alternates. Offloading areas must be clearly labeled to prevent accidental cross-contamination.

3) Chemicals shall be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved storage unit.

4) Liquid chemical storage tanks shall:

- Have a liquid level indicator.
- Have an overflow, a drain, and secondary containment that provides sufficient containment for 110% of the storage tank volume to prevent accidental discharge in the event of failure.

5) Solution storage or day tanks supplying feeders directly should have sufficient capacity for one day of operation.

6) Acid storage tanks should be vented to the outside atmosphere but not through vents in common day tanks.

5.2.4 Housing

In addition to the following general equipment requirements, facilities for housing specific chemicals shall be designed in accordance with the applicable requirements of Sections 5.3 and 5.4.

1) Structures, rooms, and areas accommodating chemical feed equipment shall provide convenient access for:

   - Servicing and repair.
   - Observation of operation.

2) Floor surfaces shall be smooth and impervious, slip-proof, and well drained.

3) Open basins, tanks, and conduits shall be protected from chemical spills or accidental drainage.

4) Vents from feeders, storage facilities, and equipment exhaust shall discharge to the outside atmosphere above grade and be located as not to contaminate fresh air intakes.

5.2.5 Handling

1) Carts, elevators, and other appropriate means shall be provided for lifting chemical containers to minimize excessive lifting by operators.

2) Provisions shall be made for disposing of empty bags, drums, or barrels by an approved procedure which will minimize exposure to dusts.

3) Provisions must be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers, in such ways as to minimize the quantity of dust which may enter the room in which the equipment is installed. Control should be provided by use of:

   - Vacuum pneumatic equipment or closed conveyor systems.

   - Facilities for emptying shipping containers in special enclosures.

   - Exhaust fans and dust filters which put the hoppers or bins under negative pressure.

4) Provisions shall be made for measuring quantities of chemicals used to prepare feed solutions.

5.3 Operator Safety

In addition to the following requirements, the AWWA's Manual M-3, Safety Management for Utilities should be used as a guide for operator safety.

5.3.1 Ventilation

Special provisions shall be made for ventilation of chemical feed and storage rooms. Exhaust systems must:

1) Not exhaust into fresh air intakes.

2) Not exhaust contaminants into areas where they may represent a hazard to employees.

3) Not draw contaminants through employee work areas.

4) Be in operation continually when needed.

5.3.2 Respiratory Protection Equipment

Respiratory protection equipment, meeting the requirements of NIOSH and MSHA shall be available where gases are handled, and shall be stored at a convenient location, but not inside any room where the gas is used or stored. The units shall use compressed air, have at least a 30-minute capacity, and be the same type of unit, or compatible with the units used by the fire department responsible for the plant. Respiratory equipment shall be inspected and maintained as per the manufacturer's recommendations.

5.3.3 Protective Equipment

1) At least 1 pair of rubber gloves, a dust respirator of a type certified by NIOSH or MSHA for toxic dusts, an apron or other protective clothing, and goggles or face mask shall be provided for each operator. A deluge shower and/or eye washing device should be installed where strong acids or alkalis are used or stored.

2) A water holding tank that will allow water to come to room temperature must be installed and connected to the water line feeding the deluge shower and eye washing device. Other methods of water tempering will be considered on an individual basis.

3) Other protective equipment should be provided as necessary.

4) Protective equipment shall be inspected and maintained or replaced at least quarterly. Maintenance records should be kept for at least one year.

5.3.4 Chlorine Leak Detection

A bottle of ammonium hydroxide, 56 percent ammonia solution, shall be available for chlorine leak detection. Where 150 lb. cylinders, ton containers, tank cars, and stationary storage tanks are used, a leak repair kit as approved by the Chlorine Institute, Inc. shall be provided. Continuous chlorine leak detection equipment is recommended. Where a leak detector is provided, it shall be equipped with both an audible alarm and a warning light. Masks and equipment should be tested at least annually.

5.4 Specific Chemicals

5.4.1 Acids and Caustics

1) Acids shall be kept in closed corrosion-resistant shipping containers or storage units.

2) Acids and caustics shall not be handled in open vessels, but should be pumped in undiluted form from original containers through a suitable hose to the point of treatment or to a covered day tank.

3) Systems designed to add strong acids or caustics shall include a flow sensor or a secondary mechanism to provide redundant controls that will ensure the acid or caustic will not be pumped into the system when there is inadequate water flow to provide dilution.

5.4.2 Activated Carbon

Activated carbon is a potentially combustible material requiring isolated storage. Storage facilities should be fire proof and equipped with explosion-proof electrical outlets, lights, and motors in areas of dry handling. Bags of powdered carbon should be stacked in rows with aisles between in such a manner that each bag is accessible for removal in case of fire.

5.4.3 Gas Chlorine

(Also see Section 4.1.1)

While neither explosive nor flammable in its elemental form, chlorine is capable of supporting combustion of other substances. Therefore, chlorine must be stored away from other compressed gases, organic matter, and other flammable material.

1) Chlorinators should be housed in a room separate from, but adjacent to, the chlorine storage room.

2) Both the chlorine gas feed and storage rooms should be located in a corner of the building on the prevailing downwind side of the building and be away from entrances, windows, louvers, walkways, etc.

3) Chlorinator rooms should be heated to 60ºF and be protected from excessive heat. Cylinders and gas lines should be protected from temperatures above that of the feed equipment.

4) Chlorine gas feed and storage shall be enclosed and separated from other operating areas. Both the feed and storage rooms shall be constructed to meet the following requirements:

- Provided with a clear, gas-tight, shatter-resistant inspection window installed in an interior wall to permit the chlorination system to be viewed without entering the room.

- Constructed in such a manner that all openings between the chlorine room and the remainder of the plant are sealed.

- Doors shall be equipped with panic hardware, assuring ready means of exit and opening outward only to the building exterior.

- Each room shall have a ventilating exhaust fan with a capacity to provide one complete air change per minute when the room is occupied.

- The ventilating exhaust fan shall take suction near the floor as far as practical from the door and air inlet. The point of discharge shall be located away from air inlets to any rooms or structures and designated walkway areas.

- Air inlets with corrosion resistant louvers shall be installed near the ceiling.

- Louvers for air intake and exhaust shall facilitate airtight closure.

- Separate switches for the ventilating exhaust fan and for the lights shall be located at each entrance to the chlorine room and at the inspection window. Outside switches shall be protected from vandalism. A signal light indicating fan operation shall be provided at each entrance when the fan can be controlled from more than one point.

- Vents from chlorinator and storage area(s) shall be located at ground level and discharge to the outside atmosphere, above grade, at a safe distance from the plant.

- Floor drains shall not be provided.

- Provisions must be made to chemically neutralize chlorine gas (or other acceptable measures as approved by DEP) in the event of any measured chlorine release. The chemical neutralizing equipment must be sized to treat the entire contents of the largest storage container on site.

5) Pressurized feed lines shall not carry chlorine gas beyond the chlorinator room.

6) Chlorine gas feed systems shall be of the vacuum type and include the following:

- Vacuum regulators on all individual cylinders in service.

- Service water to injectors/eductors shall be of adequate supply and pressure to operate feed equipment within the needed chlorine dosage range for the proposed system.

7) All chlorine gas feed lines located outside the chlorinator or storage rooms shall be installed in air tight conduit pipe.

8) Full and empty cylinders of chlorine gas shall be:

- Housed only in the chlorine storage room.
- Isolated from operating areas.
- Restrained in position to prevent upset.
- Stored in rooms separate from ammonia storage.
- Stored in areas not in direct sunlight or exposed to excessive heat.
- Stored with the hood connected.

5.4.4 Sodium Chlorite

Sodium chlorite is a strong oxidizing agent that can be ignited by friction, heat, shock or contamination with organic matter. Provisions shall be made for proper storage and handling the sodium chlorite to eliminate any danger of fire or explosion.

5.4.4.1 Storage

Sodium chlorite shall be stored by itself in a separate room and should be stored in an outside building detached from the water treatment facility. It shall be stored away from organic materials because many materials will catch fire and burn violently when in contact with sodium chlorite.

If combustible sodium chlorite is used, the storage structures shall be constructed of noncombustible materials. Adequate water to keep the sodium chlorite area cool enough to prevent heat induced explosive decomposition of the sodium chlorite shall be accessible.

5.4.4.2 Handling

1) Care should be taken to prevent spillage.

2) An emergency plan of operation shall be available for the cleanup of any spillage.

3) Storage drums must be thoroughly flushed to an acceptable drain prior to recycling or disposal.

5.4.4.3 Feeders

1) Positive displacement feeders shall be provided.

2) Tubing for conveying sodium chlorite or chlorine dioxide solutions shall be Type 1 PVC, polyethylene or materials recommended by the manufacturer.

3) Chemical feeders may be installed in chlorine rooms if sufficient space is provided or in separate rooms.

4) Feed lines shall be installed in a manner to prevent formation of gas pockets and shall terminate at a point of positive pressure.

5) Check valves shall be provided to prevent the backflow of chlorine into the sodium chlorite line.

5.4.5 Sodium Hypochlorite

Sodium hypochlorite storage and handling procedures should be arranged to minimize the slow natural decomposition process either by contamination or by exposure to more extreme storage conditions. In addition, feed rates should be regularly adjusted to compensate for this progressive loss in chlorine content.

5.4.5.1 Storage

1) Sodium hypochlorite shall be stored in the original shipping containers or in sodium hypochlorite compatible storage tanks.

2) Storage containers or tanks shall be sited out of the sunlight in a cool area and shall be vented to the outside of the building.

3) Wherever reasonably feasible, stored hypochlorite shall be pumped undiluted to the point of addition. Where dilution is unavoidable, deionized or softened water should be used.

4) Storage areas, tanks, and pipe work shall be designed to avoid the possibility of uncontrolled discharges and enough appropriately selected spill absorbent shall be stored on-site.

5) Reusable hypochlorite storage containers shall be reserved for use with hypochlorite only and shall not be rinsed out or otherwise exposed to internal contamination.

5.4.5.2 Feeders

1) Positive displacement pumps with hypochlorite compatible materials for wetted surfaces shall be used.

2) To avoid air-locking in smaller installations, small diameter suction lines shall be used with foot valves and degassing pump heads.

3) In larger installations, flooded suction shall be used with pipe work arranged to ease escape of gas bubbles.

4) Calibration tubes or mass flow monitors which allow for direct physical checking of actual feed rates shall be provided.

5) Injectors shall be made removable for regular cleaning where hard water is to be treated.

5.4.6 Calcium Hypochlorite

The storage of calcium hypochlorite is a major safety consideration. It should never be stored where it is subject to heating or allowed to contact any organic material of an easily oxidized nature. The decomposition of calcium hypochlorite is exothermic, and will proceed rapidly if any part of the material is heated to 350°F.

5.4.7 Ammonia

Ammonia for chloramine formation may be added to water as a water solution of ammonium sulfate, as aqua ammonia (ammonia gas in water solution), or as anhydrous ammonia (purified 100 percent ammonia in liquid or gaseous form). Protective equipment consisting of rubber gloves, an apron or similar clothing, goggles or face mask, deluge shower, and eye-washing device shall be provided. Special provisions required for each form of ammonia are listed below.

5.4.7.1 Ammonium Sulfate

A water solution is made by addition of ammonium sulfate solid to water with agitation.

1) The tank and dosing equipment contact surfaces should be made of corrosion-resistant nonmetallic materials.

2) Provision should be made for removal of the agitator after dissolving the solid.

3) The tank should be fitted with a lid and vented outdoors. Injection of the solution should take place in the center of treated water flow at a location where there is high velocity movement.

4) The application point should be at the center of treated water flow at a location where there is high velocity movement.

5.4.7.2 Aqua Ammonia (Ammonium Hydroxide)

1) Aqua ammonia feed pumps and storage shall be enclosed and separated from other operating areas.

2) A corrosion-resistant, closed, unpressurized tank shall be used for bulk storage, vented through an inert liquid trap to a high point outside, and an incompatible connector or lockout provisions shall be made to prevent accidental addition of other chemicals to the storage tank.

3) An incompatible connector or lockout provisions shall be provided to prevent accidental addition of other chemicals to the bulk liquid storage tank(s).

4) The bulk liquid storage tank(s) shall be designed to avoid conditions where temperature increases cause the ammonia vapor pressure over the aqua ammonia to exceed atmospheric pressure. Such provisions shall include either:

   - Refrigeration or other means of external cooling.

   - Dilution and mixing of the contents with water without opening the bulk liquid storage tank.

5) An exhaust fan shall be installed to withdraw air from high points in the room and make-up air shall be allowed to enter at a low point.

6) The aqua ammonia feed pump, regulators, and lines shall be fitted with pressure relief vents discharging outside the building away from any air intake and with water purge lines leading back to the headspace of the bulk storage tank.

7) The aqua ammonia shall be conveyed directly from storage to the treated water stream injector without the use of a carrier water stream unless the carrier stream is softened.

8) The point of delivery to the main water stream should be placed in a region of rapid, preferably turbulent, water flow.

9) Provisions should be made for easy access for removal of calcium scale deposits from the injector.

10) Provision of a modestly-sized scrubber capable of handling occasional minor emissions should be considered.

5.4.7.3 Anhydrous Ammonia

Anhydrous ammonia is readily available as a pure liquefied gas under moderate pressure in cylinders or as a cryogenic liquid boiling at -15ºC at atmospheric pressure. The liquid causes severe burns on skin contact.

1) Anhydrous ammonia and storage feed systems (including heaters where required) shall be enclosed and separated from other works areas and constructed of corrosion-resistant materials.

2) Pressurized ammonia feed lines should be restricted to the ammonia room.

3) An emergency air exhaust system, as in Section 5.3.1 but with an elevated intake, shall be provided in the ammonia storage room.

4) Automatic leak detection systems shall be provided in all areas through which ammonia is housed or piped. The alarms shall be both and audible and a warning light.

5) Special vacuum breaker/regulator provisions must be made to avoid potentially violent results of backflow of water into cylinders or storage tanks.

6) Carrier water systems of soft or presoftened water may be used to transport ammonia to the finished water stream and to assist in mixing.

7) The ammonia injector should use a vacuum eductor or should consist of a perforated tube fitted with a closely fitting flexible

rubber tubing seal punctured with a number of small slits to delay fouling by lime deposits.

8) Provisions should be made for the periodic removal of scale/lime deposits from injectors and carrier piping.

9) Consideration shall be given to the provision of an emergency gas scrubber capable of absorbing the entire contents of the largest ammonia storage unit whenever there is a risk to the public because of potential ammonia leaks.

10) Full and empty cylinders of ammonia shall be:

- Stored separately.
- Isolated from operating areas.
- Restrained in position.
- Stored in rooms separated from chlorine storage.
- Stored in areas not in direct sunlight or exposed to heat.

5.4.8 Potassium Permanganate

1) A source of heated water should be available for dissolving potassium permanganate.

2) Mechanical mixers shall be provided.

5.4.9 Fluoride

Prior to adding or removing fluoride, systems shall provide evidence that the affected public has been adequately notified of the community water supplier's proposal to provide or remove fluoridation and will be adequately notified prior to commencement of operation.

Notification may include, but is not limited to, items such as website posting, newspaper articles, or direct emails or postal mailings to each customer. Fluoridation proposals often receive serious consideration and generate considerable controversy and publicity. In these cases, public meetings or referendums should be held. These activities serve to provide notice to the customers, physicians, dentists, and other medical professionals that the water supplier is proposing to fluoridate. Such notices, public hearings, or referendums are considered adequate public notification prior to issuance of a construction permit. Proof of these notification shall be provided with the permit application.

Commercial sodium fluoride, sodium silicofluoride, and fluorosilicic acid shall conform to the applicable AWWA standards and ANSI/NSF Standard 60. The proposed method of fluoride feed shall be discussed with DEP prior to preparation of final plans and specifications.

5.4.9.1 Storage

1) Fluoride chemicals shall be isolated from other chemicals to prevent contamination.

2) Compounds shall be stored in covered or unopened shipping containers and should be stored inside a building.

3) Unsealed storage units for fluorosilicic acid should be vented to the atmosphere at a point outside any building. The vents to atmosphere shall be provided with a corrosion resistant 24 mesh screens.

4) Bags, fiber drums, and steel drums should be stored on pallets.

5.4.9.2 Chemical Feed Equipment and Methods

1) At least two diaphragm operated anti-siphon devices shall be provided on all fluoride saturator or fluorosilicic acid feed systems.

    - One diaphragm operated anti-siphon device shall be located on the discharge side of the feed pump.

    - A second diaphragm operated anti-siphon device shall be located at the point of application unless a suitable air gap is provided.

2) A physical break box may be required in high hazard situations where the application point is substantially lower than the metering pump. In this situation, either a dual head feed pump or two separate pumps are required and the anti-siphon device at the discharge side of the pump may be omitted.

3) Scales, loss-of-weight recorders, or liquid level indicators, as appropriate, accurate to within five percent of the average daily change in reading shall be provided for chemical feeds.

4) Feeders shall be accurate to within five percent of any desired feed rate.

5) Fluoride compound shall not be added before lime-soda softening or ion exchange softening. Fluoride compounds should be added after filtration to avoid losses which can be caused by pretreatment chemicals.

6) The point of application if into a horizontal pipe, shall be in the lower half of the pipe, preferably at a 45-degree angle from the

bottom of the pipe, and protrude into the pipe one third of the pipe diameter.

7) Except for constant flow systems, a device to measure the flow of water to be treated is required.

8) Water used for sodium fluoride dissolution shall be softened if hardness exceeds 50 mg/L as calcium carbonate.

9) Fluoride solutions shall be injected at a point of continuous positive pressure unless a suitable air gap is provided.

10) The electrical outlet used for the fluoride feed pump should have a nonstandard receptacle and shall be interconnected with the well or service pump or have flow pacing.

11) The fluoride feed pump shall be flow paced.

12) Saturators should be of the upflow type and be provided with a meter and backflow protection on the makeup water line.

13) Consideration shall be given to providing a separate room for fluorosilicic acid storage and feed.

5.4.9.3 Secondary Controls

Secondary control systems for fluoride chemical feed devices shall be provided as a means of reducing the possibility for overfeed; these may include flow or pressure switches, break boxes, or other devices.

5.4.9.4 Protective Equipment

Personal protective equipment as outlined in Section 5.3.3 shall be provided for operators handling fluoride compounds. Deluge showers and eye wash devices shall be provided at all fluorosilicic acid installations.

5.4.9.5 Dust Control

1) Provision must be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust which may enter the room in which the equipment is installed. The enclosure shall be provided with an exhaust fan and dust filter which places the hopper under a negative pressure. Air exhausted from fluoride handling equipment shall discharge through a dust filter to the outside atmosphere of the building.

2) Provision shall be made for disposing of empty bags, drums, or barrels in a manner which will minimize exposure to fluoride dusts. A floor drain should be provided to facilitate the washing of floors.

5.4.9.6 Testing Equipment

Equipment shall be provided for measuring the quantity of fluoride in the water. Testing equipment shall utilize an EPA accepted method and be equipped with a digital display. The testing equipment should be of the colorimetric or electrode-type and shall be subject to DEP approval.

6 PUMPING FACILITIES

6.0 Design

Pumping facilities shall be designed to maintain the sanitary quality of pumped water. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pump station shall be subject to flooding.

6.1 Location

The pumping station shall be located so that the proposed site will meet the requirements for sanitary protection of water quality, hydraulics of the system, and protection against interruption of service by fire, flood, or any other hazard.

6.1.1 Site Protection

The station shall be:

1) Elevated to a minimum of 3 feet above the 100-year floodplain elevation or 3 feet above the highest recorded flood level, whichever is higher, or protected to such elevations.

2) Readily accessible at all times unless permitted to be out-of-service for the period of inaccessibility.

3) Graded around the station to lead surface drainage away from the station.

4) The pump station shall be located within a secure area such as a locked building or fenced area.

5) Labeled such that the pumps and valves in the station are tagged to correspond to the maintenance record and for proper identification.

6.2 Pumping Stations

Both raw and finished water pumping stations shall:

1) Have adequate space for the installation of additional units, if needed, and for the safe servicing of all equipment.

2) Be of durable construction, fire, and weather resistant and with outward-opening doors. The use of tamper-proof hinges is recommended at remote locations.

3) Have floor elevation of at least 6 inches above finished grade.

4) Have all floors drained in such a manner that the quality of the potable water will not be endangered. All floors shall slope at least 3 inches for every 10 feet to a suitable drain.

5) Provide a suitable outlet for drainage without allowing discharge across the floor, including pumping glands, vacuum air relief valves, etc.

6.2.1 Suction Well

Suction wells shall:

1) Be watertight.

2) Have floors sloped to permit removal of water and settled solids.

3) Be covered and protected against contamination, including pump lubricants.

4) Have two pumping compartments or other means to allow the suction well to be taken out of service for inspection maintenance or repair.

6.2.2 Equipment Servicing

Pump stations shall be provided with:

1) Craneways, hoist beams, eye bolts or other adequate facilities for servicing or removal of pumps, motors, or other heavy equipment.

2) Openings in floors, roofs, or wherever else is needed for removal of heavy or bulky equipment.

3) A convenient tool board or other facilities as needed for proper maintenance of the equipment.

4) Walkways for servicing or lubricating points of equipment if these are located at intermediate points between floors.

6.2.3 Stairways and Ladders

Stairways and ladders are preferred in areas where there is frequent traffic or where supplies are transported by hand. All materials should be rust and corrosion resistant. They shall have risers not exceeding 9 inches and treads for safety. Where ladders are used, intermediate landings should be provided if the vertical distance exceeds 10 feet.

Stairways and ladders shall:

1) Be provided between all floors and in pits or compartments which must be entered.

2) Have handrails on both sides with treads of nonslip material.

3) Conform to the requirements of the Uniform Building Code or relevant state and/or local codes.

6.2.4 Heating

Enough heat shall be provided to prevent freezing of equipment and to allow proper operation and servicing of equipment and treatment processes.

6.2.5 Ventilation

Ventilation shall conform to existing local and/or state codes. Adequate ventilation shall be provided for all pump stations for operator comfort and dissipation of excess heat from the equipment. Switches for operation of ventilation equipment should be conveniently located, marked, and protected from vandalism, where appropriate.

Forced ventilation of at least 6 changes of air per hour shall be provided for:

1) All rooms, compartments, pits, and other enclosures below ground level.

2) Any area where unsafe atmosphere may develop or where excessive heat may be built up.

6.2.6 Dehumidification

In areas where excess moisture could cause hazards to safety or damage to equipment, means for dehumidification shall be provided.

6.2.7 Lighting

Pump stations shall be adequately lighted throughout. All electrical work shall conform to the requirements of the National Electric Code or related agencies and to the relevant state and/or local codes.

6.2.8 Sanitary and Other Conveniences

All pumping stations that are manned for extended periods should be provided with potable water, lavatory, and toilet facilities. Plumbing must be installed to prevent contamination of a public water supply. Wastes shall be discharged in accordance with Section 9.

6.3 Pumps

At least 2 pumping units shall be provided. With any pump out-of-service, the remaining pump or pumps shall be capable of providing the maximum daily pumping demand of the system.

The pumping units shall:

1) Have ample capacity to supply the peak demand without dangerous overloading.

2) Be driven by a prime mover able to meet the maximum horsepower requirements of the pump.

3) Have spare parts and tools readily available.

4) Be served by control equipment that has proper heat and overload protection for air temperatures encountered.

6.3.1 Suction Lift

Suction lift shall:

1) Be avoided, if possible.
2) Be within allowable limits, preferably less than 15 feet.

If suction lift is necessary, provisions shall be made for priming the pumps. Water level sensors should be considered to prevent pump operation when the suction well is dry.

6.3.2 Priming

Prime water must not be of lesser sanitary quality than that of the water being pumped. Means shall be provided to prevent back-siphonage. When an air-operated ejector is used, the screened intake shall draw clean air from a point at least 10 feet above the ground or other source of possible contamination unless the air is filtered by an apparatus approved by DEP. Vacuum priming may be used. Priming water sensors should be installed to prevent the operation of a pump if it is unprimed.

6.3.3 Submersible Pumps

See Section 3.5.

6.4 Booster Pumps

6.4.1 Distribution System Booster Pumps

1) Booster pumps shall be located and controlled so that they will not produce negative pressure in their suction lines.

2) Pumps installed in the distribution system shall maintain inlet pressure as required in Section 8.2.1 under all operating conditions. Pumps taking suction from storage tanks shall be provided adequate net positive suction head.

3) Automatic shutoff or low-pressure controller shall maintain at least 20 psi in the suction line under all operating conditions, unless otherwise acceptable to DEP. Pumps taking suction from ground storage tanks shall be equipped with automatic shutoffs or low-pressure controllers as recommended by the pump manufacturer.

4) Automatic or remote-control devices shall have a range between the start and cutoff pressure which will prevent excessive cycling.

5) A bypass shall be provided.

6) At least 2 pumping units shall be provided. With any pump out-of-service, the remaining pump or pumps shall be capable of providing the maximum daily pumping demand of the system.

7) All booster pumping stations shall be fitted with a flow rate and totalizer meter.

6.4.2 Individual Residential Booster Pumps

Private booster pumps shall:

1) Have adequate backflow prevention.

2) Have adequate suction supply.

3) Have adequate size to provide the necessary volume of water at the required pressures.

6.5 Automatic and Remote-Controlled Stations

All automatic stations should be provided with an automatic signaling apparatus which will report when the station is out-of-service. All remote-controlled stations shall be electrically operated and controlled and shall have signaling apparatus of proven performance. Installation of electrical equipment shall conform with the applicable state and local electrical codes and the National Electrical Code.

6.6 Appurtenances

6.6.1 Valves

Pumps shall be adequately valved to permit satisfactory operation, maintenance, and repair of the equipment. If foot valves are necessary, they shall have a net valve area of at least 2.5 times the area of the suction pipe and they shall be screened. Each pump shall have a positive-acting check valve on the discharge side between the pump and the shutoff valve. Surge relief valves or slow acting check valves shall be designed to minimize hydraulic transients.

6.6.2 Piping

In general, piping shall:

1) Be designed so that the friction losses will be minimized.

2) Not be subject to contamination.

3) Be sloped in one direction to drains.

4) Have watertight joints.

5) Have adequate cleanouts.

6) Be protected against surge or water hammer and provided with suitable restraints where necessary.

7) Be such that each pump has an individual suction line or that the lines shall be manifolded so that they will ensure similar hydraulic and operating conditions.

8) Be protected against freezing.

6.6.3 Gauges and Meters

Each pump shall have:

1) A standard pressure gauge on its discharge line.
2) A compound gauge on its suction line.
3) A recording gauge in the larger stations.
4) A means for measuring the discharge.

6.6.4 Water Seals

Water seals shall not be supplied with water of a lesser sanitary quality than that of the water being pumped. Where pumps are sealed with potable water and are pumping water of lesser sanitary quality, the seal supply line shall:

1) Be provided with either an approved reduced pressure principle backflow preventer or a break tank open to atmospheric pressure.

2) Have an air gap of at least 6 inches or 2 pipe diameters, whichever is greater, between the feeder line and the spill line of the tank.

6.6.5 Controls

Pumps, their prime movers, and accessories shall be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provisions shall be made for alternate operation. Provisions shall be made to prevent energizing the motor in the event of a backspin cycle. Electrical controls shall be located above grade. Protection against low voltages, power surges, and phase failure also shall be provided.

6.6.6 Power

All pumping stations shall be provided with an auxiliary source of power. Consideration must be given to fire flow needs and the station's vulnerability to flooding. Power supply shall be available from at least two independent sources. For safety purposes, adequate warning regarding air quality and other hazardous conditions that may exist within the pumping facility should be posted on all entrance ways.

6.6.7 Water Prelubrication

When automatic prelubrication of pump bearings is necessary and an auxiliary direct drive power supply is provided, the prelubrication line shall be provided with a valved bypass around the automatic control so that the bearings can, if necessary, be lubricated manually before the pump is started or the prelubrication controls shall be wired to the auxiliary power supply.

6.6.8 Oil or Grease Lubrication

All lubricants which come into contact with the potable water shall be acceptable to the Department. Chemicals which are certified for conformance with ANSI/NSF Standard 60, or meet the food grade standards of the United States Pharmacopeia, are deemed acceptable to the Department.

6.7 Cross-Connections/Interconnections

There shall not be, at any point in the pumping station, any cross-connection or interconnection between a potable water supply, and any supply which has not been approved by DEP. Steam engine exhaust shall not be returned, nor shall the cooling water from engine jackets or any other heat-exchange devices be returned to the potable supply. No plumbing fixtures or devices shall be installed which will provide interconnection or make possible the backflow of sewage or wastes into the water supply system.

7 FINISHED WATER STORAGE

7.0 Design and Construction

The materials and designs used for finished water storage structures shall provide stability and durability as well as protect the quality of the stored water. Structures shall comply with the current editions of the AWWA standards concerning storage tanks, standpipes, reservoirs, clearwells, and elevated tanks wherever they are applicable. Other materials of construction are acceptable when properly designed to meet the requirements of this section.

7.0.1 Sizing

1) Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands, and where fire protection is provided, fire flow demands.

2) Fire flow requirements established by the Insurance Services Office shall be satisfied where fire protection is provided.

3) The minimum storage capacity (or equivalent capacity) for systems not providing fire protection shall be equal to 1 day's average consumption. This requirement may be reduced when the source and treatment facilities have sufficient capacity with standby power to supplement peak demands of the system.

4) Excessive storage capacity should be avoided to prevent potential water quality deterioration problems. Storage structures shall be designed to be able to maintain a turnover time (or water age) of 5 days or less.

7.0.2 Location of Water Storage Structures

1) Consideration should be given to maintaining water quality when locating water storage facilities.

2) The lowest elevation of the floor and sump floor of ground level storage structures shall be placed above the 100-year flood elevation or the highest flood of record, whichever is higher, and at least two feet above the groundwater table. Sewers, drains, standing water, and similar sources of possible contamination must be kept at least 50 feet from the storage structure. Gravity sewers constructed of water main quality pipe, pressure tested in place without leakage, may be used at distances of less than 50 feet, but greater than 20 feet.

3) The bottom of ground level storage structures should be placed at or near the normal ground surface. If the bottom of a storage structure must be below the normal ground surface, adequate provisions shall be made to protect the structure from hydrostatic uplift forces and at least 50 percent of the water depth must be above grade. The top of a partially buried storage structure

shall not be less than two feet above normal ground surface. Clearwells constructed under filters may be exempted from this requirement when the design provides adequate protection from contamination. Adequate protection shall include waterproofing the tank below grade; flexible membrane materials meeting the requirements of AWWA D130 and/or concrete admixtures may be considered as possible waterproofing alternatives. Gravity underdrains to capture surface water runoff may be considered, providing that pumping of the drainage water will not be required and underdrains discharge to daylight.

7.0.3 Protection from Contamination

All finished water storage structures shall have suitable watertight roofs which exclude birds, animals, insects and excessive dust. The installation of appurtenances, such as antenna, shall be done in a manner that ensures no damage to the tank, coatings, or water quality, or corrects any damage that occurred.

7.0.4 Security

Fencing, locks on access manholes or external ladders, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage. High strength, cut-resistant locks, or lock covers to prevent direct cutting of a lock should be provided.

7.0.5 Drains

If a gravity drain is provided, an air gap must be maintained at the outlet. No drain on a water storage structure shall have a direct connection to a sewer or storm drain. The design shall allow draining the storage facility for cleaning or maintenance without causing loss of pressure in the distribution system.

The drain shall have a solid flapper or duckbill valve. If a solid flapper is used, a 24-mesh noncorrodible screen shall be provided. The screen shall be installed within the overflow pipe at a location least susceptible to damage by vandalism. A mesh-fitted mechanical flap valve is acceptable provided the flapper is supplied with non-corroding and non-seizing hinges. The flap valve shall be spring loaded or counterweighted so it closes and forms a tight seal after the overflow event. If a duckbill valve is used, a screen is not required.

7.0.6 Overflow

1) All water storage structures shall be provided with an overflow which is brought down to an elevation between 12 and 24 inches above the ground surface and discharges over a drainage inlet structure or a splash plate.

2) No overflow may be connected directly to a sewer or a storm drain. All overflow pipes shall be located so that any discharge is visible. Disposal of

overflow water must be consistent with the requirements of the Clean Streams Law (CSL).

3) When an internal overflow pipe is used on elevated tanks, it should be located in the access tube. For vertical drops on other types of storage facilities, the overflow pipe should be located on the outside of the structure.

4) The overflow shall open downward and shall have a solid flapper or duckbill valve. If a solid flapper is used, a 24-mesh noncorrodible screen shall be provided. The screen shall be installed within the overflow pipe at a location least susceptible to damage by vandalism. A mesh-fitted mechanical flap valve is acceptable provided the flapper is supplied with non-corroding and non-seizing hinges. The flap valve shall be spring loaded or counterweighted so it closes and forms a tight seal after the overflow event. If a duckbill valve is used, a screen is not required.

5) The overflow pipe shall be of sufficient diameter to allow overflow of water in excess of the maximum filling rate.

7.0.7 Access

Finished water storage structures shall be designed with reasonably convenient access to the interior for cleaning and maintenance. At least 2 manholes shall be provided above the waterline at each compartment where space permits.

7.0.7.1 Elevated Storage Structures

1) At least one of the access manholes shall be framed at least 4 inches above the surface of the roof at the opening. They shall be fitted with a solid watertight cover which overlaps the framed opening and extends down around the frame at least 2 inches, shall be hinged on one side, and shall have a locking device.

2) All other manholes or access ways shall be bolted and gasketed according to the requirements of the DEP.

7.0.7.2 Ground Level Structures

1) Each manhole shall be elevated at least 24 inches above the top of the tank or covering sod, whichever is higher.

2) Each access manhole shall be fitted with a solid watertight cover which overlaps a framed opening and extends down around the frame at least 2 inches. The frame shall be at least 4 inches high. Each cover shall be hinged on one side and shall have a locking device.

7.0.8 Vents

Finished water storage structures shall be vented. The overflow pipe shall not be considered a vent. Open construction between the sidewall and roof is not permissible. Vents:

1) Shall prevent the entrance of surface water and rain water.

2) Shall exclude birds and other animals.

3) Should exclude insects and dust, as much as this function can be made compatible with effective venting.

4) Shall, on ground level structures, open downward with the opening at least 24 inches above the roof or sod and be covered with a 24-mesh noncorrodible screen. The screen shall be installed within the pipe at a location least susceptible to vandalism.

5) Shall, on elevated tanks and standpipes, open downward, and be fitted with a 24-mesh noncorrodible screen in combination with an automatically resetting pressure-vacuum relief mechanism.

6) Shall be located and sized to avoid blockage during winter conditions.

7.0.9 Roof and Sidewall

The roof and sidewalls of all water storage structures must be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow. Attention shall be given to the sealing of roof structures which are not integral to the tank body including access tubes.

1) Any pipe running through the roof or sidewall of a metal storage tank must be welded or properly gasketed. In concrete tanks, these pipes shall be connected to standard wall castings which were poured in place during the forming of the concrete. These wall castings should have seepage rings imbedded in the concrete.

2) Openings in the roof of a storage structure, designed to accommodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent contamination from surface or floor drainage water.

3) Valves and controls should be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir.

4) The roof of the storage structure shall be sloped to facilitate drainage. Downspout pipes and drains from access hatches shall not enter or pass through the reservoir. Parapets, or similar construction which would tend to hold water and snow on the roof, will not be approved unless adequate waterproofing and drainage are provided.

5) For reservoirs with concrete roofs, if a minimum slope of 1.5 percent is not provided, reservoir roofs must be made watertight with the use of a waterproof membrane or similar product.

6) When earthen cover is used on concrete reservoirs, it shall be sloped to facilitate drainage.

7.0.10 Construction Materials

The material used in construction of reservoirs shall be acceptable to DEP. Porous materials, including wood and concrete block, are not suitable for potable water contact applications.

7.0.11 Safety

Safety must be considered in the design of a storage structure. The design shall conform to pertinent laws and regulations of the area where the water storage structure is constructed.

1) Ladders, ladder guards, balcony railings, and safely located entrance hatches shall be provided. Access to roof hatches and vents shall be provided. When a fixed ladder is used, the bottom shall be located at least 12 feet above ground (refer to OSHA standard) to prevent the entrance of unauthorized personnel.

2) Ladders having an unbroken length in excess of 20 feet should be provided with appropriate safety devices. This requirement applies both to interior and exterior reservoir ladders.

3) Elevated tanks with riser pipes over 8 inches in diameter shall have protective bars over the riser opening inside the tank.

4) Railings or handholds shall be provided on elevated tanks where persons must transfer from the access tube to the water compartment. Fall protection shall be provided in accordance with OSHA standards.

7.0.12 Freezing

Finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents, shall be designed to prevent freezing which will interfere with proper function. Equipment used for freeze protection that will come into contact with the potable water shall meet ANSI/NSF Standard 61 or be approved by DEP. If a water circulation system is used, it is recommended that the circulation pipe be located separately from the riser pipe.

7.0.13 Internal Catwalk

Every catwalk over finished water in a storage structure shall have a solid floor with sealed raised edges designed to prevent contamination from shoe scrapings and dirt.

7.0.14 Prevention of Internal Contamination

The internal superstructure (i.e., rafters, ridgepole) or other facilities as covered in Sections 7.0.11 and 7.0.13 shall not be constructed of materials treated with any chemical which is toxic or can otherwise degrade the quality of the finished drinking water.

7.0.15 Silt Stop

Effluent pipes from all storage structures shall be located in a manner that will prevent the flow of sediment into the distribution system. Removable silt stops should be provided.

7.0.16 Grading

The area surrounding a ground level structure shall be graded in a manner that will prevent surface water from standing within 50 feet of it.

7.0.17 Liners and Flexible Covers

Where liners or flexible covers are proposed, they shall be of a material acceptable to DEP. Careful attention must be given to the chemical characteristics of the adhesive or bonding material, if used, to ensure that no toxic contaminants are imparted to the stored water. DEP shall be consulted prior to the installation or use of any materials of unknown or questionable characteristics.

7.0.18 Painting and/or Cathodic Protection

Proper protection shall be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.

1) Paint systems shall meet ANSI/NSF Standard 61 and be acceptable to DEP. Interior paint must be applied, cured, and used in a manner consistent with the ANSI/NSF approval. After curing, the coating shall not transfer any substance to the water which will be toxic or cause taste or odor problems. Prior to placing in service, an analysis for VOCs is advisable to establish that the coating is properly cured. Consideration should be given to 100 percent solids coatings.

2) Storage tank exteriors should be painted with a light-colored paint that will minimize water temperature increases from sun light.

3) Wax coatings for the tank interior shall not be used on new tanks. Recoating with a wax system is strongly discouraged. Old wax coatings must be completely removed before using another tank coating.

4) Cathodic protection should be designed and installed by competent technical personnel and a maintenance contract should be provided.

7.0.19 Disinfection

1) All new, cleaned, repaired or repainted steel tanks, standpipes, reservoirs, and elevated tanks used for finished water shall be disinfected in accordance with the current addition of AWWA's Standard C652 for Disinfection of Water Storage Facilities. Two or more successive sets of samples taken at 24-hour intervals shall indicate microbiologically satisfactory water before the facility is placed into operation.

2) The disinfection procedure specified in AWWA Standard C652 Chlorination Method 3, which allows use of the highly chlorinated water held in the storage tank for disinfection purposes, is not recommended. The chlorinated water may contain various disinfection by-products which should be kept out of the distribution system. If this procedure is used, it is recommended that the initial heavily chlorinated water be neutralized and discharged to waste.

3) Disposal of heavily chlorinated water from the tank disinfection process shall be in accordance with 25 Pa. Code § 92a.

7.1 Treatment Plant Storage

The applicable design standards of this section shall be followed for plant storage.

7.1.1 Filter Wash Water Tanks

Filter wash water tanks shall be sized, in conjunction with available pump units and finished water storage, to provide the backwash water required by Sections 4.3.1.12. Consideration must be given to the backwashing of several filters in rapid succession.

7.1.2 Clearwell

1) Clearwell storage shall be sized to allow the filters to operate at a constant rate.

2) Clearwells shall be sized to provide required disinfection contact time. Special attention must be given to the minimum water height, the flow existing the clearwell, and the baffling.

3) Clearwells shall be designed as plug flow. For rectangular facilities, longitudinal baffling with a length to width ratio below 50 and the use of turning vanes (180º turns) provide the most effective baffling.

4) Finished water storage should not be used to provide disinfection contact time.

5) Clearwells also should be designed so that 50 percent of the clearwell can be isolated for routine cleaning, inspection and maintenance. An overflow and vent shall be provided.

6) A minimum of two clearwell compartments shall be provided.

7.1.3 Adjacent Storage

Finished or treated water shall not be stored or conveyed in a compartment adjacent to or below an untreated or partially treated water compartment when only a single wall or floor separates the two.

7.1.4 Other Treatment Plant Storage Tanks

Treatment plant storage tanks/basins such as detention basins, backwash recycle tanks, receiving basins, and pump wet wells shall be designed as finished water storage structures. Tanks are exempted from this requirement if they contain water that will receive full treatment for which the plant is designed, such as a pre-sedimentation basin at a surface water treatment plant, or water that will not be returned to the treatment process and is separated from the treatment plant by appropriate cross-connection control measures.

7.2 Hydropneumatic Systems

Hydropneumatic (pressure) tanks, when provided as the only water storage, are acceptable only in smaller water systems. For systems serving more than 50 homes, ground or elevated storage should be designed in accordance with Section 7.0. Hydropneumatic tank storage is not permitted for fire protection purposes. Pressure tanks shall meet American Society of Mechanical Engineers (ASME) code requirements or an equivalent requirement of state and local laws and regulations for the construction and installation of unfired pressure vessels. Non-ASME factory-built hydropneumatic tanks may be allowed if approved by DEP.

7.2.1 Disinfection Contact Time

Hydropneumatic tanks shall not be is used to provide disinfection contact time.

7.2.2 Location

1) The tank shall be located above normal ground surface and be completely housed.

2) Hydropneumatic tanks should be located after all the required chlorine contact time is achieved.

7.2.3 System Sizing

1) The capacity of the wells and pumps in a hydropneumatic system shall be at least ten times the average daily consumption rate.

2) The gross volume of the hydropneumatic tank, in gallons, should be at least 10 times the capacity of the largest pump, rated in gpm, unless other measures (e.g., variable speed drives in conjunction with the pump motors) are provided to meet the maximum demand.

7.2.4 Piping

The hydropneumatic tank(s) shall have bypass piping to permit operation of the system while the tank is being repaired or painted.

7.2.5 Appurtenances

Each tank shall have a drain and control equipment consisting of a pressure gauge, water sight glass, automatic or manual air blow-off, means for adding air, and pressure operated start-stop controls for the pumps. A pressure relief valve shall be installed and be capable of handling the full pumping rate of flow at the pressure vessel design limit. Where practical, there shall be an access manhole measuring 24 inches in diameter.

7.3 Finished Water Storage

The applicable design standards of Section 7.0 shall be followed for finished water storage. Finished water storage facilities shall not be used to provide chlorine contact time. Finished water storage facilities shall be designed with the ability to be removed from serves for cleaning and inspection.

7.3.1 Pressures

The maximum variation between high and low levels in storage structures providing pressure to a distribution system should not exceed 30 feet. The minimum working pressure in the distribution system shall be 35 psig and a normal working pressure should be approximately 60 to 80 psig. When static pressures exceed 100 psig, pressure reducing devices shall be provided on mains or as part of the meter setting on individual service lines in the distribution system.

7.3.2 Drainage

Finished water storage structures which provide pressure directly to the distribution system shall be designed so they can be isolated from the distribution system and drained for cleaning or maintenance without causing a loss of pressure in the distribution system. Drains shall discharge to the ground surface with no direct connection to a sewer or storm drain. Disposal of drainage water shall be in accordance with DEP Clean Water Program requirements.

7.3.3 Level Controls

Adequate controls shall be provided to maintain levels in distribution system storage structures. Level indicating devices should be provided at a central location.

1) Pumps should be controlled from tank levels with the signal transmitted by telemetering equipment when any appreciable head loss occurs in the distribution system between the source and the storage structure.

2) Altitude valves or equivalent controls may be required for a second and subsequent structure on the system.

3) Overflow and low-level warnings or alarms should be located where they will be under responsible surveillance 24 hours a day.

7.3.4 Stored Water Turnover/Age

Water quality degradation in distribution system storage facilities, such as loss of disinfectant residual, microbial growth, formation of disinfection byproducts, nitrification, and taste and odor problems, result from incomplete mixing, or high-water-age, or a combination of both. Distribution system storage facilities shall be designed to eliminate short-circuiting and stratification and achieve adequate mixing.

1) Separate inlet/outlet pipe shall be provided.

2) Finished water storage shall be designed to facilitate fire flow and pressure requirements and meet average daily demand while maximizing daily volume turnover to minimize water age.

3) Storage structures shall be designed to ensure the turnover time is less than or equal to 5 days or an alternative turnover rate must be establish based on water quality, environmental conditions, retention of fire flow, demand management, velocity of influent water, and operational level changes.

7.3.5 Passive Mixing

Finished water storage facilities shall be designed as mixed flow. Incomplete mixing of finished water storage can cause loss of disinfectant residual, disinfection byproduct formation, bacteria formation, variance in pH and dissolved oxygen, taste and odor problems, biofilm growth, and nitrification in chloraminated systems.

1) If the height of a storage facility is larger than the diameter, the inlet pipe should be in vertical direction. If the diameter of a storage facility is larger

than the height, the inlet pipe should be in horizontal direction (i.e., the inlet flow should be placed where it will have the longest flow path).

2) The inlet diameter should be minimized to maximize inlet velocity. Multiple smaller inlets should not be considered.

3) Deflectors on inlets, tangential inlets, inlets into sumps, or wall side and inlets discharging above the water surface should not be provided.

4) Baffling should not be provided.

5) Finished water storage should be designed to have long drawdown and fill cycles to increase mixing. Multiple smaller tanks should be considered over larger tanks.

7.3.6 Mechanical Mixing

This pertains to in-tank mixers and in-tank aeration units that are being installed to maintain or improve finished water quality.

1) All equipment materials being placed inside the tank and headspace, including a power cable, shall have ANI/NSF Standard 61 certification.

2) All penetrations shall be properly sealed and water tight. All power or air lines shall penetrate the facility above the maximum water height in the storage facility.

3) Installed equipment shall have the capability to function continuously on a year-round basis. Aeration units should have the ability to stop/resume operation based on total trihalomethanes (TTHM) levels, as well as based on water level changes. Generally, it is recommended that aeration units not be operated during the winter months

4) For the proposed in-tank mixer model and configuration, the manufacturer shall provide, at a minimum, data from laboratory-scale and/or full-scale representative systems which demonstrates the equipment's capability to produce fully mixed conditions.

7.4 Comprehensive Inspection Plan

PWS should develop a comprehensive plan to routinely inspect the internal and external components of each storage structure. The inspection should identify sanitary, structural, and coating defects as well as security and safety matters. The plan should include a maintenance history log and a checklist of critical components including but limited to:

- Overall Condition
- Drain
- Overflow

- Hatch
- Vent
- Paint
- Cleaning Needs
- Security Concerns

8 DISTRIBUTION SYSTEMS

8.0 General

Water distribution systems shall be designed to maintain treated water quality. Special consideration should be given to distribution main sizing, providing for multidirectional flow, adequate valving for distribution system control, and provisions for adequate flushing. Systems should be designed to maximize turnover and to minimize residence times while delivering acceptable pressures and flows.

8.1 Materials

8.1.1 Standards, Materials Selection

1) All materials, including pipe, fittings, valves, fire hydrants, and those for the rehabilitation of water mains shall conform to the latest standards (where such standards exist) issued by AWWA, ANSI/NSF, American Standards Association, and/or ASTM and be acceptable to DEP.

2) All plastic pipes for potable water use also must be approved by NSF and bear the logo "NSF-pw" indicating such approval. DEP may approve materials for which there are no accepted standards provided acceptable supporting information is provided.

3) Special attention shall be given to selecting pipe materials which will protect against both internal and external pipe corrosion.

8.1.2 Permeation by Organic Compounds

Where distribution systems are installed in areas of groundwater contaminated by organic compounds, materials which do not allow permeation of the organic compounds shall be used for all portions of the system, including pipe, joint materials, hydrant leads, and service connections.

8.1.3 Re-Use of Materials

Water mains and appurtenances which have been used previously for conveying potable water may be reused provided they comply with all applicable parts of this section and have been restored practically to their original condition.

8.1.4 Joints

Packing and jointing materials used in the joints of pipe shall meet the standards of the AWWA. Pipe with mechanical joints or slip-on joints with resilient gaskets is preferred. Gaskets containing lead shall not be used. Lead joints should be replaced in lieu of repair. Manufacturer approved transition joints shall be used between dissimilar piping materials.

8.2 System Design

8.2.1 Pressure

All water mains, including those not designed to provide fire protection, shall be sized after a hydraulic analysis based on flow demands and pressure requirements. The pipe system and its appurtenances shall be designed to maintain a minimum pressure of 20 psig at ground level at all points in the distribution system under all conditions of flow. The normal working pressure in the distribution system shall be at least 35 psi and should be approximately 60 to 80 psig at ground level.

8.2.2 Diameter

The minimum size of water main which provides for fire protection and serving fire hydrants shall be 6-inches in diameter. Larger sized mains will be required if necessary to allow the withdrawal of the required fire flow while maintaining the minimum residual pressure of 20 psig.

The minimum size of water main in the distribution system where fire protection is not to be provided shall be a minimum of 3-inch diameter. Any departure from minimum requirements shall be justified by hydraulic analysis and future water use and can be considered only in special circumstances.

8.2.3 Fire Protection

When fire protection is to be provided, system design should be such that fire flows and facilities are in accordance with the requirements of the State Insurance Services Office.

8.2.4 Dead Ends

Dead ends shall be minimized by looping all mains whenever practical to provide increased reliability of service and reduce head loss. Where dead end lines are necessary in the first stage of construction of a distribution system, the lines shall be provided with the appropriate flushing devices as outlined in Section 8.2.5.

8.2.5 Flushing

Where dead end mains occur, they shall be provided with an approved blow-off or flushing hydrant for flushing purposes. Flushing devices should be sized to provide flows which will give a velocity of at least 2.5 feet per second in the water main being flushed. Fire hydrants may be used for this purpose provided they comply with all of DEP’s requirements on fire hydrant installation. No flushing device shall be directly connected to any sewer.

8.2.6 Shut-Off Valves

Enough valves shall be provided on water mains to minimize inconvenience and sanitary hazards during repairs. Valves should be located at not more than 500-foot intervals in commercial districts and at not more than one block, or 800-foot intervals, in other areas of the distribution system. Where systems serve widely scattered customers and where future development is not expected, the valve spacing should not exceed one mile.

8.3 Hydrants

Where freezing temperatures prevail, hydrants of the dry barrel type are preferred. Hydrants of this type should comply with the criteria set forth in AWWA's Standard C502 for Dry Barrel Fire Hydrants. Wet barrel fire hydrants, where used, shall comply with AWWA's Standard C503 for Wet Barrel Fire Hydrants.

8.3.1 Location and Spacing

1) Hydrants should be provided at each street intersection and at intermediate points between intersections as recommended by the State Insurance Services Office. Hydrants should be spaced from 350 to 600 feet depending on the area being served.

2) Water mains not designed to carry fire flows shall not have fire hydrants installed. It is recommended that flushing hydrants be provided on these systems. Flushing devices shall meet the requirements of Section 8.2.5. No flushing device shall be directly connected to any sewer.

8.3.2 Hydrant Valves and Nozzles

Fire hydrants should have a bottom valve size of at least 5 inches, one 4.5-inch pumper nozzle, and two 2.5-inch nozzles.

8.3.3 Hydrant Leads

The hydrant leads shall be a minimum of 6 inches in diameter. Auxiliary valves shall be installed on all hydrant leads.

8.3.4 Hydrant Drainage

1) Hydrant drains shall be plugged where groundwater rises above the drain port. When the drains are plugged, the barrels must be pumped dry after use during freezing weather.

2) If there is any question as to whether the barrel can be kept dry, an ANSI/NSF 60 certified solution, which is acceptable to DEP, can be used to prevent freezing and cracking of the barrel.

3) Where hydrant drains are not plugged, a gravel pocket or dry well shall be provided unless the natural soils will provide adequate drainage.

4) Hydrants with open drains shall not be located within 50 feet of leach fields.

5) Hydrant drains shall not be connected to or located within 10 feet of sanitary sewers, storm sewers, or storm drains.

8.4 Air Relief Valves and Piping

8.4.1 Air Relief Valves

At high points in water mains where air can accumulate, provisions shall be made to remove the air by means of air relief valves. Use of manual air relief valves is preferred wherever possible. Automatic air relief valves shall not be used in situations where manholes or chambers are located within the 100-year floodplain.

8.4.2 Air Relief Valve Piping

1) The open end of an air relief pipe from a manually operated valve should be extended to the top of the pit and provided with a screened, downward-facing elbow if drainage is provided for the manhole.

2) The open end of an air relief pipe from automatic valves should be extended to at least 1 foot above grade and provided with a screened, downward-facing elbow.

3) Discharge piping from air relief valves shall not connect directly to any storm drain, storm sewer or sanitary sewer.

8.5 Valve, Meter, and Blow-Off Chambers

Chambers, pits, or manholes containing valves, blow-offs, meters, or other such appurtenances to a distribution system shall not be located in areas subject to flooding or in areas of high groundwater. Such chambers or pits should drain to the ground surface or to absorption pits underground. The chambers, pits, and manholes shall not be connected directly to any storm drain or sanitary sewer. Blow-offs shall not be connected directly to any storm drain or sanitary sewer.

8.6 Installation of Water Mains

8.6.1 Standards

Specifications shall incorporate the provisions of the appropriate AWWA Standards and/or manufacturer’s recommended installation procedures.

8.6.2 Bedding

Continuous and uniform bedding shall be provided in the trench for all buried pipe. Backfill material shall be tamped in layers around the pipe and to a sufficient height above the pipe to adequately support and protect the pipe. Stones found in the trench shall be removed for a depth of at least 6 inches below the bottom of the pipe. If coarse bedding is used, it should be interrupted every 250 feet by an earth dike or barrier to prevent dewatering or drainage from the entire upland area of the bedding.

8.6.3 Cover

All water mains shall be covered with sufficient earth or other insulation to prevent freezing. A metallic tracer strip should be buried 1 foot above all nonmetallic pipe.

8.6.4 Blocking

All tees, bends, plugs, and hydrants shall be provided with reaction blocking, tie rods, or joints designed to prevent movement.

8.6.5 Pressure and Leakage Testing

All types of installed pipe shall be pressure tested and leakage tested in accordance with the latest edition of AWWA Standards.

Additional restraint may be necessary on fusible pipe at the connection to appurtenances or transitions to different pipe materials to prevent separation of joints. The restraint may be provided in the form of an anchor ring encased in concrete or other methods as approved by DEP.

8.6.6 Disinfection

All new, cleaned, or repaired water mains shall be flushed, disinfected, and microbiological tested in accordance with AWWA's Standard C651 for Disinfecting Water Mains. Bacteriological sample results must be analyzed by a certified laboratory submitted to DEP with the Certificated of Construction/Modification.

8.6.7 External Corrosion

If soils are found to be aggressive, the water main shall be protected by encasement in polyethylene, the provision of cathodic protection (in very severe instances), or the use of corrosion resistant water main materials.

8.6.8 Separation from Other Utilities

Water mains should be installed to ensure adequate separation from other utilities such as electrical, telecommunications, and natural gas lines for the ease of rehabilitation, maintenance, and repair of water main.

8.7 Separation Distances from Contamination Sources

8.7.1 General

The following factors should be considered in providing adequate separation:

1) Materials and type of joints for water and sewer pipes.
2) Soil conditions.
3) Service and branch connections into the water main and sewer line.
4) Compensating variations in horizontal and vertical separations.
5) Space for repair and alterations of water and sewer pipes.
6) Off-setting of pipes around manholes.

Sanitary sewer shall be defined as a gravity pipe carrying untreated wastewater. Storm sewer shall be defined as gravity pipe carrying surface water runoff to a point of discharge.

8.7.2 Parallel Installation

1) Water mains shall be laid at least 10 feet horizontally from any existing or proposed sewer, septic tank, or soil treatment system. The distance shall be measured edge-to-edge.

2) In cases where it is not practical to maintain a 10-foot separation, DEP may allow deviation on a case-by-case basis (see Section 8.7.4), if supported by data from the design engineer. Such deviation may allow installation of the water main closer to a sewer, provided that the water main is laid in a separate trench or on an undisturbed earth shelf located on one side of the sewer at such an elevation that the bottom of the water main is at least 18 inches above the top of the sewer.

8.7.3 Crossings

1) Whenever water mains must cross building drains, storm drains, or sanitary sewers, the water main shall be laid at such an elevation that the bottom of the water main is 18 inches above the top of the drain or sewer. This vertical separation shall be maintained for the portion of the water main located within 10 feet horizontally of any sewer or drain it crosses. The 10 feet is to be measured as a perpendicular distance from the drain or sewer line to the water line.

2) At crossings, one full length of water pipe shall be located so both joints will be as far from the sewer as possible. Special structural support for the water and sewer pipes may be required.

8.7.4 Exception

When it is impossible to obtain the proper horizontal and vertical separation as stipulated in Sections 8.7.2 and 8.7.3, both the water main and sewer line shall be constructed of cast iron, ductile iron, galvanized steel, or protected steel pipe having mechanical joints. Other types of joints of equal or greater integrity may be used at the discretion of DEP. Thermoplastic pipe may be used provided mechanical or solvent weld pipe joints are used. These shall be pressure-tested to ensure water tightness before backfilling. Where water mains must cross under a sewer, additional protection shall be provided by:

1) A vertical separation of at least 18 inches between the bottom of the sewer and the top of the water line.

2) Adequate structural support for the sewers to prevent excessive deflection of the joints and the settling on and breaking of the water line.

3) The length of the water line being centered at the point of the crossing so that the joints shall be equidistant and as far as possible from the sewer.

DEP shall be consulted when any of the above conditions cannot be met to discuss the use of double casing or concrete encasement of sewer and/or water lines as possible alternatives.

8.7.5 Sewer Manholes, Inlets, and Structures

No water pipe shall pass through or come in contact with any part of a sanitary or storm sewer manhole, inlet, or structure. Water mains shall be located at least 10 feet from sewer manholes, inlets, and structures. Any deviation from this requirement must be approved by DEP.

8.7.6 Separation of Water Mains from Other Sources of Contamination

Design engineers should exercise caution when locating water mains at or near certain sites such as sewage treatment plants or industrial complexes. On-lot waste disposal facilities, including absorption fields, must be located and avoided. The engineer must contact DEP to establish specific design requirements for locating water mains near any source of contamination.

8.8 Surface Water Crossings

In accordance with Chapters 105 and 106 of DEP's Rules and Regulations, all stream crossings, headwalls, pipelines, aerial crossings, and other analogous structures which are placed in, along, across, over, or under the regulated waters of the Commonwealth of Pennsylvania, are defined as encroachments or obstructions and, as such, require a permit from DEP. The DEP Bureau of Waterways Engineering and Wetlands must be contacted before final plans are prepared.

8.8.1 Aerial Crossings

In addition to the general criteria for stream crossings as outlined in 25 Pa. Code § 105.311 of DEP's Rules and Regulations (available at www.pacode.com), aerial crossings shall be adequately supported and anchored, protected from vandalism, damage and freezing, and accessible for repair or replacement.

8.8.2 Underwater Crossings

Pipelines under stream beds shall be located such that there will be a minimum of 3 feet of cover between the top of the pipe or encasement and the lowest point in the stream bed; provided that, if the pipeline is in rock, it shall have the depth of granular soil plus 6 inches for cover, but never less than 1 foot of total cover. In addition, the following shall apply when crossing water courses which are greater than 15 feet in width:

1) The pipe shall be of special construction, having flexible restrained, or welded watertight joints.

2) Valves shall be provided at both ends of water crossings so that the section can be isolated for testing or repair; the valves shall be easily accessible and not subject to flooding.

3) Permanent taps or other provisions to allow insertion of a small meter to determine leakage and for sampling purposes and obtain water for samples shall be made on each side of the valve closest to the supply source.

4) Pipelines under the stream bed shall be as near to horizontal as possible.

8.9 Cross-Connections

There shall be no physical connection between the distribution system and any pipes, pumps, hydrants, or tanks whereby unsafe water or other contaminating materials may be discharged or drawn into the system. Neither steam condensate nor cooling water from engine jackets or other heat exchange devices shall be returned to the potable water supply. Backflow prevention devices of the type specified in Part VII of the PWSM, Cross-connection Control/Backflow Prevention, shall be installed where water supply mains are connected to residential, commercial, and industrial customers which present a potential contamination hazard to the public water supply system.

8.10 Water Services and Plumbing

8.10.1 Plumbing

Water services and plumbing shall conform to relevant local plumbing codes or to the International Plumbing Code.

8.10.2 Booster Pumps

Individual booster pumps shall not be allowed for any individual residential service from the public water supply mains unless adequately protected against backflow. Where permitted for other types of services, booster pumps shall be designed in accordance with Section 6.4.

8.10.3 Service Meters

Each service connection should be individually metered.

8.11 Bulk Water Loading Stations

8.11.1 Fixed Bulk Water Loading Station

Bulk water loading stations present special problems since the fill line may have been used for filling both potable water vessels and other tanks or contaminated vessels. To prevent contamination of both the public supply and potable water vessels being filled, the following principles shall be met in the design of bulk water loading stations:

1) The loading station shall be located in an area that ensures the station will not change to flow direction or adversely affect the distribution supply or pressure. Locating the loading station near a storage facility is recommended.

2) All materials including pipes, fittings, valves, and transfer tubing shall be certified for conformance with ANSI/NSF Standard 61.

3) Any transfer pump shall be enclosed in a cabinet to protect against contamination.

4) An air gap or a reduced pressure zone device back flow preventer shall be provided to inhibit backflow to the public water supply. If a reduced pressure zone device (RPZD) is used, it shall be properly sized for the service water flow. The RPZD shall be properly sized to withstand the backpressure. The RPZD shall be periodically tested and properly maintained.

5) The piping arrangement shall prevent contaminants from being transferred from a hauling vessel to others subsequently using the station.

6) The loading station shall be designed to ensure the hoses will not be contaminated from contact with the ground.

7) All cleaning or disinfecting chemicals used in the loading station shall be certified for conformance with ANSI/NSF Standard 60.

8.11.2 Mobile Bulk Water Loading Station

Mobile bulk water loading stations shall meet all the same regulatory and design standards as fixed loading stations. Mobile bulk loading station equipment may only be used at approved taking points to ensures the station will not change to flow direction or adversely affect the distribution supply or pressure.

9 TREATMENT PLANT WASTES

Thorough consideration must be given to the waste streams that are generated by treatment equipment and treatment technologies that are chosen. Wastes that discharge to municipal sewer systems may impact the ability of the wastewater treatment facility to meet discharge permit limits. Alternative methods of water treatment and chemical use should be considered as a means of reducing waste volumes and the associated handling and disposal problems.

Provisions must be made for proper disposal of water treatment plant wastes such as sanitary and laboratory wastes, clarification sludge, softening sludge, iron sludge, filter backwash water, backwash sludge, and brines (including softener and ion exchange regeneration wastes and membrane/reverse osmosis wastes). In locating sewer lines and waste disposal facilities, consideration shall be given to preventing potential contamination of the water supply.

Discharges from online analyzers and turbidimeters shall not be recycled into the potable water system.

The appropriate federal, state, and local officials shall be notified when designing treatment facilities to ensure that the local sanitary sewer system can accept the anticipated wastes.

Adequate cross-connection control/backflow prevention measures, as required in Public Water Supply Manual Part VII, shall be provided as needed to protect the public water supply.

Subsequent discharges to the waters of the Commonwealth and the ultimate disposal of waste solids also must be approved by DEP. Applicants shall contact the Department's Bureau of Clean Water for specific information on how to obtain these approvals.

9.0 Filter Backwash Recycling

The recycling of filter-to-waste water, filter plant backwash water, thickener supernatant, liquids from the dewatering process, and other process wastewater streams, is an acceptable method of water conservation and minimizing chemical usage for conventional and direct filtration water treatment systems. However, the recycling of wastewater may adversely affect the water treatment process by recycling substances which produce taste and odors, increase pathogen concentrations, increase chlorine demand, or otherwise add to the difficulty of treating the water. To prevent possible adverse effects to the water treatment process, an evaluation of the chemical characteristics and quantity of wastewater to be recycled must be made to ensure its acceptability for reuse. When recycling is proposed, the water supplier shall:

1) Operate the facility to minimize production of the wastewater streams to be recycled.

2) Provide instrumentation needed to be able to measure and record the instantaneous flow rates of both the raw water and all recycle streams. If the recycle streams are combined prior to their return, it is sufficient to measure and record their combined flow rate.

3) Control the rate of recycling to minimize the impact to the treatment process and finished water quality. The maximum instantaneous rate of recycling shall be maintained at no greater than to before the point of primary coagulant addition.

9.1 Discharge to Sanitary Sewer Systems

The sanitary waste from treatment plants, pumping stations, etc. shall receive treatment. Wastes from these facilities shall discharge directly to a municipal sanitary sewer system when feasible, or if that option is not available, to an adequate on-site sewage treatment system or holding tanks. The water supplier shall obtain approval from DEP for its proposed method of dealing with sanitary wastes. **Sanitary wastes shall not be recycled or introduced into the potable water treatment facilities in any manner**.

Filter backwash waters and sludges can be discharged to municipal sanitary sewer systems if the owner/operator of the sewerage treatment system and DEP give approval before final designs are made. Special consideration must be given to the nature of sludges so as not to adversely affect the sewage treatment process or cause hydraulic problems in the sewer lines. An equalization basin or tank is recommended to prevent overloading of sewerage treatment systems. Design shall prevent cross-connections and there shall be no common walls between potable and non-potable water compartments.

9.2 On-lot Waste Treatment, Storage, or Stream Discharge

On-site treatment, storage, and stream discharge of all wastewaters and sludges require approval from the Department's Clean Water Program. For design standards and requirements, contact the appropriate Clean Water Program Regional Office.